AGRICULTURAL RESEARCH INSTITUTE

PUSA

# RECORDS

OF

# GEOLOGICAL SURVEY OF INDIA.

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# THE GEOLOGICAL SURVEY OF INDIA

## VOLUME LIV.

*Published by order of the Government of India.*

CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY OF INDIA,
27, CHOWRINGHEE ROAD.

1923.

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RECORDS

OF

# THE GEOLOGICAL SURVEY OF INDIA

Part 1] 1922 [August

## GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1921. BY L. L. FERMOR, O.B.E., A.R.S.M., D.Sc., F.G.S., F.A.S.B., M.I.M.M., *Officiating Director.*

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## DISPOSITION LIST.

1. During the period under report the officers of the Department were employed as follows :—

*Superintendents.*

MR. E. VREDENBURG . Returned from combined leave on 30th November 1921 and placed in charge of Bihar and Orissa and the Central Provinces Party.

DR. L. L. FERMOR . Continued in charge of the Bihar and Orissa and Central Provinces Party until the end of August. Left headquarters for field work in the Central Provinces on 21st January 1921 and returned on 8th May 1921. Appointed to officiate as Director from 29th August 1921.

DR. G. E. PILGRIM . Continued in charge of office up to 7th November 1921 and as Palæontologist up to 21st November 1921. Placed in charge of the North-western Party and proceeded to the field (Punjab) on 21st November 1921.

MR. G. H. TIPPER . Returned from field work in charge of the Bombay and Rajputana Party on 12th March 1921; again left for Chitral on 26th April 1921. Returned on 2nd November 1921. Placed in charge of office from 8th November and appointed Palæontologist on 22nd November 1921.

MR. G. DE P. COTTER . Returned from leave on 31st May 1921. Placed in charge of the Burma Party and left for Rangoon on 26th June 1921.

DR. J. COGGIN BROWN . On deputation with the Imperial Mineral Resources Bureau, London, up to 14th September 1921. Proceeded on privilege leave for six months from 15th September 1921.

*Assistant Superintendents.*

MR. H. WALKER . . Returned from combined leave on 2nd November 1921. Attached to the Bihar and Orissa and Central Provinces Party. Left for the field on 22nd November 1921.

MR. K. A. K. HALLOWES Returned to headquarters from Bombay on 4th May 1921. Proceeded to Hyderabad on 12th November 1921 for field work.

MR. H. C. JONES . Continued to officiate as Superintendent with effect from 26th January 1920. Returned to headquarters from Bihar and Orissa on 4th May 1921. Left for the field on 15th November 1921 to continue the investigation of the iron-ore deposits of Bihar and Orissa.

DR. A. M. HERON . Continued to officiate as Superintendent up to 29th November 1921. Returned to headquarters from Burma on 17th April 1921. Left Calcutta on 3rd May 1921 to join the Mount Everest Reconnaissance Expedition and returned on 31st October 1921. Attached to the Burma Party and left for Mergui on 11th November 1921.

| | |
|---|---|
| DR. M. STUART . . | Appointed to officiate as Superintendent from 17th November 1920 to 31st May 1921 and again from 29th August 1921 to 14th September 1921. Returned from deputation with the Hukong Valley Railway Survey Party on 9th June 1921. Resigned the service on 12th October 1921. |
| MR. C. S. FOX . . | Continued to act as Curator, Geological Museum and Laboratory up to 19th August 1921. On deputation in the office of the High Commissioner for India, London, with effect from 20th August 1921. |
| CAPTAIN R. W. PALMER | Returned to headquarters from field work in Assam on 26th April 1921. Deputed to investigate the gas seepages of Baroda on 8th October 1921 and returned to headquarters on 24th October 1921. Permitted to resign the service with effect from 4th December 1921. |
| RAO BAHADUR S. SETHU RAMA RAU. | Returned to headquarters from Burma on 21st April 1921. Granted privilege leave for 1 month and 8 days from 29th August 1921. Attached to the Bihar and Orissa and Central Provinces Party and left for the field (Central Provinces) on 16th November 1921. |
| RAO BAHADUR M. VINAYAK RAO. | Returned to headquarters from field work in Burma on 19th May 1921. Granted combined leave for 3 months and 12 days from 25th May 1921. Returned and resumed duty on 6th September 1921. Attached to the Burma Party and left for the field on 8th November 1921. |

MR. H. CROOKSHANK . Returned to headquarters from field work in Jodhpur State and Quetta on 4th April 1921. Appointed Curator of the Geological Museum and Laboratory with effect from 20th August 1921.

CAPTAIN C. T. TEYCHENNÉ. Returned to headquarters from field work in Bihar and Orissa on 4th May 1921. Granted combined leave for 6 months with effect from the 4th November 1921.

MR. E. L. G. CLEGG . Attached to the Bihar and Orissa and Central Provinces Party and left for the field (Central Provinces) on 8th January 1921. Returned to headquarters on 18th April 1921. Left headquarters for Dhanbaid on 13th August 1921 in connection with the water supply of the proposed Indian School of Mining and Geology, and returned to headquarters on 30th August 1921. Left headquarters for Chittagong on 31st October 1921 to examine a reservoir site in connection with water supply at Chittagong. Returned to headquarters on 6th November 1921. Attached to the Burma Party and left for the field on 13th November 1921.

MR. D. N. WADIA . Appointed Assistant Superintendent, Geological Survey of India on 16th April 1921. Posted to Poonch Ilaqa in Kashmir State. Returned to headquarters on 23rd January 1921. Attached to the North-western Party and left for the field on 26th October 1921.

MR. G. V. HOBSON . Appointed Assistant Superintendent, Geological Survey of India on 29th October 1921. Attached to the Bihar and Orissa and Central Provinces Party and left for the field (Central Provinces) on the 25th November 1921.

MR. F. W. WALKER . Appointed Assistant Superintendent, Geological Survey of India on 3rd November 1921. Attached to Burma Party and left for the field on the 25th November 1921.

MR. J. A. DUNN . . Appointed Assistant Superintendent, Geological Survey of India on 17th December 1921. At headquarters.

*Chemist.*

DR. W. A. K. CHRISTIE Reverted to his substantive appointment as Chemist on 28th December 1920 on termination of his deputation under the Government of India in the Finance Department. At headquarters during the year.

*Artist.*

MR. K. F. WATKINSON At headquarters. Granted privilege leave for 3 months from 10th September 1921; returned to duty on 9th December 1921.

*Sub-Assistants.*

BABU BANKIM BEHARI GUPTA. Returned from field work in Burma on 28th April 1921. Attached to Burma Party and left for the field on 8th November 1921.

BABU DURGA SHANKAR BHATTACHARJEE. Attached to the Bihar and Orissa and Central Provinces Party and left for the field (Central Provinces) on 8th January 1921. Returned to headquarters on 19th April 1921. Granted privilege leave for 2 months and 7 days from 3rd June 1921. Again attached to the Central Provinces Party and left for the field on 5th November 1921.

*Assistant Curator.*

BABU BARADA CHARAN GUPTA. At headquarters.

2. The cadre of the Department continued to be 6 Superintendents, 22 Assistant Superintendents, and one Chemist. Of the 12 vacancies in the grade of Assistant Superintendent existing in 1920, three were filled during that year. There were thus 9 vacancies in the grade of Assistant Superintendent at the beginning of the year under report. One retirement and two resignations occurred during the year. On the other hand four new Assistant Superintendents were appointed, leaving at the end of the year eight vacancies.

## ADMINISTRATIVE CHANGES.

**Retirements, resignations, promotions, and appointments.**

3. Sir H. H. Hayden, Kt., C.S.I., C.I.E., Director, retired with effect from 1st June 1921.

The following officers were permitted to resign the service with effect from the dates shown against each :—

(1) Dr. Murray Stuart, from the 12th October 1921.

(2) Captain R. W. Palmer, from the 4th December 1921.

Dr. E. H. Pascoe was confirmed as Director with effect from 1st June 1921 *vice* Sir H. H. Hayden, retired.

Dr. L. L. Fermor was appointed to officiate as Director with effect from 29th August 1921 *vice* Dr. E. H. Pascoe on leave.

Dr. J. Coggin Brown, Assistant Superintendent, was promoted Superintendent with effect from 1st June 1921.

The following officers were appointed during the period under report to officiate in the grade of Superintendent :—

Dr. J. Coggin Brown continued to officiate as Superintendent up to 31st May 1921 *vice* Dr. G. de P. Cotter on leave.

Mr. H. C. Jones continued to officiate as Superintendent up to 31st May 1921 *vice* Dr. E. H. Pascoe, officiating as Director; from 1st June 1921 to 29th November 1921 *vice* Mr. E. Vredenburg on leave; and from 30th November 1921 *vice* Dr. L. L. Fermor officiating as Director.

Dr. A. M. Heron continued to officiate as Superintendent up to 14th September 1921 *vice* Dr. J. Coggin Brown on deputation, and from 15th September 1921 to 29th November 1921 *vice* Dr L. L. Fermor officiating as Director.

Dr. Murray Stuart continued to officiate as Superintendent up to 31st May 1921 *vice* Mr. E. Vredenburg on leave, and from 29th August 1921 to 14th September 1921 *vice* Dr. L. L. Fermor officiating as Director.

Dr. G. E. Pilgrim continued to act as Palæontologist till 21st November 1921, and thereafter Mr. G. H. Tipper from 22nd November 1921.

Mr. C. S. Fox continued to act as Curator, Geological Museum and Laboratory, till 19th August 1921, and thereafter Mr. H. Crookshank from 20th August 1921.

The following officers joined the Department during the year :—

Mr. D. N. Wadia, M.A., B.Sc., F.G.S., on 16th April 1921.

Mr. H. V. Hobson, B.Sc., A.R.S.M., on 6th October 1921.

Captain F. W. Walker, M.C., B.A., B.A.I. (Dublin.), on 3rd November 1921.

Mr. J. A. Dunn, B.Sc., (Melbourne) on 17th December 1921.

The following Sub-Assistants in the Geological Survey of India have been granted gazetted status with effect from the 1st April 1921 :—

(1) Mr. Bankim Behari Gupta.

(2) Mr. Durgashankar Bhattacharjee.

Leave.

4. Dr. E. H. Pascoe was granted combined leave for one year with effect from the 29th August 1921.

Dr. J. Coggin Brown was granted privilege leave for six months with effect from the 15th September 1921.

Rao Bahadur S. Sethu Rama Rao was granted privilege leave for one month and eight days with effect from the 29th August 1921.

Rao Bahadur M. Vinayak Rao was granted combined leave for three months and twelve days from the 25th May 1921.

Captain C. T. Teychenné was granted combined leave for six months from the 4th November 1921.

Mr. K. F. Watkinson was granted privilege leave for three months from the 10th September 1921.

Mr. Durgashankar Bhattacharjee was granted privilege leave for two months and seven days from the 3rd June 1921.

## OBITUARY.

5. The death of Mr. F. R. Mallet, late Superintendent, Geological Survey of India, and a member of the Department from 1859 to 1889, has been referred to in the preceding volume of these *Records*. With Mr. Mallet's death we have lost the Father of Indian Mineralogy.

## PROFESSORSHIPS AND LECTURESHIPS.

6. Mr. E. Vredenburg was Professor of Geology at the Calcutta University. Mr. C. S. Fox continued as Lecturer on Geology at the Presidency College up to 19th August 1921 when he was replaced by Mr. H. Crookshank.

## POPULAR LECTURES.

7. A course of six popular lectures on geology was delivered by Mr. D. N. Wadia in the Indian Museum during the monsoon, the subjects selected being as follows :—

(1) The Natural History of a Piece of Chalk.
(2) The Himalaya Mountains.
(3) The Ice Age.
(4) Fossil Fuel: The Coal and Petroleum of India.
(5) The Age of the Earth and the Age of Man.
(6) The Interior of the Earth.

## PUBLICATIONS.

8. The following publications were issued during the year under report :—

Memoirs, Vol. VI, Part 2 (Reprinted).
" " XL, " 3.
" " XLIV, " 1.
Records, " LI, Parts 2, 3, and 4.
" " LII, (complete in one volume).
" " LIII, Part 1.
Bibliography of Indian Geology, Part 2 (Index of localities).

## LIBRARY.

9. The additions to the Library amounted to 6,653 volumes, of which 2,249 were acquired by purchase and 4,404 by presentation and exchange.

## MUSEUM AND LABORATORY.

**Staff.**

10. Mr. C. S. Fox was Curator of the Geological Museum and Laboratory from the beginning of the year until 19th August 1921, when he proceeded on deputation to England and made over charge to Mr. H. Crookshank. Babu Barada Charan Gupta was Assistant Curator throughout the year. The services of the two Museum Assistants, Babus Provat Kumar Dey and Surendra Chandra Das Gupta were dispensed with, with effect from the 2nd April 1921 and 16th November 1921, respectively. Babu Anil Chandra Bose, M.Sc., was appointed as Museum Assistant on the 18th October 1921, but resigned his appointment with effect from 24th November 1921.

**Chemist.**

11. Dr. W. A. K. Christie continued as Chemist throughout the year.

**Determinative work and analyses.**

12. The number of specimens referred to the Curator for examination and report was 544. Assays and analyses were made of 89. The corresponding figures for the preceding year are 420 and 98.

**Meteorites.**

13. During the year the following acquisitions to the meteorite collection were made :—

(1) A meteoric stone in five fragments. Fell on the 30th August 1920 at Merua in the Allahabad district. Total weight 71·406 kilogrammes.

(2) A meteoric stone in three fragments. Fell on 23rd December 1920 at Turra near Manikpur in the Banda district. Total weight 1079·92 grammes.

(3) A meteoric stone accidentally broken in two pieces. Fell at Haripura, Jaipur State, Rajputana, on the 17th January 1921. Total weight 315·12 grammes.

(4) A meteoric stone. Fell on the 9th September 1921 in a village in the Purnea district. Weight 3679·7 grammes.

(5) A meteoric iron in two pieces. Fell on the 20th May 1921 in the Shimelia and Beshki jungles, 7 miles N. W. of Shahpura. The pieces weighed 1125·30 grammes and 586·88 grammes, respectively. The rarity of this occurrence may be gauged from the fact that up to the present date not more than 12 meteoric irons have been seen to fall throughout the world.

**Donations to Museums, etc.**

14. During the year presentations of geological specimens were made to the following institutions :—

(1) G. B. B. College, Muzaffarpur.
(2) Central Museum, Nagpur.
(3) Victoria Memorial M. E. School, Gopalgunge.
(4) Presidency College, Calcutta.
(5) South Suburban College, Bhowanipur.
(6) Wilson College, Bombay.
(7) New School, Bombay.
(8) The Burma Museum.

**Additions to the collections.**

15. The following foreign specimens were added to the collections during the year :—

(1) Various mineral specimens from Canada, including niccolite, argentite, erythrite crystals, ruby silver, wolframite, molybdenite, phlogopite, temiskamite, scapolite, corundum, scheelite, a vein showing native silver and smaltite, ulexite on gypsum, native bismuth, cobaltite crystals, annabergite, breithauptite, bornite, and tourmaline ; presented by Dr. T. L. Walker, Royal Ontario Museum of Mineralogy.
(2) A collection of mineral and rock specimens from Rhodesia and the Belgian Congo, including malachite, chrysocolla, chalcopyrite, wad, asbestos, chrysotile, breccia cemented by chalcocite, copper phosphate, trap, blue ground, and laterite ; presented by Sir H. H. Hayden.
(3) Head of a monkey, carved in soapstone. Pen-y-gwryd, Llanberis ; presented by Mr. A. Lockwood.
(4) Manganese-amphibole in slag ; presented by Mr. G. V. Wilson.
(5) Brown coal and briquettes from Cologne ; presented by Mr. H. L. Cole, Secretary, Railway Board.
(6) Oxide of iron paints ; presented by Zach. Cartwright, Ltd.
(7) Finished asbestos goods ; presented by the Cape Asbestos Co., Ltd.
(8) Finished asbestos goods ; presented by James Walker & Co., Ltd.

The following Indian specimens were among those added to the collections during the year :—

(1) Crude tin, tin concentrates, and tin-ore, Nurunga, Hazaribagh district ; presented by Sandermall & Co.

(2) Copper ore, Bawdwin, Northern Shan States; presented by the Burma Corporation, Ltd.

(3) Stolzite, Hermyingyi mine, Tavoy; presented by Mr. A. W. Ross.

(4) Lignite, resin in lignite, fullers' earth, and marcasite, Bikanir; presented by Mr. H. L. Cole, Secretary, Railway Board.

(5) Hollandite, Balaghat manganese mine; presented by Mr. L. E. Bartlett.

(6) Red and yellow ochre: presented by Turner, Morrison & Co., Ltd.

(7) Barytes, Bhankera, Ramsingpur; presented by Mr. S. K. Roy.

(8) Kaolin, Lameta Ghat; presented by P. R. Patell & Co.

## MINERALOGY.

**Bitumen.**

16. In 1918, quarrying operations led to the discovery, in a cavity in basalt west of Seori fort, Bombay, of solid bitumen or mineral-pitch, and Sir Henry H. Hayden was able to visit the locality and obtain specimens. In 1921, the discovery in the same neighbourhood of additional cavities of similar nature, in which crude rock-oil and mineral wax were associated with the solid bitumen, excited public interest; but the known relative ages of the Deccan Trap and of the petroliferous strata of India rendered improbable the occurrence of oil-bearing beds beneath the Trap, and some other source for these bituminous materials seemed likely. Mr. C. S. Fox, whilst *en route* to England, was fortunately able to examine these occurrences before further quarrying operations had destroyed the evidence, and he has submitted an interesting report thereon.

The cavities were in a greenish dolerite, and ranged in size up to 30'×20'×8', these being the dimensions ascribed to the cavity found in 1918. Associated with the bitumen were crystals of calcite, quartz (including minute doubly-terminated crystals) and various zeolites, amongst which Dr. Christie has identified apophyllite, laumontite, scolecite, analcite, and prehnite, whilst in some specimens purchased from Mr. J. Ribeiro, Dr. Christie has identified in addition okenite, gyrolite, and stilbite. The mode of association suggests that the bitumen was formed before the zeolites. Mr. Fox considers, indeed, that the evidence in the quarry indicates that the carbonaceous material was included in the dolerite whilst the latter was still in a plastic hot condition, and that the original organic bituminous matter suffered some degree of modification due to the removal by distillation of certain volatile products. The composition of the solid bitumen or mineral pitch has been determined by Dr. Christie on one specimen as follows:—

| | Per cent. |
|---|---|
| Carbon | 88·15 |
| Hydrogen | 5·20 |
| Oxygen (by difference) | 4.01 |
| Nitrogen | 1·04 |
| Sulphur | 0·32 |
| Moisture | 0·58 |
| Ash [1] | 0·70 |
| TOTAL | 100·00 |

The Geology of Bombay Island was described by Wynne in *Memoirs, Geological Survey of India,* Vol. V, pages 173-225, and the map accompanying his paper indicates separately the various lava flows and associated freshwater sediments with their well-known frog remains. In the limited time at his disposal Mr. Fox visited all the chief rock exposures in the island, and, whilst agreeing generally on the accuracy of Wynne's mapping, he disagrees with Wynne's interpretation thereof. According to Wynne, the lava flows with associated sediments comprise a conformable succession with a steady and gentle dip to the west. According to Mr. Fox, the particular sheet of dolerite that contains the cavities with bitumen is an intrusive sill; Mr. Fox considers also that the evidence warrants the insertion on the map of a north and south strike fault traversing the island from end to end, with a down-throw to the east, as the result of which the strata forming the ridges along the eastern side of the island must, at least in part, be regarded as a repetition of those on the west. To the distillation of the carbonaceous matter of the organisms in the invaded strata Mr. Fox attributes the formation of the cavities containing bitumen. Mr. Fox's views can at present be regarded as a hypothesis with a considerable degree of probability, and it is evident that a detailed study of the stratigraphy, petrology, and mineralogy, as well as the chemical composition, of the Deccan Traps of Bombay Island, should yield results of great interest.

[1] Mainly ferric oxide—silica 0·13 per cent.

## PALÆONTOLOGY.

17. Mr. Vredenburg's comparative diagnoses of certain families of gastropoda from the Tertiary formations of Burma, commenced in *Records, Geological Survey of India*, Vol. LI, p. 339, by an account of the Terebridæ, were continued by the publication of papers dealing with the Pleurotomidæ, Conidæ and Cancellariidæ. Other papers by the same writer, still in the Press, and which will, it is hoped, appear shortly, include "Mollusca from the Post-Eocene Tertiary formations of North-West India," "A Review of the genus Gisortia," "A Zone-Fossil from Burma: Ampullina (Megatylotus) Birmanica." Dr. N. Annandale's paper on "Indian Fossil Viviparæ," Dr. B. Prashad's paper "On a new fossil Unionid from the Intertrappean Beds of Peninsula India," and Mr. Vredenburg's descriptions of "Unionidæ from the Miocene of Burma." were published during the year.

Other works in the Press include Dr. Cotter's "Lamellibranchiata of the Eocene of Burma," Dr. Cowper Reed's "Devonian fossils from Chitral and the Pamirs," Mr. C. Foster Cooper's "Anthracotheridæ of the Dera Bugti deposits in Baluchistan," Dr. Spengler's "Contribution to the Palæontology of Assam," and Mr. T. H. Wither's "Revision of some Fossil Balanomorph Barnacles from India and the East Indian Archipelago."

During the period under review Mr. Vredenburg has continued his studies of Indian Tertiary Gastropoda, Captain R. W. Palmer has submitted a paper entitled "An incomplete skull of Dinotherium with notes on Indian forms," while short papers on various Gondwana plants have been sent in by Prof. B. Sahni and Mr. B. B. Gupta. In Europe, Dr. Cowper Reed has continued his examination of the Anthracolithic and Triassic fossils from Yunnan, and Dr. Matley his studies of the Dinosaurian remains from near Jubbulpore in the Central Provinces.

## STRATIGRAPHY.

18. The discovery, towards the end of 1921, by Mr. K. P. Sinor, State Geologist to the Rewah Durbar, of marine fossils in association with beds of Lower Gondwana age at Umaria, is of great interest. It may be regarded as an example of the important discoveries that are likely from time to time to follow from close geological work in the Peninsula.

As described by Mr. Sinor, not far from the junction of the Gondwana rocks and the underlying gneisses and in what are usually ascribed to the Talchir stage, there is a narrow band, 3 inches thick, composed almost entirely of shells of the genus *Productus*. Specimens of this shell-band, first sent to the Geological Survey of India by Mr. Sinor, contained nothing but *Productus*. Below the shell-band are quartz, grits, which pass up through the band conformably into sandstones of Lower Barakar age. The dip of the beds is about 30°

Early in 1922, Mr. P. N. Mukherji, Field Collector, was deputed to visit Umaria and make further collections from the locality, in the hope that a regular fauna might be obtained by means of which the age of the deposit could be more definitely fixed. The only fossils that Mr. Mukherji succeeded in discovering, in addition to the *Productus* already found, were two specimens of *Spiriferina*.

The *Productus* has not yet been identified, but according to Mr. Tipper it is new to India. This is not surprising if, as it seems reasonable to assume, the strata in which the above marine fossils occur are of Talchir age, for marine fossiliferous beds of that age are unknown. The *Spiriferina* is close to, and probably identical with, *Spiriferina cristata* var. *octoplicata*. As, however, this species seems to have a considerable vertical range, its presence is not of great assistance in determining the precise age of the fossil band.

If we except the coastal fringes of India and a tract of country stretching from Indore State in Central India to Kathiawar and Cutch in the west, no marine rocks have hitherto been discovered in the Peninsula later in age than the Vindhyans, which, in the absence of fossil evidence, are by many geologists regarded as of pre-Cambrian age. This discovery at Umaria suddenly provides evidence of the presence of the sea in Carboniferous times over a portion of what is now Rewah State in the middle of the northern part of the Peninsula, suggesting that in Talchir times the northern Carboniferous sea must have extended at least as far south as Umaria, giving a northern limit to the edge of Gondwanaland in this neighbourhood in Talchir times. As the marine *Productus* bed of Umaria is followed by the freshwater coal-bearing Barakar series, it is evident that the sea must have retreated northwards immediately after, or towards the end of, Talchir times. We may perhaps picture this arm or bay of the Carboniferous sea as having been flanked on the west by the Aravalli ranges of Rajputana. After his visit to Umaria Mr. P. N. Mukherji was deputed to search the Talchir outcrops of the Mohpani area for further occurrences of *Productus*, in the hope that we might obtain evidence of the westward trend of the coastline of this presumed bay of the northern Carboniferous sea. His visit was, however, fruitless. In view of the fact that portions of western Central India and of the northern parts of the Bombay Presidency were under the sea in pre-Deccan Trap times (Cretaceous and Jurassic), it does not, however, seem possible definitely to exclude the alternative idea that the presumed arm of the Carboniferous sea may have encroached on the Peninsula from the west and have extended as far as Umaria : but it must be noted that the most eastern of these marine outcrops is about 300 miles west of Umaria, namely at Barwai in Indore, where marine Cretaceous rocks occur.

## ECONOMIC ENQUIRIES.

### Amber.

19. During his deputation with the Hukong Valley Railway Survey, Dr. Murray Stuart had an opportunity of examining the Maing-kwan Hills from which the well-known Burmese amber is obtained. The eastern flank of the hills consists of grits and conglomerates belonging to the basal beds of the Tipam series. Underlying them on the west is a blue clay in which the amber is found in irregular lumps. The principal localities are at the northern end of the range, and also at its southern extremity, near Lalaung. No mines were actually being worked at the time, but the whole outcrop of the clay appears to have been dug over in past years. Based on the discovery amongst the debris round the amber pits of a fragment of rock containing *Nummulites Biaritzensis*, D'Arch. Dr. Stuart believes that the clay is of Lower Khirthar (Eocene) age. It is interesting to note that Dr. F. A. Bather, as the result of a preliminary study of the insects in a collection of Burmese amber presented to the British Museum by Mr. R. C. J. Swinhoe of Mandalay, states in a letter that there is reason to suppose that the amber is of Eocene and possibly Lower Eocene age.

### Arsenic.

20. During his tour in Chitral, Mr. G. H. Tipper was able to visit the orpiment mines of the State, from which a small production has been reported regularly for years, but which have never previously been visited by a geologist. The deposits noted by Mr.

Tipper are: (1) Mirgasht Gol (11,000 ft.); (2) Aligot (13,000 ft.); (3) Londku (11,000 ft.); (4) Wizmich (16,000 ft.); (5) Moghono Zom (15,000 ft.); and (6) Stach: of which he succeeded in visiting all except No. 5. The figures in brackets show the approximate heights of the deposits. The first four deposits lie on one line of strike, Mirgasht Gol and Aligot being on the north-west side of the Tirich valley, Londku in a tributary of the Tirich of the same name, and Wizmich on the ridge separating Chitral from Wakhan in Afghanistan.

The Tirich valley is formed along a line of fault running N.E.-S.W., on the northern side of which occurs a large mass of altered limestones and calcareous shales. The limestones are mostly altered to marbles, but are in places still fossiliferous and contain well-preserved *Fusulinæ*. Along the fault line, well exposed in the upper portion of the Tirich valley and continuing to the north-east, is a V-shaped body of basic intrusive rocks. On the south side these abut on the shales and quartzites of the Sarikol Shales. The orpiment mines occur on the northern side close to the intrusive rocks and in the calcareous shales that are associated with the marbles. These shaly beds have been baked and altered by the intrusives.

The ores have, as a rule, been worked by means of irregular narrow tunnels, which are now often blocked by debris and abandoned. But judging from Mirgasht Gol, where Mr. Tipper was able to examine the ores *in situ* underground, the deposits dip in some cases with the enclosing rocks, and in others form veins cutting definitely across. At Mirgasht Gol specimens of great beauty were collected, composed of red realgar and orange-yellow orpiment. Cubes of fluorite occur in both minerals.

The deposits of Moghono Zom and Stach lie respectively S.S.E. of the village of Andraghach in the Khut valley and on the ridge west of the Yarkhun river. In both cases the orpiment occurs in unfossiliferous marble.

## Bauxite.

21. During the year Mr. Fox completed his memoir on the bauxite deposits of India: the memoir is now in the press.

**Bombay: Salsette Island.**

22. During his survey of Salsette Island, Mr. K. A. K. Hallowes found bauxite of fairly good quality on the summits of two hills, Baumdungri (19°10′ 72°56′) and Bombassadungri, (△1,280) (19°

11′; 72° 56′). The quantity available is, however, estimated at less than 10,000 tons.

## Building Stones.

**Bombay: Salsette Island.**

23. Mr. K. A. K. Hallowes made an exhaustive examination of the quarries from which building stone is obtained in the island of Salsette. At each quarry the dip and the character of the jointing and of the rock were noted. Cubes were prepared and were tested for crushing strength and porosity by Professor Chree Brown, Acting Principal of the College of Engineering, Poona. The results of these physical tests were correlated with macroscopic and microscopic characters and a comparative table constructed. From a consideration of all the data Mr. Hallowes concludes that building stones from the weathered layers of the traps are often poor, that the quality would be greatly improved by using a less weathered variety, but that there is no necessity to use absolutely unweathered material. There is, in fact, a fairly good degree of correlation between the results of the physical tests and the amount of alteration of the rock as determined microscopically.

Recommendations are also made for the suitable location of new quarries and concerning improved methods of work.

## Coal.

**Talcher coalfield.**

24. The occurrence of coal in Talcher State, Orissa, has long been known; and, in fact, the Talcher coalfield was the first to be described in the Memoirs of this Department [see Vol. I.]. Nevertheless, until recently the existence of workable coal has remained unproved. In 1918 I had occasion to cross the field whilst examining mica occurrences in Orissa, and visited Gopalprasad, the best-known locality. I found myself compelled to agree with the unfavourable views on the economic possibilities of the exposed coal-seams of this locality expressed previously by others, and reported that any further enterprise in examining this field should be directed to drilling in search of possible seams not exposed at the surface. Without being aware of my report, such work was commenced by Messrs. Villiers Limited about a year later, and, as the result of a systematic drilling campaign, the

existence in two seams was speedily proved of considerable quantities of coal, which, when tested, gave satisfactory results on railway trials. I was asked to visit the field in June, 1921, and take additional samples, which on analysis gave the following results :—

| — | SEAM 1 (AVERAGE OF 12 SAMPLES). | | SEAM 3 (AVERAGE OF 8 SAMPLES). | |
|---|---|---|---|---|
| | As taken. | Moisture-free. | As taken | Moisture-free. |
| | Per cent. | Per cent. | Per cent. | Per cent. |
| Moisture | 11 33 | .. | 11·71 | .. |
| Volatile matter | 35·65 | 40·20 | 30·54 | 34·59 |
| Fixed carbon | 44·11 | 49·75 | 46·18 | 52 31 |
| Ash | 8 91 | 10 05 | 11 57 | 13·10 |
| | 100 00 | 100 00 | 100 00 | 100 00 |
| Calorific value of dried sample (calories) | .. | 7056 | .. | 6737 |

The two seams sampled were respectively 12 and 8 feet thick where sampled, and probably underlie a considerable area. In addition, the boring operations have proved the existence of several other seams of coal, the extent and quality of which have yet to be determined. With the increasing difficulty of obtaining adequate supplies of coal in India for the country's needs, the discovery of workable coal in this field must be regarded as an event of importance, which is increased by the greater proximity of the Talcher field to the Madras Presidency than the other fields of Bengal, Bihar and Orissa. Some 65 miles of railway are required to connect the field with the Bengal Nagpur Railway at a point north of Cuttack, and the survey for the alignment has been completed.

**Karanpura coalfield.**

25. During the year I was also asked to advise the Railway Board concerning the selection of blocks in the Karanpura coalfields.

**Boring for coal at Bhusawal.**

26. As noticed in the General Report for 1920, the boring for coal at Bhusawal by the Great Indian Peninsula Railway Company in search of possible coalfields below the Deccan Trap reached a

a depth of 558 feet by the 8th of March, 1920. On the arrival of the necessary lining tubes, boring was resumed on the 1st of August 1921, and the hole had reached a depth of 1,165 feet from the surface on the 17th of January, 1922. As before, I examined the cores on the ground, finding that the hole was still in the Deccan Trap at the depth of 1,165 feet. The height of Bhusawal above sea-level is about 700 feet. The boring has therefore already reached a depth of 400 feet below sea-level. The Deccan Trap lava flows of India are generally regarded as having been extruded under sub-aerial conditions. Assuming the correctness of this view, which there seems no reason to doubt, this boring has already afforded evidence of a considerable downthrow by faulting of the Deccan Traps in this part of India. When it is remembered that the base of the Deccan Trap where seen exposed in the neighbourhood of Nagpur to the east is at about 1,000 feet above sea-level, it becomes evident that the traps of Bhusawal have been faulted down at least several hundred, and probably over a thousand, feet. It seems, in fact, justifiable to deduce that the Deccan Traps of India have at least as far east as Bhusawal been affected by the vast earth movements that led to the foundering of the Deccan Traps over what is now the Arabian Sea. The introduction of this factor of uncertain magnitude makes it impossible to form any idea of the depth to which this boring at Bhusawal must be pursued in order to pierce the trap. It has been decided, therefore, to continue to the capacity of the machine, which is about 1,500 feet, and, if the trap has not been pierced by that depth, to discontinue the experiment.

**Korba coalfield.**

27. To meet a request of the Government of the Central Provinces, Mr. H. Walker paid a brief visit in November to Ghordeva on the Korba coalfield, Bilaspur district, in order to examine certain prospecting operations there in progress.

## Copper.

28. Captain Palmer records the discovery by prospectors of native copper in the Sylhet Trap in the bed of the Um Sohryngkew below Mawsmai, south of Cherrapunji. The metal occurs in leaves developed on a fault face, and its discovery has led to prospecting in other areas where the Sylhet Trap is exposed. Captain Palmer himself found indications of the presence of copper in the bed of

the Rilang river ¼ mile west of height 187 below Langpa in Langrin. Here a spring issuing from a fault plane has deposited on the cliff face a blue-green film of a copper salt. By micro-chemical methods Dr. Christie has determined that this salt is a basic sulphate of copper, allied to, or identical with, brochantite. Captain Palmer expresses the opinion that the ultimate source of this copper salt is to be sought for in the Sylhet Trap, which crops out about a mile away.

## Engineering Questions.

**Sutlej River Hydro-Electric project.**

29. During December, 1920, and January, 1921, Mr. Fox examined the sites involved in the Sutlej River Hydro-Electric Project lying in Bilaspur State and the Hoshiarpur district of the Punjab, and also the Anu Khad (Subsidiary) Hydro-Electric Project in Suket State, with the object of reporting upon the geological stability of the sites of the engineering works contemplated. The principal work for the Sutlej River Project is the driving of a tunnel through the Naini Devi ridge in order to short-circuit the Sutlej and thus provide a head of water. The most advantageous alignment from the engineering point of view is from the Malauna bend (31° 16′ N.: 76° 37′ E.) of the Sutlej river to a point east of Paharpur (31° 15′ N.: 76° 35′ E.), where the tunnel will terminate in a surge chamber 200 feet below the surface. The main channel will be continued southwards first as a tunnel and then as steel pipes to the power-house site near Naki above Kirithpur, whence the waste water from the turbines will be returned to the Sutlej. The effective fall that will thus be provided is nearly 340 feet. The consideration of this case was complicated by the project to construct for irrigation purposes a great dam in the Bhakhra gorge[1] of the Sutlej, which, when built, will give a depth of over 180 feet of impounded waters in the Sutlej at the intake end of the proposed tunnel in the Malauna bend.

According to Mr. Fox, the alignment of the proposed tunnel is at right angles to the strike of the rocks: it traverses the Nahan beds (according to Dr. Pilgrim) forming the northern slope and crest of the Naini Devi ridge and the Dagshai beds forming the southern slope of the ridge. The general dip is to the N. E. Both the Nahan

[1] The site for this dam was examined by Mr Vredenburg in 1916—see *Rec. G. S. I.* XLVIII, p. 13.

and Dagshai beds consist of alternating sandstones and marls, the Nahans containing a higher proportion of sandstone than the Dagshais. After considering the details of composition, disposition and structure of the rocks, Mr. Fox concludes that it is only in minor works that any difficulties of a geological nature are likely to be met, and that no alignment could be selected in which the structural conditions are better and in which the engineering operations would be so simple.

**Anu Khad Hydro-Electric project.**

30. The Anu Khad (Subsidiary) Hydro-Electric Project is a proposal to harness the waters of the Anu Khad, a large stream tributary to the Sutlej in Suket State, 10 miles N. N. W. of Simla. Five possible water power schemes exist; and they were all visited and examined by Mr. Fox. This project is concerned with much older rocks than the Tertiaries of the Naini Devi ridge, *viz.*, massive limestones, slates, quartzites, conglomerates and epidioritic traps, divisible into two series, of which the upper is of Krol and Infra-Krol type, and the lower of the Blaini and Infra-Blaini type. Mr. Fox reports that in all the 5 schemes the geological aspects are favourable, except that in Nos. 4 and 5, certain, though not insuperable, difficulties exist. Otherwise, the relative merits of the various schemes depend upon engineering considerations relating to the power to be obtained, cost of construction, and convenience of approach.

## Graphite.

31. Rao Bahadur Vinayak Rao reports the existence of graphite near Onzon, E. S. E. of Thabeikkyin, in the Ruby Mines district of Burma. This graphite occurs as an irregular thin band some 3 to 4 inches thick along a fault line in decomposed granite, and appears to be associated with pegmatite. Other parallel bands of graphite have been found. The graphite is of good quality, and has been worked by Burmese enterprise for at least the past two years.

## Iron-ore.

**Singhbhum and Orissa.**

32. During the field season 1920-21, Mr. H. C. Jones continued his work on the iron-ore deposits of Singhbhum and Orissa, and completed the preliminary survey undertaken with the object of forming a minimum estimate of the total amount of iron-ore available. Amongst the deposits

visited may be mentioned Sasangda in Singhbhum; Katamati, Thakurani Buru, Barabil, Bolani, and Joda in Keonjhar State; the main iron-ore range in Bonai State; and the iron-ore bodies on the Kemsara and Mitiurda plateaus. He was helped in some of this work by Mr. C. T. Teychenné, who also examined an isolated group of deposits in the Gandamardan range west of Keonjharghar. As the result of the preliminary survey thus completed, Mr. Jones finds that the iron-ores are fairly evenly distributed between the Singhbhum district, Keonjhar State, and Bonai State.

The iron-ore usually occurs at the tops of hills or ranges of hills, but in Keonjhar State it is often found at low levels, and in some cases actually in the plains. The most important of these ranges of hills is the one that starts near Kompilai in Bonai State and continues in a N. N. E. direction to near Gua in the Singhbhum district, a distance of about thirty miles. This main range rises some 1,800 feet above the plains, and iron-ore averaging over 60 per cent. of iron occurs at the top of the ridge for practically the whole of the thirty miles. A few small breaks occur where the rock has not been replaced by hematite, but these are negligible compared with the total length. The rocks forming the range dip about 70° to 80° in a W. N. W. to N. W. direction, so that the width of the outcrop of hematite gives practically the thickness of the ore-body, which varies up to about 1,000 feet. No work has been done to determine the depth to which these ore-bodies extend, but, in view of their great length and breadth, it seems probable that they continue to a considerable depth. In making the estimates, however, in no case has a depth of more than 150 feet below the surface been taken into account, although, from differences of height, between the ore at the top of a hill and the ore exposed in stream-beds on the slopes of the hill, a depth of as much as 700 feet has been deduced.

The minimum quantities of ore of first quality containing not less than 60 per cent. of iron may be summarised as follows:—

| | Tons. |
|---|---|
| Singhbhum district | 1,074,000,000 |
| Keonjhar State | 806,000,000 |
| Bonai State | 656,000,000 |
| Doubtful (Bonai or Keonjhar) | 280,000,000 |
| Mayurbhanj State | 16,000,000 |
| TOTAL | 2,832,000,000 |

Concerning the nature of the ores, Mr. Jones reports that practically the whole of the ore is hematite, in which are occasionally found small octahedral crystals that are mainly martite. The high quality of the ore is indicated by the following figures representing the range of analyses shown by samples taken from four of the chief deposits held by the Tata Iron & Steel Co.:

| | Per cent. |
|---|---|
| Iron . . . . . . . . | 63·33 to 64·3 |
| Sulphur . . . . . . . . | 0·015 to 0·030 |
| Phosphorus . . . . . . . . | 0·058 to 0·088 |
| Insoluble residue . . . . . . | 1·12 to 2·49 |
| Manganese . . . . . . . . | Trace to 0·104 |
| Titanium . . . . . . . . | Trace |

**Chitral.**

33. Mr. Tipper records that hematite occurs in quantity in the quartzites of the Chitral Slate series half way between Sanoghar and Mastuj on the right bank of the Chitral river, where the talus slope consists of blocks of hematitic quartzite.

## Lead-ore.

34. The galena deposits examined by Dr. Murray Stuart, between the Fen-shui-ling and Lagwi passes, in the neighbourhood of Htawgaw, close to the Burma-China frontier, north-east of Myitkyina, occur in a zone at the junction between altered sedimentary limestones and tuffs. This zone is veined and partially impregnated with the lead-ore. In addition to this, there is at the contact a pegmatite carrying galena, pyrite and chalcopyrite. The silver content is low, being only from 5 to 10 ozs. per ton of ore. Veins of slightly cupriferous pyrite, frequently 10 feet and more in thickness, also occur, and occasionally carry subsidiary veinlets of galena.

The deposits are situated at an elevation of approximately 11,000 feet above the level of the sea, in a very bleak and inaccessible region, snow and frost-bound for a considerable part of the year. They possess no immediate commercial value.

## Manganese-ore.

35. Amongst the proposals of the Indian Industrial Commission was the addition to the duties of the Geological Survey of India of the work of periodical inspection of concessions of mineral rights belonging to Government, with a view to ensuring that the conces-

sions were being worked to the best advantage and without undue waste. Until the Department reaches full strength it will probably prove very difficult to give adequate effect to this proposal; but as an experimental measure, and at the request both of the Central Provinces Government and of the Central Provinces and Berar Mining Association, I made a tour, in April, 1921, through the manganese districts of the province with a view to examining the methods of work and suggesting possible directions in which improvements could be effected, and also with a view to advising the Local Government of the extent to which the lessees were complying with the general terms of the mining leases.

At each mine visited I made such geological examination as was necessary to enable me to unravel the structure of the mineral deposit and explain it to the manager. The large amount of development and excavation work that had been carried out since my tours of the manganese deposits made in the years 1903 to 1907, had revealed a much greater complexity of structure than could originally be deduced. The manganese-ore deposits appear to belong to a definite geological horizon in the Archæans. This horizon has of course been involved in the very complicated folding movements to which the Archæan rocks of the Central Provinces have been subjected. The consequence is that in the workings the ore-bed is often seen to be repeatedly folded, fold-axes having as a rule a marked pitch. The pitch of the fold-axes determines the direction in which a given body of ore will persist in depth and consequently the direction in which future work should be prosecuted. Failure to detect this pitch and to understand its effects had resulted in several cases in failure to realise the structure of the deposit, and the concessionaires had in many cases obtained surprising results in the way of discovering 'country' where ore was expected and *vice versa*. No serious harm had been done, but comprehension of the effect of pitch upon the ore-bodies should help the mining community substantially in planning future development.

Concerning the extent to, which the lessees were complying with the terms of their leases, it was found that in many cases no plans were being kept. Failure to keep such plans often results in unintelligent work and not infrequently in the loss of a portion of the mineral deposits available. It also results in the history of a deposit being lost should there be lack of continuity of management, as so often happens. The Local Government were therefore advised to direct the attention of the lessees to this particular requirement of their leases.

## Mercury.

36. Hitherto no undoubted occurrence of mercury or its ores has been recorded in any part of the Indian Empire. During his work in Chitral in the year under report, Mr. Tipper found that the sands of the Chitral river were in many places being washed for gold. As there is always a possibility of the occurrence of other rare minerals in such sands, a large sample of the concentrate was sent to Mr. Fox, the Curator of the Geological Survey of India, for examination. He found associated with the gold the following minerals: quartz, beryl, tourmaline, garnet, apatite, magnetite, ilmenite, zircon, pyrite, tetrahedrite and cinnabar, but no platinum or other metals of the platinum group. The occurrence of cinnabar in these sands is of great interest, and points to the existence of a deposit of this mineral somewhere in the State. Mr. Tipper intends to search for this mineral with great care during the present field season. Needless to say the discovery of a deposit of cinnabar would be of great economic importance to the State.

## Mica.

37. Certain occurrences of mica near Nweyon in the Mandalay district and near Chaunggyi in the Ruby Mines district were examined by Rao Bahadur Vinayak Rao. The mica, in all cases, occurs in pegmatite traversing the Archæan complex of gneiss, granite, chloritic and micaceous schists and marbles, that of Nweyon being amber-coloured, and of other occurrences either white, green, or dark-coloured. In no case was the mica seen large enough or abundant enough to be worth exploitation.

## Natural Gas.

38. During the year, the occurrence of natural inflammable gas at Jagatia, a small village lying about 8 miles to the N. E. of the town of Kodinar in the Amreli Prant of Baroda State in Kathiawar, was brought to the notice of this Department, and Captain Palmer was deputed to make an examination. Seven bore-holes had been put down at Jagatia by the Tata Engineering Company on behalf

of Baroda State, of which four, varying in depth from 76 to 185 feet, had yielded gas. The closed pressures, as measured by Captain Palmer, were found to range from 12·5 lbs. per square inch to practically *nil*. Samples from Jagatia had already been analysed by Dr. Watson of Bangalore with the following results:—

| — | JAGATIA. | | BARODA (DIWAN'S WELL). |
|---|---|---|---|
| | Dr. Watson. | | Dr. Christie. |
| | Per cent. | Per cent. | Per cent. |
| Methane . . . . . . | 97·5 | 98·0 | 94·2 |
| Carbon dioxide . . . . . . | 1·0 | 1·0 | *Nil* |
| Hydrogen . . . . . . | 1·5 | 1·0 | *Nil* |
| Nitrogen . . . | .. | .. | 5·15 |
| Oxygen . . . . | .. | .. | 0·65 |

The cores of 5 bore-holes were examined by Captain Palmer, and show that the surface miliolite of recent age is underlain by a series of horizontal marine Tertiary clays and limestones of very variable character; these Tertiary beds rest direct upon the Deccan Trap, which was reached at a depth of 185′ 6″ in bore-hole No. 3. The occurrence of an impure, soft, white nummulitic limestone at a depth of 620 feet in this bore-hole, is taken by Captain Palmer as indicating a Lower Tertiary (Khirthar) age for these marine beds. But as the nummulites have not been specifically recognised, this correlation must be accepted with reserve, particularly in view of the fact that all the known outcrops of Tertiary beds along the Kathiawar coastal area are of Gaj (Miocene) age or younger.

Captain Palmer is of the opinion that the gas is indigenous to the Tertiary beds with their blue and calcareous clays and carbonised plant remains, and that there are no prospects of finding additional gas supplies by deep boring at Jagatia owing to the proximity of the Trap to the surface. There are, in fact, no indications of the existence at Jagatia of a gas field of economic value, for the reservoir of gas cannot be large, whilst the gas is under no great pressure.

Immediately before Captain Palmer's departure to undertake this investigation reports of additional discoveries of gas in Baroda city itself were received. Baroda lies on a large alluvial tract, and none but recent rocks are exposed in the neighbourhood. In the hope of increasing the supply of water in three wells, borings were made in the bottom of each and in two cases pierced gas-bearing strata, from which, in one case, considerable quantities of gas were emitted. These two borings are situated respectively in the compound of the Diwan's bungalow and in the park of the Lakhshmi Villas Palace. Gas first issued from the Diwan's well on September 25th when the borings had reached a depth of 145 feet 6 inches from the surface. With an aperture-meter Captain Palmer attempted to measure the open-flow pressure of the gas; he obtained variable results, owing to leakages from the lining tubes, that indicated a flow approximating to 100,000 cubic feet per 24 hours. These leakages were subsequently stopped, and Mr. Dotivala, Assistant to the Director of Commerce and Industries, Baroda State, obtained results indicating a flow of about 85,000 cubic feet per 24 hours. The closed pressure was measured by Captain Palmer as amounting to 26 lbs. per square inch, but, owing to the leakages, this must be much below the truth. According to the rule often found to apply that the pressure of natural gas is that equivalent to the hydrostatic head, the closed pressure in the present case should be about 47 lbs. per square inch. The result of an analysis by Dr, Christie of a sample of gas collected by Captain Palmer is shown above.

In the Lakhshmi Villas Palace well, 82 feet deep, two bore-holes were sunk to 79 feet and 52 feet, respectively, below the bottom of the well, and both yielded gas. The quantity, however, was small, and according to a measurement by Mr. Dotivala, the closed pressure was only 2·5 lbs. per square inch.

Captain Palmer was not able to obtain from these borings at Baroda any reliable information concerning the nature of the strata underlying the alluvium. But from the occurrence of gas it may be deduced that Tertiary rocks similar to those of Jagatia underlie the alluvium of Baroda. A deep boring for water at Nimetha, 8 miles east of Baroda city, passed through 5 feet of soil, 41 feet of clays and sands (apparently alluvial) and 786′ 3″ of Deccan Trap.

The discovery of natural gas at these two localities on opposite sides of the Gulf of Cambay is probably one of considerable significance. The Gulf of Cambay is flanked to the east and west by land built of the Deccan lava flows, which are either horizontal or have only low dips. South of Broach, in Guzerat, and sporadically round the littoral of Kathiawar, Tertiary rocks overlie the traps and are themselves overlain by recent rocks, in consequence of which, it follows that the Tertiary rocks are much more widely spread than appears from the map. It is, in fact, a justifiable use of the scientific imagination to suggest that Tertiary rocks underlie large parts of the Gulf of Cambay, and that they also occupy large areas under the alluvium at the head of the Gulf, including the area under Baroda. It is, therefore, reasonable to conclude that, as gas has been proved to exist in concealed Tertiaries under Jagatia, the gas discovered at Baroda is also issuing from concealed Tertiaries.

The geological considerations advanced above indicate that in Tertiary times—Captain Palmer would say early Tertiary times—the geography of Kathiawar and Guzerat was very similar to that of the present time. Kathiawar was then a peninsula, with much of its present form, but smaller in area. The Gulf of Cambay was more extensive than now, so that its waters covered the area of Broach and washed the shore-line lying between Baroda and Nimetha. In this old gulf, clays, marls and limestones were deposited, and the vegetable remains, which were buried in these sediments, gave rise to the natural gas which is now issuing from the borings.

The conditions in the Tertiary Gulf of Cambay were, as far as we know, favourable to the production of petroleum, but the subsequent history of the area has left the old sea-bed relatively undisturbed, and, in the absence of structures favourable for the accumulation of oil, no borings for it seem justifiable. With gas, however, the case is different, for some of the gas-fields of the North American continent are situated in strata that are nearly horizontal. It is not impossible, therefore, that there is a gas-field of great value beneath Baroda city. It is also possible that the gas seepages in Baroda will fail after a few months, but this seems somewhat unlikely, as according to reports received four months after the initial discovery, the rate of flow of the gas has shown no decrease.

## Oil-shales.

39. The occurrence in the Amherst district of Burma of basins of Tertiary rocks containing oil-shales in the upper beds is noticed on page 53. Of these Tertiary basins only one, according to Dr. Cotter, lies entirely in British territory. The remainder lie

partly in Burma and partly in Siam, and are bisected by the Thaungyin river. The basins are as follows:—

(1) The Htichara basin, lying between Thingannyinnaung and Tawok, about 14 miles in length, and about 9 miles in width, traversed by the Mepale river, and entirely in British territory.

(2) The Phalu basin. This extends to about 10 miles south of Myawaddi, but lies mainly in Siam.

(3) The Mesauk-Mehtalaun-Melamat basin lying mainly in Siam, but extending westwards across the Thaungyin into Burma. It is not clear whether this is distinct from the Phalu basin or a northward continuation of it.

Of these three basins the Htichara basin is the most accessible, whilst it appears also to be the least disturbed; it is, therefore, to this basin that, in Dr. Cotter's opinion, attention should first be directed in testing the economic possibilities of the oil-shales. It would be premature to say anything regarding the prospects of working these shales. Dr. Cotter has, however, taken samples of oil-shale from various localities, and he hopes, as soon as the analyses are completed, to submit a full account of the economic geology of the area.

## Petroleum.

40. During August Dr. Cotter paid a brief visit to the Padaukbin oilfield in the Thayetmyo district, Lower Burma. The results of his observations are recorded in a paper appearing in this issue of the Records.

## Sulphides.

**Burma.**

41. Associated with the galena deposits of the Shweli-N'Maihka divide, already described under 'Lead', are veins of iron pyrites, containing a small percentage of copper pyrites. Although some of these veins are more than 10 feet wide, the locality is so remote from civilization and access to it so difficult, that the occurrence has no commercial value at present.

**Chitral.**

42. During his survey of Chitral, Mr. Tipper found numerous occurrences of sulphide minerals, the usual association being galena, zinc-blende, copper-pyrites, iron-pyrites, tetrahedrite, and jamesonite, in varying

quantities. The majority of the occurrences lie in the formation named by Sir Henry Hayden the Sarikol Shales. This formation is probably of Lower Carboniferous age, and is well exposed on the right bank of the Chitral river opposite Chanan and forms the ridge separating the Tirich valley from the main river. The Sarikol Shales continue on the same line of strike to the N. E., and have been followed continuously southward as far as the Barir. The formation may be separated into two divisions—an upper, mainly quartzitic, and a lower, mainly shaly with subordinate quartzitic bands. The folding has been intense, and complicated overfolds are very common: in addition, dip faults have complicated the structure. Two sets of intrusive rocks traverse this formation:—(1) a set of mica-peridotite dykes and (2) granitic dykes, of which the former are older. The Tirich granitic gneiss has also contributed to the modification of this formation in its southern extension. There seems to be little doubt that the mineralization has been almost wholly confined to the quartzitic portion, whether it be the more massive upper quartzites or the irregular quartzite bands of the lower division. In some localities, as, for example, at Zani Kap, two miles north of the village of Kushm, a small amount of excavation has been done in the search for purer patches of galena in the mineral veins, which at this place are banded, from 2 to 6 inches thick, and cut across the quartzites.

## Water Supplies.

**Baluchistan: Quetta.**

13. The question of increasing the water supply at Quetta, by sinking deep borings in the alluvial plain in search of artesian water at 500 to 1,000 feet below the surface, was referred to in the General Report for 1919 (*Records*, LI, p. 17). In 1920, Mr. Crookshank paid a brief visit to Quetta to advise on the selection of a site for an experimental deep boring to test the possibilities noted by Dr. Cotter in his report of 1919; two alternative sites were selected by Mr. Crookshank in consultation with the local authorities.

**Bengal: Chittagong.**

44. In order to provide a comprehensive water-supply to meet the increased requirements of the Assam-Bengal Railway at Chittagong, Pahartali, and Chittagong port, the Assam-Bengal Railway has under consideration the construction of a reservoir by placing an earth embankment

across the Gahur Nala in a catchment area enclosed by low hills to the north of Pahartali. This Department was asked to arrange for a geological examination of this site in order to ascertain its water-holding qualities. Sir Henry Hayden in 1906 reported on the water-supplies of Chittagong, and examined then the site of the proposed reservoir; he came to the conclusion that a large amount of water would be lost by percolation, and that a much better alternative measure would be to obtain a supply from artesian sources. The latter alternative was adopted, and the Municipality of Chittagong is supplied from this source at the present time. The Assam-Bengal Railway are now seeking for a supply of water additional to that obtainable from the Municipality, and, rather than sink additional wells to tap the same artesian supply, would prefer to construct the reservoir referred to. In view of Sir Henry Hayden's opinion on this site, the problem put before the Geological Survey was the determination of the upper limit of the possible losses by percolation. The additional supply of water required by the Railway is 185,000 gallons a day, whilst this reservoir, allowing for evaporation, but not for percolation, would give 740,000 gallons daily under the worst conditions. Thus, about 75 per cent. of the possible supply could be spared for percolation, or, say, 50 per cent. allowing for future requirements. The problem for solution is, therefore, whether the loss by percolation is likely to amount to anything like 370,000 gallons a day. Although the problem is really an engineering one, yet Mr. E. L. G. Clegg was deputed to visit Chittagong and see if a solution was possible. Owing to the thickness of the jungle, the geology was for the most part obscured, but sufficient was seen to show that the hills are composed of soft friable Upper Tertiary (Siwalik) sandstones, with alternating bands of shale, and occasional thin limestone bands dipping in an E. by S. direction at low angles (10°). The soft sandstone is the predominant rock, and one in which a large amount of water will be lost by percolation. Owing to the low dip of the strata and the presence of impervious shale bands, a fair quantity of water lost by percolation in the upper portions of the catchment area during the rainy season, is recovered in the lower portions of the catchment area from springs which contribute in the dry season to the perennial streams. From this Mr. Clegg deduces that some idea of the amount of percolation that takes place may be obtained by measuring the quantity of water flowing from the catchment area during the dry season. Corrections must be made, of course, for flood waters due to rainstorms during the dry season. Based on this idea, Mr. Clegg has devised a formula for determining the loss of water by percolation; the utilisation of this formula depends upon the actual determination of the run-off during the wet and the dry season separately and the determination or assumption of the losses due to evaporation. Until these data have been ascertained, it is of course impossible to give a definite answer to the problem propounded, and the railway authorities have in consequence been advised to take immediate steps to determine the run-off experimentally.

**Berar : Amraoti.**

45. Owing to the increasing inconvenience caused by the very deficient rainfall at Amraoti in Berar in 1920, it was necessary in the early part of 1921 to give further attention to the possibility of effecting an improvement in the water-supply of this town. A summary of Mr. Fox's conclusions concerning the possible methods of improving the water-supply of Berar in general and of Amraoti in particular is given on page 14 of the General Report of 1920. None of the measures there suggested, however, would, even if successful, lead to any early result. Amraoti is situated partly direct on the Deccan Trap and partly on alluvium overlying the Deccan Trap, and many of the wells obtain their water direct from the decomposed upper portions of the Trap. As each basalt flow has a vesicular surface, I raised the question whether the surface of each successive flow was not likely to be water-bearing and thus provide a freshwater stratum every 50 to 100 feet, according to the thickness of the flows, and as long as access of water from the surface to the various flows was possible. With such a possibility it seemed desirable to prepare a geological map of Amraoti, showing each flow separately, similar to the map prepared some years ago by Mr. Fox and myself of the Linga tract in the Chhindwara district. Mr. Fox, therefore, revisited Amraoti in 1921 and prepared such a detailed map, in particular of the quadrant to the S. E. of Amraoti, where the rocks are best exposed. The result of his work has been to establish definitely the following points :—

(1) The water obtained in wells sunk into the Deccan Trap is derived either from the decomposed upper portion of the trap, or more usually from the porous horizons marking the junction of each pair of flows and composed

mainly of the vesicular surface of the underlying flow, but also to a small extent of the somewhat vesicular and decomposed base of the overlying flow.

(2) It follows from (1) that the non-vesicular and hard portions composing the interior of each flow must be regarded as relatively impervious to water, except for fissures and joint planes.

(3) The flows at Amraoti have been thrown into gentle corrugations aligned W. by S. to E. by N., with an average difference of about 40 feet between crest and trough.

(4) The whole mass of flows has a very gentle tilt to the W. N. W., which Mr. Fox estimates as ranging from 1° to 2°. 1° corresponds to a fall of 92 feet per mile. Judging from Mr. Fox's map, however, this is too large a figure to use over any distance, and the best figure to use would be 40 feet $\pm$ 10 feet per mile.

With this knowledge it is possible to explain the apparently capricious differences between existing wells, some of which provide a relatively abundant supply of water, whilst others are very disappointing. Based on this work, Mr. Fox recommends that should it be desirable to sink any further wells, the sites should be selected as close as possible to the axes of the troughs as demarcated upon his map, provided that any such sites can be found that are not nearer than, say, 500 feet to any existing wells on or near the trough axis; otherwise the additional supply yielded by such fresh wells will be in part neutralised by a decrease in the supply from the adjoining wells.

**Bihar and Orissa: Dhanbad.**

46. To meet a request from the Governing Body of the projected Indian School of Mining and Geology, Mr. Clegg was asked to visit the School site and report on the possibilities of obtaining an adequate water-supply. The site is on high ground on the Govindpur road, $1\frac{1}{2}$ miles N. E. by N. of Dhanbad railway station. A survey of a few square miles of country showed that the rocks in the vicinity of the School site are all crystalline, consisting of various types of biotite-gneiss, with schists (hornblende, and quartz-felspar), amphibolitic intrusives, and fault-breccias. The gneiss, which is the principal rock, strikes N. W., and is traversed by parallel bands of fault-breccias with a similar strike, the breccias cutting both

the gneiss and the amphibolites. From a comparative study of the rocks and of the existing wells at Dhanbad, Mr. Clegg considers that, given a proper selection of sites, adequate supplies of water should be obtainable by means of wells, partly from the decomposed gneiss, and partly from the dykes of fault-breccia. At the site selected for the first well Mr. Clegg recommends sinking on the gneiss close to a dyke of fault-breccia to a depth of 100 to 120 feet from the surface, and then, if a sufficient supply of water has not been obtained, driving galleries from the base of the well in N. E. and S. W. directions, *i.e.*, at right angles to the strike, in order to intersect the joint planes and fault-breccias. Mr. Clegg anticipates that a deep well sunk at the point selected will yield a water supply of about 15 gallons per minute or 21,600 gallons per day.

**Bombay: Salsette Island.**

47. During his investigation of the geology and mineral resources of Salsette Island, Mr. K. A. K. Hallowes also considered the question of improving the existing water supply of the island. The geological structure is such that there is no hope of obtaining an artesian supply, whilst absence of porous intertrappean horizons precludes any hope of success from deep boreholes into the trap. Mr. Hallowes suggests that the present supply might be slightly improved by deepening many of the wells which have been sunk into the decomposed upper layers of the trap. This deepening would have the effect of opening up more of the porous layers and also give increased storage. The deepening should not be undertaken where there is a possibility of allowing the inflow of salt water, as on the coastal flats or on the shell concrete. The real solution, according to Mr. Hallowes, lies in the construction of storage reservoirs. Several suitable sites are described in his report.

**Rajputana: Jodhpur-Bikanir Railway.**

48. During the early part of field season 1920-21 on account of a proposed change of gauge of the Jodhpur-Bikanir Railway which would necessitate an increased comsumption of water, Mr. G. H. Tipper examined the present supply available to the railway between Luni junction and Khokropahar. This line of country, running almost east and west, is of varied character geologically. Climatically it is arid and largely buried under subaerial deposits. In the report submitted by Mr. Tipper, which does not lend itself to summarisation, he has made suggestions for experimental work

which may lead to an increased supply at different points on this part of the line.

**Jodhpur City.**

49. While in Jodhpur, Mr. G. H. Tipper examined and submitted a brief report on the borings undertaken by the Jodhpur Durbar to test the water carrying capacity of the Vindhyan sandstones forming the high ground to the north of Jodhpur city. The experimental work connected with these borings is still in progress.

## Wolfram.

50. During his survey of Jodhpur State, Mr. Tipper, accompanied by Mr. Crookshank, made a further examination of the Rewat Hill near Degana railway station, an account of which has already been given by Sir Henry Hayden.[1] Mr. Tipper has submitted a report with more details than were previously obtainable. Rewat Hill is composed almost entirely of gneissose granite, which has been intruded into dark-coloured schists. From a study of the workings, in which wolfram is still visible, Mr. Tipper concludes that apparently wolfram is developed only in those quartz-veins that carry mica, and are either in or close to the gneissose granite. He notes also that the alluvial deposits surrounding the hill contain a considerable amount of wolfram, which, as is well known from experience in the moist climate of Tenasserim, is a mineral that breaks up easily and disappears readily in the ordinary process of weathering. These natural processes are reduced to a minimum in such a locality as Rewat Hill, and the wolfram has therefore remained. Mr. Tipper records the presence in the wolfram workings of fluorite, and of a composite phosphate, to which the name 'triplite' has been given; whilst liebethenite has been noticed on one specimen. One specimen of fluorite picked up on the south side of Rewat Hill gave reactions for tungstic oxide, bismuth and uranium, and Mr. Tipper suggests that it is possible that the two latter metals are combined to form the mineral uranosphaerite.

## GEOLOGICAL SURVEYS.

**Assam : Khasi Hills.**

51. Captain R. W. Palmer devoted the entire field-season of 1920-21 to the survey of some 600 square miles of the Khasi Hills lying to the west of

[1] *Rec. G. S. I.*, XLVII, p. 26.

Cherrapunji, thus connecting up the work of Medlicott on the east to that of La Touche and Bose further west. The area surveyed consists largely of the plateau country, but includes a strip of low ground at the southern foot of the plateau. On account of the heavy rainfall, generally regarded as the largest in the world, and of the sudden fall of the plateau on its southern edge, the intensity of erosion in these hills is very great, resulting in the formation of deep canyon-like valleys with plateau remnants between. On account also of this heavy rainfall, the valleys are filled with almost impenetrable jungle, and for this reason, combined with the high topographical relief, the tracing of exact geological boundaries is a matter of impossibility, and it is necessary in many cases to select their positions on the map from a general knowledge of the disposition of the rocks. In his survey Captain Palmer encountered all the rock series met by Medlicott in the Cherrapunji tract, with the exception of the Shillong series.

The Assam plateau is an ancient land mass, composed in the area mapped by Captain Palmer entirely of igneous rocks. In the north of this tract it is built of gneiss and granite, and in the south of a massive series of lava-flows named by Medlicott the Sylhet Trap, and considered by some to be equivalent to the Jurassic Rajmahal Trap and, in any case, to be earlier than Upper Cretaceous in age. These lavas, with the gneisses and granites, formed in pre-Cretaceous times the north-eastern corner of the great continent now represented by the Peninsula of India. In Cretaceous times, according to Captain Palmer, this land mass became slowly submerged, due to a transgression of the ocean from the south, and a carpet of sedimentary rocks was laid down upon the igneous sea-bed. Deposited in a transgressive sea, the Cretaceous rocks thin to the north, and are conformably overlain by nummulitic limestone with a somewhat similar distribution. In the case of the latter rocks, the marine limestones in the south show signs of passing northward into estuarine fragmentary deposits in which beds of coal are frequently developed. The nummulitic rocks are in turn conformably overlain by a series of later Tertiary sands and clays, the age of which is not at present ascertainable, as the only organic remains discovered in them are indeterminable fragments of rotten wood. In the area with which Captain Palmer's report deals, the post-nummulitic rocks are confined to the foot of the plateau. In the north of the area surveyed sedimentary rocks lie undisturbed on the plateau, but in the south they are bent down in a monocline and sink beneath the alluvium of the plains. The steep southern edge of the plateau is in general the dip slope of the bent Cretaceous rocks, and the foot-hills are built of the basset edges of the overlying Tertiaries. Captain Palmer describes in some detail the composition of the rocks composing the various formations and their relationship one to another. The detailed observation of the distribution of the Cretaceous rocks in particular and their relationship to the underlying rocks affords ample evidence of this transgression of the southern ocean postulated by Captain Palmer. The evidence indicates, in addition, that there was a pause in the period of transgression before the higher portions of the plateau were finally submerged, as the result of which Cretaceous outliers are to be found both on the hill-tops and in the pre-Cretaceous valleys.

Although Captain Palmer has not attempted to sub-divide the Tertiary rocks overlying the nummulitics, yet they are roughly divisible into a lower series, about 5,000 feet thick, of clays, and an upper series, some 10,000 feet thick, in which sandstones predominate. The lower series is, according to Captain Palmer, probably to be correlated with the coal measures of Upper Assam, and the upper series with the Tipam group.

Three oil seepages were visited, and, according to Captain Palmer, they lie near the summit of the lower series corresponding to the coal-measures of North-Eastern Assam; Captain Palmer suggests that they indicate the existence of an extensive and probably rich oilfield. The oil is seeping out, however, from the broken ends of a monocline, and the emission of gas suggests that this oil is being forced up the steeply dipping strata by the pressure of gas accumulated in a dome of oil-bearing strata underlying the alluvium of the Sylhet plains. This oil-field, Captain Palmer thinks, must be regarded as inaccessible, for it is overlain by both alluvium and the Tipam series, and even should the difficulty of its great depth not prove insuperable, there would still remain the difficulty of locating the exact situation of the oil-dome.

At the end of his progress report Captain Palmer indulges in an interesting speculation concerning the origin of the faunas in the Cretaceous and Tertiary rocks of Assam. According to him, the Shillong plateau consists of two distinct elements. There is the Peninsular element consisting of gneiss and granite (with the pre-Cambrian Shillong series), the lava flows of the Sylhet Trap, and the overlying Cretaceous rocks with a faunal affinity to the Cretaceous of South-Eastern India. Above these is the Himalayan element of Tertiary rocks.

The Shillong plateau is the north-eastern corner of Peninsular India, from which it has been cut off by the subsidence of the Ganges valley area; to the north it is bounded by the recently elevated Himalayan region.

The great southern ocean of Cretaceous times was bounded on the north, according to Suess, by a shore-line stretching from the Cape of Good Hope to Cape Comorin and then north-eastward to Assam. This ocean swelled up over the land in Cenomanian times, and it is possible that the Cretaceous rocks of the Khasi Hills were deposited during some such great transgression.

While the southern Cretaceous ocean was flooding the highlands of Assam, the Tethys, with a distinct fauna, was extending its range eastwards from the region of the Gulf of Cambay. When the nummulitic fauna had been born and established in the Tethys, tectonic movements brought its waters into communication with the Assam gulf of the southern ocean. The geographical change that mingled the waters of the two seas brought about a change in the nature of sedimentation. The sea-bed was undisturbed in the Assam region, but limestones were formed on it in place of sandstones. The nummulitic fauna replaced the Cretaceous by invasion, and by this invasion Captain Palmer explains the occurrence of a faunal break between the Cretaceous sandstones and the overlying conformable nummulitic limestones. According to Captain Palmer, these deductions follow logically from the facts of the geographical distribution of the nummulites, which were evolved in and confined to the ancient Tethys, so that the very fact of nummulitic rocks being found in Assam shows that the Tethys ranged into that province. This speculation of Captain Palmer involves as a corollary the extension of the Tethys to Burma, where nummulitic rocks are also found.

In his account of the physical features of the Khasi Hills, Captain Palmer draws special attention to the straightness of many of the river valleys, which can be seen at once from an inspection of the new contoured one-inch maps of this portion of Assam, in particular from sheet No. 78·0-7. In one case, Captain Palmer is able to show that three different river valleys occupy in turn a faulted boundary between gneiss and granite for a total distance of 6 miles. In other cases it is demonstrable that straight valleys are attributable to straight master joints in the overlying Cretaceous sandstones, and that denudation has pursued its course along such joints down into the underlying gneiss or granite.

**Bihar and Orissa and Central Provinces Party.**

52. During the field-season of 1920-21, the Bihar and Orissa and Central Provinces Party consisted of myself (in charge), Messrs. H. C. Jones, C. T. Teychenné, E. L. G. Clegg, and Sub-Assistant Durgashankar Bhattacharjee recently promoted from the rank of Field-Collector. My own time was divided between a continuation of the survey of the Sausar tahsil, Chhindwara district, a visit to Amraoti in connection with water-supplies (see page 33), and a visit of inspection to the manganese mines of the districts of Chhindwara, Nagpur, and Balaghat (page 24). Whilst awaiting my arrival in the field, Messrs. Clegg and Bhattacharjee went to Linga and studied the Deccan Trap lava flows with the aid of the detailed map prepared some years ago by Mr. Fox and myself. Subsequently they joined me in the Sausar tahsil for initiation in the methods of work applicable to local geology, before being assigned separate areas for independent work in the Nagpur district. Mr. Jones continued his examination of the iron-ore deposits of Singhbhum and Orissa, and also undertook the initiation of Captain Teychenné into Indian field-geology. Captain Teychenné was subsequently assigned independent work in the estimation of quantities of iron-ore in portions of Keonjhar State. His figures have been incorporated by Mr. Jones in the totals summarised on page 23.

**Bihar and Orissa: Singhbhum.**

53. Reference has already been made in the two preceding General Reports to the geological results obtained by Mr. H. C. Jones during his survey of the iron-ore deposits of Singhbhum and Orissa. Important additional information obtained this year makes it necessary to refer to previous work in this part of India. The tract on which Mr. Jones bases his geological results is the part of the Kolhan estate in Singhbhum lying to the south of the area represented by V. Ball in his map published in 1881 in Vol. XVIII of the *Memoirs of the Geological Survey of India;* to the south also of Ball's area lie, it is interesting to note, all the valuable iron-ore deposits. Ball grouped under the term 'sub-metamorphic'

all the slaty and schistose rocks of Singhbhum, including the slaty shales that are found further south to be associated with the iron-ore deposits. J. M. Maclaren, in his survey of the gold deposits of Chota Nagpur[1] in 1903, decided on lithological grounds that these sub-metamorphic rocks could be correlated with the Dharwars of Southern India, and applied to them the term Dharwarian.

This correlation was accepted by myself as a probable one during my visits from time to time to scattered mineral deposits in various parts of Singhbhum, and in my Presidential Address to the Geological Section of the Indian Science Congress at Bombay in 1919, I put forward the following general classification of the Archæan rocks of Chota Nagpur :[2]—

(1) Oldest gneisses and granites, not yet certainly identified.
(2) Dharwar sediments and contemporaneous lavas.
(3) Oldest gneisses re-melted—now post-Dharwar and probably forming a considerable portion of the 'fundamental gneiss.'
(4) Post-Dharwar intrusives—
 (*a*) Peridotites and other ultra-basic rocks.
 (*b*) Granites and pegmatites.
 (*c*) Epidiorites (altered dolerites and gabbros).

The rocks regarded by me as Dharwars in the Kolhan to the west are, however, markedly less metamorphosed than those of Dhalbhum to the east; but I ascribed the difference as due to a decrease in the intensity of metamorphism on passing from east to west. During the year under review, however, Mr. Jones has discovered indubitable evidence that two distinct sedimentary series have been grouped under the term Dharwars, for at Jagannathpur south of Chaibassa, what he describes as the Iron-ore series is seen resting unconformably upon the upturned edges of schists and quartzites, to which it may now be necessary to restrict the term Dharwar.[3]

[1] *Rec. G. S. I.*, Vol. XXXI, p. 70.
[2] *Proc. As. Soc. Beng.*, Vol. XV, p. clxxvii.
[3] Mr. E. Parsons, Geologist to Messrs. Villiers, Limited, also states that the Iron-ore series is later than the Dharwars and gives a succession for the Iron-ore series similar to that worked out by Mr. Jones. See 'Indian Iron-ores,' *Mining Magazine*, XXVI, Jan. 1922, pp. 9-13.

According to Mr. Jones, the composition of the Iron-ore series is as follows :—

(1) Newer slaty shale
(2) Banded hematite quartzite } A great thickness of each.
(3) Older slaty shale
(4) Purple and pale-grey limestone (40 feet).
(5) Basal sandy conglomerate[1] (60 feet).

According to Mr. Jones, the position of this Iron-oreseries lies between groups (3) and (4) of my classification. After the deposition of the rocks of the Iron-ore series upon the upturned and denuded edges of the Dharwars, the granite of Central Singhbhum was then intruded into the whole, but this granite seems, as a rule, to have raised and folded the rocks of the Iron-ore series rather than to have penetrated them; but in places the lower beds of the series have been penetrated and absorbed by the granite. This penetration was followed by a period of basic intrusions mainly as dykes in the granite, but to a less extent in the Iron-ore series. There are also large quantities of interbanded basic igneous rock in the Iron-ore series, some of which is apparently contemporaneous and some later. Ash-beds have also been found in the interbanded basic rocks. There is evidence of more than one period of basic intrusion, whilst intrusions of ultrabasic rocks have also been found. These intrusions of igneous material were accompanied by, or followed shortly by, folding and faulting of the Iron-ore series on a very extensive scale. Near the granite south of Chaibassa, the rocks of the series have a general N. N. E to S. S. W strike, and are gently folded. Towards the west, however, the dips become greater, and the rocks have been very much folded and faulted. This faulting is well seen near Lipunga, and a strike fault apparently runs along the whole length of the east side of the main iron-ore range. The rocks to the west of the fault have a very steep dip in a westerly direction. In the north part of the range the banded hematite-quartzites and associated iron-ore bodies have a general N. N. E. to S. S. W. strike, and dip at about 70° to W. N. W.; towards the south the strike becomes nearly north and south with a similar high dip to the west. The hematitic iron-ore bodies are associated with the

[1] The presence of a conglomerate quartzite at Amdiha between Saraikela and Dugni, and north of the area examined by Mr. Jones, may now find an explanation. See Ball, *Mem. G. S. I.*, XVIII, p. 127.

hematite-quartzites, forming division 2 of the Iron-ore series. Concerning the origin of these enormous bodies of iron-ore, Mr. Jones is not yet prepared to give a definite opinion, but he has evidence indicating their origin as a replacement product in the banded hematite-quartzites and to a much smaller extent in the shales underlying and overlying the quartzite. Notes on the magnitude of the ore-bodies and the quantities thereof are given on page 23. Concerning the relationship of the Iron-ore series to the Cuddapahs, Mr. Jones has recorded the presence above the newer slaty shale division of the Iron-ore series of a conglomeratic breccia, which he refers tentatively to the Cuddapahs (*Rec. G. S. I.*, LI, p. 18), thus treating the Iron-ore series as pre-Cuddapah. But this view cannot be confirmed until the geological survey is undertaken of the ground intervening between the portions of the Kolhan already mapped and the tracts mapped as Cuddapah in Gangpur State to the west and Bonai State to the south-west. The intrusive relationship of the rocks of my division (4) to the Iron-ore series tends, however, to support the view that the Iron-ore series is Archæan and pre-Cuddapah in age. Should further work confirm this view, it will then be necessary to decide whether the term *Dharwar* should remain restricted to the lower division, as is at present proposed, or whether these rocks should be treated as Lower Dharwars and the Iron-ore series as Upper Dharwars in accordance with the view that the term *Dharwar* should be used in a comprehensive manner for all the stratified rocks lying below the Eparchæan unconformity, as is in fact the practice in Mysore.[1]

**Central Provinces: Chhindwara district.**

54. During February and March, I was able to devote about $1\frac{1}{2}$ months to the continuation of the geological survey of the Sausar tahsil of the Chhindwara district. As in previous years, the formations mapped included alluvium, Deccan Trap, Infra-trappeans and Archæans, and the general results obtained confirmed work previously done. A study of the edge of the Deccan Trap south of Sausar and west of Lodhikhera led to the discovery of a number of normal faults ranging in strike from E. 40° S. to E. 10° N. It would prove exceedingly difficult and probably impossible to trace these faults to any distance westwards through the Deccan Trap country, but it is perhaps significant that the region of faulted

[1] *Mem. G. S. I.*, XXXVII, p. 1120 (1909).

country north and south of Sausar is on the strike of the great Ellichpur fault in Berar. Three small basalt dykes of Deccan Trap age were also discovered.

As usual, the infra-trappean rocks were found to consist partly of true sediments (argillaceous sandstones, clays and conglomerates), and partly of siliceous rocks and limestones formed by the chemical replacement of these sediments or of the Archæan rocks, whichever the Deccan Trap happens to rest upon. Near Borgaon a Lameta conglomerate, which has escaped replacement, contains pebbles and boulders, up to a yard in diameter, mainly of Archæan gneisses and granites in a matrix of argillaceous sandstone. One pebble, however, was composed of a dark limestone of Cuddapah aspect and another of a graphitic phyllite. As neither of these rocks have been observed *in situ* in this part of the Central Provinces, this discovery indicates that these conglomerates are not always of local origin, and suggests the remote possibility that, instead of belonging to the Lameta series, they may possibly constitute an outlying patch of Talchirs. The nearest known occurrence of rocks of Talchir age is at Koda Dongri 20 miles to the S. E. in the Nagpur istrict. Near Jamlapani, about 2 miles west of the conglomerate of Borgaon, is an exposure of conglomerate of which both pebbles and matrix have been completely converted by replacement into limestone, except for an occasional pebble of vein quartz and some of the sand grains of the matrix.

In the area mapped this year a large proportion of the Archæan tract is obscured by the alluvium of the Kanhan and Jam rivers, in consequence of which, the outcrops of Archæan rocks tend to be isolated. The prevailing strike over most of this tract is W. N. W. with a swing round to E. N. E. near Satnur in the south. Evidence of repeated isoclinal folding with a general dip to the S. W. quadrant at angles of 30° to 90° was obtained.

Amongst the varieties of rocks noted were biotite-gneisses, dolomitic and calcitic marbles, and calc-gneisses, of the types discussed in previous Annual Reports. In addition, the following rocks were seen :—biotite-schists, garnet-granulites, garnet-pyroxene-labradorite rocks, various amphibolitic rocks, gondites, and a very acid gneiss with associated 'microcline-quartzite.' Of these rocks the biotite-schists, which are seen sparingly from Jamgaon to Lodhikhera, are composed practically entirely of biotite, and may be regarded as a basic facies of the coarse-grained schistose biotite-gneiss so common in this tract. The garnet-granulites are abundant in the belt stretching from Waghora to Lodhikhera and frequently give rise to tor-like outcrops. They are of leucocratic composition and often quite free from biotite. Curious banded garnet-pyroxene-labradorite rocks occur near Khairi (N.), Lodhikhera and Satnur; some bands are composed of pyroxene (green) and felspar, whilst others, carry also garnet, fringing the pyroxene and evidently the product of a reaction between the pyroxene and felspar. These rocks are considered to belong to the amphibolitic suite. Amongst numerous additional occurrences of the gondite series the most interesting was in a small nala W. S. W. of Savarni, where nodules and lenticles of gonditic rock were found enclosed in a schistose muscovite-gneiss; the gneiss is probably a crushed form of the porphyritic gneiss of this area that has broken up the pre-existing gonditic band. But the most remarkable discovery was of a suite of acid gneisses and 'microcline-quartzites' seen specially well-developed in the mass of hills S. E. of Lodhikhera (Lodhikhera-Sangam hills), where these rocks are folded into a syncline. The central band simulates a quartzite. Under the microscope it is seen to contain also microcline and grains of a curious green tourmaline. In places the rock has escaped crushing, and then resembles vein-quartz. That it is of igneous origin is shown by the fact that it is overlain and underlain by a gneissose granite containing abundant pink microcline, similar green tourmaline and a black ore. Rocks belonging to the same suite occur also in the hillocks between Khairi (S.) and Borgaon. It must be here remarked that with the possible exception of the quartzose bands interlaminated with the gonditic rocks, sedimentary quartzites have not yet been found in the Sausar tahsil.

**Nagpur district.**

55. In the two months of the field-season still remaining after leaving my camp, Messrs. E. L. G. Clegg and D. S. Bhattacharjee mapped portions of the plains tract of the Ramtek tahsil of the Nagpur district on sheets 55 O/3 and O/7 south of latitude 21° 25′. They first made a joint examination of the Pench river section from the junction with the Kanhan northwards as far as Maholi. Thereafter Mr. Clegg mapped the country west of the Pench as far as the Kanhan river, the eastern boundary of the ground mapped by Dr. Cotter in the previous field-season; meanwhile Mr. Bhattacharjee mapped the tract east of the Pench as far as the Gahtalab-ka-Sand nala, south of Ramtek.

The whole of this tract consists mainly of the older alluvium at the surface, with strips of the newer alluvium in places along the river-beds, and with scattered inliers of Archæan rocks cropping out in the stream-beds and forming hills protruding through the alluvium. The types of rock found were chiefly those already seen in the Sausar tahsil *i.e.*, calc-gneisses, marbles (calcitic and dolomitic), amphibolites, manganese-ore and associated gonditic rocks, with biotite-gneisses and pegmatites. In addition, there are numerous outcrops of quartzites, forming prominent hills at Kothulna, Bhagimahari, and Parseoni, in the area mapped by Mr. Clegg. These quartzites, according to Mr. Clegg, usually show muscovite and felspar in varying amounts, a fact that suggests that some at least of these quartzites are of igneous origin and, therefore, analogous to the tourmaline-microcline-quartzites of Lodhikhera in the Sausar tahsil (see page 45). Small exposures of quartz-iron-ore rocks were noticed at Maholi and Gundri in Mr. Bhattacharjee's area.

Both workers paid careful attention to such structural information as could be obtained from scattered outcrops. In my own ork I had become much impressed with the great importance of recording the pitch of the fold axes in the Archæan rocks if the structure and sequence thereof was to be successfully unravelled. The grooving and striation in various types of Archæan rocks referred to in my memoir on the manganese-ore deposits of India as 'slickensides-grooving,' the full significance of which I did not at the time realise, proved later to be a visible record of the pitch of the folding. Consequently, I asked Messrs. Clegg and Bhattacharjee to record on their maps the pitch as thus indicated. Throughout the area mapped, the strike of the folding averages east and west with local variations at the termination of folds. East of the Pench the pitch of the folds, as recorded by Mr. Bhattacharjee, is easterly at an average angle of about 30°. West of the river also the general direction of pitch is easterly, but Mr. Clegg records a subsidiary western pitch shown by the calc-gneisses west of the hills of Nimbha and Sakaria and in the Chicholi hills. Faults demarcated by fault-breccias are mapped by Mr. Clegg in the Bhagimahari hills and by Mr. Bhattacharjee near Gundri and Nandgaon. On account of the preliminary nature of their work and the discontinuity of outcrops, both geologists hesitate to dogmatise concerning the sequence of rocks and structure of the area mapped, but they realise that their results tend to indicate a sequence the reverse of that worked out by me in the Sausar tahsil. In Dr. Cotter's area also, to the west of the Kanhan, which is directly on the strike of Mr. Clegg's ground, the scattered nature of the Archæan exposures made it impossible to work out the sequence, but suggestions were obtained of a reversal of the sequence determined by me in the Sausar tahsil, *i.e.*, in ground lying to the north of the tract mapped by Dr. Cotter. Judging from such scattered observations as I have myself been able to make from time to time (*e.g.*, round Junawani and Chorbaoli) in the hilly tracts of the Nagpur district north of the plains tract mapped by Messrs. Clegg and Bhattacharjee, the Sausar sequence will probably be found to persist eastwards into these hilly tracts.

We shall then be forced to seek for an explanation of the occurrence of one sequence of Archæan rocks in the folded northern belt of hilly country and of the reverse sequence in the folded southern belt of plains country. If we assume that the sequence of the northern belt is the normal one, then the structure of the southern belt can only be explained if we assume the existence of dissected recumbent folds of the Alpine type. Both Mr. Clegg and Mr. Bhattacharjee are to be congratulated on the careful detail that they have put into their first season's work. Mr. Bhattacharjee's skill as an artist seems likely to be helpful to him in his mapping.

**Bombay and Rajputana Party.**

56. During the field-season 1920-21, the Bombay and Rajputana Party consisted of Mr. G. H. Tipper Superintendent in charge, Messrs. K. A. K. Hallowes and H. Crookshank.

**Bombay: Salsette Island.**

57. To meet a request from the Government of Bombay Mr. K. A. K. Hallowes was deputed to study the water-supplies and building stones of Salsette Island, north of Bombay. As an aid to this work, he completed a geological survey of the island. As was already known, he found that the major portion of the island is composed of basaltic flows belonging to the Deccan Trap of Western India. The dip of the flows is gentle, varying from 8° to 10° in a direction almost due west. In the east of the island these flows reach a height of almost 2,000 feet. Associated with the Traps are intercalated layers of brecciate materials regarded by Mr. Hollowes as ashes and agglomerates. At Kanheri these materials form a wedge-shaped mass approximately 900 feet thick, and

in them have been excavated the Buddhist caves. From the size of the included masses of basalt, and other points, Mr. Hallowes concludes that this mass of volcanic debris must have accumulated close to some focus of eruption. Mr. Hallowes, however, identifies his 'ashes' with Wynne's 'trappean breccia' of Sion Hill, Bombay Island; Wynne has not expressed any definite opinion on the origin of this braccia, but Mr. Fox (see p. 125) agrees with Dr. Carter that this braccia is due to intrusion. The determination of which of these opposed views is correct must be left to the future.

Intertrappean deposits are rare, such as are found being non-porous and unfossiliferous.

Dolerite dykes of varying sizes cut through the traps and are particularly common in and around the Vehar Lake.

Mr. Tipper inspected the work in Salsette during March.

**Rajputana: Jodhpur (Marwar) State.**

58. Mr. G. H. Tipper's time was occupied in inspecting mineral occurrences in the State to enable the Durbar to form some estimate of the value of its mineral resources. An attempt was, however, made to map a portion of the Aravalli range which occurs within the boundary of the State. At the end of December 1920 Mr. H. Crookshank, who had been recently appointed an Assistant Superintendent, joined Mr. Tipper for instruction and remained with him until the end of January 1921.

The area surveyed is comprised in sheets 165, 166, 167 of the Rajputana Survey. That portion of the Aravalli range lying in Marwar comprises a narrow strip of varying width on the western edge of the range, the breadth of the strip varying from two to twenty miles. Being limited by the nature of his main enquiry to the boundaries of the State, Mr. Tipper's mapping is mainly lithological. It is hoped, however, that it will be of assistance as a basis for future work.

The main structural feature is a narrow anticlinal ridge, running almost N. and S., within which the lowest beds exposed are comparatively soft biotite-schists. The western limit is a succession of calc-gneisses, amphibolites, marble and phyllites arranged in regular bands. Above these, is a band of crushed conglomerate, of which the pebbles, in a schistose matrix, consist chiefly of quartzite; but other pebbles composed of various types of gneiss are also present. These pebbles are now, from crushing, elongated and pointedly ovoid in section, but there seems, in Mr. Tipper's opinion, little doubt that the rock was once a true conglomerate. Separated from the main ridge by a broad mass of schist with almond-shaped knots of quartz and sillimanite is a subsidiary ridge of crystalline limestone exhibiting complicated folding. Where first met with the limestone is unaltered, dark blue in colour, and contains bits of mica schist, small pieces of quartz and other inclusions: in fact in the field it has all the appearance of an intrusive rock. Followed along the strike this limestone quickly becomes crystalline and eventually a pure marble at the Makrana quarries. The western limit of the anticlinal ridge has not been examined in detail, but it does not agree with the eastern, and it is probable that the section is complicated by faulting. All the above rocks belong to what is usually known as the Aravalli series.

Of later date are the masses of granitic gneisses which have broken through the rocks mentioned above. Still later are the pegmatite intrusions, which cut the above in all directions, and are often tourmaline-bearing. They seem to carry very little mica.

59. At the end of January Mr. H. Crookshank proceeded to Saran (25° 42′; 73° 51′) to map the Aravalli range to the south, and before leaving for Quetta in the middle of March he mapped some 200 square miles comprised in sheets 141, 142, 143, Rajputana Survey. The northern boundary of the area mapped is lat. 25° 45′, the southern 25° 13′, the eastern the Jodhpur-Mewar boundary, and on the west the alluvium of the Jodhpur State.

Unfortunately the area is devoid of structural features and consists of three more or less well marked parallel bands, granitic gneiss to the west, granulites, mixed amphibolites, quartzites, schists, and calcareous rocks in the centre, and hornblende-gneiss to the east.

**The Burma Party.**

60. During the field-season 1920-21, the Burma party consisted of Dr. A. M. Heron (in charge), Rao Bahadurs S. Sethu Rama Rau and M. Vinayak Rao, all of whom were engaged in the continuation of the geological survey of the Mergui district; and Mr. Bankim Bihari Gupta, Sub-Assistant, who was employed in the Pakokku and Lower Chindwin districts of Upper Burma.

On the close of field work Dr. Heron paid a short visit to Tavoy to advise the Deputy Commissioner on certain mining questions, whilst Rao Bahadur Vinayak Rao visited certain mica areas in the Ruby Mines District (see p. 26).

**Mergui district.**

61. In Mergui the whole or portions of the following one-inch sheets were surveyed geologically as completely as the great natural difficulties of the country permitted :—95 $\frac{L}{11}$, $\frac{L}{12}$ (A. M. H), $\frac{L}{15}$, $\frac{I}{16}$ (S. S. R.), $\frac{P}{3}$, $\frac{P}{4}$ (M. V. R.) ; in addition, Sellore Island, and the islands that fall outside the operations of the Survey of India, were mapped by Dr. Heron on the Admiralty chart, Mergui Archipelago. During the census operations, Dr. Heron had an opportunity of making a general tour of the Mergui Archipelago to ascertain the best method of undertaking the survey of the outer islands.

Tertiary beds, consisting largely of coarse river conglomerates, with some sandstones and clays, cover a great area in the Tenasserim valley above Tenasserim town. Mr. M. L. Patterson, of Messrs. Wightman & Co.'s Thabawleik mines, has drawn attention to fossils in carbonaceous and ferruginous clays, presumably of Tertiary age, which Dr. Baini Prashad, of the Zoological Survey, states may be the ancestral form of the present day Burmese form *Vivipara bengalensis* race *doliaris* (Gould).

Pataw and Patit islands, and the undulating country extending to the east of Mergui town as far as Sandawut, are occupied by coarse conglomerates belonging to the series, noticed in last year's Report, of red sandstones, shales, and conglomerates, exposed in the swamp islands north of Mergui. These beds lie unconformably on the rocks of the Mergui series, but as further examination has failed to lead to the discovery of any fossils, the age of these beds is still uncertain.

Limestones belonging to the Moulmein series crop out near Tharabwin, where they are isolated amid alluvium, and at the source of the Kyaukpyu chaung, north-west of Peinchaung, where, according to Rao Bahadur Sethu Rama Rau, they are seen to rest almost horizontally, and therefore unconformably, upon the steeply-dipping quartzites of the Mergui series. The Therabwin outcrops are locally recrystallised into coarse marble, but have yielded a marine fauna indicating an Upper Carboniferous age.[1]

The rocks of the Mergui series show little of novelty. They have in general a more arenaceous composition than in the same series further to the north in the Tavoy district, quartzites being more prominent, whilst conglomerates also appear. These latter

[1] P. N. Bose, *Rec. G. S. I.*, XVI, p. 151 (1893).

have pebbles up to 3 inches in diameter, consisting mainly of quartz and felspar. A single pebble was observed, of a biotitic and well-foliated granite, confirming previous indications of the existence of a pre-Mergui granite.

The unfossiliferous argillites and quartzites, composing the dominant formation of the Mergui and Tavoy districts have been described by the members of the present Burma party as the Mergui series. The same rocks were, however, mapped by Bose[1] in the Theindaw-Kawmapyin coalfield as the Moulmein series. The terms 'Moulmein' and 'Mergui' were originally introduced by Dr. T. Oldham[2]; the former to include reddish sandstones, marl, and the associated massive marine limestones so conspicuously developed in the neighbourhood of Moulmein, and at least in part of Carboniferous age; and the latter to designate an older formation of semi-metamorphic rocks. As mentioned above the limestones are unconformable to the older series, to which the term 'Moulmein' cannot therefore be applied.

On the mainland the biotite boss-granite intrusive in the Mergui series is exposed in two areas, the larger including the summits Wabyauk-taung (1,945′) and Tagu-taung (1,750′), and the smaller Cheyadaw-taung (2,390′). The former intrusion carries ores of tin and tungsten around Tagu-taung, near Banlamut, and near Kawmapyin (not the same as the coal locality), at all of which places residual 'cappings' of undenuded sedimentaries rest on the upper margin of the granite. The sections exposed on the cart-road from Sindin to Tagu show exceptionally numerous patches of argillites converted into hard slates and hornstones by the intrusive granite.

The Tagu mines, which were for several years important wolfram producers, are characterised by the unusual thickness of some of the mineral veins traversing the granite and by the presence of arsenopyrite in quantity, with also galena and chalcopyrite.

In the coastal tract, a small sill-like intrusion of granite occurs in Natlaintaung, the range east of Mergui town: but the largest masses form two lines of islands, one continuing the King Island boss through Range, Merghi, Sellore and Tucker Islands, and the other, to the west, running from the Pickwick group through Domal to Sir Jn. Malcolm and Sir E. Owen Islands.

[1] *Loc. cit*
[2] *Sel Rec. Govt. India,* X, p. 33 (1856).

There are also large bosses of granite in the Ross and Elphinstone group, associated with massive porphyries and volcanic agglomerates; and on the western side of Elphinstone Island is the focus of the eruptions which have distributed their debris so widely through the Mergui series in the Tavoy and Mergui districts.

Tourmaline-muscovite-pegmatites, locally carrying cassiterite but never wolfram, are common along a zone running south from Natlain-taung; also near Kazat and on the Yamon Chaung. Alluvials derived from these have for long been mined by Chinese methods and latterly by dredging on a small scale. Alluvial tin is worked also at the eastern foot of Tagu-taung and is there derived from the tin and tungsten-bearing veins in the local granite. The extensive tin alluvials of Messrs. Wightman & Co.'s area at Thabawleik are unusual in being derived neither from pegmatites nor from veins in visible association with granite, which does not outcrop anywhere in the neighbourhood; nor have granite fragments been found in the workings. The ore comes from thin, but often rich, quartz-cassiterite stringers penetrating the Mergui rocks.

Besides in the area mapped coal occurs in well-known Tertiary deposits at Theindaw-Kawmapyin, and also on the Thagyet Chaung and near the Liepok Chaung, 3 miles south of Thabawleik.

**Pakokku and Lower Chindwin districts.**

62. During the field-season 1920-21, Sub-Assistant B. B. Gupta surveyed geologically portions of the Pakokku and Lower Chindwin districts represented in the 1″ sheets 84 $\frac{K}{9}$ and $\frac{K}{18}$. The formations mapped are alluvium, Irrawaddy series, Pegu series, the Yaw stage, and the Pondoung sandstone. The three latter formations dip conformably to the west and south, the Pondoungs being separated from the Irrawaddy series to the east and north-east by an important fault. Vertebrate fossil remains were collected from the Irrawaddy series, the Yaw stage and the Pondoung sandstones, whilst invertebrate fossils were obtained from the Pegu series and the Yaw stage. Fossil wood was found in the Irrawaddy series, the Pegu series and the Pondoungs, and some well-preserved fossil leaves were obtained from the last-named formation. None of the fossils collected have yet been specifically identified. An interesting lithological type is a bed of conglomerate in the Pondoungs found near Thibingaing and in the Ngapyaung Chaung. Amongst the pebbles the following rocks were identified: granite, diorite, quartz-augite-rock, rhyolite, trachyte, quartz-

andesite, trap (decomposed), quartz-porphyry, orthoclase-porphyry, porphyrite, quartzite, and jaspideous rocks. Mr. B. B. Gupta's maps and his progress report constitute a creditable record of a first season's independent work.

**Hukong Valley Survey.**

63. Dr. Murray Stuart accompanied the Hukong Valley Railway Survey Party from Ledo in Assam, to Mogaung in the Myitkyina district of Upper Burma. From Myitkyina he proceeded in a north-easterly direction to the Burma-China frontier in the vicinity of Htawgaw. He has submitted a report dealing with the outlines of the geology of the North-Eastern Frontier, based on the results of these expeditions, on a previous one made in 1917-18, and on the work of earlier observers.

The Hukong valley proves to be a plain of alluvium, deposited in a broad basin of Tipam sandstones, which, towards the north, rest unconformably on slatey sandstones and shales. The latter, which in places are pierced by intrusions of serpentine, correspond, Dr. Stuart believes, with the Disang series, probably of Cretaceous age.

Dr. Stuart's three traverses from Htawgaw revealed the presence of wide expanses of intrusive granite-gneiss, of crystalline limestones, and of ordinary limestones, shales and tuffs in this part of the N'Maikha valley. Lithologically, the latter rocks appear to be very similar to those of Lower Palæozoic age found further towards the east in Yunnan.

**Amherst district.**

64. Dr. G. deP. Cotter, who was placed in charge of the Burma Party at the end of June, was engaged during November and December in examining the oil shales of the Amherst district. These shales lie to the east of the Dawna range of mountains, which extends in a N.N.W. direction through the Amherst and Thaton districts: the shales are found both in the east of the Kawkareik township of Amherst between the Dawna range and the Thaungyin river, which forms the boundary between Burma and Siam, and to the east of the Thaungyin in Siamese territory. As this work took Dr. Cotter to country not hitherto examined geologically, a summary of his geological results will prove of interest.

The oldest rocks of the district are regarded by Dr. Cotter as of Archæan age, and comprise biotite-granite-gneisses, tourmaline-gneisses, and mica-schists, and are confined to the Dawna range.

The lesser hills on the east and west of the Dawna are mainly of limestone, and exhibit a characteristic castellated and rugged appearance. As early as 1860 to 1870 fossils of Carboniferous age[1] were found in the 'Duke of York's Nose' or Zwe-ka-pin, a limestone hill near Moulmein, which continues northwards as a range until it meets the Salween near Pa-an. These fossils, however, could not be found in the Museum in 1893, and it is not known what had become of them. This limestone, termed the Moulmein Limestone by T. Oldham, has been regarded on this somewhat unsatisfactory evidence as Carboniferous.

Towards the close of December, Captain F. W. Walker, at Dr. Cotter's request, searched the Zwe-ka-pin at Pa-an for fossils, and succeeded in obtaining a fair collection from this type locality, amongst the genera found being *Productus*. This corroborates the views held regarding the age of the Moulmein Limestone, although it is not improbable that the term 'Carboniferous' used in the papers cited above may prove to be too restrictive, and that the limestone as a whole may cover a longer period of geological time, and be more nearly equivalent to the Plateau Limestone of the Shan States. It is interesting to record also that Prof. J. W. Gregory has presented this office with a specimen of a lamellibranch, probably *Palaearodonta*, from the limestones at Martaban railway station. This would seem to show that the Martaban rocks belong to the same group.

The limestone ranges east of the Dawna yielded fossils in three localities, *viz.*—

(1) In the Thaungyin river, Lat. 16° 47′ 15″: Long. 98° 32′ 8″.

(2) In the Thaungyin. Lat. 17° 3′ 18″: Long. 98° 26′ 55″.

(3) In the Kamawkala gorge, Thaungyin, Lat. 17° 3′ 20″: Long. 98° 25′ 15″.

The collections from these three localities were submitted to Mr. G. H. Tipper, Palæontologist, Geological Survey of India, who reports the presence of one genus of ammonite, many small *Rhynconellas*, an unidentifiable gastropod, two lamellibranchs that may be either *Lima* or *Pecten*, and some colonial and solitary corals, of which the first is apparently close to *Latimaeandrarea*. Polyzoa may also

[1] Theobald, *Mem. Geol. Surv. Ind.*, X, p 326; and Nœtling, *Rec. Geol. Surv. Ind.* XXVI, p. 96.

be present. Assuming that these fossils are from one horizon, as seems likely, Mr. Tipper considers that they are probably Lower Mezozoic in age, and that any closer approximation cannot be attained on account of the poor quality of the material, due largely to the crystalline nature of the limestone. The limestone east of the Dawna range appears therefore to be later than the Moulmein Limestone.

The limestone east of the Dawna forms the core of the Kamawkala range, and it is proposed to allude to it as the Kamawkala Limestone. The Kamawkala Limestone is overlain unconformably by a series of red and purple sandstones and earthy beds, closely resembling these recorded by C. S. Middlemiss from the Southern Shan States.[1]

Very poorly preserved fossils, mainly lamellibranchs, were obtained from this series, but have not yet been identified. Associated with this red sandstone series are bands of conglomerate with pebbles of red sandstone and of limestone, forming a rock which exactly resembles certain conglomerates in the red and purple sandstones of Kalaw in the Southern Shan States. It may, therefore, be regarded as highly probable that the red sandstone series of Amherst is identical with that of the Southern Shan States.

Both the limestones and the sandstones are highly disturbed, the dips being as a rule vertical. In the valleys, resting unconformably upon the Red Sandstones, Kamawkala Limestones, and Archæans, are found several synclinal basins of Tertiary age, very probably Upper Tertiary. The lower beds of these basins comprise sands, boulder beds, and conglomerates, containing fossilised dicotyledoneous wood, with, locally, freshwater limestones containing *Unio, Viviparа* and *Potamides.* The upper beds of these Tertiary basins are mainly shales, amongst which occur the oilshales, abundantly developed and dipping at gentle angles.

The oilshales have yielded good collections of fossil dicotyledoneous leaves and of fish remains. The economic aspect of these shales is referred to on page 29.

65. On his return from Rajputana and Bombay, Mr. G. H. Tipper was deputed to undertake a general geological and mineral survey of the State of Chitral, where he spent the period May to October 1921.

**Chitral.**

[1] *General Report, Geol. Surv. Ind.* for season 1899-1900, p. 143.

The bases of a correct interpretation of the geology of Chitral were laid by Sir Henry Hayden[1] when, in 1914, he made a traverse through the State on his way to the Pamirs: although his work very naturally left many points obscure, yet Mr. Tipper, found it of the greatest assistance.

Some of these points have been cleared up by Mr. Tipper during the course of the season's work. The Reshun conglomerate, of Upper Cretaceous or Lower Tertiary age, has been let down between two faults of great throw against the Devonian beds on the north-west side and against the Chitral Slates on the south-east. The conglomerate and associated shales have been traced continuously from Reshun as far north as the Khut pass, where they appear to be thinning out and are not more than 50 feet thick. Generally, beds of presumed Lower Devonian age abut on the conglomerate and shales, but occasionally the fossiliferous Upper Devonian beds occur, the lower beds being cut out. Along this fault line isolated masses of massive crystalline limestone occur at intervals. At present their age is unknown.

The Chitral Slate series, previously considered to be unfossiliferous, has after close search yielded a small collection. Up the valley known as the Chitral Gol one of the interbedded calcareous bands has yielded a *Spirifer*, a small *Dielasma* and two as yet undetermined corals. This portion of the series may, therefore, be considered of Upper Palaeozoic age.

The relationship of the Upper Devonian to the Sarikol Shales, assumed by Sir Henry Hayden to be of Lower Carboniferous age, is still obscure. A thorough search for fossils in the latter has so far only yielded a few crinoid stems and two badly preserved *Orthoceratites*. Good sections, *e.g.*, in the Kosht ridge, show that these shales and quartzites have been extensively overfolded and faulted. Intrusions of mica-peridotites and aplites are frequent.

Fusulina limestones have been found in two areas and show important differences of occurrence. The north side of the Tirich valley is composed of strongly folded masses of crystalline limestone and calcareous shales. *Fusulina* occurs in great numbers in patches of unaltered limestones in this mass at the entrance to the Rosh Gol, while the shales in the Odhren still further south-west show impressions of *Syringothyris* and *Fenestella*. *Fusulina*

[1] *Rec. G S. I.*, XLV, pp. 275-293.

also occurs further along the strike in the Londku; but the structure is gradually disappearing, and at Wizmich, except for a few odd cells, the calcification is complete.

In the neighbourhood of the hamlet of Neuk, the Fusulina beds, a succession of shales, quartzites and limestones, lie almost flat and have the appearance of having been let down by block faults between the Devonian beds and the Sarikol Shales. Followed along the strike the Fusulina beds in the neighbourhood of Odir in the Mhelp valley have a dip of 30° to the south-east. Still further at Parmer and the Khut valley, the Fusulina beds appear to be incorporated in the general folding. The exact significance of this is still obscure.

The Tirich Mir mass of granite is later than the Fusulina beds. Traced to the south it cuts these beds out and comes with contact with the Sarikol Shales. The latter have been altered by the contact and where altered, are physically very similar to the Chitral Slates. In the Tirich valley the granite is a biotite-granite containing large porphyritic crystals of felspar up to 4 inches in length and ½in. in breadth. Along the strike southward it becomes a regular augen-gneiss, the rounded eyes of felspar being surrounded by layers of dark biotite. Still further south it becomes a fine-grained foliated gneiss.

From the physical point of view Mr. Tipper's work in Chitral must have been as arduous as that undertaken by Dr. Heron in Tibet.

**Poonch.**

66. On appointment to this Department, towards the end of the field season, Mr. D. N. Wadia was deputed to Poonch to commence a geological survey of that state. He utilised the remaining month and a half of the field season by making a few traverses from end to end of the State, with a view to ascertaining the main structural features of the geology and the nature of the rocks, as a preliminary to a detailed survey to be undertaken in subsequent seasons. His observations, while in accord with the maps hitherto published by Medlicott and Lydekker (*Rec. Geol. Surv. India*, Vol. IX, and *Mem. Geol. Surv. India*, Vol. XXII) in their broad outlines, make it evident that the geological boundaries will require very material alteration on the larger scale and more accurate maps now obtainable.

One of the most important of these boundaries is that constituted by the fault separating the Murrees and Siwaliks: the trace of this fault curves round hill-slopes and tongues up valleys in the manner characteristic of an overthrust fault of low dip—an interpretation given by Mr. Middlemiss to the same fault to the south-east in Jammu State.

North-east of the main boundary of the Murrees on the southern flank of the Pir Panjal range, Medlicott and Lydekker mapped a series of beds that they provisionally assigned to the Silurian and Trias. Mr. Wadia has identified much of this on lithological grounds with the nummulitic facies of Mozufferabad, Kalamula and Riasi. Tightly folded amongst these beds, Mr. Wadia has recognised with certainty, both by its lithological character and by its fossils, a representative of the Permo-carboniferous Limestone (Zewan beds) of Kashmir. The Panjal Trap and agglomeratic slate crop out in positions adjacent to the assumed nummulitic strata.

One of the most interesting results of Mr. Wadia's work is his discovery of two or more bands of bituminous limestone intercalated in steeply dipping Murree beds. These appear to extend from the Haji Pir pass in a S. S. E. direction as far as the latitude of Poonch town. They contain both nummulites and oyster beds and are associated with greenish and red shales. The absence of any repetition in the sequence on either side of the limestones and the fact that purple sandstone, indistinguishable from Murree sandstone, is intercalated in bands of 10 to 50 feet in thickness amongst the limestones and shales, point to a marine transgression during the Murree period rather than to an eroded anticline of Eocene rocks folded up with the newer Murrees. Unfortunately the fossils so far obtained are unidentifiable, but it is hoped that sufficiently well-preserved specimens may be obtained this season, to enable this view to be definitely confirmed or disproved. The limestone with its associated shales and sandstones is some 300 feet in thickness.

**Tibet : Mount Everest Reconnaissance Expedition.**

67. On his return from Mergui, Dr. A. M. Heron had the good fortune to be selected to accompany the Mount Everest Reconnaissance Expedition; he left Darjeeling in May, and returned in October. During this period, he succeeded in preparing a geological map of over 8,000 square miles of territory, comprising the western portion of the Tibetan section of the Arun drainage area, and, in the west, the region drained by the headwaters of the Bhotia

Kosi and its tributaries. The circumstances of the Expedition were not favourable for detailed work, and Dr. Heron endeavoured, therefore, to traverse and map as large an area as possible. His work was done on a scale of ¼ inch to the mile on skeleton maps very kindly furnished by Major Morshead and his surveyors as their plane-tabling proceeded, and Dr. Heron, therefore, regards his investigations as forming a reconnaissance survey only. The value of his work will, however, become evident from his map when this is published: but the magnitude of the physical achievement in surveying this large area will be understood at once when it is mentioned that the whole of the work was done at an altitude of 13,000 feet and upwards.

The area surveyed by Dr. Heron lies to the west of the country surveyed by Sir Henry Hayden during the Tibet Expedition in 1903-4. As in the country described by Sir Henry Hayden, the area is geologically divisible into two broad zones: (*a*) Tibetan and sedimentary, and (*b*) Himalayan and crystalline—a division that is clearly reflected in the topography resulting from the underlying geological structure, the somewhat tame and lumpy mountains of Tibet in the north contrasting sharply with the higher, steeper and more rugged Himalayas in the south.

The Tibetan zone consists of an intensely-folded succession of shales and limestones with subordinate sandstone-quartzites; the folds strike east and west, with their axial planes dipping, as a rule, in a northerly direction, indicating, in Dr. Heron's opinion, that the movements that caused the folding came from the north.

The uppermost rocks consist of the Kampa system of Hayden, a great thickness of limestones ranging in age from Cretaceous to Eocene, as determined by fossils preserved in places where the rocks have escaped alteration. Below these is a monotonous succession of shales, practically unfossiliferous, with occasional quartzites and limestones representing the Upper and Middle Jurassic, with, at the base, beds probably belonging to the Lias. These Jurassic shales are by far the most conspicuous formation in this part of Tibet, being repeated many times in complicated folds. The Cretaceous-Eocene limestones form comparatively narrow bands occurring as compressed synclines caught up in the complex of Jurassic shales. Along the southern border of the Tibetan zone, below the base of the Jurassic shales, is a great thickness (2,000′—3,000′) of flaggy limestones in which the fossils have been destroyed and the rocks themselves converted over considerable areas into crystalline limestones and calc-silicate-rocks containing tremolite, epidote, tourmaline, etc., but still retaining their original bedded structure in the banding of the altered rock. The scarcity of determinable fossils makes it impossible to ascertain definitely the age of these beds, but it is possible that they are of Permian and Triassic age.

The Himalayan and crystalline zone is composed essentially of folded and banded gneisses, usually garnetiferous, on which lie, at comparatively low angles and with a general northerly dip, the above-mentioned calc-silicate-rocks. These schists occur most abundantly to the north and west of Mount Everest in the Keytrak, Rongbuk, Hlelung, and Raphu valleys. The group of high peaks to the north-west of Everest (overlooking the Nangba La) is made up of these metamorphic rocks with intrusive schorl-granite, and it would seem from inspection that the precipitous north-western face and spurs of Everest itself are composed of the same rocks. The eastern and north-eastern valleys Chengphu, Kharta and Karma, which are in general at a lower level than the north-western valleys, are, however, excavated in the biotite-gneiss. On the north-eastern face of Everest fresh snow was too abundant to permit the recognition of the rocks present, and the examination of Makalu was inhibited by bad weather. The base of Makalu in the Karma valley is of gneiss, but, according to Colonel Howard-Bury, the upper portion appears to consist of white granite. Associated with the limestones and calc-silicate-rocks already referred to are quartzites and tourmaline-biotite-schists, which probably represent the lowest portions of the shales lying immediately on the limestones.

Both biotite-gneiss and metamorphosed sedimentaries are penetrated with such an abundance of dykes and sills of all sizes, of schorl-granite or pegmatite, that the granite is frequently the predominating rock. It is highly resistant to weathering, so that its presence in large amount enables such comparatively soft rocks as the schists to take part in forming some of the highest summits. The relationship of the biotite-gneisses to these metamorphosed sedimentaries is uncertain, but Dr. Heron inclines to the view that the gneiss is intrusive, and had he been permitted to accompany the second Expedition this year (1922), he had intended to devote special attention to this important point.

In the same way the scattered peaks of over 20,000 feet along the watershed between the Arun and the Tsangpo owe their prominence to the presence of groups of veins of a very similar granite, which, however, differs from the Himalayan granite in containing biotite in place of schorl. Around these separate centres of intrusion are aureoles of metamorphism in which the Jurassic shales have been converted into slates and phyllites.

Economically, the area traversed by the Expedition is devoid of interest, except for a little staining by copper salts on a few boulders in moraines. No traces of ores were seen.

## Miscellaneous Work.

68. A note on the mineral resources of Bihar and Orissa was prepared by myself for the Mining Manual of the province, and has been published in part 3 of Vol. LIII of the Records of this Department.

69. Dr. Coggin Brown, whilst on deputation in London, prepared a series of reports on varous minerals, which have been published by the Department of Industries of the Government of India as Bulletins of Industries and Labour.

70. The Director of the Geological Survey of India has been appointed *ex-officio* President of the Governing Body of the Indian School of Mining and Geology at Dhanbad.

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# CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YUNNAN IN WESTERN CHINA. 6. TRAVERSES BETWEEN TALI FU AND YUNNAN FU. BY J. COGGIN BROWN, O.B.E., D.Sc., F.G.S., M.I.M.M., *Superintendent, Geological Survey of India.* (With Plate 1.)

## INTRODUCTION.

IN the previous paper of this series I have described the geology of the Mekong Valley as it is displayed on the main trade route across Western Yunnan as far as Tali Fu[1], and it now remains to record my observations in Central Yunnan between Tali Fu and Yunnan Fu, in order to connect my traverses across the province with the map of the French geologists who surveyed north from Tongking to Yunnan Fu. The area dealt with is contained on sheet No. 31 N. W., North Eastern Frontier Surveys, published by the Survey of India in June 1904, and lies between lats. 25° and 26° and longs. 100° and 102°. This topographical map is sketchy and incomplete as well as being on the small scale of 1 inch=4 miles. Such boundary lines as are given are therefore only approximately correct. My own observations were made during rapid journeys across the region in the years 1908-10, and are necessarily incomplete. The map is only intended to show the results of somewhat rough reconnaissance work and the general situation of the larger rock groups, but it may be of some help to the future worker in this isolated region.

The publication of these notes has been deferred in the hope that the detailed investigation of my fossil collections would be finished. But as they still remain to be described. and as the field work was commenced more than ten years ago, it seems desirable to put the stratigraphical and descriptive portions on record without waiting any longer.

In addition to traversing the main trade route between Tali Fu and Yunnan Fu which leads through the towns of Hsia-kuan·

[1] Contribution No. V. 'Geology of parts of the Salween and Mekong Valleys.' *Rec. Geol. Surv. Ind.*, Vol. XLVII, pp. 205-266.

Chao Chou, Chen-nan Chou, T'su-hsiung Fu and Kuang-tung Hsien, as the map shows, I have visited the area around the northern end of Lake Erh Hai, and surveyed the country towards the south and south-east about Mung-hua T'ing, Nan-chien and Mi-chih. Further, two short traverses to the north of the main route were undertaken, the first, from Yunnan Hsien through Pin-chuan Chou, and the other from T'su-hsiung Fu through the salt-producing region around Ting-yuan Hsien.

Yunnan Fu, the capital of the province lies some 48 miles, as the crow flies, to the east-south-east of Tai-kuan-ch'ang at the edge of sheet No. 31 N. W., and the geology of the intervening portion has already been described[1].

## PREVIOUS OBSERVERS.

A. Leclère travelled between Tali Fu and Yunnan Fu *viâ* H-i-ching between the 14th and 29th November 1898, and has given a short account of his journeys, from which the following notes of geological interest are taken.

At the extreme south of lake Erh Hai, the Productus Limestone is still superposed, in small outlying masses, on the porphyrite shown on L. von Loczy's map. Variegated sandstones of Upper Permian age form the low hills about Hsia-kuan and Chao Chou, a region lying between the three basins of the Mekong, the Yang-tze and Red rivers.

The bottoms of ancient lakes now almost entirely dried up and covered with rice fields, are spread everywhere in the spaces between the sandy hills. Twenty kilometres from Chao Chou, the Productus Limestone appears again bordering the plain of Hung-ai and Mi-tou. The altered porphyrite is found below the limestone, twelve kilometres to the south-east of Hung-ai. A limestone outlier, isolated on the porphyrite, is found at the edge of the stream which descends to the Yang-tze past Pe-yen-ching, and separated by a mass of porphyrite from the large Yunnan Hsien plain, quite as extensive, but not so exceptionally fertile, as that of Tali Fu. Before descending to this plain, at an altitude of 1,900 metres, there is a small lake near the hamlet of Chin-ho-tong, bordered by sharp outcrops of very

[1] Contribution No. IV, 'The country around Yunnan Fu' *Rec. Geol. Surv. Ind.*, Vol. XLIV, pp. 85-122.

weathered limestone. This yielded fossils determined by Douvillé as Permian. The same structure continues from one hill to the next along the Yunnan-i plain, and up to ten kilometres to the south-east of this locality, along the road to Pu-pung. Then the limestone outcrops disappear. The variegated sandy formation of the upper Permian is now developed, dipping constantly towards the east. At certain points faulted beds are almost vertical. Afterwards, above these strata, a very compact, fine-grained, red sandstone is found, which as far as Yunnan Fu is the most constant horizon of the Upper Permian. The road rises up to 2,100 metres on these sandstones, but towards the north and east there are still higher hills composed of Triassic rocks. A Rhaetic horizon is probably reached, because coal seams are met with at Mu-pang-pu yielding an ashy coal which is made use of as far as Yunnan-i.

This sandy region is practically a desert, but all the same rather well wooded. A tributary of the Yang-tze rises in it, flowing towards the south-east as far as T'su-hsiung Fu, a direction parallel to the course of the Red River. This valley is bordered towards the south by a low cliff of limestone, which Leclère correlates with the Middle Triassic horizon of Mĕng-tzu; gradually broadening out on the shaley beds of the Lower Trias, the bottom of the valley is about four kilometres across at Chen-nan Chou, where it is flat and covered with rice fields.

To the east of this town the limestones assume an exceptional development, which is seen in the ravines. They are composed of a marly limestone, several metres in thickness over which alternations of sands and clays with lignite are laid.

Close to Kao-fung-sao (a military post to the east of Chen-nan Chou), the sands are quite felspathic and micaceous. They are probably formed from the disintegration of the surrounding Trias. Around Lu-ho, these deposits, which are correlated with the Tertiary, stretch for more than ten kilometres from north to south, at about 1,500 metres above sea level. Lignitic horizons about two metres in thickness are found in them about here.

At this place Leclère left the ordinary track followed by the caravans between Ta-li and Yunnan Fu, to enable him to visit the salt-producing region of Hei-ching situated towards the south of the Mesozic coal-field of the Yang-tze.

The structure of the country he then traversed is said to be that of an undulating plateau of Permo-Triassic age, which dips towards the escarpments on the Yang-tze, maintaining altitudes of from 1,600 to 1,800 metres. All forest vegetation has disappeared for great distances around the salt works, while the streams flow in deep and narrow ravines exposing the variegated beds of the Permian.

The town of Ting-yuan Hsien is situated about twenty-five kilometres to the north-north-east of Lu-ho, in a shallow lake basin, probably on the marly horizon of the Lower Trias.

Fifteen kilometres towards the north-north-east, the village of Lan-ching is situated, at about 1,300 metres elevation, on a small stream which flows into the Hei-ching river.

The latter flows towards the north, in the direction of the bend which the Yang-tze makes, following the course of the Ya-lung, along the foot of the granite cliffs of Sie-ke-ta.

The salt-bearing beds at Lan-ching crop out at the side of the stream, under about 300 metres of variegated beds. They are opened up by seven rectangular galleries which penetrate the slope of the hill as far as possible, in order to tap therein the subterranean waters, naturally saturated with salt.

Hei-ching is situated 20 kilometres to the east-north-east of Lan-ching at an elevation of about 1,250 metres, in a very deep ravine. The salt-bearing horizon crops out parallel to the north and south course of the stream, on the right bank. Its average dip appears to be about 10° towards the west.

Leclère's return route to Yunnan Fu, continued through Tcha-ui-kieou, a hamlet about thirty-five kilometres to the south-east of Hei-ching, and six kilometres east of the salt mines of Hou-ching. In the latter locality the horizon of the salt-bearing sandstones, which rises rapidly towards the east, is found at about 1,500 metres altitude and, consequently, above the level of ground water. Exploitation is carried on by galleries, and the sandstone so obtained is treated in tanks at the surface. The same method is employed on the banks of the Yang-tze, where the salt horizon is found again, in the northern extension of the Hei-ching zone, about 1,000 metres above sea level.

From Tcha-ui-kieou to Lu-fung Hsien, a ravine is followed forming the northern extremity of the valley in which this town is situated, and which continues straight to the south to join the Red River.

The town has an altitude of 1,300 metres and is in the middle of a large and well-cultivated lacustrine plain.

The Productus Limestone appears under the Upper Permian and forms the eastern border of the basin. It is found again around Lu-piao containing curious patches of variegated strata, cut through by a tributary of the Lu-fung river. The base of the sandy Permian beds rises higher and higher the nearer one approaches An-ning. It reaches 2,100 metres at the edge of the cliff bordering the Yunnan Fu basin, the latter resting on a shaley horizon of the Permian limestone, characterised by its richness in *Bellerophon* sp[1].

## PERSONAL OBSERVATIONS.

The crystalline rocks of the T'sang Shan complex.

The rocks of the T'sang Shan complex are gneisses, gneissose granites and schists of many kinds which build up the high mountain wall immediately to the west of Tali Fu. In this latitude they occupy a width of about ten miles and rise to some 13,000 feet above sea level. They appear to stretch far to the north towards Li-chiang Fu, but their limit in this direction is not known. To the south of Hsia-kuan, they seem to be abruptly terminated by overlapping Red Beds. The Tali Fu marble quarries which supply the fine-textured white stone, so curiously marked and mottled with vivid green and brown tints, and renowned throughout Western China for monumental and ornamental purposes, are situated on the lower slopes of the range a short distance to the north-west of the city, but as I was not permitted to pay more than a hurried visit to them, I do not know whether the stone comes from bands of crystalline limestone within the crystalline series, or whether it is a metamorphosed variety of the younger limestones which flank both sides of the range.

## A.—From Hsia-kuan to the Yunnan Hsien Plain.

Hsia-kuan is an important trading centre, situated at an elevation of 6,900 feet near the south-western corner of Lake Erh Hai, and on the river which carries its drainage through the T'sang Shan range to the Yang-pi Ho, a tributary of the Mekong. It lies eight miles to the south-south-east of Tali Fu, which is not actually on the main route across the province. The town is close to the junction of the

[1] A. Leclère: *Annales des Mines*, Vol. XX, 1901, pp. 287—492.

T'sang Shan crystalline complex with the Permo-Triassic Red Beds Series.

The Chao Chou valley.

From Hsia-kuan the road proceeds north-east for four miles parallel to the southern shore of Lake Erh Hai before turning to the south down the Chao Chou valley. In places poor exposures of red sandstones and shales pierce the thin covering of recent deposits. The Chao Chou valley is a narrow one, about twelve miles in length, running approximately from north to south and tapering gradually in the same direction. It is drained by a small stream which empties itself into Lake Erh Hai near its south-eastern corner. The valley deposits are of fluvio-lacustrine origin and appear to have been formed partly by the waters of the lake and partly by stream action. For the first seven miles the eastern side of the valley is bordered by limestones of Permo-Carboniferous age and associated rocks, which stretch away to the north along the eastern shores of Erh Hai, but on the west, low rounded hills built up of rocks belonging to the Red Beds Series are seen. The paving stones of the mule track are obtained from the limestone bands and occasionally show sections of Cyathophyllid corals on their polished surfaces. The limestone is first seen coming up through the alluvial deposits just north of the village of Chao-chuang, but it is soon followed by soft white sandstones belonging to the same series. In them I noticed fragmentary remains of a small *Orthis*. Near Hsin-pu-tang the road passes on to the Red Beds Series, and it is quite evident that somewhere very close to this point the junction of the Permo-Carboniferous and the younger series exists. The valley gradually becomes more and more constricted as the route rises to the south, and this feature is particularly pronounced near Hsin-shao where it is very narrow and enclosed by low hills sparsely clad with pine forests. Near Ta-shao the sandstones strike west-north-west, east-south-east and dip to the north-north-east at 32°.

Unconformity between the Permo-Carboniferous and the Red Beds Series.

In the three miles of country between the head of the Chao Chou valley and the Mi-tu plain to the south-east, the road crosses the ridge separating the basins of the Mekong and Red Rivers, through a pass at an elevation of 7,700 feet above sea level. Near the top of the pass the limestone is first found *in situ* as a somewhat brecciated rock full of calcite infiltrations. The junction between the limestone and the Red Beds practically follows the path on the descent. On the northern side are typical exposures of weathered limestones, striking approximately north and south and dipping from 45°—50° west, whilst on the other hand is the red soil of the Red Beds Series, pierced here and there by outcrops of the red sandstone. Towards the bottom the alluvial deposits of the Mi-tu plain mask the older strata, but before this point is reached the basement bed of the Red Beds Series is seen to be a coarse conglomerate, containing many quartz pebbles and also rolled fragments of the Permo-Carboniferous limestone.

**Permo-Carboniferous volcanic rocks between Mi-tu and Yunnan Hsien.**

The Mi-tu plain is a stretch of rich arable land drained by one of the small streams which form the head-waters of the Red River. It is about twenty-five miles long from north-west to south-east and six miles in breadth at its northern end, gradually narrowing to a little over one mile at its other extremity. It is intensely cultivated and covered with small villages. In all probability its deposits are of lacustrine and fluvio-lacustrine origin belonging therefore to the Nan-Tien Series. The route passes through Hung-ai, elevation 5,950 feet, about 2 miles from the foot of the pass, and continuing in an eastern direction for a further two miles across the fields, leaves the plain and turns towards the north-east to reach Yunnan Hsien, a distance of eleven or twelve miles. In the earlier papers of this series I have shown that the Permo-Carboniferous rocks of both Eastern and Western Yunnan are characterised by the presence of contemporaneous igneous rocks. In Central Yunnan, and especially towards the north in the valley of the Yang-tze-chiang, these attain their maximum development. They seem to be associated rather with the Permian period than with the Carboniferous, but extensive detailed surveys are required before this is proved.

Immediately after leaving the Mi-tu plain a decomposed andesitic flow is found *in situ* between two limestone bands. Further on, in a small stream, good specimens of a fresher rock may be obtained. It is a hard, bluish-grey, amygdular variety. Bands of tuff are sometimes interbedded with the flows, which continue as far as I-chiang-pu, though few good exposures are found owing to the tendency of these rocks to weather down into rounded hills covered with thick soil and overgrown by grass. No attempt has been made to separate the igneous and sedimentary beds of the Carboniferous and Permian on the map.

Permian limestones of Ching-hua-tung.

The village of Ching-hua-tung is two miles to the east of I-chiang pu and near this point, looking towards the north-east, the Yunnan Hsien plain is first seen. From Ching-hua-tung to near Kou-t'sun pu, a distance of two miles as the crow flies but more by the road winding along the southern edge of the plain, the ground is occupied by greyish-white, fossiliferous limestones of permian age. The best exposures are obtained half a mile to the south-east of the former village along the Mi-tu road, and the locality is well known to the Chinese, who frequently visit the caverns which exist in the limestone. Certain bands of the rock are largely composed of polyzoan remains and crinoid stems. My own collection from this place still remains to be described, but Douvillé has examined the specimens taken from it by Leclère and a translation of his notes is given below[1].

'Greyish limestone from Yunnan-i, near Tali Fu.

*Littorina* (*Eunema*).
*Straparollus*.
Crinoid ossicles.
*Pachypora* cf. *jabiensis* Wagen.
*Stenopora* (*Geinitzella*) cf. *crassa* Lonsdale.
*Stenopora* sp.
*Peronella*.
*Endea*.

This fauna is composed mainly of little corals (*Favositidae* or *Multiporidae*) and of branching sponges; the internal characters are not well preserved and, consequently, exact determinations are extremely difficult.

The presence of the genus *Stenopora* appears almost certain and leads me to correlate this fauna with the Russian Permian or with the Indian Productus Limestone. In particular, very analogous forms have been figured by Waagen, from the Jabi locality (Upper Productus Limestone).

Nevertheless, similar small corals have been figured by Loczy, (*Favosites reticulatus*, *Stromatopora concentrica*), as coming from the Devonian of Pe-su-kiang in Kansu.'[2]

[1] *Loc. cit*, pp. 312-313.
[2] *Die wissenschaftlichen Ergebnisse der Reise des Grafen Bela Szechenyi in Ost-asien.* p. 793.

Leclère notes that the stratigraphical position of the Yunnani-limestone, forming the upper part of a formation the lower beds of which are classified according to Loczy with the Carboniferous, does not allow the Yunnan-i beds to be considered as Devonian. In addition to this, the Permian affinities of the limestones regarded as Carboniferous in Southern China have been pointed out by Loczy himself.[1]

**The Triassic and Rhaetic deposits of the Yunnan-i valley.**

After crossing the Permian limestones the road enters the Mesozoic basin of Yunnan-i, which in this locality has a breadth of fourteen miles from east to west and probably extends northwards into the valley of the Yang-tze-chiang in the neighbourhood of Ma-chang. Triassic deposits belonging to the lower, middle and upper parts of the system are well known in South-Eastern Yunnan, and Deprat has shown that although of considerable thickness they are strictly localised in a band of country passing between the neighbourhoods of A-mi Chou and Mĕng-tzu in an approximately north-eastern direction, and limited in extension by great faults which bring them into contact with palaeozoic rocks. To this faulting their preservation during the erosion of the Pliocene period is due. The similarity between the faunas of the Middle Trias in South-Eastern Yunnan and Loczy's locality, at Chung-tien in Ssu-ch'uan, two hundred and fifty miles away to the north-west, seems to prove the extension of the Middle Triassic sea for considerable distances, whilst the pelagic conditions indicated by the prevalence of ammonites in the Upper Trias of South-Eastern Yunnan point to the same conclusion. The close of the Upper Trias in these regions was marked by a regression of the sea and the deposition of thick sandstones with coal seams.

Deprat considers that great areas of Triassic rocks were removed during the Pliocene erosion—a conclusion which is probably true as regards Eastern and Central Yunnan and the regions further north.

That the close of the Permian period was marked by a great orogenic movement followed by a continental epoch, during which volcanic activity prevailed, is clearly proved by the occurrence of those massive deposits to which I have given the name of the Red Beds Series.

[1] *Loc. cit.*, p. 793.

In Eastern Yunnan, Deprat has shown that the Lower Trias deposits frequently rest unconformably on the denuded folds of older strata, and that their formation commenced by the accumulation of coarse sandstones in lagoons, followed by beds in which the remains of land plants and marine organisms alternate.

**Comparison with the Shan States.**

I think that the transgression of the Triassic sea was a slow and progressive one from east to west in Yunnan and that the formation of the Red Beds Series persisted in Western Yunnan to a later period than it did in the east of the province. According to La Touche, the Trias is entirely absent in the Northern Shan States, which nevertheless contain Rhætic and Jurassic deposits of a marine facies. These facts seem to indicate a wide-spread movement of such a nature, and to justify the assumption that the Red Beds Series though confined to the Upper Permian in Central and Eastern Yunnan, may be of true Permo-Triassic age further west.

The fauna of the Yunnan-i basin is sure to prove a very interesting one, but in the absence of palæontological determinations it is impossible for me to fix the horizons of the different beds represented. If a guess may be hazarded, the general appearance of the fossils seems to indicate that both Middle and Upper Trias and perhaps Rhætic beds occur.

**Western development of the Triassic basin.**

The first good exposures of the Mesozoic rocks are seen near Shai-ching-po as indurated white shales striking north and south and dipping towards the west at about 20°, further on towards the east, soft grey sandstones crop out. But near Kou-t'sun-pu there are a few poor outcrops of shales which dip towards the west and probably belong to the same series. Near the village of Pan-chiao thin bands of hard bluish limestone, occasionally brecciated and traversed by calcite-filled cracks, are found. They are unfossiliferous and have a vertical dip with the prevalent north and south strike. Between the limestones and the fossiliferous marls at Yunnan-i, there is a development of dark calcareous shales from which I obtained fragmentary fish remains. Near the village of Yunnan-i, the fossiliferous beds are found as yellowish, and variegated shales of fine texture followed by dark indurated shales. On the topographical map the region is shown as a flat plain, but actually the valley was found to be divided by a low ridge of these rocks. The sequence of the fossil-bearing beds is as follows :—

Yellow marls,
Yellow shales,
Yellowish and marly shales with streaks and blotches of red.
Dark greenish slaty shales.

Numerous bivalves were collected from the yellow marls and shales, while the dark shales contain forms apparently related to *Daonella* sp. The series is practically vertical, somewhat contorted, with a general strike of north-east—south-west. The greenish indurated shales continue as far as Kao-kuan-po, though they are often obscured by alluvial deposits.

**Development to the south.**

About three miles to the south of Yunnan-i, the village of Miaotsway is situated and in the hills adjoining the plain in its vicinity, another fossiliferous locality was found. Here a series of practically vertical beds strike north 15° west—south 15° east, composed of soft, greyish-white, sandy shales and harder, yellowish-white and yellow sandstones, full of red joint planes, nodular in places and containing a few thin bands of quartz. There are extensive alternations of these beds, but the fossiliferous band is confined to a few inches of a soft yellowish marl, followed by yellowish and white shales. Another fossil horizon was discovered a few hundred yards further south in a kind of shelly marl, containing small rounded pieces of quartz, broken bits of shells and lamellibranch casts in a fine-grained yellow to yellowish-red sandy matrix. The casts appear to belong to genera like *Myophoria*, *Gervillia* and *Cardita*.

On another occasion I found a third fossil band still higher in the sequence near the coal seams which are worked in the vicinity. There are three seams in hard yellow and yellowish-white sandstones separated by bands of bluish and bluish-white shales. The sandstones become soft and assume reddish and brownish tints on exposure. The strike is north 15°-20° east—south 15°-20° west, with a high dip towards the east. There has been considerable local disturbance. Plant remains in a fragmentary condition were obtained in a dark shale on the mine heaps. They appear to belong to the genera *Taeniopteris* and *Neuropteridium*.

**Development to the east.**

After crossing the alluvial deposits of the Yunnan-i basin which reach to the immediate vicinity of Mu-pang-pu, at an elevation of 6,775 feet above sea level, the road rises during the next four or five miles to An-nan-kuan, elevation 8,250 feet above the sea, across a series of rocks which in all probability belongs to the Triassic system. The recent deposits at the foot of the hill, belonging to the Nan Tien series are of considerable thickness and are dissected into miniature cañons by torrents in the rainy season. They are followed by soft, white or yellowish sandstones, bluish-black and yellowish sandy shales. The prevalent strike is north 5°-10° west—south 5°-10° east and the dip at fairly high angles to the east. As far as I could make out they are unfossiliferous, but I believe they belong to the coal-bearing series.

**Probable faulted junction of the Trias with the Permian.**

A rapid traverse across the Mesozoic basin of Yunnan-i, did not allow me to come to any definite conclusions regarding the nature of the junction between the rocks of which it is composed and the older systems that lie both to the east and west of it. At An-nan-kuan typical red sandstones of the upper Permian are found in contact with the Triassic deposits. These sandstones moreover have a westerly dip which may indicate a faulted junction. The straightness of the western contact between the Triassic and the Permian limestones and igneous rocks, leads me to imagine that it too will prove to be a faulted junction rather than an overlap. If this is eventually found to be the case, this, the most westerly zone of fossiliferous Mesozoic beds in Western Yunnan, will come into line with the better known ones further to the south-east, which are now known to owe their preservation to the action of long fractures with considerable throw.

**Lacustrine Deposits of the Yunnan Hsien plain.**

The late Tertiary and Recent lacustrine and fluvio-lacustrine deposits of the Yunnan Hsien plain are the same kinds of sand, sand rock and clay found in similar positions in other parts of the province, and of the same character as those typical ones in the Nan Tien valley from which I have taken a name for the group. The Yunnan Hsien lake in which they were deposited had two long arms, one about twelve miles long and one to four miles broad, running from north-west to south-east, and the other twelve miles long and four or five miles broad running from north-east to south-west. The narrowest portion is at the meeting of the two arms. A small remnant of the former lake still exists about the centre of the first arm, and in it deposits are being laid down to-day in perfect continuity with the older ones of the plain itself.

**Triassic beds between Mi-chih and the Mi-tu plain.**

The distance to which the Triassic zone extends towards the south of the Yunnan Hsien plain is quite unknown, but I found strata of this age *in situ* towards the southern end of the Mi-tu plain as indicated on the map. Here coal seams occur in sandy shales of the same character as those found around Miao-tsway. In close proximity to the village of Li-kang-chang decomposed volcanic rocks were found. These are probably of Permian age. The locality is a bad one for geological work owing to the grassy nature of the hillsides, and it was impossible to do very much in one hurried march. The coal seams however prove the presence of Triassic rocks hereabouts, and if the Chinese reports of coal mines to the north of the southern extremity of the Mi-Tu plain, towards Yunnan Hsien are correct, there is reason to suppose a continuity of the Trias right through.

## B.--Yunnan Hsien to Tsung-Fu-Chuang.

During a journey from Yunnan Hsien I traversed Sheet No. 31 N. W. northwards to the Yang-tze-chiang.

**Triassic beds east of Yunnan Hsien.**

Coal is mined on the south-western slopes of peak 6,950 B which lies to the east-north-east of the city but does not form a very conspicuous land-mark because the surrounding plain has an elevation of more than 6,000 feet. The thick soil cap hides most of the rocks in the vicinity of the mines, but the exposures that are seen exhibit the same soft, yellow sandstones and marls as those found at Miao-tsway, further south on the other side of the plain. The strike is north and south and the dip very high towards the east. A few fragmentary plant remains were collected from a weathered shale on an old mine heap.

**Permo-Carboniferous limestones and volcanic rocks between Yunnan Hsien and Tong-chuan.**

After leaving the city of Yunnan Hsien the road proceeds north across the deposits of the plain for two miles before entering the hills near Hung-tu-po. Very decomposed lavas are then found on the eastern side of the stream valley followed by the path as far as the village of Ta-wa-tzu. On the western side of the track limestones crop out but their junction with the igneous rock is marked by such profound decomposition that nothing can be learnt from it. Behind the limestones the volcanic rocks can be seen rising in steep cliffs. At the edge of the watershed beyond Hsin-tsun, elevation 7,250 feet, good exposures of a metamorphosed and brecciated limestone occur, while a little further on, masses of limestone are seen actually within the volcanic rocks which settles finally the relative ages of the two groups. After crossing the watershed the road descends rapidly into the valley of the Pin-chuan Ho, and nothing more is seen of the limestones, volcanic rocks occupying the whole country. As a rule the outcrops are soft and decomposed, but the stream bed is full of hard boulders and pebbles. Dolerites and amygdaloidal basalts appear to be the commoner types.

**Triassic beds near Tong-chuan.**

I was informed that coal occurred near Tong-chuan, a small village about $1\frac{1}{2}$ miles north-east of Lung-yu-ts'un and close to a point where a small tributary from the east enters the plain. The road to the mines winds up the valley of this stream for a mile or so. At first the volcanic rocks build up the whole valley; decomposed along the path, they are seen in fresh exposures in the bed of the torrent crossing them in a number of rapids and small falls. Solid and amygdaloidal lavas, volcanic breccias and agglomerates with an occasional layer of a tuff-like appearance were all noticed. They strike north-east, south-west and dip north-west at 65°-70°. After crossing the volcanic series the road at once passes on to dark indurated shales followed by coarse, gritty sandstones which strike north-east, south-west and dip south-east at 42°. Unfortunately there is a thick soil cap which hides the rocks in the vicinity of the mines themselves. I only succeeded in finding a few badly preserved and indeterminable lamellibranchs in the shales enclosing the coal seams. The coal-bearing horizon is probably the same as the one seen near Yunnan Hsien, from which it is separated by a distance of about fourteen miles as the crow flies.

**Triassic beds to the west of Pin-chuan Chou.**

Coal seams also occur on the western side of the Pin-chuan valley. From the small walled city of that name, a road leads in a north-westerly direction to Kan-tien at the edge of the plain. Here coarse sandstones and shales are found striking north 30° west, south 30° east and dipping north-easterly at 55°. Two miles further west there are exposures of coarse grey sandstones in thin beds separated by layers of grey micaceous shales. The dip is towards the north-west at 55°. Further on still, the shaley beds become more numerous and coal is mined about two miles to the south-west of Kan-tien, a small village lying at the foot of a spur running out from a well-marked ridge. Very few rocks are visible near the mines owing to the thick soil cap, but the type of strata found further away is lithologically identical with the coal-bearing horizons of Tong-chuan and Yunnan Hsien.

**Alluvial deposits of the Pin-chuan Ho valley.**

Marching north along this valley towards the Yang-tze-chiang, no rocks are visible for miles owing to the thick recent and sub-recent alluvial deposits. The ground is covered with boulders and pebbles washed down from the hills on either sides. They are nearly all composed of greenish, greyish and reddish sandstones with a few smaller ones of shale, and recall the Triassic rocks found about the coal seams. The smaller tributaries, dry in April, when I made the journey, have cut deeply into the deposits of red clay with boulders, and sometimes a thickness of more than 100 feet is exposed without the rocky bottom being reached. The small valley near Hsiao-lo-ho is a typical example. At this point the track turns sharply to the north-west and descends to the main northerly flowing stream, which it meets near Sha-ting (5,100 feet). There are no rocks visible in the bottom of the valley here, though a descent of 650 feet has been made from Pin-chuan-Chou.

**Volcanic rocks and limestones of the Yang-tze-chiang valley.**

Towards Te-shin-tang, the valley narrows, though this is not indicated well on the topographical map. A spur from the eastern ridge and another from the higher range on the west close it in, and the long stretch of continuous alluvium comes to an end, though a smaller isolated band is found further north. The sandstone boulders are replaced by rounded blocks of basic igneous rocks. Just beyond Shun-tang these are found *in situ* on the road and also crop out in cliff exposures higher up. The dark greenish rock is in bands, perhaps of separate flows which are very cracked and decomposed. Some of them are practically holocrystalline, while others are very amygdaloidal and contain zeolites and quartz. The valley is narrow and hot as it shut in by high walls. The cultivation is devoted to sugar cane, an unusual crop in this part of Yunnan. Further north the igneous rocks give place to the underlying brecciated limestone, which appears at intervals separated by stretches of volcanic rocks. At the point where the Yangtze-chiang, just beyond the northern limits of the sheet, is first seen, decomposed andesites weathering with a spherulitic structure strike north-west, south-east, and dip north-east at 40°. In the bottom of the tributary valley before it joins the great river I found white limestone pebbles with fragmentary brachiopod remains.

## C.—Yunnan Hsien Basin to the east of T'su-hsiung Fu.

**The Red Beds series.**

Near An-nan-kuang, at the crest of the range which borders the Yunnan Hsien basin on the east, the rocks of the Red Beds series are first found and from this point they build the whole country to the eastern limit of Sheet No. 31 N. W. beyond T'su-hsiung Fu, a distance of 70 miles as the crow flies. They continue a further 16 miles on to the next sheet to the east (No. 31 N. E.) as described in a previous paper of this series[1].

Between An-nan-kuang and Shui-pang-pu there are excellent exposures of fine-grained reddish sandstones striking a few degrees east of north and dipping in an easterly direction at high angles. Between the latter place and Pu-pung the outcrops are not so good but the same kind of rock continues. Just before Chin-chi-tang is reached, rather coarse reddish and reddish-yellow sandstones strike north 30° west—south 50° east, and dip at 22° in a south-westerly direction. Pu-pung has an elevation of 7,175 feet and is 16 miles from Yunnan-i. From the ridge above the village the Red Beds are seen to stretch far to the north and south in broad ranges separated by wide valleys, which do not run in any particular direction and seem to be the result of general sub-aerial denudation. On the tops of the ridges red rocks can occasionally be seen cropping out.

The same remarks hold good for the country seen to the south from the road between Pu-pung and Pu-chang-ho. Between these two places there is a gradual descent to the east followed by an ascent to T'ien-shan-t'ang, 12 miles from the former place. Throughout this march shales are equally developed with the sandstones; the former being sometimes of greenish and yellowish-red shades,

[1] Contribution No. 4.

while the sandstones are all alike, either of the fine-grained red type or of red speckled with white. Under the action of the weather the shales break up into small angular fragments which eventually form a heavy clayey soil. Through this the streams cut narrow valleys on the sides of which rain pillars are very common. Just beyond Pu-chang-ho the strike is north-west, south-east and the dip at 30° to the south-west taken on red shales enclosed in sandstones.

From T'ien-shan-t'ang, a march of 7 miles to the south-east brings one to the head of the alluvial deposits which, with one small break, continue on and past the small walled city of Chen-nan-Chou, a further distance of 16 miles. Between Ying-wu-kuan and Ta-fu-ssu, the red sandstones are mainly in evidence and the shales only occupy a subordinate portion of the series. Near Ying-wu-kuan the sandstones strike north-west, south-east and dip south-west at 45°, but further on, about Hsin-pu-tang, the strike veers round to north and south while the variable dips indicate folding.

**Deposits of unknown age to the east of Chen-nan Chou.**

To the west of Chen-nan Chou there are only poor exposures of red sandstones and shales with an occasional band of quartzite. About Kao-fung-shao, however, east of the city, a series of dark carbonaceous shales with thin partings of sandstone and shale is seen. The surrounding strata are yellowish and dark grey shales with thick bands of coarse, white, friable sandstones. They strike north-west, south-east and dip south-west at 45° and contain fragmentary plant remains too friable to be collected. In general appearance these beds recall those of the Nan Tien series of Tertiary age, but on the other hand, their high dip and occurrence away from the valley deposits seems to indicate that they may belong to a Triassic horizon. They are, however, quite different from the ordinary facies of the Red Beds series. Similar greyish and black shales containing broken plant remains also occur just beyond Li-ho, four miles further east.

Beyond this point to T'su-hsuing Fu and to the north-east of this city through Kuang-tung Hsien to the edge of the map, typical members of the Red Beds series are found. Around the former place sandstones prevail and are seen bordering the alluvial deposits of the plain. One mile to the west of the city there are building stone quarries in a speckled grey and white sandstone. Hard yellowish shales at the end of the plain strike west 32° north—east 32° south. The surrounding country consists of low rounded hills, dissected by wandering streams and thinly covered with scrub growth.

## D.—Salt-producing Region east of Ting-yuan Hsien.

Ting-yuan Hsien lies two stages north of T'su-hsiung Fu. The road after crossing the alluvial deposits of the plain ascends to the top of a high ridge along which it continues. Good sections of the Red Beds series are exposed the whole way, shales being more prevalent than sandstones. Near Lao-kan-ch'ung they strike north-west, south-east and dip south-west at 31°. The first stage is reached at Shin-tang which lies just off the crest of the ridge, ten miles from T'su-hsiung Fu, at an elevation of 6,850 feet above sea level.

A further 10 miles leads to the Ting-yuan Hsien valley, which is an old lake basin filled with fluvio-lacustrine deposits. Near the city reddish and reddish-violet shales with thin quartzite bands strike north-north-west, south-south-east and dip from 40° to 45° in a westerly direction.

Lan-ching is a large village situated at an altitude of 5,600 feet, about eight miles to the east of Ting-yuan Hsien; between the two places there are many exposures of red shales and nearer Lan-ching, of hard red sandstones in thick bands with an easterly dip. There are several brine wells here and the salt-bearing horizon is low down in the Red Beds series. Brine wells are also worked at Hei-ching a village about six miles to the north-east of Lan-ching. After leaving the latter place the road ascends the steep north and south running range which here forms the western boundary of the Tso-ling Ho valley. The crest has an elevation of 7,800 feet and there is a steep descent at once to the river at Hei-ching, 5,500 feet. A massive red sandstone of great thickness, weathering into huge buttresses, is found on the way down, and it is in this rock that the salt occurs. It strikes north 24° west—south 24° east and dips easterly at 66°. The wells are situated about three quarters of a mile along the bottom of the valley under the steep slopes of its western wall.

Twelve miles to the south-east of Hei-ching and about three miles south of Hsiang-chi-shao on the main road from Tingyuan Hsien to Yunnan Fu, lies Hou-ching, owning both salt mines and brine wells and one of the more important salt-producing areas of this part of the province. A very steep climb out of the Hei-ching valley brings the road to the top of a south-easterly running ridge, along which it winds at a general elevation of 8,000 feet until Hsiang-chi-shao is passed. Typical red sandstones and a few shaley horizons occur all the way. From Hsiang-chi-shao there is a very precipitous descent into Hou-ching. The salt occurs disseminated in a hard red sandstone at least 20 feet thick and perhaps much more. It is well developed both outside and within the town and appears to strike west-north-west, east-south-east and dip at 50° or 60° to the north-north-east. On the ascent out of this valley the red sandstones are followed by red shales, which later gives place to more typical soft red sandstones and thin shaly layers of the Red Beds series.

## EXPLANATION OF PLATE.

PLATE 1.—Geological map of the country between Tali Fu and Yunnan Fu.

# THE GEOLOGY OF THE TAKKI ZAM VALLEY, AND THE KANIGURAM-MAKIN AREA, WAZIRISTAN. BY CAPTAIN MURRAY STUART, D.SC., F.G.S. (With Plate 2.)

## CONTENTS.



## I.—INTRODUCTION.

IN the autumn of 1919, I was attached to the Waziristan Field Force to survey geologically, as far as possible, the country passed through by the expedition. In November, 1919, I was attached to the Tochi Column headquarters under Major-General A. Skeen, C. M. G. The Tochi Column proceeded up the Tochi valley as far as Datta Khel, and I was thus able to examine the sections described by F. H. Smith (*Rec. Geol. Surv. Ind.*, Vol. XXVIII, pp. 106—110, 1895), and to confirm his observations. From December, 1919, to May, 1920, I was attached to the Derajat Column headquarters, under Major-General Skeen, for the whole of the Mahsud campaign. My best thanks are due to the Force Commander, Major-General S. H. Climo, C.B., D.S.O., and to the Column Commander, Major-General A. Skeen, both of whom always gave me every assistance, and facility to work, compatible with the conduct of the campaign.

Owing to the severity of the fighting, and the revolution in tribal mountain warfare brought about by the enemy possessing the most modern type of high velocity rifle, it was not possible to work outside the line of piquets, and consequently a narrower geological traverse was obtained than has been customary in previous campaigns. Nevertheless, a complete traverse was obtained of the country passed through, and the geological section mapped throws valuable light on the complex geology of Waziristan.

The Derajat Column started operations from the frontier post of Khirgi (70° 12′ 30″ : 32° 18′ 27″), and proceeded up the bed of the Takki Zam (sometimes called the Tank Zam) to the confluence of the Dara Toi and Baddar Toi at Dwatoi (69° 53′ 45″ : 32° 35′ 15″) from there up the bed of the Dara Toi to Makin (69° 49′ : 32° 37′ 30″), from Makin, back along the Dara Toi, to Dwatoi, and from there along the bed of the Baddar Toi, through Kaniguram (69° 47′ : 32° 31′ 15″) to Giga Khel (69° 40′ 15″ : 32° 32′ 15″).

From Khirgi to Sorarogha (70° 1′ 45″ : 32° 30′ 50″), the country passed through was almost devoid of vegetation, the rocks were generally bare and devoid of any soil covering, and the country exhibited the denudation features common to dry zone areas. Where a patch of recent alluvium has collected on the inside of a bend of the river, the same has been almost invariably protected by breakwaters, erected by the Mahsuds, and used for cultivation. Such an area is known locally as a *Kach*. Other than on these small alluvial patches the country is, generally speaking, devoid of cultivation. Above Sorarogha the country becomes sparsely wooded, and on the gentler slopes is fairly thickly covered by the evergreen holm oak (*Quercus ilex*) and wild olive. This type of vegetation persists up to Giga Khel, which is 7,709 feet above sea level. Above Giga Khel the predominant vegetation is pine. A peculiar feature is exhibited in the Kaniguram-Makin area, which is composed of a large sheet of gravel cut into ravines and gently rolling hills (downs) by recent erosion and denudation. In this area the northern and north-eastern slopes of the hills are covered by a fairly thick growth of holm oak, whereas the southern and south-western slopes are bare and devoid of vegetation. There is no geological reason for this, the explanation being probably connected with prevailing winds.

The country between Giga Khel and Khirgi slopes somewhat steeply, Giga Khel being 7,709 feet above sea-level, Kaniguram 6,250 feet, Sorarogha 4,031 feet, and Khirgi about 1,650 feet. The course of the river lies alternately through wide terraces of old river alluvium and narrow ravines and gorges, of which the local name is *Tangi*. The formation of the terraces of older alluvium was probably due to the river being held up at the *tangis*, or narrow gorges, sufficiently long for the sheet of alluvium to form.

The geology of the Tochi valley, as mapped by Smith, is shown on Plate 2, and the line along which his sections were drawn is indicated. I had no opportunity on this expedition to search for fossils in his Middle and Lower Nummulitic beds, but there is no reason to doubt his identification of their geological horizon. According to Smith, there are no sedimentary rocks of an earlier age than Eocene in the Tochi valley, with the possible exception of a hill of black limestone near Miran Shah. I visited this hill and failed to find any fossils in it, but agree with Smith in thinking that it is not a part of the Eocene system. At the same time, after going through the Takki Zam, I do not agree with him that it is of Cretaceous age. The Cretaceous rocks in the Takki Zam do not exhibit the black limestone facies, whereas the plant-bearing series does contain occasional unfossiliferous black limestones, and from the geological structure of the country, as far as it has been seen (see Plate 2), I am inclined to the view that the Lower Nummulitics of Smith are resting unconformably on the plant series in the Miran Shah area. I will refer to this again when I have described the geology of the Takki Zam area.

## II.—STRATIGRAPHICAL.

In the Tochi valley, about thirty miles to the north, Smith recognised the following five rock groups (in descending order):—

(*e*) Siwalik
(*d*) Upper } Nummulitic.
(*c*) Lower }
(*b*) Mesozoic
(*a*) Igneous series.

The geology of the Takki Zam valley is distinctly different. I have divided the rocks of the area I was able to visit into the following series:—

(*e*) Older Alluvium.
(*d*) Siwalik.

*Fault.*

(*c*) Nummulitic.

*Fault.*

(*b*) Lower Cretaceous.

*Fault.*

(*a*) Janjal plant series (?Jurassic)

## Janjal Plant Series.

This consists of a series of blue, dark blue and black shales with occasional thin black and dark blue limestones. It is well exposed under Janjal village. The base of the series appears to consist of dark red shales and silicious limestones in which I found no trace of any fossils. This lower and reddish portion of the series is seen from the Barari Tangi to Bangiwala. These beds are all dipping at steep angles, and weather into a succession of knife edge ridges. Above this lower portion comes the main portion of the Plant series, dark blue shales and subordinate black or deep blue limestones, with occasional black pencil slaty shales. The limestones and blue shales are filled with carbonaceous markings (K. 21. 169), none of which are determinable, but which seem generally to resemble simple sea weed impressions. The upper portion of the series is more arenaceous and contains brown sandstones and occasional quartzites. These arenaceous beds yielded no fossils, but their weathered surfaces showed markings very similar in character to the fucoid marking that occur on the Pab sandstones.

Owing to the absence of determinable fossils in this series, it is difficult to fix its geological age with any certainty. The nearest area to which reference can be made is the Sherani country mapped and described by La Touche in 1893 (*Rec. Geol. Surv. Ind.*, Vol. XXVI, pp. 77-96). In connection with this it is necessary to point out that the geological ages assigned by La Touche to his subdivisions require modifications in light of more recent work. His subdivisions and their geological ages as at present recognised are as follows :—

| | | | |
|---|---|---|---|
| 14. | Conglomerates, sandstones and clays | | Siwalik. |
| 13. | Sandstones and clays (Murree in part) | | Siwalik. |
| 12. | Olive shales and clays (Nari in part) | | Oligocene. |
| 11. | Limestones with *Nummulites*. | | Eocene. |
| 10. | Olive shales | | Eocene. |
| 9. | Nummulitic limestone | | Eocene. |
| 8. | Shales with gypsum | | Eocene. |
| 7. | Shales and sandstones | representatives of Laki, Khirthar, etc. | Eocene. |
| 6. | Massive limestone band | representatives of Laki, Khirthar, etc. | Eocene. |
| 5. | Quartzose sandstone (Pab sandstones) | | Cretaceous. |
| 4. | Shales with minute *Nummulites* | | Cretaceous. |
| 3. | Thin limestone with *Belemnites* | Neocomian | Cretaceous. |
| 2. | Black shales with *Belemnites* | Neocomian | Cretaceous. |
| 1. | Massive block limestone | | Jurassic. |

There is a distinct resemblance between the black limestone in which the carbonaceous markings occur in the Takki-Zam area and the massive black Jurassic limestone of the Sherani country.

As the base of the Janjal plant series is cut off by a fault, and as I could not go into the territory containing the uppermost portions of the series, its stratigraphical position cannot be determined with reference to the other rocks of the area.

If it is regarded as the probable equivalent of the massive black Jurassic limestone of the Sherani country, then the throw of the fault between it and the Belemnite shales need not be great. There is another incident which may possibly lend support to this view that the age of the series is Jurassic. While going through Kaniguram, after its occupation by us, I found in one of the houses a small ammonite of the species *A. communis*. It seems to me more probable that this specimen was picked up by one of the local inhabitants in the immediate neighbourhood rather than that it had been brought in from a long distance, and if this is admitted its presence is significant in view of the fact that Liassic shales with ammonites occur in the Sherani country underneath the massive Jurassic limestone. From the evidence at my disposal, I am inclined, therefore, to regard the Janjal plant series as of Jurassic age.

## Cretaceous.

The Cretaceous rocks consist of olive green and dull chocolate red shales with harder calcareous bands and occasional brown sandstones weathering to a black surface. In the Ahnai Tangi are occasional thin partings of black limestone and a thick band of reddish brown nodular limestone. At the top of the exposed series near Mandanna Kach is a series of bright purple-red shales, and white gypseous indurated clays (practically porcellanite), with occasional hills of black earth, resembling the black mud which is ejected from certain sulphurous springs. It is not certain that this is the origin of these black earths, but their relationship to the other beds is obscure, and they do not seem to have any definite stratigraphical arrangement.

Although no fossils were discovered in the upper bright red and white series, it seems not unlikely from its striking colouration that it may represent part of the 'Parh' series or Upper Neocomian of Baluchistan, while the lower series, consisting of olive green and dull chocolate red shales with occasional calcareous bands and sandstones, represents the Belemnite shales or Lower Neocomian. The olive green and dull chocolate red shales of the main series contain in certain horizons abundant belemnites of which the commonest are *Belemnites subfusiformis*, Rasp. and *Belemnites dilatatus*, Blaino (K. 21. 168[1]), two of the commonest fossils of the Belemnite shales of Baluchistan. These belemnites were responsible for the rumour, current throughout the force, that the Mahsuds were using stone bullets, the end portion of the belemnite being almost identical in shape and size with the Mark VII bullet used both by us and the Mahsuds. The rumour, needless to say, was entirely without foundation.

## Nummulitic Series.

The outcrop of the Nummulitic series is limited to a narrow tract of country bounded on both sides by faults, in the neighbourhood of Palosina and Mandanna Kach. The upper portion of the series is typical white nummulitic limestone, and forms the Palesina ridge and the Sagarzai.

Dipping underneath the nummulitic limestone of the Sagarzai are bands of olive green and chocolate shale and coarse dark brown sandstone and grit, weathering to a shiny black surface.

I discovered no fossils in these shales or sandstones, but have little doubt from their position and stratigraphical arrangement that they correspond to what Smith called 'Lower Nummulitics' in the Tochi Valley section.

## Siwaliks.

The Siwalik rocks exposed consist almost entirely of coarse ferruginous conglomèrates. Very occasional subordinate bands of red sandstone occur in the conglomerate series, but the series as a whole is essentially a conglomerate series. Since in both the Sherani and the Tochi areas the Siwaliks consist of an upper portion composed of massive conglomerates, and a lower portion consisting of sandstones, and since in the Khirgi-Jandola area the conglomerates are dipping westwards, I do not think it likely that the lower division is exposed in the area mapped, as, to think so, necessitates

[1] The number in brackets refers to the registered number of the specimens in the Geological Survey of India collections.

the assumption that the sandstone series of both the Tochi section and the Sherani section is represented by massive conglomerates in the Khirgi-Jandola area, a possibility which I hold to be unlikely.

## Older Alluvium.

The older alluvium consists of ancient river terraces of coarse gravel. Frequently several terraces can be seen. For example, south of the junction of the Inzar Toi with the Takki Zam at Kotkai, at the site of the camping ground, three such river terraces are very clearly demarcated. The largest stretch of older alluvium is that seen in the Kaniguram-Makin area. Here, a vast deposit of older gravel stretches from the present bed of the Baddar Toi on the south to the Razmak on the north—a distance of over eighteen miles—and averages in width from over five miles in the Kaniguram-Giga Khel area to over a mile in the north.

The origin of this vast stretch of gravel is not clear, but some of it is probably partially of glacial origin. In the Kaniguram-Giga Khel area the gravel contains much angular and unworn material of unsorted sizes ranging from the finest silt to angular boulders weighing many tons each.

This portion of the gravel area is situated over 6,000 feet above sea-level. Below 5,500 feet, that is to say, near Ladha, the gravel exhibits ordinary fluviatile characters, and I am inclined to think that the explanation of the deposit is primarily glacial, but that the lower portions of it are of fluviatile origin and were accumulated on the melting of the ice at the end of the glacial conditions.

Kaniguram has now a temperate climate in the summer, but in the winter and spring is frequently covered with snow, and a temperature as low as 25° below freezing (7°F.) was experienced as low down as Aka Khel (69° 58′ 25″: 32° 33′, 4,860 ft.) on this campaign. The high range including Pir Gal (11,556 ft.) bounds this area to the N. W., and it seems to me not improbable that in former times glaciers from this mountain range to the N. W. may have been partially responsible for the accumulation of this gravel.

In composition the gravel consists chiefly of pebbles of igneous rock, ranging from intermediate to basic in composition, which could quite easily come from the igneous series described by Smith as occurring in the Tochi, and which probably extends southwards and forms part at least of the Pir Gal-Spinkamar range.

The Makin-Kaniguram gravel area is comparatively low, open, gently rolling country, cut up by ravines, with more or less vertical sides eroded by the existing streams and rivers.

## III.—DESCRIPTIVE.

**I. The Khirgi Jandola Area.**

The first rocks seen west of the frontier at Khirgi are hard, massive ferruginous conglomerates, belonging to the Siwalik system. Practically along the line of the frontier these conglomerates are cut by a fault running approximately N. 20° E.—S. 20° W. This fault is well seen just west of the guard tower south-south-west of Khirgi post, where beds of conglomerate dipping 5° eastwards on the west of the fault are faulted against vertical beds on the east of the fault. Proceeding westward up the Takki Zam, one sees the strata bending over in a very flat anticline until at Sperwam Khajur Kach the beds are dipping W. 35° N. at 15°. This dip steadily increases as the rocks are traversed in a westerly direction until at Karariwam the dip is 30°, at Khagurlar 45° and in the Hines Tangi 50°. West of the Hines Tangi is a broad expanse of older river gravel due to the river having been held up in former times by the hard, steeply dipping conglomerates of the Hines Tangi.

Ridges of Siwalik conglomerate again outcrop to the west of Jandola Forts with a dip of 60°-70° to the W. 35° N. The most westerly exposure of Siwalik conglomerates seen is that composing the Sarkai ridge, where the beds are dipping steeply to the W. 35° N.

**II. The Palosina Mandanna Kach Area.**

This area is much cut up by faults. North-west of the Sarkai ridge with its north-westerly dipping Siwalik conglomerates is the Palosina plain of older alluvium, bounded on the north-west by a ridge of nummulitic limestone forming the Palosina ridge, and on the north by the Sagarzai ridge, consisting at its crest of nummulitic limestone, under which dip the olive green and chocolate-coloured shales of the presumed Lower Nummulitics. The southern end of the Sagarzai ridge and the northern end of the Palosina ridge are cut off by a fault which must run approximately east and west.

It was not possible to go to the Khuza Sar ridge, but it apparently consists of dark-red sandstones which appear to conformably overlie the nummulitic limestone of the Sagarzai ridge and so may possibly correspond to a portion of the Murree Series. Both the Khuza Sar ridge and the Sagarzai ridge appear to end abruptly at their southern ends against the north-westerly dipping Siwalik conglomerates, and the only feasible explanation is that a fault runs along the north-western flank of the Sarkai ridge and cuts off the ends of the Sagarzai and Khuza Sar ridges.

Immediately to the east of Mandanna Kach village bright purple-red shales and white porcellenoid beds of the presumed Upper Neocomian crop out These beds are dipping steeply in an E. 20° S. direction. They can be seen extending in a S.S.W. direction across the Shahur river, and from the apparent discordance of their strike with that of the nummulitic limestone, there is, I think, little doubt that the junction of the two is due to a fault running approximately N. 20° E.—S. 20° W. through Mandanna Kach.

**III. Mandanna Kach to Barari Tangi.**

Dipping under the bright red and white rocks of the presumed Upper Neocomian, are a series of olive green and chocolate red shales with occasional calcareous bands which are exposed up the bed of the Takki Zam from Nai Kach to Lawats Tower opposite Kotkai. The general dip is S. E. at about 30°. On the left bank of the Takki Zam between Lawats Tower and the Ahnai Tangi is a band of brown sandstone weathering to a black surface. This sandstone area was the scene of fierce fighting and was eventually left by us, so that no opportunity occurred of properly examining it, but the sandstone appeared to form part of the series. At the Ahnai Tangi, and forming it, subordinate thin intercalations of black flaggy limestone occur in the green shales and also a thick band of red nodular limestone. This red nodular limestone is practically vertical in the Ahnai Tangi, and forms the sharp knife edge cliffs characterising the Tangi. The cliffs are about 200 feet high.

From Flathead left (the northern extremity of the Ahnai Tangi gorge) to Barari Tangi olive green and chocolate red shales are seen dipping normally S. E. at a general angle of 60°. In this dark red and green shale series *belemnites* are found below and opposite Nai Kach, under Lawats Tower in the Ahnai Tangi, and opposite the Sorarogha plain. There is little doubt that this series corresponds to the Belemnite Shales of Baluchistan and is Lower Neocomian in age.

Between Mandanna Kach and the Barari Tangi one encounters two large areas of older alluvium. There is the Kotkai area, which stretches from the south-eastern scarp of the Ahnai Tangi to near

Nai Kach. This in places shows several distinct river terraces, and its formation has been due almost certainly to the river having been held up by the hard porcellenoid rocks of Mandanna Kach. This area of older alluvium is confined to the right bank of the river.

Above the Ahnai Tangi another large area of older alluvium stretches from near Gana Kach to Sorarogha. This area also is confined to the right bank of the river.

**IV. Barari Tangi to Makin.**

North-west of the Sorarogha plain, hard red and whitish calcareous and siliceous rocks with intercalated dark red and purple shales crop out dipping steeply W. 35° N. These rocks form the mountain ridge through which the Takki Zam cuts the narrow gorge known as the Barari Tangi. On the left bank of the river further along the outcrop to the north-east, the dip becomes vertical, and still further to the north-east becomes reversed and dips in a south-easterly direction. These rocks yielded no fossils, but they dip under the blue, dark-blue and black shales and thin black limestones of the plant series, which are well exposed at Aka Khel and which persist from there up to Tauda China. Where rocks again crop out on the north-west of the Makin gravel area at Band Khel, they are of the same type and contain the same obscure plant markings. The prevailing dip of this series is in a north-westerly direction, but the series is highly contorted, and intense contortion and overfolding are the striking structural features of the area occupied by these rocks. Consequently, no estimate of the thickness of the series can be made. Since the prevailing dip of this plant series is in a north-westerly direction and the dip of the Lower Neocomian immediately south-east of the Barari ridge is in a south-easterly direction, and since each of the two series is restricted to its own side of the Barari ridge and is not seen on the opposite side, the deduction is unavoidable that the structure is not a simple antilicne, but that two distinct series are faulted against one another and are dipping away from each other in opposite directions.

The bed of the river passes alternately through narrow gorges where hard bands (generally of limestone) have been encountered, and through areas of shale and softer rock where plateaus of older alluvium have been accumulated; Bangiwala, Shin Konr, and Pizha Raghza are examples of large plateaus of older alluvium.

**V. Dwatoi to Kaniguram and Giga Khel.**

From Dwatoi to Ladha the rocks exposed in the river bed are the same as those seen in the Dwatoi-Tauda China section. Near Ladha, however, it becomes evident that the gravel in the river bed is altering in character. Instead of normal, fairly uniformly sized river-gravel, frequent small boulders occur in the gravel, and these boulders increase in frequency and in size up the river bed, until at Kaniguram quite large angular boulders are encountered (particularly in the Trikh Kohnr Algad). Between Larelar and Giga Khel angular boulders occur which not only weigh many tons each, but which cause miniature waterfalls and deep pools in the river. It is the presence of these huge and generally angular boulders that leads me to suppose that this portion of the Kaniguram-Makin gravel area has had a glacial origin.

Above Ladha the rocks exposed in the river bed are of a different character. On the left bank from Giga Khel to Ladha, only the gravel of the Kaniguram Makin area is seen, but, since the present course of the river (the Baddai Toi) is approximately the boundary of the gravel area, rocks are exposed in or near the right bank. Between Ladha and Larelar these show chiefly a sandstone facies consisting for the most part of light brown or buff sandstones, occasional whitish quartzites and subordinate greenish arenaceous shales.

No fossils were found in these rocks, but they were characterised by frequent strongly developed surface markings similar in character to the fucoid markings commonly seen on exposed surfaces of Pab sandstone. Between Larelar and Giga Khel, black slatey indurated shales occur, and at Giga Khel the foot-hills of the Pir Gal range consist of soft green argillaceous sandstones. As the survey between Kaniguram and Giga Khel had to be done hurriedly and under fairly heavy fire, there was no opportunity of searching for fossils, but in the sections examined no trace of fossils was discovered.

**VI. Pir Gal.**

It was not possible to penetrate into the Makin gorge or beyond Giga Khel, so that no information was obtained as to the nature of the rocks forming the Pir Gal-Spinkamar range. From their appearance, seen through field-glasses, from their mode of weathering, and from the nature of the pebbles forming the Makin-Kaniguram gravel area, it seems to me likely that they may belong to the igneous series of Smith, which would in that case be continuous from Spinchilla in the Dátta Khel area of the Tochi, through Shuidar, Spinkamar and the Pir Gal range. There is no evidence on the point, but it seems not unlikely.

## IV.—CONCLUSION.

The geology of the Takki Zam valley is strikingly different from the geology of the Tochi valley. The map shows both the geology of the Takki Zam area and the geology of the Tochi as mapped by Smith in 1895. It will be seen that, whereas the Takki Zam area contains Neocomian and probably Jurassic rocks, the Tochi area contains no sedimentary beds older than Tertiary age, with the possible exception of the black limestone exposed under the nummulitic rocks near Miran Shah in the Tochi, the age of which is uncertain (see Smith, *op. cit.*, p. 109). I am inclined to the view that this is one of the black limestones of the plant series, which, if so, is then overlaid unconformably by the Nummulitic series of the Tochi area.

## V.—ECONOMIC CHAPTER.

No minerals of economic value were encountered. There were traces of old iron slag around Marrobi, Dwatoi and Ladha, but Intelligence agents reported that the iron-ore was brought originally from the Makin hills.

The only other two minerals which may be mentioned are salt and petroleum.

### Salt.

During the campaign, frequent reports were current that salt had been discovered in the neighbourhood of Mandanna Kach. I investigated these supposed finds, and found that one lump was found lying outside the wire of a piquet on the Palosina nummulitic limestone ridge, and the other in the gravel of the river bed. In each case the salt discovered consisted of weathered lumps of pink Punjab salt that had been dropped either by men or from loads carried by camels of the supply convoy. There is no evidence of the existence of salt in the area examined.

### Petroleum.

The area was very carefully examined with a view to the possibility of petroliferous strata being present. The only Tertiary rocks present are the Nummulitics of the Palosina-Sagarzai area and the

Siwalik conglomerates. The Siwalik conglomerates may be dismissed at once as being entirely unsuitable for the storage of oil, as well as unlikely ever to have contained it. The small, faulted area of nummulitic rocks shows no trace of oil, and has not the structure necessary for its storage. Other than in the nummulitic rocks there is, practically speaking, no likelihood of oil occurring. Not only is there no trace of oil, therefore, but there is nowhere any exposure of rock where oil is likely to be found.

## Other Minerals.

No traces of other minerals of economic value were found, nor is there any probability of any occurring.

### EXPLANATION OF PLATE.

PLATE 2.—Geological index map of South Waziristan.

## LOCALITY INDEX.

| — | Latitude (N). | | | Longitude (E) | | |
|---|---|---|---|---|---|---|
| | Deg. | Min. | Sec | Deg. | Min. | Sec. |
| Ahnai Tangi | 32 | 28 | 0 | 70 | 2 | 25 |
| Aka Khel | 32 | 33 | 0 | 69 | 58 | 25 |
| Band Khel | 32 | 37 | 30 | 69 | 49 | 0 |
| Bangiwala | 32 | 32 | 47 | 69 | 59 | 30 |
| Barari Tangi | 32 | 31 | 55 | 70 | 0 | 47 |
| Dwatoi | 32 | 35 | 15 | 69 | 53 | 45 |
| Flathead left | 32 | 29 | 15 | 70 | 2 | 45 |
| Giga Khel* | 32 | 32 | 15 | 69 | 40 | 15 |
| Hines Tangi | 32 | 19 | 35 | 70 | 9 | 20 |
| Inzar Toi | 32 | 24 | 45 | 70 | 3 | 0 |
| Jandola | 32 | 20 | 25 | 70 | 7 | 0 |
| Kaniguram | 32 | 31 | 15 | 69 | 47 | 0 |
| Karariwam | 32 | 18 | 10 | 70 | 10 | 15 |
| Khajur Lar | 32 | 19 | 30 | 70 | 9 | 30 |
| Khirgi | 32 | 18 | 27 | 70 | 12 | 30 |
| Khuza Sar | 32 | 24 | 30 | 70 | 6 | 0 |
| Ko'kai | 32 | 25 | 15 | 70 | 2 | 5 |
| Ladha | 32 | 33 | 55 | 69 | 50 | 20 |

| — | Latitude(N). | | | Longitude(E). | | |
|---|---|---|---|---|---|---|
| | Deg. | Min. | Sec. | Deg. | Min. | Sec. |
| Larelar | 32 | 29 | 50 | 69 | 44 | 30 |
| Lawats Tower | 32 | 25 | 47 | 70 | 2 | 26 |
| Makin | 32 | 37 | 30 | 69 | 49 | 0 |
| Mandanna Kach | 32 | 22 | 30 | 70 | 4 | 35 |
| Marobi | 32 | 36 | 0 | 69 | 52 | 0 |
| Miran Shah | 32 | 55 | 0 | 70 | 4 | 30 |
| Nai Kach | 32 | 23 | 5 | 70 | 4 | 0 |
| Palosina | 32 | 23 | 4 | 70 | 5 | 0 |
| Piazha Rughza | 32 | 35 | 30 | 69 | 55 | 30 |
| Pir Gal | 32 | 36 | 15 | 69 | 42 | 15 |
| Razmak | 32 | 44 | 0 | 69 | 51 | 0 |
| Sagarzai | 32 | 23 | 35 | 70 | 5 | 20 |
| Sarkai | 32 | 21 | 30 | 70 | 5 | 35 |
| Shahur river | 32 | 20 | 0 | 70 | 5 | 0 |
| Sheranni hills | 31 | 40 | 0 | 70 | 10 | 0 |
| Shin Konr | 32 | 33 | 50 | 69 | 57 | 30 |
| Shuidar | 32 | 46 | 0 | 69 | 46 | 45 |
| Sorarogha | 32 | 30 | 50 | 70 | 1 | 45 |
| Sperwam Khajur Kach | 32 | 18 | 30 | 70 | 12 | 0 |
| Spinchilla | 32 | 55 | 0 | 69 | 48 | 30 |

| | Latitude (N). | | | Longitude (E) | | |
|---|---|---|---|---|---|---|
| | Deg. | Min. | Sec. | Deg. | Min. | Sec. |
| Spinkamar . . . . . . . . | 32 | 44 | 0 | 69 | 47 | 0 |
| Tauda China . . . . . . . . | 32 | 36 | 40 | 69 | 50 | 30 |
| Trikh Kohnr Algad . . . . . . | 32 | 31 | 20 | 69 | 47 | 30 |
| Tochi valley . . . . . . . . | 32 | 57 | 0 | 69 to 70 | 30 to 30 | 0 to 0 |

## CORRIGENDA.

In the table of sections which accompanies Dr. G. de P. Cotter's paper entitled "A note on the Geology of Thayetmyo and neighbourhood including Padaukbin," on page 114 of this volume, the following corrections should be made :—

In the column showing the Minbu sequence, the words "Kyet-u-bok beds with *Orthophragmina omphalus*" should be enclosed in brackets and should follow immediately after the words "Velates Beds" and should be on a level with the words "Yaw Shale" in the Pakokku section. Again the words "Nwamataung sandstones" in the Minbu section should be on a level with "Pondaung Sandstones" in the Pakokku section. The space in the Minbu section level with the words "Tabyin Clay" in the Pakokku section may be left blank. In the Thayetmyo section the words "*Orthophragmina* beds" should also be on a level with the Yaw Shale.

# A NOTE ON THE GEOLOGY OF THAYETMYO AND NEIGHBOURHOOD, INCLUDING PADAUKBIN. BY G. DE P. COTTER, B.A., SC. D. (DUB.), F.G.S., *Superintendent, Geological Survey of India*; with a map by the late H. S. BION, B.SC., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plate 3.)

WITH this paper is now published for the first time an unfinished map by my late friend and colleague, Mr. H. S. Bion, whose untimely death from appendicitis on June 6th 1915 left a gap in the ranks of the Geological Survey, that to those who remember him must remain unfilled. The map now published was found amongst his papers after his death, and he had no opportunity to revise it for publication; certain of his boundaries he intended should be indicated as faulted boundaries, but the state of his field-map leaves some slight doubt as to which boundaries should be so regarded. I have endeavoured to represent the boundaries as I think he intended. In the neighbourhood of Padaukbin I have added eight dips taken by myself during a visit in August 1921: otherwise the map is exactly as it was left by H. S. Bion.

The area shown in the map forms part of the country mapped by W. Theobald[1], but Theobald's map is on too small a scale (8 miles= 1 inch) to show detail. The western part of Bion's map has been mapped by Dr. M. Stuart, whose report on Padaukbin has been already published[2]. On comparing Bion's map with that of M. Stuart, it will be observed that the boundary adopted as the base of the Irrawaddy series is different in each map, that of Bion being a considerably higher horizon. To explain this discrepancy it will be necessary to show how the revised boundary was adopted.

In Stuart's original paper[2], and in his paper on the geology of Prome[3], published in the same year, the following classification of

[1] W. Theobald: Geology of Pegu. *Mem. Geol. Sur. Ind.*, X., p. 189.
[2] M. Stuart: Recorrelation of Pegu System, etc. *Rec. Geol. Sur. Ind.*, XXXVIII, p. 271.
[3] M. Stuart: Geology of Western Prome and Kama. *Ibid.*, p. 259.

the Burma Tertiaries, founded mainly on Theobald's work, was adopted :—

| | | |
|---|---|---|
| IRRAWADDY SERIES | . | Upper freshwater deposits.<br>Lower marine deposits=Theobald's Mogaung sands[1], of Allanmyo, and his *Turritella* sands[2] of the Pani valley S. W. of Padaukbin. |
| PEGU SERIES | . . | Unconformity.<br>Kama clays.<br>Upper Prome sandstones.<br>Lower Prome sandstones.<br>Sitsayan shales. |

The classification of the Irrawaddy series into an upper freshwater and a lower marine division followed the scheme recommended by Theobald. I may mention here that Mogaung is a village 3 miles N.N.E. of Allanmyo, while the Pani stream passes to the S.W. of Padaukbin, and its nearest point is about 7 miles distant. Owing to the development of the geological map of Minbu, Magwe, and Pakokku districts in Upper Burma in the years 1910 and 1911 it became clear that the greatest break in Upper Burma in the Upper Tertiary sequence came at the base of the freshwater division of the Irrawaddy series as tabulated above; meanwhile Stuart while working near Akauktaung in Henzada had obtained identifiable fossils from the horizon of the Mogaung sands[3]. These fossils appeared to represent the Burdigalian, (but E. Vredenburg has recently referred them to the Pontian) and thus indicated that the Akauktaungs were more closely related to the Pegus than to the freshwater Irrawaddy beds. Stuart therefore proposed the name Akauktaung beds for the marine deposits between the freshwater Irrawaddy beds and the Kama clays; also after consultation with his colleagues, he grouped the Akauktaungs with the Pegus thus :—

| | | |
|---|---|---|
| IRRAWADDY SERIES | . | (Upper freshwater deposits of first classification.) |
| PEGU SERIES | . . | Akauktaung series (stratigraphical gap).<br>Kama clays.<br>Prome series.<br>Sitsayan shales. |

In passing I may notice that the stratigraphical gap below the Akauktaung series is a gap separating them from the 'Sitsayan

[1] Theobald: *loc., cit.,* p. 260.
[2] *Ibid.,* p. 281.
[3] M. Stuart: Geology of Henzada. *Rec. Geol. Sur. Ind.,* XLI, p. 240.

shales, the Kama clays and the Prome series being missing. The Akauktaungs are nowhere in contact with the Kama clays. In the Thayetmyo district and in Prome certain beds formerly correlated by Stuart with the Akauktaungs rest upon the Kama clays, according to Stuart unconformably. These latter beds however are regarded by Vredenburg as probably older than the Akauktaung beds and are called the Pyalo stage. The age of the Akauktaung beds is discussed at the close of this paper.

The boundary adopted by H. S. Bion is the base of the fresh-water deposits which rest upon the *Turritella* sands. This boundary agrees both with the boundary adopted in Upper Burma, and with Stuart's revised scheme as given above. While the revision adopted brings the system of mapping used in Lower Burma into line with that of Upper Burma, it necessitates a modification of Theobald's original scheme, thus :—

*Classification of Burma Tertiary Rocks.*

| Theobald 1873, Stuart 1910 | | Stuart 1912. | |
|---|---|---|---|
| FOSSIL WOOD GROUP | Upper Freshwater | Irrawaddy series (freshwater). | |
| | Lower Marine (Mogaung sands). | PEGU SERIES | Akauktaung beds. |
| PEGU SERIES | Kama clays | | Kama clays. |
| | Prome beds (section B) | | Upper Prome beds. |
| | Prome beds (section A) | | Lower Prome beds. |
| | Sitsayan shales. | | Sitsayan shales. |

The revised boundary not only appears to be the same as that adopted by Pascoe and myself as the base of the Irrawaddy series in Upper Burma, but it has the advantage of being a more easily recognised horizon in the field. Like the Irrawaddy series of Western Minbu,[1] these deposits in Thayetmyo are largely gravels and gravelly sands, and may be easily distinguished from the more homogeneous and well-bedded rocks below. The incoherence of the Irrawaddy series results in a characteristic type of scenery[2] with thin and stunted vegetation. On the other hand, the *Turritella* sands and the Padaukbin clays below are covered with dense forest,

[1] G. de P. Cotter: Pegu-Eocene Succession near Ngape; *Rec. Geol. Sur. Ind.*, XLI, p. 221.

[2] E. H. Pascoe: Oil-fields of Burma; *Mem. Geol. Sur. Ind.*, XL, p. 7.

and are concealed with a heavy soil-cap, so that as a rule good exposures are rare. The scenery contrasts with that of the Irrawaddy beds in that it displays the usual dip and scarp structure. As a result of the rarity of exposures, it is in my opinion impossible to map accurately the junction between the base of the *Turritella* sands and the Padaukbin clays beneath. The junction is in any case obscure, for while the sands contain intercalated clays (as may be seen in an exposure near the 9th mile and 5th furlong on the high road to Nathé), the clays beneath have frequent intercalated sandstones; the junction is therefore not a sharp one, nor is it marked by any surface features. Although it would be feasible to map such a junction in country like that near Singu and Yenangyat, where the rocks are well exposed, the task at Padaukbin seems to be extraordinarily difficult owing to the dense jungle and soil-cap. In the country where the Padaukbin clays are exposed, the high ground of the plateaux exhibits only exposures of sandstone, so that the geologist who examines this type of forest-clad country, may conclude (but erroneously) that the entire area is underlain by sandstone. On descending to an adjacent ravine, which in Burma, —a country of immature denudation—is deeply cut, he will find a preponderance of shale.

Stuart, when he mapped Padaukbin in 1910, had not yet adopted the revised boundary between the Irrawaddy series and the Pegus; he had therefore to attempt the task of mapping the base of the *Turritella* sands in accordance with the scheme adopted by Theobald. His map however seems to indicate that he has included part of the Padaukbin clay division, where it outcrops on plateau country, in his marine Irrawaddy series (*Turritella* sands), while he has limited the outcrops of Padaukbin clay to ravine sections where a preponderance of clay is exposed.

This very natural error in mapping the base of the *Turritella* sands has led Stuart to conclude that these beds overlap the Padaukbin clays unconformably. His map indicates that the sandstones extend across the crest of the Padaukbin anticline from west to east in the plateaux, while the Padaukbin clays are shown to outcrop only in the crestal area and in the ravines. Such a structure seems capable of explanation only in the manner explained by Stuart, *viz.* that an overlap exists. The conclusion was supported by the fact that an unconformity had previously been found at the same horizon in Prome district by Stuart.

The true explanation however in my opinion, and one which I understand Dr. Stuart himself now accepts[1], is that the *Turritella* sands are exposed only on the anticlinal flanks and do not occur on the crestal plateaux; the sandstones of the latter being intercalated sandstones of the Padaukbin clays which have pierced the soil-cap, while the clay (which is really strongly in preponderance) lies completely concealed, except in the ravines.

This revision of the map no longer necessitates the assumption that there is any unconformity or overlap between the *Turritella* sands and the Padaukbin clay beneath, and Stuart's section given on plate 24 of the volume of the *Records of the Geological Survey* in which his paper is published[2] requires emendation by making the Padaukbin clays dip parallel to the sandstones above. They thus show the same anticlinal curve as the sandstones.

In the paper referred to[3] Stuart frankly makes it clear that his theory of overlap results entirely from tracing the boundary between the sandstones and the shales, and is not supported by dip evidence, for he remarks (p. 271) 'These sandstones, which seem to lie conformably upon the Kama clays' (= Padaukbin clays) 'when seen in any individual section, are found on tracing their outcrop to overlap the Kama clays unconformably.'

From my examination of the country near Padaukbin, there is no doubt in my mind that Stuart's observation as to the conformity in any actual section between the *Turritella* sandstones and the Padaukbin clays is substantially correct. I have made many careful dip observations to corroborate this.

An important feature of the Padaukbin clays is mentioned by Stuart (p. 273) where he states that while there is a definite anticline in the *Turritella* sands (or 'Irrawaddy sandstones' as he termed them in 1910,—a term now no longer applicable) the underlying Padaukbin clays ('Kama clays') show 'subordinate puckerings,' which he considers obscure the definiteness of the anticline. The puckering in soft shale is apparently developed in the process of folding. The shale zone is overlain by massive sandstones; the greater rigidity of the latter has caused certain differential movements near the junc-

[1] During this year Dr. Stuart made a flying visit to Padaukbin, but had no time to work out the structure of the field; he has stated however that his original views of overlap require modification and I understand is in agreement with the emendation suggested above (G. de P. C.)

[2] Vol. XXXVIII.

[3] *Ibid.*, p. 271 *et. seq.*

tion of the shales and the sandstone, whereby the shales have been slightly rolled, warped and crumpled. E. H. Pascoe gives an instance of local crumpling of this kind (associated in this instance with local unconformity as well), where contorted clays and sandstones are overlain by non-crumpled horizontal beds at Yedwet[1]. I have also alluded to a similar occurrence in shales near the Yaw River[2]. The feature is termed 'intercalated contortion' by Geikie[3], and is frequently met with in Burma in areas where sandstone and clay deposits have been folded.

This warping is frequently observed in the Padaukbin clays, and as a result in the crestal area, where the dips are gentle, little reliance can be placed upon the actual angle and direction of each dip, since each dip will slightly vary from the true as the result of warp. To unravel the structure and ascertain the crest maxima, only average dips should be made use of. This however is hardly possible owing to the infrequency of exposures.

It might be possible to determine the rise and fall of the crest by tracing out outcrops of sandstone and shale on a large scale map. No such large scale topographical maps exist however, while I have already shown above that the mapping of any bed is difficult in this forest-clad country.

I am therefore unable in the absence of large-scale maps, to determine where the crest-maxima lie or the position of any crestal domes, if any such exist. The general conclusions to which I have come regarding the Padaukbin anticline, as a result of my examination and from the data on H. S. Bion's map may be summarised as follows :—

(1) There is an anticline both in the Padaukbin clays and in the sandstones above. The two formations are conformable, but owing to differential movement during folding, the clays show warping.

(2) The anticline is a flat-topped asymmetric fold, with steep dips on the N. E. flank grading up to 70°, and with gentle dips on the S. W. flank averaging from 15° to 25°. The direction of the crest is about 40° W. of N., passing close to the intersected point 561 marked on the map, and

[1] E. H. Pascoe: Yedwet anticline; *Rec. Geol. Sur. Ind.*, XXXVI, p. 287.
[2] G. de P. Cotter: Coal-seams of Yaw River; *Rec. Geol. Sur. Ind.*, XLIV, p 167
[3] Sir A. Geikie: Text-book of Geology, p. 637.

running N. W. past the western edge of Ngahlaingyen village.

(3) I am unable to state anything about the northward extension of the anticline north of Ngahlaingyen, nor the southward extension south of the high road. I cannot determine the position of maximum elevation of the crest.

Padaukbin has long been known as an area from which oil was obtainable. Theobald[1] in 1873 mentions the existence of 'square shafts' (*i.e.*, hand-dug wells) about 20 feet in depth, from which small quantities of oil had been obtained, but he states that the work had been abandoned. In 1885 R. Romanis[2] states that at this time only three hand-dug wells out of seven were kept in repair, while one only was producing. There are two hand-dug wells in working order at the present time: the depth of one of these is 85 cubits; small quantities of oil are periodically obtained. Noetling states[3] that the Burma Oil Company had several dėep wells drilled at Padaukbin before they commenced to drill at Yenangyaung. Since boring for oil was first commenced at Yenangyaung in 1887, it appears that Padaukbin must have been first tested a little before this date. The Burma Oil Company eventually abandoned the field. Pascoe[4] has the following note on Padaukbin :—

'Several native wells have been dug in this place and small quantities of oil obtained. The Burma Oil Company have drilled eight or nine wells here and at Bambyin, but although oil and gas have been met with in nearly all, they have never been struck in paying quantities.'

Recently however the Indo-Burma Oilfields (1920), Ltd., report that they have met with oil in one of their wells now being drilled to the north-west of the area originally tested by the Burma Oil Company, and in quantities which they regard as promising. At the time of writing however (August 1921) I understand that the preliminary operation of cleaning, under-reaming down a larger bore pipe, and setting up pumping and storage apparatus is not yet complete, so that the actual figures of daily production are not available.

I need make no comment upon Pascoe's note on the field, except to observe (1) that, owing to the increased value of crude oil at the

[1] *Op. cit.*, p. 347.
[2] R. Romanis : Oil-wells and Coal in Thayetmyo ; *Rec. Geol. Sur. Ind.*, XVIII, p. 149.
[3] F. Noetling : Petroleum in Burma ; *Mem. Geol. Sur. Ind.*, XXVII, pp. 77, 245.
[4] E. H. Pascoe : *op. cit*, p. 171.

well-head in the present day as compared with pre-war prices, the term "paying quantities" has considerably changed its meaning since he penned his Memoir, and (2) that the present Company is testing an area situated in a different part of the crest from that originally tested by the Burma Oil Company; it would therefore be unsound to deduce that the former results of drilling will be exactly repeated. I have however stated that I am unable to determine the position of the crest maxima, and I cannot therefore say which is the most favourable area. Nothing but actual testing can after all decide this.

Having dealt with the structure of the Padaukbin area, attention may be drawn to the remarkable series of faults throughout the country mapped by H. S. Bion, whereby in many cases the Irrawaddy series are faulted down against the Pegus. These faults appear to belong to the category of fold-faults and seem to be connected with anticlinal folding in which one limb of the anticline collapses; but the origin of the structures is obscure, and the folding is highly complex, especially between Padaukbin and the Myinmagyitaung.

It remains to discuss the age of the rocks exposed. Stuart has suggested that the Padaukbin clay is the equivalent of the Kama clay. Of the fossils he records from Padaukbin, the following belong to the Kama stage:—

*Leda virgo* Martin; *Corbula socialis* Martin; *Ficula* sp Noetl. (=*Pirula promensis* Vred.)

[1]Of the remaining fossils, all appear to have a wide range, except the curious form *Lucina globulosa* Desh. This form is known from the Miocene of Italy, and when Stuart wrote his paper it was considered indicative of a Miocene age, which would support the view that these clays were the Kama horizon. Subsequently I found this species in Minbu at the horizon of the Padaung clay near the base of the Pegus. If then the Padaukbin clays are really Kama stage, *Lucina globulosa* Desh. must be assumed to have a wide range in Burma. The stratigraphical position of the Padaukbin clay beneath the *Turritella* sands agrees with that of the Kama stage beneath the Mogaung sands as given by Theobald, and there is nothing beyond the presence of the species *Lucina globulosa* to invalidate the view that the Padaukbin clay is the Kama clay; certainty however will shortly, it is hoped, be obtained when the geological map of Thayet-

[1] *Rec. Geol. Surv. Ind.*, XLI, p. 222.

myo is completed. Stuart records the occurrence of *Turritella acuticarinata* Dunker (=*T. angulata* Sow.) from the sands above the Padaukbin clays (*Turritella* sands).

A fauna resembling the Singu fauna is found at Letpanzeik 5 miles north of Thayetmyo[1]. Vredenburg mentions three species from this locality, *viz. Surcula fusus* Vred.; *Terebra quettensis* Vred.; *Tritonidea martiniana* (Noetl.) If Vredenburg's views of the distribution of species are correct, this indicates the Singu stage, *i.e.* a horizon below the Kama stage. The next lower stage, the Padaung clays are also represented in this area by the beds containing *Lepidocyclina theobaldi.* The type locality of *L. theobaldi* is on the bank of the Irrawaddy close to and north of the Lime Hill.[2] The locality was first discovered by Theobald between 1865 and 1872. Subsequently it was visited by E. Vredenburg in 1912-13, but a careful search failed to disclose the fossil-bed[3], which according to Theobald is a hardish sandstone.

The stratigraphical position of the *Lepidocyclina theobaldi* bed just north of the Lime Hill and Myinmagyitaung shows that these hills consist of strata lower in the sequence than the Padaung clay. Theobald has placed the Lime Hill in the Eocene (Nummulitic) group. I have written a short note upon the Lime Hill[4], in which Theobald's fossil evidence is discussed. A greyish pink limestone forms the crest of the hill; this is the limestone regarded by Theobald as containing nummulites and therefore Eocene. Theobald's own specimens of this limestone, and also some specimens brought by Rao Bahadur Sethu Rama Rau about 1910, contain lepidocyclines and not nummulites. A similar *Lepidocyclina* limestone in Henzada was mapped by Theobald as Nummulitic. It is therefore clear that much of Theobald's Nummulitic group is really Lower Pegu, provided of course we attach an Eocene age, as Theobald obviously intended, to his Nummulitics. If, on the other hand, we abandon the Eocene connotation, it might be more consistent with Theobald's scheme to include the Padaung and Shwezetaw stages in the Nummulitic group; this course, however, would both introduce confusion into the now well established scheme of division of

[1] E. Vredenburg: Noetling's Tertiary fauna of Burma; *Rec. Geol. Sur. Ind.*, LI, p. 234.

[2] W. Theobald: *op. cit.* p. 275, where the *Lepidocyclina* is called an Orbitolite.

[3] E. Vredenburg: *op. cit., p.* 248.

[4] G. de P. Cotter: Note on the Limestone Hill near Thayetmyo; *Rec. Geol. Sur. Ind.*, XLI., p. 323.

the Burma tertiaries, and enforce the mapping of what appears to be a vague boundary in Lower Burma. The Lime Hill then, may be 'Nummulitic' in Theobald's original sense, although Oligocene, not Eocene; but, unless it contains Eocene strata below the Oligocene *Lepidocyclina* limestone, it must be placed entirely in the Pegus in accordance with our revised system of sub-division. The strata below the *Lepidocyclina* limestone are described by R. Romanis[1], as containing coal-seams in hard blue shale, near the base of the exposed strata, and on the S. W. spur of the middle of the three hills which form the Myinmagyitaung (the Lime Hill being the easterly). The blue shale above the coal is full of vegetable remains, and above this horizon the shales appear to be unfossiliferous, until the limestone capping of the hill range is reached. There is no evidence therefore that the shales are much older than the *Lepidocyclina* limestone. If we place the latter in the Padaung stage, which appears most probable, then the shales below may perhaps represent the Shwezetaws. The presence of coal-seams would seem to suggest either the Shwezetaw sandstones or the Yaw stage[2].

The question is complicated by the occurrence amongst Theobald's specimens of three species of *Orthophragmina* (*O. omphalus*, *O. javanus*, and *O. sp. indet.*) of undoubted Eocene age. These three specimens are entered in the Museum fossil register as having come from the Lime Hill. They were collected by Theobald between 1865 and 1872, when it was customary to store our collections in trays with loose paper labels. Although numbers were painted on the specimens some 30 years later it is possible that the labels had already become misplaced. It is strange that no *Orthophragmina* have since been found on the Lime Hill by R. Romanis, by S. Rama Rau, nor by H. S. Bion. On the other hand H. S. Bion informed me that *Orthophragmina* is extraordinarily abundant in the western part of Thayetmyo near Mindon. He also brought back specimens of *Orthophragmina* with him which exactly resembled those of Theobald. Since we know from Theobald's memoir that he also visited this western region of the district, it seems possible that the true locality of these *Orthophragmina*, reputed to have come from the Lime Hill, is in reality the west of the Thayetmyo district, where rocks of undoubted Eocene age occur.

[1] R. Romanis: *op. cit.*

[2] K. A. K. Hallowes: Coal-seams of Arakan Yoma: *Rec. Geol. Sur. Ind.*, LI., p. 34.

We may regard the Myinmagyitaung and Lime Hill, therefore, as containing in its upper horizons the equivalent of the Padaung clays (*i.e.* the *Lepidocyclina* beds) and beneath probably the Shwezetaw stage, and possibly also the Yaws; but there are no fossils to indicate the age, and the evidence of coal-seams is very unreliable. For convenience I give a table below showing the correlation of the Thayetmyo sections with those of Pakokku, Minbu, Prome and Henzada. The table must be regarded as provisional only. The Kyet-u-bok horizon was originally correlated by me[1] with the *Velates* bed, but the dissimilarity of the fauna, coupled with the presence of *Orthophragmina omphalus* (a Lutetian form from Borneo), and a large *Campanile*, suggest the Middle Eocene. Nevertheless it would appear that the Kyet-u-bok horizon is to be correlated with the Yaw stage, in spite of its apparent Middle Eocene affinities. The results obtained during the course of field mapping in South Minbu by Mr. E. L G. Clegg seem to prove that the Kyet-u-bok bed is high up in the Eocene, and probably at the top of the Yaw stage. We must therefore be prepared to admit a wider range for such species as *Orthophragmina omphalus* than formerly appeared probable to me from a consideration of the work of H. Douvillé on the fauna of the Borneo Eocene.

I have suggested that the Sitsayan shale of Prome and Henzada is possibly the representative not only of the Padaung clay of Minbu but of the Shwezetaw stage below. The Sitsayan shales are unfossiliferous, and their age cannot be settled, except by the included *Lepidocyclina* limestone near their upper limit in Henzada. This limestone probably is of Padaung age. The thickness of the formation and the fact that the shales rest, according to Stuart, directly on the Eocene, would seem to suggest that their lower horizons extend downwards below the base of the Padaung clay. Dr. Stuart has himself drawn attention (unpublished note) to the possibility that the Sitsayan shales are not co-extensive with the Padaung clay, and my suggestion is in agreement with his views.

In the last column of the table I have given the stage names as finally shown by E. Vredenburg in his most recent paper on the Burmese sequence[2]. The stage-names are based for the Eocene and Lower Pegus on my own work, and that of the late H. S. Bion, in Pakokku and Minbu. For the Middle and Upper Pegus, the work of S. Rama Rau and M. Stuart forms the main basis.

[1] *Rec. Geol. Sur. Ind.*, XLI, p. 221.
[2] E. Vredenburg; Marine Fossils of Garo Hills; *Rec. Geol. Sur. Ind.*, LI, p. 303.

*Comparative Table of sections through the Pegu and Upper Eocene of Burma.*

| — | PAKOKKU. | MINBU (WEST.) | THAYETMYO. | PROME. | HENZADA. | STAGE NAMES AFTER E. VREDENBURG. |
|---|---|---|---|---|---|---|
| UPPER PEGUS | Deltaic and Shore deposits. | Deltaic and Coastal deposits. | Mogaung sands and *Turritella* sands. | 'Marine Irrawaddy' (Stuart, 1910). | Akauktaung beds . | AKAUKTAUNG AND PYALO. |
| | Ditto . | Deltaic and shallow marine deposits. | Kama clay ?= Padaukbin clay. | Kama clay . . | (wanting-Stuart) . | KAMA. |
| MIDDLE PEGUS | Deltaic and shore deposits. | Shallow marine deposits. | Letpanzeik beds. | Upper Prome stage | (wanting—Stuart) . | SINGU. |
| | Ditto . | Ditto . | Ditto. | Lower Prome stage | (wanting—Stuart) . | MINBU. |
| LOWER PEGUS | Deltaic and shore deposits. | Padaung clay . | *Lepidocyclina* beds. | Sitsayan shale . | *Lepidocyclina* limestone and associated Sitsayan shale. | SITSAYAN. |
| | Ditto, with Coal-seams. | Shwezetaw sandstones. | ?Coal-measures of Lime Hill. | ? Lower part of Sitsayan shale (doubtful, no fossils). | ? Lower part of Sitsayan shale. | SHWEZETAW. |
| UPPER EOCENE | Yaw shale . | *Velates* beds . . | ? lower shales of Lime Hill. | Not examined . | Sandstones without fossils ? | YAW. |
| | Pondaung sandstone. | Kyet-u-bok beds with *Orthophragmina omphalus*. | *Orthophragmina* beds. | Not examined . | Unfossiliferous . | PONDAUNG. |
| MIDDLE EOCENE. | Tabyin clay . | Nwamataung sandstones. | not known . | Not examined . | Unfossiliferous . | |

The stage name *Sitsayan* is perhaps open to objection, since at Sitsayan, the type locality, the shales appear to be barren and we do not know how far they extend in range as compared with the west Minbu section. I would suggest that the name be discarded and the name *Padaung* adopted,—a name already adopted by myself[1] in consultation with G. H. Tipper and H. S. Bion for this horizon. It is true that in my paper on west Minbu[2], I correlated the Padaung clay with the Sitsayan shale, but the correlation appears to me now to have been unwise.

The basal beds of the Irrawaddy series are referred by G. E. Pilgrim[3] to the Pikermi stage or Upper Pontian; the oyster species of the Akauktaungs on the other hand may indeed represent the incoming of the Pontian, but appear to be more suggestive of the Miocene than the Pliocene.

I at present incline to the view that the Akauktaung oyster beds are pre-Irrawaddian, while the Irrawaddy series themselves only touch the Pontian in their basal beds, but are probably in the main Pliocene.

The further consideration of this question may however be deferred until the geological map is extended further southwards, and further light is thrown on the correlation by field mapping.

Perhaps too much stress has been laid upon the Pontian, and too little upon the Pliocene, age of the Irrawaddy series. In concluding this paper, it seems advisable to sum up the evidence in our possession regarding the age of the Irrawaddy series. A collection from the basal beds at Yenangyaung[4], has been shown by Pilgrim to contain a Dhok Pathan (Pikermi) or *Upper* Pontian fauna. The higher horizons of the Irrawaddies at Yenangyaung are sparsely fossiliferous, and the presence of *Stegodon clifti* recorded by Pilgrim, and of *Rhinoceros* sp. ? =*sivalensis* by Pascoe may perhaps indicate a Tatrot horizon (Lower Pliocene) for the higher horizons. The fauna found by myself near Chaingzauk in the Pakokku district[5] is undoubtedly Tatrot in age, and indicates the Lower Pliocene. Further vertebrate evidence is wanting; the genera *Dorcatherium*, *Telmatodon*, *Cadurcotherium*, recorded from

[1] G. de P. Cotter: Coal-seams of Yaw River; *Rec. Geol. Sur. Ind.*, XLIV, p. 167.
[2] *Op. cit.*
[3] G. E. Pilgrim: Tertiary Freshwater Deposits of India; *id.* XL., p. 196, and Correlation of Siwaliks: *id.* XLIII, p. 306.
[4] E. H. Pascoe: *op. cit.* p. 65, and G. H. Pilgrim: *op. cit.* p. 196.
[5] *See* Rec. Geol. Sur. Ind., XLV, p. 126.

Burma by Pilgrim all come from the Pegu series. The fossil *Unionidæ* from the basal Irrawaddy beds in Thayetmyo district described by E. Vredenburg and B. Pershad[1] are closely related to living Burmese species, while the single Melaniid found (*Acrostoma variabile*) is still living. Although the evidence is meagre, such as there is favours the view that the bulk of the Irrawaddy series is Pliocene.

[1] E. Vredenburg and B. Pershad: *Unionidæ* from the Miocene of Burma. *Rec Geol. Sur. Ind.*, LI, p. 371.

## EXPLANATION OF PLATE.

PLATE 3.—Geological map of Padaukbin and Thayetmyo, Scale 1″=2 miles.

# THE OCCURRENCE OF BITUMEN* IN BOMBAY ISLAND. BY C. S. FOX, B SC., M.I.M.E., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 4 and 5.)

BOMBAY Island is one of a group of islands lying off the coast of the Konkan. It is now connected by causeways and breakwaters with the larger island of Salsette on the north and so continuously with the mainland of western India. On it is situated the city and port of Bombay. The island has an area of about 30 square miles and has the shape of a trapezoid (see map). It consists of a low lying plain about 11 miles long by 3 to 4 miles broad flanked by two parallel ridges of low hills. On the west are Malabar point, the Cumballa ridge, and Warli hill. To the east is Colaba point, the headland which protects the harbour from the force of the open sea, and several lesser hillocks which extend northwards to Sion hill.

Geologically the island appears to consist of a conformable series of basaltic lava flows and interbedded sedimentary beds which dip gently 10° to 15° to the west and have a general strike of N. 10° E. to S. 10° W. These rocks are well seen in the hills on each side of the island, whereas the central plain is covered with recent alluvial deposits. There are raised terraces of marine sediments 12 feet above sea level which indicate that large tracts of the western side of the island have been recently elevated from beneath the sea. Submerged forests have been discovered 40 feet below sea level on the eastern shore, thereby affording evidence that the eastern side of the island has been depressed within recent times.

An announcement was made in the Engineering Supplement of *The Times of India* of July 29th 1921 (page 4) to the effect that petroleum, mineral wax and bitumen had then quite recently been discovered within the municipal limits of the city of Bombay. It was stated that the locality, a road-metal quarry at Sewri, had been

* In this paper the term *bitumen* is used in its comprehensive sense in accordance with which mineral pitch, ozokerite and petroleum are all regarded as varieties of bitumen.

vi ited and that the above mentioned substances were seen. The suggestion was also made that the Government of India should make a thorough examination of the neighbourhood and of the mainland east of Bombay 'even to the extent of making trial borings to a considerable depth.'

Asphalt had, however, been recorded from the same place, *i. e.*, the basalt quarry behind Mackenzie's Saw Mills due west of Sewri Fort, three years before (September 1918) when Sir Henry Hayden, then Director of the Geological Survey of India, had visited the locality and collected specimens from the quarry. He found that the asphalt occurred as a layer on the floor of a large, low-roofed cavity in a peculiar greenish dolerite. The sides and particularly the roof of the cavity were lined with crystals of various minerals, chiefly calcite, quartz and zeolites—all of common occurrence in the geodes of the Deccan Trap of India. In addition, the whole inner surface of the cavity—floor, sides, roof and the faces of the encrusting crystals—was lightly coated with specks and chip-like fragments of hard, black, bituminous matter.

Where did the bitumen come from? Was it carried up with the basaltic lava as an essential constituent from the plutonic magma? Or did the dykes of dolerite break through coal-bearing beds, or through strata containing an abundance of animal remains, as they forced their way to the earth's surface? These were the questions that presented themselves after Sir Henry Hayden's visit.

The probability of oil-bearing beds beneath the traps of Bombay had never been seriously entertained, for the simple reason that the basalts of the island, probably of Upper Cretaceous age, are much older than the Nummulitic (Eocene) beds of Surat and Kathiawar, whereas the petroleum horizons in India and Burma occur in Miocene strata of the Tertiary period.

The possible existence of a hidden coalfield, buried under the traps of Western India, had long beem recognised. But, as this question was already receiving attention from the Great Indian Peninsula Railway, there seemed to be nothing to do but wait until the results of the proposed boring at Bhusawal were available.

The possibility that the presence of lenticular patches of coaly matter and of an abundance of frog remains, which were known to occur in the interbedded sedimentary beds of Warli and elsewhere, might offer an explanation was not examined owing to the assumption, based on previous careful mapping, that the traps were simple lava flows.

The *Times of India* report of fresh discoveries of bitumen—asphalt, mineral-wax and petroleum—in the Sewri quarry was therefore very welcome. It was thought that perhaps new clues might be obtained which would help to elucidate the problem. At the time that the announcement was made in the papers, I was under orders to proceed to London on deputation and had already arranged to leave from Bombay. I was asked to investigate the matter before embarking. The following observations and conclusions are based on my examination of the newly exposed cavities in Sewri quarry and on visits to certain geological sections upon which the interpretation of the true structure of the island appeared to me to depend. Although the investigation of the Sewri quarry did not take long, I would not, in the time at my disposal, have been able to check Wynne's wonderfully accurate map without the assistance of Mr. J. W. Mackison, the Engineer-in-Chief of the Bombay Municipality, who, knowing every road and corner of the island, took me to all the exposures I wanted to see—including the Port Trust quarries at Anik on the west side of Trombay Island.

## The Bitumen and its Mode of Occurrence in the Sewri Quarry.

The accompanying photographs give an idea of the size of the newly opened cavities. The quarry is being worked in a single rock-mass of a peculiar, greenish dolerite. This material has been found sufficiently hard and tough to make an excellent road-metal. The rock is jointed and has a rough-bedded appearance owing to the preponderant development of discontinuous horizontal joints. The irregular joint-planes have a distinct slope or dip to the west at low angles. All the cavities are found in a small area of the quarry—along a north and south strip 150 feet long by 30 feet wide. The largest cavity, that of 1918, was uppermost and the new ones occur at various levels below it. The vertical height from the roof of the big (1918) cavity to the floor of the lowest at present seen would not exceed 15 to 20 feet. The big cavity has unfortunately been destroyed but its size is stated to have been 20 feet wide, 30 feet deep (long) and 8 feet high under the crown of the dome. The recently exposed cavities are much smaller, and are said to have been full of water. In one instance this water is known to have been saline; but little importance can be attached to this point, as the sea is barely half a mile away and not at a very much lower level.

The cavities have a certain feature in common—their floors are generally plane surfaces which dip gently to the west—so that the solid, black bitumen is found accumulated as a layer on the dip side. Sections along the strike and parallel to the dip of a cavity are shown in Figs. 1 and 2. The internal structure is similar to the

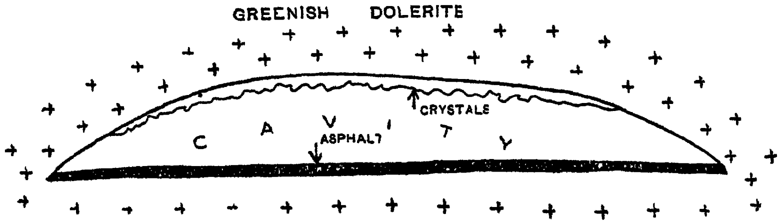


Fig. 1.

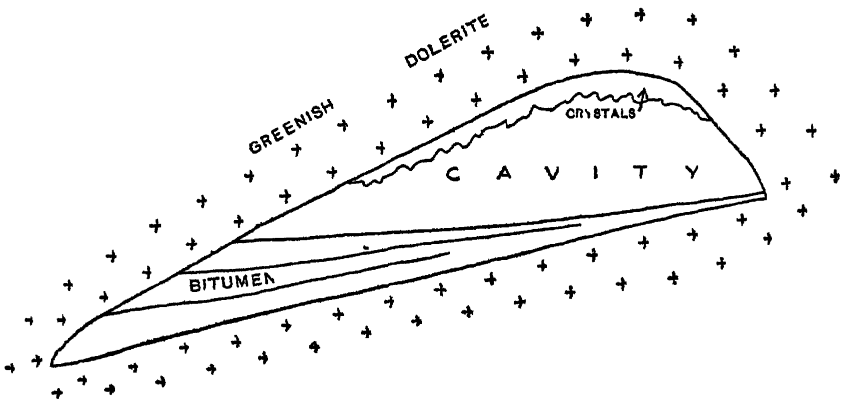


Fig. 2.

large one already described. The sides and roof *and the surface of the bitumen on the floor* are encrusted with crystals of calcite, quartz and various zeolites. Occasionally, beautiful, little, doubly-terminated, quartz crystals are found on the surface of the bitumen on the floor. Sprinkled over the whole encrusted surface there are specks and tiny fragments of solid black bitumen.

On the surface of the asphalt from a cavity immediately below the site of the large one there were a few clotted patches of mineral-wax, while from the lowest cavity both mineral-wax (ozokerite) and thick liquid petroleum were found on the surface of the asphalt. The liquid petroleum had become quite viscous when I saw the specimens. These samples were unfortunately collected without due regard to their mode of occurrence in the cavity and the accounts I received on the ground tended to confuse the problem at issue. It was difficult to make certain if the ozokerite and petroleum were floating on the water when the cavity was first opened. It is certain that these substances were collected from the floor when the water drained away.

According to an examination of specimens from the top cavity made by Dr. W. A. K. Christie the pitch is amorphous and in thin section quite structureless; its fracture is usually conchoidal but sometimes remarkably plane. The hardness is about 2—that of some pieces is slightly less than 2, that of others greater but less than 2·5. It is quite brittle. The specific gravity is 1·090 ($\frac{25°}{4°}$). The lustre is vitreous to dull. The colour is black, but delicate surface films of limonitic material impart various colours to it, mostly pale yellow to brown, but occasionally green or whitish and sometimes beautifully iridescent embracing all the colours of the spectrum. The streak is also black. It is not a homogeneous substance, part of it being soluble in carbon disulphide and part not. It is infusible at 1700° C. It burns easily in air with a smoky flame and the resulting ash consists largely of ferric oxides. Heated in a neutral atmosphere the pitch gives a slight brownish distillate; otherwise it is non-volatile.

The pitch contains:

| | Per cent. |
|---|---|
| C | 88·15 |
| H | 5·20 |
| O (by difference) | 4·01 |
| N | 1·04 |
| S | 0·32 |
| Moisture | 0·58 |
| Ash[1] | 0·70 |
| | 100·00 |

[1] Mainly ferric oxide—silica 0·13 per cent.

The most acceptable view[1] regarding the formation of petroleum is that certain forms, chiefly aquatic types, of vegetable and animal matter, when decaying by putrefaction or fermentation, become subject to bacterial action whereby the cellulose in the plants and the albumen (nitrogenous tissues) of the animals are attacked and eliminated, while the fatty matters at first remain; that subsequently, by saponification of these glycerides, free fatty acids are produced and the waxy esters are more or less hydrolysed; and that at a later stage carbon dioxide is given off from the fatty acids and esters and finally the petroleum is formed. Although the processes involved in the various stages of petroleum formation appear to take place exceedingly slowly in nature they do not require great pressures or high temperatures to promote their reactions. The essential product is petroleum and it is from this liquid that natural gases are given off and, if it is exposed to slow evaporation and atmospheric oxidation, mineral-wax (ozokerite, etc.) and asphalt may be left as residual products of the petroleum. This view obviously implies that the formation of petroleum takes place in the rocks in which the organic remains were originally entombed.

The evidence in the quarry pointed to the hydrocarbon having been included in the dolerite while the latter was in a plastic hot condition and suggested that the original, organic, bituminous matter had evidently suffered some degree of distillation—the various cavities representing bubbles or pockets in which the evolved gases had accumulated. The presence of unescaped gas bubbles as large as that of the big cavity, a volume of roughly 1,000 cubic feet, appeared difficult of explanation in a supposed lava flow. It would have seemed more natural for the gas bubbles to rise to the surface of the molten lava and eventually to escape, either into the air or into the sea according to whether the flow was of subaerial or submarine type. Did the lava become so viscous as it spread over the surface of the ground, or sea bottom, that even large bubbles of gas could not escape? Or is the dolerite of Sewri part of a sill?

Dr. H. J. Carter (*Journ. Bombay Branch, Roy. As. Soc.*, Vol. IV, p. 161, 1852) had definitely pointed to the occurrence of a sill-like sheet of basalt among the strata of Bombay Island, and Dr. Buist (*Trans. Bombay Geogr. Soc.*, Vol. X, p. 167, 1851) had given sketches,

[1] See 'A Treatise on Petroleum' by Sir Boverton Redwood, Vol. I, pp. 347-363, 1922 Edn

particularly of sections in and around Sewri, shewing that the relationship between the basalt and the fresh-water sedimentary beds was of an intrusive nature. However, Bombay Island was geologically mapped in detail in 1863, nearly 60 years ago, by Mr. A. B. Wynne of the Geological Survey of India who found he could not agree with Dr. Carter's views regarding the occurrence of intercalated intrusive trap in the bedded series of rocks of Bombay Island. He states, carefully choosing his words, that 'the whole island presents an ascending series of stratified deposits commencing with the black basaltic rock of Seoree (Sewri) on the east, succeeded by ........traps and shales ........ and terminated by the basaltic beds of Malabar ridge and Wurlee (Warli) ...... and this interpretation is not the less likely to be correct on account of its simplicity.' (See *Mem. Geol., Surv. Ind.*, Vol. V, p. 185, 1864.)

Was Wynne mistaken by the apparently conformable aspect of the strata and not fully alive to the possibility of a sill ?

## Visit to Various Exposures in the Island.

Wynne regarded the remarkable black, felsitic rock seen at Sewri Fort, in Cross Island and on Antop hill, and said to occur farther north in the vicinity of Vehar lake (Salsette), as the basal sheet of the Bombay series. The exceedingly fine texture, glass hardness and colour of this rock is quite unlike the dolerite of the Sewri quarry. In some respects, particularly chemical composition, fine texture and great hardness, the Sewri Fort rock closely resembles the lava capping Golangi hill (west of Sewri) and the trap on the hills of Malabar ridge, Cumballa hill and Warli, on the west of island. The following analyses are remarkable both for their similarity with each other and exceptional composition as regards the normal basalts of the Deccan volcanic period :—

| | I | II |
|---|---|---|
| $SiO_2$ | 61·60 | 59·80 |
| $Al_2O_3$ | 27·12 | 22·75 |
| $Fe_2O_3$ | 2·12 | 4·92 |
| FeO | 4·60 | 5·88 |
| CaO | 2·10 | 1·80 |
| MgO | ... | ... |
| $K_2O$ } $Na_2O$ } | trace | 2·50 |
| $H_2O$ and organic matter | 2·46 | 2·36 |

I. Specimen from Sewri Fort, analysis by A. B. Wynne, Geol. Surv. Office, Calcutta.
II. Specimen from upper basaltic rock of Malabar hill, analysis by A. Tween, Geol. Surv. Office, Calcutta.

The rock exposed in Nowroji hill quarry is, however, very similar to the dolerite of the Sewri quarry, but it has this peculiar feature; it is found to contain occasionally included fragments of sedimentary rock—some of the pieces being as big as a man's fist. Similar included fragments of sedimentary material are also found in the lower trap of the Golangi hill quarry. This quarry, which lies less than half a mile to the west of the Sewri quarry, is of importance. In it is seen a much-fissured, greenish, doleritic basalt which is overlain by a hard, black trap not unlike the upper traps of Malabar hill, Warli, etc. The lower trap of Golangi hill is well known for the nests of beautiful zeolite crystals which are found in it (and it also contains calcite crystals having scalenohedral faces with a development of the basal plane—a combination which results in forms of a barrel-shaped habit). Although the upper trap directly overlies the lower trap in this quarry the actual contact is not clearly seen and occasional thin laminae of sedimentary strata further confuse the section. However, outside the limits of the quarry, both to the north and to the south, well developed sections of fresh-water sedimentary beds are exposed, evidently on the same line of strike, in a manner suggestive of the sedimentary rock having been eliminated from the quarry section. A closer examination of the junction of the two traps in the quarry section shows that the one does not merely overlie a weathered surface of the lower—there is evidence of disturbance.

On the western side of the island there are also two well marked sheets of trap, but wherever these are seen, as in Malabar hill, Cumballa ridge or the high ground of Warli, there is always a thick group (40 feet or so) of fossiliferous, fresh-water, sedimentary beds between them. As has been said before, the upper trap is very like the overlying rock of Golangi hill and has the remarkable composition of an acid intermediate type of rock. It weathers very well and rings when struck with a hammer like a phonolite. It is not used for road metal owing to the glass-like sharpness of the angular fragments. The texture though micro-crystalline in the lower part of the trap, becomes more coarsely crystalline when followed upward in section. The high silica and alumina content make it, owing to low alkali percentage, an exceptional type of acid intermediate rock—possibly in some way related to the intrusive nepheline-syenites of Girnar hill in Kathiawar.

The junction of the upper trap with the underlying sedimentary beds is not clear in any of the sections I saw and it is difficult to say whether it is a subaerial or submarine lava flow or whether it is intrusive. The lower trap on the other hand, though much fissured and veined and silicified, has certainly disturbed the sedimentary strata above it. These beds are frequently buckled and crushed—sometimes dipping to north-west and in a few yards found to dip to the south-east. Further, the lower trap of the Warli section near Love Grove is very like the lower trap of Golangi hill, and I would have little hesitation in correlating them as part of a single sheet. It is true that in the exposures where the lower trap and the sedimentary beds are seen in contact the intrusive relationship of the former is not perfectly clear, but the whole evidence is decidedly in favour of the lower trap being an intrusive sill. However, if definite evidence of the existence of an intrusive trap is wanted, it can be supplied in the trap quarries of Anik, only 3½ miles as the crow flies east-north-east of Sewri. Two dykes are very well seen in these quarries: one, striking north 5° west to south 5° east is a great mass of coarse, greenish, pyritiferous dolerite; the other, striking north 25° east to south 25° west is a composite dyke of basalt. These dykes are closer to Sewri than the exposures at the Love Grove sluices at the south end of Warli hill. I am of the opinion that, although Wynne's mapping of the exposed rocks of Bombay island is correct, his deductions based on a belief in a simple conformable series, are not. I find myself in agreement with Dr. Carter's conclusions regarding the basalts of Malabar ridge and the Warli hills, that 'there was a second effusion, which coming up under the first, and not finding a ready outlet, followed the course of the freshwater strata below it, intercalating them and breaking them up into all sized fragments.' [Cf. p. 47.]

## Evidence of Tectonic Disturbance.

In accepting the view that the dolerite of Sewri quarry and Nowroji hill is part of the same sheet as the lower traps of Golangi hill and the hills of Malabar, Cumballa and Warli, and that the upper traps of the west of the island are represented on the east by the outlier on Golangi hill, we are confronted with a serious difficulty. The dips and strikes of the rocks seen on the west of the island would, if an imaginary trace of the strata were continued into the air eastward, take the same beds some hundreds of feet above the top of Golangi hill! Therefore my conclusions are either wrong or must invoke a north and south line of folding or faulting down the middle of the island. There is no indication of the existence of folding, but there is much evidence in favour of a relative displacement of the rocks on each of the island.

In his paper (See *Rec. Geol. Surv. Ind.* Vol. XLIX, p. 214, 1919) Mr. T. D. La Touche says 'it had been shown by Dr. Buist (*Trans. Bom. Geog. Soc.*, Vol. X, p. 179) that a raised beach, composed of shelly gravel partly consolidated into a littoral concrete, is found at many places on the western side of the island, extending to a height of 12 feet above high water mark.' Further, Mr. La Touche goes on to say that 'The existence of a number of forest trees (Khair, *Acacia catechu*) was brought to light during the excavation of the Prince's dock on the eastern side of Bombay island about the year 1878'; also that fresh discoveries of trees were made in 1910 during the construction of Alexandra dock. Here, 'the depth below high water mark of the rock surface on which the trees found at Alexandra dock were rooted is about 40 feet.' It is evident therefore that in a distance of 4 miles from east to west across the island there is an area of elevation in close proximity to an equally well authenticated region of very recent depression. The whole island has either been tilted along a north and south axis so that the western side has been elevated more than 12 feet and the eastern side submerged at least 40 feet, or this deplacement of upwards of 52 feet, is due to a relative movement of the rocks on each side of a northward trending fault. That tectonic movements have taken place in western India is well known. A depression in the Runn of Cutch was caused by the disturbance of an earthquake as recently as 1819. However, the mere tilting of the island would not account for the discontinuity in the trace of the beds from the Warli ridge over the low ground of Parel and Byculla to the exposures of Golangi hill and Sewri. That faulting is not absent in Bombay is shown by Wynne himself who marks on his map an east and west fault north of Antop hill. The presence of a great fault, out at sea, parallel to the west coast of India has long been suspected and it is well known that the hot-springs, which occur at intervals along the coastal strip of the Konkan from south of Ratnagiri to north of Bombay, lie on a remarkably straight line indicative of a band of fracture.

## Origin of the Bitumen.

The circumstantial evidence is very strongly in favour of the structure of Bombay island being due to the faulting of a single group of bedded rocks which consist of an intrusive sill of dolerite, a series of fresh-water sedimentary beds with abundant plant and animal remains, and an overlying mass of trachytic trap. Once this structure is admitted there is no need to speculate on the possibility of coal or oil bearing strata beneath the traps of Bombay. All the facts can be accounted for from the evidence available in the fossiliferous, fresh-water, sedimentary beds. These beds are known to be missing from the section seen in the Golangi hill quarry and it is considered that their absence is not due to lack of deposition, but to their subsequent local removal by the intrusion of the lower trap, as this mass of molten rock forced its way along the horizon of the sedimentary beds.

The best exposed section, a thickness of over 30 feet, of these fresh-water strata is seen at the south-west end of the Warli ridge just north of the Love Grove pumping station. Several observers have noted the lenticular patches of bright coaly matter in the upper part of the beds, and the frog beds of the lowest part of the section are of course well known everywhere. Carter actually marked the word 'coal' on his map in this vicinity and subsequent writers have spoken of the abundance of carbonaceous matter in the upper part of the sedimentary beds. This 'coal' although bright and hard and of the appearance of anthracite burns easily in air with a smoky flame and great intumescence.

J. Ribeiro (*Journ. Bom. Nat. Hist. Soc.*, Vol. XXVII, p. 586, 1921) in a paper full of observant information describes the lower part, the frog-beds, of the Warli section as follows:— 'Immediately resting on the lower trap there is a layer about 3 or 4 inches thick of a very dark coloured shale in a good state of preservation which splits into very thin laminæ. It consists of an extremely fine sediment, so fine that when held against the sunlight it gives out iridescent colours. When wetted and exposed to the sun it emits a strong smell of naphta. This is more pronounced in a newly broken rock and the quarrymen are quite aware of it. This naphthous smell is probably the result of the large amount of organic matter incorporated in the shale.'

These and many other similar observations are very significant when it is known that the total quantity of asphalt and other bituminous matter taken from the several cavities so far exposed is trifling—an amount not exceeding 5 cwts. This quantity could be easily accounted for as having come from the mass of the sedimentary beds which are missing from the Golangi hill section, assuming that these beds had as much organic matter present in them as is known to occur in the Warli section. With these points in view it is quite unnecessary to speculate on vague sources for the origin of the bitumen. The occurrence is of great scientific interest but unfortunately it holds no potentialities of an important commercial nature.

## EXPLANATION OF PLATES.

Plate 4.—Map of Bombay Island showing locality for Bitumen. Scale $\frac{1}{4}''$=1 mile.
„ 5. Fig. 1.—Quarry at Warli Hill, Bombay, showing trog beds.
„ 2.—Cavities containing bitumen. at Sewri, Bombay.

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# RECORDS

OF

# THE GEOLOGICAL SURVEY OF INDIA.

**Part 2.]** **1922** **[September.**


## THE MINERAL PRODUCTION OF INDIA DURING 1921. BY L. LEIGH FERMOR, O.B.E., D.SC., A.R.S.M., F.G.S., M.I.M.M., *Officiating Director, Geological Survey of India.*

### CONTENTS.



### INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these Records (Vol. XXXII), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. As the methods of collecting the returns become more precise and the machinery employed for the purpose more efficient, the number of minerals included in class I—for which approximately trustworthy annual returns are available—increases, and it is hoped that before long the minerals of class II—for which regularly recurring and full particulars cannot be procured—will be reduced to a very small number. In the case of minerals still exploited chiefly by primitive native methods, and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible, but the total error from year to year is not improbably approximately constant and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small indigenous alluvial industry contributes such an insignificant portion to the total outturn that any error from this source may be regarded as negligible.

In the previous Review the statement of values of the Indian Mineral Production for the year under review and for the preceding year was drawn up for purposes of comparison on the basis of an exchange value of the rupee at 2*s.* in each year, although this figure applied in practice only to the year 1920. With the great fall of the value of the rupee during 1921, it has become impossible to maintain this method of comparison, and the values shown in table 1 of the present Review are given on the basis of the actual average exchange values of the rupee for each year. For the sake of completeness, the values of the mineral production for 1919 have also been recalculated on the basis of the actual value of the rupee for that year. In the year 1919, the highest value reached was 2*s.* $4\frac{7}{8}$*d.*, and the lowest 1*s.* $5\frac{31}{32}$*d.*, the actual average value of the rupee during the year being 1*s.* $8\frac{27}{32}$*d.*; for purposes of calculation, a value of 1*s.* $8\frac{7}{8}$*d.*, corresponding to Rs. 11·5 to the £, has been adopted. In 1920, the highest value reached was 2*s.* $10\frac{1}{2}$*d.*, and the lowest value 1*s.* $4\frac{3}{4}$*d.*, the actual average value during the year being 2*s.* $0\frac{1}{16}$*d.*; the value of 2*s.* has been adopted in the table. In 1921, the highest value reached was 1*s.* $6\frac{1}{8}$*d.* and the lowest 1*s.* $2\frac{7}{8}$*d.*, the actual average value of the rupee during the year being 1*s.* $4\frac{1}{32}$*d.*, and the value of 1*s.* 4*d.* has been adopted. With these rates of exchange the total production of 1921 shows a decrease in value compared with 1920 of £8,232,930 or 27·3 per cent. as contrasted with an increase in 1920 compared with 1919 of £5,282,130 or 21·3 per cent. Decreases in value during 1921 were shown by all the metals and minerals produced, with the exception of iron-ore and a few unimportant minor mineral products. The largest percentage decreases amongst important minerals are shown by wolfram, mica, tin, manganese, chromite, and salt. These changes in value are, of course, an expression in part of the great variation in the prices of metals and ores in the world's markets, due first to the boom that followed immediately on the cessation of the war, and then to the succeeding and still existing period of depression, and in part of variations in the quantities produced, due partly to the variations in market price. It is interesting to compare in the figures of total value recorded in table 1 with the variations in the average annual value of the leading metals in the world's markets as summarised in table 2.

The number of mineral concessions granted during the year amounted to 651 as against 652 in the preceding year; of these 4 were exploring licenses, 563 were prospecting licenses, and 84 were mining leases.

TABLE 1.—*Total Value of Minerals for which returns of Production are available for the years 1919, 1920 and 1921.*

| —— | 1919. (Rupee =1s. 8⅞d.) | 1920. (Rupee =2s.) | 1921. (Rupee =1s. 4d.) | Increase. | Decrease. | Variation. Per cent. |
|---|---|---|---|---|---|---|
| | £ | £ | £ | £ | £ | |
| Coal . . . | 8,799,353 | 9,297,853 | 8,673,377 | ... | 624,476 | —7·2 |
| Petroleum . . | 7,252,951 | 7,954,632 | 5,603,975 | ... | 2,350,657 | —29·6 |
| Gold . . . | 2,127,708 | 2,733,115 | 2,050,576 | ... | 682,539 | —25·0 |
| Manganese-ore(*a*) . | 1,344,634 | 3,586,072 | 1,537,068 | ... | 2,049,004 | —57·1 |
| Lead and lead-ore . | 581,427 | 975,927 | 781,586 | ... | 191,341 | —19·6 |
| Salt . . . | 1,585,671 | 1,446,409 | 742,147 | ... | 704,262 | —48·7 |
| Silver . . . | 409,780 | 843,109 | 593,008 | ... | 250,101 | —29·7 |
| Mica(*a*) . . | 750,824 | 1,065,438 | 426,274 | ... | 639,164 | —60·0 |
| Building materials | 379,280 | 454,750 | 422,219 | ... | 32,531 | —7·1 |
| Saltpetre . . | 409,780 | 590,854 | 357,032 | ... | 233,822 | —39·6 |
| Tin and tin-ore . | 218,904 | 325,626 | 162,770 | ... | 162,856 | —59·4 |
| Iron-ore . . | 39,902 | 118,163 | 140,555 | 22,392 | ... | +18·9 |
| Carried over . | 23,900,223 | 29,391,948 | 21,493,587 | 22,392 | 7,920,753 | .. |

(*a*) Export values.

TABLE 1,—*Total Value of Minerals for which returns of Production are available for the years 1919, 1920 and 1921*—contd.

| —— | 1919 (Rupee =1*s.* 8⅜*d*.) | 1920 (Rupee =2*s*.) | 1921 (Rupee =1*s*. 4*d*.) | Increase. | Decrease. | Variation per cent. |
|---|---|---|---|---|---|---|
| | £ | £ | £ | £ | £ | |
| Brought forward . | 23,900,223 | 29,391,948 | 21,493,587 | 22,392 | 7,920,753 | ... |
| Jadeite(*a*) . . | 75,742 | 180,728 | 126,535 | ... | 54,193 | —29·9 |
| Ruby, sapphire and spinel. | 93,989 | 61,982 | 50,165 | ... | 11.817 | —19·1 |
| Clays . . . | 43.451 | 40,812 | 37,378 | ... | 3,434 | —8·4 |
| Chromite . . | 77,151 | 79,970 | 36,492 | ... | 43,478 | —54·3 |
| Copper-ore . . | 45,379 | 42,250 | 32,560 | ... | 9,690 | —22·9 |
| Monazite . . | 52,793 | 49,231 | 30,959 | ... | 18,272 | —37·1 |
| Tungsten-ore . | 453,212 | 139.707 | 29,292 | ... | 110,415 | —79·0 |
| Magnesite . . | 17.155 | 17,216 | 15,632 | ... | 1,584 | —9·2 |
| Steatite . . | 5.650 | 10,585 | 5,880 | ... | 4,705 | —44·4 |
| Diamonds . . | 18,109 | 4,125 | 4.865 | 740 | ... | +17·9 |
| Alum . . | 4,174 | 7,320 | 4,293 | ... | 3,027 | —41·3 |
| Barytes . . | 1,357 | 1.553 | 3,485 | 1,932 | ... | +124·4 |
| Bauxite . | 1,682 | 5.331 | 3,280 | ... | 2.051 | —38·5 |
| Gypsum . . | 2,494 | 3,693 | 2,267 | ... | 1,426 | —38·6 |
| Ochre . . . | 3,130 | 5,356 | 2.174 | ... | 3,182 | —59·4 |
| Aquamarine and beryl | ... | 1,225 | 1,274 | 49 | ... | +4·0 |
| Amber . . | 536 | 1,666 | 1.123 | ... | 543 | —32·6 |
| Fuller's earth . | ... | ... | 966 | 966 | ... | ... |
| Asbestos . | 1,440 | 7,272 | 884 | ... | 6,388 | —87·8 |
| Apatite . . | ... | ... | 231 | 231 | ... | ... |
| Antimony-ore . | 177 | 40 | 70 | 30 | ... | +75·0 |
| Corundum . . | 4,649 | 575 | 55 | ... | 520 | — 81·7 |
| Graphite . . | 713 | 560 | 52 | ... | 508 | —90·7 |
| Soda . . . | ... | ... | 24 | 24 | ... | ... |
| Molybdenite . | 88 | 19 | 13 | ... | 6 | —31·6 |
| Potash. . . | 37 | 25 | ... | ... | 25 | ... |
| Samarskite . . | 9 | 12 | ... | ... | 12 | ... |
| Total . | 24,803,540 | 30,053,201 | 21,883,536 | 26,364 | 8,196,029 | 27·3 |
| | | | | —8,169,665 | | |

(*a*) Export values.

TABLE 2.—*Average Prices in the United Kingdom of Principal Metals and Ores during 1919, 1920 and 1921.**

| — | 1919. | 1920 | 1921. |
|---|---|---|---|
| | £ per ton. | £ per ton. | £ per ton. |
| *Metals*— | | | |
| *Copper*, standard . . . . | 92·29 | 99·78 | 69·69 |
| *Lead*, pig, soft foreign . . . | 27·96 | 39·31 | 22·69 |
| *Spelter*, ordinary . . . . | 42·41 | 46·61 | 26·06 |
| *Tin*, standard . . . . | 253·17 | 299·9 | 166·02 |
| *Pig-iron*, Cleveland foundry No. 3 . | 6·84 | 10·53 | 6·89 |
| *Steel*, heavy rails . . . . | (*a*) | 23·04 | 15·62 |
| *Ferro-manganese* . . . . | 25·5 | 34·58 | 20·37 |
| *Gold*, fine, per ounce . . . | 84·954 *sh.* (*b*) | 112·960*sh* | 107·041*sh.* |
| *Silver*, standard, per ounce . . | 57·709*d.* | 61·590*d.* | 36·80*d.* |
| *Ores*— | | | |
| *Chromite*, 48-51%, per ton . . | £9·4 | £8·7 | £4·59 |
| *Manganese-ore*, first grade, per unit | 30*d.* | 45*d.* | 17*d.* |
| *Wolfram*, per unit . . . | 33·4*sh.* | 28·52*sh.* | 13·96*sh.* |

* Compiled mainly from the *Mining Journal* and the *Iron and Coal Trades Review.*
(*a*) Not available.
(*b*) Royal Mint price.

## II.—MINERALS OF GROUP I.

| | | | | |
|---|---|---|---|---|
| Chromite. | Gold. | Lead. | Monazite. | Salt. |
| Coal. | Graphite. | Magnesite. | Petroleum. | Saltpetre. |
| Copper. | Iron. | Manganese. | Ruby, Sapphire and Spinel. | Silver. |
| Diamonds. | Jadeite. | Mica. | | Tin. |
| | | | | Tungsten. |

## hromite.

The continued decrease in the output of chromite during the years 1919 and 1920 from the peak production of 1918 was not continued in 1921, when there was an increase in output of nearly 8,000 tons over the previous year, the output for Baluchistan being the maximum on record.

TABLE 3.—*Quantity and Value of Chromite produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. (Rupee=2s.) | | Quantity. | Value. (Rupee=1s. 4d.) | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Baluchistan*— | | | | | | |
| Zhob . . | 20,577 | 6,68,744 | 66,875 | 25,122 | 3,76,826 | 25,122 |
| *Bihar & Orissa*— | | | | | | |
| Singhbhum . | 2,546 | 57,394 | 5,739 | 2,605 | 52,610 | 3,507 |
| *Mysore*— | | | | | | |
| Hassan . . | 3,400 | 68,000 | 6,800 | 6,486 | 116,748 | 7,783 |
| Mysore . . | 278 | 5,560 | 556 | 549 | 1,198 | 80 |
| **Total** . | **26,801** | *7,99,698* | *79,970* | **34,762** | *547,382* | *36,492* |

## Coal.

In contrast to public expectation, there was an increase during the year of over 1,300,000 tons, or somewhat over 7 per cent., in the output of coal. This increase was due largely to Bihar and Orissa and the Central Provinces, but all the other provinces show increases, with the exception of Assam and Hyderabad, which show small decreases. The considerable increase shown by Bihar and Orissa was due chiefly to the Jharia and Bokaro fields, whilst the increase in the Central Provinces was due mainly to the Pench Valley and Ballarpur fields. In Hyderabad State the Singareni field showed a decrease of about 48,000 tons, which was nearly balanced by an initial production of over 42,000 tons from the Sasti coalfield opposite to Ballarpur in British territory. There was a general increase in the pit's mouth value of coal, except in Baluchistan, the rate of increase varying from as little as Re. 0-5-7 in Assam to Rs. 2-9-10 in the Punjab ; the increase in the fields of Bihar and Orissa averaged Re. 1-13-8 and in Bengal Re. 1-6-3. The decrease in Baluchistan was Rs. 2-8-1 per ton. During the year, the existence was proved in the Talcher coalfield of considerable quantities of good steam coal, and this field is now in course of commercial development.

TABLE 4.—*Average Price (per ton) of Coal extracted from the Mines in each province during the year 1920 and 1921.*

| —— | 1920. | 1921. |
|---|---|---|
| | Rs. A. P. | Rs. A. P. |
| Assam | 7 7 9 | 7 13 4 |
| Baluchistan | 16 9 9 | 14 1 8 |
| Bengal | 6 5 5 | 7 11 8 |
| Bihar and Orissa | 4 9 2 | 6 6 10 |
| Burma | ... | 11 7 6 |
| Central India | 4 4 10 | 5 11 6 |
| Central Provinces | 5 13 3 | 7 0 0 |
| Punjab | 12 3 10 | 14 13 8 |
| Rajputana | 7 7 1 | 8 13 4 |

TABLE 5.—*Origin of Indian Coal raised during 1920 and 1921.*

| —— | Average of last five years | 1920. | 1921. |
|---|---|---|---|
| | Tons. | Tons. | Tons. |
| Gondwana coalfields | 18,953,226 | 17,526,444 | 18,843,792 |
| Tertiary coalfields | 402,769 | 435,770 | 459,155 |
| Total | **19,355,995** | **17,962,2 4** | **19,302,947** |

TABLE 6.—*Provincial Production of Coal during the years 1920 and 1921.*

| Province. | 1920. | 1921. | Increase. | Decrease. |
|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Tons. |
| Assam | 325,535 | 312,465 | ... | 13,070 |
| Baluchistan | 33,941 | 54,627 | 20,686 | ... |
| Bengal | 4,207,452 | 4,259,642 | 52,190 | ... |
| Bihar and Orissa | 11,975,656 | 12,990,481 | 1,014,825 | ... |
| Burma | ... | 300 | 300 | ... |
| Central India | 158,051 | 192,034 | 33,983 | ... |
| Central Provinces | 491,205 | 712,914 | 221,709 | ... |
| Hyderabad | 694,080 | 688,721 | ... | 5,359 |
| Punjab | 58,078 | 67,242 | 9,164 | ... |
| Rajputana | 18,216 | 24,521 | 6,305 | ... |
| Total | **17,962,214** | **19,302,947** | ***1,359,162*** | ***18,429*** |

TABLE 7.—*Output of the Gondwana Coalfields for the years 1920 and 1921.*

| Coalfield. | 1920. | | 1921. | |
|---|---|---|---|---|
| | Tons. | Per cent. of Indian Total. | Tons. | Per cent. of Indian Total. |
| *Bengal, Bihar and Orissa*— | | | | |
| Bokaro . . . . . | 857,522 | 4·78 | 929,143 | 4·81 |
| Daltonganj . . . . | 39,113 | 0·22 | 36,590 | 0·19 |
| Giridih . . . . . | 831,293 | 4·63 | 818,580 | 4·24 |
| Jainti . . . . . | 118,651 | 0·66 | 105,632 | 0·55 |
| Jharia . . . . . | 9,294,040 | 51·74 | 10,068,856 | 52·16 |
| Rajmahal Hills . . . | 960 | ... | 2,170 | 0·01 |
| Ramgarh . . . . . | 6,863 | 0·04 | ... | ... |
| Rampur (Raigarh-Hingir) . | 36,987 | 0·21 | 77,277 | 0·40 |
| Raniganj . . . . . | 4,997,679 | 27·82 | 5,211,855 | 27·00 |
| *Central India*— | | | | |
| Sohagpur . . . . . | ... | ... | 37,060 | 0·19 |
| Umaria . . . . . | 158,051 | 0·88 | 154,974 | 0·80 |
| *Central Provinces*— | | | | |
| Ballarpur . . . . . | 128,162 | 0·71 | 171,425 | 0·89 |
| Mohpani . . . . . | 83,335 | 0·47 | 89,623 | 0·47 |
| Pench Valley . . . . | 279.483 | 1·56 | 449,311 | 2·33 |
| Shahpur . . . . . | ... | ... | 210 | ... |
| Yeotmal . . . . . | 225 | ... | 2,345 | 0·01 |
| *Hyderabad*— | | | | |
| Sasti . . . . . | 27,745 | ... | 42,674 | 0·22 |
| Singareni . . . . . | 666,335 | 3·86 | 646,047 | 3·35 |
| Total . | **17,526,444** | **97·58** | **18,843,792** | **97·62** |

TABLE 8.—*Output of the Tertiary Coal-fields for the years 1920 and 1921.*

| Coalfield. | 1920. | | 1921. | |
|---|---|---|---|---|
| | Tons. | Per cent. of Indian Total. | Tons. | Per cent. of Indian Total. |
| *Assam—* | | | | |
| Khasi and Jaintia Hills . | 570 | 1·81 | 443 | 1·62 |
| Makum . . . . | 285,974 | | 269,198 | |
| Naga Hills . . . | 38,991 | | 42,824 | |
| *Baluchistan—* | | | | |
| Kalat, Mach, Sor Range . | 11,406 | 0·19 | 23,374 | 0·28 |
| Khost . . . . | 22,535 | | 31,253 | |
| *Burma—* | | | | |
| Loi-an (Kalaw) . . . | ... | ... | 300 | ... |
| *Punjab—* | | | | |
| Jhelum . . . . . | 47,803 | 0·32 | 50,639 | 0·35 |
| Mianwali . . . . . | 6,835 | | 11,852 | |
| Shahpur . . . . . | 3,440 | | 4,751 | |
| *Rajputana—* | | | | |
| Bikanir . . . . | 18,216 | 0·10 | 24,521 | 0·13 |
| **Total** . | **435,770** | 2·42 | **459,155** | **2·38** |

In spite of the considerable increase, the total production was nevertheless nearly 3 million tons below the output of 1919, and the coal situation became so acute that it was found necessary early in the year to prohibit the export of Indian coal to foreign ports. The effects of this step are seen in the export statistics, which show a fall from a total of nearly 1¼ million tons in 1920 to slightly over ¼ million tons in 1921. On the other hand, the imports rose from the insignificant figure of under 40,000 tons in 1920 to over 1 million tons in 1921, 462,000 tons coming from South Africa, 436,000 tons from the United Kingdom, 111,000 from Australia (including New Zealand), and the balance from other countries.

TABLE 9.—*Exports of Indian Coal and Coke during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| To— | | | | | | |
| Aden and Dependencies . | 83,668 | 10,81,370 | 108,137 | 17,575 | 2,01,166 | 13,411 |
| Ceylon . . . . . | 684,930 | 86,87,960 | 868,796 | 236,179 | 32,01,578 | 213,439 |
| Straits Settlements (including Labuan). | 228,108 | 29,79,060 | 297,906 | 10,682 | 1,52,100 | 10,140 |
| Sumatra . . . . . | 69,473 | 8,38,060 | 83,806 | 6,251 | 87,514 | 5,834 |
| Egypt . . . . . | 102,457 | 13,41,870 | 134,187 | 200 | 400 | 27 |
| Other Countries . . . | 53,981 | 7,23,210 | 72,321 | 2,761 | 1,11,119 | 7,408 |
| TOTAL . | 1,222,517 | 1,56,51,530 | 1,565,153 | 273,648 | 37,53,877 | 250,259 |
| Coke . . . . . . | 2,241 | 61,510 | 6,151 | 1,923 | 93,518 | 6,234 |
| Total of Coal, Coke, etc. . . | 1,224,758 | *1,57,13,040* | *1,571,304* | 276,571 | *38,47,395* | *256,493* |

TABLE 10.—*Imports of Coal, Coke and Patent Fuel during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| From— | | | | | | |
| Australia (including New Zealand). | 8,134 | 2,01,380 | 20,138 | 111,384 | 37,58,254 | 250,550 |
| Natal . . . . . | 7,596 | 2,30,940 | 23,094 | 306,235 | 1,13,16,644 | 754,443 |
| Portuguese East Africa . | 7,933 | 2,37,110 | 23,711 | 156,555 | 58,74,560 | 391,637 |
| United Kingdom . . | 4,122 | 2,08,600 | 20,860 | 436,012 | 1,86,17,067 | 1,241,138 |
| Other Countries . . . | 10,801 | 3,04,180 | 30,418 | 74,501 | 25,57,310 | 170,487 |
| TOTAL . | 38,586 | 11,82,210 | 118,221 | 1,084,687 | 4,21,23,835 | 2,808,255 |
| Coke . . . . . | 1,141 | 1,10,800 | 11,080 | 6,051 | 5,01,811 | 33,421 |
| Patent fuel . . . . . | .. | .. | .. | 11 | 2,502 | 167 |
| Total of Coal, Coke, etc. . . | 39,727 | *12,93,010* | *129,301* | 1,090,749 | *4,26,27,648* | *2,841,843* |

This decrease in the production of coal in India, in the years 1920 and 1921, as compared with 1919, is probably to be correlated to a large extent with the decreased efficiency of labour, following at least in part on increases in wages, which enabled the worker to obtain his requirements in a smaller number of working hours per day; and to a smaller extent to the increased price of coal, which resulted in an increase in the number of shallow workings, to which labour was attracted from the better organised mines. A higher output per head is probably to be obtained in the future only by the greater use of mechanical means of cutting, extraction, and transport. Any large increase of output in the near future will not, however, relieve the situation in full, until the railways have provided themselves with increased terminal facilities and doubled or trebled some of the existing lines.

The average number of persons employed daily in the coalfields during the year increased by 15,537 or about 8 per cent., the total number of persons employed exceeding even the total for the year 1919; but the average output per person employed was less even than that of the preceding year, being 93·98 tons per person as against 94·37 tons in 1920 and 111·05 tons in 1919. The total number of deaths by accident was 286, corresponding to a death-rate of 1·39 per thousand persons employed, which compares very unfavourably with 189 deaths by accident and a death-rate of 0·99 per thousand in 1920; the 1921 figures are, however, very similar to those of 1919, which were 287 deaths or 1·41 per thousand persons employed.

TABLE 11.—*Average number of persons employed daily in the Indian Coalfields during 1920 and 1921.*

| Province. | Number of persons employed daily. | | Output per person employed. | Number of deaths by accident. | Death-rate per 1,000 persons employed. |
|---|---|---|---|---|---|
| | 1920. | 1921. | 1921. | 1921. | 1921. |
| | | | Tons. | | |
| Assam | 3,171 | 3,389 | 92·2 | 16 | 4·7 |
| Baluchistan | 986 | 1,330 | 41·1 | 9 | 6·7 |
| Bengal | 43,782 | 45,813 | 93·0 | 48 | 1·05 |
| Bihar and Orissa | 118,260 | 126,431 | 102·7 | 163 | 1·3 |
| Burma | 242 | 270 | 1·1 | 1 | 3·7 |
| Central India | 1,617 | 1,967 | 97·6 | 8 | 4·0 |
| Central Provinces | 8,403 | 12,152 | 58·6 | 18 | 1·5 |
| Hyderabad | 12,446 | 12,502 | 55·1 | 21 | 1·7 |
| Punjab | 1,320 | 1,898 | 35·4 | 2 | 1·05 |
| Rajputana | 115 | 127 | 193·1 | ... | ... |
| **Total** | **190,342** | **205,879** | ... | 286 | ... |
| AVERAGE | ... | ... | 93·76 | ... | 1·39 |

## Copper.

The output of copper-ore in Singhbhum has been maintained at a fairly steady level since 1919, following the commencement of smelting operations at the Rakha Mines during the year 1918. The output in 1919 was 32,756 tons, which fell in 1920 to 28,167 tons, valued at £42,250, and again in 1921 to 23,089 tons, valued at £32,560. Smelting operations, commenced during the year 1918, resulted in the production of 980¼ tons of refined copper in the year 1919, 512 tons in 1920, and 1,143 tons in 1921. There was also a small production of 30 tons of copper-ore in Mysore State.

## Diamonds.

The output of diamonds from Central India amounted to 126·1 carats, valued at Rs. 72,970 (£4,865), as against 85·1 carats, valued at Rs. 41,252 (£4,125) in the preceding year.

## Gold.

The continuous decrease in the output of gold in India from the maximum production of 616,728 ozs. reached in 1915, continued during the year 1921, when the total output of gold was 432.723 ozs., valued at £2,050,576, as compared with an output of 499,068 ozs., valued at £2,733,115 in the previous year. This decrease was due partly to the cessation of operations of the Hatti (Nizam's) Gold Mines, Limited, and to a decrease of some 50,000 ozs. from the gold mines of Kolar.

TABLE 12.—*Quantity and value of Gold produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | | Labour. |
|---|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | | |
| | Ozs. | Rs. | £ | Ozs. | Rs. | £ | |
| *Burma*— | | | | | | | |
| Katha . | 3·04 | 202 | 20 | 15·66 | 927 | 62 | 112 |
| Upper Chindwin. | 7·69 | 717 | 72 | 26·503 | 3,115 | 208 | |
| *Hyderabad* . | 12,390 | 5,88,695 | 58,869·5 | | | | |
| *Madras*— | | | | | | | |
| Anantapur . | 13,645 | 8,03,535 | 80,353·5 | 10,108 (*a*) | 7,21,359 | 48,001 | 535 |
| *Mysore* . . | 472,958 | 2,59,33,544 | 2,593,354 | 422,533 (*b*) | 3,00,30,373 | 2,002,025 | 23,344 |
| *Punjab* . . | 61·18 | 4,274 | 427 | 39·43 | 2,833 | 190 | 45 |
| *United Provinces* | 2·7 | 100 | 19 | *Nil.* | *Nil.* | .. | *Nil.* |
| Total . | 499,067·61 | *2,73,31,158* | *2,733,115* | 432,722·593 | *3,07,58,027* | *2,050,576* | 24.045 |

(*a*) Fine gold.
(*b*) Contains 380,780·49 ozs. fine gold.

## Graphite.

There was a fall in the output of graphite from 100 tons, valued at Rs. 5,600 (£560) in 1920, to 25 tons, valued at Rs. 784 (£52) in the year under review. This decrease in output was due largely to the discontinuance of operations in Patna State and Ajmer-Merwara.

TABLE 13.—*Quantity and value of Graphite produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Bihar and Orissa*— | | | | | | |
| Bhagalpur . | ... | ... | ... | 1 | 60 | 4 |
| Patna . . | 60 | 3,600 | 360 | *Nil* | .. | .. |
| Singhbhum . | 0·2 | 15 | 1·5 | *Nil* | .. | .. |
| *Central Provinces*— | | | | | | |
| Betul . . | 23·1 | 540 | 54 | 24·1 | 724 | 48 |
| *Rajputana*— | | | | | | |
| Ajmer-Merwara | 16·8 | 1,445 | 144·5 | *Nil* | ... | ... |
| **Total** . | **100·1** | *5,600* | *560* | **25·1** | *784* | *52* |

## Iron.

There was an increase in the output of iron-ore of about 70 per cent., *viz.*, from 558,005 tons, valued at Rs. 11,81,628 (£118,163) to 942,084 tons, valued at Rs. 21,08,329 (£140,555). This increased production was due largely to the increased activity of the Tata Iron and Steel Company, Limited, who blow in their third blast furnace (the Batelle furnace) in August 1919, the full effect of which was not felt until 1921, when the company produced 281,541 tons of pig iron, 125,336 tons of steel including rails, and 3,076 tons of ferro-manganese. The Bengal Iron Company record a slightly smaller output than in the preceding year, *viz.*, 86,445 tons of pig iron and 27,219 tons of cast iron castings, with no production of ferro-manganese. The remainder of the increased production of iron-ore is due largely to extraction by the Indian Iron and Steel Company in anticipation of the commencement of smelting operations at Burnpore. In the Central Provinces, the number of indigenous furnaces in operation fell from 225 in 1920 to 155 in 1921, the decrease being mainly in the Raipur district. The output in Burma is by the Burma Corporation, Limited, for use as a flux in lead-smelting.

TABLE 14.—*Quantity and value of Iron-ore produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Bihar and Orissa—* | | | | | | |
| Mayurbhanj . . | 403,359 | 8,06,718(*a*) | 80,672 | 651,495 | 13,02,990(*a*) | 86,866 |
| Sambalpur . . . | 1,010 | 5,722 | 572 | 797 | 4,602 | 307 |
| Singhbhum . . . | 113,008 | 2,08,641 | 20,864 | 237,173 | 5,88,774 | 39,251 |
| *Burma—* | | | | | | |
| Mandalay . . . | 19,104 | 77,716 | 7,772 | 11,916 | 47,664(*a*) | 3,178 |
| Northern Shan States . | 18,279 | 72,045 | 7,204 | 37,915 | 1,51,660(*a*) | 10,110 |
| *Central Provinces* . . | 3,241 | 10,786 | 1,079 | 2,433 | 9,925 | 662 |
| *Other Provinces and States* | 4 | (*b*) | .. | 355 | 2,714 | 181 |
| TOTAL . | 558,005 | *11,81,628* | *118,103* | 942,084 | *21,08,320* | *140,555* |

(*a*) Estimated. (*b*) Not available.

## Jadeite.

There was a small increase in the output of jadeite in Burma, which rose from 3,429 cwts., valued at Rs. 4,83,514 (£48,351) in 1920, to 3,815 cwts., valued at Rs. 7,01,673 (£46,778) in the year under review. The output figures are, however, always incomplete, and a better idea of the extent of the jadeite industry is obtainable from the export figures, which for the year 1920-21 were 5,094 cwts., valued at Rs. 18,07,284 (£180,728), increasing in the year under review to 5,374 cwts., valued at Rs. 18,98,030 (£126,535)

## Lead.

The production of lead-ore at the Bawdwin mines increased by some 15,000 tons; and the total amount of metal extracted increased from 23,821 tons, valued at Rs. 97,56,213 (£975,621), to 33,717 tons, valued at Rs. 1,17,46,967 (£783,131). The quantity of silver extracted rose from 2,869,727 ozs., valued at Rs. 83,37,362 (£833,736), to 3,555,021 ozs., valued at Rs. 88,20,855 (£588,057). The value of the lead extracted decreased from Rs. 409 (£40·9) per ton in 1920 to Rs. 348 (£23·2) per ton in the year under review, and that of silver from Rs. 2-14-0 per oz. (69*d.*) to Rs. 2-7-8 (39·7*d.*) per oz.

TABLE 15.—*Production of Lead and Silver Ore during 1920 and 1921.*

| | 1920. | | | | | 1921. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | QUANTITY. | VALUE. | | | | QUANTITY. | VALUE. | | | |
| | Lead-ore. | Lead-ore and lead. | | Silver. | | Lead-ore. | Lead-ore and lead. | | Silver. | |
| | Tons. | Rs. | £ | Rs. | £ | Tons. | Rs. | £ | Rs. | £ |
| *Burma*— | | | | | | | | | | |
| Northern Shan States. | 128,008 (ore) | 97,56,213(*a*) | 975,621 | 83,37,362(*b*) | 833,736 | 114,080 | 1,17,16,967(*c*) | 783,131 | 88,20,855(*d*) | 588,057 |
| Southern Shan States | 88·25 | 2,708 | 271 | .. | .. | 138·1 | 21,812 | 1,451 | .. | .. |
| *Central Provinces*— | | | | | | | | | | |
| Drug . . . | 0·05 | 350 | 35 | .. | .. | 0·5 | 10 | 1 | .. | .. |
| Total . | 128,096·30 | *97,59,271* | *975,927* | *83,37,362* | *833,736* | 144,227 6 | *1,17,38,789* | *784,586* | *88,20,855* | *588,057* |

(*a*) Value of 23,821 tons of lead extracted.
(*b*) Value of 2,869,727 ozs. of silver extracted.
(*c*) Value of 33,717 tons of lead extracted.
(*d*) Value of 3,555,021 ozs. of silver extracted.

## Magnesize.

The check on the revival of the Indian magnesite industry recorded last year disappeared during 1921, when the output increased by nearly 6,000 tons over the figure for the preceding year, reached the highest figure that has yet been recorded.

TABLE 16.—*Quantity and value of Magnesite produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Madras*— | | | | | | |
| Salem . . | 11,300 | 1,35,600 | 13,560 | 17,152 | 205,824 | 13,722 |
| *Mysore*— | | | | | | |
| Hassan . . | 640·5 | 7,686 | 769 | 50 | 500 | 33 |
| Mysore . . | 2,406 | 28,872 | 2,887 | 2,815 | 28,150 | 1,877 |
| **Total** . | **14,346·5** | *1,72,158* | *17,216* | **20,017** | *2,34,474* | *15,632* |

## Manganese.

In the year 1920 the output of manganese-ore in India reached a figure, 736,439 tons, which has previously been exceeded only twice, *viz.*, in the year 1907, when the output was 902,291 tons, and in 1910 with 800,907 tons. In value, however, the output for 1920 reached by far the highest figure hitherto recorded, *viz.*, £3,586,072, this being the f. o. b. value at Indian ports of the total production, calculated from the average c. i. f. value at United Kingdom ports and the average freight rates from India to the United Kingdom, taken respectively at 45*d.* per unit and £4 9*s.* 4*d.* per ton. During 1921, there was a small fall in output to 679,286 tons, valued at £1,537,068 f. o. b. at Indian ports, calculated from an average c. i. f. value at United Kingdom ports of 17*d.* and an average freight rate from India to United Kingdom ports at £1 5*s.* From tables 17 and 18 it will be seen, however, that the exports during the year were about 130,000 tons less than the production, as compared with 1920, when the exports corresponded almost exactly with the production. The figures of distribution of the exported ore according to destination show that this decrease in exports was due chiefly to the enormous decrease of over a quarter of a million tons in the quantity of ore taken by the United Kingdom, due, of course, to the disastrous reduction in steel-smelting in Britain due to the effects of the coal strike and high labour charges. The large exports to Belgium are in part for transmission to Germany.

TABLE 17.—*Quantity and value of Manganese-ore produced in India during 1920 and 1921.*

| — | 1920. | | 1921. | |
|---|---|---|---|---|
| | Quantity | Value f. o. b. at Indian ports. | Quantity. | Value f. o. b. at Indian ports. |
| | Tons. | £ | Tons. | £ |
| *Bihar and Orissa*— | | | | |
| Gangpur | 21.161 | 103,865 | 19,823 | 45,427 |
| Singhbhum | 500 | 2.454 | 425 | 974 |
| *Bombay*— | | | | |
| Chota Udepur | 29,230 | 143.471 | 29.467 | 67,5[illegible]8 |
| Panch Mahals | 34,166 | 167,698 | 44,276 | 101,465 |
| *Central Provinces*— | | | | |
| Balaghat | 257,857 | 1,262,026 | 253,509 | 581,160 |
| Bhandara | 90,919 | 446.469 | 69,291 | 158,790 |
| Chhindwara | 51,517 | 252,896 | 43,661 | 100,055 |
| Nagpur | 221,912 | 1,089 366 | 186,491 | 427.372 |
| *Madras*— | | | | |
| Sandur State | .. | ... | 567 | 921 |
| Vizagapatam | 7,386 | 27,882 | 16,593 | 26,964 |
| *Mysore*— | | | | |
| Chitaldrug | ... | ... | 1,000 | 1,750 |
| Shimoga | 21,667 | 89,556 | 13,493 | 23,612 |
| Tumkur | 94 | 389 | 600 | 1,050 |
| **Total** | ***736,439*** | ***3.586,072*** | ***679,286*** | ***1,537,068*** |

TABLE 18.—*Exports of Manganese-ore during 1920 and 1921 according to ports of shipment.*

| Port. | 1920. | 1921. |
|---|---|---|
| | Tons. | Tons. |
| Bombay . . . . . . . | 377,148 | 271,826 |
| Calcutta . . . . . . . . | 323,258 | 259,621 |
| Vizagapatam . . . . . . . | 10,450 | 8,442 |
| Mormugao . . . . . . . | 25,745 | 10,874 |
| Total . | **736,601** | **550,763** |

TABLE 19.—*Distribution of Manganese-ore exported during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| To— | | | | | | |
| United Kingdom . . | 350,383 | 68,73,700 | 687,370 | 96,759 | 24,05,918 | 160,395 |
| Belgium . . . | 164,832 | 37,92,760 | 379,276 | 228,764 | 55,71,269 | 371,118 |
| France . . . | 70,091 | 15,50,040 | 155,004 | 79,855 | 17,95,707 | 119,714 |
| Italy . . . . | 15,300 | 3,88,120 | 38,812 | 9,600 | 3,07,300 | 20,487 |
| Japan . . . . | .. | .. | .. | 2,250 | 58,225 | 3,882 |
| United States of America | 105,600 | 25,91,150 | 259,115 | 86,360 | 23,28,925 | 155,262 |
| Other Countries . . | 4,650 | 1,25,300 | 12,530 | 30,301 | 9,04,600 | 60,311 |
| **Total** . | **710,856** | *1,53,20,160* | *1,533,016* | **539,389** | *1,33,72,004* | *891,409* |

## Mica.

The declared output of mica shows a large decrease, amounting to over 14,000 cwts., from that of the previous year. As has frequently been pointed out, the output figures are incomplete, and a better idea of the state of the industry is obtained from the export figures, which show a fall from 76,517 cwts., valued at Rs. 1,06,54,380 (£1,065,438) in 1920 to 30,944 cwts., valued at Rs. 63,94,113 (£426,274) in 1921, corresponding to a change in the average price from Rs. 139 (£13·9) per cwt. to Rs. 206·6 (£13·8) per cwt.

TABLE 20.—*Quantity and value of Mica produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Cwts. | Rs. | £ | Cwts. | Rs. | £ |
| *Bihar and Orissa—* | | | | | | |
| Gaya | 4,822 | 1,90,864 | 19,086 | 5,013 | 1,77,473 | 11,882 |
| Hazaribagh | 26,984 | 13,93,209 | 139,321 | 20,740 | 10,82,535 | 72,169 |
| Manbhum | 0·5 | 102 | 10 | 4 | 60 | 4 |
| Monghyr | 1,069 | 44,232 | 4,423 | 291 | 7,597 | 506 |
| Sambalpur | 8 | 300 | 30 | 4 | 150 | 10 |
| *Central Provinces* | 0·3 | 12 | 1 | .. | .. | .. |
| *Madras—* | | | | | | |
| Kistna | 83 | 2,701 | 270 | 8 | 499 | 33 |
| Nellore | 11,160·8 | 5,60,979 | 56,098 | 4,297 | 2,05,140 | 13,677 |
| Nilgiris | .. | .. | . | 11 | 1,696 | 113 |
| Salem | 509 | 46,203 | 4,620 | 20 | 1,595 | 106 |
| Travancore | 175 | 4,531 | 453 | 37 | 1,503 | 100 |
| *Mysore—* | | | | | | |
| Hassan | .. | .. | . | 118 | 4,120 | 275 |
| Mysore | 55·2 | 2,125 | 213 | 69 | 133 | 10 |
| *Rajputana—* | | | | | | |
| Ajmer-Merwara | 2,085·7 | 1,05,517 | 10,552 | 1,872 | 111,083 | 7,402 |
| **Total** | **46,952·5** | *23,50,775* | *235,077* | **32,488** | *15,93,566* | *106,337* |

## Monazite.

There was a further decrease in the output of monazite in Travancore, which fell from 1,641 tons, valued at £49.231 in 1920 to 1,260 tons, valued at £30.959 in the year under review.

## Petroleum.

In the previous Review it was necessary to record a decrease of 12½ million gallons in the output of petroleum from the production of 305,749,138 gallons recorded for the year 1919. In the year 1921 the total production almost equalled that of 1919, amounting to 305,083,227 gallons, important increases being recorded for the Singu and Yenangyaung fields, partly balanced by a large decrease at Badarpur, and small decreases at every other field, except the Akyab and Upper Chhindwin fields in Burma, and the Mianwali and Attock fields in the Punjab. Owing, however, to the fall in the exchange value of the rupee, the value of the production has fallen from £7,951,632 in 1920 to £5,603,974 in 1921.

During the year active prospecting was conducted in the Punjab, Sind, Assam, and Burma, by a variety of oil interests and several important concessions were demarcated. The only case, however, that has come to notice of the actual proof by drilling of the existence of oil in an area not hitherto producing is the Padaukpin area in Thayetmyo, from which the Indo-Burma Oilfields, Limited, are now obtaining a small production. In the Punjab the oil industry has entered on a new phase with the completion at Rawalpindi, and the opening in February 1922, of the refinery erected by the Indo-Burma Petroleum Co. to deal with the production of the Khaur oilfield in the Attock district. The refinery has a daily capacity of 65,000 gallons of crude oil.

TABLE 21.—*Quantity and value of Petroleum produced in India during 1920 and 1921.*

| | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Gals. | Rs. | £ | Gals. | Rs. | £ |
| *Assam*— | | | | | | |
| Digboi . . | 5,206,870 | 2,57,630 | 25,763 | 5,069,401 | 2,50,833 | 16,722 |
| Badarpur . . | 8,151,322 | 6,11,349 | 661,135 | 4,431,473 | 3,34,611 | 22,308 |
| *Burma*— | | | | | | |
| Akyab . . | 9,770 | 2,747 | 275 | 9,780 | 2,321 | 185 |
| Kyaukpyu . | 30,375 | 8,459 | 846 | 27,560 | 19,124 | 1,275 |
| Minbu . . | 3,835,148 | 10,78,649 | 107,865 | 3,706,831 | 11,58,385 | 77,226 |
| Singu . . | 95,250,773 | 2,67,99,962 | 2,679,996 | 104,167,740 | 2,02,97,179 | 1,353,145 |
| Thayetmyo . | 91,329 | 25,680 | 2,569 | 60,372 | 33,186 | 2,212 |
| Upper Chindwin | 1,022,706 | 2,87,653 | 28,765 | 1,182,782 | 2,95,695 | 19,713 |
| Yenangyat . | 3,176,221 | 8,93,315 | 89,331 | 2,510,533 | 7,84,541 | 52,303 |
| Yenangyaung | 176,285 18 | 4,93,80,170 | 4,938,017 | 184,420,141 | 5,18,68,165 | 3,457,878 |
| *Punjab*— | | | | | | |
| Attock . . | 30,040 | 9,405 | 940 | 59,306 | 14,820 | 988 |
| Mianwali . . | 852 | 213 | 21 | 930 | 261 | 17 |
| Total . | 283,116,834 | *7,95,46,328* | *7,954,632* | 305,683,227 | *8,40,59,027* | *5,603,975* |

During the year, there was a large decrease in the imports of kerosene oil, amounting to over 20 million gallons, the decrease being chiefly in the imports from Borneo, Persia and the Straits Settlements, set off by a small increase in the imports from the United States of America. During the same year, however, the export of paraffin wax increased from 23,093 tons, valued at £1,014,392, in the year 1920 to 31,069 tons, valued at £940,623 in the year under review.

TABLE 22.—*Imports of Kerosene oil during 1920 and 1921.*

| | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Gals. | Rs. | £ | Gals. | Rs. | £ |
| From— | | | | | | |
| Borneo . | 18,351,378 | 88,98,770 | 889,877 | 8,179,354 | 43,81.022 | 292.068 |
| Persia . | 7,234,277 | 51,92,060 | 519,206 | 236,374 | 1.77,280 | 11,819 |
| Russia . | 819.407 | 4,09,700 | 40,970 | .. | ... | ... |
| Straits Settlements (including Labuan). | 4,909.819 | 26,09,460 | 260,946 | 5,025 | 7,388 | 493 |
| United States of America. | 32,283,533 | 2,93,74,330 | 2,937,433 | 34,441,518 | 2,73,50.225 | 1,823,348 |
| Other Countries | 746 | 1,760 | 176 | 1,504 | 1,567 | 104 |
| **Total** . | **63,599,160** | *4,64.86.080* | *4.648,608* | **42,863,775** | *3,19,17,482* | *2.127,832* |

TABLE 23.—*Exports of Paraffin Wax from India during 1920 and 1921.*

| | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| To— | | | | | | |
| United Kingdom. | 6,752 | 27,80.600 | 278,000 | 5,013 | 22,80,915 | 152,061 |
| Italy . . | ... | ... | ... | 10,270 | 46,72.850 | 311,523 |
| China. . | 1,160 | 5,27,800 | 52,780 | 2,420 | 10.86,906 | 72,460 |
| Japan . | 7,262 | 33,04,550 | 330.455 | 3,814 | 17,35.256 | 115,684 |
| Egypt . | 20 | 9,100 | 910 | 190 | 86,450 | 5,763 |
| Portuguese East Africa. | 560 | 2,54.800 | 25.480 | 50 | 22,750 | 1,517 |
| United States of America. | 914 | 4,15,470 | 41,547 | 1.134 | 5,15,970 | 34,398 |
| Australia (including New Zealand). | 4,040 | 18,38,200 | 183,820 | 1,768 | 8,08,492 | 53,899 |
| Other Countries | 2,385 | 10,13,400 | 101,340 | 6,401 | 28,99,768 | 193,318 |
| **Total** . | *23,093* | *1,01,43,920* | *1,014,392* | *31,069* | *1,41,09,357* | *940,623* |

## Ruby, Sapphire and Spinel.

There was, during the year 1921, a considerable increase in the output of the ruby mines from 155.604 carats. valued at Rs. 6,19,820 (£61,982) in 1920 to 193,915 carats, valued at Rs. 7,52,468 (£50,165) in 1921.

TABLE 24.—*Quantity and value of Ruby, Sapphire and Spinel produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Carats. | Rs. | £ | Carats. | Rs. | £ |
| *Burma—* | | | | | | |
| Mogok . . | 88,491 (Rubies). | 5,54,636 | 55,464 | 112,197 (Rubies). | 6,91,209 | 46,081 |
| | 33,015 (Sapphires) | 60,832 | 6,083 | 48,916 (Sapphires) | 57,232 | 3,816 |
| | 34,098 (Spinels) | 4,352 | 435 | 32.802 (Spinels) | 4,027 | 268 |
| Total . . | **155,604** | *6,19,820* | *61,982* | **193,915** | *7.52,468* | *50,165* |

## Salt.

There was a further decrease in the output of salt, amounting to nearly 100,000 tons in the year 1921. This decrease was borne largely by Northern India and Aden, the smaller decreases in Burma and Madras being balanced by a moderate increase in Bombay and Sind. The quantity of rock-salt produced decreased from 209,839 tons in 1920 to 148,038 tons in 1921. The imports of salt decreased from 614,674 tons, valued at £2,369,897, in 1920, to 479,306 tons valued at £1,052,984, in 1921.

TABLE 25.—*Quantity and value of Salt produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| Aden . . | 181,174 | 22,86,015 | 228,601 | 156,584 | 9,06,402 | 60,427 |
| Bengal . . | 30 | 553 | 55 | 35 | 1,160 | 77 |
| Bombay and Sind | 473,376 | 28,37,992 | 283,799 | 514,379 | 28,96,623 | 193,108 |
| Burma . . | 65,107 | 40,00,475 | 400,048 | 43,028 | 26,01,004 | 173,400 |
| Central India . | 12 | 797 | 80 | 1 | 72 | 5 |
| Gwalior . . | 232 | 11,045 | 1,104 | 159 | 7,585 | 506 |
| Madras . . | 453,547 | 29,78,471 | 297,847 | 446,113 | 26,22,460 | 174,831 |
| Northern India . | 456,538 | 23,43,308 | 234,331 | 373,184 | 20,87,279 | 139,152 |
| Rajputana (Jaisalmer). | 107 | 5,437 | 544 | 196 | 9,615 | 641 |
| **Total** . | **1,630,123** | *1,44,64.093* | *1,446,409* | 1,533,679 | 1,11,32,200 | 742,147 |

TABLE 26.—*Quantity and value of Rock-Salt produced in India during 1919 and 1920.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| Salt Range . | 181,480 | 6,17,536 | 61,754 | 123,084 | 5,98,823 | 39,922 |
| Kohat . . | 23,142 | 55,813 | 5,581 | 19,635 | 48,969 | 3,265 |
| Mandi . . | 5,217 | 93,195 | 9,319 | 5,319 | 1,28,968 | 8,598 |
| **Total** . | *209,839* | *7,66,544* | *76,654* | **148,038** | *7,76,760* | *51,785* |

TABLE 27.—*Quantity and value of Salt imported into India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| From— | | | | | | |
| United Kingdom. | 93,440 | 38,22,180 | 382,218 | 73,756 | 26,63,389 | 177.559 |
| Germany . | 78,628 | 28,40,480 | 284,048 | 56,568 | 17,36,663 | 115,778 |
| Spain . . | 64,515 | 23.55,920 | 235.592 | 58,413 | 21,55,623 | 143,708 |
| Aden and Dependencies. | 194,269 | 75,73,110 | 757.311 | 142,044 | 44,94.987 | 299,666 |
| Egypt . | 131,326 | 50.79,260 | 507,926 | 97.694 | 30,78.881 | 205,259 |
| Italian East Africa. | 47,920 | 18,27,540 | 182.754 | 50.765 | 16,58,724 | 110,581 |
| Other Countries | 4,576 | 2.00.480 | 20,048 | 66 | 6.496 | 433 |
| **Total** . | ***614,674*** | *2,36.98.970* | *2,369,897* | ***479,306*** | *1,57,94,763* | *1,052.984* |

## Saltpetre.

There was a fall in the total production of saltpetre of nearly 1.000 tons, representing chiefly the balance between a decrease of over 33 per cent. in the production of the Punjab and an increase of 22 per cent. in the output of Bihar. The figures for 1920 have been increased by the inclusion of the output of *kuthea* saltpetre produced in Bihar, which has not hitherto been included in the total. This not inconsiderable production of *kuthea* saltpetre is used in the manufacture of gunpowder and fireworks. The total Indian production of saltpetre in 1921 amounted to 15.894 tons, valued at Rs. 53,55,478 (£357,032). Exports decreased from 22.000 tons in 1920 to less than 13,000 tons in the year under review, the decreases being largely in the exports to the United Kingdom, Ceylon, Mauritius and the United States, with a considerable increase in the exports to Hongkong.

TABLE 28.—*Quantity and value of Saltpetre produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| Bihar (refined) . | 3,830 | 12,24,221 | 122,421 | 4,277 | 13,96,264 | 93,084 |
| Do. (kuthea) . | 1,855 | 5,08,415 | 50,842 | 2,681 | 5,86,464 | 39,098 |
| Central India . | 44 | 2,596 | 260 | 1 7 | 450 | 30 |
| Punjab . . | 6,548 | 25,82,376 | 258,238 | 4,339 | 19,04,208 | 126,947 |
| Rajputana . | 217 | 63,970 | 6,397 | 229 | 82,752 | 5,517 |
| United Provinces | 4,380 | 15,26,961 | 152,696 | 4,366 | 13,85,340 | 92,356 |
| **Total** . | **16,874** | *59,08,539* | *590,854* | **15,893·7** | *53,55,478* | *357,032* |

TABLE 29.—*Distribution of Saltpetre exported during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Cwts. | Rs. | £ | Cwts. | Rs. | £ |
| To— | | | | | | |
| United Kingdom. | 135,797 | 25,26,420 | 252,642 | 88,294 | 15,10,773 | 100,718 |
| Ceylon . . | 84,835 | 11,12,380 | 111,238 | 16,376 | 2,25,403 | 15,027 |
| Hongkong . | 28,072 | 4,95,590 | 49,559 | 65,241 | 14,74,118 | 98,275 |
| Japan . . | 2,292 | 35,300 | 3,530 | 496 | 11,540 | 769 |
| Mauritius and Dependencies. | 84,728 | 16,85,450 | 168,545 | 59,464 | 10,46,876 | 69,792 |
| United States of America. | 86,694 | 13,25,030 | 132,503 | 15,002 | 2,32,580 | 15,505 |
| Other Countries | 20,236 | 3,47,230 | 34,723 | 12,908 | 2,92,182 | 19,479 |
| **Total** . | **442,654** | *75,27,400* | *752,740* | **257,873** | *47,93,472* | *319,565* |

## Silver.

The output of silver from Bawdwin again showed a considerable increase, whilst there were small decreases in the production of silver from the Anantapur gold mines in Madras and the Kolar gold mines in Mysore. The total Indian production amounted to 3,587,587 ozs., valued at Rs. 88,95,121 (£593,008), corresponding to an average value of 39·7 pence per ounce, as compared with 2,906,397 ozs., valued at Rs. 84,31,092 (£843,109), corresponding to an average value of 69·6*d*. per ounce in the previous year.

TABLE 30.—*Quantity and value of Silver produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Ozs. | Rs. | £ | Ozs. | Rs. | £ |
| *Burma*— | | | | | | |
| Northern Shan States. | 2,869,727 | 83,37,362 | 833,736 | 3,555,021 | 88,20,855 | 588,057 |
| *Madras*— | | | | | | |
| Anantapur . | 868 | 2,270 | 227 | 619 | 1,419 | 95 |
| *Mysore*— | | | | | | |
| Kolar . . | 35,802 | 91,460 | 9,146 | 31,947 | 72,847 | 4,856 |
| **Total** . | **2,906,397** | *84,31,092* | *843,109* | **3,587,587** | 88,95,121 | 593,008 |

## Tin.

In contrast to the previous year, when it was possible to record a considerable increase in the output of tin-ore, there was in the year under review a moderate decrease from an output of 2,117·6 tons of tin-ore (excluding the low-grade ore) in 1920 to 1,701·6 tons of tin-ore in 1921. The whole of this production was derived from Burma, Tavoy contributing 73 per cent. of the output and Mergui 24 per cent.; both these districts showed increases of production over the previous year, which increases were, however, more than balanced by an almost complete cessation of production in the Southern Shan States. In addition, Mergui produced 171·2 tons of block tin, showing a small increase over the figure for previous year. The imports of unwrought tin showed a small increase from 50,146 cwts. in 1920 to 53,114 cwts. in 1921. Of these imports by far the greater part came from the Straits Settlements.

TABLE 31.—*Quantity and value of Tin and Tin-ore for the years 1920 and 1921.*

| — | 1920. | | | | | | 1921. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BLOCK TIN. | | | TIN-ORE. | | | BLOCK TIN. | | | TIN-ORE. | | |
| | Quantity. | Value. | | Quantity. | Value. | | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Bihar and Orissa*— | | | | | | | | | | | | |
| Hazaribagh . | 1·6 | 2,847 | 285 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Burma*— | | | | | | | | | | | | |
| Amherst . | .. | .. | .. | 41·5 | 49,200 | 4,920 | .. | .. | .. | 30·9 | 30,948 | 2,063 |
| Mergui . | 163·3 | 5,92,793 | 59,279 | 366·2 | 5,74,658 | 57,466 | 171·2 | 4,62,104 | 30,807 | 409·9 | 5,95,306 | 39,687 |
| Do. Low-grade ore. | .. | .. | .. | 1,220 | 91,500 | 9,150 | .. | .. | .. | .. | .. | .. |
| Southern Shan States. | .. | .. | .. | 628·5 | 7,54,248 | 75,425 | .. | .. | .. | 9·8 | (*a*) | .. |
| Tavoy . . | .. | .. | .. | 1,063 | 11,69,366 | 1,16,936 | .. | .. | .. | 1,250 | 13,52,227 | 90,149 |
| Do. Low-grade ore. | .. | .. | .. | 3 | 2,550 | 255 | .. | .. | .. | .. | .. | .. |
| Thaton . . | .. | .. | .. | 18·4 | 19,102 | 1,910 | .. | .. | .. | 1 | 960 | 64 |
| Total . | 164·9 | *5,95,640* | *59,564* | 3,340·6 | *26,60,621* | *200,062* | 171·2 | *4,62,104* | *30,807* | 1,701·6 | *19,79,411* | *131,963* |

(*a*) Figures not available.

TABLE 32.—*Imports of Tin, unwrought (block, ingots, bars and slabs) into India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Cwts. | Rs. | £ | Cwt. | Rs. | £ |
| From— | | | | | | |
| United Kingdom | 2,165 | 4,64,540 | 46,454 | 2,148 | 3,05,230 | 20,349 |
| Straits Settlements (including Labuan). | 45,542 | 70,67,630 | 706,763 | 50,141 | 72,06.768 | 480,451 |
| Other Countries | 2,439 | 2,79,920 | 27,992 | 825 | 1,13,417 | 7,561 |
| Total | 50,146 | *78,12,090* | *781,209* | 53,114 | *76,25,415* | *508,361* |

## Wolfram.

The large decrease in the output of wolfram recorded for the year 1920 was followed by a still larger decrease in the year 1921, *viz.*, from 2,346·2 tons, valued at Rs. 13,97,075 (£139,707), in 1920 to 898·3 tons, valued at Rs. 4,39,388 (£29,292) in 1921. The whole of this output was derived from Burma, and all but about 12 tons from the Tavoy district.

TABLE 33.—*Quantity and value of Tungsten-ore produced in India, during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Burma*— | | | | | | |
| Mergui | 191·5 | 1,73,352 | 17,335 | 4·9 | 1,597 | 106 |
| Southern Shan States. | 474·2 | 2,63,178 | 26,318 | 7·4 | (*a*) | (*a*) |
| Tavoy | 1,679 | 9,59,420 | 95,942 | 886 | 4,37,791 | 29,186 |
| Thaton | 1·5 | 1,125 | 112 | ... | ... | ... |
| Total | *2,346·2* | *13,97,075* | *139,707* | 898·3 | *4,39,388* | *29,292* |

(*a*) Not available.

## III.—MINERALS OF GROUP II.

Alum.

The production of alum rose from 2,691 cwts., valued at Rs. 73,200 (£7,320), in 1920, to 3,380 cwts., valued at Rs. 64,400 (£4,293), in the year under review. The whole output came from the Mianwali district in the Punjab.

Amber.

There was a large decrease in the production of Amber from the Myitkyina district of Upper Burma, *viz.*, from 72 cwts., valued at Rs. 16,660 (£1,666), in 1920, to 26·3 cwts., valued at Rs. 16,840 (£1,123), in 1921.

Antimony.

There was a production of 32·5 cwts. of antimony-ore, valued at Rs. 250, from the Southern Shan States, and of 20 seers (about 40 lbs.) valued at Rs. 800 (£53), from the Jhelum district in the Punjab. The high value placed on the Jhelum product is due to its use as *surma*, for the eyes.

Aquamarine and Beryl.

27·5 seers of aquamarine, 173·5 seers of beryl, and 12 seers of rock-crystal, valued altogether at Rs. 19,000 (£1,267), were produced in Kashmir. Ajmer-Merwara (in Rajputana) records a production of 6,300 carats of beryl, valued at Rs. 100 (£6·7), the low value of the beryl from Rajputana being an index of the poor quality of the mineral won.

Asbestos.

In 1920 the output of asbestos totalled 1,818 tons, of which 1,711 tons came from the district of Hassan, and the balance, 107 tons, from the district of Bangalore, in Mysore State. In the year under review the production from these two districts fell to 237 and 67 tons respectively, with a total value of Rs. 12,160 (£811). In addition, 11½ tons of asbestos were produced in the Seraikela State, Singhbhum, valued at Rs. 1,100 (£73).

Barytes.

1,457 tons of barytes, valued at Rs. 47,603 (£3,173), were produced in 1921 in the Kurnool District of the Madras Presidency, against 678 tons valued at Rs. 15,528 (£1,553) in 1920. In addition, there was an output of 234 tons of barytes, valued at Rs. 4,680 (£312) in Alwar State in Rajputana.

TABLE 31.—*Production of Building Materials and Road Metal in India during 1921.*

| | Granite and Gneiss. | | Laterite. | | Lime. | | Limestone and Kankar. | | Marble. | | Sandstone. | | Slate. | | Trap. | | Miscellaneous. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. | Quantity. | Value. |
| | Tons | £ | Tons | £ | Tons | £ | Tons | £ | Tons | £ | Tons | £ | Tons | £ | Tons | £ | Tons | £ |
| Assam . . | 8,361 | 1,318 | (a)2,000 | 293 | ... | ... | 98,391 | 15,034 | ... | ... | ... | ... | ... | .. | | ... | 88,021 | 13,173 |
| Baroda . . | 182 | 333 | ... | ... | ... | ... | ... | .. | 143 | 200 | ... | ... | ... | ... | ... | ... | ... | ... |
| Bihar and Orissa . | ... | ... | 560 | 23 | 53,174 | 11,321 | 171,977 | 46,871 | ... | ... | 14,718 | 1,325 | 2,820 | 3,016 | 19,461 | 3,028 | 517,831 | 13,098 |
| Burma. . . | 72,932 | 7,772 | 287,527 | 35,005 | ... | ... | 236,151 | 20,069 | ... | ... | 318,456 | 13,016 | ... | ... | 30,151 | 1,500 | 507,907 | 28,290 |
| Central India . | ... | ... | ... | ... | 21,539 | 35,091 | 203,716 | 9,732 | ... | ... | 21,111 | 7,167 | ... | ... | ... | ... | 918 | 542 |
| Central Provinces . | ... | ... | ... | ... | ... | ... | 335,319 | 36,333 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Madras . . | 26,218 | 930 | 58,751 | 3,011 | ... | ... | 17,160 | 4,271 | ... | ... | ... | ... | 213 | 23 | ... | ... | 80,321 | 9,077 |
| Mysore . . | ... | ... | ... | ... | 1,147 | 279 | 306 | 130 | ... | ... | ... | ... | 1 | ... | ... | ... | 3,519 | 525 |
| N.-W. F. Province. | ... | ... | ... | ... | ... | ... | 4,071 | 290 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Punjab . . | ... | ... | . . | ... | ... | ... | 30,597 | 2,129 | ... | ... | . . | ... | 47,508 (b) | 8,105 | ... | ... | 84,625 | 6,762 |
| Rajputana . . | ... | ... | ... | ... | 16,285 | 880 | 1,133 (e) | 164 | . | ... | 35,111 | 16,168 | 185 | ... | ... | ... | 53,759 (c) | 13,323 |
| United Provinces . | ... | ... | ... | ... | ... | ... | 363,607 (f) | 16,017 | ... | ... | 8,909 | 327 | 1,977 | 398 | ... | ... | 204,467 | 33,712 |
| Total[1] . | 107,696 | *10,353* | 349,438 | *38,33[illegible]* | 95,445 | *47,577* | 1,763,658 | *151,010* | 8,853 (d) | *200* | 398,605 | *38,003* | 52,713 (g) | *11,542* | 58,615 | *4,528* | 1,640,971 | *119,402* |

GRAND TOTAL . 4,467,098 tons valued at £4[illegible],219.

(a) Does not include 1,600 tons for which value not known.
(b) Does not include 337,500 slates valued at £900, weight unknown.
(d) Does not include 8,710 tons for which value not received.
(c) Does not include 69,798 tons and 9 383 units for which value not received.
(f) Does not include 106,751 tons for which values not received.
(g) Does not include 186 tons for which value not received.

**Bauxite.**

There was again a considerable increase in the production of bauxite from Kaira in Bombay, from 3,931·5 tons, valued at Rs. 41,280 (£4,128), to 4,653 tons, valued at Rs. 39,550 (£2,637) in 1921 for use in the refining of oil. In addition, there was an output at Katni in the Jubbulpore district in 1920 of 2,368 tons of bauxite valued at Rs. 12,028 (£1.203) falling in 1921 to 1,999 tons, valued at Rs. 9,651 (£643), for use mainly in the cement industry. Investigations were continued on the important bauxite deposits discovered in Jammu and referred to in the previous Review, but hitherto with no tangible result.

**Building Materials.**

The total estimated value of building stone and road-metal produced in the year under review was Rs. 63,33,285 (£422,219). Certain figures returned only in cubic feet have been converted into tons on the basis of certain assumed relations between volume and weight.

**Clay.**

The recorded production of clay rose from 156,524 tons, valued at Rs. 4,08,121 (£40,812), in 1920, to 199,266, valued at Rs. 5,60,664 (£37,378) in 1921.

TABLE 35.—*Production of Clays in India during 1921.*

| — | Quantity. | Value. | |
|---|---|---|---|
| | Tons. | Rs. | £ |
| Bengal | 9,117 | 19.413 | 1.294 |
| Bihar and Orissa | 32,280 | 3,35,177 | 22.345 |
| Burma | 30.321 | 27.765 | 1,851 |
| Central India | 669 | 1.630 | 109 |
| Central Provinces | 52,284 | 31,869 | 2.125 |
| Kashmir | 2 | 45 | 3 |
| Mysore | 52.328 | 1,15,156 | 7.677 |
| Punjab | 12,801 | 28.449 | 1,897 |
| Rajputana (*a*) | 464 | 1,160 | 77 |
| **Total** | **199,266** | ***560,661*** | ***37,378*** |

(*a*) Value of 90 tons from Alwar not included.

**Fuller's Earth.**

The production of fuller's earth is recorded separately, and amounted to, in 1921, 2,807 tons, valued at Rs. 14,490 (£966).

TABLE 36.—*Production of Fuller's Earth in India during 1921.*

| — | Quantity. | Value. | |
|---|---|---|---|
| | Tons. | Rs. | £ |
| *Central Provinces—* | | | |
| Jubbulpore | 113 | 554 | 37 |
| *Mysore—* | | | |
| Tumkur | 139 | 195 | 13 |
| *Rajputana—* | | | |
| Bikaner | 1,675 | 8,799 | 587 |
| Jodhpur | 880 | 4,942 | 329 |
| Total | 2,807 | *14,490* | *966* |

**Garnet.** An output of 407·4 cwts. of garnet in 1920 was reported from Hyderabad. No returns have been received for the year under review.

**Gypsum.** The production of gypsum showed a slight increase, the total output being 33,801 tons, valued at Rs. 34,018 (£2,267), as against 33,551 tons, valued at Rs. 36,932 (£3,693) in 1920.

TABLE 37.—*Production of Gypsum during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Punjab—* | | | | | | |
| Jhelum | 7,378 | 17,218 | 1,722 | 5,329 | 4,663 | 311 |
| *Rajputana—* | | | | | | |
| Bikanir | 16,173 | 13,122 | 1,312 | 16,285 | 13,204 | 880 |
| Marwar | 10,000 | 6,592 | 659 | 12,000 | 5,000 | 333 |
| *Kashmir* | ... | ... | ... | 187 | 11,151 | 743 |
| Total | *33,551* | *36,932* | *3,693* | *33,801* | *34,018* | *2,267* |

**Molybdenite.**

Only 2 cwts. of molybdenite, valued at Rs. 200 (£13), were won during the year 1921; this amount was recovered in the course of wolfram-mining operations in Tavoy.

**Ochre.**

The output of ochre for which figures of both quantity and value have been supplied increased from 2,635 tons, valued at Rs. 33,431 (£3,343), in 1920, to 5,812 tons, valued at Rs. 32,606 (£2,174) in 1921.

TABLE 38.—*Production of Ochre during the years 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| Bihar and Orissa | 400 | 20,000 | 2,000 | 450 | 12,600 | 840 |
| Burma . . | ... | ... | ... | ... | ... | ... |
| Central India (*a*) | 1,001 | 10,307 | 1,031 | 3,877 | 15,200 | 1,013·3 |
| Central Provinces (*b*). | ... | ... | ... | 221 | 126 | 8·4 |
| Gwalior . . | 1,082 | 1,900 | 190 | $1{,}014\frac{2}{3}$ | 2,180 | 145·3 |
| Madras . . | 100 | 600 | 60 | ... | ... | .. |
| Mysore . . | 52 | 624 | 62 | 250 | 2,500 | 167 |
| **Total** . | **2,635** | ***33,431*** | ***3,343*** | **5,812** | ***32,606*** | ***2,174*** |

(*a*) Ochre (weight not reported) valued at Rs. 1,014 from Kothi and 2,000 tons of ochre (value not reported) from Bundelkhand not included.
(*b*) 60 tons of ochre (value not reported) from Chanda not included.

**Phosphates.**

347 tons of apatite valued at Rs. 3,420 (£231), were produced in the Singhbhum district in 1921.

**Soda.**

10 tons of soda, valued at 30 seers per rupee, were produced in the Ladak tahsil, Kashmir, in the year 1921.

**Steatite.**

The output of steatite rose by 35 per cent., from 3,681 tons, valued at Rs. 1,05,554 (£10,585), to 5,703 tons, valued at Rs. 88,202 (£5,809).

TABLE 39.—*Quantity and value of Steatite produced in India during 1920 and 1921.*

| — | 1920. | | | 1921. | | |
|---|---|---|---|---|---|---|
| | Quantity. | Value. | | Quantity. | Value. | |
| | Tons. | Rs. | £ | Tons. | Rs. | £ |
| *Bihar and Orissa—* | | | | | | |
| Bhagalpur . . . . | .. | .. | .. | 90 | 900 | 60 |
| Mayurbhanj . . | 52 | 3,600 | 360 | 62 | 3,850 | 257 |
| Singhbhum . . . . | 412 | 25,409 | 2,541 | 27 | 3,356 | 224 |
| *Burma—* | | | | | | |
| Meiktila . . . . . | .. | .. | .. | 3,152 | 22,233 | 1,482 |
| Myingyan . . . . | .. | .. | .. | 107 | 964 | 64 |
| Pakokku Hill Tracts . . | ·4 | 105 | 10·5 | 1·5 | 270 | 18 |
| Sagaing . . . . . | .. | .. | .. | 374 | 3,223 | 215 |
| *Central Provinces—* | | | | | | |
| Jubbulpore . . . . | 2,295·5 | 43,342 | 4,334 | 1,080 | 19,699 | 1,313 |
| *Madras—* | | | | | | |
| Bellary . . . . . | 3 | 15 | 1·5 | .. | .. | .. |
| Nellore . . . . . | 32 | 2,864 | 286 | 40·5 | 5,866 | 391 |
| Salem . . . . . | 538·5 | 14,650 | 1,465 | 528 | 13,987 | 932 |
| *Mysore—* | 265 | 5,300 | 530 | 188 | 414 | 28 |
| *United Provinces—* | | | | | | |
| Hamirpur . . . . | 73 | 10,069 | 1,007 | 98 | 13,200 | 880 |
| Jhansi . . . . | 10 | 500 | 50 | 5 | 240 | 16 |
| Total . | 3,681·4 | *1,05,854* | *10,585* | 5,703 | *88,202* | *5,880* |

## IV.—MINERAL CONCESSIONS GRANTED.

TABLE 40.—*Statement of Mineral Concessions granted during 1921.*

### ASSAM.

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Cachar | (1) The Burma Oil Co., Ltd. | Mineral oil | P. L. | 6,169·6 | 8th April 1921 | 1 year. |
| Do. | (2) Do. | Do. | P. L. | 4,409·6 | 12th April 1921. | Do. |
| Do. | (3) Do. | Do. | P. L. | 4,947·2 | 26th September 1921. | Do. |
| Do. | (4) The Indo-Burma Petroleum Co., Ltd. | Do. | P. L. | 5,056 | 4th March 1921. | Do. |
| Garo Hills | (5) Messrs. Kilburn & Co., on behalf of Garo Hills Mining Syndicate. | Coal | P. L. | 49,280 | 9th May 1921 | Do. |
| Khasi and Jaintia Hills. | (6) The Khasia Mines, Ltd. | Minerals other than mineral oil. | P. L. | 7,564·8 | 10th January 1921. | Do. |
| Sylhet | (7) The Burma Oil Co., Ltd. | Mineral oil | P. L. | 4,691·2 | 22nd March 1921. | Do. |
| Do. | (8) The Indo-Burma Petroleum Co., Ltd. | Do. | P. L. | 3,008 | 31st August 1921. | Do. |

### BALUCHISTAN.

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Kalat | (9) The Whitehall Petroleum Corporation Ltd. of London. | Mineral oil | E. L. | Bolan Pass | 18th March 1921. | 1 year. |
| Do. | (10) Do. | Do. | E. L. | Whole of the Lasbela State. | 30th March 1921. | Do. |
| Do. | (11) Do. | Do. | E. L. | Whole of the Kalat State. | 30th March 1921. | Do. |
| Do. | (12) The Burma Oil Co. of Rangoon. | Oil | P. L. | 3,200 | 1st September 1921. | Do. |
| Quetta Pishin. | (13) General Manager, Baluchistan Chrome Co., Ltd., Hindubagh. | Chromite | M. L. | 10 | 1st April 1921. | 30 years. |
| Sibi | (13) Captain R. C. Blackwood on behalf of the Whitehall Petroleum Co., Ltd., of London. | Crude Petroleum and its associated Hydro-carbons. | P. L. | 49,606·4 | 28th December 1921. | 2 years. |
| Do. | (15) Do. | Mineral oil | E. L. | Whole of Sibi District except Marri and Bugti countries. | 24th May 1921. | 1 year. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.* E. L.—Exploring License.

## BALUCHISTAN—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Zhob . . | (16) Baluchistan Chrome Co., Ltd., Hindubagh. | Chromite . . | M. L. . | 10 | 1st July 1921 | 30 years. |
| Do. . | (17) Do. . | Do. . . | M. L. . | 10 | 1st July 1921 | Do. |
| Do. . | (18) Do. . | Do. . . | M. L. . | 10 | 1st July 1921 | Do. |
| Do. . | (19) Do. . | Asbestos . . | M. L. . | 20 | 1st July 1921 | Not given in the lease. |

## BENGAL.

| | | | | | | |
|---|---|---|---|---|---|---|
| Chittagong . | (20) Burma Oil Co., Ltd. | Mineral oil . . | P. L. . | 4,000 | 12th December 1921. | 2 years only. |

## BIHAR AND ORISSA.

| | | | | | | |
|---|---|---|---|---|---|---|
| Gaya . | (21) M. Kumar Krishna Mittra. | Mica . . . . | M. L. . | 486·6 | .... | 15 years. |
| Hazaribagh. | (22) Babu Dvijendra Nath Mukherji. | Do. . . . . | P. L. . | 65 | 27th February 1921. | 1 year. |
| Do. . | (23) Babu Harihar Nath Singh. | Do. . . . . | P. L. . | 140 | 20th January 1921. | Do. |
| Do. . | (24) Babu Girish Chandra Sen. | Do. . . . . | P. L. . | 97·60 | 28th April 1921. | Do. |
| Do. . | (25) Babu Banka Bihari Chaudhuri. | Do. . . . . | P. L. . | 280 | 18th May 1921. | Do. |
| Do. . | (26) Babu Lakshmi Narain Sukhani. | Do. . . | M. L. . | 120 | 12th September 1921. | 30 years. |
| Do. . | (27) Babu Bhujendra Nath Dass. | Do. . . . . | M. L. . | 440 | 10th November 1921. | Do. |
| Sambalpur . | (28) Babu Shanker Prashad Misra. | Coal . . . | P. L. . | 2,874·80 | 23rd May 1921. | 1 year. |
| Do. . | (29) Do. . | Oxide of Iron . | P. L. . | 86·91 | .... | Do. |
| Do. . | (30) Seth Puranmal Marwari. | Mica . . . . | M. L. . | 591·20 | 10th May 1921. | 30 years. |
| Do. . | (31) Do. . | Do. . . . . | M. L. . | 154·56 | 10th May 1921. | Do. |
| Do. | (32) Mr. J. Sonbolle . | Coal . . . . | P. L. . | 1,123·40 | 6th September 1921. | 1 year. |
| Do. . | (33) Do. . | Do. . . . . | P. L. . | 1,434 | 6th September 1921. | Do. |
| Do. | (34) Babu Debi Prasad Misra. | Do. . . . . | P. L. . | 2,376·99 | 28th November 1921. | Do. |

P. L.=*Prospecting License*. M. L.=*Mining Lease*. E. L.—Exploring License.

## BIHAR AND ORISSA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Sambalpur . | (35) Seth Puranmal Marwari. | Mica . . . | P. L. . | 30·98 | 20th December 1921. | 1 year. |
| Santhal Parganas. | (36) Babu Jetha Mulji . | Coal . . . | M. L. . | 5 | 1st April 1921 | 2 years. |
| Do. . | (37) Babu Bhudhar Chandra De. | Do. . . . | M. L. . | ·99 | 1st April 1921 | Do. |
| Do. . | (38) Do. . | Do. . . . | M. L. . | ·99 | 1st April 1921 | Do. |
| Do. . | (39) Babu Binod Bihari De. | Do. . . . | M. L. . | 2·15 | 1st April 1921 | Do. |
| Do. . | (40) Babu Girish Chandra Mandal. | Do. . . . | M. L. . | ·92 | 1st April 1921 | Do. |
| Do. . | (41) Do. . | Do. . . . | M. L. . | 2·16 | 1st April 1921 | Do. |
| Do. . | (42) Do. . | Do. . . . | M. L. . | 1·62 | 1st April 1921 | Do. |
| Do. . | (43) Babu Bansi Ram Marwari. | Do. . . . | M. L. . | 1·9 | 1st April 1921 | Do. |
| Do. . | (44) Do. . | Do. . . . | M. L. . | ·3 | 1st April 1921 | Do. |
| Do. . | (45) Babu Ganga Ram Marwari. | Do. . . . | M. L. . | 2·6 | 1st April 1921 | Do. |
| Do. . | (46) Babu Bhudhar Chandra De. . . | Do. . . . | M. L. . | 1·64 | 1st August 1921. | 1 year and 8 months |
| Singhbhum . | (47) Babu Jogendra Nath Roy. | Chromite . . | P. L. . | 172 | 15th January 1921. | 1 year. |
| Do. . | (48) The Villiers Colliery Company, Ltd. | Iron Ore . . | P. L. . | 371·20 | 9th February 1921. | Do. |
| Do. . | (49) Babu Arjun Ladha | Manganese . . | P. L. . | 72 | 20th April 1921. | Do. |
| Do. . | (50) The Villiers Colliery Co., Ltd. | Iron Ore . . | P. L. . | 620·8 | 9th May 1921 | Do. |
| Do. . | (51) Babu Rajanikanta Pattadar, M.B.E. | Do. . . | P. L. . | 2,560 | 11th June 1921. | Do. |
| Do. . | (52) Messrs. Byramjee Pestonjee and Co. | Do. . . | P. L. . | 1,798·4 | 13th May 1921. | Do. |
| Do. . | (53) Babu Rajani Kanta Pattadar, M.B.E. | Chromite . . | P. L. . | 1,004·8 | 13th May 1921. | Do. |
| Do. . | (54) The Nagpur Clay Co., Ltd. | All minerals . | P. L. . | 529·60 | License not yet executed. | Do. |
| Do. . | (55) The Orissa Minerals Development Company, Ltd. | Iron Ore and manganese. | M. L. . | 2,624 | Lease not yet executed. | 30 years |
| Do. . | (56) Mr. A. N. Paston James. | Iron Ore . . | P. L. . | 1,110 | 8th December 1921. | 1 year. |
| Do. . | (57) The Nagpur Clay Co., Ltd. | All minerals . | P. L. . | 3,140·71 | 25th November 1921. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## BOMBAY.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Belgaum | (58) Messrs. Tata & Sons | Manganese | P. L. | 499·65 | 10th January 1921. | 1 year. |
| Savantwadi State. | (59) Messrs. Dalchand Bahadur Singh of Calcutta. | Bauxite | P. L. | 620 | License not yet executed. | Do. |

## BURMA.

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Akyab | (60) Messrs. The Indo-Burma Petroleum Co., Ltd. | Mineral oil | P. L. (renewal.) | 5,440 | 15th December 1920. | 1 year. |
| Do. | (61) Messrs. The Indo-Burma Petroleum Co. | Do. | P. L. | 1,280 | 22nd April 1921. | Do. |
| Amherst | (62) Maung Saw Maung and Ma Kywe. | All minerals (except oil). | P. L. | 640 | 21st March 1921. | Do. |
| Do. | (63) Mr. A. C. Jeewa | Do. | P. L. | 640 | 15th March 1921. | Do. |
| Do. | (64) Maung Ba Han | Do. | P. L. | 1,830·88 | 21st June 1921. | Do. |
| Do. | (65) K. E. I. Solomon | Do. | P. L. | 1,280 | 29th June 1921. | Do. |
| Do. | (66) K. P. M. K. Narayan Chetty. | Do. | P. L. | 2,240 | 11th June 1921. | Do. |
| Do. | (67) Messrs. Cookson & Co., Ltd. | Do. | P. L. | 319 | 23rd June 1921. | Do. |
| Do. | (68) Mr. R. A. Park | Do. | P. L. | 960 | 7th June 1921. | Do. |
| Do. | (69) K. P. M. K. Narayan Chetty. | Do. | P. L. | 1,280 | 11th June 1921. | Do. |
| Do. | (70) Saw Lein Lee | Do. | P. L. (renewal). | 640 | 5th April 1921. | Do. |
| Do. | (71) A. C. Jeewa | Do. | P. L. (renewal). | 640 | 8th May 1921 | Do. |
| Do. | (72) Messrs. The Talaing Exploration Syndicate. | All minerals | P. L. (renewal). | 2,880 | 16th November 1921. | 2 years. |
| Do. | (73) Dr. M. Shawloo | All minerals (except oil). | P. L. (renewal). | 640 | 21st January 1921. | 1 year. |
| Do. | (74) Saw Eu Hoke | Do. | P. L. | 4,480 | 17th February 1921. | Do. |
| Do. | (75) Maung Po Thine & One. | Do. | P. L. | 1,280 | 26th September 1921. | Do. |
| Do. | (76) M. E. Mooin | Oil shale | P. L. | 22,822·4 | 27th August 1921. | Do. |
| Do. | (77) Maung Choon | All minerals (except oil). | P. L. | 640 | 31st August 1921. | Do. |

P. L. = *Prospecting License.*

## BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Amherst . | (78) Messrs. Balthazar & Son. | All minerals (except oil). | P. L. . | 640 | 9th September 1921. | 1 year. |
| Do. . | (79) Mrs. M. M. Hla Aung. | Do. . | P. L. . (renewal). | 2,880 | 16th November 1920. | Do. |
| Do. . | (80) K. P. N. K. Narayan Chetty. | Do. . | P. L. . (renewal). | 320 | 5th August 1921. | Do. |
| Do. . | (81) Maung On Maung . | All minerals . | P. L. . | 1,280 | 5th December 1921. | Do. |
| Do. . | (82) Saw Lein Lee . | Do. . | P. L. . | 640 | 1st November 1921. | Do. |
| Henzada . | (83) Mr. L. D'Attaides . | All minerals (except oil) | P. L. . | 148·80 | 8th June 1921 | Do. |
| Do. . | (84) Mohamed Edries . | Mineral oil . . | P. L. . | 2,042·50 | 12th April 1921. | Do. |
| Do. . | (85) Mr. L. D'Attaides . | All minerals (except oil). | P. L. . (renewal). | 1,320 | 11th April 1921. | 2 years. |
| Do. . | (86) Su Kwin Ping . | Mineral oil . . | P. L. . | 761 6 | 9th September 1921. | 1 year. |
| Do. . | (87) U Po Tha . . | Coal . . . | P. L. . | 7,558·4 | 5th September 1921. | Do. |
| Do. . | (88) Messrs. H. Abdul Shakoor Hajee Cassim and Sons. | All minerals including mineral oil. | P. L. . | 2,560 | 26th September 1921. | Do. |
| Katha . | (89) Ma Ma . . | All minerals (except oil). | P. L. . | 1,280 | 6th May 1921 | Do. |
| Do. . | (90) Ma Kyaw . . | Do. . | P. L. . | 640 | 7th May 1921 | Do. |
| Do. . | (91) Chan Chor Khine . | Do. . | P. L. . | 2,984 | 24th March 1921. | Do. |
| Do. . | (92) Maung Shu Maung | Do. . | P. L. . | 960 | 18th June 1921. | Do. |
| Do. . | (93) Do. . | Do. . | P. L. . | 640 | 31st May 1921. | Do. |
| Do. . | (94) Jamal Brothers & Co. | Do. . | P. L. . | 27,865·6 | 31st August 1921. | Do. |
| Do. . | (95) Maung Po Hte | Do. . | P. L. . | 2,560 | 23rd August 1921. | Do. |
| Do. . | (96) Maung Pan Nyo . | Do. . | P. L. . | 640 | 20th October 1921. | Do. |
| Do. . | (97) Maung Po Hte . | Do. . | P. L. . | 3,200 | 21st September 1921. | Do. |
| Do. . | (98) Ko Ko Gyi . . | Do. . | P. L. . (renewal). | 3,840 | 12th August 1921. | Do. |
| Kyaukpyu . | (99) Messrs. The Burma Oil Co., Ltd. | Mineral oil . . | P. L. . (renewal). | 2,105·6 | 27th May 1921. | 2 years. |
| Kyaukse . | (100) Maung Aung Ko . | All minerals (except oil). | P. L. . | 2,650 | 8th February 1921. | 1 year. |

P. L. = *Prospecting License.*

BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Lower Chindwin. | (101) Mr. Lawrence Dawson. | Mineral oil | P. L. | 3,008 | 17th February 1921. | 1 year. |
| Do. | (102) Indo-Burma Petroleum Co. | Do. | P. L. | 9,920 | 23rd August 1921. | Do. |
| Do. | (103) Do. | Do. | P. L. | 3,200 | 23rd August 1921 | Do. |
| Do. | (104) Do | Do. | P. L. | 6,553·6 | 19th September 1921. | Do. |
| Do. | (105) Do. | Do. | P. L. | 5,248 | 2nd September 1921. | Do. |
| Do. | (106) Do. | Do. | P. L. | 3,200 | 25th October 1921. | Do. |
| Do. | (107) Messrs. The Burma Finance and Mining Co., Ltd. | All minerals including mineral oil. | P. L. | 16,480 | 13th October 1921. | Do. |
| Do. | (108) Do. | Do. | P. L. | 9,440 | 13th October 1921. | Do. |
| Do. | (109) Messrs. The Indo-Burma Oil-fields (1920), Ltd. | Mineral oil | P. L. | 2,560 | 18th October 1921. | Do. |
| Do. | (110) Do. | Do. | P. L. | 1,280 | 13th October 1921. | Do. |
| Do. | (111) Messrs. Indo-Burma Petroleum Co., Ltd. | Do. | P. L. | 8,960 | 12th December 1921. | Do. |
| Do. | (112) Maung Kyaw | Do. | P. L. (renewal). | 9,600 | 25th October 1921. | 2 years. |
| Magwe | (113) Maung Po Kin | Do. | P. L. | 1,280 | 7th March 1921. | 1 year. |
| Do. | (114) Maung Po Tun | Do. | P. L. | 1,280 | Do. | Do. |
| Do. | (115) Do. | Do | P. L. | 960 | 15th March 1921. | Do. |
| Do. | (116) Mr. G. H. Surty | Do. | P. L. (renewal). | 640 | 21st February 1921. | Do. |
| Do. | (117) Maung Po Aung | Do. | P. L. | 640 | 26th May 1921. | Do. |
| Do. | (118) Union Oil Company. | Petroleum | P. L. | 960 | 29th August 1921. | Do. |
| Do. | (119) Sasson Solomon | Do. | P. L. | 640 | 14th July 1921. | Do. |
| Do. | (120) H. E. Malin | Do. | P. L. | 640 | 20th August 1921. | Do. |
| Do. | (121) Maung Kin | Gold | P. L. | 300 | 21st August 1921. | Do. |
| Do. | (122) Burma Oil Co. | Petroleum | P. L. | 2,259·2 | 25th June 1921. | Do. |

P. L. = *Prospecting License.*

## BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Magwe | (123) Maung Po San | Petroleum | P. L. | 640 | 9th June 1921. | 1 year. |
| Do. | (124) M. E. Moolla | Mineral oil | P. L. | 1,050 | 18th June 1921. | Do. |
| Do. | (125) Messrs. The Burma Oil Co. | Do. | M. L. | 1,920 | 1st August 1919. | 30 years. |
| Do. | (126) Maung Maung Pe. | Do. | P. L. | 1,280 | 16th November 1921. | 1 year. |
| Do. | (127) Mr. A. Davies | Do. | P. L. | 2,880 | Do. | Do. |
| Do. | (128) Abdul Rahman | Do. | P. L. | 76 | 11th November 1921. | Do. |
| Do. | (129) Do. | Do. | P. L. | 640 | Do. | Do. |
| Do. | (130) Jaffer Ali Tar Mahamed. | Do. | P. L. | 640 | 5th December 1921. | Do. |
| Do. | (131) Messrs. The Union Oil Co. | Do. | P. L. (renewal). | 20,480 | 21st January 1921. | 2 years. |
| Do. | (132) Messrs. The Burma Oil Co., Ltd. | Do. | P. L. (renewal). | 3,840 | 2nd June 1921. | 1 year. |
| Mandalay | (133) Messrs. The Burma Mines, Ltd. | Iron ore | P. L. | 3,640 | 17th June 1921. | Do. |
| Do. | (134) Sir Abdul Jamal | All minerals (except oil). | P. L. | 3,200 | 2nd June 1921. | Do. |
| Do. | (135) Messrs. Steel Bros. & Co., Ltd. | Do. | P.L. | 2,560 | 1st October 1021. | Do. |
| Mergui | (136) Mr. A. C. C. Rogers | Do. | P. L. | 1,873·92 | 14th January 1921. | Do. |
| Do. | (137) Messrs. The Burma Finance and Mining Co., Ltd. | Coal | P. L. | 1,076·52 | 7th January 1921. | Do. |
| Do. | (138) Do. | Do. | P. L. | 1,409·60 | Do. | Do. |
| Do. | (139) Mr. C. Chan Shwe | All minerals (except oil). | P. L. | 547·84 | 20th December 1920. | Do. |
| Do. | (140) Mr. S. O. Holmes | Do. | P. L. | 024·64 | 7th March 1021. | Do. |
| Do. | (141) Maung Choon | Tin and allied minerals. | P. L. (renewal). | 25·37 | 22nd November 1920. | 6 months. |
| Do. | (142) Saw Lein Lee | Do. | P. L. | 640 | 27th June 1921. | 1 year. |
| Do. | (143) Mr. S. O. Holmes | All minerals (except oil). | P. L. | 327·68 | 1st April 1921. | Do. |
| Do. | (144) The Mergui Tin Dredging Co., Ltd. | Do. | P. L. | 240·64 | 7th April 1921. | Do. |
| Do. | (145) Mr. M. E. Bhymeah | Do. | P. L. (renewal). | 414·72 | 1st December 1920 | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Mergui | (146) Mr. W. H. Olivent | All minerals (except oil) | P. L. (renewal) | 286·72 | 19th January 1921. | 1 year. |
| Do. | (147) Do. | Do. | P. L. (renewal). | 442·88 | Do. | Do. |
| Do. | (148) Maung Po Thaik | Tin and Wolfram | P. L. (renewal). | 486·40 | 1[illegible]th February 1921 | 6 months. |
| Do. | (149) Aung Sein Swai | All minerals (except oil). | P. L (renewal). | 2,088·06 | 12th January 1921. | 1 year. |
| Do. | (150) Mr. Chas. Ellis | Tin | P. L. (renewal). | 701·44 | 5th May 1921 | Do. |
| Do. | (151) Lim Shain | Tin and Wolfram | P. L. (renewal. | 517·56 | 17th February 1921. | Do. |
| Do. | (152) Messrs. H. V. Low & Co., Ltd. | All minerals (except oil.) | P. L. (renewal.) | 814·08 | 16th August 1921. | Do. |
| Do. | (153) Do. | Do. | P. L. (renewal). | 1,433·60 | Do. | Do. |
| Do. | (154) Do | Do. | P. L. (renewal). | 1,889·28 | Do. | Do. |
| Do. | (155) Maung Po Thaik | Tin and Wolfram | P. L. (renewal). | 486·40 | 13th August 1921. | 6 months. |
| Do. | (156) Mr. C. Chan Shwe | All minerals (except oil). | P. L (renewal). | 2,362·88 | 6th September 1921. | 1 year. |
| Do. | (157) Maung E. Gyi | Tin and allied minerals. | P. L. (renewal). | 640·00 | 4th October 1921. | Do. |
| Do. | (158) Mr. C. Chan Shwe | All minerals (except oil). | P. L. (renewal). | 1,351·68 | 2nd February 1921. | Do. |
| Do. | (159) A. S. Mahomed | Tin, Wolfram and allied minerals. | P. L. (renewal). | 3,008 | 12th March 1921. | Do. |
| Do. | (160) Messrs. H. V. Low & Co., Ltd. | All minerals (except oil). | P. L. (renewal). | 1,203·20 | 9th September 1920. | Do. |
| Do. | (161) Mr. T. Greenhow | Tin and Wolfram | P. L. (renwal). | 194·56 | 14th March 1921. | Do. |
| Do. | (162) Maung Choon | Tin and allied minerals. | P. L. (renewal) | 25·37 | 23rd May 1921. | 6 months. |
| Do. | (163) Messrs. The Mergui Tin Dredging Co., Ltd. | Tin and Wolfram | M. L | 110·40 | 19th May 1917. | 30 years. |
| Do. | (164) Do. | All minerals (except oil.) | M. L. | 158·86 | 24th February 1919. | Do. |
| Do. | (165) Yew Shwe Ni | Do. | M. L. | 1,518·51 | 5th May 1919 | Do. |
| Do. | (166) Mr. W. D. Abreu | Tin | P. L. | 3,276·80 | 8th August 1921. | 1 year. |
| Do. | (167) Mr. W. H. Olivant | All minerals (except oil). | P. L. | 2,046·80 | 30th July 1921. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Mergui . | (168) Mr. J. T. Doupe . | Tin . . . | P. L. . | 640 | 10th August 1921. | 1 year. |
| Do. . | (169) Messrs. The Burmese Minerals Exploration, Ltd. | Do. . . . | P. L. . | 519·68 | 30th July 1921. | Do. |
| Do. . | (170) Mr. V. A. R. Sutherland. | Cassiterite and gold. | P. L. . | 640 | 22nd July 1921. | Do. |
| Do. . | (171) Messrs. The Mergui Tin Dredging Co., Ltd. | Wolfram and tin | P. L. . (renewal) | 2,150·40 | 2nd November 1920. | Do. |
| Do. . | (172) Maung Pe Kin . | Wolfram, tin and allied minerals. | P. L. . (renewal). | 250·88 | 6th February 1921. | 6 months. |
| Do. . | (173) Do. . . | Do. . . | P. L. . (renewal). | 788·48 | Do. | Do. |
| Do. . | (174) Messrs. The Mergui Tin Dredging Co., Ltd. | Tin and allied minerals. | P. L. . . (renewal). | 1,802·24 | 16th February 1921. | 1 year. |
| Do. . | (175) Mr. J. F. Leslie . | All minerals (except oil). | P. L. . (renewal). | 798·72 | 18th February 1921. | 6 months. |
| Do. . | (176) Mr. Charles Kitchen | Do. . . | P. L. . (renewal). | 716·80 | 28th May 1921. | 1 year. |
| Do. . | (177) Maung E Gyi . | Tin and allied minerals. | P. L. . (renewal). | 588·80 | 14th May 1921 . | Do. |
| Do. . | (178) Maung Po Thaik | Tin . . . | P. L. . (renewal). | 66·56 | 10th June 1921. | Do. |
| Do. . | (179) Messrs. The Leibaoak Syndicate, Ld. | All minerals (except oil). | P. L. . (renewal). | 1,239·04 | 21st May 1921. | Do. |
| Do. . | (180) Mr. T. Greenhow | Tin and Wolfram | P. L. . (renewal). | 4,597·76 | 14th July 1921. | Do. |
| Do. . | (181) Maung Pe Kin . | Wolfram, tin and allied minerals. | P. L. . (renewal). | 250·88 | 6th August 1921. | 6 months. |
| Do. . | (182) Do. . . | Do. . . | P. L. . (renewal). | 788·48 | 6th August 1921. | Do. |
| Do. . | (183) Saw Lein Lee . | Tin and allied minerals. | P. L. . | 640 | 27th June 1921. | 1 year. |
| Do. . | (184) Mr. A. E. Ahmed | Wolfram, tin and Allied minerals. | P. L. . | 844·80 | 16th September 1921. | Do. |
| Do. . | (185) Maung San Dun . | Do. . . | P. L. . | 1,120 | 27th October 1921. | Do. |
| Do. . | (186) Mr. A. C. Martin | All minerals (except oil). | P. L. . | 2,060·80 | 28th October 1921. | Do. |
| Do. . | (187) Mr. Chan Khain Lock. | Do. . . | P. L. . | 2,150·24 | 14th October 1921. | Do. |
| Minbu . | (188) Messrs. The British Burma Petroleum Co., Ltd. | Mineral oil . . | M. L. . | 471·72 | 3rd August 1919. | 30 years. |
| Do. . | (189) Messrs. The Union Oil Co., of Burma, Ltd. | Do. . . | P. L. . | 3,168 | 17th February 1921. | 1 year. |

P. L.=*Prospecting License.* M.L.=*Mining Lease.*

## BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Minbu . | (190) Messrs. The Irrawaddy Petroleum Oil Syndicate, Ltd. | Mineral oil . . | P. L. . | 640 (block 16 S. in Minbu oil field). | 5th March | 1 year. |
| Do. . | (191) Mr. A. Rahim . | Do. . . | P. L. . | 2,904 | 3rd March 1921. | Do. |
| Do. . | (192) Mr. Ali Hashim Mehtar. | Do. . . | P. L. . | 408 | 14th March 1921. | Do. |
| Do. . | (193) Mr. M. G. H. Surty | Coal . . . | P. L. (renewal). | 4,857·6 | 28th January 1921. | Do. |
| Do. . | (194) Mr. Yeo Eng Byan | Do. . . . | P. L. (renewal). | 1,542 | Do. | Do. |
| Do. . | (195) Messrs. The British Burma Petroleum Co. | Mineral oil . . | P. L. (renewal). | 388 | 12th February 1921. | Do. |
| Do. . | (196) Irrawaddy Petroleum Oil Syndicate Ltd. | Do. . . | P. L. . | 23·76 | 16th July 1921. | Do. |
| Do. . | (197) Maung Tha Ya . | Do. . . | P. L. . | 320 (block 3 S. in Minbu oil field). | 5th July 1921 | Do. |
| Do. . | (198) Do. . . | Do. . . | P. L. . | 160 Acres in block 10 S. in Minbu oil field. | Do. | Do. |
| Do. . | (199) Yomah Oil Co., (1920) Ltd. | Coal . . . | P. L. (renewal). | 400 | 1st April 1921 | Do. |
| Do. . | (200) Messrs. The Union Oil Co., Ltd. | Mineral oil . . | P. L. (renewal). | 38,400 | 8th January 1921. | Do. |
| Do. . | (201) Mr. Sulaiman . | Do. . . | P. L. (renewal). | 320 (Northern half of block 16 N in the Minbu oil field.) | 6th May 1921 | Do. |
| Myingyan . | (202) Messrs. The Union Oil Co. | Do. . | P. L. (renewal). | 6,720 | 17th September 1920. | 2 years. |
| Do. . | (203) Messrs. The Burma Oil Co., Ltd. | Do. . . | P. L. . | 2,960 | 24th June 1921. | 1 year. |
| Do. . | (204) Do. . . | Do. . . | P. L. . | 4,107·52 | 29th June 1921. | Do. |
| Do. . | (205) Maung Kyi . | Do. . . | P. L. (renewal). | 31·50 | 7th May 1921 | Do. |
| Do. . | (206) Messrs. Burma Oil Co., Ltd. | Do. . . | P. L. . | 1,158·4 | 17th September 1921. | Do. |
| Do. . | (207) Messrs. H. H. Johnson & Co. | Petroleum . . | P. L. . | 1,920 | 22nd September 1921. | Do. |
| Do. . | (208) Maung Net . . | Mineral oil . . | P. L. . | 100 | 3rd November 1921. | Do. |

P. L.=*Prospecting License.*

## BURMA—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Myitkyina . | (209) Messrs. The Tavoy Tin Syndicate. | All minerals (except oil). | P. L. (renewal). | 4,800 | 6th August 1921 | 1 year |
| Northern Shan States | (210) Messrs. Frank Johnson Sons & Co. | Do. . . | P. L. . | 2,560 | 1st August 1921 | Do. |
| Do. . | (211) Messrs. Hamid & Co. | Coal, copper and galena. | P. L. . | 3,200 | 1st September 1921 | Do. |
| Do. . | (212) Messrs. The Coal Fields of Burma, Ltd. | All minerals (except oil). | P. L. . | 3,840 | 1st October 1921 | Do. |
| Pakökku . | (213) Baijnath Singh . | Mineral oil . | P. L. . | 2,400 | 28th March 1921 | Do. |
| Do. . | (214) Messrs. J. A. Beglie & Co. | Do. . . | P. L. . | 845 | 10th February 1921 | Do. |
| Do. . | (215) Mr. C. M. Surty . | Do. . . | P. L. . | 640 | 11th March 1921 | Do. |
| Do. . | (216) Maung Po Kin . | Do. . . | P. L. . | 100 | 16th February 1921 | Do. |
| Do. . | (217) Messrs. The Indo-Burma Petroleum Co., Ltd. | Do. . . | P. L. . | 800 | 4th February 1921 | Do. |
| Do. . | (218) Messrs. The Indo-Burma Petroleum Co. | Do. . . | P. L. (renewal). | 2,400 | 17th October 1920 | Do. |
| Do. . | (219) Maung Maung Pe | Do. . . | P. L. . | 100 | 20th May 1921. | Do. |
| Do. . | (220) Baijnath Singh . | Do. . . | P. L. . | 4,145·5 | 18th June 1921. | Do. |
| Do. . | (221) Ma Zan . . | Do. . . | P. L. . | 100 | 30th June 1921. | Do. |
| Do. . | (222) Messrs. Frank Johnson Sons & Co., Ltd. | Do. . . | P. L. . | 1,920 | 29th June 1921. | Do. |
| Do. . | (223) Do. . . | Do. . . | P. L. . | 5,760 | Do. | Do. |
| Do. . | (224) Do. . . | Do. . . | P. L. . | 1,920 | Do. | Do. |
| Do. . | (225) Messrs. Nath Singh Oil Co. | Do. . . | P. L. (renewal). | 2,240 | 16th May 1921. | Do. |
| Do. . | (226) Do. . . | Do. . . | P. L. (renewal). | 12,399·36 | 9th June 1921 | Do. |
| Do. . | (227) Maung Hmon and Maung Thin. | Do. . . | P. L. . | 100 Acres in width Eastern portion of demarcated block No. 14. | 31st August 1921. | Do. |
| Do. | (228) Do. . . | Do. . . | P. L. . | 320 Acres comprising Western half of block No. 70. | Do. | Do. |

## BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Pakôkku . | (229) Mr. S. Soloman . | Mineral Oil . | P. L. (renewal). | 9,280 | 23rd August 1921. | 2 years. |
| Do. . | (230) Messrs. The British Burma Petroleum Co., Ltd. | Do. . | M. L. . | 0·40 | 16th August 1919. | 30 years. |
| Do. . | (231) Messrs. The Burma Oil Co., Ltd. | Do. . | M. L. . | 800 (Eastern halves of blocks 15 and 16 and Eastern quarter of block 17 in the Yenangyat oil fields). | 7th November 1921. | 1 year. |
| Do. . | (232) Maung Lu Gyi Gale | Do. . . | P. L. (renewal). | 1,280 (Block 74 and area adjoining thereto in the Yenangyat oil fields). | 11th August 1921. | Do. |
| Do. . | (233) Messrs. Indo-Burma Petroleum Co., Ltd. | Do. . . | P. L. (renewal). | 2,400 (Blocks 18, 19, 20 and 21 in the Yenangyat oil fields). | 16th October 1921. | Do. |
| Prome . | (234) Maung Bo Ni . | Do. . . | P. L. . | 46·08 | 22nd December 1921. | Do. |
| Do. . | (235) Maung Myat Thin | Do. . . | P. L. . | 320 | 23rd December 1921. | Do. |
| Do. . | (236) Maung Aung Nyein | Do. . . | P. L. (renewal). | 409·60 | 3rd September 1921. | Do. |
| Do. . | (237) Ma Nyein Hla . | Do. . . | P. L. (renewal). | 123 | 24th August 1921. | Do. |
| Shwebo . | (238) Mr. M. E. Moolla | All minerals (except oil). | P. L. . | 7,680 | 6th December 1920. | Do. |
| Do. . | (239) Messrs. The Indo-Burma Petroleum Co., Ltd. | Mineral oil . | P. L. . | 3,232 | 5th November 1920. | Do. |
| Do. . | (240) Messrs. Frank Johnson Sons & Co., Ltd. | All minerals (except oil). | P. L. . | 1,920 | 18th February 1921. | Do. |
| Do. . | (241) Mr. Ellis . . | Mineral oil . | P. L. . | 2,560 | 23rd February 1921. | Do. |
| Do. . | (242) Ko Ko Gyi . . | All minerals (except mineral oil). | P. L. . | 640 | 23rd December 1920. | Do. |
| Do. . | (243) Messrs. The Burma Oil Co., Ltd. | Mineral oil . . | P. L. (renewal). | 7,040 | 8th December 1920. | 2 years. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral | Nature of grant. | Area in acres. | Date of commencement | Term. |
|---|---|---|---|---|---|---|
| Shwebo | (244) Messrs The Burma Oil Co. Ld | Mineral oil | P. L. | 4,160 and 7,993·6 | 19th April 1921 | 1 year. |
| Do. | (245) Mr. Tan Ba Thwin | Do | P. L. | 100 | 31st March 1921. | Do. |
| Do. | (246) Maung Kyaw | Do | P. L. (renewal). | 100 | 14th September 1921. | 2 years. |
| Southern Shan States. | (247) Mr. C. A. Petley | All minerals (except oil). | P. L | 1,792 | 7th January 1921. | 1 year. |
| Do. | (248) Ma Ngwe Nyun | Do. | P. L. (renewal). | 320 | 14th June 1919. | 2 years. |
| Do. | (249) Maung Shwe Yin | Do. | P. L. (renewal). | 80 | 13th December 1920. | 1 year. |
| Do. | (250) Maung Maung | Do. | P. L | 1,088 | 2nd May 1921. | Do. |
| Do. | (251) U. Myaing Daw Mi & Sons. | Antimony | P. L. (renewal). | 160 | 15th October 1920. | Do. |
| Do. | (252) Mr. Lim Chin Tsong. | Lead | P. L. | 40 | 1st August 1921. | Do. |
| Sagaing | (253) Ma Ma | Copper, silver and lead. | P. L. | 1,675·08 | 30th May 1921. | Do. |
| Do. | (254) Do | All minerals (except oil). | P. L. | 2·56 | 20th September 1921. | Do. |
| Tavoy | (255) Maung Po Swe | Do. | P. L. | 492 | 18th January 1921. | 6 months. |
| Do. | (256) Messrs. W. C. Toms and M. Hangan. | Do. | P. L. | 684 | 15th March 1921. | 1 year. |
| Do. | (257) Ong Hoe Kyin | Do | P. L. | 614 | 28th February 1921. | Do. |
| Do. | (258) Mr. C. Wathway | Do. | P. L. | 640 | 24th January 1921. | Do. |
| Do. | (259) Md. Aslam Khan | Do. | P. L. | 138 | 25th February 1921. | 6 months. |
| Do. | (260) Ong Hoe Kyin | Do. | P. L. (renewal). | 1,113 | 19th November 1920. | 1 year. |
| Do. | (261) Maung Maung | Do. | P. L. (renewal). | 1,059 | 4th November 1921. | Do. |
| Do. | (262) Mr. J. J. A. Page | Do. | P. L. (renewal). | 142 | 26th January 1921. | 2 years. |
| Do. | (263) Maung Po Myee and Maung Ni Toe. | Do. | P. L. (renewal). | 455 | 1st January 1921. | 6 months. |
| Do. | (264) Maung Ni Toe | Do. | P. L. (renewal). | 1,385 | 20th January 1921. | Do. |

P. L.=*Prospecting License.*

BURMA—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Tavoy | (265) Ma Thaw | All minerals (except oil). | P. L. (renewal). | 636 | 28th February 1921. | 1 year. |
| Do. | (266) Quah Cheng Guan | Do. | P. L. | 253 | 25th April 1921. | Do. |
| Do. | (267) Mr. R. C. N. Twite | Do. | P. L. | 574 | 13th June 1921. | 6 months. |
| Do. | (268) Messrs. J. A. Ali Bros. | Do. | P. L. | 236 | 30th May 1921. | 1 year. |
| Do. | (269) Mr. T. Fowle | Do. | P. L. | 307 | 4th May 1921 | Do. |
| Do. | (270) Maung Ni Toe | Do. | M. L. | 1,104·08 | 26th September 1917. | 30 years. |
| Do. | (271) Mr. G. Lovell | Do. | P. L. (renewal). | 476 | 20th November 1920. | 2½ years. (The original P. L. being for 6 months only). |
| Do. | (272) Mr. R. C. N. Twite | Do. | P. L. (renewal). | 358 | 1st January 1921. | 6 months. |
| Do. | (273) Khoo Tun Byan | Do. | P. L. (renewal). | 558 | 23rd January 1921. | 1 year. |
| Do. | (274) Mr. E. M. Lefroy | Do. | P. L. (renewal). | 360 | 1st June 1921 | Do. |
| Do. | (275) Messrs. The Indo-Burma Tin Corporation, Ltd. | Coal | P. L. | 753 | 1st June 1921 | Do. |
| Do. | (276) Messrs. The Indo-Tin Corporation, Ltd. | Tin | P. L. | 4 | 20th September 1921. | Do. |
| Do. | (277) Mr. W. C. Toms | All minerals (except oil) | P. L. | 240 | 8th August 1921. | Do. |
| Do. | (278) Mr. M. Manekji | Coal | P. L. | 1,835 | 20th August 1921. | Do. |
| Do. | (279) Mr. R. C. N. Twite | All minerals (except oil). | P. L. | 380 | 13th August 1921. | 6 months. |
| Do. | (280) Maung Maung | Do. | P. L. | 287 | 22nd July 1921 | 1 year. |
| Do. | (281) Mr. J. J. A. Page | Do. | P. L. | 358 | 21st July 1921. | Do. |
| Do. | (282) Ong Hoe Kyin | Do. | M. L. | 237·27 | 13th June 1919. | 30 years. |
| Do. | (283) Ma Ma. | Do. | M. L. | 46·88 | 23rd February 1910 | Do. |
| Do. | (284) Messrs. Tata Sons, Ltd. | Do. | P. L. (renewal.) | 595 | 1st April 1921. | 1 year. |
| Do. | (285) Messrs. Bulloch Bros. & Co., Ltd. | Do. | P. L. (renewal.) | 640 | 18th June 1921. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Tavoy . | (286) Ma Yai . . | All minerals (except oil.) | P. L. (renewal.) | 610 | 8th May 1921. | 1 year. |
| Do. . | (287) Messrs. Tha Dun U Bros. | Do. . | P. L. (renewal.) | 1,088 | 9th June 1921. | Do. |
| Do. . | (288) Do. | Do. | P. L. (renewal. | 1,260 | 15th June 1921. | Do. |
| Do. . | (289) Mr. R. C. N. Twite | Do. . | P. L. (renewal.) | 358 | 1st July 1921 | Do. |
| Do. . | (290) Maung Po Myee and Maung Ni Toe. | Do. . | P. L. (renewal.) | 296 | 1st July 1921 | Do. |
| Do. . | (291) Maung Ni Toe . | Do. . | P. L. (renewal.) | 307 | 20th July 1921. | Do. |
| Do. . | (292) Eu Shwe Swai . | Do. . | P. L. (renewal.) | 612 | 1st July 1921. | Do. |
| Do. . | (293) C. Soo Don . | Do. . | P. L. (renewal.) | 1,692 | 1st July 1921. | Do. |
| Do. . | (294) Maung Po Swe . | Do. . | P. L. (renewal.) | 492 | 18th July 1921. | Do. |
| Do. . | (295) Mahomed Aslam Khan. | Do. . | P. L. (renewal.) | 138 | 25th August 1921. | Do. |
| Do. . | (296) Maung Ba Oh . | Do. . | P. L. (renewal.) | 2,340 | 7th October 1921. | Do. |
| Do. . | (297) Mr. J. M. Manekji | Do. . | P. L. . | 1,106 | 27th October 1921. | Do. |
| Do. . | (298) Messrs. Steel Bros. & Co., Ltd. | Do. . | M. L. . | 801·14 | 19th July 1917. | 30 years. |
| Do. . | (299) Messrs. The High Speed Steel Alloys Mining Co., Ltd. | Do. . | M. L. . | 2,105·86 | 20th April 1917. | Do. |
| Do. . | (300) Messrs. The London and Burmese Wolfram Co., Ltd. | Do. . | M. L. . | 2,103·61 | 15th March 1918. | Do. |
| Do. . | (301) Messrs. The Bombay Burmah Trading Corporation, Ltd. | Do. . | M. L. (dredging lease.) | 250·91 | 2nd February 1920. | 15 years. |
| Do. . | (302) Maung Me . . | Do. . | P. L. (renewal.) | 640 | 1st September 1921. | 1 year. |
| Do. . | (303) C. Wa Thway . | Do. . | P. L. (renewal.) | 1,247 | 1st September 1921. | 9 months. |
| Do. . | (304) Maung Maung . | Do. . | P. L. (renewal.) | 2,048 | 1st October 1921. | 1 year. |
| Do. . | (305) Do. | Do. . | P. L. (renewal.) | 256 | 20th October 1921. | 6 months. |
| Do. . | (306) Do. . | Do. . | P. L. (renewal.) | 1,059 | 4th November 1921. | 1 year. |

P. L.=*Prospecting License* M. L.=*Mining Lease.*

BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Thaton . | (307) Messrs. T. D'Castro & Son. | All minerals (except oil.) | P. L. . | 396·8 | 21st March 1921. | 1 year. |
| Do. . | (308) Ma Lon . . | Do. . | P. L. . | 1,120 | 28th February 1921. | Do. |
| Do. . | (309) Maung Tha Dun . | Do. . | P. L. . | 1,171·2 | 5th April 1921. | Do. |
| Do. . | (310) Mr. A. J. Argent | Do. . | P. L. . | 819·2 | 4th April 1921. | Do. |
| Do. . | (311) Maung Pu . . | Do. . | P. L. . | 1,260·8 | 10th September 1921. | Do. |
| Do. . | (312) Ma Bwa . . | Do. . | P. L. . (renewal.) | 2,060·8 | 20th September 1921. | Do. |
| Thayetmyo | (313) Maung Tun Aung Gyaw. | Mineral oil . | P. L. . | 100 | 18th May 1921. | Do. |
| Do. . | (314) Messrs. Indo-Burma Oil-fields (1920), Ltd. | Do. . . | P. L. . | 2,560 | 12th July 1921. | Do. |
| Do. . | (315) Messrs. The Coal-fields of Burma, Ltd. | Coal . . . | P. L. . | 960 | 6th August 1921. | Do. |
| Do. . | (316) Messrs. The Indo-Burma Oil-fields (1920), Ltd. | Mineral oil . | P. L. . | 11,840 | 23rd July 1921. | Do. |
| Do. . | (317) Do. | Do. . | P. L. . (renewal.) | 6,080 | 17th August 1921. | Do. |
| Do. . | (318) Do. . | Do. . | P. L. . (renewal.) | 4,800 | 6th October 1921. | Do. |
| Toungoo . | (319) Maung Maung . | All minerals (except oil) | P. L. . (renewal.) | 148·48 | 27th January 1921. | Do. |
| Upper Chindwin. | (320) Messrs. Frank Johnson Sons & Co., Ltd. | Mineral oil and Coal. | P. L. . | 1,824 | 7th February 1921. | Do. |
| Do. | (321) Mr. W. R. Smith | Gold . . . | P. L. . | 2,400 | 11th April 1921. | Do. |
| Do. | (322) Messrs. The Indo-Burma Petroleum Co., Ltd. | Mineral oil . | P. L. . | 3,840 | 16th May 1921. | Do. |
| Do. | (323) S. Solomon . | Do. . | P. L. . (renewal). | 2,560 | 29th April 1921. | Do. |
| Do. . | (324) Do. . | Do. . | P. L. . (renewal.) | 3,200 | 24th May 1921. | Do. |
| Do. | (325) Messrs. The Indo Burma Petroleum Co., Ltd. | | P. . | 2,560 | 12th February 1921. | Do. |
| Do. . | (326) Sir Abdul Karim Jamal, Kt., C.I.E. | All minerals (except oil.) | P. L. . | 2,560 | 22nd December 1920. | Do. |
| Do. . | (327) Messrs. The Indo-Burma Petroleum Co. Ltd. | Mineral oil . | P. L. . | 12,800 | 12th November 1920. | Do. |

P. L.=*Prospecting License.*

## BURMA—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Upper Chindwin. | (328) Mr. W. R. Smith | Gold and associated minerals. | P. L. | 608 | 5th August 1921. | 1 year |
| Do. | (329) Do. | Do. | P. L. | 1,280 | Do. | Do. |
| Do. | (330) The Burma Finance and Mining Co., Ltd | All minerals including mineral oil. | P. L. | 8,730 | 8th September 1921. | Do. |
| Do. | (331) The Coal-fields of Burma, Ltd., Rangoon. | Coal | P. L. | 1,632 | 15th September 1921. | Do. |
| Do. | (332) Do. | Do. | P. L. | 2,188·8 | 31st August 1921. | Do. |
| Do. | (333) Messrs. Frank Johnson Sons & Co., Ltd. | Mineral oil | P. L. | 6,176 | 5th October 1921. | Do. |
| Do. | (334) Messrs. The Coal-fields of Burma, Ltd. | Coal | P. L. | 10,284 8 | 26th November 1921. | Do. |
| Do. | (335) Messrs. Frank Johnson Sons & Co, Ltd. | Mineral oil | P. L. | 3,078·4 | 26th October 1921. | Do. |
| Yamethin | (336) Messrs. Hajee Abdul Shakoor Hajee Cassim & Sons. | All minerals (except oil.) | P. L. | 518·4 | 29th January 1921. | Do. |
| Do. | (337) Mr. B. R. Fernandez. | Do. | P. L. | 3,392 | 20th December 1920. | Do. |
| Do. | (338) Messrs. Hajee Abdul Shakoor Hajee Kasim & Sons. | Do. | P. L. (renewal) | 1,779 2 | 7th January 1921. | Do. |

## CENTRAL PROVINCES.

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Balaghat | (339) Messrs. Tata Sons, Ltd. | Bauxite | P. L. (renewal.) | 533 | 1st February 1921. | 1 year. |
| Do. | (340) Do. | Do. | P. L. (renewal.) | 325 | Do. | Do. |
| Do. | (341) Do. | Do. | P. L. (renewal.) | 65 | Do. | Do. |
| Do. | (342) Do. | Do. | P. L. (renewal.) | 20 | Do. | Do. |
| Do. | (343) Do. | Do. | P. L. (renewal.) | 267 | Do. | Do. |
| Do. | (344) Do. | Do. | P. L. (renewal.) | 151 | Do. | Do. |
| Do. | (345) Do. | Do. | P. L. (renewal.) | 116 | Do. | Do. |
| Do. | (346) Do. | Do. | P. L. (renewal.) | 64 | Do. | Do. |

P. L.=*Prospecting License.*

## CENTRAL PROVINCES—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Balaghat . | (347) Messrs. Tata Sons, Ltd. | Bauxite . . | P. L. (renewal.) | 93 | 1st February 1921. | 1 year. |
| Do. . | (348) Do. . | Do. . . | P. L. (renewal.) | 96 | 31st December 1920 | Do. |
| Do. . | (349) Do. . | Do. . . | P. L. (renewal.) | 68 | Do. . | Do. |
| Do. . | (350) Do. . | Do . . | P. L. (renewal.) | 107 | Do . | Do. |
| Do . | (351) Pandit Rewashanker. | Manganese . . | M. L. . | 73 | 9th February 1921. | 10 years. |
| Do. . | (352) Do. . | Do. . . | P. L. . | 81 | 11th February 1921. | 1 year. |
| Do. . | (353) Seth Gowardhan Das. | Do. . . | M. L. . | 28 | 6th January 1921 | 15 years. |
| Do. . | (354) Do. . | Do. . . | M. L. . | 19 | 3rd January 1921. | 5 years. |
| Do. . | (355) Do. . | Do. . . | P. L. . | 2 | 9th March 1921. | 1 year. |
| Do. . | (356) Mr. C. S. Harris . | Do. . . | M. L . | 14 | 4th January 1921 | 30 years. |
| Do. . | (357) Do. . | Do. . . | P. L. . | 6 | 14th March 1921 | 1 year. |
| Do. . | (358) Seth Shriram . | Do. . . | M. L. . | 58 | 6th March 1921 | 30 years. |
| Do. . | (359) Central India Mining Company, Ltd. | Do. . | P. L. . | 99 | 10th March 1921. | 1 year. |
| Do. . | (360) Mr. Balkrishna Narayan Soparkar. | Do. | P. L. . | 77 | 16th February 1921. | 1 year. |
| Do. . | (361) Do. . | Do. . | P. L. . | 450 | Do. . | Do. |
| Do. . | (362) Do. . | Do. . | P. L. . | 133 | Do. . | Do. |
| Do. . | (363) Do. . | Do. . . | P. L. . | 278 | Do. . | Do. |
| Do. . | (364) Rai Sahib Chajjooram. | Do. . . | P. L. . | 102 | 29th January 1921. | Do. |
| Do. . | (365) Do. . | Do. . . | P. L. . | 22 | 19th February 1921. | Do. |
| Do. . | (366) Do. . | Do. . | P. L. . | 46 | 22nd February 1921 | Do. |
| Do. . | (367) Pandit Rewashanker. | Do. . . | P. L. . | 38 | 6th April 1921. | Do. |
| Do. . | (368) Do. . | Do. . . | P. L. . | 23 | 21st May 1921. | Do. |
| Do. . | (369) Seth Shriram . | Do. . . | P. L. . | 56 | 8th May 1921 | Do. |
| Do. . | (370) Do. . | Do. . . | P. L. . | 13 | Do. . | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## CENTRAL PROVINCES—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Balaghat . | (371) Indian Manganese Co., Ltd. | Manganese . | P. L. . | 392 | 22nd June 1921. | 1 year. |
| Do. . | (372) Central India Mining Co., Ltd. | Do. . . | P. L. . | 753 | 20th May 1921. | Do. |
| Do . | (373) Do. . | Do. . . | P. L. . | 34 | 15th May 1921. | Do. |
| Do. . | (374) Mr. M. A. Pasha, minor, guardian Shaikh Alimuddin. | Do. . . | P. L. . | 741 | 17th May 1921. | Do. |
| Do. . | (375) Pandit Kripashanker. | Do. . . | P. L. . | 129 | 21st May 1921. | Do. |
| Do. . | (376) Do. . | Do. . . | M. L. . | 57 | 17th May 1921. | 15 years. |
| Do. . | (377) Seth Mahanandram Sheonarayan. | Do. . . | P. L. . | 12 | 22nd May 1921. | 1 year. |
| Do. . | (378) Seth Gowardhandas | Do. . . | P. L. . | 52 | 28th May 1921. | Do. |
| Do. . | (379) Mr. C. S. Harris . | Do. . . | M. L. . | 9 | 5th May 1921 | 30 years. |
| Do. . | (380) Messrs. Tata Sons, Ltd. | Bauxite . . | P. L. . (renewal.) | 38 | 5th November 1921. | 2 years. |
| Do. . | (381) Do. . | Do. . . | P. L. . (renewal.) | 54 | Do. . | Do. |
| Do. . | (382) Do. . | Do. . . | P. L. . (renewal.) | 1,696 | Do. . | Do. |
| Do. . | (383) Do. . | Do. . . | P. L. . (renewal.) | 238 | Do. . | Do. |
| Do. . | (384) Do. . | Do. . . | P. L. . (renewal.) | 902 | Do. . | Do. |
| Do. . | (385) Pandit Rewashanker. | Manganese . . | M. L. . | 69 | 1st July 1921 | 15 years. |
| Do. . | (386) Do. . | Do. . . | M. L. . | 30 | 28th September 1921. | 20 years. |
| Do. . | (387) Do. . | Do. . . | P. L. . | 84 | 8th July 1921. | 1 year. |
| Do. . . | (388) Pandit Kripashanker | Do. . . | M. L. . | 173 | 4th July 1921. | 15 years. |
| Do. . | (389) Netra Manganese Co., Ltd. | Do. . . | P. L. . | 216 | 8th July 1921. | 1 year. |
| Do. . | (390) Mr. M. A. Pasha, minor, guardian Shaikh Alimuddin. | Do. . . | P. L. . | 532 | 5th July 1921. | Do. |
| Do. . | (391) Mr. Sunderlal Golcha | Do. . . | P. L. . | 10 | 8th July 1921. | Do. |
| Do. . | (392) Do. . | Do. . . | P. L. . | 14 | 31st August 1921. | Do. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

## CENTRAL PROVINCES—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Balaghat . | (393) Mr. Sunderlal Gokha. | Manganese . . | P. L. . | 145 | 2nd September 1921. | 1 year. |
| Do. . | (394) Do. . | Do. . . | P. L. . | 210 | 26th September 1921. | Do. |
| Do. . | (395) Mr. C. S. Harris . | Do. . . | M. L. . | 3 | 15th August 1921. | 5 years. |
| Do. . | (396) Do. . | Do. . . | M. L. . | 30 | 9th August 1921. | 30 years. |
| Do. . | (397) Rai Bahadur Bansilal Abirchand Mining Syndicate. | Copper . . | P. L. . | 533 | 31st August 1921. | 1 year. |
| Do. . | (398) Mr. Balkrishna Narain Soparkar. | Manganese . . | P. L. . | 19 | Do. . | Do. |
| Do. . | (399) Do. . | Do. . . | P. L. . | 36 | 26th September 1921. | Do. |
| Do. . | (400) Do. . | Do. . . | P. L. . | 95 | 27th September 1921. | Do. |
| Do. . | (401) Pandit Kripashanker of Balaghat. | Do. . . | M. L. . | 50·43 | 22nd October 1921. | 10 years. |
| Do. . | (402) Do. . | Do. . . | M. L. . | 39·00 | 12th December 1921. | Do. |
| Do. . | (403) Messrs. Tata Sons, Ltd. | Bauxite . . | P. L. . (renewal.) | 386·99 | 13th December 1921. | 1 year. |
| Do. . | (404) Do. . | Do. . . | P. L. . (renewal.) | 213·95 | Do. . | Do. |
| Do. . | (405) Do. . | Do. . . | P. L. . (renewal.) | 322·01 | Do. . | Do. |
| Do. . | (406) Messrs. Martin & Co. | Manganese . . | P. L. . (renewal.) | 14·06 | 16th December 1921. | Do. |
| Do. . | (407) Do. . | Do. . . | P. L. . (renewal.) | 14·39 | 16th December 1921. | Do. |
| Do. . | (408) Do. . | Do. . . | P. L. . (renewal.) | 108·14 | Do. . | Do. |
| Do. . | (409) Pandit Rewashanker of Balaghat. | Do. . . | P. L. . | 89·00 | 3rd October 1921. | Do. |
| o. | (410) Mr. Balkrishna Narayan Soparkar. | Do. . . | P. L. . | 23·33 | 19th December 1921. | Do. |
| Do. . | (411) Do. . | Do. . . | P. L . . | 42·84 | Do. . | Do. |
| Do. . | (412) Do. . | Do. . . | P. L. . | 131·57 | Do. . | Do. |
| Do. . | (413) R. S. B. Chajjooram. | Do. . . | P. L. . | 14·19 | 10th October 1921. | Do. |
| Do. . | (414) Do. . | Do. . . | P. L. . | 34·35 | Do. . | Do. |
| Do. . | (415) Do. . | Do. . . | P. L. . | 13·39 | Do. . | Do. |

P. L.=*Prospecting License*. M. L.=*Mining Lease*.

## CENTRAL PROVINCES—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres | Date of commencement | Term. |
|---|---|---|---|---|---|---|
| Balaghat | (416) K. B. B. P. Byramji & Co. | Manganese | M. L. | 1 40 | 9th November 1921. | 5 years. |
| Do. | (417) Mr. Bakaram Singh | Do. | P. L. | 106 67 | 17th November 1921. | 1 year. |
| Do. | (418) The Central India Mining Company, Ltd. | Do. | M. L. | ·62 | 26th November 1921. | 2 years. |
| Do. | (419) Mr. M. A. Pasha, minor, guardian Munshi Ahmuddin. | Do. | P. L. | 347 00 | 3rd October 1921. | 1 year. |
| Do. | (420) Do. | Do. | P. L. | 29·90 | Do. | Do. |
| Do. | (421) Seth Shriram | Do. | M. L. | 1·28 | 4th October 1921. | 30 years. |
| Do. | (422) Do. | Do. | M. L. | 107·00 | 22nd December 1921. | 10 years. |
| Do. | (423) Do. | Do. | M. L. | ·55 | 4th October 1921. | 30 years. |
| Do. | (424) Do. | Do. | M. L. | 34 00 | 22nd December 1921. | 5 years |
| Do. | (425) Do. | Do. | M. L | 14 05 | 26th October 1921. | 3 years. |
| Do. | (426) Mr. Balkrishna Narain Sopaikar. | Do. | M. L. | 243 84 | 8th December 1921. | 30 years. |
| Do. | (427) Do. | Do. | P. L. | 336 08 | 30th November 1921. | 1 year. |
| Do. | (428) Do. | Do. | P. L | 12 25 | 10th October 1921 | Do. |
| Do. | (429) Do. | Do. | P L. | 92 51 | 24th October 1921. | Do. |
| Do. | (430) Do. | Do. | P. L. | 22 43 | 17th November 1921. | Do |
| Do. | (431) Do. | Do. | P. L. | 21·25 | Do. | Do. |
| Do. | (432) Do. | Do. | P. L. | 19·00 | 19th December 1921. | Do. |
| Betul | (433) Mr. R. Bazaj | Coal | P. L. | 840 | 19th January 1921. | Do. |
| Do. | (434) Shaikh Shahabuddin. | Ferric oxide (ochre) | P. L | 635 | 21st May 1921. | Do. |
| Do. | (435) Rai Sahib Chhajjuram. | Coal | P. L. | 331 | 6th June 1921. | Do. |
| Do. | (436) Do. | Do. | P. L. | 97 | 6th June 1921 | Do. |
| Do. | (437) Do. | Do. | P. L. | 113 | Do. | Do. |
| Do. | (438) Mr. R. Bazaj | Do. | M. L. | 2,419 | 8th September 1921. | 30 years. |

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

## CENTRAL PROVINCES—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Betul . | (439) Mr. R. Baraj . | Coal . . . | M. L. . | 2,813 | 28th July 1921. | 30 years. |
| Do. . | (440) Messrs. Nabibux Inayatullah. | Manganese, Iron and Ferric oxide. | P. L. . | 1,059·01 | 9th December 1921. | 1 year. |
| Do. . | (441) Banshidhar Ramniwas. | Coal . . . | P. L. . | 798·11 | 18th November 1921. | Do. |
| Do. . | (442) Jagannath Bisheshwarlal. | Do. . . | P. L. . | 937·45 | 27th October 1921. | Do. |
| Bhandara . | (443) Messrs. Lalbehari Narayandas and Ramcharan Shankerlal. | Manganese . | M. L. . | 30 | 23rd May 1921. | 20 years. |
| Do. . | (444) Seth Shriram . | Do. . . | P. L. . | 3 | 29th June 1921. | 1 year. |
| Do . | (445) Rai Sahib Seth Gowardhan Dass. | Do. . . | M. L. . | 29·30 | 18th November 1921. | 10 years. |
| Do. . | (446) Seth Shriram . | Do. . . | M. L. . | 27 | 20th August 1921. | 30 years. |
| Bilaspur . | (447) Messrs. Chari & Co.: Ltd. | Coal . . . | P. L. . | 1,630 | 18th January 1921. | 1 year. |
| Chanda . | (448) Mr. H. Verma and Munshi Kanhaiyalal. | Galena . . | P. L. . | 614 | 14th April 1921. | Do. |
| Do. . | (449) Rao Sahib D. Lakshminarayan. | Coal . . . | P. L. . | 179 | 2nd May 1921. | Do. |
| Do. . | (450) Do. . | Do. . . . | P. L. . | 93 | 26th May 1921. | Do. |
| Do. . | (451) Messrs. Hajibhai Lalji & Co. | Do. . . . | M. L. . | 981 | 22nd July 1921. | 30 years. |
| Do. . | (452) Messrs. Martin & Co. | Manganese . . | P. L. . | 709 | 29th July 1921. | 1 year. |
| Do. . | (453) Messrs. T. F. Karaka & Co. | Iron . . . | P. L. . | 472 | 4th August 1921. | Do. |
| Do. . | (454) Do. . | Do. . . . | P. L. . | 272 | 17th August 1921. | Do. |
| Do. . | (455) Rao Sahib Mathura Prasad Motilal & Co. | Coal . . . | P. L. . | 461 | 16th November 1921. | Do. |
| Do. . | (456) Rao Sahib D. Laxmi Narayan of Kamptee. | Do. . . . | P. L. . | 1,334·81 | 18th November 1921. | Do. |
| Do. . | (457) Do. . | Do. . . . | P. L. . | 1,858·80 | Do. . | Do. |
| Do. . | (458) Do. . | Do. . . . | P. L. . | 996·33 | Do. . | Do. |
| Chhindwara. . | (459) Indian Manganese Co. | Manganese . . | P. L. | 79 | 7th January 1921. | Do. |
| Do. . | (460) Do. . | Do. . . | P. L. . | 182 | Do. . | Do. |
| Do. . | (461) Pandit Kripashanker. | Coal . . . | P. L. . | 203 | 22nd March 1920. | Do. |
| Do. . | (462) Mr. R. Bazaj . | Do. . . . | M. L. . | 571 | 21st June 1921. | 30 years. |

P. L.=*Prospecting License*. M. L.=*Mining Lease*.

## CENTRAL PROVINCES—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Chhindwara | (463) Mr. B. V. Buti . | Coal . . . | P. L. . | 589 | 30th April 1921. | 1 year. |
| Do . | (464) Mr. R. Bazaj . | Do. . . | P. L. . | 495 | 25th April 1921. | Do. |
| Do. . | (465) Mr. B. V. Buti . | Do. . . . | P. L. . | 74 | 30th April 1921. | Do. |
| Do. . | (466) Seth Lakshmichand of Seoni. | Do. . . . | P. L. . | 229 | 15th June 1922. | Do. |
| Do. . | (467) Do. . | Do. . . . | P. L. . | 333 | 31st May 1921. | Do. |
| Do. . | (468) Mr. A. H. Wasudeo Rao. | Do. . . . | P. L. . | 48 | 21st May 1921. | Do. |
| Do. . | (469) Shaikh Shahabuddin. | Do. . . . | P. L. . | 263 | 18th May 1921. | Do. |
| Do. . | (470) Seth Jagannath . | Do. . . . | P. L. . | 133 | 19th April 1921. | Do. |
| Do. . | (471) Rai Sahib Sunderlal | Do. . . . | P. L. . | 358 | 6th May 1922 | Do. |
| Do. . | (472) Seth Gowardhandas | Do. . . . | P. L. . | 213 | 29th April 1921. | Do. |
| Do. . | (473) Do. . | Do. . . . | P. L. . | 236 | 3rd June 1921. | Do. |
| Do . | (474) Do. . | Do. . . . | P. L. . | 163 | 11th May 1921. | Do. |
| Do . | (475) Rai Sahib Chhajjuram. | Manganese . . | P. L. . | 235 | 2nd June 1921. | Do. |
| Do. . | (476) Do. . | Do. . . | P. L. . | 138 | Do. . | Do. |
| Do. . | (477) Seth Lakshmichand of Betul. | Coal . . . | P. L. . | 573 | 9th May 1921 | Do. |
| Do. . | (478) Seth Lakshmichand of Seoni. | Do. . . . | P. L. . | 255 | 18th May 1921. | Do. |
| Do. . | (479) Pandit Kripashanker. | Do. . . . | P. L. . | 184 | 9th June 1921 | Do. |
| Do. . | (480) Do. . | Do. . . . | P. L. . | 48 | 28th May 1921. | Do. |
| Do. . | (481) Rai Sahib Sunderlal | Do. . . . | P. L. . | 213 | 6th May 1921 | Do. |
| Do. . | (482) Do. . | Do. . . . | P. L. . | 306 | 14th May 1921. | Do. |
| Do. . | (483) Seth Lakshmichand of Betul. | Do. . . . | P. L. . | 142 | 9th May 1921 | Do. |
| Do . | (484) Rai Sahib Sunderlal | Do. . . . | P. L. . | 84 | 14th May 1921. | Do. |
| Do. . | (485) Do. . | Do. . . . | P. L. . | 178 | 5th May 1921 | Do. |
| Do. . | (486) Do. . | Do. . . . | P. L. . | 15 | Do. . | Do. |

P. L. = *Prospecting License.*

## CENTRAL PROVINCES—*contd.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Chhindwara | (487) Rai Sahib Sunderlal | Coal . . . | P. L. . | 182 | 15th June 1921. | 2 years. |
| Do. . | (488) Rai Sahib Hiralal Verma and Munshi Kanhaiyalal. | Do. . . . | P. L. . | 624 | 29th September 1921. | 1 year. |
| Do. . | Sir M. B. Dadabhoy . | Manganese . | P. L. . | 103 | 21st July 1921. | Do. |
| Do. . | (490) Mr B. V. Buti . | Coal . . | P. L. . | 85 | 7th September 1921 | Do. |
| Do. . | (491) Do. . | Do. . . . | P. L. . | 195 | Do. . | Do |
| Do. . | (492) Shaikh Shahabuddin. | Do. . . . | P. L. . | 359 | 16th July 1921. | Do. |
| Do. . | (493) Mr. M. V. Kaorey | Manganese . . | P. L. . | 48 | 6th September 1921. | Do. |
| Do. . | (494) Seth Jagannath . | Coal . . . | P. L. . | 139 | 7th July 1921. | Do. |
| Do. . | (495) Do. . | Do. . . . | P. L. . | 215 | 22nd August 1921. | Do. |
| Do. . | (496) Do. . | Do. . . . | P. L. . | 204 | 7th July 1921. | Do. |
| Do. . | (497) Do. . | Do. . . . | P. L. . | 244 | 10th July 1921. | Do. |
| Do. . | (498) Seth Lakshmichand of Betul. | Do. . . . | P. L. . | 1,127 | 3rd August 1921. | Do. |
| Do. . | (499) Pandit Kripashanker. | Do. . . . | P. L. . | 105 | 8th September 1921. | Do |
| Do. . | (500) Do. . | Do. . . . | P. L. . | 192 | Do. . | Do. |
| Do. . | (501) Do. . | Do. . . . | P. L. . | 421 | Do. . | Do. |
| Do. . | (502) Seth Lakshmichand of Betul. | Do. . . . | P. L. . | 586 | 16th September 1921. | Do. |
| Do. . | (503) Rai Sahib Sunderlal. | Do. . . . | P. L. . | 616 | 25th July 1921 | Do. |
| Do. . | (504) Seth Gowardhandas. | Do. . . . | P. L. . | 222 | 3rd September 1921. | Do. |
| Do. . | (505) Seth Lakshmichand of Betul. | Do. . . . | P. L. . | 119 | 22nd September 1921. | Do. |
| Do. . | (506) Pandit Kripashankar. | Do. . . . | P. L. . | 338 | 8th September 1921. | Do. |
| Do. . | (507) Seth Lakshmichand of Seoni. | Do. . . . | P. L. . | 66 | 25th August 1921. | Do. |
| Do. . | (508) Do. . . | Do. . . . | P. L. . | 637 | 25th August 1921. | Do. |
| Do. . | (509) Rai Sahib Minnamal and Nandlal. | Do. . . . | P. L. . | 324 | 21st July 1921. | Do. |

P. L. = *Prospecting License.*

## CENTRAL PROVINCES—*contd.*

| DISTRICT. | Grantee | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Chhindwara | (510) Seth Behārilal . | Coal . . . | P. L. . | 210 | 17th August 1921. | 1 year. |
| Do. . | (511) Do. . . | Do. . . . | P. L . | 92 | 17th September 1921 | Do |
| Do. . | (512) Messrs. Maharaj Kishan & Co. | Do . . . | P. L . | 204 | 6th September 1921 | Do. |
| Do. . | (513) Seth Beharilal . | Do . . . | P. L. . | 65 | 10th September 1921 | Do |
| Do. . | (514) Do. . . | Do. . . . | P L . | 199 | 21st September 1921 | Do |
| Do. . | (515) Khan Sahib Mulla Hassanji & Sons. | Do . . . | P. L . | 194 | 24th September 1921. | Do |
| Do. . | (516) Seth Naraindas . | Manganese . . | P L . | 64 | 16th August 1921 | Do |
| Do. . | (517) Mr. B. V. Buti . | Coal . . . | P. L. . | 175 00 | 28th November 1921. | Do. |
| Do. . | (518) Messrs. H. Verma and Munshi Kanhaylal. | Do. . . . | P L. . | 318·51 | 3rd December 1921 | Do. |
| Do. . | (519) Seth Jagannath Tumsar. | Do. . . . | P. L . | 115·20 | 15th October 1921. | Do. |
| Do. . | (520) Rai Sahib Sunderlal. | Do. . . . | P. L. . | 467·00 | 10th November 1921 | Do. |
| Do. . | (521) Messrs. B P. Byramji & Co., Nagpur. | Do. . . . | P. L. . | 177·58 | 15th November 1921 | Do. |
| Do. . | (522) Seth Jagannath . | Do. . . . | P. L. . | 97·76 | 27th October 1921 | Do. |
| Do. . | (523) Seth Goverdhandas | Do. . . . | P. L. . | 151·20 | 19th October 1921. | Do. |
| Do. . | (524) Seth Jagannath . | Do. . . . | P. L. . | 87·78 | 27th October 1921. | Do. |
| Do. . | (525) Pandit Kripashanker. | Do. . . . | P. L. . | 336·00 | 1st December 1921. | Do. |
| Do. . | (526) Hazi Fazal & Sons | Manganese . . | P. L. . | 60·78 | 19th December 1921. | Do. |
| Do. . | (527) Do. . . | Do. . . | P. L. . | 31·22 | Do. . | Do. |
| Do. . | (528) Seth Minamal and Nandlal. | Do. . . | P. L. . | 677·49 | 12th October 1921. | Do. |
| Do. . | (529) Seth Narayandas . | Do. . . | P. L. . | 65 00 | 4th November 1921. | Do. |
| Do. . | (530) Messrs. M. L. Bharadwaj. | Do. . . | P. L. . | 249·05 | 9th December 1921. | Do. |
| Do. . | (531) M. Hasanji & Sons | Do. . . | P. L. . | 186·00 | 27th October 1921. | Do. |
| Do. . | (532) Messrs. Maharaj Kishan & Co. | Do. . . | P. L. . | 52·49 | 25th November 1921. | Do. |

P. L.=*Prospecting License.*

## CENTRAL PROVINCES—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Chhindwara | (533) Messrs. M. L. Bharadwaj & Co. | Manganese . . | P. L. . | 199·88 | 18th October 1921. | 1 year. |
| Do. . | (534) Khan Sahib M. Hasanji & Sons. | Do. . . | P. L. . | 475·41 | 27th October 1921. | Do. |
| Do. . | (535) Do. . . | Coal . . . . | P. L. . | 200·94 | Do. . | Do. |
| Do. . | (536) Messrs. Bharadwaj & Co. | Do. . . . . | P. L. . | 166·5 | 18th October 1921. | Do. |
| Do. . | (537) Do. . . | Do. . . . . | P. L. . | 75·41 | 28th November 1921 | Do. |
| Do. . | (538) Lala Beharilal . | Do. . . . . | P. L. . | 159·33 | 8th October 1921. | Do. |
| Do. . | (539) Do. . . | Do. . . . . | P. L. . | 178·18 | Do. . | Do. |
| Do. . | (540) Seth Girdharilal . | Do. . . . . | P. L. . | 147·37 | 17th October 1921. | Do. |
| Do. . | (541) Do . . | Do. . . . . | P. L. . | 165·47 | 16th November 1921. | Do. |
| Do. . | (542) Messrs. M. L. Bharadwaj & Co. | Do. . . . . | P. L. . | 95·82 | 23rd December 1921. | Do. |
| Do. . | (543) Laxmichand, Betul | Do. . . . . | P. L. . | 84·00 | 21st December 1921. | Do. |
| Do. . | (544) Seth Girdharilal . | Do. . . . . | P. L. . | 187·20 | 16th November 1921. | Do. |
| Do. . | (545) Do. . . | Do. . . . . | P. L. . | 234·50 | 28th November 1921. | Do. |
| Do. . | (546) Messrs. Maharaj Kishan & Co | Do. . . . . | P. L. . | 544·13 | 16th December 1921. | Do. |
| Do. | (547) Seth Girdharilal . | Do. . . . . | P. L. . | 200·47 | 21st October 1921. | Do. |
| Do. . | (548) Do. . . | Do. . . . . | P. L. . | 129·61 | 16th November 1921. | Do. |
| Do. . | (549) Do. . . | Do. . . . . | P. L. . | 220·69 | 8th November 1921. | Do. |
| Do. . | (550) Pandit Thakur Prasad. | Do. . . . . | P. L. . | 127·85 | 19th December 1921. | Do. |
| Do. . | (551) Seth Girdharilal . | Do. . . . . | P. L. . | 284·57 | 16th November 1921. | Do. |
| Do. . | (552) Seth Sheolal, M.L.C. | Do. . . . . | P. L. . | 605·35 | 12th December 1921. | Do. |
| Do . | (553) Messrs. Bharadwaj and others. | Do. . . . . | P. L. . | 95·00 | 23rd December 1921. | Do. |
| Do. . | (554) Seth Sheolal, M.L.C. | Do. . . . . | P. L. . | 106·08 | Do. . | Do. |
| Do. . | (555) Messrs. Bharadwaj & Co. | Do. . . . . | P. L. . | 62·53 | .. | Do. |

P. L.=*Prospecting License.*

## CENTRAL PROVINCES—*contd.*

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement | Term. |
|---|---|---|---|---|---|---|
| Chhindwara | (556) Seth Sheolal . | Coal . . . | P. L. . | 138·74 | 23rd December 1921. | 1 year |
| Do. . | (557) A. H. Wasudeo Rao. | Do. . . . | M. L. . | 25·64 | 29th November 1921. | 30 years. |
| Jubbulpore | (558) Messrs. Grandage Moir & Co. | Bauxite . . | P. L. . | 252 | 5th April 1921. | 1 year. |
| Do . | (559) Do. . . | Do. . . | P. L. . | 27 | Do. . | Do. |
| Do. . | (560) Mr. George Forrester. | Do. . . | P. L. . | 210 | 5th July 1921. | Do. |
| Nagpur . | (561) Gosai Ramkrishnapuri. | Manganese . . | P. L. . | 26 | 16th March 1921. | Do. |
| Do. . | (562) Mir Aslam Khan . | Do. . . | P. L. . | 70 | 7th January 1921. | Do |
| Do. . | (563) Do. . . | Do . . | M. L. . | 108 | 3rd January 1921 | 10 years. |
| Do. . | (564) Do. . . | Do. . . | P. L. . | 268 | 8th February 1921. | 1 year. |
| Do. . | (565) Central India Mining Co., Ltd. | Do. . . | M. L . | 6 | 11th January 1921. | Will expire with the mining lease, dated the 7th February 1906, to which it is supplementary. |
| Do. . | (566) Indian Manganese Co. | Do. . . | P. L. . | 42 | 2nd March 1921. | 1 year. |
| Do. . | (567) Do. . . | Do. . . | P. L. . | 135 | 2nd March 1921. | Do. |
| Do. . | (568) Mr. C. S. Harris . | Do. . . | P. L. . | 181 | 10th June 1921. | Do. |
| Do. . | (569) Mir Aslam Khan . | Do. . . | P. L. . | 61 | 1st June 1921 | Do. |
| Do. . | (570) Gosain Ramkrishnapuri. | Do. . . | P. L. . | 709 | 18th May 1921. | Do. |
| Do. . | (571) Do. . . | Do. . . | M. L. . | 6 | 2nd May 1921 | 30 years. |
| Do. . | (572) Do. . . | Do. . . | M. L. . | 4 | Do. . | Do. |
| Do. . | (573) Do. . . | Do. . . | P. L. . | 52 | 13th June 1921 | 1 year. |
| Do. . | (574) Mr. M. V. Kaorey | Do. . . | P. L. . | 61 | 27th June 1921. | Do. |
| Do. . | (575) Do. . . | Do. . . | P. L. . | 72 | 27th June 1921. | Do. |
| Do. . | (576) Rao Sahib D. Lakshmi Naryan. | Do. . . | P. L. . | 26 | 25th May 1921. | Do. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## CENTRAL PROVINCES—*concld.*

| District. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Nagpur . | (577) Messrs. Goredutta Ganeshlal and M. D'Costa. | Manganese . | P. L. . | 99 | 19th May 1921. | 1 year. |
| Do. . | (578) Mr. Laxman Damodhar Lele. | Do. . . | M. L. . | 14 | 16th August 1921. | 30 years. |
| Do. . | (579) Messrs. Lalbehari Narayandas and Ramcharan Shankerlal | Do. . . | M. L. . | 20 | 26th August 1921. | 5 years. |
| Do. . | (580) Seth Mahanandram Sheonarayan. | Do. . . | P. L. . | 85 | 17th September 1921. | 1 year. |
| Do. . | (581) The Central India Mining Co. | Do. . . | P. L. . | 89 | 31st August 1921. | Do. |
| Do. . | (582) Rai Sahib Ramkrishna Puri Gosai of Nagpur. | Do. . . | P. L. . | 166·94 | 5th November 1921. | Do. |
| Do. . | (583) Do. . . | Do. . . | P. L. . | 103·73 | Do. . | Do. |
| Do. . | (584) Do. . . | Do. . . | P. L. . | 31·78 | Do. . | Do. |
| Do. . | (585) Mr. Balkrishna Narayan Soparkar of Balaghat. | Do. . . | P. L. . | 43·17 | Do. . | Do. |
| Do. . | (586) Seth Mahanandram Sheonarayan of Kamptee. | Do. . . | P. L. . | 28·55 | 22nd December 1921. | Do. |
| Do. . | (587) Mr. Ganpat Rao Laxman of Nagpur. | Wolfram and Galena. | P. L | 185·03 | 22nd November 1921. | Do. |
| Do. . | (588) Mir Aslam Khan of Nagpur. | Manganese . . | P. L. . | 6·16 | 8th December 1921. | Do. |
| Do. . | (589) Mir Aslam Khan . | Do. . . | P. L. . | 30·66 | Do. . | Do. |
| Do. . | (590) Mr. Shamji Narayanji of Kamptee. | Do. . | P. L. . | 19·76 | 22nd December 1921. | Do. |
| Do. . | (591) Nagpur Manganese Mining Syndicate. | Do. . . | M. L. . | 61·91 | 1st December 1921. | 10 years. |
| Narsinghpur | (592) Mr. C. S. Harris . | Copper . . | P. L. . | 212 | 18th April 1921. | 1 year. |

## COORG.

| | | | | | | |
|---|---|---|---|---|---|---|
| Coorg | (593) Mr. Albert Henry Gaston, Madras. | Mica . . . | To prospect for and mine Mica. | 412·90 | 31st August 1920. | Up to midnight of 31st December, 1921. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## MADRAS.

| DISTRICT. | Grantee | Mineral. | Nature of grant. | Area in acres | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Anantapur . | (594) A Ghosh . | Barytes . . | P. L. . | 12·30 | 18th October 1920. | 1 year. |
| Do. . | (595) B. P. Sesha Reddi | Do. . . | P. L. . | 13·50 | 1st February 1921. | Do. |
| Do. . | (596) Moriston, Agent, Anantapur Gold Fields. | Gold . . | P. L. . | 2,933·58 | 22nd February 1921. | Do. |
| Do. . | (597) B. P. Sesha Reddi | Asbestos . . | P. L. . | 7·32 | 21st June 1921. | Do. |
| Do. . | (598) Do. . . | Barytes . . | P. L. . | 42·77 | Do. . | Do. |
| Do . | (599) Do . . | Steatite . . | P. L. . | 27·96 | 30th July 1921. | Do. |
| Cuddapah . | (600) Messrs. Lakshmi-rattan & Co. | All minerals . | P. L. . | 64 00 | 7th July 1921 | Do. |
| Guntur . | (601) Messrs. Gillanders, Arbuthnot & Co, Calcutta. | Diamonds . . | P. L. . | 42·70 | 8th January 1921. | Do. |
| Do. . | (602) The Travancore Mining and Trading Co. | Galena . . | P. L. . | 640 | 16th April 1921. | Do. |
| Kistna . | (603) Messrs. Best & Co. | Coal . . . | P. L. . | 242 94 | 24th June 1921. | Do. |
| Do. . | (604) The Hyderabad Deccan Co, Ltd. | Do. . . . | P. L. . | 3577·60 | 27th July 1921. | Do. |
| Kurnool . | (605) B P. Sesha Reddi | Barytes . . | P. L. . | 4 20 | 2nd May 1921 | Do. |
| Do. . | (606) Do . . | Steatite . | P. L. . | 69 04 | Do . | Do. |
| Do. . | (607) Do. . . | Barytes . . | P. L. . | 6 56 | Do . | Do. |
| Do. . | (608) Do. . . | Do. . . | P. L. . | 3 03 | Do. . | Do. |
| Do. . | (609) Do. . . | Do. . . | P. L. . | 16·75 | Do. . | Do. |
| Do. . | (610) A. Ghosh . . | Do. . . | M. L. . | 55·45 | 3rd May 1921 | 30 years. |
| Do. . | (611) Do. . . . | Do. . . | M. L. . | 66·97 | Do. . | Do. |
| Do. . | (612) Do. . . . | Do. . . | M. L. . | 49·60 | 12th June 1921. | Do. |
| Do. . | (613) B. P. Sesha Reddi | Do. . . | P. L. . | 0·80 | 23rd August 1921. | 1 year. |
| Do. . | (614) Do. . . | Do. . . | M. L. . | 42·15 | 15th August 1921. | 30 years. |
| Nellore . | (615) M. Varadha Reddi. | Mica . . . | P. L. . | 27·90 | 14th March 1921. | 1 year. |
| D . | (616) N. Raghavulu Nayakar. | Do. . . | M. L. . | 57·00 | 17th January 1921. | 30 years. |
| Do . | (617) S. Venkatasubba Reddi. | Do. . . . | P. L. . | 16·64 | 28th February 1921. | 1 year. |

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

## MADRAS—*contd.*

| DISTRICT. | Grantee | Mineral. | Nature of grant. | Area in acres | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Nellore . | (618) K. Venkatasubbayya. | Mica . . . . | M. L. . | 1·63 | 7th January 1921. | 30 years. |
| Do. . | (619) Moherji Cowasji . | Do. . . . . | P. L. . | 7·81 | 15th January 1921. | 1 year. |
| Do. . | (620) S. Ramalinga Reddi. | Do. . . . . | P. L. . | 15·73 | 14th March 1921. | Do. |
| Do. . | (621) G. Gopalakrishnayya. | Do. . . . | P. L. . | 136·86 | 8th February 1921. | Do. |
| Do. . | (622) V. Rami Reddi . | Do. . . . . | P. L. . | 10·05 | 2nd February 1921. | Do. |
| Do. . | (623) V. Venkatakumara Krishna Yechendra, Bahadur. | Do. . . . . | M. L. . | 98·06 | 6th May 1921 | a |
| Do. . | (624) Sankara Mining Syndicate. | Do. . . . . | M. L. . | 71·39 Extension of area held under previous lease. | 4th October 1920. | Do. |
| Do. . | (625) R. K. Subbaraghava Ayyar. | Do. . . . . | M. L. . | 301·00 | 3rd April 1921. | Do. |
| Do. . | (626) R. Sundarami Reddi. | Do. . . . . | P. L. . | 3·07 | 26th May 1921. | 1 year. |
| Do. . | (627) K. Ramasubba Reddi. | Do. . . . . | P. L. . | 26·20 | 1st March 1921. | Do. |
| Do. . | (628) T. C. Dandayutham Pillai. | Do. . . . . | P. L. . | 8·82 | 13th June 1921. | Do. |
| Do. . | (629) Do. . . | Do. . . | P. L. . | 15·00 | 21st June 1921. | Do. |
| Do. . | (630) Messrs. Christien & Co. | Do. . . . . | M. L. . | 7·73 | 11th June 1921. | 30 years. |
| Do. . | (631) T. Subbarami Reddi. | Do. . . . . | M. L. . | 30·00 | 23rd June 1921. | Do. |
| Do. . | (632) K. Penchelu Reddi. | Do. . . . . | P. L. . | 10·31 | 2nd April 1921. | 1 year. |
| Do. . | (633) G. V. Subba Reddi | Do. . . . . | P. L. . | 150·30 | 15th May 1921. | Do. |
| Do. . | (634) I. Rama Subba Reddi. | Do. . . . . | P. L. . | 3·75 | 17th August 1921. | Do. |
| Do. . | (635) K. Panchelu Reddi | Do. . . . . | P. L. . | 4·14 | Do. | Do. |
| The Nilgiri District. | (636) A. H. Gaston . | Do. . . . . | P. L. . | 56·57 | 14th June 1921. | Do. |
| Tinnevelly . | (637) Sri Krishna Doss of Bikaner. | Garnet . . . | P. L. . | 10·40 | 21st September 1921. | Up to the end of December 1921. |

P. L.=*Prospecting Licence.* M. L.=*Mining Lease.*

## NORTH-WEST FRONTIER PROVINCE.

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Bannu . | (638) The Indo-Burma Petroleum Co., Ltd., Rangoon. | Kerosine oil . | P. L. . | 18,880 acres in the Bannu and Dera Ismail Khan Districts | 5th February 1921. | .. |
| Do. . | (639) The Rangoon Oil Co., Ltd., Rangoon. | Do. . . | P. L. . | 19,200 between Pezu and Bain passes in the Bannu and D. I. Khan Districts. | 5th November 1920. | 1 year. |
| Hazara . | (640) R. S. Seth Chuhar Lal & Sons, Bankers, Abbottabad. | Minerals . . | P. L. . | 20·7 | 17th September 1921. | Do. |
| Do. . | (641) Messrs. Lane Brown and Hewlett, Civil Engineer, Lucknow. | Do. . . | P. L. . | 9,099 | 15th December 1921. | Do. |

## PUNJAB.

| DISTRICT. | Grantee. | Mineral. | Nature of grant. | Area in acres. | Date of commencement. | Term. |
|---|---|---|---|---|---|---|
| Attock . | (642) Sir Vithaldas D. Thackersey, *Kt.*, of Bombay. | Mineral oil . | P. L. . | 2,560 | 21st March 1921. | 1 year. |
| Do. . | (643) Lt.-Col. Frank Johnson, of the firm of Frank Johnson & Co., Ltd., Calcutta. | Do. . . | P. L. . | 800 | 10th February 1921. | Do. |
| Do. . | (644) The Attock Oil Co., Ltd. | Oil . . . | P. L. . | 4,480 | 15th September 1921. | Do. |
| Do. . | (645) Whitehall Petroleum Corporation, Ltd. | Mineral oil . | P. L. . | 24,480 | 22nd December 1921. | Do. |
| Do. . | (646) Attock Oil Co., Ltd. | Do. . . | M. L. . | 1,278 | 23rd December 1921. | 30 years. |
| Gujrat . | (647) Whitehall Petroleum Corporation, Ltd. | Do. . . | P. L. . | 70,451·2 | 15th December 1921. | 1 year. |
| Jhelum . | (648) Pandit Gian Chand of Dandot. | Coal . . . | P. L. . | 5 | 26th August 1921. | Do. |
| Do. . | (649) Messrs. Madan Lal Manohar Lal. | All minerals other than oil. | P. L. . | 564 | 17th September 1921. | Do. |
| Rawalpindi | (650) Rangoon Oil Co., Ltd. | Mineral oil . | P. L. . | 2,880 | 9th November 1921. | Do. |
| Shahpur . | (651) The Indo-Burma Petroleum Co., Ltd., of Rangoon. | Petroleum . . | P. L. . | 16,000 | 4th January 1921. | Do. |

P. L. = *Prospecting License.*

## SUMMARY.

| PROVINCE. | Exploring Licenses. | Prospecting Licenses. | Mining Leases. | Total of each Province. |
|---|---|---|---|---|
| Assam . . . . . . . | ... | 8 | . | 8 |
| Baluchistan . . . . . . | 4 | 2 | 5 | 11 |
| Bengal . . . . . . . | ... | 1 | . | 1 |
| Bihar and Orissa . . . . . | ... | 20 | 17 | 37 |
| Bombay . . . . . . . | ... | 2 | .. | 2 |
| Burma . . . . . . . | ... | 265 | 14 | 279 |
| Central Provinces . . . . . | ... | 217 | 37 | 254 |
| Coorg . . . . . . . | ... | 1 | ... | 1 |
| Madras . . . . . . . | ... | 33 | 11 | 44 |
| North-West Frontier Province . . . | ... | 4 | ... | 4 |
| Punjab . . . . . . . | ... | 9 | 1 | 10 |
| United Provinces . . . . . | ... | ... | ... | ... |
| Total of each kind and grand total for 1921 . | 4 | 563 | 84 | 651 |
| TOTAL FOR 1920 . | ... | 572 | 80 | 652 |

# CLASSIFICATION OF LICENSES AND LEASES.

TABLE 41.—*Prospecting Licenses granted in Assam during 1921.*

| DISTRICT | 1921. | | |
| --- | --- | --- | --- |
| | No | Area in acres | Mineral. |
| **Prospecting Licenses.** | | | |
| Cachar . . . . | 4 | 20,582·4 | Mineral oil |
| Garo Hills . . . . . | 1 | 49,280 | Coal |
| Khasi and Jaintia Hills . . | 1 | 7,564·8 | Minerals other than mineral oil. |
| Sylhet . . . . . . | 2 | 7,699·2 | Mineral oil. |
| TOTAL . | 8 | ... | |

TABLE 42.—*Exploring Licenses, Prospecting Licenses and Mining Leases granted in Baluchistan during 1921.*

| DISTRICT | 1921 | | |
| --- | --- | --- | --- |
| | No | Area in acres | Mineral |
| **Exploring Licenses.** | | | |
| Kalat . . . . | 3 | Bolan Pass, whole of Las Bela State and whole of Kalat State | Mineral oil |
| Sibi . . | 1 | Whole of Sibi District except Mari and Bugti countries. | Do |
| TOTAL . | 4 | ... | |

TABLE 42.—*Exploring Licenses, Prospecting Licenses and Mining Leases granted in Baluchistan during 1921*—contd.

| DISTRICT. | 1921. No. | 1921. Area in acres. | 1921. Mineral. |
|---|---|---|---|
| **Prospecting Licenses** | | | |
| Kalat | 1 | 3,200 | Mineral oil. |
| Sibi | 1 | 49,600·4 | Do. |
| TOTAL | 2 | ... | |
| **Mining Leases.** | | | |
| Quetta-Pishin | 1 | 10 | Chromite. |
| Zhob | 3 | 40 | Do. |
| Do. | 1 | 20 | Asbestos. |
| TOTAL | 5 | ... | |

TABLE 43.—*Prospecting License granted in Bengal during 1921.*

| DISTRICT | 1921. No. | 1921. Area in | 1921. Mineral. |
|---|---|---|---|
| Chittagong | 1 | 4,000 | Mineral oil. |

TABLE 44.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during 1921.*

| District. | 1921. No. | 1921. Area in acres. | 1921. Mineral. |
|---|---|---|---|
| **Prospecting Licenses.** | | | |
| Hazaribagh | 4 | 582·8 | Mica |
| Sambalpur | 4 | 7,808·09 | Coal. |
| Do. | 1 | 80·98 | Mica. |
| Do. | 1 | 86·91 | Iron oxide. |
| Singhbhum | 2 | 1,176·8 | Chromite. |
| Do. | 5 | 6,460·4 | Iron-ore. |
| Do. | 2 | 3,670·31 | All minerals. |
| Do. | 1 | 72 | Manganese. |
| TOTAL | 20 | ... | |
| **Mining Leases.** | | | |
| Gaya | 1 | 186·6 | Mica. |
| Hazaribagh | 2 | 560 | Do. |
| Sambalpur | 2 | 745·76 | Do. |
| Santal Parganas | 11 | 20·27 | Coal. |
| Singhbhum | 1 | 2,624 | Iron-ore and manganese. |
| TOTAL | 17 | ... | |

TABLE 45.—*Prospecting Licenses granted in Bombay during 1921.*

| District. | 1921. No. | 1921. Area in acres. | 1921. Mineral. |
|---|---|---|---|
| Belgaum | 1 | 499·65 | Manganese. |
| Savantvadi State | 1 | 620 | Bauxite. |
| TOTAL | 2 | ... | |

TABLE 46.—*Prospecting Licenses and Mining Leases granted in Burma during 1921.*

| DISTRICT. | 1921. No. | 1921. Area in acres. | 1921. Mineral. |
|---|---|---|---|
| **Prospecting Licenses.** | | | |
| Akyab | 2 | 6,720 | Mineral oil. |
| Amherst | 3 | 4,800 | All minerals. |
| Do. | 1 | 22,822·4 | Oil shale. |
| Do. | 17 | 21,149·88 | All minerals except oil |
| Henzada | 2 | 1,458·8 | Do. |
| Do. | 1 | 2,560 | All minerals including oil. |
| Do. | 1 | 7,558·4 | Coal. |
| Do. | 2 | 2,804·1 | Mineral oil. |
| Katha | 10 | 44,609·6 | All minerals except oil. |
| Kyaukpyu | 1 | 2,105·6 | Mineral oil. |
| Kyaukse | 1 | 2,650 | All minerals except oil. |
| Lower Chhindwin | 10 | 53,529·6 | Mineral oil |
| Do. | 2 | 25,920 | All minerals including mineral oil. |
| Magwe | 1 | 300 | Gold. |
| Do. | 18 | 40,827·2 | Mineral oil. |
| Mandalay | 1 | 640 | Iron-ore. |
| Do. | 2 | 5,760 | All minerals except oil. |
| Mergui | 21 | 24,950·72 | Do. |
| Do. | 2 | 3,386·12 | Coal. |
| Do. | 7 | 4,351·78 | Tin and allied minerals. |
| Do | 7 | 7,051·52 | Tin, wolfram and allied minerals. |
| Do. | 6 | 8,432·88 | Tin and wolfram. |
| Do. | 5 | 5,204·48 | Tin. |
| Do. | 1 | 640 | Cassiterite and gold. |
| Minbu | 10 | 46,731·76 | Mineral oil. |
| Do. | 3 | 6,879·6 | Coal. |
| Myingyan | 7 | 16,997·42 | Mineral oil. |
| Myitkyina | 1 | 4,800 | All minerals except oil. |
| Northern Shan States | 2 | 6,400 | Do. |
| Do. | 1 | 3,200 | Coal, copper and galena. |
| Pakokku | 19 | 49,152·86 | Mineral oil. |
| Prome | 4 | 898·68 | Do. |
| Shwebo | 3 | 10,240 | All minerals except oil. |
| Do. | 6 | 25,185 | Mineral oil. |
| Southern Shan States | 4 | 3,280 | All minerals except oil. |
| Do. | 1 | 160 | Antimony. |
| Do. | 1 | 40 | Lead. |
| Sagaing | 1 | 1,675·08 | Copper, silver and lead. |
| Do. | 1 | 2·56 | All minerals except oil. |

TABLE 46.—*Prospecting Licenses and Mining Leases granted in Burma during 1921.*

| DISTRICT. | 1921. No. | 1921. Area in acres. | 1921. Mineral. |
|---|---|---|---|
| **Prospecting Licenses—*contd.*** | | | |
| Tavoy | 42 | 28,527 | All minerals except oil. |
| Do. | 2 | 2,586 | Coal. |
| Do. | 1 | 4 | Tin. |
| Thaton | 6 | 6,828·8 | All minerals except oil |
| Thayetmyo | 5 | 25,380 | Mineral oil. |
| Do. | 1 | 960 | Coal. |
| Toungoo | 1 | 148·48 | All minerals. |
| Upper Chindwin | 7 | 34,214·4 | Mineral oil. |
| Do. | 3 | 14,105·6 | Coal. |
| Do. | 1 | 1,824 | Mineral oil and coal. |
| Do. | 1 | 2,400 | Gold. |
| Do. | 1 | 1,560 | All minerals except oil |
| Do. | 2 | 1,888 | Gold and associated minerals. |
| Do. | 1 | 8,736 | All minerals including mineral oil. |
| Yamethin | 3 | 5,689·6 | All minerals except oil |
| TOTAL | 265 | ... | |
| **Mining Leases.** | | | |
| Magwe | 1 | 1,920 | Mineral oil. |
| Mergui | 1 | 110·4 | Tin and wolfram. |
| Do. | 2 | 1,677·37 | All minerals except oil |
| Minbu | 1 | 471·72 | Mineral oil. |
| Pakokku | 2 | 806·4 | Mineral oil. |
| Tavoy | 7 | 6,649·75 | All minerals except oil |
| TOTAL | 14 | ... | |

TABLE 47.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1921.*

| DISTRICT. | 1921. | | |
|---|---|---|---|
| | No. | Area in acres. | Minerals. |
| **Prospecting Licenses.** | | | |
| Balaghat | 20 | 6,449 | Bauxite. |
| Do. | 51 | 6.316 | Manganese. |
| Do. | 1 | 533 | Copper. |
| Betul | 6 | 3.116 | Coal. |
| Do. | 1 | 635 | Ferric oxide (ochre). |
| Do. | 1 | 1,059 | Manganese, iron and ferric oxide. |
| Bhandara | 1 | 3 | Manganese. |
| Bilaspur | 1 | 1.630 | Coal. |
| Chanda | 1 | 614 | Galena. |
| Do. | 6 | 4,921 | Coal. |
| Do. | 1 | 709 | Manganese. |
| Do. | 2 | 744 | Iron. |
| Chhindwara | 14 | 2,101 | Manganese. |
| Do. | 83 | 20,646 | Coal. |
| Jubbulpore | 3 | 405 | Bauxite. |
| Nagpur | 23 | 2.783 | Manganese. |
| Do. | 1 | 185 | Wolfram and galena. |
| Narsinghpur | 1 | 212 | Copper. |
| TOTAL | 217 | ... | |
| **Mining Leases.** | | | |
| Balaghat | 22 | 520 | Manganese. |
| Betul | 2 | 5,232 | Coal. |
| Bhandara | 3 | 86 | Manganese. |
| Chanda | 1 | 981 | Galena. |
| Chhindwara | 2 | 596 | Coal. |
| Nagpur | 7 | 219 | Manganese. |
| TOTAL | 37 | ... | |

TABLE 48.—*Prospecting Licenses granted in Coorg during 1921.*

| DISTRICT | 1921 | | |
|---|---|---|---|
| | No. | Area in acres | Mineral. |
| **Prospecting License** | | | |
| Coorg . . . . | 1 | 412·90 | Mica |

TABLE 49.—*Prospecting Licenses and Mining Leases granted in Madras during 1921.*

| DISTRICT. | 1921 | | |
|---|---|---|---|
| | No. | Area in acres | Mineral |
| **Prospecting Licenses.** | | | |
| Anantapur . . . . . | 3 | 68·57 | Barytes |
| Do. . . . . . | 1 | 2,933·58 | Gold. |
| Do. . . . . . | 1 | 7·32 | Asbestos |
| Do. . . . . . | 1 | 27·96 | Steatite |
| Cuddapah . . . . . | 1 | 64 | All minerals. |
| Guntur . . . . . | 1 | 42·70 | Diamond |
| Do . . . . . | 1 | 640 | Galena. |
| Kistna . . . . . | 2 | 3,820·54 | Coal. |
| Kurnool . . . . . | 5 | 31·34 | Barytes. |
| Do. . . . . . | 1 | 69·04 | Steatite |
| Nellore . . . . . | 14 | 436·78 | Mica. |
| The Nilgiri District . . | 1 | 56·57 | Do. |
| Tinnevelly . . . . . | 1 | 10·40 | Garnet. |
| TOTAL . | 23 | ... | |
| **Mining Leases.** | | | |
| Kurnool . . . . . | 4 | 214·17 | Barytes. |
| Nellore . . . . . | 7 | 567·52 | Mica. |
| TOTAL . | 11 | ... | |

TABLE 50.—*Prospecting Licenses granted in North-West Frontier Province during 1921.*

| DISTRICT | 1921. | | |
|---|---|---|---|
| | No. | Area in acres. | Mineral. |
| **Prospecting Licenses.** | | | |
| Bannu . . | 2 | 38,080 | Kerosine oil |
| Hazara . . . . | 2 | 10,028 | Minerals. |
| TOTAL . | 4 | ... | |

TABLE 51.—*Prospecting Licenses and Mining Leases granted in the Punjab during 1921.*

| DISTRICT. | 1921. | | |
|---|---|---|---|
| | No. | Area in acres. | Mineral. |
| **Prospecting Licenses.** | | | |
| Attock . . . . . . | 4 | 32,320 | Mineral oil. |
| Gujrat . . . . . . | 1 | 70,151 | Do. |
| Jhelum . . . . . . | 1 | 5 | Coal. |
| Do. . . . . . . | 1 | 504 | All minerals other than oil. |
| Rawalpindi . . . . | 1 | 2,880 | Mineral oil. |
| Shahpur . . . | 1 | 16,000 | Petroleum |
| TOTAL . | 9 | ... | |
| **Mining Lease.** | | | |
| Attock . . . . . | 1 | 1,278 | Mineral oil. |

# THE IRON-ORES OF SINGHBHUM AND ORISSA. BY H. CECIL JONES, A.R.S.M., A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India.* (With Plate 6.)

**Introduction.**

The most important iron-ore area in India is situated some 150 to 200 miles to the west of Calcutta in the province of Bihar and Orissa and contains extremely large and rich deposits of iron-ore. These occur in the Kolhan Government Estate in the Singhbhum district, and in the Feudatory States of Keonjhar, Bonai, and Mayurbhanj. Good iron-ore is reported to occur also in the Feudatory State of Pal Lahara, and in the Zemindary of Sukinda, but these two latter areas I have not had the opportunity of examining. This note deals mainly with the Singhbhum district, and the Feudatory States of Keonjhar and Bonai. The deposits in these areas are remarkable for the enormous quantities of extremely rich ore they contain, and will undoubtedly prove to be amongst the largest and richest in the world.

In this note I propose to describe only briefly the geology of the area, and the investigation has not gone far enough at present, to enable me to put forward a theory of the origin of the ore; but everything points to the ore bodies being replacement deposits.

The Bengal Iron Co., Ltd., first started operations in this area in 1910, but during the last three years much prospecting work has been carried out by other Companies, and the Tata Iron and Steel Co., Ltd., the Indian Iron and Steel Co., Ltd., Messrs. Bird & Co., and Messrs. Villiers, Ltd., have all been granted or have applied for mining leases in the area.

**History and previous literature.**

Ball (*Mem. Geol. Surv. Ind.*, Vol. XVIII) gives a general account of the distribution of iron-ores in the districts of Manbhum and Singhbhum, but the localities mentioned by him are to the north of the areas examined by me.

Maclaren examined the auriferous occurrences of Chota Nagpur, and in his account (*Rec. Geol. Surv. Ind.*, Vol. XXXI) he describes the geology of the area, but does not mention the iron-ore.

Fermor in his account of the manganese-ore deposits of India (*Mem. Geol. Surv. Ind.*, Vol. XXXVII) refers to the iron-ores of Singhbhum, but deals mainly with the area near Chaibassa.

In the Quinquennial Review of the Mineral Production of India for 1909-1913 (*Rec. Geol. Surv. Ind.*, Vol. XLVI, p. 105) it is stated that 'Recently, magnetite and hematite have been obtained from the Manbhum and Singhbhum districts.' In this review it is also stated that 'the Bengal Iron and Steel Company, Limited, have now given up the use of ores obtained from the neighbourhood of Barakar and Raniganj and are now obtaining their ores exclusively from the Kolhan Estate, Singhbhum.'

In the Quinquennial Review of the Mineral Production of India for 1914-1918 (*Rec. Geol. Surv. Ind.*, Vol. LII, p. 112) it is stated that the main deposits worked by the Bengal Iron and Steel Co., Ltd., 'are known as Pansira Hill and Buda Boru Hill situated about 12 miles and 8 miles respectively south-east of Manharpur station, Bengal-Nagpur Railway. The total quantity of ore in sight in these two deposits is estimated at not less than 10 million tons. The ore is a high grade hematite with an average analysis of—

| | Per cent. |
|---|---|
| Iron | 64·0 |
| Silica | 2·10 |
| Lime | ·15 |
| Alumina | 1·25 |
| Magnesia | ·18 |
| Manganese oxide | ·05 |
| Sulphur | ·032 |
| Phosphorus | ·05 |

A 2′ 6″ railway line has been constructed by the Bengal Iron Company, Limited, from Manharpur to Pansira with

* Now known as the Bengal Iron Co., Ltd

a branch through the Ankua Valley to Buda. An aerial ropeway with a capacity of 50 tons hourly transports the ore from the top of Pansira Hill to the light railway at the foot. The use of this ore makes the quality of the Company's pig iron equal to that of the best known imported brands.'

The iron-ores of Mayurbhanj State, from which the Tata Iron and Steel Co., Ltd., draw their supplies, were first noticed by P. N. Bose (*Rec. Geol. Surv. Ind.*, Vol. XXXI, p. 168), and have been examined and described more recently by Messrs. C. P. Perin and C. M. Weld (*Iron Age*, Vol. LXXXVIII; *Econ. Geol.*, Vol. X).

**Maps available.**

For mapping the iron-ore deposits, and in the estimation of quantities, the Forest Survey maps of Singhbhum on the scale of four inches to the mile proved extremely good. For the Keonjhar and Bonai States, however, the best maps available are the Bihar and Orissa sheets on the scale of one inch to two miles for a small portion of the northern parts of the States. For the remainder of the area in these States, the best maps are the old Bengal Survey sheets on a scale of one inch to the mile, made about fifty years ago. These maps are not contoured and are very inaccurate.

Owing to these unsatisfactory maps, to the hilly country covered with thick forest in which the iron-ore occurs, and to the uncertainty of the depth to which a replacement deposit extends below the surface, the estimates have necessarily been framed on very conservative lines.

**Topography.**

The area consists of a mass of hills and ridges largely covered with reserved and protected forests of sal trees. The small valleys between the hills are usually covered with soil, which has been cultivated. The hills rise about 1,000 to 1,500 feet above the valleys. The iron-ore, and the hematite-quartzites with which it is often associated, being the hardest and most weather-resisting rocks in the area, are mainly responsible for the topography of the country; and these rocks almost always form the tops of the hills. In Keonjhar State, the valleys are more open, but soil usually covers the rocks of the low ground, so that with the exception of the hematite-quartzites, good exposures are seldom seen.

The general drainage of the area is towards the north-east,—the principal rivers being the Karo, the Koina, and the Baitarani.

Owing to its hilly character and the small extent of the plains, the area is sparsely inhabited, and the scarcity of roads makes travel and communication extremely difficult.

Geology.

The rocks of the area are shown by Maclaren in his account of 'The Auriferous Occurrences of Chota Nagpur, Bengal,' as Dharwars (*Rec. Geol. Surv. Ind.*, Vol. XXXI).

Fermor in 'The Manganese Ore Deposits of India' (*Mem. Geol. Surv. Ind.*, Vol. XXXVII, footnote p. 619), in referring to the area south of Chaibassa, says 'The but slightly metamorphosed character of these sandstones and grits and their gently rolling disposition would be more consistent with a Kadapah than a Dharwar age for them; but I think that in this case we have to deal with some Dharwar sediments that have escaped being much folded and have therefore been but slightly metamorphosed.' This is a point which early attracted my attention,—the metamorphism being very much less than one expects to find in Dharwar rocks, and I was not surprised at finding undoubted proof near Jagannathpur, south of Chaibassa, that the Iron Ore Series rests unconformably on the upturned Dharwar schists and quartzites.

Fermor in his Presidential Address to the Geological Section of the 6th Indian Science Congress[1] gives the following general classification of the Archæan rocks of Chota Nagpur:—

(1) Oldest gneisses and granites—not yet certainly identified.

(2) Dharwar sediments and contemporaneous lavas.

(3) Oldest gneisses re-melted—now post-Dharwar and probably forming a considerable portion of the 'fundamental gneiss.'

[1]*Proc. Asiatic Soc., Bengal,* Vol, XV, p. clxxvii.

(4) Post-Dharwar intrusives—
(*a*) Peridotites and other ultra-basic rocks.
(*b*) Granites and pegmatites.
(*c*) Epidiorites (altered dolerites and gabbros).

The Iron Ore Series, which has now been found to be of later age than the Dharwars (*cf.* p. 206), evidently lies between Fermor's groups 3 and 4; for though this series is certainly later than the Dharwars yet in places the lower beds of the series have been penetrated and absorbed by the granite.

The Dharwars are certainly the oldest rocks recognised in the area, and after their uplift and denudation, the rocks of the Iron Ore Series were laid down on them unconformably. A mass of granite was then intruded into the whole, but it seems to have raised and folded the Iron Ore Series rather than penetrated them to any large extent. This was followed by a period of basic intrusions, which took the form of dykes in the granite area, and to a less extent in the Iron Ore Series. There are also large quantities of interbanded basic igneous rock in the Iron Ore Series, some of which appears to be contemporaneous and some later than the Series. Some ash beds have been found in the interbanded igneous rock. These intrusions of igneous material were accompanied or followed shortly by folding and faulting of the Iron Ore Series on a very extensive scale. That there was more than one period of basic intrusion is proved by the presence of fragments of the basic rock in some of the fault breccias, with a similar basic rock acting as a cementing material to the same breccia.

Some intrusions of ultra-basic rocks also occur, but these have not been thoroughly examined.

The Dharwar rocks consist mainly of quartzites with hornblende-, quartz- and mica-schists. The strike and dip is variable.

The Iron Ore Series commences with a basal sandy conglomerate, ranging in thickness up to about 60 feet, and in places very coarse-grained; it consists of angular and rounded pebbles of red jasper and white quartz cemented together by purple sandy material. This conglomerate is overlain by about 40 feet of purple and pale greyish limestone, which contains a considerable amount of fine-grained chloritic material along the bedding planes. This in its turn is overlain by a great thickness of shales, which are often very ferruginous and penetrated by thin veins of quartz. Above these shales come banded hematite-quartzites comprised of bands up to about an inch in thickness of hematite, chert and jasper in varying proportions. In places the hematite-quartzites are seen to pass along the strike into good ore. Above the hematite-quartzites is another thick group of shales, which is also often very ferruginous. Both groups of shales contain small lenticular beds of sandstone. The hematite occurs as a replacement product in the banded hematite-quartzite, and to a much less extent in the shales above and below the quartzite.

The rocks of the Iron Ore Series near the granite south of Chaibassa have a general north-north-east to south-south-west strike, and are gently folded. Towards the west the dips become greater, and the rocks have been very much folded and faulted. This faulting is well seen near Lipunga, and a strike fault apparently runs along the whole length of the east side of the main iron-ore range. The rocks to the west of the fault have a very steep dip in a westerly direction. In the north part of the range the banded hematite-quartzites and the hematite have a general north-north-east to south-south-west strike, and dip at about 70° to the west-north-west; but towards the south the strike becomes nearly north and south with a similar dip to the west.

**Mineralogy and nature of the ores.**

Practically the whole of the ore is hematite and as far as I know no quantity of magnetite occurs in the ore bodies. Small octahedral crystals occur in the ore occasionally, but they appear to be mainly martite (L. 584) as the rock has no appreciable effect on the magnetic needle. Small octahedral crystals some of which are magnetite and some of which appear to be martite occur also in the banded hematite-quartzite. The hematite is rather variable in character and the varieties may be grouped as follows:—

(1) Massive hematite.

(2) Laminated hematite.

(3) Micaceous hematite.
(4) Lateritic hematite.
(5) Hematite breccia.

(1) The massive ores, which are practically pure hematite, have a steel grey colour, and are usually extremely fine-grained and compact. This ore has a specific gravity of about 5·0 and specimens have yielded on assay 70 per cent. of iron, whilst samples of exposures of the massive ore yield over 66 per cent. of iron. These massive ores occupy about 8 cubic feet per ton, but usually pass into the laminated variety.

(2) The laminated variety is variable in character, varying from a solid reddish type (L. 567) through a solid laminated variety (L. 627) to a less solid laminated variety (L. 622) which is often inclined to a shaly character, and is often extremely porous (L. 624, L. 585). This shaly character is usually due to laminae of the massive grey variety interbanded with laminae of less compact ore, often of a reddish colour and usually very porous. The specific gravity varies considerably, depending on the proportion of the massive ore and the amount of porosity. Owing to their porous nature these ores often become hydrated, and tend to become lateritised. This type varies in density from about 10 to 12 cubic feet to the ton, ranging up to 15 cubic feet, when very porous. As would be expected from their nature, the iron content varies considerably, but is usually well over 60 per cent. and in some of the denser types it approaches very closely to that of the massive varieties.

(3) The micaceous variety is usually so fine-grained and unconsolidated that it falls into powder at a touch. This type is looked on with disfavour, as the material tends either to get blown out of, or to choke, the blast furnace. As it contains well over 60 per cent. of iron, it is much too valuable a product to waste, and could be used if it were either sintered or made into briquettes.

(4) The lateritic variety occurs in large quantity throughout the area, as a surface alteration product, sometimes of the iron-ore itself, at other times of the ferruginous shales, and at still other times of the hematite-breccia. The quan-

tity of iron in these types varies considerably and ranges up to about 60 per cent.

(5) The hematite-breccia (L. 628) consists of the debris material which accumulates on the slopes of hills, in old river valleys, and on plains between the hills, and it becomes cemented together by lateritic or hematitic material. A hematite-breccia (L. 576) caused by faulting has also been noted. In some cases, such as in Pachri Buru and in Thakurani Buru, there are big accumulations of this material, and as the fragments often consist of very solid hematite, these will give large supplies of good ore.

**Quality of the ore.**

On page 204, an average analysis of the ore at Pansira Buru is given. This agrees fairly well with a number of analyses given to me by the Tata Iron and Steel Co., Ltd., of samples collected from the deposits prospected by them:—

| — | Sasangda. | Jarida area 15 samples. | Katamati 19 samples | Pachri Buru |
|---|---|---|---|---|
| Iron . . . . . | 64·2 | 63·74 | 63·33 | 63·94 |
| Sulphur . . . | 0·015 | 0·019 | 0·030 | 0·024 |
| Phosphorus . . . . | 0·058 | 0·080 | 0·088 | 0·072 |
| Ins. Res. . . . . | 1·12 | 2·35 | 2·14 | 2·40 |
| Manganese . . . . . | . | 0·104 | trace | trace |
| Titanium . . . . . | ... | trace | ... | . |

In the Sasangda deposit the phosphorus varies considerably, ranging up to a maximum of 0·103 per cent.

In the above samples from the Jarida Buru area the phosphorus varied considerably, namely, from 0·038 up to 0·152 per cent. Two of the above samples from the Katamati area were tested for titanium, and gave 0·25 and 0·20 per cent. titanium respectively. Four specimens from Pachri Buru tested for titanium, only gave traces.

The main points of these analyses are the high iron content, the low percentage of sulphur and titanium, and the variability of the phosphorus content. Manganese in any quantity seems to occur only in the lateritic variety of the ore.

The average of samples taken by me from the deposits at Sasangda, Jarida, Pansira, Gua, etc. and assayed in the Geological Survey Laboratory, gave about 64 per cent. of iron. Samples of the better parts of the deposits often run up to 68 or 69 per cent. of iron.

**Methods of estimation of quantities of ore.**

The estimates have been made almost solely from surface observations. In all cases the figures refer to ore-bodies containing not less than 60 per cent. of iron, and must be looked on as an absolute minimum. In the case of certain hematite debris (so-called 'float ore')[1] areas, it is probable that the debris covers solid ore, but prospecting pits are necessary to prove this. In these debris deposits, an average thickness of five feet has been taken and from 30 to 50 cubic feet of ground to the ton of ore. With the more massive ore the exactitude of the estimates depends largely on a correct appreciation of its porosity. For the solid ore, in no case has less than 10 cubic feet to the ton been taken, although theoretically 7 cubic feet of solid hematite goes to the ton, and there seems little doubt that ore from parts of some of the ore bodies, such as Pachri Buru, Joda, Sasangda, etc., will probably correspond in density very nearly to the theoretical figure. With the porous shaly ores 12 to 15 cubic feet has been taken to the ton.

With a replacement ore-body it is impossible to say what happens below the surface, but it is difficult to suppose that a big deposit such as the main iron-ore range, where the rocks dip at about 70° to the west, and where replacement has been almost continuous for a length of thirty miles, and across a series of beds varying from say 400 to 1,000 feet in thickness, will die out in a short distance from the sur-

[1] Fermor discards this humorous misnomer as applied to similar occurrences of manganese-ore and uses the term *detrital ore* or *talus ore*. *Mem. Geol. Surv. Ind.* XXXVII, p. 563.

face. I have no doubt therefore, that replacement will be found in parts to have taken place to a depth of many hundreds of feet; but boring or other prospecting work is of course necessary to prove this. The slopes of the hills are usually covered, and it is only occasionally from observations of differences of height between the ore at the tops of hills, and the same bed of ore in streams cutting or running away from these hills, that one gets any idea as to the depth to which replacement has taken place. In no case however, has ore been taken as extending to more than 150 feet below the surface although from differences of height, a depth of ore of as much as 700 feet has been deduced.

Very little real prospecting work has been done by the various companies that have taken up or applied for areas, but from the small amount done, it seems possible that the solid ore may give place to the unconsolidated micaceous variety at depths of about 100 feet below the surface.

As will be seen the figures adopted for the estimates are all well on the conservative side, and I have little doubt that when the deposits have been opened up and proved by borings, etc., the true figures will be found to be more than double my estimates.

**Distribution and quantity of ore.**

The major part of the iron-ore seems to be fairly evenly divided between the Singhbhum District, the Keonjhar State and the Bonai State. The minimum quantities estimated up to the present for ore of not less than 60 per cent. of iron are—

| | Tons. |
|---|---|
| Singhbhum district | 1,074,000,000 |
| Keonjhar State | 806,000,000 |
| Bonai State | 656,000,000 |
| Doubtful, Bonai State or Keonjhar State | 280,000,000 |
| Mayurbhanj State | 16,000,000 (?) |
| TOTAL | 2,832,000,000 |

I have not made an estimate of the quantities of ore in the Mayurbhanj State, and am unable to express any opinion on the correctness of the amount of 16,000,000 tons reported to occur there.

The iron-ore usually occurs at or near the tops of hills or ranges of hills, but near Jamda in the south of the Singhbhum District, and in parts of the Keonjhar State it is often found at very low levels, and in some cases actually in the plains themselves. The most important of these ranges or hills is the one that starts near Kompilai in the Bonai State, and continues to the north-north-east to a point about three miles south-west of Gua, a distance of about thirty miles. Running more or less parallel to this range, and possibly faulted from it, are other smaller ranges which contain good iron-ore. The main range rises some 1,500 feet above the plain, and iron-ore averaging over 60 per cent. of iron occurs for practically the whole length of the thirty miles. A few small breaks occur, where the rock has not been replaced, or where folding has occurred, but these are negligible compared with the total length. The rocks forming this range dip at about 70° in a north-west to west direction, so that the width of the outcrop of the iron-ore which varies up to 1,000 feet, gives practically the thickness of the ore bodies.

**Transport of the ore.** Owing to the hilly nature of the country, it will prove rather difficult to get the ore away. The main line of the Bengal-Nagpur Railway, which runs in a more or less east and west direction, lies some twenty to forty miles north of the main deposits, and is separated from them by hilly country.

In the western part of the Kolhan, the Bengal Iron Co., Ltd., have a light railway running along the Koina river valley from Manharpur to their deposits at Pansira, with a branch running to their Ankua deposits. It seems doubtful if there is any other possible route into the western part of the iron-ore area on which extensive tunnelling would not be necessary.

In order to tap the deposits on the east side of the area, the Bengal-Nagpur Railway are constructing a line from Amda on the main line, through Chaibassa running down on the east of the hilly country, to the south of Singhbhum. This line lies to the east of the hilly country and from it branches will be constructed to the various deposits in Singhbhum and also to parts of Keonjhar State.

As far as I know, no definite scheme has yet been proposed for extracting ore from Bonai State.

The Bengal Iron Co., Ltd., transport their ore from the working places by means of gravity inclines and trams to central storage bins, from which it is taken by an aerial ropeway at Pansira and by a self-acting incline at Ankua to the foot of the hills.

## EXPLANATION OF PLATE.

PLATE [illegible].—The Iron-ore Area of Singhbhum and O[illegible]a. Scale 1" = 4 miles.

# GEOLOGICAL RESULTS OF THE MOUNT EVEREST RECONNAISSANCE EXPEDITION. BY A. M. HERON, D.SC., F.G.S, *Officiating Superintendent, Geological Survey of India.** (With Plates 7 to 13.)

## I.—THE ARUN BASIN, TIBET.

### Introduction.

The area geologically examined consists of over 8,000 square miles, included within a rectangle some 120 miles from east to west and 70 miles from north to south. This corresponds with the Tibetan portion of the drainage area of the Arun river, a complicated system of valleys the streams of which unite to form the Arun before it breaks through the main Himalayan range in the impressive gorge below Kharta. The headwaters of the Rongshar Chu and the Bhutia Kosi (Po Chu) above Nyenam were also examined.

The southern watershed is the line of great snowy peaks running from the Khungphu or Nangba pass south-eastwards through Everest and Makalu to the Arun, and, to the east of the Arun, is the continuation of the range which divides Sikkim from Tibet, a range which lies considerably to the north of the great Kanghhenjanga group of peaks. The northern watershed may be the extension of what has been termed the Ladak or Northern range of the Central Himalaya; but here this is hardly a definite range, but rather a broad belt of high and much dissected country, with a few peaks of over 20,000 feet, distributed without linear arrangement. To the north of this watershed short tributaries drain to the Brahmaputra (Tsangpo).

I am greatly indebted to the promoters of the Expedition for the privilege of accompanying it and in particular to Colonel C. Howard Bury, D.S.O., the leader, for much assistance and practical interest in my work.

* Read before the Indian Science Congress, Madras. 1st. Feb. 1922.

My work is virtually a continuation, to the westward, of Sir Henry Hayden's pioneer investigations during the Tibet Expedition of 1903-04[1]; with the exception of Sir Henry Hayden no geologist had visited this part of Tibet.

My mapping was done on a scale of 4 miles to the inch on skeleton maps furnished by the topographical surveyors as their plane-tabling proceeded. My very cordial thanks are due to Major H. T. Morshead, R.E., D.S.O., in charge of the Survey of India detachment, for many such facilities given and for valuable information, accompanied by specimens, from localities which I could not visit. Over a considerable portion of the area however my work had to proceed in advance of the surveys, geological boundaries in such cases having to be drawn on the maps subsequently from memory, supplemented by sketch maps and notes. The general conditions of the Expedition were indeed unfavourable to detailed work, in consequence of which I endeavoured to traverse as large an area of Tibet as possible and to lay down on the map with fair accuracy the boundaries of the different formations where they were accessible. A considerable amount of interpolation was however necessary and my work must be considered as a reconnaissance and nothing more.

If I had had the good fortune to accompany the second Expedition I had hoped to examine more carefully the crystalline area in the neighbourhood of Mount Everest, with the assistance of Major Wheeler's map, constructed from photographic surveys on a scale of 1 inch to 1 mile, and to cast some light on the many problems connected with the granites and gneisses and their relationships with the metamorphosed sedimentaries. The quarter-inch map was on too small a scale and was available too late to be of use in the mapping of the crystalline complex.

Geologically the area is divided into two:

(*a*) Tibetan and sedimentary to the north.

(*b*) Himalayan and crystalline to the south. This distinction is clearly displayed in the topography

[1] The Geology of the Provinces of Tsang and Ü in Central Tibet. *Mem. Geol. Surv. Ind.*, XXXVI, pp. 122-201. (1907).

resulting from the underlying geological structure, for to the north we have the somewhat tame, rounded and lumpy mountain ranges of Tibet, with their broad and flat-bottomed valleys, contrasting with the higher, steeper and more rugged Himalayas on the south.

Economically the Expedition met with nothing of interest. On moraines stones showing the green staining of copper compounds were now and again seen, but beyond that I saw no signs of mineralisation. A few clear fragments of pink tourmaline and garnet were picked up by the coolies, but none were sufficiently free from flaws to be worth cutting. I panned the gravels in several places for gold but without getting a colour.

## Physical Features.

River systems.

The two main branches of the Arun river, the Phung Chu (or Men Chu as it is called in its upper portion) and the Yaru Chu (Ko Chu) flow from the west and the east respectively, in a general east and west direction, uniting near the village of Lashar and then flowing southwestwards and southwards through the main Himalayan range. The Yaru Chu rises in the hills to the north of Kampa Dzong and meanders through the broad plain which here lies at the northern foot of the snowy range, until at Sar it meets a high spur of crystalline rocks projecting northwards. This deflects it in a great sweep to the north-east and it finally cuts through the toe of this spur in the Rongme gorge, instead of flowing round its end. The Men Chu rises on the northern slopes of Gosainthan, above the Pekhü Tang, a great plain which contains a basin of enclosed drainage, the Pekhü Tso. On leaving the plain it finds its way for some distance along a valley excavated in a syncline of Cretaceous limestones and then cuts northwards in a fine gorge through intervening Jurassic shales to another parallel limestone syncline; some sixteen miles along this valley it is deflected back again to the original syncline by a N-S ridge-barrier of pegmatite veins and hard shales. Along this syncline it then flows as the Phung Chu for between fifty and sixty miles to near its junction with the Yaru.

Two of its more important northern tributaries, the Shi Chu and the Lo Chu, also have their courses largely determined by the presence of the softer bands of Cretaceous limestones.

Parallel to the Phung Chu and joining the Arun twenty miles below the confluence at Lashar, is the Dzakar Chu, which, with its tributaries the Ding Chu and the Neo Chu, drains the mountainous district of Pharuk. In these tributaries also the synclinal origin of the valleys is distinct. The main drainage lines are therefore parallel to and dependent on the folding to which the region has been subjected: the general strike direction of the folds is W. N. W.—E. S. E.

Approximately at right angles to the longitudinal drainage system are a number of transverse tributaries. Those from the northern slopes of the Great Himalaya are turbulent glacial torrents with straighter courses and greater discharge than those from the Ladak range. Of the latter the more important occupy valleys intervening between tracts of high land which owe their prominence to their being composed of hardened and partly metamorphosed shales with clusters of intrusive granite veins.

**Lakes.**

Except for glacial tarns held up by moraine dams the Arun region is devoid of lakes; at either end however are basins of enclosed drainage, that of the Tso Mo Tre Tung to the east and to the west that containing the Pekhü Tso, the Kharru Ochen Tso and the Khomen Tso. All these are very shallow and vary greatly in extent according to the season of the year. In the broader valleys are extensive swamps and tracts temporarily flooded during the rains, and the so-called lakes are in fact little more.

**Changes in drainage lines.**

There is little doubt that the Arun has cut back through the Great Himalaya range and has captured a river which possibly flowed east from the vicinity of Gosainthan more or less along the present courses of the Men Chu and the Phung Chu and then through the Jikkyop gap and over the plain to the south of Kampa Dzong: this river may even, as Hayden[1] suggests, have flowed northward to join the Tsangpo, perhaps on the line of the Nyang Chu, the river which passes Gyantse and Shigatse. The Dzakar Chu, now also captured by the Arun, probably joined the above conjectural river flowing northeastwards on a course approximately from the Kuyok La above Lungme, along the present valley of the Arun between Kharkung and Lashar.

The Arun has two gorges. The lower, in which the river falls 4,000 feet in the 18 miles measured in a straight line between Khuta and Kyimatang, is fairly straight, with walls rising 5,000 feet and more in uninterrupted slopes so steep as to prevent human passage, but allowing bushes and trees precarious roothold. The upper gorge is an extraordinary one and so far I am unable to give an explanation of its origin. Where it enters the gorge the river is flowing through a fairly open valley with immense terraces of boulders and gravel, in the direction of the Küyok La, a low pass over comparatively soft schists. Abruptly the river turns upon itself and then plunges at a right angle into the heart of a high mountain (Yö Ri) of hard gneiss, in a gloomy canyon with almost vertical walls. Through this gorge the river flows south for three miles, then swings again and flows west for four miles, finally emerging from the gorge on the other side of the Küyok La, into an open valley which has exactly the same line and character as the original valley. Thus it cuts along two sides of a triangle in hard gneiss, in preference to following the hypotenuse in soft schists. The Rongme gorge on the Yaru Chu (Ko Chu of the map) is somewhat similar, as the stream now cuts through the end of a northward trending spur of gneiss and adjacent hard phyllites. It seems probable from the configuration of the country that the Yaru once flowed through the Jikkyop gap four miles to the north, the present course of the Chiblung Chu, and that it was subsequently captured by a tributary from the east.

[1] *Loc. cit.*, p. 12?.

**Glaciers.** I was able this year to devote only an occasional day or two to the vicinity of glaciers, but I am able to add my testimony to that of Hooker, Blanford, Hayden, Garwood and others, concerning the former much greater extension of glaciation. The present glaciers are but puny representatives of their former might, as shown by the huge moraines which encumber all the northern valleys. Two at least of the main glaciers of Makalu flowing to the Karma valley, show evidences of recent advance.

## The Himalayan Zone.

The Himalayan and crystalline zone is essentially composed of a foliated and banded biotite-gneiss, usually garnetiferous, intimately injected with dykes and sills of all sizes of a schorl-muscovite-granite or pegmatite. The latter is often present to such an extent that it is the predominant rock. Forming an intermediate zone between the gneiss and the Tibetan sedimentaries is a band of metamorphic rocks, regarded as altered representatives of the latter; these are also penetrated by intrusions of the schorl-granite in great profusion. The metamorphic rocks appear to lie upon the gneiss, which is probably intrusive in them, but this point is one which I was unable to investigate. Other questions which arise are to what extent the gneiss represents very highly metamorphosed sedimentaries, and to what extent it is an injection-gneiss formed by the intrusion and rolling out of granite veins along the foliation of mica-schists.

**Biotite-gneiss.** Although the rock shows but little variation in mineral constituents, it varies so greatly in their proportion, in structure, and in texture, that it is difficult to believe that the whole of the rock is of one origin. Much of it is undoubtedly derived from granite, as for example the porphyritic augen-gneiss type and a less common variety found in large amount near Kharta, in which thin and rather sparse foliae of biotite with abundant felspar form lenticles twisted and contorted in every direction. In the Kharta and Dzakar valleys this resembles a type common around Darjeeling, in which alternate dark and light bands, biotitic and felspathic respectively form a rock which from a little distance has the appearance of a bedded sedimentary series. As is the case near Darjeeling, the planes of foliation or banding have usually low dips, and this variety is notably garnetiferous. Low down in some of the valleys towards the Nepal frontier, as for instance below Nyenam and Tasam and also probably near Kyimatang, large bodies of mica-schist are found, analogous to the schist occurring in the bottom of the Tista valley near Darjeeling and in other localities said to be found underlying the gneiss of Sikkim.[1]

The latter have been mapped by Bose as the Daling series; it is however uncertain whether the schist near the Nepal frontier belongs to an altered sedimentary series or is a variety of the gneiss.

**Schorl-granite.**

The schorl-granite varies in texture from a fine homogeneous granite to a coarse porphyritic pegmatite, sometimes with graphic intergrowths of quartz and felspar. It is the latest in age of the igneous rocks and occurs practically everywhere in the crystallines examined, penetrating both gneiss and metamorphics in veins and sills of all sizes. The habit of the sills is specially characteristic, namely concordance with the foliation of the rocks into which they are intruded.

Intrusion has taken place to such an extent that schorl-granite is often seen to be the predominating rock, and also its toughness and lack of joints and foliation cause it to resist weathering and abrasion in screes, moraines and streams, so that it nearly always is the main constituent of detrital accumulations. In addition to the essential minerals quartz, plagioclase, black tourmaline (schorl) and muscovite, the granite has as accessory minerals garnet, yellow and pink tourmaline, and beryl.

**Metamorphic rocks.**

The metamorphics comprise a considerable variety of rocks, all of which, except certain massive quartzites, are distinctly banded or foliated

[1] Garwood, in Freshfield's 'Round Kangchenjunga', p. 275; Mallet, *Mem. Geol. Surv. Ind.*, Vol. XI, p. 41 (1874); Bose, *Rec. Geol. Surv. Ind.*, Vol. XXIV, pp. 46, 221 1891).

in layers of differing mineral composition, the directions of which are determined by the original stratification. They range from quartzites and micaceous quartzites to mica-schists and tourmaline-mica-schists, representing the arenaceous and argillaceous sedimentaries, with crystalline marbles and banded actinolite-, diopside-, and epidote-schists representing the calcareous rocks. Graphitic schists have also been noted, but are rare.

Considering how dislocated are the metamorphics due to intrusion of vein-granite, the comparatively low angles at which their planes of foliation lie as a rule, strike one in the field as surprising, especially in comparison with the intense crumpling which the same rocks have undergone in the Tibetan Zone. As one ascends any of the headwaters of the Dzakar Chu towards the Everest group, one leaves the twisted and crumpled Jurassic shales and passes downwards in the section, as the general dip is northwards, though actually rising in elevation, to the gently rolling limestones underlying them, which flatten out as they become more altered and the snowy range is neared. In the Rongbuk valley for instance, above the Chobu monastery, are limestones much fissured and veined with crystalline calcite, underlain by a thick sill of schorl-granite and pervaded by innumerable smaller sills and streaks. Some sixty feet of the limestone immediately above the main sill has been converted into amphibole-schist and below the sill is a band of mica-schists streaked and knotted with granite in *lit-par-lit* injection to such an extent that the product has a very strong resemblance to the banded variety of the biotite-gneiss. In the gorge of the Dzakar Chu between Kal and Tsa is exposed a great thickness of flaggy limestones with clayey partings. At the base of the section there are great masses of schorl-granite with amphibole- and epidote-schists; upwards the former becomes more definitely sill-like, interbedded with schists and finely crystalline and mottled limestone. The limestones remain crystalline for a considerable distance above the horizon of the topmost sill and then pass upwards into black limestones, non-crystalline and calcite-veined, and are finally succeeded by Jurassic shales and quartzites. In the valleys above Raphu and Chodzong alteration takes place independently of granite intrusions, calcite-veined, knotted and brecciated limestones passing downwards into pyroxene-, actinolite- and epidote-schists. In the above-described sections the change from sedimentary to metamorphic rock is very clearly seen, taking place gradually in magnificent cliff-faces with no break nor discordance in the stratification; from a short distance away it is indeed often impossible to say whether one is looking at limestone or calc-schist.

Speaking generally it may be said that the valleys to the north-west and north of Everest, *i.e.*, valleys above about 15,000 feet, are excavated in metamorphic rocks, whereas those to the north-east and east, for the most part below about 15,000 feet, are in gneiss. It was impossible, in the time at my disposal and with a small scale skeleton map, to attempt to lay down a boundary between metamorphics and gneiss, but it would appear possible that the metamorphics form a sheet dipping gently northwards and underlain by the gneiss. The gneiss is probably intrusive in the metamorphics, judging from evidences of its age elsewhere in the Himalayas, and it may be possible to ascertain this definitely on further investigation.

The group of high peaks between the Nangba La and the Rongbuk glacier, and the north-western side of Everest itself up to the summit are composed of metamorphics, with, of course, much schorl-granite, to the resistant power of which, and not to the easily eroded metamorphics, is due to the eminence of these peaks. When I visited the Kharta and Karma valleys on the east of Everest before the end of the monsoon, the mountain was too much covered with fresh snow to show any geological structure. The base of Makalu in the Karma valley is gneiss, but Col. Howard Bury states that its upper portion is pale granite.

**Amphibolites.**

In the neighbourhood of Dak in the Arun valley, numerous fragments of amphibolites, both foliated and granitoid, were observed, but the parent mass was not found. The nature of these amphibolites is therefore uncertain, but they are probably altered igneous rocks of intermediate or basic composition.

## Tibetan Zone.

The Tibetan Zone consists in the main of a great thickness of intensely folded Jurassic shales, the folds in general striking east and west. Pinched up in these folds in several very elongated and narrow synclines, are limestones belonging to the Kampa System of Hayden, of Cretaceous and Eocene age. These synclines are closely compressed and overfolded, their axial planes dipping to the north, showing that the compressive force which produced them acted from that direction.

Along the southern border of the Tibetan Zone, below the base of the Jurassic shales, is a great thickness of flaggy limestones, in which the fossils have been destroyed and the rocks themselves converted in part into crystalline limestones and calc-schists. The age of these cannot be determined with certainty, but their character and position in the sequence indicate that they are possibly Trias or Permian.

From a palæontologist's standpoint the country which I covered was very disappointing, but I am, nevertheless, much indebted to my colleague, Mr. G. H. Tipper, for identifying for me the small collection of fossils which I made. The Jurassic shales are almost unfossiliferous and yielded only a few ammonites, belemnites, and crinoid stems of little interest. The thick limestones bordering the crystalline zone show, near their top, abundant signs of organisms in the form of curved layers of crystalline calcite which in all probability are the remains of large lamellibranchs or brachiopods; but in several days search in favourable localities I failed to discover a single specimen showing anything more definite.

The Eocene and Cretaceous limestones, the zones of which have been worked out in great detail by Sir Henry Hayden in the magnificent and less disturbed sections of the Kampa ridge, here occur in much compressed synclines, in which fossils have been destroyed or damaged by the shearing which they have undergone and in which it is almost impossible to work out the zones owing to faulting and interruption by stretches of alluvium. It is only in the Tsipri ridge that a satisfactory and detailed study of the Eocene and Cretaceous rocks can be made; but for this I was unable to spare the time, for when I passed it I had been separated from the Expedition by floods and had exhausted all my money and almost all my food. It is, however, unlikely that I could have added anything of value to Sir Henry Hayden's description of these rocks.

**The Kampa System.**

The Kampa System is developed in two main synclines, the northern of which may be called the Tsipri syncline from the picturesque and sacred ridge on it, and the southern the Phung Chu syncline, from the chief river of this area, which has excavated its valley along it; there are besides a number of smaller synclines.

It is in the northern syncline only that the Eocene beds above the 'ferruginous sandstone' of Hayden* are found.

In the exposures between the Yao La and Gutso this 'ferruginous sandstone' is a massive pink and white quartzite, about 100—150 feet thick, weathering into large blocks. In its degree of metamorphism it is like a typical Pre-Cambrian quartzite, although the brown shales below it and the blackish grits above are almost unaltered; the latter contain dicotyledonous fossil wood, and are the highest formation present in the section.

The Tsipri ridge gives the only fair sections of the combined Eocene and Cretaceous of the Kampa System. I was unable to examine this in detail but the general section is as below:—

Bold scarp . . . Massive thick-bedded grey limestones with abundant *Alveolina* and *Operculina*, alternating with massive, white, very fine-grained and unfossiliferous limestones and thin-bedded limestones.

* *Loc. cit.*, pp. 165, 169-172.

| | |
|---|---|
| Minor scarp . . . | A series of limestones in regular beds of medium thickness; about the middle of this series comes the 'ferruginous sandstone.' |
| Undercliff of above . | Grey flaggy limestones. |
| Lower scarp rising from plain. | Brown argillaceous limestones in thin regular beds. |
| Usually covered, but exposed at east end of ridge. | Great thickness of grey unfossiliferous calcareous shales. |
| East end of ridge . . | Black and brown splintery shales with large septarian nodules. |
| North side of Shi Chu valley. | Grey limestone. Massive quartzite, the 'wall' quartzite. |

The upper limestones on the south side of the ridge are corrugated and as they pass to the northern side dip steeply up to vertical; further north, on the northern side of the Shi Chu valley, the limestones and quartzite at the base of the syncline are inverted, with the Jurassic shales overlying them and dipping to north at 30° to 80°. The Shekar hill shows a subordinate anticline formed to the north of the main syncline. At the western end the outcrop of the topmost limestones descends to plain-level due to a westward pitch of the syncline; in the short ridge to the west of Temi, they show undulating dips and a great overfold.

In the Tsipri ridge the ferruginous sandstone is not so highly indurated as in the Yao La sections; it contains abundant spherical concretions of iron oxide and is in certain layers finely conglomeratic, the little pebbles, of the size of buckshot, consisting of transparent quartz, quartzite of various colours, and white chert.

At the western end of the northern syncline, where it emerges from the alluvium of the Pekhu plain, the Cretaceous limestones, in their upper portion, contain numerous intercalated thin bands of sandstone and are themselves distinctly arenaceous, indicating, with the occurrence of fossil wood in the Eocene grits above the ferruginous sandstone, the prevalence of shallower water conditions than obtain as one passes to the east.

The structure is that of a recumbent isocline, of which both limbs dip north at 20° to 40°, affected however by minor rollings and corrugations; the northern margin is considerably altered by metamorphic agencies connected with the granite intrusions of the Northern Range.

Locally, the prominent sandstone-quartzite band which is found elsewhere in the shales a little distance below the base of the limestones is wanting. This I call the 'wall' quartzite. Here there is a passage into the Jurassic shales through shaly limestones. Just below these passage beds, at Menkhap Me and on the Lungchen La, fragments of ammonites of Upper Jurassic type, but not determinable with certainty, were found.

East of Gutso and Menkhap Me a broad alluvium-filled river-valley and a southward-trending spur of semi-metamorphic rocks and granite veins (the Burtra ridge) cut off this syncline, but there is little doubt that it is structurally continuous with that of Tsipri.

The Tsipri syncline has been described above. It also is overfolded by pressure from the north. To the east of Shekar the outcrop of the syncline narrows, through the beds becoming more vertical, and as it swings to the north-east in the valley of the Lo Chu it flattens out again to a very recumbent isocline.

A day's search in the Cretaceous beds round Shekar failed to yield a fossil. The beds appear to have been sheared to some extent and are shattered and veined with calcite, but have not been rendered crystalline; in the Lo Chu valley the shaly partings between the limestones are silvery from the presence of sericite mica.

The Phung Chu syncline, also, is overfolded, but not to quite the same extent as the Tsipri syncline. It also extends to an unknown distance through the Pekhu plain to the westwards. Where first encountered, in the west, the Men Chu flows along a valley excavated therein; to the south lies a wide plateau of undulating Jurassic shales, on which is a shallow saucer-like syncline containing the 'wall' quartzite and a trifling thickness of limestone above it. At the edge of this plateau the shales and the 'wall' quartzite roll steeply over into the Men Chu valley.

On the northern bank of the stream is a fine scarp of regularly bedded limestone, in places crowded with small lamellibranchs (unidentifiable) and what appear to be casts of brachiopods in crystalline calcite. To the north of this a double fault is well seen, bringing the limestone against the 'wall' quartzite and the Jurassic shales, which dip vertically at the junction.

Between Nelung and Tingri, where the Men Chu, now known as the Phung Chu, returns to and again excavates a valley along the syncline, both limbs dip northward at about 60°. From Tingri eastwards to where the syncline disappears near Tsonga, the southern limb is fairly regular and the 'wall' quartzite stands up conspicuously along the valley, dipping at angles of 45° to 80°. Its boldness and continuity along this valley led me to give to this distinctive bed the field name which I have used here. It is about 120 feet thick; next above it is a thin but massive limestone followed by 300-400 feet of shales passing into the slabby limestones, which form the bulk of the visible section.

The northern edge is not so regular; usually it is overfolded, but in places the dip is high but normal; south of Shekar runs a strike fault cutting out the 'wall' quartzite. South of the Tsipri ridge the two synclines approach closely, with an intervening anticline of Jurassic shales. All along the Phung Chu valley exposures of the Cretaceous limestones are much disconnected by detrital deposits, and usually occur as isolated hills of bizarre form, in which the beds are seen to be intensely crumpled and sheared, and fossils are represented by streaks of calcite. At Kyishong, near its eastern end, the syncline widens out, due to the presence of a subsidiary anticline along its centre.

The groups of synclines to the south, in the Pharuk district, display such great irregularities and complexity of structure that I found it impossible to map them in detail on a ¼ inch scale and have been compelled to show them in a general and diagrammatic way. The syncline that forms the valley of the Neo Chu and passes eastwards to near Aya, is very elongated and narrow, with the strata disposed vertically or slightly overfolded in the usual direction, and the 'wall' quartzite standing up on either side of the valley. Midway along the syncline a strike fault repeats it, bringing in a wedge of Jurassic shales. At its western end, it is continued by another similar syncline, slightly *en échelon*. In the two miles south of the Neo Chu syncline, between Namda and Tashidzom, the "wall" quartzite and the basal beds of the Cretaceous limestones are repeated again and again by sharp folds and faults of small throw. Needless to say they are veined with calcite and in places brecciated. South of this again, from Tashidzom to Kuyul, besides the double syncline shown on the map, small sections of the Cretaceous limestones are pinched up and faulted into the Jurassic shales.

In the double syncline there is no inversion, the northern lobe being shallow, saucer-like, and fairly symmetrical, while in the southern the beds are undulating and almost horizontal.

The only remaining outcrop of Cretaceous rocks lies far to the north-east, and is a shallow syncline similar to the last, with the quartzite dipping gently inwards round the periphery and the centre occupied by horizontal and undulating sericitic limestones.

**Jurassic shales.**

The most striking features, in fact the only striking features of the Jurassic beds, are the extent and the monotony of their outcrops. They consist for the most part of dark brown and black shales and argillaceous sandstones, with subordinate quartzites, representing a purer type of sandstone, and limestones which are usually darker and more argillaceous than those of the overlying Cretaceous System.

In the tract of country between the crystalline zone and the Northern Range of the Central Himalaya, the Jurassic strata are thrown into great folds and corrugated in the most fantastic fashion, and even in cases where the general dip approaches horizontality the beds roll about irregularly. In such highly compressed country, faulting, especially thrust-faulting, must be very prevalent, but where strata are so uniform in appearance such faulting is extremely difficult to detect.

The general strike of these folds is that of the 'grain' of the country, *i.e.*, in a E.-W. or E.S.E.-W.N.W. direction, but the folds are subject to far more irregularities than is the case in the more persistent synclines of the Kampa System limestone.

In the Northern Range, and also where they pass downwards into the thick limestones along the boundary of the crystallines, the shales dip less variably and at lower angles. A certain amount of injection by granite veins has taken place in the Northern Range accompanied by a widespread regional induration of the rocks, which attain, however, to only a low degree of metamorphism. The intermediate belt, where the Cretaceous and Eocene limestones have been compressed into overfolded synclines and the Jurassic shales have been so intensely folded, has been a region of weakness between two more resistant blocks. The alteration of the rocks in the Northern Range extends considerably further outwards from the areas of granite intrusion than is the case in the opposite section of the Great Himalaya, but is, as I have said, of less degree. Pebbles of garnetiferous mica-schist and hornblende-schist (of the 'feather amphibolite' type) were found in gravels below the Mon La, but the parent rock was not found *in situ* nor were such highly metamorphosed types met with elsewhere in the Northern Range.

For the most part the shales have become hardened and have acquired the beginning of slaty structure, being knotted and breaking into prisms, or have had developed in them a certain amount of secondary sericitic mica and of aluminous silicates such as staurolite; in certain cases they have become phyllites. Often they have a baked appearance, being whitish or red, contrasting with the black or rusty brown tints of the unaltered shales. The quartzites show no more alteration than they do amongst the unaltered strata, but then in this area the usual Jurassic sandstone-quartzite, fairly free from impurities, is just as hard and vitreous as any typical Pre-Cambrian quartzite.

**Igneous rocks in the Tibetan Zone.**

The intrusive granite of the Northern Range is very similar in appearance to the schorl-granite of the Himalayas, but is uniformly fine-grained instead of showing the great variation in texture of the latter rock. Like it, it is a white rock and is very tough and resistant to weathering.

Mineralogically it differs from the schorl-granite in that it contains biotite (with muscovite as well) instead of schorl, and from the Kyi Chu granite described by Hayden, it differs in the absence of hornblende and the scarcity of plagioclase and of sphene, epidote and calcite.

Near Nelung and Khakyu, and between Namda and Aya, small dykes of dark rock were seen, in the last case strung out along a line running E. and W. appearing at intervals over a length of 2½ miles. The dykes individually extend for only a hundred feet, less or more, and are up to 3 feet in width. The rock is too thoroughly decomposed for determination, but is probably of basic composition. Judging from the crushing and dislocation which the dykes have undergone they are probably antecedent in age to the folding of the rocks. Pebbles of an augite-bearing rock, probably of basaltic or andesitic composition, but with felspars too much altered to be determinable, are common in the gravels of the Phung Chu and may be derived from such dykes.

**Permo-Trias limestones.**

Between the crystalline and the sedimentary zones crops out a thick series of limestones, of which 2000 to 3000 feet are exposed in a very uniform assemblage of rather thin beds of 1 to 3 feet in thickness, with shaly partings. The overlying shales, of which the major portion has been shown by Hayden to be Jurassic, pass down without any visible discordance into the limestones. As has been stated, the limestones as a whole are considerably altered, all fossils having been destroyed and now appearing as streaks of crystalline calcite. Further, they have been extensively invaded by granite veins, converted into crystalline limestones and calc-schists, and involved in the crystalline complex in such fashion that to lay down a true boundary upon the map is impossible. The line which I have drawn between limestones and crystallines is an arbitrary one and represents generally the upper and outer limit of granite intrusions; to the south of this line there is much of the limestone in its metamorphosed forms, but intimately associated with the schorl-granite. The lowest portions of the limestones are thus obliterated and their relation to the biotite-gneiss is obscure, but it is probable that the latter is intrusive in them. The limestones were probably continuous right along the southern margin of the Jurassic exposures, but the zone of metamorphism and granite veining has encroached on them to a varying extent, in some places affecting them throughout and transgressing upwards as far as the Jurassic shales and in others leaving a great thickness unaltered, so that their outcrop has now the irregular breadth shown upon the map. Their general dip is northward at low angles; at Yalep on the Po Chu and at Kal are anticlinal flexures and south of Raphu and Hlelung dips undulate somewhat.

The bifurcation of the outcrop east of Tulung is, as far as I was able to ascertain, due to the limestones emerging again to the north of the main exposure along an anticlinal axis; the structure is however doubtful and may be due to faulting. My examination of this portion of the area was much hindered by repeated snowfalls and heavy mist.

The age of these rocks is very doubtful, but may be put down provisionally as Permo-Trias. Sir Henry Hayden[1] has described, under the name of the Dothak series, an assemblage of limestones and other sedimentary rocks between the Chumbi valley and Bhutan, which in his opinion may include part or all of the Trias and possibly one or more of the Palaeozoic systems.

He also suggests that Triassic rocks occur along the northern slopes of the Lhonak range between Tibet and Sikkim,[2] and fossils typical of the Productus Shales (Upper Permian) are known to have been collected from near the Kongra La, the pass which crosses the Lhonak range south of Kampa Dzong. The situation of these exposures with regard to the crystalline zone is very similar to the belt of Permo-Trias rocks described above.

Direct evidence of their age, though not very definite, is given by two sections in the ridges to east and west of Hlelung. At the base of the great series of shales which overlie the limestones, just as they pass downwards into the latter, is a thin ferruginous bed crowded with *Spirifer* and *Productus*, not, however, specifically determinable. These

[1] *Loc. cit.*, p. 142.
[2] *Loc. cit.*, pp. 144 and 145.

would indicate that the top of the limestones is about Upper Permian in age, if the section is a straightforward one, which there is no reason to doubt. The bulk of the limestones would then represent the Permian of the European scale, with perhaps a portion of the Carboniferous. Judging from field relationships and lithological characters, I had in my own mind considered these limestones as approximately equivalent to the Kioto limestone of the Zangskar range in Spiti (Lower Jurassic and Upper Trias) which in that country underlies the Spiti Shales (Upper Jurassic), but the fossil evidence puts them much lower in the geological scale, and indicates that the Trias is represented by the lower portion of the great succession of shales; it is unfortunate that the absence of recognisable fossils from the limestones themselves leaves the question so indefinite.

## THE GEOLOGICAL STRUCTURE OF MOUNT EVEREST.

During the attacks on the mountain by the climbers of the second Expedition, a small collection of rock-specimens was made at heights of from 23,000 to 27,000 feet. I am greatly indebted to those who collected them, at altitudes and under difficulties hitherto unequalled in geological field-work.

These specimens confirm the views arrived at last year, as a result of inspecting the mountain by telescope from the Rongbuk valley from a distance of about ten miles, and by examination of moraine material derived from its northern faces and spurs.

These data show Mount Everest to be a pile of altered sedimentary rock—shales and limestones—converted into banded hornfels, finely foliated calc-silicate schists and crystalline limestones. The hornfels and fine schists are in the field blackish or dark green rocks, conspicuously slabby and with a general low dip to the north, which I believe adversely and even dangerously affected climbing. The crystalline limestones are fine-grained pure white rocks.

A general description of the various types has been given in the paragraph on metamorphic rocks and it may suffice to say here that the actual specimens from 23,000 and 25,000 feet show in microscope sections a very fine-grained aggregate of quartz and a greenish mica, with irregular lenticles and veins of chlorite and epidote and in addition sometimes calcite and sphene.

The mountain, from 21,000 to 27,000 feet, is made up of these black and dark green rocks, with occasional beds of white limestone and veins of quartz and muscovite-granite. From 27,000 to 27,600 feet extends an almost horizontal belt, a sill in fact, of schorl-muscovite-granite, along the whole length of the mountain, which rock presumably, by its superior hardness, gives rise to the prominent shoulder of the mountain north-east of the main peak (shown as 27,390 on Major Wheeler's photographic survey map). Above this again are black schists.

As to the age of the rocks forming Mount Everest, they may perhaps be assumed, for the present, to be Jurassic or Trias.

## EXPLANATION OF PLATES.

PLATE 7.—View of Mount Everest from the north.

PLATE 8.—Geological map of the Arun River Area, Tibet: scale 1″=8 miles.

PLATE 9.—Diagrammatic Sections across the Arun river area, Tibet.

PLATE 10.—FIG. 1.—Alluvial gravel terraces and hills of Jurassic shales, Kyishong, Phung Chu valley.

FIG. 2.—Folded Cretaceous limestones, Men Chu above Mento.

PLATE 11.—FIG. 1.—Folded Jurassic shales.

FIG. 2.—General view of Phung Chu valley, from Memo, looking east, Tsipri ridge on right.

PLATE 12.—FIG. 1.—Synclinal hill of Cretaceous limestone, Memo, Phung Chu valley.

FIG. 2.—Eastern end of Tsipri ridge, showing folded Cretaceous limestones.

PLATE 13.—FIG. 1.—Folded Cretaceous limestones, Palding near Dzakar Chu.

FIG. 2.—Folded Cretaceous limestones, Riphe near Dzakar Chu.

# THE NORTHERN EXTENSION OF THE WOLFRAM-BEARING ZONE IN BURMA. BY J. COGGIN BROWN, O.B.E., D.SC., F.G.S., M.I.M.M., *Superintendent*, AND A. M. HERON, D.SC., F.G.S., *Officiating Superintendent, Geological Survey of India.*

In a paper entitled 'The Distribution of Ores of Tungsten and Tin in Burma,' published in the *Records of the Geological Survey of India*, Vol. L, pp. 101-121, (1919), we summarised briefly the information then available regarding the located deposits of these ores, tracing them district by district from Byingyi on the borders of Yamethin and Loi Long in the Southern Shan States, to the southern extremity of the Mergui district. We demonstrated there that all the wolfram and cassiterite veins in Burma are closely associated with a biotite boss-granite which forms the cores of the ranges of the Indo-Malayan mountain system. At the time that paper was written the Byingyi occurrence marked the northern termination of the zone.

Since then however other occurrences have been located and although little is known of them and they have not proved of any economic importance, we consider it desirable to place on record the information we possess regarding them.

## Southern Shan States, Yengan State.

Yengan is one of the most northerly of the States in the Myelat division of the Southern Shan States, lying between 20° 55′ and 21° 14′ N. and 96° 13′ and 96° 38′ E., with an area of 400 square miles. It is separated from the Meiktila district in Burma by a lofty mountain barrier rising in places to over 5,000 feet in height. The whole of the western part of the State is hilly and drained by the Panlaung river and its affluents. Five prospecting licenses for wolfram covering a total area of 8,000 acres, had been granted in the State by the end of 1918, but details are available concerning only one of them, held at that time by Messrs. Steel Bros. & Co., Ltd. This firm has supplied the information given below, based on reports made by its geologist, and has given permission for it to be published. Our thanks are due to Messrs. Steel Bros. & Co., Ltd. for this courtesy.

The concession lies on the banks of the Panlaung river, 15 to 18 miles due east of Thedaw railway station, at mile 322 from Rangoon in the direction of Mandalay. In it there are two main granite exposures separated by a series of altered sedimentary rocks, chiefly clay slates and hard white quartzites. Compact grey limestones are also found but their relationship with the other series is not known. Numerous quartz veins varying in thickness from a few inches to three feet, traverse both the granite and the clay slates and quartzites. Their strike varies from a few degrees north of east and south of west to N. E.—S. W., and the dip is generally steep towards the north. The thinner veins often die out in a short distance along their strike and are replaced by parallel ones *en échelon*. Close to the granite contact they contain wolfram both in the granite and sedimentary rocks, but further away they become barren. The veins are said to be most productive when they occur in fissures at right angles to the major axis of the intrusion. As is usual in better known localities, the distribution of the wolfram within the veins is irregular and patchy and greisenisation is common where they traverse the granite. In one part of the concession molybdenite occurs with the wolfram. Oxidised compounds of copper and iron are found in the upper portions of the veins and appear to indicate the presence of sulphides below the zone of decomposition.

## Mawnang State.

Mawnang, a small State of the Myelat division of the Southern Shan States, known to the Burmese as Bawnin, lies between 20° 38′ and 20° 44′ N. and 96° 44′ and 96° 51′ E., with an area of 40 square miles. In November 1918, the Superintendent of the Southern Shan States reported that wolfram had been found on a small concession in Mawnang. The total output from the concessions in

Mawnang and Yengan States in 1917 and 1918 approximated only 2½ tons.

## Kyaukse District.

Returns of mineral production for 1919 record the output of 2 cwts. of wolfram from the Kyaukse district. This was obtained in the course of prospecting operations on concessions near Sabedaung and in the Pyetkaywetaung forest reserve of the Myittha township between the villages of Kyidankanzwe and Zalonegaw. No information is obtainable regarding this prospect, which appears to be the most northerly reported occurrence of wolfram in Burma. Myittha itself is only some 35 miles in a direct line southwards of Mandalay.

## Conclusion.

The striking similarity between the geological conditions, vein structures and mineral associations of the Yengan concession and those described in our earlier paper are apparent. The almost constant recurrence of such features amongst practically all the various wolfram deposits which have hitherto been described, stretching as they do over hundreds of miles of territory further to the south, appear to us to indicate a strong probability of the presence of identical rocks with similar origins in those occurrences of which we know nothing, beyond the mere fact of their existence, at present.

# MISCELLANEOUS NOTE.

## Barytes in Alwar.*

During a mineral survey of Alwar in the year 1911 by the writer, deposits of barytes, one at Bhankhera (27° 32′ : 76° 38′) three miles south-west of Alwar City and another at Ramsinghpur (27° 10′ : 76° 32′) ten miles south-west of Rajgarh Railway Station (Bombay, Baroda and Central India Ry.), were discovered. A third deposit was subsequently discovered at Jamraoli (27° 9′ : 76° 44′) ten miles south-east of Rajgarh railway station, but the quality of the material is inferior and the commercial value of the deposit is doubtful.

Some attention has been devoted to the development of these deposits and some 12 tons were despatched to Calcutta about the year 1919 for testing purposes as paint.

Recently another outcrop of barytes was noticed by the writer at Sainpuri (27° 46′ : 76° 43′) 4 miles north-north-east of Parisal Railway Station. The vein was traced for 110 feet and is approximately 15 feet thick. It is coarsely crystalline, pure white in colour and in quality appears to bear comparison with the Madras barytes. It is considered that the exploitation of this particular deposit should be remunerative.

The four deposits of barytes all occur in the Alwar quartzites, a series in the Delhi system corresponding perhaps to a low horizon of the Purana group (Pre-Cambrian). Further search along the outcrops of these quartzites may possibly reveal the presence of other deposits of the same mineral.

The barytes is not an original constituent of the quartzite ; it invariably occurs in veins filling fissures opened long after the formation of the quartzite. All the deposits so far discovered are situated near the base of the hill slopes and are absent from the crests of the ridges, a fact which seems to indicate that the barytes-bearing veins characterise the less compact and more easily weathered varieties of the quartzite. Except at Jamraoli, the strike of the fissure-veins generally agrees with that of the bedding.

The junction between the barytes and the 'country' is quite abrupt just as it is in the case of the quartz and pegmatite veins of this region. There is no impregnation of the 'country' along the walls by the vein minerals which, contrary to what has been observed in the case of the ancient intrusive amphibolites of this region, do not penetrate into minute joints nor into planes of bedding.

* Published with the kind permission of His Highness the Sri Sewai Maharaj Dev of Alwar.

The intrusive rocks of the Alwar region have been classified by Dr. Heron according to their relative ages into three groups (*Mem. Geol. Sur. Ind.*, Vol. XLV, p. 88).

3. Pegmatites.
2. Granites.
1. Amphibolites.

The barytes veins have probably crystallised from solutions at a relatively low temperature, and at no great depth. They belong to a later geological phase than that of the intrusive granites and pegmatites to which they are probably totally unrelated in origin.

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

Part 3 ] 1923 [ June

# RUPERT WILLIAM PALMER: BORN JULY 4TH, 1890. DIED OCTOBER 12TH, 1922.

IT is with great regret that I have to record the death of Captain Rupert William Palmer, M.C., M.Sc. (Manch.). F.G.S., formerly an Assistant Superintendent of the Geological Survey of India. Captain Palmer joined the Department on the 13th of December, 1913. Being a Special Reserve officer (2nd Lieutenant) of the East Lancashire Regiment, he received mobilization orders on the 6th August, 1914, after the outbreak of war, in reply to a cable from himself to his regiment offering to resign his post in India. He left immediately for England, and was placed on extraordinary leave without pay. It is interesting to note that the period for which this leave was granted was six months. In February, 1915, he was placed on the same footing as other civil officers in India who accepted military service. His regiment was one of the first to be sent to France, and took part in the retreat from Mons. Few of us will forget the letters Palmer wrote from the front, with their terse graphic descriptions of the retreat and their warm praise of his Lancashire men. He was one of the first recipients of the Military Cross in November, 1914, and remained in France till he was invalided home. He was subsequently sent on service of a confidential nature to Palestine, and returned to Calcutta on the 25th March, 1920, after an absence of 5½ years.

His scientific work was marked by acumen and thoroughness, and his reports were distinguished by their clarity and balance. Although quite young, he had already gained some standing as a vertebrate palaeontologist. His investigations on the Mandi Salt deposits and on the Tertiary outlier in the Simla Hills were followed by some excellent work on the Shillong Plateau, where, unfortunately, the disease which he contracted on military service and from which he eventually died, handicapped his efforts. On medical advice he resigned his appointment in India on the 4th December, 1921, to take up a lectureship in Manchester University. As the result of haemorrhage of the brain brought on by septicoemia, he died on the 12th October, 1922, at the early age of 32, leaving a wife and child. His fellow officers deplored the resignation from the department and now mourn the loss of a keen scientist, a good fellow and a gallant gentleman.

E. H. PASCOE.

# INDIAN TERTIARY GASTROPODA, IV. OLIVIDÆ, HARPIDÆ, MARGINELLIDÆ, VOLUTIDÆ AND MITRIDÆ, WITH COMPARATIVE DIAGNOSES OF NEW SPECIES. BY THE LATE E. VREDENBURG, *Superintendent, Geological Survey of India.* (With Plates 14—16.)

THE present contribution is a continuation of the three notices previously published in these pages (*Rec. Geol. Surv. Ind.*, Vol. LI, p. 339; Vol. LIII, pp. 83 and 130) containing brief diagnoses of undescribed species of gastropods from the Tertiary beds of Burma. In addition to the new species, these notices recorded, in tabular form, all the species of each genus already known from the Tertiary of Burma and of other parts of India, together with their geographical and geological distribution. Species from the post-eocene of north-western India need but the briefest allusion as their full descriptions will shortly appear in Volume L of the Memoirs of the Geological Survey of India. The lower eocene species from the Ranikot of Sind have also been included in the lists. It has been necessary in some instances to make amendments to the determinations of the monograph on the Ranikot fauna already published (*Pal. Ind.*, new ser., Vol. III, Mem. No. 1). These amendments are briefly recorded in the tabular statements of each genus.

The present instalment includes the family Volutidæ which is largely represented both in the eocene and oligocene of Burma and in the Ranikot fauna. Owing to the difficulties of identification of d'Archiac and Haime's species from Sind, published in the well known "Description" of the nummulitic fauna of India, many errors have crept into the treatment of the Ranikot Volutidæ. Several undescribed species of great stratigraphical importance from certain horizons of the Ranikot have been overlooked, being inadvertently identified with forms from other horizons. The fact that d'Archiac and Haime's monograph includes miocene as well as eocene species constantly gives rise to difficulties of interpretation. The confusion that has resulted in the present instance is serious and cannot be dealt with in the same summary manner as the amendments recorded in previous instalments of the present series. Consequently the Ranikot Volutidæ have been treated at some length, though as concisely as possible, and the present notice contains therefore the diagnoses of several new Ranikot forms in addition to the Tertiary species from Burma.

A discussion of the classification of the Ranikot series in successive zones will be found in the introduction to the above-mentioned Memoir in the Palæontologia Indica.

The Burmese fossils dealt with in the present instalment are mostly from the same localities as those published in the previous notices. For the geographical bearings and for the geological ages of these occurrences, the instalments already published may be consulted (Vol. LI, pp. 340, 341; Vol. LIII, pp. 84, 130, 131).[1]

Some of the fossils here dealt with are from the following localities not previously recorded :—

1. 2½ miles S.E. of Aleywa : 20°51′, 94°18′, Chakalu stream section.
2. Banbyin : 19°25′, 95°4′.
3. Kongya : 20°46′, 94°25 .
4. In the Kyettin Chaung at a spot (21°22′, 94°15′) situated some two miles north-west of Man (21°22′, 94°17′).
5. Kyadaw Chaung, east of Pasok.
6. Kywe-u : 20°45′, 94°19′.
7. Near Lepagaing, Minbu district, bed B2. The locality Lepagaing is not shown on the published maps, but the fossil occurrence B2, as indicated on Dr. Cotter's map, *Rec. Geol. Surv. Ind.*, Vol. XLI, Pl. 21, is situated in 20°5′, 94°5′.
8. Ngahlaindwin : 20°51′, 94°16′.
9. Ngashandaung : 20°39′, 95°5′, Myingyan district.
10. On the road from Payawa (20°6′, 94°34′) to Sedaw.
11. Pyatgale : 20°51′, 94°16′.
12. In the Sit Chaung, at a spot situated in 21°2′, 94°14′. The Sit Chaung is a small tributary of the Salin, which, in its turn, flows into the Irrawadi.
13. Subagyidan : 20°4′, 94°34′.
14. Yethama : 20°52′, 94°24′.
15. Zabyaw : 20°52′, 94°20′.

[1] The locality "Kyundaw" was accidentally omitted from the list on p. 130, LIII. Its bearings are : 19° 52′, 95° 11′ The fauna from this locality probably belongs to the Singu stage.

Of these various occurrences, those numbered 2, 4, 5, 11, 13, 14, 15 belong to the Yaw stage of upper eocene age. Those numbered 1, 3, 6, 7, 9, 10, 12 belong to the Sitsayan or Padaung stage, middle oligocene. Several horizons are exposed round Ngahlaindwin, No. 8, but the fossils from that locality dealt with in the present notice are also from the middle oligocene.

## Family: OLIVIDÆ.

### Genus: OLIVA Bruguière 1789.

The following species of *Oliva* are known from the Tertiary formation of India:—

1. *Oliva* (*Neocylindrus*) *mustelina* Lamk. (Cossmann, *Journ. Conch.*, 1903, Vol. L, p. 112, Pl. III, figs. 12, 13.) Tertiary beds of Karikal and Mekran beds.
2. ,, (*Neocylindrus*) *irisans* Lamk. (Cossmann, *Journ. Conch.*, 1903, Vol. L, p. 113, Pl. III, figs. 19, 20.) Tertiary beds of Karikal.
3. ,, (*Strephona*) *australis* Duclos, var. *indica* Vred.
4. ,, (*Strephona*) *Duclosi* Reeve, var. *kyundawensis n. var.*

### OLIVA (STREPHONA) AUSTRALIS Duclos *var.* INDICA nov. var. (vel species distinguenda).

1835 *Oliva australis* Duclos.—Chenu, Ill. Conch., Mon. Oliv., Pl. VIII, figs. 3, 4.

1851. *Oliva australis* Duclos.—Reeve, Mon. of the gen. Oliva, sp. 42.

1883. *Oliva australis* Duclos.—Tryon, Man. Conch., Vol. V, p. 85, Pl. XXXII, figs. 19, 20.

1899. *Oliva* (*Strephona*) *australis* Duclos.—Cossmann, *Essais Paléoconch. comp.*, Fasc. 3, p. 49.

1901. *Oliva* (*Strephona*) *rufula* Duclos *sec.* Noetling (*pars*).—*Pal. Ind.*, new ser., Vol. I, part 3, p. 326.

As frequently happens with fossil forms of *Oliva*, the identification of this shell gives rise to a great deal of hesitation. Compared with *Oliva australis* Duclos from the eastern seas (Australia and New Guinea according to Tryon), the fossil under consideration is smaller and not quite so symmetrically barrel-shaped, its maximum thickness being further from its anterior than from its posterior extremity instead of being placed approximately at half the length as in the living species. From the Tertiary formations of Java, Martin has described a form regarded as a variety of *Oliva australis* (*Samml. d. geol. R.-Mus. in Leid.*, new ser., Vol. I, p. 60, Pl. VIII, figs. 137, 138) which does not attain the full dimensions of the living form from which it differs more than the Indian fossil under consideration. In shape it is further removed from the living form than the Indian fossil, for not only is the region of maximum thickness shifted to the posterior side of the middle zone, but it is accompanied by a rudimentary angulation of the surface. With regard to the disposition of the inner border of the aperture, the Indian fossil closely corresponds with the living type while the Javanese fossil exhibits a decided difference in the relative position of the borders, of the anterior zone of accretions and of the columellar swelling, which remain wide apart on reaching the aperture instead of closely converging. It follows therefore that the Indian fossil is closer related to *Oliva australis* than the Javanese form, and, if the latter be accepted as a variety, a similar course may be adopted for the Indian shell.

*Oliva cylindracea* Born., from the oligocene and miocene of Europe, *O. Dufresnei* Basterot from the miocene of Europe and the living. *O. panniculata* Duclos, resemble the Indian fossil under consideration, but are all distinguished by the want of convergence of the borders of the anterior zone and of the columellar swelling.

Amongst various forms from Burma referred by Noetling to *Oliva rufula*, that represented by the specimens from Kama is identical with the fossil under consideration. The illustrations in Noetling's monograph represent a fossil from Yenangyat belonging to the genus *Olivella* (see : *Rec. Geol. Surv. Ind.*, Vol. LI, p. 275).

*Occurrence.*—Dalabe, Kama, Kyaungon, Myaukmigon, Myauktin, Myingabaing, Thanga, Tittabwe. Also in the Gáj of Kachh.

OLIVA (STREPHONA) DUCLOSI Reeve, var. KYUNDAWENSIS n. var.

1835. *Oliva jaspidea* Duclos (*non* Gmelin).—Chenu, Ill. Conch., Pl. IX, figs. 9,10.
1851. *Oliva Duclosi* Reeve.—Monograph of the genus Oliva, sp.44.
1883. *Oliva Duclosi* Reeve.—Tryon, Man. Conch., Vol. V, p. 85.

On account of its relatively small dimensions (17·2 × 8·3 mm.), I have separated this fossil as a variety from the living *O. Duclosi* with which it otherwise agrees. The wide space between the edges of the terminal zone of accretions and of the terminal columellar swelling as they penetrate into the aperture, readily distinguishes this fossil from the one previously referred to as a variety of *Oliva australis*, and recalls the Javanese fossil described by Martin as *Oliva australis* var., the outline of which is more decidedly angulated at the widest part of the body-whorl.

*Occurrence.*—Kyundaw.

Genus: OLIVANCILLARIA d'Orbigny 1839.

The following species of *Olivancillaria* are known from the Tertiary formation of India:—

1. *Olivancillaria gibbosa* Born. (=*Oliva cheribonensis* Mart. sec. Cossmann, *Journ. Conch.*, 1903, Vol. L, p. 111, Pl. III, fig. 16). Pliocene of Karikal.
2. " *birmanica* n. sp.
3. " (*Agaronia*) *acuminata* Lamk. (Cossmann, *Journ. Conch.*, 1903, Vol. L, p. 114, Pl. III, fig. 21). Pliocene of Karikal.
4. " (*Agaronia*) *nebulosa* Lamk. var. *pupa* J. de c. Sowerby. Burma: Dalabe; Kyaungon; Minbu, "zone of *Cancellaria martiniana*"; Myaukmigon; Singu, H, F, L, N; Tittabwe Western India: Gáj beds of Kachh and Sind.
5. " (*Agaronia*) *pagodula* n. sp.
6. " (*Agaronia*) *Cossmanni* n. sp.

OLIVANCILLARIA BIRMANICA n. sp.

Pl. 14, fig. 1.

This handsome shell is closely related to the common *Olivancillaria gibbosa* [Born], living in the Indian Ocean, which it fully equals in size. The bend or shoulder of the body-whorl is much further removed from the suture in the fossil than in the living species. The posterior callous thickening of the columellar lip is feebly developed in the fossil, in consequence of which its last spire-whorl exhibits a somewhat concave outline instead of the convex outline exhibited in the recent shell. The columellar lip expands much further over the ventral surface in the recent shell than in the fossil. Its plications, distinct in the recent form, are absent from the fossil.

In the upper tertiary formations of Java, *Olivancillaria s. str.* is represented by a number of shells which, in his latest work on the subject, Prof. Martin has regarded as partly representing a distinct species, *O. cheribonensis*, partly as a variety *Jenkinsi* of *O. gibbosa* (*Samml. des geol. R.-Mus. in Leiden*, new ser., Vol. I, pp. 64, 65). Taking into consideration the extreme degree of variability of the recent shell, the differences between the various Javanese fossils seem insufficient for establishing specific differences amongst them. It seems more probable therefore that all the Javanese fossil specimens should be regarded as representing a single species which should be known as *Olivancillaria Jenkinsi* Martin, specifically distinct both from the Burmese fossil and from *Olivancillaria gibbosa* though more nearly related to the latter. In every case in which their outline is well preserved, the Javanese specimens exhibit a more symmetrical spindle-shape and more continuous curvature of the body-whorl than either the Burmese fossil or the recent species. Their greatest thickness is somewhat more removed from the suture than in the recent shell, in which respect they come closer to *O. birmanica*, but their anterior portion has a curved instead of conical outline so that they are less distinctly shouldered than either *O. birmanica* or *O. gibbosa*. The callosity of the columellar lip of the Javanese fossils spreads over the ventral surface of the shell more than in *O. birmanica*, less than in *O. gibbosa*. The plications of the columella in the Javanese fossils are distinct, and, in this respect, they agree with the living form, not with the Burmese fossil.

On carefully comparing a large series of specimens recently collected from the beach at Puri with the excellent illustration published by Cossmann, there can be no doubt that the Karikal fossil referred by Cossmann to *O. cheribonensis* (*Journ. Conch.*, 1903, Vol. L, p. 111, Pl. III, fig. 16), is really a specimen of *O. gibbosa*.

The general outline of the Burmese fossil closely recalls that of *Oliva fusiformis* Lamk. from the West Indies which, however, is an *Oliva* not an *Olivancillaria*.

All the available specimens are incomplete. The annexed restored outline will help to make clear the true shape of the shell.

*Occurrence.*—Tittabwe.

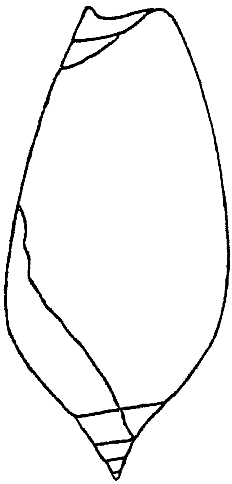

FIG. 1.—Restored outline of *Olivancillaria burmanica.*

OLIVANCILLARIA (AGARONIA) PAGODULA n. sp.

Pl. 14, fig. 4.

Compared with *Olivancillaria nebulosa* Lamk. (*Oliva pupa* J. de C. Sow.), this species is distinguished by its relatively narrower, taller spire, its posteriorly much less convex outer lip, the more prominent ridges of its columellar lip, and its smaller dimensions. There do not appear to be any other described species that call for comparison.

*Occurrence.*—Myauktin, Tittabwe.

OLIVANCILLARIA (AGARONIA) COSSMANNI n sp.

Pl. 14, fig. 3.

The tall elongate spire readily distinguishes this remarkable shell from all other known species of *Agaronia*, and, together with the absence of parietal ridges induces a close resemblance to certain forms of *Olivella*. Although distinguished by its narrower shape, it shows a striking resemblance to *Oliva gracilis* Brod. and Sow. from the eastern coast of the Pacific, classified as an *Olivella* by Tryon, but of which the ventral aspect does not seem to have been either figured or accurately described, nor the presence of an operculum recorded, and which therefore possibly may not belong to this genus. In the fossil under consideration, there is no indication of the posterior columellar depression characteristic of *Olivella*. The polygyrate protoconch is abnormal for *Agaronia*, but, at the same time, completely excludes the possibility of a reference to *Olivella* in which the protoconch is even shorter and fewer-whorled than in the normal forms of *Agaronia*. In conclusion, therefore, it seems proper to classify this shell as an exceptional *Agaronia*.

*Occurrence.*—Tittabwe.

Genus: OLIVELLA Swainson, 1835.

The following species of *Olivella* are known from the Tertiary formation of India :—

1. *Olivella Hollandi* C. and P. (*Pal. Ind.*, new ser., Vol. III, Mem. 1, p. 20, Pl. II, figs. 21, 22, Pl. VII, fig. 49). Lower eocene of Sind.
2. ,, *Vredenburgi* C. and P. (*Pal. Ind.*, new ser., Vol. III, Mem. 1, p. 21, Pl. III, figs. 8, 9). Lower eocene of Sind.
3. ,, *elegantula* Rovereto. Nari of Sind.
4. ,, *minbuensis* Vred. (*Rec. Geol. Surv. Ind.*, Vol. LI, pp. 275, 286). Yenangyat, "zone of *Paracyathus cæruleus*": Minbu, "zone of *Cancellaria martiniana*"; Mindegyi.

Genus: ANCILLA Lamarck 1799.

The following species of *Ancilla* are known from the Tertiary formation of India :—

1. *Ancilla* (*Sparella*) *olivula* Lamk. ? (d'Archiac and Haime, Descr. an. foss.. gr. numm. Inde, p. 356). Eocene of Subathoo.
2. ,, (*Sparella*) *cinnamomea* Lamk. (Cossmann, *Journ. Conch.*, 1903, Vol. L, p. 115, Pl. III, figs. 14, 15). Pliocene of Karikal.
3. ,, (*Sparella*) *indica* Vred. Nari of Sind.

3a. ,, (*Sparella*) *indica* var. *arakanensis* n. var.

4. ,, (*Sparella*) *birmanica* Vred.
5. ,, (*Alocospira*) *tornata* Cossmann (*Journ. Conch.*, 1903, Vol. L, p. 116, Pl. III, figs. 22, 23). Pliocene of Karikal.

6. *Ancilla* (*Alocospira*) *inopinata* C. and P. (*Pal. Ind.*, new ser. Vol. III, Mem. 1, p. 20, Pl. II, figs. 16, 17). Lower Eocene of Sind.
7. ,, (*Sparellina*) *candida* Lamk. (Cossmann, *Journ Conch.*, 1903, Vol. L, p. 115, Pl. III, figs. 17, 18). Pliocene of Karikal.
8. ,, (*Sparellina*) *pœnitens* n. sp.

ANCILLA (SPARELLA) INDICA Vred. var. ARAKANENSIS.

Pl. 14, fig. 9.

This variety is distinguished from the type from the Nari of Sind [1] by its smaller dimensions. It does not otherwise exhibit any differences of sufficient precision for specific discrimination.

The characters of this species are typically those of the section *Sparella*. Nevertheless, on the early part of the spire, wherever the thick coating of enamel has either not been developed or has been accidentally detached, the spiral grooves mentioned in the description of the Sind fossil are clearly visible in the Burmese specimens. They indicate a very close relationship between the sections *Sparella* and *Alocospira*.

*Occurrence*.—Tetma.

ANCILLA (SPARELLA) BIRMANICA Vred.

Pl. 14, fig. 2.

1901. *Ancillaria* cf. *Vernedei* Sow. Noetling, *Pal. Ind.*, new ser. Vol. I pt. 3, p. 327, Pl. XXII, fig. 6.

1921. *Ancilla* (*Sparella*) *birmanica* Vred. *Rec. Geol. Surv. Ind.*, Vol. LI, pp. 275, 280.

Illustrations of this species are here published to supplement the unsatisfactory figure of a fragmentary specimen in Noetling's second monograph.

*Occurrence*.—"*Cytherea promensis* bed" opposite Prome, Myauktin.

ANCILLA (SPARELLINA) PŒNITENS n. sp.

Pl. 14, fig. 5.

This shell is larger, much more elongate, much more cylindrical and more flattened than the two living forms *Ancilla candida* Lamk. and *A. ampla* Gmel., both occurring fossil, the one in the pliocene of Karikal, the other in the miocene of Java, and so much alike

[1] The description of the type will shortly appear in *Mem. Geol. Surv. Ind.*, Vol. L

that they perhaps belong to a single species. The fascicle in these living forms is divided into two zones only, not into three as in the Burmese fossil. The latter difference is to be regarded as specific only: as there has hitherto been practically but a single species contained in the section *Sparellina*, the generic or sectional diagnosis corresponds with the specific characters. It is merely necessary therefore to state that in *Sparellina* the fascicle may be divided into three zones. All the other generic characters are typically developed in the Burmese shell, particularly the absence of a bare dorsal zone which constitutes the most important difference between *Sparellina* and *Tortoliva s. str.*. This fossil is the oldest known representative of *Sparellina*.

In its general outline this shell has a very weird appearance somewhat recalling a hooded monk, or the "penitents" in an Italian or Spanish procession.

*Occurrence.*—Mindegyi.

## Family: HARPIDÆ.

Genus :—HARPA (Rhumphius 1705) Lamarck, 1799.

The following species of *Harpa* are known from the Tertiary formation of India :—

1. *Harpa* (*Eocithara*) *Morgani* C. and P. (*Pal. Ind.*, new ser., Vol. III, Mem. 1, p. 22, Pl. II, fig. 25, Pl. III, fig. 24). Lower eocene of Sind.
2. ,, (*Eocithara*) *birmanica* n. sp.
3. ,, (*Eocithara*) *narica* Vred. Nari of Sind.

### HARPA (EOCITHARA) BIRMANICA n. sp.

Pl. 14, fig. 6.

Although the solitary available specimen is very incomplete, its distinct characteristics make it worthy of record. It is very closely related to *Harpa mutica* Lamk. of the middle eocene of the Paris region, from which it is distinguished by its smaller size and the much more delicate intercostal reticulation. The latter character distinguishes it still more decidedly from *Harpa Morgani* C. and P. occurring in the lower eocene of Sind. Compared with *Harpa narica* Vred. from the oligocene of Sind, the Burmese shell is smaller, with a relatively taller spire and with wider-spaced axial lamellæ.

*Occurrence.*—Thetkegyin.

## Family : MARGINELLIDÆ.

### Genus : MARGINELLA Lamarck, 1801.

The following species of *Marginella* are known from the Indian Tertiary :—

1. *Marginella orientalis* n. sp.
2. „ *singuènsis* Vred. (*Rec. Geol. Surv. Ind.*, Vol. LIII, p. 340, Pl. XXII, fig. 1). Singu, N.
3. *Marginella* (*Eratoidea*) *Boureti* Cossmann (*Journ. Conch.*, 1903, Vol. L, p. 117, Pl. IV, figs. 1, 6). Pliocene of Karikal.
4. „ (*Eratoidea*) *karikalensis* Cossmann (*Journ. Conch.*, 1903, Vol. L, p. 118, Pl. IV, figs. 2, 3). Pliocene of Karikal.
5. „ (*Glabella*) *oligoptycha* Cossmann (*Journ. Conch.*, 1903, Vol. L, p. 119, Pl. IV, figs. 4, 5). Pliocene of Karikal.
6. „ (*Glabella*) *narica* Vred. Nari of Sind.

#### MARGINELLA ORIENTALIS n. sp.

Pl. 14, fig. 7.

The shortness of the spire and the narrow elongate body-whorl, combined with the rather large dimensions readily distinguish this shell from other described species. It closely resembles *Marginella brevispira* Bellardi from the miocene of Piedmont though this is more ventricose with a more developed spire. *Marginella singuènsis*, also from Burma, is still more ventricose than *M. brevispira*. These two Burmese fossils are the only forms of *Marginella s. str.* known from the east. The living species of this section are restricted to the shores of the Atlantic.

*Occurrence.*—Myaungu (lower horizon, Sitsayan stage), Thetkegyin

### Genus : CRYPTOSPIRA Hinds, 1844.

The following species of *Cryptospira* are known from the Tertiary of India :—

1. *Cryptospira birmanica* n. sp.
2. „ (*Gibberula*) *tectiformis* Cossmann (*Journ. Conch.*, 1903, Vol. L, Pl. IV, figs. 7, 8). Pliocene of Karikal.

3. *Cryptospira* (*Gibberula*) *cuneata* Cossmann (*Journ. Conch.*, 1903, Vol. L, Pl. IV, figs. 9, 10). Pliocene of Karikal.
4. „ (*Gibberula*) *glandina* [Vélain] (Cossmann, *Journ. Conch.*, 1903, Vol. L, Pl. IV, fig. 14). Pliocene of Karikal.

### CRYPTOSPIRA BIRMANICA n. sp.

Pl. 14, fig. 11.

1901. *Marginella* (*Glabella*) *scripta* Reeve, *sec.* Noetling.—*Pal. Ind.*, new ser., Vol. I, part 3, p. 321, Pl. XXI, fig. 10.

*Marginella elegans* Gmelin, as represented by figure 4*b* of Reeve's monograph seems closely related to this species, but is larger, with a relatively shorter spire. *Marginella sangiranensis* Martin from Java (*Samml. d. geol. R.-Mus. in Leiden*, new ser., Vol. I, p. 301, Pl. XLIII, fig. 716) is very closely related, differing by its somewhat larger size and greater elongation, and by the disposition of the columellar folds of which the posterior ones do not exhibit the abnormal obliquity which characterises *C. birmanica.*[1]

*Occurrence.*—Dalabe, Kama, Kyaungon, Myaukmigon, Thanga, Tittabwe.

## Family: VOLUTIDÆ.

### Genus: ATHLETA Conrad, 1853.

The following species of *Athleta* are known from the Tertiary beds of India :—

1. *Athleta Blanfordi* n. sp.
2. „ (*Neoathleta*) *Theobaldi* n. sp.
3. „ (*Neoathleta*) *Noetlingi* C. and P.
4. „ (*Neoathleta*) *Rosalindæ* n. sp.
5. „ (*Neoathleta*) *pernodosa* [Dalton]. (*Q. J. G. S.*, 1908, Vol. LXIV, p. 640, Pl. LVII, fig. 4). Man Chaung near Subagyidan, Minbu district.

[1] The illustration in Noetling's monograph (*loc. cit. in syn.*) is quite inaccurate, the posterior folds being represented with an obliquity opposite to their true direction. In reality the Kama specimen figured by Noetling agrees exactly with the one from Tittabwe here illustrated, only that it is crushed and lacks the edge of the outer lip.

6\. *Athleta* (*Volutospina*) *Jacobsi* Vred. (*Rec. Geol. Surv. Ind.*, 1921, Vol. LI, pp. 275, 286). 2½m. S.E. of Aleywa (20° 51′, 94° 18′), Chakalu stream section; near Lepagaing, Minbu district, bed B2 (see: Cotter, *Rec. Geol. Surv. Ind.*, Vol. XLI, Pl. XXI); Minbu, "zone of *Cancellaria martiana*"; Mindegyi; Myaungu (lower horizon, Sitsayan stage); Ngashandaung, Myingyan district; Payagyigon; Sedaw-Payaywa road, Minbu district, bed B (see: Cotter, *Rec. Geol. Surv. Ind.*, Vol. XLI, Pl. XXI); Singu C-D, P; Singu, T (as internal casts); Tetma; Yenangyat, "zone of *Puracyathus cœruleus*." This is one of the commonest and most characteristic fossils of the Burmese oligocene.

6a. ,, (*Volutospina*) *Jacobsi* var. *singuënsis* n. var.

7\. ,, (*Volutospina*) *sindiensis* Vred. Nari of Sind.

8\. ,, (*Volutospina*) *dentata* [Sow.]. Gáj of Kach.

8a. ,, (*Volutospina*) *dentata* var. *Sykesi* d'A. and H. Gáj of Sind.

9\. ,, (*Volutospina*) *mekranica* Vred. Talar stage of the Mekran beds.

10\. ,, (*Volutospina*) *Annandalei* n. sp.
11\. ,, (*Volutospina*) *Isabellæ* n. sp.
12\. ,, (*Volutospina*) *Augustæ* n. sp.
13\. ,, (*Volutocorbis*) *Eugeniæ* n. sp.
} Group of *Athleta elevata* [Sow.].

14\. ,, (*Volutocorbis*) *Victoriæ* n. sp.

15\. ,, (*Volutocorbis*) *Burtoni* n. sp.

16\. ,, (*Volutocorbis*) *Archiaci* Dalton.

## ATHLETA BLANFORDI n. sp.

**1909.** ***Aulicina Haimei*** **d'Arch. (*pars*) *sec.* Cossmann and Pissarro.—*Pal. Ind.*, new ser., Vol. III, Mem. No. 1, p. 25, Pl. II, fig. 27 (*non* figs. 28, 30=*Aulica Sismondai, nec* fig. 29=*Aulica Haimei*), Pl. VIII, fig. 2.**

This shell closely resembles the Bartonian species *Athleta athleta* [Sol.] from which it is distinguished by the absence of ribs and of duplicated spines even at an early stage of growth, while its three columellar folds are more equal and of more constant character, and its columellar lip spreads further posteriorly. It also reaches larger dimensions.

*Athleta strombiformis* [Desh.] from the upper eocene of the Paris basin also exhibits the closest resemblance to *Athleta Blanfordi* which it equals in size, its entire surface being similarly smooth; nevertheless, the Paris shell is distinguished by its wider aperture, its more tortuous columella and its wider-spaced spines.

In the monograph on the Ranikot fauna published in the *Palæontologia Indica* (*loc. cit. in syn.*), this species has been confounded partly with *Aulica Sismondai* [d'Arch.], partly with *Aulicina Haimei* [d Arch.] which only grows to a moderate size, closely resembles *Athleta Blanfordi* in shape, but is readily distinguished, even when the internal characters are obscured, by its spirally striated spire and the wider spaced spines of its body-whorl.

*Occurrence.*—Upper Ranikot. Zone 1: underscarp of Jakhmari peak (Noetling, K $\frac{7}{660}$).

ATHLETA (NEOATHLETA) THEOBALDI n. sp.

Pl. 15, fig. 8.

This shell exhibits the closest resemblance to *Voluta lineata* Desh. from the middle eocene of the Paris region. Nevertheless, the Paris shell, even at a dimension of 60 mm., shows no indication of the dimorphism of the Burmese species, and the spiral decoration of its body-whorl, when full-grown, is much more distinct.

*Occurrence.*—3½ miles west-north-west of Kongya, north of Kywe-u footpath. Ngahlaingdwin Clay: Sit Chaung (Bion K $\frac{17}{601}$).

ATHLETA (NEOATHLETA) NOETLINGI C. and P.

?1854. *Voluta cythara* Lamk. sec. d'Archiac and Haime.—Descr. an. foss. gr numm. Inde, p. 325, Pl. XXXII, figs. 4, 5.

1909. *Volutospina Noetlingi* Cossmann and Pissarro—*Pal. Ind.*, new ser. Vol. III, Mem. No. 1, p. 24, Pl. II, figs. 23, 24.

1909. *Volutospina intercrenata* Cossmann and Pissarro.—*Ibid*, p. 24, Pl. II, figs. 18—20, Pl. III, figs. 1—3.

Owing to the strongly contrasted appearance of the adult body-whorl as compared with the preceding whorls, full-grown specimens of this shell exhibit a very different appearance from those that are more or less immature. Consequently, in the monograph describing the Ranikot fauna published in the *Palæontologia Indica* (*loc. cit.*), the shell has been described under two specific names: Immature specimens have been named "*V. intercrenata*," while the full-grown shell has been described as *V. Noetlingi*. The transition from the immature to the adult condition is very well seen in specimens of the size represented in Pl. II, fig. 18 (*loc. cit.*), the dorsal aspect of which corresponds with that stage of growth in which the ribs begin to grow wider apart and tend to become spinose simultaneously with the conspicuous widening of the posterior declivous concave zone.

This shell belongs to the same group as *Voluta cithara* Lamk. and *V. ventricosa* Defr. from the middle eocene of the Paris region, from both of which it is clearly distinguished by the more crowded ribs of its spire-whorls. As already noticed by Cossmann and Pissarro in the Memoir above alluded to, it is closely related to *V. depauperata* Sow. from the middle and upper eocene of the Anglo-Parisian region in which the spire-whorls are more distinctly angulated, while the shell, in its full-grown condition, is less globose than the Indian species.

As already mentioned in the Memoir above alluded to, the casts of Ranikot age referred by d'Archiac to *Voluta cithara* Lamk. perhaps belong to *Athleta Noetlingi.*

*Occurrence.*—The species has a much more extensive vertical range than would appear from the above mentioned Memoir. The following occurrences have been ascertained.

Upper Ranikot. Zone 2: amongst gypseous shales three miles east of Leilan coal-pit, lower and upper horizon (Fedden, $G\frac{280}{126a}$, $G\frac{280}{126}$). Zone 3: highest horizon north of Leilan coal-pit (Fedden, $G\frac{280}{129}$); lower limestone of Jhirak (Vredenburg, $K\frac{6}{826}$). Zone 4: Jhirak (Fedden $G\frac{280}{124a}$; Vredenburg $K\frac{7}{174}$, $K\frac{7}{178}$).

### ATHLETA (NEOATHLETA) ROSALINDÆ n. sp.

Pl. 14, fig. 8.

This shell bears the closest resemblance to *Voluta cithara* Lamk. from the eocene of the Anglo-Parisian region; yet, even on the supposition that the solitary available specimen is immature, the minute dimensions of the protoconch and the number of spire-whorls clearly indicate a much smaller species than the European form. It cannot therefore be regarded as specifically identical with *Voluta cithara,* one of the largest species of the genus.

*Occurrence.*—Thetkegyin.

ATHLETA (VOLUTOSPINA) JACOBSI Vred. var. SINGUENSIS.

In this variety the spines and ribs are much wider spaced than in the type, especially on the body-whorl upon which the ribs are prominent and persist up to the aperture, while the convexity of the base is much more inflated. All the other details of shape and ornamentation are the same as in the type. There is the same characteristic anterior swelling, and the columellar folds exhibit the same disposition.

*Voluta pernodosa* Dalton (*Q. J. G. S.*, Vol. LXIV, p. 640, Pl. LVII, fig. 4) also from Burma, has a somewhat similar body-whorl but is readily distinguished by its much taller spire.

*Occurrence.*—Mindegyi; Singu L.

ATHLETA (VOLUTOSPINA) ANNANDALEI n. sp.

Pl. 15, fig. 1.

In shape and ornamentation, this shell recalls *Voluta elevata* Sow. from the eocene of the Anglo-Parisian region, but is generally rather more slender and is distinguished by the more crowded spiral ornaments of its body-whorl and the crenulations of its outer lip.

It is more convex than the majority of specimens of *Voluta ambigua* Solander, from the upper eocene of the Anglo-Parisian region, which it recalls by its apertural crenulations, but in which the spiral ornamentation is much less profuse, especially on the spire.

*Occurrence.*—Thetkegyin.

ATHLETA (VOLUTOSPINA) ISABELLÆ n. sp

Pl. 16, fig. 3.

This shell bears the closest resemblance to *Voluta elevata* Sow. from the eocene of Europe. Nevertheless the posterior thickening of the ribs and the resulting prominence of the two posterior circles of crenulations, communicate to the Indian shell a very distinctive appearance which is not seen in any of the European specimens in which, even on the body-whorl of full-grown shells, the posterior circles of crenulations are not so prominently differentiated as they already appear on the spire-whorls of the small Indian species

The shell also resembles immature specimens of *Athleta Noetlingi* from which it is distinguished by the relatively taller, more steeply conical, more distinctly stepped spire, and by the more crowded spiral imbrications of the body-whorl.

*Occurrence.*—Upper Ran kot. Zone 3: three miles east of the old coal-pit near Leilan, Vera plain east, from a brown limestone on the road to Unerpur (Fedden, G-$\frac{280}{127}$).

ATHLETA (VOLUTOSPINA) AUGUSTÆ n. sp.

Pl. 15, figs. 6, 9.

This species also belongs to the group of *Voluta elevata* Sow. from the eocene of the Anglo-Parisian region, to which it is very closely related. *Voluta elevata* is slightly more ventricose. Its columellar lip does not spread so far posteriorly as in the Burmese fossil. The circumsutural step is not deepened into a groove, and, apparently, the walls of the shell are not lirate internally as in the Burmese species. The imbricated bands upon the base are somewhat more prominent in the Burmese fossil than in *Voluta elevata.*

*Occurrence.*—1½ miles S.W. of Kywe-u on the Mitche footpath, junction of streams; Thetkegyin; 3½ miles W.S.W. of Yethama along the Nagagyin Chaung; 2 miles north of Zabyaw.

ATHLETA (VOLUTOCORBIS) EUGENIÆ n. sp.

Pl. 15, figs. 5, 7.[1]

1909. *Volutospina Sykesi* d'A. and H. sec. Cossmann and Pissarro.—*Pal. Ind.*, new ser., Vol. III, Mem. No. 1, p. 23, Pl. II, figs. 32, 33.

This shell also exhibits the closest resemblance to *Voluta elevata* Sow. from the eocene of Europe from which it is distinguished principally by the character of the axial ornaments which, in the European specimens can be more readily assimilated to genuine ribs than in the Indian shell where they assume more the character of angular corrugations, the floor of the depressions being just as

[1] Excellent figures of the well preserved specimens from zone 4 of the Ranikot have been published in the *Palæontologia Indica* (*loc. cit. in syn.*). The present illustrations have for their object to show the same species as occurring in zone 3 and in another locality of zone 4.

angular as the crest of the elevations, while in the European form the shallow intervals are flat or concave. Consequently the Indian form exhibits the characters of a genuine *Volutocorbis* more than the European species. Nevertheless, both *Athleta Eugeniæ* and *Athleta elevata* stand on the border-line between *Volutocorbis* and *Volutospina*.

In the monograph describing the Ranikot fauna, published in the *Palæontologia Indica* (*loc. cit. in syn.*), this shell was referred to *Voluta Sykesi* d'A. and H., which is now known to represent the immature stage of the Sind variety of *Voluta dentata* Sow., a Gáj fossil. The adult shells of both species are quite different. The immature shells exhibit a certain general similarity but are readily distinguishable on closely comparing the actual specimens. One of the most conspicuous differences is the position of the posterior ledge which, in the earlier whorls of *Volutospina dentata* is not horizontal and is much less prominent than in the corresponding whorls of *Volutocorbis Eugeniæ*, and which corresponds with the interval between the two first rows of crenulations, while in *Volutocorbis Eugeniæ* it is situated between the first row of crenulations and the actual suture. The axial ribs of *Volutospina dentata* also increase rapidly in number with increasing growth, while their number, in each successive complete volution, remains stationary or increases very slightly on the spire of *Volutocorbis Eugeniæ*.

*Occurrence.*—Upper Ranikot. Zone 3 : Jhirak (Vredenburg, K$\frac{7}{820}$). Zone 4 : Jhirak (Fedden, G$\frac{280}{124a}$ ; Vredenburg, K$\frac{7}{178}$) ; left bank of Indus opposite Jhirak (Vredenburg). The occurrences from other horizons recorded in the Memoir on the Ranikot fauna belong to other species.

### ATHLETA (VOLUTOCORBIS) VICTORIÆ n. sp.

Pl. 15, fig. 4.

This shell, in most of its characters, exhibits the closest resemblance to *Voluta radula* Sow. from the cretaceous of southern India, but is distinguished by its more regularly distributed crenulations and the much shallower anterior concavity, indicating that the anterior part of the columella cannot be diverted as in the south Indian form.

*Occurrence.*—Upper Ranikot. Zone 1 : underscarp of Jakhmari peak (Noetling).

ATHLETA (VOLUTOCORBIS) BURTONI n. sp.

Pl. 15, fig. 2.

This shell exhibits the closest resemblance to *Voluta scabricula* [Sol.] from the upper eocene of the Anglo-Parisian region from which it is distinguished by its smaller size and somewhat more convex spire-whorls. The structure of the columella and the disposition of the columella folds are practically identical in the European and Indian fossils. *Volutocorbis Victoriæ* is larger with more convex spire-whorls and more evenly distributed crenulations.

*Occurrence.*—Upper Ranikot. Zone 1: two miles east of Kandaira, Vera plain east (Fedden, G $\frac{226}{156}$, G $\frac{280}{131}$); north of Leilan coal pit (Fedden, G $\frac{280}{132b}$); underscarp of Jakhmari hill (Noetling, K $\frac{7}{659}$).

ATHLETA (VOLUTOCORBIS) ARCHIACI Dalton.

1883. *Mitra* sp.—Boettger, Pal., suppl. Vol. III, fasc. 10 and 11, p. 134, Pl. XI, fig. 11.

1908. *Voluta d'Archiaci* Dalton.—*Q. J. G. S.*, Vol. LXIV, p. 640, Pl. LV, fig. 5.

1914. *Volutilithes (Volutocorbis) Ickei* Martin.—*Samml. d. geol. R.—Mus. in Leid,* new ser., Vol. II, p. 134, Pl. III, figs. 70, 71.

*Athleta Ickei* Martin, from the upper eocene of Java, agrees so essentially with this fossil that the slight differences which it exhibits are insufficient for specific distinction.

The principal difference of the Burmese form resides in the somewhat less crowded spiral imbrications of the body-whorl, the ornamentation being apparently still flatter than in the type specimen of the Java form, and excessively regular, the whole surface being divided into almost perfectly square spaces by the evenly spaced, very narrow, shallow furrows that divide the very flat imbrications, both spiral and axial. The circumsutural channel surrounded by an almost vertical rim of crenulations anteriorly separated from the next row of crenulations by a very narrow spiral band on the later spire-whorls and on the body-whorl, is disposed exactly as upon the Javanese type. There are also, as in the Javanese form, three very prominent columellar folds anteriorly to which there is another subsidiary fold, which disposition corresponds with one of those recorded by Martin for the Javanese fossils. Again, as in the Javanese form, there is no trace of a columellar lip posteriorly to the columellar folds. The walls of the shell are internally lirate.

*Dimensions.*—The restored measurements of the solitary specimen at present available in Calcutta are as follows :—

| | mm. |
|---|---|
| Height . . . . . . . . . . . . | 41 |
| Thickness . . . . . . . . . . . | 20 |
| Height of spire . . . . . . . . . | 12 |
| Height of body-whorl . . . . . . . . | 33 |

The type figured by Martin measures 44×23 mm., while some of the fragments from Java indicate, according to Martin, a maximum height of 60 mm.

*Occurrence.*—Stream between 32nd and 31st mile, nearly 31¼, on the Yaw-Pasok Road, Sheet 84 $\frac{K}{3}$ ; also north-east of Subagyidan, Minbu district (Dalton).

## Genus : VOLUTILITHES Swainson, 1831.

The following species of *Volutilithes* are known from the Tertiary formation of India :—

1. *Volutilithes jhirakensis* C. and P.
2. " *arakanensis* n. sp.
3. " (?) *sihesurensis* [d'A. and H.] (Descr. an. foss. gr. numm. Inde, p. 327, Pl. XXXII, fig. 7, Pl. XXXIII, fig. 12). Eocene of the Salt Range.

The generic attribution of the last-named species is doubtful. D'Archiac and Haime have compared it with *Voluta muricina* Lamk., the genotype of *Volutilithes*, and it is therefore provisionally placed in that genus.

## VOLUTILITHES JHIRAKENSIS C. and P.

1909. *Volutilithes jhirakensis* Cossmann and Pissarro.—*Pal. Ind.*, new ser., Vol. III, Mem. No. 1, Pl. III, figs. 13, 14.

This species was figured in the monograph of the Ranikot fauna published in the *Palæontologia Indica* (*loc. cit. in syn.*), but was apparently overlooked in the preparation of the descriptions. I have endeavoured to remedy this deficiency.

This shell closely resembles *Voluta muricina* Lamk., genotype of *Volutilithes*, from the middle eocene of the Paris region from which it is distinguished by its shorter spire. It is also very closely related to *Volutilithes sanurensis* Oppenheim, from the Upper Mokattam of Egypt (*Pal.* Vol. XXX, 1906, 3rd part, p. 328, Pl. XXIV, fig. 21) with which it shares the circumsutural furrow regarded by Oppenheim as its chief distinguishing feature from *Voluta muricina*. The Egyptian species is distinguished by the more definite posterior angulation of its whorls developed not only on the body-whorl but also upon the spire-whorls upon which it is not observed in the Sind fossil. The Egyptian shell also appears to have a more ventricose body-whorl.

*Occurrence.*—Upper Ranikot. Zone 4 : Jhirak (Vredenburg $K\frac{7}{187}$); left bank of Indus opposite Jhirak (Vredenburg $K\frac{7}{330}$).

### VOLUTILITHES ARAKANENSIS n. sp.

Pl. 16, fig. 1.

? 1895. *Voluta Junghuhni* (?) Martin.—*Samml. des. geol. Reichs-Mus. in Leiden*, new ser., Vol. I, p. 74, Pl. XI, fig. 167.

In spite of the poor state of preservation of this shell, the straightness of the columella, the pronounced anterior notch and differentiated zone of accretions, as well as the disposition of the columellar folds, clearly establish its position within the genus *Volutilithes*. It is specially characterised by the proportions of its spire which is exceptionally short for the genus. Amongst European species, the only one with so short a spire is *Volutilithes Goldfussi* [Desh.], from the upper eocene of the Paris region, which is much more convex. The only other Indian species is *Volutilithes jhirakensis* C. and P., from the lower eocene of Sind, which also has a relatively short spire and which closely resembles in shape the Burmese fossil, but in which the body-whorl carries much more distinct ribs which tend to develop into spines along the posterior angulation of full-grown specimens. The specimen from "Mount Sela" in Java, doubtfully referred by Martin to *Voluta Junghuhni* closely resembles the Burmese fossil.

*Occurrence.*—Kyaukkwet Chaung.

## Genus : LYRIA Gray, 1847.

The following species of *Lyria* are known from the Tertiary formation of India :

1. *Lyria Cossmanni* n. sp.
2. „ *Feddeni* n. sp.
3. „ *varicosa* n. sp.
4. „ *anceps* Micht. Nari of Sind and Baluchistan.
5. „ *jugosa* J.de C. Sow. Gáj of Kachh and Sind.

### LYRIA COSSMANNI n. sp.

1909. *Lyria sihesurensis* d'A. and H. *sec.* Cossmann and Pissarro.—*Pal. Ind.*, new ser., Vol. III, Mem. No. 1, p. 29, Pl. III, figs. 25, 26[1] (*non* Pl. II, fig. 31=*Lyria Feddeni*).

In the monograph describing the Ranikot fauna published in the *Palæontologia Indica* (*loc. cit. in syn.*), under the heading of *Lyria sihesurensis* d'A. and H., two different species have been included, neither of which corresponds with d'Archiac and Haime's species. The specimen figured in figs. 25 and 26, Pl. III (and fig. 26, Pl. II), is from Jhirak and belongs to zone 4 of the upper Ranikot. It may be distinguished as *Lyria Cossmanni.* The specimen represented in Pl. II, fig. 31, was obtained to the north of Leilan coal pit, from the strata of zone 3. It may be named *Lyria Feddeni.*

The detailed description in the Ranikot monograph refers exclusively to the Jhirak specimen with the exception of the final clause regarding the columellar folds, which refers to the species hereafter described as *Lyria Feddeni.* The columellar lip is not preserved in the available specimens of the Jhirak form.

In d'Archiac and Haime's "Description", *Voluta sihesurensis,* a Salt Range fossil of middle eocene age is illustrated with two figures which the authors of the Ranikot monograph have interpreted as representing separate specimens, which they have attributed to two different species. An examintion of d'Archiac and Haime's types has shown that both figures represent the same specimen. Moreover, it is not a cast as might be thought from the appearance of the illustrations, but it has the shell well preserved. The genus of the Salt Range fossil is doubtful. It may be a *Volutilithes.*

[1] Fig. 26, Pl. II, represents the same specimen as fig. 26. Pl. III.

It differs from the Jhirak fossil owing to its more rounded spire-whorls without any spinose terminations to the ribs, while, on the body-whorl, the ribs become wide-spaced, coarse, blunted and nodose in a manner of which there is no indication in specimens of the same size of the Jhirak form.

On account of its oblique ribs, the Jhirak fossil was compared by the authors of the Ranikot monograph with the diminutive *Lyria Coroni* Morlet, of the Paris eocene. Except for the obliquity of the ribs, it closely resembles *Lyria turgidula* [Desh.] from the Paris eocene, in dimensions, outline, proportions, and ornamentation.

*Occurrence.*—Upper Ranikot. Zone 4: Jhirak (Vredenburg $K\frac{7}{174}$, $K\frac{7}{176}$).

### LYRIA FEDDENI n. sp.

1909. *Lyria sihesurensis* d'A. and H. *sec.* Cossmann and Pissarro.—*Pal. Ind.*, new ser., Vol. III, Mem. No. 1, p. 29, Pl. II, fig. 31 (*non* Pl. II, fig. 26, Pl. III, figs. 25, 26=*Lyria Cossmanni*).

Large-medium, elongate, with broad conoidal spire slightly exceeding one-quarter of the total height.

The apex is missing. The number of spire-whorls following the protoconch is probably four or five. They are separated by linear sutures. Their outline is somewhat hemispherical, dome-shaped, the height being equal to two-fifths of the width at early stages of growth, increasing to nearly half the width in the last spire-whorl, the maximum thickness coinciding with the anterior margin. Each whorl carries twelve moderately prominent blade-like ribs, narrower than the intervening spaces, slightly curved with forward facing concavity, steeply antecurrent to both sutures, the apex of the curve being situated nearer to the posterior than to the anterior margin and coinciding with the maximum prominence of the ribs, without any tendency towards the formation of spines. There are no spiral ornaments. The lines of growth share the direction of the ribs.

The large elongate body-whorl measures eight-ninths of the total height. It exhibits posteriorly an elongate ovoid convexity, the degree of curvature of which decreases in an anterior direction till the outline anteriorly becomes almost rectilinear, or even, on the left side of the shell, slightly concave in consequence of the slight bulge of the winding zone of accretions of the terminal notch.

The axial ribs, the number of which is reduced to ten, are slightly more prominent than on the spire. Posteriorly they are disposed in the same manner as has already been described for the spire-whorls. Throughout a considerable part of their length they are practically vertical, finally becoming slightly curved and anteriorly retrocurrent on approaching the anterior extremity of the shell, finally disappearing before reaching the anterior bulging zone, being replaced by lines of growth which recede anteriorly till they join the sinuous accretions of the terminal bulging zone. As with the spire-whorls, there are no spiral ornaments.

The narrow aperture is angulated posteriorly, feebly contracted anteriorly. The feebly twisted terminal edge of the columella is rather steeply oblique, and, with an angular bend passes into an almost vertical portion which posteriorly joins the base of the penultimate whorl. At about the level of the bend is an oblique spiral fold followed apparently by two more folds which are ill-seen in consequence of a rocky incrustation. The columellar lip is thin and narrow and carries close-set, short, oblique ridges throughout the greater part of its length. The outer lip, externally thickened by the last rib, is steeply antecurrent to the suture and is vertical throughout the greater part of its length.

*Dimensions.*

| | | |
|---|---|---|
| Height | 46 | mm. |
| Thickness | 22 | ,, |
| Height of spire | 12 | ,, |
| Height of body-whorl | 40 | ,, |

*Occurrence.*—Upper Ranikot. Zone 3: north of Leilan coal pit (Fedden G $\frac{280}{129}$).

*Comparison.*—This shell is not closely related to any other previously described species.

LYRIA VARICOSA n. sp.

Pl. 15, fig. 3.

This fossil belongs to the same group of fusoid varicose species with numerous columellar folds as *Lyria anceps* [Micht.] from the oligocene of Liguria and of north-western India, and *Lyria jugosa* [Sow.] from the lower miocene of Kachh and Sind. It has a relatively shorter spire and wider-spaced ribs than *Lyria anceps.* Owing to the narrowness and feeble depth of the sutural groove, the spire-whorls do not exhibit the same distinctly stepped appearance as in *Lyria jugosa.* But for its shorter spire and the presence of varices, it corresponds exactly with Bellardi's figure of *Lyria parens* (Moll. terr. terz. Piem. e Lig., parte VI, p. 6, Pl. I, fig. 2) of which it is perhaps to be regarded as a variety.

*Occurrence.*—Ngahlaindwin, Payagyigon.

### Genus : AULICA[1] Gray, 1847.

The following species of *Aulica* are known from the Tertiary of India :

1. *Aulica Sismondai* [d'Archiac].
2. ,, *multidentata* [d'A. and H.] (1854, Descr. an. foss. gr. numm. Inde, p. 326, Pl. XXXII, fig. 1) with which should perhaps be united *Voluta Humberti* d'A. and H. (*op. cit.*, p. 327, Pl. XXXIV, fig. 9). Middle eocene of Sind.
3. ,, *salsensis* [d'A. and H.] (1854, Descr. an. foss. gr. numm. Inde, p. 328, Pl. XXXIV, figs. 10, 11). Middle eocene of the Salt-Range.
4. ,, *birmanica* [Dalton], perhaps identical with the preceding.
5. ,, (*Aulicina*) *Haimei* [ d'Archiac ].

### AULICA SISMONDAI [d'Archiac].

1850. *Voluta Sismondai* d'Archiac.—Hist. des progrès de la Géol., Vol. III, p. 298.

1854. *Voluta Sismondai* d'Arch.—D'Archiac and Haime, Descr. an. foss. gr. numm. Inde, p. 326, Pl. XXXI, fig. 25.

[1] Rovereto in 1899 (Prime rich. sinonim. sui Gen. dei Gasteropodi, Genoa, *Atti Soc. lig. Soc. nat.*, Vol. X) has altered this name to *Heteroaulica* on account of the previous existence of a genus *Aulicus* Spin. amongst the Coleoptera. Commenting upon this change, Cossmann, in 1901 (Essais Pal. comp., III, p. 252), has regarded it as just admissible in spite of the difference of gender. The difference, though slight, seems nevertheless sufficient, especially as there is not the remotest risk of confusion between a beetle and a *Voluta.* Instead of seizing upon every pretext to alter the existing nomenclature, we should, on the contray, avoid any modification that is not absolutely necessary. In the latest scheme of classification of the *Volutidae* published by Cossmann (1909, Ess. Pal. comp., Vol. VIII, p. 217), *Aulicina* (Rovereto 1899) is the type of a genus with *Heteroaulica* as a sub-genus. By restoring Gray's designation, *Aulica* might assume the position of a generic type to which *Aulicina* could then be subordinated as a sub-genus, and we would thereby avoid the illogical use of a diminutive to designate these large shells.

1909. *Aulicina Haimei* d'Arch.—Cossmann and Pissarro, *Pal. Ind.*, new ser. Vol. III, Mem. No. 1, p. 25, Pl. II, figs. 28, 30 (*non* fig. 27=*Athleta Blanfordi nec* fig. 29=*Aulica Haimei*, *nec* Pl. VIII, fig. 2=*Athleta Blanfordi*).

1909 *Volutoconus ? corrugatus* Cossmann and Pissarro, *Pal. Ind.*, new ser., Vol. III, Mem. No. 1, p. 28, Pl. III, figs. 6, 7.

In its earlier stages of growth, owing to the absence of spines this shell exhibits a very different appearance from that which it assumes at intermediate and adult stages when it reaches a large size and is encircled with rather crowded spines of moderate dimensions. Consequently, in the monograph of the Ranikot fauna published in the *Palæontologia Indica* (*loc. cit. in syn.*), an immature specimen was described as "*Volutoconus ? corrugatus*", though the authors specially mentioned that the sinuosity of the outer lip rendered this generic attribution uncertain. The existence of this sinuosity and the structure of the large protoconch clearly establish the identity of *Volutoconus corrugatus* with d'Archiac's type of *Voluta Sismondai* in which it can clearly be recognised that the first whorl following the protoconch does not bear any spines or nodosities. D'Archiac's type is not full-grown, but it readily establishes a link between the quite immature type of *Volutoconus corrugatus* and the large nodose adult specimens.

*Aulica Sismondai* appears to be related to certain forms from the middle or upper eocene of India or of Egypt, such as *Voluta salsensis* d'A. and H. and *Voluta arabica* Mayer-Eymar. generally distinguished by the feebler development or absence of spines. Amongst related living species, *Voluta aulica* Solander has a relatively much taller spire, while *Voluta imperialis* Lamarck is much larger and more ventricose.

*Occurrence.*—Upper Ranikot. Zone 2, higher beds: 3 miles east of the old coal-pit near Leilan, Vera plain east (Fedden, G $\frac{280}{126}$). Zone 3: north of Leilan coal pit (Fedden, G $\frac{280}{129}$); three miles east of Leilan coal pit, in brown limestone on the road to Unerpur (Fedden G $\frac{280}{127}$). Zone 1: Jhirak (Fedden G $\frac{280}{124a}$, Vredenburg K $\frac{7}{174}$, K $\frac{7}{178}$); left bank of Indus opposite Jhirak (Vredenburg K $\frac{7}{326}$).

AULICA BIRMANICA [Dalton].

? 1854. *Voluta salsensis* d'Archiac and Haime.—Descr. an. foss. gr. numm. Inde, p. 328, Pl. XXXIV, figs. 10, 11.

1908. *Voluta* (?) *birmanica* Dalton.—*Q.J.G.S.*, Vol. LXIV, p. 632, Pl. LVII, fig. 10.

This shell belongs to a group of short-spired species abundantly represented in the Tertiary of India and Australia. Compared with *Voluta Sismondai*, dArchiac and *Voluta Haimei* d'Archiac, from the lower eocene of Sind, it is readily distinguished by the absence of spines, while it is differentiated from *Voluta multidentata* d'A. and H., from the middle eocene of Sind, by its wider-spaced internal folds. Its specific distinctness from *Voluta salsensis* d'A. and H. from the eocene of the Salt Range is doubtful as this latter species is also characterised by rather wide-spaced internal folds.

*Occurrence.*—Kyettein Chaung, N.W. of Man; Kyudaw Chaung, east of Pawk; 3 miles N. of Pyatgale; Thetkegyin, 3½ miles W.S.W. of Yethama; 2 miles N. of Zalyaw.

The type-locality is "Yenanin Chaung, near Banbyin (Thayetmyo district)."

AULICA (AULICINA) HAIMEI [d'Archiac].

1850. *Voluta Haimei* d'Archiac.—Hist. des progrès de la Géol., Vol. III, p. 298.

1854. *Voluta Haimei* d'Arch.—D'Archiac and Haime, Descr. an. foss. gr. numm. Inde, p. 325, Pl. XXXI, figs. 26, 27.

1909. *Aulicina Haimei* d'Arch.—Cossmann and Pissarro, *Pal. Ind.*, new ser. Vol. III, Mem. No. 1, p. 25, Pl. II, fig. 29 (*non* fig. 27=*Athleta Blanfordi*, *nec* figs. 28, 30=*Aulica Sismondai*, *nec*. Pl. VIII, fig. 2= *Athleta Blanfordi*).

1909. *Aulicina pusiola* Cossmann and Pissario.—*Pal. Ind.*, new ser., Vol. III, Mem. No. 1, p. 26, Pl. II, fig. 34, Pl. III, figs. 4, 5.

1909. *Volutoconus funiculifer* Cossmann and Pissarro.—*Pal. Ind.*, new ser., Vol. III, Mem. No. 1, p. 27, Pl. III, figs. 10—12.

In the Ranikot monograph (*Pal. Ind., loc. cit. in syn.*), all the large specimens of *Volutidae* from the Ranikot Series have been referred to *Aulicina Haimei*, to which species none of them belong. These large specimens are adult individuals either of *Aulica Sismondai* which reaches a height of 90 mm., or of *Athleta Blanfordi*, some specimens of which must have attained as much as 130 mm. Full grown specimens of *Aulicina Haimei* do not exceed 45 mm. in height.

Adult specimens of these three species may be differentiated by some easily recognised features.

In *Athleta Blanfordi*, the protoconch is relatively small, not exceeding 2 mm.; the lines of growth on the spire-whorls are crescentic with forward facing concavity; the body-whorl carries ten prominent spines; the entire surface of the shell is smooth; there are three internal spiral folds.

*Aulica Sismondai* has a very large protoconch, measuring up to 8 mm.; the lines of growth on the spire-whorls are sigmoidal; the body-whorl carries from 9 to 12 blunt nodes; the spire-whorls are decorated with spiral threads; there are from 5 to 7 internal spiral folds

In *Aulicina Haimei*, the protoconch averages 4 mm., more or less; the lines of growth on the spire-whorls are nearly straight; the body-whorl carries from seven to nine prominent spines; the spire is covered with crowded spiral threads alternating in two sizes · the number of internal folds is usually ten.

*Athleta Blanfordi* is exclusively restricted to zone 1; *Aulica Sismondai* ranges from zone 2 to zone 4; *Aulicina Haimei* characterises zones 3 and 4.

Compared with the recent *Voluta vespertilio* Linn., the genotype of *Aulicina* Rovereto (= *Vespertilio* Klein), *Voluta Haimei* is distinguished by its relatively shorter spire and its much smaller dimensions.

*Occurrence.*—Upper Ranikot. Zone 3: Jhirak (Vredenburg K $\frac{6}{814}$). Zone 4: Jhirak (Vredenburg, K $\frac{7}{174}$, K $\frac{7}{175}$); left bank of Indus opposite Jhirak (Vredenburg, K $\frac{7}{328}$).

The supposed occurrences from zone 1, mentioned in the Ranikot Memoir, refer to *Athleta Blanfordi*.

### Genus: SCAPHELLA Swainson, 1832.

The species recorded below is the only one hitherto known from the Tertiary of India.

According to Cossmann (Essais pal. comp., fasc. III, p. 127) the geologically earliest recorded representative of this genus is *Voluta piriformis* Forbes from the upper cretaceous of southern India.

### SCAPHELLA HUMILIS n. sp.

Pl. 14, fig. 10.

In shape this shell closely resembles the living *Voluta Junonia* Hwass, the genotype of *Scaphella* which grows to a much larger size. Amongst fossil species, the form nearest related is *Scaphella tongrica* Cossmann from the lower oligocene of North Germany (= *Voluta obtusa* v. Koenen, *non* Emmons), which is also much larger. *Voluta McCoyi* T. Woods and *Voluta polita* Tate from Muddy Creek and other Tertiary exposures of Australia and Tasmania are not much larger than the Burmese shell, but are readily distinguished by their relatively much larger spire.

*Occurrence.*—Thetkegyin.

## Family : MITRIDÆ.

### Genus : MITRA Lamarck, 1799.

The following species of *Mitra* are known from the Tertiary formation of India :

1. *Mitra singuènsis* Vred. (*Rec. Geol. Surv. Ind.*, Vol. LIII, p. 340, Pl XXII, fig. 2). Singu, N.
2. ,, *birmanica* n. sp.
3. ,, *iravadica* n. sp.
4. ,, *buddhaica* n. sp.
5. ,, *chinensis* Gray. var. *subscrobiculata* d'Orb. Gáj of Kachh.
6. ,, *granatinæformis* Martin.
7. ,, *tittabweensis* n. sp.
8. ,, *inquinata* Reeve. Mekran beds.
9. ,, (*Cancilla*) *brachyspira* C. and P. (*Pal. Ind.*, new ser., Vol. III, Mem. 1, p. 30, Pl. III, figs. 31, 32). Lower eocene of Sind.
10. ,, (*Cancilla*) *rembangensis* Martin. (*Samml. d. geol. R.—Mus. in Leiden*, new ser., Vol. I, p. 304, Pl. XLIV, figs. 722, 723). Dalabe, Kyaungon, Kyudawon, Myaukmigon. Thanga. Also probably in the Gáj of Sind.
11. ,, (*Cancilla*) *sucabumiana* Martin. (*Samml. d. geol. R.-Mus. in Leid.*, new ser., Vol. I, p. 303, Pl. XLIV, fig. 721). Dalabe, Kyaungon, Myaukmigon, Myingabaing, Tittabwe.
12. ,, (*Cancilla*) *flammea* Inoy. Pliocene of Karikal and Mekran beds.
13. ,, (*Cancilla*) *circulata* Kiener (Cossmann, *Journ. Conch.*, 1903, Vol. L, p. 123, fig. 13). Pliocene of Karikal.
14. ,, (*Chrysame*) *Sowerbyi* d'Orb. Gáj of Kachh.
15. ,, (*Chrysame*) *kyaungonensis* n. sp.

MITRA BIRMANICA n. sp.

Pl. 16, fig. 5.

This sheli seems related to the living *Mitra rubiginosa* Reeve, in which the ornamentation is more pronounced and the columella bears five folds instead of three, though the two anterior ones are often very feeble.

Amongst fossil species, *Mitra atava* Bellardi, from the pliocene of Bordighera, resembles the Burmese shell very closely, but is larger and has four spiral folds, while *Mitra peracuta* Bellardi, from the miocene of the neighbourhood of Turin is almost identical, but much larger.

*Occurrence.*—Thanga.

MITRA IRAVADICA n. sp.

Pl. 16, fig. 4.

This shell resembles the living *Mitra melaniana* Lamk. from Port Jackson in Australia in which the spiral ornaments are more crowded and the terminal zone of accretions less sharply demarcated.

Several fossil species from the upper tertiary of Europe, such as *Mitra conspicienda* Bellardi and *M. proxima* Bell., from the miocene, and *M. astensis* Bell., and *M. decipiens* Bell. from the pliocene, also resemble the above-described species, but attain larger dimensions.

*Occurrence.*—Migyaungye, Myaukmigon, Myauktin, Titttabwe.

MITRA BUDDHAICA n. sp.

Pl. 16, fig. 9.

Compared with this shell, *Mitra inquinata* Reeve, living in the eastern seas and fossil in the Mekran beds of western India, is distinguished by its slightly more convex whorls and deeper spiral grooves. *Mitra istulata* Reeve, from the Viti Islands, has a closely similar shape, but its spiral striations are apparently more crowded.

*Occurrence.*—Myaukmigon.

MITRA GRANATINÆFORMIS Martin.

1884. *Mitra granatinæformis* Martin.—*Samml. des geol. Reichs-Museums in Leiden*, ser. I, Vol. III, p. 86, Pl. V, fig. 87.

So far as can be ascertained from the available figure and description, the fossil here recorded is specifically identical with *Mitra granatinæformis* Martin occurring in the Tertiary formation of Ngembak in Java. Martin compared the Javanese species with a fossil from the Gáj formation of Kachh hesitatingly referred by Sowerby to *Mitra scrobiculata* Brocchi and renamed by d'Orbigny *Mitra subscrobiculata*, which, on re-examination, does not seem to be specifically different from the living *Mitra chinensis* Gray of the Eastern Seas. The Burmese fossil is certainly very closely related to the Gáj and living species. Moreover, the distinction indicated by Martin as separating both shells, that is the relatively taller aperture of the solitary Java specimen compared with the Kachh specimen figured by Sowerby, does not hold good when more numerous series of shells are examined, for there are many Kachh specimens in which the height of the aperture equals or exceeds half the height of the shell, and is relatively quite as great as in the Javanese type of *Mitra granatinæformis*. Nevertheless, the undoubtedly smaller dimensions of the Javanese and Burmese forms as compared with the Kachh fossil and living shell, constitute a sufficient difference for specific distinction. The Burmese shells have the ornamentation more pronounced than the Kachh and recent species, and a similar difference seems to characterise the Javanese specimen.

Compared with *Mitra scabriuscula* Linn. (=M. *granatina* Lamk.), *M. granatinæformis* is readily distinguished by its smaller size and less prominent sculpture.

*Occurrence.*—Kyudawon, Myauktin.

MITRA TITTABWEENSIS n. sp.

Pl. 16, fig. 8.

This shell resembles the previously recorded form referred to *Mitra granatinæformis* so closely as to give rise to some hesitation as to whether it should not be regarded as a variety of the same species. Nevertheless, the more delicate thinner grooves, their tendency to multiply by intercalation, and the absence of any tendency to a stepped disposition of the suture, constitute constant differences.

*Occurrence.*—Kyaungon, Myaukmigon, Tittabwe. Some rather weathered specimens from Thanga probably also belong to this species.

MITRA (CHRYSAME) KYAUNGONENSIS n. sp.

Pl. 16, fig. 6.

Although the outer lip of the solitary available specimen is incomplete, this species has been referred to the section *Chrysame* of *Scabricula* on account of its extremely close resemblance to *Mitra pellis-serpentis* Reeve which is a typical *Chrysame*, from which the fossil is distinguished by the greater width of the sunken intervals between the raised ornaments, giving a more trellised appearance to the ornamentation, and by the presence of five columellar folds instead of four.

*Occurrence.*—Kyaungon.

Genus: TURRICULA Klein, 1753.

The following species of *Turricula* are known from the Tertiary formation of India:

1. *Turricula birmanica* n. sp.
2. „ *thangaensis* n. sp.
3. „ *minima* n. sp.
4. „ *lirocostata* Cossmann (1899, Essais Pal. comp., III, p. 196, Pl. VIII, figs. 20, 21). Pliocene of Karikal.

TURRICULA BIRMANICA n. sp.

Pl. 16, fig. 10.

This shell is so closely related to *Turricula zonalis* [Inoy and Gaimard] (Voy. Astrolabe, II, p. 654, Pl. XLV *bis*, figs. 16, 17) from the Philippines, as to render specific discrimination uncertain. The only difference that can be detected is that the fossil is somewhat more concave at the neck and consequently more rostrated. The ornamentation appears to be strictly identical.

*Occurrence.*—Payagyigon, Tetma.

TURRICULA THANGAENSIS n. sp.

Pl. 16, fig. 2.

This shell exhibits the closest resemblance to *Turricula gembacana* Martin from the Tertiary formation of Java, but its spire is not distinctly stepped as in the Javanese form, the sutures are less impressed, and the spiral striations appear to be wider-spaced.

*Turricula taeniata* Lamk., from the eastern seas, has a very similar appearance, but grows to a much larger size.

*Occurrence.*—Thanga.

TURRICULA MINIMA n. sp.

Pl. 16, fig. 7.

This species is closely related to the equally small *Turricula lirocostata* Cossmann (Essais de Pal. comp. III, p. 196, Pl. VIII, figs. 20, 21), from the Tertiary of Karikal. The Burmese fossil is still more elongate, its ribs are relatively broader as they leave practically no interspaces; the spiral ornaments are much more delicate and much more crowded.

*Occurrence.*—Thanga.

Genus VOLVARIA Lamarck, 1801.

The following species is the only representative of this genus so far known from the Tertiary formations of India.

VOLVARIA BIRMANICA Noetling.

1895. *Volvaria birmanica* Noetling. *Mem. Geol. Surv. Ind.*, Vol. XXVI, p. 37, Pl. VIII, fig. 7.

1901. *Volvaria birmanica* Noetling. *Pal. Ind.*, new ser., Vol. I, part 3, p. 322, Pl. XXI, fig. 11.

1921. *Volvaria birmanica* Noetling, Vredenburg. *Rec. Geol. Surv. Ind.*, Vol. LI, pp. 275, 286.

This species bears the closest resemblance to *Volvaria multicingulata* Sandberger, from the oligocene of Mainz, from which it is distinguished by its acuminate non-umbilicated apex and by the presence of four columellar folds instead of three as in the Rhenish species. *Volvaria acutiuscula* Sow. from the upper eocene of the Anglo-Parisian region is also very closely related, but is likewise distinguished from the Burmese shell by the presence of only three columellar folds as well as by its more crowded spiral ornaments.

*Occurrence.*—Minbu, " zone of *Cancellaria martiniana*."

## EXPLANATION OF PLATES.

### PLATE 14.

FIG. 1.—OLIVANCILLARIA BIRMANICA n. sp. Tittabwe. $\frac{1}{1}$.
FIG. 2.—ANCILLA (SPARELLA) BIRMANICA n. sp. Myauktin. $\frac{3}{2}$.
FIG. 3.—OLIVANCILLARIA (AGARONIA) COSSMANNI n. sp. Tittabwe. $\frac{3}{2}$.
FIG. 4.—OLIVANCILLARIA (AGARONIA) PAGODULA n. sp. Tittabwe. $\frac{3}{2}$.
FIG. 5.—ANCILLA (SPARELLINA) PŒNITENS n. sp. Mindegyi. $\frac{3}{2}$.
FIG. 6.—HARPA (EOCITHARA) BIRMANICA n. sp. Thetkegyin. $\frac{2}{1}$.
FIG. 7.—MARGINELLA ORIENTALIS n. sp. Thetkegyin. $\frac{5}{2}$.
FIG. 8.—ATHLETA (NEOATHLETA) ROSALINDÆ n. sp. Thetkegyin. $\frac{3}{2}$.
FIG. 9.—ANCILLA (SPARELLA) INDICA VRED. var. ARAKANENSIS n. var. Tetma. $\frac{3}{2}$.
FIG. 10.—SCAPHELLA HUMILIS n. sp. Thetkegyin. $\frac{3}{2}$.
FIG. 11.—CRYPTOSPIRA BIRMANICA n. sp. Tittabwe. $\frac{3}{1}$.

### PLATE 15.

FIG. 1.—ATHLETA (VOLUTOSPINA) ANNANDALEI n. sp. Thetkegyin. $\frac{3}{2}$.
FIG. 2.—ATHLETA (VOLUTOCORBIS) BURTONI n. sp. Probably from the underscarp of Jakhmari peak. $\frac{2}{1}$.
FIG. 3.—LYRIA VARICOSA n. sp. Payagyigon. $\frac{3}{1}$.
FIG. 4.—ATHLETA (VOLUTOCORBIS) VICTORIÆ n. sp. Underscarp of Jakhmari. $\frac{3}{2}$.
FIG. 5.—ATHLETA (VOLUTOCORBIS) EUGENIÆ n. sp. Upper Ranikot, zone 3 : Jhirak. $\frac{2}{1}$.
FIG. 6.—ATHLETA (VOLUTOSPINA) AUGUSTÆ n. sp. Thetkegyin. $\frac{2}{1}$.
FIG. 7.—ATHLETA (VOLUTOCORBIS) EUGENIÆ n. sp. Upper Ranikot, zone 4 : left bank of Indus opposite Jhirak. $\frac{2}{1}$.
FIG. 8.—ATHLETA (NEOATHLETA) THEOBALDI n. sp. Sit Chaung. $\frac{1}{1}$.
FIG. 9.—ATHLETA (VOLUTOSPINA) AUGUSTÆ n. sp. Thetkegyin. $\frac{3}{2}$.

### PLATE 16.

FIG. 1.—VOLUTILITHES ARAKANENSIS n. sp. Kya kkwet Chaung $\frac{1}{1}$.
FIG. 2.—TURRICULA THANGAENSIS n. sp. Thanga. $\frac{2}{1}$.
FIG. 3.—ATHLETA (VOLUTOSPINA) ISABELLÆ n. sp. Near Leilan on the road to Unerpur, Sind. 9.
FIG. 4.—MITRA IRAVADICA n. sp. Myauktin. $\frac{1}{1}$.
FIG. 5.—MITRA BIRMANICA n. sp. Thanga. $\frac{3}{2}$
FIG. 6.—MITRA (CHRYSAME) KYAUNGONENSIS n. sp. Kyaungon. $\frac{4}{1}$.
FIG. 7.—TURRICULA MINIMA n. sp. Thanga. $\frac{5}{1}$.
FIG. 8.—MITRA TITTABWEENSIS n. sp. Kyaungon. $\frac{3}{2}$.
FIG. 9.—MITRA BUDDHAICA n. sp. Myaukmigon. $\frac{3}{1}$.
FIG. 10.—TURRICULA BIRMANICA n. sp. Tetma. $\frac{3}{2}$.

# ON THE STRUCTURE OF THE CUTICLE IN GLOSSOPTERIS ANGUSTIFOLIA BRONGN. BY B. SAHNI, *Professor of Botany, University of Lucknow.* (With Plate 17).

THE genus *Glossopteris* is known only from impressions. It comprises over a dozen species, of which the distinctions are based entirely on such characters as the shape of the leaf and the details of the venation. In dealing with material of this nature any information that takes us beyond the gross features would be welcomed. Whenever the preservation is favourable, therefore, a study of the cuticular structure may usefully be made, for it is likely to help in the diagnosis of the species. And a special advantage of such studies is that, once we have learnt to associate certain epidermal characters with certain species, it would thenceforth be easy to identify even small fragments which may otherwise be unrecognizable. To the student of fossil floras the value of such identifications is considerable.

During a recent visit to Raniganj I collected some plant remains with a view to investigate their epidermal structure. I had only a few hours at my disposal, and although a considerable number of specimens were obtained, they were mostly small fragments. It was easy to refer the majority of them to either *Glossopteris* or *Gangamopteris*, but the species could not be ascertained except in one case. This specimen was a broken leaf which, by its linear shape and the character of its venation, could be recognised as *Glossopteris angustifolia* (see natural size [photograph on Pl. 17, fig. 1). The fossil is in fact almost identical, except for its larger dimensions, with those figured by the late Professor Zeiller (6) from the same locality.

None of my specimens were found *in situ*, but there is scarcely any doubt that they all belong to the Raniganj Stage of the Lower Gondwana System, these being the only beds that are worked at the mine visited. These beds are probably homotaxial with the Upper Permian of Europe.

Quite a number of the fossils yielded well preserved cuticular preparations among which apparently several distinct species are represented. But it would be scarcely worth while describing all these before they can be assigned to their respective species: only those prepared from *G. angustifolia* are here described.

The only species of *Glossopteris* whose epidermal structure we know is *G. indica* Schimp. In 1896 Zeiller (5) gave a figure showing a few stomata among epidermal cells of a rectangular shape. The cuticle appears to have been relatively thick, for the stomata are shown sunk in depressions with well-defined contours. The lumina of contiguous cells are shown far removed from each other, as if the separating walls were exceedingly thick, but it is doubtful if this is a natural feature. There is no mention of epidermal hairs or appendages of any kind.

In *G. angustifolia*, on the other hand, as a glance at the figures will show, the structure of the epidermis is very different; and this is a point of some taxonomic use, because the distinctness of the two forms has several times been questioned. Thus, while Zeiller (5, 6) regarded them as distinct species, Professor Seward (3) originally included the two forms as varieties under *G. Browniana* Brongn., later (4) according them specific rank on grounds of convenience. In 1905 Dr. Newell Arber (1) thought it probable that the leaves known as *G. angustifolia* may have been borne on the same plant as *G. indica*, a possibility that has more recently been admitted also by Dr. Halle (2), although this author, like others, is inclined towards a provisional separation.

The following account of *G. angustifolia*, when compared with what we know of *G. indica*, appears to leave no doubt that the two forms are distinct.

The stomata are confined to one surface of the leaf which, by analogy with existing land plants, may safely be taken as the lower. The cell-walls in the upper epidermis are sinuous, the cells being about three times as long as broad (Pl. 17, fig. 2).

The lower epidermis is more complex (Pl. 17, fig. 3). The stomata occur in distinct areas which are separated from each other by a net-work of narrow strips devoid of stomata. It is likely that this net-work corresponds to that formed by the veins of the leaf. The epidermal cells overlying the veins are similar to those of the upper epidermis, except that the sinuosities in their walls are less pronounced. The cells of the stomatiferous regions are much smaller than those of the parts devoid of stomata; they are also more or less isodiametric. A feature worthy of note is that the subsidiary cells (*i.e.*, the cells in the immediate neighbourhood of the stomata) are often distinguished by large ring-shaped marks. These marks can only be either short papillæ on the cuticle or the scars of epidermal hairs. The impression gained is that a tubular appendage has dropped off, the stain-less centre of the scar representing the lumen of the hair. The presence of epidermal hairs in the region of the stomata is easy to explain on physiological grounds.

The subsidiary cells vary from four to six in number. The two guard-cells of each stoma together form an elliptical area, and between them the slit-like pore is as a rule clearly visible. The orientation of the stomata does not seem to follow any rule.

I may also mention that on the tangential walls of some cells numerous extremely fine punctuations are seen, closely arranged along wavy parallel lines which are themselves close together. These wavy lines are not in continuation from cell to cell, but follow a direction of their own within their respective limits. They seem to represent an unusually fine sculpturing of the cuticle—too fine to be accurately drawn on the scale of the figures in this note.

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4. *Ibid* . . . (1910) Fossil Plants, Vol. II, p. 508.

5. Zeiller, R. . . (1896) Études sur quelques plantes fossiles, en particulier *Vertebraria* et *Glossopteris*, des environs de Johannesburg (Transvaal). *Bull. Soc. géol. France.* Sér. III, Vol. XXIV, fig. 13, pp. 368, 369.

6. *Ibid* . . (1902) Observations sur quelques plantes fossiles des Lower Gondwanas. *Pal. Ind.*, new ser. Vol. II. Mem. No. 1, pl. IV, figs. 3, 4.

## EXPLANATION OF PLATE.

PLATE 17

FIG. 1.—GLOSSOPTERIS ANGUSTIFOLIA BRONGN.—PORTION OF A FROND COLLECTED AT RANIGANJ. NATURAL SIZE.

FIG. 2.—GLOSSOPTERIS ANGUSTIFOLIA BRONGN.—CAMERA LUCIDA SKETCH OF UPPER EPIDERMIS. CIRCA × 240.

FIG. 3.—GLOSSOPTERIS ANGUSTIFOLIA BRONGN.—CAMERA LUCIDA SKETCH OF LOWER EPIDERMIS. SHOWING STOMATA, SUBSIDIARY CELLS AND SCARS OF EMERGENCES. CIRCA × 240.

# REVISION OF SOME FOSSIL BALANOMORPH BARNACLES FROM INDIA AND THE EAST INDIAN ARCHIPELAGO. BY THOMAS H. WITHERS, F.G.S. (With Plates 18 and 19).

IN 1905, a series of Miocene fossils from the Mekran Coast, formerly in the collection of the late Miss C. Birley, and now in the Geological Department of the British Museum, were described by Messrs. R. B. Newton, H. W. Burrows, and Dr. H. Woodward (*Geol. Mag.*, Dec. v, vol. ii, pp. 293-310). These fossils were found in nodules obtained from the beach off the Ormara Headland, facing the Mekran or Baluchistan Coast, 130 miles W. of Karachi, and they were procured for Miss Birley by Mr. F. W. Townsend, Chief Executive Officer of the Submarine Telegraph Service in the North Indian Ocean.

The following year Mr. F. W. Townsend presented to the Geological Department of the British Museum a further series of nodules from the same locality and horizon as those just mentioned, and some of these when broken open were found to contain examples of *Balanus* precisely similar to those described by Dr. H. Woodward (*Geol. Mag.*, 1905, p. 310, fig. 2).

When investigating this new material from Mekran together with some specimens submitted to me by the late Mr. E. W. Vredenburg of the Geological Survey of India, it became necessary to compare the material with the original specimens from Kachh and Sind described by J. de C. Sowerby (1840), and by d'Archiac and Haime (1854), as *Balanus sublævis*, with the result that it showed the necessity for some revision of the nomenclature.

Since the Geological Department of the British Museum possesses in addition to the above important material from India, the series of *Balanus* from Karachi mentioned by Darwin (1855, p. 5), the specimens from Burma recorded by L. V. Dalton (1908) as *Balanus tintinnabulum*, and some specimens from Java named by Prof. K. Martin as *B. tintinnabulum*, it would seem a fitting opportunity for a revision of the whole of this material.

Indeed no progress could be made with the Indian *Balani* until this early described material had been re-studied, for the various authors have paid no attention to the structure of the shell-walls, and the opercular valves, which are so essential for the correct determination of species, have so far been entirely wanting.

Family: BALANIDÆ Gray.

Sub-family: BALANINÆ Darwin.

Genus: BALANUS E. M. da Costa.

Compartments six, and except for the carina, usually having radii: sheath distinctly differentiated from the rest of the inner wall. Scutum and tergum interlocked.

Genotype: BALANUS BALANUS (Linnæus).

Sub-genus: MEGABALANUS Hoek.

*Balani* having the parietes, basis and radii permeated by pores.

Sub-genotype: BALANUS TINTINNABULUM (Linnæus).

BALANUS (MEGABALANUS) JAVANICUS sp. nov.

(Plate 18, figs. 1—8.)

1879-80. *Balanus tintinnabulum* Linnæus: J. K. L. Martin, Die Tertiärschichten auf Java, p. 131, pl. xxiii, figs. 3, 3a, 4, 4a.

1879-80. *Balanus amphitrite* Darwin: J. K. L. Martin, *Ibid.* p. 132, pl. xxiii, figs. 8, 9.

1883. *Balanus tintinnabulum* Linnæus: J. K. L. Martin, Palæontologische Ergebnisse von Tiefbohrungen auf Java: *Samml. geol. Reichs-Mus. Leiden*, ser. i, Bd. iii, Hft. i, p. 40, pl. iii, fig. 36.

*Diagnosis.*—Scutum smooth with the growth-ridges not at all raised and not forming prominent teeth on the occludent margin, basal margin about two-thirds the height. Septa of radii denticulated almost wholly on the lower side only. Tergum with a closed longitudinal furrow.

*Distribution.*—Miocene (Aquitanian): Java.

*Holotype.*—The shell figured Pl. 18, fig. 1, In. 20239.[1]

[1] This and similar numbers are those under which the specimen is registered in the collections of the British Museum.

*Description.*—Shell rather small, cylindrical, apparently varying between 16-18 mm. in height, walls folded but not regularly ribbed, parietes narrow. Radii wide with level summits, and their lateral edges as well as the opposed sutural edges coarsely septate; the septa are rather short and denticulated almost wholly on the lower side only (Pl. 18, figs. 2a, 3) and in a polished section the denticles are seen to reach the inner margin and to form small pores or openings near the inner lamina (Pl. 18, fig. 3); the horizontal pores of the radii (Pl. 18, fig. 2a) are small but readily seen. Basis (Pl. 18, fig. 8) with a distinct underlying cellular layer. Inner surface of parietes distinctly ribbed, about 14 ribs in one rostrum and 16 in another, and the ribs near the base stand out and are denticulated on both sides: parietal pores somewhat rounded, with occasional lamellæ sometimes extending to the inner lamina to form additional ribs which are denticulated, but in other cases the lamellæ do not extend quite to the inner lamina.

Scutum (Pl. 18, figs. 4a, b) somewhat elongate with the basal margin rather short, surface smooth, with narrowly spaced growth-ridges which do not form prominent teeth along the almost straight occludent margin; there is no trace of longitudinal striæ. Only a narrow portion of the valve along the tergal margin is deflected. The articular ridge is high and prominent and apparently reflexed, for the valve is worn; there does not appear to be any distinct adductor ridge, but the adductor muscle pit is deep.

Tergum (Pl. 18, figs. 5, 6, 7) with the longitudinal furrow almost entirely closed, the basal margin varying from almost straight to steeply sloping towards the spur, and the basi-carinal angle variously rounded. Spur short, standing well away from the level of the rest of the inner surface, with bluntly rounded, almost truncated extremity, and situated about its own length from the basi-scutal angle. Articular ridge well-developed, and the articular furrow deep. Inner surface smooth to slightly roughened and without crests for the depressor muscle.

*Remarks and comparison with other species.*—Prof. Martin (1879-80, figs. 3, 4) first described this small barnacle as *Balanus tintinnabulum* and he figured (fig. 3) a shell having a height of 18·6 mm., and a width of 15·1 mm., together with a detached scutum (fig. 4). It is doubtful whether the group of larger shells figured by him later (1883, fig. 36) belong to the same form, but the rostrum figured by him (1879-80, figs. 8, 9) as *Balanus amphitrite* would seem to belong here. In the

Geological Department of the British Museum were two pieces of shelly marl from Java containing the remains of a species of *Balanus* received in exchange from Prof. Martin and named by him as *Balanus tintinnabulum*. From one of these pieces I was able to develop a complete, small, but apparently fully-grown shell, having a height of 15·8 mm. and a width of 10·5 mm. (Pl. 18, fig. 1) and from both pieces I was able to extract altogether some thirteen portions of the shell and opercular valves including those figured, Pl. 18, figs. 1-8. These specimens, which are now registered, In. 20239—In. 20251, are evidently conspecific with those described by Prof. Martin (1879-80) as *B. tintinnabulum*. The structure of the septa of the radii of these barnacles is quite unlike that seen in *B. tintinnabulum*, for in that species the septa are straight, long, and regularly denticulated on both sides, and although the tergum is of the type seen in *B. tintinnabulum* and its varieties, the scutum is quite different, and consequently we are not justified in referring the present barnacles to that species, or to consider it as a variety, although it is clearly a related form. A closer relationship, however, is shown with a small recent barnacle described by Pilsbry (1916, p. 72 (fig. 12), Pl. xii, figs. 3-3g) as *Balanus algicola* from South African waters. That species agrees with the present form in having more simple radial septa than in *B. tintinnabulum*, for they are denticulated on the lower side only, but the denticles in *B. algicola* do not appear to be so numerous or so irregular. Dr. Pilsbry did not notice in his very numerous specimens of *B. algicola* an underlying cellular layer to the basis, although this is the case in *B. javanicus*. The main difference lies in the opercular valves, for in *B. algicola* the scutum is very broad, the growth-ridges are wide apart and prominent, and form teeth along the occludent edge, and a broad shallow depression extends down the middle of the valve. The tergum has a more or less open longitudinal furrow, and the basi-carinal angle is much less rounded, but in other respects the valve appears to be very similar.

This form and *B. algicola* may represent varieties of a more widely distributed species, but until further forms are discovered, I think it advisable to give specific rank to this fossil from Java.

### Sub-genus: CHIRONA GRAY.

*Balani* with thin solid walls, and calcareous basis, with or without pores; orifice toothed; radii narrow or wide, with thin, smooth, or sometimes weakly, and rarely strongly crenated, sutural edges. Scuta without crests for the depressor muscles. Tergum with the spur moderately long, not tapering.

Sub-genotype: BALANUS HAMERI Ascanius.

BALANUS (CHIRONA) SUBLÆVIS J. de C. Sowerby.

(Pl. 18, figs. 9-14; Pl. 19, fig. 1.)

1840. *Balanus sublævis* J. de C. Sowerby, Appendix to Capt. Grant's 'Memoir to illustrate a Geological Map of Cutch': *Trans. Geol. Soc.*, London, 2nd ser. vol. v, p. 327, pl. xxv, fig. 3 (and Expl. to plate).

1854. non *Balanus sublævis* J. de C. Sowerby: d'Archiac and Haime, Anim. Foss. d'Inde, p. 341, pl. xxiv, figs. 15, 15a (=*B. indicus* sp. nov.)

1854. *Balanus amaryllis* Darwin, *Ray Soc. Monogr.* Sub-class Cirripedia, Balanidæ, p. 279, pl. vii, figs. 6a-c.

1854. *Balanus sublævis* J. de C. Sowerby: Darwin, *Ibid*, p. 493.

1879-80. *Balanus amaryllis* Darwin: J. K. L. Martin, Die Tertiärschichten auf Java, p. 131, pl. xxiii, figs. 5, 5a, 6.

1881. *Balanus amaryllis* Darwin: J. K. L. Martin, On a post-tertiary fauna from the Stream-Tin-Deposits of Blitong (Biliton): Notes Leyden Museum, vol. iii, p. 19.

1881. *Balanus amaryllis* Darwin: J. K. L. Martin, Jungtertiære Ablagerungen im Padangschen Hochlande auf Sumatra: *Samml. geol. Reichs-Mus. Leiden*, ser. i, Bd. i, p. 85, pl. iv, fig. 1

1905. *Balanus tintinnabulum*, var. *coccopoma* Darwin: H. Woodward, *Geol. Mag.* dec. v, vol. ii, p. 310, fig. 2

*Diagnosis.*—Radii usually narrow, with their oblique summits smooth and rounded, and the sutural edges crenated below; basis porous. Scutum distinctly striated longitudinally and with a distinct adductor ridge. Tergum with a longitudinal furrow, the spur narrow, and slight traces of longitudinal striæ.

*Distribution.*—(Recent) Mouth of Indus; East Indian Archipelago; Philippine Archipelago; Moreton Bay, and north-east coast of Australia; Torres Strait; near Hiogo Harbour and Kobe, Japan.

(Fossil) Miocene (Aquitanian): Soomrow, Kachh, and d'Hala Range, Sind[1]; Java. Miocene (Tortonian): In nodules on beach off Ormara Headland, facing the Mekran or Baluchistan Coast, 130 miles W. of Karachi; in sandstone at Pohr Sunt, near the headland of Pohr Sunt, about 80 miles west-north-west of Karachi. Newer Tertiary: Padang highlands of Sumatra. Post-Tertiary: Stream-

[1] In all old maps of Sind the Khirthar and some other ranges of hills were united under the name of the Hala Range, though no such name is recognised in the province. See, W. T. Blanford, "On the Geology of Sind," *Rec. Geol. Surv. Ind.*, Vol. IX, p. 8. (1876).

tin deposits. Island of Billiton, off E. coast of Sumatra. Upper Pliocene; I. of Karrak. Persian Gulf.

J. de C. Sowerby (1840) founded the species *Balanus sublævis* on a group of three broken shells, without opercular valves, collected by Capt. Grant at Soomrow, Kachh; Darwin (1854, p. 493) said of Sowerby's figure and description "Plate extremely imperfect; description extremely short and useless; a species from India not to be recognised." While it is true that the figure and description would not enable one to determine the species, an examination of the holotype (In. 20211) leaves no doubt in my mind that it is specifically identical with the recent and well-known species *Balanus amaryllis* Darwin. The walls of the holotype are solid, the basis porous, the radii are rather narrow and peculiarly rounded and inturned, a feature so characteristic of *B. amaryllis*, and the sutural edges are very finely crenated. We will therefore in future have to use the name *B. sublævis* J. de C. Sowerby.

While the specimens from the Yellow Limestone of the d'Hala Range, Sind, figured by d'Archiac and Haime (1854) as *B. sublævis* do not belong to that species, there is a small group of *Balani* with them, registered In. 20219, which is no doubt referable to *B. sublævis*, so that the species occurs in Sind. The late Mr. Vredenburg was of the opinion that the *Balani* from Sind and Kachh are of Aquitanian age.

From the nodules from the Mekran coast, Dr. H. Woodward (1905, p. 310, fig. 2) described two groups of *Balani* (registered I. 14991, I. 14992) as *Balanus tintinnabulum*, var. *coccopoma* Darwin, the larger group (I. 14991) being figured. It was impossible to see any trace of pores in the parietes and radii of these specimens as there should be if the species were *B. tintinnabulum*, and consequently it was very doubtful whether they belonged to that species or even to the same sub-genus, and it seemed more likely from the characters shown that they were really examples of *B. sublævis*.

The new specimens obtained from the Mekran nodules presented by Mr. F. W. Townsend are registered I. 15124-I. 15132, In. 20235. Advantage was taken of the fact that some of the specimens were broken, to search for the opercular valves, and I was successful in finding several examples of the tergum. Several scuta were obtained later by clearing away the matrix with a needle, and by the same method it was possible to extract from a badly crushed nodule a well preserved rostrum with part of the basis (I. 15130; Pl. 18, figs.

10, 11), and a carino-lateral and lateral compartment of another individual (I. 15131) entirely free from matrix. This material shows conclusively that the parietes and radii are solid and the basis porous, and the other characters show that the species is *B. sublævis*.

Two well preserved scuta, free from matrix, and belonging also to *B. sublævis* were submitted to me by the late Mr. E. W. Vredenburg. These two specimens, however, did not occur in the nodules, but were obtained at Pohr Sunt, about 80 miles west-north-west of Karachi, in a sandstone regarded by Mr. Vredenburg as representing a slightly higher horizon than the nodular bed of Ormara. Both this sandstone and the Ormara nodular bed were considered by Mr. Vredenburg to be of Tortonian age

Three shells (In. 20236-8) of 'Upper Pliocene' age from the Island of Karrak, Persian Gulf, in one of which was found a scutum (Pl. 18, fig. 14; Pl. 19, fig. 1), undoubtedly belong to *B. sublævis*, although the shells are larger and the sculpture of the scutum more prominent than in the Mekran form.

*Description.*—This species is somewhat variable, but it is characterized by the usually narrow radii with very oblique summits, which are smooth and peculiarly rounded and inflected: the sutural edges are most finely crenated on their lower portions only; the parietes and radii are solid, only the basis (Pl. 18, fig. 11) having pores, and often with an underlying cellular layer.

Scutum (Pl. 18, fig. 12, Pl. 19, fig. 1) plainly striated longitudinally, with the rather coarse striæ dividing the prominent growth-lines into squarish beads, and the tergal margin is deflected to a variable extent. On the inner surface the upper part of the valve is somewhat roughened, the articular ridge is short and rather prominent, but not reflexed; the adductor ridge is blunt and slightly prominent, varying in position from being almost confluent with the articular ridge or well separated from it; there is a deep but variable depression for the lateral depressor muscle.

Tergum (Pl. 18, fig. 13) sometimes with traces of longitudinal striæ; the longitudinal furrow is deep, with the sides folded in and quite closed in full grown specimens; the scutal margin is considerably curved towards the scutum. Spur variable in length but usually long and narrow, with the end bluntly pointed and placed at rather above its own width from the basi-scutal angle; basal margin usually sloping slightly towards the spur, and the crests for the depressor muscles feebly developed.

BALANUS (CHIRONA) BIRMANICUS sp. nov.

(Pl. 19, figs. 2-6.)

1901. *Balanus tintinnabulum* Linn.: F. Nœtling, Fauna of the Miocene Beds of Burma: *Pal. Ind.*, n. s., vol. i, p. 368, pl. xxiv, figs. 1, 2.

1908. *Balanus tintinnabulum* Linn.: L. V. Dalton, 'Notes on the Geology of Burma': *Quart. Journ. Geol. Soc.*, London, vol. lxiv, p. 633.

*Diagnosis.*—Radii rather wide with their oblique summits and the whole of their sutural edges coarsely crenated; basis without pores. Scutum with the tergal margin not inflected, but forming a sharp edge, and the adductor ridge moderately long and prominent. Tergum with a few longitudinal ridges on the carinal side, the longitudinal furrow shallow and open, and on the inner surface the carinal half is most distinctly roughened.

*Distribution.*—Miocene: ¼ mile W. of Banbyin (Thayetmyo district), Lower Burma.

*Holotype.*—The shell figured Pl. 19, fig. 2 (I. 15438), from which was broken the fragment of the basis (Pl. 19, fig. 4).

F. Noetling (1901) figured as *Balanus tintinnabulum* two shells from the Miocene rocks of Thayetmyo, Lower Burma, and agreeing with Prof. K. Martin he was of the opinion that the specimens described as *B. sublævis* by d'Archiac and Haime (1854) belong also to *B. tintinnabulum*, and he further included the holotype of the species *B. sublævis* J. de C. Sowerby (1840). It has already been shown that Sowerby's *B. sublævis* is not *B. tintinnabulum*, and the specimens referred to *B. sublævis* by d'Archiac and Haime are included under the species *B. indicus* sp. nov. Noetling's figures are not good, but since the present specimens from the same district agree with them, it is in the highest degree probable that they all belong to the form described here as a new species allied to *B. sublævis*, namely *B. birmanicus*. This is based on a number of shells, registered I. 15433-42, collected and recorded by L. V. Dalton (1908) as *B. tintinnabulum*. The shells have the parietes, radii, and basis solid, and therefore certainly do not belong to *B. tintinnabulum*, which has porous walls. A fairly good scutum and a mere fragment of a tergum was extracted from one of the crushed shells.

*Description.*—Shell globulo-conical with the orifice rather large and the walls smooth, the largest complete shell having a height of 28·2 mm., and a basal diameter of 23·8 mm. Radii rather wide, flat, not very oblique, and the lateral edges and the opposed sutural edges are coarsely crenated along their whole extent; alæ not so oblique as the radii. On the inner surface the parietal walls are not ribbed except near the base, and the sheath hardly at all overhangs except at the sides. Basis solid, its outer edge ornamented by strong ribs (Pl. 19, fig. 4).

Scutum (Pl. 19, fig. 5) flat, with a proportionally wide basal margin, the growth-ridges hardly at all prominent, and crossed by very numerous excessively fine, but distinct, longitudinal lines; the occludent margin is not distinctly toothed, and the tergal margin not at all deflected. On the inner surface the upper part of the valve is roughened by very distinct ridges, the articular ridge stands rather high, but is little reflexed, and the adductor ridge is moderately long and prominent, and nearer to the occludent than to the tergal margin; the pit for the adductor muscle is rather shallow.

Tergum (Pl. 19, fig. 6). This is represented by a mere fragment, but it has a few longitudinal ridges on the carinal side and the longitudinal furrow is shallow and open. On the inner surface the whole of the carinal portion is most distinctly roughened by straight and mostly continuous ridges.

*Remarks, and comparison with other species.*—In some respects, such as the poreless basis and characters of the sheath, and the rather wide radii, this form is related to *Balanus hameri*. Taking all the characters into consideration, however, it would seem to be more nearly related to the living *B. amaryllis* (=*B. sublævis*), and to the group of recent East Indian species closely related to *B. amaryllis*, namely *B. albus*, *B. bimæ*, *B. maculatus*, and *B. tenuis*, described by Dr. Hoek (1913, The Cirripedia of the Siboga Expedition, Pt. ii (xxxi$^{b}$), Cirripedia Sessilia, pp. 182-192, pls. xvi-xviii).

The shell differs from *B. sublævis* in the wider, flatter, and much less oblique radii, in the sutural edges of the radii and the opposed sutural edges being coarsely crenated, the crenation not being confined to the lower portion, and in the poreless basis. The scutum has excessively fine and more numerous longitudinal ridges, the valve is flatter, the basal margin is proportionally longer, the tergal margin is not inflected but meets the inner surface to form a sharp edge, and the adductor ridge is situated nearer to the occludent margin. The tergum has a more shallow and open longitudinal furrow.

*B. tenuis*, which agrees in having a solid basis, differs in the more oblique and narrower radii, which usually have their sutural edges thin and smooth, but sometimes the lower portion is excessively finely crenated, and in the scutum by the inflected tergal margin, and among other characters on the inner surface by the absence of an adductor ridge.

Unfortunately in the species *B. albus*, *B. bimæ*, and *B. maculatus*, Hoek did not make known the details of the sutural edges and basis, but *B. birmanicus* would seem to be sufficiently distinguished in the wider radii and in the scutum having a moderately long and prominent adductor ridge, in the articular ridge standing up high and prominent, and in the flat and sharp tergal margin.

Sub-genus : Balanus E. M. da Costa.

*Balani* in which the parietes but *not* the radii are porous ; basis calcareous, either solid or porous.

Balanus (Balanus) amphitrite Darwin.

1854. *B. amphitrite* Darwin : *Ray Soc. Monogr.* Sub-class Cirripedia, Balanidæ.; p. 240, pl. v, figs. 2a-2o.

1879-80. *B. amphitrite* Darwin : J. K. L. Martin, Die Tertiärschichten auf Java, p. 132, pl. xxiii, figs. 7, 7a-c (non figs. 8, 9=*B. javanicus* sp. nov.)

1883. *B. amphitrite* Darwin (?) : J. K L. Martin, Palæontologishe Ergebnisse von Tiefbohrungen auf Java : *Samml. geol. Reichs-Mus. Leiden*, ser. i, Bd. iii, Hft. i, p. 40, pl. iii, fig. 37.

*Diagnosis.*—Shell usually small, steeply conical or depressed, orifice nearly entire or deeply toothed, varying from rhomboidal to rounded trigonal. Scutum with a prominent broad adductor ridge, and the articular ridge prominent and reflexed.

*Distribution.*—(Recent) Mouth of the Indus ; Philippine Archipelago ; Australia.

(Fossil) Miocene (Aquitanian) : Java. Miocene (Tortonian) : Sandstones of Pohr Sunt. near the headland of Pohr Sunt, about 80 miles west-north-west of Karachi.

With the two scuta of *Balanus sublævis* from Pohr Sunt Mr. Vredenburg submitted a group of small *Balani* attached to an example of a *Pecten* which he regards as an undescribed species closely related to *P. tranquebaricus* Gmelin. The specimens consist of two complete shells with twelve examples of the basis, one of which had only the carinal and a lateral compartment, and these were removed to study their inner structure ; the opercular valves are missing. In the characters of the carinal and lateral compartments, which still plainly exhibit traces of a purplish or purplish-brown tint, in the irregular cup-shape of the basis, and in their size, these *Balani* agree well with *B. amphitrite*, var. *cirratus* Darwin, and probably belong to that variety, although in the absence of the opercular valves this cannot be positively asserted.

### BALANUS (BALANUS) INDICUS sp. nov.

(Pl. 19, figs. 7-11.)

1854. *Balanus sublævis* J. de C. Sowerby : d'Archiac and Haime, Anim. Foss. d'Inde, p. 341, pl. xxiv, figs. 15, 15a.

*Diagnosis.*—Shell smooth, weakly folded but not ribbed, varying in shape from sub-cylindrical to depressed conic, with an ovate orifice. Parietes with deeply sunken radii, and with numerous closely-set transverse septa extending from the apex to the base; basis porous and with an underlying cellular layer. Scutum thick with feebly developed zones of growth and distinctly but finely striated longitudinally.

*Distribution.*—Miocene (Aquitanian): d'Hala Range, Sind; Karachi, Mouth of Indus,

*Holotype.*—The shell figured Pl. 19, fig. 7. In. 20233.

*Material.*—7 shells from d'Hala Range, Sind, collected by Lt. Blagrove (In. 20212-18); 2 shells from Sind, collected by Capt. Baker (In. 20220-21); 13 shells from Karachi. comprising 8 shells collected by Capt. Baker (In. 20222-30), and 4 shells presented by Charles Darwin, and presumably collected by Capt. Baker (In. 20231-34).

D'Archiac and Haime (1854, Pl. xxiv, figs. 15, 15a) figured two shells (In. 20212-3) as *Balanus sublævis* J. de C. Sowerby, but since the parietal walls in those specimens have longitudinal septa, they cannot possibly belong to that species or to the same sub-genus, and they agree with the specimens described here.

Some of the specimens from Karachi (In. 20222-30) are those of which Darwin said (1855, *Pal. Soc. Monogr.* Foss. Balanidæ, p. 5) "I have seen, in the British Museum, specimens said to have come from the eocene nummulitic beds, near the mouth of the Indus, belonging to that section of the genus, which has the walls and basis permeated by pores." One of the four specimens presented by Darwin (In. 20234) was broken into four pieces, presumably by him to show the structure of the walls. and on seeing what I took to be opercular valves in section. I cleaned away the matrix with a needle, and in that way found the broken right scutum and a left tergum (Pl. 19, figs. 8, 9) as well as the right tergum and its impression. There is also part of a left scutum shown in juxtaposition with the left tergum within the cavity of the shell.

*Description.*—Shell varying from sub cylindrical to depressed conical, one large depressed shell (In. 20222) having a basal diameter of about 55 mm., and the cylindrical forms having a basal diameter of under half that size. Walls strong and thick with a rather small ovate orifice; radii rather deeply and abruptly sunken; carino-lateral compartments very narrow, and lateral and rostral compartments broad. Surface usually smooth, sometimes weakly folded but not regularly ribbed.

Radii rather narrow, with level or slightly oblique summits usually broken, and the lateral edges and opposed sutural edges coarsely crenated; alæ with somewhat rounded and oblique summits.

Sheath rather close to the wall, not overhanging to any extent. and below it the parietal walls are either strongly or weakly ribbed or smooth. Parietal tubes large and squarish, about 19 in one rostrum, divided off by very numerous closely disposed transverse septa (Pl. 19, fig. 10) into square or oblong cells, which in some weathered specimens are open, but in others are filled by matrix, the infilling standing out as square or oblong excrescences. Basis strongly attached to the walls and radially ribbed on its inner surface, porous, the pores divided off by transverse septa; the basis has usually a thick underlying cellular layer (Pl. 19, fig. 11), which is much reduced in thickness towards the centres.

Scutum thick, with narrowly spaced and weakly developed growth-ridges, the most conspicuous feature of the ornament being the fine but prominent longitudinal ridges, which are not broken up by the growth-ridges; the basi-tergal angle is narrowly rounded, and above this angle the margin is thick and inrolled. On the inner surface the articular ridge is low and the articular furrow narrow and shallow; adductor ridge removed from the articular ridge rather short and prominent, situated close to and extending above the moderately deep pit for the adductor muscle; there is a very deep angular depression for the depressor muscle.

Tergum flat, with well marked growth-ridges, no trace of longitudinal striæ, and with a rather wide 'spur-fasciole' faintly impressed on the carinal side and moderately impressed on the acutal side;

the scutal margin only narrowly inflected. Spur close to the basi-scutal angle, tapering to a narrow, obliquely truncate extremity.

*Remarks and comparison with other species.*—This form is evidently closely related to *Balanus rostratus* Hoek, but although it agrees with it in several characters of the shell, especially in the characteristic closely set transverse septa which extend from the apex to the base, it differs from it in having a porous basis with a thick underlying cellular layer, for in *B. rostratus* the basis is thin and without pores. It differs further in the ornament of the scutum, for the longitudinal ridges are stronger than the growth-ridges, while the reverse is the case in *B. rostratus*, the valve itself is thicker, the basi-tergal angle more narrowly rounded, and above the angle the tergal margin is thick and inrolled. I can see no evidence that the ribs on the inner surface of the parietes are more numerous than the longitudinal septa, or any thin lamellæ within the margin of the outer lamina, but despite this there would seem to be a near and possibly direct relationship with *B. rostratus*. *B. balanus* (=*B. porcatus*) is an allied form.

## CONCLUSION.

Notwithstanding the frequency with which the species *Balanus tintinnabulum* Linnæus, occurs in the literature of the Indian Tertiary *Balani* dealt with here, in no case can the reference to that species be confirmed. It is represented, however, in the present Indian Ocean fauna, and the possibility is that it will be found in the Tertiaries of India and the East Indian Archipelago.

*Balanus sublævis* (=*B. amaryllis*) occurs in the Upper Pliocene Beds of Karrak Island, Persian Gulf, in the Aquitanian beds of Kachh and Sind, in the nodules of Tortonian age on the beach off the Ormara Headland, and in beds of approximately the same age at Pohr Sunt. At the latter locality it is associated with other *Balani* probably belonging to *B. amphitrite*, var. *cirratus*, and it is interesting to note that both these forms are now found living together at the mouth of the Indus, not many miles distant from the localities where they are found fossil. The only other records that I can find of *B. sublævis* (=*B. amaryllis*) occurring fossil are those by J. K. L. Martin, who records the species from the Post-Tertiary stream-tin deposits of the Island of Billiton, off the east coast of Sumatra, from rocks of newer Tertiary age in the Padang highlands of Sumatra, and from the Miocene rocks of Java, in which latter *B. amphitrite* occurs also

The occurrence of these two species in the Miocene Balanomorph fauna certainly gives point to the view held by Dr. F. Nœtling, the late Mr. E. W. Vredenburg, and others, that the present Indian Ocean fauna was directly derived from the Miocene faunas of India, Burma, Java, and adjoining Islands.

On the other hand we have in *Balanus javanicus* sp. nov. a species from Java, closely allied to the recent *B. algicola* Pilsbry, of South African waters, and in *B. indicus* sp. nov., a species occurring commonly in the Miocene rocks of Sind, we have a species closely related to the living *B. rostratus* Hoek, a North Pacific form, recorded by Pilsbry from the Ocean coast and Inland Sea of Japan, with varieties in Bering Sea and Puget Sound.

The remaining species *B. birmanicus* sp. nov., which occurs in beds of Miocene age near Banbyin (Thayetmyo district), Lower Burma, belongs to the group of species allied to *B. sublævis* (=*B. amaryllis*).

## EXPLANATION OF PLATES.

### PLATE 18.

BALANUS (MEGABALANUS) JAVANICUS sp. nov.

Miocene (Aquitanian) : Java.

FIG. 1.—Small complete shell. × 2 diam. In. 20239.

FIG. 2.—Rostrum. a, inner view ; b, view of base to show septa. In. 20240.

FIG. 3.—Rostrum. Longitudinal section across radius and obliquely across parietes to show character of septa. In. 20241.

FIG. 4.—Scutum (right). a, outer view ; b, inner view. In. 20242.

FIG. 5.—Tergum (incomplete left valve). a, outer view ; b, inner view. In. 20243.

FIG. 6.—Tergum (incomplete right valve). a, outer view ; b, inner view. In. 20244.

FIG. 7.—Tergum (complete left valve). Outer view. In. 20245.

FIG. 8.—Basis (part of), to show cellular structure. In. 20246.

All except fig. 1 × 4 diam.

BALANUS (CHIRONA) SUBLÆVIS J. de C. Sowerby.

Miocene (Tortonian) : Mekran Coast.

FIG. 9.—Small complete shell. nat. size. In. 20235.

FIG. 10.—Rostrum (inner view), to show fine crenation on lower edge of radii. × 4 diam. I. 15130.

FIG. 11.—Basis (edge of), to show porous structure. × 4 diam. I. 15130.

FIG. 12.—Scutum (right). a, outer view ; b, inner view. × 4 diam. I. 15132.

FIG. 13.—Tergum (right). Outer view. × 4 diam. I. 15125.

Upper Pliocene: I. of Karrak.

FIG. 14.—Shell (incomplete). nat. size. In. 20237.

PLATE 19.

BALANUS (CHIRONA) SUBLÆVIS J. de C. Sowerby.

Upper Pliocene: I. of Karrak.

FIG. 1.—Scutum (left). a, outer view; b, inner view. × 4 diam. In. 20237.

BALANUS (CHIRONA) BIRMANICUS sp. nov.

Miocene: Banbyin (Thayetmyo district), Lower Burma.

FIG. 2.—Shell. nat. size. I. 15438.
FIG. 3.—Rostrum. Inner view to show sheath and coarsely crenated edges of radi. ×2 diam. I. 15440.
FIG. 4.—Basis (edge of). × 4 diam. I. 15438.
FIG. 5.—Scutum (incomplete right valve). a, outer view; b, inner view. × 4 diam. I. 15441.
FIG. 6.—Tergum (outer view of fragment of right valve). ×4 diam. I. 15442

BALANUS (BALANUS) INDICUS sp. nov.

Miocene (Aquitanian): Karachi, Mouth of Indus.

FIG. 7.—Shell (small conical form). nat. size. In. 20233.
FIG. 8.—Scutum (incomplete right valve). a, outer view; b, inner view. × 4 diam. In. 20234.
FIG. 9.—Tergum (incomplete left valve). Outer view. × 4 diam. In. 20234.
FIG. 10.—Rostrum (part of). To show parietal septa. × 2 diam. In. 20217.
FIG. 11.—Carina and basis (longitudinal section of). To show structure, especially the cellular basis. × 2 diam. In. 20217.

# CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YUNNAN IN WESTERN CHINA. 7. RECONNAISSANCE SURVEYS BETWEEN SHUN-NING FU, PU-E'RH FU, CHING-TUNG T'ING AND TA-LI FU. BY J. COGGIN BROWN, O.B.E., D.SC., F.G.S., M.I.M.M., M.I.M.E., *Superintendent, Geological Survey of India.* (With Plate 20).

## 1. SHUN-NING FU TO MIEN-NING T'ING.

SHUN-NING Fu is the central frontier prefecture of Yunnan south of Lat. 25° for it lies between the northern one of Yung-ch'ang Fu and the southern one of P'u-erh Fu. Its administrative headquarters is a small walled city of the same name, situated in Lat. 24°35': Long. 99°55', at an elevation of 5,800 feet above the sea on the lower slopes of a high range, and only approximately 70 miles as the crow flies from the nearest point on the Burma frontier where the latter is crossed by the Salween river. In the bottom of the valley there is a fairly level strip of ground, half a mile in width, divided by a small stream known as the Pei-ch'iao Ho, a tributary of the Mekong. I have described the geology of the country between Shun-ning Fu and Têng-yüeh in an earlier paper of this series,[1] and I now propose to record my notes made on a journey in 1910, from Shun-ning Fu to Ssu-mao T'ing and thence to Tali Fu, for as far as I am aware this part of Yunnan has never been examined by a geologist before.

The alluvial deposits of the small Pei-ch'iao Ho stream consist of flat bands of clay, bluish shaley clay and an occasional bed of fine sand. They must attain a considerable thickness as they form cliffs 80 or 90 feet high without the basal layers being exposed. There is also a great thickness of soil, which aided by the extent and height to which terrace cultivation is carried out on the hill slopes, effectually covers all outcrops, so that it would probably be necessary to ascend into the hills on either side of the valley for some distance before exposures *in situ* could be obtained.

[1] Contribution No. 5. *Rec. Geol. Surv. Ind.*, Vol. XLVII, pp. 205-266 (1916).

**Granitic and Metamorphic rocks between Shun-ning Fu and Yun Chou.**

Yun Chou lies 24 miles to the south-east of Shun-ning Fu and the route follows the course of the Pei-ch'iao Ho downstream. The first stage is at Lao-t'ang 12 miles from Shun-ning. After leaving the city the road crosses the plain and is then carried over the river by a fine granite bridge. It re-crosses again a little further on. This road is paved with blocks of light and dark varieties of granite, the former predominating. In the small tributary valleys I found boulders of similar rocks. The side valleys are as a rule cut deep and have a wide outline. Towards To-tien, where the road leaves Sheet No. 23 S.E. and enters No. 31 S.W., (North-Eastern Frontier Surveys), the granite boulders in the tributaries become fewer and are eventually replaced by others consisting of gneisses and mica schists. At a point 1¼ miles before reaching Lao-t'ang I found the only outcrop seen in this stage. It consisted of white quartz schists with grey and greyish-yellow bands, also of greyish-black mica schists containing small lenses of quartz. The strike and dip observations are not very reliable but were N.40° W. to NW.-SE. and the dip SW. at 55°. Lao-t'ang itself has an elevation of 5,200 feet but the road is to all intents and purposes level beyond a few minor ascents and descents over the ends of small spurs running down towards the main stream. It keeps on the southern bank high above the river except towards Lao-t'ang where it comes lower down. The Pei-ch'ia Ho, augmented by many tributaries, has here become a fair-sized stream. Its actual valley is never more than half a mile wide, but the slopes, or rather the lower portions of them, are so terraced and covered with fields that it appears to be much wider. The hills are bare of grass and trees usually and even at high levels there is much cultivation. Patches of forest are sometimes seen and all the villages are built on the lower slopes.

Leaving Lao-t'ang the road gradually descends across terraced land to the river. Opposite the small village of Pa-pien-kuan finely-banded, decomposed, augen-gneisses crop out. Near this village the road leaves the river, which now enters a narrow gorge with little cultivation at the bottom and bare grassy slopes rising steeply up for hundreds of feet above. The temple of Pa-pien-t'zŭ is built at the top of a small spur which the road crosses and half a mile beyond this point, where the river becomes visible again, coarse white gneiss is found *in situ*. Another half mile further on biotite schists are penetrated by thin quartz veins. Where the road begins to meet cultivation again vertical bands of white gneiss strike NW.-SE., and similar rocks crop out at intervals for the next three miles. Near Shin-tang, where there is said to be a hot spring in the river bed, the road is cut into the side of a cliff composed of quartz schists. At this place the valley is very narrow for a few hundred yards and there is a break in the cultivation of its alluvial deposits, which otherwise continue along the whole 24 miles between Shun-ning Fu and Yun Chou. There is high level terracing however all along. Yun Chou is suddenly entered as the road goes through a narrow pass. It is a poor town of about 800 houses surrounded by a low brick wall but is an important trading centre for various Chinese Shan States, though this trade is not large. The plain around the town is not a very fertile one and sugar cane is one of the better crops. Yun Chou lies on the line of the proposed railway from Lashio to Tali Fu. Like Shun-ning Fu it was formerly the capital of a Shan State and was taken by the Chinese from the Shans. It is situated at the junction of the Pei-ch'iao Ho and the Pan-ch'iao Ho, at an elevation of 3,800 feet, about 35 miles west of the Mekong.

**Correlation of the Crystalline Rocks of the Shun-ning Fu and Yun Chou areas.**

From the lithological point of view the gneisses and mica schists with their bands of intrusive granite, met with in the Shun-ning Fu and Yun Chou region, are identical with the crystalline rocks of the frontier ranges crossed between Bhamo and Têng-yüeh, with those exposed in the heights of the Irrawaddy-Salween divide and with the crystalline complex of the T'sang Shan range immediately west of Tali Fu. Another feature that they have in common is the occurrence of bands of crystalline limestone, for although this rock was not met with *in situ*, between Shun-ning Fu and Yun Chou, owing to lack of good exposures, its presence was indicated definitely by rolled pebbles in the small tributary streams of the Pei-ch'iao Ho. Again, the gneisses, mica schists and intrusive granites of the T'sang Shan are in the same line of strike as those of the region under consideration, but until the intervening country in the basin of the Yang-pi river has been explored it is impossible to say whether they are actually continuous or not. About 45 miles to the east of Yun Chou, across the valley of the Mekong rises the Wu-liao Shan, a range bordering the Chuan Ho valley on the west, which attains a height of 11,500 feet in the vicinity of Ching-tung T'ing. I was unable to make a traverse in this direction, but the altitude and general aspect of the range incline me to think that it may be composed of crystalline rocks in part.

**Rocks of the Kao-liang Series between Yun Chou and Mêng-yung.**

From Yun Chou I travelled to the south-west down the valley of the Nan Ting as far as Mêng-sa. The first stage is at T'ou-tao-shui, 14½ miles from Yun Chou, the road crossing the Mekong-Salween divide between miles 11 and 12 at an elevation of 5,000 feet.

Crystalline rocks fringe a portion of the southern edge of the Yun Chou plain, but the road leaves them near the village of Fung-pien and the first exposures of the Kao-liang Series are encountered as glistening purple slates interbedded with bands of coarse white quartzite. The Yun Chou valley contains a thick alluvial terrace of which 110-120 feet are exposed without the base being visible. Near the village of Ch'ang-po-ling the track crosses the main stream and continues to ascend on the northern bank. Boulders of gneissose and schistose rocks predominate in the stream bed and the alluvium here is at least 300 feet thick. At first one gets the impression that Ch'ang-po-ling is built on a high river terrace, which has a corresponding one on the other side of the valley, but as a matter of fact it is merely on the original level of the alluvial deposits into which the stream is rapidly cutting its way. There are no rocks *in situ* in the stream bed about this point but poor exposures of decomposed phyllites and similar rocks make their appearance and are found at intervals up to T'ou-tao-shui.

From this village the road continues in a south-westerly direction down the valley of the Pang-wa Ho passing Pang-wa, the second stage at 12 miles, Ping-chuang the third stage at 24 miles and reaching Mêng-yung, 16½ miles further on in the same direction, a total distance of 55 miles from Yun Chou.

There is a narrow band of alluvium down the valley of the Pang-wa but the rocks on either side of it consist of a typical Kao-liang suite, phyllites, fine-grained mica schists, cleaved argillites, purple and reddish-purple slates, quartzites, hard sandstones and grits with rare bands of conglomerate. There is much vegetation and exposures are poor. Four miles from T'ou-tao-shui contorted black phyllites strike N. 15° W.—S. 15° E. and dip in a westerly direction at 50°. The metamorphism of these rocks has been extreme, even the thin quartz veins which pierce them are crushed and squeezed out into lenticles. The road ascends and descends a good deal in this stage though for most of the way it keeps high up above the river on the northern bank. Purple slates and red sandstones, with conglomerates containing large numbers of quartz pebbles, are seen near the point where the road first meets the river. Beyond this there are thin bands of gneissose granite probably intrusive into the metamorphosed sediments. The river has a rapid fall and a strong current and the sides of the tributary valleys are very steep and scarred with small land-slips. Villages are few and poor and usually built on spurs overlooking the main valley.

Pang-wa has an elevation of 5,400 feet and the next stage commences with an ascent for a mile and then a long descent of 3 miles into the Mêng-lai plain, elevation 3,500 feet. Rocks of the same series continue all the way down, shining fine-grained phyllites of stained yellowish and reddish shades are the usual forms. Thin quartz veins were noticed in them here and there. In the first stream crossed at the bottom there are large blocks of a black and white granite which are not *in situ*. About a mile further on granite outcrops are again met with, but I could not decide definitely whether they were true exposures or transported pieces. They are followed by more phyllites, harder than usual, and interbedded with decomposed felspathic quartzites. There is a broad belt of alluvium in the valley which is covered with a dense growth of high grasses. It continues on towards the south-east of Mêng-lai. The main stream is crossed about 2 miles from this place at an elevation of 3,450 feet and after that there is a steep ascent for 4 miles to Ping-ch'uang, elevation 5,200 feet, similar rocks of the Kao-liang Series continuing the whole way. The first mile of the ascent is more gradual than the remainder and is along the alluvium of the valley until the road leaves the Nam Ting and turns more to the south, across a fast-flowing tributary which has thrown out a delta and altered the direction of the main stream somewhat. Its bed is full of boulders of fine-grained, contorted, greyish-blue mica schists. The rest of the ascent is very steep.

The next stage leads from Ping-ch'uang to Mêng-yung a distance of 16½ miles. The track keeps along the top of a ridge for 2 miles, which in places is almost knife-edged, with steep falls into deep valleys on both sides. Unfortunately mists and rain clouds obscured the view but glimpses of a high snow-covered range towards the north, were obtained every now and then. Its peaks seemed to be 9,000 or 10,000 feet high. There is now a very steep descent for 1½ miles down to the Mêng-yung Ho, another small tributary of the Nan Ting. It is merely a torrent with a broad flood level and a bed full of boulders of quartzite and greyish-blue phyllites. There is little cultivation in the valley which is clothed with thick spear grass rising in places to a height of 20 feet. Outcrops of red quartzites with bands of quartz-bearing conglomerates apparently dip up stream, but the grass growth was thick enough to prevent proper observations. The road now leaves the valley of the main stream and turns to the south-east down a side valley filled with alluvium and overgrown with the same thick grass. The hamlet of Wan-nien-chuang is passed at 9 miles. Its only importance is that it marks the boundary between the Chinese district of Mien-ning Ting and the Shan State of Keng-ma, one of the larger Chinese Shan States, the plains of which are inhabited by Shans and the hill tracts by Las, Lolos and Lahus. Mêng-yung, a small Shan town of about 200 houses is 7½ miles from Wan-nien-chuang towards the south-east. In the river bed below the town the alluvium is seen to be of great thickness and to consist of pebble beds and red and greenish-white silts with a few bands of blue clay.

Exposures are poor between Wan-nien-chuang and Mêng-yung, contorted, drab-coloured argillites being the prevalent rock. In the stream beds pebbles of red and white sandstone, red grit and twisted phyllites are common.

**Plateau Limestones between Mêng-yung and Mêng-hsa.**

One stage intervenes between Mêng-yung, 4,300 feet, and Mêng-sa, 4,450 feet, this is at the village of Na-hee, 13 miles from the former place and 9 from the latter. As one leaves the town the hills to the south-west are seen to be of limestone. The road crosses the alluvial plain which is about 5 miles long and from 1 to 2 miles wide, its upper part covered with rice fields. Continuing along the side of the same valley for 6 miles it then descends rapidly to the village of Man-hkü. The head of the Mêng-yung valley is sculptured deep into limestone. To the north and north-west limestone cliffs form scarps on the hill sides and about their tops. There are plenty of exposures along the road and the typical rock is a grey or greyish-white, brecciated variety very like the Plateau Limestone of the Northern Shan States. The only fossils seen were two crinoid stems on a detached piece of limestone. Man Hkü is 8 miles from Mêng-yung and is situated in a small alluvial-filled valley clothed in the same giant grass. After crossing three small tributaries of the Nam Ting the road leaves the valley, turns to the south, and ascends rapidly in that direction for 2 miles with the narrow ravine of the stream below it on the east. At this point a turn to the south-east is taken into a smaller valley which is followed for 2 miles to the valley in which T'sin-men-k'ou is situated. This valley is bounded on both sides by very high limestone cliffs, fallen blocks from them being scattered over the lower slopes. Soon after leaving T'sin-men-k'ou the road suddenly emerges from the hills on to the Mêng-hsa plateau, appearing from this point as a long expanse of dry and level land, covered for the most part with spear grass and bounded by rocky limestone escarpments at this, its northern end. Naheo lies on the plain about a mile further on, at an elevation of 5,100 feet, while Mêng-hsa is 9 miles south of it.

**Enclosed drainage of the Mêng-hsa plateau.**

The Mêng-hsa plateau, with a general elevation of 4,500 feet is approximately 15 miles long and 2 to 4 miles wide. It is bounded on both sides by limestone ranges, the one on the south being the more precipitous of the two. The surface is almost waterless; there is little cultivation and consequently few villages. The only irrigated fields are on the terraces cut out by the Nam Hsa and its tributaries in their winding courses across the plain. The Nam Hsa itself enters from the east above the town, makes a bend for a few miles and then turns south into the southern boundary range, 3 miles north-east of the town, where it disappears under a high limestone cliff. I estimated the height of the plain above the river bed near the point where it flows underground at 250 feet, and I believe that this is the minimum thickness which can be attributed to the alluvial deposits. The limestones weather down into a clayey soil and there is no "Terra Rossa" locally.

Mêng-hsa is in the jurisdiction of the Keng-ma chief. It is a small Shan town containing about 200 houses, surrounded with a low mud wall and built on the general level of the plain. To the north the high ridge beyond the Nam-ting valley is visible and in between these appears to be at least one lower limestone range.

**Types of limestone in the Mêng-hsa region.**

The usual type of limestone as seen in fallen blocks from the scarps, or in the polished paving stones of the mule tracks, is a light bluish-grey rock, often approaching creamy-white in colour and rarely of a greenish-white tint. It generally contains patches of a darker grey shade. It is always cracked and lined in every direction. When weathered it assumes a typical and peculiar surface. Dissolution takes place along the cracks and lines and proceeds deep into the rock, the softer parts are weathered away and those able to resist denudation longer stand out, sometimes rounded, but oftener of every imaginable shape. A mass of this rock, with the peculiar blackish-blue colour which the surface then assumes, looks like a heap of ancient clinkers when seen closely. If the texture of the original rock is more even-grained and uniform, a porous or honey-combed surface is formed and when the individual pieces are unusually hard they stand out like pebbles in a weathered conglomerate. Selective dissolution extends deep, the outer crust may become soft and yellowish, inside this are ferruginous patches in the grey and greyish-white mosaic of the slightly altered mass. In addition to these, the following rarer types were observed:—

(*a*) Hard, white, finely crystalline limestone with greyish bands and cracks marked in yellow.

(*b*) Greyish-white, brecciated and recemented limestone. The junctions of the fragments show on the surface and on fractures.

(*c*) Hard, white, saccharoidal limestone with a glittering fracture. This material is entirely recrystallised.

(*d*) Dark, greyish-blue limestone with drab brecciation patches in irregular outlines and red ferruginous blotches.

(*e*) Hard, white and yellow, calcite-filled limestone, weathering with a characteristic warty or nodular structure.

**Continuation of the rocks of the Kaoliang Series, between the Nam Ting valley and Mien-ning T'ing.**

I returned from Mêng-hsa to Wan-nien-chuang and then travelled south-west to Mien-ning Ting, a distance of 23 miles which was traversed in two stages, halting at the village of Ping-yüan-hsün *en route*. The road leaves the Wan-nien-chuang valley at an elevation of 3,800 feet and commences a long ascent up a spur to the south-east. Red sandstones, hard red slates, conglomerates with small quartz pebbles and reddish-grey grits are seen in weathered outcrops. The section is not a continuous one owing to the soil cap, but the sandstones greatly predominate. At 5 miles, elevation 5,450 feet, the strike appears to be N. 15° W.-S. 15° E. and the dip practically vertical. Near the village of Wu-lu-tsin, 6.600 feet, greyish-green phyllites with thin quartz veins strike N.W.-S.E. and dip to the N.E. at 40°. The road ascends for half a mile above this village and then reaches the top of the ridge about 6,800 feet. Here there are extensive views not only of the Wan-nien-chuang and Mêng-yung valleys, but also of the Nam Ting valley beyond them further north. The country to the north-east and south-west is also well displayed; the valleys are deep and broad and have a scattered village population. At the top of the ridge thick forest growth ceases and there are more open spaces covered with grass and bracken. The road continues along the top of the ridge to Ping-yüan-hsün at 10 miles, elevation 7.000 feet above sea level. Scattered outcrops of contorted mica schists and of silvery muscovite phyllites are seen at intervals but exposures are very poor. In the village itself similar rocks. stained red and yellow, with thin, elongated stringers of clear quartz in them are interbedded with hard. speckled grey and white quartzites.

From Ping-yüan-hsün to Mien-ning T'ing is a distance of 13 miles and similar rocks are found to within 6 miles of the city. At first there is a rapid descent to a small stream beyond the village, round the valley of which the road runs, followed by a steep rise to 7,400 feet where an escarpment of grey and purple grits, interbedded with purple slates is found. Another steep descent takes place, after which the road winds gently down through open pine forests in which rock exposures are very rare. One mile to the north-west of Sin-chai, coarse felspathic grits crop out and form a well-marked band towards the north-west. They are very decomposed and the path is worn deeply into them. When broken they are found to consist of clear quartz grains about the size of peas, set in a matrix of pure white kaolin. The main stream is met with opposite the Lolo village of Tang-mai and it contains pebble beds of alluvial origin. The stones are up to 4 inches in length; they are all water-worn and consist of white quartz, grits and phyllites of various kinds. I found also a few pieces of lignite here which probably come from the alluvial deposits. The recent wash of the stream contains small boulders of fine-grained quartzites, vein quartz, dark phyllites, fine muscovite schists. fine red grits and scarce pieces of biotite granite, possibly from veins intruded into the metamorphic rocks.

For the next 2½ miles the road crosses the alluvium or the soil covered slopes immediately above it. Then there is a short and steep ascent over a ridge from the top of which the Mien-ning valley is first seen.

**Granite of the Mien-ning T'ing vicinity.**

At the top of the ridge a coarse white granite occurs into which the road is deeply worn. The surrounding country is made up of this soft decomposed granite dissected to an unusual degree both by the water courses and by general denudation. The stream down which the road descends to the plain has a ravine-like character, the sides rising 600 or 700 feet but broken in places by tributaries. Sometimes the granite becomes porphyritic with felspar crystals up to 3 inches in length set in a pink groundmass of smaller crystals and biotite. The road continues down this narrow valley until it broadens out into the Mien-ning plain. This has an elevation of 5,000 feet above sea level and is about 8 miles long and 3 miles broad at its widest part. The city lies on the western side some 3 miles above the southern end of the plain. Mien-ning T'ing was originally a Shan State and many of its inhabitants bear traces of their Shan descent. It contains about 250 houses but there are equally large suburbs outside the walls.

## 2. MIEN-NING T'ING TO WEI-YÜAN T'ING.

**Granites between Mien-ning T'ing and the Mekong.**

From Mien-ning I walked to Wei-yüan T'ing crossing the Mekong at the second stage. After reaching the river the route I followed does not appear to have been traversed by a European before. The only available map is of the sketchiest character and my geological observations cannot as a consequence be very accurate, but this is all the more reason why they should be given in detail.

The first stage is reached at Ch'ih-lu-shu, a distance of 9 miles. The road leaves the city from the south-east, crosses the plain and then commences to ascend a steep spur to the south-east. Near the village of Nam-tung-shan, ½ mile up the ridge, immense rounded blocks of granite are strewn about, but the road itself is cut deep into the rotten rock, the places once occupied by the porphyritic crystals being marked by white patches of kaolin in the reddish groundmass. As the road ascends exposures become poorer. At 5 miles, elevation 7,000 feet, an even-grained variety with little quartz and abundant biotite is seen. From this point to Ch'ih-lu-shu, there are practically no outcrops. The hill-sides are bare of trees, but covered with bracken and scarred with the numberless small hollows, to which this type of country gives rise under excessive denudation.

From the top of the Mekong-Salween divide at an elevation of approximately 8,000 feet, wide views are obtained of low but well-individualised ridges which appear to run north and south on the eastern side of the Mekong.

The second stage of 11 miles commences with a level stretch of about 2 miles after which the descent to the river begins. At 8 miles it becomes very steep. Similar granites continue but good outcrops of fresh rock are practically non-existent. The prevalent material seen in the rounded weathered masses, scattered about the hill-sides, and showing through the soil cap, contains large clear quartz grains, idiomorphic yellowish felspars and small shreds of biotite. The Mekong river is first observed from an elevation of 6.500 feet. It is in a deep gorge, the sides of which are cut by tributaries with broad valleys. The drainage system extends in small branching glens right up to the tops of the boundary ridges.

The descent continues to Ma-t'ai-ts'un at 9 miles. Here the road is level for a few hundred yards on to a narrow ridge along which the track goes. The ridge is only a few feet across in places and drops precipitously down into the deep ravines on either side. It is formed of soft, rotten rock of a pink colour representing one of the later stages of the granite decomposition. After winding down this for a mile, the eastern edge of the granite mass is reached and a series of ancient metamorphosed sediments met with.

**Metamorphosed sediments of the Mekong valley.**

These are greenish slates, fine biotite phyllites and blue and grey siliceous limestones with bands of white crystalline limestone and marble in places. They are very contorted and continue down to the village of Chen-pien on the western bank of the Mekong. This village has an elevation of 2,800 feet and is 11 miles from Ch'ih-lu-shu and 20 miles from Mien-ning T'ing. The river is about 240 feet wide at the ferry. At the water's edge very metamorphosed slatey limestones crop out, pierced by narrow dykes of a basic rock. The limestones weather with sharp edges and points, owing to the extreme cleaving they have undergone.

After crossing the river the road ascends a steep spur to the south-east and in the first 1½ miles rises 1,500 feet. Half a mile above the river there are thick bands of dark crystalline limestone very cracked and jointed. They are followed 300 yards further on by a decomposed igneous rock, perhaps a flow, of a greyish-white colour and containing radiating spherules of a greenish mineral. The top of the ridge is reached at 1½ miles and for the next 3½ miles winds along it, gradually ascending through open pine forest. The general direction is south and south-east and there is a thick red soil cap. There are deep valleys on either side of the ridge in the bottoms of which small streams wind their way down to the Mekong. At 3½ miles the village of Tsin-chia-chai is passed, and near it, on the western slope of the ridge, purple slates and soft yellowish sandstones are seen. The top of the ridge is reached by an easy ascent at 6½ miles, elevation 5,800 feet. On the descent at 6¾ miles felspathic grits crop out in a little stream bed. They strike N. 35° E. and S. 35° W. The general direction keeps to the south-east. At 8½ miles, elevation 4,500 feet, a small stream is crossed. In its valley I found hard conglomerates with pebbles of red slate, reddish porphyry, reddish quartz, and quartz in a speckled white and red matrix. There are also red and white speckled grits; soft, white sandstones with brown bands; hard, greenish quartzites; hard, chocolate-coloured slates and other varieties of coloured grits and quartzites, there are also large pieces of amygdaloidal andesite in the conglomerates.

Close to this point the stream is joined by a slightly larger one coming from the north-east and up the bed of which the road goes for a short distance before ascending steeply to the south-south-east for a mile to mile 9½. From this point to Mong-pai, at 11¾ miles and an elevation of 5,050 feet, the road is practically level in a south-eastern direction along the side of a pine-clad ridge. A few poor exposures of reddish-purple shales were the only rocks seen hereabouts.

**Age of the rocks in the vicinity of the Mekong.**

The determination of the age of the rocks met with about the Mekong and in this stage presents difficulties: after seeing the phyllites near Chen-pien, I was inclined to classify them with the Kao-liang group, but the great development of limestones met later made me modify this opinion. Calcareous rocks are not known to occur in this group. The key to the problem perhaps is the presence of the dykes and interbedded lavas amongst the limestones, which is a point of resemblance with the Devonian and Permo-Carboniferous succession found further north in the same valley. In addition to this we find the Upper Permian conglomerates, which are the lowest beds of the Red Beds Series immediately above them. They may perhaps represent a Palaeozoic succession of shales, limestones, interbedded flows and dykes highly metamorphosed by the great granitic intrusion to the west of them.

**The Red Beds Series.**

The lowest beds of the Red Beds Series seem to come in three miles to the north-west of Mong-pai. They extend for considerable distances and indeed form the southern part of the great region occupied by these rocks in central Yunnan. From Mong-pai to Wei-yüan T'ing, four stages, and thence to beyond Mong-chu, five stages, no other rocks are seen, and the succession of their red sandstones and shales becomes extremely monotonous to the traveller crossing them.

From Mong-pai the road ascends to the south-east for a mile and then slowly descends. At 2¾ miles the small hamlet of Sha-pa-tzu is passed where weathered purple shales alternate with sandstone bands of the same colour. At 3 miles a small stream is crossed in the bed of which red shales crop out. Keeping to the south the road descends to a big stream at 4½ miles: its bed is 150 feet across, and in it sandstone pebbles of various light tints and a few pieces of porphyry are found. The elevation here is 3,800 feet. Following up the bed of a small tributary, dark grey sandstones and black shales are seen which strike N. 30° E.-S. 30° W. and dip easterly at 65°. To the 8th mile, elevation 4,100 feet, the direction is south-east, winding through deeply dissected pine forest country. At 8 miles, hard, red, nodular shales strike N-S. and at 8¾ miles the road enters a small open valley in which the little Shan village of Ton-ch'ia-chai is situated. In the next 2 miles undulating country with a thick red soil and occasional outcrops of sandstone and shale is crossed. At 12 miles there is a well-marked N-S. strike on hard, fine-grained, yellowish-white sandstone bands standing out in a small, dry streamlet above violet, reddish-violet and white weathered shales. On all sides the soil is of an orange red hue and hides the continuity of the exposures. Descending to 13 miles and then ascending to 13¼, elevation 4,600 feet, two bands of light green shales crop out and form a striking contrast with the red shales by which they are surrounded. Following the same spur to its junction with the main ridge, the road then ascends this, reaching the top at 14 miles, elevation 5,100 feet. From this point the Ong-kong valley is first seen. There is now a steep descent of 2½ miles, reaching the village of Ong-kong at 16½ miles, elevation 4,200 feet. On the descent there are outcrops of various coloured shales, purple, reddish-purple, lavender, violet, red, and pink, with more bands of green, greenish-white and white tints. The shales are uniformly soft and weather into small fragments. It is impossible to work out any continuous sequence owing to the rapid changes of colour. A few sandstone bands stand out as ribs amid the bright Indian red soil.

The next stage is from Ong-kong to Chu-ho, a distance of 9 miles. Rocks of the same series continue the whole way. In the stream bed beyond the village, massive bands of reddish sandstone, 4 or 5 feet thick appear to dip gently up stream. For the first 2 miles there is a gradual ascent followed by a descent of 1 mile to Liang-yen-tsun. At 3¾ miles hard, fine-grained, greyish-white sandstones strike N.E.-S.W. and dip S.E. at 32°. Ascending to the east, excellent exposures of reddish-purple shales strike N. 30° E.-S. 30° W. and dip in an easterly direction at 5 miles. The road follows the same valley as far as Chu-ho, 9 miles, elevation 4,800 feet. A few sandstone exposures were seen at intervals.

The next stage is from Chu-ho to Ta-hai, 7½ miles. Good outcrops of shales cross the stream at ¾ mile, striking N.E. and dipping high to the S.E. At 3 miles the village of Tsin-tsun is passed, around which typical red sandstones with the same prevailing strike are seen. The road now ascends slowly towards the east-south-east. Fine-grained, reddish sandstones with well-developed joint planes strike N-S, and dip W. at 45°, at 6 miles, a height of 5,200 feet being reached at 6¼ miles on the top of the ridge. Ta-hai lies a little lower at 7½ miles. From Ta-hai to Wei-yuan T'ing is a distance of 10 miles. At the end of the small Ta-hai plain there are exposures of bleached shales and weathered sandstones. Massive sandstones crop out at 2½ miles in large rounded masses. At mile 4, an elevation of 5,300 feet is attained, and from this point the range which bounds the eastern side of the Wei-yüan valley is visible for the first time. This range forms the divide between the Mekong and the Pa-pien Ho, the Black River of Tongking. At 4½ miles the plain, with the river running through it, comes into view, and there is then a rapid descent to mile 8 where the low foot-hills on the west of the valley are seen. At this point the road comes down to the level of the stream, the valley of which it has previously followed at a higher elevation. Two miles more of level road separate this point from Wei-yüan T'ing.

### 3. WEI-YUAN T'ING TO PU-E'RH FU.

Wei-yüan T'ing is a small walled city situated at an elevation of 3,150 feet on a plain 12 miles long and 3 miles broad, in the valley of the Wei-yüan Chiang. It is a place of little importance as it does not lie near any of the main trade routes. Like most of the other cities in the far west of Yunnan it was formerly the capital of a Shan State named Möng Wan and it was doubtless a military outpost originally, established at the time the Chinese attempted to absorb the frontier tribes. Here, as elsewhere, these movements were eventually stopped by the pestilential climate of the Mekong and Salween valleys. Wei-yüan T'ing is still largely Shan because that race appears to be more immune to malaria and its effects than the Western Chinese. Any slight importance which the region possesses is due to its salt production from horizons in the Red Beds Series.

**Red Beds Series between Wei-yuan T'ing and Mong-chu.**

The rocks of the Red Beds Series continue south for some distance down the valley of the Wei-yüan Chiang until, as the map indicates, they are replaced by strata higher up in the Mesozoic succession, but they come to the surface again around S'su-mao T'ing. My route from Wei-yüan T'ing led first in a south-westerly direction to Mêng Pan, thence east back to the river which I recrossed and continued south-east to S'su-mao T'ing and Pu-e'rh Fu.

Hsian-yen-ching, the first stage is 10 miles south-south-west of Wei-yüan T'ing. The road traverses the level plain for most of the way, then rises gently at its end and drops steeply into Hsian-yen-ching, elevation 3,500 feet. The only rock exposures seen were in the last mile and consisted of pinkish sandstones striking a few degrees west of north. In the stream bed near the village soft reddish sandstones with false bedding and well-marked jointing strike N-S. The rolled boulders and pebbles give a good indication of the various kinds of local rocks of the series. There were soft, light-red sandstones, rough to the touch; hard, reddish-black, fine-grained sandstones with small inclusions of dense red clay; hard, reddish marls showing dark ochreous stains; light red and yellowish banded sandstones; hard white sandstones, composed of a closely fitting mosaic of tiny quartz grains; rough bluish-grey, fine-grained sandstones often with gritty bands containing rounded pieces of dull quartz and clouded yellowish felspar about the size of peas.

The village has two productive salt mines and two underground brine wells of the usual type.

The next stage is at Ho-ti-tang, a small village 12 miles to the south-south-west of Hsiang-yen-ching. The road ascends steeply out of the first valley and then descends into another one at 6 miles. Both streams are tributaries of the Wei-yüan Chiang. The second stream is crossed and recrossed many times. Numerous exposures of red shales and sandstones are seen, the former weathering down into irregular fragments. The region is very dissected by small tributary streams and there is much vegetation. At 8 miles thin bands of oolitic limestone are interbedded in the red shales. The exposed surfaces of the bands simulate an organic structure but this is due to the weathering out of the oolites as no trace of fossils was found. The road now leaves the valley and still keeping south-south-west rises to 5,400 feet at 9 miles, followed by a steep descent to 11 miles and then winds along into Ho-ti-tang which has an elevation of 4,300 feet. In the stream below the village, a series of rocks strikes N.-S. and dips at 45°—50° W. The rocks are hard, fine-grained red and bluish-white sandstones, with quartz infiltrations, alternating with the usual type of irregularly breaking, soft, red, marly shales. Ho-ti-tang, or as it is also known I-shang-ching, has two salt mines which were opened about 1899.

Leaving Ho-ti-tang, the road continues at the same level to mile 4, where the valley turns west and the road ascends steeply up the southern boundary range in a south-westerly direction. Fine-grained red and reddish-purple sandstones, occasionally with narrow bands of a lighter colour and with dark, soft, reddish-purple shales crop out in places along the bed of the river. At

5 miles there is a steep and winding descent to the west and at 6½ miles red sandstones appear in the rocky bed of a torrent, which the track follows to 7½ miles when it leaves it and rises steeply to the west, reaching the summit at 8 miles, elevation 3,550 feet. A steep descent of half a mile brings one to the Wei-yüan Chiang and the ferry is another half mile up stream at 9 miles. The river is here in a smooth reach with rapids further down, the bed is about 150 yards across and red, ferruginous sandstones crop out on both banks. Opposite the ferry a small tributary enters from the south-west and the track continues up this to 10½ miles which brings it to the camping ground at Man La.

From Man La the track proceeds in a general south-south-westerly direction. In a small stream below the village grey sandstones with yellow stains and dark, olive-green shales strike N. 15° E.-S. 15° W. and dip towards the W. at 45°. At 4 miles, the stream which the road has followed to this point, meets a tributary from the south-east and the track ascends the steep spur between them. Bands of dark grey and mottled blue, earthy limestone are found on this ascent, striking N. 25° W.-S. 25° E. and dipping at 40°-55° towards the N.E. The weathered surfaces of this rock are very rough and crossed by cracks in all directions, giving it a fragmental appearance. It was impossible to decide whether the limestone bands belong to the Red Beds Series itself, and it is possible that they may represent an outlying patch of the younger Mesozoic rocks which are known to occur a short distance further to the south. At 7 miles the top of a minor spur is reached, but the road still continues to ascend through the hamlet of Hsiao-tou-shu. A series of hard, greyish-yellow sandstones follows the limestones. The road now turns to the south and after a very steep ascent reaches the summit at 10 miles, elevation 6,100 feet. A descent for 2 miles towards the south-south-west brings one to the next stage of Sha-sung-ling at 12 miles, elevation 5,600 feet, and on the way down hard reddish sandstones and red shales crop out.

A march of 11¾ miles from this village in a general westerly direction brings the road to the edge of the small cultivated plain of Mêng Pan, one of the smaller Southern Shan States of Yunnan. There is a continual slight change of elevation, the road winding along or over low pine-clad ridges in which rock exposures are poor and scattered, consisting usually of purple or red shales, weathered down into small fragments, and scarce bands of harder sandstone. At $10\frac{1}{2}$ miles these rocks strike N. 15° E.-S. 15° W. and dip towards the E. at 43°. They are followed by grey and yellow nodular marls.

Viewed from a distance the Mêng Pan valley appears as a small, flat plain about 4 miles long and 4 miles broad, under cultivation and set amongst the low, forest-clad and rounded hills of the Red Beds Series from which long spurs run down into the plain. To the north and north-west the trans-Mekong mountain ranges are visible rising to much greater heights, with more serrated contours and undoubtedly belonging to a different geological group. To the north-west of Mêng Pan there is a wide and low gap in its boundary range, which is higher towards the south and it is through this that the distant mountains are seen to best advantage.

From Mêng Pan, I made my way to S'su-mao in six stages, halting at Mêng-chu, P'ing-chang, Ta-huang-ti, Na-hsai and Na-ku. At the south of the plain, the track turns up a low ridge towards the south for 2 miles and then ascends gradually to the south-east to 3 miles, whence it descends into the small valley of the Chiang-hsi-ho and keeps to the east-south-east up a small tributary. On the ascent soft, reddish-white sandstones were noted and in the valley red shales and marls. The road now leaves the valley and ascends to 4,700 feet at 6 miles whence it winds into Mêng-chu, at 8 miles, elevation 4,500 feet. The strike of the rocks seen in this march varies from 10° to 25° east of north and the dip from 55° to 60° in an easterly direction. The occurrence of red shales one mile to the west-north-west of Mêng-chu, identical in lithological appearance with those seen near the Chiang-hsi-ho seems to indicate the presence of a low fold between the two localities, but, unfortunately, I could not stay to confirm this.

**Upper Mesozoic succession of the Wei-yüan Chiang valley.**

Four miles beyond Mêng-chu travelling in an easterly direction and crossing several small tributaries of the Ta-kai Ho, soft, pale, reddish-grey sandstones in well-marked laminae, interbedded with thin bands of light, greyish-green shales, strike N. 10° E.-S. 10° W. and dip towards the east at 35°. At 7 miles there is a very steep descent to a stream lying in a deep ravine and here earthy, reddish shales with thinner bands of soft, reddish sandstones strike N.-S. and dip W. at 43°, in excellent exposures on the steep hill side. The regular dip of the beds forms a noticeable feature of the hills on the other side of the Wei-yüan Chiang. The shales weather into small, irregular fragments and on fresh surfaces are seen to be cracked and broken in all directions. On the ascent again, thin bands of dark, bluish-black limestone crop out, parts of which are shaley and split easily, while others are more massive and lighter in colour, containing calcite bands and possessing a bituminous smell when broken. The whole occurrence is not 50 feet thick and the limestones appear to strike in the general direction, *i.e.*, N.-S. They are followed at once by greenish marls, reddish shales and soft sandstone bands. On both sides of the village of Chiang-liang-tzu, 9½ miles, I saw thin limestone bands but the prevailing rocks are dirty red shales and soft reddish sandstones. They weather characteristically and build hill sides with but little soil covered with thin grass and a few scattered pines. The ascent continues to the top of the ridge at 12 miles, elevation 4,800 feet, and then the road winds along the crest to Ping-chang at 13 miles, elevation 4,600 feet. Just after passing Huang-ho-chai I found a limestone scarp some 60 or 70 feet thick cropping out across the road. The junction of the underlying rocks and this limestone band is hidden by grass and soil but close by I discovered a small outcrop, doubtfully *in situ*, of a conglomerate which had a red, clay-stone matrix and contained rolled limestone pebbles, from the size of an egg to that of a man's head, and numerous smaller ones like big beans. The lower limestone layers are hard, massive and white in colour, breaking with a sharp, even fracture. A careful search revealed no fossils. The upper layers are not so thick and are darker coloured with spots and bands of hard argillaceous inclusions. They break with an irregular fracture. I found small crinoid stems and one small gastropod in them. (No. 69b.) Directly above the limestones come dark greenish calcareous shales, from which I obtained a few badly preserved fossils (No. 70b). These shales are followed by light yellowish marls and shales. From this point to P'ing-chang the road sections are hidden.

From P'ing-chang there is a short ascent to 5,000 feet and thence a winding descent through Pe-yin-shan at 3 miles to the Wei-yüan-Chiang at 6½ miles, elevation 2,500 feet. Near the ferry is the Puman village of Pe-te. After crossing, the track keeps to the south-east ascending to Kun-yang-chai where there is a slight descent, followed by a rise through a small valley to Ta-huang-ti at 11 miles.

Near P'ing-chang dark calcareous shales with subordinate limestone bands strike N. 10° W.-S. 10 E. and dip E. at 45°. The crests of the ridges to the east and south of the village form great limestone scarps. The rock itself is bluish-white in colour, with irregular, calcite-filled cracks and contains crinoid stems and sections of small shells. As far as Pe-yin-shan, hard greyish-green shales and shaley limestones alternate with thin layers of limestone in plates of uneven thickness. The shales are hard when fresh but weather down into soft, yellowish marls in which I found a few small lamellibranchs near Pe-yin-shan. Below this village thin beds of darker limestone occur. These contain small shells which recall *Pecten sp.* (No. 73b). At this point the deeply cut valley of the Wei-yüan Chiang lies at one's feet. On the opposite side towards the north-north-east, a regular series of well-marked, long, dip-slopes can be traced with their corresponding steep escarpments, the latter doubtless due to the hard limestone bands and the former to the softer shales which come between them. To the north-east there are numerous long ranges stretching one behind the other across the unexplored patch of country through which the Möng-nai Ho flows. Beyond Pe-yin-shan, the road winds steeply down to Pe-te. At first, on the top of the descent more massive limestones of a dark blue colour crop out and the hillside is littered with fragments from them. From one exposure a few fossils were obtained (No. 74b). Lower down and occupying the greater part of the hill is a series of limestones and shales. The former take the shape of lenticular or nodular masses or bands, either of a yellow, dolomitic variety, or of an earthy grey or blue appearance. The bands are thin and pass gradually into the shales which are yellowish, greenish and buff in colour, with no well-marked lamination and a very irregular fracture. Thick layers of clear calcite crystals are common in the limestone bands. Crinoid stems are frequent (No. 75b) and I also noticed sections of small lamellibranchs and little turreted gastropods. From the upper part of this series I obtained the head of a crinoid which in general appearance resembles *Encrinus lilliformis* (No. 75b).[1] Another type of the limestone has a broken or rubbly appearance of a pale, greyish blue colour, in rounded pieces loosely held together but compact enough individually.

[1] This determination has been confirmed recently by Dr. F. R. Cowper Reed and thus proves the Muschelkalk age of these beds.

In the river bed at Pe-te nodular, greenish-grey shales are bent into low folds while pebbles of limestone and small rounded pieces of reddish sandstones form the burden carried by the river. Looking up stream the view is shut in by spurs, but down stream, to the south-west, there is a high limestone escarpment with an almost horizontal sky line. The higher parts of this are very precipitous. From the river to Ta-huang-ti the road traverses jungle and long thick grass, but greenish shales were seen in the beds of the small tributaries and there are occasional small exposures of limestone of the type already described.

From Ta-huang-ti the road runs for 2 miles to the south-east high up along the southern slope of a deep valley. Good exposures of dark greyish-blue limestones crop out in platey bands but a careful search only revealed large crinoid stems and one small broken lamellibranch (76b). Towards Ch'ou-shui and Ping-chang (2½ miles) hard calcareous shales of the same colour as the limestones crop out in well-marked bands. The limestones often contain patches of a darker colour, sculptured out by denudation into rough, irregular shapes on the weathered surfaces. The calcareous shales are followed by limestone bands of a lighter grey colour containing round and pentagonal crinoid stems and sections of gastropods and lamellibranchs (77b). The limestone bands alternate with layers of dark grey and yellowish shales from which a form recalling the genus *Daonella* was obtained (78b). Similar rocks continue to Ping-chang, the road following the general direction of the strike which is N.W.-S.E., with a moderate dip to the N.E. in this vicinity. From this village there is a short but steep ascent to the crest of a ridge topped with limestone, elevation 4,000 feet. On the descent to Ta-shan-shao (4 miles) yellowish shales with fragmentary *Daonella*-like forms are seen followed by limestones in well-defined bands containing corals (78b).[1] Ta-shan-shao is situated in a hollow containing a little lake and is bounded by high limestone ranges on the W. and S.W. Yellow shales and limestone bands now alternate until the road enters a narrow valley in which exposures are hidden by soil and cultivation as far as Shih-ke-la (6 miles), though limestone can be seen cropping out on the high valley sides.

From Shih-ke-la there is a steady descent to the south-east down to the Nam-ka Ho at 8 miles. Near the village yellow and

[1] The corals include *Thecosmilia* aff. *fenestrata* Reuss, according to Dr. Cowper Reed.

yellowish-grey sandy shales strike N. 30° W.-S. 30° E. and dip steeply to the N.E. They are soon followed by a series of hard, purple and violet, nodular sandstones which continue down to the river. These rocks, with a few sandy bands, seem to be quite conformable with those already described but no fossils were found in them.

The valley of the Nam-ka Ho running in a southerly direction and joining the Pu-e'rh Ho at 9 miles, is now followed. Very few rock exposures were seen as the bottom of the valley is covered with dense, tall grass, but the purple sandstones appear to continue. After crossing the main stream, a small tributary entering on the other bank from the south is ascended to the stage of Na-hsai at 11 miles, elevation 3,100 feet.

The next stage is at Na-ku, only about 7 miles in an east-south-easterly direction from Na-hsai, as the crow flies, but 14 miles by road, which for the greater part of the way follows approximately the winding course of the Na-hsai stream. From Na-hsai to Man-mu ($5\frac{1}{2}$ miles), elevation 3,300 feet, the general direction is south-easterly and along the strike of the purple sandstones met with in the previous march, but only very poor outcrops were found. At 5 miles hard, dark, calcareous shales occur. Beyond these, to 8 miles, poor exposures of reddish-purple slates with alternations of green bands in places are found. At $8\frac{1}{2}$ miles little exposures of greyish-blue banded limestone occur on the hill side. After crossing the stream and ascending to Kuang-shan a well-developed argillaceous series is again found. Close to Kuang-shan village the strike of certain yellowish, sandy shales is N. 25° W.-S. 25° E. and the dip in a south-westerly direction at 51°. A few small and badly preserved lamellibranchs (No. 80b) were obtained close to this place, from greenish-grey shales with brown spots and yellowish-white bands.[1] These are followed by limestones forming a conspicuous, rounded peak to the south-south-east. In the remaining 4 miles until the village of Naku is reached, rock exposures are poor and consist mainly of yellowish shales, stained red in places and sometimes containing hard, dark blue, earthy bands. These outcrops yielded no fossils and were small, much weathered and broken.

[1] These include various species belonging to the genera *Pecten, Pseudomonotis, Modiola, Gervillia, Anodontophora, Pleuromya* and *Cardium.* Dr. Cowper Reed's list of these and other fossils collected by myself in Yunnan will be published shortly.

**The Red Beds Series near S'su-mao T'ing.**

The last stage leads from Na-ku to S'su-mao T'ing, a distance of 13 miles. Leaving Na-ku the track keeps along the crest of a ridge for 1½ miles and then winds gradually down to a small stream at 4 miles. From this point there is a steep ascent to the top of a small spur running out towards the south from the Na-ku range. The summit of this is reached at 5½ miles, whence a gradual descent brings the traveller to the small cultivated valley of the Mong-li Ho. Around Na-ku, yellow and yellowish-white shales predominate. At the top of the little spur there are a few isolated exposures of dark limestone, but to the north, a high limestone mass is visible, some 8 or 10 miles distant. Beyond this point, the road traverses dense pine forest and outcrops are infrequent and poor but when visible they are of reddish shales and soft, reddish-blue sandstone bands very similar to the rocks of the Red Beds Series. At the same time they appear to dip in an easterly direction but this is not certain. It is highly probable that the Upper Mesozoic strata finish about this point to the east of Na-ku, and that they are followed by the Permo-Triassic horizons. As far as the alluvial plain (at 11 miles) of the S'su-mao valley, red shales and thin reddish sandstone bands were crossed at intervals. The small walled city of S'su-mao T'ing lies 2 miles across the little plain and near its eastern edge at an elevation of 4,700 feet.

S'su-mao is the "treaty-port" of south-western Yunnan and lies on the main southerly caravan route to Keng-Tung in the Southern Shan States of Burma. Other routes radiate from it to the French Laos and to the important tea-producing districts of the Sip-song-pan-na.

Pu-e'rh Fu lies 27 miles to the north of S'su-mao. The journey was done in two stages halting at Na-k'o-li, 13 miles from the latter town. The road leaves S'su-mao at an elevation of 4,700 feet and descends some 300 feet down into the flat, lacustrine plain. It continues across this for 3 miles and then ascends rapidly over a ridge of rocks belonging to the Red Beds Series to an elevation of 6,700 feet at 8 miles. From this point there is a steep descent to a small stream at 10 miles and the road then winds over the level alluvium of the valley to Na-k'o-li. Typical forest growth covers the whole country, but rock exposures are good in the road cuttings and stream beds. The strata are of the same type as those already described. Three miles to the south of Na-k'o-li thick beds of reddish sandstone strike N.-S. and dip W. at 35°.

Permian Limestones of P'u-erh Fu.

The Red Beds continue for 7 miles from Na-k'o-li as red shales and sandstones with odd bands of hard greyish-blue sandstone, but at the point where the P'u-erh Fu plain is first seen the underlying Permian limestones crop out in isolated exposures of light and dark grey varieties. Some of these contain foraminifera (No. 81B). At 10 miles the alluvium of the narrow plain, at the northern end of which the city is situated, is encountered. It has an elevation of 4,500 feet above sea level. The limestones form a line of fantastic peaks rising to a height of 800 or 900 feet to the west of the city and falling away precipitously to the north-west and north.

## 4. PU-E'RH FU TO TA-LI FU.

With the exception of a few inliers of Permian limestones found to the north-east of Pu-e'rh Fu on the ascent from the city to the Mekong-Black River watershed, and basic rocks—not seen *in situ*, occurring in the same limited area, probably in association with the limestones,—the whole of the rocks seen in this traverse as far as Hsia-kuan, a few miles from Ta-li Fu, belong to the Red Beds Series. The journey was accomplished in 20 stages, roughly from south to north more or less along the strike of the Permo-Triassic rocks which occupy so much of this part of Yunnan. For this reason I shall not describe them so fully as I have done others in the earlier sections of this paper.

In the first stage between Pu-e'rh Fu and Mo-hei, a distance of 12 miles, the last outcrop of the limestones is seen near Ch'ang-an, 7 miles from the city and a mile below the crest of the watershed already referred to. This has an elevation of 6,200 feet and there is a steep descent to Mo-hei at 4,200 feet across typical rocks of the lower horizons of the Red Beds Series, though the actual contact is not visible. Mo-hei has several important salt mines and brine wells. From this place the road turns abruptly north leaving the main trade route across Southern Yunnan to continue to the north-east, into the deeply excavated valley of a tributary of the Pa-pien Ho or Black River. Rock exposures are poor but the material brought down by the torrents from the 10,000-foot boundary range on the west is all of "Red Beds" appearance.

The second stage is reached at Mo-po, a distance of 12 miles. From Mo-po the road continues directly north up the valley which becomes smaller. At 4 miles it closes in and a small watershed is crossed into another little valley. Man-pieh, the third stage, 13 miles from Mo-po, lies in this at an elevation of 4,600 feet. The whole of the country hereabouts is covered with forest except the tops of the high ridges and the alluvial flats of the valley bottoms under terraced cultivation of rice. Red sandstone, grits and shales prevail, the soil has a red colour and the water in the streams is laden with red silt from the irrigation channels. Similar rocks continue to Man-lien, the fourth stage, 12 miles further on, at an elevation of 3,700 feet. Here the Chuan-Ho, as the Black River is called in the upper part of its course, is first met with. It is a large river in a narrow valley the sides of which rise to 7,000 or 8,000 feet. From Man-lien to Hsin Fu, the fifth stage, is a distance of 10 miles. Rock exposures are poor and infrequent but the red sandstones, grits, and conglomerates continue to strike N.-S. and to dip towards the E. The sixth stage is at Kuan-yi, elevation 3,900 feet and 13 miles further north. From this place to Enlo, stage seven, still going in the same northerly direction is 17 miles. Between En-lo and Chê-hu, stage eight, 14 miles, the alluvial deposits of the river become thicker and wider, and if anything, the exposures of red sandstones and shales are more infrequent than in the earlier marches. Similar conditions prevail between Che-hu and Man-ma-kai, 12 miles to the north-north-west, the only rocks seen being a few red and yellow sandstone boulders. Nineteen miles to the north-north-west of Man-ma-kai lies Ching-tung T'ing, 10 stages from Pu-e'rh Fu, but there is little to be seen on the journey except the red sandstone pebbles in the stream beds which are crossed, or the hard reddish grits containing quartz pebbles which are used to pave the roads in the neighbourhood of the city.

In the vicinity of Ching-tung T'ing, elevation 4,000 feet, the alluvial deposits of the river are so cemented as to deserve the term conglomerates: bands of sandy clay and of reddish sand rock are interbedded with them. There are a few small outcrops of sandstones and of red shales to the north of the city but at Hui-yao, 8 miles, a limestone scarp rises on the east bank of the river. It strikes N. 25° W.-S. 25°E. and forms a small chain of hills. Ascending from this place, red and greenish shales underlying the limestone are crossed, and are followed by soft, reddish, sandy shales with a doubtful dip towards the E. The limestone may be a local band interbedded in the Red Beds Series, or belong to a higher horizon in the Trias. It is unfossiliferous. On the steep descent to Pan-chiao-chai red shales and massive sandstone bands alternate. Near here the river valley, constricted by the limestones further down, again opens out. This village is the eleventh stage and lies 12 miles north-north-west of Ching-tung T'ing at an elevation of 4,450 feet.

Between Pan-ch'iao-chai and Hsiao-lo-ho, stage 12, elevation 4,700 feet, and 11 miles further up the valley, the same limestone band occurs again, followed by reddish marls. Near the village of Chêng-yüan-shao an excellent view of the Mekong-Black River divide is obtained. It is a high mountain range rising steeply with a very irregular and serrated outline culminating in the peak Wu-liao-shan, 11,500 feet high, to the west of Ching-tung T'ing. A large stream which seems to drain the divide enters the Chuan Ho near Lung-kai but the only pebbles found in its bed were red and light coloured sandstones, typical rocks of the Red Beds Series.

In the next two stages to Hsin-ma-kai, No. 13, 10 miles and Mao-kai, No. 14, 11 miles, elevation 7,150 feet, the direction is more to the north-west as the head of the valley is approached. The limestone band is again met with at first, the river breaking through its outcrop in a short and narrow gorge. From this point onwards the character of the country begins to change. Higher spurs separated by deep ravines run down to the river. The road follows the strike of the limestone and of the green and red shales which come above it. Near Hsin-ma-kai the shales become of darker colours and develop a very marked lamination. This locality was the scene of an extensive land-slip in 1907 when the whole of the mountain side gave way and fell into the river. It was probably brought about by the extensive destruction of the forests by the local Chinese. Near Niu-kai the rocks underlying the limestone band are seen to be sandstones associated with grey and yellowish-white shales. At Shih-tung-ssu, the dark, greyish-blue limestones are again breached by the river, which, by the time Mao-kai is reached, is nothing more than a good-sized stream. The rocks around this place are purple and pink variegated shales with a well-developed cleavage.

Nan-chien ,the next stage (No. 15), lies at an elevation of 4,800 feet, 15 miles further north. The road gradually rises across good exposures of laminated red shales near San-yen-ching. Beyond A-k'e yellowish-brown shales with black bands strike N. 22° W.-S. 22° E. and dip in an easterly direction at 43°. They may belong to an upper Triassic horizon but they are conformable with the red shales. The ascent finishes 3 miles beyond A-k'e and here the road leaves the valley of the Chuan Ho (Black River) and enters that of the Red River. From the summit a wide view towards the north is obtained and the valley of the Yang-pi Ho breaking through to the Mekong is plainly visible. All down the long descent to the Nan-chien plain there are excellent outcrops of sandstones and shales of the Red Beds Series, the strike varying from N.-S. to 20° W. of N.-E. of S. Sections exposed in a stream bed lower down show much disturbance with a variable dip. Small faults also occur which increase the dip beyond the normal. The plain is about 3 miles long and is surrounded by high, bare ranges. There is a high-level gravel deposit 200 feet above the present bed of the river, containing large sandstone pebbles. Underneath the main gravel band, which is some 8 to 10 feet thick, there are layers of finer assorted material, of gravel beds with smaller stones and of soft, red silts. Rain pillars are very common as the arrangement of the stratification tends to preserve the easily disintegrated lower bands.

From Nan-chien to Mi-chih, stage 16, is 12 miles, again in a northerly direction. A long ascent of 8 miles brings the road to an elevation of 8,400 feet whence there is a drop to 7,150 feet at Mi-chih. Sandstones of the Red Beds Series crop out over the greater part of the way. The dip varies a great deal and the strike veers more to the E. and W.

A march of 15 miles from Mi-chih leads to Mi-tu in the Hung-ai plain (stage 17), the general direction being north and then north-east. Alternations of soft, red shales, sandstone bands and grits continue to an elevation of 7,750 feet, where earthy shales worn down into small red fragments come in amongst soft sandstones of red, purple and yellowish-white colours. The strike is N.-S. and there is a high dip to the W. From the crest the long cultivated Hung-ai valley is visible and to the north-west the high, snow-covered peaks of the T'sang Shan behind Ta-li Fu. Similar rocks crop out on the descent, followed by limestones and decomposed basic rocks of the Permo-Carboniferous which are hidden eventually by soil and the alluvial deposits of the plain. Two or three coal seams crop out in Triassic rocks near the village of Li-kang-ch'ang towards the southern end of the Mi-tu plain.

The remaining three stages between the Hung-ai plain and Tali Fu have been described in earlier papers.[1]

[1] Contributions Nos. 5 and 6.
See also "Mines and Mineral Resources of Yunnan," *Mem. Geol. Surv. Ind.*, Vol. XLVII, p. 66.

## EXPLANATION OF PLATE.

### PLATE 20.

Reconnaissance Surveys between Shun-ning Fu, P'u-êrh Fu, etc Scale 1 inch=20 miles.

# CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YUNNAN IN WESTERN CHINA. 8. A TRAVERSE DOWN THE YANG-TZE-CHIANG VALLEY FROM CHIN-CHIANG-KAI TO HUI-LI CHOU. BY J. COGGIN BROWN, O.B.E., D.SC., F.G.S., M.I.M.M., M.I.M.E., *Superintendent, Geological Survey of India.* (With Plate 21.)

**Introduction.**

IN this, the final paper of my series dealing with the geology of Yunnan, I propose to record observations made during a traverse along a portion of the valley of the Yang-tze-chiang, from Chin-ching-kai, north-east of Tali Fu to Hui-li Chou, a city in the province of Ssu-ch'uan. The route followed was much the same as that taken by M. A. Leclère in 1898, who has published a brief account of his journey to which references are made later.[1]

Proper survey work is impossible during rapid marches of this kind, especially in mountainous country of which only sketchy topographical maps exist. As a consequence, accuracy is not claimed for such boundaries as are shown on the map nor finality for any of the conclusions arrived at in this report. These, by nature of the case, must be regarded as tentative and subject to modification in the light of further knowledge. The only justification for their publication lies in the fact that they deal with an isolated region exceedingly difficult of access, yet, at the same time, of great interest from a geological point of view.

**Volcanic rocks between Ta-li Fu and the Yang-tze-chiang.**

The village of Chin-chiang-kai is situated on the northern bank of the Yang-tze-chiang, at an elevation of 4,050 feet above sea-level, four stages to the north-east of Ta-li Fu. From the eastern shores of Lake Erh-hai, opposite this city to the great river itself, contemporaneous volcanic rocks of Permo-Carboniferous age intervene, surmounted here and there by outliers of limesonet of varying extent.

[1] "Étude géologique et minière des Provinces chinoises voisines du Tonkin" A. Leclère : *Ann. des Mines,* 9th Série, Mem XX, 1901, pp. 381-395.

From one of these, near Ta-wang-miao, 23 miles from Ta-li Fu, a few fossils were collected. They seemed to resemble the fauna from the white limestone of Yunnan-i, considered by Douvillé to be of Permian age.[1]

There is an important ferry at Chin-chiang-kai, where two minor trade routes from Ta-li Fu and Yunnan Hsien respectively, meet, cross the river and continue north to Yung-pei T'ing. On the northern bank of the river the andesites, basalts and associated rocks which attain so extensive a development further south, are masked somewhat by the older, high-level alluvial deposits of the Yang-tze.

**Junction of the Permo-Carboniferous limestones and the Red Beds Series.**

Three marches to the north of Chin-chiang-kai lies Yung-pei T'ing and for the greater part of the way the track follows a small tributary flowing south to the Yang-tze. The first stage is at Man-kuan, a distance of 13½ miles. At 3½ miles from the starting point there are good exposures of Permo-Carboniferous limestone, and at 4½ miles numerous fossils were collected from small outcrops on the western slopes of the valley. These are now being determined by Dr. F. R. Cowper Reed.[2] On the eastern bank of the stream at 5 miles, the rocks of the Red Beds Series are seen, dipping to the east and overlying the limestones of the western bank. The junction is marked by a conglomerate in which pebbles of red jasper and red and green porphyry are the commonest rocks. The line followed by the stream roughly divides the two groups, indeed its tributaries from the east are full of red sandstone and conglomerate boulders, but the thick blanket of alluvium often hides the strata for miles and makes observations difficult elsewhere.

**Fluvio-lacustrine deposits of Lake Pan-hai.**

The second stage leads from Man-kuan to Pan-hai-tzu, a distance of 14 miles, and here again, fluvial and lacustrine deposits in a wide-bottomed valley generally bury the rocks. The outlines of the western boundary ridges in the first few miles of the stage, nevertheless suggest the development of limestone in them. At 13 miles, soft, speckled grey sandstones and red, nodular shales strike north 30° west-south 30° east, and dip north-east at 60°. The upper part of the valley is occupied by a deep lake and the road runs for several miles along its eastern shores. This lake, like many others in Central

[1] Contribution No. 6 *Rec. Geol. Surv. Ind.*, Vol. LIV, p. 70.

[2] Dr. Cowper Reed has studied this collection and attributes a Devonian age to the fossils. On stratigraphical grounds I believe however that Permo-Carboniferous limestones also occur in the vicinity.

Yunnan, is merely a remnant of a much larger sheet of water which existed in Plio-Pleistocene times and its deposits fill a large part of the valley further south and are particularly well displayed between miles 7 and 8.

**The Red Beds Series.**

From Pan-hai-tzu, elevation 5,650 feet, to Yung-pei T'ing, elevation 7,250 feet, is a distance of 15½ miles. Continuing to the north along the eastern margin of the lake, there are poor exposures of sandstones of light colours on the hill-sides as far as Liu-chia-wan at 3 miles. Beyond this village, and as far as Liu-shui-tang at 7¼ miles, the track crosses cultivated land or grassy slopes on which greenish and reddish shales, interbedded with friable sandstones, crop out. A steep ascent to Ho-ti-tang follows, across the range stretching north and south on the western side of the Yung-pei T'ing plain. Reaching the summit at 8,150 feet, the path continues along the crest for half a mile before it descends into the plain at its southern extremity. The only visible rocks belonged to the Red Beds Series. The plain is about 8 miles long and 2 miles wide at its broadest part and is undoubtedly a dessicated lake basin.

**Permo-Carboniferous Rocks west of Yung-pei T'ing.**

From the city a visit was paid to the copper-mining centre of Pao-p'ing-ch'ang two stages further west. As an account of this journey has already been given it is only necessary to recall that fossiliferous Permo-Carboniferous limestones, similar to those found near Chin-chiang-kai-occur in the ridge separating the Yung-pei T'ing plain from the larger one of San-ch'uan-pa, while further west still, the country is built up of igneous strata identical in every respect with those examined between Ta-li Fu and the Yang-tze. The volcanic series is of great thickness and contains flows, tuffs and ash beds, intercalated with bands of shale and grit. The tuffs disintegrate at the surface into red and green spotted, angular fragments and the shales into easily broken, nodular masses.[1]

**The Red Beds succession east of Yung-pei T'ing.**

From Yung-pei T'ing I marched east to Hui-li Chou, a distance of 132¼ miles, covered in 8 stages. The first halt is at Ta-lu, a distance of 15 miles. After crossing the alluvial plain the path ascends to the south-east across very broken country

[1] "The Mines and Mineral Resources of Yunnan." *Mem. Geol. Surv. Ind*, Vol. XLVII, Pt. 1, pp. 109-117.

covered with pine trees. The rocks in the rare instances where they are seen, consist of alternations of soft, light-coloured shales and sandstones with bands of coarse, friable yellow sandstone. A hard white sandstone also forms a well-marked horizon and makes prominent bluffs on the hill-sides. Near Lan-yi-chi thin beds of white marly limestone occur. Beyond this place the outcrops of the light-coloured rocks become still poorer and soon, intercalations of nodular shales and darker speckled sandstones are seen. On the descent to the stream flowing at the foot of the Ta-lu ridge there are good continuous exposures which dip to the west-north-west at 15°. The red colour of the sandstones in this vicinity is only a superficial effect induced by weathering, and when freshly broken they are seen to be of a dark grey shade, or of drab speckled with white. Thin layers of small quartz pebbles occur in some of them.

In a small side stream on the last ascent to Ta-lu, blocks of a coarse white granite were found. The most interesting feature of this march is the occurrence of the conglomerate horizon on this ascent, containing pieces of limestone two or three inches across identical in appearance with that from the Permo-Carboniferous, as well as sandstone and quartz pebbles. Great pieces of the conglomerate strew the hill-sides and are followed higher up by crumbling yellow sandstones and yellowish marls, striking north 20° west-south 20° east and dipping towards the south-west at 20°. Ta-lu (7,700 feet) is a small scattered village built on the gentle upper slopes of what must be an horizon low down in the Red Beds Series.

**Correlation of the Conglomerate.**

As one approaches Ta-lu from the west the rocks are seen to dip in a westerly direction, but on the rounded tops of the hills to the east there is an apparent easterly dip, indicating low folding. In this way the friable yellow sandstones and marls just described may perhaps be the representatives of the soft, light-tinted shales and sandstones observed in the early part of the march, though there, the basal conglomerate appears to be hidden under the alluvial cloak of the Yung-pei T'ing plain. At the same time there are differences between this conglomerate and the one I regard as the true basement bed found five miles to the north of Chin-chiang-kai. In the latter the predominant elements are pebbles of jasper, porphyrite and related rocks undoubtedly derived from the underlying volcanic series The present one contains practically nothing except limestone pebbles, for although a few volcanic constituents were seen, they are exceedingly scarce. Again, it is a much coarser rock with a finer and paler cement and its pebbles do not appear to have travelled far, whereas in the other type they are small, as a rule, and very well rounded. These differences may be the result of variations in the conditions of deposition of the same band in two localities, or, they may point to the presence of a second conglomerate of slightly younger age than the true basal one. The matter could not be settled in a single rapid traverse, but I think it advisable to record my suspicions for the benefit of any future surveyor who may have the opportunity of working over this region systematically.

The next stage leads to Wei-sha, a distance of 14 miles. The road ascends to the east attaining an elevation of 9,800 feet at 5 miles. Large blocks of the conglomerate are common just to the east of the village and there are also a few exposures of hard, white, marly beds, striking north and south and dipping at low angles to the east. Further up the ascent, outcrops are poor and consist of light-coloured sandstones and shales still possessing the low easterly dip. Towards the north the Red Beds can be seen cropping out on the hill-sides.

**The Mesozoic Succession between Ta-lu and Hsin-chuang.**

At the crest of the ridge a limestone is found striking north and south and dipping east at 30°. It is a hard, bluish-white rock weathering into slabs. It is fossiliferous but it is almost impossible to extract the remains, as they break with the rock and weather below its surface, so that only a few fragmentary bivalves were obtained here. I believe that this limestone band marks the commencement of the higher part of the Triassic succession which stretches for 40 miles in an easterly direction as the crow flies, and is the northern counterpart of the Triassic and Rhaetic deposits of Yunnan-i.[1] I could form no opinion as to the nature of its junction with the older rocks without spending more time there and this was impossible. Leclère's views are as follows:—" Superposed on the Palaeozoic formations of the Ta-li Fu region, the Triassic, Rhaetic and Liassic sediments are extended eastwards by means of a transgression which seems to result in the Rhaetic stage resting in places on the diorite fringe of the Ch'ien Shan massif. The ancient shore line runs nearly north and south for unknown distances on both sides of the Yang-tze and encloses very

[1] Contribution No. VI, *loc cit.*, pp. 76-78.

rich deposits of coal."[1] It is beyond question that this extensive Mesozoic basin owes its origin to the gradual spread of the sea in Triassic times over the ancient Palaeozoic land surface. Yet this by no means precludes the possibility of later faulting along the old shores, especially as it has been proved that the Mesozoic basins of Eastern Yunnan owe their preservation to the action of long fractures with considerable throws.

The limestone to which attention was directed at the commencement of the last paragraph, continues for about two miles and is then replaced by yellow and white shales, marls and thick bands of soft, yellowish sandstone, striking a few degrees west of north-east of south and still dipping to the east. Exposures of dark shales and sandstones follow for the next four miles when a second limestone zone forms cliff-like outcrops. From these three brachiopods of a *Terebratula*-like form were collected. At the point where the last ascent to Wei-sha starts, a succession of hard, fine-grained purple shales is followed by another limestone band dipping to the east. A series of beds in a similar position to these, found by Leclère between Chiu-ya-p'ing and Chao-chou-la is regarded by that writer as probably representing a Jurassic facies owing to the fact that it overlies a limestone of presumed Liassic age. This is too far-reaching an assumption to make in the absence of palaeontological evidence.

Wei-sha lies at an elevation of 7,800 feet in a small valley surrounded by limestone cliffs.

The next stage is at Chiu-ya-p'ing, a distance of 20 miles. Leaving Wei-sha, a thick soil cap hides the rocks at first, but at 1½ miles, red shales interstratified with thin layers of sandstone, dip towards the east. A second village bearing the same name of Wei-sha is passed at 3 miles and in the bed of a small stream just beyond it, blocks of white granite with large porphyritic felspar crystals are seen. The path now crosses a ridge and descends to Ping-wa at 9 miles. Reddish and reddish-purple shales occur on the ascent and are followed by bluish-white limestone near the top. The high position of these beds again led Leclère to suggest that they may belong to a Jurassic horizon, but a study of any fauna they may contain is necessary before this can be confirmed. Small limestone cliffs are seen on the descent and at the bottom of the hill at 12

[1] Leclère, *loc. cit.*, p. 385.

miles the track enters a gorge in this rock, excavated by the Hsing-chaung Ho, an easterly flowing tributary of the Yang-tze.

**Coal Measures of the Chiu-ya-p'ing neighbourhood.**

The limestones attain a very considerable development around Chiu-ya-p'ing, a little town lying at an elevation of 4,200 feet in the narrow valley of a small stream flowing from the north-west to join the Hsing-chuang Ho. Coal seams crop out on both slopes of the valley and the tops of the ridges are capped with limestones which may be of Rhaetic age. Leclère, basing his opinion on stratigraphical grounds, regarded them as Liassic. On the west, the coal seams at Pa-sha-shan are about 6,000 feet above the sea, that is to say about 1.800 feet above Chiu-ya-p'ing itself. After crossing one thick limestone band, the path ascends across red shales topped by steep limestone crags. The seams themselves are in a series of soft, grey sandstones, banded with variegated and yellowish shales with carbonaceous partings.

Leaving Chiu-ya-p'ing and starting the ascent on the east to the next stage at Hsin-kai, a distance of 11 miles, the red shales already seen on the western slopes are again met with. Here, they are interstratified with a few, thin, bleached bands and followed by limestones dipping to the east-north-east at 20°. These, in their turn, give place to conformable, light yellow shales and they are overlain by limestones again. Coal is mined from seams in the yellow shales at We-pan-tsun and Ta-pin-tzu. Leclère places the upper limestones in the Lias and has referred to the characteristic karstic appearance of the scenery in this district. Further limestone bands, followed by shales and by grey sandstones, interbedded with thick, carbonaceous layers, occur before the last steep climb to the crest at 7 miles. Here, an extensive view of the country further to the east is obtained. Several well-displayed horizons are to be seen, one behind the other, stretching to the north and south and dipping to the east. They form low escarpments with long, gentle, intervening dip slopes. Sandstones are the prevailing rocks hereabouts and the hard and soft layers are very well-defined and separated by reddish-yellow shales. Near Ta-wa-ya-kou, 7½ miles, a coal seam crops out. Descending the little side valley to Hsin-kai, hard, massive sandstone bands are exposed on both sides, while under them on the south, a hard, bluish-white limestone appears. The sandstone cliffs come close up to the village on the south-west. There are numerous, abandoned coal workings in the sandstones and others in operation further away. The coal used locally as a domestic fuel, is a hard, bright variety of excellent appearance.

From Hsin-kai (elevation 4,650 feet). proceeding east, the next stage is reached at Hsing-chuang (4,400 feet), a distance of 16 miles. The coal-bearing series continues most of the way. Outcrops of limestone occur just outside the village, but after that cultivated land obscures the rocks for the next 4 miles. Poor exposures of shales and marls are then followed by grey, fine-grained sand-tones striking east and west and dipping south at 18°. Further on, towards Ma-ch'ang, which is 8 miles from Hsin-kai, alternations of yellow sandstone and soft. arenaceous shales strike north 35° east-south 35° west and dip in a south-easterly direction at 60°. Near this place the Yang-tze is encountered again and the track proceeds just above the river, but the detritus from the hills and the travertine on the surface, mask the occurrences of solid rock which were expected in such a situation. Nevertheless, the sandstones seem to continue to mile 11, that is to say to a mile beyond the village of Ke-ti-ping, when they are succeeded by limestones once more. Coal was not being mined at Ma-ch'ang at the time of my visit but there was an active mine at Mo-so-ho, four miles further to the east. Indeed, for at least this distance below Ma-ch'ang, on both banks of the Yang-tze, there is a prominent coal-bearing zone.

**Zeiller's evidence for the Rhaetic age of the Yang-tze Coal Measures.**

From the roof of a mine in this locality, in a seam 6 feet thick, dipping to the east at 40°, fossil plants were collected by Leclère and described by Zeiller as follows:—

"Tai-pin-ch'ang, on the frontier of Yunnan and Ssu-Ch'uan, to the east of Yung-pei T'ing. FERNS; *Cladophlebis Roesserti* Persl. (sp.); *Ctenopteris* n. sp., identical with an undescribed species from Tong-king, with long pinnules, recalling slightly *Nilssonia Blasii* Brauns; *Taeniopteris* n.sp., with simple fronds and thick nerves, related to *Taeniopteris immersa* Nathorst; *Glossopteris indica* Schimper, represented by fronds with a pauci reolate nervation, exactly resembling that which I have observed on certain specimens from South Rewah in India; *Dictyophyllum exuile* Brauns (sp.); *Clathropteris platyphylla* Gœppert.

"Amongst the Cycads: a *Pterophyllum* with large folioles truncated at the vertex, showing resemblances on the one hand to *Ptero-*

*phyllum longifolium* Brongniart, and on the other to certain species from the Rajmahal beds of India; *Anomozamites inconstans* Brauns (sp.); finally two small fragments of fronds which, although incomplete, seem to deserve identification without hesitation with *Ptilophyllum acutifolium* Morris, from the Upper Gondwanas of India.

" The assemblage of these forms, containing at the same time species from the European Rhaetic and from the Lias of India, leads to the correlation of the Tai-pin-ch'ang coal-bearing horizon with the Rhaetic stage, the same as those of Hon-gay and Ke-bao in Tong-king, with which it presents a remarkable similarity of flora."[1]

This palaeobotanical evidence is sufficient to determine the comparative age of the coal seams in this vicinity. I have shown elsewhere that the field may persist for some 80 miles or more further to the south-west, to the latitude of Pin-ch'uan Chou and Yunnan Hsien, but whether the coal seams of the latter portion belong to the Rhaetic, or some lower portion of the Triassic system, is a question which cannot be answered until the fauna and flora collected there by myself, and now in the hands of Dr. Cowper Reed, has been investigated.[2]

**Gold-bearing alluvial deposits of the Yang-tze.**

The high-level pebble beds and older alluvial terraces of the Yang-tze itself around Ma-ch'ang, and for some miles both up and down stream from this place, have been worked extensively by the local inhabitants for gold. Drifts are made into the river benches, following the layers in which the gold is concentrated, and these small-scale mining operations are helped considerably by the infiltration of calcium carbonate, doubtless derived from the Mesozoic limestones into the gravels.

After crossing the Pan-han Ho, at mile 13½, in the bed of which boulders of a fine-grained granite were seen, an exposure of a very decomposed basic igneous rock was found, probably intrusive into the Rhaetic sandstones. At this point the Yang-tze takes a short bend to the south and displays the limestone hills on its left bank, but along the remainder of the road to Hsing-chuang (elevation 4,400 feet) the rocks are hidden by a thick capping of red soil. One of the most interesting features of this march is the veering

[1] *C. R. Acad. Sc.*, 22 Jan. 1900, quoted by Leclère, *loc. cit.*, p. 349.

[2] Dr. Cowper Reed has since concluded that this abundant fauna is of upper Triassic age exhibiting much the same characters as that of the Nucula marls of the Sunda Islands and of the Padang beds of Sumatra.

round of the dip to the west. At Hsin-chuang the boundary between the provinces of Yunnan and Ssu-ch'uan is crossed.

**Diorites and associated rocks beyond Hsin-chuang.**

From Hsin-chuang I proceeded east along the north bank of the Yang-tze to San-tui-tzu, a distance of 18½ miles, crossing the Ya-lung river at mile 15½. The general direction is towards the east and the track is at first some 200 to 300 feet above the level of the river below. About 1 mile from Hsin-chuang the first exposures of the diorite, which with its associated rocks builds up the greater part of the ground traversed in this stage, are seen, the track, for a short distance, being cut out of the decomposed surfaces of high cliff-like occurrences of these rocks. At the same time it must be pointed out that the definite boundary between the diorite and the Mesozoic limestones, etc., to the west has not been mapped owing to the thick surface covering and the fact that this portion of the march had to be done in the dark. From general appearances however I am inclined to think that the line is some two miles to the east of Hsin-chuang.

Although the term "diorite" is a useful one to apply to the rocks of this massif in the field, and although a large part of it is made up of a true diorite, in some places it appears to shade into gabbro and in others to be altered into amphibolite. Thus, Levy and Lacroix, who examined the specimens collected by Leclère, state that:—"in the region of the porphyritic effusions of the Yang-tze, the rock at depth is a bytownite-diorite, passing into a schistose amphibolite. The diorite encloses veins of a rock formed at two periods and composed of a microgranulite containing amphibole, black mica, oligoclase and pyrites." [1]

After crossing the diorite outcrops, conglomerates are found which at first sight appear to be the same as the cemented bands of the high level river terraces, but a little further on they proved to be interbedded with red sandstones and to dip at low angles to the east. This small exposure may be an outlying patch of the Triassic rocks lying on the diorite and the possibility of other occurrences of the same type is not overlooked. Thus, certain contorted rocks seen on the right bank of the Yang-tze at the commencement of this march are perhaps of a similar character, but this is

[1] *Loc. cit.*, p. 302.

not proved as they were only viewed from a distance and across the river.

Exposures are very poor as far as the 6th mile when diorite is seen below the soil in small dry watercourses running down to the river near the hamlet of Ma-ch'ang-tzu. After passing Tao-ma at 8½ miles, a rocky spur is crossed in which good exposures of the igneous rocks are visible though unfortunately they are very decomposed. Here, there are coarse, medium and fine-grained bands, in the first of which plagioclase and hornblende are the predominant minerals. Thin veins and films of serpentine traverse the rock in some places and in others there are stringers and veinlets of black, practically pure iron ore.

The constricted character of the Yang-tze valley hereabouts together with its rapid current, forms a striking contrast to the wider Mesozoic valley and the placid nature of the stream further to the west. At this point there were several gold-washing installations at work on the high-water deposits of the river and not on the older terraces. From mile 11 to mile 15, the track follows the bed of the river across sand banks and boulder and pebble beaches, the materials of which are derived from the basic rocks of the surrounding region. Close to the village of Cha-ho, at 15½ miles, the Ya-lung joins the Yang-tze, the tributary river appearing to the eye to be practically as large as the main stream. The diorite is met with again on the left bank, traversed by many thin veins of serpentine. The same rock continues from the right bank to San-tui-tzu (elevation 3,850 feet), at mile 18½. Leclère's description is so exact that it is best to give it in his own words :— "La diorite renferme de nombreuses enclaves schistöides, et passe souvent à l'amphibolite. On y rencontre aussi des filons microgranulitiques sans amphibole, disséminés et parfois comme diffusés dans la masse dioritique. On y trouve aussi des injections basiques plus récentes, complètement transformées en matières serpentineuses, et des filonnets quartzeux traversant toutes les autres formations pétrographiques." [1]

Near San-tui-tzu the road finally leaves the Yang-tze which turns in a sharp bend to the south, and continues east to I-lang-ho, the next stage, 22 miles, and thence north-east to Hui-li Chou which is 16 miles further on. Typical diorite exposures are found in the

[1] *Loc. cit.*, p. 383.

first mile or two from San-tui-tzu. but beyond this and up to the 8th mile, there is much soil and stratified alluvium. Where the latter is cut away, however, the diorite is seen to underlie it.

**Granite and associated rocks of the Ch'ien Shan.**

At 9½ miles near the village of Si-ka-ta, small boulders of fine-grained mica schist and rocks of a phyllitic nature are seen in the beds of the streams, but the diorite is believed to continue almost up to this point. There is now a gradual ascent to the east, passing the village of Tsin-ye-kou, at 10½ miles, where there is an outlier of limestone, but it is followed at once in the ravine beyond the village by blue phyllites and white quartzites. At mile 13, the track passes Pan-ching where there are numerous limestone exposures, but at mile 13½ on the gradual descent to the east-south-east, granite is first seen. It is very decomposed and soft, so much so that the foot-paths wear deeply into it. Further on there is a steep ascent, keeping a little to the north of east and the summit is reached at mile 18, elevation 7,700 feet. From the crest the road descends very steeply to the north-east for four miles to I-lang-ho, elevation 6,850 feet. Decomposed granite continues the whole way. It is a coarse, even-textured rock, the quartz grains of which weather out in large numbers.

The correlation of the metamorphosed rocks seen in this march is a difficult matter. The phyllites, mica schists and quartzites recall very much those of the old Kao-liang system, but the presence of the limestones militates against the supposition that they are identical. On the small map accompanying my economic report on Yunnan, I have indicated them as representatives of the Palaeozoic (Devonian, Carboniferous and Permian in part), being led to this conclusion by the lithological resemblance of the limestone with those of the older Palaeozoic generally in Yunnan, and regarding the arenaceous groups as shales and sandstones metamorphosed by the I-lang-ho granite. The question cannot be settled as the result of one rapid traverse and must be left open.

With the exception of a sandstone outlier just outside I-lang-ho the beds of which strike north 20° east-south 20° west and have a vertical dip, the granite continues for the next 9 miles to Lo-ko-tsin, where it gives place to hard sandstones, white quartzites and blue slates. Intruded into these rocks are two sills of basic rock now in a very decomposed state. These are presumably the "melaphyre labradorique" of Leclère.

The granite itself has been described by Levy and Lacroix as follows :—

"A massif of leptinite with very abundant vermicular quartz enclosing to the east of Hui-li Chou, dykes of nepheline syenite containing aegyrine. Accessory minerals are an amphibole of the arfvedsonite family, lepidomelane, sphene, sodalite and cancrinite. One of the specimens contains a mineral which is probably new associated with the aegyrine." [1]

**Palaeozoic rocks near Hui-li Chou..**

Ascending to the east, purple slates strike north and south and dip east at 82°. They are followed by quartzites, variegated slatey beds and then by the Palaeozoic brecciated limestone which crops out in small isolated pieces and in cliff-like exposures in the stream beds. From the top of the ascent at 12 miles, the valley in which Hui-li Chou is built is first seen. On the descent to the plain the brecciated limestone continues forming a chracteristic Indian red soil. According to Leclère it is overlaid by diabases but I was unable to find these rocks. The Hui-li Chou plain has an elevation of about 6,500 feet above the sea and is a narrow, elongated expanse of flat land, running north and south for some 15 miles and broadening out slightly at its southern end. It is drained by a stream which finds its way south to the Yang-tze. The city is a prosperous commercial centre, on an important trade route between Yunnan Fu and the Chen-ch'ang valley of Ssu-ch'uan.

[1] *Loc. cit.*, p. 302.

## EXPLANATION OF PLATE.

PLATE 21.

Geological Sketch Map of a Traverse in the Yang-tze Valley. Scale 1 inch = 20 miles.

# NOTE ON THE BOULDER BEDS BENEATH THE UTATUR STAGE OF THE TRICHINOPOLY DISTRICT. BY HEM CHANDRA DAS GUPTA, M.A., F.G.S.

IN his description of the rocks of the Trichinopoly district Blanford mentioned the occurrence of boulder-beds lying below the rocks of Utatur age. No fossils were recorded from these boulder-beds and they were supposed to be of the same age as the Upper Gondwanas on which the Utatur beds were deposited. It must be pointed out that these beds are quite distinct from those containing concretions with fossil shells sufficiently well preserved to indicate their age.

A number of nodules collected in 1912 from the neighbourhood of Utatur are variable in size and usually spheroidal in shape, the difference between the two axes of the spheroid being sometimes very considerable. One of the nodules gives 67 mm. and 37 mm. as the lengths of the two axes; in other cases the difference between the two axes is very much reduced. They often have a white coating and when broken, exhibit a dark grey interior with white crystalline portions. The specific gravity of the nodules was found to be 2·80.

The white outer coating effervesces with hydrochloric acid and the rest of the nodule is partially soluble with effervescence. The nodules are phosphatic and the presence of iron, aluminium, calcium and magnesium was determined qualitatively. The insoluble portion is black, but loses its colour on ignition, a white-coloured substance remaining behind.

Sections, when examined under the microscope, show chiefly a yellowish-brown substance which is non-pleochroic and isotropic, and gives the chemical reaction of a phosphate. It may be noted in this connection that while describing the phosphorite nodules of the middle oligocene beds of Leipzig, Prof. Credner described the presence of a "phosphoric cement of a yellowish-brown colour."[1] According to Gosselet, lime phosphate may occur under three different forms—(*a*) crystalline, (apatite), transparent, aniso-

[1] *Abh. d. K. Sach. Gesell. der Wiss.*, Vol. XXXVII, p. 11.

tropic; (*b*) non-crystalline, istropic, transparent and (*c*) opaque, brown and earthy.[1] The phosphate occurs in patches and calcite is also found abundantly. Among other ingredients may be mentioned small grains of quartz and a number of opaque patches chiefly black and rarely green in colour. Besides these ingredients some of the slides reveal the presence of foraminifera which are of very minute size and belong mostly to the genera *Globigerina*, *Cristellaria*, *Nodosaria* (?) and *Textularia*. Many of the foraminiferal chambers give a black cross under crossed nicols, recalling a phenomenon already recorded by Gosselet.[2] Though nothing beyond the generic determination of these fossils is possible, their existence is of interest for the reasons given below.

Phosphatic nodules have been previously described from Mussouri,[3] Dandot,[4] Pondicherry[5] and the Perambulur taluq of Trichinopoly district.[6] The nodules of Mussouri have not yielded any organic remains and the Dandot nodules contain broken fragments of shells which can be observed microscopically. The Pondicherry nodules are very rich in fossils which can also be seen by the naked eye. The fossils in the Utatur nodules are, on the other hand, discernible only with the help of the microscope. Our knowledge of the Cretaceous foraminifera of Southern India is very meagre, Dr. Stoliczka having described one *Orbitoides*, with a few specimens of *Rotalia* and *Lagena*[7] and Kossmat having described *Amphistegina* and *Orbitoides*.[8] The occurrence of foraminifera in the boulder-beds shows that they cannot belong to the plant beds which are of fresh-water origin.

An inspection of the map published by Blanford shows that the boulder-beds lie along the border of the Cretaceous deposits. According to the late Dr. Oldham these boulder-beds are "nothing but the deposits locally formed.....close to the old shores,"[9] while, in the opinion of Mr. R. D. Oldham, "on the whole there appears every reason to believe that the Utatur beds were formed in the

[1] *Ann. de la Soc. Géol. du Nord.*, Vol. XXXI, p. 44.
[2] *Op cit.*, p. 43.
[3] *Ind. Forester*, Vol. VI, pp. 211-218.
[4] *Rec. Geol Surv. Ind.*, Vol. XX, p. 50.
[5] *Ibid*, Vol. XXVIII, pp. 15-21.
[6] *Ibid.*, Vol. XLVI, p. 283.
[7] *Pal. Ind.*, Ser. VIII, Vol. IV, p 193. Stoliczka described the Orbitoides as *O. Faujasi*, but according to Prof. Vredenburg it is *O. minor* (*Rec. Geol. Surv. Ind.*, Vol. XXXVI, p. 25).
[8] *Rec. Geol. Surv. Ind.*, Vol. XXX, p. 97.
[9] *Mem. Geol. Surv. Ind.*, Vol. IV, p. 40, footnote.

neighbourhood of a coast-line."[1] This statement receives support from the phosphatic nature of the nodules, since according to Dr. Teall "the formation of phosphatic deposits may take place on the surface of the land or beneath the waters of the ocean. In the latter case they appear to be limited to continental borders where deposition is slight, and where current action is often well marked."[2]

Two types of phosphatic nodules were recognised by Dr. Collet, namely, (*a*) nodules with foraminifera or other calcareous organisms and (*b*) nodules without calcareous organisms.[3] These two types have different modes of origin. The Utatur nodules belong to class (*a*) and according to the author the origin of the calcium phosphate is due to the action of ammonium phosphate on calcium carbonate in the way cited.

$2(NH_4)_3PO_4 + 3CaCO_3 = Ca_3(PO_4)_2 + 3(NH_4)_2CO_3$. The action is one of pseudomorphism and "calcareous shells are often replaced by phosphate."[4] Such phosphatisation of the foraminiferal tests is seen in the case of the Utatur nodules, as examination of the sections of the nodules shows, in some cases, a number of circular microscopical patches filled up with phosphate. One of the patches in which phosphatisation has been incomplete illustrates the fact that the pseudomorphism began at different centres, from each of which radiating canals filled up with phosphatic substance were sent out.

That shells found in phosphatic deposits are themselves also rich in phosphate has been known for a long time. Thus Penrose, in the course of his description of the phosphatic limestones of Kentucky, referred to the numerous univalve shells of microscopic size found in these beds, which have been stated to be phosphatic.[5] In a later communication Miller referred to these shells (probably *Cyclora minuta* Hall) and, from detailed chemical examination, came to the conclusion that the casts of *Cyclora* are invariably rich in phosphate of lime.[6] It seems possible that the phosphatic nature of the shells is not due to any phosphate of lime originally present in them but to the pseudomorphous replacement of calcium carbonate by ammonium phosphate in the manner mentioned above.

[1] A Manual of the Geology of India, 2nd edition, p. 235.
[2] *Proc. Geol. Assoc.*, Vol. XVI, p. 385 (1899-1900).
[3] *Proc. Roy. Soc. Edin.*, Vol. XXV, Pt. 2, pp. 862-85.
[4] Collet: *op. cit.*, p. 881.
[5] *Bull. U. S. Geol. Surv.*, Vol. VII, p. 591 (1888).
[6] *Amer. Geol.*, Vol. XVII, p. 76 (1896).

An animal origin is usually assigned to ammonium phosphate. Analyses of the tests of foraminifera have shown that, though in some cases, phosphate of lime is present, it is always present in very small quantities. Fossil sharks have been found in the Utatur beds[1] and the ammonium phosphate necessary for the changes suggested might have been derived from these fishes. Another possible source of ammonium phosphate is the drift wood found in parts of the Utatur group[2] and derived from the plants which grew on the high cliffs bordering the shore of the Southern Indian Cretaceous sea.

[1] *Pal. Ind.*, Ser. VIII, Vol. IV. pp. 198 *et. seq.*
[2] *Mem. Geol. Surv. Ind.*, Vol. IV, p. 79.

# MISCELLANEOUS NOTES.

## Galena near Nardha, Seonhra Tehsil, Datia State.

A quartz vein carrying galena traverses red ferruginous quartzites and sandstones belonging to the Par stage of the Gwalior series, about 1½ miles S. E. of the village of Nardha (Seonhra Tehsil) and some 41 miles to the N.N.E. of Datia (Central India). The existence of this deposit of galena has long been known, and it was mentioned by Medlicott (*Rec. Geol. Surv. Ind.*, Vol. VIII, p. 58) and V. Ball (Geology of India, Vol. III, p. 299) as early as 1875, but nothing was known regarding its extent or value.

A few small sporadic outcrops of rocks of the Par stage are exposed round about Seonhra from underneath thick alluvium. The rocks are deep red quartzites, quartzitic sandstones and hæmatitic shales (often papery) with a few interstratified siliceous or cherty banded layers. On weathered surfaces a thin granular incrustation of hæmatite is often present. In age the rocks belong to the older division of the Gwalior series, a member of the lower part of the Cuddapah system of South India. There is very little structural disturbance visible in this series, the stratification being for the most part horizontal, but here and there local disturbances of dip are discernible with occasional sharp folding of small amplitude. One of these folds, a narrow sharp monocline near Nardha, on the Sind river, has snapped and the resulting fissure being filled up by quartz and galena, has given rise to a vein, which constitutes the lead deposit under consideration. The vein is for the most part buried under deep alluvium and is exposed only for about 20 yards on the south bank of the Sind river. To the north it rapidly branches in the course of a few yards, into thin stringers of quartz. Around the fissure or in the mass of the country rock, there is no indication of any degree of superinduced mineralisation, nor is there evidence of igneous action in the immediate vicinity either of the nature of contact or intrusion, having affected the rocks.

The vein outcrop is only about 20 yards in length. It runs due N.E.-S.W. and hades steeply to S.E. It is from 6 inches to 1 foot in width. The vein-stone is white quartz in which nests and irregular masses of coarsely crystallised galena are dispersed. It is impossible to trace its course to the south because of the thick overlying alluvium, while to the north (although it can be traced to the opposite bank of the river) it is rapidly impoverished in its ore-content by repeated branchings into a mass of barren quartz-stringers carrying insignificant quantities of galena.

Besides galena, the oxidised ores, cerussite and pyromorphite occur in the exposed parts of the vein. There are no associated minerals present except tiny patches of malachite and a few pyrite grains. There is no blende, argentite or stibnite.

Cupellation tests to determine the silver content of the lead yielded (as a mean of 3 determinations) 4·76 oz. of silver to the ton of ore. The silver content of the vein is not therefore a promising factor in its economics.

In view of the thinness of the vein, the sporadic nature and the limited area of the outcrops of its country-rock, coupled with the state of mineralisation of the latter, no liberal estimate can be formed of the quantity of galena available at this locality. The fault-fissure is not of any considerable dimensions and there is no evidence to suggest any considerable widening with depth.

D. N. WADIA.

## Ochre Pits around Daroli.

About 6 miles west of Nardha, Seonhra Tehsil, Datia State, a few pits have been dug into rocks of the Par series from which red ochre of good quality is extracted. Lithologically the ochre beds belong to the highly ferruginous portions of the Par stage of sandstones and shales. The ochre is soft, easily friable and sectile, fine-grained and entirely free from grit. If its occurrence over a fairly wide area can be established among the Par outcrops of the neighbourhood, there are good prospects of its being successfully worked for the manufacture of red paints.

D. N. WADIA.

## Note on the oil-shales of Mergui.

Thin-bedded shales of varying thickness and colour have recently been found in the river valleys of Tavoy and Mergui in Burma. They are considered to be of Tertiary age and are often associated with bands of coal.

The earliest reference to deposits of this kind is by Dr. Helfer[1] who found a "slaty coal" 5-6 feet thick, with a dip of about 20° occurring in a branch of the little Tenasserim, 5 days' march above the village of Tenasserim in a S. E. direction. The latitude given, 11°52′37″, agrees fairly well with the latitude of the locality of the shales found by me. Dr. T. Oldham who visited the same area some years later found coal seams of varying thickness (0-4″ to 2′-0) south of Naungbwa, a ruined village on the Theinkun, in Lat. 11°51′ 40″; Long. 99°29′10″. He estimated the associated sandstones and shales to be about 200 feet thick, and considered that the 'slaty coal' was really a very earthy bituminous shale with only a few inches of good coal.[2]

The oil-shales found by me are probably the same, though Dr. Helfer mentions that coal is found in other places also. At the time of my

[1] "Report on the coal discovered in the Tenasserim Provinces." *J.A. S.B.*, Vol. VII, p. 701, 1838.
"The Provinces of Ye, Tavoy and Mergui" Second Report, pp. 37-40, 1839.

[2] "Papers on the Geology and Minerals of British Burmah," p. 375.

visit (Jan. 1922) there had been continuous heavy rain for a week and the river was flooded. Only the top of the beds was visible consisting of a dark thinly laminated shale passing down into a light-coloured reddish shale. There are bright patches in the partings and the beds which are about 6 feet thick dip N.N.E. at about 15°.[1]

The Theinkun is a branch of the Little Tenasserim river. The tide is felt up this stream as far as Letpanthaung about a day-and-a-half's journey from Tenasserim village. Thence the journey can be accomplished in small canoes up the Theinkun river,[2] which during the dry season is not navigable for about 15 miles below Naunghwa. The valley of the Theinkun, here about 7 miles long and about 1½ miles broad, is probably entirely made up of these Tertiary deposits.

The locality is about 35 miles from Prachuab Kirikan, an important railway station and port on the Gulf of Siam. The pass leading into Siam is about 750 feet above sea-level or 400 feet above the Theinkun valley. On the other side of the pass the rocks are granites. No Tertiary deposits were seen on the route to Prachuab Kirikan. The connection of Mergui with the Siamese State Railway along the Theinkun valley has been under consideration, and if any such project eventuated, the oil-shales are worth further examination.

The neighbouring river valleys would also be worth a detailed search for similar deposits.

M. VINAYAK RAO.

## Note on the Age of the Limestone opposite Martaban Railway Station, Thaton District, Burma.

Professor J. W. Gregory, F.R.S., who visited Moulmein in October 1921 has kindly given me permission to publish the following note on the age of the limestones opposite Martaban Railway Station.

In these limestones Prof. Gregory discovered the following species of *Palæanodonta* :—

*Palæanodonta okensis* Amalitsky
*Palæanodonta subcastor* Amalitsky.

Both these species are characteristic of the upper horizons of the Permian marls and sandstones of the Oka-Volga basin, which according to Amalitsky correspond to the German Zechstein. I may add to the above information kindly given to me by Prof. Gregory that the Martaban limestone is of a dark colour, and thus corresponds to the dark coloured Anthracolitic limestone of the Shan States (*vide* La Touche, *Mem. Geol. Sur. Ind.*, Vol. XXXIX, p. 256) in appearance rather than to the grey type which characterises the Devonian.

G. DE P. COTTER.

[1] Thin flakes of the shale burn well when ignited with a match.
[2] Theinkun village is about 2 miles across the bend of the river from Letpanthaung.

## The Classification of the Terebridæ.

In a paper entitled "Illustrated Comparative Diagnoses of Fossil Terebridæ from Burma,"[1] I mentioned my inability to trace Dall's classification of the Terebridæ of which an abridged outline was published in the "Nautilus" in 1908. Thanks to the information conveyed through the courtesy of Mr. Woodring of the United States Geological Survey, I have been able to consult the full classification.[2] In this paper Dall has shown that *Duplicaria* and *Hastula* are generically separable from *Terebra* on anatomical grounds. *Hastula* is distinguished from *Terebra* by the presence of a radula. *Duplicaria* also has a radula but differs from *Hastula* and from *Terebra* by the absence of a poison gland, of eyes, and of tentacles. *Duplicaria* is readily distinguished by the external characters of the shell. Much hesitation is sometimes felt in separating *Hastula* from the *Myurella* section of *Terebra*. A renewed study of the shell of *Hastula* to establish its precise distinctive characters is desirable.

E. VREDENBURG.

[1] *Rec. Geol. Surv. Ind.*, Vol. LI, p. 341, 1921.
[2] W. H. Dall: *Bull. Mus. Comp. Zoo.*, Vol. XLIII, No. 6. pp. 215-250, 1908.

CALCUTTA: PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8 HASTINGS STREET.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

Part 4.] 1923 [September.

# THE GEOLOGY OF WESTERN JAIPUR. BY A. M. HERON, D.SC. (EDIN.), F. G S., *Officiating Superintendent, Geological Survey of India.* (With Plates 22 to 28.)

## INTRODUCTION.

THE geological survey work of which this paper is an account occupied me during about half of the field season 1911-12, and the whole of the season 1912-13, and was part of the programme of the Rajputana and Central India party under the superintendence of Mr. C. S. Middlemiss.

The area included is about 9 000 square miles and on the accompanying map the geological results are reduced from the actual scale of survey, which was one inch to the mile. For convenience in printing and to keep it to a reasonable size, the map does not extend to the actual boundaries of the State, but so far as solid geology is concerned, what is excluded is quite negligible. To the west is a line of outcrops of the Delhi System, running from the Shekhawati hills towards the Sambhar Lake, which however are in border territory administered jointly by the Jaipur and Jodhpur States, and to the south of the railway, between the boundary of the State and that of the map, are a few outposts of the gneiss of Ajmer and Kishengarh. All the rest is sandy desert or alluvial plain.

To the east the map abuts against and overlaps slightly those accompanying my papers on "The Delhi System in North-Eastern Rajputana" (*Mem., Geol. Surv. Ind.*, Vol. XLV. Pt. 1), "The Biana-

Lalsot Hills" (*Rec., Geol. Surv. Ind.*, Vol. XLVIII, pp. 181—203) and "The Vindhyan and Gwalior Systems in Eastern Rajputana" (in the Press), the relevant parts of which complete the geology of the State. Besides Jaipur State, the present account includes the Chiefship of Lawa, parts of Tonk and Bundi States, and of Patiala and Nabha States in the north.

The only previous observer is C. A. Hacket, who has very briefly outlined the geology and mineral occurrences of economic interest in three papers: —

"Arvali Series in N. E. Rajputana," *Rec., Geol. Surv. Ind.*, Vol. X, (1877).

"Useful Minerals of the Arvali Region," *Rec., Geol. Surv. Ind.*, Vol. XIII, (1880).

"Arvali region, Central and Eastern," *Rec., Geol. Surv. Ind.*, Vol. XIV, pt. 4, (1881).

P. N. Bose just touches the north-eastern corner in his "Geology and Mineral Resources of Narnaul District" *Rec., Geol. Surv. Ind.*, Vol. XXXIII, (1906).

## FORMATIONS PRESENT.

Several of the formations in the table on the opposite page may be dismissed in a few words.

The Raialo limestone and quartzite just enter the area from the east,[1] visibly thinning out, and are absent in all the other sections where the base of the Delhi System is seen. The Kushalgarh limestone and the hornstone breccia, which in Alwar separate the Ajabgarh and the Alwar Series, are also missing here and the latter formation passes insensibly upwards into the Ajabgarhs.

The Malani volcanics are represented by a few knolls around Jhunjhnu, in the extreme north-west, coloured by Hacket as gneiss on his map; but I obtained specimens through the Nazim of Shekhawati, and found them to be typical Malani rhyolites with quartz phenocrysts; they thus form a connecting link between the main development of these beds near Jodhpur[2] and the widely separated locality of Tusham.[3]

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, pp. 23—28.
[2] *Mem., Geol. Surv. Ind.*, Vol. XXV, pp. 14—24.
[3] *Rec., Geol. Surv. Ind.*, Vol. XIX, p. 101.

## *TABLE OF FORMATIONS PRESENT.*

| | | Jaipur and Alwar. | | W. Jaipur and Jodhpur. | S. E. Jaipur and Karauli |
|---|---|---|---|---|---|
| Recent and sub-recent | | Alluvium, blown sand, etc. | | .... | .. |
| Purana | Vindhyan System | .... | .... | Vindhyans | Upper Vindhyans. Lower Vindhyans. |
| | | | | .........*Unconformity*......... | |
| | Delhi System | Ajabgarh Series | Intrusive epidiorites, granite and pegmatite. | Malani rhyolites | |
| | | Alwar Series | | | |
| | | Raialo limestone and quartzite. | | | Gwalior System (position uncertain). |
| | .. | | | | |

*Unconformity.*

| | | | | | |
|---|---|---|---|---|---|
| Archæan | Aravalli System | | Intrusive epidiorites, granite and pegmatite. | | |

The Gwalior and Vindhyan outcrops are near Bhagwantgarh and Sawai Madhopur, in the south-east corner of the State, outside the present map, and are described in a Memoir now in the press. The position of the Gwalior System chronologically with regard to the Delhi System is uncertain, all that is known being that the Lower Vindhyans rest on the Gwaliors with a strong unconformity, and that the Gwaliors and Aravallis are faulted against one another near Chauth (Chout) ka Barwara. Comparing their degrees of alteration, the Gwalior System must be considerably younger than the Aravallis and may perhaps be even younger than the Delhis, but, as I say, the question of their relative age is a matter of conjecture.

The Vindhyans of Western Rajputana [1] have been laid down on the folded and denuded Malani volcanics; the latter I have suggested elsewhere [2] may be an uppermost division of the Delhi System.

The Aravalli System and the Alwar and Ajabgarh Series of the Delhi System, with their respective igneous intrusives, I shall describe in some detail in the following chapters.

The Jaipur State may be said to consist of two great plains, divided by the Shekhawati hills. The northern, the semi-desert tract of Shekhawati, slopes gently north-westward from the base of the hills towards the Jodhpur and Bikanir frontiers and is drained by the Kantli and other minor streams which disappear into the sands within the confines of the State. The central plain has its greatest elevation on a line running due north from Jaipur City along the western foot of the hilly country on the Alwar frontier. Its drainage finds its way westwards into the salt lakes of Sambhar and Kuchor-Rewassa, northwards into the sands by the Kantli and the Basi rivers, through gaps in the Shekhawati hills, and southwards flows into the Banas by an extensive system of tributaries. The watershed is quite independent of the hill-ranges, and the rivers have often cut their way through great belts of quartzite, as for instance the Banganga at Ramgarh and the Banas at Rajmahal, to mention two of the more striking instances.

Curving round the north of the central plain are the intricate ranges forming the Shekhawati and Torawati hills, and the wild country extending along the Alwar border from Torawati as far south as Jaipur City. The southern portion of the plain is open but

[1] *Mem., Geol., Surv. Ind.*, Vol. XXXV.
[2] *Mem., Geol. Surv. Ind.*, Vol. XLV, p. 114.

traversed by several low interrupted ridges with a general N.E.—S.W. trend and dotted with various clusters of hills and isolated summits.

The Shekhawati, Torawati and the border hills are made up of rocks belonging to the Delhi System and owe their prominence to the superior resistance of these, while the plain, if the alluvium were removed, would be seen to be floored with Aravalli rocks, which only exceptionally project above the surface. As outliers from the main Delhi massif there are at Chandsain, Nawai, Rajmahal, Dhulc and Banskho, isolated and highly compressed synclines of the Delhis caught up in the Aravalli complex into which the Delhi System has been folded.

As usual, the materials for the study of the Aravalli System are scanty, owing to the way in which great expanses of it are covered by thick alluvium, without showing an outcrop; when exposures do occur they are more often than not quartzite bands or groups of quartzite layers, which stand out owing to their hardness, and this predominance of quartzites in the visible portions of the formation tends to give one an undue idea of their relative importance; wherever any considerable area of the Aravallis is available for examination, they are seen to be essentially argillaceous (or micaceous) rocks in which siliceous types play a minor part.

Both the Alwar and the Ajabgarh Series show more intense folding and alteration than they do in the country to the east, already described,[1] doubtless owing to the proximity of this area to the core of the ancient Aravalli Range. Still further to the west, in Ajmer-Merwara, plication and metamorphism are still greater. Igneous intrusions, comprising sill or laccolite-like masses, veins and minute *lit-par-lit* injection sheets of epidiorite, bosses of foliated granite and large veins of pegmatite, are in great profusion and invade the Ajabgarhs as well as the Alwars; in the country to the east intrusives are rare in the Ajabgarhs. The area is in short one of great complexity but when the difficulties are overcome the results amply confirm my previous work. Had I commenced my survey here instead of in Alwar the unravelling of the sequence of the metamorphosed sedimentaries would have presented serious difficulties; on the other hand, the abundance of the igneous intrusives makes their relationship to the invaded rocks and to each other much clearer.

[1] *Mem., Geol. Surv. Ind.,* Vol. XLV.

Generally speaking, the geological structure of alternating anticlines and synclines is the same as in Alwar and the Lalsot-Biana area but the folds are more elongated and closely compressed and the prevalence of regular isoclines dipping to the north-west is less noticeable. In the areas occupied by the Delhi System which have been examined during the last few years, it has been usual to find the Ajabgarhs occupying subordinate synclinal valleys (outliers) folded into extensive massifs of the Alwars, but in the Shekhawati and Torawati country the Ajabgarhs form by far the major portion of the rocks exposed, the Alwars emerging from below them as anticlines (inliers). Not only are the rocks more highly metamorphosed than in the country to the east, but the number and magnitude of the igneous intrusions are greater, and, what renders the geology specially difficult to decipher, is the way in which the folds are pressed into narrow complex synclines which, when cut across by denudation in horizontal section, exhibit in plan sinuous and intricate outlines. Inversion occurs almost as often as the normal sequence; there is no datum line to work from, such as the Kushalgarh limestone or the unconformity at the base of the Delhis, and in the Ajabgarhs there are occasionally siliceous bands which are liable to be confused with the Alwars.

## THE ARAVALLI SYSTEM.

Except in the south of the State the Aravalli outcrops consist of small isolated hills, usually of quartzite, standing alone in the alluvial plains, or narrow strips emerging from below the base of the Alwar quartzites and conglomerates, which rest on them with a profound unconformity. In the south however they form several continuous ridges and groups of small hills, elongated in the direction of the strike, and it is evident, from the debris brought up from many of the deep wells, that Aravallis extend over a very large area in which they do not appear at the surface.

They are divisible into metamorphic rocks of clearly sedimentary origin, and intrusive epidiorites, granites, pegmatites and quartz veins. In using the term "Aravalli System" to include all the rocks below the unconformity at the base of the Delhi System, a reservation must be made—that it is possible that representatives of more than one geological system may be present below the unconformity. In the portion of Rajputana which has so far been geologically examined, exposures of the pre-Delhi rocks are so small and scattered, and consist so largely of igneous rocks, that we must admit our scanty knowledge of their composition.

## Metamorphics of Sedimentary Origin.

Perhaps the most noticeable feature of the metamorphics is their uniformity in composition and in strike over the whole area. They are almost exclusively argillaceous rocks varying in degree of alteration from hardened but uncleaved shales to coarsely foliated crystalline schists containing staurolite or large garnets in great quantity. Generally speaking, the farther we proceed along the strike towards the south-west, the greater does the alteration become, but there are many exceptions to this, depending on the local abundance or absence of intrusives.

Quartzites are locally present, usually impure, argillaceous and ferruginous, but they form zones of thin-bedded strata with shale or schist partings, rather than massive beds. They are generally very highly altered, vitreous and closely jointed, and stratification is usually obscured except for the above mentioned partings. Schistosity is often developed, coinciding with the bedding, and causing crumpling and pinching out of the laminae. In contrast with the Alwar quartzites ripple-markings were never observed. Owing to their superior hardness the quartzites are more prominent, forming hill ranges and peaks, than the schists occupying the lower ground, though the area which the latter cover is much greater. In colour the quartzites are dark red, brown or dark grey, occasionally of pale tints of these colours or white, and they weather with a rough and rusty surface.

The slates are brown, olive or blackish grey, becoming silvery by the development of mica in the more altered varieties. Strike is wonderfully constant over the whole area, varying little from N.E.—S.W. The dip is as constantly to N.W. at high angles, 30° to vertical. By dip is meant the inclination of the planes of foliation, which coincide in the main with the bedding.

As well as metamorphosed shales and quartzites there also occur schistose conglomerates and grits, impure argillaceous limestones and epidiorites of uncertain origin, but these are strictly subordinate and will be described in the detailed description of exposures.

## Igneous Intrusives.

The schists and quartzites are copiously injected with veins of quartz and pegmatite, especially the schists, to which the pegmatites are practically confined.

Obviously the greater hardness and lesser fissility of the quartzites present mechanical impediments to igneous intrusion. Besides pegmatites there are many granite bosses, usually rising from the alluvium some distance from any outcrop of the sedimentary metamorphics, but which are so situated with regard to these, and which are so similar in composition to, and so graduate into, the intrusive pegmatites that there is little room left for doubt that granite and pegmatite have the same magmatic origin and are both intrusive.

Little need be said about the quartz veins. They are either pure white or with greasy lustre and slightly ferruginous. A small amount of tourmaline may occur in them. They often take the form of small sills, following the planes of schistosity for some distance; in some cases where the injection has been copious on a small scale and pressure has subsequently taken place, a quartz-mica schist has been produced in which the quartz appears as lenticular layers rolled out between the folia of mica. It would seem that these quartz veins produced less alteration in the country-rock than did the pegmatites. They must be of several ages, as near Lalsot they are seen cutting through, and therefore subsequent to, the Aravalli pegmatites and yet are cut off at the unconformable junction with the Alwars, though elsewhere they are often found of a later age penetrating both Alwars and Ajabgarhs.

The granite which is taken to be intrusive in the Aravalli System, and on an eroded surface of which the basal beds of the Delhi System so often lie, has been described before.[1] It is a biotite granite, usually porphyritic and foliated and often traversed by tourmaline pegmatite veins. In the present area it is only met with at Morijo (27° 10′, 75° 49′), near Isarda (26° 10′, 76° 5′) and south-east of Dhule (26° 56′, 76° 12′). The granite shown on the map 2 miles west of Kakor (26° 1′, 75° 59′) is an occurrence of the younger granite which is intrusive in the Delhis and of course passes through the Aravallis also. The two are similar mineralogically but can be distinguished in the field.

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, pp. 15—22.
*Rec., Geol. Surv. Ind.*, Vol. XLVII, p. 186.

On the western frontier of the State, mainly south of the railway, another granite, or gneissic granite, is found, of the type which is so greatly developed in Ajmer and Kishengarh. At Karela (26° 17′, 75° 33′) it is very coarsely porphyritic and dark in colour, and consists of large pale pink or white microcline phenocrysts in a fine-grained dark groundmass, chiefly of biotite. Quartz is not visible in hand specimens but under the microscope is seen to occur with microcline in small crystals in the groundmass. The microcline of the phenocrysts is graphically intergrown with quartz.

There are no pegmatite nor quartz veins. The rock is, in places, distinctly foliated, the phenocrysts subrounded, with the micaceous fine material drawn in curves round them.

The group of hills stretching south-west from Ganor (26° 22′, 75° 23′) is obviously composed of a rock very similar mineralogically to that of Karela but in a much greater state of pressure alteration. It is a very distinctly banded gneissic rock, with only traces of "augen," with narrow black bands (mica) and thicker bands of pink (quartz and felspar), much twisted and contorted, but with a distinct general north-westerly dip of the foliation planes. Microscopically it is seen at Ganor to consist of quartz, microcline, orthoclase, brown biotite, ilmenite and apatite. The rock in the group of hills next adjoining to the south is the same but contains also hornblende, sphene and very numerous corroded pink garnets. A clue as to the age of this granite is given by a small exposure at Asilpur Station (26° 56′, 75° 29′) where a very black micaceous "augen gneiss," resembling the above, is intrusive in quartzite. It has "augen" or phenocrysts of pink felspar, arranged in straight lines, and is so well and straightly foliated that it splits into slabs used for building. Veins of normal pegmatite run through it and the quartzite. If this is the same, it would seem to be intrusive in the Aravallis and older than the pegmatite intrusions.

The pegmatites have a much wider distribution, in fact wherever any considerable extent of the micaceous Aravallis are exposed, pegmatites are present, but are practically absent from the quartzites, owing to the greater resistance which the latter offered to the forces causing intrusion. They form masses of all sizes from a fraction of an inch up to many yards across and occur mostly as layers running along the foliation of the schists, *i.e.*, along the strike. They are never in the least degree schistose, however much the schists carrying them are foliated. They vary in grain from medium to extremely coarse, and vary quite irregularly and sharply. This seems in part due to motion having taken place during crystallisation, breaking up crystal aggregates.

The mineral constituents are quartz, microcline, orthoclase, muscovite and tourmaline. Acid plagioclase is doubtfully present. The quartz is characteristically intergrown with orthoclase and microcline, both micropegmatitically and in graphic structures visible in hand specimens. These pegmatites differ from the boss granites associated with the Aravallis only in their texture and in the presence of tourmaline, and are identical with the pegmatites *in* these granites.[1] The question then arises—are the pegmatites in the schists apophyses of the boss granites, the pegmatites *in* the granites representing the residuum which has not been extruded, or are the pegmatites of the schists and granites both newer than the granites and have they intruded both schists and granites at the same period ? This must for the present remain unanswered.

Like the granites, there are pegmatites of at least two ages—the above described, which were intruded and denuded before the Delhis were laid down, and a younger set, which invade the Delhis, and are distinctly subsequent to the post-Delhi granite, itself intrusive in the sedimentaries of the Delhi System.

## Description of Exposures.

The most continuous Aravalli exposure is the remarkable ridge which extends in an almost straight line for eighty miles from near the termination of the Lalsot hills to the extreme south of the State and beyond, far into North Mewar. It might seem from a casual glance at the map that this ridge is a continuation of the Lalsot hills, but this is not the case. It is true that the ridge, if produced along the strike north-eastwards, would pass near Lalsot, but it is almost certain that beyond the point at which it disappears below alluvium its strike curves sharply eastwards and it reappears in the three small hills at Bagri (highly metamorphosed and quartz-veined quartzite). The parallel groups of hills to the westward, passing through Tonk and Siris, are clearly seen to trend in that direction.

Throughout both these lines of exposures Hacket[2] has mapped quartzites as Delhis and mica-schists as Aravallis, thus erroneously

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, pp. 20—21.
[2] *Rec., Geol. Surv. Ind.*, Vol. XIV.

carrying on the great unconformity of the Lalsot-Bansa hills through a perfectly concordant sequence of beds. In view of the very important bearing this has on the interpretation of the geology of North Mewar, I shall describe this belt of country in some detail and attempt to clear up this misconception.

The Baonli ridge consists of schists (Aravallis of Hacket) dipping at about 80° under a thick band of quartzite (Delhis of Hacket). There is certainly no unconformity between these—they are both members of the same conformable sequence. The strike and dip of both are everywhere perfectly concordant, there is no trace of grit nor conglomerate on the junction and, throughout the many miles along which the beds were followed, the underlying schists are the same except for slight changes in the degree of metamorphism and the amount of quartz veining. If an unconformity were present over such a distance, different beds would at different places be overlapped by the quartzite. Near the north end of the ridge the junction is well exposed at intervals for about two miles, without a sign of grit and with the beds quite parallel. The division between quartzite and schist is abrupt, but near it the former becomes very thinly bedded, and beyond the dividing line, intercalated in the schists, are several thin and somewhat lenticular beds exactly like the quartzite. About a mile to the north-west, *i.e.*, above the quartzite and therefore in the Delhis according to Hacket, are two exposures of the typical Aravalli granite on which, everywhere else, the Delhis lie unconformably, and, in several places above the quartzite, schists similar to those below are exposed, confirmatory evidence, if such were required, that the micaceous and siliceous beds are not separable into two series, but are both Aravallis.

The quartzites are reddish, thin-bedded, and rather highly jointed and altered. They are thick and prominent at Baonli but thin out to north-east and south-west. About five miles south-west of Baonli they seem to die out or to become micaceous but they reappear after a space, either on the same horizon or a higher one. The schists are reddish and greenish, well foliated, and bearing quartz veins, often in lenticles rolled out along the planes of foliation.

The hills due south of Baonli, near Sarwar, are composed of a foliated hornblende-quartz rock with streaks of unmixed hornblende rock along the foliation, and weathering after the manner of a gneissic granite. I was unable to satisfy myself as to whether it is wholly an igneous rock, of a type not yet met with elsewhere, or quartzite intimately injected with the ordinary hornblendic "trap", or epidiorite.

South-west as far as Sarsop (26° 11′, 76° 7′) the quartzite band is very narrow, with schists exposed above and below it, but at Sarsop rises a prominent hill, crowned, like all the eminences of the neighbourhood, with the inevitable fort. The hill is formed by a thickening of the quartzites combined with a local resistance to denudation in the schists, and beyond it the ridge rapidly diminishes in height and breadth again. A section is exposed where the railway passes through, in which the quartzites are seen to be flaggy and twisted, with a certain amount of interbedded mica-schist in thin layers, and are irregularly compressed and pinched out.

From the Banas River the ridge continues unbroken and of a fairly uniform breadth to Gar (26° 52′, 75° 14′) where it is interrupted by alluvium, and, when it emerges again four miles farther on, the quartzites are found to have split into a group of thin layers in the schists, and near Awan they pass in this phase out of Jaipur into North Mewar. These quartzite layers are considerably puckered and contorted without departing from the general strike and dip. Throughout this eighty miles of almost continuous outcrop the dip of the strata, to north-west at 80°, or vertical, has been remarkably constant in direction and amount, and the rocks themselves have not varied in general character, though differing from point to point in the relative proportions of quartzite and schist.

Running parallel to the Baonli-Awan range a short distance to the north-west is a much-interrupted belt of schists extensively intruded by pegmatite and with one or two bosses of granite. Unfortunately exposures are poor and it is only in the hills south-west of Duni (25° 52′, 75° 35′), that much information can be gathered. There the schists are highly crystalline and crowded with large pink garnets. The pegmatite is of the normal type, of white or pale pink orthoclase, quartz (often graphically intergrown with the orthoclase) muscovite and tourmaline, and often contains garnets as well, perhaps derived from the schists passed through. The veins are as a rule intruded along the planes of foliation; in certain places they appear interbedded with the schists, so closely do they keep to the foliation planes. In dimensions the veins vary from a fraction of an inch up to many yards across; sometimes the schist is quite subordinate in amount compared with the pegmatite. The other two exposures on this belt, north-west of Kakor and near Isarda (26° 10', 76° 5') are much concealed by soil, but so far as seen are similar to that of Duni. Near this band at Shakra, Kabro, Sewar, and Bire are hills, elongated in a direction transverse to the general strike, composed of massive crystalline quartz, associated with normal pegmatite and quartz-muscovite pegmatite. Still farther to the north-west is another well marked belt of hills commencing at Tonk City (26° 10', 76° 51') and running north-east as far as the end of the Baonli-Awan ridge. Near Tonk they are a broad mass of hills, through which flows the Banas River, but a short distance along the strike they narrow to a ridge, with disconnected fragments of a second parallel to it. They consist of alternations of mica-schist and thin rusty quartzites, schistose and argillaceous or micaceous, dipping north-west at angles of 80° to vertical. Valleys are formed along the zones where mica-schist predominates (sparingly veined with quartz and the usual pegmatite) while peaks and ridges mark the strike of the more quartzitic belts. Here again Hacket has mapped quartzites as Delhis and schist as Aravallis throughout a conformable sequence.

Scattered over the great plain lying between the Banas River in the south and the Shekhawati and Torawati hills in the north, are evidences of the continuity of the Aravallis beneath the alluvium, some of these being strips of mica-schist appearing below the base of the Delhis in the outlying synclines of Rajmahal, Chandsain and Nawai; others, these being more often quartzites, show as isolated hills amidst the alluvium. The main spread of the former type is around Rajmahal, where for several square miles the alluvial mantle is very thin, allowing the underlying rocks, mainly garnetiferous mica-schists and pegmatites, the latter carrying beryl, to appear here and there at the surface. It was on these that the old garnet mines of Jaipur were worked, where garnets had weathered out of the schists and collected in hollows on their surface.

Of the latter class a belt runs from near Mundeta (27° 1', 75° 38') through Kalegh and Asilpur, expanding into a group of hills, considerable both in area and height, near Bechun, of very highly altered, vitreous and coarsely crystalline quartzites and mica-schists invaded by small masses of foliated granite and by later veins of tourmaline pegmatite and tourmaline-quartz rock, which cut through the granite and are never foliated.

North of Basi (26° 50′, 76° 6′) is a semicircular ridge of rocks which show certain differences from the Aravallis so far described; they are light and dark coloured quartzites, much jointed and thin bedded, with intercalated bands of micaceous crystalline limestone and amphibolites. In the eastern half of the semicircle dips are towards its centre, in the western half they are outwards. Near here, at Dadeha, south of the Dhule syncline, are several sharply peaked hills of fissile quartz-magnetite schists, extensively brecciated, and west of Kalaotha (26° 58′, 76° 29′) is a group of small hills of very heterogeneous composition—amphibolites, slates, mica-schists, highly jointed white quartzites and schistose quartz conglomerates, they quite evidently are continued by the very similar exposures south and north-east of Gudha (27° 4′, 76° 31′) into the massive conglomerates below the base of the Delhis at Rewasa.[1]

From Dausa (26° 54′, 76° 24′) running north-east along the railway, is a band of Aravallis dipping north-west at 30°, a bed of schistose quartzite, white and micaceous, lying conformably on black mica-schists containing staurolite and some garnets. They are copiously penetrated by very thick white quartz veins, which supply material for glass bangle making in Agra. In the schists are some thinner quartzite bands, extensively quarried at Bhankari and Kalaotha for "paltis" or "pattis" (beams) and "katlas" (flagstones).

South of Basi, emerging from below the enormous development of arkose conglomerates which marks the base of the Delhi System at Lalgarh (26° 47′, 76° 9′), is a group of ancient volcanic rocks, considerably less metamorphosed than the Aravallis to the south and west. The lowest beds seen are fine-grained hornblendic rocks, containing also grains of iron-ore, epidote and quartz, and with spherical vesicles filled with crystalline quartz. In the field they look exactly like greenish amygdaloidal lavas. Associated with them are regularly bedded or banded strata of quartz and epidote with, in certain bands, much biotite and ilmenite. These doubtless represent bedded tuffs. A little to the south rusty slates and impure limestones appear, dipping at an angle to the base of the overlying basal conglomerate of the Delhis and striking against it.

All these outcrops (Basi, Dadeha, Kalaotha, Dausa and Lalgarh) are somewhat aberrant from the other Aravallis of Jaipur

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, p. 17.

in their heterogeneous composition, less degree of alteration and amount of igneous intrusion and irregularity of strike; there is however no doubt as to their pre-Delhi age, for their position with regard to the base of the Delhi System, exposed in the Dhule syncline, the Lalgarh ridge and the large syncline north of Basi, makes it clear that the Delhis rest on them unconformably; they may however belong to another pre-Delhi system distinct from the Aravallis.

## THE DELHI SYSTEM.

### The Alwar Series.

Before describing the main exposures of the Alwar Series in the Shekhawati and Torawati hills, I may briefly describe the isolated synclines in which the basal beds of that formation occur folded into the Aravalli complex.

The hill at Dhule (26° 56′, 76° 12′) is an oval syncline of quartzite, grits and felspathic rocks. The actual junction with the underlying Aravalli granite is covered by *débris*, but just above the granite is a conglomerate of quartz pebbles in a reddish felspathic matrix, and this conglomerate is repeated on the west side of the hill.

In the Lalgarh (26° 47′, 76° 9′) ridge, at its south-eastern end, the basal conglomerate lies on the irregular surface of a quartzite, a distinctive rock faintly mottled with red, and the boulders in the conglomerate, some of which are angular and of great size, are obviously derived from the underlying quartzite. Further to the north-west along the ridge the conglomerates are very coarse, the boulders of granite being of three or four feet diameter, and they show no signs of bedding save in a very occasional finer band. The ingredients are coarse-grained unfoliated granite with little mica, cream-coloured crystalline limestone, tremolitic limestone, quartzite finely banded in lines of black and dark grey, dark and pale homogeneous quartzites and red jasper, (but practically no vein quartz), set in a micaceous and arkose matrix. The granite boulders are rounded, the others subangular. No pebbles of trap are present. In the few cases where dip can be made out, it is at 25°—30° to north-north-east. North-west of Lalgarh granite boulders are absent and the rock is foliated in a direction perpendicular to the presumed dip. (Pl. 22.)

Hacket[1] considers that the quartzite boulders of the conglomerate were derived from the prominent quartzite of the ridge, and that the "banded semi-jaspideous rock and yellow limestone" are from the Aravalli hills near Dadeha, north of the railway, but I was unable to appreciate any particular resemblance. Passing north-north-east towards Banskho in the direction of the dip, the beds become gradually finer in grain stratigraphically higher in the section, such as pebbly conglomerates, arkose grits and, in the Banskho hill, pale, compact and vitreous quartzite, typical of the Alwars. This quartzite is much jointed and in only one place was stratification visible, dipping in a direction the same as that of the underlying grits and conglomerates. If the dip were here in the opposite direction, with a repetition of the basement conglomerates, the relationship of the Banskho-Lalgarh conglomerates to the quartz-magnetite schists of Dadeha would be simply explained by their being a syncline folded into the Aravallis, like that of Dhule, but the facts make it necessary to assume some structure such as two dip faults intersecting north of Banskho and dying out southwards, thus letting down a triangular section of Alwars bounded on the third (unfaulted) side by the unconformable junction. There is no field evidence for such a supposition, but it is quite a probable one and some such assumption has to be made to explain the structure.

Between Tonk and Jaipur are several detached hills isolated on the plain. That at Nawai (26° 22′, 75° 59′) is of fairly typical Alwars, almost vertical. At its south end are mica-schists with quartz laminae, dipping below the quartzites and apparently parallel with them in dip and strike, but there is a conglomerate band, quartz pebbles in a micaceous matrix, at or near the base of the quartzite. It is doubtful if this is another case of the Delhi-Aravalli unconformity, but I consider it probable. Of the others, that near Renwal (26° 42′, 75° 44′) is probably Alwars, those near Chatsu (26° 36′, 75° 59′), at Nimora, Gararwansi, Ruphari, and Tunga are probably Aravallis, judging from their lithological character.

The large hill mass of Rajmahal, at its southern end, is composed of compact pinkish, rather obscurely bedded and much jointed quartzites, fine-grained and very like the Alwars, except that they are somewhat more highly altered than the average. They pass northwards (along the strike) into a great development of schistose

[1] *Rec., Geol. Surv. Ind.*, Vol. XIV, p. 296.

grits and conglomerates. These are very micaceous and dark in colour, are hard and split easily into thick slabs of large area. The pebbles in them are of pink microcline and quartz, rounded and often much flattened. The matrix has in addition biotite, muscovite and tourmaline. In hand specimens they look like foliated "augen gneiss", but in the field the perfection of their straight and flaggy bedding (or foliation) and the fact that they pass along the strike into quartzites leave no doubt that they are sedimentaries. Their fragments clearly come from rocks similar to the massive Aravalli granites outcropping to east and west of Chandsain and not from the pegmatites in the schists near by. The quartzites and conglomerates present some uncertainty in their relationship with these schists. The dips of the former give evidence that they form a syncline, and the fact that at their southern end their outcrops curve round in a semicircle, with schists and pegmatite veins curving with them, would indicate the same. Such thick conglomerates also strongly suggest an unconformity somewhere immediately below them, and the similarity of the finer rocks to the Alwars leads to the conclusion that this is another syncline of Alwars lying unconformably on, and folded into, the Aravalli schists. I found it impossible to map the junction other than approximately: it is above the level of the plain at the southern end of the hills only, and here the basal beds are arkose and schistose grits passing apparently insensibly into the mica schists below, and the junction is also obscured by the abundant intrusion of pegmatite veins into the lowest beds of the syncline, if syncline it be, as well as into the surrounding schists.

Passing northwards over an alluvial plain in which pegmatite and schists are found in places outcropping at the surface in such a way as to indicate that they underlie the alluvium throughout, we come to the very similar hills south of Chandsain (26° 19′, 75° 30′). These consist of a single ridge on the east side and a much shorter one on the west, in both of which the rocks dip east or east-south-east. At the south, where the two ridges join, the lowest beds seen are alternations of schists and conglomerates, the latter containing quartz pebbles and small felspar fragments, only slightly flattened by compression. Northwards along the ridge, compact quartzites, resembling the Alwars, come in, probably on a higher horizon, the conglomerates passing below them by the downward pitching of the syncline. On the eastern side of the ridge, schists with pegmatite veins are seen, which I could not classify with certainty as either Delhis or Aravallis. Just as in the Rajmahal hills, these compact quartzites pass gradually to the north along the strike into felspathic and well-foliated conglomerates. This syncline is abnormal in being over-folded in the reverse direction to the usual.

In the main area of exposures of the Delhi System, the Shekhawati and Torawati hills, the base of the Alwar series is seen only at Morijo (27° 10′, 75° 49′), where it rests on granite of Aravalli age with a very clear unconformity. The basement bed of the Alwars is a black, very ferruginous and intensely hard quartzite, with numerous conglomerate bands in which the pebbles, of quartz and pink felspar, are about the size of walnuts. They are not at all sheared nor crushed. There is an unusually large amount of hematite in the rock, disseminated in the matrix and in many places seeming to form its chief or sole ingredient. This conglomeratic quartzite is about forty feet thick, and as it is sparingly jointed and stratified, it forms a smooth and prominent cliff, strewing the granite slopes below with enormous blocks, detached from it. Above it is a thicker zone of reddish and stratified quartzites and above that again a less conspicuous black quartzite. About 1½ mile north-east of Morijo, conglomerate, coarse and pale in colour like the normal Alwar basal conglomerate, appears in a detached hill. Though the actual line of unconformity is not seen, it is evident that its horizon is near here, the basal beds sweeping round in a semicircle from Morijo and forming the other side of an anticlinal dome on the granite.

In describing the Alwar Series as it is developed in the Shekhawati and Torawati hills, I shall commence at Jaipur City and follow the eastern margin of the State, where it adjoins portions of Alwar already described in my Memoir on "The Geology of North-Eastern Rajputana and Adjacent Districts,"[1] as far as the north-eastern limit of solid geology, then westwards and southwards along the edge of the Shekhawati plain.

The city of Jaipur (26° 56′, 75° 53′) is enclosed on three sides, north, east and south, by bold ridges of Alwar quartzites picturesquely crowned by forts and temples.

A synclinal valley in which Jaipur and Amber, the ancient capital, are situated, divides the hills into two unequal portions ; the eastern ranges extending some miles to the south of the city and striking

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, pt. 1.

N.—S. curving round to N.E.—S.W. and N.W.—S.E. to south and north of the city respectively. Dips are to the west at 30°—50°. The rocks are ordinary quartzites with gritty and conglomeratic bands. This syncline seems to die out near Amber, owing to abrupt upward pitching of its axis, but parallel to it another very elongated syncline appears, with a considerable area of Ajabgarh rocks in its centre. This opens out into the plain north of Atchraol (27° 8′, 76° 1′) dotted with Ajabgarh outcrops. The axis of the anticline which adjoins this syncline on the east, passes through Atchraol, where the bending of the beds at the termination of the anticline is well seen in the field and shown in the topography of the map. East of Atchraol the curved ends of two similar anticlines are seen and east of them again is a syncline, containing Ajabgarhs near Nimi (27° 4′, 76° 5′) and opening northwards into the plain which encircles Atchraol. The long open valley, at the south-western end of which lies Ramgarh (27° 1′, 76° 4′), is almost entirely filled with alluvium, but in some small hills near its centre there is evidence from the dips of the strata, that they form part of an anticline or at least an anticlinal roll of the strata. East of this the Alwars lie with a constant dip away from the Aravalli granite near Raialo.

West of the Atchraol-Amber syncline are again two anticlines, narrow and very elongated and traceable only by small and widely separated outcrops. West of this again is the high and massive hill of Samod (27° 12′, 75° 52′), in which folding cannot be discerned.

All the above folds observe a close parallelism in a direction about N.N.E.—S.S.W., and the dips generally approach verticality. An east and west section drawn through Atchraol would thus cut at least thirteen alternating anticlines and synclines in a distance of about twenty-five miles.

Near Manoharpur (27° 18′, 76° 1′), the Alwars may be said to divide into two sets of ridges, one running north towards the Torawati hills, the other trending north-east and joining the hills in Alwar State near Bairat (27° 26′, 76° 15′).

The rocks of the Alwar Series north of Jaipur City so far described have been almost free from intrusive rocks, but from here onwards, the Alwars, and still more so the Ajabgarhs, are full of intrusive epidiorites, granites and pegmatites. Between Manoharpur and Bairat the quartzites dip south-east at high angles or are vertical, and curve round the intrusive granite bosses at Baroda (27° 20′, 76° 6′). On the margins of these granites the quartzites show no more metamorphism than elsewhere, but at several places in the hills violent brecciation has taken place. Conglomerate bands of quartz pebbles are fairly often met with. It is impossible to say with any certainty whether the strata here are folded into an isocline or represent a simple and unrepeated section ; the presence of Ajabgarhs on both sides, at a short distance, makes the former structure the more probable one.

Just west of Manoharpur, three curiously twisted ridges meet. the beds composing them lying usually at low but very variable angles and with a sinuous strike. On the extreme west they are of typical regularly bedded Alwars, and preserve this facies to Ajmiri (27° 30′, 75° 58′), where they abruptly terminate. The other rocks exposed near Manoharpur are lithologically much more similar to the Ajabgarhs, though they would appear to be on the same strike as, and to continue, the Alwar exposures just described. They are mostly dark grey or brown quartzites, impure and weathering with a thick crust, and bands of soft black mica schist are in great force. To the north-north-east they are connected with the Ajabgarh exposures in Torawati by an interrupted double ridge consisting of granular, dark grey vitreous quartzites lying conformably above soft dark micaceous beds which can best be described as sandstones. Quartzites and sandstones are almost certainly Ajabgarhs.

The first of the anticlines in Torawati proper extends from Chiplata (27° 34′, 75° 53′) for about twelve miles to the north, and has a maximum east to west breadth of about four miles, but its outline is very irregular. It is probably the result of several minor anticlines being pressed together (anticlinorium), the ends of which are visible like promontories when jutting into the Ajabgarhs around, but which cannot be distinguished from each other when in contact. Its general strike is north-south in its southern half, swinging to north-east—south-west in the north.

The quartzites are usually gritty or conglomeratic, with rounded or flattened quartz pebbles (not arkose), are pale in colour and give rise to the usual Alwar topography.

In this particular anticline the evidence obtained regarding the relative ages of its strata in the ridges, and of those forming the lower ground about it, was inconclusive, but no doubt was felt that the former were Alwars and that their junction with the latter was a conformable one. Extensive scree-slopes conceal much of the junction between the two sets of rocks (the Alwars and the argillaceous beds of the lower ground), but when seen it is found to be a conformable one, with a gradual change in the lithological character of the beds across the strike, and exact concordance in their strike. The conglomerate bands are not near the passage, but among the quartzites some distance from it. In other parts of the Torawati and Shekhawati hills the structure is clear enough to show that the quartzites are older than the softer argillaceous beds; these are then equivalent to the Ajabgarhs, which they greatly resemble. Round the northern part of this anticline the dips at its margin are as often as not reversed, but near Chiplata, where lateral compression seems to have been less intense, dips are at comparatively low angles and are outwards from the axis of folding. Two miles north of Chiplata the ridge forming the visible edge of the anticline is interrupted, presumably by faulting, and about half a mile width of Ajabgarhs occupies the gap. The line of the fault or faults was not seen. Taking into consideration the intense crumpling and intricate folding over the whole of North Rajputana it is surprising that evidences of extensive faulting have been so few. There can be no doubt that thrust-faulting at least must have taken place to a much greater extent than I have been able to make out, though often suspected from those variations in the thickness of strata which are so common. Where rocks are much sheared, brecciated and contorted, and where beds giving a reference horizon over some distance are rare, thrusts of considerable amount may easily pass unnoticed among the multitude of minor distortions. Along the line of fault denudation is easy and it will naturally tend to be obscured by soil or *débris* collecting over it.

To the south-east of this anticline and partly enclosed by two of its lobes, but separated from them, is a narrow quartzite area which I take to be also an anticline of Alwars.

The second anticline to be considered lies north-west of Patan (27° 48′, 76° 2′). This is of much larger size and extends to the north-east into Narnaul (Patiala State), where it is much broken up by strips and arms of alluvium. Its general trend is north-east—south-west, but many minor irregularities are displayed by the festooned or denticulate shape of its south-eastern margin, where alone it is visibly in contact with the Ajabgarhs. It also seems to be an anticlinorium, but the separate folds have not been so closely squeezed together, so that where they extend out from the main mass we get in horizontal section rounded outlines rather than the acute angles in the anticline last considered. Along this margin the passage of the

Alwars into the Ajabgarhs is well seen, the quartzites dipping steadily under the argillaceous beds at angles varying from 60 upwards, with a transition belt of thin-bedded quartzites and micaceous flagstones. Along the north-west side a broad stretch of alluvium conceals the junction.

The general dip is to south-east, in the reverse direction to what has been found to be the normal in these folds. The quartzites are coarse, with abundant flakes of muscovite along the bedding-planes, and in the zones where the rocks partake of the nature of mica-schists, large garnets are abundant. In many places the rocks are intensely puckered and contorted, but they keep to an average strike. Intrusions of epidiorite and pegmatite are very numerous.

The next two anticlines, in the Shekhawati hills, are somewhat doubtfully Alwars, but taking all the circumstances into account the balance of probability is that they are Alwars, but the boundary between them and the Ajabgarhs must be regarded only as an approximation. The more northern of these lies immediately east of Khetri (28° 0′, 75° 51′) commencing six miles south of Khetri, and running about twenty miles to the north-east, where it disappears under alluvium. Its maximum breadth is about six miles. Instead of forming a hilly region standing up over a low-lying tract of Ajabgarhs as is usual, the Alwars here (except at the north-eastern end) form comparatively low irregular hills quite overshadowed by the high ridge of the Khetri Fort, which is, I consider, of Ajabgarh schists and quartzite. The anticlinal structure is very clear at the south-western end, near Babai.

The rocks which I consider to be probably Alwars are largely thin-bedded quartzites with micaceous laminae, and broader zones rich in mica, and a few brown and black limestones. They are usually fine-grained, reddish, yellow or gray in colour and are softer than the typical Alwars, but are similar in colour and, to judge by appearances, the same in the amount of minerals present other than quartz. The unusually low relief of their outcrops may be partly due to the abnormal number of intrusives penetrating them, epidiorites, granites and pegmatites, as well as to the presence of micaceous laminae. Upwards in the section these quartzites are seen to pass into the mica-schists and black slates which carry the copper ores of Singhana, Khetri and Babai. Dips in this anticline (or isocline) are to the north-west, quite moderate (20°—40°) on the north-west side and steeper on the other, of course reversed on the latter side. Near

Khetri the strike swings to the north-west—south-east for a space, returning again to the normal, and with this flexure the width of the anticline abruptly increases.

The last anticline to be considered is that running from Ponk-Gurha (27° 50′, 75° 41′) for about 26 miles south-westwards to Sangrua (27° 25′, 75° 22′), forming the backbone of the Shekhawati hills and culminating in the highest point in North Rajputana, 3,450 ft. Here also there is some doubt as to the correlation with the Alwars but the balance of probability is in favour of its correctness. The boundary with the Ajabgarhs, in the absence of any well-marked horizon, had to be somewhat arbitrarily marked. The form of this area of Alwars is very narrow and elongated, its maximum breadth being about 2½ miles, and in one place it is broken across and laterally shifted by a large granite intrusion. Except near its south-western termination, where it is joined to a subsidiary parallel fold, it appears to be a simple anticline.

Near Ponk-Gurha the end of the anticline forms a high hill-mass, in which dips are clearly seen swinging round from north-west to north and then to east. The rocks are dark grey and reddish quartzites, bedded in a similar manner to the Alwars and differing from them only in being slightly darker in colour, and more argillaceous and ferruginous than the normal.

Where the granite intrusion cuts across it, the width of the Alwar outcrop abruptly decreases, and layers of conglomerate appear in large amount. The pebbles of these are of quartz and quartzite, up to two inches in diameter, and imbedded in a matrix of slate or mica-schist. Farther along the anticline, from the termination of the granite intrusion south-westwards to Sangrua, siliceous conglomerates predominate over non-conglomeratic quartzites. Except at the north-eastern end, where the anticline is not recumbent, dips on both sides are in general to the north-west. Igneous intrusions, excepting the above-mentioned granite mass, are almost absent from this outcrop, which no doubt is an important factor in its resistance to denudation.

## The Ajabgarh Series.

For convenience of description the areas occupied by the Ajabgarh Series may be divided into two sections; (1) the enclosed valley between Manoharpur and Atchraol and (2) the very extensive areas n Torawati and Shekhawati.

The first is a plain, enclosed on all sides by hills of Alwar quartzite, with a few tortuous Ajabgarh ridges, of little breadth and elevation, emerging from the alluvium. The Ajabgarh outcrops themselves are too meagre to give any information as to the hidden structure, but the surrounding Alwars show it to be a syncline, or several confluent synclines, with two long arms extending southwards towards Amber and Nimi. In the main syncline and in the Nimi arm, the rocks are dark grey and brown distinctly bedded quartzites, rather coarse, and weathering with a thick, cellular crust. The usual soft grey argillaceous beds are present and a rock practically identical with the "Berla quartzite,"[1] and, like it, used for millstones; the general facies therefore is exactly that of the Ajabgarhs in the south-east of Alwar State and, as there also, the ridges are intricately twisted, with abrupt changes in the direction and amount of dip.

The synclinal valley north of Amber is floored with the outcrops of Ajabgarh rocks resembling the calcareous beds in the Ajabgarh valley[2] above the Kushalgarh limestone. They are soft rocks, banded in shades of black and dark grey, and often show intense crumpling and puckering. Mineralogically they are rather indeterminate and difficult to describe, but might be called siliceous and argillaceous (sometimes ferruginous) limestones and calcareous slates. They weather like limestones, but are so impure as hardly to deserve the name. Thin bands of dark quartzite and slate also occur ; there is a complete absence of any definite or lithologically distinct strata, such as pure limestones or hard quartzites.

The Torawati Ajabgarhs are connected with the Alwars near Manoharpur by the two ridges of quartzite and micaceous " sandstone " mentioned on p. 364, but, as the correlation of the rocks here is doubtful, much reliance cannot be placed on this. To the north-east they are practically continuous with the Mandan group of Hacket, near Tasing, which I have elsewhere shown to be identical with the Ajabgarhs[3]. Westwards, though they are not absolutely connected with the Shekhawati Ajabgarhs, the interval of alluvium intervening is so small and the rocks outcropping on each side of it are so similar, that there is no question that they are one and the same formation. Their correlation with the Ajabgarhs elsewhere rests chiefly on their general character and their relationship to the undoubted Alwars of the Patan anticline.

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, pp. 65, 81, 126.
[2] *Mem., Geol. Surv. Ind.*, Vol. XLV, pp. 84-85.
[3] *Mem., Geol. Surv. Ind.*, Vol. XLV, pp. 75 77.

East of Buchara (27° 33′, 76° 2′) is a lofty group of hills presenting a magnificent scarp eastwards to the valley of the Sabi river. They are the continuation of the double ridge from Manoharpur, mentioned above, and in the scarp the same rocks are exposed, massive, dark, granular and vitreous quartzites forming a cliff above, and much softer argillaceous and micaceous quartzites (almost like sandstones) in the slopes below, both with bedding and jointing obscure. This has been mapped by Hacket as an unconformity, Alwars on Aravallis, and on a cursory examination this appears correct, as the lower, soft strata are intruded in all directions, chiefly along the strike, with pegmatite veins, some of enormous size, seeming to stop at the junction between the two sets of strata. On further investigation, however, the lower beds are seen to pass upwards gradually and conformably into the upper, with no basement conglomerate, and with concordance in dip and strike.

The pegmatites too, are seen to intrude the upper series, but are greatly diminished in size and in number, and are not obvious from a distance. The superior hardness of the upper quartzites has evidently been a partial barrier to the pegmatites, for, on the dip-slope behind, where softer beds (mica-schists, etc.) appear, the intrusives are again seen in force. Westwards, overlooking Buchara, another hard zone occurs, also rather free from pegmatite, but around Buchara soft strata occur, in which the veins attain an impressive development. Another disproof of the unconformity is that, all along the scarp, and in the ridges extending to Manoharpur, the same two sets of strata are in contact, without transgression or overlap.

The massive quartzites, though so prominent, are merely another case of those resistant quartzite zones which elsewhere form a feature of the Ajabgarhs, and have only an accidental similarity to the Alwars. The dips in these hills are rather low, less than 30°, and are to west and north-west, except about 3 miles south-east of Buchara, where the strike swings round in a semicircle (dips to south and south-east), abruptly returning again to the former direction.

In the area of intense pegmatite injection west and north of Buchara, the Ajabgarhs are mainly mica-schists and soft micaceous quartzites, with impure limestones which are often altered to coarse grey crystalline rocks, with bundles of columnar tremolite crystals several inches long, and in which the diffused silica has been concentrated into knots. On the non-calcareous rocks the pegmatite seems to have had little thermal effect, and the small amount of crumpling or distortion present, apart from simple disruption, is rather unexpected. About 1 mile north-east of Buchara, the schists are markedly graphitic. Over much of this area far more pegmatite is visible than metamorphic rocks. The dip is naturally irregular, seemingly chiefly to the south-east, the reverse direction to the normal.

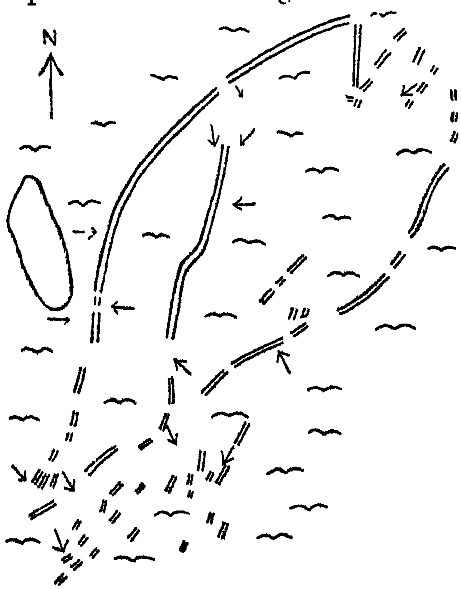
North-west of a line drawn from Chiplata to Dantal (27° 40', 76° 4') the pegmatites are practically absent, and the Ajabgarhs are exposed over a wide area. They are similar to those mentioned as forming the Amber syncline (p. 368) and, generally speaking, are an assemblage of rocks which show frequent variations in character, but which nevertheless are much of a type and vary within narrow limits. They are mostly quartz-mica schists and impure crystalline limestones, siliceous, argillaceous, actinolitic or ferruginous, and are banded and thinly bedded in layers of slightly varying composition, yet all of a monotonous black or rusty colour and usually weathering with a rough and cellular crust. It is seldom that a bed is homogeneous to a thickness of more than a foot or two; also change in the nature of the beds in short distances along the strike is often noticed and is sometimes very puzzling. The amount of metamorphism which they have undergone varies with the local conditions and may take the forms of development of mica or actinolite, the concentration of silica into knots and, less often, the formation of staurolite, garnet and graphite.

In the centre of the Torawati hills, a common type is grey, soft quartz-mica schist, looking and weathering like a micaceous grit. Pure, pale coloured quartzites are not uncommon, but are usually thin-bedded and intercalated with schist or slate layers, and die out rather rapidly or change along the strike into other types. In the north-eastern portion of the hills, north of Dantal (27° 40', 76° 4') such quartzites are the predominating rocks, giving high elevations. Along the eastern margin of the large granite intrusion at Jainthpura (27° 39', 76° 00'), and curving towards Chiplata, is a broad belt of pink fine-grained arkose quartzite, which does not show bedding, and near the granite contact is much twisted and brecciated, and apparently partially fused.

Regarding the structure of the Ajabgarhs in Torawati, comparatively little was definitely made out as to the way in which they are folded. Their strike is north-east—south-west in the south, north-south about the middle (locally even north-west—south-east), veering round again to north-east—south-west in the north. Though with considerable irregularities, a concordance in dip was noted over considerable areas. For instance, east of Buchara, the quartzite ridges dip to west and north-west; west of Buchara the inclination seems to be in the opposite sense but there is no sign of the quartzites again coming to the surface.

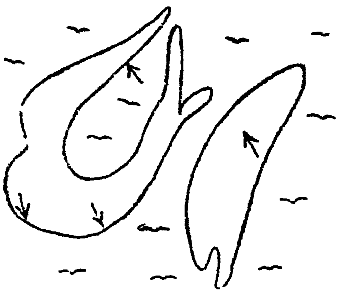
Beyond the limits of the pegmatite-intruded area north-westwards to near the Patan anticline, dips are mostly to north-west or west, while immediately north of Dantal there is a distinct syncline, the shape of which is very puzzling. North of this syncline and on its eastern limb, the strata are much brecciated over several square miles, and north of this again, to the Narnaul frontier, dips are consistently to east and south-east. Apart from brecciation there is much less metamorphism of the rocks than in the pegmatite intruded area to the south.

A sketch plan of the Dantal syncline is as below, the ridges being formed of thin flaggy quartzites with interbedded schists and limestones. A strange phenomenon is the wide separation of the two ranges which are in contact in the south, but divide and enclose a wide valley, covered with detritus, in which the intervening beds and the reason of the separation of the ridges are concealed.




Diagrammatic plan of Dantal syncline, showing quartzite ridges.
Scale 1 inch to 2 miles.

Between this syncline and the Jainthpura granite the strata are much twisted. Parallel to the Jainthpura granite and a little distance from its western side, is a long ridge of quartzite, resembling the Alwars in several points, which may perhaps be an elongated Alwar anticline, though I consider it more probably a siliceous band in the Ajabgarhs. After running for about six miles with uniform width, it abruptly thickens and then thins out again in a way which can only be explained on the assumption that it is repeated by strike-faulting or by folding. Though looked for carefully, no evidence could be found as to this. At its broadest part, epidiorite intrusions are very numerous. At its southern end, it strikes at an angle to the pink arkose quartzite above-mentioned, possibly through being cut off by a concealed fault.



Diagrammatic plan of Dariba anticline.
Scale 1 inch to 1 mile.

At Dariba (27° 40′, 75° 57′) is a horse-shoe shaped hill of quartzites, dipping quaquaversally, with limestones in the centre and round the outside, with which the quartzites are seen to be interbedded. At the curved part of the horse-shoe the quartzites are thick, but thin out or pass laterally into limestones quite rapidly towards the points. At Ahirwala (27° 37′, 75° 54′) is an isolated hill of compact quartzite, surrounded on all sides by quartz-mica schists and quartzites finely injected with veins and films of epidiorite. Evidently this hill owes its prominence over the plain of less resistant rocks around, partly to its being a roughly lenticular mass which has escaped intrusion, and has so been enabled to withstand denudation. There are several cases similar to this. Such a ridge of strong quartzite often appears to be much broader than it really is, as it strews its slopes with large detached blocks, thus concealing and protecting the immediately adjoining softer rocks.

West of Toda (27° 38′, 75° 59′) is a compact black (hematitic) quartzite, which runs south and then south-west towards Chiplata and gives a well-marked horizon. At Chiplata about half a mile intervenes between this bed and the edge of the Alwar anticline, while at Toda, 5 miles farther north, the distance has been increased tenfold by the interpolation of intermediate folds. Two of these, anticlines of Alwar quartzites, are seen, but there must be other anticlines in the Ajabgarhs themselves which could not be made out, owing to the absence of distinctive beds in the latter, but which can under favourable circumstances be seen, *e. g.*, at Dariba.

The above selected cases give some idea of the complex folding of this area and the puzzling manner in which many beds appear to thicken or die out when followed along the strike.

The rocks of the Ajabgarh Series in Shekhawati are practically identical with those in the Torawati hills, except in the immediate neighbourhood of the anticlines of Alwar quartzites, where they are more argillaceous and siliceous, and form a broad zone of passage upwards into the Alwars, the gradation being more gradual than in Torawati. There is however considerable doubt as to the true position of the boundary line and some might consider that these beds should be included in the Alwars.

The Ajabgarhs form a wide band of low rolling hills and uneven stony plain (Pl. 23.) along the south-eastern side of the Alwars which form the axis of the hills, and on the other side a narrower belt of long and lofty ridges. Strike is fairly constant at about north-east—south-west, dip in the area south-east of the axis is quite irregular and very extensively obscured, in the north-western area it is to the north-west. In the former belt, epidiorite and pegmatite intrusions are very numerous. In it, north-east of Babai, Hacket has mapped a large exposure of granite. On microscopical examination I found this not to be granite, though in the field closely resembling micro-granite, but probably not of igneous origin. This had also been seen on a smaller scale south-west of Raipur (27° 44′, 76° 1′). It might be termed a hornstone,[1] porcellanite or granulite. In hand specimens it is a fine-grained, compact, unfoliated red rock,

[1] Harker's "Petrology," p. 302.

sometimes streaked with green. Under the microscope it shows small ragged crystals of quartz, pale green amphibole, calcite, tourmaline, ilmenite, sphene and doubtful pyroxene, in a brown cloudy groundmass of indistinct crystals which may be quartz or secondary felspar. In the field it occurs not in veins nor in clearly defined intrusions but in indefinite and ramifying masses which merge gradually into the impure limestones and schists, somewhat as if the latter had soaked up a red colouring matter along their joints and lamination, or after the manner of colour-mottling in sandstones, but without sharp margins. In the field I took the rock for micro-granite or a hybrid interaction product of granite and argillaceous rock, but microscopical examination shows that in parts it is clearly unaltered siliceous limestone, and is most probably the result of extreme metamorphism of the Ajabgarhs, causing fusion and recrystallisation of the fragmentary materials (with production of secondary felspar), and is in fact a stage in the formation of felspathic para-gneiss. This hornstone is the predominant rock in a band running from about Maonda (27° 49′, 75° 52′) to Teonda (27° 58′, 75° 56′), of an irregular width with a maximum of three miles. In this band a few small bosses of the true intrusive granite, biotitic, porphyritic and foliated, are found.

South-west of Maonda, solid geology is visible only in scattered outcrops of the same impure limestones and schists.

Across the axis of the range, near Singhana (28° 6′, 75° 54′), the Ajabgarhs are rather different, being white and reddish, thinly bedded, micaceous flagstones, with slates in the valleys, dipping regularly to the north-west. They are practically free from igneous intrusives and are not greatly metamorphosed. In several ways their resemblance to the Alwars is marked. There are two main ridges, one of which comes to an end about ten miles south-west from Singhana, the other bends southward near Khetri and for a long distance has an elevation of over 2,000 feet, carrying the conspicuous forts of Khetri and Bagor. Its prominence is due to several hard quartzite beds, separated by black slates, and as the dip is unusually low (20°—30°), an abrupt scarp is formed. (Pl. 25.) Below the scarp is the bed containing the copper ores of Singhana, Khetri and Babai and the cobalt ore of Babai ; it varies from a black slate, locally containing very large chiastolite crystals, to a coarse schist of brown mica with large knots of greyish-blue cryptocrystalline quartz. This passes downward into brown impure limestones and these into the quartzites which I have classified as Alwars. The brown limestones may perhaps represent the Kushalgarh limestone but they do not resemble it. Below the quartzites of the ridge epidiorites are common, but not above. West of Babai (27° 53′, 75° 49′), the end of the anticline is well seen, quartzites and intercalated slates curving round, and at Babai rapidly steepening in dip from 10° to about 50°. Beyond Babai north-eastwards on the other limb of the anticline in the direction of Teonda, the above described beds cannot be followed with certainty, owing to higher metamorphism and the confusion caused by profuse igneous invasions.

In the south-western part of the Shekhawati hills there seems to be a gradual diminution in the amount of the limestones, which, taken with an apparent coarsening in the grain of the slates and quartzites (in the Ajabgarhs as well as in the Alwars), would indicate the proximity of the land-surface from which their materials were derived.

North-west of the core of the range, the Ajabgarhs form a belt, about a mile broad, of high parallel ridges. Near Ponk-Gurha, at the north-eastern end of the south-western section of the hills, they are hard siliceous phyllites and slates, banded in shades of black, grey and red running along the strike, and sometimes irregularly mottled. They show a distinct dip to the north-west, and pass down by gradations into the impure Alwar quartzites of the Ponk-Gurha hills. The banding is merely of colour, and not of differences in hardness, so the hills are not longitudinally ribbed, but steep-sided and serrate. A band of conglomeratic grit was noted, a rare occurrence in the Ajabgarhs. Along the strike towards Udepur (27° 44′, 75° 32′), fine quartzites appear in the ridge, and, in the valley, some gritty bands in the slates, and along the margin with the Alwars, conglomerate layers occur among the slates, commencing the gradual upward transition to the Alwar quartzite conglomerates. Beyond Udepur to where the hills end at Ragonathgarh (27° 40′, 75° 24′) and Sangrua, flagstones and slaty quartzites prevail, almost to the exclusion of slates, and in them are several conglomerates. Herein lies the difficulty of drawing a division between the Alwars and the Ajabgarhs, as I should certainly have mapped these rocks as Alwars had I not seen them passing horizontally into fairly typical Ajabgarhs. The progressive increase in arenaceous content in the Ajabgarh rocks as one passes south-westward is in accord with the coarsening of the Alwars, to which I have drawn attention, and which I have suggested may be due to the proximity of the original margin of deposition.

The synclinal valley of Kot (27° 40′, 75° 29′) in the centre of the hills, is floored with gray micaceous Ajabgarh quartzites and hard black slates, and mica-schists along the outer (southern) margin. From Ponk-Gurha to here, igneous rocks, except a few epidiorites in the Kot valley, are absent from the above described rocks.

On the south-eastern side of the Ponk-Gurha anticline is a much wider expanse of Ajabgarhs, in this case of the usual limestones, schists and soft quartzites, with a broad belt of lofty hills running north-east from Khandela (27° 36′, 75° 33′). The less outstanding rocks, forming a thin-soiled cultivated plain studded with hillocks, call for no remark. Intrusions, chiefly of epidiorite, abound. The Khandela hills, which start as insignificant quartzite ridges near Babai, and increase gradually along the strike, are dark grey, fine grained, ferruginous and porcellanic quartzites interbedded with schists, and are in several places much brecciated. No limestones are present and epidiorites occur only at the Khandela end, where however, they form great lenticular masses.

The topography which the Ajabgarhs give rise to in Torawati and Shekhawati is typically a confused expanse of low black hummocks with little or no relation, in their trend, to the geology. They bear a sparse scrub jungle of scattered bushes, mainly *Euphorbia* and other shrubs of a similar formidable spininess. Where, through the presence of quartzites or harder slates, they rise into serrated ridges and peaked hills, their slopes are steep and conspicuously barren even for this arid land; *Euphorbia* alone finds sustenance and that seemingly with difficulty. It is curious that this hardy plant grows only on rocky ground and slopes of *débris*, it is *never* found on sand or alluvium except when artificially planted.

## Igneous Rocks Intrusive in the Delhi System.

In order of age the three classes of igneous rocks intrusive in the Delhi System are :—

I.—Epidiorite sheets and veins.

II.—Granite bosses.

III.—Pegmatite veins.

I.—EPIDIORITE.

These have been elsewhere described as " amphibolites, " but in accordance with the recommendations of the Committee on British Petrographic Nomenclature, I now term them " epidiorites," but they are identical with the amphibolites of Alwar.[1]

I may briefly recapitulate their description. They are seldom schistose, usually homogeneous and visibly crystalline, dark green, unbedded and irregularly jointed. Their structure may be described as granulitic or sometimes granitoid.[2]

Under the microscope they are seen to consist chiefly of hypidiomorphic green hornblende with secondary felspar and quartz. Ilmenite or sphene is always present, accessories are biotite, apatite, and pink garnet.

In mapping, the scale of 1 inch to 1 mile was too small for me to do more than indicate diagrammatically the approximate extent of the areas in which occurrences were numerous, with their general strike, but an endeavour was made to show on the map all isolated outcrops and those of outstanding size. In the accompanying reduced map the still smaller scale, and difficulties in reproduction, have necessitated the omission of the epidiorites.

It is found that bands of mica-schist and conglomerates with a micaceous matrix, seem to be favoured as an avenue of injection, from obvious mechanical reasons, while in limestones it would appear that the thinner sills and veins are to some extent absorbed, with mutual chemical reactions resulting in the formation of actinolite, tremolite and epidote, as streaks and knots in crystalline marble. This is seen near Khetri, Babai and Patan.

As a rule the epidiorites here are finer grained than most in the south of Alwar, there are fewer thick, massive and persistent sills (except near Khandela), and profuse and minute *lit-par-lit* injection is very much more frequent. In Alwar also, the epidiorites are practically confined to the Alwar Series, while here they invade the Ajabgarhs as well.

In several places (*e.g.*, the south end of Beharipur hill), the laminae along bedding-planes of quartzite are so straight and regular, so numerous and so thin, that one is inclined to believe them to be lines of metamorphosed volcanic dust, *e. g.*, augitic tuff. The

[1] *Mem. Geol. Surv. Ind.*, Vol. XLV, pp. 90—92 etc.
[2] Harker's " Petrology ", p. 334.

supposition that some of them are altered tuffs or contemporaneous flows does not, of course, negative the proofs that the majority are intrusive.

Only a few cases need be referred to. There are numerous occurrences in which bands outcropping on the low ground at the base of hills which cross their strike, suddenly terminate at their foot and, in the precipitous cliffs above, where they would be very conspicuous, they are entirely absent, or are present in much reduced thickness ; evidently denudation is greatly aided by their presence in introducing a source of weakness and it is in fact exceptional to find an epidiorite mass of any dimensions except on low ground. Not only do these intrusions facilitate denudation, but, as I have pointed out, they originally invade the softer types of rock much more than they do the more resistant.

That the epidiorites have been injected previously to the granite is shown by the veins of granite in epidiorite near Bairat [1] and by the total absence of any epidiorite in the granite, save in the Chapoli boss, an apparent exception which is in reality a proof, for the epidiorite is clearly in the form of xenoliths, associated with similar quartzite fragments. That they are earlier than the pegmatites is directly proved by a zone of epidiorite injection north of Buchara, forming a regular band cut through in all directions by the pegmatite veins.

It is strange that the amphibolites are somewhat seldom schistose, while the granite is typically foliated. Their temperature and viscosity conditions at the time of intrusion must have been widely dissimilar, as the epidiorites copiously and minutely inject their country rocks in sills, veins and stringers, while the granite forms compact and sharply margined masses and very rarely sends out apophyses. The pegmatites have an intermediate character, as their veins, through ramifying, are of large size and meet the enclosing rocks sharply and without any *lit-par-lit* injection ; they are always coarse-grained and quite unfoliated.

The present crystalline structure of the epidiorites cannot have been produced during consolidation,[2] as the minerals now occurring probably crystallised long after that, but it may have been induced along with the foliation of the surrounding rocks, pressure and high temperature causing shearing and schistosity in yielding rocks like

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, p. 88.
[2] Harker's "Petrology", p. 25.

mica or chlorite schists, while in stronger and tougher rocks like epidiorite and quartzite granulation and recrystallisation might take place.

The origin of these epidiorites is probably in diorite or dolerite, as has been traced in other similar rocks elsewhere,[1] but here the conversion of pyroxene into amphibole seems to have been in all cases complete; in none of the specimens examined is there any trace of the original pyroxene.

## II.—GRANITE BOSSES.

The granite occurrences, which I describe separately below, all belong to the type which in Alwar State is intrusive in the Alwars.[2] In this area they invade the Ajabgarhs as well. The chief variations in the different masses are in the degree of foliation, the coarseness or fineness in grain, and their porphyritic or non-porphyritic character. Under the microscope they show quartz, microcline or orthoclase or both, sometimes acid plagioclase in small amount, sphene (and ilmenite) and biotite. Muscovite and apatite are sometimes present and in two slides a little doubtful green hornblende, much altered to chlorite and epidote, was present.

*Barha.*—(27°16′, 75°55′) (Reg. No. 26.844, slide 9859). At the base of the quartzite ridge is a small exposure of pink, fine-grained gneissic granite, with clusters of biotite, foliated in perfectly straight lines and almost as fissile as a slate. (Under the microscope it shows chiefly quartz and microcline, some orthoclase, a little biotite and apatite). It has been intruded into a band of mica-schist with quartzitic layers, and merges insensibly into this, which again passes upwards into normal quartzite.

*Manoharpur.*—2 miles west-north-west of Manoharpur, at Bishangarh, there is an isolated hill composed of foliated yellow granite, fine and medium grained, the same as that of Bairat and Baroda.

*Baroda.*—The Baroda granite (Reg. No. 26.845, slide 9860) is fine-grained, unfoliated and indistinctly porphyritic, pinkish-grey in

[1] *Bull. 62, U. S. Geol. Surv.*, Ch. 1.
*Q. J. G. S.*, Vol. XLIV, pp. 429-435.
*Q. J. G. S.*, Vol. XLI, pp. 133-144.
Blake, *Rep. Brit. Ass.*, 1888, p. 406.
Teall's "British Petrography", pl. xxviii, fig. 2, pl. xl, fig. 2.
[2] *Mem., Geol. Surv. Ind.*, Vol. XLV, pp. 92-93.

colour and somewhat resembles trachyte in the field; being dense and compact, without much biotite, it weathers into angular and sub-angular blocks instead of the more usual domes and piles of rounded boulders. There is little variation throughout the mass, which is devoid of pegmatite or quartz-veins. It is composed of corroded phenocrysts of quartz, orthoclase and acid plagioclase in a finer quartzose ground-mass of the same, with a little biotite, ilmenite and sphene. On the east its contact is seen with grey, ashy, flaggy quartzites, striking at an angle to the local direction of the margin. The junction is not quite definite, a little interaction seeming to have taken place, and a short space away from the margin the quartzites are twisted and brecciated.

*Ajitgarh.*—(27°25′, 75°52′). (Reg. No. 26.848-9, slide 9862-3). This is a detached hill of a rock very like that of Baroda, but medium-grained and non-porphyritic. and with a few quartz-orthoclase-tourmaline pegmatite veins. Under the microscope it shows quartz and orthoclase micrographically intergrown, some plagioclase, abundant sphene, biotite, apatite and hornblende which has largely altered to epidote.

*Jainthpura.* (Reg. No. 26·852, slide 98.64). This is one of the largest bosses and has associated with it five others much smaller. Its shape is peculiarly elongated, being seven miles long by a mile broad. The rock is pink, fine-grained (medium-grained near the centre) and largely non-porphyritic; when porphyritic the phenocrysts are somewhat rounded or flattened. It carries no pegmatite nor quartz-veins but has a few of microgranite. Foliation is very pronounced, with foliation dip to the west, and on the margins is so straight and perfect that the granite closely resembles felspathic flagstones and can be split with almost equal facility. It is composed of quartz, microcline, kaolinised orthoclase, biotite and sphene.

On the west the margin follows the strike of micaceous quartzites, very irregularly however, with large blocks immersed in the granite, and veins invading the quartzites. There are no signs of localised metamorphism. On the east of the granite is a pink quartzite, previously mentioned (p. 370), which in some places is fused, twisted and brecciated and probably mixed with the granite, so that the junction is indefinite. It may perhaps be a quartz-felspar granulite resulting from the metamorphism of argillaceous and siliceous sediments, similar to the red hornstone between Teonda and Maonda (p. 374).

*Gori.*—(28°2′, 76°1′). Immediately south of Gori and also 2 miles to the south-west, are two more exposures of well-foliated granite, the latter of which has a bed of white crystalline marble running along its midst. Its minerals comprise quartz, microcline, cloudy orthoclase, abundant sphene, ilmenite and green hornblende with very little biotite.

*Biharipur.*—(27°53′, 75°57′). The hill south of Biharipur is composed of a very quartzose pink and yellow granite, foliated and obscurely porphyritic. At each end of the hill a pink rock occurs, like the quartzite on the east side of the Jainthpura granite, which, at the south end, passes into undoubted quartzites, very soft and copiously streaked with hornblende. Passing out from the granite into these quartzites is a sill of felspar-porphyry about two feet thick, composed of phenocrysts of microcline and orthoclase microperthitically intergrown, in a ground-mass showing quartz, microcline, plagioclase, sphene, apatite and traces of biotite.

Between Singhana and Khetri are three large and one small bosses of schistose and porphyritic granite. Of the same type are the granite hills at Gudha (75°35′, 27°51′), isolated in the desert, and at Chinchroli (27°50′, 75°48′).

*Chapoli.*—The Chapoli (27°44′, 75°36′) intrusion is by far the largest met with up to the present in the Delhis, and has besides, to the south-east, several minor bodies of the same composition. Its shape is curious—two masses, lenticular in plan, parallel but not in the same line, and joined by a narrow neck of granite which cuts traversely across an anticline of Alwar quartzite, this being laterally shifted along the line of intersection. It is similar to all the other occurrences above described, medium-grained, foliated and porphyritic, and encloses several xenoliths of epidiorite and very many of dark-grey quartzite. East of Chapoli, near Mandhaora, pieces of quartzite are enclosed in the granite near its margin, and have obviously been torn from the rocks *in situ* close by. North-east of Chapoli the actual junction is obscured by *débris*, but seems to be with mica-schists, which are succeeded upwards by the conglomerates of the ridge. West of Udepur the contact is well seen, and is with similar rocks to those north-east of Chapoli, also passing up into conglomerates. The margin here is sharp, the granite stopping for the most part at a particular plane of bedding or schistosity, without much irregularity. At the south end also, a sharp contact is seen, with quartzite blocks torn off and included in the granite, and at the base of the semicircle of hills at the extreme south the foliation of the granite curves round parallel to the margin.

### III.—PEGMATITE VEINS.

The pegmatites, like the epidiorites, are distributed practically all over the area, and are in force in more or less the same localities. They reach their maximum development near Buchara, to which place the following description more especially applies. In other parts they vary little from this, except in colour and in the relative proportion of the component minerals. They are very coarse in grain, always unfoliated, and form veins (or sills) several feet thick and in the Buchara area often several yards across. Owing to the small scale of the accompanying map and the multitude of the intrusions, I have been compelled to omit them altogether.

Near Buchara their felspar is salmon colour or pale pink, (in other places often white), and is the dominant mineral, forming large, optically continuous areas, as much as a foot across, in which felspar and quartz are graphically intergrown on a large scale. On weathered surfaces the felspar is shown as two varieties, perthitically intergrown on a small scale as well as pegmatitically with quartz. Under the microscope the dominant pink felspar is seen to be microcline, the other perthitic ingredient being orthoclase or acid plagioclase. The eutectic portion of the magma is therefore a mixture of quartz, microcline and another felspar.

Between these large compound crystals is a finer grained, but still coarse aggregate of pale-pink or white felspar (orthoclase), with greenish muscovite and tourmaline in quite subordinate amount. The muscovite plates are smaller than a rupee, and the tourmaline crystals are 2 to 3 inches long and $\frac{1}{4}$ to $\frac{1}{2}$ inch thick as a maximum. In smaller veins the graphic intergrowths are often not developed, quartz and felspar crystallising together in the ordinary way, and either muscovite or tourmaline may be absent. Both muscovite and tourmaline were never found together in large amount; if one is in force the other is absent, or present only in very small quantity.

An extreme modification of the pegmatite is the quartz-tourmaline vein-rock so widely distributed, in which tourmaline crystals are often zonally arranged along the centre of the vein, or at the sides with their bases parallel to the walls of the vein. The greatest development of these quartz-tourmaline rocks is east of Ajitgarh in the range of Alwar quartzites, forming large masses of tourmaline and quartz banded in black and white, as well as intermixed. The pegmatites were doubtless cooler or more viscous than the epidiorites and granites at the time of their intrusion, as they have had little thermal effect on the rocks they invade; they include sharp-edged xenolithic blocks, without mutual interaction on their margins, and do not finely inject nor fray out the laminæ of the country rock.

Their relatively younger age than that of the granites is shown by their cutting across the Jainthpura boss at its south end, and at its north end near Raipur, and by the total absence of foliation or crushing, indicating that they belong to an age when folding had entirely or almost entirely ceased.

It is only near Buchara that the pegmatites are sufficiently abundant to produce a distinctive topography of their own—bare rocky ribs extending along the general strike, with longitudinal gullies between, excavated in the less resistant metamorphics. The larger intrusions resemble sills in keeping more or less to definite horizons, but the smaller ones cut across the strike in all directions. and the parallelism of the larger is visible chiefly through the dissection of the country by stream-courses.

## SOIL, ALLUVIUM AND BLOWN SAND.

The soil is the usual light loam of the Indo-Gangetic plain, and even where the surface material is loose and shifting sand, this more fertile and coherent loam forms a sort of subsoil a few feet below the surface, exposed in stream channels and in wind-eroded hollows amongst the hummocks.

Dunes of blown sand cover considerable areas on the plains, especially in Shekhawati, but they are of low altitude and support a certain scanty vegetation of specialised types, and the tall "sirkanda" or "munj" grass. Being small and partially fixed by plants, they are here not the formidable enemy of cultivation that they are in Marwar. These sandy tracts support large but widely separated villages dependent on a single monsoon harvest of "bajra" (bullrush millet - *Pennisetum typhoideum*) and pulses such as "mung" (*Phaseolus mungo*) and "moth" (*Phaseolus aconitifolius*); underground water is usually at too great a depth to enable irrigated crops to be grown in the dry season and the soil is too poor and too porous for unirrigated crops. Large flocks are kept, as the village tracts are large and as there is much unculturable land growing coarse grass and shrubs suitable for pasturage.

I have elsewhere[1] described the accumulations of sand and loam on the western sides of rocky ridges, heaped up by the strong hot-weather wind which blows steadily from the west when the land is at its driest and barest of vegetation. Other things being equal, the greater the length of unobstructed plain blown over, the greater should the accumulation be when an obstacle is encountered. This is exemplified by the enormous masses piled up against the western-most ridge of the Shekhawati hills (Pl. 24), in which may be noted also the deep watercourses cut by short spells of torrential rain, and the characteristic longitudinal ravine running parallel to the rock ridge and excavated by the concentrated drainage flowing off it. In some cases, where a break in the crest of the barrier allows of it, the sand is carried over and deposited as a fan or tongue on the lee side. Pl. 25 shows one of these close to Khetri, where the spit of sand is prevented from advancing across the valley by the stream which truncates its tip every rainy season.

On a lesser scale, a similar accumulation is met with on the lee, or eastern side, of the larger river-courses. Their beds contain no water except for a day or two in the year, when heavy floods bring down great quantities of detritus. This remains in the stream-bed, loose and unbound by vegetation, until the steady west wind of the hot season starts, when it is carried out of the channel and forms a belt of sandhills on the eastern or leeward bank.

## ECONOMIC RESULTS.

Barring the copper and garnet mines the region is devoid of mineral wealth either actual or potential, for every show of a mineral known to them as an ore has been prospected by the inhabitants, and the country is in general so bare that nothing familiar to them can have escaped. In such circumstances it is only rarer minerals and those which the metal workers of a century or two ago did not use which can have remained undiscovered, such as samarskite,

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, p. 102.

scheelite, wolfram, chromite, etc. Having always in mind the possibility of finding such as these, I particularly searched the pegmatites and quartz veins, without success.

I give particulars of all occurrences of economic minerals so far as known ; most of them are of no importance, being merely unsuccessful prospects or the sites of extinct activity. In the days before imported iron and copper, when the Khetri and Singhana mines were supplying much of India with copper, and when every important village in the Torawati and Shekhawati hills had its local iron-forge to supply the less fortunately situated plainsmen with swords and ploughshares, as well as for its own needs, a knowledge of simple mineralogy and metallurgy, now quite extinct, must have been fairly widely disseminated. Metals doubtless had then a higher value measured against other local products, such as grain and live-stock, than they have at the present day, and deposits could then be worked which now cannot be. To greater profits in working and greater knowledge and interest among the people is due the activity in prospecting which these occurrences bear witness to, an activity which is surprising when it is considered how valueless most of them are according to present day standards.

## Copper.

**Gaonri.**

Traces of copper were seen in the detached hill one mile N. E. of Gaonri (27°42′, 75° 53′) where a small shaft had been sunk, and in a shallow open working at Khora 5 miles S. W. of Gaonri.

**Mokata.**

According to Bose copper occurs at Mokata (27°19′, 76°8′) in Narnaul, and 3 miles W.N.W. of Mokata, near Gohora, I saw some traces of copper, and in a well being dug, the schists excavated contained abundant iron pyrites lining cavities.

**Beleshwer.**

The Beleshwer copper and copper sulphate mines are situated halfway between Gaonri and Raipur, near a noted temple of that name, and are ten or twelve small deep circular pits, most of which have fallen in, along a band of hard black quartzose schists about the junction of the Alwars and Ajabgarhs. The Daribo mines in Alwar are similarly situated stratigraphically.

There are large slag-heaps and a group of ruined huts about the mines, but there is no local tradition of their having been worked and very few fragments of green-stained ore are lying about. In the same bed, or a closely adjoining one, are large garnets, brown and quite opaque, but which are locally said to have been worked.

Singhana, Khetri and Babai.

The Khetri and Babai mines are owned by the Khetri State, of Singhana half belongs to Khetri and the other half is divided among the numerous Bhumias and Rajas of Shekhawati. A full description of these, and of the methods of extracting copper, copper and iron sulphates, and alum is given in the Manual of the Geology of India, Part III, Economic Geology, by Ball, pp. 260—263, 431, 324—326, largely taken from a paper by Col. Brooke[1], to which I need add little. Copper is not now extracted and was not being worked at the time of Hacket's visit, but there seems to have been a revival of the industry during the reign of Raja Jai Singh of Khetri, about 22 years ago. The reasons given for the stoppage of work are various, *e.g.*, the necessary increase in the depth of the workings, causing the expense of emptying them of water after the rains to be prohibitive, absence of capital on the part of the miners and the discontinuance, on the death of Raja Jai Singh, of financial assistance from the Khetri State in clearing the mines of water; neither exhaustion of ore, competition with imported copper nor scarcity of fuel was mentioned as a reason for stoppage. I saw much ore in the walls and the miners say that beneath the water which partially fills the mines, there is abundance still untouched.

At Singhana about a dozen men, and at Khetri two, were, at the time of my visit, employed in steeping the efflorescence which coats the walls of the mines and fragments of weathered slates, and evaporating the liquor to extract the mixed salts, copper sulphate, alum, and ferrous sulphate. This is sold as "nila-thotha" (copper sulphate, probably the chief ingredient) at Rs. 7 per maund.[2] Formerly copper sulphate and alum were extracted and sold separately at Rs. 14 and Rs. 4 per maund respectively, the mixed sulphate remaining fetching Re. 1. "Kasis" (ferrous sulphate) is also scraped from the walls and exported crude without purification or lixiviation. It fetches Re. 1 per maund. The "kasis" efflorescence is grey, lighter and more powdery than that used for "nila-thotha," which is bluish or greenish, and tends to form in mammillated and stalactitic growths.

[1] *J. A. S. B.*, Vol. XXXIII, p. 519.
[2] These are pre-war prices.

The Babai mines have long been disused as far as copper is concerned, but "sehta" (cobaltite and danaite)[1] was worked for colouring enamels until about 1908, when it was displaced in the favour of the Jaipur enamellers by a dearer but purer imported substance containing cobalt. "Seypoorite" or "Jaipurite"[2] sulphide of cobalt, Mallet seems to consider does not exist. "Sehta" consists of minute silvery crystals sparsely scattered through the same black slates which contain the copper ore, a good deal of which occurs with the "sehta." The slates are ground in ordinary hand-mills and the powder washed; the heavy concentrate is sold at Rs. 10 per seer.

The mines (of copper and "sehta") are in the upper part of the slate and schist zone lying below the quartzite on which Khetri and Bagor forts stand, and are almost continuous from Singhana to Babai, 15 miles; there are said to be some near Paprona also, but these I could not find. A few pits occur elsewhere than in this belt but would seem to be little more than prospecting shafts.

The workings are quite irregular, commencing as narrow inclines, widening out into large chambers, contracting to narrow burrows, and ramifying as the ore led the miners, but their general direction is with the dip of the slates at a steep angle of 30°—60°.

The ore, copper pyrites with iron pyrites, is in irregular strings, layers and lenticles without any semblance of a true lode; the country rock is mostly black slate (sometimes uncleaved) more or less siliceous and splintery, with indefinite bands of impure quartzite, and amphibolite intrusions.

Owing to the amount of water in the mines, their ruinous condition and the reluctance of the local officials to allow investigation, I was unable to make any proper examination of them, but from what I did see I am of the opinion that the ore is in sufficient quantity to justify a mining company in prospecting the deposits. To drain and reopen the workings would be of course a lengthy and expensive operation, but one offering possibilities of a large, low grade concern. The entrances to the inclines are high on the hill-side, where the black slate outcrops, dipping into the ridge, and it is probable that many of the workings have not gone down as far

[1] Manual of the Geology of India, Pt. III, p. 324; Pt. IV, pp. 27—28.
[2] „ „ „ „ Pt. IV, p. 17.

as the level of the valley floor; adits driven from the base of the ridge would probably offer facilities for the drainage and exploration of the ore-body.

## Iron.

All over the Torawati and Shekhawati hills, near villages and sometimes in the jungle, are heaps of iron slag, the relics of a small but widely distributed industry when most villages had their own iron-furnaces. Few traces of actual mining have been seen, but there are many small ore-bodies the outcrops of which probably supplied enough material without excavation.

**Raipur.**

In the Ajabgarhs between Raipur and Jainthpura (Jaitpura) are bands of micaceous hematite-schist, quartz veins with hematite crystals and irregular hematite masses in the limestones (metasomatic replacements?). 1¼ mile W. of Raipur, are two vertical beds of massive hematite (or a single bed faulted), varying from 5 yards to 1 yard thick, in mica schists, and traceable for over two miles along the strike; they are rather irregular, dying out and reappearing again several times and breaking up into thinner bands, but seem to be fairly free from visible impurities. (Reg. No. 26·864).

S. and S. E. of Raipur are numerous similar masses, but smaller, and also quartz-veins containing much hematite in crystals. (Reg. No. 26·863).

Among the hills between Teonda and Maonda there are many lenticular bodies of massive hematite, none of them large, and falling short of economic importance.

**Ragonathgarh.**

The iron-mine at Ragonathgarh is in brecciated ferruginous quartzites and is quite useless economically.

## Quartz, rock-crystal, "Bilor."

**Dosa.**

Where the Agra-Ajmere road crosses the low ridge of Aravallis 1 mile N. E. of Dosa, are a number of very thick white quartz veins, the outcrops of which are chipped and the pieces sent to Agra to be used for glass for bangle-making.

The crystal quarry at Nawai is long disused. It is a fissure in the quartzites lined with well crystallised quartz. All I saw was quite milky, but in crystals up to 3 inches long and 1 inch in diameter.

Nawai.

The rock-crystal mine at Hathuna, 9 miles N.E. of Tonk, is a deep shaft sunk in the Aravalli quartzites. No quartz nor even fragments of pegmatite was seen near the pit, and there is only a tradition that "bilor" was once quarried there.

Hathuna.

## Mica, "Bhodal."

An occurrence of muscovite at Kacherda (Katrera or Kacharara), east of Raipur, is trifling and useless.

Kacherda.

That of Kaisar (marked on the 1 inch map as "Mandar," in a gorge 2½ miles west of Patan) is the best seen in Jaipur. It is a large pegmatite vein, which at this point is rich in muscovite, but elsewhere carries tourmaline and little muscovite. The plates are as large as 6 inches by 3 inches, but are nearly all cracked and break easily (Reg. No. 26·867). It has been prospected to some extent and large piles of fragments lie about.

Kaisar.

The next best mica was seen immediately east of Sialdro or Sarodhara (27°52′, 76°2′) in Narnaul, in plates up to 2½ inches by 1 inch, and in large quantity. It also has been worked.

Sialdro.

Two other instances of muscovite mined to a trifling extent for purely local uses are at Nasirda, 5 miles N.W. of Rajmahal, and Charund, 6 miles E.N.E. of Tonk, both in pegmatite intrusive in the Aravallis. The largest pieces seen were about 1 inch by 2 inches and quite clear.

Nasirda and Charund.

The chief local uses of mica are as ornamental discs sewn on women's clothes, as a decoration on pottery, and, mixed with red powder, to throw about during the Holi festival.

## Garnets.

The old garnet mines are at Toda Rai Singh and a number of villages south and west of Rajmahal—Gaonri, Saroi, Kundero, Dudas, Khera, Khusialpura and Nasirda. They have long been closed by the Maharajah's order and a guard of State troops is posted continuously

Toda Rai Singh and Rajmahal.

to prevent anyone from examining them. They are really alluvial workings, small pits dug in the soil lying in hollows on the surface of the Aravalli schists and in stream-beds, where the garnets weathered out of the schists collect naturally. They were disused at the time of Hacket's visit but have since been worked for a short period by a Mr. Tellery who was for some time manager of the Jaipur gasworks. The stones were exported, I believe, to Austria. The "real Jaipur garnets" so extensively sold to tourists by the Jaipur jewellers probably come from localities in Ajmere and Kishangarh. The sand of the Banas River and its tributaries is highly garnetiferous.

Other localities in the north of the State where garnets are said to have been worked in the past are Beleshwer (*see* copper), north of Babai and near Paprona.[1]

A garnet mine reported at Rondil, was probably amethyst.[2] This was opened about 1885, but the amethysts were small and inferior. I was unable to find this mine.

## Beryl, "Beruj."

**Toda Rai Singh.**

A mile south of Toda Rai Singh, in the pegmatite veins which here profusely inject the schistose conglomerates at the base of the Alwar Series, are several excavations in which beryl was worked. Many years ago, they were stopped and filled up by order of the Maharaja. The crystals of beryl occur scattered irregularly through the whole width of the pegmatite veins and are usually of a pale green colour, opaque and excessively cracked. Between this and Tonk,[3] pieces of beryl are frequently picked up, and it is a very common mineral in the pegmatites north of Ajmere City, in the latter case being usually honey-yellow and opaque; the pale blue variety (aquamarine) is rarer. I have never seen any worth cutting as a gem, nor have I heard of any such being found in recent years.

**Ninjar.**

At Ninjar (27° 26′, 76° 3′) there is said to be a "panna" mine, closed by the State many years ago. I enquired at the village but the existence of any such thing was emphatically denied by the patel and patwari

[1] Manual of the Geology of India, Pt. IV, p. 89.
[2] " " " " Pt. IV, p. 67.
[3] " " " " Pt. IV, pp. 53 and 86.

As I heard of it from several unconnected sources, in other villages, I have no doubt that some green stone has been worked here. "Panna" is the Hindustani name for emerald.

In this connection some stones sold by the Jaipur jewellers, cut into smooth ovoid beads, may be mentioned. They are translucent, slightly clouded quartzite of two shades of green, spangled with small scales of silvery mica. The paler kind is said to come from Khandela and is sold as "beryl," the dark shade, alleged to be from near Ajmere, is known in the trade as "jade." A pink stone called "pink topaz," the jewellers told me, was the "beryl" artificially coloured. (Green and pink stones exactly like these are sold in Kashmir as beryl.)

The colour in the green stone is not homogeneous and is completely discharged on strong heating, leaving the quartzite white, crumbling and porous. On soaking in coloured ink, a certain amount of the dye was absorbed by minute cracks, so that it is possible that even the green colour is artificially introduced.

## Steatite.

**Nawai.**

There is an unimportant occurrence of steatite in a layer in Aravalli schist at the south end of Nawai hill. It is contaminated by cellular ferruginous silica, and is schistose and unsuitable for carving.

## Kaolin.

**Buchara.**

The kaolin mine of Buchara is in pegmatites just above the village. There are two excavations, running 30 to 40 feet into the hill and about 10 feet in diameter. It is worked by the village potters and the method of washing the kaolin is the same as that followed at Kasumpur, near Delhi.[1]

## Marble.

**Baislana and Maonda.**

The Baislana (27° 39′, 76° 9′) quarries are in crystalline Ajabgarh limestones, dark grey, or banded light and dark grey, lying in low undulating folds with minor contortions and puckerings. The stone is hard and homogeneous, of pleasing colour and takes carving well. It

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, p. 124.

is in extensive local demand for images, millstones, mortars, door-lintels, etc., as well as for ordinary masonry and lime-burning. There is a little white marble at Maonda.

## Lime.

The usual source of lime is concretionary carbonate of lime, "kankar," which is found almost everywhere a little distance below the surface of the alluvium, but many of the limestone bands are quarried in a small way for burning. At Raori (26° 57′, 76° 2′) is a large excavation in a trap-veined limestone which is said to produce a specially good lime.

## Building Stone.

All over the State there are numerous small quarries, usually in the more flaggy and micaceous beds of the Aravallis and Alwars, and these supply the villages in their neighbourhood with their limited requirements in the way of building stone.

A few have a wider market, either on account of their being on the railway or because of some superiority in their product. Of these I have described the Raialo marble quarries in my Memoir on North-Eastern Rajputana[1], and those of Baislana I have mentioned above.

**Bankri and Kalaotha.**

The flagstone quarries of Bankri (Bhan Kari Railway Station) and Kalaotha, on the railway line from Jaipur to Agra, produce a rough, hard, strong stone, unsuitable for ornamental work, but cheap and well suited for purely utilitarian structures. "Pattis," prismatic monoliths for beams, lintels and jambs, I have seen up to 25 feet long, and "katlas," paving and roofing flagstones, up to 4 feet square.

**Jasrapura.**

Similar stones are got from the quarries of Jasrapura (28° 2′, 75° 46′).

**Ragonathgarh.**

When I visited Ragonathgarh, before the branch railway which now passes near it was constructed, there was a considerable local industry in quarrying and carving this excellent stone, and it was exported by camel all over Shekhawati and Bikaner, and even to the Punjab. The railway should give it a more extended market, for it is a white, fine-grained

[1] *Mem., Geol. Surv. Ind.*, Vol. XLV, pp. 26—28.

freestone and can be extracted in very large thick slabs. South west of Ragonathgarh, as far as Lorero, are numerous quarries of inferior stone.

## EXPLANATION OF PLATES.

PLATE 22.—Lalgarh conglomerate.

PLATE 23.—FIGS. 1 AND 2.—Topography of Ajabgarh schists and quartzites, near Khetri.

PLATE 24.—Sandhills on west of range, near Khetri.

PLATE 25.—Panorama of Khetri.

PLATE 26.—Sections across geological maps.

PLATE 27.—Geological map of Western Jaipur, northern section: scale 1″=4 miles.

PLATE 28.—Geological map of Western Jaipur, southern section: scale 1″=4.

## LOCALITY INDEX.

| — | Latitude. | | Longitude. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| Atchraol | 27 | 8 | 76 | 1 |
| Ahirwala | 27 | 37 | 75 | 54 |
| Ajitgarh | 27 | 25 | 75 | 53 |
| Ajmiri | 27 | 30 | 75 | 58 |
| Asilpur | 26 | 56 | 75 | 29 |
| Awan | 25 | 48 | 75 | 40 |
| Babai | 27 | 53 | 75 | 49 |
| Bagri | 26 | 27 | 76 | 26 |
| Baislana | 27 | 39 | 76 | 9 |
| Banskho | 26 | 50 | 76 | 12 |
| Baonli | 26 | 20 | 76 | 17 |
| Barha | 27 | 16 | 75 | 55 |
| Baroda | 27 | 20 | 76 | 6 |
| Basi | 26 | 50 | 76 | 6 |
| Bechun | 26 | 49 | 75 | 25 |
| Bhagwantgarh | 26 | 9 | 76 | 18 |
| Biharipur | 27 | 53 | 75 | 57 |
| Buchara | 27 | 33 | 76 | 2 |
| Chandsain | 26 | 19 | 75 | 30 |
| Chapoli | 27 | 44 | 75 | 38 |
| Chatsu | 26 | 36 | 76 | 0 |

| —— | Latitude | | Longitude. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| Chauth (Chout) ka Barwara . . . . . . | 26 | 3 | 76 | 12 |
| Chinchroli . . . . . . . . . | 27 | 50 | 75 | 48 |
| Chiplata . . . . . . . . . | 27 | 34 | 75 | 53 |
| Dadeha (near Jatwara) . . . . . . . | 26 | 52 | 76 | 12 |
| Dariba . . . . . . . . . | 27 | 40 | 75 | 57 |
| Dantal . . . . . . . . . | 27 | 40 | 76 | 4 |
| Dhule . . . . . . . . . | 26 | 56 | 76 | 12 |
| Dausa . . . . . . . . . | 26 | 54 | 76 | 24 |
| Duni . . . . . . . . . . | 25 | 52 | 75 | 35 |
| Ganor . . . . . . . . . . | 26 | 22 | 75 | 23 |
| Gaonri . . . . . . . . . | 27 | 42 | 75 | 53 |
| Gar . . . . . . . . . . | 26 | 52 | 75 | 44 |
| Gori . . . . . . . . . . | 28 | 2 | 76 | 1 |
| Gudha . . . . . . . . . | 27 | 53 | 75 | 36 |
| Isarda . . . . . . . . . | 26 | 10 | 76 | 5 |
| Jainthpura (Jaitpura) . . . . . . . | 27 | 39 | 76 | 0 |
| Jaipur City . . . . . . . . . | 26 | 56 | 75 | 53 |
| Jusrapura . . . . . . . . . | 28 | 2 | 75 | 46 |
| Kakor . . . . . . . . . | 26 | 1 | 75 | 59 |
| Kalaotha . . . . . . . . . | 26 | 58 | 76 | 29 |
| Karela . . . . . . . . . | 26 | 17 | 75 | 33 |
| Khandela . . . . . . . . . | 27 | 36 | 75 | 33 |

| — | Latitude. | | Longitude. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| Khetri . . . . . . . . | 28 | 0 | 75 | 51 |
| Kot . . . . . . . . . | 27 | 40 | 75 | 29 |
| Lalgarh . . . . . . . . | 26 | 47 | 76 | 9 |
| Manoharpur . . . . . . . | 27 | 18 | 76 | 1 |
| Maonda . . . . . . . . | 27 | 49 | 75 | 52 |
| Mokata . . . . . . . . | 27 | 49 | 76 | 8 |
| Morijo . . . . . . . . | 27 | 10 | 75 | 49 |
| Mundeta . . . . . . . . | 27 | 1 | 75 | 38 |
| Nawai . . . . . . . . | 26 | 22 | 75 | 59 |
| Nimi . . . . . . . . . | 27 | 4 | 76 | 5 |
| Ninjar . . . . . . . . | 27 | 26 | 76 | 3 |
| Paprona . . . . . . . . | 27 | 56 | 75 | 51 |
| Patan . . . . . . . . . | 27 | 48 | 76 | 2 |
| Ponk-Gurha . . . . . . . | 27 | 50 | 75 | 41 |
| Ragonathgarh . . . . . . . | 27 | 40 | 75 | 24 |
| Raipur . . . . . . . . | 27 | 44 | 76 | 1 |
| Rajmahal . . . . . . . . | 25 | 53 | 75 | 32 |
| Ramgarh . . . . . . . . | 27 | 1 | 76 | 4 |
| Renwal . . . . . . . . | 26 | 42 | 75 | 43 |
| Rondil . . . . . . . . | 27 | 14 | 75 | 56 |
| Salaidipura . . . . . . . . | 27 | 39 | 75 | 35 |
| Samod . . . . . . . . | 27 | 12 | 75 | 52 |

| — | Latitude. | | Longitude. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| Sangrua . . . . . . . . | 27 | 35 | 75 | 22 |
| Sarsop . . . . . . . . | 26 | 11 | 76 | 7 |
| Sialdro (Sarodhara) . . . . . . | 27 | 52 | 76 | 2 |
| Singhana . . . . . . . . | 28 | 6 | 75 | 54 |
| Teonda . . . . . . . . | 27 | 58 | 75 | 56 |
| Toda (Rai Singh) . . . . . . | 26 | 2 | 75 | 33 |
| Toda (Torawati) . . . . . . . | 27 | 38 | 75 | 59 |
| Tonk . . . . . . . . . | 26 | 10 | 76 | 51 |
| Tori . . . . . . . . . | 26 | 13 | 75 | 29 |
| Udepur . | 27 | 44 | 75 | 32 |

# GEOLOGICAL TRAVERSES FROM ASSAM TO MYITKYINA, THROUGH THE HUKONG VALLEY; MYITKYINA TO NORTHERN PUTAO; AND MYITKYINA TO THE CHINESE FRONTIER.

BY MURRAY STUART, D.SC. (BIRM.), F.G.S., *late Assistant Superintendent, Geological Survey of India.* (With Plate 29.)

## I.—INTRODUCTION.

THE area covered by this report is that lying between longitude 96° E. and the Chinese frontier, and between latitudes 25° N. and 28° N. In the north-west of the area the inhabitants are Mishmis, Singphos, and Nagas. The Singphos occupy the low flat land and practise wet cultivation. The Nagas are an exceedingly primitive people; they live in the mountainous area and practise hill-side cultivation. The Mishmi country was not visited by me but the people are similar in habits to the Nagas. In the north-east of the area and down to about latitude 27°30′, the inhabitants of the country are Nungs. South of the Nung country is a region inhabited by the warlike Lisus, and south of this is the Htawgaw Hill Tract inhabited by Lisus, Lushais, Marus, Chinese Shans, and Kachins.

The Putao plain is occupied by an isolated colony of Shans, a few representatives of which are to be found within the Assam border, having been expelled from the Putao plain in past inter-village wars. Between the Naga Hills on the west and the various tribes mentioned above as inhabiting the eastern side of the area, is a vast tract of country peopled almost entirely by Kachins.

The central portion of the tract consisting of the Naga Hills, the Hukong Valley, and what is known as the "Triangle"—the country lying between the Mali Hka and the 'Nmai Hka—is all unadministered, and almost unexplored, country.

In November 1920 I was deputed to accompany the Hukong Valley Railway Survey on an exploratory trip through the Hukong Valley from Ledo in Assam to Mogaung in the Myitkyina district of Upper Burma. While on this expedition I received orders to proceed from Myitkyina to the Chinese border to investigate some galena deposits there. In this way I made a geological traverse from Ledo in Assam, through Myitkyina to China. In 1917-18 I made a geological traverse from Myitkyina to Putao through much of the Nung country.[1] These traverses, together with what was already known from geological surveys by F. Noetling, C. L. Griesbach, J. M. Maclaren, A. W. G. Bleeck, and J. Coggin Brown, are sufficient to enable me to describe approximately the geological structure of the North-East Frontier; they are especially interesting in that they confirm former theories regarding the ancient distributions of land and water, and the ancient river systems of the north-east corner of the Indian Empire.

**General Geography and Climate.**

Neglecting the Brahmaputra valley in the north-west of the area and the Irrawaddy valley south of Myitkyina, the general geography is that of a large alluvial plain surrounded on all sides by mountains, highest and most rugged towards the Tibetan and Chinese borders, and lowest to the south. In addition to the Hukong Valley, there is a second smaller alluvial plain surrounding Fort Hertz, the headquarters of the Putao district, also completely shut in by mountains. Its ancient name, Hkampti Long, is now rapidly falling into disuse in favour of the more modern designation, the Putao plain. Geographically the area can be divided into two portions, western and eastern. The western portion consists of the Hukong valley surrounded by mountain ranges which follow a more or less elliptical course around its borders, with rivers and streams that meander about the valley following no one definite direction; the eastern portion consists of high mountains and steep narrow valleys, containing the great rivers Mali Hka, 'Nmai Hka (Irrawaddy

[1] "The Galena deposits of North-Eastern Putao," *Rec. Geol. Surv. Ind.*, Vol. L. pp.241-254, (1919).

proper), and Salween, all of which run approximately from north to south.

The climate of the area can also be divided into two kinds, that of the northern portion, or the portion lying north of latitude 26°40′, and that of the portion lying south of it. The climate of the northern portion is one of wet mists and rain. A period of almost daily rain commences in February and continues until June, when the downfall becomes much heavier with the advent of the ordinary south-west monsoon. This continues usually until well into September. For the rest of the year a heavy wet mist envelopes the country each night, and remains filling the valleys until it is dissipated by the sun at about nine or ten o'clock in the mornings. The natural consequence of this is that the country is covered with dense forests with thick luxuriant undergrowth. So thick is this undergrowth as a rule, that progress across country can only be made by cutting a path, and the rate of progress is limited to a few miles a day. The climate of the southern portion is less humid. Rainfall during the period February to June is generally restricted to occasional showers and storms, and, speaking generally, the Rains do not break until the commencement of the south-west Monsoon in June. There is of course no hard and fast line between these two climatic areas, but latitude 26°40′ is the approximate dividing line between the two.

In the wet northern zone leeches abound and form one of the most vivid memories of a trip through the area. Except high on the mountains the area is unhealthy, malaria being prevalent, and in places, especially towards the north-east, black-water fever is common.

Roads are few and far between throughout the area. There is a badly kept mule track through the Hukong valley, more or less impassable during rain. A district road is being constructed from Mogaung to Kamaing, whence there is a good road to the Jade mines. A good mule road exists from Myitkyina to Fort Hertz, another from Myitkyina to Forts Htawgaw and Hpimaw, though all of these are closed during the rains. In addition there are numerous good mule tracks through the Nung country and through the Htawgaw Hill Tract. A motor road is being constructed from Myitkyina to Fort Htawgaw, but it will be many years before it is completed.

## II.—GEOLOGICAL TRAVERSE FROM ASSAM, THROUGH THE HUKONG VALLEY, TO MYITKYINA IN BURMA.

The route of the traverse is along the proposed railway track from Namchik, near Ledo, in Assam, over the Patkai range, which is the watershed between Assam and Burma, along the valley of the Loglai river to its junction with the Taron, thence down the Taron approximately to its junction with the Tanai Hka (Upper Chindwin river); from that point the traverse follows the main trade route through the centre of the Hukong valley and down the Mogaung Chaung to Mogaung Railway Station (Burma Railways). Certain areas on or adjoining the route traversed have already been surveyed and reported on. The principal publications which I would refer to are:—

La Touche, T. D. . Geology of the Upper Dehing Basin in the Singpho Hills, *Rec. Geol. Surv. Ind.*, Vol. XIX, pp. 111-115, (1886).

Noetling, F. . . Jadeite in Upper Burma, and Burmite a new fossil-resin from Upper Burma, *Rec. Geol. Surv., Ind.*, Vol. XXVI, pp. 26-31, and 31-40, (1893).

Maclaren, J. M. . Geology of Upper Assam, *Rec. Geol. Surv. Ind.*, Vol. XXXI, pp. 179-204, (1904).

Bleeck, A. W. G. . Jadeite in the Kachin Hills, Upper Burma, *Rec. Geol. Surv. Ind.*, Vol. XXXVI, pp. 254-285, (1908).

Hayden, H. H. . Coal Fields in North-East Assam, *Rec. Geol. Surv. Ind.*, Vol. XL, pp. 283-319, (1910).

Oldham, R. D. . Report on the Geology of parts of Manipur and the Naga Hills, *Mem. Geol. Surv. Ind.*, Vol. XIX, pp. 217-242, (1883).

Pascoe, E. H. . . Petroleum Occurrences of Assam and Bengal, *Mem. Geol. Surv. Ind.*, Vol, XL, p. 270, (1914).

,, ,, . . Coal in the Namchik valley, Upper Assam, *Rec. Geol. Surv. Ind.*, Vol. XLI, p. 214, (1912).

The above is not intended to be an exhaustive list of all the publications containing references to portions of this area. Earlier references are given in the various reports and the results have been incorporated in the papers enumerated above.

Leaving the boundary of Maclaren's Carbonaceous series near Namphuk village, the route lay approximately south across the hills of Tipam sandstone and down again into the valley of the Nam Phuk. Here grey slaty sandstones and slaty arenaceous shales were met with, dipping at about 45° upstream, and apparently covered unconformably by the Tipam sandstones. The age of these slaty sandstones and shales is obscure. No fossils were found in them, but from their striking resemblance to similar rocks on the other side of the Patkai range, which I correlate with Mallet and Hayden's Disang series, there seems no alternative but to class them with the Disang series.

Near Nam Bong these Disang rocks are again covered by the sandstones of the Tipam series, which constitute the Patkai range and extend across the range to the Dugung river, where again the underlying Disang rocks are exposed. The structure of the Patkai range is that of a broad syncline, the axis of the syncline being approximately coincident with the crest of the range. From the Dugung river slaty shales and sandstones of the Disang series are exposed all down the valley of the Loglai river to its junction with the Taron, and thence down the valley of the Taron as far as the Gedu river, the strike of the slaty cleavage being almost universally parallel to the axis of the Patkai range and the dip generally at a high angle towards the range. From the splintery nature of the shales, and their general characteristics, and from the fact that about four miles below the Dugung river they contain a bed of distinctly carbonaceous shale and in places salt licks, the similarity between these rocks and Hayden's Disang series seems to be complete.[1] Near the bed of carbonaceous shale I discovered a few poorly preserved Lamellibranchs which do not admit of identification (K. 21,200).[2]

A point of interest about these rocks is that in the neighbourhood of the Namyung river, and between that and the Ta-ap river, and also in the Gedu river, serpentine intrusions occur in them, similar to the occurrences mentioned by Mr. R. D. Oldham (*Mem. Geol. Surv.*

[1] Edit. Carbonaceous shales are more typical of the "Coal Measures"; salt licks are also characteristic of this series.

[2] The numbers in brackets refer to the registered numbers of the specimens in the collections of the Geological Survey of India.

*Ind.*, Vol. XIX, p. 224) and Dr. Pascoe (*Rec. Geol. Surv. Ind.*, Vol. XLII, p. 251). The Disangs of the Nam Phuk, Loglai, and Taron are practically free from quartz veins, but in the neighbourhood of the Ta-ap serpentine intrusions they show signs of metamorphism and are in places converted into what might almost be called mica-schists.

I obtained no direct evidence whatever to enable me to form an opinion as to the age of the Disang series and have therefore no option but to accept the present view that they are probably the equivalents of part of the Negrais rocks of the Arakan Yoma. The discovery of the ammonite found by Noetling in a pebble[1] strengthens this view since the only formation from which that pebble could have come would appear to be the Disang series. The age of the serpentine intrusions when established will help to fix the age of the Disangs. The youngest rocks that I know of at present that are traversed by serpentine intrusions are the coal-bearing sandstones of Henzada, which I correlated provisionally with the Laki stage.[2] The evidence provided by Noetling's ammonite, the poorly preserved ammonite found by Hayden *in situ*[3] and the serpentine intrusions, seems to support the view that these rocks are in part at least Cretaceous and equivalent to some of the Negrais rocks. It is the view held by Hayden and is supported by all the evidence I have been able to obtain.

South of the Gedu river the Tipam sandstones again overlie the Disangs, and dip S. S. E. at 25°. The junction with the Disangs is an unconformable one and the basal beds of the sandstone series are conglomeratic, containing pebbles and fragments of both the Disang rocks and the serpentine. Southwards, down the Taron river, the dip of the sandstones becomes steeper, until in the Taron gorge, commencing at the Siluk confluence, the beds are dipping at 45°, the northern bank of the gorge being formed by the dip slope of the rocks, and the southern side by the scarp face. The course of the river here is determined by the strike of the rocks, the mountain range which forms the southern side of the gorge being apparently formed by beds of Tipam sandstone that are slightly harder than usual and consequently form a marked geographical feature

[1] *Loc. cit.*, p. 34.
[2] *Rec. Geol. Surv. Ind.*, Vol. XLI, p. 250, (1912).
[3] *Loc. cit.*, p. 288.

This portion of the area is quite unsurveyed and the topographical maps of this vicinity available at the time of my traverse were merely the result of guess work and unfortunately give no idea of the actual topography. Below the gorge and down to Ṣiraw the dip gradually flattens, and the Hukong valley is situated in a broad flat basin of Tipam sandstones. The centre of the valley is covered by a broad flat sheet of recent alluvium. A few miles S.S.W. of Maingkwan a low range of hills crops out from under the alluvium. It is on these hills that the famous amber mines are situated. The eastern flank of the hills consists of grits and conglomerates belonging to the basal beds of the Tipam series; these are dipping at a low angle towards the east.

Underneath them on the western portion of the hills is a blue clay weathering to a dull brown colour at the surface. This blue clay is the true home of the amber, which is found in the form of irregular lumps in the clay. No mines were actually being worked when I visited the hills, but the whole outcrop of the clay seems to have been dug over at one time or another; the principal localities are at the north end of the range where work is done nowadays, and at the southern end of the range, near Lalaung, which used to be the chief mining centre. No dips were visible in the clay when I visited the hills, but Noetling records a dip of 88° towards the west. Just below the base of the Tipam basal conglomerate numerous pits had been sunk in the clays for flint, which occurs as nodules in a thin chalky limestone. This limestone was nowhere exposed, but much of the débris around the pits contained fragments of it and amongst these fragments I discovered one containing numerous specimens of *Nummulites biarritzensis*, d'Arch., which is a characteristic fossil of the uppermost beds of the Lower Kirthars. This was not found *in situ*, but the improbability of its having come from anywhere but the chalky limestone of the pit is so great that I have no hesitation in accepting it as evidence of age of the lowest exposed beds of the clay. There is further evidence in support of this view that the clays are Eocene. Dr. F. A. Bather of the British Museum after examining some insect-containing amber collected by Mr. R. C. J. Swinhoe of Mandalay, concluded that there is reason to believe that the insects are Eocene and possibly lower Eocene. The fossil evidence, such as it is, assigns the clays to the top of the lower Kirthars, a conclusion in close agreement with the age deduced by Dr. Bather from a preliminary study of the insects in the amber.

At the southern end of the Hukong valley proper and between it and the Kamaing sub-division of the Myitkyina district, Tipam sandstones again crop out from under the alluvium, being buried along the neighbourhood of the main trade route by a covering of sandy laterite. From there onwards to Mogaung, the geology, wherever I saw it, agreed with Noetling's published map. As the geology of the Jade Mines area had been thoroughly worked out by Dr. Bleeck, I gave up the idea of visiting it.

## III.—GEOLOGICAL TRAVERSE FROM MYITKYINA TO NORTHERN PUTAO.

This traverse was made by me in 1917-18, and the portion of it situated north of latitude 27° has already been described [*Rec. Geol. Surv. Ind.*, Vol. L, pages 241-245, (1919).] It is now of interest to publish an account of the remainder of the traverse, namely, the portion from Myitkyina to Lat. 27°, because it indicates the extent and eastern boundary of the Tipam sandstone area.

Proceeding northwards from Myitkyina the Putao road lies first on river alluvium as far as Sa-kap, where slates, phyllites and quartzites of the Metamorphic Series are encountered. Just north of the Pungin Hka these metamorphic rocks are pierced by an intrusion of serpentine. In the neighbourhood of Nsop Hka they contain 'calc-gneisses,' and from there onwards the road passes over slates and phyllites as far as the 54th mile, where Tipam sandstones, dipping gently to the W.N.W., are encountered. From this point as far as the Putao plain the road follows roughly the boundary of the Tipam sandstones with the older rocks. The general dip of the sandstones is towards the west, and they can be seen forming one low ridge after another, all dipping gently towards the Kumon range. In character they are exactly similar to the Tipam sandstones met with in the previously described traverse through the Hukong valley. Along the Putao road they contain occasional thin bands of blue clay, which is frequently full of leaf impressions; in places the sandstones themselves show leaf impressions. As in the Naga hills and the Hukong valley, the sandstones are conglomeratic at their base, and contain in their lowest beds fragments and pebbles derived locally from the rocks on which they are unconformably superimposed. This is particularly noticeable north of Lat. 26°30′ where the basal beds are thick coarse conglomerates containing pebbles of the syenite-gneiss, which is there intrusive into the underlying metamorphic series. Moreover, for some distance above the basal conglomerate the sandstones are full of kaolin due to the decomposition of the felspar derived from the underlying gneiss. For a description of the rest of the traverse the reader is referred to the published report, already quoted, on the galena occurrences of north-eastern Putao.

## IV.—GEOLOGICAL TRAVERSES ALONG THE CHINESE FRONTIER IN NORTH-EASTERN MYITKYINA.

These traverses were made during a visit paid in 1921 to the galena mines situated on the Shweli-Nmai Hka divide between the Fenshuiling and Lagwi passes. The route followed lay first through Wasang and Seneku to the 'Nmai Hka, then along the left bank of the 'Nmai Hka to the Chipwi Hka and finally along the military mule track to Fort Htawgaw. Thence I made three traverses, one through Fort Hpimaw and Chueh-ho to the Fenshuiling pass, one to the galena mines *viâ* the Lagwi pass, and one along the Ngawchang Hka to its confluence with the 'Nmai Hka.

From Waingmaw, opposite Myitkyina, to Wasang the road passes over recent alluvium. At Wasang the basic trap, mapped by Griesbach, crops out in the river bed, and thence to Seneku the rocks are Metamorphics with much intrusive granite-gneiss and basic trap. From Seneku to Chipwi Hka the rocks are practically all intrusive granite-gneiss. Here and there, small areas of the Metamorphic series are included in the main granite-gneiss intrusion, but these are neither frequent nor big enough to show on a map of the scale of that published with this report. From Chipwi Hka to the Hpyepat valley the same intrusive granite-gneiss is seen, while in the Hpyepat valley itself finely crystalline white and bluish white limestones are met with, running in a northerly direction and dipping almost vertically. The same crystalline limestones are seen again in the Ngawchang valley at the mouth of the Wuniaw Hka, and forming the central core of the range west of Kabap. This strip of crystalline limestone is included in the great granite-gneiss intrusion and along its edges the limestone is penetrated by numerous veins of granite, making it impossible to map a definite boundary between the two rock series. The eastern boundary of the crystalline limestone area is found near Langyang and from this point to Hpimaw village and also to the foot of the final steep ascent up the Lagwi pass, the routes pass over the intrusive granite-gneiss. The route along the Ngawchang valley follows the boundary of the crystalline limestone area, metamorphosed sediments traversed by veins of granite occupying the west bank and the main granite-gneiss intrusion the right bank. At the confluence of the Ngawchang Hka with the 'Nmai Hka the rocks are massive granites slightly foliated.

From Hpimaw a band of sedimentary rocks consisting of limestones and shales stretches in a southerly direction to the Fenshuiling pass, the pass itself being a low col in the frontier range formed by the denudation of a band of soft red shales. Near Hpimaw yellow shales are met with as far as Chueh-ho, where red earthy crinoidal limestone is exposed on the road below the district hut. This limestone appears to be identical with that described by Dr. Coggin Brown as occurring in western Yun-nan and ascribed by him to the Ordovician.[1] South of Chueh-ho these red, earthy, crinoidal limestones are associated with greyish white, brecciated limestones which seem to correspond in every way with Dr. Coggin Brown's Devonian. These brecciated limestones stretch away southwards to the neighbourhood of the Fenshuiling pass. The Lagwi pass, on the other hand, is situated on dark grey, fine-grained, siliceous tuff, composed of highly angular quartz fragments surrounded by finer material containing much chlorite. The tuff has obviously undergone alteration, chlorite having developed at the expense of the original dust. Tuffs of this type, with very little variation, extend north-eastwards throughout the core of the frontier mountain range for about three and a half miles to the sharp easterly bend in the frontier, where the Chinese galena mines are situated. Here the tuff, slightly more silicified but otherwise exactly similar to that exposed in the Lagwi pass, is in contact with white crystalline limestones, which I regard as altered Palæozoic limestones similar to those seen near Kamaing in the Hukong valley. At the contact of the limestones and the tuff a band of crystalline zoisite occurs, the mineral showing beautifully developed radiating structure.

A peculiar calcite-mica-magnetite-pegmatite carrying occasional galena, pyrite, and chalcopyrite, also occurs along the contact plane. The frontier range at this point is between 11,000 and 11,500 feet above sea level. The contact zone between the tuff and the

[1] *Mem. Geol. Surv. Ind.*, Vol. XLVII, p. 52, (1920).

crystalline limestone is veined and sparsely impregnated with galena. Veins of slightly cupriferous pyrites frequently 10 feet and more across, also occur, and these occasionally carry subsidiary veinlets of galena.

## V.—ECONOMIC GEOLOGY.

**Amber.**

As already described the amber mines are situated in blue clay, which apparently corresponds to the uppermost part of the lower Kirthar in age. The usual method of working is to sink a shaft into the clays to a depth seldom exceeding forty feet, and then to run lateral galleries in any direction from the bottom of this shaft. The finding of amber is entirely a matter of chance. In some cases numerous finds are made, while in other cases the season's work yields practically nothing. I have nothing to add to Dr. Noetling's description of the pits or method of working.

**Jadeite.**

Jadeite is found west of Kamaing and the mines and geology of the area have been described by Dr. Bleeck. Jadeite also is reported from the serpentine intrusions of the Gedu river in the Naga hills, but no work seems to be done there.

**Galena.**

The galena deposits of north-eastern Putao have already formed the subject of a special report. There remains only the galena deposits of the Shweli-'Nmai Hka divide near the Lagwi pass. Numerous adits have been driven into the hill on both sides of the divide by the local people and galena obtained. They seldom obtain massive ore, but find the mineral disseminated through the country rock. They crush the ore by pounding it on wooden planks and wash the powdered product to obtain the galena. Its silver content is low, varying generally between 5 and 10 ounces per ton of ore. There is no evidence of any large replacement orebody, and since the mines are situated about 11,000 feet above sea-level in one of the most inaccessible parts of the range, and are only workable during the rains, being either under snow or having all the springs frozen solid for the remainder of the year, they have no present commercial value.

**Cupriferous Pyrites.**

Associated with the galena on the Shweli-'Nmai Hka divide are veins of iron pyrites containing a small percentage of copper pyrites. Although some of these veins of pyrites are more than 10 feet wide, the locality is so far away from civilisation and access to it is so difficult, that the occurrence has no present commercial value.

**Iron.**

Iron occurs as schistose hæmatite at the bottom of the Hpyepat valley on the eastern bank of the stream, but the quantity of it is too small to be of any economic interest.

## EXPLANATION OF PLATE.

**PLATE 29.**—Geological map illustrating traverses from Assam to Myitkyina ; Myitkyina to Putao ; Myitkyina to the Chinese frontier : scale 1·014″ = 16 miles.

## LOCALITY INDEX.

| Locality. | Latitude. | Longitude. |
|---|---|---|
| Myitkyina . . . . . . . . . | 25° 22′ | 97° 23′ |
| Nam Bong . . . . . . . . . | 27° 17′ | 96° 10′ |
| Namchik . . . . . . . . . | 27° 23′ | 96° 0′ |
| Namphuk . . . . . . . . . | 27° 24′ | 96° 10′ |
| Nam Tamai . . . . . . . . . | 27° 50′ | 97° 48′ |
| Nam Yung (Namyung river) . . . . . | 26° 59′ | 96° 15′ |
| Ngawchang Hka . . . . . . . . | 26° 0′ to 26° 20′ | 98° 13′ |
| Nsop Hka . . . . . . . . . | 25° 51′ | 97° 29′ |
| Patkai range . . . . . . . . | 27° 10′ to 27° 20′ | 96° 0′ to 96° 40′ |
| Pidaung plain . . . . . . . . | 25° 27′ | 97° 15′ |
| Pungin Hka . . . . . . . . | 25° 49′ | 97° 27′ |
| Sa-kap . . . . . . . . . | 25° 30′ | 97° 25′ |
| Seneku . . . . . . . . . | 25° 33′ | 97° 47′ |
| Siraw . . . . . . . . . | 26° 37′ | 96° 23′ |
| Songsan . . . . . . . . . | 27° 3′ | 97° 4′ |
| Ta-ap river . . . . . . . . . | 26° 57′ | 96° 16′ |
| Waingmaw . . . . . . . . . | 25° 19′ | 97° 5′ |
| Wuniaw Hka . . . . . . . . | 26° 0′ | 98° 7′ |

# OLIGOCENE ECHINOIDEA COLLECTED BY RAO BAHADUR S. SETHU RAMA RAU IN BURMA. BY THE LATE E. VREDENBURG, B.SC., A.R.S.M., A.R.C.S., *Superintendent, Geological Survey of India.* (With Plate 30.)

RAO Bahadur S. Sethu Rama Rau's detailed survey of the Singu anticlinal area (*Rec. Geol. Surv. Ind.*, Vol LIII, pp. 321-330) has shown that while the bulk of the fossiliferous beds which have been selected as the type of the "Singu Stage" are newer than the main fossiliferous horizons of Minbu and Yenangyat (Noetling's "so-called" zones of "*Cancellaria Martiniana*" and "*Paracyathus cœruleus*" which are now referred to the Sitsayan or Padaung stage), yet along the region of the crest of the anticline, the oldest fossiliferous beds exposed share the character of the typical Minbu fauna and may be regarded as representing the uppermost horizon of the Sitsayan or Padaung stage. Amongst the characteristic fossils of these oldest beds of the Singu region is a small echinoid belonging to the genus *Thylechinus* which occurs plentifully in a layer situated about 20 feet above the bed "D" of Mr. Sethu Rama Rau's survey.

On a previous occasion, I have already noticed that, in Mr. Sethu Rama Rau's surveys of the northern part of Thayetmyo district, the richly fossiliferous Kama clay is separated by a thickness of strata of several thousand feet from the uppermost layers of the Sitsayan shales, which outcrop along an anticlinal region occupying both banks of the Irrawaddy not far from Thayetmyo (*Rec. Geol. Surv. Ind.*, Vol. LI, p. 234), where they have yielded a *Dendrophyllia* and a *Nucula* characterising the oldest Singu beds, together with a few gastropods, some of which are particularly characteristic of the Sitsayan or Padaung stage. It is gratifying to find that the Singu *Thylechinus* also occurs in these oldest exposed beds of northern Thayetmyo, still further confirming the proposed synchronism.

In northern Thayetmyo, the *Thylechinus* is accompanied by two more echinoidea, a *Brissopsis* (erroneously referred to as *Schizaster* in *Rec. Geol. Surv. Ind.*, Vol. LI, *loc. cit.*) and a *Breynia*. As all these forms are easy to recognise and may constitute good zone fossils, I have thought that it would be useful to illustrate them with diagnoses.

BREYNIA BIRMANICA, n. sp.

Pl. 30, Fig. 1.

Medium size, heart-shaped, apex central or even slightly posterior.

Poriferous zones sunken in petals of paired ambulacra, 13 pairs of normal pores in anterior zones of anterior petals: 21 in posterior zones, of which the first 2 or 3 are rudimentary. In outer zone of posterior petals, 18 normal pairs and probably 2 rudimentary; 8 or 9 normal in posterior zones.

All the ambulacra entering the peristome.

Labrum completely separated from sternum by a very wide interval.

Tubercles crenulate and strongly perforate. Number of differentiated primary tubercles in paired interambulacra or abactinal surface very variable: 8 to 13 anteriorly, 16 to 23 posteriorly.

3 rows of granules in internal fasciole, 4 in peripetalous, as many as 8 in subanal.

This form shares with the other Indian fossil species the remarkable peculiarity of the complete separation between the labrum and sternum constituting them into a group different from all other known species of *Breynia*. The interval, in the present instance, is even greater than in the two previously known Indian species *Breynia carinata* and *Breynia multituberculata*, from both of which the Burmese species is moreover readily distinguished by the central or even posterior situation of the apex, and the much less regularly disposed primary tuberculation of the abactinal surface.

The specimens were collected by Rao Bahadur S. Sethu Rama Rau in the northern part of the Thayetmyo district in a bed considered to belong to the upper part of the Sitsayan or Padaung stage of Middle Oligocene age, at the following spots: ¼ mile E. by S. of Shadaing (19° 36′, 95° 12′); ¼ mile S. E. of Kanhla, S. of △ 276 (19° 33′, 95° 13′); 1½ miles W. S. W. of Tubak (19° 44′, 95° 10′).

BRISSOPSIS FERMORI, n. sp.

Pl. 30, Fig. 2.

This species exhibits the closest relationship to *Brissopsis lusonica* Gray, the common form living at the present day along all the coasts of the Bay of Bengal. It evidently represents an ancestral predecessor. The relative dimensions, the shape, the characters and shape of the petals, the numbers of pores either normal or atrophied, the characters of the fascioles, apical disc, and peristome, are all practically identical.

Under the circumstances, for the sake of brevity, a short differential diagnosis will suffice for the present.

The only distinguishing features are :—

Firstly, the position of the apex which is more posterior in the fossil.

Secondly, the position of the peristome which is, on the contrary, more anterior.

Thirdly, the relatively narrower dimensions of the anterior extremity of the test measured across the protuberances of the anterior interradia.

These differences are constant in the specimens examined, but none of them are conspicuous. There is less difference between *Brissopsis Fermori* and *Brissopsis luzonica* than between any two of the living species, though some of these are closely interrelated.

This fossil occurs at the same localities as *Breynia birmanica.*

THYLECHINUS SETHURAMAE, n. sp.

Pl. 30, Fig. 3.

Small, hemispherical, elevated; peristome a little more and apical disc a little less than one-third the diameter; 11 to 12 tubercles in each ambulacral zone; 11 to 12 tubercles in each inter-radial zone; granulation abundant and varied; the extremity of ocular I reaching the apical ring.

At the same geological horizon as the beds yielding the Burmese species, the Oligocene Nari of Baluchistan contains a form which is only distinguished by its much larger dimensions from *Thylechinus Sethuramae* of which it might be regarded as an enlarged variety.

*Thylechinus Sethuramae* belongs to the typical group of the genus with intertubercular granulation abundant and two rows of principal tubercles in each inter-radium. Other species of the group are *T. Said* Peron and Gauthier, a much larger species from the Maestrichtian of Algeria; *T. londi* P. and G., a small, subconical species with relatively large peristome from the Campanian and Maestrichtian of Algiers and Tunis; *T. lybicus* Fourtau, a small depressed species, from the Upper Eocene of the Lybian desert. *T. tunetanus* Gauthier constitutes the section *Orthechinus* with inter-tubercular granulation relatively sparse, and four rows of principal tubercles in each inter-radium. It is from the Middle Eocene of south Tunis.

The presence of *Thylechinus* in the Middle Oligocene of Baluchistan and Burma extends the longevity of the genus to a later period than was known hitherto.

*Thylechinus Sethuramae* was first obtained by Rao Bahadur S. Sethu Rama Rau from the shale bed marked " A " in the Singu area about 20 feet higher than the bed " D." All these beds belong to the oldest portion of the strata exposed at Singu.

The species was also obtained at the Shadaing locality of Thayetmyo district.

## EXPLANATION OF PLATE.

PLATE 30.—FIG. 1.—*Breynia birmanica*, n. sp., Shadaing. Natural size.

,, FIG. 2.—*Brissopsis Fermori*. n. sp.. Shadaing. Enlarged $\frac{3}{2}$.

,, FIG. 3.—*Thylechinus Sethuramae*, n. sp., bed A, Singu ; a, abactinal view ; b, actinal view ; c, left side. Enlarged $\frac{2}{1}$.

# THE MINERAL RESOURCES OF THE KOLHAPUR STATE.

BY H. CECIL JONES, A.R.S.M., A.R.C.S., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 31.)

## INTRODUCTION.

KOLHAPUR is the largest and most important of the Indian States of the South Mahratta Country, and is situated to the south of the Bombay Presidency. The State lies between latitudes 15° 50′ and 17° 11′, and between longitudes 73° 43′ and 74° 44′. It has a number of large Talukas and Jahagirs under its administration, and these will no doubt complicate the working of ore deposits in the area. The State is very badly off in the matter of roads, which makes communication and transport difficult. Kolhapur City is connected, by the Kolhapur State Railway with the Madras and South Mahratta Railway at Miraj, a distance of 35 miles.

The investigation of the occurrence of bauxite, being one of the main objects of my visit, I went over practically the whole of its area, during the time (May and June) that I was in the State, and have examined most of the localities where bauxite is likely to occur. Owing to the Rains and the impassability of some of the roads I was unable to visit the northern part of the Vishalgad State, or the north-west portion of the Bawda State.

**Previous observers.**

R. Bruce Foote in his memoir "The Geological Features of the South Mahratta Country and adjacent Districts"[1] describes some of the rocks of certain parts of the Kolhapur State, but refers mainly to the inliers of Kaladgi rocks.

H. J. Eunson was employed by the State for two years 1889-1891 in making a geological survey and report of the State. A report and a series of geological maps on the scale of one inch to four miles which he produced, was published by the State in 1892. This

[1] *Mem., Geol. Surv. Ind.*, Vol. XII, Pt. 1.

report, which is rather an optimistic one, gives a general description of the geology of the area, and of the principal mineral occurrences of economic value. No reference is made to bauxite, however, in the report, as it was made some years before the attention of the public was drawn by the Geological Survey of India to the aluminous character of some of the laterites of India. Eunson deposited in the State museum a collection of the rocks and minerals he collected, but these cannot be found at the present time.

C. S. Fox of the Geological Survey of India visited in 1920 three areas in the State where bauxite was likely to occur, and in his paper on "The Bauxite Resources of India"[1] refers briefly to the bauxite at Panhala and near Radhanagri in the Kolhapur State. Also in his memoir on "The Bauxite Occurrences in India"[2] he gives particulars of the bauxite occurrences at Panhala Fort, Radhanagri (Valivda) and at Gaola-ka-Serai in the Kolhapur State; he also refers to several possible localities for bauxite, and to sites for water power schemes.

**Topography and drainage.**

The western boundary of the State runs for a large part of its distance along the Western Ghats, so that the western part of the area is very hilly and rugged. Most of the area is covered by Deccan trap, which in the higher hills is capped by laterite. This laterite on weathering often gives rise to level plateaux with almost perpendicular cliffs falling away from it; occurring at the tops of the higher hills this gives them a bold and rugged appearance. In a few places in the lower ground the Deccan trap has been denuded away and the older Kaladgi rocks have been exposed. The eastern part of the State is fairly level. The drainage of the area is mainly to the east, and away from the edge of the Ghats.

**Geology.**

The oldest rocks seen in the State are gneisses and schists, possibly of Dharwar age. These occur as two small exposures within three miles of each other at Nesari (74° 22′ : 16° 03′) and Hadlag (Hadalge) (74° 24′ : 16° 02′) in the Gaj-Hinglaj Taluka. The first of these, seen in the valley just to the west of Nesari, is a soft purple micaceous

[1] *Min. Mag.*, Vol. XXVI, No. 2, 1922.
[2] *Mem., Geol. Surv Ind.*, Vol. XLIX, now in the Press.

schist (32/126), but just to the south of the village are small granitic bands consisting of quartz and felspar with an occasional quartz vein. The second exposure is in the valley to the south of Hadlag, two miles south-east of Nesari. Here the rock is much more granitic and consists of granitic rock with bands of soft mica schist and hard quartz-mica schist. The granitic rock (32/125) is made up of coarse white to colourless quartz and pink felspar.

Next above these comes a group of conglomerates, sandstones, quartzites, limestones and shales belonging to the Kaladgi Series, which in the main part of the State is largely covered with Deccan trap, but exposures are seen at the foot of the Ghats in Bawda State, and a large area consisting mainly of limestones occurs in the Torgal State. Several inliers consisting mainly of sandstones and shales occur in the valleys of the Vedganga and Dudhganga rivers, and also in the Ghutraprabha and Hiranyakeshi river valleys in the Ajra Taluka. At Nesari, Kaladgi sandstones overlie the gneissic rocks.

The Deccan trap, which is much younger than the rocks mentioned above, covers a very large part of the Kolhapur State. It consists of a great thickness of nearly horizontal beds of basalt, amygdaloidal basalt, ash and bole beds, and is not likely to contain any minerals of economic value, except where prolonged weathering of the rock under favourable conditions, has resulted in the formation of laterite and aluminous laterite or bauxite.

Some small exposures of Lameta beds, mainly unconsolidated calcareous conglomerates, are said by Eunson to occur beneath the trap at one or two localities, but I did not find an opportunity to examine any of them.

At the tops of the higher hills and ranges of hills, there results from the continued alteration and weathering of the Deccan trap, a deposit known as high level laterite. It often forms flat or slightly undulating plateaux, usually at heights of over 2,900 feet on which very little vegetation occurs. These plateaux often have nearly vertical cliffs 20 to 100 feet in depth, caused by the falling away of large blocks of laterite, owing to the weathering of the softer material below. These laterite scarps often contain valuable deposits of bauxite. Frequently between the true laterite and the trap there is a band of more or less altered trap having the composition of kaolin or lithomarge.

Alluvium occurs in most of the river valleys, and covers large areas to the east of Kolhapur City, which are all under cultivation. It is important because of the large quantities of *kankar* found in it. This *kankar* was largely burnt at Pal (16° 18′ : 74° 13′) and other places for lime for the building of the new dam near Radhanagri.

The geological history of the area is fairly simple. The Kaladgi rocks were laid down on a denuded surface of the gneissic and Dharwar rocks. After being raised above the sea, they remained exposed to denudation for a long period, during which Gondwana rocks were deposited in certain parts of India. Then the volcanic outbursts occurred which resulted in such a large area of the centre and western side of India being covered with the Deccan trap. This has gradually been altered, denuded away and cut up by rivers and streams, forming the valleys and hill ranges seen at the present time.

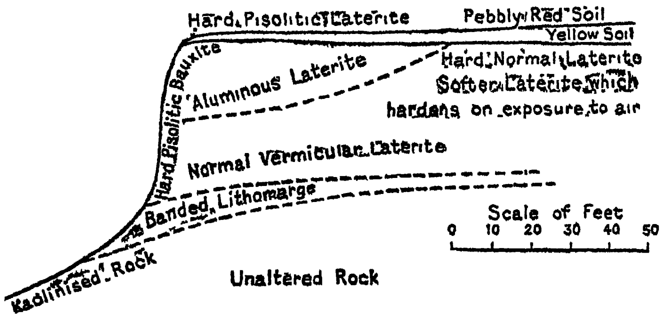
## II. -MINERAL DEPOSITS.

### Bauxite.

This is the chief mineral of economic value in the State, and fairly large quantities of it occur. Bauxite is the principal ore of aluminium, and is the source of almost the whole of the world's supply of that metal. Bauxite varies considerably in composition, but contains from say 50 to 75 per cent. of $Al_2O_3$, 1 to 26 per cent. of $Fe_2O_3$, and 10 to 30 per cent. of $H_2O$, with usually small quantities of silica and titanium. Nearly all the bauxite produced in the world is purified to alumina and then reduced to aluminium, or used in the manufacture of aluminium salts and in the glass industry, but small quantities of bauxite are used for manufacturing artificial abrasives, refractory bricks, the filtration and decolourising of mineral oils, etc. The possibility of manufacturing alumina in India, and the other uses of bauxite have been considered by C. S. Fox.[1] The price of bauxite at Marseilles is quoted in the Mining Journal (Oct. 1922) as 35 shillings per ton containing 60 to 70 per cent. $Al_2O_3$, so that the export of the raw ore would not be remunerative at the present moment. The following section taken from Fox's paper gives an idea of the shape

[1] *Min. Mag*, *loc. cit.*

of one of these laterite scarps, and also of the occurrence of bauxite in these scarps.—




**Occurrence of bauxite in Kolhapur State.**

Fox in his memoir has described the occurrence of the following three deposits in the State,—1. Panhala Fort, 2. Radhanagri, 3. Gaola-ka-Serai. In addition to these I have examined deposits near the following places, 4. Dhangawadi, 5. Rangawadi, 6. Gargotti, 7. Waki, 8. Nesari, 9. Bhudargad Fort.

1. Panhala Fort (16° 49′ : 74° 09′). A small deposit of excellent quality bauxite occurs below the Bagh Darwaza of the Panhala Fort, 12 miles north-west of Kolhapur City. The bauxite (32/142) is seen in contact with kaolin, which passes down into kaolinised trap. Fox gives the following analyses :—

| —— | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$ . . | 1·44 | 0·80 | 42·79 | 40·97 | 37·31 |
| $TiO_2$ . . | 6·32 | 3·23 | 9·08 | 6·44 | 3·33 |
| $Al_2O_3$ . . | 62·32 | 64·77 | 23·96 | 22·97 | 27·85 |
| $Fe_2O_3$ . . | 2·65 | 0·31 | 7·89 | 13·41 | 17·35 |
| CaO . | trace | — | — | — | — |
| MgO . . | 0·38 | trace | 8·54 | 2·00 | 0·76 |
| $H_2O$ . . | 26·27 | 31·54 | 14·73 | 14·77 | 13·40 |
| Miscellaneous | 0·28 | — | — | — | — |

1 Bauxite analysis,, by R. V. Briggs, Calcutta.
2 ,, ,, ,, Geological Survey Laboratory.
3 Kaolin ,, ,, ,, ,, ,,
4 ,, ,, ,, ,, ,, ,,
5 Kaolinised trap ,, ,, ,, ,,

Fox states "This bauxite is perhaps the purest material of i kind in India but unfortunately the quantities are very smal The kaolin is good and could be largely used. Pottery works coul be established at Panhala or at Kolhapur, and small quantiti of the bauxite could be utilized for the manufacture of alun alumina or other substances which require a very high grade bauxit It must be remembered by the State authorities that any activit here must mean the destruction of the Bagh darwaza gateway an the garden below."

The hills to the west of Panhala contain aluminous materia (32/143), but are not rich enough in aluminium to be considere at the present time. The following two analyses by R. V. Briggs Calcutta, are of samples collected from the hills about four mile west of Panhala,—

| — | 1 | 2 |
|---|---|---|
| $SiO_2$ | 3·25 | 11·52 |
| $Al_2O_3$ | 39·68 | 19·63 |
| $Fe_2O_3$ | 22·13 | 40·64 |
| $TiO_2$ | 10·80 | 12·00 |
| CaO | trace | trace |
| MgO | trace | trace |
| Loss on ignition | 24·84 | 16·21 |

2. Radhanagri (Valivda) (16° 25′ : 74° 02′). North of Radhanagri on the main road from Kolhapur City to the Phonda Ghat and 24 miles south-west of Kolhapur City as the crow flies, is a good deposit of bauxite (32,135, 32/136). Fox states "The elongated plateau (spur '3,244' feet) north-west of Valivda is capped with highly aluminous laterite. An average sample collected from various parts of this peneplain has the following analysis:—$SiO_2$ 3·44, $TiO_2$ 7·00, $Al_2O_3$ 59·35, $Fe_2O_3$ 4·25, CaO trace, MgO 0·64, $H_2O$ 25·00, Alkalies 0·32. (R. V. Briggs, Calcutta.) The whole of the plateau at this eastern end is, to a depth of about 12 feet, composed of aluminous laterite of a quality not much inferior to that shown in the analysis. There is, on the high ground in the middle, a slight thickness (10 inches or so) of a ferruginous

laterite and some yellow clay soil. Masses and boulders of bauxite occur on the southern slopes of the ridge above Padli village. Further west on the next plateau (about north of Karanja), the quality is distinctly poorer and the laterite is more ferruginous. In the extreme west, north of Olvan, about peaks '3,250' feet, and '3,308' feet, the capping is a ferruginous laterite. It is difficult to determine the quantity of the bauxite or aluminous laterite which occurs on the spur north-west of Radhanagri, but it is of the order of 2,000,000 tons. There is also a large, unknown quantity of richer bauxite scattered as débris on the southern slopes of the hill and in the valley below."

To the north-west of survey level "3308" however, the laterite (32/144) becomes decidedly aluminous and some of it is quite good bauxite, but most of it seems ferruginous. An analysis of a sample collected by me shows :—$SiO_2$ 0·89, $Al_2O_3$ 54·44, $Fe_2O_3$ 11·86, $TiO_2$ 3·15, CaO trace, MgO trace, Loss on ignition 29·68. (R. V. Briggs, Calcutta.)

Between th enorthern slopes of level "3308" and the ridge "3313," there are large quantities of aluminous laterite, but the low part of the ridge is concealed.

The high plateau "3313" consists of a few feet of ferruginous material covering aluminous laterite and bauxite. Most of the latter (32/145) is rather ferruginous but patches and boulders of extremely good grey bauxite occur. There must be several million tons of this ferruginous ore present, but much prospecting is necessary to get any idea of quantity and quality. The area is covered with thick forest in which there are practically no paths, and it is extremely difficult to reach it. An analysis of a sample obtained from here shows :—$SiO_2$ 0·87, $Al_2O_3$ 51·66, $Fe_2O_3$ 11·69, $TiO_2$ 6·30, CaO trace, MgO trace, Loss on ignition 29·48. (R. V. Briggs, Calcutta.)

Fox in his memoir states "The ridge to the south of the Bhogavati river is also disappointing but the western portion of this area must not be taken as fully examined." The extreme western end of this hill contains some good quality grey bauxite (32/146) but most of the material is ferruginous, and there does not seem any large quantity of good ore. The plateau at elevation "3335" to "3319" feet is of aluminous laterite of poor quality (32/135, 32/136), and the remainder of the ridge to the east is disappointing.

3. Gaola-ka-Sera (16° 00′ : 74° 08′). This deposit is situated near the tri-junction of Kolhapur State with Savantwadi State

and the Belgaum District, but most of the bauxite lies in the Ajra Taluka of the Inchalkaranji Taluka. It lies 10 miles to the south-west of Ajra as the crow flies. This deposit is now being prospected by an Indian Company who state that, from the results obtained from 32 pits and trenches put down, they have proved a workable thickness of 40 feet of ore, of which four to ten feet appear to be of first grade, *i.e.*, containing above 55 per cent. of $Al_2O_3$, and thirty feet or so of second grade, *i.e.*, from 45 to 55 per cent. $Al_2O_3$, but prospecting is still going on. Fox gives the following analyses :—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $SiO_2$ . . . | 1·25 | 2·28 | 4·12 | 2·94 | 0·50 | 1·84 | 1·16 |
| $TiO_2$ . . . | 1·00 | 1·60 | 5·60 | 2·70 | 2·30 | 3·60 | 1·54 |
| $Al_2O_3$ . . . | 61·14 | 50·27 | 47·08 | 51·22 | 62·94 | 52·86 | 52·94 |
| $Fe_2O_3$ . . . | 8·26 | 22·21 | 20·92 | 17·96 | 4·96 | 16·44 | 13·72 |
| CaO . . . | ... | ... | ... | 0·40 | 0·36 | ... | 4·96 |
| MgO . . . | 0·25 | 0·34 | 0·43 | ... | 0·13 | 0·25 | 0·18 |
| $H_2O$ . . . | 28·00 | 23·12 | 21·10 | 24·00 | 29·10 | 24·80 | 24·85 |
| Loss . . . | 0·10 | 0·18 | 0·75 | 0·42 | 0·07 | 0·21 | 0·65 |

4. Dhangarvadi (16° 56′ : 73° 53′). The best deposit found by me occurs in the hill near Dhangarvadi, five miles west of Malkapur in the Feudatory State of Vishalgad. It is situated some 28 miles to the south-west of Kolhapur, in a straight line. Practically the whole of the eastern half of the plateau forming the top of this hill consists of good quality, mainly white to greyish-white bauxite. In places it is somewhat ferruginous, but from surface indications it appears to be mostly first class ore. In cliffs at the northern edge of the plateau, it appears to be quite forty feet thick, but thins in places towards the east, and just west of Dhangarvadi village there is only about ten feet of bauxite overlying variegated clays or lithomarge. Some of the top of the scarp has been cultivated, but all round the edge of the cultivated ground, good bauxite is seen. Without prospecting pits it is difficult to estimate quantities, but there are probably some eight to ten million tons of good ore present. The bauxite (32/149) is well seen in the stream valley running south-east to the north-west of the village of Dhangarvadi, and also near the tank just east of level " 3335 " (32/150). The northern slopes

of the hill, especially above Dhangarvadi village are largely covered with blocks and boulders of the same type of rich ore. The southern side of the hill does not appear to be so rich as the northern side, but to the west of the tank there is a vertical cliff which shows good bauxite at the top, but which I could not examine lower down. A thin layer of limonitic material occasionally covers the bauxite, but this can be easily removed. Analyses of two samples collected from this plateau, No. 1 carried out by Mr. Briggs. Calcutta, and No. 2 done in the Geological Survey Laboratory, gave the results (1 and 2) shown below and seem to be much more what one would expect.

| — | 1 | 2 |
|---|---|---|
| $SiO_2$ | 1·24 | 0·17 |
| $Al_2O_3$ | 59·60 | 54·63 |
| $Fe_2O_3$ | 5·50 | 8 34 |
| $TiO_2$ | 4·65 | 7·60 |
| CaO | trace | 0·94 |
| MgO | trace | 1·10 |
| Loss on ignition | 29·01 | 28·96 |

5. Rangewadi (16° 51′ : 73° 58′). Another good deposit, but smaller than the one near Dhangarvadi, occurs in the hills south of Rangewadi. It is situated some 22 miles in a straight line from Kolhapur, in an approximately north-western direction. The bauxite (32/151, 32/152) is of a grey, white or yellowish colour, and often has a pisolitic character. The deposit appears to contain something like four to five million tons of good quality ore. An analysis by R. V. Briggs, Calcutta, of a sample collected by me from this plateau gave

| | |
|---|---|
| $SiO_2$ | 1·08 |
| $Al_2O_3$ | 53·02 |
| $Fe_2O_3$ | 6·64 |
| $TiO_2$ | 10·25 |
| CaO | trace |
| MgO | trace |
| Loss on ignition | 29·01 |

This grey and yellowish bauxite runs from the narrow ridge one-and-a-half miles west-south-west of Ambawadi, along the plateau for at least a mile to the west, where the ore begins to get poorer in quality. From the narrow ridge west-south-west of Ambawadi (16° 51′ : 73° 59′) stretching to the hills south of that village is an aluminous laterite with irregular patches of good bauxite. Prospecting pits will have to be put down to decide if this be worth working.

6. Gargotti (16° 20′ : 74° 12′). A small deposit of rich grey bauxite occurs in the range of hills to the north-west of Gargotti. The bauxite (32/153) occurs in the two little hillocks on the top of the range between level " 3190 " and Dhangarvadi (16° 22′ : 74° 07′), and probably contains something like 750,000 tons of good ore. The western side of the two hillocks and the ground towards Dhangarvadi becomes too ferruginous to be of economic value. An analysis by R. V. Briggs, Calcutta, of a sample collected by me is as follows :

| | |
|---|---|
| $SiO_2$ | 0·48 |
| $Al_2O_3$ | 57·22 |
| $Fe_2O_3$ | 5·78 |
| $TiO_2$ | 8·40 |
| CaO | trace |
| MgO | trace |
| Loss on ignition | 28·15 |
| | 100·03 |

7. Hills south-west of Waki (Vaki) and approximately 21 miles west of Nesari measured on the map (16° 17′ : 74° 03′). This group of hills is very disappointing. At level " 3338 " and on the slopes of plateau " 3372 " south-west of Waki is aluminous laterite (32/154) but the quantity is small and most of it is too ferruginous to be of much economic value. At level " 3321 ", south of Waki is some ferruginous bauxite (32/155) but the quality does not seem good and the quantity is small.

8. Hills west of Nesari (16° 03′ : 74° 22′). This range of hills running along the Belgaum-Kolhapur State boundary six miles west of Nesari, consists of Deccan trap with a capping of laterite which is often pisolitic and aluminous, and contains patches of good grey bauxite. The centre of plateau " 3200 " contains good bauxite (32/140) but the small plateau half a mile to the west is more ferruginous. The big plateau about a mile to the west of level " 3200 " is more ferruginous, but still contains aluminous material (32/157). These hills should be thoroughly prospected by prospecting pits.

9. Bhudargad Fort (16° 15′ : 74° 11′). The range of hills running south and south-west of Bhudargad Fort to the edge of the Ghats is disappointing, until almost the extreme south-west point near Kitauda (16° 04′ : 74° 05′) is reached. Here a certain amount of aluminous material occurs, mostly of a reddish variety (32/158). Although from surface indications it does not look particularly promising, it is worth a little prospecting, and I understand a prospecting license has been applied for.

## Building Materials.

The State is well off as regards building stone, the best of which is obtained from some of the beds of the Kaladgi Series, and also from some of the beds of the Deccan trap.

The quartzites and sandstones of the Kaladgi Series have been worked at several localities, such as near Ajra (16° 06′ : 74° 15′) and Gargotti (16° 19′ : 74° 10′) in the main part of Kolhapur State, and also at Bijikupi (16° 06′ : 75° 14′) and other localities in the separated Torgal State. The rock (32/137) gives a fair building stone, but much of it breaks with a conchoidal fracture, which makes dressing difficult. Some of the beds are also used for making grinding stones. The siliceous limestones (32/130, 32/132, 32/133) of this series in the Torgal State have also been largely used locally for building purposes. Large slabs of excellent material can be obtained from these beds, and it is very largely quarried near Sidnal (16° 01′ : 75° 12′) and along the side of the main road running to the north-east. Some of the whiter beds of this limestone have been tried as lithographic stones, but it is said to be too soft for the purpose. Some of the shales, notably one which occurs at Salpevadi (16° 18′ : 74° 10′) to the south of Gargotti, in the Vedganga valley are white and are used as whitewash (32/138).

Some of the harder varieties of the Deccan trap are extremely good, and the stone worked in the Jotiba hill quarries (16° 48′ : 74° 13′) is well known. The bed worked is a fine-grained, extremely hard, compact, bluish-grey rock (32/128), which can be traced to the Panhala Fort hill and along the range for many miles to the west. There seems to be no systematic method of working these quarries; the quarrymen work the boulders and loose blocks, as they consider them less liable to split, after, and during the dressing of the rock.

Laterite is abundant and has been largely used for the walls and buildings in some of the old forts. It forms an excellent road metal, and has been used together with the bauxite that occurs with it at Radhanagri, for making this part of the main road from Kolhapur City to the Phonda Ghat.

*Kankar* occurs in large quantities in some of the alluvium, and also in the black cotton soil. There seems to be no special industry, but it is collected and burnt when required. It occurs in very large quantity in the Torgal State.

Bricks are sometimes made from some of the alluvium.

## Copper.

Eunson refers to traces of copper being found in an excavation in the trap in Kolhapur City, and also in a railway cutting 11½ miles from Kolhapur City. He states "the mineral presented a thin film of native metallic copper changed in places to the black oxide." It is extremely unlikely that any quantity of copper will be found in the trap area of the State.

## Gold.

Eunson in his report on the State holds out the prospect of the possible occurrence of gold near Nesari (16° 03′ : 74° 22′). I examined the area and found the exposures of gneissic and schistose rocks extremely small. I washed the material from some of the small quartz veins which occur, and found no trace of the precious metal. I think there is very little prospect of finding gold at this locality.

## Gypsum.

In the extreme south-west corner of the State to the north of the village of Tambichiwadi (16° 06′ : 74° 55′), irregular-shaped nodules and veinlets of gypsum occur in a reddish clayey soil. In the past, quantities of this gypsum have been collected and made into Plaster of Paris. The exact locality is about two miles north of the village of Tambichiwadi, and is situated near the edge of the Ghats, and some 2,350 feet above sea level. The reddish clay occurs in a small stream valley, the sides of which are formed of Deccan trap, and has apparently resulted from the weathering of that trap. The clay deposit appears to be quite thin, and the gypsum occurs scattered irregularly through it. The gypsum (L. 856) is fibrous and has the appearance of having formed small veins, possibly in thin irregular cracks in the clay. Eunson, who put down some trial pits, states that the gypsum occurs in the lower part of the clay deposit as thin veins up to 1½ inches in thickness and also that very little of the mineral was obtained from these pits. The area covered by the red clay is small, and that from which I was able to collect gypsum was only 60 to 70 feet by about 30 feet. There seems to be no prospect of getting any large quantity of gypsum from this deposit, and as the price of gypsum is only about one rupee a ton in India, the cost of transport alone, would make it an impossible proposition from an economic point of view.

## Iron.

Iron ore of fair quality occurs in small quantities at various localities in the State, and was largely used in the old days when the quantity of ore required at each smelting locality during the year, was only a matter of a few tons. The deposits are quite useless for modern methods, where a present day blast furnace may use 500 or more tons of ore a day.

The ore (L. 859) in the State was mainly obtained from patches in the laterite which have been locally enriched by percolating solutions depositing limonite or hæmatite in veins and stringers. Sometimes the rich iron ore nodules found in the weathered material which accumulates at the foot of the laterite cliffs were used by the old iron smelters. Eunson states that Sonurla (16° 48′ : 73° 59′) is the area where the ore is richest and where the largest quantity occurs, and estimates that there are 25,000 tons of iron ore there; he remarks, however, that not all of this would be suitable for smelting. Analyses given by Eunson of poor and good varieties of the ore show 30 and 43·28 per cent. iron, respectively. The ore (L. 857) which I found to occur in a stream valley north-east of Dhondawadi, two miles north-west of Sonurla, is laterite which has been locally enriched, partly to hæmatite and limonite. The better parts would probably average about 40 per cent. iron, but specimens from the small veins and local enrichments might contain nearly 60 per cent. I examined these local enrichments at several places including Sonurla; Jotiba Hill (16° 48′: 74° 13′); the Tin Darwaza at Panhala Fort (16° 49′: 74° 08′); a locality south of Radhánagri (16° 25′ : 74° 02′); etc., but it is unnecessary to give further details of them as they are all small and quite useless from the present day economic standpoint.

## Kaolin.

1. Panhala Fort (16° 49′ : 74° 09′). This has already been referred to under bauxite (p. 420). The material (L. 858) is greyish-white containing specks of yellowish matter. These specks would possibly discolour any porcelain made from it. The kaolin passes downwards into variegated lithomarges (L. 860), of which large quantities occur all round the fort hill, and this could undoubtedly be used for making pottery. Fox in his memoir on the bauxite deposits of India states "The kaolin is good and could be largely used. Pottery works could be established at Panhala or Kolhapur."

2. Gudalkop (16° 07′ : 74° 30′). The top of hill "2988" to the south of Gudalkop in the Gaj-Hinglaj Taluka consists of laterite, some of which is pisolitic and aluminous (32/159). Between this and the underlying Deccan trap is a thin band of white pisolitic kaolin (32/160). An analysis of this kaolin made in the Geological Survey of India laboratory shows :—$SiO_2$ 40·79, $Al_2O_3$ 44·97, Moisture 1·49.

The hills to the north-west and west-north-west of Gudalkop are similar, consisting of Deccan trap overlain by pisolitic aluminous laterite (32/162) with a thin layer of white pisolitic kaolin (32/161) between the two. There seems to be a fair quantity of this kaolin,—the band in places being ten to twelve feet thick. Without prospecting pits it is impossible to get any reliable idea of the quantity present. A sample of this kaolin collected by me and analysed in the Geological Survey of India laboratory gave :—$SiO_2$ 40·20, $Al_2O_3$ 45·52, Moisture 1·38.

3. Bhudargad Fort (16° 15′ : 74° 11′). The old fort at Bhudargad is built on a plateau of ferruginous laterite, but just below the main west entrance (the Shivapur Peth doorway), are two pits or caves about twenty feet deep in a kaolinised trap. The kaolin is fairly white, but still contains some incompletely altered trap which in parts gives it a purple tinge (32/163).

## Manganese.

Eunson mentions the occurrence of manganese near Bijikupi (16° 06′ : 75° 14′) in the Torgal State. I visited this place, which is about one mile north-east of the village, and found small veinlets and films of manganese oxide (32/131) in a rather broken up and disturbed siliceous limestone (32/130). It seems to be of no economic value.

## Saltpetre.

A certain amount of saltpetre was collected and partially refined near Chinchlee (16° 34′ : 74° 51′), Raibagh (16° 29′ : 74° 49′) and other places, but the industry was stopped some years ago. The occurrence is the usual one, resulting from a village soil being well charged with wood ash, cow dung, etc., from which the potash salts are brought to the surface in solution by capillary action, and remain as an efflorescence on evaporation of the water. The efflorescence is collected from the surface soil, the salts dissolved, crystallised out and then sold for further refinement. It seems to have been quite a small local industry, and there is little prospect of its ever attaining big proportions.

## Slates.

Eunson refers to slates occurring in the Torgal State, but states that they are hardly true slates in the usual acceptation of the term. I examined the area and find that they are really shales that have been somewhat metamorphosed, but have very few of the characteristics of a slate. The rock (32/134) is a purplish-grey shale having no marked cleavage, but which splits along the bedding planes, giving slabs one inch or more in thickness. Near Torangatti (15° 58′ : 75° 09′), Katkol (15° 59′ : 75° 10′), etc., it is largely used in the form of slabs about ten feet by four feet and three inches thick, for flooring purposes, for which it is excellently suited. The thinner slabs of about one inch in thickness are occasionally used for roofing purposes, but are rather heavy for this work. The limestone also, is capable of being split into slabs a few inches thick, and is also largely quarried at Sidnal (16° 01′ : 75° 12′), etc., in the form of slabs for flooring purposes.

### EXPLANATION OF PLATE.

**PLATE 31.**—Map showing the bauxite deposits of Kolhapur State: scale 1″ = 4 miles

# NOTES ON THE KUNGHKA AND MANMAKLANG IRON ORE DEPOSITS, NORTHERN SHAN STATES, BURMA. BY E. L. G. CLEGG. B. SC. (MANCH.), *Assistant Superintendent, Geological Survey of India.*

## THE KUNGHKA IRON ORE DEPOSIT.

**Introduction.**

THE ore at Kunghka is one of the deposits worked by the Burma Corporation in the Northern Shan States. Kunghka village is situated in Latitude 23°13′, Longitude 99°19′, on sheet No. 93 $\frac{L}{8}$ of the 1 inch = 1 mile sheets (new issue), the Bench Mark which demarcates the centre of the mining lease being at the stream junction in the steep-sided valley ⅓ mile north of the position of the village as depicted on the map, and 3,000 feet above the level of the sea. The area is approached by mule tracks from Nam Tu (Panghai) and from Bawdwin. That from Nam Tu is the better, is 17 miles in total length, and has a gentle gradient throughout; it winds north from Nam Tu through Möng Hseng and the Nam Krak and Nam Tat valleys to the deposit, and was the one used by Chinese mule contractors for transporting lead slags and ores from Bawdwin to the Corporation's smelter at Nam Tu before the present railway was constructed. The iron ore was, and is used as a flux in the reduction of the Bawdwin ores.

Although the whereabouts of the deposit were known, no development work was considered until November 1916, at which time a Chinese contractor started to quarry and bring in the ore to Nam Tu. In the following month trenching was commenced by Mr. Loveman, Geologist to the Corporation, to ascertain the resources of the deposit. Since then about 5,000 tons of ore have been won, but development work has shown that the prospects were not so good as at first anticipated, and at the time of my visit in April 1922, quarrying had ceased, and the last dumps of ore were being brought into Nam Tu.

**Physical Features.**

The general features of the area west of the Nam Tu have been described by Dr. Coggin Brown as follows:—"The surface is mountainous and entirely occupied by steep slopes produced by the erosion of many streams. Flat ground either as plateaux or in valley bottoms is conspicuously absent, the nearest approach to it being the sinuous, narrow tracts of alluvium which rarely border the banks of the larger streams. Even the larger valleys are deep and V-shaped, separated from one another by steep knife-edged ridges, their sides scored by innumerable glens and ravines which make up the amazing net-work of the feeder drainage system of the country. Dense temperate evergreen forest generally clothes the hills from base to summit. In proportion to their lengths, the streams possess high gradients."[1] This general description applies to the country in the immediate vicinity of the ore deposit, which cuts across a precipitous valley, separating two knife-edged ridges. The stream which cuts the deposit and which has denuded away a considerable portion of ore, drops 1,500 feet in its course between the ore-body and the Nam Tat, which it joins 1½ miles below.

General Geology.

The deposit is situated on the Pang Yun Series described by Dr. J. Coggin Brown who also quotes Dr. J. M. Maclaren's description of them as "the Banyan Beds" in an unpublished manuscript in 1906, and the attention drawn to them in 1909 by Mr. T. H. D. LaTouche.[2] The series is unfossiliferous, but, as it lies between the Bawdwin volcanics below and the fossiliferous Naungkangyis above and is conformable with them, it is believed to be either of Cambrian or Ordovician age. At Kunghka the Pang Yuns are a series of fine-grained, thinly-bedded, white and chocolate-coloured sandstones; micaceous shales; quartzites; and occasional conglomerates. In places a thinly banded chocolate and white sandstone is seen, with dendrites of iron ore along the bedding planes. Microscopically, the quartzitic nature of the series as a whole is well shown, and the rocks are seen to vary from a practically pure quartzite found near the Manager's bungalow one mile east of the deposit, to a fine-grained sandstone whose cementing material has been completely altered to iron oxide by the impregnation of iron-bearing waters. A section of conglomerate shows the outlines of large rounded quartz grains and of smaller quartz grains outlined by iron oxide, the interstitial indeterminable matrix not

[1] *Rec., Geol. Surv. Ind*, Vol. XLVIII, p.131 (917).
[2] *L c cit.*, pp. 145-149.

having been altered to any great extent. Sections of the sandstones from the vicinity of the ore deposit show varying degrees of impregnation. Eastwards in the Nam Tat valley, Plateau Limestone is found whilst westwards the series continues to the Kunghka-Penglun divide. Outliers of Plateau Limestone form the high peaks of "5224" and "5537" to the west. The general dip of the rocks of the area is westerly, high dips prevailing east of the ore body and low ones to the west. The outliers of Plateau Limestone have a low westerly dip (18°—20°) whilst in the main mass of the limestone in the Nam Tat valley the dip is not perceptible.

**Occurrence and description of the ore deposit.**

The ore body occurs in a fault which strikes N.15° W. and hades in a westerly direction. The rocks of the hanging-wall dip W.15°S at from 20° to 30°, whilst those of the foot-wall are vertical, contorted and much smashed. Eastwards the underlying strata are first vertical and then dip westerly at steep angles (60°—80°). The fault is filled in with lenticles and veins of hard, solid hæmatite in a soft matrix of red and yellow limonite. In the soft matrix platy crystals of specular hæmatite are abundant, and also small nodules and veins of barytes, some of which show crystal intergrowth with specular hæmatite. Lenticles of sandstone are also included, and a passage is seen from solid, slightly magnetic hæmatite, through highly ferruginous sandstones, to the hard, whitish, quartziferous sandstones of the Pang Yun series. The outline of the body is irregular.

About half-a-mile east of Penglun a detrital deposit of angular fragments of solid hæmatite exists but has not been worked. Mr. E. C. Bloomfield, the present Geologist of the Burma Corporation, believes that it is derived from the Plateau Limestone found overlying the Pang Yun Series immediately to the north of that point and in which he has seen hæmatite *in situ*.

**Origin of the ore.**

The deposit has been formed by the infiltration of iron-bearing waters down the fault-plane; the alteration, besides having acted on the material of the fault fissure itself, has also affected the contiguous sandstones. The iron is probably derived from the Plateau Limestone originally overlying the Pang Yun Series, on which numerous occurrences of residual deposits have been reported, and some of which have and are being worked. No reliable estimate of the quantity of ore present is available.

Composition of the ores.

The following analyses were kindly supplied by the Burma Corporation, Ltd. The hard and soft types of ore, *i.e.*, the hard inclusions of hæmatite and the soft earthy matrix, were estimated to exist in equal quantities and to contain the following percentages of metallic iron :—

Hard type : Fe = 61 per cent.
Soft type : Fe = 47 „ „

The percentage of iron in the hard type was derived from the approximate average composition of 2,500 tons which had been hauled to Nam Tu, and of the soft variety from scattered samples taken from various points within the workings.

## The Manmaklang Iron Ore Deposit.

This is another of the deposits of iron ore worked by the Burma Corporation in the Northern Shan States. Manmaklang is situated in Latitude 22° 50', Longitude 97° 40', 1 inch = 1 mile sheet No. 378 (old series) on the Plateau Limestone Series.

At the time of my visit (April 1922) no ore had been extracted for over a year and the workings had been allowed to fall into a state of disrepair. The adit had collapsed and the rest of the workings had become partially filled with mud and water, so that little beyond the general residual nature of the deposit could be seen. The following notes are based on a report by Mr. M. H. Loveman, late Geologist to the Burma Corporation, written after the deposit had been opened up and kindly supplied to me by the Corporation. The deposit was closed down owing to the high cost of working and the difficulty of dealing with the slimy limonite during the wet season.

Situation.

Manmaklang is situated 2 miles east of Man Pwe and about $2\frac{1}{2}$ miles from a new siding on the Burma Railways, the nearest point to the deposit. It is at the foot of a S.W.—N.E. trending range of limestone in a country of low relief. The ground slopes gradually in a N.W. direction to the Nam Yaw River and the railway. Prospecting operations were started in 1917.

The country rock is limestone containing beds of sandstone.

**Mode of occurrence.**

At first, loose pieces of ore were seen scattered about the surface, but on trenching the iron ore was found to occur as ledge-like masses and as loose pebbles. Further development was carried out by stripping the overburden, sinking shafts and driving a tunnel. The thickness of overburden was considerable and the development work not sufficient to clearly define the shape of the deposit. The iron ore in the tunnel and lower portions of the shafts does not occur as distinctly separate boulders, but rather as a mass of ore fragments separated by slight amounts of clay and by open crevices tending towards the vertical. Besides the clay intimately associated with the ore there are also bands several feet thick running through the iron ore. Towards the S.E. the ore is covered by travertine 10 feet thick in one shaft. Neglecting the travertine junction, the other observed edges of the iron ore (with one exception) are contacts with the surface soil. The exception is at the bottom of shaft No. 2, where at a depth of 40 feet the ore was found lying directly on the limestone surface. This fact together with the general fragmental character of the ore and its similarity to numerous other residual deposits points to a residual origin. If this supposition is true its western extension is probably limited.

**Character of the Ore.**

Iron sulphide in the form of marcasite is present in small amounts but the ore itself is largely limonite with probably some hæmatite. The approximate average analysis of the ore as shown by shipments to the smelter is as follows:—

| | |
|---|---|
| Fe= 52 per cent. | $Al_2O_3$=6·5 per cent. |
| $SiO_2$=15 „ | CaO =1·8 „ |

The limonite is light yellow to red in colour and generally rather porous. The shape of the deposit is unknown but the tunnel passes through 115 feet of ore and its face was still in ore at the time of writing. Shaft No.1 passed through 75 feet of ore with the base still in ore when it was discontinued.

**Mining.**

The ore was won by stripping off the overburden and quarrying. The average thickness of overburden was 15 feet but it varied greatly at different points. After removal of the overburden the ore was extracted through the tunnel.

# INDEX TO RECORDS VOLUME LIV.

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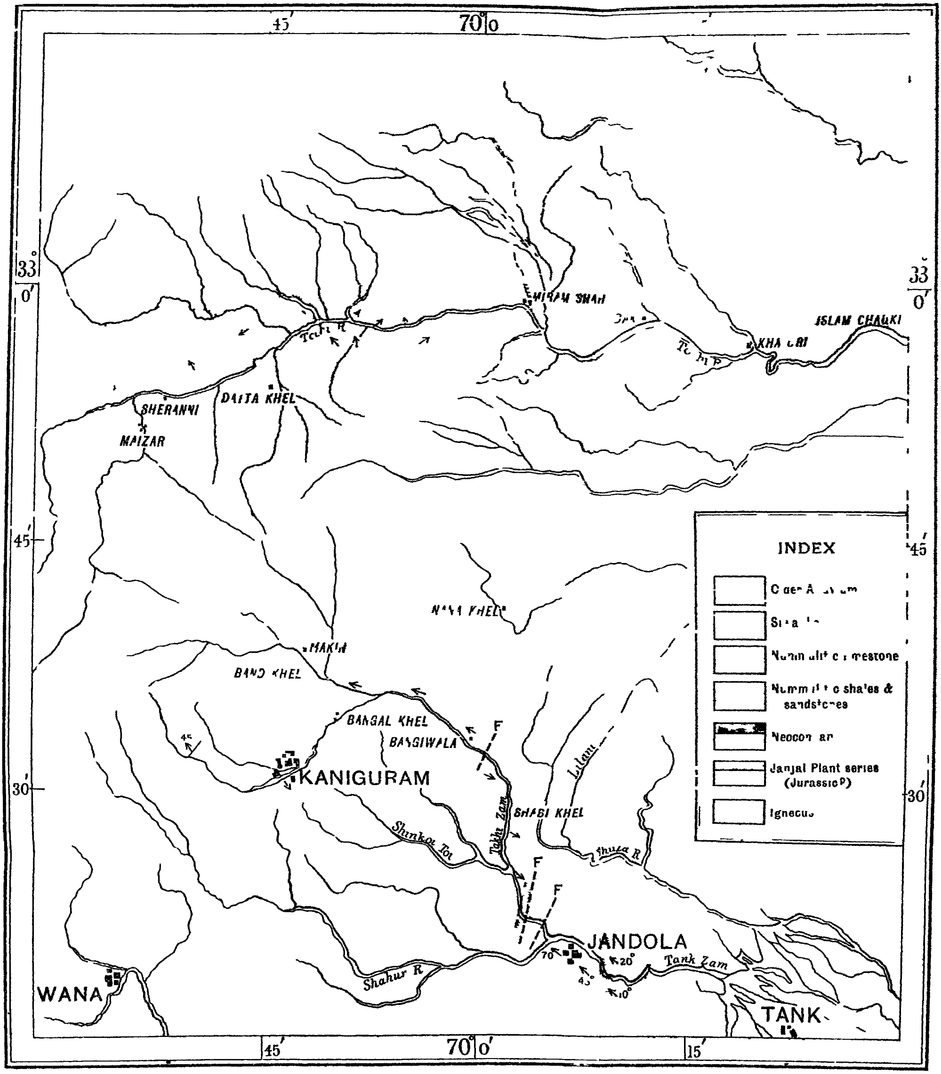
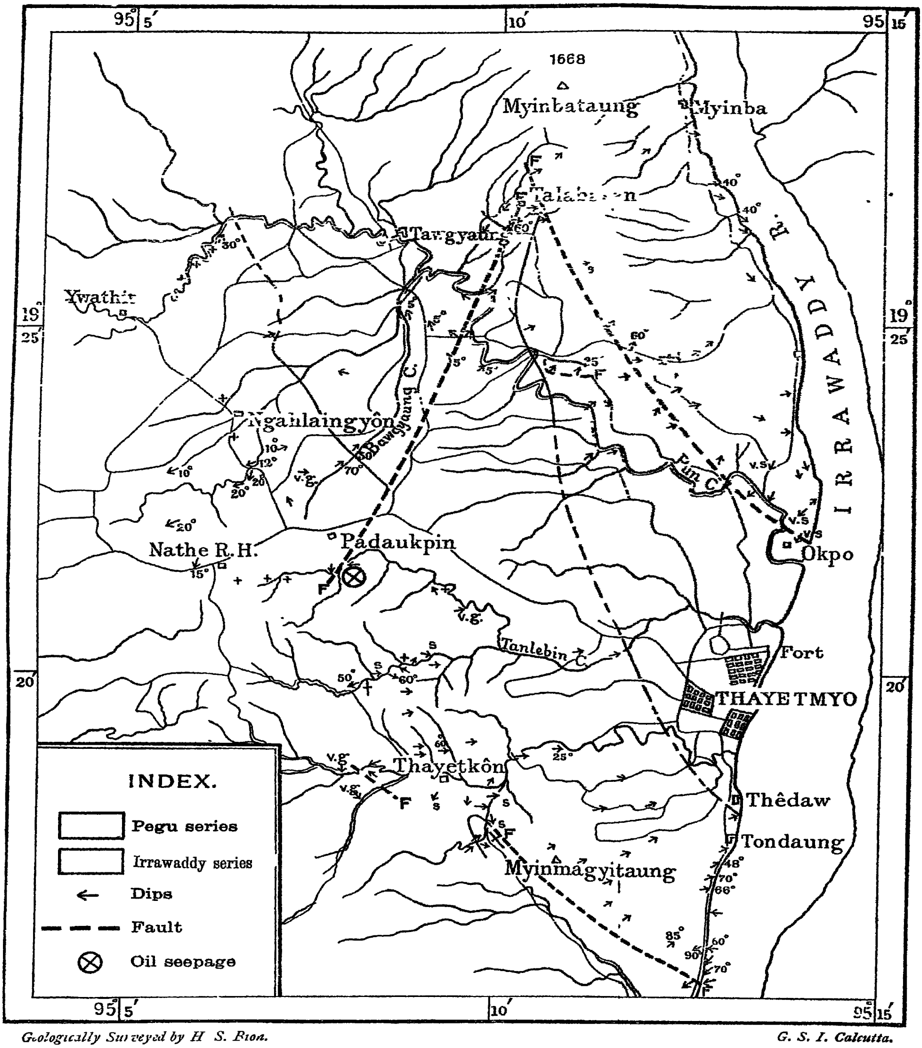



G S I Calcutta

GEOLOGY OF WAZIRISTAN

*FROM TRAVERSES BY MURRAY STUART & F H SMITH*

*Scale 1 inch = 8 miles*

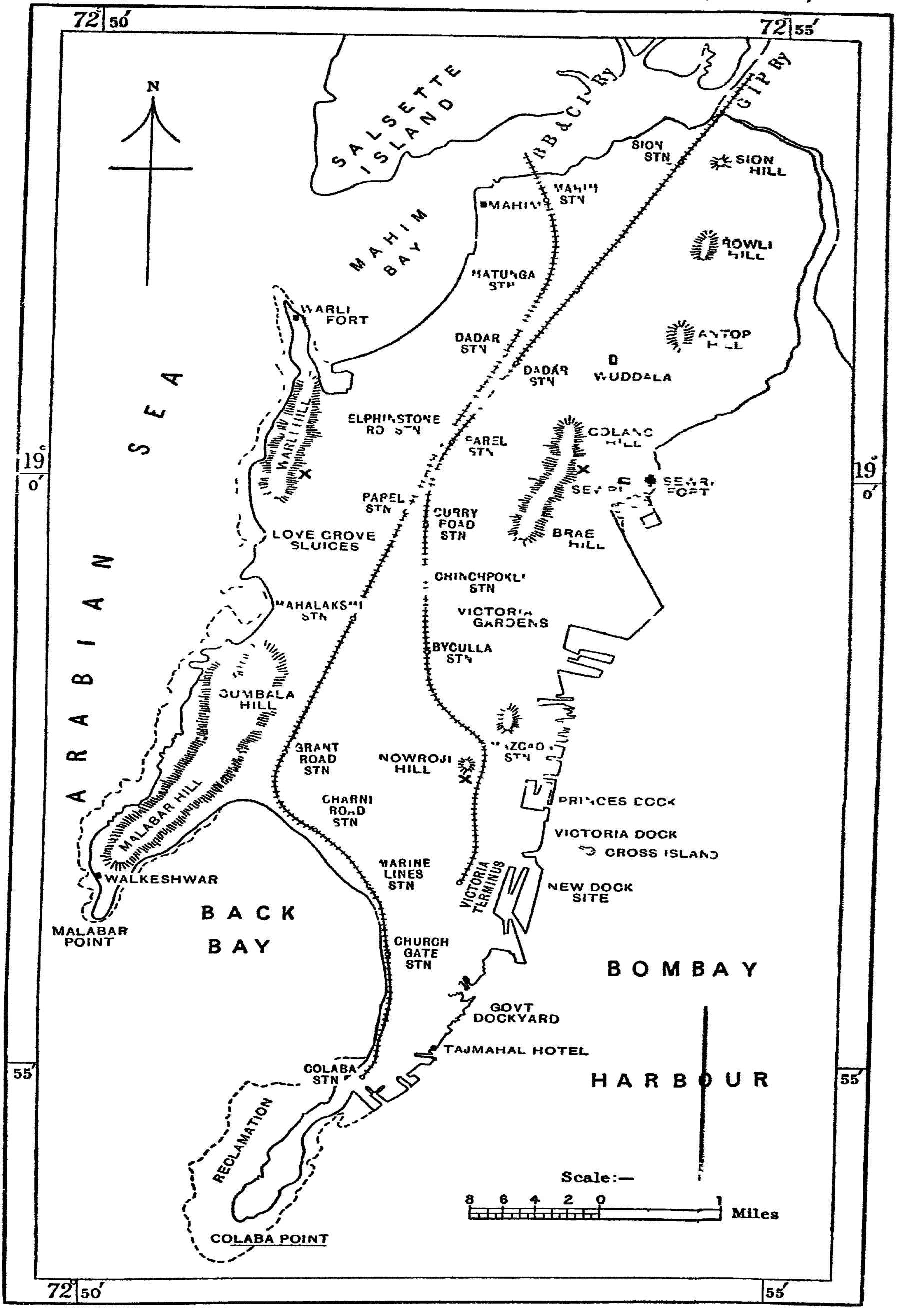



*Geologically Surveyed by H. S. Bion.*

*G. S. I. Calcutta.*

GEOLOGICAL MAP OF PADAUKPIN AND THAYETMYO.

*Scale 1 inch = 2 miles*



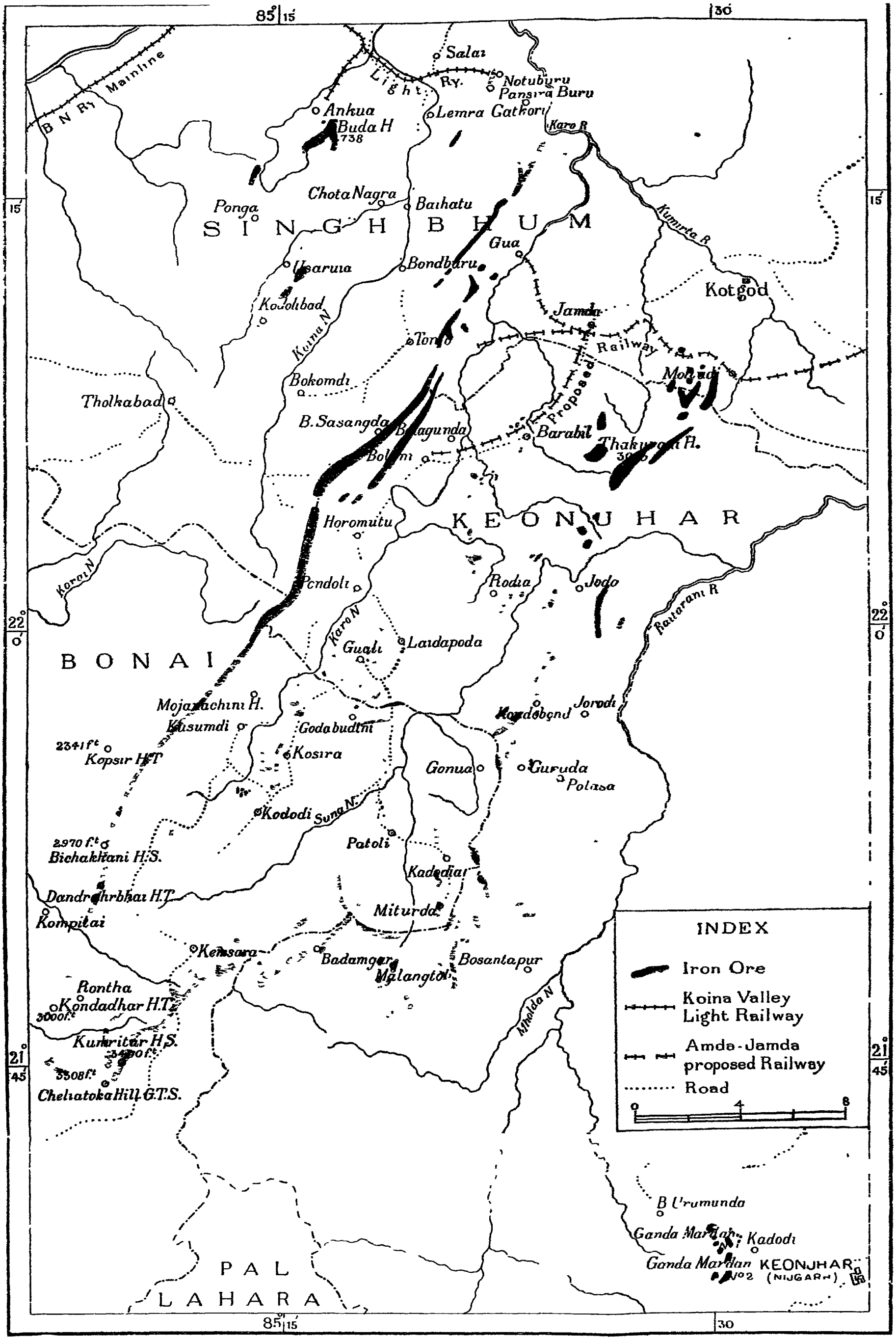

*C. S. Fox, Sketch.* *G. S. I. Calcutta.*

MAP OF BOMBAY ISLAND SHOWING LOCALITY FOR BITUMEN.

FIG. 1. QUARRY AT WARLI HILL, BOMBAY, showing frog beds.

*C. S. Fox, Photos.* *G. S. I Calcutta.*

FIG. 2. CAVITIES CONTAINING BITUMEN AT SEWRI, BOMBAY.




Topography from sheets No. 73 G and F. Scale of 1 inch = 4 miles.

Col ftd G. S. I. Calcutta

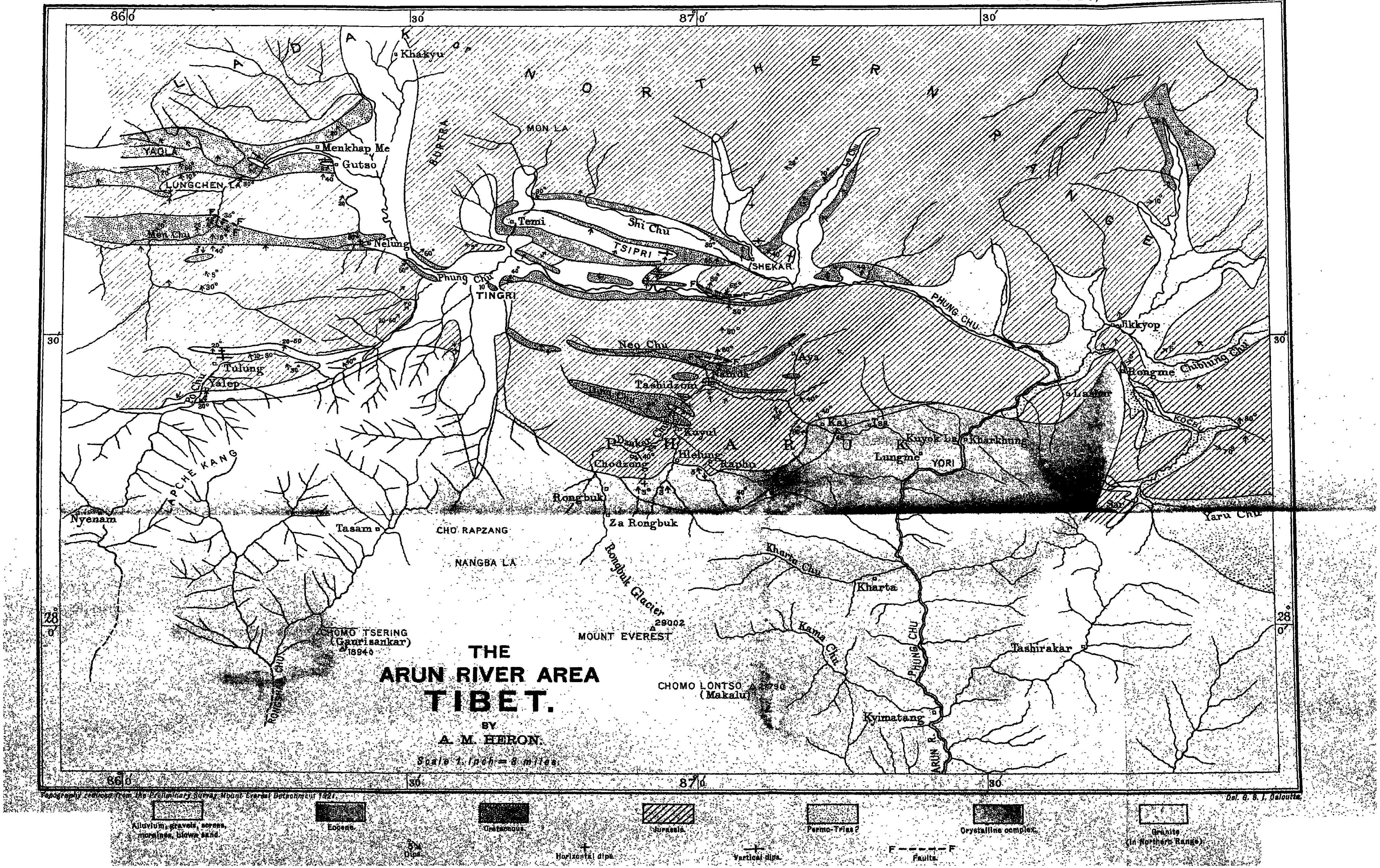
MAP OF THE IRON-ORE AREA OF SINGHBHUM & ORISSA

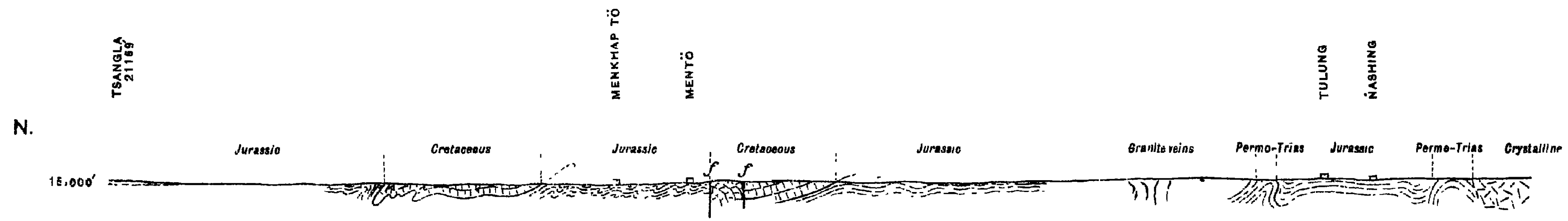
Photographed by A. M. HERON

Photogravure, Survey of India Offices Calcutta 1923

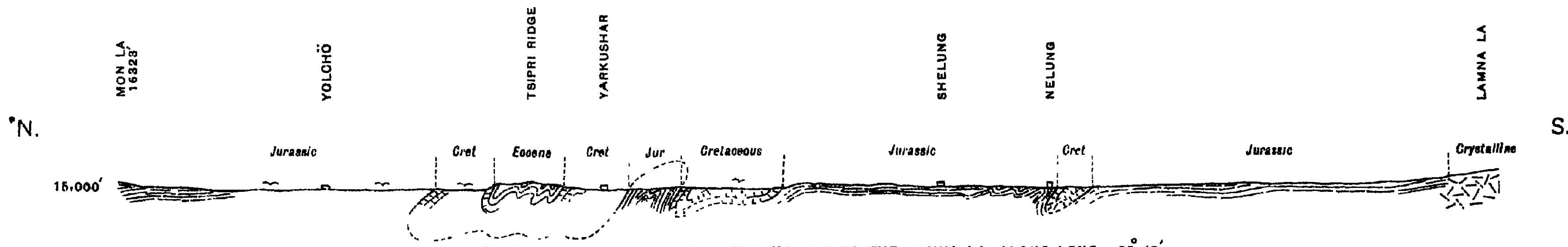
THE NORTHERN FACE OF MOUNT EVEREST,

FROM THE RONGBUK VALLEY, SHOWING NEARLY HORIZONTAL STRATIFICATION OF ALTERED SEDIMENTARIES

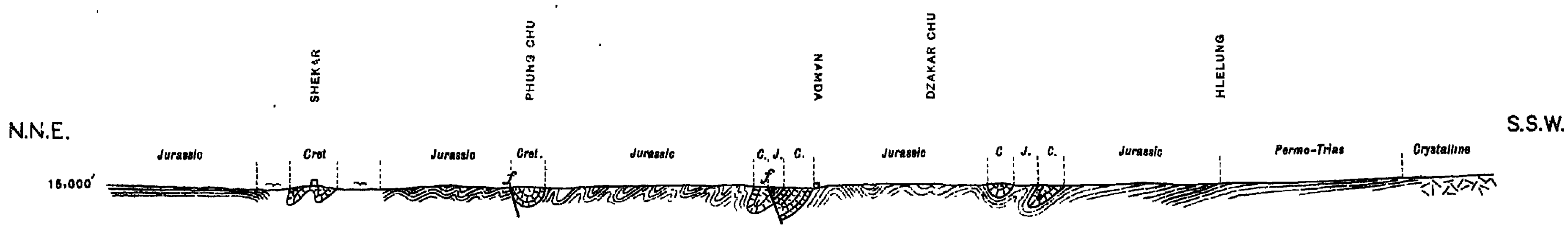

THE
ARUN RIVER AREA
TIBET.
BY
A. M. HERON.
Scale 1 inch = 8 miles.
NORTHERN RANGE
PHUNG CHU
TINGRI
SHEKAR
TSIPRI
Shi Chu
Temi
Nelung
Menkhap Me
Gutso
LUNGCHEN LA
YAGLA
Khakyu
MON LA
BURTRA
Phung Chu
Neo Chu
Tashidzom
Chodzong
Hlelung
Rongbuk
Za Rongbuk
Rongbuk Glacier
MOUNT EVEREST
29002
CHO RAPZANG
NANGBA LA
Tasam
Nyenam
CHOMO TSERING
(Gaurisankar)
23440
CHOMO LONTSO
(Makalu)
Kharta
Kama Chu
Kyimatang
ARUN R.
Tashirakar
Yaru Chu
Lungme
YORI
Kharkhung
Kuyok La
Rongme
Chiblung Chu
Jikkyop
KOCHU
Tulung
Yalep
Aya
Kuyul
Topography reduced from the Preliminary Survey Mount Everest Detachment 1921.
Dal. G. S. I. Calcutta.
Alluvium, gravels, screes, moraines, blown sand.
Eocene.
Cretaceous.
Jurassic.
Permo-Trias?
Crystalline complex.
Granite (in Northern Range).
Dips.
Horizontal dips.
Vertical dips.
F - - - - F Faults.




DIAGRAMMATIC SECTION THROUGH TSANGLA, MENTO AND TULUNG, ALONG LONG. 86° 8'.




DIAGRAMMATIC SECTION FROM THE MON LA TO THE LAMNA LA, ALONG LONG. 86° 42'.



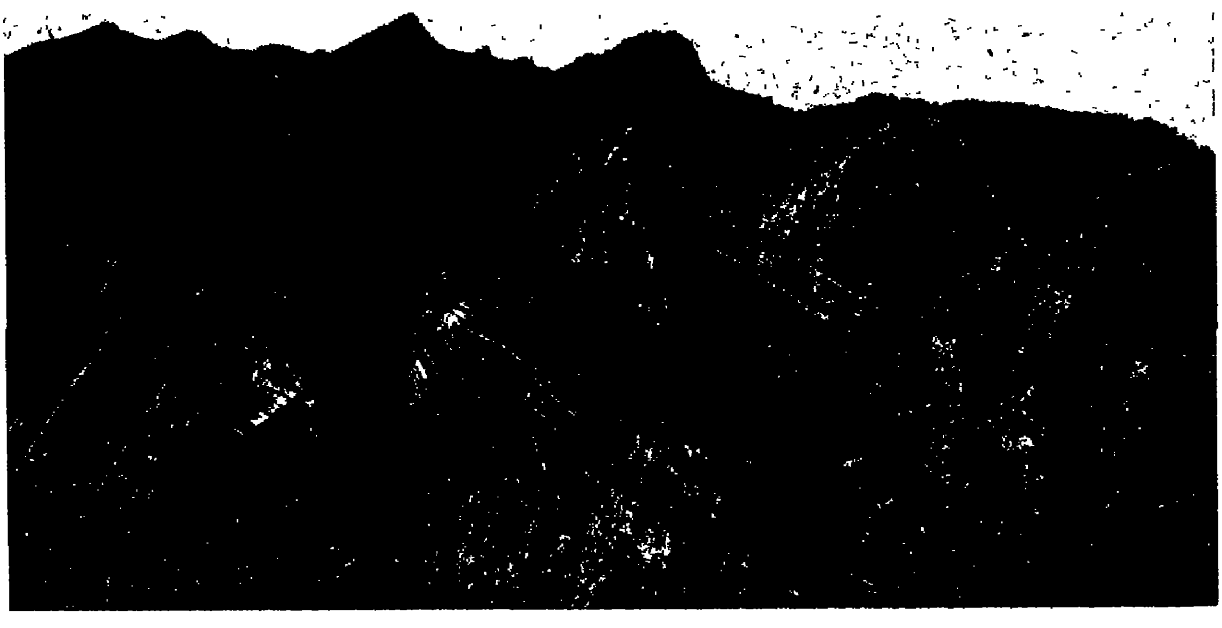

DIAGRAMMATIC SECTION THROUGH SHEKAR, NAMDA AND HLELUNG.

Thicknesses of formations shown have no exact significance.

*Scale of sections 4 miles to 1 inch.*

*Litho G. S. I. Calcutta.*

FIG. 1. ALLUVIAL GRAVEL TERRACES AND HILLS OF JURASSIC SHALES, KYISHONG, PHUNG CHU VALLEY.



*A. M. Heron, Photos.* *G. S. I. Calcutta.*

FIG. 2. FOLDED CRETACEOUS LIMESTONES, MEN CHU, ABOVE MEN TO.

FIG 1 FOLDED JURASSIC SHALES NEAR MEN TO

I M Heron, Photos

G S I Calcutta

FIG 2 GENERAL VIEW OF PHUNG CHU VALLEY, FROM MEMO LOOKING EAST, TSIFRI RIDGE ON LEFT

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FIG 1 SYNCLINAL HILL OF CRETACEOUS LIMESTONE, MEMO, PHUNG CHU VALLEY.

A M Heron, Photos G S I Calcutta

FIG 2 EASTERN END OF TSIPRI RIDGE, SHOWING FOLDED CRETACEOUS LIMESTONES

FIG 1 FOLDED CRETACEOUS LIMESTONES, PALDING, NEAR DZAKAR CHU

A. M. Heron Photos — G. S. I. Calcutta

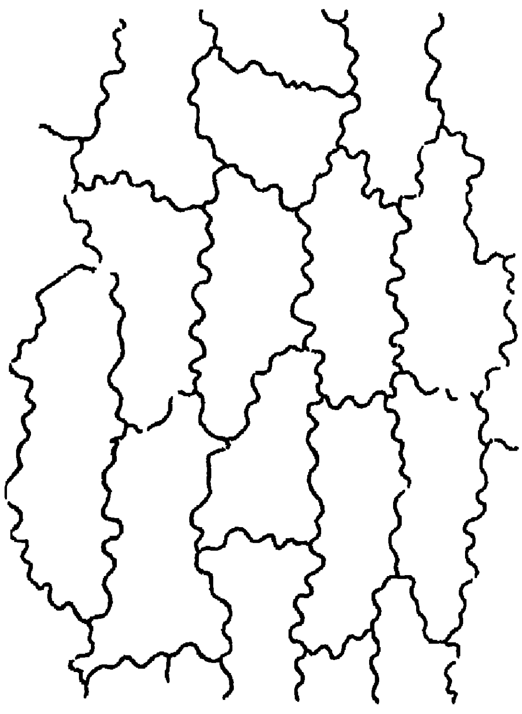
FIG 2 FOLDED CRETACEOUS LIMESTONES RIPHE NEAR DZAKAR CHU


Photographs by S. C. Mondal

Photogravure Survey of India Offices Calcutta 19

TERTIARY MOLLUSCA FROM SIND AND BURMA


TERTIARY MOLLUSCA FROM SIND AND BURMA



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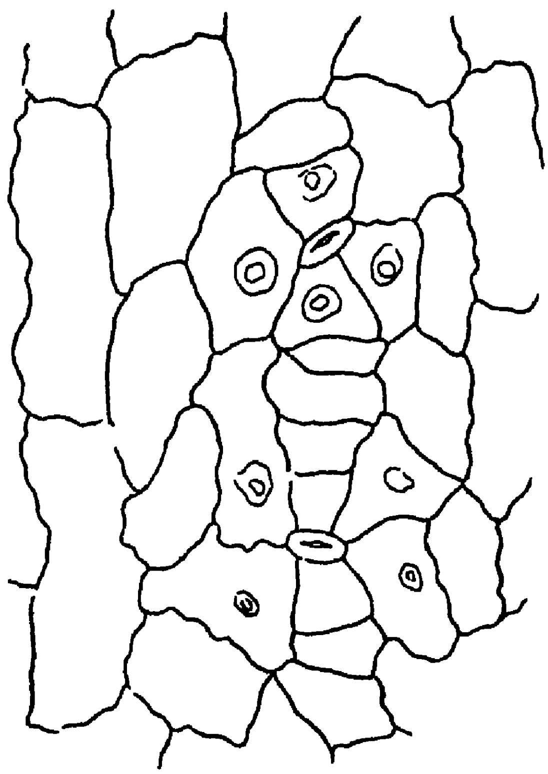

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B Sahni, Photo G S I Calcut

Fig 1. *Glossopteris angustifolia* Brongn.—Portion of a frond collected at Raniganj *Natural siz*

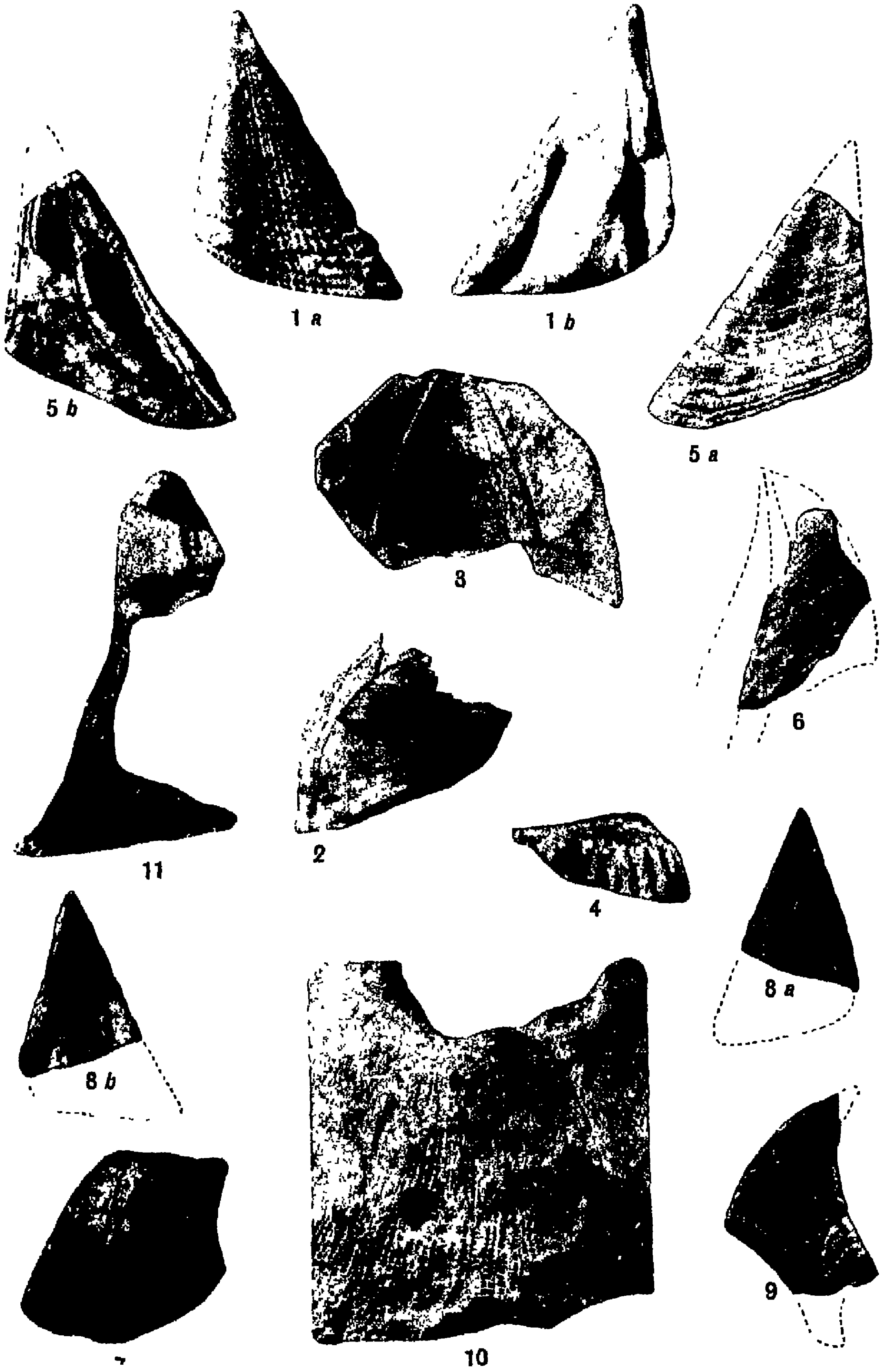
Fig 2 *Glossopteris angustifolia* Brongn —Camera lucida sketch of upper epidermis *Circa* × 24

Fig 3 *Glossopteris angustifolia* Brongn – Camera lucida sketch of lower epidermis, showi stomata subsidiary cells and scars of emergences *Circa* × 240.


*H G Hunm , Photos*

TERTIARY BALANI

*G S I Calcutta*

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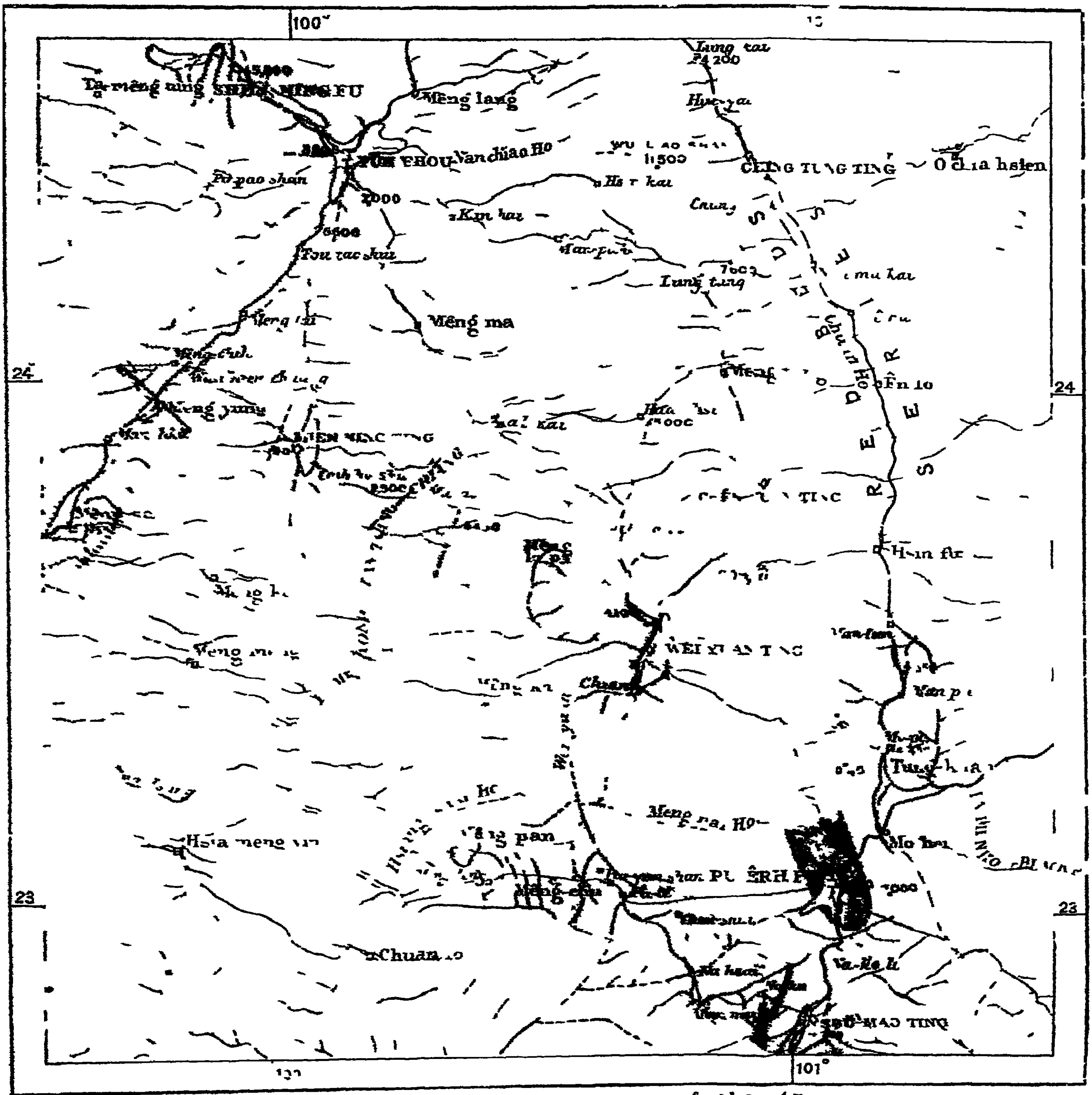


# GEOLOGY OF YUNNAN.

Sh... Fu, Pu-êrh Fu, etc

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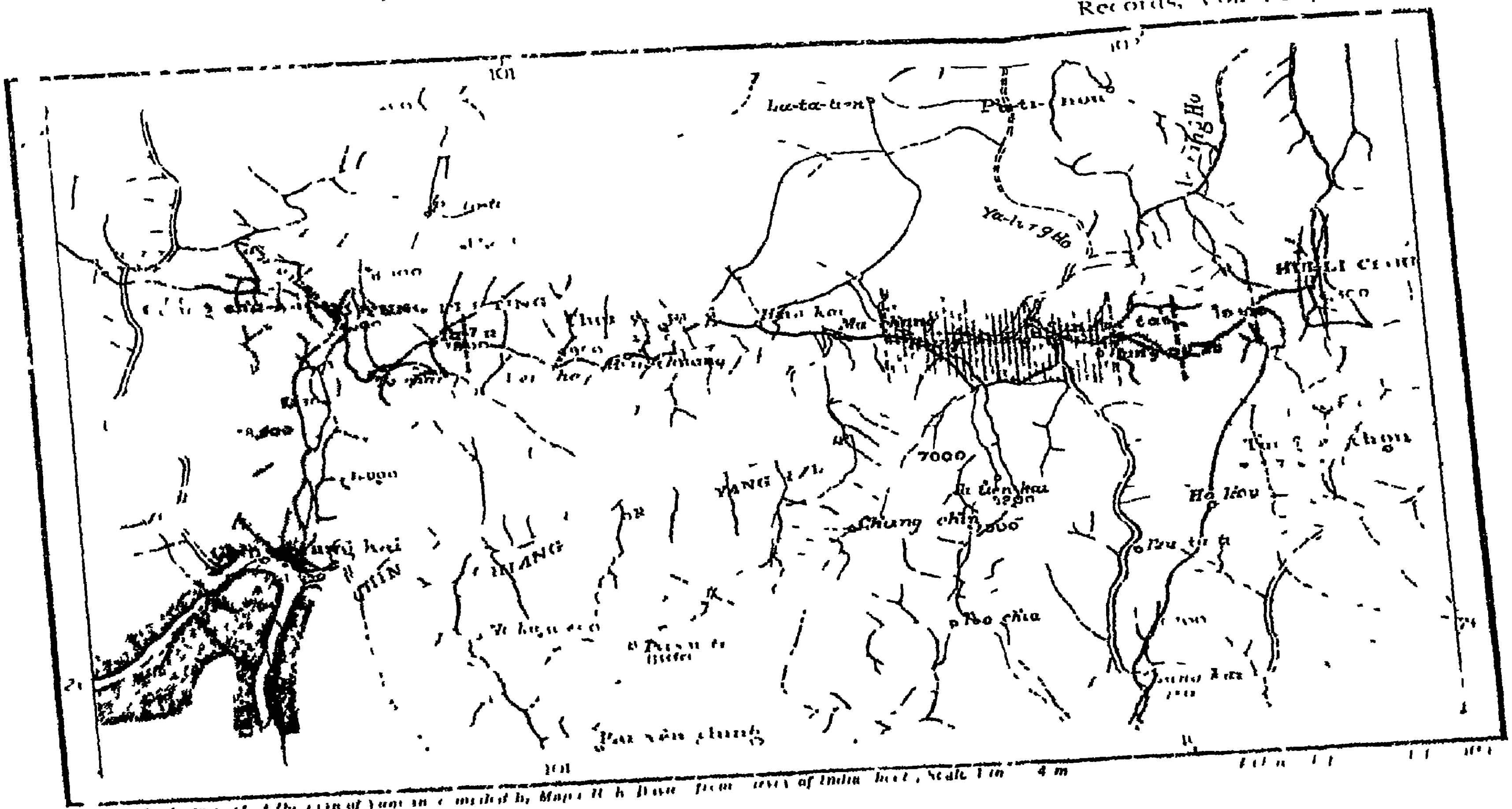
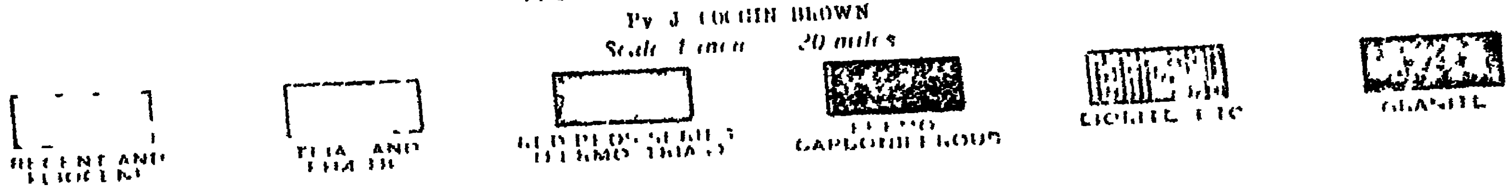


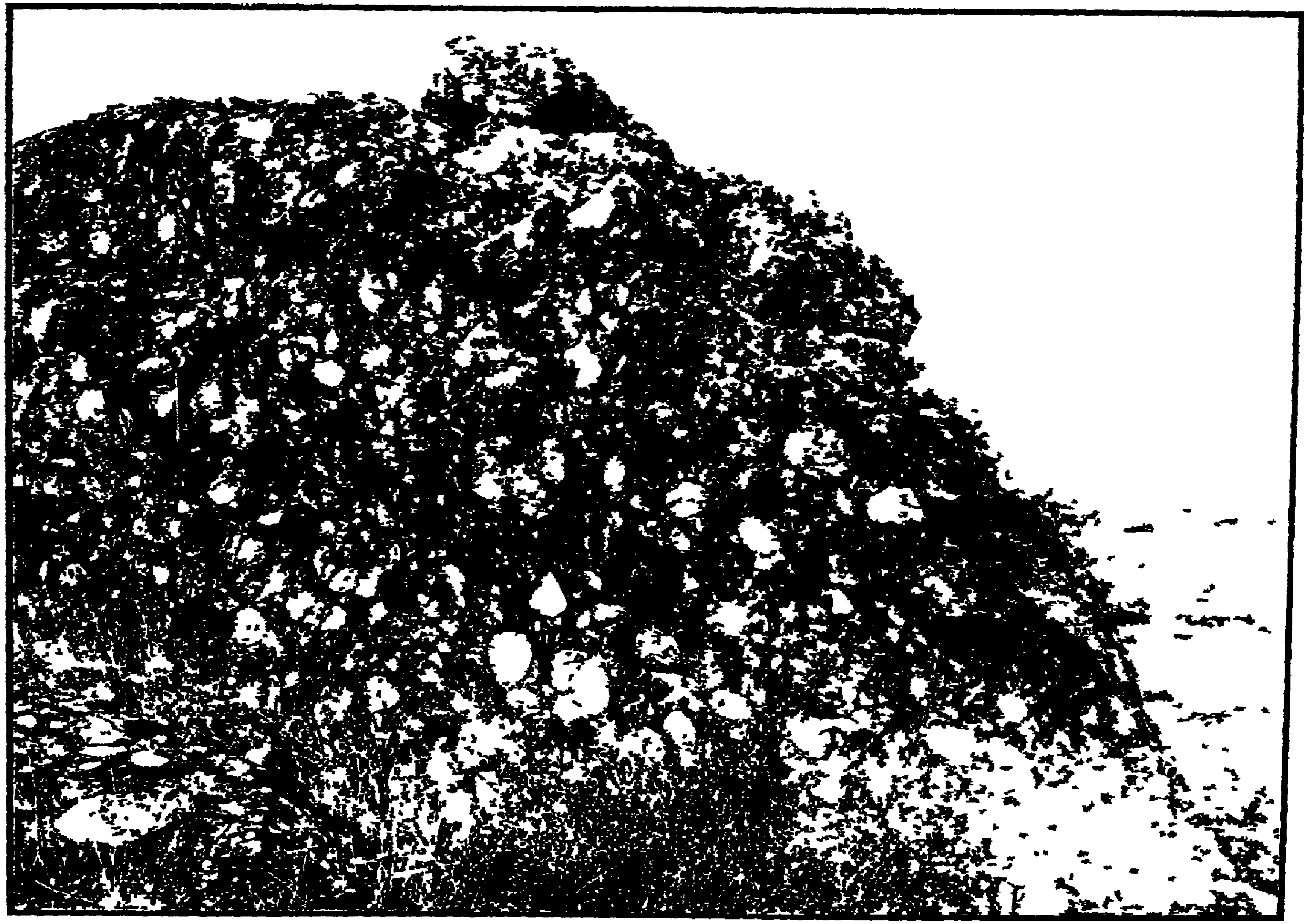

# GEOLOGY OF YÜNNAN.

Traverse in the Yangtze Valley

By J. COGGIN BROWN

Scale 1 inch = 20 miles





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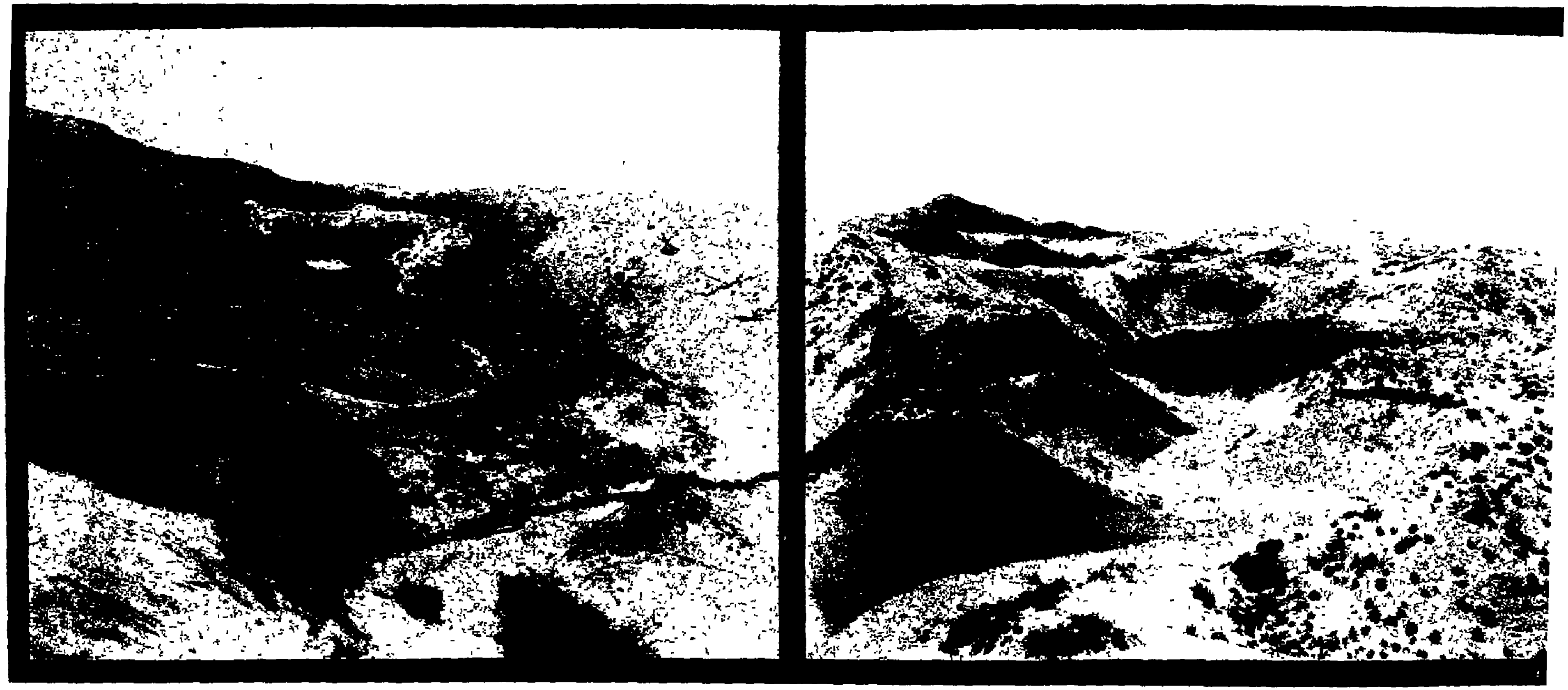
LALGARH CONGLOMERATE.

FIG 1 TOPOGRAPHY OF AJABGARH SCHISTS AND QUARTZITES WITH EPIDIORITES
8 miles south of Khetri, (looking north)

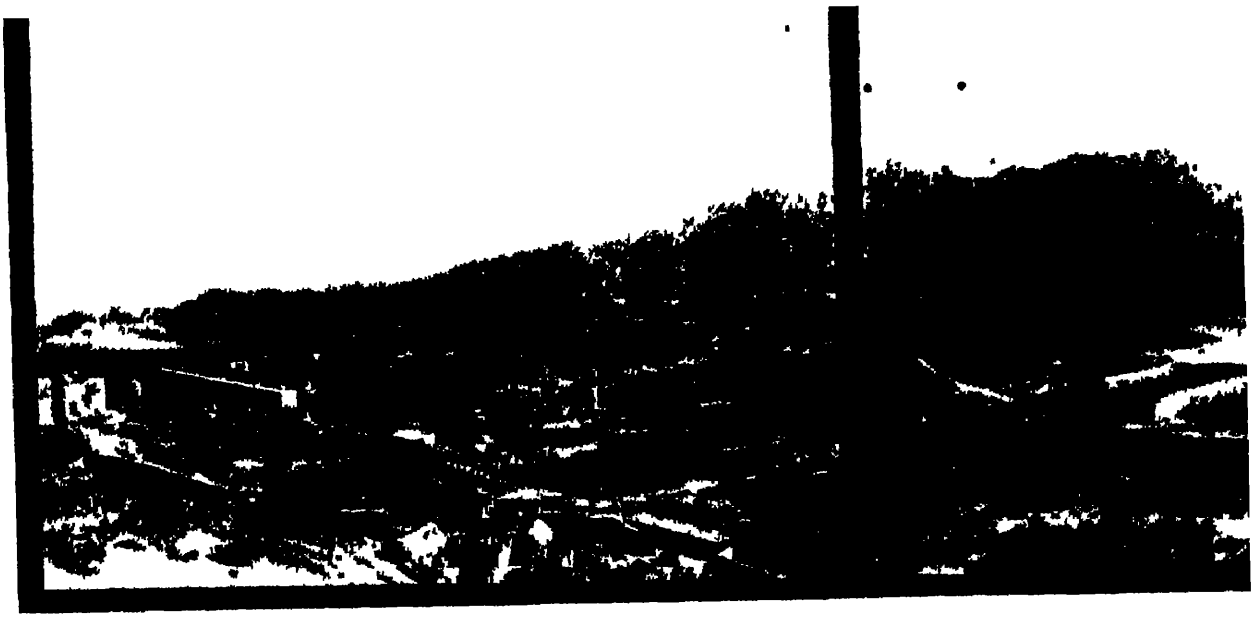
A M Heron Photo G S I Calcutta

FIG 2 TOPOGRAPHY OF AJABGARH SCHISTS AND QUARTZITES WITH EPIDIORITES,
8 miles south of Khetri, (looking north east)



*A. M. Heron, Photo.* *G. S. I. Calc*

SANDHILLS ON WEST SIDE OF RANGE, NEAR KHETRI, (looking south.)



A M Heron, Photo

PANORAMA OF KHETRI, showing sulphate evaporating

*G S. I Calcutta*

ƺ pans (centre), and sand drifted over range (right)