Some Recent Advances in Indian Geology.*

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4. The Geology of Burma.

DURING the past fifteen years a considerable advance has been made in our knowledge of the geology of Burma, and although valuable contributions have been made by workers outside the Geological Survey of India, especially concerning the Tertiary oil belt, for the most part the progress has been mainly due to the official survey. In order, therefore, to follow the progress made in Burma during recent years, it is necessary to follow the activities of the official survey in the province.

Since 1920, about when systematic survey operations were resumed in Burma after a lapse of several years, large tracts of the country have been mapped on the standard topographical sheets of the scale of one inch to one mile. For several years in the beginning of the period practically the whole strength of the Burma party was devoted to the mapping of the Tertiary belt. But later on, while this work continued, activities became scattered over areas so wide apart as Mogok and Myitkyina in the north, Amherst and Mergui in the south, and the Shan Plateau on the east. These centres of investigation are geologically so distinct and independent of each other that our best course will be to follow the trend of investigation in each separately.

THE TERTIARY BELT.

Since Sir Edwin Pascoe's classic memoir on the oilfields of Burma,[1] the most important contribution to our knowledge of the history of Tertiary deposition in Burma has been made by G. de P. Cotter with the help of his colleagues, through their field work in the foot-hills of the Arakan Yoma in Upper Burma, and through the valuable palæontological researches of E. W. Vredenburg.[2] The record of the Tertiary sequence on the eastern flanks of the Arakan Yoma is preserved so fully that it really constitutes the key to the history of deposition in the Tertiary Era in the province. Cotter was able to prove through his work in the western parts of the Minbu district that the Arakan Yoma existed as a narrow strip of land at the commencement of the Tertiary, and was able to demonstrate a lateral as well as vertical variation of rock facies according to which each stage is represented by a gradually shallower condition of deposition when followed northwards, the variation amounting to replacement of the marine by estuarine and fresh-water beds. Research along those lines led Cotter to the important conclusion that the Tertiary basin of deposition was in reality a typical geosynclinal area lying between the Shan Plateau and the narrow strip of land representing the Arakan Yoma, and that as the head of the gulf that occupied it gradually filled up in the north, where the major portion of the sediments came from, the sea retreated to the south. Thus the fluviatile sediments and deltaic deposits kept continually advancing southwards pushing the sea before them, and at the same time the area of subsidence also kept shifting to the south. Cotter published his views in 1918, and it is necessary to refer to them here since his conception of the history of Tertiary deposition has formed the basis of subsequent research in this line.

In a series of papers from 1922 onwards L. Dudley Stamp attempted to elaborate the original conception of Cotter with slight modifications and additions of detail.[3] In 1922 he emphasised the existence of intermittent folding movements at an early stage in the evolution of the geosyncline, which caused further elevation of the Arakan Yoma and further depression and buckling of the floor of the geosyncline, resulting in the temporary returns northward of marine conditions that have left wedges of marine sediments in between layers of continental type. Subsequently he postulated a marked variation between the time-planes and the lithological planes,[4] and advocated a grouping on the basis of cycles of marine invasion.[5] At the same time he suggested a modification of Vredenburg's sub-division of the Pegu Series. But these views have not found

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[1] *Mem. Geol. Surv. Ind.*, 1912, **40**, 1-269.

[2] *Journ. As. Soc. Beng.*, 1918, **14**, 409.

[3] *Geol. Mag.*, 1922, **59**, 481.

[4] *Op. cit.*, 1925, **62**, 515.

[5] *Trans. Min. Geol. Inst. Ind.*, 1923, **17**, 161.

support in more recent work, as we shall see presently. They are mentioned here only to show the different lines that have been explored in recent years to arrive at a satisfactory understanding of the Tertiary sequence in Burma.

At the World Petroleum Congress held in London in July 1933, G. W. Lepper of the Burma Oil Company Limited, briefly outlined the Tertiary geology of Burma, and contributed a large amount of hitherto unpublished information based on the results of many years' incessant work by the geological staff of the Company.[6] This contribution, therefore, is of unusual authority and interest, and carries us a long way in our knowledge of the sequence and structure of the Tertiary deposits of Burma and the connection of the latter with the occurrences of commercial petroleum. P. Evans summarised the paper recently,[7] but some points of unusual interest must be mentioned here even at the risk of repetition.

A very important point brought out by Lepper is the recognition of a long synclinal trough which forms a striking feature of the geological structure of the Chindwin-Irrawaddy Valley, and which separates the western monocline, composed of a complete succession of the Tertiary deposits flanking the Arakan Yoma, from a broad series of folds to the east. This structure is found to persist from latitude 24° (west of the Indaw anticline) in the north, across the Chindwin River near Mingin, to the west of the Mahudaung anticline. From there it runs through the Pakokku district and the oilfields, into the Thayetmyo district in the south, where it narrows and becomes split up by anticlinal folds running across its strike. It reaches its maximum development west of the Yenangyaung and Singu-Lanywa-Yenangyat oilfields, and separates these and the Minbu oilfield from the monoclinal succession in the west. This median syncline is of very great importance not from the structural point of view alone but because the occurrence of commercial petroleum is closely connected with it. It has been established that all the producing fields lie in the closed structures that border the synclinal immediately on the east, and with the exception of the Indaw oilfield, situated near its north end, the main group of oilfields lies near its maximum development opposite Yenangyaung. According to Lepper circumstances similar to those attending the origin and migration of oil in some of the American fields, as explained by V. C. Illing,[8] may have prevailed in Burma from Middle Eocene to Middle Miocene. Conditions favourable for the accumulation of organic matter suitable for the formation of petroleum persisted more continuously in the shallow marine tract occupied by the synclinal, where thinner sediments were deposited, than on its east and west. And with the compaction of the strata oil and salt water were expressed and moved laterally to the coarser deposits of the margins. Uplift of the latter initiated the segregation of gas, oil and salt water during the post-Pliocene folding. Thus we find oil in quantity confined to the belt of folds that lie immediately to the east of the syncline. Beyond this belt the oil seepages are rare and test wells have struck little or no oil. The oil which migrated towards the western margin of the syncline had no opportunity to accumulate as no closed structures exist on that side.

Another equally interesting contribution made by Lepper gives the result of a close examination of the whole Tertiary sequence forming the long easterly-dipping monocline along the eastern flank of the Arakan Yoma. Members of the Pegu Series (Oligo-Miocene) were found to become more arenaceous when followed northwards, as demonstrated by Cotter, but in addition well-defined palæontological breaks are recognised at the top of the Yaw Stage (Eocene), and between the Oligocene and Miocene, the latter break dividing the Pegus into two parts of equal thickness. Another widespread unconformity is recorded between the Irrawaddy series (Mio-Pliocene) and the Pegu series, and a new classification has been suggested.[9]

An important result of these researches is that the divergence of time-planes and lithological planes advocated by Stamp all these years does not find support in the evidence brought forward by Lepper. With the present facilities of coring the underground strata of the central oilfields by rotary drilling it has become increasingly possible to correlate the stratigraphical sequence of this area with that of the outcrops west of the syncline, in spite of the difficulties raised

[6] World Petroleum Congress, London, 1933, reprint 169.

[7] *Trans. Min. Geol. Inst. Ind.*, 1934, **29**, 67.

[8] *Journ. Inst. Petr. Tech.*, 1933, **19**, 229.

[9] See Reference 6.

by lateral lithological variations of the beds from west to east.

As regards the progress which has been made during recent years in the oilfields development, the reader is referred to the proceedings of the World Petroleum Congress of 1933, and to the annual reports of the Director, Geological Survey of India, since 1927, when the practice of having a Resident Geologist permanently at Yenangyaung was revived.

THE TERTIARY IGNEOUS ROCKS OF BURMA.

Tertiary igneous activity in Burma began in Eocene times, and with intermittent quiescent periods of varying duration revived in early Irrawaddy (Mio-Pliocene) and again in Pleistocene and sub-recent times. The different periods of activity are remarkable more for the extent in space over which the phenomena are exhibited than for the amount of material poured out, and all the successive activities appear to have followed more or less the same tectonic lines from beginning to end. The present-day surface indications suggest that the later activities were the more energetic and, although still following the older zones, their manifestations extended far beyond the earlier limits.

The most important centres of activity are seen to follow an important tectonic line that traverses the entire length of Burma and runs approximately through the centre of the Irrawaddy-Chindwin basin. Beginning with the Myitkyina occurrences in the north it runs through the Mingin Range volcanics west of Wuntho, to the explosion craters of the Lower Chindwin district, and from there it continues south through the Shinmadaung hill range in Pakokku district, and through Mount Popa to the dolerite dykes and sills of the Pegu Yoma. When continued further south this line passes through the volcanic islands of Narcondam and Barren to the volcanic regions of Sumatra. In the Lower Chindwin district a subsidiary line runs parallel to it, in the hill ranges east of Monywa.

Another line, though of less importance, runs along the western edge of the Shan Plateau. Along this line are found the intrusive and extrusive rocks of the Male-Kabwet area in the Shwebo district in the north, the rhyolites and tuffs in Thaton, the volcanics of Maingy and Elphinstone Islands off the coast of Tavoy, and the basalts of Medaw Island south of Murgyi. Only a very short account of the various centres of activity in which research has been carried out in the period of the present review can be attempted here, beginning in the north.

H. L. Chhibber, during his recent work in the Jada Mines area in the Myitkyina district, which is the point furthest north at which Tertiary igneous rocks have so far been mapped, found the extinct volcano of Mount Loimye, which rises 5,124 feet above the sea-level, and is thus higher than Mount Popa which it somewhat resembles in its structure and ejectamenta.[10]

Although the volcanic rocks of the Mingin Range form the biggest centre of vulcanicity in Burma, practically nothing has been added to Noetling's description of long ago.[11]

In Lower Chindwin district there is a belt of volcanic occurrences 25 miles wide, following roughly a N.–S. direction. It includes the string of eleven extinct explosion-craters situated in a straight line, some 13 miles long, running across the Chindwin river at Shwezaye in a N.E.–S.W. direction. From the spectacular point of view they form the most interesting occurrence, being represented by great hollow pits the bottoms of most of which are now covered by lakes. R. D. Oldham[12] was the first to describe these explosion-craters, and so far as the description of surface features goes his observations can hardly be improved upon, though the rocks themselves have since been studied in greater detail. In 1925 P. Kelterborn published a short note on some specimens collected from this area.[13] In 1927 Messrs. Pinfold, Day, Stamp and Chhibber described the igneous rocks of the whole district,[14] while during 1926-28 the writer mapped these occurrences in the course of the systematic mapping of these districts. The most important account, however, is the one given by C. Burri and H. Huber in 1932.[15] According to these workers the rock types include liparites, andesites, basalts, ultra-basic rocks, and tuffs and similar rocks. The olivine-basalts are the most widespread, and some of them have proved to be alkali basalts under-saturated with silica and containing normative nepheline. The ultra-

[10] *Rec. Geol. Surv. Ind.*, 1930, **63**, 101.
[11] *Op. cit.*, 1893, **26**, 26.
[12] *Op. cit.*, 1906, 137.
[13] *Eclog. Geol. Helv.*, 1925, **19**, 352.
[14] *Trans. Min. Geol. Inst. Ind.*, 1927, **21**, 145.
[15] *Schweiz. Min. Petr. Mitt.*, 1932, **12**, 286.

basic rocks ejected by the Twindaung crater are represented by pyroxene-hornblendite which is found to contain by mode 85 per cent. hornblende and 15 per cent. pyroxene, approaching nepheline-basanite in chemical composition, and by biotite-pyroxenite which is found to contain 40 per cent. biotite and 60 per cent. augite, approaching leucite-basanite to olivine-leucitite in chemical composition.

In the hills west of Monywa devitrified rhyolites, quartz-porphyry and muscovite-porphyry have been recorded. The detailed survey of the part of the Lower Chindwin east of Monywa by the present writer in 1927-28 brought to light a few additional volcanic occurrences. Most of them are situated along a fault line that runs in an approximate N.–S. direction.

The next volcanic occurrences to the south are found in the Salingyi upland (sheet 84 0/1) mapped by Barber in 1925-26. The rocks here comprise dacites, dolerites and coarse diorite forming a suite of pronounced calc-alkali type. Further south the line passes through a small outcrop of lava exposed in the Shinmadaung hill range, along the western flanks of which hornblende-andesites, basalts, tuffs and rhyolitic agglomerates and breccia occur.

Although dolerite dykes and sills are known to occur in the Pegu Yoma further south, Mount Popa in the Mingyan district forms the most conspicuous southerly manifestation of late Tertiary volcanic activity in the Irrawaddy basin. A preliminary account of the lava flows of this area was given by Sir Edwin Pascoe in 1909, and more recently the rocks have been described by Chhibber.[16] Barber worked on the eastern slopes of the mountain in 1926 and the representative collections made from this area and from the Shinmadaung range and Salingyi area are at present being studied by him. Volcanic activity in this region probably commenced at an earlier time than elsewhere, although the period of maximum activity may be Irrawaddian.

Mount Popa itself is built of lava flows, tuffs and agglomerates of Pleistocene to sub-Recent age. Older volcanic rocks also occur and include a repetition of different types of andesites and rhyolitic rocks, both associated with tuffs. The different rock types in the younger lavas are all easily matched with one or the other of the types occurring in the Lower Chindwin, so that it is quite clear that igneous rocks in these two distant centres belong to the same petrographic province.

The most important centre of igneous activity on the second line—that following the western edge of the Shan Plateau, is the most northerly known occurrence, that of Male-Kabwat region. Stamp and Chhibber published an account of this area in 1927.[17] The present writer mapped the area in the course of his routine survey of the Shwebo district during the season of 1928–30, and whilst his mapping is mainly in agreement with that of Stamp and Chhibber, he made one noticeable addition by discovering that the anticlinal axis through Nattaung Hill and Letkokpin is followed by a parallel synclinal axis to the east running through Kabwet, and that the spheroidal lava regarded by Stamp and Chhibber as a dyke intrusion was in fact a sheet of lava, taking part in the fold and appearing on either limb of the syncline.

Records of more than one period of igneous activity are preserved here. The older lava is interbedded with the Irrawaddy beds and shows beautiful examples of pillow structure. Intrusions are represented by a sill and dykes, and the younger olivine basalts, extruded in Pleistocene or sub-Recent times, build the hill Lethataung, 1,674 feet above sea-level, opposite Kabwet. The peak is regarded by Stamp and Chhibber as marking the focus of eruption; but the writer is of opinion that those lavas came from fissures, one of which passed through the position that now forms the crest of the hill range of which Lethataung is the culminating point. The lavas of Singu to the south are part of the same extrusion. North of Kabwet the volcanic activity is represented by decomposed amygdaloidal lava interbedded with the Irrawaddy beds, and by the long lines of dolerite dykes between Kabwet and Male. This line of activity corresponds with a zone of tight folding and crushing of the late Tertiary beds against the crystalline rocks of the Mogok series, and the junction between the two is most probably a faulted one. A very interesting character of the rocks of this region is that they show an 'Atlantic' or alkaline tendency of differentiation, whereas the rocks of all the igneous centres on the main line

[16] *Trans. Min. Geol. Inst. Ind.*, 1927, **21**, 129.

[17] *Op. cit.*, 1927, 97.

to the west show definite 'pacific' or calc-alkali affinities.

The next known area of vulcanicity along this line lies near Mokpalin, in the Thaton district, where rhyolites and rhyolitic tuffs are seen to overlie a sedimentary series of probably Carboniferous age.[18] They strongly resemble the occurrences west of Monywa in Lower Chindwin district, and are regarded as of the same age. Continuing along this line to the south we come to the coarse volcanic agglomerates of Maingy Island and a series of rhyolites and porphyries on the western coast of Elphinstone Island, off the Tavoy Coast. The age of these rocks is uncertain. The southernmost volcanic occurrence is that of the island of Medaw in Mergui, where basalt fills up most of the low-lying ground. The area was visited by M. Vinayak Rao in 1922,[19] and a description of the rocks is included in Sethu Rama Rau's memoir on the Geology of Mergui.[20]

The Mogok Gem Stone Tract.

The large-scale geological mapping of the Mogok stone tract that has been in progress for the last few years and is now nearing completion has considerably increased our knowledge of the geology of this interesting area. The Archæan rocks which occur here have now been divided into a number of stages and mapped separately. This work was begun by J. Coggin Brown and A. K. Banerjee in 1929, and has since been continued by E. L. G. Clegg and L. A. N. Iyer.[21]

The rocks found here include metamorphosed sediments, now appearing as crystalline schists, and a varied suite of intrusive igneous rocks. The metamorphic rocks include quartzites, limestones, calciphyres, and a number of unclassified gneisses. The quartzites, which may be either of replacement or of sedimentary origin, occur in association with calc-gneisses, in some cases passing imperceptibly into calc-granulites. The limestones, calciphyres and calc-gneisses are usually found in association and grade into one another. Although at first sight they appear to occur in discontinuous bands following the general E. 30° N. strike, the mapping indicates that they are probably the remnants of continuous strata reduced to the present isolated fragments by the combined effects of intrusions of syenites and granites, which have eaten their way into them to a large extent, and of the folding and denudation that did the rest. These rocks are of wide-spread occurrence in the tract and show a variety of types containing a number of accessory minerals. Prof. Alam's statement that the limestones and gneisses exposed continuously from Thabeitkyin to Mogok strike north and south is not borne out in general in the area.[22]

The unclassified crystalline rocks, comprising a variety of gneisses and intrusive rocks, appear to be the metamorphosed derivations of argillaceous and arenaceous sediments, intruded along their planes of schistosity by a series of granites, syenites and pegmatites.

The igneous rocks occur in great variety, and the following are the chief types found. The basic and ultrabasic rocks are represented by medium to coarse-grained holocrystalline peridotites. The hornblende-ægirine-nepheline rocks and hornblende-ægirine-scapolite rocks occur in small intrusions or bands usually associated with limestones or, in certain instances, as marginal fringes of syenite intrusions. The syenites were first recognised in the field by Dr. L. L. Fermor and are of a wide distribution, ranging from quartz-syenite to dioritic monzonite. The felspar of the latter are predominantly andesine, and the pyroxene is either augite, ægirine augite or ægirine. Certain types containing hypersthene approach the intermediate members of the charnockite family of Southern India. The augite and hornblende-granites of the area appear to be a more acid phase of the syenitic magma.

Apart from the description of the various rock formations and their large-scale mapping, which have a value and interest of their own, the recognition of certain points of resemblance between the Burmese Archæan rocks and those of similar composition in Peninsular India constitutes a considerable advance in our knowledge, and we owe it largely to Dr. Fermor's short visit to the Mogok area and his subsequent study of rock specimens collected therefrom. Some of the garnet-sillimanite-gneisses occurring in patches in the Bernardmyo tract have been found by Dr. Fermor to be identical with the khondalite of Peninsular India. Rocks of the Mogok stone tract, according to him,

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[18] *Proc. 14th Ind. Sci. Congr.*, 1927, 239.

[19] *Rec. Geol. Surv. Ind.*, 1921, **55**, 32.

[20] *Mem. Geol. Surv. Ind.*, 1933, **55**.

[21] *Rec. Geol. Surv. Ind.*, 1931, **65**, 80-86; *op. cit.*, 1932, **66**, 92-96; *op. cit.*, 1934, **68**, 50-57.

[22] *Op. cit.*, 1931, **65**, 80.

exhibit a grade of metamorphism characteristic of the hypomorphic zone (Grubenmann's 'katamorphic zone') and have their analogues in the rocks of the Eastern Ghats of India and Ceylon. The garnetiferous granulites are especially interesting in this respect because they approach in mineral composition the felspathic khondalites of Ceylon. Certain hypersthene-biotite-granulites show a charnockite type of metamorphism, and the cordierite-rocks from the Yebu Chaung recall some of the hybrid rocks described by T. L. Walker and W. H. Collins from the Vizagapatam district of South India.

THE JADE MINES AREA.

Since A. W. G. Bleek's description of the geology of the Kachin hills in connection with the jadeite, published in 1908,[23] there has been practically no serious geological work done in this region, with the exception of Murray Stuart's traverses across portions of it in the field season 1920-21,[24] until Chhibber commenced the survey of the Jade mines area in 1928.[25] These investigations are still in progress. Systematic mapping has so far been confined to the Jade mines area, in the Kamaing sub-division, but the geology of large tracts of the neighbouring areas is known through traverses to the Chinese frontier and to the Hukawng valley.

The most interesting feature of this region lies in the preservation of the record of several periods of igneous activity dating from post-Permo-Carboniferous up to sub-Recent times. The chief sedimentary formations are the Permo-Carboniferous limestones and the Tertiary rocks. The former overlie unconformably towards the north-east rocks resembling Chaung Magyis (Pre-Cambrian) in lithology, while into the Tertiary rocks are intruded a variety of igneous rocks. There are also crystalline schists which are regarded by Chhibber as ortho-schists. The Permo-Carboniferous are intruded by a batholith of a medium grained granite, represented by a variety of types among which biotite and muscovite-granites predominate. The intrusion is regarded as of Triassic age in common with certain other intrusions in Burma. There are also peridotites and serpentines of probable Upper Cretaceous or Lower Eocene age. Into these latter are intruded the albite-jadeite rocks which are the parent rock of the well-known jade.

The sedimentary Tertiary rocks of the area are now sub-divided as follows:—

Uri boulder conglomerates.
Namting series.
Hkuma series.

The Hkuma series is a thick deposit of a well-bedded sandstone in which occasional intercalations of shaly layers occur. An interesting feature of this series is that the heavy mineral assemblages of these rocks correspond to those of the Barail series (Eocene-Oligocene) of Assam, which corresponds to the Upper Eocene and lower half of the Pegus in Central Burma. Similarly, the Namting series, composed of a considerable thickness of sandstones, shales and conglomerates, has yielded heavy minerals that agree closely with the Tipam series of Assam, corresponding to a portion of the Upper Pegus.

Another interesting feature of this area is the manifestation of igneous activity in post-Tertiary times. This has already been referred to above.

THE MERGUI ARCHIPELAGO.

During the period under review the geological survey of the accessible parts of the Mergui district was completed, and an account by Sethu Rama Rau was published in 1930.[26] The geology of the northern portion of the archipelago was described by Coggin Brown and A. M. Heron in 1923.[27]

An area in this region that has attracted geological attention in recent years is the Amherst district, where a considerable amount of work has been done. It is impossible, however, to summarise it all within the limits of this article, and a few only of the more important conclusions will be referred to here. Towards the end of 1921 J. W. Gregory[28] and G. de P. Cotter[29] examined the eastern parts of the district in connection with the investigation of the oil shales that occur there, and important knowledge of this hitherto unexplored but geologically very interesting part of Burma was obtained. The oil shales are of late

[23] *Op. cit.*, 1908, **36**, 257.
[24] *Op. cit.*, 1923, 54, 398.
[25] *Op. cit.*, 1929, **62**, 108-114; *op. cit.*, 1930, **63**, 97-102; *op. cit.*, 1932, **66**, 50-57.
[26] *Mem. Geol. Surv. Ind.*, 1933, **55**.
[27] *Op. cit.*, 1923, **44**.
[28] *Geol. Mag.*, 1923, **60**, 152.
[29] *Rec. Geol. Surv. Ind.*, 1927, **55**, 273.

Tertiary age, and were deposited in basins comparable with those found in the Shan Plateau, Tavoy and Mergui, and indeed far beyond the limits of British India, in Yunnan, Indo-China and Siam. The main Tertiary basin of Pliocene age in which oil shale occurs is the structural valley enclosed by the Dawna range and the Choehko Taung. The Dawna range is built mainly of banded gneisses, schists and gneissose granite, and Cotter's discussion of the age of the gneissose granite constitutes a valuable contribution to our knowledge of the granites of Burma as a whole. In this paper he has gathered together evidence from within Burma and from the neighbouring country of Siam pointing to a Triassic age for some of the Burmese granitic intrusions. Coggin Brown has since brought forward evidence to prove a similar age for the Thaton granite which, he believes, is identical in composition, age and mineral association with the major granite intrusions that stretch from Mergui into the foothills of the Shan Plateau, east of the Kyaukse and Yamethin districts.[30] Most probably these are all of the same age and comparable with the granites of British Malaya, Sumatra, Borneo and the Dutch East Indies.

Another point of much geological interest connected with Cotter's work in this area is his discovery of fossils in the limestones exposed in the Thoungyin river. Although the fossils were found to be in a most disappointing state of preservation, G. H. Tipper, who examined them tentatively, came to the conclusion that they indicated a Triassic age. The attribution of this age to the limestone came rather as a surprise at the time and was accepted only doubtfully, because no limestone of that age had been recorded from the extensive developments of the formation in the surrounding regions of the Shan Plateau, Mergui and Moulmein. Tipper's view, however, was later proved to be perfectly correct by specialists such as Gregory, Julius Pia, Trouth and Weir[31], who worked out the collections a few years ago. It appears possible, therefore, that these limestones represent an upward extension of the Plateau Limestone into the Trias, though hitherto it was considered to have ended with the Permian.

THE SHAN PLATEAU.

Work by the Geological Survey of India on the Shan Plateau was resumed simultaneously in the Northern and Southern Shan States in 1928. In the Northern States the work has mainly been confined to the extension northwards of T. de la Touche's map of this area published in 1912.[32] In the course of this work several new fossil localities have been discovered, of which the most important is M. R. Sahni's discovery of a unique assemblage of ammonites, gastropods and lamellibranchs in the Plateau limestone at Nam Hkyam.[33] The ammonites include *Xenorpis carbonaria* Waagen, recorded from the Permian of the Salt Range and from Chitral. Another genus is *Nannites*, of which two species have been found, one of which shows affinities with a species recorded from the Otoceras beds of Spiti. The new genus *Hungoritidæ* is the most common ammonite represented. Among the gastropods *Pleurotomaria* and *Naticopsis* are the most dominant. Of the lamellibranchs *Schizodus* is very common.

As regards the Southern Shan States, our knowledge of the geology of this area was very meagre prior to the period under review. As a result of recent work by Coggin Brown and the writer some 2,900 square miles have already been mapped on the scale of one inch to one mile, and in addition extensive traverses have been made running up to the eastern frontier of the Indian Empire. Generally, the geology of this region is essentially the same as that of the Northern Shan States and the only differences are those of minor details. The chief interest of the region is centred on the Ordovician-Silurian succession of which a number of rock facies and horizons are present. Several new fossil localities have been discovered, but, although of very great interest to the science, most of the assemblages have been rather disappointing as regards their correlative value, for in almost all the collections so far examined the majority of forms that are specifically identifiable have turned out to be new to science, except in the case of the graptolite and tentaculite horizons at the bottom and top of the Silurian respectively.

A description of the geology of the country was published recently, and it need not be discussed in detail here.[34] Broadly speaking,

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[30] *Op. cit.*, 1928, **60**, 79.
[31] *Op. cit.*, 1930, **63**, 155.
[32] *Mem. Geol. Surv. Ind.*, 1913, **39**.
[33] *Rec. Geol. Surv. Ind.*, 1932, **66**, 97.
[34] *Op. cit.*, 1933, **67**, 135.

the numerous isolated outcrops of Ordovician rocks have been grouped into three divisions based on their fossil contents and lithology. The further sub-division of these groups has been rendered difficult owing to the lateral variations in the lithology and to the sharp differences in the fossil assemblages of different localities. From a number of large collections made by the writer from the Ordovician, F. R. Cowper Reed has been able to find only 33 forms which are in a sufficiently well-preserved state for specific description.[35] Of these 23 are new species. In the Silurian, excepting the graptolite and the tentaculite zones, there are only 4 specifically identifiable forms, and all of them are new. The Ordovician is much better developed here than in the Northern States, the Lower Ordovician, which is not found in the north, having been found in the south with forms allied to those occurring in Annam.

In the Plateau Limestone group the true limestones have hitherto been regarded as forming the upper division and the dolomitic variety the lower division. Recent work in this field, however, has shown that this method of sub-division is not a sound one, and that dolomitisation is not confined to the lower division. A portion of some fossil collections from the 'Upper' Plateau Limestone has recently been described by F. R. Cowper Reed, who has referred them unquestionably to the Anthracolithic system.[36] A remarkable feature of the fauna is the large number of peculiar bryozoans, many of which are new species.

In the next higher formation, namely, the Coal Measures, a flora and fauna, of Middle Jurassic age has been obtained thus indicating them to be contemporaneous with the Namyau beds.[37] It is the writer's view, however, that these extensive deposits include at least a portion of the Napeng beds of Northern Shan States. They are succeeded unconformably by Red Beds, the age of which has been fixed through the discovery by C. S. Fox of a few fossils which indicate them to be equivalent to the Trichinopoly beds of the Coromandel coast, which are Upper (Ariyalur) to Middle (Utatur) Cretaceous in age.[38] This discovery is of unusual interest, as no beds younger than Jurassic were hitherto known from the Shan States, excepting the Pliocene-Pleistocene lake deposits. It is noteworthy that after the deposition of the Permo-Carboniferous limestone all the subsequent deposits were laid down in inland seas and large lake basins. These decreased in extent as time went on, until in Pliocene-Pleistocene times the areas of deposition were restricted to isolated lake basins, remains of which are found far and wide in Eastern Asia, including the Shan States, Yunnan, Siam and French Indo-China.

[35] *Pal. Indica* (in the press).

[36] *Rec. Geol. Surv. Ind.*, 1933, **67**, 83.

[37] See Reference 34.

[38] *Rec. Geol. Surv. Ind.*, 1930, **63**, 182.

Obituary.

Sir Horace Lamb, F.R.S. (1849-1934).

WE regret to record the death of the eminent applied mathematician Prof. Sir Horace Lamb on December 3, 1934 (born on November 27, 1849). He made valuable contributions to the subject of Hydrodynamics; and his first book *Hydrodynamics* (1870) which was published for the sixth time in 1924 is one of the standard treatises in the subject. In 1884 he was elected Fellow of the Royal Society. He was Professor of Mathematics at Manchester and was recipient of the Copeley Medal of the Royal Society in 1924.