V. *The Geology and Physical Geography of Chinese Tibet, and its Relations to the Mountain System of South-Eastern Asia, from Observations made during the Percy Sladen Expedition*, 1922.

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PART I.—THE ENIGMAS OF CHINESE TIBET AND PREVIOUS LITERATURE.

1. The mountainous highlands of south-western China, Chinese Tibet and north-eastern Burma, consist of a high platform which projects southward from the Tibetan tableland. That platform lies along the foundations of the ancient Indo-Malayan mountains and athwart the eastern end of the Himalaya. It appears, on examination of a map, to have caused the eastern continuation of the Alpine-Himalayan Systems to have been diverted southward as the Burma and Malay Arcs. Further to the north-east the tableland of east central Asia ends abruptly above the lowlands of eastern China. Its eastern front forms the Great Khingan Mountains, which have been regarded by the late Prince KROPOTKIN (1904, p. 333) as the continuation of the Himalaya. This view of the eastern prolongation of the Himalaya into central China has been also adopted by ARCHIBALD LITTLE (1905, map opposite p. 19, and p. 209). The whole geography of south-western China and the adjacent lands is dominated by the interaction of mountain movements belonging to two far-distant periods. The older mountains, the Indo-Malayan, belong to the Hercynian group of earth movements, which happened toward the end of the Paleozoic Era. The younger mountain system, the Himalayan, is Kainozoic, and though its uplifts happened at intervals from Upper Eocene to Pliocene, its movements culminated in the Middle Kainozoic, and were probably most important in the Oligocene and Miocene. The mountain plan of south-eastern Asia has been considered as a combination of the mountain lines of Eurasia, which trend from W. and E., with the border chains of the Pacific, which cross at high angles the eastern end of the Asiatic mountains.

The history of the Indian Ocean is incomplete, until it be known what was happening on its north-eastern side synchronous with the movements which made the rift-valleys of East Africa. Chinese Tibet is one of the critical areas for the solution of these problems, for it is opposite the eastern end of the Himalaya. This country has also attracted attention from the parallelism of the three great rivers which cross it.

The geographical relations of the mountains of Chinese Tibet and Yunnan were the more difficult of determination owing to the contradictory interpretations that had been given of their structure. VON LOCZY (1893, p. 759) regarded the plateau of central and southern Yunnan, which he compared to the Dinaric Alps, as intensely folded, as it had been jammed against older blocks to the south. This view was developed by DEPRAT (*e.g.* 1912, pp. 256, 315–6) and adopted by COGGIN BROWN (1920, p. 59); on the other hand VON RICHTHOFEN (1900, pp. 899, 916, 919) described the plateau of northern Yunnan as a horst, and its curved southern border, his "Yunnan Bogen" (the Yunnan Arc of DEPRAT), as the steps from the horst down to the southern lowlands.

Chinese Tibet is a land of many geographical enigmas, to which the answers depend on the geological structure of the country. We were therefore glad of the opportunity, aided by a grant from the Trustees of the Percy Sladen Memorial, to visit a part of Chinese Tibet which offered to throw special light on the geographical, geological and biological problems of south-eastern Asia.

2. *Previous Work.*—The foundation of the geology of this area was laid by LUDWIG VON LOCZY, the former head of the Geological Institute of Hungary, who accompanied GRAF BÉLA VON SZÉCHENYI in his expedition across western China from 1877 to 1880. VON LOCZY'S work (1897 and 1899) showed the structure of the belt of country along his route from Ta-chien-lu westward to Ba-tang, thence S.S.E. to the Upper Yangtze, across it and the mountains east of it to Ta-li-fu, and thence westward to the Irawadi at Bhamo. VON LOCZY prepared a most valuable geological map of the whole of this route and instructive geological sections across most parts of it.

The second main contribution is by Mr. J. COGGIN BROWN (1913–23 and 1920), who, on behalf of the Geological Survey of India, surveyed the country from Bhamo eastward to Yunnan-fu and also prepared a general memoir on the mineral resources of Yunnan. Between the Burmese frontier on the west and the belt of which the geology was determined by VON LOCZY on the east, and to the north of the belt surveyed by him and COGGIN BROWN, lay an area of which the geology was unknown. Important information on some adjacent areas has been contributed by LEGENDRE (1916) for the country from Ta-chien-lu south to Yunnan-fu; by DEPRAT (1912, &c.) for south-eastern Yunnan in connection with his well-known monographs on Tongking; and by Mr. MURRAY STUART (1919) in north-eastern Burma, of which, however, his observations to the north-east of Bhamo have not yet been published.

Valuable information on the country to the south of the area visited has been given by various workers in the Shan States and especially in the important memoir by LA TOUCHE (1913). Recent mining operations in the country north of the Shan States and north of Teng-yueh have yielded important information which has been recorded by M. H. LOVEMAN (1919) and A. M. THOM respectively. In the area to the west of VON LOCZY'S route, north of the Bhamo–Ta-li-fu road and east of the Burmese frontier, the only geological information known to us consisted of occasional records of rocks by various travellers. The late ABBÉ DESGODINS (1876) collected Carboniferous fossils and described the red sandstones of the salt basin at Ya-ka-lo, near Ba-tang; his further results were incorporated in the memoir by VON LOCZY. Mr. KINGDON WARD (1913, &c.) has shown the former extension of the glaciers, has described the formation of the river valleys, recorded rocks from various localities within the area, and made a collection of rocks from Mi-li, east of the Yangtze.

The primary contribution to the topography of the area was by GILL, who traversed much the same route as VON LOCZY. General H. R. DAVIES' (1909) volume on Yunnan and his map, which was compiled from the work of himself, Colonel RYDER, General Sir C. C. MANIFOLD, and others, are the main authorities for the geography and cartography of the province. Subsequently M. BACOT (1909 and 1912), the distinguished French Tibetan scholar and traveller, has described many new routes across the country. Mr. GEORGE FORREST (1908), in addition to his invaluable contributions to the flora of the area, has described part of the valley of the Salween, which he explored in his joint expedition with the late G. LITTON. Dr. HANDEL-MAZETTI (1919, 1921) has contributed an important map, based upon five years' work from 1914 to 1919, during which he made extensive collections; his memoir contains important contributions to the glacial geology of the country. Mr. OLIVER COALES (1919) and Mr. ERIC TEICHMAN (1922), both of the Consular Service, have contributed to the geography, especially of the down country of Tibet, to the north of VON LOCZY's route. Colonel F. M. BAILEY (1912), in his daring journey from Ba-tang to Assam in 1911, in addition to his topographic discoveries, showed that the area he traversed was mainly composed of Archean rocks.

The object of our expedition was to cross the geologically unknown areas along such lines as would appear to throw most light on the mountain structure of Chinese Tibet and on the development of its existing physiography. As our work was geologically a reconnaissance survey, our observations may prove of most use if they are so stated that they can be linked on to the new routes that may be geologically surveyed. Hence it appears desirable to record briefly the observations made along our route and then summarise the general results as regards the stratigraphy, palæontology, glacial geology, petrology, and physiography. The conditions under which the observations were made are described in a narrative of the expedition published by the authors, 1923—3.

We are much indebted to Dr. GERTRUDE L. ELLES and Dr. F. R. C. REED for appendices on the Graptolites and on the Mollusca and Brachiopoda collected; also to Mr. R. B. NEWTON, Dr. F. A. BATHER, Dr. W. D. LANG, Dr. STANLEY SMITH, and Mr. W. N. EDWARDS for examining some of the other fossils. To Dr. G. W. TYRRELL our thanks are due for frequent help and advice as to the rocks, and to Miss ETHEL CURRIE for the drawings in Plate 8. We are also deeply indebted to Mr. E. A. REEVES, of the Royal Geographical Society, who kindly calculated the heights of our boiling-point stations and superintended the drawing of our map of the route (*cf.* Plate 7).

Arrangements for the journey were greatly aided by the kind advice of Mr. COGGIN BROWN, Mr. V. K. TING, then Director of the Geological Survey of China, and

Mr. KINGDON WARD. During the journey we received generous hospitality and help from Mr. H. P. HEWITT, District Commissioner of Bhamo; Mr. O. COALES, the Consul at Teng-yueh; Mr. J. H. W. HOUSTON, Imperial Commissioner at Teng-yueh; Rev. P. KLAVER and Mr. G. FORREST at Li-kiang; Rev. A. G. LEWER at Wei-si; Pères OUVRARD, GENESTIER and ANDRÉ of the French Mission to Tibet; M. G. PERONNE at A-tun-tze; and Mr. W. N. FERGUSSON.

PART II.—GEOLOGICAL STRUCTURE OF THE COUNTRY TRAVERSED.

§ 1. *Bhamo to Yung-chang-fu.* (See Map, Plate 7.)

The first section of our journey was across the mountainous borderland along the Burmese-Chinese frontier. The section from Bhamo on the Irawadi to the Chinese Treaty Port of Teng-yueh, 90 miles beyond the frontier, is well known as it has been described by Mr. COGGIN BROWN (1913). We passed most of the way south of his route—the historic Ambassadors' Road on the northern bank of the Taping River. We went by a new road south of that river. The geological conditions along both roads are essentially similar. The country consists of a broad belt of gneiss, schist and granite, including some limestones. Upon this foundation rest lavas of Kainozoic age near Teng-yueh, and some deep basins contain Upper Kainozoic clays and brown coals. It has been suggested that some of the granite in the basal series is much younger than was thought, and is in part Upper Paleozoic in age, as some limestones of that age are enclosed in the foundation. We had to hasten across this area, and could only examine the rocks close beside the track; we saw nothing to throw doubt on Mr. COGGIN BROWN's conclusions as to the pre-Cambrian age of the granites.

As the strike of the rocks is significant as to the mountain structures we recorded it at intervals. We first observed it 18 miles from Bhamo, where it is 60° in a coarsely grained porphyritic gneiss. At 23 miles, just before the bungalow at Kuli-kha, in a similar rock, the strike is 40°, and it is the same at 24 and 28 miles, at the latter of which the dip is 80° S.E. From 28 to 30 miles, strikes were observed of 60° and 67° in rocks, some of which resemble the gray Lewisian gneisses of Scotland, and some, by the regular banding, the Moine gneiss. At 30 miles, above a fort in a horseshoe bend of the Taping River, muscovite-gneiss is succeeded by a crystalline limestone. From the village of Pa-chiao-chai at 46 miles, to the frontier at 51 miles, the common rock is a crystalline limestone with green silicates and bands of pegmatite. Coarse gneiss reappears and near the 54th mile-post is represented by a rock resembling a rhyolite by its well-marked fluxion; but a microscopic section showed that this structure is due to flow during brecciation.

Between 56 and 57 miles the gneiss strikes 60°, and after crossing the Kan-ai basin this strike recurs in the gorge of the Nam-ti River leading to the Nan-tien basin. Near the stepped ascent in this gorge is a schistose quartzite, including varieties similar to those of the Scottish Highland quartzite.

The foliation of the gneiss in this part of the Taping valley is, therefore, on the average about N.E. to S.W. and E.N.E. to W.S.W., instead of from N. to S., which is the predominant trend in Indo-China. The limestones are very well shown on the southern road, as between miles 48 and 50 and near the 30th mile-post. They are holocrystalline and contain streaks blackened by graphite, green bands due to forsterite, and a pyroxene, which Dr. Tyrrell has kindly determined as a colourless diopside of the variety malacolite. These limestones appear to us to correspond with those of the Eozoic or oldest of the pre-Paleozoic divisions. The occurrence of granitic intrusions of Upper Paleozoic age along this belt had appeared to us probable; but we saw no evidence on the route traversed to support that supposition.

The Kainozoic volcanic rocks near Teng-yueh, as Mr. Coggin Brown (1913-1, pp. 188–199) has shown, belong to two distinct series. The older lavas have been steeply tilted and greatly denuded; their high dips suggest their pre-Miocene, and possibly pre-Oligocene age, for they were earlier than the last epoch of mountain disturbance in this area. The later lava flows are obviously Pleistocene; there appears to be no record or tradition of volcanic activity at Teng-yueh; the last eruptions may be earlier than those of Mt. Popa in Burma, which continued into historic times.

East of Teng-yueh the foundation of gneiss reappears on the plateau, covered at intervals by remnants of the earlier lavas. East of the Shweli River the gneisses disappear beneath the green schists, quartzites, phyllites, and slates of the Kao-liang series. The prevalent dip in these rocks is eastward, and it is often gentle, as *e.g.*, 5°, 12°, and 15° in the cherty siliceous schist at Hsiao-pien-ho on the summit of the Shweli-Salween divide; in places the dip is vertical or even inverted. The strike is generally between N.W. to S.E. and N.N.W. to S.S.E. In the descent of the eastern slope of the divide toward the Salween the strikes noted varied from 5° W. of N. to N.E. by E. The rocks include dykes of pegmatite (with muscovite mica one and a half inches in diameter), green schists, and phyllites, and in the upper part of the series near the Salween occur quartzite, slate, and some thin bands of crystalline limestone. On the floor of the Salween valley are the relics of a thick deposit of red sands. They now extend from 2200 feet at the level of the Salween to the height of 3500 feet up the flanks of the valley, and they form the conspicuous red hills on its floor. These residual hills are due to an increase in the power of the Salween, which enabled it to wash away most of the sheet of red sands.

The Shweli valley appears to have been determined by a fault line, for the western front of the range which forms the Shweli-Salween divide, has the aspect of a weathered fault scarp. The Salween basin, on the other hand, has been probably determined in the main by erosion of the soft slates and limestones of the upper part of the Kao-liang Series. The high cliff at the eastern end of the Salween Bridge consists of a white dolomitic and brecciated limestone, which forms the southern part of the hills between the Salween and a river to the east that flows from Ta-pan-ching past Taio-cho-shui.

Around the latter village are beds of limestone breccia composed mainly of fragments of the Kao-liang limestones. Of the age of this breccia we obtained no conclusive information. Similar breccias have doubtless been formed in the country at various times ; but the breccia at Taio-cho-shui may be part of the sheet which occurs five miles to the N. around the village of Ta-pan-ching, where it underlies the red shales. If so, both outcrops of limestone breccia are pre-Devonian and belong to the Kao-liang Series.

The gorge of the Ta-pan-ching River presents a very instructive section, of which the facts recorded in our note books during our hasty traverse of the gorge indicate the following incomplete sequence. The rocks have been thrown into a series of folds and have also been traversed by faults, and in one place by a small thrust-plane. The predominant strike of the rocks is from 330° to 340°, so that the grain of this block of hills, of which the western front here trends N. and S., is cut across obliquely by the Salween valley ; hence the Salween valley, like that of the Shweli, is bounded on the E. by a dissected fault scarp. After leaving Taio-cho-shui the Kao-liang limestones and limestone breccia extend up the valley for a short distance ; at the bridge by which the road crosses to the eastern bank of the river they have disappeared beneath buff to gray sandstones, which are seen at intervals in the ascent of the gorge.

The sandstones are succeeded by black shales with an interbedded bluish limestone with irregular calcite veins. In the second outcrop of this limestone we saw some obscure fossils on the face of a slab of limestone ; the specimens collected are indeterminable. Above the limestone-black shale series occur red shales. In the lower part of the gorge the red shales are cut through by a vertical diabase dyke. Above the point where we observed the fossils is another outcrop of diabase, but we did not see the junction ; a large sheet of diabase caps the hill on the western side of the valley at Ta-pan-ching village, and there are extensive outcrops of diabase on the northern front of this range near the market town of Fang-ma-chang. This diabase overlying the shales at Ta-pan-ching and that seen at the level of 3400 feet on the track are doubtless both intrusive.

Faults of two types were seen in the gorge. Nearly two miles south of Ta-pan-ching the red shales on the right bank are faulted against the sandstones, and a little farther up the valley some vertical red shales are cut off below by black shales, owing to a nearly horizontal fault in which the heave of the overlying beds is to the south. At Ta-pan-ching a beautiful limestone breccia reappears on the floor of the valley and forms the lower part of the western wall, where it underlies the red shales. The fossils found here are indeterminable, but the microscopic character of the limestone indicates that the series is Carboniferous.

From Ta-pan-ching the track rises northward to the pass (altitude 4600 feet) leading to Fang-ma-chang and the valley of Pu-piao. To the N. of Ta-pan-ching the hills on both sides consist largely of diabase. The exposures on the track are of a brown sandstone which is veined in places ; this rock is followed by purple shale, which appears to be the lower part of the red shale series, as further N. it is followed by blue and white sandstones which dip S. The same rocks are found on the beds of the streams from both sides of the valley. The pass is on diabase, beneath which, to the N., the upper limestone reappears, and it is still dipping S.

Below the limestone are shales with limestones containing crinoid stems and calcareous concretions. East of Fang-ma-chang the ground rises to exposures of diabase, which is vesicular and probably eruptive. The south-western side of the Pu-piao valley has the aspect of a fault-scarp trending from N.W. to S.E. Distant views suggest that this fault is cut off to the W. by the major fault along the eastern side of the Salween trough.

The lower part of the southern side of the valley between Fang-ma-chang and Pu-piao consists of shales interbedded with the blue, gray-weathering, white-veined Minchia limestone. Above this series lies a thick, earthy limestone which is pale gray to cream coloured, is not interbedded with red shales, has a gentler dip, and contains very few calcite veins. The base of this limestone, at the level of 5000 feet, yielded some well-preserved crinoid stems and a fossil coral. Though we saw no definite junction, the upper cream-coloured limestone probably rests unconformably on the veined limestone series.

The Pu-piao basin ends to the S.E. at some gravel hills, which have the aspect of a moraine, though they were clearly not formed by ice. The north-eastern bank of the Pu-piao valley rises steeply to a limestone plateau. The lower part of the slope E. of the town of Pu-piao is an inlier of steeply tilted Ordovician beds, which were discovered by VON LOCZY (1899, p. 767) and have been carefully investigated by COGGIN BROWN (1916, pp. 232–3). The upper part of these Lower Paleozoic beds is a pink marl, which at the height of about 6400 feet is covered unconformably by a massive limestone which weathers into karst-like forms. We found no fossils in it, and its slight dip, which is to the S., shows that it is unconformable to the Ordovician. The bed is thicker and the rock of different characters from the veined Minchia limestone, and it is doubtless younger. Good sections are shown along the bank of the valley of Leng-shui-ching : the strike there is N. and S., and the dip W., the normal dip having been resumed after the disturbance along the Pu-piao basin. East of Leng-shui-ching the track rises again on to the undulating plateau of yellow shales and calcareous shales which dip W. The country descends gently to the N.E. with sections showing buff sandstones and irregular shales, interbedded with a limestone which is much like that of some of the cement stones of the Scottish Lower Carboniferous. The beds dip to the W.

This series ends at a deep valley through which the road descends to the Yung-chang basin at the village of A-shih-wo. Below the cement stone is a series of sandy shales and two beds of limestone which contain Carboniferous fossils, including Fenestella, simple corals, plates of *Melonites*, large crinoid stems, with a crinoid crown like *Amphoracrinus*, and various brachiopods. Near A-shih-wo this series rests on more steeply dipping red shales, interbedded at 5600 feet with a band of the veined limestone and a sheet of diabase. Red shales again outcrop at the base of the series just above the village (altitude 5500 feet).

From A-shih-wo to the city of Yung-chang-fu the road crosses alluvial plains which end to the N.W. at the foot of a steep hill front in which are exposures of red shales and sandstones; these beds rise to the N. until near the city of Yung-chang they form most of the lower part of the slopes.

The plateau between Pu-piao and A-shih-wo may be regarded as capped by Carboniferous rocks of a cement-stone type, overlying fossiliferous, thin-bedded Carboniferous limestones, which at A-shih-wo rest unconformably upon the red shales, sandstones, and diabase.

§ 2. *Yung-chang-fu to Yun-lung.*

The main road into southern China from Yung-chang-fu crosses alluvial plains that end to the N.W. at the plateau-front, in which are seen exposures of the red rocks of the lower part of the Carboniferous. At Pan-kiao we turned northward into mountainous country between the Salween and the Mekong, which was geologically quite unknown. We continued through irrigated rice-fields to the village of Sha-pa-kai at the foot of the hills, which we entered along the valley of a small stream. From this valley a low pass led to a deep basin, which is drained through an outlet on the western side to the head stream of the main river of Yung-chang. This basin was clearly once part of the valley of the stream above Sha-pa-kai, which has been beheaded by the western outlet. The rocks along the outlet valley and the larger stream to the W., which rises near Lan-tien-pa, consist of reddish shale, that become yellowish when weathered, of veined blue limestone that often occurs in thin bands, banded cherts, black shales, and basalt or diabase. The ridge to the N. of the outlet valley consists mainly of banded limestones, in beds from 1 to 2 feet thick and dipping 12° W.; they are accompanied by a sheet of diabase which has been in places altered to laterite. The banded cherty limestone is also exposed just N.W. of Lan-tien-pa, a village near the head of the Yung-chang River, on the divide between the Salween and the Mekong. The divide is formed by a series of low drift hills deposited across a long N. to S. valley, in which the Yung-chang River once rose farther to the N. Some of the Salween drainage has here been captured by the Mekong.

The strike of the rocks in this district is in general from N. to S., with a dip to the W. The strike trends 30° with a dip of 70° westward along the pass just N. of Sha-pa-kai; it is about 10° in the banded limestone and cherts N. of the new outlet from the basin of Sha-pa-kai; a little further N. the strike is altered to a direction of nearly E. and W. South of Lan-tien-pa the bedded limestones strike to W.N.W. with a dip of 15° to S.S.W.; and just N. of that village they strike W.S.W. and dip S.S.E. A little further N. they still strike to W.S.W. Further N. of Lan-tien-pa the strike again becomes nearly meridional, as its direction is to 10° E. of N., and its dip steeply to the E., and later on the dip is 45° W. Further N., E. of the valley of A-shih-chai, the strikes vary from 20° to 30° E. of N.

The country rises to the W. to the high Salween-Mekong divide, which a little to the

N. appears rough and broken and doubtless consists of gneiss; from this part of the range a series of rugged spurs pass off to the N.N.E., while the trend of the main range is meridional. Hence the trend of the range is not determined by the grain of its rocks.

The drainage from the A-shih-chai basin is through a deep gorge which turns eastward to reach the Mekong. We descended into this gorge from the Lolo hamlet of Cheng-mu-pa. At the beginning of the descent occurs a hard rectangular jointed shale formed of thin bands alternately black and white; the strike is N.E. with a dip of 15° S.E., but this dip increases in a few yards to 30°. Our search for fossils on the southern side of the valley was fruitless. On the floor of the valley (at 6060 ft.), 300 ft. lower, the strike of the shales is 10° W. of N., with a steep variable dip to the W. The lower part of the northern bank of this gorge consists of a buff shale of which the joint blocks when unweathered are blue-hearted—and contain graptolites which show that the valley cuts through an inlier of the Ordovician. The graptolites have been determined by Dr. Elles (Appendix II) as *Climacograptus scharenbergi*, LAPW., *C. bicornis* (HALL), *Cryptograptus tricornis* (CARR.), and *Amplexograptus perexcavatus* (LAPW.); she refers them to the zone at the junction of the Lower and Middle Ordovician. Above the graptolite beds at 6500 ft. are green shales which pass up at 6600 ft. to thin-bedded black and white shales, like those seen immediately N. of Cheng-mu-pa. A hundred feet higher is a black shale with a strike to W.N.W. and dip N.; it yielded an obscure graptolite which Dr. Elles has determined as *Climacograptus* sp. These Ordovician beds are covered by a band of tuff, above which, at the village of Lao-wu (6900 ft.) is an outcrop of earthy limestone. N. of Lao-wu the red and buff weathering shales are exposed on the edge of the plateau. From there we looked down into the valley of the Mekong at a conspicuous back bend, which represents, on a small scale, the N.-shaped bends of the Ya-lung and the Yangtze, which occur along the same line farther to the N.E. The back bend of the Mekong is in line with the Ho-wan valley, and they both lie along a change in the strike; the beds trend to W.N.W. and dip 33° to the N.N.E. In the upper part of the descent to the Ho-wan valley we crossed an earthy limestone with an imperfect Orthoceras. The lower part of the steep descent to the Ho-wan bridge (5000 ft.) is over weathered shales with a strike to E. by S. Beside the bridge is an outcrop of limestone, which is nearly vertical and strikes to N. by W. The valley is littered with large boulders of coarse gneiss and schist, which have clearly been brought down by a tributary to the Ho-wan from the rugged hills along the Mekong-Salween divide.

The Ho-wan valley trends generally W.N.W. in line with the back bend of the Mekong. West of the village the rocks include hard green and black shales with rectangular jointing. Some of them are silicified and quartzitic. The strike is from N. to 20° W. of N. with steep dips as, *e.g.*, 70° eastward. We found no fossils in these beds, but they agree so closely lithologically with the unfossiliferous upper part of the Ordovician beds S. of Lao-wu that they may be regarded as an extension of those rocks. Along the valley there are many large boulders of gneiss and schist which have come from the hills to the W. and W.S.W. Below the village of La-shi-pa we crossed limestones, including oolitic bands, striking to the W.N.W. and dipping N.

Beyond La-shi-pa the Ho-wan valley continues towards a deep gap in the Salween-Mekong divide, which, with the Ho-wan valley and the back bend of the Mekong, are probably due to erosion along a fracture across the main grain of the country.

At La-shi-pa we turned N. up a tributary valley and reached the village of Ma-un-shan, where the limestone strikes W.N.W. with a dip of 60° N.N.E. About a mile from the village, following a stream from the N.W., Eozoic rocks rise from beneath the shales; the first of these rocks seen was a white crystalline limestone, followed by coarsely crystalline schistose quartzite, purple mica schist, schistose pebbly quartzite, a paragneiss with a strike to N.N.W., and coarse-grained felspathic and hornblendic-gneiss. These rocks continued to the village of Chung-tang, where they include a varied series of porphyritic gneisses, granulites containing granite veins, epidotic gneiss, and rocks altered by pneumatolytic action into bands of kaolin containing large radial groups of tourmaline.

The special industry of this village is smelting a brown hæmatite, which is mined an hour and half's distance from the village. The ore, we were told, comes from rock similar to that at the village. From Chung-tang (6600 ft.) a steep path climbs to the ridge along the western side of the Mekong gorge. The rocks seen in the ascent are biotite-gneiss and coarsely porphyritic gneiss and schist; they strike W.S.W. or W.N.W., or N.W., and dip. S. or are vertical. At the summit (9500 ft.) the strike alters to N.N.W. On the higher part of the range occurs much chloritic schist with some bands of pegmatite associated with kaolin and schorl rock.

The summit commands an impressive view up the deep trough of the Mekong. The main trend of the valley and the strike of the rocks are to N.N.W. A series of spurs project N.N.E. from the western wall of the valley and the streams between them flow in a direction opposite to that of the Mekong and they join the river like barbs. The direction of these spurs may be due to denudation along the strike of the beds in the lower part of the valley wall.

Just below the summit the schists strike to N. 67° W. and dip 60° W. The upper part of the wall includes blue schists, quartz-schists, and a strongly banded Moine-like gneiss. At 7800 ft. the well-banded gneiss strikes to N.N.W. At 7000 ft. white banded gneiss, which is invaded by veins of granite, contains large black inclusions, and resembles the rock at about 30 miles from Bhamo in the Taping gorge. At the level of 6400 ft. the road enters a stupendous V-shaped gorge cut through green evenly banded schist, with a strike to 30° N.E. by N. and dip of 70° N.W. by W. This schist is interbedded with a compact quartzitic schist, some of which is gneissose.

The river is at the level of 4200 ft. It flows through a V-shaped gorge about 3000 ft. deep, which has been cut into the floor of a broad high-level comparatively shallow valley, the floor of which is marked by the gently sloping shoulders of the spurs. The dip of the rocks on both sides of the valley is in opposite directions, so that the valley lies along the axis of an anticline.

The characteristic rock for some distance up the valley from Lu-chang is a blue flaggy schist with large patches of chlorite ; some varieties are phyllitic and even slaty.

Three miles N. of Lu-chang the chloritic schist strikes to N.N.W. and dips to W.S.W. The river has cut an even channel through these rocks, the only rapids occurring where boulders have been thrown into the river by recent landslips.

Near Chiu-chou the valley widens, for the slates are soft. Tributaries from the W. have brought in large boulders of gneiss, slate, and of chocolate and purple sandstones like those associated with the Minchia limestone.

On the floor of this basin lie sheets of red sands similar to those near the Salween bridge. Their thickness is about 1500 ft. Huge talus banks constantly encroach on the river so that its bed is contracted and littered with boulders. Its passage through the basin is therefore rough as compared with its course through the gorge near Lu-chang.

At Fei-lung-chiao the most northerly foot bridge on the Mekong crosses the river to a cliff of wash, containing boulders of slate, green schist, gneiss, granite, &c. From the bridge a track goes northward along the eastern bank for half a mile over slate and chloritic schist, which strike N. and S. The rocks are in places seamed with quartz veins. The green chloritic schists form the steep eastern wall of the valley. They are succeeded on the plateau to the E. at the level of about 6700 ft. by a varied red rock series, which is seen in a long gentle ascent through the village of Sha-chow to the summit of the pass (8900 ft.) that leads to Yun-lung. This red series includes sandstones, shales, and some cement-stones. The series begins with yellowish-limestone, false-bedded purple sandstone, and chocolate brown shales, which are sometimes slaty. At a somewhat higher level are a band of black shale and a white micaceous quartzitic sandstone. Near the village of Sha-chow (6900 ft.) occur purple slates, cement-stones, and calcareous sandstones ; at 8500 ft. is a coarse red grit ; at 8700 ft. nodular jointed shales ; at 8900 ft. brown shales strike E. and W., whereas during most of the ascent the strike is approximately meridional. The descent to Yun-lung is over cement-stones, false-bedded red sandstones, and red shales, with strikes varying from N. to N.N.E. At 7400 ft. massive purple sandstones dip W. ; below them is a yellow calcareous quartzite, and at 7000 ft. hard jointed sandstone and shale dipping to the W. A large assortment of boulders lies at the mouth of a tributary from the N. at 7000 ft. and it shows that this stream flows over rocks of the same red series. At 5900 ft. calcareous red shales strike to 12° and dip 75° and 80° W. by N.

§ 3. *Up the Lo-ma Ho to Lan-ping.*

Yun-lung (5200 ft.) was one of the leading centres of the salt mining industry of western Yunnan. It has been visited and its geology described by Mr. COGGIN BROWN ; so after reaching it we followed for six miles a route which was geologically known.

The views across the Yun-lung basin from the pass had shown us that it consists of a wide peneplane, at the level of about 7500 ft., which had been dissected by a network of deep gorges. The rocks are all of a red series, chiefly shales and sandstones with some calcareous beds. They are unfossiliferous, but (see p. 224) are assigned to the Upper Permian and the Lower Trias. We therefore observed with interest the high dip of these beds, which are occasionally inverted. Their steep dip is well shown in the hill to the S. of Yun-lung bridge, at the entrance to the gorge by which the river continues its course to the Mekong. Across the northern part of the Yun-lung basin a band of red sandhills rises 600 ft. above the floor. The river, the Lo-ma Ho, enters the Yun-lung basin from the N. through a deep gorge, excavated along a fault, from which discharges a hot spring, recorded by Mr. Coggin Brown (1920, p. 170).

Further evidence of this fault is seen beside Yun-lung. On the western side of the town the rocks dip 15° W., while on the eastern side the strike is to E.S.E. and the dips are steep both to N.N.E. and S.S.W. Faults are shown on the track through the gorge by fault breccias trending N.N.W. Toward the southern end of the gorge the beds are folded and the strike is generally from N.N.W. to N.W. by N.; it suddenly changes to N.E. by E. with a dip of 50° S.E. by S. Just S. of the covered bridge in the gorge the beds strike to S.E. by E. and dip S.W. by S., while N. of it the strike is to N.E. by N. with a dip of 35° N.W. by W.

The rocks include hard greenish sandstones with a siliceous cement, breccia of red shale fragments, quartz conglomerate with the pebbles faceted by wind action, marls like those of the English Trias, and a freestone strikingly like that of the St. Bees sandstone of the English Lower Trias. In the northern part of the gorge the cliffs on the eastern bank are capped by buff or yellowish sandstone.

At Shih-men-ching the main route turns to the E., but we continued northward into unknown country along the valley of the Lo-ma Ho. We there traversed the red sandstone series, with bands of gritty and white quartzite, and red and green mottled shales much like the Permian gypseous series at Whitehaven. On the western border of the series the sandstone was especially apt to be hard and micaceous. The strikes observed, proceeding N. from Shih-men-ching, were to the N.E. with dip 70° N.W.; strike N., dip 30° W.; strike N., dip 20° W.; strike N.E., dip 32° N.W.; strike E., dip S.; strike E.N.E., dip 70° S.; about 5 miles N. of Shih-men-ching the dip was N.; and thereabout the trend of some ridges to the E.S.E. appears due to their development along that strike.

Opposite the village of Tung-tien indirect evidence of the Lo-ma Ho fault is supplied by two groups of sinter terraces. The water in the basins was cold, but the sinter was probably deposited by former hot springs. The beds on the path beside the terraces strike N.E. and dip 65° S.E. Above Tung-tien the valley contracts to a gorge and we climbed over a spur to Chien-tsow, "the place of the bamboo aqueduct." The ascent to the pass (7500 ft.) is over yellow and red sandstones; they at first strike N.E. and dip N.W.; then strike N.N.W. and dip 50° W.S.W.; farther on they strike N.W. and dip

N.E. In places the beds are sharply folded on axes trending N., the beds on either side dipping to 50° or 60°. Near the summit of the pass mercury is worked on a small scale; this deposit probably indicates the occurrence here of former hot springs. The beds at the pass are nodular red shales. On the descent to Chien-tsow these shales strike N.W. and dip N.E. Chien-tsow is on the Sze-ting Ho, a tributary to the Lo-ma Ho, in a broad valley containing large areas of cultivated ground. The rocks on the whole strike generally about N.N.W. but varying to N.N.E. and dipping either E. or W. An escarpment of red shales on the western bank of the stream at the southern end has the normal meridional strike; but at the northern end the strike suddenly changes to W. with dip S.

About five miles N. of Chien-tsow the strike is to N.N.E. and the dip W.N.W. Still farther N. some ripple-marked sandstones strike N.N.W. and dip 50° W.S.W. Brown shales and chocolate marls at the village of Sze-ting-kai strike N.E. by N. and dip S.E. by E. Looking thence to the divide on the eastern side of the Mekong the rocks in a high peak a little S. of W. dip S. and strike approximately E. to W.; farther N. along this range the dip is to the N. The rocks E. of Sze-ting-kai consist of brown sandy shale with quartz pebbles and strike N. About two miles E. of the village are two groups of sinter basins due to extinct hot springs. They probably indicate a transverse E. to W. fault; and a notch in the Mekong divide on the same line may mark the continuation of this fault. East of Sze-ting-kai a pass at the level of 9200 ft., in a ridge of hard white gritty quartzite with a meridional strike, leads to a dissected plateau traversed by long ridges trending from N. to S. At the eastern foot of the pass, a mile away, we were surprised to see large heaps of slag and ruined mining works at the village of Pey-yun-chang. The waste heaps at the mine contain malachite and azurite. We were informed that the mine had been worked for silver, and that an unsuccessful effort to re-open it had been made about ten years previously.

At Pey-yun-chang the red rocks are indurated and fractured, and the ore deposits have been probably formed along the fault indicated by the sinter terraces near Sze-ting-kai or along a parallel fault. The plateau consists largely of a light red well-bedded freestone, strikingly similar to that of the St. Bees sandstone of the English Lower Trias. It is interbedded with red shales and in places with chocolate marls also similar to the British Trias. The red freestone is quarried into arches for tombs and into large slabs.

North-east of the mine the strike resumes its meridional direction and the beds dip E. The route descends over red flaggy sandstone through forest to a deep valley, tributary to the Lo-ma Ho. Shales with green calcareous nodules and cement-stones strike to E.N.E. and dip S. This change in strike is doubtless due to faults, of which there is abundant evidence. A large slicken-sided surface is due to a fault which strikes 30° W. of N. with a dip of 35° E., while the beds strike 20° W. of N. and dip 50° E. In the lower part of this valley red shales and ripple-marked sandstones with carbonaceous fragments dip S. Ascending the Lo-ma Ho the most conspicuous rocks are red sandstones and conglomerate which dip E. Above the sharp bend of the river at Shuan-tan-chang, it flows southward through a deep straight gorge cut through greenish sandstones, quartz conglomerate, a false-bedded dark brown sandstone and breccia; the top of the cliff is formed of hard quartzitic grit. The dip at Shuan-tan-chang is E. The gorge is crossed by a fault with a down-throw to the S.E. and the beds beside it dip 40° N. The gorge is due to the undercutting of the quartzitic grit, which, while it resisted, upheld a large lake in a basin to the N. The beds along the valley dip E., N.E., and at places N. Quartz conglomerate, sandstone, and shale at the head of the gorge strike W. and dip N. At a mile farther on, near the hamlet of Shih-ten-chuan, the strike varies from N. to N.N.W. with dip E. The valley there widens out to a broad basin in which stands the town of Lan-ping (or Pei-ti-ping of Litton's map; 1903, map No. 4) on the route from Ying-pan-kai on the Mekong to Kien-chwan-chow. About two miles S. of Lan-ping a hill of cherty limestone with caves and many calcite veins rises from beneath the red rock series, and a striking change in physiography shows that Lan-ping is near the northern margin of the red sandstone basin. A salt mine occurs one day's journey to the S.W. and numerous salt deposits are worked to the E. and S. of the route from Lan-ping to Kien-chwan-chow. A brachiopod seen in the cherty limestones suggested their Carboniferous age.

§ 4. *Lan-ping to Li-kiang-fu.*

Some cherty limestones occur N.W. of Lan-ping, where they dip 45° N. To the N.E. of the town the Yelu Shan rises approximately to 13,000 ft.; its summit consists of bedded limestones dipping to the N. The Minchia limestone (*cf.* p. 220) outcrops at lower levels E. of Lan-ping; it is steeply inclined; it is black when fresh and weathers gray; it includes seams of breccia and innumerable calcite veins; it strikes E. and generally dips N. On the lower ground it is covered unconformably by red shales which dip W. or N. Ascending the track to the E. the Minchia limestone strikes 20° S. of E. and dips 60° N.; it disappears at about 9400 feet beneath red and buff shales which also dip N. From the village of Chung-weh-tun or Tang-wei the bedded limestones of Yelu Shan are seen to strike N.E. by N. and dip N.W. by W. Farther E. crushed red shales strike N.N.W. and dip 50° E.N.E. The track rises over red shales and flaggy red sandstones which are sometimes indurated and of a slaty aspect. They strike to N.N.E. and are vertical in places. Large slicken-sided surfaces mark the position of strong faults. In most of this area the red sandstone series is approximately meridional with a dip in one place 70° E. and in another 30° W. A band of limestone pebbles in the red shales may be a basal conglomerate marking an unconformity with the limestones to the N. From the pass at 12,180 feet the track descends over the red sandstone series with in places hard green shales, as on the descent to a picturesque basin on one of the headstreams of the Yang-pi. The rocks to the N.E. of this basin are well-bedded, like those of Yelu Shan, and have a prevalent dip to the N.W., and looking back to the Yelu Shan range and the plateau W. of the basin, the prevalent apparent dip is to the N.

The floor of this basin is composed of alluvium with hillocks of tufa ; in the northern part rises a steep-sided island-like limestone hill. The basin is closed to the S. by a long spur in which the apparent dip is about 30° W. The river which drains this basin flows along its eastern edge and on its bed at Kho-li-tsun are large boulders of porphyritic rhyolite and hard bedded grits.

South of Kho-li-tsun the river enters a gorge which must have been cut when the basin was occupied by a lake. The sandstone on the N. front of the gorge contains fossil leaves and plant impressions, which Mr. Edwards, however, reports to be indeterminable. The gorge is cut mainly through a torrential boulder wash, containing boulders of tuff and diabase. At Chang-wei the track turns E.N.E. up a sinuous ravine, the banks of which show good sections in limestone, limestone breccia, decomposed shale, and sandstones. About two miles from Chang-wei the track passes a cave in which the rocks strike N. and dip W., and show complex contortions in which the bedding has been inverted, the lower side having been underthrust to the E. Near by a flaggy limestone with numerous calcite veins resembles the Minchia limestone. The strike is predominantly N.W. and the dip S.W. About five miles from Chang-wei is a village of iron workers, who smelt a carbonate ore from the hills. A mile farther E. the limestones strike N. by W. and dip 70° E. After another mile the track turns S.E. up a tributary, and a mile along it is an intrusion of porphyry belonging to the series containing enstatite-granite-porphyry (163),* followed in the steep ascent to 9500 feet by a volcanic series of green and variegated tuffs. The volcanic beds continue to the pass ; there an augite-quartz-syenite-porphyry and ash are interstratified with red nodular clays, which strike N.N.W. and N. by W. and dip eastward. Plant impressions occur here in sandstone interstratified with red and green shales. Beside the pass (at 9600 feet) occur cornstone and a sandstone which forms a high boss to the N. The cornstone is interbedded with conglomerate, purple sandstone and red sandstone, which are succeeded at about 9400 feet on the descent by blue and pink Carboniferous limestones ; they are unveined and contain crinoid stems, fragments of brachiopods and bryozoa, and a foraminifer which Mr. R. B. Newton has determined as Fusulina. At 8900 feet, lower down in the forest, we again reached the Permo-Triassic red sandstones with a limestone conglomerate, which indicates the unconformity of the red rocks on the Carboniferous limestones. East of the village of Shiu-tze-ping is a synclinal in red shales and sandstones ; its axis lies E.–W. Then a sudden change in strike from N. by W., with the dip 30° W., to a strike of E. to W., with the beds almost vertical, marks another fault. A little farther down the valley the N. to S. strike is resumed with eastward dip. Sections are scarcer ; a completely decomposed igneous rock extends along the track for a quarter of a mile ; one specimen was found sufficiently fresh for identification, and is a decomposed mica-trap. Thence to Yang-tsen the only exposures noted were of nodular red shales with a strike to the E.N.E. and a dip to N.N.W. The beds are folded and the N. dips are the steeper. The river at Yang-

* The numbers refer to the field catalogue of the specimens in the Hunterian Museum, Glasgow.

tsen must discharge S. into the Yang-pi, and not, as shown on the current maps, through the Hsi-ma Ho to the Yangtze. We left the Yang-tsen river near its bend to the S. and crossed two passes over thin limestones interbedded with grit, and with igneous rocks, including rhyolite with well-marked fluxion, porphyritic diorite and mica-trap. This igneous series continued till the rocks were covered by the drifts on the western flank of the basin of Kien-chwan-chow.

The Kien-chwan basin is about six miles wide and is bounded on both sides by roughly parallel hill fronts, both of which have been deeply incised by tributary valleys. The general straightness of course of the hill fronts and the absence of outliers suggest that both walls are dissected fault scarps, and that the valley was formed as a rift-valley. The foot of the hill slopes is often buried by vast fans of gravel with large boulders. A lake lies in the south-eastern part of the basin and is marked on General Davies' map as draining to the Yang-pi (Genschow's map, 1905, suggests otherwise). We were too far from the southern outlet of this basin to see whether an outlet from the lake passes south-westward to the Yang-pi. The large temple at Chiao-san-tun, three miles S. of Kien-chwan, stands on some tufa terraces deposited by former hot springs.

We there reached a route which had been traversed by Loczy, so that its geology had already been described. He maps a band of the older limestone along the floor of the valley, and the tufa at the temple may be derived from it, for near by is a calciphyre with green silicates. In the eastern wall of the valley the beds dip 60° S.; some of them are purple and some have the brilliant pink to red tints often shown in this area by decomposed diabase. On the western wall of the valley the prevalent dip is W.

Near Kien-chwan-chow the road crosses alluvium; but the boulders on the stream beds show that the hills to the W. include tuff and a purplish augite-syenite-porphyry (174) with sanidines up to an inch in length. North of Kien-chwan-chow the blue calcite-veined Minchia limestone outcrops E. of the southern Pagoda hill, about three miles N. of the town. The boulders in the stream there included the Minchia limestone, basalt, chert and pink quartzite, while the hills on the eastern wall of the valley belong to the red sandstone series dipping to the N.W. At its northern end the Kien-chwan basin bifurcates. We followed the western branch over low hills which rise above the alluvium; they consist of red freestone followed by a decomposed basic volcanic ash and tuff. These beds are traversed by a decomposed basalt dyke. On descent northward to the eastern margin of a wide alluvial basin the Minchia limestone outcrops with a strike N.W. and dip S.E., and is interstratified with beds of volcanic ash. A stream bed on the descent from the village N. of the Pagoda hill exposed vesicular andesine-basalt, augite-syenite-porphyry, and altered vesicular basalt containing prehnite and natrolite. A cleft hill, passed to the E. of the track, proved to be an outcrop of Minchia limestone, which also forms elongated ridges, and with the rocks striking N. and S. Approaching Chun-ho the limestones dip N. and the ridges trend E. and W. At Chun-ho crushed and distorted shales strike 25° W. of N. and dip S. of W. Just S. of Chun-ho is a melanocratic olivine-gabbro (181). North of Chun-ho, at the eastern wall of the valley, the boulders in the streams consist of porphyry, amygdaloidal basalt with quartz-filled vesicles, and veined cherty Minchia limestone. The basalt was in one place a pipe amygdaloid. The rocks seen *in situ* were mainly decomposed diabase and buff, red and brown sandstones. Kuan-shan (7700 ft.) stands in a wind-gap where the valley begins its descent northward to the Yangtze, and a lake lies on the summit of the pass.

Thence we turned E. to climb on to the plateau, up a wall of white massive unfossiliferous limestone, at the foot of which veined Minchia limestone is interbedded with brown sandstone. At 8600 ft. the thick limestone, which probably belongs to the Kao-liang Series, is brecciated and faulted, and is interbedded with shales. At 9500 ft. we reached the edge of a limestone down, of which the highest ridge crossed was at 9800 ft. This down country presented a striking change from the valley to the W. as its topography is clearly old ; its gentle, rounded hills, low ridges, and broad shallow valleys represented an old surface with a mature relief. Its features were obviously developed before the formation of the deep valley from the Yangtze to Kien-chwan-chow. The rocks exposed on the western part of the downs belong to the Kao-liang Series, and in the limestone are deep swallow holes. The track descended northward to a basin of internal drainage and the lake of La-shi-pa. This basin is bounded to the E. by a basalt and spilite ridge, which rises to two high peaks—Ma-an Shan or Horse Saddle mountain, W. of Li-kiang, and the still higher An-tan-ndii. Later views of these mountains showed that they are probably both volcanic necks. The western foot of this ridge consists of basalt, andesine-basalt, and spilite, in some of which natrolite and prehnite have developed ; the stream beds are in places strewn also with porphyritic albite-rhyolite and with boulders of gabbro. A low pass at the height of 8300 ft. crosses the ridge between the basins of La-shi-pa and Li-kiang. The southern side of the pass is a volcanic neck composed of limburgite tuff and agglomerate with dykes of limburgite ; these rocks rest, N. of the track, on the Minchia limestone. The limestone close to the junction is strongly slicken-sided, but clear sections on the eastern slope show that the volcanic rocks were deposited on an irregular surface of the limestone. A tongue of basalt projects into the limestone ; and the lowest bed of tuffs contains some altered nodules of a coral which is probably Pleurodictyum. This limburgite is probably Kainozoic in age.

From this pass to Li-kiang-fu the road crosses an alluvial plain with occasional exposures of a limestone breccia of uncertain age. The alluvial plain is of the form of the letter H and discharges from its S.E. arm to the Yangtze.

The town of Li-kiang-fu (8000 ft.) stands on the southern slopes of the range between the two northern arms of the basin. The town is paved with a beautiful limestone conglomerate, which at once roused interest as, in addition to pebbles of the widely spread Minchia limestone, it contained a cream-coloured limestone, which we had not seen *in situ*, and being unveined was obviously younger than the Minchia limestone. This cream-coloured limestone forms the range N. of the town which ends to the S.

near the Temple of the Black Dragon. Its dip is obscure owing to the difficulty of distinguishing the bedding from the joints. The rock contains nodular masses of coral, some of which are 4 ft. thick and 6 ft. in diameter. Their arrangement and other features indicate that the strike is N.E., and the general dip is S.E., and is in places as steep as 60°. Steep dips to the N. were also observed. The only fossil found of any value as evidence of age is the coral, which is determined (Appendix III) as *Thecosmilia fenestrata* (REUSS), a Triassic species. The range farther N. is of igneous rocks, and probably yielded the specimens of porphyritic albite-trachyte found in the stream bed near the Black Dragon Temple.

The conglomerate used for paving the town is quarried at the southern end of this range; the age of this rock is uncertain as we found no fossils in it. It is younger than the limestones of the Black Dragon Range, and also later than the Himalayan movements. It is probably early Pliocene.

From Li-kiang we made a hasty visit to Mr. GEORGE FORREST at the village of Nguluke, or Shueh-shan-tsuen, at the eastern foot of the snow-capped range, which in fair weather is the most striking feature in the view from Li-kiang. The route crosses an alluvial plain, and the geological interest is in the view of the hills bounding the north-western quarter of the Li-kiang basin. The southern part of the peak of Yulung Shan, the Li-kiang Snow Range, consists of basalts, resting upon the Minchia limestone. Farther N., at the foot of this range and at the northern end of the Black Dragon Range, are broad areas of a dark gray to black flaggy limestone. Some boulders collected in the moraine, which appear to belong to this well-bedded limestone, contain the Devonian coral *Idiostroma*. The base of the range at the southern end consists of the Minchia limestone, and its overlying oligoclase basalt, and the northern end of the *Idiostroma* limestone. Above this foundation rises a high peak of cream-coloured limestone, in boulders of which, near Mr. Forrest's house, we found some crinoid stems, broken shell fragments, and a minute fragment of a coral indistinguishable from the *Stromatomorpha*, of which we obtained good specimens in the Triassic limestones near Pei-ma Shan. This fragment and the resemblance of the limestone to that near the Black Dragon Temple indicate that this massive limestone is of Triassic age.

The scenery resembles that of the dolomites of the Tyrol. The steep tilting and isoclinal folding of this Triassic limestone is therefore significant, as it is necessarily post-Hercynian. On the southern wall of the valley leading up to the main eastern glacier of the Li-kiang peak, Mr. JOSEPH ROCK kindly guided us to a great overfold in the limestone due to pressure from the W.

We did not delay to examine the geology of the mountain, as it had been examined by Mr. FORREST, Mr. ROCK, and Dr. HANDEL-MAZZETTI.

§ 5. *By the Yangtze to Wei-si.*

To the S.W. of the La-shi-pa basin the road to Tibet passes through the village of Chi-tsuan tsun. The first rock exposed where the road ascends the hills is a decomposed sandy shale, of which some bands had the brilliant tints of decomposed diabase.

We were therefore not surprised soon to reach weathered diabase and diabase conglomerate. A ravine leads up to the limestone plateau and discloses an instructive section; at the lower end is a conglomerate with many fragments of igneous rocks, including porphyritic andesite and pebbles of an older conglomerate. A large slicken-sided surface in it marks a fault. The conglomerate is interbedded with red and purplish sandstone which is traversed by a thick spilitic dyke. Higher up the ravine green and red shales strike a little W. of N. and dip 60° W. They are succeeded by buff tuffs and tuffaceous sandstone, yellow sandstone and chocolate-coloured shale. At the upper end of the ravine these rocks are covered by the Minchia limestone.

This rock was in turn overlain by a thick bed of buff slate which also dips W. The plateau is the northern continuation of that crossed between Chun-ho and La-shi-pa, and also consists in the main of the limestones of the Kao-liang Series. Lines of large swallow holes mark underground stream channels. The soil is a bright red clay residual from dissolved limestone. The rocks observed were a hard buff shale and limestone; the dips seen along the track were generally to the W., but the beds are probably repeated by fold or fault, or the thickness of the series would be enormous. On the western edge of the downs, at 8800 feet, the dip is 60° W. In the descent to the W. the track passes at 8300 feet a ridge of creamy white limestone with calcite veins an inch in thickness, and this rock is associated with a limestone breccia similar to that of the Kao-liang Series at Taio-cho-shui. At the height of 7400 feet a slaty shale and sandstone occur in thin beds, from half an inch to an inch in thickness; their strike is to N.N.E. and the dip 50° E.S.E.; then follow a limestone breccia and undulating shales and limestones with the dip often to the E. These rocks are probably weathered slates and quartzites belonging to the Kao-liang Series. The strike suddenly changed to N.W.–S.E. with a dip to the N.E., and after crossing some brown sandstones and an outcrop of crushed schist dipping E., we found at 7400 feet a *Stromatopora* limestone containing pebbles of veined limestone, and also a few simple corals which we had no time to extract. This limestone extends down the hill side for 1000 feet to the hamlet of Lan-shueh-ko, at about 6400 feet.

There a limestone (belonging to the Kao-liang Series), containing large quartz veins, outcrops from beneath the *Stromatopora* limestone, and is well exposed on the stream bed and western bank of the Lan-shueh-ko valley. This limestone is succeeded westward on the southern bank of the Yangtze by a chloritic schist with a strike to N. by W. and a dip of 70° E. by N. The chloritic schist is interbedded with quartzite and purple slate with many quartz veins. The metamorphic rocks extend westward from the Lan-shueh-ko stream to beyond the great bend of the Yangtze at Shih-ku. The predominant rock is a granular chloritic schist, and the field aspect of one variety suggests that it had been a vesicular lava. This schist passes into black micaceous phyllite and is interbedded with a saccharoidal limestone, of which some layers are massive and others well stratified. The limestone is sometimes dark in colour owing to flakes of biotite and is interbedded with black biotite-schist. The strike of the rocks is meridional and the prevalent dip is steeply to the E. East of Shih-ku a torrent fan contains boulders of limestone, hard blue quartzite, and granite. To the W. of this valley a thick mass of white crystalline limestone dips to the W. and is exposed in some marble crags undercut by the swirling Yangtze. The strike there is to the N.N.E. and the dip 75° W. At Shih-ku (6200 feet) green chloritic schists are interbedded with limestones.

At Shih-ku the Yangtze turns from its long straight south course from the N.N.W. from Tibet and begins its extraordinarily sinuous course eastward across western China. After this great bend the river continues the course of its tributary the Hsi-ma Ho, which appears to be along a powerful fault trending W.S.W.; for looking up the valley of the Hsi-ma Ho, a limestone bar in the conspicuous isolated hill W. of Shih-ku has a moderate dip to the N. in the base of the hill, whereas near the summit it is steeply tilted (fig. 1). The eastward extension of the Hsi-ma Ho fault along the reach of the

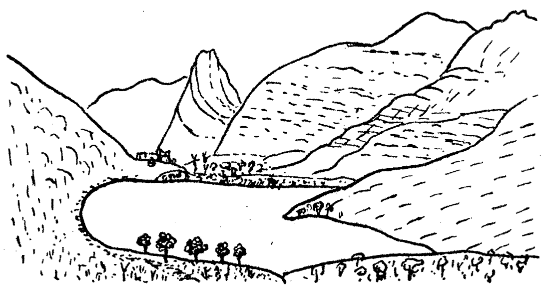


FIG. 1.—Great bend of Yangtze Kiang at Shih-ku, looking up valley of Hsi-ma Ho to the fault by the hill W. of Shih-ku.

Yangtze below Shih-ku explains some fractures seen in the cliffs N. of the river. At the end of this reach the Yangtze, by another sharp bend, turns at a right angle northward and flows along the axis of an anticlinal.

North of the Hsi-ma Ho bridge at Shih-ku cliffs of limestone and biotite schist are traversed by faults; the upper bed is a massive limestone, below which is a craggy limestone containing caves; still lower is a well-bedded limestone overlying a blue saccharoidal holocrystalline limestone. On the eastern bank of the Yangtze a long spur, which descends to the Yangtze at the bend, has a synclinal structure with a fault along the axis. Ascending the Yangtze valley from Shih-ku the sections at first are in crystalline limestones interbedded with biotite schist. As the craggy limestone seen high on the hillside N. of the Hsi-ma Ho bridge reaches the river level about two miles up-stream the dip is northward, but the predominant strike along the valley is N.N.W. parallel to the river; the dip on the western bank is to the W. and is sometimes as high as 70°, while the exposures seen on the eastern bank mostly dip E. On the eastern wall of the valley the most conspicuous rock is a thick brown bed, which, from its resemblance to the material on the western bank, is doubtless a weathered biotite schist interstratified with crystalline limestone. A mile N. of Mu-chu-tai the bed of a river from the W. is littered with hornblende-granodiorite-porphyry, syenite-porphyry, diabase, rhyolite (256), sericite-schist, and quartzite.

The rocks seen N. of Shih-ku lithologically agree with the Upper Eozoic or Ta-li series and the Mu-chu-tai river bed showed no material from any other formation. Lhe spurs on both sides of the valley afforded clear evidence of folding and faulting. North of Mu-chu-tai the river flows at the eastern end of a high spur crossed by a syncline; in the high bluff of limestone above the river the strike varies from 355°, with a dip of 70° W., to 10° with a dip of 75° W.; while in the opposite spur on the eastern bank of the Yangtze the dip is to the E. An anticline occurs in this limestone beside a temple on the western bank. Later views to the N. showed again the westward dip of the beds on the western bank and eastward dip on the eastern bank.

At Su-chai the bed of a tributary contains boulders of contorted green schist and chloritic schist with crystals of magnetite (240); and at the northern end of the same village is an altered trachyte-tuff (241), but neither limestone nor granite. On the eastern bank a peak S.E. of Taliya shows a reversed overfold.

From opposite Akola or Gad-sze downstream to the limestone gorge the eastern bank of the valley for four miles is apparently along a fault, owing to the straightness of the line marking the abrupt truncation of the four spurs, their faceted ends, and absence of outliers. From Akola, looking northward, a broad syncline and small secondary fold occur E. of the river and parallel to it. The Yangtze lies along the axis of an anticline as the dip on the western bank is westerly. The stream bed S. of the village of Gad-sze (27° 4′ N.) yielded evidence of a change in the composition of the range to the W., as the bed of a tributary contained abundant red sandstones, pebbles of probably the Minchia limestone, granite, hornstone, and the Kao-liang crystalline limestone. At Gad-sze the rocks exposed *in situ* belong to the green schists; the strike has been altered to W.N.W., apparently by a fault as the rocks are seamed with abundant quartz veins. The normal strike is still to N.N.W. with a dip which, for the western bank, is exceptional in direction, as it is 60° E.N.E.

From Gad-sze up the Yangtze valley to Chi-tien the rocks seen *in situ* belong to the green schist and crystalline limestone series. The hills to the W. include, in addition to these rocks, some mica schist, and a gneiss, like albite-gneiss, schistose quartzite, like some of that in the Scottish Dalradians, various igneous rocks, including biotite-granite, pegmatite, syenite-porphyry, uralitised gabbro, and granite full of xenoliths; also hornstone and baked epidotic grits from igneous contacts; and quartzite, purple sandstone, occasional pebbles of red sandstone, and a purple grit resembling the British Torridonian sandstone. A stream bed S. of Wu-cha yielded hornblende-quartz-syenite, hornblendic-granite-porphyry, quartz-diorite, and a muscovite schist with garnets (252), while opposite Wu-cha the stream from the W. had brought down syenite-porphyry (249). The exposures near the river are in the green-schist series and we saw no certain specimens of the Minchia limestone or its associated black slate, though high on the eastern plateau a bed of limestone with a low dip lies apparently unconformably on the crystalline limestone and biotite-schists. It may be the Minchia limestone, but its identity is doubtful, as it was not, so far as we could see, associated with red rocks, and no specimens of the Minchia limestone were found in the neighbouring gravels. It is therefore more likely to be an outlier of the Kao-liang limestone.

This part of the Yangtze valley is a faulted anticline. The fault is indicated by the section near Chli-ho-lin, where the western bank of the river consists of green chloritic schists dipping steeply to the W., while at the same level on the eastern bank crystalline limestone and biotite schist (which on the western bank occur at higher levels) dip eastward. Further N., near Wu-lu-tin, banded biotite-limestone occurs at the same level on both banks, and on both the dip is away from the river. East of the Yangtze anticline a syncline forms the summit of the mountain E. of Si-kic. This structure is also seen to the N. of Chi-tien; the prevalent dip is W. on the western side of the Yangtze and E. near the river on the eastern side, with a large synclinal forming peaks to the E. of the river.

The general strike N. of Gad-sze is to the N.N.W. until it bends to N.W. by W. to W. by N. and dip S., near Wu-ho, and to W.S.W. with dip 30° S.S.E. near the Pa-lo Ho.

VON LOCZY, who had travelled down the eastern bank of the Yangtze, had represented it as a valley formed in places along an anticline. This conclusion we found fully supported by the evidence. We were therefore anxious to examine the parallel part of the Mekong valley, as we expected to see the Yangtze farther N. during our return journey.

From Chi-tien the road across the Mekong-Yangtze divide to Wei-si follows up the Chi-tien River on a course to W.S.W. On the southern side of the lower part of the valley the crystalline limestones dip 40° W. Farther up, the folds trend W. until they are bent abruptly to N.E. At the village of Be-ta, mica schists, in which the foliation strikes to 30° W. of N. and dips S.W., and there are many faults, appear from beneath the Kao-liang Series. Above Be-ta, mica schists of a crushed flaser type dip W. At Lu-lu-wa, the next village, phyllitic schist with many quartz-veins and some flaggy limestone strike N.W. and dip S.W. This calcareous phyllitic stage is succeeded by crumpled quartz-mica schist, and as the valley narrows to a ravine the river bed is littered with igneous rocks (257), including biotite-granodiorite-porphyry, hornblende-granodiorite and boulders of schistose-quartzite and garnetiferous mica schist. The schists *in situ* there dip 40° S.W. The path climbs steeply to a level track at 7500 ft., after which it rises gently to the floor of an older valley at the height of 7800 ft. The strike gradually returned to the widespread N.N.W. trend with a dip to the W.S.W. The quartz veins in the garnetiferous mica schist have been broken and the fragments separated by crushed schist. At the height of 8000 ft. the path turns S.S.W. up a side valley; the schists in it strike to 15° W. of N. and dip W. After passing the village of Tai-sing-tang, with a strike of 20°, we crossed hard bands of dark blue schist in a white mica schist with some garnetiferous schist and syenite (261). About five miles up this branch valley the rock is of a hard Moine-like gneiss, with a strike N.N.W. and dip W.S.W.; the river flows through a narrow ravine, above which we suddenly emerged on to the basin of Li-tien. Its eastern wall trends to N. by W. and cuts across the grain as the dip is N.W. On the floor of this basin the most conspicuous rocks are biotite-quartz-diorite-porphyry, rhyolite, epidotised trachyte or trachyte-tuff, and felsite (264). The village of Li-tien, at the height of 9000 ft., is situated on decomposed outcrops of the eruptive rocks.

The diorite-porphyry and granite are better preserved at 9400 ft. on the ascent of the Li-ti-ping Pass; a coarse porphyry was seen at 9600 ft.; at 10,200 ft., porphyry with a purple base; a thick belt of banded hornstone at 10,700 ft.; at 11,000 ft., schists with a strike a little to the E. of N.; at 11,250 ft., buff medium-grained felspar porphyry; more hornstone is followed by an outcrop of a massive green epidote-schist, similar to a rock that we had occasionally seen in the tributaries to the Yangtze. At 11,400 ft., pink and gray porphyry are followed by a bed of limestone which is interstratified with red and buff shales with a strike to 5° E. of N. These rocks agree lithologically with those of the Minchia Series. The top of the Li-ti-ping Pass at 11,600 ft. consists of a ridge of porphyry. The descent westward is over decomposed igneous rocks with occasional outcrops of flaggy limestone, bluish gray felsite, an altered porphyritic spilite (270) and dolerite (281). The track rises to a ridge W. of Siao-li-ti-ping at 11,400 ft., where the rock is a blue quartz-syenite-porphyry (272) associated at 11,500 ft. with chert and hornfels (274A). The porphyry series provided most of the outcrops, but at 11,000 ft. we reached a phyllite with many quartz veins. Its strike is to N.N.E. with a dip of 30° to W.N.W. From 10,800 ft. a long spur descends to S.W. by W. towards Wei-si. The upper part consists of slate with a strike to N.N.W. and a steep dip to the E. On the lower part of this spur, at 8750 ft., rhyolite is intrusive into black slate or phyllite; at 8400 ft. this black slate occurs along the floor of the valley leading westward to Wei-si, and intrusive into it are rhyolite, felsite (276), and a rock composed of chalcedonic spherulites. This series continued till we reached the Ying-an River at Wei-si, where the bridge is built of Minchia limestone; abundance of this rock was seen, but not *in situ*, on the lower slopes of the western bank rising up to Wei-si.

The Wei-si or Ying-an River is a tributary to the Mekong, but flows to the N.N.W. Its valley is separated from the Mekong by a high ridge with a steep eastern scarp. This ridge consists of coarse gneiss and schists like those of the Taping. Most of the floor of the Wei-si basin consists of confluent series of delta fans which have been deposited at the foot of the scarp. Looking northward, numerous parallel spurs project into the valley from the eastern plateau; the dip in the spurs seen to the N. from Wei-si is to the E., whereas in the hills E. of Wei-si the prevalent dips are N. or S. from an upfold with an axis trending approximately E. and W.

The general evidence observed during the traverse from Chi-tien to Wei-si may be summarised as follows: the rocks of the Ta-li series, seen along the Yangtze Kiang, rest upon schists and gneisses, upon which, in the hills E. of Wei-si, lie remnants of the Minchia Series; this series has been intruded by various porphyries and some felsite.

We saw no direct evidence of the intrusion of the granite into the Minchia Series, but only into the older schists and gneiss; but that the granite also is post-Minchia is probable from the evidence seen farther to the N.

§ 6. *The Ying-an River to the Mekong.*

Amongst other evidence of great changes in the river system of this region is the fact that many of the tributaries flow northward, in the direction opposite to that of the river which they join. Thus, the Ying-an River rises near a windgap S.S.E. of Wei-si, flows past that town and reaches the Mekong after a northward flow in a direct line of 25 miles. At Wei-si a broad valley separates the high gneiss range to the W. and the hills formed of the Minchia Series and igneous rocks near the Li-ti-ping.

The Ying-an River a little N. of Wei-si flows past a bluff on the eastern bank of Minchia limestone and buff shales which dip to the W. These beds are much disturbed and have been altered by the intrusion of rhyolite (285, 286). The shales and sandstones are also disturbed by some movement which is probably a fault along the Wei-si valley. Farther N. the Minchia limestone and its shales strike N. by W. and have resumed the eastward dip which is usual on the eastern bank of the valley. At Si-ku-fu, three miles from Wei-si, occur purple sandstone, purple grit, quartz-conglomerate, and altered Minchia limestone; and on a stream bed are boulders of biotite-granite (291), granodiorite-porphyry (290*a*), and quartz-dolerite (292*a*). The spur beyond Si-ku-fu consists of slate, shale, and a sandstone which has been disturbed, for it contains many quartz veins; the beds are either vertical or have a steep easterly dip. In the next spur, sandstones and shales dip steeply W. and the track passes over an exposure of a black shale containing ironstone nodules and slicken-sided surfaces lustrous with graphite. This shale is probably a down-faulted Carboniferous bed; for N. of this outcrop are buff sandstone and purple shale, and a conglomerate which is nearly vertical and contains pebbles of Minchia limestone, so that it is later than the Minchia Series.

At Ku-tsung the Minchia limestone is interbedded with red shale, red freestone, green cornstone, and purple sandstone with a dip of 60° E. The general character of the rocks in this part of the Ying-an Valley is strikingly like that of the Old Red Sandstone of South Wales. Some of the quartz pebbles in the conglomerates, as at Ka-ka-tang, are faceted by wind action. The gneiss ridge of Wei-si sinks beneath these red beds. They continue for some distance farther N., the chief variation being the occurrence of boulders of rhyolite with porphyritic quartz in the stream beds, and the extensive development of chocolate shales associated with buff sandstone and quartz conglomerate; the prevalent dip is to the W. Some of the sandstones are seamed with gash veins of quartz along fractures. At O-shia, red sandstone and gray grits with patches of manganese dioxide and iron oxide strike N. A quicksilver mine is reported half a day's journey to the W. North of O-shia, red and buff sandstone with some black shales are interbedded with a band of Minchia limestone 200 ft. in thickness. Five miles down the valley from O-shia the strike of the chocolate shales changes to E.S.E. with dip to N.; about a mile farther on the strike is to S.E. with dip N.E.

About three miles from Ka-ka-tang the Ying-an sharply bends W. against a cliff of hard black jointed slate and an earthy black limestone with a strike to W.N.W. and dip S.S.W., varying to strike N.W. and dip S.W., and later to strike to W. and dip N. We did not find any fossils in the slate, the lithological resemblance of which is to the Ordovician. On the north-western margin of this outcrop the slates strike E. by S., dip 70° S. by W., and disappear under fallen boulders of the Minchia limestone. These boulders mark the reappearance of the cornstone and red sandstone series. Opposite the village of Shia-fang we found in the bed of a stream pebbles of kersantite (299), of yellow sandstone with casts of indeterminable fossils, and of Minchia limestone. Below this point the Ying-an bends suddenly W. and flows through a romantic canyon to the Mekong; before the junction of the last tributary to the Ying-an the rocks on the river bank are very contorted red and green slate. Red and white sandstone, Minchia limestone, and rhyolite (300, 301) were found on the river bed. Continuing W.S.W. through the gorge the prevalent dip is to the W.; the eastern end of the gorge is in purple sandstone; then follows gray to pink quartzite, which is traversed by fault breccias resting on a strong fault, with a hummocky fault-plane; the fault is normal and has its downthrow to the W.; the strike of the fault is 18° W. of N. Toward the western end of the gorge the rocks consist of black and green slates with a dip of 70° W., and a bar of Minchia limestone.

Here the Ying-an, with its clear greenish water, enters the Mekong, of which the water, at the time of our visit, was of a deep Indian red colour.

§ 7. *The Mekong Valley from the Ying-an to Tze-ku.*

North of the confluence with the Ying-an the Mekong valley has been cut through gray shales and purple sandstones interbedded with the Minchia limestone, which on the eastern bank of the river strikes N. and dips E. On the western bank the dip is apparently S.W.; the valley is situated along an anticline which the difference in the direction of dips on both sides shows to have been faulted along its axis. At Pu-chi-hsien the slates strike W.N.W. and dip 25° N.; at Bad-chi, the next village to the N., black and chocolate-coloured slates strike to N.E. by N. and dip 15° S.E. by E.; but as a little farther N. the dip is steeply N. a secondary anticline crosses the valley. Half an hour's march N. of Bad-chi the S.E. dip was resumed; we searched for fossils in some black slates, but without success. At Lo-chang on the western bank the dip is W.; at Lo-chi-ku on the eastern bank the dip is E.; the valley is therefore along an anticline; the recent age of the lower part of the valley is shown by the occurrence of a high waterfall close to the river on the eastern bank. North of Siao-wei-si is an outcrop of chloritic schist covered by a litter of purple and chocolate slates, black slate, and Minchia limestone.

These chloritic schists disappear in less than two miles to the N. at Pa-lung-tan under a rough craggy sandstone; thence on to Chu-ta (Ohuta of the Indian Survey map, sheet China 92M) purple slate and false-bedded buff sandstone dip W. and S.W. Large boulders of contorted quartz-chlorite schist in a stream bed at Chu-ta show that the Kao-liang schists occur in the hills to the E. North of that village the Mekong makes two right-angled bends near Ai-wa; it flows from W. to E. at the foot of cliffs, which at the eastern part consist of black and green slates which strike 15° W. of N. and dip 80° E. At the base of the slates is a chloritic breccia composed of débris from the underlying chloritic schists, which contain large surfaces of chlorite and dip from 70° to 80° W. The slates rest on the schists discordantly. A conical hill on the western bank appears to consist of schists with a high dip to the N., suggesting that, as at Siao-wei-si, the chloritic schists have been brought to the surface by an upfold on an E. to W. line. North of the Ai-wa bend the sandstones and shales of the Minchia Series reappear. One strike observed was to 4° E. of N. with the beds either vertical or dipping from 70° to 80° E. and showing evidence of great disturbance. They are traversed by an overthrust fault about two and a half miles S. of Ta-chiao. Just S. of Ta-chiao a tributary comes in from the E. and near the confluence indurated slates and quartzites strike 4° E. of N. and are traversed by a jointing like a second cleavage. This disturbance, however, is local, and as at Ta-chiao the slates and sandstones dip 15° E. Around the basin of Kang-pa occur cracked and veined purple sandstones and liver-coloured quartzite, like that common in the English Triassic conglomerates. A little S. of Cha-wa-tsun a breccia of chloritic schist indicates the proximity of the schists. Gypsum is mined in the hills to the E., but according to the headman of the village it is not associated with salt, of which none is known in this district. The local salt supply is brought from Ya-ka-lo, 100 miles to the N. We made frequent enquiries as to the occurrence of salt, as the best available clue as to whether any Permo-Triassic beds might be included amongst the red rocks of this area. In a wall at Sha-wa-tsun we were cheered by finding a fossiliferous gray unveined limestone; we found this rock *in situ* at the height of 6500 ft., where it is associated with a typical veined Minchia limestone; some bands in the unveined limestone contain crinoid stems, fragments of bryozoa, corals and shells. These rocks strike from 20° to 30° and dip about 70° to E.S.E. Close to the fossiliferous limestone are conglomerate, purple green black and buff slates of the variety usually associated with the Minchia limestone. The probability is that this fossiliferous limestone is Carboniferous and that it was deposited upon and enfolded with the Minchia Series.

The Mekong here emerges from a gorge in which it narrows to the most terrific rapid which we saw along its course. This gorge has been cut through conglomerate and black slate, which dip from 60° to 70° W. on both banks; the anticlinal axis of the Mekong and a high-level valley along it lie a short distance to the E. The gorge now occupied by the Mekong is obviously quite young, and is probably due to the diversion of the river from its former course along the anticline by the disturbances which upraised the chloritic schists. The river has cut out a fresh course along the relatively soft black slates. Above this gorge the river has a wide eastward bend through a broad basin, which is continuous with the high-level valley along the anticline axis. The beds on the eastern side of this basin dip 70° E., so that the river is again along the anticlinal axis. The purple slates have been crushed and veined, and a tributary from the E. contains boulders of chloritic schist and cobbles of granite, rhyolite with flow structure (311), hornstone, and altered rocks of the Minchia Series. On the northern bank of this river the purple and green slates, which are vertical, strike 2° W. of N. At the village of Kuna, a mile farther N., similar rocks occur on a stream bed with abundant hornstone, granite, and porphyry, which show that the rugged hills to the E. of that village and above Yei-chih consist largely of igneous rocks, and especially of felspar-porphyry.

Along the Yangtze N. of Yei-chih black and purple shales and purple grits dip to the S. The Minchia limestone is one of the commonest rocks in the bed of a tributary two miles N. of Yei-chih ; farther N. the porphyry becomes scarcer, and the bulk of the material on the stream beds consists of black slate, quartz breccia, and Minchia limestone. An intrusion of porphyry occurs a mile farther N. on a bend of the Mekong, and is associated with black slate which has been shattered and cemented by numerous quartz-veins ; the Minchia limestone is altered and the black slates contorted. After crossing chocolate sandstones and slates striking 25° E. of N., and dipping 30° W.N.W., for more than two miles, we reached the village of A-wa, near which is granodiorite porphyry (316) with felspars an inch in length, and banded rhyolite. On the river bed are boulders of contorted schist like some of the Highland albite schists (315). A cliff of purple slate is traversed by a series of horizontal faults which dip E., while the rocks strike to 5° W. of N. Thence on to the village of I-li the rocks are greatly disturbed. Quartz-veins in the slate and sandstone have been broken into eyes ; some of the local folds trend W. and E. Near I-li is another outcrop of the coarse granodiorite-porphyry (318), and that it is intrusive is indicated by boulders of hornstone, due to the alteration of the sandstone. Above I-li is a high peak of porphyry, while the pebbles of slate and hornstone in the stream from the E. are so small that they must have been derived from far upstream. Horizontal faults were noticed against To-pa-ko, and on the floor of the Mekong valley are high alluvial terraces. After rounding the bluff of Minchia limestone and of crushed green slate and vertical sandstone and conglomerate we reached the village of Pu-ti, where the Mekong has been forced into a horseshoe-bend by the resistance of the conglomerate. This rock contains muscovite-gneiss, quartzite, chert, black limestone, green schists, and various igneous rocks ; but apparently none of the porphyry so conspicuous in this part of the Mekong valley. The conglomerate, therefore, probably belongs to the lower part of the Devonian Series, and the local porphyry was probably intruded either later in the Devonian or Carboniferous.

In the day's march to Pu-ti we had been impressed with the increasing intensity of the disturbances in the rocks. Above Pu-ti the river makes a series of right-angled bends while the valley contracts to gorges, which are deeper and are separated by basins that are smaller than those farther S. The Minchia Series continues and it includes occasional igneous rocks which have contributed the comparatively scarce igneous pebbles to the tributary streams. The absence of hornstone is further evidence of the decrease in the igneous rocks. The sudden bends in the course of the Mekong appear due to disturbances by which the normal meridional strike is suddenly altered to about W.N.W. to E.S.E., or even closer to an E. to W. trend. A little N. of Pu-ti crushed porphyry with green slates strike to W.N.W. and dip S.S.W. Farther on the slates contain many quartz veins, are vertical and are often crushed, and they are in places sub-schistose. At Pu-ti the slate is phyllitic and the Minchia limestone crushed. At Nan-tao the chocolate slates are seamed with calcite veins and the rocks are near the centre of a crushed anticline. The Nan-tao basin is small; above and below it the course of the Mekong is very sinuous and the profiles of the opposite spurs overlap repeatedly. North of Nan-tao the black slates and Minchia limestone on the eastern bank of the Mekong both dip W. from 60° to 70°. At Lo-ta the river emerges from a gorge which in the lower part is across the strike of the rocks, which is there generally to 10° W. of N., and owing to the folding the dips are both to W. and E. Calcareous grits, enclosing lenticular masses of limestone, contain numerous stems and some arms of crinoids, which Dr. Bather reports as indeterminable, and shell fragments. One band contains a foraminifer, which Mr. R. B. Newton has identified as *Neoschwagerina.* These limestones are therefore of Carboniferous age. The limestones are unveined, often fissile, and fine-grained, and pass to sandy flags; they are therefore different in aspect from the Minchia limestone. The gorge is in places so narrow that the track passes above the river on a wooden platform fastened to the limestone cliff. In the gorge the river makes a right-angled bend from the N. and there flows along the strike of a series of quartzites, green grits, quartzitic sandstone, black, chocolate-coloured and green slates, purple grits and thin-bedded limestone. The black slates are in places interbedded with thin layers of quartzite. The strike varies only a few degrees from N.; the prevalent dip is to the E., though the beds are often almost vertical. Some of the conglomerates contain pebbles of limestone with crinoid stems, which are probably fragments of the Minchia limestone. North of the gorge at Tseh-im-po, which is in the almost vertical quartzitic series, the river makes another bend to Tze-ku along rocks striking to 20° E.S.E. and dipping 70° to N.N.E.; these rocks are traversed by a nearly horizontal fault with a dip to the N., and due apparently to a thrust from the N. Above Tze-ku the river bank is strewn with boulders of coarse-grained purple porphyry and rhyolite (389B), which marks the beginning of another extensive development of igneous rocks.

§ 8. *From the Mekong to Pehalo across the Salween-Mekong Divide.*

As we had now marched for 60 miles along the eastern banks of the Ying-an and Mekong we were anxious to reconnoitre the country farther W. We therefore crossed the Mekong by the rope bridge at Tsed-rong, and owing to the kindness of Père Ouvrard, who engaged three porters for us, we began a hasty excursion across the Mekong-Salween divide. The river bank at Tsed-rong (6550 ft.) consists of a pink and black porphyry. This rock extends up the hillside till, at 6800 ft., we reached black slate striking N. to S. Green grits, purple grits and slate succeeded at 7000 ft., and purple breccia at 7200 ft. Porphyritic spilite (334) followed by red and green shales extend to 8400 ft.; green and purple slate occurs at 8900 ft., black slate at 9200 and then purple and green slate, often in thin alternate bands, formed the rest of the ascent to the first pass at 10,150 ft.; thence we descended to the Lo-shi Chu, where it flows northward to join the Mekong at Tsed-rong. The descent to the river (9900 ft.) is over slates, which rest at the river on coarse biotite-gneiss and granitic gneiss. The lower part of the valley is on black and red slate, but as we ascended to the W. schists and gneiss rose from the floor to form the walls.

The first evidence of former glacial action is given by some moraines at 11,100 ft., which farther up the valley rest on beautifully glaciated surfaces of a gray to brownish quartzose gneiss striking to N.W. At 12,000 ft. the characteristic rock is a gray schistose quartzite, with some black schist, dipping 60° E. The quartzite has been formed from a grit. The ascent to the Si La pass is over schistose grits, which strike N. and dip from 70° E. to vertical, and form the peaks on both sides of the pass (14,000 ft.). These peaks have been overfolded by pressure from the W. On the southern side of the pass the folds are clearly shown on the western face and the spur to the S.E. has a close narrow doublefold (fig. 3, p. 235). The intense folding does not apparently affect the foundation of the range and is probably due to a movement of comparatively modern geological date. The descent into the Seroua Lomba or "Valley of Hail" is precipitous; at about 12,500 ft. the Si La schistose grits rest on crystalline marbles, like that at Ta-li-fu, interbedded with black calc-biotite schist. This limestone series dips to the E. and continues to the floor of the valley (11,500 ft.), which is crossed by huge moraines. We descended this valley for about two miles and then climbed its western wall—over quartz-schist and black mica-schist, with Ta-li marble at about 11,700 ft., and over white schistose quartzite in layers from one-eighth to a quarter of an inch in thickness, biotite- and muscovite-schists and a quartz-schist striking to S.S.W. and dipping W.—to the pass at 13,600 ft. The western slope to Pehalo is down a steep dip slope with few exposures; the rocks seen were schist with granite veins and bands of gneiss; Pehalo (8500 ft.) is on granite-gneiss. The steep descent from the Mission to the river Do-yon crosses marble and black schists dipping W.; crags of the same rocks could be seen at the height of 2000 ft. above the river bed. The boulders on the river include granite, micrographic granite (359), crystalline limestone, hornstone, and a breccia with a black schistose matrix.

Famine rendered any stay in the Salween valley impossible and we therefore returned toward the Mekong by the Chamutong to Yang-tsa track, which we joined, N. of the huts of Lompeur, at 9200 ft. West of the Salween the dips seen were to the S. of W., and the hanging valleys there indicate that the Salween valley is not appreciably, if any, older than that of the Mekong. The ridge W. of the Do-yon consists of brown schistose grit and black schist. A moraine-like bar crosses the valley and inspection of this ridge from above showed that it was due to a sudden change in the size of the valley owing to a difference in the rocks. The burial of the rock face by drift has produced the morainic aspect when seen from the S. We crossed the Do-yon river at the height of 8180 ft. where the boulders included schistose breccia, cherty quartzite, a black massive schistose grit and the Ta-li marble. The rocks beside the river belong to the Ta-li marble series with a dip to the S.W.; this dip is clear in the southern part of the section, but is obscured in the northern by vertical jointing due to lateral pressure. The route continued along the eastern side of the river, crossing spurs and valleys from which waterfalls leap straight into the river; the black schists near the river crossing strike about E. and W., but as a rule the Do-yon Valley is along an anticline, with dips to W. and E. Above the Ta-li marble, green schist like that E. of Shih-ku, is found at 9300 ft. A fractured black schist occurs at 11,400 ft., and green schist with quartz veins at 12,200 ft. The pass at 12,900 ft. is at the foot of the crags of banded crystalline limestone of Mt. Francis Garnier, the dip is W., but some pinnacles owe their form to pressure jointing and not to bedding. From this pass, the Jeu-dson La, the moraines continue to the level of about 11,400 ft. down a valley cut out of biotite-granite-porphyry (374: 11,500 ft.), and the Si La schistose grits. Below 10,000 ft. the grit is succeeded by calc-biotite-schist, coarse mica-schist, with muscovite-pegmatite, and green marble; the dip is sometimes S.W. and sometimes N.E. This schist series continues eastward to Lon-dre at 7400 ft. Thence the gorge of the Londre River gives an excellent section of the rocks to the W. of the Mekong. At Lon-dre the schists are replaced by gneiss and foliated biotite-granite with a strike of about 30° W. of N. and dip to 30° S. of W. The gneiss is succeeded eastward by green slate, cherty slate, and hornstone (380), which is a baked grit and has been formed by contact alteration around intrusive masses of biotite-granite. The centre of the larger masses consists of biotite-hornblende-granite with a greenish felspar and biotite in patches; the selvage in places is spessartite. At the third crossing of the river, at 7000 ft., a white fine-grained felspathic sandstone or quartzite is followed by a purple sandstone which strikes to the E.N.E. and dips S.

The eastern end of the gorge gives a deep section through the red sandstones. The strike is to 5° W. of N. and the dip varies from 75° W. to vertical and is in places inverted by pressure from the W. The sandstone is cut through by numerous thrust-faults which dip W.; the beds above the fault plane have been thrust to the E. One of the more powerful vertical faults trends to 20° E. of N. The sandstone beside the faults contains many gash-veins of quartz. On the northern bank a horizontal fault has a 12-foot throw and a vertical fault has produced large slicken-sided surfaces.

§ 9. *From the Lon-dre River up the Mekong to Kia-pieh.*

From the mouth of the Lon-dre valley we turned northward along the western bank of the Mekong to Yang-tsa, where we crossed the river by rope-bridge. During the walk from Lon-dre to Yang-tsa we crossed a landslip composed of a greenish biotite-granite similar to that of the Lon-dre gorge; on one torrent bed the stones consisted of 95 per cent. of granite, 4 per cent. of red and white grit, which showed no signs of contact alteration, and 1 per cent. of Minchia limestone. Half a mile N. of this fan is an exposure of biotite-granite-porphyry and biotite-granite (344) associated with hornstone and altered green rock. A little farther N. green breccia is faulted against the granite; and still farther on an altered red sandstone is seamed with quartz veins and is partly bleached. Half a mile farther N. red sandstone and shales with the Minchia limestone dip N.W., and again show signs of contact alteration. A fault trending N.E. and S.W. throws the grits against black shale, the beds dipping S. A little distance S. of Yang-tsa a small headland of black slate is traversed by a vein of iron ore along one of the Mekong faults. South of this headland the proximity of the igneous rock is indicated by an outcrop of breccia like that at the bridge over the Do-yon River near Pehalo. The limestone at the headland contains crystalline black calcite, and the altered condition of the Minchia limestone at Yang-tsa is probably due to the porphyry found in the drifts.

We hoped in the walk from Lon-dre to Yang-tsa to find clear evidence as to the age of the greenish granite. The local porphyries are clearly intrusive in the Minchia Series, and at two localities we saw features suggestive of a felspar-porphyry being part of the granite selvage, and therefore that the porphyries intrusive in the Minchia Series are off-shoots from the granites. We, however, found at this locality no clear evidence of the granite being intrusive into the Minchia Series, in which we saw no granite veins or contact metamorphism produced by the granite, and all the alteration seen might be due to the porphyries.

The sections on the eastern bank of the Mekong near Jih-tze, the village opposite Yang-tsa, show that the sequence of the Minchia Series in that district is as follows in descending order:—Red beds; Minchia limestone and black shale; red sandstones and shales; brown, buff and green sandstones; purple sandstone and slate; green grits with material derived from the chloritic schists. This series is sometimes altered by an intrusive felspar-porphyry, the red shales being turned into red jasper, the limestone crystallised, and the sandstone clearly baked. A mass of green mudstone with shell fragments and tuff (340) cap the cliff at Jih-tze; and near the bend of the river farther N. dykes of porphyritic spilite (463) in the red sandstone include baked fragments of that rock.

After passing the bend of the river we crossed 1500 feet of red sandstone thrown against yellow grit by a fault which trends to about 35° W. of N.; the yellow grits are also faulted against the green porphyry which passes into a greenish biotite-hornblende-granite (464) that is traversed by crushed bands along E. to W. faults. On the opposite bank of the river the sandstone occurs opposite the granite, so that the river here probably lies along an E.-W. fault. The red sandstone lies on top of the granite on the E. bank; we had no time to climb up to the junction, but the fallen blocks of the red sandstone showed no signs of contact alteration, nor could we see from below any protrusions of granite into the sandstone. The red sandstone is, however, altered by intrusions of felspar porphyry, and before reaching a Tibetan village in a small irrigated oasis we passed a vertical 8-feet dyke in the red and green shales; both rocks have been so crushed that the margin of the dyke is indefinite. North of the Tibetan village the track rises to a granite moorland, where hardened shale and Minchia limestone lie directly on the granite. The limestone was not crystallised, but on the other hand it contained no granitic detritus. The xenoliths in the granites did not, moreover, appear to be of the red rock series; they included altered limestone caught up in the granite, which shows that the granite was intruded into the Upper Palæozoic limestones. Some of the adjacent limestones contain crinoid ossicles and indistinct bryozoa, corals and shells. On the ridge S. of Kon-ya the shales strike to N.N.W. and have a steep dip to E.N.E., and the anticlinal arrangement of the beds along the Mekong was well exposed. Above the granite lies a brown bed, similar in appearance to rock seen farther N., which proved to be ironstained limestone and black shale. This brown material is often formed along fault planes and might imply a faulted junction between the granites and the overlying rocks.

On the descent to Kon-ya the Minchia limestone was seen underlying the black shales and overlying red sandstones which rest upon the green grits. South of Kon-ya two strike faults have strongly contorted the brown beds.

On its northern margin the Kon-ya biotite-hornblende-granite is intrusive into the shales of the Minchia Series; this granite is intruded by an olivine-lamprophyre; three tongues of white clay have no doubt been formed by the decomposition of apophyses from the granite. These tongues intrude into baked green grits, which are covered by red slates and Minchia limestone; this rock is succeeded by breccia, black slate and coarsely porphyritic trachyte (402, 402*b*). The limestone contains crinoid and shell fragments. The Mekong flows through a double horseshoe bend at the bottom of a canyon, while the track rises over a succession of porphyries to the pass leading to Kia-pieh. The ridge to the W. of this pass consists mainly of brown grits and sandstones which dip W. and are traversed by two powerful strike faults. At the pass red slate dips E. under the Minchia limestone and its black shales, which are capped by porphyries. The limestones and porphyries are faulted against the brown grits of the western spur. On the western bank of the Mekong a massive grey limestone rises into bold peaks, which pass westward into the glacier-covered summits of the Do-kar-la.

§ 10. *Kia-pieh to A-tun-tze.*

From Kia-pieh the track turns W. down a valley cut through the brown sandstones which, on the southern side of the Kia-pieh valley, dip to the W. though the general dip of the shales on the northern side is to the E. Farther down this valley the brown sandstones occur also on the northern side and there dip N.E. That this valley is situated along a powerful fault is shown by large slicken-sided surfaces. Boulders of limestone are abundant and include blocks of an unveined limestone, which probably comes from the mountains on the western side of the Mekong. The Mekong clearly follows a great fault which separates the limestone mass on the W.—which probably belongs to the Kao-liang Series—from the Minchia Series and gneiss on the E. In addition to the meridional Mekong fault a series of faults and folds trend E. to W. Huge masses of brown beds occur on the valley floor; they are shattered and traversed by many slicken-sides and may have reached their present place either by fault or landslip. The brown beds consist of iron-stained limestone and sandstone; some of this material occurs in veins in the limestone; the chief bands of it are along large faults. On the floor of the valley lie blocks of a crinoid limestone, some of which are 20 ft. in diameter; they are probably Minchia limestone.

North of the Kia-pieh River a white muscovite-biotite gneiss (453) rises from under the red shales and sandstones on both banks of the Mekong. Associated with it occurs an altered peridotite (454). Chocolate shales at the next spur descend to the river level, probably owing to faulting; but the track rises over gneiss, Minchia limestone and shales which dip E. to the valley of Yung-kun-ko, which is followed by the track to A-tun-tze. The northern bank of the Yung-kun-ko Ho, where its ravine widens out into the valley of the Mekong, shows contorted overfolds due to pressure from the W. W. of the Mekong the beds dip to the N.W., probably owing to the cross faults which have brought up the Yung-kun-ko gneiss. The gorge of the river traverses black shale, but on the beds of the tributaries from the S. are large boulders of granite. A little E. of the first tributary from the S. three faults with a steep hade to the W. are seen on the northern bank. The ravine continues to the E. and N.E. through the Minchia Series; a little S. of the village of Kungha gray silvery mica-schist forms the end of the western spurs and most of the slope on the eastern bank, where it is capped by red rocks of the Minchia Series. The mica-schists strike N.W. and dip S.W. Near Kungha the schists are covered by a red conglomerate including boulders of red jasper, varieties of coarsely porphyritic red and green rhyolite (406) and quartz pebbles. But we saw in it neither of the local granites; hence these rocks, like the later porphyries, were exposed later than the conglomerate, and are intrusive into the Minchia Series. Passing up a northern tributary to the Yung-kun-ko to the oasis of Chung-kung (9500 ft.) the mica-schists on the eastern bank strike N.N.E. and dip 60° to E.S.E. The western bank, however, consists of the red beds of the Minchia Series until the river turns eastward and both banks consist of mica-schist. The next main turn of the valley to the N. leads to A-tun-tze between hills of mica-schist on the western bank and of the Minchia Series intruded by rhyolites to the E.

§ 11. *The Mountains East of A-tun-tze.*

East of A-tun-tze (10,800 ft.) the Mekong-Yangtze divide reaches its greatest height S. of the Ba-tang district, and we made an excursion into these mountains to investigate their structure and the relations of a peak seen by Mr. KINGDON WARD.

The A-tun-tze valley is bounded on the E. by the steep wall of a plateau, from the edge of which, at the height of about 13,000 ft., the country rises through undulating downs to the rough rocky peaks of the Mekong-Yangtze divide. At the foot of the valley wall E. of A-tun-tze biotite-hornblende-granite (Z 35) outcrops beneath black slate and green grits. At 13,000 ft. we entered a hanging valley, across the mouth of which lies a small terminal moraine containing boulders of schistose quartzite, rhyolite, and slate. The bare hill face to the S. of the valley contained yellow weathered sheets of rhyolite and stained slates. Above the moraine the Jsu-su valley continues eastward across a series of slates and grits and then bends northward. It passes the foot of a band of limestone which rises into a high pinnacle at the height of about 13,700 ft.

The limestone is much altered and in the scar on the western side of the valley it is garnetiferous, owing probably to the effect of the intrusive rhyolite. Several well-preserved terminal moraines cross the valley at just over 13,700 ft., and amongst them, at 14,220 ft., behind a moraine-dam, is the lowest of four lakes. The Jsu-su valley there trends from W.S.W. to E.N.E. at the foot of an even slope of a schistose rhyolite, some of which has a greasy aspect on weathered surfaces. This rock is intrusive into the Minchia Series, which is represented by black slate, cleaved quartzite, green grits with many quartz veins, and crushed and cleaved Minchia limestone, striking N.E. by N. The limestone is also seen at the height of 15,600 ft. by Lake Tsu-na, of which the outlet through a rocky gorge has been described by Mr. KINGDON WARD (*Land of the Blue Poppy*, 1913, p. 170). Above Lake Tsu-na the slates of the Minchia Series are intruded by a band of gabbro (419), which is also seen (Z 33 *a*, *b*, *d*) with dolerite (Z 33 *c*) on the western side of the Jem-sa La Pass (16,800 ft.). The pass is a notch formed by the weathering of the softer black slate, which strikes to 18 E. of N., and is nearly vertical, but has a slight dip to the W. On the eastern side of the pass is a high boss of rock intrusive in the slate. The descent of the eastern side is over black slate, Minchia limestone and gabbro (Z 32, 436 *b*, 437). The limestone usually dips E.; it has been cleaved and in places altered by silicification to a banded chert. It has been intruded by rhyolite and dolerite (431); frequent slicken-sided surfaces show the extent to which the rocks have been faulted. At the eastern foot of the Jem-sa La is the small Lake Tse-kon, in the valley of Mi-tu-tong. Both sides of this valley consist in the main of the sedimentary rocks of the Minchia Series, with an undulating dip. On the ridge to the E. of the camp the rocks at the northern end of the valley consist of porphyry and dolerite, which abut against a thick series of red sandstones and slates with a regular dip to the S. They are succeeded to the S. by the Minchia limestone and farther S. the high peaks to the S. of the Ni-ma La or Chnu-ma La consist of red shales and sandstones intruded by masses of kersantite (430, Z 31). At the northern end of this section the rocks have been shattered by a great crush zone, which includes huge lenticles of the igneous rocks. We did not reach this fault on the eastern side of the valley, but the fault is clearly shown in photographs, and we had to trust in the identification of the rocks to those of similar appearance on the western side of the valley.

We saw no peak in the group higher than about 19,000 ft., but it is nevertheless the highest part of the Mekong-Yangtze divide in Chinese Tibet. This group consists of the Minchia Series intruded by abundant rhyolite, dolerite, and gabbro. The area has been intensely disturbed by faults and overthrusts. One of the most striking is that which passes through the Jem-sa La and throws the sandstones N. of Lake Tse-kon against igneous rocks. The country has clearly been disturbed by folds on lines trending E. to W. due to pressure from the N. The folding was followed by violent faults due to pressure in the same direction. These transverse movements are clearly later in age than the N. to S. strike caused by the Indo-Malayan movements.

A-tun-tze is separated from the Mekong by a mountain mass of which the most remarkable peak is Mt. Regni, due W. of the town. The base of the range consists of mica-schist, covered by Minchia limestone and black shale, which are overlain by basalt, which lies beneath tuffaceous trachyte (465) with a coarsely porphyritic sanidine trachyte (466) on the summit. The Minchia Series extends N. of Mt. Regni; for we could recognise its usual rock-association in a view of the mountains between Adong and the Mekong valley.

From A-tun-tze we turned south-eastward to reach Pei-ma Shan. The ascent past Chih-sui led over the Minchia Series dipping E. with typical black slate and Minchia limestone; this series has been invaded by the A-tun-tze granite, in contact with which is a staurolite-hornfels (470). The ravine followed by the track exposes black shale and green porphyry; and at 500 ft. below the pass occurs purple slate. The pass leads over to the upper valley of the Yung-kun-ko bounded on the E. by a line of cliffs of the yellow weathering rock which we had seen also S.E. of A-tun-tze, and which we were now able to verify as rhyolite. It has well marked banding and is intrusive into the Minchia Series, for we crossed exposures of sandstones, red shale and banded limestone all showing evidence of contact alteration. The prevalent strike is meridional, but in the afternoon we reached a blue quartzite striking to the S.W. and dipping S.E. This change was explained by an outcrop of gray dolerite (504, 505) followed by green grits and black slate which strike S.E. and dip N.E.

Moraines with ice-scratched rocks occur in the angle between the two branches of the Yung-kun-ko river, at the height of 12,700 ft.; on the bed of the eastern branch are boulders of enstatite-granite-porphyry, limestones, sandstones and shales of the Minchia Series, and a cream-coloured limestone belonging to a later formation. Boulders also occur of a red conglomerate which contains abundant jasper and porphyry, and one pebble of granite; but we saw in it no specimen of either the dolerite or younger granite, which therefore probably had no outcrop during the formation of the conglomerate.

We followed up the western branch of the river. The ascent was first over a biotite-hornblende-granite which contains many xenoliths of the Minchia Series, and is clearly intrusive into it. During the ascent to the moraine-capped ridge which rises southward to Pei-ma Shan, we crossed more baked rocks of the Minchia Series on the edge of the granite. When we reached the pass (14,400 ft.) Pei-ma Shan was hidden by clouds, but we saw to the E. a pinnacled range of cream-coloured limestone, from which no doubt had come the boulders previously observed. At the pass is a brownish biotite-granite-porphyry (500).

In the descent to the valley of Janu-la, after leaving the granite-porphyry, we crossed a massive limestone with few calcareous veins and some obscure crinoid stems. It represents the Minchia limestone somewhat less veined than usual, and the Upper Devonian fossil (*Uncinulus*), subsequently found in the stream at Janu-la, doubtless came from a band interbedded with this limestone. The cream-coloured limestone range to the E. is cut through by a stream at Janu-la, of which the bed is littered with boulders of this rock; in them is a coral which we at once recognised as similar to the Spongiomorphoid corals of the Triassic limestones of the Tyrol. It is associated with brachiopods which have been determined by Dr. Cowper Reed as Triassic. The dip in the Triassic part of the range is generally to the S.E.; but its southern end consists of rocks resembling those of the Minchia limestone with a dip to the S.W. or W. East of Janu-la the Triassic limestones rest unconformably upon the Minchia Series. Dr. Cowper Reed has also identified some Upper Carboniferous fossils which were collected from boulders farther down the Janu-la river.

§ 12. *Pei-ma Shan.*

The south-western side of the Janu-la valley is a ridge 1000 ft. high, of which the base consists of granite and the upper part of Devonian rocks and conglomerate. Exposures on it are scanty, as the hillside is covered by moraine matter, which in one section was 150 ft. thick. To the S.W. of this ridge lies the Cho-ni valley, which leads to the northern front of Pei-ma Shan. The valley is broad and glaciated, and successive terminal moraines lie across its floor. Descending obliquely its northern side we crossed coarse granite and felspar-porphyry, succeeded to the W. by chocolate-coloured slates which strike to 170° and dip 80° S.E. Beside this slate is a yellow, crushed limestone containing blows of quartz; this rock is followed by granite, crushed slate, and graphitic slate. These representatives of the Minchia Series rest to the W. against a belt of black mica-schist, like that of A-tun-tze. The schists are very contorted and become coarser toward the W., where, beside our camp, they pass into ordinary gneiss. The southern side of this valley is formed mainly of a ridge of schists, which at the western end have been thrown by a reversed fault upon Devonian rocks. A broad intrusion of quartz-syenite-porphyry (494) traverses these Devonian slates, and on the western side ends, also at a reversed fault, against the mass of the Pei-ma Shan granite. This rock is a biotite-hornblende-granite, and it forms the axis of the northern part of the range; its selvage is in places spessartite. It has been subjected to heavy pressure since its intrusion. It shows in places a pseudo-bedding due to pressure; the dip of these planes is towards the E.; they are crossed by nearly vertical joints with a very steep easterly dip. (Fig. 2.)

A depression in the ridge to the S. of the Cho-ni valley leads to the Cho-nung valley, of which the upper part lies along the eastern foot of Pei-ma Shan till the valley makes a right-angled turn to the E. So far as we could see, the central part of the range consists of granite; the slates and Minchia limestone, which dip westward, form the eastern foothills, and farther E. the ridges are of mica-schist. The upper part of the Cho-ni valley traverses the granite axis of the range. The rock is often greatly crushed, sometimes having been converted into gneiss; in one place the severity of the earth movements is shown by the inclusion of a slab of Devonian rock in brecciated banded granite.

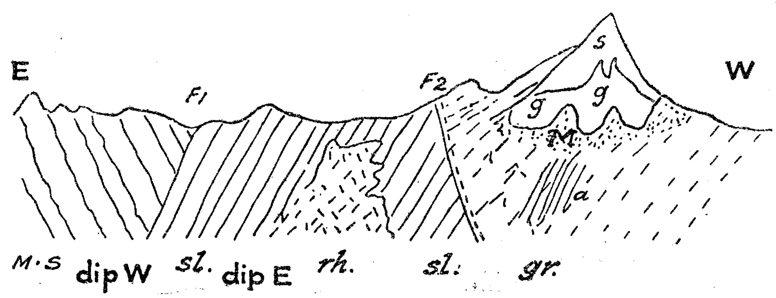


FIG. 2.—S. side of Cho-ni valley, traversing N. end of Pei-ma Shan. *M.S.* mica-schist. *sl.* slate. *gr.* granite. *rh.* quartz-syenite-porphyry. *g.* north glacier of Pei-ma Shan. *M.* moraines. *s.* snowfield on N. peak. *a.* pressure jointing. F_1, F_2 faults.

Pei-ma Shan appears, therefore, to consist mainly of a mass of granite that was intrusive into the Minchia Series. The granite has subsequently been affected by intense earth-movements due to pressure from the W., by which it has been forced along overthrust faults against the Devonian sediments.

§ 13. *Janu-la to the Yangtze at Chi-tsung.*

In the descent of the Janu-la River from our camp we passed fossiliferous Triassic limestone, and saw its well-marked unconformity on the Minchia limestone. The track descends over syenitic gneiss (519), and at the beginning of the ascent to the Janu-la—Tung-chu-ling divide it crosses a stream beside an exposure of oligoclase-basalt and black slates, and rises over Minchia limestone and its associated grits. These rocks are followed by granite, while on the moraine-covered moorland above the scattered blocks seen are porphyry and green grits. At the height of 14,500 feet a stream has cut through the moraine into chocolate-coloured shales and green and brown grits. Red sandstones are abundant in the morainic material, but we found none of the Pei-ma Shan granite. The descent eastward from this divide is over a rock so similar to typical Old Red Sandstone that it increased the resemblance of these misty moorlands to parts of the Scottish Highlands. A thousand feet below the pass exposures of green grit and conglomerate occur beneath a moraine with ice-scratched boulders. Farther down the slope exposures are more abundant and show red sandstone, conglomerate, Minchia limestone, green porphyry, green shale, a yellowish-brown sandstone, and also some indurated black and green shales which probably indicate the presence of thin intrusions. The lowest glacial deposits seen are at about 13,500 feet. Below this level occur diabase (527*b*), yellow sandstones, green shales and black slates, striking to 110° and dipping 60° N.N.E. Some hard folded contorted green slates, with a strike of 135°, indicate local faulting which has brought up the green grits. The first house E. of the pass, Ji-chia-po (altitude 11,500 feet), stands beside the contact of hornblende-granite (518) with the Devonian sediments. The route then descends steeply over green grits and slates to a belt of schistose rhyolite (523). At 10,600 feet occurs the Minchia limestone, and black slates are associated with green porphyry. Farther down the valley is more rhyolite. The river gorge is mainly cut through black slate, green shale and Minchia limestone, with another exposure of rhyolite crushed by faulting. A deep sinuous gorge has been cut through green grits, black slate, Minchia limestone, calcified crush-rock (Z 43), and some red and blue shales which dip eastward. Schistose rhyolite is exposed half a mile up-stream from the hamlet of Tse-chio, below the famous lamasery of Tung-chu-ling.

Just E. of Tse-chio is a belt of coarse red porphyry like that of Kon-ya (*cf.* p. 203). East of it is a belt of mica-schist followed by Minchia limestone which dips to the W.S.W. The route down the valley to Reni-kon-ka is over the Minchia Series; the beds are repeated by folding and are traversed by powerful meridional faults which are well shown on the northern side of the lower end of the valley near Nru-inda. The Tung-chu-ling River there turns northward through a gorge along a broken anticline; the dip away from the river on its eastern bank is part of the synclinal fold of the Pang-tze-la hill. East of the village of Reni-kon-ka further evidence of this syncline is given by the westerly dip of the Minchia limestone, below which, in an arid kloof, we came unexpectedly on to biotite-granite (Z 42) and biotite-quartz-syenite (529*d*); some of the granite is crushed and gneissose. On the dry bed of the kloof we found a block of Ta-li marble. Here we left the direct route to Pang-tze-la and turned S. to cross the mountains on a route parallel to the Yangtze. We left the Pang-tze-la track at about 8600 feet and soon passed from granite and schist to black slates dipping southward. They are followed by other members of the same series, including Minchia limestone, green grits, and black slate. The slates are often vertical or have a slight dip to the S.W.; they are traversed by veins and blows of quartz. Beside the village of Ba-zin, on the floor of the valley (altitude 8100 feet) the red and green shales are silicified and strike to N. by E. and dip 85° W. by N. In a further exposure the beds strike to N.N.W. and have been overfolded by pressure from the W. Views from the hills show that the Pang-tze-la syncline continues northward on the eastern side of the Yangtze. From Ba-zin a track ascends the Sha-hi River with exposures of bedded red sandstone, quartz-conglomerate, green beds, Minchia limestone and its accompanying black slate. Just N. of the village of Sha-hi the valley rises in steps over a mass of biotite-granite. This rock continues up-stream beyond the village (9200 feet), where it is covered by horizontal red sandstone capped by the Minchia limestone, which forms a plateau on either bank. The red sandstone is of the St. Bees Sandstone type and is over 100 feet in thickness.

On the path to the Jin-go La the Minchia limestone is overlain at 10,000 ft. by brown grits and red sandstones ; at 11,000 ft. occurs black slate, which is traversed by slickensided faults trending E. and W. These slates are associated with porphyry and then follow Minchia limestone and black slates which dip N.W. The ascent of the Jin-go La pass from about 12,000 to 13,500 ft. is successively over felspar-porphyry, green grits, blue sandstone, quartz-porphyry, a red felspar-porphyry, and then a thick series of red sandstones, blue quartzite and grits, and green grits. The summit of the pass (alt. 13,500 ft.) consists of black slate which is exposed beneath morainic drift. We had seen from the N. a small glaciated corrie to the W. of the track. The glacial drift contains numerous ice-scratched boulders and extends down the valley to the S. of the pass to 11,800 ft. ; the descent from the Jin-go La to Ka-ri was mainly over the Minchia Series, represented by yellow sandstone, bluish quartzite, and a blue quartzitic grit and intrusions of porphyritic biotite-granite (Z 47). In one place a 4-foot dyke of the granite has altered the blue grits into banded quartzite. These intrusions are doubtless offshoots from a mass of granite seen lower down the valley, beyond which is a long dyke, about 1-foot in width, of granite in Minchia limestone. Porphyritic biotite-granophyre (Z 48) also occurs. South of Ka-ri* the rocks are Devonian sediments which form the hills to the S. of the Ju-geh River, where there are numerous crags of Minchia limestone dipping to the W.

The Ju-geh River comes from the N.W. along a valley eroded in an anticline. We followed this river from the confluence of the Ka-ri River (8800 ft.) to Ron-sha. The rocks along the valley are mainly sediments of the Minchia Series intruded by various porphyries. At the falls in the Ju-geh River a little below its junction with the Ka-ri River is an amygdaloidal porphyry associated with blue grits. Below this point the valley alternately widens into a dale where it crosses the black slates and contracts to a gorge where it cuts through the quartzites. The slates below the falls strike N.N.E. by E. and dip W.N.W. by N. On the eastern bank of the river the rocks have been disturbed by a fault overthrust from the N. ; on its southern side the blue quartzites are thrown into folds of which that nearest the fault is overfolded to the S. These rocks are followed by massive green grits and slates, which strike S.W. and dip N.W. Half a mile farther S. red shales and sandstones strike 10° and dip E. by S. A couple of miles farther S. the Minchia limestone dips to the N.E. ; then follow black slates which strike N. by E. and then grits. Near Shieh-sung occurs amygdaloidal trachyte and the Minchia limestone on both banks dips away from the river. The main valley is along an anticline, with a parallel syncline to the E. At Do-song (7800 ft.) the general strike of the district, namely, from N.N.W. to S.S.E., is resumed ; the dip is W. One clear

* Near Ka-ri we found the only ancient stone implement, a quartz arrow head, seen during the expedition.

exposure showed a strike of 12° and a dip of 65° to E. by S. South of Do-song are extensive exposures of the green grits that underlie the Minchia limestone; many of the surfaces are slicken-sided and some black shale with the N.N.W. dip is intensely crushed and slicken-sided. A tributary from the W. exposes the Minchia limestone and black shale with a dip to the W.; but we could see no porphyry boulders on the stream bed. About 5 miles down stream from Do-song the limestone contains obscure fossils that might be crinoid stems and the rock resembles the cream-coloured Li-kiang limestone. We found no definite evidence of the occurrence of Triassic rocks, for the exposures to the S. consist of green shales striking from N.W. to S.E. and dipping S.W., of black shales and Minchia limestone which dip N.W., and later of green grits which strike N.N.W. South of the hamlet of Kuan-sa the black shales and slates are extremely contorted and dip S.W. Near Sa-ka-ting some of the Minchia limestone and its black shales are intensely contorted along parallel bands; the beds have mostly a gentle dip to the S., which is broken repeatedly by contorted bands with a steep dip to the N.; these bands are composed of numerous small horizontal overfolds.

At Se-kon the black slate is capped by the Minchia limestone and both dip W. Farther S. are vertical green shales with a strike from N. to S. In a tributary to the S. the limestone is banded and corrugated and dips W. After crossing this river (6800 ft.) black shale and Minchia limestone strike to the N.N.E. and dip to the E.S.E. A large tributary joins the Ju-geh River. The structure of the country to the W. of the Ju-geh is shown by the boulders on its bed; they are mostly of granite, gneiss (552*b*), granite-porphyry (552*e*) with a few of limestone and its associated grits.

The bend of the Ju-geh River W. of Ron-sha exposes the Minchia limestone striking N. and dipping steeply to the W. A broad valley there joins the Ju-geh River from the W.S.W. and most of the rocks on its bed are gneiss and granite. At Don-sha, the next village down-stream, the green grits have been thrown into a double overfold with a dip to the W.; but to the E. of these folds, and apparently faulted against them, is a band of Minchia limestone with a dip to the E.

From Ron-sha we began the ascent to the Ju-go Shan pass; the track rises over green grits and shales which strike N.N.W. and dip E.S.E. These rocks are exposed at the village of Kwei-jen-yera, while both banks of the valley show exposures of the Minchia limestone.

The summit of the pass consists of green shale striking to N. by E., and with a steep dip to E. by S. This pass, at the height of 12,000 ft., showed no trace of glacial action. The pass commands a broad view to the S. over a dissected peneplane in which the N. and S. ridges follow along the grain of the rocks, while the major E. to W. valleys have been dissected along faults and folds. South of the pass the green slates show a well marked cleavage across the bedding. The track descends steeply to the Chi-tsung River along a valley between Minchia limestone on both sides; the rock strikes to the W.N.W. and dips N. Farther S. the dip is to the W. The limestone overlies red shale, and on the southern side of the Chi-tsung valley it occurs in two bands interbedded in red shale. Our route turned sharply to the E. along the valley of the Chi-tsung Ho to the Yangtze. The Chi-tsung Ho comes from the Mekong divide, near the Li-ti-ping Pass; many of the boulders on its bed are of granite, but we saw none of gneiss or crystalline schist.

Near Ta-cheng the rocks belong to the Minchia Series with a predominant dip to S. and S.W., owing to one of the E. to W. dislocations. The chief rocks there and at Yen-in-wan consist of the Minchia limestone in two bands, which are intercalated in a thick series of red shales with some green shale. East of Yen-in-wan is an exposure of mica-schist, which extends up a tributary to the N. The slopes on the hillside above it consist of the red shale under the Minchia limestone, which rests directly on the schists.

At the Chi-pieh-Na-pu bridge the rocks on the northern bank of the river consist of green and red shales and strike from N.W. to N.N.W. and dip about 60° S.W. South of the river the Minchia limestone and slates strike to the N.W. and dip N.E. The beds are disturbed and include crushed slate and green beds which dip W.

At the town of Ka-li-tsa or Ta-sa green grits dipping S.W. rest on graphitic and phyllitic-schists which dip W.; these rocks are succeeded eastward by a quartzitic schist which dips to the E. The river contracts to a gorge and is broken by rapids in a gorge cut through crystalline limestones and schists, which strike to 140° and dip S.W. These limestones form the precipices above the Yangtze at Chi-tsung (river altitude 6800 feet); they belong to the Ta-li Series.

§ 14. *The Yangtze from Chi-tsung to Chi-tien.*

South of Chi-tsung the track beside the river climbs over a ridge at 8000 feet of gray corrugated schist which dips E. The Yangtze valley is there in a trough fault; the band of crystalline limestone on its floor, having been nipped between two faults, has been bent into a synclinal. The main structure of the valley is, however, generally anticlinal. The river valley continues southward, through biotite-schist and crystalline limestones which dip S. The beds of the streams from the W. include cobbles of granite, red sandstones and green grits, but we saw no porphyry. At Lung-pa Ho the bed of the tributary from the W. is littered with boulders of granite and tonalite-porphyry (545*b*), but has no red sandstone, so that the Minchia Series is farther from the river. The spur to the S. of the stream there is anticlinal, and its southern slopes consist of blue biotite-schist. In the next spur, where the schists strike N.N.W., the descent to the wide basin of Te-lo is over a vast fan of outwash gravel, no doubt accumulated as a delta at the northern end of the Te-lo basin. The rocks consist of green schists and limestone. Five spurs descend to the river from the E., and the dip in them is to N. or N.E. As the Te-lo basin is contracted by the Pai-lien ridge the anticlinal structure is again obvious, owing to the westerly dip of the rocks in the western ridge, and of the easterly dip on the continuation of that ridge on the eastern bank of the river.

That the Yangtze is rapidly deepening its bed is shown by the freshness of some pot-holes 30 feet above the river level. From the Pai-lien ridge to Chi-tien occur green schists which strike N.W. and dip N.E. The view to the hills S. of the Chi-tien basin includes three ranges to the W. of the Yangtze, and in all the dip is to the W. At the northern corner of the Chi-tien basin, however, the black schists strike N.W. by N. and dip N.E. by E. The track crosses a large delta fan in which the chief rocks are red grits and sandstone, green porphyry, green breccia, pink granite, and black slate; but we saw no Minchia limestone. On the floor of the Chi-tien basin there are thick deposits of red sands similar to those near the Salween Bridge (*cf.* pp. 176, 225).

The view southward down the valley up which we had come on the outward journey from Li-kiang, showed its anticlinal structure, with a well marked dip away from the river on both banks.

§ 15. *Li-kiang-fu to Yung-chang-fu.*

From Li-kiang the track to Ho-king crosses the alluvial plain to Tung-yuan-tsun (8480 feet), a limestone ridge which is adorned with a conspicuous pagoda. The track there turns S. along this ridge, passing to the E. of a conspicuous series of banded limestones which abut to the W. against the basalts that form the hills on the southern side of the Li-kiang basin. The banded limestones so closely resemble those seen at the north-eastern foot of the Li-kiang Snow Range that they are doubtless Devonian. The basalts appear to overlie them. Above the banded limestone is a cream-coloured limestone which dips W. It contains some obscure fossils; but as we were making a long march we had no time to collect more than a few shell and coral fragments which are indeterminable. The lithological character of the rock renders it probable that it is a continuation of the Triassic limestones of the Black Dragon Temple Range (*cf.* p. 189). We continued along the foot of the limestone range, but for several miles of our march to Feng-ming-kai the journey was in the dark.

The road from Feng-ming-kai to Ho-king crosses alluvial plains and is paved with limestone blocks of three different kinds—ordinary Minchia limestone, a banded limestone which is probably of the same age as that containing Idiostroma, and a crystalline limestone like the Ta-li marble. A little E.N.E. of Ho-king the limestone range to the W. is interrupted by a sudden E.-W. upfold by which the banded (? Idiostroma) limestones are flung from a horizontal position with a N. to S. strike into an almost vertical position, with a strike from W. to E. and a slight dip to the S. due to overfolding (fig. 9, p. 239). Parallel to this W.-E. fold is a series of faults. South of Ho-king the river passes to the Yangtze through a gap around the eastern end of a ridge in which the dips are to the W. The track to Ta-li-fu climbs on to the western end of this ridge over buff, black, and red shales to the bluish-gray Minchia limestone; the strike is S.W. and dip S.E. The pagoda-crowned hill which rises from the plain below consists of the banded limestone (probably Devonian), and its strike is from E. to

W. and dip to the S., in accordance with the Ho-king fold. Higher on the range (at 8800 feet) is a cherty cream-coloured limestone with obscure fossils; it is probably a continuation of the Triassic limestone of Li-kiang. The first pass, 9400 feet, is through banded limestone with black shales which dip N.

Near the pass some of the limestone has been crushed to a breccia and the adjacent shales show a low dip to the N. Some of the limestone has weathered into a karst-land, but, as we passed its pinnacles, darkness fell upon us and we missed the next part of the route in a long night march. It is clear, however, that in this locality there were limestones which belonged to at least three distinct series. A basal series of limestones belonging to the Ta-li group, banded limestones which are Devonian, and an uppermost massive cream-coloured limestone which from the evidence near Li-kiang is probably Triassic. These Triassic limestones appear to form the higher peaks to the W. and S.W. of Ho-king and to the S. of them is a wide dissected plateau of the Devonians.

At Khreh-ni-sowa (9200 ft.), where we resumed our march in the daylight, shales and mudstones just above the village contain a seam of earthy anthracite. A mile up the pass these beds are succeeded by green shale which strikes S.S.W. and dips W.N.W. Upon this shale lie dolerite, oligoclase-basalt, some of which is vesicular with a red spotted base, and layers of basaltic volcanic ash. These volcanic rocks are associated with red shales which have been slicken-sided by faulting. The basalts are followed by purple shales with intrusive diabase. This association indicates that these rocks are the southern continuation of the shale and volcanic series which we crossed to the S.W. of La-shi-pa (*cf.* p. 190). Some boulders of the Minchia limestone occur at the fork of this valley where a porphyritic spilite contains quartz-filled vesicles. The main track rises over purple shale interbedded with lavas to the pass at 10,200 ft. We saw no trace of any glacial deposits on the pass. The path descends over shales to a compact basalt at 9900 ft. and massive and porphyritic spilite (555) at the village of Kuan-nan-po (9700 ft.). The Minchia limestone outcrops at 9300 ft., but the main descent to the Na-sui Ho or "Lost Water River," is over a banded vesicular basalt; at 8500 ft. a volcanic neck with altered fragmental olivine-basalt, which is very vesicular (568 and 570). We crossed the river at 8100 ft.; on its bed are pebbles of red sandstone and breccia, altered Minchia limestone, and a coarse porphyritic basalt like that of Kien-chwan-chow. The deep gorge of the Na-sui River cuts through the Minchia limestone, which strikes to N.N.W. and dips W.; the lower part of the valley is in massive white cherty limestone and limestone breccia, which are probably the southern extension of the Kao-liang limestones W. of La-shi-pa. At the mouth of the valley of the Na-sui Ho the hills to the W. are volcanic, while the western wall of the main valley consists of contorted crystalline limestones, which strike N. and S. and dip 80° W. They represent an outcrop of the limestones of Ta-li-fu. The route then crosses for some miles over a plain of alluvium to Niu-kai, 6750 ft., which lies at the foot of the eastern wall of the valley. The hot springs of Niu-kai probably rise along the bounding fault of this basin; they smell of sulphur-dioxide, and their hottest water was at 174° F. The Pagoda Hill to the S. of Niu-kai has a steep western front covered by tufa, but most of it consists of dark blue shale with some carbonate veins. The route passes along the foot of the hills on the eastern side of the alluvial basin; the hill front is a weathered fault-scarp, in which the beds dip E. while those at the southern end of the basin dip W. At Si-ying-kai the bed of the river from the E. is littered with pebbles of Minchia limestone and of a conglomerate which includes red sandstone and Minchia limestone. The stream comes from a gorge with high dips to the W.N.W., but from Si-ying-kai southward the prevalent dip is eastward in the hills to the E. of the basin. About 10 miles S. of Niu-kai the track rises over some hills that project from the eastern side of the basin. These hills include red and chocolate sandstones, green grits and Minchia limestone, but they consist mainly of fine-grained gabbro and porphyritic spilite (582). The series is mainly volcanic and includes coarse tuffs passing to agglomerate.

According to Mr. W. N. Fergusson, of the Imperial Salt Commission, some of the volcanic rocks of this basin may be of modern date, as he considers the Lang-kiung hot springs as of volcanic origin.

At the village of Sin-chang we reached the bank of the river which carries the discharge from the Niu-kai basin through a gorge to the basin of Chung-so. This Chung-so gorge gives an instructive section, through the Minchia Series with its intrusive spilites and flows of basalt. In the upper part of the gorge the grits and shales have been baked. East of the bridge at the guardhouse are beds of volcanic tuff and agglomerate with flows of coarse purple spilite, some of which is coarsely porphyritic. Interstratified with these rocks is a purple shale, dipping eastward and traversed by a dyke. Farther down the gorge, purple shales dip W. and are interstratified with coarse conglomerate; then follow vesicular basalt and Minchia limestone, which has been altered, and red sandstone. The lower part of the gorge trends to the S.S.E. and is cut through red and green shales which strike N.E. and dip N.W. At the mouth of the gorge are diabase and shale. The track then continues along the embankment of the Chung-so River, which is raised above the level of the adjacent flood plain. The floor of the Chung-so basin is a wide alluvial plain which is bounded by hills to the E., N. and W. These hills appear to consist of rocks of the Minchia limestone and diabase series.

In Chung-so a siliceous pudding stone is largely used for paving stones, and is probably one of the Minchia conglomerates baked by the intrusive rocks. Our road to the S. lay over the alluvium, but the nature of the neighbouring rocks may be judged by the paving-stones which include augen-gneiss, Ta-li marble, and calc-biotite-schist. We left the alluvial plain at Teng-chwan, to the S. of which occur coarse diabase and variolite, and also augen-gneiss, which appears to form the bulk of the western hills. On the bed of streams S. of Teng-chwan are pyroxenite-gabbro (580, Z 70) and pyroxenite (Z 69). The rocks exposed beside the track included gneiss, biotite-schist, and granite. Most of the route, however, from a little S. of Teng-chwan to Ta-li was over the recent deposits of the Ta-li plain.

At Ta-li-fu we rejoined the road across southern Yunnan of which the geology has already been described by VON LOCZY and Mr. COGGIN BROWN, whose accounts we supplement by a few notes. The river valley which descends first S. and then westward from Sia-kwan, the commercial centre of this part of Yunnan, is cut through gneiss, mica-schist, and black schist, of which the strike is from E. to W. These rocks are intruded by veins of granite and upon them rest purple slate, which dips N.W. and N., and also sandstones and grits; these red rocks clearly represent the Minchia Series, and rest unconformably upon the Eozoic. Before reaching the hamlet of Ho-kiang (4800 ft.) we passed from the Devonian rocks to schists, including a greenish schist like that at Lan-shueh-ko, and to an augen-gneiss striking N. to S. These metamorphic rocks are accompanied by Ta-li marble and black schist. In the ascent of the Yang-pi River the rocks exposed as far as Ping-po are gneiss and schist with some quartzitic gneiss, also some blue schist and chloritic schist. Then at the sudden bend of the river W. of Yang-pi the crystalline rocks are covered by a series of red and green sandstones and grits, and chocolate-coloured shales beginning with a coarse basal conglomerate. The grits resemble those of the Minchia Series, but a little farther S. the Permo-Trias must rest directly on the pre-Paleozoic. Some specimens of the grits found on the river bed contain the copper ores, malachite and azurite.

From Yang-pi we marched for three days westward over the Permo-Triassic Red-rock Series. They have been greatly disturbed as their dip is high; sometimes it is vertical, and the rocks are in places broken by pressure cracks, as, for example, W. of Tai-ping-pu. VON LOCZY, who crossed this belt of rocks to the N. of our route, represents on his section some recumbent folds. Though we did not see hereabout any cases of such extreme overfolding, the dip was in places slightly inverted, and we saw no reason to distrust VON LOCZY'S section for the line he followed. East of Ku-tung on the Yung-ping River, the recent age of the earth-movements is indicated by seven parallel faults traversing the drifts, which are probably Pliocene. At Shan-yang, E. of the Mekong River, the Red-rock Series is succeeded by the Kao-liang Series, which is there represented by hard blue flags. The Mekong Gorge is in the Kao-liang Series, upon which at Shui-chai rest Carboniferous limestones containing crinoid stems, an indeterminable coral, and brachiopods.* These rocks are overlain by wide sheets of basalt, as N. of Ta-li-shao, with some olivine gabbro and tuffs. This basic series with some volcanic necks is extensively developed between the Mekong and the Yung-chang basin.

At Yung-chang we rejoined the route by which we had entered the country.

* Carboniferous fossils have been recorded from this locality and Ta-li-shao by VON LOCZY (1893, p. 765) and Mr. COGGIN BROWN (1916, p. 237).

Part III.—The Stratigraphical Succession.

1. The stratified rocks met with in our journey may be classified as follows :—

Kainozoic—	
Pleistocene	Alluvial deposits and drifts on the floors of the valleys and basins, in delta fans, &c. Moraines in Chinese Tibet above 10,500 ft. Volcanic—Teng-yueh.
Pliocene	Lower lacustrine beds in basins. Red sands on the floors of the river valleys and basins.
Middle or Lower Kainozoic	Volcanic series of Teng-yueh, and Li-kiang.
Mesozoic—	
Upper Trias	Dolomites and limestones of Janu-la, Li-kiang, &c.
Lower Trias	Red rock series of Yun-lung Salt Basin.
Paleozoic—	
Upper Permian ..	Red rock series of Yun-lung Salt Basin.
Upper Carboniferous	Limestones with Productus, Neoschwagerina, Fusulina, Fenestella, &c. ; at Lota Gorge, Shui-chai, Yang-tsen, &c.
Lower Carboniferous	Limestones at A-shih-wo.
Devonian, Upper ..	Minchia Series. Veined limestone and black shales, red and green shales and sandstones ; purple sandstones. Limestone with Uncinulus at Janu-la.
Devonian, Middle ..	Stromatopora limestone ; Idiostroma limestone ; Janu-la limestone, &c.
Silurian	Monograptus shales of Shih-tien and Pei-ma.
Ordovician	Lower Bala—Upper Llandeilo. Graptolitic shales of A-shih-chai River. Ho-wan.
	Arenig—Lower Llandeilo. Shales and sandstones of Pu-piao.
Archeozoic—	
Kao-liang Series ..	Phyllites and chloritic schists, quartzites, crystalline limestone and limestone breccia ; Shweli-Salween divide ; Mekong Valley E. of Bridge and E. of Fei-lung Bridge ; W. of La-shi-pa ; nr. Niu-kai ; Siao-wei-si ; S.E. of A-tun-tze ; N.E. of Yung-chang.
Eozoic—	
Ta-li Series	Si La schistose quartzites and grits. Crystalline limestones and biotite-schists of Yang-tze above Shih-ku, W. of Si La, &c.
Taping Series	Gneisses, with some schists and crystalline limestone. Taping Valley ; Ho-wan ; W. of Tsed-rong ; W. of Ta-li ; Li-tien basin ; Wei-si ; W. of A-tun-tze ; N.E. of Pei-ma Shan.

Eozoic.

The oldest known rocks in Yunnan and the adjacent territories are a thick series of coarse gneisses. The most extensive development of them we saw was in the Taping valley between the Irawadi near Bhamo and Teng-yueh. The rocks include biotite-quartz-gneiss, garnetiferous gneiss, hornblende and biotite-schists, intrusive granites and some pegmatite. The rocks as a whole are similar to those of the Lewisian gneiss of Scotland, the Ottawa gneiss of Canada, the Swaziland system of S. Africa, the Bengal gneisses of India, and the Mogoke and Martaban gneisses of Burma. They are associated with bands of crystalline limestone, containing diopside and various green and black streaks due to forsterite and graphite. These limestones are well seen in the Taping valley at miles 30 and 48–50 from Bhamo.

The strike of the foliation in the rocks along the Taping is usually between E.N.E. and N.E., but occasionally it is as far from the average as N.N.W.

These rocks are also exposed W. of the Mekong, near Tsed-rong, where they are represented by coarse biotite-gneiss and amphibolites. They have a wide extension to the W. of the Salween. We saw them also between Teng-yueh and the Shweli; near Ho-wan; in the Li-tien basin; W. of Wei-si; and W. of Ta-li Lake.

The division containing a predominance of coarse gneiss is succeeded by rocks which, though still holocrystalline, are well stratified. They correspond to the Dalradians of Scotland, the older Huronian of Canada, and the Dharwars of India. This series in Yunnan may be conveniently grouped as the Ta-li Series, as they form the eastern slopes of the Tsang Shan range W. of Ta-li-fu. Their best known rock is the Ta-li marble.

The characteristic rocks of the Ta-li Series are biotite-calc-schist, biotite-schist, and crystalline limestone, which is usually saccharoidal and contains green and dark streaks which cause the landscapes for which the Ta-li marble is famous.

The Ta-li series occurs on the mountains along the western side of the Ta-li Lake. They must outcrop near Ho-king, as they are there used for paving stones; along the Yangtze Kiang, N. of Shih-ku, they present the aspect of a normal sedimentary series; they form the lower rocks in the "Valley of Hail," the Seroua Lombwa, on the western side of the Si La; they also form the peak of Mt. Francis Garnier.

The range crossed by the Si La consists of a thick series of schistose grits and schistose quartzites which overlie the Ta-li limestones and biotite-schists. West and S.W. of A-tun-tze are outcrops of a mica-schist which from its lithological character is referable to the Eozoic division.

The Archeozoic Group.

The holocrystalline metamorphic rocks are succeeded by a widespread series of unfossiliferous slates, phyllites, quartzites, and crystalline limestones. The alteration of the sedimentary rocks of this series has not gone further than into phyllites and slaty chloritic schists.

Mr. Coggin Brown (1913—1, p. 188; 1916, p. 212) grouped these rocks as the

Kao-liang Series. There is no conclusive evidence of the precise age. It may, perhaps, be Lower Paleozoic; or it may be pre-Paleozoic, corresponding to the non-foliated pre-Cambrian systems; these rocks are somewhat more altered than the Keweenawan of Canada, the Torridonian of Scotland, the Vindhyan of India. The Kao-liang beds resemble lithologically the pre-Cambrian slates rather than the uncleaved Torridonian sandstones. They are older than the earliest known fossiliferous rocks of the region—the Ordovician at Pu-piao, and the Cambrian of eastern Yunnan. Hence we regard the Kao-liang series as corresponding to one of the later pre-Cambrian divisions, somewhat earlier than the Torridonian or Keweenawan.

This series in north-western Yunnan is best represented in the mountains of the Shweli-Salween divide, where they are crossed by the main road from Teng-yueh to Ta-li, between the Taping and the Salween. The rocks there are mainly phyllitic slates and quartzites with some limestones. The Kao-liang Series may also include the chloritic schists which occur along the Mekong and the Yangtze. The relations of these schists to the overlying rocks were at no place clearly seen; but at Lan-shueh-ko they underlie the Stromatopora limestone, and near Ai-wa, on the Mekong, N. of Siao-wei-si, they are below the Minchia Series, of which the basal beds are made up of material derived from the chloritic schists.

Ordovician.

The presence of Ordovician fossils at Pu-piao was discovered by VON LOCZY in 1880 (1893, p. 767). The beds have been described more fully, with lists of the fossils, by COGGIN BROWN. They are steeply tilted sandstones and shales, which form an inlier in the Upper Paleozoic. The fossils have been determined by Dr. COWPER REED, and they show that the horizons represented are the Upper Arenig and Lower Llandeilo (BROWN, 1913—3, p. 330).

Some hard, jointed, unfossiliferous shales W. of Ho-wan resemble Ordovician rocks; these shales are near an outcrop of gneiss and underlie the Minchia Series. Similar shales and sandstones, which, owing to their difference from the rocks of the Minchia Series, are probably pre-Devonian, occur on the Ying-an River, at the bend about 11 miles N.W. of Wei-si. Hard greenish shales on the western slopes of the Kho-li-tsun basin may be an indurated variety of the Minchia Series, or are perhaps Lower Paleozoic.

We found some graptolitic shales belonging to a higher Ordovician horizon than that at Pu-piao when crossing the deep valley of the A-shih-chai River (the southern branch of the Ho-wan Ho) N. of the village of Cheng-mu-pa. The determination of the fossils by Dr. ELLES (Appendix II, p. 290) shows that they belong to the zone of *Climacograptus peltifer*, at the junction of the Llandeilo and Bala Beds.

Silurian.

Mr. COGGIN BROWN (1913—3, pp. 331, 334) has described occurrences of Silurian shale with graptolites belonging to the Llandovery Series at Shih-tien, 22 miles S.E. of Pu-piao, and at Pei-ma, 10 miles farther S.

Middle Devonian.

The most definitely determinable Devonian rocks which we saw are coral-bearing limestones near Li-kiang. A coral reef of *Stromatopora vesiculosa* occurs at Lan-shueh-ko, a day's march W. of Li-kiang-fu, and E. of the great bend of the Yangtze Kiang at Shih-ku. Its fossils are described in Appendix III, pp. 291–3, and are referred to the Middle Devonian.

To the N.W. of Li-kiang-fu at the northern end of the Yu-lung Shan is a widespread limestone occurring in thin beds, which give a markedly stratified aspect to its outcrops. The limestone is often dark and bituminous, and usually free from calcite veins. We found in a moraine on the Yu-lung Shan a block of this limestone containing *Idiostroma*, which is described in Appendix III, pp. 293–4, and referred to the Middle Devonian. These limestones also form the northern part of the range of the Black Dragon Temple, N. of Li-kiang-fu. Bedded limestones, which appear to belong to this horizon, occur beneath the Triassic limestones S. of Li-kiang-fu, W. of the track to Ho-king. The pagoda-crowned hill, S. of Ho-king, consists of rocks similar in aspect.

The Minchia Series.

The rocks grouped as the Minchia Series cover an extensive area in north-western Yunnan. The characteristic feature of this series is the association of a dark gray to bluish limestone, with white calcite veins along a network of cracks, with black shale, purple, red and green sandstones and grits, some of which are indurated into quartzites, and with purple, red, and green shales which are occasionally phyllitic. For this group of rocks we adopt the name of the Minchia Series, after the tribe in whose territory it is widely developed. These rocks are often associated with various porphyries and coarse porphyritic basalts and diabase, sometimes in dykes, but sometimes effusive. The series as a whole is unfossiliferous; the limestone has been largely recrystallised; it occasionally contains obscure crinoid stems, which give no clue as to age. The associated shales contain rare and indeterminable shell fragments; the only fossil from the Minchia Series whose identification is reliable is that by Dr. Reed of an Upper Devonian *Uncinulus*.

The upper part of an intrusive limburgite W. of Li-kiang yielded some nodules of a tubular coral which had been caught up from the Minchia limestone. This coral, in the large size of its corallites and the form and size of the nodules, agrees with *Pleurodictyum*. A section through one specimen showed a curved structure like that of the worm (*Hicetes*), which is so constantly commensal with *Pleurodictyum*. The coral is only a cast and its identification is necessarily doubtful, but its resemblance to *Pleurodictyum* supports the Devonian age of the Minchia Series.

The Minchia Series lies below thick sheets of diabase, and below shales and bedded limestones which contain shell fragments, bryozoa, and foraminifera, in which the minute structure is remarkably well preserved. The fossil shells in these upper limestones have been determined by Dr. REED as Carboniferous and some foraminifera by Mr. R. B. NEWTON as *Fusulina* and *Neoschwagerina*. Mr. COGGIN BROWN has collected, at several localities, fossils which Dr. REED has determined as Permo-Carboniferous.

Below the Minchia Series near the Salween Bridge is a massive brecciated dolomitic limestone which is more fully altered than the veined limestone. This brecciated limestone we refer to the Kao-liang Series.

Mr. COGGIN BROWN (1916, p. 226) has described the Minchia limestone as the "Older Paleozoic Limestone," meaning thereby, as is shown by his reference (*ibid.*, p. 228), Devonian or perhaps Lower Carboniferous, as the horizon above it is called Permo-Carboniferous. The Minchia Series is certainly older than the Carboniferous, for it underlies the Lower Carboniferous at A-shih-wo (*cf.* p. 178). Mr. COGGIN BROWN (*ibid.*, p. 227) has noted the marked resemblance of the veined limestone to the Plateau Limestone of the Shan States, which is proved by fossils found at one locality to be Devonian.

The Minchia Series is post-Ordovician, for both at Pu-piao and by the A-shih-chai River the Ordovician beds underlie it unconformably. The age of this series is therefore limited to either the Silurian or the Devonian. Its Silurian age was suggested by two considerations. The first is the general resemblance of this series, with its beds of rarely fossiliferous limestone and red quartzites, to the Muth Series of Spiti (*cf.* HAYDEN, 1904, p. 24) in the central Himalaya. The second is the possibility that the Minchia Series might be earlier than the Middle Devonian and separated from the limestones of that epoch by a strong unconformity ; this conclusion was suggested by the presence in the *Stromatopora* limestone at Lan-shueh-ko of a veined limestone pebble, which was at first regarded as the Minchia limestone ; if it were so, the Minchia limestone would have been fractured and veined before the deposition of the Stromatopora limestone. As, however, that coral reef lies against a bank of older limestones, the pebble may have come from them.

The post-Silurian age of the Minchia limestone is indicated by the following facts :— First, the nearest Silurian beds to the Minchia Series are the graptolitic slates at Shih-tien, about 22 miles S.S.E. of Pu-piao, which underlie a limestone that, according to Mr. BROWN's description (1913—3, p. 331), appears to be the Minchia limestone. These graptolitic slates being Llandovery in age, do not, however, preclude the Minchia beds belonging to the Middle or Upper Silurian. Secondly, farther to the S.E. the Silurian beds of Tongking and eastern Yunnan offer no resemblance to the Minchia Series, while the Devonian there are shallow water or terrestrial beds, and are consistent with geographical conditions in north-western Yunnan suitable for the deposition of the Minchia Series. Thirdly, we failed to find graptolites in the black shales associated with the limestone, a negative argument which, if worth anything, would be against the Silurian age of the series, whereas the only fossils found are Devonian in affinity. Fourthly, the abundance of associated igneous rocks and frequent interstratification with diabase are also considerations in favour of a Devonian as against a Silurian age.

We, moreover, regard the Minchia Series as Upper Devonian. It is the most widespread formation that we saw in Yunnan. We met it first near Yung-chang, whence it extends northwards as far as A-tun-tze, where it forms the mountainous country between the Mekong and Yangtze. It forms the foundation of the plateau W. of Li-kiang, whence it extends southward in the ranges between Ho-king, Niu-kai, and Chung-so, and as far S. as Yang-pi. Farther N. it rests on the gneisses and schists, as near Wei-si; and schists outcrop from below it at intervals along the Mekong and Yangtze valleys as far N. as A-tun-tze.

The sequence of beds on the Minchia limestone is very variable, but the following, in descending order, is the general succession on the Mekong near Yang-tsa and Kon-ya :—

Green shale and fine sandstone (with indeterminable fossil shells).
Red shale and sandstone.
Minchia limestone and black shales.
Red sandstone and shale.
Green grits.

The Minchia limestone sometimes occurs in more than one band. In some localities the limestone is associated with purple sandstones and slates; in others with brown sandstone, and in some districts with interbedded volcanic rocks, including tuffs, agglomerates, and flows of dolerite, spilite, and rhyolite. A coarse conglomerate is often present at the base of the series, and is especially developed at Pu-ti, where it forms the horseshoe meander of the Mekong. The conglomerates are important as they show the age of the igneous rocks, since those of which pebbles are found in this conglomerate are earlier than the Minchia Series.

Carboniferous.

The Carboniferous System is represented in southern and eastern Yunnan by scattered outcrops of Fusulina and Productus limestones. Carboniferous and Permian marine rocks, according to Mr. Coggin Brown, cover a wide area to the E. and N.E. of Lake Ta-li, and around Yunnan-fu; but in north-western Yunnan these systems are scantily developed. The occurrence of Upper Paleozoic fossiliferous limestones are isolated, so that their relative ages are uncertain; but they include relics of a widespread sheet of Upper Carboniferous (Uralian) limestones. The chief localities at which we found rocks which we refer to the Carboniferous System are as follows :—

A-shih-wo, in the lower part of the valley W. of the village, which is four miles S. of Yung-chang. The fossiliferous rocks consist of two limestones containing many fossils of which we had only time to collect or observe a few from the lower limestone; they include Fenestella, a crinoid like *Amphoracrinus*, a few corals, and brachiopods. The last have been described by Dr. Cowper Reed (Appendix I, pp. 269 and 270), and he identifies them as Upper Carboniferous. Below the lower limestone is a sheet of diabase. The limestones overlie the Minchia Series.

At Shui-chai, W. of the Mekong Bridge, is a yellow sandy limestone with crinoids, and fragments of brachiopods and corals.

The Lo-ta Gorge, above To-pa-ko on the Mekong, is cut through a thick limestone series containing fragments of crinoids and a few foraminifera which we determined in the field as Schwagerina ; the best specimens occurred on the face of a band of limestone, and as the caravan was far ahead it was impossible to collect them. A poor specimen has been identified by Mr. R. B. NEWTON as Neo-schwagerina, so that the age is either Carboniferous or Permian.

In the descent from the pass (9600 ft.) crossed on the road from Lan-ping to Kien-chwan, to the W. of Yang-tsen at the level of about 8900 ft., are some gray and pink limestones, with fragments of brachiopods, bryozoa and foraminifera ; the microscopic structure of the fossil fragments in these limestones is well preserved. Mr. R. B. NEWTON has identified a *Fusulina* so that the age is Carboniferous or Permian. Massive red sandstones, with a conglomerate containing pebbles of the Minchia limestone occur about 400 ft. below these fossiliferous limestones ; the conglomerate marks an unconformity between the Carboniferous and Minchia Series.

At Janu-la a dark bituminous limestone yielded some brachiopods which Dr. COWPER REED has identified as Upper Carboniferous. Some sandstones at the south-eastern corner of the basin of Kho-li-tsun, which is S.E. of the Ye-lu Shan, and on the western side of the pass half a day's march farther E., contain indeterminable plant remains ; they are probably Carboniferous as they outcrop on the outer margin of the Permo-Triassic Red-rock Series. If so, they indicate land conditions toward the end of the Carboniferous.

The paucity of fossils in the Carboniferous and Minchia Series in contrast to the rich faunas of southern and south-eastern Yunnan and of the Shan States recalls the explanation offered by M. DEPRAT (1912, p. 144) of the diminution northward of fossils in Yunnan. He attributes this fact to the destruction of the fossils by the increasing dynamo-metamorphism of the beds ; the excellent preservation of the fossil fragments in these scattered limestone outcrops as far N. as Lo-ta is, however, fatal to that hypothesis. The rarity of fossils in the Carboniferous, and especially in the Minchia Series, may be due to their deposition in conditions similar to the Cement-stones of the Lower Carboniferous of Scotland. Fossiliferous beds are scarce in that series, and the commonest are earthy limestones containing crinoid stems. The Minchia Series, with its variously coloured shales and sandstones, appears to have been laid down in shallow lagoons in which lived few animals that have left definite fossils. L. VON LOCZY (1893, p. 815) has emphasised the repetition of Flysch-like beds in this region ; and the Flysch is a series of sediments deposited under conditions unsuited to the preservation of fossils.

Permo-Triassic Systems.

The Carboniferous was succeeded in north-western Yunnan by a widespread series of red rocks, which are economically important for their beds of salt. The Red-rock Series occupies three basins; the largest extends from near Lan-ping on the N.W. past Shih-men-ching and Yun-lung—once the chief salt centre—across the Yung-chang–Ta-li road, and from near the Yung-ping River on the W. to Yang-pi on the E. The extent of red beds in this basin is about 1300 square miles. A second basin lies farther E. near Yunnan-fu. A third basin occurs at Ya-ka-lo on the Mekong, S.W. of Ba-tang.

The rocks are chiefly red shales and sandstones, some of aqueous and some of subaerial origin. We saw no trace of marine rocks in the series; but the proximity of the sea during the deposition of part of these rocks is indicated by the thick beds of rock-salt and gypsum. The rocks, as a whole, are strikingly similar to those of the British Trias. One of the most widely used freestones, which is cut into slabs and arches for graves, would be indistinguishable in hand specimens from the St. Bees Sandstone of the English Bunter. Some of the red marls are similar to the Keuper marls.

The age of this series is fixed, in the absence of fossils, by its stratigraphical relations. It rests against the Carboniferous along its northern margin between Lan-ping and Yang-tsen, and clearly overlies the fossiliferous Carboniferous limestone near Shui-chai, and, according to DESGODINS and VON LOCZY (in VON LOCZY, 1893, p. 723), also near Ya-ka-lo. Mr. COGGIN BROWN (1920, pp. 56–58) refers these beds to the Upper Permian and Lower Trias, and that age seems most probable. Their deposition earlier than the marine Trias of north-western Yunnan agrees with the physical history; for the marine limestones of Li-kiang and Janu-la and the salt-bearing red beds of Ya-ka-lo and the Yun-lung basin indicate such different geographical conditions that these two series of rocks were probably formed at different times.

Upper Triassic Marine Limestones.

The upper part of the snow peak of Li-kiang, the southern end of the Black Dragon Temple Range near Li-kiang, the summit of the ranges S. of Li-kiang and Ho-king, and a rugged white limestone range at Janu-la, to the N.E. of Pei-ma Shan, consist of massive unfoliated limestone. This rock beside the Temple of the Black Dragon at Li-kiang contains large blocks of a cæspitose reef-coral, which has been identified as *Thecosmilia* cf. *fenestrata* (REUSS), and as of Triassic age; the Janu-la limestones contain a series of brachiopods which have been determined by Dr. COWPER REED as Upper Triassic (Appendix I).

VON LOCZY (1893, pp. 737–8) discovered some marine Trias on the plateau of Chung-tien E. of the Yangtze, which he identified as Middle Trias, and therefore as representing a marine transgression corresponding to the Muschelkalk of Germany. Prof. DIENER (1912, p. 151) has, however, referred VON LOCZY's fossils to the Upper Trias; and this age agrees better with the physical geology of the district.

Lower or Middle Kainozoic.

After the Trias there is a long gap unrepresented or only doubtfully represented in north-western Yunnan. Some Rhætic beds containing plants occur in western

Szechwan (von Richthofen, 1912, vol. III, pp. 143, 155 and pl. II; and F. Pelourde, in Legendre, 1916, p. 228); and the possible occurrence of marine Cretaceous on the eastern frontier of Yunnan is indicated by an ammonite recorded by Monod (*cf.* p. 257) as *Schloenbachia*. A doubtful impression of an ammonite has been recorded from near Ta-chien-lu (Bonvalot, 1892, p. 486).

We found no evidence of either the Jurassic or Cretaceous Systems, and the only Lower or Middle Kainozoic representatives are the volcanic rocks, of which those at Teng-yueh have been described by R. C. Burton (1913) from material collected by Mr. Coggin Brown.

This volcanic field is of interest as the northern end of the volcanic line that crosses Central Burma, where it is represented by Mt. Popa, and that continues southward to the volcanic chain of the Eastern Archipelago. The eruptions from Mt. Popa lasted till historic times. There is no conclusive evidence as to the age of the older eruptions of the Teng-yueh district. The latest of them are probably contemporary with part of those of Mt. Popa; but as the earlier andesites have a steep dip, and according to Mr. Coggin Brown (1913—1, p. 194) are in places even vertical, as they are very dissected and altered, and as all traces of the contemporary craters have completely disappeared, they are clearly of considerable antiquity. The older lava flows are cut across by the walls of the Nan-tien basin and must be older than that basin. They are, therefore, early Pliocene or pre-Pliocene. Volcanic eruptions often occur along the margin of a folded belt during the reaction from the folding after the pressure has ceased. If so, the older Teng-yueh eruptions may be Miocene and may correspond in time with the great basaltic eruptions of northern and eastern China.

Upper Kainozoic.

We made no attempt, through lack of time, to secure palæontological evidence as to the age of the deposits on the floor of the great basins of Yunnan. The deposits must belong to some part of the Upper Kainozoic from analogy with the fossiliferous deposits from S.E. Yunnan and the adjacent parts of Tongking, identified by M. Mansuy (in Deprat, 1912, pp. 225–7; Mansuy, 1912, pp. 16–18), and those from the western basins of China described by Schlosser (1903, pp. 218–9).

The Upper Kainozoic beds include four main types (loess and red beds, gravels, moraines, and volcanic), exclusive of the local drift deposits which have no special bearing on the geological history of the region.

The oldest deposits are the red sands and loess on the floors of the main valleys and basins. They are well developed near the Salween Bridge, where they form a series of high red hills. They are residual from a sheet of æolian deposits, which we crossed on the sides of the valley to the height of 900 ft. above the river. We saw no fossils in these sands. They were clearly formed in part as confluent delta fans, which were deposited at the mouths of the tributaries to the Salween and were once united into a continuous sheet. The sands must have been laid down in a time of an arid climate after the formation of the Salween valley. The deposits show that after the formation of the Salween valley the climate for a while was dry, the river was then unable to keep its valley clear, and the red sands were spread over its floor by irregular floods of water. Subsequently the climate became wetter and the river more powerful. It therefore deepened its bed and reduced the sheet of red sand to scattered hills.

Similar deposits occur on the floor of the Mekong valley, in the Chiu-chou basin S. of Fei-lung bridge; there the alternation of coarse beds of boulders and red sands shows that torrential floods happened at intervals; during the dry periods wind and sluggish water buried the boulder beds and united the fans into a continuous sheet.

Red silts occur on the floor of the old lake basins along the course of the Lo-ma Ho. They once filled the basin at Yun-lung where a ridge of red sands, which rise 600 ft. above the river, has been left by their denudation across the northern part of the basin. Near the head of the Lo-ma Ho these beds cover a wide basin above its entry into the gorges near the hamlet of Shih-ten-chuan. Beds of the same character occur in the upper Mekong near Ba-dia and Nan-tao.

In connection with these beds may be noticed the huge bank of coarse gravel at the northern end of the Te-lo basin, on the Yangtze Kiang above Chi-tien. From Chi-tsung southward the river flows through a deep narrow valley, which suddenly expands to a broad flat-floored basin. The descent into the Te-lo basin is over a vast bank of outwash gravel. The lower beds in these basins are probably Pliocene, while the upper beds are clearly Pleistocene. The moraines and glacial drifts deposited around the higher mountains of Chinese Tibet, in land now below the level of glacial action, are probably also Pleistocene.

PART IV.—GLACIAL GEOLOGY.

The existence of snowfields and glaciers on the higher mountains of Chinese Tibet has long been known. Travellers along the main road from southern China to Lhasa saw large glaciers on the mountains to the N. of them between Ta-chien-lu and Ba-tang; these glaciers were described by GILL (1880, vol. II, p. 167) and in greater detail by VON LOCZY (1893, pp. 710, 711, 714, etc.). A. LITTLE (1905, p. 207) gave that mountain chain the name of Ta-shueh-shan or the "Great Snow Range." Another series of glaciers lies on the eastern front of the Ka-kar-po Mountains, where they have been especially described by Mr. KINGDON WARD (1913—1, p. 55, pl. xix, opp. p. 150; and 1916, pp. 57–61). Glaciers and snowfields on the mountains between the Irawadi and the Salween have been mentioned by WARD (1923, p. 9) and BRUNHUBER (1912, map W. of 25° 45′ and 26° 15′); on the northern end of the range between the Salween and the Mekong by TEICHMAN (1922, p. 214); on the mountains E. and S.E. of A-tun-tze by R. L. JACK (1904, p. 177), LEGENDRE (1913, pp. 286, 293) and WARD (1922, p. 364); and for the mountains of Li-kiang by FORREST (1908, pp. 257, 263) and DAVIES (1909, pl. xxxvi, opp. p. 154).

The former greater extension of glacial action in Chinese Tibet has also been established and has an important bearing on the age and nature of the latest earth movements in this region. The glacial geology may be expected to show whether there have been any recent regional movements of elevation or depression, and if so whether they have been differential.

The largest glaciers that we saw are on the Do-kar-la and the eastern slope of Ka-kar-po, where the snow-line is at about 19,000 feet. The snout of Ward's glacier is at 9000 feet (Ward, 1916–1, p. 59). The glaciers and snowfields on the Yu-lung Shan or Li-kiang Snow Peak we saw only through occasional breaks in the clouds; its chief glacier now ends, according to HANDEL-MAZZETTI (1919, p. 264, amended by letter), at about 13,100 feet. On the eastern side of Pei-ma Shan are two large glaciers which end at about 14,500 feet, while the perpetual snow-line on the eastern slope is at about 19,000 feet. In the mountain group to the E. of A-tun-tze are a number of small corrie glaciers at levels as low as 17,000 feet.

Evidence of the former greater glaciation of the district was first reported with any precision by VON LOCZY (1893, pp. 699, 701, 710, 713, 714, 717), who described moraines at several localities on the southern sides of the Ta-shueh-shan to the W. of Ta-chien-lu, at levels usually varying from 13,000 to 15,000 feet, while the existing glaciers end there at levels between 16,400 and 18,000 feet. VON LOCZY (1893, p. 694) also supported the identification by BABER (1882, pp. 48–49) of a moraine in the Lu-hu Valley at the level of just below 5000 feet. HANDEL-MAZZETTI (1919, p. 264) reports the occurrence of moraines on the Li-kiang Peak at the level of 11,000 feet. Photographs in BACOT'S "Tibet Révolté" (1912, opp. pp. 78, 88, 112, and 140) show glaciated forms in the neighbourhood of the Ta-shueh-shan mountains and near Sampiling. LEGENDRE (1916, pp. 230, 275) records moraines to the E. of the Yangtze at the levels of from 13,100 to 14,700 feet. Mr. WARD (1922, pp. 364, 368) has described moraines E. of the Yangtze, on the mountains W. of Mu-li at the altitude of 14,000 feet. He has also discovered moraines in the mountains E. of A-tun-tze (Ward, 1913—1, p. 113).

We found traces of former glaciation in many localities; the lowest levels varied from 13,500 to 10,500 feet. Glacial drifts were seen only in the neighbourhood of mountains with sufficient high slopes to have nourished extensive snowfields. The chief high-level valley on the eastern side of the Li-kiang snow mountain is bounded on its northern side by a magnificent moraine, which rests abruptly at its western end against the foot of the limestone cliffs of the upper part of the range; thence the moraine extends eastward as a high straight line till it curves round to the S. The moraine on the southern side of the valley is less regular, and is covered by forest. The lowest level at which we saw this moraine was 10,500 feet. The glacier which deposited this moraine must therefore have extended 2500 feet below its present level.

The valleys that lead up to the Salween-Mekong divide near Tsed-rong have typical river-cut contours to about three miles E. of the Si La pass; there, at the level of a little below 11,000 feet the valley changes from a V-shaped to a U-shaped section with some irregular drifts on its floor. The banks of drift were so denuded and overgrown that their nature was uncertain ; but a little farther up the valley, the floor of which was in places covered by hard sheets of avalanche snow, typical moraines lie on ice-scratched rock surfaces. From that level (11,200 feet) the moraines continue to near the summit of the Si La (14,000 feet). Moraines also occur along the valley at the western foot of the Si La down to the level of about 11,000 feet, and on the western side of that valley conspicuous moraines rest in corries at the height of about 12,500 feet. At six miles N.W. of the Si La, moraines occur near the summit of the Jeu-dson-la (12,900 feet), at the foot of Mt. Francis Garnier, and extend down the valley to the E. of that pass at least as low as 11,800 feet ; others may be hidden in the dense forests lower down the valley.

Near A-tun-tze we saw no glacial drifts on the floor of the main valley, but a typical moraine occurs at the level of 13,000 feet across the mouth of the Jsu-su valley, which ends as a hanging valley 2200 feet above A-tun-tze. Denuded moraines were passed until, above the height of 13,700 feet, the valley is crossed by a series of well-preserved terminal moraines, with four small lakes in the hollow ; morainic drift extends up the valley at the foot of the Jem-sa La.* Both walls of the valley show ice-worn surfaces and the ridge to the N. of the valley has been overridden by ice. To the E. of the Jem-sa La the moraines are less extensive, though they surround a small lake at the level of 15,700 feet on the valley floor. The main snowfields were apparently on the western front, though the glaciers have existed longest in the corries on the eastern face.

South-east of A-tun-tze we met with no trace of glacial action until we reached the fork of the Yung-kun-ko River at the level of 12,700 feet, where there are some low denuded moraines containing ice-scratched boulders. The track to Tung-chu-ling, up the southern branch of the Yung-kun-ko valley, ascends to a conspicuous moraine which is crossed at the pass at the height of 14,400 feet ; it continues westerly, and was probably the main terminal moraine of the north-eastern glaciers of Pei-ma Shan. Denuded moraines occur to the S.E. of this pass to Janu-la, at the level of 13,500 feet. The floor of the Cho-ni valley, which descends eastward from the northern end of Pei-ma Shan, is crossed by a series of typical terminal moraines, of which the lowest that we passed was at the height of 13,800 feet. The glaciers of the northern Pei-ma Shan once extended for several miles to the N.E. and E. of their present range.

South of Janu-la the next morainic drift seen was at the height of 14,500 feet, on the moorlands that separate the Janu-la River from the streams that flow past Tung-chu-ling. As our search in these moraines for rocks from Pei-ma Shan was in vain, its glaciers apparently did not reach this divide, and the moraines there were probably due to glaciers from an independent centre on the mountains to the N. The lowest observed moraines in this locality are on the south-eastern slope at 13,500 feet.

* M. G. Peronne of A-tun-tze has recently visited the valley S. of a second Lake Tsu-na to the N. of A-tun-tze and he tells us by letter (9th August, 1923) that the three valleys descending the western slopes of the range N. of the Jem-sa La and immediately S. of this Lake Tsu-na are glaciated.

On the northern side of the range crossed by the Jin-go La, S. of Sha-lu, corrie-like depressions suggested from a distance the former presence of corrie glaciers, and the summit of the Jin-go La (13,500 feet) is covered by moraines, and glacial drift descends the southern slope towards Ka-ri to the height of 12,000 feet.

On the next high pass to the S., the Ju-go Shan (altitude 12,000 feet), we found no traces of glacial action.

So far as our observations go, the former glaciation of N.W. Yunnan was due to a series of isolated glacial centres around peaks which have considerable areas above the level of 14,000 feet. The following list states the lowest levels of the glacial drifts seen. The variation appears to be due mainly to the size of the formerly adjacent snowfields.

List of Lowest Moraines seen.

10,500 feet at the N.E. side of Yu-lung Shan, N.W. of Li-kiang-fu.
11,000 feet in valleys E. and W. of Si La.
12,000 feet at S. side of Jin-go La, S. of Sha-hi.
12,400 feet mouth of Jsu-su Valley, E. of A-tun-tze.
12,700 feet in valley of the Yung-kun-ko, S. of A-tun-tze.
13,500 feet on divide N.W. of Tung-chu-ling.
13,500 feet in valley E. of Pei-ma Shan at Janu-la.

The glacial evidence bears upon important physiographic problems as to the earth movements and climatic history of south-western China. Von Loczy (1893, p. 725), impressed by the general plateau character of the area, attributed this feature to glacial planation; but the plateau structure existed much earlier than the glaciers which deposited the moraines. They were formed by glaciers which flowed down valleys that were already in existence. These valleys have been moulded by the ice, but were pre-glacial.

These Pleistocene glaciers give evidence as to the earth-movements in south-western China. The reduction in size of the glaciers of this region may have resulted from either a reduction of precipitation or from a fall in temperature due to some general climatic change or from a variation in level. Mr. Kingdon Ward (1916, pp. 64–65) made the interesting suggestion that the diminution of the glaciers on the mountains near the Mekong and Yangtze was due to a decrease in the precipitation owing to a recent uplift of the Irawadi–Salween divide; its uprise would have deprived the mountains to the E. of some of the precipitation which they had previously received. This view assumed that the glaciers on the Irawadi–Salween divide had not shared in the general reduction in size. They would, on the contrary, have grown and probably be still growing. Mr. Ward's observations during his journey in 1922 from the Mekong to the Upper Irawadi show, however, that the western glaciers have also dwindled (Ward, 1923, p. 12); and that fact is inconsistent with the later uplift of the mountains along the Burmese frontier.

Part V.—Petrology of the Igneous Rocks.

The igneous rocks along the route traversed proved to be of remarkable variety. As preliminary to a detailed account of the rocks, some reference to their general relations is given here. The rocks may be classified as follows :—

Section 1.—Granites ; biotite-granite ; biotite-hornblende-granite ; granophyre.
Quartz-syenite. Syenite.
Hornblende-granodiorite.
Quartz-diorite. Quartz-monzonite.

Section 2.—Biotite-granite-porphyry ; muscovite-granite-porphyry ; hornblende-granite-porphyry ; enstatite-granite-porphyry.
Biotite-granodiorite ; hornblende-granodiorite ; enstatite-granodiorite.
Quartz-syenite- and syenite-porphyry.
Quartz-diorite-porphyry and aplite.
Tonalite-porphyry.

Section 3.—Rhyolite and felsite.

Section 4.—Trachyte.

Section 5.—Spilite.

Section 6.—Gabbro and olivine-gabbro.
Dolerite and olivine-dolerite.
Quartz-dolerite.
Diabase.

Section 7.—Andesite and basalt.
Hyalo-andesite. Oligoclase-, andesine-, and olivine-basalts.

Section 8.—Kersantite.
Spessartite.
Basic Lamprophyre.

Section 9.—Pyroxenite-gabbro.
Pyroxenite.
Ultra-basic olivine-gabbro.
Limburgite.

The rock types are therefore very varied, and they belong to at least five ages.

(1) The pre-Paleozoic igneous rocks are represented by granites, granitic-gneisses, amphibolites, etc., which are not included in the previous list.

(2) Some pre-Upper Devonian igneous rocks are represented by pebbles in the Devonian conglomerates. They include granites and porphyries.

(3) Upper Devonian : Minchia Series. The Minchia Series is associated with intrusive

granites, syenites, etc. ; deep-seated porphyries, kersantites, and spessartites, and extensive flows, especially of rhyolite, spilite and trachyte. In the upper part of the Minchia Series are also widespread sheets of diabase.

(4) The Carboniferous, and perhaps also the Permian Series are associated with basic rocks, including intrusions of gabbro, flows of various basalts, sheets of basaltic tuffs and, as near Ta-li-shao, with volcanic necks.

(5) *Kainozoic.*—A series of lavas, ranging from hyalo-andesites to olivine basalts of Lower to Upper Kainozoic age, occur around Teng-yueh.

Devonian Igneous Series.—Devonian igneous activity in this area was unexpected. Carboniferous and Permian igneous rocks in S.W. China were already well known. M. DEPRAT (1912, pp. 228–237) has described from the neighbourhood of Yunnan-fu Middle Carboniferous basalts (labradorites, with 48 per cent. SiO_2) and Upper Permian basalts, dolerites, andesites, and basaltic tuffs.

Mr. COGGIN BROWN (1920 and 1922–1, pp. 74, 82) has recorded from the same district an extensive basic volcanic series both in the Permian and the Carboniferous, and also spherulitic andesites and amygdaloidal lavas in the Permian ; but he does not record Devonian igneous rocks.

In northern Tongking, however, there is a group of eruptive rocks, including a " microgranite or rhyolite " and a diabasic " microgabbro," which were regarded as post-Rhætic, but according to M. DEPRAT (1915, pp. 112–114) are certainly pre-Uralian (Upper Carboniferous). He suggests their Moscovian (Middle Carboniferous) age. As they include a more acid type than the Moscovian of eastern Yunnan, they may represent the Minchia Series.

Colonel AZEMA, working with Prof. LACROIX, has described varied igneous rocks collected by M. LEGENDRE (in LEGENDRE, 1916, pp. 201–216) from a belt of country E. of our route. They include biotite-granite, aplite, and rhyolite ; diorite, kersantite, and andesite ; gabbro, norite, diabase, olivine-diabase, basalt, and melaphyre. The alkaline rocks are represented by ægyrine-granite and nepheline-syenite. As to the age of these rocks there is little definite evidence, except for the rhyolite, which is recorded as intrusive into the Rhætic. The general list resembles that of the rocks which we refer to the Minchia Series, but if M. LEGENDRE's field evidence be correct the rhyolite cannot be earlier than Jurassic.

As the well-established Devonian sequence in eastern Yunnan includes no evidence of igneous activity, the reference to the Minchia Series of a very varied series of igneous rocks may suggest doubt as to its age. The porphyry, spilite, and rhyolite clearly belong to the Minchia Series, for they are associated from Li-kiang to A-tun-tze. The granites are intrusive into the older grits, but we could not at first find clear evidence of their intrusion into the Minchia Series ; it was possible that they might be pre-Minchia in age, and the metamorphism of the Minchia beds might be due to the porphyries ; but later field evidence left no doubt that the granites are intrusive into the Minchia Series. This fact does not, however, prove the post-Minchia age of the igneous rocks ;

for the volcanic rocks of the upper part of the Minchia Series, including the trachyte tuffs and trachytes of A-tun-tze and Li-kiang, are doubtless superficial representatives of the granodiorites and porphyries.

The Minchia igneous series is predominantly sub-acid, whereas the Carboniferous igneous rocks are basic. The absence of the Minchia type in S.E. Yunnan is an indication that during the volcanic activity in N.W. Yunnan the S.E. part of the province was covered by the sea and undergoing quiet sedimentation.

The area where M. LEGENDRE made his collection is part of the same igneous province as north-western Yunnan; and it may include an Upper Devonian series of biotite-granites, and diorite and kersantites; a Middle Carboniferous basic series (gabbro and basalts), and also Jurassic or later rhyolites.

No analyses of the rocks we collected have yet been made, but their general chemical characters are obvious from their constituent mineral species. The rocks as a whole are alkali-calcic, but occasionally alkalic rocks are present. M. LEGENDRE collected an ægyrine-granite and a nepheline-syenite; and in our series albite and oligoclase are widespread, as in the spilites and basalts.

The igneous rocks are very different as a whole from those of western India and tropical East Africa, which are much later than most of the igneous rocks of Yunnan; but some resemblance to the East African province is indicated by a few Kainozoic rocks, such as a limburgite, which is similar to that of Rodriguez Island. The poverty of S.W. China in Kainozoic volcanic rocks prevents, however, the occurrence there of any full representation of the varied Cretaceous and Kainozoic igneous rocks of East Africa.

PART VI.—TECTONIC GEOLOGY.

The geological structure of Chinese Tibet and the adjacent districts in Eastern India is complicated owing to their compression during mountain formation at several far separate geological periods. It is not easy to distinguish the effects of the different movements.

The oldest compression of the area is indicated by the foliation of the metamorphic rocks. The pressure appears to have acted in general from W. or E.; but in the northern areas the strike of the foliation swings round to N.W.–S.E., though in places it has the general meridional trend. The strike of the older rocks in Indo-China appears to be predominantly N.–S. This direction was found by VON LOCZY (1893, Atlas maps B. IV, B. V, and B. VI) to be the rule along the Yangtze between Shih-ku and Ba-tang, and also between Ba-tang and Ta-chien-lu. Along the belt S. of Ta-chien-lu LEGENDRE (1916, pp. 53, 89, 184, 199, &c.) has reported many N. to S. strikes and "tectonic accidents"; but in some cases the strike has veered to N.W.–S.E., and it is especially noteworthy that between the Ya Ho and the Tong Ho the folds go W.–E., in continuation of the trend of the Ta-shueh Shan.

South of the Taping, in the Northern Shan States, the strike in the Mogok gneiss and schists on the western bank of the Irawadi is N.–S., and it is the same in places in the Chaung-Magyi slates and quartzites (T. H. LA TOUCHE, 1913, pp. 32, 49); south of the Ruby Mines the strike is S.W., and in places it is S.E. (*ibid.*, p. 49). In northern Burma the strikes are often N.–S., but at Putao they were found by Mr. MURRAY STUART (1919, pl. 38) to have curved round to roughly N.W.–S.E. In southern Burma, BLEECK (1913, p. 50) records the main strikes as varying between N.N.W. and N.N.E. in Tavoy, and one of us found them to be predominantly N.W.–S.E. in the Dawna Range, near the Siamese frontier E. of Moulmein. To the W. of Chinese Tibet, in upper Assam, J. M. MACLAREN (1904, pp. 182, 183, 186) records the strikes as varying from N.W.–S.E. to N.E.–S.W.; and J. COGGIN BROWN (1912, pp. 249–251) found the same variation in the Dihang Valley; hence in eastern Assam the Himalayan lines cut across the strikes due to the earlier movements. South of Central Assam, in the Mikir Hills, F. H. SMITH (1898, p. 77) found the strikes very variable, but they were mostly E.–W. Farther W., in Sikkim, the strike in the gneisses and associated rocks, according to P. N. ROSE (1891, p. 21), is mainly W.–E., at right angles to the main ridges, though parallel to the secondary spurs developed along the strikes. The predominant N. to S. direction holds in Central Yunnan, also along the Yangtze above Shih-ku, in the Tsang Shan of Ta-li, and in the gneiss range of Wei-si. The strike of the foliation along the Taping Valley is, however, from W.S.W. to E.N.E. The Taping strike is therefore across that predominant in Indo-China, but is parallel to the Sinian Mountain lines of VON RICHTHOFEN (1877, vol. I, pl. 3) in south-eastern Tibet. The Taping strike and those parallel with it, as in the Shan States, may represent the early Sinian System.

A second period of early mountain formation has been claimed by M. E. DEPRAT (1915, p. 120), who has described in north-western Tongking a Lower Paleozoic but pre-Silurian thrust-plane, of which the strike coincides with thrust-planes that he assigned to the early Kainozoic. The re-identification of some of the rocks by MM. JACOB and BOURRET (1920, pp. 26–27) has, however, simplified the interpretation of this area by removing this surprising coincidence of thrust-planes at the same locality with the same direction of movement, at such far distant dates.

Accordingly the second period of mountain compression of which there is adequate evidence is the Hercynian. It produced the Indo-Malayan Mountain system—the Hinterindisch system of VON RICHTHOFEN (1877, vol. I, pl. III; 1882, vol. II, p. 28). There is abundant evidence as to the trend of these mountains, as their roots have been well exposed by denudation. This Indo-Malayan mountain chain trends across Indo-China from N.N.W. to S.S.E., and ranges from Central Tibet to the Malay Peninsula.*

The Indo-Malayan movements have contributed to western Yunnan its predominant geological structure. To the W. is the great pre-Paleozoic massif of eastern Assam and north-eastern Burma. To the E. is the similar massif of the Ya-lung and western

* It includes the Mekong group or "Faisceau" of DEPRAT (1912, I, p. 300), which he represents as continuous from Tibet to S. of 20° N. DE LAUNAY (1911, pl. IV) continues the chain, with some breaks, through the Malay Peninsula.

Szechuan. Between these two areas of metamorphic rocks is the long wide basin mainly occupied by the Minchia Series with its veined limestone, variegated shales and sandstones, and many igneous rocks. The Minchia Series generally has a high dip, and its predominant strike is meridional due to powerful pressure from W. or E. The strike is diverted for short lengths owing to the movements of the country along cross faults. The Hercynian age of these movements is shown by their being post-Carboniferous and pre-Upper Permian. The Indo-Malayan Mountains are therefore part of the great Altaid Mountain System of SUESS.

The third period of mountain compression is the Himalayan, in the early or middle Kainozoic. Direct evidence as to the date of these movements is limited in Yunnan by the paucity of rocks belonging to the younger geological systems. There are no known Jurassic, Cretaceous or Kainozoic marine rocks in the Yunnan highlands, though they are well developed in some adjacent lands. The region appears therefore to have been a tableland that has remained high above sea-level since the Paleozoic. The most widespread post-Hercynian rocks in the province are the salt-bearing red series which is assigned to the Upper Permian and the Triassic. They have been described in the extreme north-western Chinese Tibet at Ya-ka-lo near Ba-tang (DESGODINS, 1876, pp. 493–6, and VON LOCZY, 1893, p. 723). They occupy the vast salt basin of western Yunnan. That these rocks are violently contorted and dislocated has been shown by VON LOCZY, COGGIN BROWN (1920, p. 167) and by DEPRAT (1912, pp. 261–272) for Yunnan, and by VON RICHTHOFEN (1912, vol. 3, p. 191) for eastern Szechuan. We saw no cases of such complete inversion as those recorded by VON LOCZY (1893, p. 763 and pl. IX, profile 4, sect. II) both E. and W. of Huan-li-pu ; but Mr. W. N. FERGUSON, of the Imperial Salt Commission, tells us that the normal succession of the salt deposits, from gypsum at the base through rock-salt to sulphate of soda at the top, is in places reversed by a complete inversion of the beds. We saw, however, a few miles S. of VON LOCZY's overfold, that the beds were in places vertical and even bent over to a reversed dip, and that they are there so crushed that they have acquired a pressure jointing across the bedding.

The strikes in the Permo-Triassic Series are extremely variable. The predominant direction along the western edge is N. and S., but strikes at right angles thereto are common, as just N. of Shih-men-ching on the Lo-ma Ho about five miles N. of the town ; also along the northern edge of the basin near Lan-ping and S. of the Yelu Shan. The great variation in strike indicates compression of the basin from all sides. These strikes therefore give uncertain evidence as to the direction of the general pressure on the region.

The folds in the Permo-Trias are clearly post-Triassic and are also pre-Pliocene. In the absence of evidence of fold-mountain formation between the Hercynian and the Kainozoic the folds in the Red-rock Series may be assigned to the Himalayan System. Evidence of Himalayan movements and overfolds is widespread through north-western Yunnan. The chief glacier valley of the Yu-lung Shan (N.W. of Li-kiang-fu) cuts through an isocline, dipping W., in a massive limestone, of which the age is probably

Triassic. The limestones at the southern end of the Black Dragon Temple Range immediately N. of Li-kiang-fu appear from their fossil corals to be Triassic. This limestone has not been altered as much as the Minchia limestone has been by the Hercynian movements; and the steep dip of the Triassic limestone was doubtless due to pressure from the same direction as the Yu-lung Shan isocline.

On the Si La (14,000 feet), between the Salween and the Mekong, the rocks S. of the pass have been bent into an isocline by pressure from the W. (figs. 3, 4, and 5). The rocks

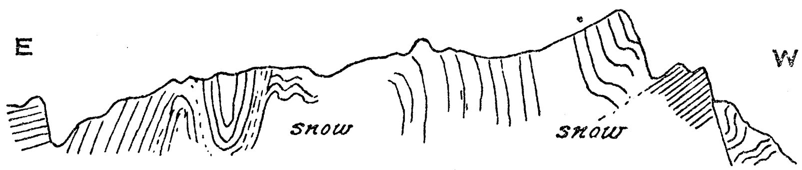


Fig. 3.—Disturbances of overfolds looking S. from the Si La.

on the western precipices S. of the pass show smaller overfolds, which gradually disappear eastward. The rocks involved are the Si La schistose grits, which are pre-Paleozoic. The age of the rock therefore gives no direct evidence as to the date of its folding; but

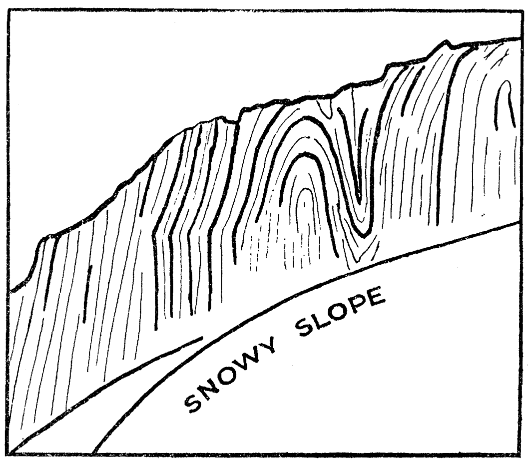


Fig. 4.—Folding S. of the Si La in Schistose Quartzites. (Another view of part of section in fig. 3.)

these folds are not seen in the lower parts of the mountains and are apparently due to the buckling of a superficial layer which included the summits of the existing peaks and ranges. The superficial corrugation by the Hercynian movements has been long

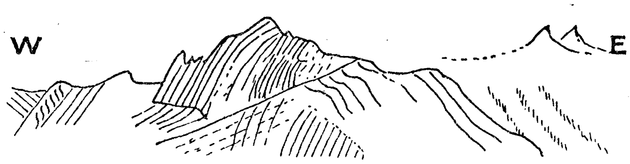


Fig. 5.—Looking N. from Si La to Peak Genestier, showing a thrust from W.

since worn away. The Si La isoclines are therefore to be attributed to the Himalayan movements.

Overfolding and small thrust-planes, due to pressure from W. to E., are common throughout western Yunnan. Amongst others noted were a recumbent fold in crushed granite porphyry just W. of the summit of the Shweli-Salween divide on the Teng-yueh road ; a series of small overfolds E. of Kho-li-tsun ; an inverted isocline, dipping eastward, in the syncline E. of the Yangtze between Shih-ku and Chi-tien in the mountain opposite Akola. In the mountains E. of A-tun-tze, along the southern side of the Jsu-su valley, the lower beds have been tilted till their dip is reversed ; and above a distinct thrust-plane, which rises from W. to E., the upper beds having been folded and contorted. In the same district a shatter-belt can be traced from the Jem-sa La to the north-western side of the Mitutong basin ; masses of igneous rock remain in this shatter-belt as colossal " augen " surrounded by brecciated material.

Faults in N.W. Yunnan are innumerable (fig. 6). They may be divided into two main groups, one trending N.–S. and the other about W.S.W.–E.N.E. The direction of both sets is variable ; many of the meridional faults lie between 10° W. of N., as in the Li-tien fault, and 30° W. of N. in the fault along the valley we descended N.E. of Pey-yun-chang.

The most important faults are those of the meridional group. The faults are sometimes inferred, as from a sudden change of the rocks at a scarp-like wall ; for example, a fault along the scarp-like eastern side of the Shweli valley may be deduced from the abrupt junction between the granites and Kainozoic basalts to the W. of it and the Kao-liang beds of the Shweli-Salween divide. Similarly the abrupt endings of the Minchia Series against the Kao-liang Series, N. of the Salween Bridge, and also against the mica-schists, in the valley of A-tun-tze, may be regarded as due to faulted junctions. Direct evidence of faults is abundant, but it is usually the smaller ones of which both sides are seen in contact ; these faults are usually parallel to the major faults. As instances of well exposed faults may be mentioned a series on the banks of a tributary to the Lo-ma Ho, N.E. of Pey-yun-chang ; they strike 30° W. of N., hade gently southward, and have large slickensided surfaces. Some of the minor faults parallel to the main Yangtze fault are well shown at Shih-ku, where three parallel faults with the down-throw E. are conspicuous in the limestone cliffs N. of the town. The faults on the Ying-an River below Wei-si are associated with shales like those of the Coal Measures, which have probably been faulted down. East of the Si La the schists are contorted and broken off along a fault which dips steeply E. In the Lon-dre gorge, on the western bank of the Mekong S. of Yang-tsa, a series of faults is well exposed, owing to the colour differences between the rocks. Some of these faults are nearly horizontal and the beds above them have been pushed eastward up a gentle rise, in one case for 12 feet. Similar faults, due to thrust from the N., a few miles farther N., in the cliffs of the Mekong above Yang-tsa, are shown on fig. 7. A conspicuous fault parallel to the Mekong occurs on the eastern cliffs above the river opposite this locality. Farther N. on the bank of the Mekong, a little S. of Yang-tsa, a fault parallel to the river is marked by a thin ironstone vein along it. The

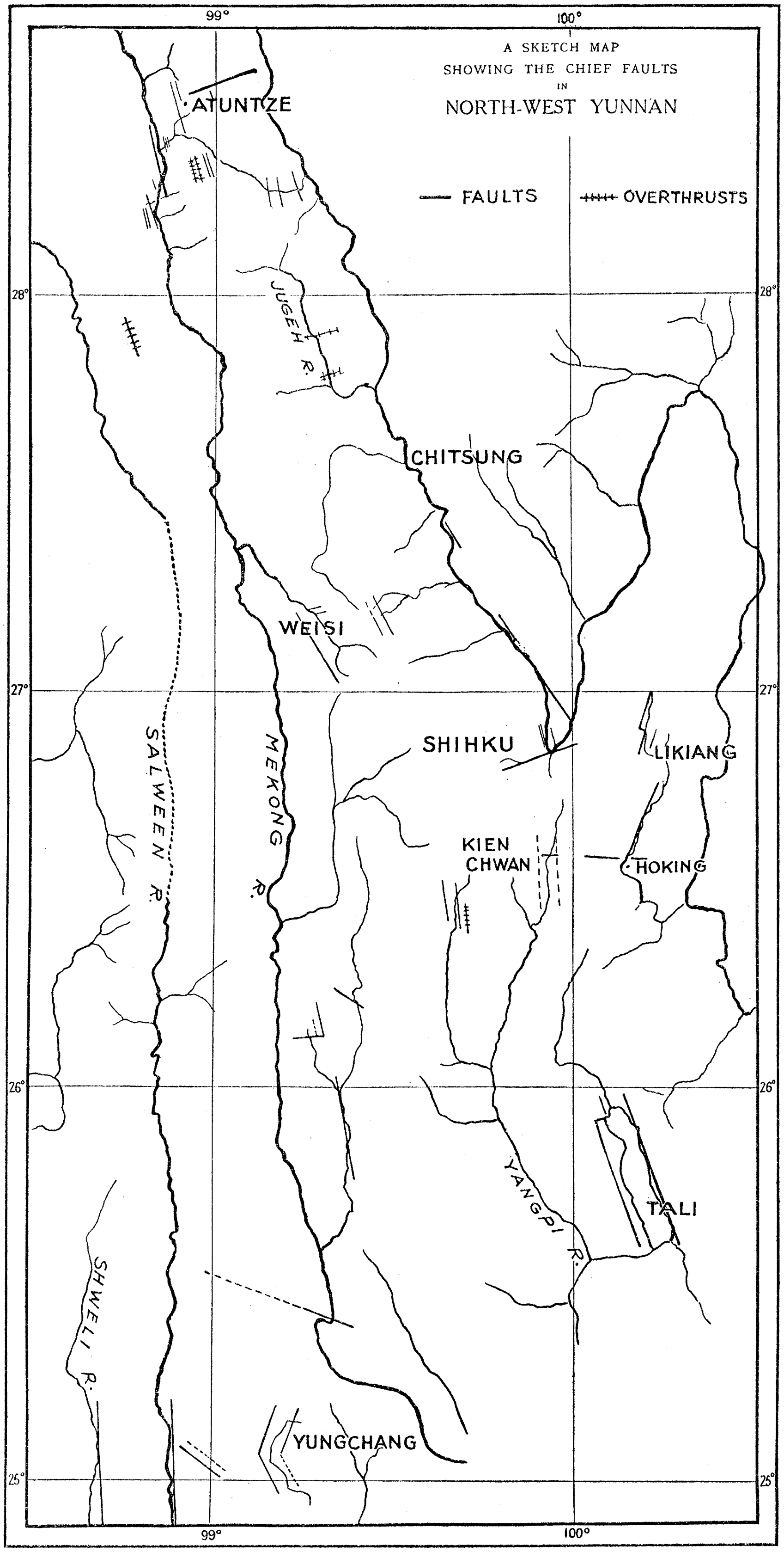

A SKETCH MAP
SHOWING THE CHIEF FAULTS
IN
NORTH-WEST YUNNAN
FAULTS
OVERTHRUSTS
99°
100°
28°
27°
26°
25°
ATUNTZE
JUGEH R.
CHITSUNG
WEISI
SHIHKU
LIKIANG
KIEN
CHWAN
HOKING
SALWEEN R.
MEKONG R.
YANGPI R.
TALI
SHWELI R.
YUNGCHANG

Fig. 6.

formation of ironstone along meridional faults occurs on a greater scale N. of Kon-ya, where different rocks of the Minchia Series are separated by broad bands of brown ironstone fault-breccia. Farther N. a meridional fault runs beside the Mekong and

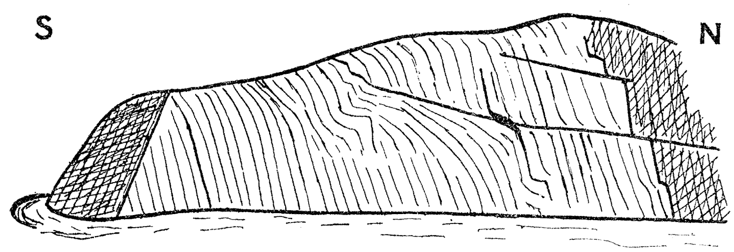


FIG. 7.—Hills W. of the Mekong 4 miles N. of Yang-tsa with horizontal thrust-planes from the North.

near Kia-pieh it has thrown the Minchia Series against the limestone that forms the hills W. of the river.

The meridional faults of this district are shown in the lower part of the Yung-kun-ko gorge ; the cliff on the northern bank of the river, a little E. of where the gorge widens

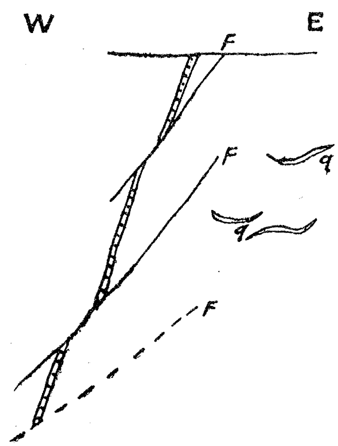


FIG. 8.—Reverse faults with gash veins of quartz (*q*) on the Yung-kun-ko River near junction with the Mekong.

into the Mekong valley, is traversed by three reversed faults with a steep hade to the W., and associated with curved but otherwise horizontal quartz veins. The beds have been heaved eastward. Many faults are shown by their effect upon the rocks. For example, at the head of the branch of the Yung-kun-ko River, N. of the pass leading to Janu-la, are some bands of smashed aplite.

Jointing due to pressure across the foliation of the schists is seen, *e.g.*, beside the footbridge over the Do-yong River, on the track from Chamutong to Yang-tsa, N. of Pehalo. On the north-eastern side of Pei-ma Shan some of the quartz-porphyry has been smashed, and a complex series of N. and S. faults cross the ridge between the

Cho-ni valley and the next valley to the S. A vertical pressure-jointing cuts obliquely across the bedding of the Permo-Triassic sandstones near Tai-ping-pu on the way from Yang-pi to the Mekong Bridge.

Transverse faults, many of which are approximately at right angles to the meridional series, are recognisable by indirect evidence and by numerous exposures of the smaller faults. Thus, on the northern side of the Lan-ping basin the older rocks have been traversed by E. to W. faults. Further E., approximately on the same line, the limestones near Ho-king, after a long strike from N. to S., are suddenly flung upward and overtilted with a reversed dip S. (fig. 9). The uptilted limb of this fold is cut across by

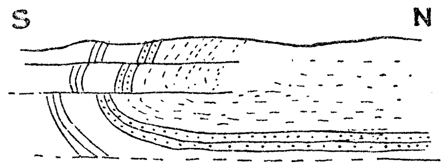


FIG. 9.—Uplift of limestones W. of Ho-king. Lower rocks Mid Devonian, upper rocks Triassic.

three horizontal faults in which the movement has been from N. to S. At Tze-ku a small thrust-plane, dipping 10° N., has heaved the beds above it southward. North of Kon-ya the granite has been smashed in belts along E. and W. faults. Along the Jsu-su valley, E. of A-tun-tze, in addition to the powerful N. and S. faults, by which the quartz-porphyry has been faulted against the altered Minchia limestone, there is a series of faults trending E. and W. The movement along one of them has formed a shatter belt through the Jem-sa La. On the Ju-geh River S. of Ka-ri, an E. to W. fault with a steep hade to the N. is obviously a reversed fault due to pressure from the N.; for the beds on the southern side have been thrown into a series of overfolds and contortions which die out to the S. (Fig. 10). Farther S. down the river, about two miles N. of Se-kon, red shales

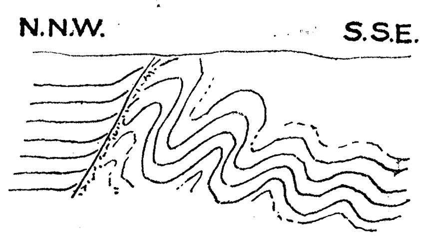


FIG. 10.—Reverse fault in the Minchia Series on Ju-geh River.

with a gentle dip S. are broken by repeated steep dips N. for a few inches; and the northern side of each fold consists of repeated narrow isoclines a few inches in length.

That some Yunnan faults are of recent age is shown by a series of parallel meridional faults in some beds of coarse gravel, at the height of about 6500 feet, four miles W. of Ku-tung; these gravels are probably of Pliocene age, and they have been broken across by small parallel faults.

The Yunnan faults are of at least five ages. Some are pre-Hercynian and some

Hercynian ; and in each of these groups there have probably been re-movements in later times. Many of the faults are long post-Hercynian ; one set is due to overthrusts and tilting during the compression of the region by the Himalayan movements ; two later sets, one earlier and the other later than the Pliocene red sands, may be assigned to normal faulting on or after release from the Himalayan compression. The later faults may be divided into two main groups, the meridional and the cross-course series trending W. and E. This division may have been partly determined by the original grain of the country. The pressure apparently came from some point W. of N., for the main mountain line through the eastern Himalaya and the Ta-shueh Shan trends to the N. of E. The cross-course faults are among the tectonic features parallel to the Ta-shueh Shan, and ready yielding along the strike of the Indo-Malayan folds led at the same time to the renewal and extension of the older meridional faulting.

PART VII.—PHYSIOGRAPHY.

§ A.—*The Yunnan Peneplane.*

VON LOCZY'S suggestion (1899, p. 725) that Chinese Tibet had been levelled by ice was based on his recognition of the country as a dissected plateau. The surface of Chinese Tibet slopes downward from the Ta-shueh Shan and mountains W. of them to southern Yunnan and Burma. The main level of the Yunnan plateau near A-tun-tze is about 15,000 feet ; 30 miles S., at the Jin-go La, S. of Sha-hi, it is about 14,000 feet ; 35 miles farther S., beside the Jugo Shan and W. of that mountain in the Kobuta Range, the level is from 13,000 to 12,000 feet ; in the Wei-si district it is 11,000 feet ; near Lan-ping and the range S. of Kien-chwan it is 10,000 feet ; and between Ta-li and Yung-chang it is about 8,000 feet. This plateau is now dissected by a labyrinth of gorges, and a traveller who crossed the country in misty weather might reject its plateau structure as ludicrous ; but the views from the peaks show that the country is a dissected peneplane, as innumerable ridges rise to the same general level. The peneplane was, however, never complete ; the existence of a still higher plane is indicated by ridges and peaks, which include platforms at about 17,000 feet near A-tun-tze, summits of 15,000 feet in the Lo-ta Shan, the corresponding peak at 14,800 feet W. of the Salween, and heights of 14,000 feet in the Tsang Shan W. of Ta-li. Above this higher plateau rise the peaks of Ka-kar-po (over 22,000 feet), the mountains E. of A-tun-tze, 19,000 feet, and the Yu-lung Shan, N.W. of Li-kiang, 19,350 feet.

There are three main plateau surfaces in Yunnan, each of which slopes southward from the highest belt of Chinese Tibet. The ancient plateaus had no general slope downward to the W., for Ka-kar-po, on the divide between the Irawadi and the Salween, is higher than the mountains W. of A-tun-tze or than Pei-ma Shan. Farther S., according to the heights adopted on the map (J. W. and C. J. GREGORY, 1923), Maya and Nalolaka (28° 4′ N) are both at the height of 14,760 feet ; but farther S., Nangei, 16,400 feet, W. of the Mekong, is again higher than Lo-pi-pema, 14,760 feet, the highest corresponding peak E. of the Yangtze. Farther down the slope a summit of 13,270 feet W. of the Salween at 27° 3′ N., though higher than mountains of 11,500 feet near the Li-ti-ping Pass E. of the Mekong, is much lower than the Chata Shan (18,700 feet) within the bend of the Yangtze. Along the parallel of 26¾° N. the heights rise eastward from 14,820 feet on the Irawadi-Salween divide to 15,800 feet on the Salween-Mekong divide, and 15,090 feet on the Lo-tue Shan, W. of Shih-ku. At 26° 7′ the Hpsimaw Bum, 13,300 feet, is lower than the 15,200 feet height E. of the Mekong. Farther S. the heights along the Kao-liang Shan, which forms the Shweli-Salween divide, rise to 14,440 feet and are higher than any peaks on the same latitude to the E. Although the summits do not descend to the W. the level of the rivers decreases steadily westward, as remarked by Mr. Kingdon Ward (1923, p. 17). The Salween is the lowest; its level is 2,300 feet at the Salween Bridge, while the Mekong is crossed by the same road at 4,400 feet, and farther E. the Yang-pi is crossed at 5,200 feet. In Chinese Tibet, however, the Salween is the highest river of the three; for, according to Teichman (1922, map), Di, on the Salween just S. of 29° N., is at 10,500 feet, the Mekong at 29° is at 7,907 feet, and the Yangtze must be much lower than the Salween as Ba-tang, which stands higher than the Yangtze, is only at 9,000 feet. The fact that farther S. the floors of the western valleys are lower than those of the eastern valleys is explicable by the greater corrosion by the western rivers owing to the numerous factors that may be grouped as the accidents of denudation. There is no general westward descent of the plateau surface (fig. 11).

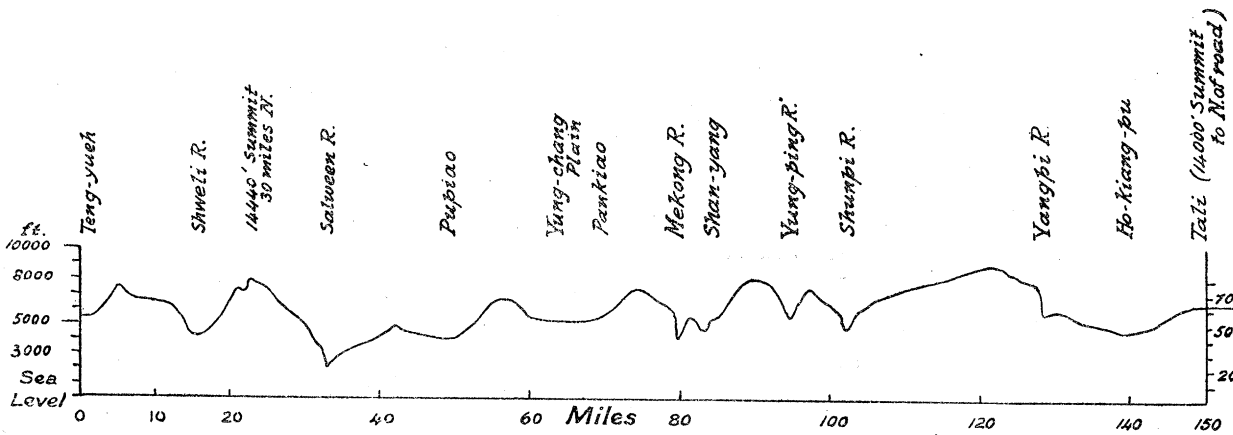


Fig. 11.—Section along route from Teng-yueh to S. end of Lake Ta-li showing westward deepening of valleys.

The age of the plateau, so far as is determined by the age of its constituent rocks, is post-Triassic and pre-Upper Pliocene. Evidence from the structure lessens this range, as the main plateau was clearly formed later than the Himalayan folding; it is therefore post-Miocene or at least post-Oligocene.

According to M. Deprat (1912, pp. 301, 302, 258), whose view has been adopted by Mr. Coggin Brown (1920, p. 5), central Yunnan, from near Li-kiang past Ta-li-fu to Yunnan-fu, is crossed by a mountain line due to folding from the N. by Miocene movements ; it has been called the Yunnan Arc. There are along this line no elevations above the oldest peneplane, and we did not see there any chain of fold-mountains. The high ground S. of Ta-li-fu seems to be part of a plateau which has been left upstanding by the denudation of the land on both sides. The beds have been tilted during the Himalayan movements, but if the Yunnan Arc ever existed, it must have been completely swept away by post-Miocene denudation.

This Yunnan Arc corresponds to the "Yunnan-Bogen" of VON RICHTHOFEN, who adopted a very different interpretation of this area. He (1900, pp. 899, 916, 919) introduced this name for one of the steps between the successive blocks which, according to his theory, form eastern Asia. He regarded the northern part of Yunnan as a horst left upraised owing to the subsidence of the country to the S., and the curved band between the northern plateau and the southern lowlands was the Yunnan Arc. We failed to see, however, any curved bounding faults, or other such southern boundary of the plateau of northern Yunnan, as would be expected if the Yunnan Arc were the boundary of a horst.

The most conspicuous plateau of north-western Yunnan is post-Miocene. The question naturally arises whether one of the three peneplane surfaces (*cf.* p. 240) of Chinese Tibet represents the great Cretaceous peneplane, which is widespread around the Indian Ocean, in Africa, India, and Australia, and is represented in China by the Pei-tai stage of Prof. BAILEY WILLIS (1907, p. 100). That Cretaceous peneplane formed the surface upon which was spread out the Deccan Traps, the older alkaline lavas (Kapitian) of East Africa, and the lower Kainozoic lavas of Australia. There is, however, but scanty evidence of any corresponding rocks in north-western Yunnan. The higher ranges, such as the Tsang Shan W. of Ta-li, doubtless represent a pre-Miocene peneplane and may date back to the Cretaceous. If so, late Cretaceous or early Kainozoic rocks may occur on some of the higher peaks which have survived from that surface ; but unless the area happened to have been a volcanic field, no rocks sufficiently durable for survival in such exposed positions may have been present. The only rocks which are clearly Lower Kainozoic are the older lavas of Teng-yueh. They were poured out over a plain which now stands at the level of about 4200 to 5500 feet. This old land surface may have been the continuation of the peneplane of the Northern Shan States, which has been cut in part in Jurassic rocks ; and as no post-Jurassic marine rocks exist there, that peneplane was probably Cretaceous. It is therefore probable that the great Cretaceous peneplane around the Indian Ocean may be represented in the Northern Shan States, and by the surface below the older lavas of Teng-yueh, and perhaps also by the high-level peneplane of which scattered fragments are still discernible in Chinese Tibet.

§ B.—*The Basins of N.W. Yunnan.*

The most direct evidence for the age of the main Yunnan plateau is afforded by the deep basins which form the chief seats of population in the country. These basins are well known in south-eastern Yunnan, where they are traversed by the railway from

Tong-king to Yunnan-fu. They contain fossils of Upper Pliocene and post-Pliocene age (DEPRAT, 1912, pp. 225–7; MANSUY, 1912, pp. 16–18). The great basins in Szechuan and other provinces of western China containing the Pliocene and Pleistocene mammals, described by SCHLOSSER (1903, pp. 19, 218–9), are no doubt of the same age. In north-western Yunnan similar basins occur, but no fossils from them have been specifically identified; but their formation may be assigned to the Pliocene from analogy with those of Szechuan and south-eastern Yunnan.

The structure of these basins, which are conspicuous features in both the political and physical geography of south-western China, throws important light on its late geological history. DEPRAT (1912, pp. 303–316, f. 12, p. 263) has shown that some of these basins in Tong-king and south-eastern Yunnan were formed by subsidence along recent faults which are chiefly meridional, though some trend N.W. to S.E. Some of the basins are broad and are sunklands; others are long and narrow and are rift-valleys. It was impossible in the time at our disposal to determine to what extent the basins of north-western Yunnan are bounded by faults. The scarps formed by faults are quickly worn back, as the rocks along a fault-plane are necessarily fractured by the movement and a bank of fallen fragments soon covers the fault line. No doubt detailed search along the spurs or in the beds of tributary streams will lead to the discovery of some of the faults, if the basins were fault-formed.

For the distinction between slopes due to erosion and those due to fracture we had to trust to the criteria which one of us had used in East Africa in 1893, where the faults were found sufficiently often to prove the reliability of these criteria. They are as follows:—

(1) If a hill front extend in a long even line, which is often straight for considerable distances and changes its course only at a sharp angle, except when it curves around some hard block of rock, just as a crack in a piece of wood curves around a knot;

(2) if the spurs projecting from such a hill front are cut off along a regular line, at which each of them may end in a triangular facet;

(3) if there are no projecting hummocks or outliers at the foot of the scarp, and if rock mounds on the floor of the basin are absent or exceptional, a sheet of unbroken alluvium extending from the foot of the scarp; and

(4) if the hill front cuts abruptly across the grain of the rocks—

then we conclude that the hill front and the basin beside it are tectonic in origin.

Fault scarps may be worn back regularly, but they are at length destroyed by enlargement of the gullies that form upon them; but if the general slope of the country is away from the edge of the basin the scarp may retain its regularity for a long time as it is only cut back by weathering. The tectonic origin of a basin traversed by an active river may be soon obscured. The river, in its shifting course, will attack both banks and cut them back into deep bays with sinuous margins, and as the land on both sides of an old valley usually has long slopes towards it, the lateral drainage will collect into large tributaries, which will excavate wide valleys separated by long irregular spurs. The topography of areas under such conditions is so moulded by denudation that only detailed mapping can determine the primary origin of the valleys.

According to the above criteria several of the basins we traversed are certainly, and others probably, of tectonic origin.

1. *The Taping Basin.*—The largest of the basins which we traversed lies along the upper part of the Taping River, W. and S.W. of Teng-yueh. This basin is double. The lower or Ka-nai sub-basin is at the level of about 2900 feet ; it is 30 miles long and from 3 to 5 miles broad ; it trends from S.W. to N.E. from Man-hsien to above Ka-nai ; it there ends against some hills of granite, gneiss, and schistose-quartzite, flanked by beds of loess and gravel. The upper or Nan-tien sub-basin, the level of which at the western end is about 3600 feet, is 25 miles long by $1\frac{1}{2}$ wide ; it appears more sinuous and less regular than the Ka-nai sub-basin as its trend varies from S.W.–N.E. at the western end to S.–N. at the upper end. The walls of both sub-basins consist of gneiss, granite and schists, with some volcanic rocks at the northern end near Teng-yueh. The strike of the rocks is in general 60° E. of N., and continues that which has determined the course of the Taping Valley from Ka-nai to the Irawadi. The Nan-tien sub-basin therefore cuts across the grain of the country. A hummock of granite rises above the floor of the basin at the village of Pang-pa-lu ; many fans of sand and gravel project from the sides, but as a whole the floor is level and covered with rice-fields. The basin was probably once occupied by a lake, which had its outlet down the Taping River. The only fossil that has yet been found in the beds was an elephant's tooth, which J. ANDERSON (1871, p. 81) said was certainly ancient. Mr. COGGIN BROWN (1913, p. 201) quotes the occurrence of some lignitic shale. Some red sands and loess on the floor and flanks of the basin indicate formation under climatic conditions drier than those of the present day ; these beds agree lithologically with those that were formed in south-eastern Yunnan in the Pliocene. The fine clays are, however, doubtless lacustrine, as was recognised by J. ANDERSON (1871, p. 83) for the adjacent Hotha basin, and by Mr. COGGIN BROWN (1913, pp. 200, 203) for the Taping and Teng-yueh basins.

The nature of the Ka-nai–Nan-tien basin indicates its tectonic origin. Its walls have the aspect of dissected fault-scarps, with the fault-trace buried by banks of talus and loam. The basin cuts across the foliation of the rocks, so that it cannot be explained by denudation along the strike. The banks have been carved by streams into spurs, each series of which ends abruptly in line ; thus from a point S.W. of Ka-nai we counted ten spurs all cut off along a straight line. The spurs, moreover, are over-steepened at their ends ; and the removal of the lower part can be more easily explained by faulting than by denudation. The southern slopes at the western end of the Nan-tien basin are long and gentle, until they are cut off abruptly at the edge of the basin ; while a little farther E. the main original slopes are southward from the basin with a short steep descent to its floor. The basin there lies below what was originally the highest ground.

East of Ka-nai a valley to the N. cuts across a series of spurs on a line varying from about 10° to 20° W. of N. ; hence this branch of the basin was probably along a branch fault. A map of the Nan-tien sub-basin represents its course as curved, owing to the denudation of the drifts which filled it; but the boundaries of the rock basin are more rectilinear, with a sharp change of trend 4 miles N.E. of Nan-tien.

2. *Pu-piao Basin.*—The basin of Pu-piao lies at the foot of a mountain mass about 7000 feet high, N.E. of the Salween Bridge. The floor of the basin is at the height of about 4400 feet. The southern wall of this basin trends approximately from N.W. to S.E.; it exposes a varied series of rocks and is in line with the gap through which the Pu-piao River descends to the Salween. The wall has been deeply eroded, but the spurs end on a regular line beyond which there are no outliers. This basin was formed between a pair of faults which trend across those of the meridional series. It may be due to denudation along a course determined by pre-existing faults, but was probably of direct tectonic origin and due to the down-faulting of the floor.

3. *The Yung-chang Basin.*—The Yung-chang basin, one of the most important Shan settlements in this part of Yunnan, is about 15 miles in length and 4 miles wide. Its floor at Yung-chang is at the height of 5500 feet. The floor descends gently to the S.E. and drains through the Wan-tien River to the Salween. The upper part of the basin trends from N.N.E. to S.S.W.; it is bounded by straight-fronted mountains composed of red shales and sandstones. On the eastern side the basin is separated from the Mekong by rugged hills of olivine-gabbro, oligoclase-basalt, diabase, spessartite and tuff, associated with Carboniferous limestones and shales.

The basin at its lower end, for about 4 miles S.W. of Yung-chang, trends from N.W. to S.E., so that, like that of the Taping, it is L-shaped in plan. We saw this basin best along its north-western wall, which, from its straight course, the independence of its trend of the grain of the rocks, the absence of outliers, and the regular ending of the spurs presents the characteristics of a fault-scarp. The basin has probably been formed by direct subsidence and not by erosion along the fault plane.

4. *The Basin of Kien-chwan.*—Kien-chwan-chow stands in a large basin trending N.–S. Its length is about ten miles and its breadth about three. Its character suggests either that it is older or that it has been more altered by river action than the Taping or Yung-chang basins. Its floor is buried by thick beds of red sand and its western wall has been breached by many valleys. According to most authorities the basin discharges to the Yang-pi. At the northern end of the basin, though the walls on both sides are steep, the floor is irregular, with many volcanic hills. Some former springs have deposited tufa mounds along the western side of the valley, as at the temple three miles S. of Kien-chwan. The basin is also subject to earthquakes, and Mr. George Forrest told us that one of them broke down part of the city wall of Kien-chwan about 1897. As the tufa springs and this earthquake were probably originated along a fault their occurrence supports the tectonic origin of the basin. It was part of a great tectonic valley through which the Yangtze above Shih-ku flowed southward past Niu-kai and Ta-li-fu. This valley has been long subject to powerful river action, and its original fault scarps have been worn and obscured. Subsequently a change in the drainage system

diverted the Yangtze and left the pass between it and the Kien-chwan basin as a windgap,* with a lake upon the divide.

5. *The Li-tien Basin*, which includes some of the sources of the Chi-tien Ho that joins the Yangtze at Chi-tien, is small, about three miles from E. to W. and two miles wide. Its eastern and western walls are scarp-like; its eastern wall is especially straight and regular, and trends from N. by W. to S. by E. The rocks in the wall and in the country around the basin mostly dip N.W. The northern and southern walls are irregular; and so also is the floor, on the western side of which are hummocks of quartz-syenite and diorite-porphyry. It is therefore a less typical tectonic basin than most of those previously described. Its outlet is through a narrow gorge that may have been cut by overflow from a lake that occupied the basin. As all the material from the basin could not have been carried away through this gorge, the basin is obviously tectonic.

6. *Niu-kai and Lang-kiung Basin.*—From Niu-kai to Lang-kiung extends a meridional basin, twelve miles in length by three miles from E. to W. It discharges through the Chung-so River, which escapes from the south-western corner and reaches Lake Ta-li. The floor is mostly a wide sheet of gravel and alluvium, which ends both to E. and W. at the foot of well defined fault-scarps. We examined the western wall near its northern end where it consists of a metamorphic marble, with a steep dip. On the eastern wall the strike is at a high angle to the fault-scarp, and the prevalent dip is N. The basin ends to the N. against volcanic hills, where the Na-sui Ho or "Lost Water River" discharges from a mountain gorge into the basin. The southern end consists of hills of porphyritic-spilite and diabase, which project from the eastern wall of the valley and divert the river to the western edge of the basin. On both sides are hot springs; one group occurs beside the market town of Niu-kai, and Mr. W. N. FERGUSSON told us that there is a group near the town of Lang-kiung-hsien. In the Pagoda Hill S. of Niu-kai, terraces of calcareous tufa occur beside the boundary fault. Looking S. from Pagoda Hill a long succession of spurs can be seen to the S., and they are all cut off abruptly to the W. along a straight line. Looking northward along this line from farther S. a fault can be seen separating the westward dipping rocks in the Niu-kai Hills from those which dip sharply to the E. on the eastern side of the Si-ying-kai River. The dip is S. along the truncated spurs in the south-eastern part of the basin.

7. *Ta-li Basin* is the best known in north-western Yunnan. It extends for about 33 miles in length from N.N.W. to S.S.E. It begins to the N. with two blunt branches which are bounded by high cliffs. The basin widens southward, sometimes suddenly by cross scarps; but the eastern and western walls are mainly straight and parallel. To the south the basin ends abruptly near Sia-kwan against hills trending from E.N.E. to W.S.W. The southern part of the basin is occupied by Ta-li Lake, which now discharges to the Yang-pi, but probably once had its outlet to the Red River through a broad windgap in line with the lake. The high western wall of the basin consists

* BACOT, 1912, p. 306, says that the Moso have a tradition that the Yangtze once continued through this windgap and joined the Mekong.

mainly of gneisses, schists and granulites, which form the high Tsang Shan (altitude 13,000 feet) W. of Ta-li-fu.

The tectonic origin of Ta-li basin is indicated by the parallelism of its sides, which cut across the country independently of the strike of the rocks. This independence is well shown on the north-eastern side of the lake. East of Teng-chwan is a high mountain mass; it is succeeded to the S. by low downs; then, opposite the sudden expansion in the width of the basin by the recession of the western wall, a large valley passes off to E.S.E., and south of it the country rises to high downs. The eastern wall of the Ta-li basin cuts straight across these three different highlands. The eastern wall farther S. truncates a succession of spurs, and on the opposite side of the lake, S. of the Muslim village of Ola-sha, the spurs from the Tsang Shan are faceted by the western margin of the basin. A further indication of the tectonic origin of the valley is the great depth of the alluvium, which is so thick that no outliers or islands of the older rocks rise above either the plain or the lake.

8. *Li-kiang Basin.*—The Li-kiang basin is unusually irregular in form; the alluvial plains on its floor have the shape of the letter H, and Li-kiang-fu stands near the middle of the cross bar. The western arm of the basin, at the foot of the Yu-lung Shan or Snowy Range of Li-kiang, is about three miles across. The western wall is occasionally bent sharply along cross fractures. The western sub-basin ends to the N. at a range of hills which project from the Yu-lung Shan; to the S. against the volcanic rocks of the An-tan-ndii and Nan Shan Range; and to the E. at the Black Dragon Temple Range and at the lower hills in line with that range S. of Li-kiang-fu. The eastern arm of the basin lies between the range of the Black Dragon Temple on the W. and the long line of hills which separates the basin from the Yangtze Kiang. This branch of the basin becomes broader and its floor more regular toward the S., around the important walled city of Ho-king (altitude 7400 ft.). North of this town are some shallow lakes. The drainage from the whole of the Li-kiang basin is through an outlet at its south-eastern corner to the Yangtze.

The tectonic origin of the Li-kiang basin is indicated by the straightness of its walls and their independence of the structure of the adjacent hills. The walls, moreover, often cut across the spurs, leaving them truncated by well preserved facets that show the recent age of the faults. That the basin is comparatively young and that the movements may be still in progress is indicated by frequent sharp earthquakes. They apparently seldom do serious structural damage; but their strength and frequency were remarked to us both by Mr. George Forrest and Rev. Peter Klaver, head of the Mission at Li-kiang-fu.

§ C.—*The Mountain Structure.*

The mountain structure and physical geography of south-western China are determined by bands of mountainous highland separated by deep parallel river valleys. The mountains and valleys trend in general from N.N.W. to S.S.E. From the valleys the intervening country appears as a series of lofty mountains. When they were examined it was found that the strike of their rocks was in general parallel to the trend of the mountains, and that the rocks had been steeply tilted and folded by powerful mountain-forming movements. VON RICHTHOFEN (1877, pl. III, and 1882, p. 28) recognised that these mountains and their rocks strike across Further India towards the Malay Peninsula. He therefore called these mountains the "Hinterindisch" System, and rightly attributed their formation to a period long antecedent to the Himalaya. These Indo-Malayan mountains form the axis of the south-eastern peninsula of Asia. They belong to the Altaid Mountain System of SUESS (1901; *cf.* GREGORY, 1915, pp. 497–509).

The age of the movements which formed the Indo-Malayan mountains and impressed upon Indo-China its older grain was post-Carboniferous. For the tilted rocks include infolds of Carboniferous, as, N. of Teng-yueh, at A-shih-wo near Yung-chang, at Shui-chai, W. of the Mekong Bridge, and in the Lo-ta Gorge on the Mekong (latitude 27° 54′ N.). The movements were pre-Triassic, for some Triassic limestones, which are comparatively little disturbed and in places retain a gentle dip, were found by VON LOCZY at Chung-tien, E. of the Yangtze, and by ourselves at Janu-la, S.S.E. of A-tun-tze. The red beds of the Salt Basin, though often violently tilted, are less altered than the similar beds in the Minchia Series, and their strikes are less regular than those due to the Indo-Malayan movements. Marine Permian rocks have been described by Mr. COGGIN BROWN (1914, pp. 109–112; 1923, p. 319) as occurring farther E. in Yunnan, and Dr. F. R. C. REED has identified some fossils as Permian from Feng-ma-chang.

The relation of the existing relief of Yunnan to the Indo-Malayan mountains is purely secondary. They have been worn down to a peneplane, which was subsequently dissected by parallel river valleys. The existing mountains are residual, and were carved by denudation out of the plain formed across the foundation of the Indo-Malayan mountains. The valleys which have produced the existing relief are due to corrosion by rivers and are in general parallel to the strike of the rocks.

There are in the existing relief traces of earth movements across the Indo-Malayan lines. The most conspicuous is the great Ta-shueh Shan Range which runs from Ba-tang E.N.E. to Ta-chien-lu. Its peaks rise to heights of over 24,000 ft. and support wide snowfields and glaciers. This mountain chain forms the divide between Chinese Tibet and the main plateau of Tibet. Its geological structure is best known from the work of VON LOCZY, who, at a time when the country was open to travellers, passed along the road at its southern foot. He showed that it is composed of metamorphic and plutonic rocks, which are wholly or mainly pre-Paleozoic; they strike across the present chain almost at right angles. The chain is therefore due to agencies much later than the Indo-Malayan compression, to which is probably due the strike of its rocks.

South of the Ta-shueh Shan rise many snow-covered mountains of which the alignment is uncertain. According to Mr. KINGDON WARD (1922, pp. 367, 369) there are "scores" of snow-capped summits which, though their present alignment is N.–S., may be the stumps of shattered ranges that had a different trend. The difficulty in determining their distribution is due to the passes being closed by snow in winter, and to the peaks being usually invisible in summer owing to continuous clouds. The name Yunnan means "South of the Cloudland."

The known heights suggest that there are two series of especially high peaks to the S. of the Ta-shueh Shan and parallel with it. The northern series includes Ka-kar-po, Pei-ma Shan, the mountains E. of A-tun-tze, and the many 19,000–20,000 ft. peaks E. of the Yangtze, which RICHARD (1908, p. 107) has called the Alps of Szechuan. The southern series in 26° 40′ N. includes the highest summits on the Nmai Hka–Salween divide and of the Kao-liang Shan, on the Salween–Mekong divide, and continues through Lotue Shan (over 15,000 ft.) W. of Shih-ku, and the Yu-lung Shan of Li-kiang. The distribution of the peaks, though still inadequately known, is not explained by the denudation of the Indo-Malayan mountains.

The prominence of the meridional highlands between the valleys naturally led to the conclusion that there was no extension of the Himalaya in these Alps of Szechuan. That view has been generally adopted, as by VON RICHTHOFEN (1877, I, p. 272, pl. III; and 1912, III, p. 356); DESGODINS (1885, p. 284); VON LOCZY (1893, pp. 816–7), who first connected the mountains of Indo-China with the Kuen-lun; SUESS (*cf.* GREGORY, 1915); BURRARD and HAYDEN (1907, pt. 2, pp. 81-82, chart XVII); DE LAUNAY (1911, pl. VII, IX); DEPRAT (1912, p. 300, fig. 15); and ARLDT (1919, p. 785).

The opposite conclusion has been adopted by various authorities. Travellers in the district have recognised the W. to E. alignment of the ridges and peaks, and have explained that arrangement as due to an eastward prolongation of the Himalayan lines. The late PRINCE KROPOTKIN (1904, pp. 333–4) and A. LITTLE (1905, opp. p. 19) both maintained the eastern extension of the Himalaya* through Chinese Tibet. The Yunnan Arc of DEPRAT (1912, pp. 301, 302), which is accepted by Mr. COGGIN BROWN (1920, p. 5), is represented as a fold-mountain line formed across the Hercynian lines by pressure from the N. at the date of the Himalayan folding; it is regarded therefore by M. DEPRAT as synchronous with the Himalaya but not a continuation of them. M. BACOT (1912, p. 257) refers to the Salween near Drongneu as cutting through a second Himalayan chain. Mr. GEORGE FORREST referred to the Snow Range at Li-kiang as the eastern end of the Himalaya.

Biological evidence is more significant than topographic features dependent on ancient Hercynian structures; Mr. KINGDON WARD (1919; 1921, pp. 54, 55) has advanced evidence from plant distribution in favour of the former extension of the Himalaya

* This use of the term Himalaya has reference to the Himalayan System, not to the Himalayan Chain. According to many authorities, such as GODWIN-AUSTEN and Sir E. BURRARD, the Himalayan Chain lies wholly between the Indus and the Dihang. The Himalayan System is much wider and includes contemporary corresponding chains to N., W., and E. This use of the term "Himalaya" is analogous to the distinction in Europe between the Alpine Chain and the Alpine System, of which the Alps form one of the constituent chains.

eastward through Chinese Tibet into western China; and he quotes Sir I. B. BALFOUR that the distribution of the rhododendron floras shows that a botanical divide runs from S.W. to N.E. between Yunnan and Szechuan.

The topographic evidence, as shown by the rivers, certainly appears at first sight inconsistent with any great structural line passing through Chinese Tibet from W. to E. Sir SYDNEY BURRARD (in BURRARD & HAYDEN, pt. II, 1907, pp. 81–2, 92, and 110, and pl. 17) has given his high support to the view that the Irawadi-Salween divide is the direct continuation of the Ninchin-thangla Range, which runs on a curve E. and W. between the uppermost Salween and the Tsang-po. According to this view the meridional eastern continuation of the Ninchin-thangla Range would sever the Himalaya from the mountains of Chinese Tibet, and the Himalaya would end eastward at the cross valley of the Dihang. This view was put forward in 1907, before reliable determination of the great height of Namcha Barwa (25,455 ft.). The new information as to the structure of the country to the E. of the Dihang suggests that Kangri Karpo (20,326 ft.) is the eastern extension of Namcha Barwa, and that the main Himalayan line passes S.E. from Kangri Karpo to Aguia (19,688 ft.), where it again turns eastward to the Salween. This range E. of Aguia is in line, across the three rivers, with the Ta-shueh Shan. A series of high peaks therefore links Namcha Barwa with the Ta-shueh Shan.

The topography, as shown by KISHEN SINGH (Rec. Surv. India, VIII, pt. 2, 1915, map No. XV), indicates the modern development of the river valleys where the heads of the Irawadi and the Zayul Chu come near the Salween. Unfortunately little is known as to the geology of that area; but the information available renders improbable the assumed southward continuity of the Ninchin-thangla to the W. of the Salween. It is true that Mr. MURRAY STUART (1919, pl. 38), in his account of the lead mines of Putao, has shown that in that area (North Burma, around $97\frac{1}{2}°$ E., $27\frac{1}{2}°$ N.), the pre-Paleozoic rocks trend from N.W. to S.E.; but that strike is probably an ancient feature dating from the Hercynian or the even earlier Sinian movements and due to the Indo-Malayan mountain lines curving to the W. as they enter Tibet. The course of the Ninchin-thangla, as marked on Sir SYDNEY BURRARD'S map (*op. cit.*, pl. 17), may correctly represent the alignment of the ancient Hercynian mountains, but not of the younger Himalayan ranges. The Irawadi-Salween divide is a secondary watershed, consequent, directly and indirectly, upon the Hercynian strikes. The existence of the Salween, Mekong and Yangtze valleys is no more conclusive against the former continuity of a mountain line across them, than the passage of the Dihang through the Himalaya in northern Assam is proof that the Himalaya there reach their eastern end; or than the passage of the Arun across the main chain E. of Mt. Everest, or of the tributaries of the Indus from Tibet into India, proves the discontinuity of the central and western Himalaya. The break in the strike near Ba-tang is similar to that along the Judicaria line, parallel to the Trient valley in the south-eastern Alps.

The most direct geological evidence of mountain lines trending W. and E. across the

Hercynian strike is given by inliers of older rocks in positions indicating uplifts trending W. and E. (fig. 12). The evidence of faults is less easy to interpret because, from whatever direction the pressure may have come, fresh faulting would tend to take place

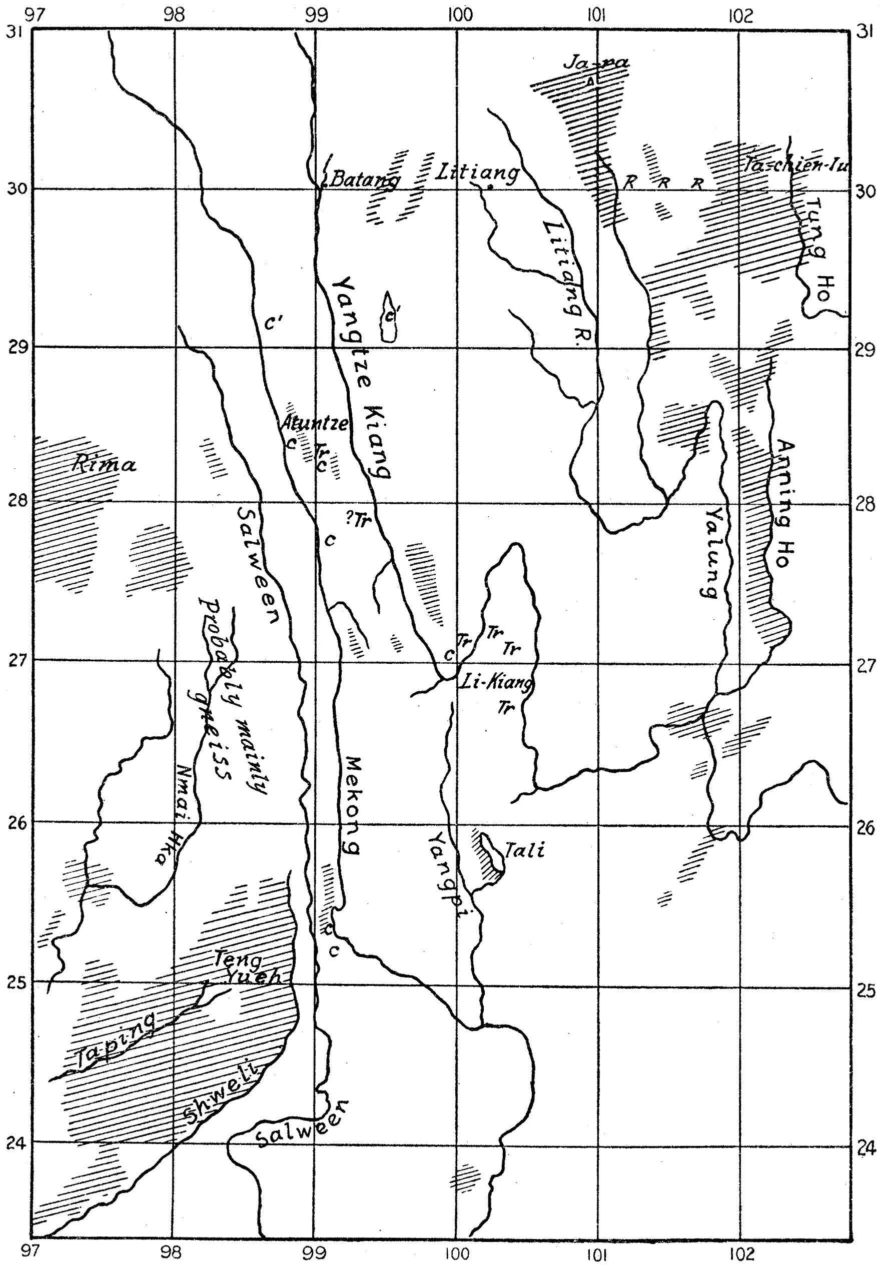


FIG. 12.—Distribution of the Older Rocks.—*Shaded*, pre-Paleozoic ; *c*. Carboniferous ; *Tr*., Trias.

along the structural lines due to the earlier movements. Heavy pressure on a piece of knotty wood causes slips along the grain around the unyielding knots. Similarly in Chinese Tibet pressure from N. or S. would renew faulting parallel to the strike, owing to the protection of some areas by resistant masses and to the easy yielding along weaker bands. Such movements give rise to an impression of pressure from W. to E. ; and there was a western component in the Himalayan compression of the district. Hence overfolding and faulting due to pressure from the W. is attributable to Himalayan movements, although they acted upon the area as a whole from N. to S.

There is abundant evidence of fractures on W.–E. lines. Faults and shatter-belts, such as that passing through the Jem-sa La, occur at right angles to the northern pressure. However, at the present stage of our knowledge of the area, the most reliable evidence is the arrangement of the inliers of older rocks. The Ta-shueh Shan from Ba-tang to Ta-chien-lu appears to consist of Eozoic and Archeozoic (Kao-liang) rocks, like the central axis of the Himalaya. The existence of this chain, with peaks from 24,000 to perhaps 25,000 feet in height, is all the more significant of a tectonic uplift, because its course is almost at right angles to the strike of its rocks. This chain is in line with high but little known mountains to the W., which connect it through Namcha Barwa with the central axis of the Himalaya.

At the southern foot of the Ta-shueh Shan lies a band which must be due to relative subsidence, as it contains younger rocks. This band crosses the Mekong at Ya-ka-lo at the Permo-Triassic salt-bearing beds, with Carboniferous rocks from which fossils were collected by the Abbé Desgodin. Due E. of this basin, to the E. of the Yangtze, is a lenticular area at Shen-te, Ku-tu La, Den-gu La and Tz-de, at which VON LOCZY (1893, pp. 730-732) obtained Carboniferous fossils, including *Athyris*, *Productus*, corals, and foraminifera. Farther E., near Ta-chien-lu, according to LEGENDRE (1916, map, N. sheet), a band of Rhætic rocks lies at the southern foot of the Ta-shueh Shan. On the northern side of the Ta-Shueh Shan an extension of the Jurassic or Cretaceous rocks of Central Tibet may be indicated by the fossil from near Ta-chien-lu recorded as a doubtful Ammonite by BONVALOT (1892, p. 486). To the S.S.W. of the Permo-Triassic basin of Ya-ka-lo the Salween-Mekong divide is crossed by a pass, the Beda La, at the height of 15,200 feet (F. M. BAILEY, 1912, p. 337). North of the Beda La TEICHMAN (1922, map) marks the Salween-Mekong divide as rising to a "Snow Range," and the few traverses across this belt indicate that it is exceptionally high and rugged.* The Salween, for example, falls 2500 feet in 80 miles (30 feet to the mile) in the belt W. of Ba-tang, between Tsawa Dzong S. of 30° N. and Di at the foot of the Beda La; whereas to the S. of this belt the Yangtze in the 60 miles from Chit-sung to Shih-ku falls only 500 feet, and the Mekong in the 80 miles N. of Siao-wei-si falls 1000 feet.

South of the Beda La, the Salween-Mekong divide rises to the lofty peaks of Ka-kar-po, much over 20,000 feet high. According to Mr. KINGDON WARD (1916–1, p. 58) the rocks of Ka-kar-po include granite and metamorphic rocks, and to the S. of it, Doker-la (WARD, 1913–1, p. 103) consists of granite to the E. and limestone to the W. Apparently Ka-kar-po consists of older rocks, with limestones referable to the Kao-liang Series on the eastern front; these limestones probably belong to the same horizon as those on

* Kishen Singh, Great Tibet and Mongolia, Map No. 2, 1884, Records Surv. India, VIII, pt. II, 1915, p. 274 and Map XV. Atma Ram, 1892, Tibet and Western China, Sheet No. 2, *ibid.*, p. 409, map XXIV.

the western side of the Mekong opposite Kia-pieh. The gorge of the Salween W. of Ka-kar-po is in part at least in purple slate (WARD, 1913–1, p. 83); and W. of the Salween, at Gomba La and the pass of Tsukue, Dr. HANDEL-MAZZETTI (1919, p. 260) has recorded gneiss and "ur-kalk" or archean limestone.

Farther S. along the Salween-Mekong watershed the gneisses occur under the Kao-liang Series at much lower levels, as they are exposed only on the floor of the valley W. of Tsed-rong; hence the ridge of gneisses pitches S. Farther S. both sides of the Mekong valley are formed of the Minchia Series; the older rocks reappear to the S. of VON LOCZY's Carboniferous area from Schente to Tzde; for VON LOCZY (1893, p. 733) found at Panto (28° 35′ N.) and at Alikung (28° 25′ N.) (*ibid.*, p. 734) his "Older Paleozoic Limestones" with indeterminable crinoid stems and sub-metamorphic Paleozoic beds. They belong to the Minchia Series and rest on schists. A second exposure at 28°, at Chung-tien, contains the Upper Triassic limestone; for VON LOCZY recorded Carboniferous rocks, apparently unfossiliferous, extending thence for some miles farther S. (VON LOCZY, 1893, p. 741). The old gneisses and schists reappear at Le-suti, where the beds are traversed by two faults, of which the eastern has thrust the schists over the Carboniferous. East of Le-suti is a wide area of the older gneisses.

We crossed the country on a line roughly parallel to VON LOCZY's and farther to the W. South of the uplift marked by the gneisses and schists of Pei-ma Shan and A-tun-tze we found a broad belt with only the Minchia Series opposite to and corresponding in position with VON LOCZY's older and submetamorphic Paleozoics; and W. of Tung-chien, where he found marine Trias, are some limestones about 5 miles below Do-sung, which we regarded as probably Triassic, though we found no fossils in them. Just S. of these limestones, and in line with Tung-chien, are repeated overthrusts and overfolds due to pressure from the N. Opposite, again, to the gneisses of Le-suti outcrop the gneisses E. of Li-tien and in the range above Wei-si. The next belt to the S., which includes the Li-kiang basin, is again one of depression; and only younger rocks belonging to the Trias and Minchia Series are seen in it. The Eozoic and Archeozoic rocks reappear to the S., to the W. of Teng-chwan; they form the Tsang Shan W. of Ta-li, and we found them on about the same parallel near Ho-wan.

The evidence is necessarily incomplete while such large areas remain geologically unknown; but it is significant that in the belt we examined there is the same succession of outcrops of older rocks, separated by geological depressions which contain younger rocks, as VON LOCZY observed in the parallel belt E. of the Yangtze. The inliers of older rocks occur in series trending W. and E., and though greatly influenced by the Hercynian structures, they occur in positions consistent with their uplift along axes which are a direct continuation of the Himalayan folds.

§ D.—*Comparison of the Himalayan Sequence with that of Chinese Tibet.*

It may be objected that there is no resemblance between the geological structure of Chinese Tibet and of the Himalaya; and a geological section N. and S. through north-western Yunnan is very different from one through the Central Himalaya. The typical Himalayan structure may be summarised as follows. To the S. is a band of foothills, the Siwaliks, formed of Pliocene sandstones which have been disturbed only by the later Himalayan movements, though they have been thereby greatly faulted and in places even over-folded. North of these foothills the southern front of the western Himalaya includes violently dislocated and tilted marine limestones of Middle Eocene age. Their typical member is a Nummulitic limestone. The disturbance of these beds shows that they are older than the main Himalayan uplifts. North of the Eocene belt is the main axis of the Himalaya, consisting of Eozoic gneisses and granites with some Upper Paleozoic rocks on the southern flanks. Finally, to the N. of the pre-Paleozoic mass of the Himalaya lie broad sheets of Triassic and Jurassic rocks, with some Cretaceous and Eocene.

This sequence is quite different from that on a parallel line across Chinese Tibet; but the comparison between two such sections would be inconclusive. An earth-movement from N. to S. in Yunnan would have produced an essentially different structure from that in the western Himalaya, because it would have acted upon different materials. Sections through parts of the Himalaya show a close resemblance to one across Chinese Tibet. In the eastern Himalaya there are no nummulitic limestones and some sections would give the same sequence as in Yunnan. Thus, in Assam, a section would begin on the S. with a low-lying plain of Pliocene freshwater sediments only locally disturbed. These beds are faulted against Upper Paleozoic rocks that rest unconformably on the metamorphic series of the Himalayan axis, at the northern foot of which lie the Tibetan ranges containing Jurassic limestones. In Yunnan, along some lines, the section would similarly begin on the S. with Pliocene freshwater deposits occupying basins formed by subsidence and corresponding both in position and age with the Siwaliks. North of these beds are severely folded Upper Paleozoics, Devonian and Carboniferous. Then follows the highest main range, the Ta-shueh Shan, which is composed of metamorphic rocks; on the plains to the N. of it are extensive deposits of limestone, recorded, for example, by TEICHMAN (1922–1, pp. 178, 213) and COALES (1919, pp. 239, 240). The age of these limestones is unknown. TEICHMAN remarks their association with red and green shales and sandstones, so they may belong to the Minchia Series; but they may include eastern extensions of the Jurassic limestones of Western Tibet.

The comparison between north-western Yunnan and the Himalaya should be made between parts of that chain where its trend is transverse to the ordinary pre-Himalayan strikes in Kashmir. No argument against the extension of the Himalayan line eastward of Assam is valid unless it recognises that the Himalayan movements had there to adapt themselves to the structure left by the Hercynian movements. When that fact is allowed for, a striking similarity between the Himalayan and Yunnan sequences is apparent.

§ E.—*The Chinese Continuation of the Himalayan Line.*

The possible further extension of the Himalayan line eastward of Chinese Tibet we do not discuss in detail, as it would involve consideration of the geological structure of parts of central and south-eastern China ; but we may refer briefly to the three possible lines of extension. The Great Khingan Mountains, which were regarded by KROPOTKIN (1904, pp. 333–4) as the Himalayan continuation, are fundamentally distinct in structure ; they are due to a great fault or monoclinal fold by which parts of the plateau of eastern Asia have sunk to form the lowlands of north-eastern China. A second view, that the Himalayan continuation is through the Yun-ling Shan of western Szechuan, has been suggested by Mr. KINGDON WARD (1919, pp. 238–9 ; 1921, p. 55), and has more topographic evidence in its support ; but those mountains appear to be the dissected ends of an area with strikes belonging to the Kwenlun system, and we are not aware of any evidence for a Kainozoic fold-mountain line traversing this region along or parallel to the Yun-ling Shan. The only fold-mountains in eastern China of the trend and date of the Himalaya are the Nan Shan of southern China, between the Yangtze and the Si-kiang.

The evidence is inadequate to justify more than a preliminary hypothesis to suggest research, but some of the information available is suggestive. The famous mercury mines of Kwei-chow occur along this line ; and, as one of us has previously pointed out,* all the chief mercury mining fields occur in rocks which have been violently dislocated and usually overthrust by mountain-forming movements of about the same age as the Himalayan. Mercury ores in the quantities that have been found along the Nan Shan of Kwei-chow are known elsewhere only in dislocated fold-mountains of the Middle Kainozoic ; and TEGENGREN (1920, pp. 4–6) reports that the mines there occur in fractured Kainozoic anticlines. The mercury mines therefore suggest the occurrence of a modern chain of fold-mountains through Kwei-chow.

More precise evidence has come from the work of the French geologists in French Indo-China. VON LOCZY (1893, p. 744) in 1880 had discovered Carboniferous rocks thrust over the Trias on the northern side of the Yangtze Kiang in north-western Yunnan. LANTENOIS in 1907 described the relations of the rocks in southern Yunnan as having many " contacts anormaux " (*e.g.*, LANTENOIS, 1907, pp. 314, 319, 322, 339–41, etc.) and some of these abnormalities were due to pressure from the N. DE LAUNAY, in 1911, accepted the view that a belt of country in southern China and northern Tongking has been thrust southward against the old South China mass. This view is, however, best known from the elaborate maps and sections prepared by M. DEPRAT (1912, 1915) who represents large tracts of Szechuan as having been pushed, like the Alpine " Decken," southward into Yunnan and North Tongking.

M. DEPRAT'S work has been severely criticised by his compatriots and it is at present under detailed revision. The re-examination of the ground has led to the rejection of some of his conclusions ; hence until the revision is completed it is necessary

* ' Journn. Chem. Soc.,' vol. CXXI, 1922, p. 769.

to suspend judgment on his work, except where it has been already confirmed.* One improbability in M. DEPRAT'S work has been removed by the re-survey, which has, however, fully confirmed the conclusion that N. Tongking and probably therefore also S. Yunnan and S.E. China have been subject to thrust-planing and folding of Alpine intensity, by pressure acting generally from N. to S. The work of M. JACOB and BOURRET (1920, p. 36) in N. Tongking and of M. DUSSAULT (1921) in western Tongking have shown that in the areas re-surveyed M. DEPRAT underrated the extent of the junctions due to overthrusting. That the great earth-movements demonstrated were Kainozoic in age also admits of no doubt, though they may be earlier than the date assigned by M. DEPRAT.

The work of the French geologists in French Indo-China therefore supports the view that the mountainous country known as the Nan Shan of Southern China represents an Alpine fold-mountain band, due to pressure from the N. (ranging from N.W. to N.E.) during the Middle Kainozoic. The folding along this line is more intense than any known along the Burmese or Malay Arcs. It is therefore probable that the Nan Shan includes the eastern continuation of the main axis of the Himalayan System.

We conclude therefore that, just as in Europe the Alpine line subdivides around the Hungarian plain and the Balkans, so in Asia the Himalayan line forks around the ancient Indo-Chinese massif.

§ F.—*The Physiographic History of Chinese Tibet in relation to that of Central China and Tongking.*

The physiography of Chinese Tibet is due mainly to features formed at five stages. The first is indicated by the remnants of a great peneplane which had been formed across the site of the Indo-Malayan Mountains and had reduced south-eastern and central Asia to a mature topography of gentle down-like uplands and broad valleys. This peneplane was formed by post-Hercynian denudation acting throughout Mesozoic times. The peneplane was practically completed in the Cretaceous, but its formation may have lasted into the early Kainozoic. The country was probably then at only a moderate elevation above the sea, for a gulf that crossed central Tibet in the Upper Jurassic still

* According to M. DEPRAT, a belt of vast "Decken" overthrusts, comparable to those claimed for the Alps, extends across S.E. Szechuan, near the southern great bend of the Yangtze (about 103° E., 26° N.) through the country N. and E. of Yunnan-fu, Kwei-chow and northern Tongking; and the compression and disturbance in that belt is equal in intensity to that of the Himalaya, and it is the only belt in eastern China with a Himalayan structure. According to M. DEPRAT, the movements were of very recent date. He says (1915, p. 81): "L'Asie sud-orientale entière du Tibet au Pacifique et au golfe du Bengale est donc entraînée dans un mouvement d'une ampleur énorme, peut-être en voie de ralentissement à l'heure actuelle, mais qui à une époque très récente était encore très rapide." Our observations indicate that the disturbed belt was further N. in western and central Yunnan than M. DEPRAT suggested, and the date of the movement was earlier. We may also remark that the essential facts shown in the section of the Kiao-ting Shan, the chain on the overthrust belt of which M. DEPRAT'S description is most precise, may be explained by overfolding with less extensive thrust planes than are required by his interpretation.

existed in the Cretaceous, though it was smaller in size and shallower. The Cretaceous sea certainly reached the coasts of southern India and covered an extensive area in western Burma ; but China was mainly, if not wholly, land.*

The second stage was that of the Himalayan uplifts ; as they uptilted the Nummulitic limestones along the southern flanks of the Himalaya they were later than the Middle Eocene. The movements probably lasted from the Upper Eocene through the Oligocene into the Miocene ; the last of them happened in the Pliocene, as they faulted and tilted the Siwalik beds. The uplifts buckled the southern margin of Tibet, but left central Tibet as a region of high plains, which still retained the gentle relief due to the Mesozoic planation. The earlier Himalayan uplifts converted the narrow sea, which had persisted from the Jurassic to the Eocene, into land valleys, down which the main rivers probably flowed from W. to E.† The drainage from the great basin of east central Asia, between the newly uplifted Himalaya to the S. and the older Kwenlun Mountains to the N., was probably across China by a river which was the progenitor of the Yangtze Kiang.

The chief development in the third stage was the formation of meridional fractures across the Himalaya which enabled much of the Tibetan drainage to escape southward. At the same time great basins were made by subsidence along faults and monoclinal folds, and the rivers which discharged into the basins dug deep valleys into the borders of the sunklands. The basins then made or enlarged include the Indo-Gangetic plain, the Irawadi basin (which had been in part an Eocene and Miocene gulf), the basin of Szechuan, the basins in south-eastern Yunnan described by DEPRAT (1912, pp. 303-316), and those in the north-western districts described on pp. 242-247. The age of these basins was probably not earlier than the Pliocene ; for no marine Miocene deposits have been found in them except in those of the Irawadi and lower Indus.

The fourth stage was the deposition of a thick series of red sands and loess in the basins formed in the preceding stage, as well as the older part of the loess on the plains of northern China. Thick deposits of red sand also occur in some of the river valleys of western Yunnan, so that those valleys must have been formed by this stage. The older fossils found in the beds on the floor of these basins are Upper Pliocene in age. That the climate was then arid is indicated by the nature of the deposits ; but as the basins were irrigated by drainage from the hills, the vegetation was sufficient to produce deposits of brown coal.

The fifth stage accompanied the development of a wetter climate, during which the valleys were enlarged owing to the increased power of the rivers, and the glaciers around the higher peaks were larger than they are now. That further faulting occurred during this period is shown by faults in the Pliocene drifts near Ku-tung, as well as by many of the fault scarps being but slightly worn.

* A reported but doubtful *Schloenbachia* from Kwei-chow is quoted by DEPRAT (1912, p. 219) from G. H. Monod, Bull. Econ. Indo-Chine ; another dubious ammonite was reported by BONVALOT (1892, p. 286) from near Ta-chien-lu.

† This course for the continuation of the Tsang-po was suggested by R. D. OLDHAM in HAYDEN, 1907, p. 7.

This succession of events is essentially similar to that described by Prof. BAILEY WILLIS (1907, pp. 98–105) from northern and central China, and for Tongking by the French geologists of the Service Géologique Indo-Chine.

Prof. BAILEY WILLIS divided the physiographic history of northern and central China into four stages; the first he named the Pei-tai, during which was formed the Cretaceous and early Kainozoic peneplane; second the Tanghien, a period of great erosion; third, the Hin-chou, the chief deposition of loess; fourth, the Fon-ho, beginning in the Pliocene but mainly Pleistocene, and marked by great continental uplift, during which the rivers further deepened their valleys, but there was comparatively little land sculpture.

The succession described by Prof. BAILEY WILLIS is in the main consistent with the evidence in Yunnan, except as regards his interpretation of the last period, the Fon-ho. According to him central China had been worn down to a low plain which lasted into the Pleistocene (Quaternary), when it was raised by a regional uplift of about 12,000 feet (BAILEY WILLIS, 1907, pp. 108, 111). This uplift is regarded as also having affected the regions to the N. and W.; in fact, according to this view, the great mountains of western China and the Tibetan tableland of east central Asia were raised from a little above sea-level during the age of man.

The similarities between the history of Yunnan and of central China are so close that if BAILEY WILLIS'S view be adopted for North China and the middle part of the Yangtze basin, the plateau of Yunnan and the surrounding regions should also have been uplifted during the Pleistocene. We saw, however, no evidence of any such great regional uplift. There is, for example, no evidence of any Upper Kainozoic marine deposits either in Yunnan or the surrounding countries. Marine deposits belonging to the Eocene and Miocene extend far up the Irawadi valley; but the Pliocene deposits there are terrestrial or fresh-water. The Pliocene and later beds in the basins of Yunnan are also terrestrial or fresh-water.

Secondly, raised beaches are inconspicuous in this part of Asia and indicate uplifts of only a slight amount. If there had been an uplift of the plateau to the extent of several thousand feet, some greater uplift of the adjacent coasts would have been expected.

Thirdly, any great Pleistocene uplift of the region is contradicted by the glacial history. If the country had been rising, the glaciers should have increased in size. The heavier precipitation during the early Pleistocene naturally enlarged the glaciers, but they have been diminishing throughout the region during the later Pleistocene.

The arguments in favour of a continental uplift of W. central China rest mainly on two considerations. Firstly, that great peneplanes are only formed at low levels; and secondly, that the deep gorges of the Yangtze Kiang are so young that they indicate a recent geographical revolution in the country, and must be due to antecedent rivers having maintained their courses through deepened channels during the slow uplift of the country. It does not seem to us that either consideration is valid. Some of the most even of the great plains of the world appear to have been developed at high levels.

The plain of the Eastern Sudan along the White Nile and the Bahr el Ghazl is situated at the level of about 1200 ft.; that plain appears to have been formed by the prolonged action of wind and rivers on the high plateau of central Africa. If the base level of the rivers be upheld by distance from the seas or by rock barriers, a peneplane may be formed high above sea level.

In the absence of any direct evidence of great recent uplift, such as the presence of marine deposits on the plateau, of beaches on the marginal lands, or great warping of the surface, it appears more probable that the plains of Yunnan and Chinese Tibet were formed high above sea level, than that east central and south-eastern Asia should have been uplifted 10,000 ft. within the human period. The dissection of this country by young canyons would have resulted from the lowering of the base level of the rivers, on the formation of the great sunklands in the early or middle Pliocene. Before the great basin of Szechuan was made by subsidence the rivers from Chinese Tibet and Yunnan would have flowed across its site to the edge of the plateau near the present boundary of the Chinese highlands. The formation of the basin of Szechuan would have produced a great lake, with an outlet eastward. The outflowing river by deepening its bed would have cut the modern gorges of the Yangtze and thus have drained the lake of Szechuan. The lake need never have been as deep as the existing basin; for the subsidence was doubtless slow, and the outflow from the lakes and swamps in the sinking ground would have cut down the outlet at the same rate.

The cutting of the Yangtze gorges was probably concurrent with the sinking of the Szechuan basin. The formation of that basin lowered the base level of the rivers which drained into it, and enabled them to cut their deep gorges through the western plateaus.

This succession of events is similar to that which has been observed in Tongking and south-eastern Yunnan. According to M. DEPRAT (1912, pp. 551–1; also 1915, pp. 77-8) the stages there are as follows:—

		Corresponding Stage.
Later Pleistocene .	5. Deepening of all the canyons . . . . 4. Beginning of excavation of the canyons of the Yangtze and its tributaries 3. Continued excavation of valleys . . . . 2. Valleys widened and their gradients steepened . . . . . . 1. Excavation of high-level valleys of Yangtze and its tributaries	Fon-ho.
Older Pleistocene .	Cycle of Lin-ngan. Accumulation of pebble beds and loess in the basins	Hin-chou.
Upper Pliocene .	3. Mountains broken into blocks by cross-faults and basins formed by subsidence Stage of Tsouei-wei-chann: 2. Land between the mature valleys reduced to narrow crests 1. Epeirogenetic uplift	Tang-hien.

			Corresponding Stage.
Lower Pliocene and late Miocene .	Stage of Kiao-ting-chann	2. Long period of peneplanation; old surfaces upraised 4500 or 6000 m. 1. Wide uplift at end of Himalayan movements. Energetic excavation of river valleys. . . .	Pei-tai *
Middle and Lower Miocene and (?) Oligocene . . .	Himalayan uplift and formation of Yunnan Arc; carriage of large areas by thrust planes from the N. on to Yunnan and N. Tongking; the belt to the N. of the older blocks of S.E. China pressed southward against it.		
Jurassic to Eocene	Area stable and completely levelled by peneplanation		

According to M. DEPRAT, all five subdivisions of the Fon-ho stage happened in the late Pleistocene and are due to an uplift during that time. In north-western Yunnan, however, the formation of the valleys began much earlier, and many of them were excavated nearly to their present depth in the Pliocene. The Pliocene age of the valleys and basins is indicated by the fossil molluscs and mammals in the beds on their floors.† The excavation of the valleys and basins was far advanced before the end of the Tang-hien, which is not later than Middle Pliocene. The Pliocene age of the valleys is indicated by the lithological as well as by the paleontological evidence, for the red beds on the floor of the Salween, Mekong and other valleys must have been deposited under an arid climate. Further, the higher segments of the valleys (*i.e.*, sub-stages one and two of DEPRAT) were certainly pre-glacial; for the early Pleistocene extension of the glaciers found these valleys already in existence.

We therefore consider that some of the events which DEPRAT referred to the two last of the five divisions of the Fon-ho happened in the third stage or Tang-hien and were therefore Middle Pliocene. This conclusion is consistent with the evidence from the Himalaya. The Upper Siwalik beds at the southern foot of the Himalaya are Pliocene and correspond to the Hin-chou stage. When they were deposited the Himalayan drainage was on much its present lines; for broad fans of gravel were deposited, according to MEDLICOTT, opposite the mouths of some of the existing valleys which were therefore well developed by the Upper Pliocene.

Mr. COGGIN BROWN has assigned to a Nan-tien stage some of the later developments in the Taping valley. He has divided the stage into three divisions—peneplanation after the Himalayan folding, the formation of basins by faulting, with the choking of the valleys by sediments, and a final uplift; he included all three stages in the Pliocene.†

* DEPRAT's reference of the Pei-tai stage to the late Miocene and early Pliocene does not agree with the Cretaceous age assigned to it by BAILEY WILLIS.

† For the Pliocene and Pleistocene ages of the mammals, see SCHLOSSER (1903, pp. 218–9); the molluscs according to MANSUY are "Quaternary" and Pliocene. (MANSUY, 1907, p. 471, and 1912, pp. 16–18.)

The following table, in which Prof. BAILEY WILLIS's terms from N. China are adopted, summarises the suggested outline of the later physiographic history of Chinese Tibet:—

Stage in N. China.		Series.	Events in Chinese Tibet and Adjacent Areas.
	Fon-ho	Late Pleistocene	Completion of canyon erosion.
		Early Pleistocene	Glacial extension; excavation of young canyons. Later volcanic eruptions and faulting.
Tsing-ling of B. WILLIS in Central China	Hin-chou	Upper Pliocene	Accumulation of lignite, loess and red sands in the main valleys and basins. Climate arid.
	Tang-hien	Middle Pliocene	Post-Himalayan faults and foundering of basins of S.W. China, Indo-China, Burma, and Assam.
		Early Pliocene / Upper Miocene	Formation of high-level valleys and post-Himalayan faults. Volcanic eruptions.
		Miocene-Oligocene	Himalayan folding.
	Pei-tai	Lower Kainozoic / Cretaceous	Peneplanation of Tibet and Yunnan. Major valleys trend W.–E.

The most important difference in this table from Prof. BAILEY WILLIS's conclusions is the omission of his great late Pleistocene uplift. FRECH (1911, in VON RICHTHOFEN, vol. V, p. 242) had previously denied the great Quaternary uplift, from the paleontological evidence; and we consider that the physiographic evidence agrees with FRECH's view.

According to the above classification the main Himalayan line continued across Chinese Tibet despite the meridional strike prevailing there. The Himalayan line may therefore be expected to extend farther eastward beyond Indo-China. The essential major facts in the structure of eastern China are the existence of two great Sinian blocks of pre-Cambrian rocks, one to the N. and one to the S., of which the latter extends south-westward into Cambodia and the Malay Peninsula. The nucleus of this South China block consists of areas of gneiss; they were united by Paleozoic rocks and the whole welded by Hercynian folding. The typical parts of China lie between these northern and southern blocks; and the land near the southern block has been disturbed by Kainozoic folding. A branch of the Himalayan fold-belt was bent backward, as the Burmese arc, on the western margin of this Indo-Chinese mass; and we consider, from the evidence referred to on pp. 255–256, that the continuation of the Himalayan line passes along the northern margin of that mass through Yunnan, S.E. Szechuan and through Kwei-chow, as the Nan Shan (*i.e.*, Southern Mountains) of eastern China.

According to this view there is a continuous belt of fold-mountains from western Europe to south-eastern China. The vast length and the course of this belt suggest its formation by the crumpling of the junction of the northern mass of Eurasia and the south temperate or tropical zone. If this long fold-mountain belt were due to the interaction between the northern cap of the earth and its tropical girdle some continuation of the crumpled belt might be expected to the E. of China; and there are indications of the extension of the Alpine-Himalayan uplift eastward into the Pacific.

PART VIII.—COMPARISON OF THE SEQUENCE IN CHINESE TIBET AND YUNNAN WITH THAT IN EAST AFRICA.

In the development of south-eastern Asia the two greatest events were the Himalayan folding and the subsidence of the Indian Ocean. In connection with the latter it is natural to consider whether the structure of the lands to the east of the Indian Ocean helps to explain that of the lands to the west of it. At first the complex topography and geology of Indo-China seemed to contain little in common with the simple plan and sequence of events in East Africa. The difference between the two areas seemed fundamental; but recent geological investigations in south-eastern Asia have revealed some important resemblances between the East African and Indo-Chinese structures.

Equatorial East Africa is essentially a plateau region, composed mainly of Eozoic gneisses and schists, which appears to have stood above sea-level throughout geological time. Its margin was first reached by the sea in the Jurassic and the Cretaceous, while from the late Paleozoic to the Kainozoic eastern Equatorial Africa was part of a continent which extended to India and Australia.

South-eastern Asia, on the contrary, throughout earlier geological times was a very disturbed region with parts below sea level. Marine representatives of all the Paleozoic Systems occur, and it was not until the end of the Paleozoic that it was raised as a whole above the sea. It became part of the same land mass as Equatorial Africa, India and Australia, and its northern coast was washed by the Upper Jurassic and Cretaceous seas, of which a gulf lay along the coast of East Africa.

In and after the Cretaceous the chief geological events in East Africa were, first, a wide uprise of the land, which may be explained by sub-crustal flow of material displaced by the subsidence of the Indian Ocean. This flow of material was partly relieved by colossal volcanic outbreaks, which discharged the Kapitian lavas of East Africa and the Deccan traps of Western India. Subsidences along the summit of the upraised African belt produced the Great Rift Valley. The subsidences occurred at intervals from the Oligocene to the Pleistocene and were accompanied by successive volcanic disturbances and probably by enlargements of the Indian Ocean.

In Yunnan a similar series of events can be recognised, including successive meridional fractures and subsidences and volcanic eruptions. A great meridional subsidence to the W. of Yunnan formed the Irawadi valley, which was occupied by the sea from the Eocene to the Miocene. During this time were discharged the lavas of Teng-yueh. The age of the first eruptions has not been established by any associated fossils, but it was certainly pre-Hin-chou, as the older lavas are cut across by the faults that formed the Nan-tien basin. The high dip of some of the lavas indicates that they were pre-Himalayan, and they may prove to be Oligocene and contemporary with the Doinyan lavas of East Africa. The next stage was the Himalayan folding due to pressure from the N.; it was approximately contemporaneous with the first series of rift-valley faults in East Africa, which were Oligocene. After the Himalayan folding the Indo-Chinese region was broken by meridional faults which were Pliocene in age and correspond to the second series of rift-valley faults in East Africa. A third series of meridional faults in Indo-China, some of which traversed the Pliocene deposits, are clearly Pleistocene and correspond in age to the last series of rift-valley faults and were accompanied by the later volcanic eruptions.

The faults in Indo-China had very different effects from those of East Africa, as they traversed a more complex structure. In Indo-China the faults are shorter and less regular than in East Africa, and they produced sunklands more often than rift-valleys. The Kainozoic faulting produced different topographic features in Indo-China from those in East Africa, as the foundations of the two regions are fundamentally distinct. Nevertheless, the meridional faults and accompanying volcanic disturbances in Indo-China correspond in age and succession with those on the African side of the Indian Ocean.

REFERENCES.*

ANDERSON, J. (1871). "A Report on the Expedition to Western Yunan via Bhamo." 3, xii, 458 pp., 5 pl., 2 maps.

ARLDT, T. (1919, 1922). "Handbuch der Palæogeographie." Vol. I, pp. 1–680; Vol. II, pp. xix, 681–1647.

BABER, F. C. (1882). "Travels and Researches in the Interior of China." R.G.S. Supp. Papers. Vol. I, x, 201 pp., 14 pl.

BACOT, JACQUES (1909). "Dans les Marches Tibetaines autour du Dokerla." 215 pp., 30 pl., and map.

(1912). "Le Tibet Révolté vers Nepemako, la Terre Promise des Tibetains." 365 pp., 32 pl., 7 maps.

BAILEY, F. M. (1912). "Journey through a portion of South-eastern Tibet and the Mishmi Hills." 'Geogr. Journ.,' XXXIX, pp. 334–347, map p. 420.

BLEECK, A. W. G. (1913). "On some Occurrences of Wolframite Lodes and Deposits in the Tavoy District of Lower Burma." 'Rec. Geol. Surv. India,' XLIII, pp. 48–73, pl. I, II.

BONVALOT, G. (1892). "De Paris au Tonkin." 511 pp., 1 pl.

BOSE, P. N. (1891). "Notes on the Geology and Mineral Resources of Sikkim." 'Rec. Geol. Surv., India,' XXIV, pp. 217–230, map.

* Complete summaries of the available literature, with full bibliographies, are given by K. BOUTERWEK (1919) for Chinese Tibet, and by Dr. EMIL TRINKLER (1922) for Tibet.

BOUTERWEK, K. (1919). "Das Land der meridionalen Stromfurchen im Indo-chinesisch-tibetanischen Grenzgebiet." 'Mitt. Geogr. Ges. München,' XIII, pp. 161–341, pls. 4–7.

BROWN, J. COGGIN—

(1912). "A Geological Reconnaissance through the Dihang Valley." 'Rec. Geol. Surv., India,' XLII, pp. 231–253, pl. 27.

(1913—22). "Contributions to the Geology of the Province of Yunnan in Western China."

(1913—1), Part 1. "The Bhamo–Teng-yueh Area." 'Rec. Geol. Surv., India,' XLIII, pp. 173–205, pl. 6–17.

(1913—2), Part 2. By R. C. BURTON. "Petrology of Volcanic Rocks of the Teng-yueh District." *Ibid.*, pp. 206–28, pl. 18–20.

(1913—3), Part 3. "Notes on the Stratigraphy of the Ordovician and Silurian Beds of Western Yunnan." *Ibid.*, pp. 327–334. With Provisional Paleontological Determinations by F. R. COWPER REED.

(1914), Part 4. "The Country around Yunnan Fu." *Ibid.*, XLIV, pp. 85–112, pl. iv.

(1916), Part 5. "Geology of Parts of the Salween and Mekong Valleys." *Ibid.*, XLVII, pp. 205–266, pl. 21–28.

(1922—1). Part 6. "Traverses between Ta-li Fu and Yunnan Fu." *Ibid.*, LIV, pp. 68–86, pl. I.

(1922—2). Part 7. "Reconnaissance Survey between Shun-ning Fu, Pu-e'rh Fu, Ching-tung T'ing and Ta-li Fu." *Ibid.*, LIV, pp. 296–323, pl. 20.

(1922). Part 8. "A Traverse down the Yang-tze-Chiang Valley from Chin-chiang kai to Hu-li Chou." *Ibid.*, pp. 324–336, pl. 21.

(1920). "The Mines and Mineral Resources of Yunnan." 'Mem. Geol. Surv. India,' XLVII, 201 pp., 4 pl., map.

[BRUNHUBER, R.]. (1912). Dr. Robert Brunhuber. "An Hinterindiens Riesenströmen. Mit einem Vorwort von Sven Hedin." 120 pp. and map.

BURRARD, S. G., and HAYDEN, H. H. (1907). "A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet."

Part I. "The High Peaks of Asia." 46 pp., 3 pl., charts I–VIII.

Part II. "The Principal Mountain Ranges of Asia." Pp. 47–117, charts IX–XXII.

Part III. "The Rivers of the Himalaya and Tibet." Pp. ii, 230, charts XXIII–XXXVII.

Part IV. "The Geology of the Himalaya." 1908. Pp. vi, ii, 207–308, pl. XXXVIII–L.

BURTON, R. C., *v.* BROWN, J. COGGIN.

COALES, OLIVER. (1919—1). "Eastern Tibet." 'Geogr. Journ.,' LIII, No. 4, pp. 228–253, 2 pl.

(1919—2). "Economic Notes on Eastern Tibet." 'Geogr. Journ.,' LIV, pp. 242–7, map.

DAVIES, H. R. [General]. (1909). "Yun-nan. The Link between India and the Yangtze." xii, 431 pp., 24 pl., and map.

DEPRAT, J. (1912). "Etude Géologique du Yun-nan Oriental." 'Mém. Serv. Géol. Indochine,' Vol. I, Ire Partie. 'Géologie Générale,' xiii, 370 pp., 20 pl. Atlas, 51 plates, 7 maps.

(1915). "Etudes géologiques Région septentrionale du Haut-Tonkin." *Ibid.*, IV, pt. 4, ii, 175 pp., 38 pl., 9 pl. of maps and sections.

DESGODINS, C. H. (1876). "Notes géologiques sur la route de Yerkalo à Patang." 'Bull. Soc. Géogr.,' Paris (6), XII, pp. 492–508.

(1885). 'Le Thibet d'après la Correspondance des Missionnaires.' 2nd Edit., 475 pp., 1 map.

DESSAULT, L. (1921). "Etudes géologiques dans le Tonkin Occidental." 'Bull. Serv. Géol. Indo-Chine,' X, fasc. 2, 72 pp., 3 pl. and maps.

FERGUSSON, W. N. (1911). "Adventure, Sport and Travel on the Tibetan Steppes," xvi, 343 pp., 2 maps.

FORREST, G. (1908). "Journey on Upper Salwen, October–December, 1905." 'Geogr. Journ.,' xxxii, pp. 239–266, map.

FRECH, *v.* VON RICHTHOFEN.

GENSCHOW, A. VON (1905). "Unter Chinesen und Tibetanern." vi, 385 pp., pls., maps.

GILL, W. (1880). "The River of Golden Sand. The Narrative of a Journey through China and Eastern Tibet to Burmah." With an Introductory Essay by Col. H. YULE.

(1880). Vol. I. 95, 420 pp., 4 pl., 3 maps.
Vol. II. xiv, 453 pp., 4 pl., 4 maps and section. (Abridged edition, 1883.)

GREGORY, J. W. (1915). "Suess' Classification of Eurasian Mountains." 'Geogr. Journ.,' XLV, pp. 497–509.

(1919). "A Low-level Glaciated Surface in the Eastern Himalaya." 'Geol. Mag.,' n.s. Dec. VI, Vol. VI, pp. 397–406.

GREGORY, J. W., and GREGORY, C. J. (1923—1). "The Alps of Chinese Tibet and their Geographical Relations." 'Geogr. Journ.,' LXI, pp. 153–179, 6 figs., 3 pl.

(1923—2). "A Note on the Map illustrating the Journey of the Percy Sladen Expedition, 1922, in North-Western Yunnan." 'Geogr. Journ.,' LXII, pp. 202–5, map.

(1923—3). "To the Alps of Chinese Tibet. An Account of a Journey of Exploration up to and among the Snow-clad Mountains of the Tibetan Frontier." 321 pp. 16 pl. and map.

HANDEL-MAZZETTI, H. (1919). "Vorläufiger Bericht über meine Forschungen in Yunnan, 1914–1919." 'Mitt. k.k. Geogr. Ges., Wien,' LXII, pp. 385–391.

(1921). "Ergebnisse der Expedition Dr. Handel-Mazzetti's nach China, 1914–1918. Neue Aufnahmen in N.W. Yunnan und S. Setschuan." 'Denk. Akad. Wiss., Wien,' XCVII, pp. 257–268, map.

HAYDEN, H. H., *v.* BURRARD and HAYDEN (1904). "The Geology of Spiti." 'Mem. Geol. Surv. India,' XXXVI, pt. 1, vi, 129 pp., 18 pl.

(1907). "The Geology of the Provinces of Tsang and U in Central Tibet." 'Mem. Geol. Surv. India,' XXXVI, pt. 2, 80 pp., 15 pl.

HERON, A. M. (1922). "Geological Results of the Mount Everest Reconnaissance Expedition." 'Rec. Geol. Surv. India,' LIV, pp. 215–234, pl. 7–13.

JACK, R. LOGAN (1904). "The Back Blocks of China. A Narrative of Experiences among the Chinese, Sifans, Lolos, Tibetans, Shans, and Kachins, between Shanghai and the Irrawaddi." xxii, 269 pp., 16 pp., 16 pl., 2 maps.

JACOB, C., and BOURRET, R. (1920). "Itinéraire Géologique dans le Nord du Tonkin." 'Bull. Serv. Géol. Indo-Chine,' IX, fasc. I, 49 pp.

JOHNSTON, R. F. (1908). "From Peking to Mandalay. A Journey from North China to Burma through Tibetan Ssuch'uan and Yunnan." xii, 460 pp., 34 pl. and map.

KENDALL, ELIZABETH (1913). "A Wayfarer in China. Impressions of a Trip across West China and Mongolia." xvi, 338 pp., 24 pl., 2 maps.

KROPOTKIN, PRINCE P. (1904). "The Orography of Asia." 'Geogr. Journ.,' XXIII, pp. 176–207, 331–361, 3 maps.

LANTENOIS, H. (1907). "Résultats de la Mission Géologique et Minière du Yunnan Méridional (1903–4)." 'Ann. Mines, (2) Mém.' XI, pp. 298–428, pl. X, XI. With contributions by COUNCILLON, LAURENT, MANSUY, and ZEILLER.

LA TOUCHE, T. H. D. (1913). "Geology of the Northern Shan States." 'Mem. Geol. Surv. India,' XXXIX, iv, 379, xli, pp., 25 pl. and 3 maps.

LAUNAY, A. DE (1911). "La Géologie et les Richesses Minérales de l'Asie," 816 pp., 9 pl.

LEGENDRE, A. F. (1916). "Massif Sino-Thibétain.—Provinces du Setschouan, du Yunnan et Marches Thibétaines. Contribution à l'étude géologique de ce massif," iii, 251 pp., 12 pl., 5 maps. With contributions by P LEMOINE, AZEMA, and F. PELOURDE.

LIMPRICHT, DR. (1919). "Reise im westlichen Szetschwan, 1914." 'Pet. Mitt.,' LXV., pp. 131–137, 173–180, 208–212.

LITTLE, A. (1905). 'The Far East,' viii, 334 pp., 9 maps.

LITTON, G. (1903). "Report by . . . on a Journey in North-West Yunnan." 'Parl. Pap., China,' No. 3, 1903 (Cd. 1836), 23 pp., 5 maps.

LOCZY, LUDWIG VON. 'Die Wissenschaftlichen Ergebnisse der Reise des Grafen Béla Széchenyi in Ostasien, 1877–1880.'

(1893). Vol. I, pp. 305–837, pl. ii–x.

(1899). Vol. II, pp. 3–227, pl. i–xi.

(1897). Atlas. Geological maps.

LOVEMAN, M. H. (1919). "A Connecting Link between the Geology of the Northern Shan States and Yunnan." 'Journ. Geol.,' XXVII, pp. 204–211.

MACLAREN, J. M. (1904). "The Geology of Upper Assam." 'Rec. Geol. Surv. India,' XXXI, pp. 179–204, map, pl. 28.

MANSUY, H. (1907). *See* Lantenois.

(1912). "Etude géologique du Yun-nan Oriental. Mém. Serv. Géol. Indo-chine." I, fasc. 2, pt. 2. Paléontologie. 147 pp., 25 pl.

PELOURDE, FERNAND. *See* LEGENDRE, A. F.

REED, F. R. C. (1917). "Ordovician and Silurian Fossils from Yun-nan." 'Pal. Ind.' n.s., VI, No. 3, 69 pp., 8 pl.

RICHARD, L. (1908). "Comprehensive Geography of the Chinese Empire." Translated and revised by M. KENNELLY, 711 pp., 4 maps.

RICHTHOFEN, FERDINAND VON (1877–1882). "China. Ergebnisse eigener Reisen und darauf gegrundeten Studien."

(1877). Vol. I, xliv, 758 pp., 11 pl.

(1882). Vol. II, xxiv, 792 pp., 8 pl.

(1912). Vol. III, xxxi, 817 pp., 5 pl.

(1883). Vol. IV. Palæontologischer Theil. By DAMES, KAYSER, LINDSTRÖM, SCHENK, and SCHWAGER, xvi, 228 pp., 54 pl.

(1911). Vol. V. [Paleontology], F. Frech, xii, 289 pp., 37 pl.

(1885). Atlas, pts. 1 and 2, 26 maps.

(1900). "Ueber Gestalt und Gliederung einer Grundlinie in der Morphologie Ost-Asiens." 'Sitz. k. Preuss. Akad. Wiss., Berlin,' Pt. II, pp. 888–925.

SCHLOSSER, MAX (1903). "Die fossilen Säugethiere Chinas, nebst einer Odontographie der recenten Antilopen." 'Abh. Math.-phys., k. Bayer. Akad. Wiss.', XXII, pp. 1–222, pl. I–XIV.

SMITH, F. H. (1898). "The Geology of the Mikir Hills in Assam." 'Mem. Geol. Surv. India,' XXVIII, pp. 71–95, pl. 4.

STUART, MURRAY (1919). "The Galena Deposits of North-Eastern Putao." 'Rec. Geol. Surv. India,' L, pp. 241–254, pl. 34–38.

SZÉCHENYI, BÉLA (1890–99). 'Die Wissenschaftlichen Ergebnisse der Reise des Grafen Béla Széchenyi in Ostasien, 1877–1880.' 3 Vols. and Atlas.

Vol. I, 1893, ccliii, 851 pp., 10 pl., 1 map (Hungarian edition 1890).

Vol. II, 1898, xiii, 783 pp., 22 pl. (Hungarian edition 1896).

Vol. III, 1899, 523, vii pp., 15 pl., 7 tables (Hungarian edition 1897).

Atlas, 1897 (Maps 1/1000,000) 32 pl.; topography by G. KREITNER; geology by L. VON LOCZY.

TEGENGREN, F. R. (1920). "The Quicksilver Deposits of China." 'Bull. Geol. Surv. China,' No. 2, 45 pp., 8 pl.

TEICHMAN, E. (1922–1). "Travels of a Consular Officer in Eastern Tibet, together with a History of the relations between China, Tibet and India." xxiv, 248 pp., 64 pl., 8 maps.

(1922—2). "Journeys through Kam, Eastern Tibet." 'Geogr. Journ.' LIX, pp. 1–19, 2 pl., 1 map.

TRINKLER, E. (1922). "Tibet. Sein geographisches Bild und seine Stellung im Asiatischen Kontinent." 'Mitt. Geogr. Gesell. München, XV, pp. 1–146, pl. 1–4.

WARD, F. KINGDON (1913—1). "The Land of the Blue Poppy. Travels of a Naturalist in Eastern Tibet." xii, 283 pp., 45 pl., maps I-V.

(1913—2). "Geological Notes on the 'Land of Deep Corrosions.'" 'Geol. Mag.,' 1913, pp 148–153, pl. V, VI.

(1916—1). "Glacial Phenomena on the Yun-nan–Tibet Frontier." 'Geogr. Journ.,' XLVIII, pp 55–68, 2 pls.

(1916—2). "Further Geological Notes on the 'Land of Deep Corrosions.'" 'Geol. Mag.,' 1916, pp. 209–219.

(1918). "The Hydrography of the Yunnan-Tibet Frontier." 'Geogr. Journ.,' LII, pp. 288–299.

(1919). "On the Possible Prolongation of the Himalayan Axis beyond the Dihang." *Ibid.*, LIV, pp. 231–241.

(1920). "The Valleys of Kam." *Ibid.*, LVI, pp. 183–195, 1 pl.

(1921—1). "The Mekong-Salween Divide as a Geographical Barrier." *Ibid.*, LVIII, pp. 49–56.

(1921—2). "In Farthest Burma." 311 pp. 16 pl., 2 maps.

(1922). "The Glaciation of Chinese Tibet." Geogr. Journ., LIX, pp. 363–369.

(1923). "From the Yangtze to the Irrawaddy." *Ibid.*, LXII, pp. 6–18, 2 pl.

WILLIS, BAILEY. "Research in China." 'Carnegie Inst.,' Public No. 54.

(1907). Vol. I, "Descriptive Topography and Geology." By B. WILLIS, E. BLACKWELDER, R. H. SARGENT and F. HIRTH, pp. xiv., 528, xxiv, 55 pl., 8 maps.

(1907). Vol. II, "Systematic Geology, pp. v, 133.

(1913). Vol. III, "[Fossils]" by C. D. WALCOTT, S. WELLER, and G. H. GIRTY, pp. lv, 375, 29 pl.

(1906). Atlas, 42 maps.

YOUNG, F. C. (1907). "A Journey from Yun-nan to Assam." 'Geogr. Journ.,' XXX, pp. 152–180, with map.

APPENDIX I.—REPORT ON TRIASSIC, CARBONIFEROUS AND DEVONIAN MOLLUSCA AND BRACHIOPODA FROM YUNNAN, COLLECTED BY PROF. J. W. AND MR. C. J. GREGORY IN 1922.

By F. R. Cowper Reed, Sc.D., Sedgwick Museum, Cambridge.

LOCALITY 1. W. OF A-SHIH-WO. (E. OF PU-PIAO.)

Upper Carboniferous.

Seven specimens of a rotten and much weathered limestone from this locality have been submitted to me for examination. The following three species have been identified indicating the Upper Carboniferous age of the rock :—

Spirifer *cf.* cameratus Morton (4)
Spirifer *cf.* nikitini Tschern. (2)
Uncinulus wangenheimi (Pand.) (1)

Spirifer cf. *cameratus* Morton.

A broken pedicle valve (F. 2) of a species of *Spirifer* occurs in the collection from this locality, and it appears to be referable to the somewhat variable *Sp. cameratus* Morton resembling the examples which Tschernyschew* figures from the Urals. The transversely subfusiform shape of the shell, the character of the beak, the hinge-area and the ribbing agree in all respects, so far as they can be observed in the one specimen. The wide shallow rounded sinus holds 8–10 ribs of the typical low rounded character, and the lateral lobes show similar ribs occasionally dividing at some distance from the beak, but mostly simple and subequal. Mansuy† records *Sp. cameratus* from Laos and Tonkin, and his figures indicate a shell like ours.

Dimensions { Length, c. 28 mm.
Width, c. 50 mm.

Spirifer cf. *nikitini* Tschernyschew.

There is a fragmentary pedicle-valve (F. 4) of a species of *Spirifer*, partly weathered out on a small piece of limestone from the same locality. The valve was apparently moderately convex and subcircular or oval in shape. The beak is moderately elevated and incurved, and the umbonal edges are rounded. The surface is longitudinally divided by a narrow rounded median groove arising from the beak and widening slowly anteriorly, becoming a flat-bottomed narrow sinus holding one rib which occupies the whole floor. On each side of it the lateral lobes arch up with a gentle convexity and are covered by 11-12 low rounded closely placed ribs of rather unequal width, and a few of

* Tschernyschew, 'Mém. Com. Géol. Russ.,' vol. XVI, p. 2, pp. 138, 531, t.v., figs. 1–9, t. VI, fig. 8, t. XI, figs. 2–4, t. XL, fig. 6.

† Mansuy, 'Mém. Serv. Géol. Indo-chine,' vol. II, fasc. 4, 1913, p. 56, pl. v, figs. 4a, 4b.

them seem to divide at about half their length. The rib in the sinus is simple and not larger than any of those on the lateral lobes.

Dimensions :—Length, c. 21 mm.

Remarks.—This specimen seems more allied to *Sp. nikitini* TSCHERN.* than to *Sp. mosquensis* FISCH (which belongs to the same group), for the sharper, more defined median groove and ribbing agree better with the former as figured by TSCHERNYSCHEW. It is a characteristic form of the Schwagerina horizon in the Urals. MANSUY† figures it from Kham-keut.

Uncinulus wangenheimi (PANDER).

In the rotten limestone from the locality W. of A-shih-wo there is on one block a weathered-out pedicle-valve of a rhynchonelloid shell, somewhat crushed but showing the external characters with sufficient distinctness. The valve is transversely sub-triangular, the beak high pointed and acute, the cardinal edges diverge at rather more than a right angle, the lateral angles are rounded and the front margin is more or less truncated in the middle. There is a strong broad median sinus deepening anteriorly, with a flattened floor, and holding five equal angular ribs ; the edges of the sinus are steep, rising up to the triangular lateral lobes, which are elevated and carry 4–5 strong angular ribs, the first two on each side of the sinus being considerably larger than those lying in it. The ribs in all cases are continuous from the beak to the margin, but are weaker posteriorly. Subparallel dental plates are represented in our specimen by slits, but the umbonal part is not well preserved.

Dimensions { Length, 16·5 mm.
Width, 18·0 mm.

Remarks.—This shell seems to be referable to *Uncinulus wangenheimi* (PANDER),‡ a characteristic Upper Carboniferous species in the Urals, while *U. jabiensis* WAAGEN, from the Salt Range§ and Timor|| is closely allied.

LOCALITY 2. JANU-LA.

The fossils from Janu-la comprise Triassic, Carboniferous and Devonian species. The Carboniferous fossils occur in a very dark grey bituminous limestone with an irregular but sharp fracture, and the rock is of an entirely different appearance to that containing the Triassic fossils. But there are also two brachiopods apparently of

* TSCHERNYSCHEW, 'Mém. Com. Géol. Russ.,' vol. XVI, pt. 2, pp. 154, 542, t. X, figs. 1, 2, t. XIII, fig. 2.

† MANSUY, 'Mém. Serv. Géol. Indochine,' vol. II, fasc. 4, p. 66, pl. vi, fig. 4.

‡ TSCHERNYSCHEW, *op. cit.*, pp. 72, 487, t. XLIV, figs. 3–5, t. XLVI, figs. 15–17, t. L, fig. 11.

§ WAAGEN, 'Salt Range Foss.' I, p. 427, pl. XXXIV, fig. 2.

|| BROILI, "Perm. Brach. Timor" ('Paleont. Timor,' Lief. VII, No. XII, 1916), p. 61, t. CXXVI, fig. 13, t. CXXVII, figs. 4–6.

Carboniferous age, which are contained in a different and more horny matrix, and the determination of the affinities of these two specimens has been a troublesome matter, and even in the end there remains some doubt in my mind as to their geological age. As far as their state of preservation allows their identification one seems comparable to *Camarophoria globosa* TSCHERN., and the other may be allied to some Carboniferous species of *Rhynchonella*, though it must be regarded as a new species (*Rh.* ? *peregrina*).

The Devonian fossil is an isolated specimen of *Uncinulus* which seems inseparable specifically from *U. procuboides*, though it does not agree with the type of the species nor with its variety *lungtungpeensis* which occurs in China and Indo-China.

The Triassic fossils comprise the bulk of the species which have been identified in the material sent to me from this locality, and quite nine-tenths of the small pieces of rock seem to be referable to the same Triassic formation.

TRIAS.

The majority of the fossils from Janu-la occur in a light gray compact limestone, which varies somewhat lithologically. The best preserved specimens are in a rock of a rather horny texture with a clean sharp subconchoidal fracture and varying in colour from light gray to pale buff or pale pinkish buff, and in some cases dark grayish brown. Scarcely separable in hand specimens is a rock of the grayish colour with an uneven, rather sugary, non-conchoidal fracture. It is possible that these lithological types represent different beds and horizons, but the fossils are insufficient to prove this, and in some cases it is difficult to separate the types of matrix. The principal type is the horny compact one (*a*), and it seems to pass (sometimes even in the same fragment) imperceptibly into the sugary type (*b*).

As regards the age of this assemblage of Triassic fossils we note that the following are allied to or comparable, if not identical with, Upper Triassic species :—

Aulacothyris angusta SCHL. var. nov. *yunnanensis*.
Terebratula (*Cœnothyris*) *janulensis* sp. nov.
Dielasma sp. b.
Athyris, *cf. dieneri* BITTN.
Waldheimia (*Cruratua*), aff. *eudoxa* BITTN.
Rhynchonella (*Halorella*) *deludens* sp. nov.
,, aff. *concordiœ* BITTN.
Pecten cf. *discites* SCHL.
Pseudomonotis aff. *illyrica* BITTN.
Daonella ? sp.
Avicula sp.
Neritaria ? sp.

Of Muschelkalk species or allied forms there are the following :—

Aulacothyris angusta SCHL.
Athyris cf. *stoliczkai* BITTN.
? *Monotis janulensis* sp. nov.
? *Orthoceras* sp.

The only Lower Triassic affinity is shown by the lamellibranch *Pseudomonotis* aff. *ivanowi* BITTN.

List of Triassic Species.

(The numbers in brackets after the names are those attached to the specimens.)

Aulacothyris angusta (SCHLOTHEIM), (82) (67) (73).
,, ,, var. nov. *yunnanensis* (85) (20) (53) (92) (38).
,, ,, aff. *angusta* (SCHLOTHEIM) (79).
Dielasma himalayanum BITTNER (80).
,, *olivæforme* sp. nov. (51).
Terebratula (*Cœnothyris*) *janulensis* sp. nov. (84).
,, sp. (29) (44) (61) (203).
,, sp. b. (42).
Athyris (*Spirigera*) cf. *dieneri* BITTN. (23).
,, ,, cf. *stoliczkai* BITTN. (28).
Waldheimia (*Cruratula*) aff. *carinthiaca* (ROTHPL.) (10).
Rhynchonella (*Halorella*) *deludens* sp. nov. (74) (202) (54).
,, aff. *concordiæ* BITTN. (58).
,, sp. (48) (37) (25) (24) (31) (21 ?).
Neritaria ? sp. (27).
Orthoceras sp. (9).
Pecten cf. *discites* SCHLOTH. (17).
Monotis janulensis sp. nov. (69).
Pseudomonotis cf. *illyrica* BITTNER (45).
,, aff. *ivanowi* BITTNER (46).
Daonella ? sp. (55).
Avicula ? sp. (214).

Aulacothyris angusta (SCHLOTHEIM).

There is one complete specimen (F 82) quite free from matrix and well preserved, which must be referred to *A. angusta* (SCHLOTHEIM), as defined by BITTNER.* It is a well known Muschelkalk species, and several varieties have been recognised.† The sharp

* BITTNER, 'Abh. k.k. Geol. Reichsanst.,' vol. XIV, p. 7, t. XXXVI, figs. 41–47.

† BITTNER, *op. cit.*, p. 8, t. XLI, figs. 23, 26; SALOMON, 'Paläontographica,' vol. XLII, I, p. 105, t. III, figs. 35–39.

umbonal ridges, defining the false hinge-area and the median longitudinal groove towards the front of the sinus in the brachial valve are distinct and help to separate it from the allied *A. lilangensis* BITTNER from the Himalayan Trias.* The median groove in our specimen only begins at about one-third the length of the brachial valve, the posterior and umbonal part of this valve being convex. The anterior margin is not produced into a tongue, and its sinuation is broad, shallow and rounded. The sinuation of the lateral margins is gentle and forms a weak sigmoidal curve. The proportions of the length and breadth of our specimen agree with the European species.

Dimensions { Length, 12·0 mm.; Breadth, 10·5 mm.; Thickness, 6·5 mm. }

Aulacothyris angusta, var. nov. *yunnanensis*.

(Plate 8, fig. 1.)

Shell suboval, very unequally biconvex, anterior end subtruncate. Pedicle valve deep, subcarinate, the gently arched sides sloping down at an angle of 60°–75° from the median carination, which becomes more marked and sharper towards the beak; lateral margins broadly but rather strongly sinuated in a sigmoidal curve; beak elevated, slightly incurved, acute, with short sharp curved umbonal ridges defining slightly concave false hinge-area. Brachial valve very shallow, arched strongly from beak to anterior margin, but more or less flattened from side to side for its whole length, with strongly impressed median longitudinal groove continuous from beak to anterior margin and lying in floor of very shallow median depression, which divides the surface of the valve into a pair of low rounded or flattened lobes. Interior of brachial valve with median septum extending nearly its whole length. Pedicle valve with pair of short dental plates diverging at 45° on each side of a short low median ridge. Surface of valves ornamented with fine concentric lines.

Dimensions	F. 85	F. 20	F. 53
Length	17·5	—	— mm.
Width	15·0	16·0	16·0 mm.
Thickness	11·0	12·0	12·5 mm.

Remarks.—There are three fairly complete specimens (F. 85, 20, 53) of this form in the collection, of which F. 85 is nearly free from matrix. Two other fragments (F. 38, 92) are probably referable to it. It is much like *A. angusta* var. *rosaliæ*, SALOMON,† but the sinus in the brachial valve is less marked in our shell, and this valve is flatter from side to side. The variety *incrassata*‡ is more closely allied, but is less carinated. Some

* BITTNER, 'Himal. Foss.,' vol. III, pt. 2 (Palæont. Ind.), p. 28, pl. VI, fig. 3.

† SALOMON, *op. cit.*, p. 105, t. III, figs. 35–38.

‡ BITTNER, 'Abh. k.k. Geol. Reichsanst.,' vol. XIV, p. 8, t. XLI, figs. 23–26.

examples of *A.* cf. *zirlensis* WÖHRMANN, figured by BITTNER* from the Veszpremer Marl of Lake Balaton seem to be identical with our variety, judging from the figures.

Aulacothyris aff. *angusta* (SCHLOTHEIM).

One small very convex pedicle-valve (F. 79) partly imbedded in a matrix of a rather darker and more horny limestone than that containing the majority of the specimens from Janu-la, is worthy of notice because of (1) the unusually well marked carination of the valve for nearly its whole length, the sides descending more steeply than in the others, and (2) the presence of two strong concentric growth-ridges which cross the surface forming a weak backward curve on the carina, which suggests that the anterior margin was slightly excavated in the middle. The posterior growth-ridge crosses the valve at about half its length; the anterior one is submarginal, and finer concentric growth-lines are present between them. The punctuate character of the shell is beautifully shown. As far as can be seen the umbonal shoulders are rather longer than usual, reaching to the middle of the shell where it is widest, and diverging at an angle of 60° to 75°. Whether this shell is more allied to *A. angustæformis* BOECKH than to some variety of *A. angusta* SCHLOTH. is uncertain, but I am inclined to associate it with the latter.

Dimensions { Length, c. 7 mm.
Width, c. 5 mm.

Waldheimia (*Cruratula*) aff. *eudoxa* BITTNER.

One pedicle-valve (F. 10) of a small brachiopod measuring 13 mm. in length and 13·5 mm. in width with the shell partly preserved has a subtriangular shape, a high acutely pointed incurved beak with long sloping shoulders, a subtruncate anterior end and a strong convexity from side to side and from back to front. In all these characters it seems to resemble *Waldheimia* (*Cruratula*) *eudoxa* BITTNER† and the closely allied *W.* (*Cr.*) *carinthiaca* ROTHPL.‡ from the Upper Trias of Southern Europe. Some smaller less perfect fragments (F. 87, F. 81, F. 77, F. 13, F. 43) may possibly belong to the same species.

Dielasma cf. *himalayanum* BITTNER.

One fairly good specimen (F. 89) which may be compared with this species§ occurs in the collection; it is partly imbedded in matrix and the anterior margin is broken off,

* BITTNER, 'Result. Wiss. Erforsch. Balaton Sees,' vol. I, i, Pal. Anh. Pt. II, 1912, p. 12, t. I, figs. 2–7.

† BITTNER, 'Abh. k.k. Geol. Reichsanst,' vol. XIV, p. 127, t. IV, figs. 18–23.

‡ *Ibid.*, p. 67, t. I, fig. 15, p. 127, t. IV, fig. 17, p. 156, t. XXXVII, fig. 20, and 'Philipp, Zeitschr. Deut. Geol. Gesell,' vol. LVI, 1904, p. 63, t. IV, figs. 1–18.

§ BITTNER, 'Himal. Foss.' vol. III, pt. 2 (Palæont. Ind.), p. 25, pl. V, figs. 1–8, 10, 11.

but it shows most of the brachial valve and the beak and umbonal region of the opposite valve. The brachial valve has a weak broad concentric depression across its middle, causing the posterior part to be somewhat more convex and elevated than the rest of the valve, and this part is also crossed by two or three low rounded concentric rugæ. But probably this character is due to an injury during growth. A low broad flattened indefinite median fold seems developed anteriorly. The strongly divergent crura and short thin medial septum are clearly visible where the shell has been worn away. The broad somewhat flattened beak of the pedicle-valve with a large apical foramen and prominent short umbonal ridges is well seen in our specimen, and in its whole assemblage of characters it most resembles figures 6 and 11 (*op. cit.*) of BITTNER's original specimens of *D. himalayanum* from the Himalaya.

Dimensions { Length, 22·0 mm.
Width 17·5 mm.

Dielasma ? olivæforme, sp. nov.

(Plate 8, fig. 2.)

Shell elongated oval, widest across middle, subequally biconvex; margins simple, regular, without sinuation. Pedicle-valve gently convex, most so posteriorly and, subcarinate near umbo; surface without fold or sinus; anterior margin sharply rounded; beak high, gently incurved, acute, with umbonal shoulders straight, rounded, and diverging at about 35° to middle of length of valve. Brachial valve less convex, without fold or sinus. Surface of shell minutely punctuate, and covered with fine concentric striæ, with a few coarser growth ridges near the anterior margin.

Dimensions { Length, 19 mm.
Width (max.), 11 mm.
Thickness, *c.* 8 mm.

Remarks.—Only one specimen (F. 51) has been observed in the collection, and this has the brachial valve buried in the matrix. The shape and general characters suggest that it is allied to *Waldheimia eudoxa* BITTN. var. *angustissima* FRECH* from the equivalent of the Raibl Beds in Hungary, but it also bears some resemblance to the Permian *Dielasma elongatum* SCHLOTHEIM. Thus the shell from the Productus Limestone of Dongvan which MANSUY† termed *D. baolacense* has a somewhat similar outline. This Permian species *D. elongatum* varies considerably in shape, and has a wide distribution, DIENER‡ recording it from Chitichun. The shape of our shell suggests the name *olivæforme*.

* FRECH, 'Result. Wiss. Erforsch. Balaton Sees,' vol. I, i, Pal. Anh. pt. 2, p. 42, text fig. 58.

† MANSUY, 'Mém. Serv. Géol. Indochine,' vol. V, fasc. 4, 1916, p. 37, pl. VI, figs. 4a–d.

‡ DIENER, 'Himal. Foss.,' vol. I, pt. 5, 1913, p. 41, pl. I, fig. 9, pl. II, fig. 4.

Terebratula (*Cœnothyris*) *janulensis*, sp. nov.

(Plate 8, fig. 3.)

Shell subovate, widest behind middle, narrowing anteriorly to subparabolic anterior end ; lateral union of valves broadly situated in gentle sigmoidal curve. Pedicle-valve strongly convex from back to front, but less convex from side to side in posterior two-thirds and flattened in anterior third, which is produced as a short tongue with slightly excavated lateral margins and sharply rounded tip. Beak moderately high and incurved, with slightly concave rounded umbonal slopes ; false hinge-area very small, with rather obscure curved sharp edges ; apical foramen small. Brachial valve less deep than opposite valve, very slightly convex from back to front, more so from side to side in posterior half ; median anterior portion forming indistinct slightly flattened broad fold, corresponding to tongue in other valve, and bounded by broad shallow rounded depressions on each side and the accompanying wide marginal rounded sinuations of the junction of the valves. Surface of shell densely pitted, the pits closely and regularly arranged in concentric and curved diagonal lines. Concentric growth-ridges fairly distinct, with one specially strong one at about two-thirds the length of the shell ; traces of a few equidistant widely spaced thread-like radial lines on anterior part of fold of brachial valve. Interior of pedicle-valve with pair of stout dental plates in beak diverging at a small angle ; brachial valve with narrow elongated muscle-scar.

Dimensions { Length, 22·0 mm.
Width (maximum), 18·0 mm.
,, of tongue at tip, 9·5 mm.
Thickness, 11·4.

Remarks.—The foregoing description is drawn up from one perfect detached shell (F. 84) with only a small piece of matrix adhering to the beak, and this consists of the pale horny type of limestone mentioned above. With regard to its affinities our specimen seems almost identical with the shell figured by BITTNER as *T. piriformis* SUESS var.* from the Alpine Trias and closely resembles the mutation *alexandrina* FRECH† from the 'Sandorhegver Kalk' (equivalent to the Raibl Beds) in the Lake Balaton area, Hungary. It also distantly resembles some of the shells attributed by Diener‡ to *Dielasma himalayanum* BITTNER. But it is sufficiently distinct from the types of both of these species to warrant a new specific designation. Its relation to *Cœnothyris vulgaris* SCHLOTH seems to be close, though it is quite unlike the shell from the Trias of

* BITTNER, 'Abh. k.k. Geol. Reichsanst.,' vol. XIV, p. 278, t. XXVI, fig. 1.

† FRECH, 'Result. Wiss. Erforsch. Balaton Sees,' vol. I, i, Pal. Anh. V, p. 70, text-figs. 9a, b, t. IX, figs. 3 a–d, 4a, b.

‡ DIENER, 'Himal. Foss.,' vol. V, pt. 3, p. 25, pl. V, figs. 1–8, 10, 11.

Pi-ché-tshai Yunnan, ascribed to this species by MANSUY,* and BITTNER'S† specimen from Spiti, compared with this species has also a completely different shape.

Terebratula, sp. a.

Shell broadly oval, widest across middle, valves somewhat compressed, without definite fold or sinus and with simple lateral union, weakly sinuated on front margin. Pedicle-valve gently convex, with high acutely pointed incurved beak, umbonal edges rounded and diverging at about 30°–45°. Brachial valve gently convex, less so than opposite valve but most elevated posteriorly ; beak small, incurved, slightly elevated ; umbonal edges diverging at 75° ; interior with thin median septum extending about one-third the length of the valve. Surface of shell ornamented with very fine concentric lines, a few stronger growth-ridges and dense punctæ.

			F. 44	F. 29
Dimensions	Length of shell	..	10·0	12·0 mm.
	Width of shell	..	10·0	9·0 mm.

Remarks.—Two fairly well preserved examples (F. 44, F. 29) of this little shell occur imbedded in matrix with the brachial valve uppermost and exposed ; the beak of the opposite valve is also visible. Several other fragmentary specimens (F. 61, 203) may belong to the same species. The true generic reference of these small shells is doubtful and they more resemble in external appearance some Upper Paleozoic species of *Eunella* and *Cryptonella* than any common Triassic forms. But the figures of the Triassic species *Terebratula neglecta* BITTNER‡ and *T. capsella* BITTNER§ given by BITTNER possess a great likeness in general shape and umbonal characters, and we may tentatively regard them as comparable with these species.

Terebratula, sp. b.

There is one nearly perfect specimen of another terebratuloid shell (F. 42) from Janu-la which seems to possess more the characters of the shell from Rimkin Paian figured by BITTNER as *Ter.* aff. *himalayana* (Himal. Foss., vol. III, p. 27, pl. V, fig. 12, non 13) rather than of the one included under this name from S.E. of Muth, Spiti (*op. cit.*, pl. V, fig. 13). The shape of our shell is, however, more subquadrate and less rounded on the sides than in the above described form, the sides being nearly parallel and the anterior end very broadly rounded ; there is also a wide but very slight anterior sinuation of the anterior margin ; the beak of the pedicle-valve is lower, less acute and less

* MANSUY, 'Mém. Serv. Géol. Indochine,' vol. I, fasc. 2, 1912, p. 119, pl. XXI, figs. 8a–f.

† BITTNER 'Himal. Foss.,' vol. III, pt. 2, p. 28, pl. V, fig. 14.

‡ BITTNER, 'Abh. k.k. Geol. Reichsanst.,' vol. XIV, p. 60, t. I, fig. 3.

§ *Ibid.*, p. 64, t. I, fig. 12.

prominent and that of the brachial valve is more obtuse, more swollen and more marked, and faint radial lines rather widely spaced are present on the flanks.

Dimensions: Length, 12 mm.; Width, 10 mm.; Thickness, 6 mm.

Dielasma haydeni DIENER* from the Carnic beds of the Himalaya may be compared for its outline, and the low obtuse beak of the pedicle-valve is rather similar, but it has a flatter brachial valve, and *T. capsella* BITTN. and *Ter.* ex. aff. *piriformis* SUESS figured by BITTNER† from the Alps are probably more closely allied.

Athyris [*Spirigera*] cf. *dieneri*, BITTNER.

There is one specimen (F. 23) comparable to this Himalayan species,‡ showing the beak of the pedicle-valve and part of the brachial valve of the same individual. The high incurved acute beak of the pedicle-valve with its concave shoulders and large apical foramen, and the rather large beak of the opposite valve with the median longitudinal impressed line traversing the valve are clearly seen. The concentric ornamentation of the surface can also be detected, but the specimen is imperfect and mostly buried in matrix. BITTNER (*op. cit.*) describes this species from the horizon of *Spiriferina griesbachi* in the Himalaya and figures many stages of growth and some varieties; those shells shown in his figures 1–5 bear the closest resemblance to our specimen. DIENER§ figures the species from the Monotis beds (Noric) of Mani.

Athyris [*Spirigera*] cf. *stoliczkai* BITTNER ?.

The variable species described as *Spirigera stoliczkai* (BITTNER)‖ from the horizon of *Spiriferina stracheyi* in the Trias of the Himalaya appears to be represented in the present collection by a brachial and pedicle-valve on the same piece of rock (F. 28). The shape of this species and the convexity of the valves varies greatly, according to BITTNER; our specimen is one of the more transverse and shorter forms, measuring 12 mm. in length and about 14·5 mm. in width.

Rhynchonella (*Halorella* ?) *deludens* sp. nov.

(Plate 8, fig. 4.)

Shell transversely subcircular, widest across middle, the anterior and lateral margins forming a regular curve; much dorso-ventrally compressed, both valves being very shallow and flattened. Pedicle-valve very slightly convex posteriorly, flattened

* DIENER, 'Himal, Foss.,' vol. V, pt. 3, p. 59, pl. CI, figs. 6–10.

† BITTNER, 'Abh. k.k. Geol. Reichsanst.,' Vol. XIV., p. 137, t. IV, fig. 13.

‡ BITTNER, 'Himal. Foss.,' vol. III, pt. 2, p. 54, pl. X, figs. 1–14.

§ DIENER, 'Himal. Foss.,' vol. V, pt. 3, 1908, p. 125, pl. XXIII, fig. 1.

‖ BITTNER, 'Himal. Foss.,' vol. III, pt. 2, p. 23, pl. III, figs. 1–17.

anteriorly, especially depressed in median portion, thus representing a very faint broad sinus ; beak prominent, erect (broken off in specimen F. 74) ; surface of valve covered with 28–30 straight low angular ribs of equal size of which the median 8–10 lie in the faint median depression and the last 2–3 lateral ones bordering the umbonal edges are slightly curved ; lateral umbonal cardinal areas small, lanceolate, concave, smooth and at right angles to general surface of valve. Brachial valve very slightly convex, not more so than opposite valve with smaller concave lateral umbonal cardinal areas having sharp curved upper edge ; ribbing apparently the same as on the pedicle-valve ; beak small, obtuse, low, incurved.

Dimensions (F. 7a) { Length, *c.* 17 mm. Width, *c.* 19 mm. Thickness, *c.* 6 mm.

Remarks.—There are two examples (F. 74 and F. 202) of this species which is remarkable for its flattened compressed form, subcircular shape, absence of distinct sinus or fold and numerous ribs. Another fragment (F. 54) is probably referable to the same species. The best preserved specimen (F. 74) has nearly the whole of the pedicle-valve exposed, but the beak is broken, and the brachial valve, except for the umbonal region, is buried in matrix. It seems probable that this shell should be referred to the subgenus *Halorella* rather than to *Rhynchonella* sens. str., for some examples of *H. pedata* Bronn.* bear a considerable resemblance.

Rhynchonella aff. *concordiæ* Bittner.

There is a weathered longitudinal natural section of a species of *Rhynchonella* (F. 58) exposed in the surface of a small piece of limestone from Janu-la which deserves description. The shell is transversely subpentagonal in shape, and the beak of the pedicle-valve is acutely pointed and elevated and shows two short dental plates diverging at about 50° ; the umbonal slopes are slightly concave and diverge from the beak at about 110°–120°. The anterior margin shows nine coarse angular ribs of equal size, of which three form a median group, apparently corresponding to a flattened fold on the brachial valve, and three lie on each side of it. The surface of the valve is completely destroyed, the ribs only showing as tooth-like projections on the margin. The length is 11·25 mm. and the width 13·0 mm. Probably this shell belongs to the group of species of *Rhynchonella* containing *Rh. concordiæ* Bittner,† but there is only the shape and small number of the ribs by which to judge.

Rhynchonella ? sp.

Several fragments (F. 48, 31, 37, 24, 25) of the valves of a Rhynchonelloid are probably referable to one and the same species, but even the genus is uncertain, as no

* Bittner, 'Abh. k.k. Geol. Reichsanst.,' vol. XIV, pp. 179–183, t. XVII.

† Bittner, 'Abh. k.k. Geol. Reichsanst.,' vol. XIV, p. 264, t. XXVII, figs. 1–17.

generic criteria are preserved. The best specimen (F. 48) shows the left half of the pedicle-valve, but the sinus is hidden by matrix. On the lateral lobe of the triangular shell there are six ribs (with traces of a seventh) ; they are strong, simple angular and nearly straight, with their extremities slightly curved back ; with the exception of the last two ribs along the cardinal margin they are of equal strength, but the cardinal rib is much smaller ; all are continuous from the beak to the margin, and the umbonal angle seems to have been larger than a right angle. The length of this specimen seems to have been 10–11 mm. Whether this shell is more allied to *Rh. bambanagensis* of the Himalayan Trias than to some other species must remain a matter of doubt.

Pecten, cf. *discites* SCHLOTHEIM.

This well known species* seems to be represented by one small specimen (F. 17) showing the beak, one ear and part of the body and part of the other ear. The characters and ornamentation agree precisely, and the straight groove on the surface running obliquely down from the beak at a slight angle to the line of junction of the body and ear can be distinctly observed. The variety *microtis* which BITTNER† figures from the Trias of Russia seems very similar to our shell, and *P. subdemissus* MUNST. from the St. Cassian beds‡ and from the Megalodon limestone of Chabrang in the Himalaya§ may be compared. KITTL|| has described three new species of *Pecten*, allied to *P. discites* from the Trias of the Sarajevo district, all of which resemble our fragmentary specimen in several respects, and *P. præmissus* BITTN.¶ from the Trias of Hungary is also much like it, but on the whole it seems preferable to refer it to *P. discites*. MANSUY** figures a fragmentary valve of a *Pecten* from the Trias of Tongking as *P.* cf. *subdemissus* MUNST., which is probably identical with our shell.

Monotis janulensis sp. nov.

(Plate 8, fig. 5.)

Shell subcircular ; hinge-line straight, less than maximum width of shell. Right valve with subcentral elevated acute beak and gently convex body, most convex in umbonal region but not sharply marked off from flattened ill-defined anterior and posterior ears ; anterior margin of valve strongly arched forwards, meeting hinge-line at very obtuse angle and passing below into general circular outline of valve ; anterior

* SALOMON, 'Palæontographica,' vol. XLII, I, 1895, p. 109, t. IV, figs. 24–26, 20–23.

† BITTNER, 'Mém. Com. Géol. Russ.,' vol. VII, No. 4, p. 2, t. I, figs. 12–18.

‡ *Id.*, 'Abh. k.k. Geol. Reichsanst.,' vol. XVIII, p. 164, pl. XIX, fig. 29.

§ DIENER, 'Himal. Foss.,' vol. V, No. 3, p. 138, pl. XXIV, fig. 12.

|| KITTL, 'Jahrb. k.k. Geol. Reichsanst.,' vol. LIII, 1903, pp. 710, 711, text-figs.

¶ BITTNER, 'Result. Wiss. Erforsch. Balaton Sees,' vol. I, i, Pal. Anh. II, No. 3, p. 38, t. V, figs. 12–14.

** MANSUY, 'Mém. Serv. Géol. Indochine,' vol. II, fasc. III, 1914, pp. 69, 70, pl. VIII, figs. 1 and 3.

ear flattened and horizontal in cardinal region but sloping up gradually into body below. Posterior margin nearly straight, meeting hinge-line at obtuse angle of about 120°; posterior ear very narrow, depressed, not clearly marked off from body, with cardinal margin somewhat thickened and raised. Surface of shell marked with 18-20 fine thread-like subequidistant radii of equal strength, of which most are primaries but some arise in the interspaces at about half the length; interspaces wide, subequal, flat; whole surface crossed by rather widely spaced concentric lines, most distinct in the interspaces. Anterior and posterior ears devoid of radial lines, but possessing concentric striation.

Dimensions { Length, 6·3 mm.
Height, 6·0 mm.

Remarks.—There is only one specimen (F. 69) of this small species, and it must be referred to the genus *Monotis*. But the radial ribbing and concentric lineation produce a faint cancellation of the surface as in *Amonotis cancellaria* Kittl*; the ears, however, in our specimen are devoid of radial markings and there are no concentric rugæ crossing the surface. The ornamentation is much like that of *Pseudomonotis* (*Avicula*) *himaica* Bittn.† of the subrobustus beds of the Himalaya.

Pseudomonotis cf. *illyrica* Bittner.

Mansuy‡ has figured an imperfect shell from the Trias of Tchong-ko-lo, Yunnan, as *Pseudomonotis* cf. *illyrica* Bittner,§ a species originally described from the Trias of the Ukraine, and in the present collection from Janu-la there is a fragment (F. 45) of a shell showing precisely the same type of ornamentation and possessing the same outline; but the ears are not visible, being buried in the tough limestone matrix. The ornamentation consists of sharp narrow rather prominent radial ribs which extend from the beak to the margin and between them are intercalated in each concave interspace a finer less prominent secondary rib arising at some distance from the beak. All the ribs seem provided with small scabrosities, and the regular equidistant arrangement of both primaries and secondaries is a marked feature. The surface valve is gently convex, most so towards the beak which is hidden, and the height of the shell seems about 8 mm.

Pseudomonotis aff. *ivanovi* Bittner.

A portion (F. 46) of the left valve of a species of *Pseudomonotis* shows the greater part of the body, beak and anterior ear, but the rest of the shell and the lower margins are broken off or hidden by matrix. The body is subtriangular and moderately convex,

* Kittl., 'Jahrb. k.k. Geol. Reichsanst.,' vol. LIII, 1903, p. 726, text-fig. 47.

† Bittner, 'Himal. Foss.,' vol. III, pt. 2, p. 10, pl. I, figs. 16–21.

‡ Mansuy, 'Mém. Serv. Géol. Indochine,' vol. I, fasc. 2, 1912, p. 120, pl. XXI, figs. 10 a–d.

§ Bittner, 'Jahrb. k.k. Geol. Reichsanst.,' vol. LI, 1901, p. 227, t. VII, figs. 13, 14.

more so towards the beak which is pointed, the sides diverging at about 60° and sloping down steeply to the anterior flattened horizontal triangular ear which is not sharply marked off from it; posteriorly the body slopes down more gradually, but is sharply separated from the depressed posterior ear which is obscurely traceable and seems to be larger than the anterior one. The surface of the body is ornamented with numerous (16–20) fine sharp equidistant radial riblets continuous from the beak to the margin, and a few (5–8) straight similar but more closely placed riblets are visible on the anterior ear. The interspaces between the ribs on the body are flattened, and occasionally a finer shorter secondary riblet seems to arise in them at about half the length of the shell; a fine concentric striation crosses the whole surface, rising into small scabrous (?) prominences on the primary ribs.

The true dimensions of our specimen are almost impossible to determine, but it seems to have had a height of 7-9 mm. and a length of about 7 mm. along the hinge-line. With regard to its affinities, we may compare *Ps. venetiana* HAUER,* *Ps. multiformis* BITTNER† and *Ps. inequicostata* BEN., all from the Lower Trias of Europe. The first-mentioned has more numerous and closer riblets and has closer relations to *Ps. illyrica* BITTNER above mentioned. A shell was described and figured by BITTNER‡ from the Otoceras beds of the Himalaya as *Avicula* aff. *venetiana*, which seems to bear a considerable resemblance to our specimen from Janu-la. But *Ps. ivanovi* BITTNER,§ from the Lower Trias of Russia, seems to be more closely allied than any of the above mentioned, though the radii are usually fainter.

Daonella sp.

One fragment of a flat valve (F. 55) shows the straight radial impressed lines of *Daonella* or *Halobia* set at rather unequal distances apart, and has the flat ribs between them usually divided unequally and rather irregularly by two or three similar shorter impressed lines towards the margins. A few low rounded concentric rugæ indicate the shape of the shell, and fine close concentric striation covers the whole surface.

The generic reference of this small fragment is doubtful, but it seems allied to *D. tommasii* PHILIPP‖ of the Predazzo Trias and to *D. indica* BITTNER,¶ which has been recorded by MANSUY** from several localities in Indo-China and by WANNER†† and others from Timor. *D. loveni* BOHM‡‡ from Bear Island may also be compared.

* BITTNER, 'Jahrb. k.k. Geol. Reichsanst.,' vol. XLVIII, 1898, p. 712, t. XV, figs. 2–4.

† BITTNER, 'Mém. Com. Géol. Russ.,' vol. VII, 4, p. 10, t. II, figs. 15–19.

‡ BITTNER, 'Himal., Foss.,' vol. III, pt. 2, p. 6, pl. I, fig. 8.

§ BITTNER, 'Mém. Com. Géol. Russ.,' vol. VII, 4, p. 8, t. I, figs. 1–9.

‖ PHILIPP, 'Zeitschr. Deut. Geol. Gesell.,' vol. LVI, 1904, p. 61, t. III, figs. 16–20.

¶ BITTNER, 'Himal. Foss.,' vol. III, pt. 2, p. 39, t. VII, figs. 4–11.

** MANSUY, *op. cit.*, vol. VIII, fasc. I, 1921, p. 84, pl. III, fig. 13.

†† WANNER, 'Neues Jahrb. f. Miner. Geol.,' Beil. Bd. XXIV, 1907, p. 202, t. IX, figs. 2, 3.

‡‡ BOHM, 'Kongl. Svensk. Vet. Akad. Handl.,' vol. XXXVII, 1903, No. 3, p. 33, t. III, figs. 22, 25, 30, 31.

Avicula ? sp.

One small but nearly perfect specimen (F. 214) of the left valve of an aviculoid shell occurs in the collection from Janu-la. The shell is high, suboblong in shape and slightly oblique, the axis of the body making a large angle with the hinge-line, and the posterior margin of the shell is nearly vertical below but excavated above. The ends of the hinge-line and extremities of both ears are hidden by matrix, but the anterior seems rather long, extending some distance down the anterior edge of the valve; the posterior ear is larger and flatter, being more sharply marked off from the body, and is apparently produced into an acute point behind. The body is narrow, elongated and triangular, and is moderately convex in the umbonal region, but is flattened below; the beak is acutely pointed, the sides diverging at about 30°, and it is situated at about one-third the length of the hinge-line; the body descends posteriorly rather steeply to the ear. A few concentric growth-ridges which are rather wide apart cross the body and ears. The height of the shell is about 11 mm.

The reference of this shell to the genus *Avicula* rather than to *Gervillia* or *Bakewellia* seems probable, and it appears to resemble *A. torelli* BOHM* of the Upper Trias of Bear Island, but its specific affinities are uncertain.

Neritaria ? sp.

The single representative of the gasteropods in the collection from Janu-la is a minute shell (fig. 27) which is partly buried in matrix, but appears to possess the characters of some species of the genus *Neritaria* KOKEN. The general shape, the large body-whorl and the two minute whorls of the low spire seem to resemble *N. candida* KITTL as figured by BOHM† from the Marmolata limestone. Our specimen is less than 1 mm. in height.

Orthoceras sp.

There is one fragmentary specimen (F. 9) of a species of *Orthoceras* in the collection from Janu-la which has both ends and most of one side irregularly broken off. The surface of the shell is weathered so that the ornamentation cannot be detected, and the siphuncle cannot be positively located. But near the upper end traces of the septa may be observed, and they are seen to be numerous, horizontal, and closely placed, eight or nine apparently occurring in a distance equal to the diameter. The section of the shell is circular or subcircular, and the rate of tapering very slow, being about 1 in 10 or 12. The length of the fragmentary specimen is about 45 mm. and its diameter at its upper end about 27 mm. None of the species of *Orthoceras* described by Diener from the Himalayan Muschelkalk seem to be identical, but at any rate our specimen is

* BOHM, 'Kongl. Svensk. Vet. Akad. Handl.,' vol. XXXVII, 1903, No. 3, p. 25, t. 3, figs. 13, 16, 17, 21, 26.

† BOHM, 'Palæontographica,' vol. XLII, 4, 5, 1895, p. 236, t. XV, figs. 11, 11a–p.

too poorly preserved and imperfect for any satisfactory comparison. It is not impossible that it should be referred to the genus *Atractites* rather than to *Orthoceras*.

CARBONIFEROUS.

A. The following fossils have been identified in the very dark gray bituminous limestone from Janu-la. Only four fragments of this rock occur in the collection and only two genera and species can be determined :—

Camarophoria cf. *mutabilis* TSCHERN. (12) (14).

Productus cf. *mammatus* KEYS. (11).

Brachiopod, gen. indet (15).

B. There are two other fossils from Janu-la which occur in a more horny and lighter coloured rock and are of rather doubtful age. Both are imperfect, but as far as their characters can be made out both have closer Carboniferous than Triassic affinities.

Camarophoria cf. *globosa* TSCHERN. (86).
Rhynchonella ? *peregrina*, sp. nov. (83) (? 7).

Camarophoria cf. *mutabilis* TSCHERNYSCHEW.

Shell transversely subelliptical. Pedicle-valve trilobed, rather strongly convex from back to front, with median sinus commencing at about one-third its length and rapidly expanding to front margin, the sides curving out and the lateral edges becoming elevated ; floor of sinus flattened and broad anteriorly occupying more than middle third of margin ; lateral lobes sharply elevated anteriorly, and more or less steeply descending to the lateral and posterior edges of the shell. Beak of pedicle-valve high, prominent, acute, erect. Surface of valve covered with strong subangular ribs, of which four lie in the sinus, the two median ones being the strongest, and six on each lateral lobe, those bounding the sinus being no stronger than those in it, but the others successively decreasing in strength; interpleural grooves subangular, as strong and wide as the ribs. Fine concentric thread-like lineation present over whole surface of shell. Dental plates and muscle-scar indistinct.

Dimensions { Length, *c.* 14 mm.
Width, *c.* 20 mm.
Width of sinus in edge, *c.* 14 mm. }

Remarks.—There is one (F. 12) nearly complete pedicle-valve and its impression (F. 14) from which the above description has been drawn up. There are also impressions of small portions of the ribbed surface of a similar shell in another piece of rock (F. 15) of the same lithological character. All the characters which are displayed incline us to compare this form with *Camarophoria mutabilis* TSCHERN.* and *C. crumena* MART., both of Upper Carboniferous or Permian age. But, unfortunately, we cannot see any of the internal characters.

Productus cf. *mammatus* KEYSERLING.

Pedicle-valve transversely extended, sub-fusiform, widest along hinge-line, with cardinal angles produced into acutely pointed ears subcylindrical and partly enrolled; surface strongly geniculated at half its length, arching down at right angles to disc; body gently convex on disc, weakly bilobed in front of it by shallow broad median furrow; a broad-rounded depression is present on each side separating the body from the ears from which the lobes of the body swell up rather suddenly; beak small, inconspicuous. Surface of shell ornamented with narrow somewhat undulating fine concentric lines and growth-striæ, having on disc a few (4–6) equidistant stronger thin sublamellar concentric rugæ with very delicate radial striæ in the spaces between them.

Dimensions { Estimated width of shell along hinge-line, *c.* 23 mm.
Length of shell, *c.* 10 mm.

Remarks.—There is only one pedicle-valve of this shell (F. 11) in the collection, and it has its left lateral portion missing. The shape of the shell, its bilobation and general characters are considerably like the species from the Carboniferous of the Petschora figured by TSCHERNYSCHEW† as *Productus mammatus* KEYS., which is rather an isolated species and no other is very closely allied to it. KEIDEL‡ has recorded and figured examples of this species from the Upper Carboniferous of the southern Tian Shan.

Brachiopod, genus indet.

Shell subcircular. Pedicle-valve strongly convex, with small low rounded incurved beak rising above hinge-line, having an apical foramen and a slightly concave small triangular false area below it. Surface of valve marked with rather coarse pits arranged in two series of intersecting curved lines, the radial ones being most conspicuous.

Dimensions:—Length, 10 mm.

Remarks.—There is only one specimen of this curious little shell (F. 15) in the collection, and it consists of a pedicle-valve exposing the beak and left side of the surface of the valve being broken off and the specimen lying at the angular junction of two fractured surfaces of the rock. The true generic reference of this shell is uncertain, though the ornamentation is rather like *Dictyonella* (cf. *D. uralica* TSCHERN.§), but the elevated and

* TSCHERNYSCHEW, 'Mém. Com. Géol. Russ.,' vol. XVI, No. 2, 1904, pp. 81, 491, t. XXII, fig. 18, t. XXIII, fig. 10, t. XLV, figs. 1–15, t. XLVI, fig. 14.

† TSCHERNYSCHEW, *op. cit.*, pp. 295, 631, t. XXXV, figs. 4–6.

‡ KEIDEL, 'Neues Jahrb. f. Miner. Geol.,' Beil. Bd. XXII, 1906, pp. 367, p. XII, fig. 5.

§ TSCHERNYSCHEW, 'Mém. Com. Géol. Russ.,' vol. IV, No. 3, 1893, pp. 76, 179, t. X, figs. 6, 7.

perforated beak and small false hinge-area are characters which are not found in that genus, and rather suggest *Martinia* or some terebratuloid.

B. *Camarophoria* cf. *globosa* TSCHERNYSCHEW.

There is one small specimen (F. 86) of a coarsely ribbed subglobose *Rhynchonella* or *Camarophoria*, of which the greater part of the pedicle-valve is preserved but only part of one side and of the anterior edge of the opposite valve. The pedicle-valve is shallow and flattened for three-fourths its length, the anterior fourth being convex; the sinus, which is flat and shallow, is only developed anteriorly and holds two coarse equal angular ribs. On each lateral lobe are three similar strong angular ribs with traces of a weaker curved fourth, one bounding the broadly lanceolate depressed area on each side of the beak. The beak has the apex broken off, but seems to have been prominent and has slightly concave umbonal edges and the plates of the sessile spondylium are visible. The brachial valve is strongly swollen and subglobose; three strong ribs form the scarcely elevated median fold, and there are 3–4 similar ones on each lateral lobe. The marginal union of the valves is broadly sinuated, arching up steeply in front, and the pedicle-valve has the floor of its sinus produced as a short rounded tongue. All the ribs are continuous from the beak to the margins, increasing gradually in strength and separated by deep angular grooves equal in width to them. The shape of the shell was apparently rounded-subtriangular, and its anterior margin was gently arched forward and not truncate, the maximum width being a little in front of the middle of the length. So far as measurements are possible its length was about 11 mm., its width about 12 mm. and its thickness about 11 mm.

Remarks.—Perhaps our shell may be best compared with such species of *Camarophoria* as *Cam. globosa* TSCHERN.* and *C. nucula* SCHELLW.†, and some varieties of *C. mutabilis* TSCHERN.‡, but the external appearance of some species of *Pugnax* is not dissimilar.

Rhynchonella (*Rhynchopora* ?) *peregrina* sp. nov.

(Plate 8, fig. 6.)

Shell subglobose, subcircular, unequally biconvex, without fold on sinus on the valves. Pedicle-valve less convex than brachial valve, somewhat flattened towards middle; beak, small, slightly elevated and incurved, with apical foramen and shoulders diverging at rather less than a right angle; surface of valve covered with 18–20 angular ribs of which the median 6 or 7 are rather smaller than the rest, the 4 or 5 on each side of this group being much larger and coarser, while the last 2 or 3 bounding the smooth

* TSCHERNYSCHEW, *op. cit.*, vol. XVI, 1920, pp. 84, 495, t. XLVI, figs. 2–3.

† SCHELLWIEN, 'Abh. k.k. Geol. Reichsanst.,' vol. XVI, Heft I, 1900, p. 100, t. XV, figs. 7, 8.

‡ TSCHERNYSCHEW, *op. cit.*, pp. 81, 491, t. XXII, fig. 18, t. XXIII, fig. 10, t. XLV, figs. 1–15, t. XLVI, fig. 14.

cardinal area on each side of the beak are faint, smaller and gently curved back; cardinal area on each side of the beak smooth, flattened, slightly excavated near the apex and sublanceolate in shape. Brachial valve with surface more convex than in opposite valve and having median group of seven smaller ribs (the median one of which is slightly smaller and sunken ?); on each side of this group are three subequal much stronger coarser ribs curving gently outwards with a fourth rather smaller lower one and a faint much narrower fifth one bounding a smooth cardinal area like that on the other valve but less defined and rather smaller. Fine concentric striæ over whole surface of both valves.

Dimensions (F. 83) { Length, *c.* 14·0 mm.
Width, *c.* 13·5 mm.
Thickness, 10·0 mm. }

Remarks.—There are two specimens (F. 83, F. 7) of this small shell of which one (F. 83) is nearly complete, and has the shell preserved, though much of the anterior half of both valves is hidden in matrix. The other is somewhat weathered and has the anterior portion broken off.

The absence of any fold or sinus, the median group of smaller ribs, the central rib of the brachial valve being apparently smaller and lying in a groove, the greater coarseness of the lateral ribs on each valve and the well-marked concentric striation over all are peculiar features. It may be suspected that this species should be placed in the genus *Rhynchopora* King, and it bears some resemblance to *Rh. nikitini* Tschern.* of the Russian Upper Carboniferous. But no pores are visible. The figured specimens from the Trogkofel beds attributed by Schellwien† to *Rh. wynnei* Waag. also seem to be much like our shells.

Devonian.

The single specimen which must be regarded as proving the presence of Upper Devonian rocks in the neighbourhood of Janu-la consists of a well-preserved example of a variety of *Uncinulus procuboides* Kayser and may be compared with the variety *lungtungpeensis*. It is completely weathered out from the matrix which consists of a tough compact horny grayish or pinkish limestone, not markedly different from that containing some of the Triassic fossils.

Uncinulus procuboides Kayser var.

Shell transversely subelliptical, subglobose, inflated. Pedicle-valve shallow, slightly convex from side to side, strongly arched from back to front, the anterior margin being produced into broad flattened subquadrate tongue bent up at right angles in front

* Tschernyschew, 'Verh. k. Miner. Gesell.,' vol. XX, 1885, p. 295, t. XVIII, figs. 34–36.

† Schellwien, 'Abh. k.k. Geol. Reichsanst.,' vol. XVI, Heft I, 1900, p. 94, t. XIV, figs. 11–13.

with a truncate nearly straight tip; sinus broad, flat, corresponding to tongue, very faintly marked, scarcely depressed (except near base of tongue) and holding six regular equal low rounded closely placed ribs; lateral lobes small, narrow, nearly horizontal anteriorly and bearing 7–8 similar ribs becoming successively smaller and fainter posteriorly, the innermost one bordering the sinus and forming its side and anterior lateral angle being the largest; a small undefined area on each side of the beak seems devoid of ribs. Beak obtuse, low (poorly preserved and eroded).

Brachial valve deep, very convex and inflated, highest at middle, strongly arched from side to side but more so from back to front; median fold very faint and indistinct, not differentiated at all from general surface except near anterior margin, where it is slightly raised and flattened, corresponding with sinus in opposite valve, and carrying seven similar equal ribs; lateral lobes steeply descending on each side and carrying 8–10 similar ribs, curving back gently and becoming successively smaller and weaker posteriorly, with a small oval area on each side of beak where they are obsolete (as on opposite valve). Beak small, incurved, low. Interior of valve with straight median septum, extending more than one-third the length of the valve; a narrow rounded vascular groove is present along each rib, and in the two median interpleural furrows on the fold, each vascular marking forking close to its tip. Union of valves nearly straight on each side, with the sutures forming a scarcely perceptible low broad sigmoidal curve extending to base of tongue, then arching up nearly at right angles (with a very slight convergence) on each side of the tongue, across the tip of which they unite in a very low flattened curve at right angles to the sides and at about half the height of the front end of the shell. Surface of shell crossed by fine concentric striæ, strongest near margins, with a few stronger concentric growth-ridges.

Dimensions:
- Length of shell, 20 mm.
- Width, 22 mm.
- Thickness, 19 mm.
- Width of sinus at base of tongue, 11 mm.

Remarks.—There is only one specimen of this shell, but it is complete and entirely free of matrix; the shell is preserved over much of the surface, but the beak of the pedicle-valve is imperfect. The general characters of this specimen at once suggest a reference to the Devonian species *Rhynchonella procuboides* KAYSER* and especially a comparison with the variety *lungtungpeensis* from China,† which has been recorded from the Devonian of the Shan States,‡ and from Tchao Koua by MANSUY.§ The

* KAYSER, 'Zeitschr. Deut. Geol. Gesell,' 1871, p. 513, t. IX, fig. 3; TSCHERNYSCHEW, 'Mém. Com. Géol. Russ.,' vol. III, No. 3, 1897, p. 94, pl. XI, figs. 11 a–d.

† KAYSER in RICHTHOFEN'S 'China,' vol. IV, p. 78, t. VIII, fig. 2.

‡ REED, 'Palæont. Ind., N.S.,' vol. 2, 1908, p. 90, pl. XIV, fig. 13.

§ MANSUY, 'Mém. Serv. Géol. Indochine,' vol. I, fasc. 2, p. 65, pl XI, figs. 10 a–d.

specimen from Po Pe attributed to *Rh. cuboides* Sow. by the same author* bears also a close resemblance, and *Rh. venustula* HALL (which is considered by HALL and CLARKE† to be inseparable from SOWERBY'S species) comprises examples with practically the same characters. The Chitral shell *Uncinulus* (*Uncinulina*) *koraghensis* var. *ponderosa* REED,‡ must also be regarded as closely allied. The whole question of the relation of *Rh. cuboides* to *Rh. procuboides* is discussed in the last-mentioned work, and judging from the position of the front suture line and tip of the tongue in the Janu-la specimen it is to the latter it must be referred. But it differs from the typical *procuboides* by the ribs being continuous over the whole surface and from the var. *lungtungpeensis* by their smaller number. We may also draw attention to its resemblance to the American species *Uncinulus nobilis* HALL§ of the Lower Helderberg Group.

The present specimen has been described in considerable detail, because it is the only possible Devonian specimen in the collection from Janu-la, and its association with the Triassic fossils from this locality, together with its somewhat similar lithological condition, was puzzling until it was learnt that all the specimens came from boulders in a stream.

It has indeed been suggested to me lately that this shell is not referable to the Devonian species *U. procuboides*, but should be regarded as a variety of the Permo-Carboniferous species *U. timorensis* BEYRICH‖ which occurs typically in the Island of Timor, but has also been recorded from the Himalaya¶ and various parts of China** and Indo-China.†† There is considerable variation in *U. timorensis*, and by some palæontologists *U. theobaldi* WAAG. of the Salt Range and *U. wangenheimi* PANDER are considered to be identical with it or merely varieties. But *U. timorensis* generally possesses many more ribs in the sinus and on the surface, though BROILI‡‡ figures some from Timor with only 5 in the sinus and 6-7 on each side. The ordinary forms of the species are, however, quite different from our specimen. MANSUY§§ has, however, figured a shell from Kham-keut, which he terms *U. timorensis* mut. *laosensis*, bearing a considerable resemblance to our shell in shape and in the diminished elevation and differentiation of the median fold, but it possesses many more ribs (10–11) in the sinus.

* *Ibid.*, vol. VIII, fasc. I, 1921, p. 22, pl. III, figs. 2a, b.

† HALL and CLARKE, 'Palæont. New York,' vol. VIII, Brach. II, pl. X, fig. 51.

‡ REED, 'Palæont. Ind. N.S.,' vol. VI, Mem. 2, 1922, p. 44, pl. VII, figs. 21, 22, pl. VIII, fig. 1.

§ HALL and CLARKE, *op. cit.*, p. LVIII, fig. 26.

‖ BEYRICH, 'Abh. k. Akad. Wiss. Berlin,' 1864, p. 72, t. I, fig. 10.

¶ DIENER, 'Himal. Foss.,' vol. I, pt. 3, 1896, p. 69, pl. X, figs. 7–10.

** LOCZY, 'Wiss. Ergeb. Reise Graf. Széchenyi,' vol. 3 (Budapest, 1898), p. 112, t. IV, fig. 12.

†† MANSUY, 'Mém. Serv. Géol. Indochine,' vol. II, fasc. 4, 1913, p. 85, pl. IX, figs. 9a–e

‡‡ BROILI, 'Perm. Brach. Timor' (Stuttgart, 1916), p. 59, t. CXXVI, figs. 6, 12, 14; t. CXXVII, figs. 1–3.

§§ MANSUY, *op. cit.*, p. 87, pl. IX, figs. 11a–d, 12a–h.

Explanation of Plate 8.

1. *Aulacothyris angusta, var. yunnanensis*, nov. Triassic. Janu-la.
   Fig. 1A. View of specimen F. 85, facing the brachial valve. × 2.
   Fig. 1B. Lateral view of same specimen. × 2.
   Fig. 1C. Anterior view of same. × 2.

2. *Dielasma olivæforme*, sp. nov. Triassic. Janu-la.
   Fig. 2A. View of specimen F. 51, facing the pedicle valve. × 2.
   Fig. 2B. Lateral view of same specimen. × 2.
   Fig. 2C. Anterior view of same. × 2. (The line of junction of the two valves is slightly contorted at the left-hand side.)

3. *Terebratula* (*Cœnothyris*) *janulensis*, sp. nov. Triassic. Janu-la.
   Fig. 3A. View of specimen F. 84, facing the brachial valve. × 2.
   Fig. 3B. Lateral view of same specimen. × 2.
   Fig. 3C. Anterior view of same. × 2.

4. *Rhynchonella* (*Halorella ?*) *delydens*, sp. nov. Triassic. Janu-la.
   Fig. 4A. View of specimen F. 74, facing the brachial valve. × 2.
   Fig. 4B. Lateral view of same specimen. × 2. Showing the broken beak of the pedicle valve.

5. *Monotis janulensis*, sp. nov. Triassic. Janu-la.
   Fig. 5A. Specimen F. 69, a right valve. Actual size.
   Fig. 5B. The same specimen. × 4.

6. *Rhynchonella* (*Rhynchopora* ?) *peregrina*, sp. nov. Carboniferous. Janu-la.
   Fig. 6A. View of specimen F. 83, facing the brachial valve. × 2.
   Fig. 6B. Lateral view of same specimen. × 2.

APPENDIX II.—ORDOVICIAN GRAPTOLITES FROM NORTH-WESTERN YUNNAN.

By Gertrude L. Elles, M.B.E., D.Sc., *Newnham College, Cambridge.*

Some graptolites were collected on the northern bank of the A-shih-chai River beside the track from Yung-chang to Ho-wan, below the village of Lao-wu (*cf.* p. 180). The locality Y. 95b is 100 ft. higher up the hillside than that of the rest of the specimens. The specimens show no great variety but the horizon indicated is definite. It is the zone of *Climacograptus peltifer* at the junction of the Glenkiln and Hartfell Slates. All the forms found are common at that horizon.

Loc. Y. 95.

Nos. 1–3. *Climacograptus scharenbergi* LAPW.
4. *Cl. scharenbergi and Diplograptus* (*Amplexograptus ?*).
5. Reverse of 4.
6. Obscure, but strongly suggestive of *Amplexog. perexcavatus* (LAPW.).
7 & 9. *Cl.* sp., prob. *scharenbergi.*
8. *Cryptograptus tricornis* (CARR.).
10. *Climacograptus bicornis* (HALL).

Loc. Y. 95b.

Climacograptus sp. indet.

APPENDIX III.—SOME DEVONIAN AND TRIASSIC CORALS.

By J. W. GREGORY, D.Sc., F.R.S.

Among the fossils collected were some corals, of which the Devonian Stromatoporoids and Triassic Thecosmilians and Stromatomorphoids are of most geological interest.

I. DEVONIAN STROMATOPOROIDS.

1. *Stromatopora vesiculosa* n. sp. (Plate 9, figs. 1–5).

This coral forms a reef in the Lan-shueh-ko Valley, a tributary to the Yangtze Kiang below its great bend at Shih-ku. The reef contains also a few simple corals of which no determinable specimens were collected.

Diagnosis.—Cœnosteum massive in nodules which are usually flat, hemispherical or elliptical, varying with the position in the reef. The concentric structure of the latilaminæ is conspicuous. The latilaminæ are regular, but may be undulating or interrupted by occasional funnel-shaped depressions.

No basal epitheca; cœnosteum attached by a concentrically wrinkled base. Upper surface usually even or gently wavy. Astrorhizæ inconspicuous or imperfectly developed.

Latilaminæ in regular convex sheets; they are usually 3 mm. thick, but they vary from 1·5 to 4 mm. thick. Upper surface is slightly undulating. Lenticular vesicular interspaces are frequent in the latilaminæ along the concentric laminæ, or between the latilaminæ. In vertical sections these vesicles are short and biconvex or concavo-convex, or are thin wavy bands. The vesicles are bounded by curved dissepiment-like membranes, and when crowded give a vesicular aspect to the cœnosteum. The simple vesicles are from 1 to 3 mm. long and about 0·3 mm. in height. Zooidal tubes (about 0·06 mm. in dia.) are well developed; they are crossed by well developed tabulæ and separated by distinct vertical pillars. The cœnosteum ranges in the largest specimens collected up to 70 mm. in dia. by 4 mm. thick, but some fragments are from much larger specimens.

Distribution. Middle Devonian. Sandy limestones. Lan-shueh-ko, between Li-kiang-fu and Shih-ku. Yunnan.

Affinities.—This coral by its regular latilaminæ, of which the uppermost are undulatory, and sub-hemispherical form, so closely resembles *S. concentrica* GOLDF.* that it suggested in the field the Middle Devonian age of the limestone. The fossil agrees with that species, moreover, in the thickness of the latilaminæ. It is, however, specifically distinct, for the zooidal tubes are much less regular in *S. concentrica*, which has better developed astrorhizæ and lacks the abundant vesicles. The nearest ally of the Yunnan coral is *S. beuthi* BARGATZKY,† which agrees with it in the well developed zooidal tubes and radial pillars and the sparseness of the astrorhizæ; but *S. beuthi* has imperfectly developed latilaminæ and no vesicular interspaces.

The affinities of the Yunnan coral to *S. concentrica* and *S. beuthi* indicate its Middle Devonian age.

Among the Stromatoporoids already known from the Far East are *Stromatopora radiata* MANSUY‡ from the Middle Devonian of Annam, which has less well developed latilaminæ and is built up of small radial groups; and *S. moluccana* VIN. DE R.§ from the Trias of Timor, which differs by the absence in that species of zooidal tubes and the irregularity of the latilaminæ.

The Stromatoporoids described by Dr. F. R. C. REED,|| from the Northern Shan States, belong to the genera *Stromatoporella* and *Actinostroma* and are markedly different from this species. So also are the Bohemian species described by POCTA.¶ Signor VINASSA DE REGNY has described** a new variety of *S. concentrica* and some new *Stromatoporæ*

* GOLDFUSS (1826), 'Petref. Germ.,' p. 22, pl. VIII, f. 5, NICHOLSON (1890), 'Mon. Brit. Stromatoporoids,' p. 164, *cf.* pl. XI, f. 18, for the less regular zooidal tubes. The species has been recorded from the province of Kansu, by FRECH, in 'Wiss. Ergeb. Grafen B. Szechenyi,' vol. III, 1899, p. 233.

† BARGATSKY (1881), 'Strom. rhein. Devon.,' p. 56; NICHOLSON (1890), *op. cit.*, p. 183, pl. V, f. 12–3, pl. XXIII, f. 8–13, pl. XXIV, f. 1.

‡ MANSUY (1920), 'Nouv. Contrib. Faunes Paléoz. et Més. Annam Sept., Mém. Serv. Géol. Indochine,' VII, fasc. I, p. 20, pl. III, f. 4.

§ VINASSA de REGNY (1915), 'Pal. Timor,' vol. VIII, p. 110, pl. LXIII, f. 7–10.

|| F. R. C. REED (1908), 'Dev. Faunas N. Shan States, Pal. Ind.,' n.s., II, No. 5, pp. 33–37.

¶ P. POCTA (1894), 'Syst. Sil. Boh.,' vol. VIII, pt. I, pp. 158–161, pl. 18 bis and 19, and 19 bis.

** VINASSA DE REGNY (1918), 'Cor. mesodevonici Carnia, Pal. Ital.,' vol. XXIV, pp. 113–117, pl. XI, XII.

from the Middle Devonian of the Carnic Alps, but his new species have less regular latilaminæ than *S. vesiculosa.* The abundance of the vesicles is the most distinctive feature of the *S. vesiculosa.* The vesicles are more frequent in Stromatoporella than in Stromatopora. For example they are shown in a figure by VINASSA DE REGNY of *S. curiosa*, BARG., var. *carnica* GORTANI,* and also in a specimen of that species in the Nicholson collection in the British Museum (No. P. 6051); also in *Stromatoporella laminata* in the same collection (No. P. 5055) from the Middle Devonian of Buchel. The fossil from Yunnan is, however, clearly not a *Stromatoporella,* as the latilaminæ and zooidal tubes are both too well developed and the astrorhizæ too scanty.

The vesicles occur more often in the Stromatoporidæ in H. ALLEYNE NICHOLSON'S collection, now in the Natural History Museum, than would appear from his figures and descriptions. Special interest attaches to these vesicles as HEINRICH† has suggested the exclusion of the Labechidæ, in which they are very abundant, from the Stromatoporoida. He lays stress on the difference between the structure of the Labechidæ with its "complex of circular, closed, flat vesicles" from the "network of meshes" of the Stromatoporidæ.

The presence of these vesicles in this species and in *Stromatoporella* may be regarded as some connecting link between the Labechidæ and Stromatoporidæ, although those structures have arisen independently in different groups of calcareous organisms.

2. *Idiostroma* A. WINCHELL, 1867.

Stromatoporidæ, structure and affinities. 'Proc. Amer. Ass. Sci.,' 1867, p. 99.

Idiostroma forresti, n. sp. (Plate 9, fig. 6.)

Diagnosis.—Cœnosteum fasciculate; of long thin blunt-ended cylindrical stems which branch at distant intervals; the stems do not anastomose. The young stems consist of irregularly reticular tissue; the more mature parts of the stems consist of dome-shaped concentric layers. About 15 radial pillars occur in section across a well-developed part of a stem. Axial tube narrow, and discontinuous, being not seen in many cross-sections; when present it is usually about one-ninth of the diameter of the stem; there are no conspicuous branches from the axial tube through the cœnosteum. The zooidal canals are small and often straight.

Dimensions.—Stems about 3 mm. diameter. Axial tube about one-ninth diameter of stem in a 3 mm. section.

Distribution.—In a black limestone, Middle Devonian; found in a moraine in Glacier Valley, alt. 11,000 feet, Yu-lung Shan, N.W. of Li-kiang-fu, Yunnan.

Affinities.—This species resembles *I. roemeri* MICH. by the regularity of the concentric layers as seen in cross section (*cf.* NICHOLSON, *op. cit.* pl. IX, figs. 7 and 8), but in the

* *Ibid.*, 1918, pl. XII, f. 11.

† 'Centralb. Min.' (1914), p. 734, and 'Journ. Geol.,' XXIV, 1916, p. 58.

new species the axial tube does not attain the proportional thickness shown in NICHOLSON'S figure (*op. cit.*, pl. IX, fig. 8), which is about one-quarter the diameter of the stem. The zooidal tubes, though numerous, are less conspicuous than in *I. roemeri*, in which the cœnosteum has thicker branches and tends to become submassive.

In the size of the branches and small size of the axial tube this new species is nearer to *I. oculatum* MICH., which has, however, an anastomosing cœnosteum and large radial tabulate branches from the axial tube; they cause the ocellar aspect from which the species takes its name. NICHOLSON remarks that these tubes may be *Caunoporæ*, so that they may be commensal and not an essential part of the *Idiostroma*.

The specific name is given in honour of Mr. G. FORREST, whose long labour in Yunnan has so greatly enriched Western gardens; the specimen was collected in an excursion from his house at Ngu-lu-ke. Specimens of *Idiostroma* (Y. 226) with thinner stems are common in a light gray dolomite which occurs below the flaggy limestone to the S. of the mouth of the Glacier Valley on Yu-lung Shan. One specimen (Y. 226) contains also a small piece of a *Favosites*. The coral is associated with crinoid stems, fragments of shells and of a Chætetoid fossil. In most of the specimens the dolomitisation has destroyed the structure, but some sections show that the species agrees with *I. forresti* in the straightness and size of the zooidal tubes, and it must be a close ally if not specifically the same; the only apparent difference is the smaller diameter of the stems.

II. TRIASSIC THECOSMILIANS AND STROMATOMORPHOIDS.

A. *From Li-kiang.*

Thecosmilia aff. fenestrata (VON REUSS), 1854 (Plate 9, fig. 7; Plate 10, fig. 1).

Calamophyllia fenestrata VON REUSS, 1854. 'Char. Gosauthale, Denk. Akad. Wiss. Wien,' VII, p. 105, pl. V, figs. 21-21.

Theocosmilia fenestrata FRECH, 1890. 'Kor. Trias, Palæontogr.,' XXXVII, p. 9, pl. I, figs. 25-27, pl. II, figs. 1-17. (VON REUSS'S type is refigured on pl. II, fig. 12.)

The creamy white limestone at the south-eastern foot of the Black Dragon Temple Range, to the N.E. of Li-kiang-fu, contains large masses of reef coral, 3 feet thick and 6 feet in diameter. The corals are so altered that their determination is doubtful, but their evidence is of value as they are the only fossils sufficiently definite to indicate the age of this limestone.

The coral is cæspitose with the branches usually cylindrical or elliptical, but sometimes flattened on four sides. There is no columella. The septa are sometimes thicker near the centre, and the symmetry appears hexameral.

The coral agrees most closely in habit and in the size and distance of the branches with *Thecosmilia fenestrata* (REUSS) from the Zlambach beds of the higher part of the Upper Trias of Gosau in the Eastern Alps. It agrees in its known characters and dimensions with that species, except that the horizontal exothecal structures shown in VON REUSS'S figure (*op. cit.*, pl. V, fig. 20) are less constant, though distinct in some specimens. They are also less apparent than in the type in the specimens from Timor on which VINASSA DE REGNY has founded a new variety.* The stems vary in diameter from 4-6 mm., but are occasionally 8 mm.; they are sometimes elliptical, the diameters being 5 and 6 mm. As a rule the septa have been destroyed, but a radial structure may be recognisable in the material filling the corallites. The septa are long and irregular and some of them thickened at the inner end.

A creamy coloured limestone from the glacier valley of Li-kiang peak contains some cylindrical branching stems of similar size and form; but no internal structure is recognisable. They may be altered specimens of the same coral.

This species agrees with *T. wanneri* VIN. DE R.†, from the Trias of Timor, in its general growth, and by the frequent absence of the exothecal rings, but that species has much thicker stems.

Prof. DIENER‡ has referred to a coral from the Upper Trias of the Central Himalaya as a *Lithodendron*; and as in that genus the growth is similar to *Thecosmilia* DIENER'S coral may be the same. He kindly tells me that the internal structure has not been preserved and that the genus is probably *Thecosmilia*.

As this coral affords the only paleontological evidence of the age of the Li-kiang limestone I have compared it with species from various Paleozoic horizons. Among Devonian species it resembles in habit *Fasciphyllum conglomeratum* (SCHLUTER§) from the Middle Devonian of the Eifel; but the diameter of the corallites in the Eifel species is from 2–3 mm. with a maximum of 4 mm., so that it is nearer the *oppeli* form. It has more conspicuous costæ and the more crowded corallites which are often attached by thin walls become prismatic; the septa are also less crowded and thinner. The allied *F. varium* SCHLUTER‖ is more similar in size but less regular in diameter, the corallites are more tapering, the septa more numerous, and the walls thinner. There is no indication in the Li-kiang coral of the tabulæ of *Fasciphyllum*.

3. *Thecosmilia* cf. *oppeli* (REUSS) 1864. (Plate 10, fig. 2.)

Calamophyllia oppeli VON REUSS 1864. 'Anth Koss., Sitz.-ber. Akad. Wiss. Wien,' L, p. 160, pl. IV, f. 1.

Thecosmilia oppeli FRECH 1890. *Op. cit.*, p. 10, pl. II, f. 18–23, pl. III, f. 4.

Thecosmilia oppeli VINASSA DE REGNY 1915. 'Pal. Timor,' VIII, p. 89, pl. LXIX, f. 7, 8.

* VINASSA DE REGNY (1915), 'Pal. Timor,' vol. VIII, p. 88, pl. LXX, f. 3.

† VINASSA DE REGNY, 'Pal. Timor,' vol. VIII, p. 87, pl. LXIX, f. 1–5.

‡ C. DIENER (1895), 'Denk. Akad. Wiss. Wien,' vol. LXII, p. 583; (1912) 'Mem. Geol. Surv. India,' vol. XXXVI, pp. 101, 102.

§ SCHLUTER (1889), 'Anth. Rhein. Mittel-Devon., Abh. Geol. Specialk. Preuss.,' vol. VIII, p. 48, pl. III, f. 7–9.

‖ SCHLUTER (1881), 'Zeit. Deut. Geol. Ges.,' vol. XXXIII, p. 99, pl. XIII, f. 1–4.

At the Black Dragon Temple the limestone contains specimens of a coral which is similar to *T. fenestrata,* except for its smaller diameter. None of the sections show the septal structure ; but the aspect is that of a *Thecosmilia.*

T. fenestrata is similarly associated in the Gosau district with narrower corallites which are only from 3–5 mm. in diameter. This coral has been described by VON REUSS as *T. oppeli* (REUSS) ; its diameter is from 3–5 mm. in contrast with the 5–10 mm. of *T. fenestrata.*

FRECH* remarked that the two species are closely related and are probably united by transitional forms. There is accordingly doubt as to their specific distinction. The difference in size between the two forms at Li-kiang is well marked. These smaller specimens probably represent the *T. oppeli* type which closely resembles the *T. weberi* VIN. DE R. from Timor.†

B. From Janu-la.

Some blocks of limestone in the river gorge at Janu-la contain corals in such excellent preservation that a collection from the outcrop of the rock would doubtless yield many determinable and interesting corals. So soon as we had recognised the Triassic age of the fauna we used the rest of our available time for work in other directions.

The blocks collected include three distinct corals.

1. *Thecosmilia* cf. *fenestrata* (REUSS) 1854, *op. cit.*

A cæspitose astrean coral, with simple septa and thick wall, and no columella appears to be a Thecosmilia. The diameter of the corallites is 6 mm. ; it may also be *T. fenestrata* (REUSS) ; its recognisable features are similar to those of the coral found in the Black Dragon Temple range near Li-kiang-fu.

2. *Stylophyllum* cf. *paradoxum* FRECH 1890. (Plate 9, fig. 8.)

A second cylindrical stem which is 2–5 mm. in diameter has a thick wall, short septa, and a number of irregular trabeculæ in the interior. It is a *Stylophyllum* REUSS em. FRECH. The species of this genus are very variable, and as there is only one specimen from Janu-la its specific determination is doubtful ; it resembles structurally the figure of *S. paradoxum* FRECH‡ (FRECH, *op. cit.*, pl. XIV, fig. 6) ; it differs from *S. pygmæa* FRECH as that species has fewer and less conspicuous trabeculæ. Its size, however, agrees with *S. pygmæa.*§ Both these species and VON REUSS's type of the genus are from the Zlambach beds in the Upper Trias.

(Pl. 9, fig. 8. The end of a branch, × 6 dia. (Y. 498).)

* FRECH (1890), *op. cit.*, p. 11.

† VINASSA DE REGNY (1915), 'Pal. Timor,' vol. VIII, p. 89, pl. LXIX, f. 6, 9–12.

‡ FRECH (1890), *op. cit.*, p. 54, pl. XIV, f. 1–24, pl. XV, f. 12.

§ FRECH, *ibid.*, p. 56.

3. *Stromatomorpha aff. stylifera* FRECH 1890, *op. cit.*, p. 79. (Plate 10, figs. 4 and 5.)

FRECH has described from the Upper Trias of the Eastern Alps a series of trabeculate corals which he referred to four genera. A coral belonging to the same group is common at Janu-la. Microscopic examination shows that it is has no vesicular dissepiments, and is therefore neither *Spongiomorpha,* the genus to which it was provisionally assigned in the field, nor *Heptastylopsis ;* its trabeculæ are not collected into radial groups, which excludes it from *Heptastylis.* It agrees with *Stromatomorpha.* There is an occasional grouping of trabeculæ into clusters of seven ; but this feature is so slight and occasional that it may be accidental, owing to one trabecula being larger than usual and slightly disturbing the arrangement of those around it.

According to HAAS* the distinction between *Spongiomorpha* and *Heptastylopsis* is invalid, and so also may be the analogous difference between *Stromatomorpha* and *Heptastylis.*

The structure of the coral is shown on Pl. 10, figs. 4 and 5. Fig. 4 illustrates the part of a vertical section (Y. 498) × 8 dia. Fig. 5 a part of another specimen (Y. 492) showing the arrangement in cross section, × 4 dia.

A tiny fragment of what appears to be the same coral was found in a boulder of limestone on the eastern slopes of the Yu-lung Shan (Li-kiang peak) near Ngu-lu-ke. Some boulders from the same locality from their lithological character and fossil fragments also indicate that the upper part of the Yu-lung Shan includes some Triassic limestones.

DESCRIPTION OF PLATES 9 AND 10.

PLATE 9.

FIG. 1. *Stromatopora vesiculosa,* n.sp. Middle Devonian. Lan-shueh-ko. The base of a small cœnosteum, nat. size. (F. 116.)

FIG. 2. Do., the base of a young cœnosteum (No. F. 267) from the same locality, × $3\frac{1}{2}$ dia.

FIG. 3. Vertical section through a small cœnosteum (F. 301) from the same locality, × $3\frac{1}{2}$ dia.

FIG. 4. Part of a vertical specimen through another specimen (F. 264) from the same locality, × 16 dia., showing the vesicles and the zooidal tubes.

FIG. 5. Part of a vertical section through two latilaminæ, from another specimen (F. 118) from the same locality, × 3 dia.

FIG. 6A. *Idiostroma forresti,* n.sp. Middle Devonian. From the glacier valley of Yu-lung Shan ; near Li-kiang (No. Y. 206), × 4 dia.

FIG. 6B. Do., part of the same slide showing a longitudinal section, × 16 dia.

FIG. 7. *Thecosmilia* aff. *fenestrata* (REUSS). Triassic limestone. Black Dragon Temple range, Li-kiang-fu. Some corallites from the side, nat. size. (Y. 204.)

* O. HAAS (1909), 'Neue Aufs. Zlambachmergeln, Beitr. Pal. Geol. Oest. Ung.,' vol. XXII, p. 155.

FIG. 8. *Stylophyllum* cf. *paradoxum* FRECH. Triassic limestone. Janu-la. End of a branch, × 6 dia.

PLATE 10.

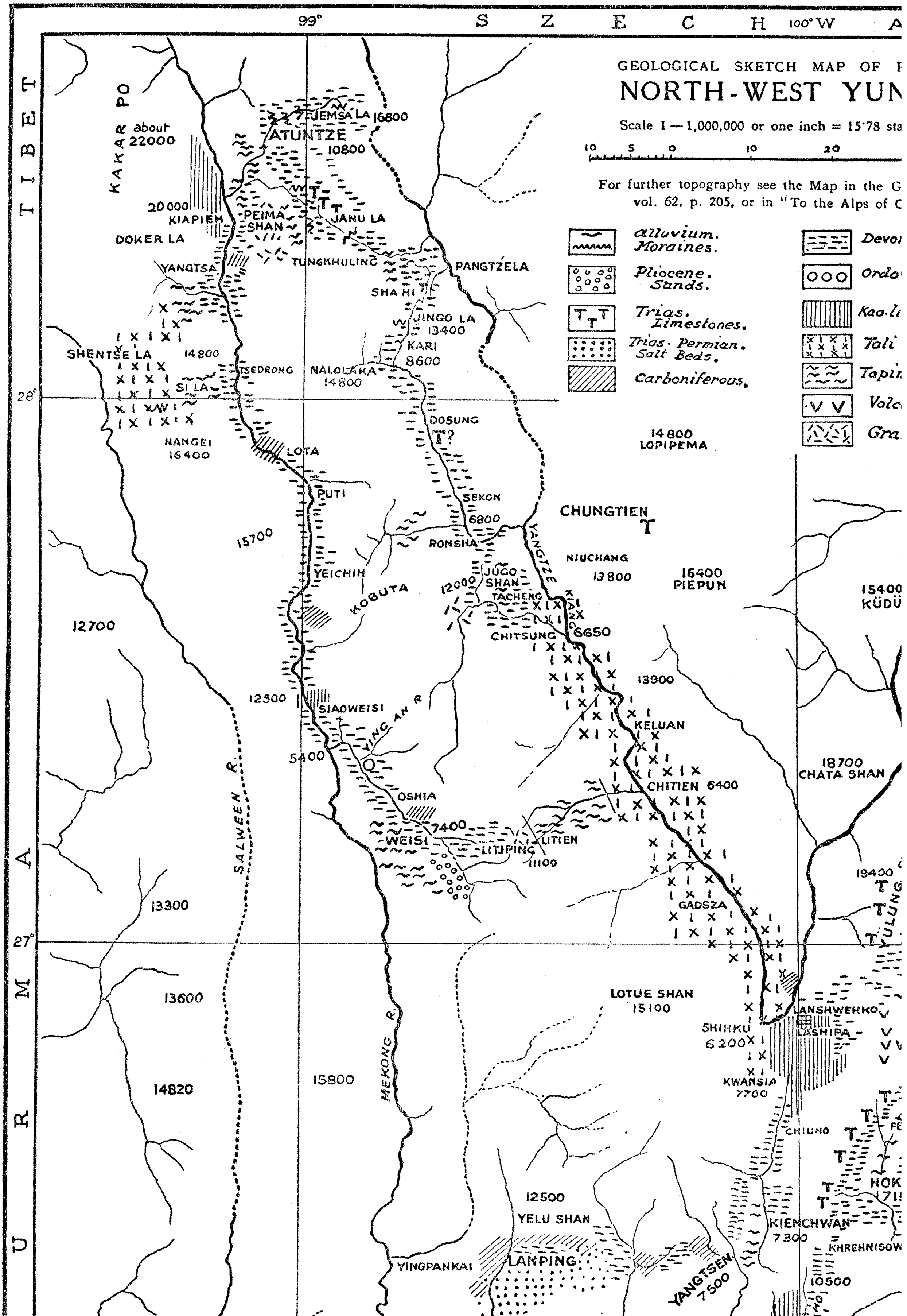
FIG. 1. *Thecosmilia* aff. *fenestrata* (REUSS). Corallites seen in horizontal sections, nat. size. (Y. 204h.) Trias. Black Dragon Temple Range, Li-kiang.

FIG. 2. *Thecosmilia* aff. *oppeli* (REUSS) from the same horizon and locality. Some corallites in cross section, nat. size. (Y. 204.)

FIG. 3. Do., part of another specimen showing the corallites from the side, nat. size. (Y. 204).

FIG. 4. *Stromatomorpha* aff. *stylifera* FRECH. Triassic limestone. Janu-la. Part of a vertical section, × 8 dia. (Y. 498.)

FIG. 5. Do. Part of another specimen showing in part a cross section and in part a nearly vertical section, × 4 dia. (Y. 492.)


GEOLOGICAL SKETCH MAP OF
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For further topography see the Map in the G
vol. 62, p. 205, or in "To the Alps of C
Alluvium. Moraines.
Pliocene. Sands.
Trias. Limestones.
Trias-Permian. Salt Beds.
Carboniferous.
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KIANG
CHUNGTIEN
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16400 PIEPUN
14800 LOPIPEMA
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KELUAN
CHITIEN 6400
GADSZA
LOTUE SHAN 15100
SHIHKU 6200
KWANSIA 7700
LANSHWEHKO
LASHIPA
CHIUNO
12500
YELU SHAN
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LANPING
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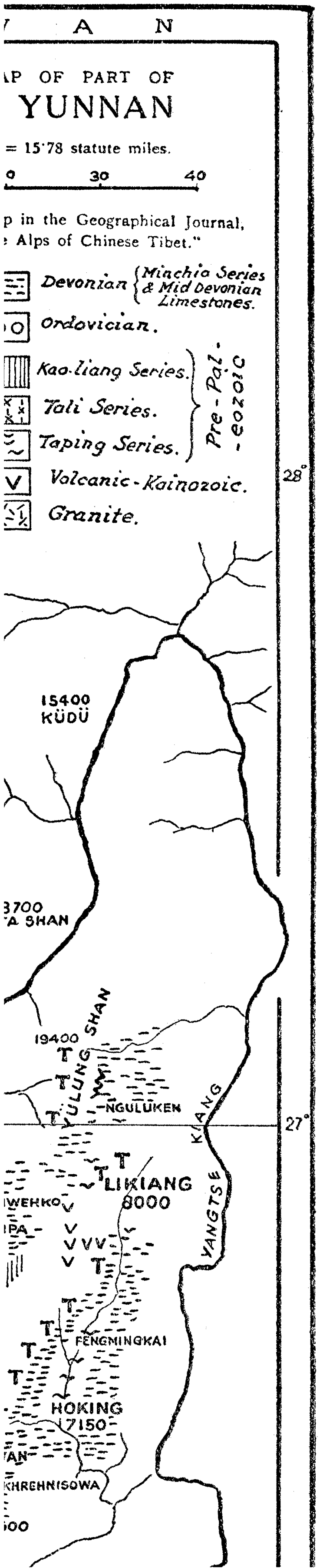
19400
YULUNG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Kao-liang Series.
Tali Series.
Taping Series.
Pre-Pal-eozoic
Volcanic-Kainozoic.
Granite.
28°
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KÜDÜ
3700
A SHAN
19400
YULUNG SHAN
NGULUKEN
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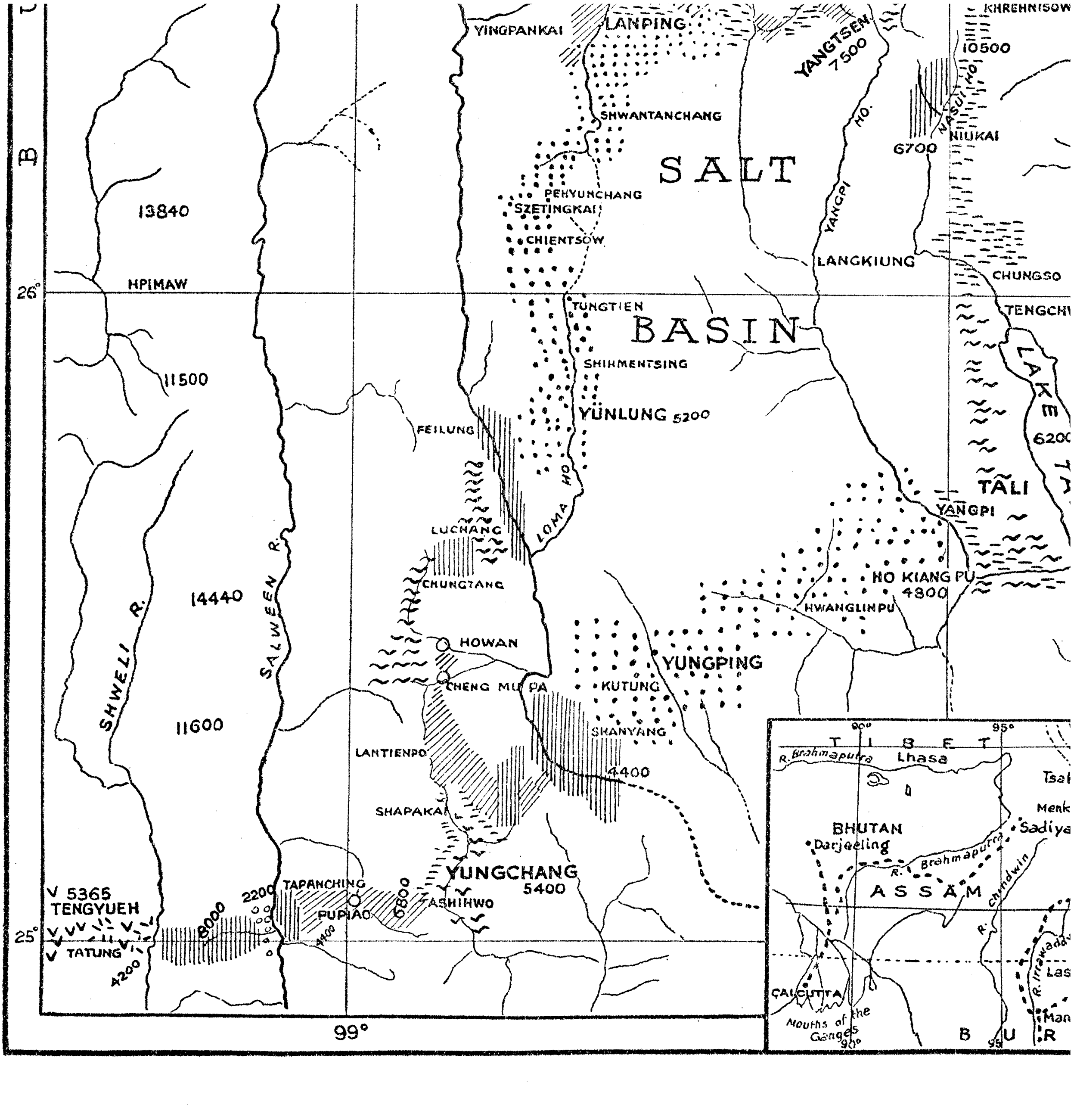

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PEHYUNCHANG
SZETINGKAI
CHIENTSOW
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YANGPI
LANGKIUNG
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HPIMAW
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TIBET
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Lhasa
BHUTAN
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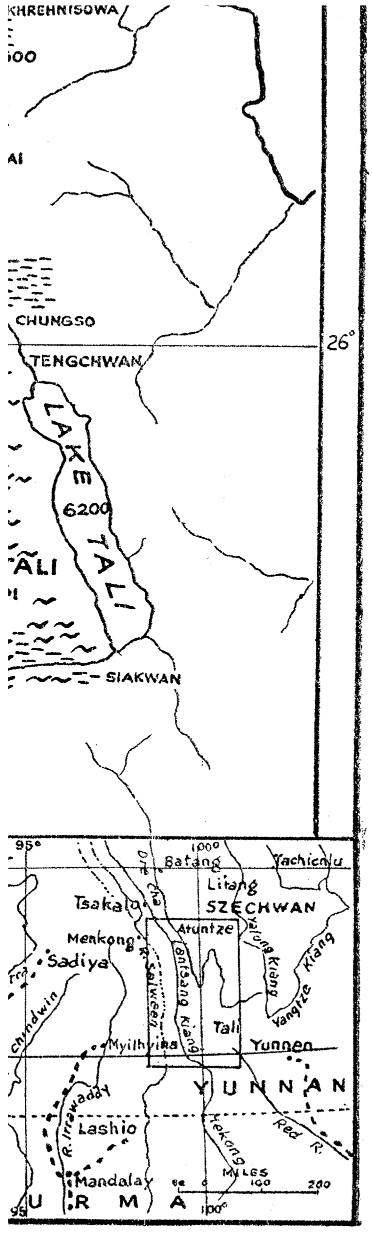

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Sadiya
R. Salween
Lantsang Kiang
Yalong Kiang
Yangtze Kiang
Chindwin
Tali
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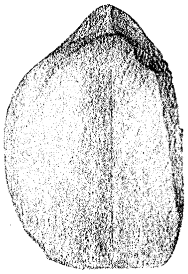
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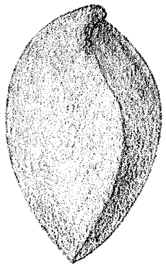
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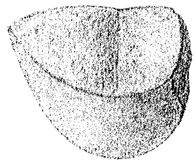
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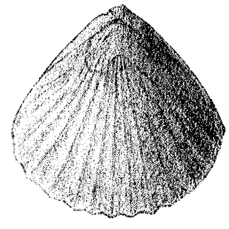
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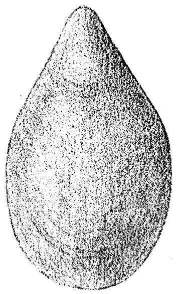
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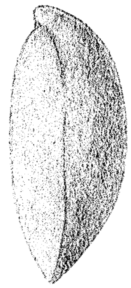
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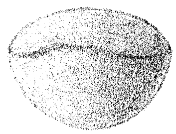
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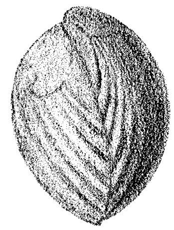
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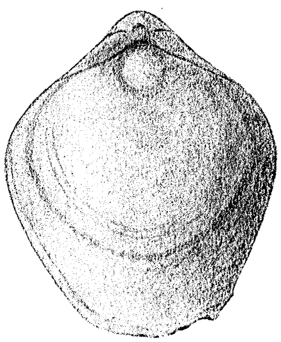
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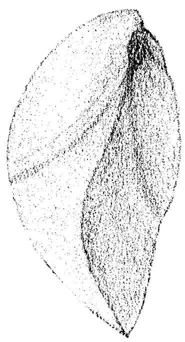
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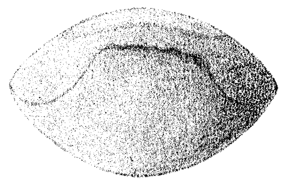
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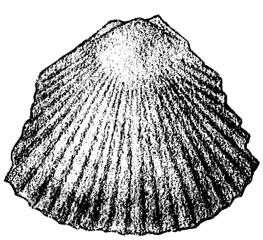
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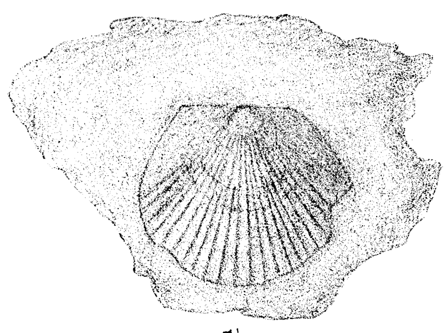
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Ethel D. Currie.

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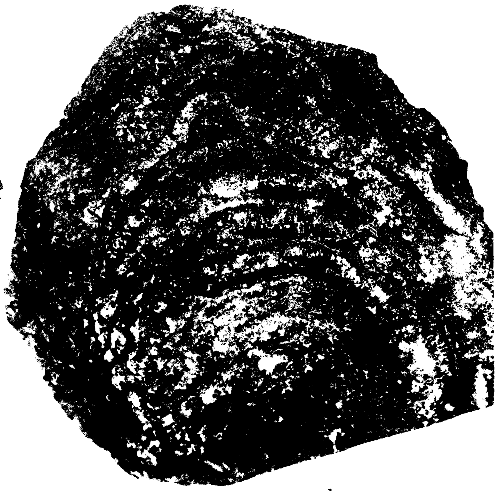

Fig. 2, × $3\frac{1}{2}$

Fig. 3, × $3\frac{1}{2}$

Fig. 4, × 16

Fig. 5, × 3

Fig. 6a, × 4

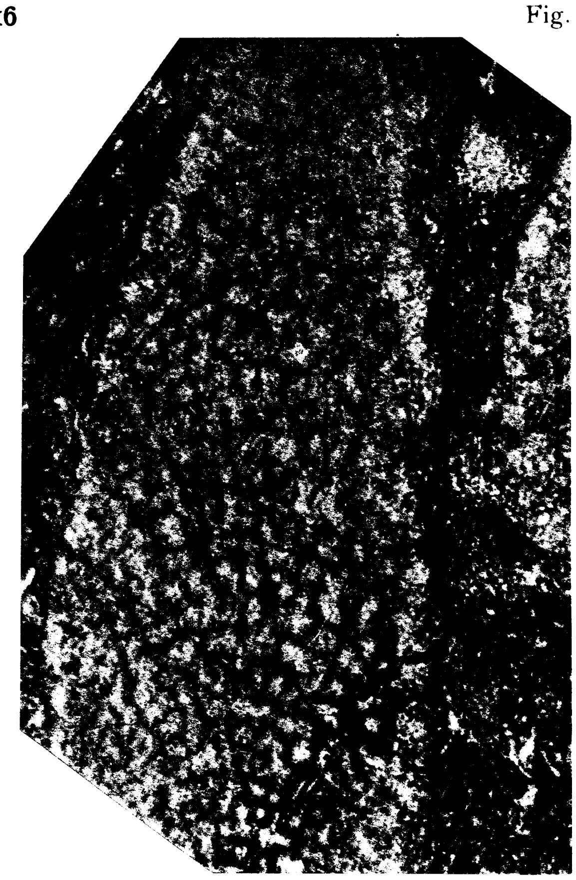

Fig. 6b, × 16

Fig. 7, n.s

Fig. 8, × 6

Photo. D. M. Filshill.

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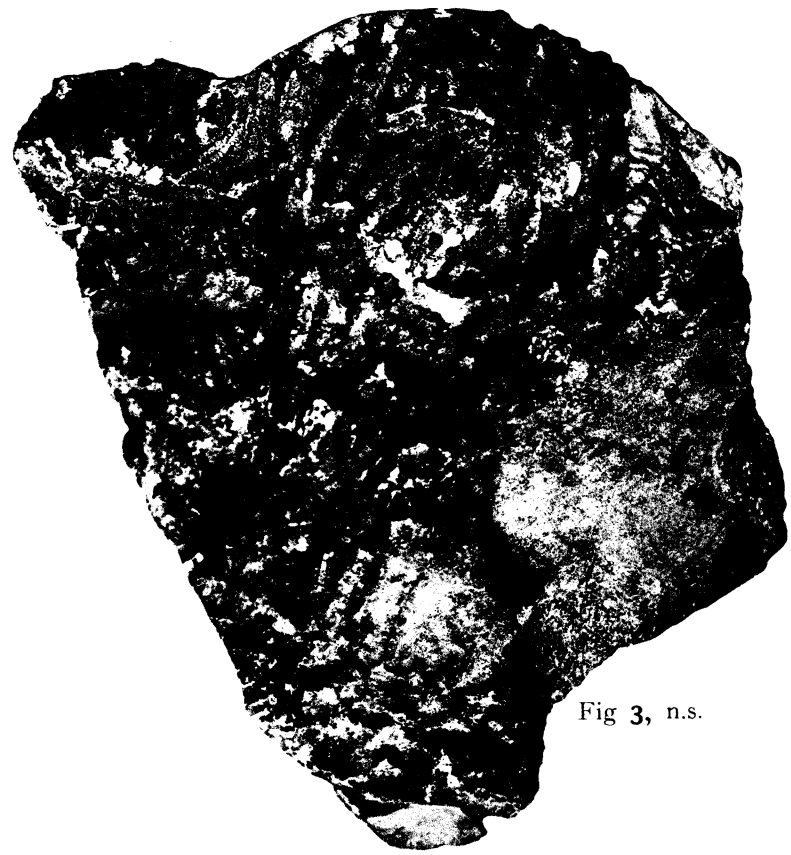
Fig. **1**, n.s.

Fig. **2**, n.s.



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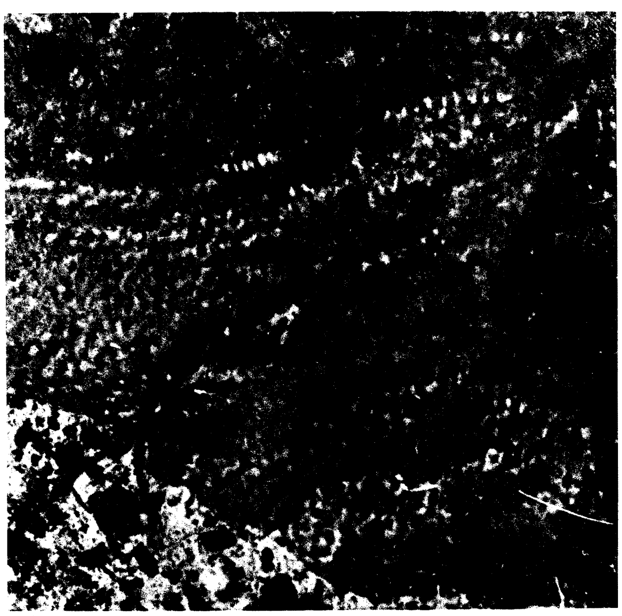


Fig. **5**, × **4**

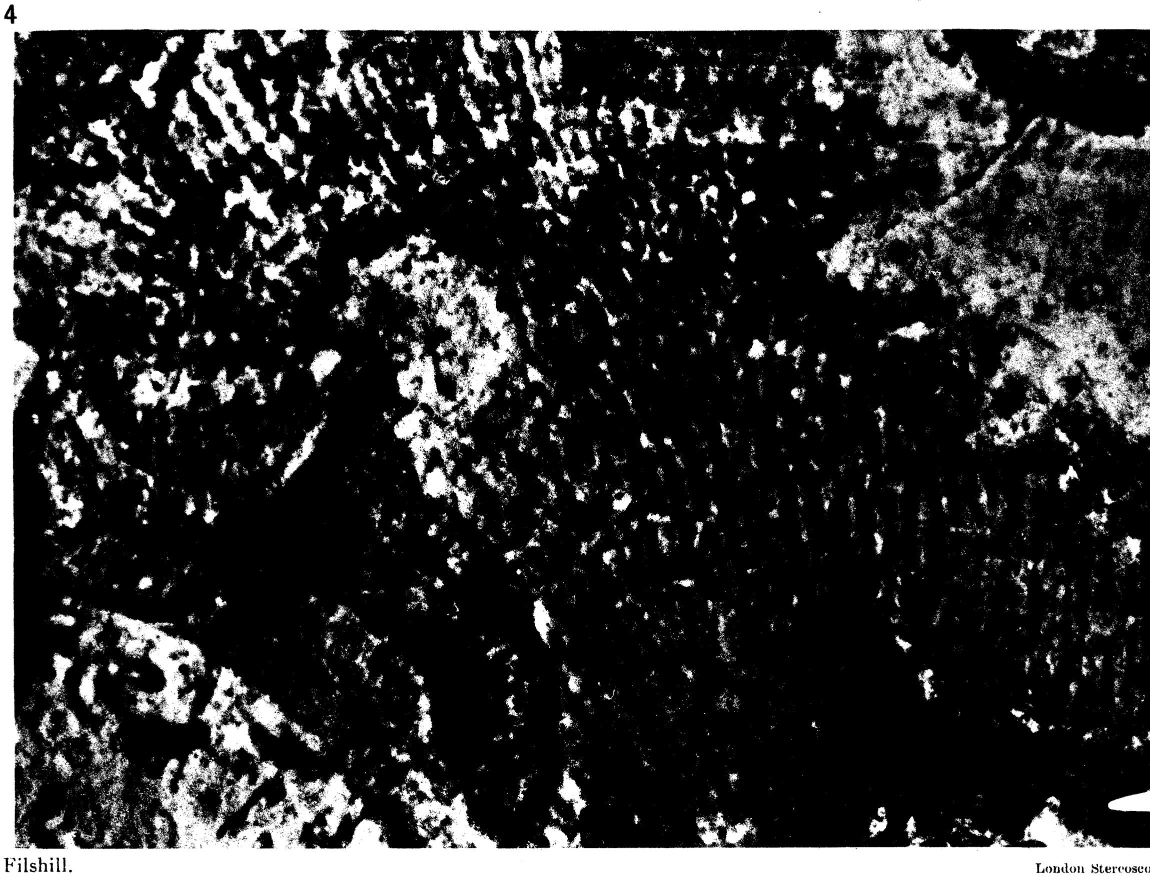
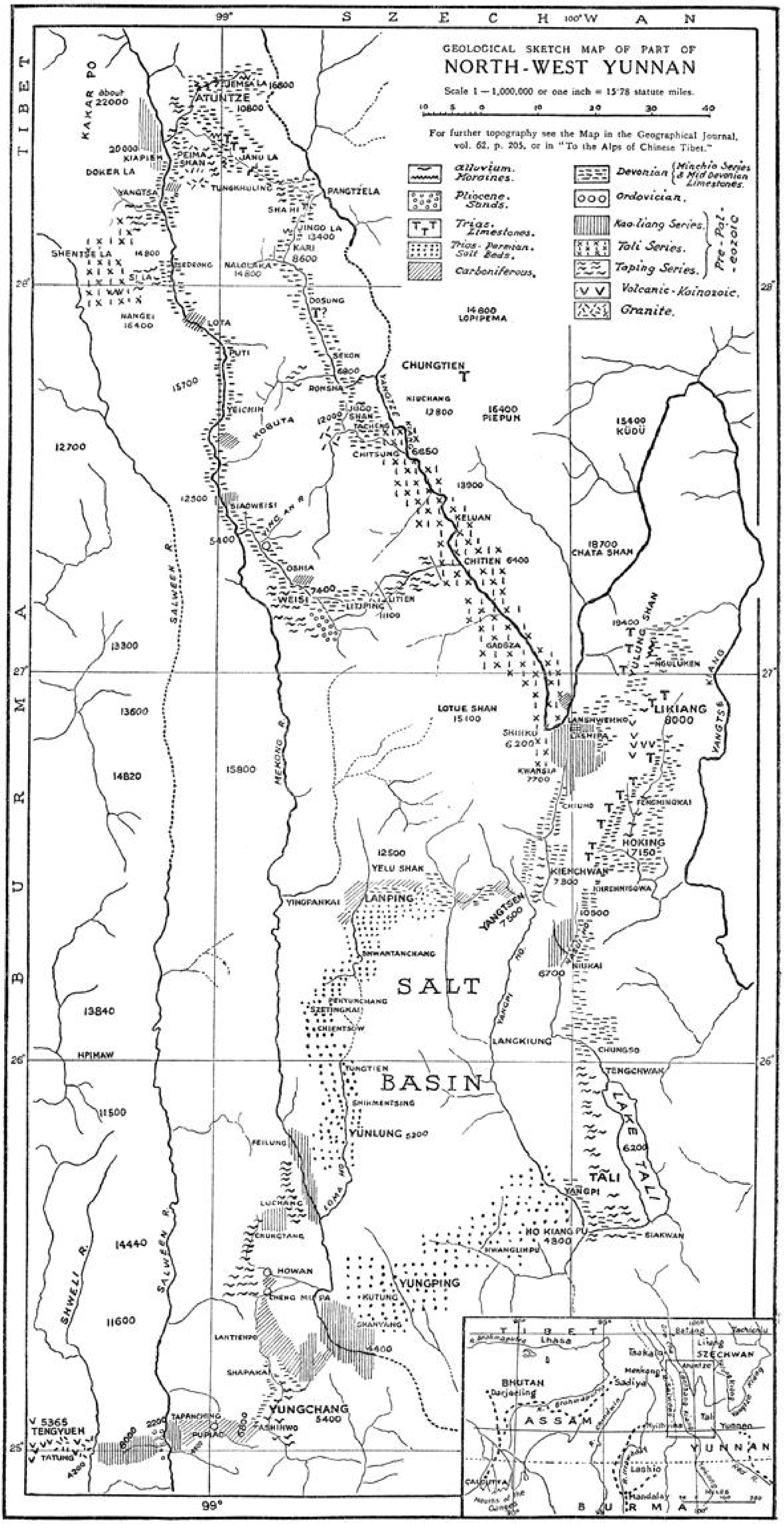


Fig. **4**, × 8

Photo. D. M. Filshill. London Stereoscopic Co., Ltd. Imp.


GEOLOGICAL SKETCH MAP OF PART OF
NORTH-WEST YUNNAN
Scale 1 — 1,000,000 or one inch = 15·78 statute miles.
10 5 0 10 20 30 40
For further topography see the Map in the Geographical Journal, vol. 62, p. 205, or in "To the Alps of Chinese Tibet."
Alluvium. Moraines.
Pliocene. Sands.
Trias. Limestones.
Trias-Permian. Salt Beds.
Carboniferous.
Devonian
Minchio Series & Mid Devonian Limestones.
Ordovician.
Kao-liang Series.
Tali Series.
Taping Series.
Pre-Palaeozoic
Volcanic-Kainozoic.
Granite.
S Z E C H W A N
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WEISI
LOTUE SHAN
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CHATA SHAN
18700
YULUNG SHAN
YANGPI
HO KIANG PU
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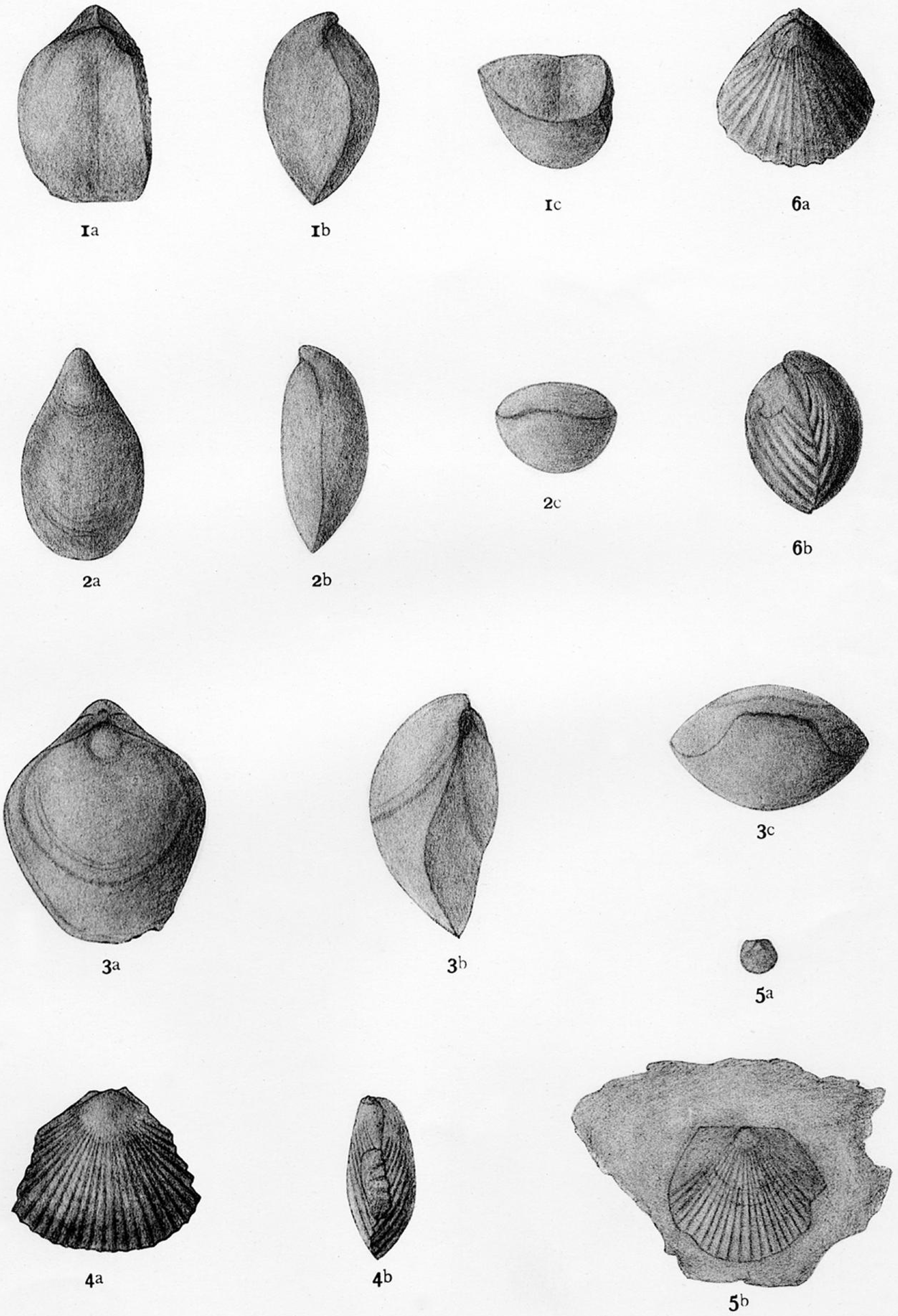

EXPLANATION OF PLATE 8.

1. *Aulacothyris angusta, var. yunnanensis,* nov. Triassic. Janu-la.
   - Fig. 1A. View of specimen F. 85, facing the brachial valve. × 2.
   - Fig. 1B. Lateral view of same specimen. × 2.
   - Fig. 1C. Anterior view of same. × 2.

2. *Dielasma olivæforme,* sp. nov. Triassic. Janu-la.
   - Fig. 2A. View of specimen F. 51, facing the pedicle valve. × 2.
   - Fig. 2B. Lateral view of same specimen. × 2.
   - Fig. 2C. Anterior view of same. × 2. (The line of junction of the two valves is slightly contorted at the left-hand side.)

3. *Terebratula* (*Cœnothyris*) *janulensis,* sp. nov. Triassic. Janu-la.
   - Fig. 3A. View of specimen F. 84, facing the brachial valve. × 2.
   - Fig. 3B. Lateral view of same specimen. × 2.
   - Fig. 3C. Anterior view of same. × 2.

4. *Rhynchonella* (*Halorella ?*) *delydens,* sp. nov. Triassic. Janu-la.
   - Fig. 4A. View of specimen F. 74, facing the brachial valve. × 2.
   - Fig. 4B. Lateral view of same specimen. × 2. Showing the broken beak of the pedicle valve.

5. *Monotis janulensis,* sp. nov. Triassic. Janu-la.
   - Fig. 5A. Specimen F. 69, a right valve. Actual size.
   - Fig. 5B. The same specimen. × 4.

6. *Rhynchonella* (*Rhynchopora ?*) *peregrina,* sp. nov. Carboniferous. Janu-la.
   - Fig. 6A. View of specimen F. 83, facing the brachial valve. × 2.
   - Fig. 6B. Lateral view of same specimen. × 2.

Fig. 1, n.s.

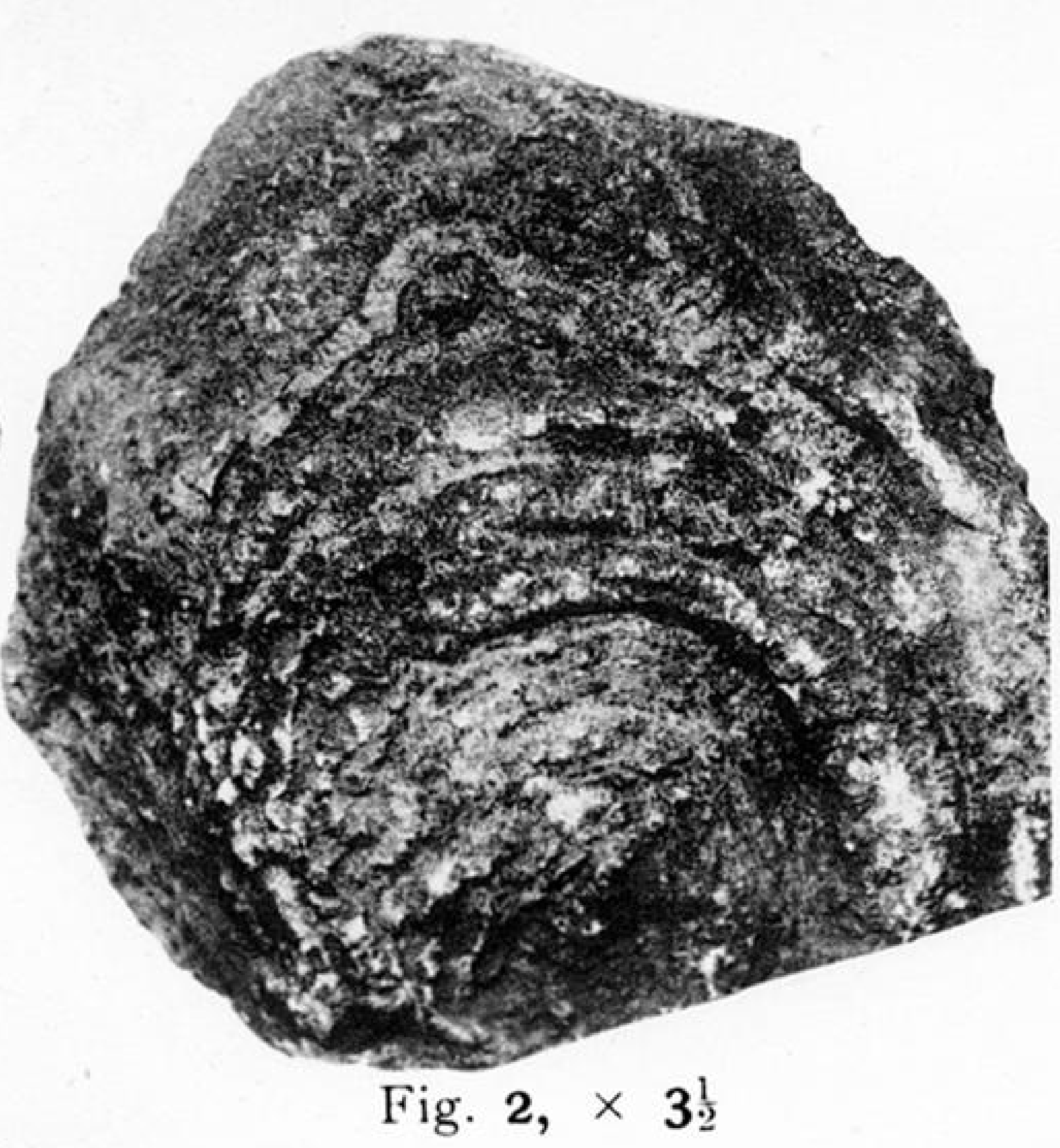

Fig. 2, × 3½

Fig. 3, × 3½

Fig. 4, × 16

Fig. 5, × 3

Fig. 6a, × 4

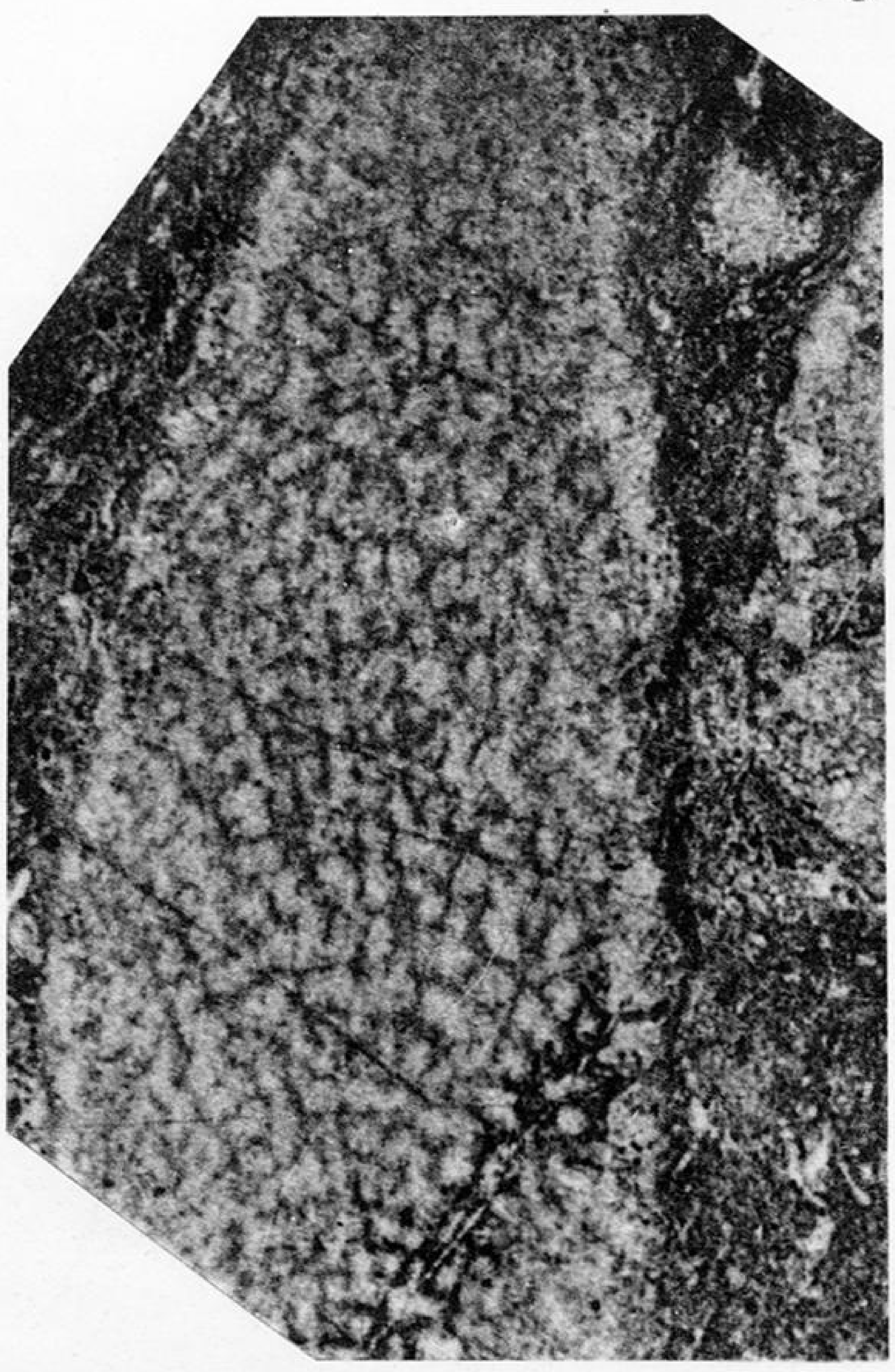

Fig. 6b, × 16

Fig. 7, n.s

Fig. 8, × 6

PLATE 9.

FIG. 1. *Stromatopora vesiculosa,* n.sp. Middle Devonian. Lan-shueh-ko. The base of a small cœnosteum, nat. size. (F. 116.)

FIG. 2. Do., the base of a young cœnosteum (No. F. 267) from the same locality, × $3\frac{1}{2}$ dia.

FIG. 3. Vertical section through a small cœnosteum (F. 301) from the same locality, × $3\frac{1}{2}$ dia.

FIG. 4. Part of a vertical specimen through another specimen (F. 264) from the same locality, × 16 dia., showing the vesicles and the zooidal tubes.

FIG. 5. Part of a vertical section through two latilaminæ, from another specimen (F. 118) from the same locality, × 3 dia.

FIG. 6A. *Idiostroma forresti,* n.sp. Middle Devonian. From the glacier valley of Yu-lung Shan ; near Li-kiang (No. Y. 206), × 4 dia.

FIG. 6B. Do., part of the same slide showing a longitudinal section, × 16 dia.

FIG. 7. *Thecosmilia* aff. *fenestrata* (REUSS). Triassic limestone. Black Dragon Temple range, Li-kiang-fu. Some corallites from the side, nat. size. (Y. 204.)

FIG. 8. *Stylophyllum* cf. *paradoxum* FRECH. Triassic limestone. Janu-la. End of a branch, × 6 dia.

Fig. 1, n.s.

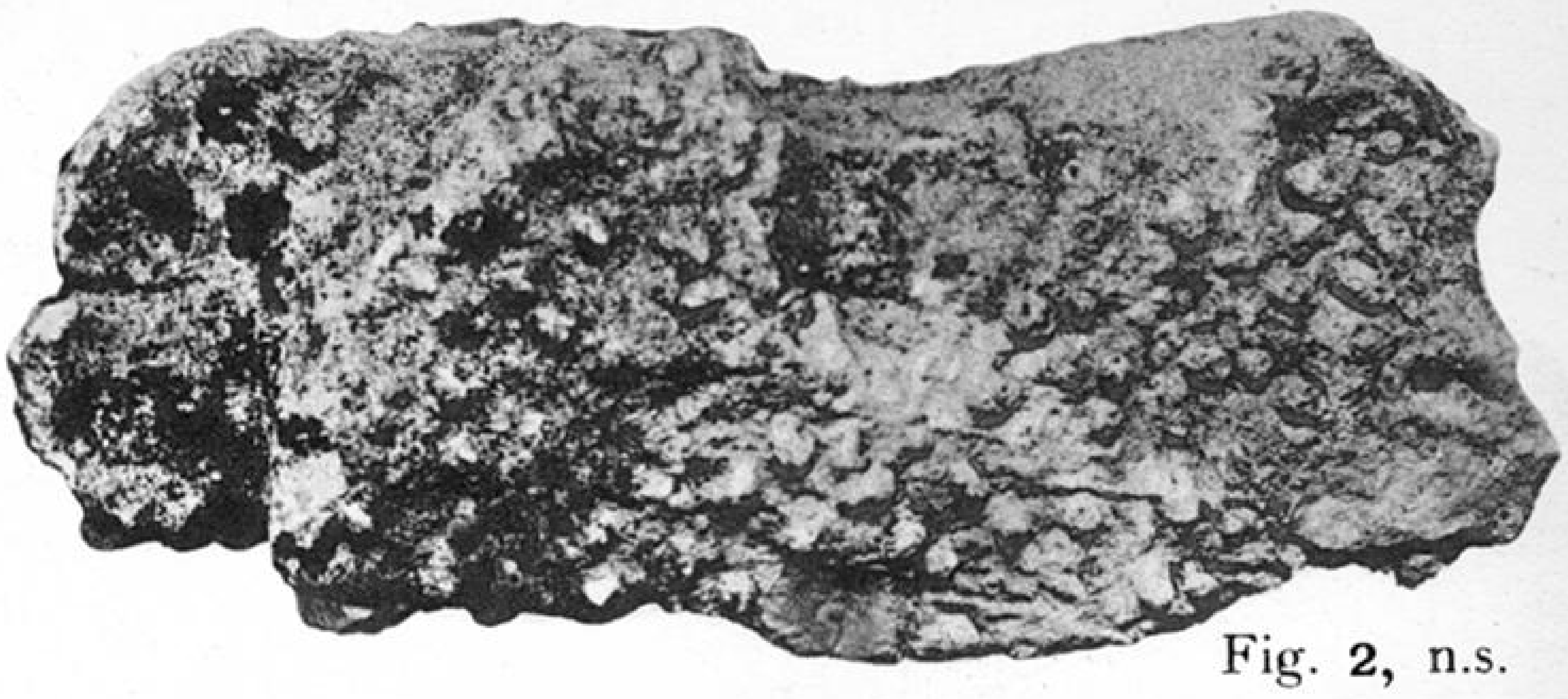

Fig. 2, n.s.

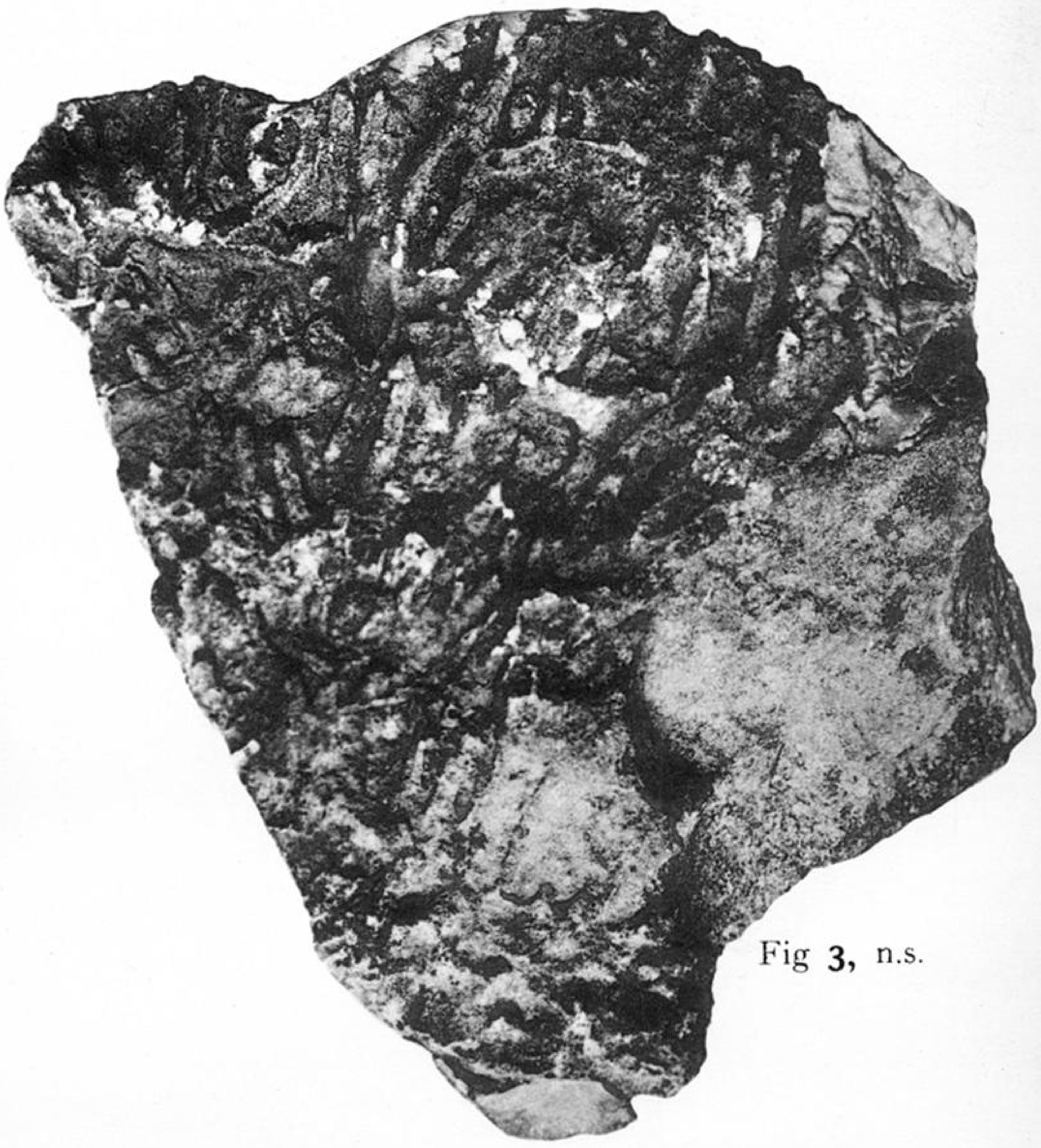

Fig 3, n.s.

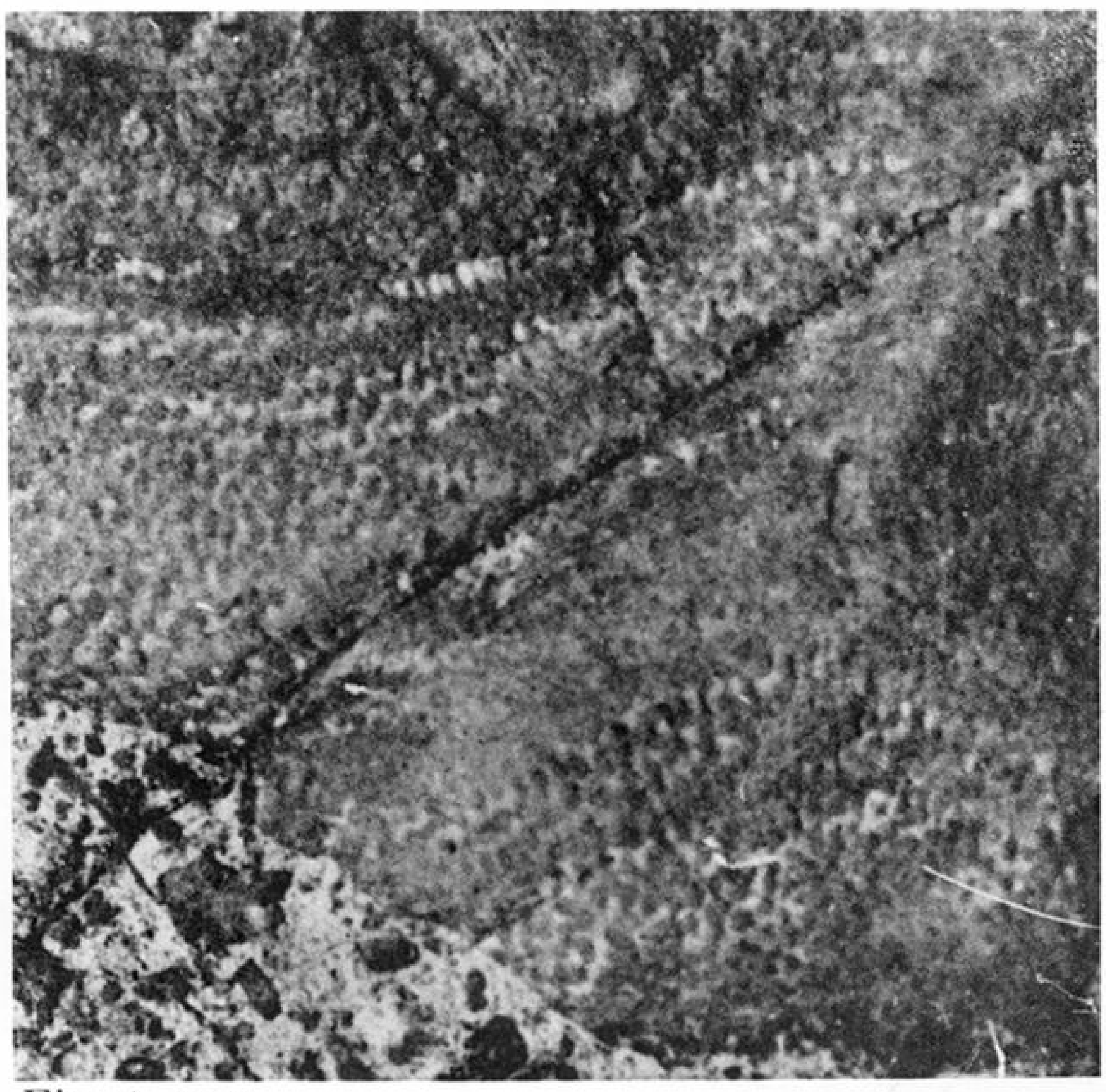

Fig. 5, × 4

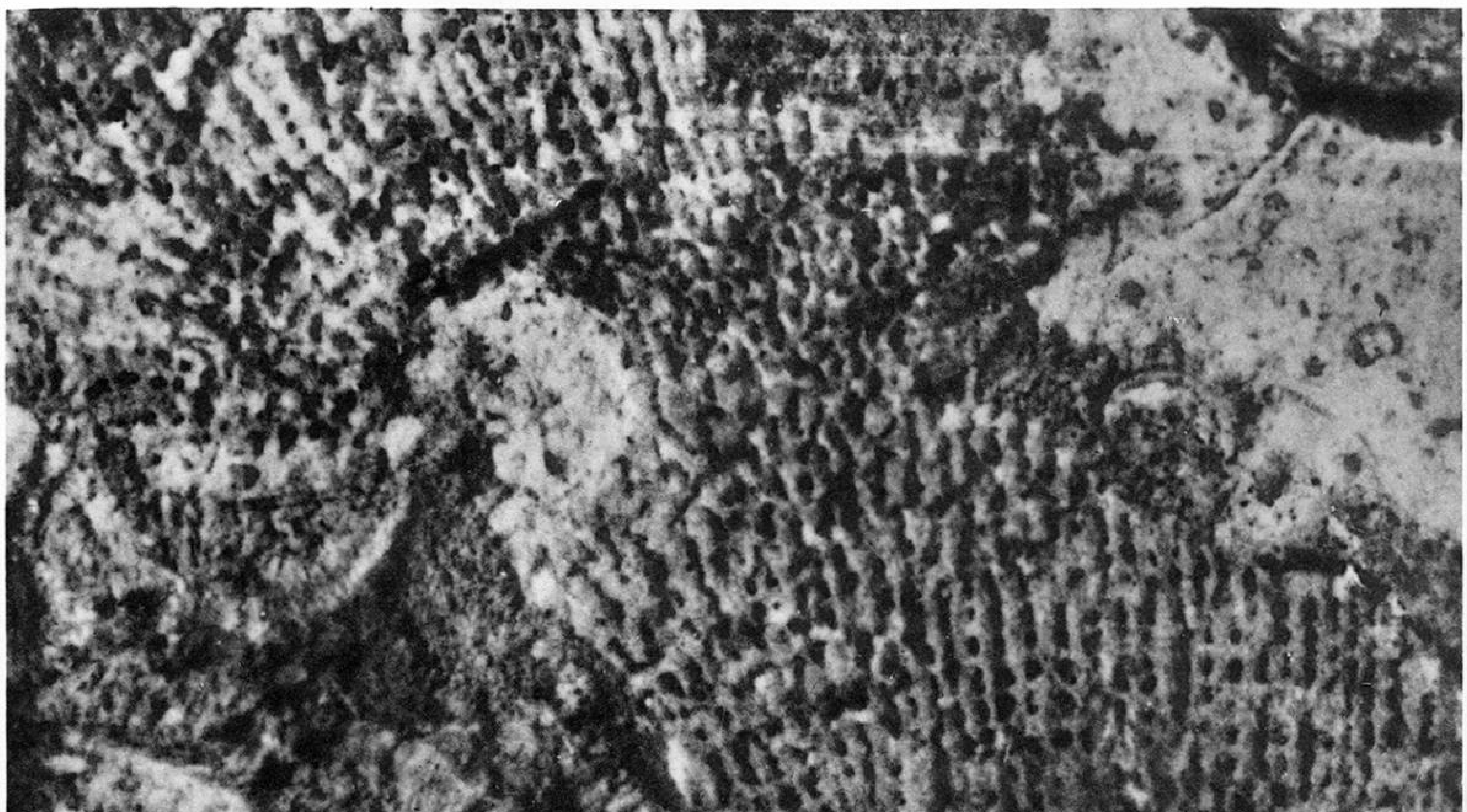

Fig. 4, × 8

PLATE 10.

FIG. 1. *Thecosmilia* aff. *fenestrata* (REUSS). Corallites seen in horizontal sections, nat. size. (Y. 204h.) Trias. Black Dragon Temple Range, Li-kiang.

FIG. 2. *Thecosmilia* aff. *oppeli* (REUSS) from the same horizon and locality. Some corallites in cross section, nat. size. (Y. 204.)

FIG. 3. Do., part of another specimen showing the corallites from the side, nat. size. (Y. 204).

FIG. 4. *Stromatomorpha* aff. *stylifera* FRECH. Triassic limestone. Janu-la. Part of a vertical section, × 8 dia. (Y. 498.)

FIG. 5. Do. Part of another specimen showing in part a cross section and in part a nearly vertical section, × 4 dia. (Y. 492.)