

The only other area where 'Tremadoc' rocks occur in the St. David's district is at Tremanhire, north-east of Solva. They have been examined recently by Mr. H. H. Thomas and Professor O. T. Jones, who kindly inform me that they consider the rocks to be undoubtedly of Arenig age. They yield an *Ogygia*, probably *O. selwyni*.

V.—WHAT IS LATERITE?

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(Concluded from the November Number, p. 516.)

Laterite a stratigraphical as well as a petrographical term.—In this paper I have urged the advisability of applying the terms *laterite*, *lithomargic* and *quartzose laterite*, *lateritic lithomarge*, etc., to certain rocks, all of which some geologists would include under the term *laterite*. This restriction of the use of the word *laterite* is advocated in the petrographical sense. Besides being used as a rock name, this word is also applied as the name of a geological formation in India, ranging from Tertiary, through Pleistocene, into recent times,¹ for probably in some parts of India, as in other parts of the tropics, laterite is still in process of formation. As the name of a formation, the term *laterite* comprises, not only substances that petrographically are true laterite, but also lithomargic and quartzose laterites, lateritic lithomarges, and lithomarges that are practically free from lateritic constituents, not to mention various laterite-cemented detrital rocks. Consequently, in mapping geologically in India it is necessary to include as laterite many rocks that petrographically are not laterite.

The parallel to such a twofold use of the word is easy to find. The Charnockite Series includes members that are not charnockite. The Bengal Gneiss is the name of a geological formation containing not only gneisses, but also limestones, dolomites, and mica-schists. No one wishes to call a piece of limestone from this formation "a piece of Bengal gneiss". Similar examples occur in the stratigraphical nomenclature of most countries.

It is probably failure to notice this twofold application of Buchanan's original term in Indian geology that has led geologists in other parts of the world to a comprehensive use of the term petrographically, as well as stratigraphically. There can be no objection to engineers using the term in a wide sense, for although some of the substances designated *laterite* by them will not be laterites in the petrographic sense, yet they will in most cases belong to lateritic formations.

IV. THE APPLICATION OF THE TERM BAUXITE.

The question whether the word *bauxite* should be retained as the name of a definite mineral or not is not difficult to answer if one appeals to the historical side of the subject. P. Berthier,² in 1821, described a supposed iron-ore (*minerai de fer*) from Beaux near Arles in Provence, which he had analysed and found to be "composé

¹ *Manual of the Geology of India*, 1893, p. 369. On p. 385 the use of this word as a lithological and a chronological term is discussed, and the former use preferred.

² *Ann. des Mines*, vi, pp. 531-4.

d'hydrate d'alumine, mélange d'oxide rouge de fer", containing 52.0 per cent of Al_2O_3 , 20.4 per cent of H_2O , and 27.6 per cent of Fe_2O_3 , with a trace of Cr_2O_3 . Berthier says that the iron is evidently present in the mineral in the anhydrous condition and in "l'état de mélange", and that "le minéral pur" would be composed of 72 per cent of Al_2O_3 and 28 per cent of H_2O , corresponding nearly to $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$. He applies the terms *mineral*, 'ore,' and *minéral*, 'mineral,' indiscriminately to his specimen, and as he proposes no name for the substance it is difficult to say whether he regarded it as a definite mineral, as the construction of a definite formula would seem to indicate.

A. Dufrénoy, on p. 347 of vol. ii of his *Traité de Minéralogie* (1845), refers to the substance analysed by Berthier, and says "Elle ne peut être regardée comme une espèce minérale". But in the index to vol. iii of this work, published in 1847, the following entry occurs (p. 799): "Beauxite, nom donné à l'alumine hydratée de Beaux," the reference being to vol. ii.

St. Claire Deville¹ in 1861 contributes a paper entitled "De la Présence du Vanadium dans un Minéral Alumineux du Midi de la France". He heads his first chapter thus: "Minerais Alumineux ou Bauxite," showing that he regarded *bauxite* (the correct spelling) as an *aluminous ore*; further, he mentions Berthier as the originator of the name, as follows: "ce minéral particulier que M. Berthier a appelé la *bauxite*." On p. 321 Deville gives a number of analyses, one of which shows 48.8 per cent of Fe_2O_3 and only 33.2 per cent of Al_2O_3 , indicating an extension of the term *bauxite* to include very ferruginous varieties. The amount of water present in these analyses is generally insufficient for the formation of $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$. The presence of TiO_2 is shown. On p. 324 the term *bauxite* is applied to an iron-ore from Paradou in Provence containing 60 per cent of Fe_2O_3 and 18 per cent of Al_2O_3 and TiO_2 .

Sufficient is quoted above to show that the name *bauxite* was not given to a definite mineral, but to an impure aluminium-ore of very variable composition, and that consequently its application has, really, always been to a rock and not to a mineral. The assumption, perhaps only intended as a suggestion, of the existence of the definite compound $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$, first made by Berthier, and adopted by Dana, is not apparently justifiable, and it seems that *bauxite* must be regarded as a true rock, and the term *bauxite* must consequently be available to petrographers for use in this sense. The matter is summed up admirably by Professor Lacroix on p. 342 of vol. iii of his *Minéralogie de la France et de ses Colonies* (1901). Lacroix says that the examination of a large number of analyses shows that *bauxite*, where it contains the minimum of impurities, approaches nearer to the composition of diasporé than of any other mineral, and that *bauxite* is to be regarded as constituted of various colloid hydroxides of aluminium, mixed with the corresponding hydroxides of iron, and with various impurities, clay, quartz, sand, etc. "C'est en réalité une véritable roche."²

¹ Ann. Chim. Phys., ser. III, lxi, pp. 309-42.

² Since the above was written we have received in the library of the Geological Survey of India, vol. cxlviii of the *Comptes Rendus* (1909), in which there are

The term *bauxite* was, as is seen above, extended by Deville to rocks very high in Fe_2O_3 , and it has often been used in France to correspond with rocks ranging from the most aluminous to the most ferruginous laterites of India. Mr. Scrivenor's contention, then, would seem to be upheld, namely, that we can replace the term *laterite* by the word *bauxite*. But it should be remembered that the term *laterite* dates from 1807, and the term *bauxite* only from 1847. The French mineralogists have, therefore, used the word *bauxite* for a substance for which a name already existed, and therefore if any change were necessary we should call upon our French colleagues to drop the term *bauxite* and to substitute for it the term *laterite*. Such a course would be absurd, and I think the most desirable procedure is to restrict the term *bauxite* to those varieties of *laterite* sufficiently rich in alumina to be used as aluminium-ores. If the rock contains more Fe_2O_3 than Al_2O_3 , it is not likely to be used as an aluminium-ore, and therefore I think the term *bauxite* might be restricted to those *laterites* that contain at least as much Al_2O_3 as Fe_2O_3 .

Lacroix follows a somewhat similar course. He says (p. 346) that he reserves the name *bauxite* (*sensu stricto*) for rocks of the type of those of Provence, and to the very aluminous and often pisolitic patches (*accidents*) in *laterite*, whilst he uses the word *laterite* in its customary sense—defined earlier (p. 345) as the red rock that is formed in tropical climes by the decomposition in situ of the most diverse rocks, e.g. granites, diorites, basalts, gneiss, etc.—and applied it in addition to rocks of the same composition, such as the bauxites of the Puy-de-Dôme (alteration of gneiss) and of Hesse (alteration of basalts), of which one can prove the formation in situ at the expense of silicate rocks (*roches silicatées*).

In closing this section it is interesting to notice that Mr. Scrivenor, whilst quoting Professor Lacroix to the effect that *bauxite* is a rock and not a mineral, has apparently overlooked the same author's distinction between the terms *bauxite* and *laterite*, which conflicts with his (Scrivenor's) suggestion that the term *laterite* should be replaced by the term *bauxite*.

V. THE LATERITIC EARTHS OF BRITISH GUIANA.

I will conclude this paper with a brief consideration of the surface decomposition rocks of British Guiana, as discussed in this Magazine (already summarized), and which have given rise to this communication. I will take Professor Harrison's paper entitled "The Residual Earths

two notes, on pp. 936-8 and 1115-18 respectively, by M. H. Arsandaux, "Sur la composition de la bauxite." In the earlier note it is shown by treating certain French bauxites with concentrated HCl , and then attacking the insoluble residue with concentrated H_2SO_4 , that nearly all the alumina is present as $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$, thus corresponding, although the rocks were found in thin sections to be completely isotropic, to the composition of diaspore. The iron is shown to be present as anhydrous Fe_2O_3 . The titania is believed to be present as metatitanic acid, $\text{TiO}_2 \cdot \text{H}_2\text{O}$, and the small quantities of silica as $2\text{H}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ (the kaolin or lithomarge formula). The second note deals with the more siliceous bauxites (also completely isotropic), and indicates the existence of every gradation between clay and $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$.

of British Guiana commonly termed 'Laterite', in the *GEOLOGICAL MAGAZINE*, 1910, pp. 439, 488, and 553.

On p. 441 is given a table of analyses of "laterite soils". Only one of those soils contains less than 50 per cent of "gravel + quartz sand + clay, silica, and insoluble silicates", namely, the soil derived from hornblende-schist at Maburima. This might be termed *argillaceous laterite*, the adjective applicable depending on the exact nature of the 29·16 per cent representing the third item above. Some of the other soils, namely, those containing considerable amounts of oxides of iron and aluminium, such as Nos. 1, 4, 9, 12, and 13, might be termed *lateritic clay, soil, or sand*, whilst the majority of the others would be best designated clay, gravel, sand, or soil, without the dignity of the adjective 'lateritic'.

In Table II, on p. 444, showing decomposition products from Issorora Hill, the *red lateritic earth* is correctly named. The *concretionary ironstones* and *ironstone pisolites* are also correctly named, but might be regarded as varieties of laterite, being the results, in fact, of the segregation of the lateritic constituents of the *lateritic earth*.

In Table V, on p. 447, three rocks are boldly classed as laterites. To none of them is the name, in my opinion, applicable. The earths from Tumatumari, Omai Falls, and Mazaruni contain 47·3, 45·8, and 39·9 per cent of lateritic constituents respectively, and should, by preference, be termed *lateritic earths*.

The sericitic earth represented by Table VII on p. 449 contains 37·6 per cent of lateritic constituents and might also be termed *lateritic*. The three samples of *bauxite* or *laterite* shown in Table IX on p. 451 are correctly so named, and are in fact the only "residual earths" noticed in Harrison's paper to which the term can be correctly applied, with the exception, perhaps, of the segregations of concretionary ironstone or lateritic iron-ore in the red lateritic earth of Issorora Hill.

But these three samples which I regard as the only true laterites described by Harrison, represent, according to this author (p. 488),

"the extreme of the formation of laterite, where the igneous rock, in place of weathering to a mixture of quartz, of kaolinite, of bauxite, and of the oxides and hydrates of iron, changes almost completely to quartz and to hydrates of alumina and the oxides and hydrates of iron."

Further, he says (p. 489) that the foregoing examples, that is to say, all the various soils, earths, and laterites noticed above,

"represent the types of the residual deposits in situ in British Guiana, which I have regarded as and termed laterite."

And in Table X he gives the mean proximate composition of the British Guiana lateritic earths examined by him as follows:—

Quartz	24
Iron-ores (including pisolites)	32
Kaolin, Sericite, and other feldspathic debris, etc.	24
Bauxite	20
	100

This corresponds to 52 per cent of lateritic material and 48 per cent

of non-lateritic material, and, although just within the limits for laterite, yet judging from Professor Harrison's descriptions and the composition of the earths taken individually, I think he would be more in conformity with usage were he to use the term *lateritic earths* when speaking of these substances as a whole, and not to use the terms 'laterite' and 'lateritic earth' as equivalent and interchangeable.

On p. 494 analyses are given of two pisolitic 'laterites' which evidently deceived Professor Harrison as much as the similar Indian pisolitic lithomarge of which the analysis is given on p. 510 deceived Maclaren and me; for the analyses quoted show that instead of obtaining rocks to correspond to Du Bois' pisolitic iron-ore and oolitic bauxite as he intended, Harrison has collected merely a ferruginous kaolin in one case, and a less impure kaolin or lithomarge in the other.

The Laterite of Surinam.—On p. 558, Table XXIV, three technical analyses of laterites from Surinam are quoted from Du Bois' monograph. These show respectively 91.4, 84.1, and 94.5 per cent of hydrated oxides of alumina and iron, and two of them are nearly as pure as some of the best Indian laterites.

On the bottom of p. 558 Harrison refers, in the following words, to the only laterite he has seen in Surinam:—

"Here there is a gradual change of the decomposing schist into its laterite, the change extending to considerable depths in the schist. The lateritic earth, covered in places by concretionary masses of ironstone, reminded me of Logan's account of the ferruginous and silico-ferruginous rocks and laterite of Singapore . . . and of Mr. Scrivenor's description of the laterite of the Malay Peninsula . . ."

Judging from the description this Surinam rock is not a residual deposit, but a metasomatic replacement deposit, for which I have offered the term *lateritoid*, which I have already remarked seems applicable to Mr. Scrivenor's laterite.

Professor Harrison is, however, only following Du Bois¹ in his wide extension of the term *laterite*, for the latter in his paper on the laterite of Surinam divides his laterites into—

- (1) Primary (Eluviale) laterite, or laterite rich in silica, and
- (2) Secondary (Alluviale) laterite from laterite detritus, or laterite rich in aluminium hydroxide.

But Du Bois has also, I think, extended the term too widely, and although some of the analyses given in his paper represent rocks that can fairly be designated laterite, the remainder cannot, in my opinion, be so classed; for example, the decomposition products of diabase given on p. 24 of Du Bois' paper, which are merely *partially altered diabase*. The analyses on p. 28 represent substances that contain some 65 per cent of quartz and clay, and might be called *lateritic sand* or *earth*, but might also be allowed the names *alluvial* or *secondary laterite*, given to them by Du Bois. The analyses given on p. 37, however, represent *true laterites*. These are the ones quoted by Harrison.

From the foregoing it will be seen that if one accepts the ideas as to what is a true laterite put forward in this paper, it becomes

¹ Tschermak's *Mittheilungen*, 1903, p. 18.

apparent, judging from the work of Harrison and Du Bois, that the term has been too widely used in the Guianas.¹

Hardening properties of laterite—Professor Harrison's paper bristles with other controversial points, but this communication has already grown to an inordinate length, and consequently I will refer to one other point only. It is a mistake to think that all laterites will behave in the way that the laterite first described by Buchanan behaved, namely, that they will be found to be soft when first quarried and will harden on exposure to the air, except to the small extent that most rocks harden owing to evaporation of contained moisture. In my experience certain varieties of laterite (e.g. high-level laterites of Balaghat) that both in chemical composition and in physical appearance are true laterites, and to which Buchanan would undoubtedly have applied the term, are not found to be markedly softer when quarried than after exposure to the air. Further, Harrison on p. 493 of his paper describes a clay-like mass that hardens on exposure, and which analysis shows to contain 50.3 per cent of feldspar and 22.1 per cent of kaolinite, with only 24.5 per cent of lateritic constituents.²

Consequently, to appeal to this setting property of a rock, in

¹ The same remark probably applies to many another tropical area in which *lateritic rocks* occur. Thus, I have quoted with approval the work of M. Arsandaux on the French bauxites (see note, p. 561). But I do not agree with his two later notes (pp. 682-5 and 1082-4 respectively, of C.R., vol. cxlix, 1909), in which he gives and discusses analyses of 'laterites' from the *French Congo* and the *Soudan*. As before, he extracts the Fe_2O_3 , and in this case the free Al_2O_3 as well, with concentrated HCl , and decomposes the insoluble residue by means of concentrated H_2SO_4 . To the former fraction (my *lateritic constituents*) he pays no attention, but shows that the portion insoluble in HCl , which amounts to 68-99 per cent of the whole rock, varies in composition from micaceous aluminopotassic silicates allied to muscovite to kaolin practically free from alkalis. Most of these rocks have been formed in situ by the weathering of crystalline rocks (granites, schists, etc.), and it is evident from the author's analyses and descriptions that his so-called laterites are really *clays* containing a certain, usually small, proportion of lateritic material. The very uppermost crust may be laterite, properly so called, but no analyses of this are given.

Reference may also be made to the analyses of 'laterites' (derived from basic rocks—diabase and ophite), from *French Guinea*, by J. Chateaud and P. Lemoine (C.R., vol. cxlvi, pp. 239-42, 1908). The analyses show, in most cases, a considerable amount of silica, but it is apparently (p. 241) almost entirely in the free condition. On this assumption, No. 11, with only 5.52 per cent of SiO_2 , is a *true laterite*; Nos. 136, 179, 180, 181, and 185, containing 12 to 28 per cent of SiO_2 , are *quartzose laterites*, whilst No. 195 (derived from phyllite) with 62.30 per cent of SiO_2 cannot be regarded as a laterite at all. That the authors do not regard these rocks as completely formed laterites (my true laterites) is indicated by the following passage: "La silice est presque complètement rendue libre; les $\frac{2}{3}$ environ ont été entraînés; le reste, qui aurait probablement disparu si la latéritisation avait été complète, ne joue qu'un rôle insignifiant et est, en majeure partie, à l'état de silice libre." A diagram illustrates the chemical losses involved in the formation of laterite No. 11 from diabase No. 2, on the assumption of constant TiO_2 .

² W. T. Blanford, in his account of the Laterite of Orissa (Mem. Geol. Surv. India, i, p. 283, 1859), referring to the lithomarge underlying the laterite, says that on exposure it becomes hard like laterite.

deciding whether or not it is a laterite, is unsatisfactory, unless considered in conjunction with the chemical composition.

VI. SUMMARY.

1. The term *laterite* is used in two ways, namely, *stratigraphically* as the name of a geological formation, and *petrographically* as the name of a tropical superficial rock. This discussion relates only to the use of the term as a rock name.

2. *Laterite* (or rather some varieties of it) is formed by a process, the *modus operandi* of which is not discussed here, by which certain rocks undergo superficial decomposition, with the removal in solution of combined silica, lime, magnesia, soda, and potash, and with the residual accumulation, assisted, no doubt, by capillary action, metasomatic replacement, and segregative changes of a hydrated mixture of oxides of iron, aluminium, and titanium, with, more rarely, manganese. These oxides and hydroxides of iron, aluminium, titanium, and manganese are designated the *lateritic constituents*.

3. This residual rock is *true laterite*, and the presence of any considerable proportion (>10 per cent) of non-lateritic constituents requires expression in the name, as it always indicates want of completion in the process of lateritization. True laterite contains, then, 90 to 100 per cent of lateritic constituents.

4. There is often a gradation in composition between true laterite as defined above and lithomarge, which is taken as the amorphous compound of composition, $2\text{H}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$, corresponding to the crystalline mineral kaolinite of the same composition. For the rocks intermediate between laterite and lithomarge the terms *lithomargic laterite* and *lateritic lithomarge* are available, the former being applied to forms containing 50 to 90 per cent of lateritic constituents, and the latter to forms containing only 25 to 50 per cent of lateritic constituents.

5. The presence of any considerable amount of quartz, either residual or secondary (this form has not, so far as I am aware, yet been noticed in Indian laterites), should be indicated by terming the rock a *quartzose laterite*, unless the amount of quartz and other non-lateritic constituents exceed 50 per cent, when the word *laterite* should appear only in the adjectival form, as in paragraph 4.

6. Many rocks to which the term *laterite* has been applied would be more aptly termed *soils*, *earths*, *clays*, and *sands*, with (>25 per cent) or without (<25 per cent of lateritic constituents) the attributive *lateritic*.

7. *Varieties* of the rock defined as true laterite are those in which one of the constituents is present in relatively large amounts, namely, the highly aluminous variety, *bauxite*, the highly ferruginous variety, *lateritic iron-ore*, and the highly manganiferous variety, *lateritic manganese-ore*. From this it follows that alumina cannot be regarded as an essential constituent of laterite, although it is usually present in smaller or larger quantity.

8. The property of *hardening on exposure* to the air is characteristic of many varieties of laterite, but it is not an essential property; for some laterites do not exhibit it, whilst cases have been recorded of

rocks that show this property and yet cannot possibly be termed laterite, although they probably contain a certain quantity of hydroxides of iron and aluminium, to the dehydration of which the setting of laterite is usually ascribed.

9. For any rocks (such as some of the *pisolitic limonites*), associated with the laterite formation, that have probably been formed by chemical deposition in lakes or bogs the name *lake laterite* is suggested. This is regarded as an unimportant variety of laterite.

10. Certain lateritic rocks that have been formed by the metasomatic replacement at the outcrops of a variety of rocks, and which cannot be regarded as residual products of the decomposition of the underlying rocks, have been designated *lateritoid*. Such rocks can usually be recognized by their preserving unaltered or but partly altered fragments of the underlying rocks, and of retaining signs of the original bedding-planes of the rocks they have replaced. They have hitherto always been found on the upturned outcrops of the quartzites and argillaceous schists and phyllites of the Dharwar formation, and usually take the form of iron-ore or manganese-ore, alumina not being an abundant constituent of the lateritoids.

11. Rocks formed by the accumulation of detritus from masses of chemically-formed laterite (or of lateritoid) either alone, or mixed with extraneous materials, such as fragments of quartz or gneiss, may be termed *detrital laterites*, as an alternative to which the term *lateritite* is suggested.

12. Most of the so-called laterites of the Guianas as described by Harrison and Du Bois are not true laterites unqualified, but are either *quartzose* or *lithomargic laterites*, or *lateritic earths*. Many of them are detrital rocks, sometimes rich enough in lateritic material to be called *detrital laterite* or *lateritite*. True laterites do, however, also occur.

13. The classification of laterites and associated rocks put forward in this paper is, of course, of a more or less tentative nature, and although it is believed to be a workable system of nomenclature, yet future work will doubtless show the desirability of various modifications and amplifications.

REVIEWS.

I.—THE ICE AGE IN NORTH AMERICA AND ITS BEARINGS UPON THE ANTIQUITY OF MAN. By G. FREDERICK WRIGHT, D.D., LL.D. Fifth Edition. 8vo; pp. xxi, 763, with 10 plates, 3 maps, and 196 text-illustrations. Oberlin (Ohio), Bibliotheca Sacra Company; London, Charles Higham and Son; 1911. Price 20s. net.

A NEW edition of Dr. Wright's great work will be widely appreciated by students and teachers, giving as it does such a clear and comprehensive view of the grander features in Glacial geology that are so well exhibited in North America. Although, as the author remarks, later investigations have not seriously affected the main theories adopted in 1889, when the first edition of his work was published, yet there have been further destructive criticisms of