Here, then, it seems to me we have a case in point, affording good evidence of an interglacial period with abundance of heat, and yet not enough to cause a decided reversal of climate, but only sufficient to clear out the heavy mass of ice which filled the basin of the Moray Firth. Such a result certainly could not have been accomplished without the expenditure of an enormous amount of heat, which in districts where there was no ice to dispel would have produced a decidedly warm climate. During the thawing of the ice and its reduction into ice-cold water the air would remain cold, and not until the ice had completely disappeared would the climate become genial. Before this could happen in the Northern districts the interglacial spell of warmth might be passing away, and hence no genial climate would result.

ELLON, ABERDEENSHIRE.

III.—ON THE ORIGIN OF CERTAIN LATERITES.

By MALCOLM MACLAREN, B.Sc., F.G.S.

THE various views put forth prior to 1893 to account for the origin of Indian laterites have been clearly and sufficiently discussed in Oldham's edition of Medlicott & Blanford's Manual of the Geology of India (pp. 369 et seq.). Since that year the only contribution of importance to the literature of lateritic genesis in India is a paper by Mr. Thos. H. Holland, F.R.S., the present Director of the Indian Geological Survey,¹ having for its text the conclusions of Bauer.² In it the author suggested that laterite might owe its origin to "some lowly organism," but no sufficient data were advanced in support of the suggestion. Bauer's specimens indicated a certain amount of dehydration in laterites, and this fact, together with the absence of hydration products from certain peridotites in Southern India,³ was deemed to indicate a general dehydration for the bauxitic laterites of the Deccan. The gibbsite ($\text{Al}_2\text{O}_3, 3\text{H}_2\text{O}$) of laterite was supposed to be dehydrated to diasporite ($\text{Al}_2\text{O}_3, \text{H}_2\text{O}$), and it was assumed that "this irregular loss of water is probably the cause of variation in bauxite."⁴

To account for the energy necessary for dehydration the ingenious theory of the possible superiority of "crystalline affinity" over "chemical affinity" was developed (loc. cit., p. 69), and the conclusion was drawn that "limonite and gibbsite must be regarded as unstable at tropical temperatures."⁵

Of late years valuable analytical researches on the constitution of laterite have been made by Dr. Warth,⁶ who may justly be considered

¹ GEOL. MAG., Dec. IV, Vol. X (1903), pp. 59-69.

² "Beiträge zur Geologie der Seychellen": Neues Jahr. für Min., vol. ii (1898), p. 163.

³ GEOL. MAG., Dec. IV, Vol. VI (1899), pp. 31, 542.

⁴ *Ib.*, Dec. IV, Vol. X (1903), p. 65.

⁵ See, however, GEOL. MAG., Dec. IV, Vol. X (1903), p. 139.

⁶ Min. Mag., vol. xiii (1902), p. 172. GEOL. MAG., Dec. IV, Vol. X (1903), p. 154; *ib.*, Dec. V, Vol. II (1905), p. 21.

the pioneer in the investigation of the nature of Indian laterites, though their aluminous character had years before been suggested by Mallet.¹ Various analyses have also been made from time to time in the laboratory of the Geological Survey of India.²

A comprehensive genetic theory of lateritic deposition must reasonably account for any or all of the following features:—

- (1) The restriction of the deposition of laterites, both geographically and in altitude.
- (2) Their general superficial occurrence.
- (3) Their internal structure—porous, vesicular, pisolitic, or concretionary.
- (4) Their peculiar composition as regards—
 - (a) The essential aluminous, ferruginous, or manganiferous hydrates or oxides.
 - (b) The general presence of titanium dioxide.
 - (c) The general absence of kaolin or silica.

The present writer's experience of Indian laterites is not geographically extensive, but is, nevertheless, fairly varied, including as it does the 'high-level' laterites of Chota Nagpur, Bengal, of the Southern Maratha country on the edge of the Deccan Trap, and of the Western Ghats, west of Belgaum, and the 'low-level' laterites of the Portuguese territory of Goa on the west coast of the peninsula. There is no necessity in this place to describe the physical aspect of laterite. A general description may be found in Oldham's edition of Medlicott & Blanford's Manual already quoted, and for fuller details the reader may be referred to the papers of Newbold³ and of Lake,⁴ which, despite the age of the former, remain by far the best descriptions of 'high-level' and of 'low-level' laterite respectively.

It was an examination of sections of the lateritic manganese deposits of Talevadi, on the edge of the Western Ghats and overlooking the Goa peneplain 2,500 feet below, that first suggested the theory of lateritic genesis presently to be outlined (see Fig. 1, p. 538). There, pits in search of manganese expose the laterite in process of formation and give sections of some 30–40 feet in depth. The bottom of a typical section shows a white decomposed friable sandy rock which, from exposures elsewhere, is regarded as a decomposed biotite-quartz schist. This passes upward without any abrupt change through a buff sandy clay to a reddish buff, soft rock containing small indistinct ferruginous secretions and minute manganese nodules. As the surface is approached the rock gradually acquires depth in colour, while the contained manganese secretions become larger and better defined until, at the surface, they are 2–3 feet across with a like depth. With increase of ferruginous content, the rock becomes so hard that, at the surface, it is often necessary to use explosives to disintegrate it. A few

¹ Rec. Geol. Surv. India, vol. xvi (1833), p. 113.

² *Ib.*, vol. xxxiii, p. 178.

³ Journ. As. Soc. Bengal, vol. xiii (1844), p. 990.

⁴ Mem. Geol. Surv. India, vol. xxiv (1890), pt. iii, p. 17.

feet below it can be cut with a spade. Through the manganese secretions there ramify veinlets of gibbsite—Fig. 1 (1)—much of it of metasomatic replacement. It is, consequently, the last deposited product. In the immediate neighbourhood of the mangani-ferous laterites the writer found small areas of high-grade pisolitic bauxites. There are, therefore, in this neighbourhood all the ordinary forms of laterite—ferruginous, aluminous, and mangani-ferous. The last has not generally been distinguished, but it cannot be dissociated genetically from the other two.¹

The low-lying country of Goa between the coast and the Deccan plateau furnishes extensive deposits of 'low-level' laterite, partly

FIG. 1.—Typical Section of Laterite, Talevadi, Belgaum.

(1) Psilomelane with gibbsite veinlets.

detrital and partly secretory in origin. Examination of this area elicited no further data than were collected by Lake for a similar coastal region further south in Malabar.² Two main forms, the vesicular and the pellety, were distinguished. The latter is often partly derived from the erosion of the former, but its final consolidation and cementation is due to the same agencies that gave rise to the first or vesicular form.

The rainfall of the edge of the Western Ghats and of the Goa country ranges from 120–180 inches in the year, but falls almost

¹ See, however, Mallet, *Rec. Geol. Surv. India*, vol. xvi (1833), p. 117; Bose, *ib.*, vol. xxii (1889), p. 225.

² *Mem. Geol. Surv. India*, vol. xxiv (1890), pt. iii, p. 17.

entirely from June to October, a period of four months. At Karwar, for example, rain has fallen on 72 successive days, and yet the total number of rainy days in the same year has been no more than 120. The average shade temperature of the same region is a trifle below 80° F., with a monthly range of from 75° to 84° F. With such rainfall and temperature vegetation is naturally luxuriant, especially in the lower-lying regions. During the cold weather, the dry field season of India, little or no idea of the moisture precipitation of these regions can be gained. Especially is this the case on the higher lands. The Atli laterite plateau, north of Castle Rock, when seen in January was a dry and arid, hopelessly waterless, area. Fortunately the exigencies of *shikar* took the writer over the same area in late July. The plateau, so far as it could be seen for the driving rain and mist, was then, to outward appearance, a morass, though, through its thin covering, one thankfully felt the hard laterite crust beneath. Periods of dessication and saturation are thus very well marked.

Regions of abundant rainfall in tropical climates are well wooded, and humus being always abundant the proportion of carbon dioxide in solution in the soil is correspondingly high. Boussingault and Lewy¹ show that, in a temperate climate, the air of a soil rich in humus may contain more than one hundred times as much carbon dioxide as atmospheric air. Considering the greater rapidity of decay and chemical change in tropical regions, this factor is likely to be greatly exceeded in India. The amount of silica dissolved in underground waters may also be taken as a measure of the amount of carbon dioxide in solution, and Struvé² has shown that the amount of silica thus dissolved is much greater in regions of abundant vegetation than in those where it is absent or sparse.

There is no need in this place to discuss at length the action on silicates of waters containing alkaline carbonates and carbon dioxide in solution. Bischoff, fifty years ago, suggested that the silicates were decomposed by these agencies, and Kahlenberg and Lincoln³ have recently shown that the resulting silica separates in the form of colloidal silicic acid.

The normal weathering change of feldspars in temperate regions is undoubtedly to kaolin, as indeed is sufficiently indicated by the analyses of the Rowley Regis dolerite by Dr. Warth⁴ in connection with this very subject. The general equation may be represented thus: taking, say, albite as a typical feldspar, $2\text{NaAlSi}_3\text{O}_8 + 10\text{H}_2\text{O} + \text{CO}_2 = \text{H}_4\text{Al}_2\text{Si}_2\text{O}_9 + \text{Na}_2\text{CO}_3 + 4\text{H}_4\text{SiO}_4$. Where abundant carbonates are produced, as is apparently the general case in humid India, the change is not to kaolin but rather to a sericitic form:⁵ thus, $3(\text{NaK})\text{AlSi}_3\text{O}_8 + 10\text{H}_2\text{O} + \text{CO}_2 = (\text{NaK})\text{H}_2\text{Al}_3(\text{SiO}_4)_3 + (\text{NaK})_2\text{CO}_3 + 6\text{H}_4\text{SiO}_4$; and herein probably lies the explanation of the general absence of kaolinite from the purely

¹ Quoted by Merrill: "Rocks, etc.," p. 178.

² Pogg. Annal., vol. vii, pp. 341, 429.

³ Journ. Phys. Chem., vol. ii (1898), pp. 77-90.

⁴ GEOL. MAG., Dec. V, Vol. II (1905), p. 21.

⁵ Lindgren: Trans. Amer. Inst. M.E., vol. xxx, p. 614.

superficial deposits of India, though, in the form of lithomarge or halloysite, it occurs in abundance at shallow depths.¹

The equation most fitted to Indian conditions is, however, one more in accordance with the general conclusions of Kahlenberg and Lincoln, and one also indicative of more energetic chemical action in the presence of abundant carbon dioxide. Here the silicates are completely decomposed, all the silica passing off as colloidal silicic acid. The action may, and doubtless often does, take place through an intermediate sericite or lithomarge stage, but the simplest expression is adopted.

By this process of carbonation aluminium hydrate may similarly be derived from any other of the felspar family, from the micas, from the feldspathoids, from the scapolites, and from many of the minerals of contact metamorphism. We have, therefore, no difficulty in finding an origin for all the aluminous hydrates of laterites. By carbonation also ferrous and probably manganese carbonates in like manner result from the decomposition of the ferro-magnesian silicates. It is, of course, not insisted that any of the resulting compounds are definitely formed, but rather that they are merely potential salts in ionized solutions.

So far the equations given are in accordance with numerous data and with generally accepted principles. The origin of the ilmenite and titanite acid met with in most laterites is by no means so clear, but it may at once be conceded that their manufacture is certainly a task from which even the stoutest-hearted of bacteria might recoil without incurring the odium of pusillanimity. Data concerning the alterations of titaniferous minerals are scanty. Rutile and ilmenite may, as suggested by Van Hise,² be derived from original sphene:

the last equation being reversible. A careful examination of thin sections failed to reveal any leucoxene in the laterite, but this form of titanic acid, unless under exceptional conditions, would be distinguishable with great difficulty from the bauxite matrix.

Titanic acid is, however, by no means confined to laterites and bauxites among superficial deposits. The extensive soil analyses of Dunnington³ showed its presence in all the 72 soils gathered from many parts of the world and examined by him. The average percentage of TiO_2 obtained for the whole series was .95. When to this normal percentage is added that collected by the exceptional facilities enjoyed by laterites for selective segregation, the high percentage contained by many bauxites is perhaps no matter for surprise.

We have thus derived by the agency of carbonating waters from

¹ [A more satisfactory formula to represent the process of sericitization in alkali felspars is that given by Van Hise (*Metamorphism*, p. 254): $3 \text{KAlSi}_3\text{O}_8 + \text{H}_2\text{O} + \text{CO}_2 + \text{K}_2\text{H}_2\text{Al}_2\text{Si}_2\text{O}_{12} + 6 \text{SiO}_2 + \text{K}_2\text{CO}_3$.—*EDIT. GEOL. MAG.*]

² U.S. Geol. Surv., Mon. 47 (1904), p. 227.

³ Amer. Journ. Sci., vol. xlii (1891), p. 491.

underlying or adjacent rock masses, in solution, and probably in ionized solution, all the materials essential to the formation of laterite. There is now to be considered the machinery necessary to bring it to its resting-place at the surface. The conditions of successive dessication and saturation in regions of lateritic growth have already been indicated. During the former period the motion of ground waters is always from the region of greater to the region of lesser humidity, or, in this case, upward to the surface. Upward transmission is effected entirely by molecular attraction, resulting where conditions are favourable in capillary motion, that directly due to dessication being intensified by the needs of forest rootlets. The potency of capillary transmission may be gathered from the experiments of King,¹ who showed that molecular attraction, acting in capillary openings in a porous rock, was capable of raising from a depth of four feet an amount of water equivalent to an annual rainfall of 63·85 inches. The larger tubes anastomosing in laterite have often been described, and microscopic examination of both ferruginous and aluminous laterites discloses numerous tubular openings both capillary (·0002–·508 mm.) and super-capillary (exceeding ·508 mm.).

With the approach of ground waters to the surface and their consequent super-saturation in the dessicated region, separation of the contained solids takes place, at first, it would seem, on the tube-walls and around pisolites. The minute tubes in the matrix of most laterites render it probable that some moisture passes entirely through the laterite crust and that a slight deposition takes place on the laterite surface exposed directly to the atmosphere, but by far the greatest amount of deposition must take place on the under side of the hard surface crust. During the dry season the whole of the contained load of the upward moving waters is thus deposited. There is at that time in the dessicated rock and soil but little metasomatic replacement, though segregation may readily take place as the solutions become more and more concentrated. During the period of saturation, however, all soluble constituents deposited during the previous dry season are dissolved and carried away. The insoluble constituents are thus left to obey in a moisture-saturated soil their natural laws of growth. They are further segregated, and deposited in most cases as fine bands around already formed concretions. Segregative action is well marked in the Talevadi sections, the lower zones, nondescript in colour and composition, passing upwards into well-defined ferruginous laterite, manganese ore (mainly psilomelane), pure bauxite, and gibbsite.

In the ordinary course of formation of laterite a surface crust is first formed which increases in purity, hardness, and depth with every successive dry season. The depth and hardness of the hard unaltering layer may, therefore, in areas in which laterite is still being formed, be some measure of the age of the deposit. All stages are met with. At Talevadi the hard crust is two to three feet thick, in the Central Provinces it is often 20–30 feet in

¹ U.S. Geol. Surv., 19th Ann. Rep. (1899), pt. ii, p. 85.

thickness, while in Goa it may often be cut from the surface with a spade.

From the foregoing it is evident that laterite must be regarded, not as the direct product of the decomposition of a rock *in situ*, but essentially as the *replacement* of such a decomposition product, for though the ground waters may have derived their mineral content from the underlying rock, they may also have brought it from sources widely separated. A laterite may thus result from the individual or combined decomposition of basalts, gneisses, or schists, and there may, in its hardened upper surface, be no particle of the rock whose former place it now occupies.

The assertion of a previous writer¹ that there always is a sharp change from the soft decomposition product beneath laterite to the absolutely fresh rock below is not borne out by field sections. Such sharp changes certainly do occur, but they are exceptional, and occur only where the laterite is 'low-level' recemented detritus,² or occasionally where laterites overlies difficultly decomposable beds in the Deccan Trap. In the latter case, the downward rate of weathering of the trap is inversely as the lateritization, since, generally speaking, with increase of the latter, flow and ingress of surface waters, the only rapid weathering agent in the case of a solid homogeneous basaltic lava, are restricted. A sharply defined boundary, therefore, indicates the horizon at which the downward lateritization finally overtook the downward weathering.

Under the replacement hypothesis, all substances dissolved in the ground waters should be brought to the surface, and some explanation of the absence of silica from lateritic deposits is, therefore, necessary. As already seen, the silica formed is carried away as colloidal silicic acid, on the instability of which it is unnecessary to dwell. When not decomposed by simple "chemical after-effect," it is probable that the humic acids of the upper portion of the zone of weathering are competent to change its state and to precipitate it. Precipitation is always liable to take place in a region where the laws of mass-mechanical action—to which silica in solution is peculiarly subject—may operate. That much of the silica formed by carbonation is thus deposited we have evidence even in the lateritic regions of the Central Provinces, where both the Lametas (Upper Cretaceous) and the underlying crystalline rocks have been so thoroughly silicified as to render it often impossible to determine whether an area is to be mapped as Upper Cretaceous or as Archæan.³ Limestones (both Lameta and Archæan), gneisses, and pegmatites are there so completely replaced by chert that only by the indications of the original structure can they be differentiated.

Though the foregoing explanation of the absence of silica is neither full nor satisfactory, yet the replacement hypothesis is not thereby vitiated, since, whatever the explanation, the facts remain that everywhere immense quantities of silica are being dissolved,

¹ GEOL. MAG., Dec. IV, Vol. X (1903), p. 69.

² Lake: Mem. Geol. Surv. India, vol. xxiv (1890), pt. 3, p. 30.

³ L. L. Fermor: Rec. Geol. Surv. India, vol. xxxiii (1906), p. 173.

and that nowhere, except in the thermal regions, are siliceous deposits brought to be deposited at the immediate surface of the earth.

The peculiar disposition in altitude of Indian laterites has always presented a difficulty to geologists, and many have called to their aid lakes, or even the sea, to account for the general horizontality noted. The 'high-level' laterite covers flat-topped hills, which may range from 2,000 to 4,700 feet above sea-level, and higher still on the Nilghiris, while the 'low-level' form occupies the eastern and western peneplains. In both upper and lower areas, however, adjacent laterite caps may occur at different levels,¹ indicating either disconnected deposits or differing age. In the region of the Deccan Trap, the widespread horizontality of the laterite is merely an expression of that of the Trap beneath (*loc. cit.*, p. 261), which has filled up the inequalities in the surface of the older rocks. A consideration of the conditions of lateritic formation will show that only on level or approximately level surfaces can laterite form. Its growth is exceedingly slow, and only the surfaces of plateau basins or plains are stable for a sufficient length of time to permit of growth. Even a moderate slope changes its surface cover rapidly in a region of excessive rainfall. Again, it is only on an approximately level surface that the continued moisture saturation necessary for the solution of the soluble constituents and for the rearrangement of the deposited salts may be obtained. Judging, therefore, by the conditions under which laterite is considered to be forming at the present day, the 'high-level' laterite capping hills represent the level of ancient upland plains, or more probably flat broad basins, which abutted against or were enclosed by hills. It is the general recognition of the horizontality of many deposits that has given rise to the hypothesis of lacustrine sedimentary origin, an origin thought to be supported by the concretionary structure before noted. Concretionary or pisolitic structure, however, as a general rule, does not arise under open water conditions, but is characteristic rather of loosely coherent muds, clays, or moist sands. An analogy with the lake iron-ores of Sweden has been sought by some writers, and the presence of limonite-secreting bacteria in those deposits has probably suggested the Indian bacterial theory.

During the progress of denudation, the high hills in the neighbourhood of the basins, being unprotected by laterite, have disappeared, and their place is now occupied by valleys. Many of these ancient basin floors are situated in what are now dry regions, and it is probable in such cases that the vanished hills attracted the necessary amount of moisture. For example, in the neighbourhood of the laterite-capped Kappat Guda (3,007 feet), east of Dharwar, the rainfall is no more than 25 inches per annum, and no laterite is being formed at the present day. This region, lying at about the same height above the sea-level as the edge of the Western Ghats, incidentally illustrates well the nature of the surface products

¹ Oldham: in *Medlicott & Blanford's Manual of Geol. India*, pp. 374 et seq.

generated in areas of deficient moisture. Its soil is crowded with 'kankar'—small irregular concretions of carbonate of lime—which may, in the stream beds, form a calcareous tufa, while the rivulets that do run in the dry season through the black cotton soil are bitter with alkaline salts. These are exactly the products removed in regions of abundant rainfall.

Except when the humidity is great, the laterite crust supports a very scanty vegetation, and, even in humid areas, it is probable that much of the carbon dioxide essential for carbonation is derived from the decaying humus on the hill-sides above the laterite basins. The older laterites on the hill-tops are devoid both of vegetation and of soil.

The chemical aspect of the Indian aluminous and ferruginous laterites has been well developed by the analyses of Dr. Warth.¹

Some little attention has been paid by the present writer to the nature of the minerals present. The bauxite, especially selected for examination since it promised to yield the most conclusive results, was one from Katni, Jabalpur district, which had been analysed in the Geological Survey Laboratory,² as follows:—

Al ₂ O ₃	65.48
Fe ₂ O ₃	3.77
H ₂ O	18.32
Moisture	1.06
Si O ₂	0.38
Ti O ₂	11.61
Mg O	trace
<hr/>	
100.62	

The molecular ratio of Al₂ O₃ to H₂ O is lower (1 : 1.58) in this specimen than in any other analysed, and for this reason it was expected to show more clearly than any other the presence of diaspoire, should the assumption of Warth and others, viz. that bauxite is a *mixture* of gibbsite and diaspoire, be correct. Neglecting, as Warth has done, and with sufficient reason,³ the consideration of the water due to possible limonite in the specimen, the foregoing ratio of 1 : 1.58 represents 29 per cent. gibbsite and 71 per cent. diaspoire. It was, therefore, considered probable that a separation might be effected with a heavy solution, the specific gravity of gibbsite being 2.4 and of diaspoire 3.4. Carefully and finely ground bauxite was treated with Sonstadt solution of 3.07 s.g. All except very fine black grains (ilmenite) floated. The specific gravity of the specimen as a whole was taken, and gave incidentally an excellent illustration of the porous nature of bauxite. A large fragment was soaked for a day in water with gentle heating, and gave a result of 2.487. Individual concretions from the same specimen gave 2.53, while the mean of three determinations of the fine powder gave 2.81. The last is taken as the true specific gravity of the Katni specimen.

¹ GEOL. MAG., Dec. IV, Vol. X (1903), p. 158.

² Rec. Geol. Surv. India, vol. xxxii (1849), p. 179.

³ Loc. cit. sup., p. 155.

The chemical analysis shows that at least 15 per cent. of the mass has, in the form of ilmenite and possible rutile, a specific gravity of more than 4.3. The remaining 85 per cent., therefore, has a specific gravity of not less than 2.65. But an intimate mixture of 71 per cent. diaspoire and 29 per cent. gibbsite should have a specific gravity of 3.03. Rough though the calculation is, it is nevertheless sufficient to show that the two lines of deduction are hopelessly conflicting, and it must either be assumed that diaspoire is not present or that the monohydrate, if present, is in a form physically different from diaspoire. Additional evidence against diaspoire lies in its absence from all thin sections examined.

FIG. 2.—Thin section of portion of a Bauxite concretion, Katni, Jabalpur, showing gibbsite crystals (colourless) in bauxitic (dark) groundmass.

A typical thin section of a concretion from the Katni rock throws considerable light on the structure and internal characters of bauxite (Fig. 2). The mass of the rock is made up of white opaque bauxite with a well-defined banded structure near the exterior of the concretion. Scattered through the interior and avoiding the outer band, are numerous irregular areas of gibbsite in rosette-like aggregates. Dispersed everywhere irregularly through the interior of the section, but disposed in more or less linear arrangement in the outer band, are numerous minute black and brown specks, too small, indeed, to be determined with ease or accuracy. The black grains are, however, almost certainly ilmenite, while the brown granules may be rutile, but, from comparison with other sections, are thought to be more probably the clove-brown micaceous ilmenite.

A consideration of the disposition of the gibbsite indicates clearly

that it is being formed at the expense of the bauxite, and, indeed, the process may be traced in the section in all its stages. A slight clearing takes place in the opaque mass, and an irregular translucent microcrystalline area is formed. In this area, tiny flecks of gibbsite are developed, gradually coalesce, and finally fill the whole area. This process of crystal growth is especially well marked along the internal edge of the concretionary border, where the gibbsite is extending outwards into the newly accreted bauxite. That bauxite is being converted to gibbsite, and not the reverse, is confirmed by the occurrence of banded gibbsite on the walls of the pores that ramify through the mass.

The evidence of thin sections, therefore, shows that the change in laterites, so far from being one of dehydration to diaspore, as postulated by Holland,¹ is one of hydration to gibbsite. This conclusion is supported by the occurrences of gibbsite found by Messrs. Warth, Fermor, and the writer in widely separated parts of India, and all these show that, at least under the generally prevailing, comparatively humid Indian conditions, gibbsite is the stable hydrate of alumina. Strong negative evidence to the same effect lies in the fact that diaspore has not yet been recorded from India. As a matter of fact, the evidence against hydration quoted by the above writer, being drawn mainly from the petrological characters of certain rocks in the Salem and Coimbatore districts, is considered by the present writer to be inapplicable to the more humid parts of India. The average annual rainfall for Salem is but 39·20 inches per annum, while that for Coimbatore is even less (21·10 inches). At both stations rain fell during ten months of the year 1904. There is thus little opportunity for hydration, while dehydration might well be effected. But the argument derived from such a dry region can obviously not be applied to the lateritic deposits of the Western Ghats with their rainfall of 120–180 inches in four months of the year.

Finally, the conclusions to which the writer has been led in connection with laterite are the following :—

1. Lateritic deposits are restricted geographically, because they require for their formation—
 - (a) Tropical heat and rain with concomitant abundant vegetation.
 - (b) Alternating wet and dry seasons.
2. Their restriction in altitude is only apparent. Their present lines of altitude merely mark ancient or existing basin floors or plains.
3. They are derived from mineralized solutions brought to the surface by capillarity, and are essentially replacements (either mechanical or metasomatic) of soil or of rock decomposed *in situ*, or of both.
4. In the humid regions of India the tendency of change in laterites is towards hydration and not towards dehydration.

¹ GEOL. MAG., Dec. IV, Vol. X (1903), p. 65.

The foregoing replacement hypothesis would appear to supply a fairly reasonable explanation for all the eccentricities of laterite. When it was first developed by the writer, it was thought to be entirely novel, but investigation of the literature of the subject has shown that several writers have suggested the alternation of wet and dry seasons as a predisposing cause¹; while Hislop² says that "the ferruginous matter coming up from among the metalliferous strata, might, by the agency of water, have impregnated every decaying rock on the surface, which, with the subsequent infiltration of rain, would then present the appearance of laterite, as we now find it"!

IV.—NOTES ON THE OPERCULATE MADREPORARIA RUGOSA FROM YASS, NEW SOUTH WALES.

By A. J. SHEARSBY.

(PLATE XXVI.)

THE town of Yass, N.S.W., is situated on the Southern Railway about 190 miles from Sydney. It is the centre of one of the most picturesque districts to be met with on the journey from Sydney to Melbourne. The surrounding country is a veritable geological and palæontological paradise for the collector, who may depend upon turning up some new and interesting specimens every trip he takes to the district. The town itself is built on the Upper Silurian rocks, which about two miles distant, at a bend in the Yass River known as Hatton's Corner, offer to the palæontologist one of the most prolific collecting-grounds in Australia. Amongst the first to investigate these rocks were the Rev. W. B. Clarke³ and Mr. C. Jenkins,⁴ whose work was followed by a survey in 1882 by the Mines Department.⁵ Further good work was done by Mr. John Mitchell⁶ whilst stationed in the district; but even at this late hour there is a large amount of interesting work awaiting completion.

About ten miles to the south and south-west of the town are found the vast accumulations of Middle Devonian deposits, which are separated from the Upper Silurian rocks by a thick bed of lavas and tuffs which I believe to be the result of volcanic action during the Lower Devonian period.⁷

¹ Broughton, Journ. As. Soc. Bombay, vol. v (1857), p. 639; Lapparent, *Traité de Géologie*, p. 1611.

² Journ. As. Soc. Bombay, vol. v (1857), p. 63.

³ W. B. Clarke: "Remarks on the Sedimentary Formations of N.S.W.," 4th edition, 1878.

⁴ C. Jenkins, "Geology of Yass Plains": Proc. Linn. Soc. N.S.W., vol. iii, pt. 1 (1878), p. 26.

⁵ T. W. E. David, "Report on the Fossiliferous Beds, Yass": Ann. Rep. Dept. Mines N.S.W., 1882 (1883), p. 148.

⁶ J. Mitchell, "Notes on the Geology of Bowning": Proc. Linn. Soc. N.S.W. (2), vol. i, pt. 4 (1887), p. 1193. "The Geological Sequence of the Bowning Beds, N.S.W.": Report Austral. Assoc. Adv. Science, vol. i, 1888 (1889), p. 291.

⁷ A. J. Shearsby, "On the Occurrence of a Bed of Fossiliferous Tuff, etc.": Proc. Linn. Soc. N.S.W., 1905, p. 275.