V.—THE WORK OF PROFESSOR LACROIX ON THE LATERITES OF FRENCH GUINEA.

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I. INTRODUCTION.

A SHORT while ago I received from Professor A. Lacroix a copy of a recently published memoir on the laterites of French Guinea, accompanied by the request that I should, if possible, give an account of this work in the *GEOLOGICAL MAGAZINE*, "puisque c'est là qu'ont paru les articles les plus importants sur cette question." I have undertaken this task with the greater pleasure because Professor Lacroix was so good as to show me, when I was passing through Paris recently, both his hand-specimens and his microscopic preparations of these rocks, and because the memoir in question seems to me to be one of the most important and thorough pieces of work on laterite published since Max Bauer's account of the laterite of the Seychelles.¹ Although Professor Lacroix' memoir deals professedly with French Guinea only, yet it is probable that many of the conclusions will be found to apply to other regions, and on this account, and because the series in which the memoir appears will probably not be readily accessible to all, I have thought it desirable to expound it at some length.

The full title of the memoir is "Les latérites de la Guinée et les produits d'altération qui leur sont associés", the medium of publication being the *Nouvelles Archives du Musée*, sér. v, tom. v, pp. 255-356, with pls. x-xvii, 1914. It is the fruit of a visit to West Africa by the author in the winter of 1912-13, when he was able not only to explore in detail the Archipelago of Los, but also to traverse many parts of French Guinea. From Konakri on the coast to the Niger

¹ *Neues Jahrb. für Min.*, etc., ii, pp. 192-219, 1898.

Professor Lacroix followed the railway line, which provided many valuable sections; then, after examining the cuttings of a line under construction from Kouroussa to Kankan, he descended the Niger to Siguiri, which is about 360 miles in a straight line from Konakri. After touring in Bouré, a part of the ancient Sudan, he returned to Siguiri by an affluent to the left bank of the Niger, the Tinkisso, returning thence to Konakri. Professor Lacroix has also made a field study of the laterites of Madagascar on the opposite side of Africa, but he is compelled by lack of space to defer to a subsequent volume of the *Archives* an account of his work in that island.

The importance of this work on Guinea results in the first place from the fact that the author was able to examine in the field a large number of fresh sections, many of which showed the complete passage from the underlying fresh rock, through the various stages of lateritization, to the surface crust or *cuirasse*; that secondly he collected his specimens with judgment from known points in the sections, and thirdly that he has supplemented the chemical analyses (due to M. Boiteau) by careful microscopical studies of the mineralogical composition. He is thus able to trace the successive stages of change in both chemical and mineralogical composition from underlying fresh rock to surface crust. His results are rendered the more convincing by a splendid series of plates showing the field relationships (twelve photos), the aspect in hand-specimens (twelve photos), and, finally, the microscopic appearance (twenty-four photos).

II. NOMENCLATURE.

In an introductory chapter Professor Lacroix discusses the nomenclature of the subject. After referring to Buchanan's original definition and the demonstration of Van Bemmelen¹ and Max Bauer² that laterites rich in hydrates sometimes contain a considerable quantity of silicates of aluminium, without differing in any way in external characters from laterites quite free from silicates,³ he concludes (p. 258)—

“Enfin, de véritables argiles, de vrais kaolins, abondent sous les tropiques, et ils sont, eux aussi, souvent colorés en rouge par de l'oxyde de fer.”

The author then arrives at the following definition of laterite (p. 259):—

“Les produits de décomposition de toutes les roches, silicatées alumineuses caractérisés, au point de vue chimique, par la prédominance de hydroxydes d'aluminium et de fer, avec généralement de l'oxyde de titane, après élimination plus ou moins complète des autres éléments de la roche fraîche: alcalis, chaux, magnésie et silice”:

this definition agreeing with that now generally accepted.

¹ *Arch. néerl. Sc. exactes et nat.*, xv, pp. 294-305, 1910.

² *Neues Jahrb. Min. u. Pet.*, Festband, 1907, pp. 33-90.

³ For the frequent difficulty or impossibility of distinguishing laterites from some clays in the absence of chemical examination, see Sir T. H. H. Holland, in the discussion on Mr. J. M. Campbell's paper on “The Origin of Laterite”, *Trans. Inst. Min. Met.*, xix, p. 455, 1910, and L. L. Fermor, *GEOL. MAG.*, 1911, p. 510.

Professor Lacroix next prints in full the tabular classification for laterites and some other surface rocks drawn up by me in 1911.¹ Putting aside for the time my terms *lake laterite*, *lateritoid*, and *lateritite*, he accepts my classification for the group “des latérites proprement dites”, with certain reservations necessitated by the characters of the rocks studied.

In the first place he joins together my divisions I (lithomarge, clay, soils, etc.) and II (lateritic rocks) in order to avoid too much detail²; and with reference to *quartzose laterites* he thinks it more logical to base the divisions, not on the composition of the rock taken as a whole, but “sur ses éléments néogènes” only. He therefore subdivides laterites carrying quartz, not according to the total tenor in lateritic constituents, but according to their richness in these latter after deducting quartz of primordial origin.³

Professor Lacroix then brings forward a much more important modification or rather improvement of my classification, which is based on chemical and not on mineralogical composition. He writes (p. 261)—

“Pour rester dans les principes généraux de la pétrographie, il est donc indispensable de tenir compte de cette composition minéralogique, et le but principal de ce mémoire [italics mine] est précisément d'apporter des documents nouveaux à ce point de vue. En conséquence, il faut faire intervenir dans la classification la notion de l'état, cristallin ou colloïdal, dans lequel se trouvent les constituants néogènes (hydrates et silicates).”

Professor Lacroix considers the physical state of the hydroxide of iron as of no importance from the point of view of classification, because the two phases *limonite* (crystalline) and *stilpnosiderite* (colloidal) are rarely completely separated. The hydrates of aluminium, on the other hand, occur either as gibbsite or in the colloidal state.⁴

In my paper already cited (l.c., p. 561) I advanced reasons for avoiding the custom of several authors in regarding *laterite* and *bauxite* as synonymous terms, and suggested the necessity of restricting the term *bauxite* to the varieties of laterite sufficiently rich in Al_2O_3 to be used as ores of aluminium. Even this restriction is not sufficient for Professor Lacroix (p. 262)—

“Puisque la bauxite—au moins celle qui a servi de type et qui constitue tous les gisements français—est caractérisée, ainsi que je l'ai montré depuis longtemps,⁵ par l'absence complète de produits cristallisés.”

Consequently he qualifies as *gibbsitic*⁶ (*gibbsitique*) those laterites

¹ “What is Laterite?” : GEOL. MAG., N.S., Dec. V, Vol. VIII, p. 514, 1911.

² There seems to be no good reason why we should exact less precision in naming products with less than 50 per cent of lateritic constituents than with products containing more than 50 per cent. Indeed, greater possibilities of variation amongst the former group necessitate greater precision rather than less.

³ The undesirability of this course is indicated by consideration of the case of *laterite d'alluvions* noticed in Section IV.

⁴ This can be regarded only as a general statement, for examples of the crystalline and colloid forms occurring together are given later in the memoir.

⁵ *Min. de la France et de ses colonies*, iii, p. 342, 1901.

⁶ Throughout this memoir the author uses the term *hydrargillite* rather than *gibbsite*, but in the adjectival form he prefers *gibbsitic* as being less cumbersome.

containing $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ in the crystalline state, and as *bauxitic* (*bauxitiques*) those containing only colloidal hydrates.¹

Then, considering the silicates of aluminium found in the laterites of Guinea, Professor Lacroix finds that they exist sometimes as crystalline *kaolinite* and sometimes as *halloysite*, the latter being either more or less crystalline or completely colloidal. He regards it, therefore, as impossible to unite all these products under the term *lithomarge* as proposed by me (l.c., p. 511), because I have suggested that lithomarge is the colloidal variety of kaolinite. This criticism seems to me perfectly valid, but see the next paragraph; the author then summarizes his conclusions in the following scheme of nomenclature, with which I agree in most respects, the mineralogical precision introduced being a very acceptable improvement:—

DIVISIONS basées sur la composition chimique.	SUBDIVISIONS basées sur la composition minéralogique.
I. Latérites (<i>Hydrates</i> ≤ 90 , p. 100).	<i>Hydrates d'alumine.</i> Cristallisé (hydrargillite).
II. Latérites silicatées (<i>Hydrates</i> = 90 à 50, p. 100).	<i>Gibbsitiques.</i> Colloïdaux. <i>Bauxitiques.</i>
III. Kaolins, argiles latéritiques (<i>Hydrates</i> < 50, p. 100).	<i>Silicates d'alumine.</i> Cristallisé (kaolinite). <i>Kaoliniques.</i> Cryptocristallins ou <i>Argileuses.</i> colloïdaux.

Each of these types should be qualified by *quartzose* (*quartzifère*) when it contains primary (*ancien*) quartz.

It will be seen that Professor Lacroix uses the term *argileuse* instead of the adjectival equivalent of *halloysite*, with which he identifies the cryptocrystalline and colloidal silicates present. It is interesting to note that other authors have referred the colloidal silicate to the same substance. Thus Bauer² regards it as a "Halloysite ähnlichen Aluminiumhydrosilikat"; whilst Mr. E. S. Simpson³ speaks of "halloysite (amorphous $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$)". Halloysite is an indefinite colloidal substance corresponding to the kaolinite formula with additional water, and may itself prove to be the colloidal form of kaolinite, with this additional water in a state of adsorption or solid solution, like a portion of the water of zeolites. Dana in his *System of Mineralogy* divides the old term *lithomarge* between kaolinite and halloysite, retaining it for the firm and compact form of kaolin. If, however, halloysite prove to be related to kaolinite in the way suggested above, then obviously the term lithomarge will be a very convenient one to use for cryptocrystalline and colloidal clays in which the ratio $\text{Al}_2\text{O}_3 : \text{SiO}_2$ is 1 : 2 with a water content varying from that of kaolinite to that of halloysite. I was probably

¹ This nomenclature appears at first sight to be heterogeneous, because gibbsite is a mineral and bauxite a rock (according to Lacroix himself); but this use of *bauxitic* must be taken as analogous to that of *lateritic*, and as referring to the presence of bauxitic constituents. It is doubtful if it will be possible thus to restrict the use of the term bauxite outside the realms of mineralogy and petrology, because for economic purposes we have available no other inclusive term, except *aluminous laterite* or *aluminium-ore*.

² *N.J. Min. u. Pet.*, Festband, 1907, p. 87.

³ "Laterite in Western Australia": *GEOL. MAG.*, 1912, p. 400.

wrong in attempting to restrict the term to the colloidal form of kaolinite. The term lithomarge has long been used in the literature of Indian geology for the variegated clays so often underlying the Indian laterites,¹ and has by several decades the priority over halloysite in application to these clays, and it seems therefore desirable to me to retain it in this connexion. Perhaps in the same way as bauxite has been shown to be a rock rather than a mineral, lithomarge must be so regarded. In fact, we might regard lithomarge as related to kaolinite and halloysite in the same way as bauxite is related to the minerals gibbsite and the aluminogels (see *infra*).

With this definition of the term lithomarge we may translate and re-arrange Professor Lacroix' improved classification as follows:—

DIVISIONS, based on chemical composition.	SUBDIVISIONS, based on mineralogical composition.
Laterites (L.C. $\geq$ 90 per cent)	Gibbsitic laterites. Bauxitic laterites.
Argillaceous laterites (L.C. = 50–90 per cent)	Kaolinic Lithomargic $\geq$ gibbsitic laterites. Kaolinic Lithomargic $\geq$ bauxitic laterites.
Kaolins, lateritic clays ³ (L.C. < 50 per cent)	Gibbsitic clays. Bauxitic clays.

After closing his introduction with a short *historical résumé* of the previous work on the laterites of Guinea,⁴ Professor Lacroix deals in four chapters with the following subjects: (i) The products of

¹ Thus in the publications of the Geological Survey of India it is used by W. T. Blanford as early as 1859; see "Note on the Laterite of Orissa" (Mem. Geol. Surv. Ind., i, p. 286). Blanford clearly distinguishes between the overlying laterite and the underlying lithomarge produced by the decomposition of gneiss. He writes: "The underlying form varies so much in constitution according to the rock from which it is derived, that scarcely any petrological term will include all its varieties. As a rule, however, it is, when derived from gneiss or other felspathic rock, a more or less ferruginous clay varying in purity. To such substances the name *Lithomarge* has frequently been applied, and it seems the most applicable in the present instance, it being understood that all the impure varieties derived from quartzose metamorphic rocks or sandstone are here included in the term." He notes the "apparent passage of Lithomarge into Laterite", but gives a different explanation from that of Professor Lacroix.

² By using the term *lithomargic* where Lacroix uses *argileuse*, we have the adjective *argillaceous* or *argileuse*, available as a comprehensive term, including both 'kaolinic' and 'lithomargic'.

³ I prefer the term *lateritic constituents* (L.C.) to *hydrates*, because, at the surface, laterite sometimes contains the anhydrous mineral *hematite*, developed as a result of dehydration.

⁴ In which, by the way, the author overlooks Mr. J. Morrow Campbell's paper entitled "The Origin of Laterite" (Trans. Inst. Min. Met., xix, pp. 432–57, 1910), based largely on observations made in Haute Guinée.

decomposition of the nepheline-syenites, gabbros, diabases, and peridotites (pp. 271–301); (ii) The products of decomposition of the mica-schists, gneisses, and granites (pp. 302–317); (iii) The *latérites Falluvions* or *lateritoids* (pp. 318–324); (iv) The minerals of laterites.

It will be convenient to notice briefly the contents of chapter iv, and then to give the substance of chapter v in some detail, which summarizes admirably the subject-matter of chapters i to iii, and also gives the author's ideas as to the conditions of formation of laterite.

III. THE MINERALS OF LATERITE.

From the mineralogical point of view the most remarkable feature of lateritization is that practically all the minerals so produced are in a state of hydration, either in a colloidal phase (hydrogel) or in a crystalline phase, and most often with the two together. In certain cases it can be shown that crystallization takes place at the expense of the hydrogels, but, as related later, this is not always the case for aluminium hydrate.

Full details are given (p. 326) of the microscopic characters of the crystalline form of aluminium hydrate, namely, *hydrargillite* or *gibbsite*, which is the only crystalline aluminium hydrate found by Professor Lacroix in the laterites of Guinea, there being no evidence for the existence of *diaspore*.

The history of the *colloidal hydrates of aluminium* in laterites cannot be divorced from that of the original *bauxite*, which is only a laterite of a former period found in regions no longer tropical. As long ago as 1901 Professor Lacroix¹ showed that the French bauxites are without exception formed of colloidal hydrates, existing alone or in association with colloidal silicates, demonstrating that bauxite cannot be regarded as a mineral, because it does not correspond with the supposed specific formula of $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$; thus in France it has a composition approaching closer to $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ than to any other, whilst in other regions, as in Arkansas, the composition approaches that of $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$. He concludes, therefore, that bauxite must be regarded as a rock composed of various colloidal aluminium hydrates mixed, according to the case, with ferric hydrates, clay, etc. Passing in review the names proposed by various authors for these colloidal hydrates, he rejects the *α -klichite* and *β -klichite* of Cornu,² the *sporogelite* of M. Křišatič,³ and Dittler & Doelter's use of *bauxite*, and their proposed *bauxitite*,⁴ adopting the term *alumogel* suggested by M. Pauls.⁵ Judging from both his own work and that of M. Arsandaux, Professor Lacroix accepts the existence of one colloidal hydrate with one molecule of water (France and Guinea), and of another with three molecules of water (Guinea and Arkansas).

Dealing with the *ferric hydrates*, he uses the term *limonite* for the crystalline form of $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$, and revives the old name

¹ *Mineral. de la France et de ses colonies*, iii, p. 342.

² *Zeitsch. Chem. indust. Kolloide*, iv, p. 90, 1909 (Lacroix).

³ *Neues Jahrb.*, Beil. Bd. xxxiv, p. 518, 1912.

⁴ *Centralblatt f. Min.*, 1912, pp. 19 and 104; and 1913, p. 193.

⁵ *Zeitsch. prakt. Geol.*, xxi, p. 545, 1913 (Lacroix).

stilpnosiderite of Ullmann (1814) for the colloidal form of the same mineral. Details are given of the microscopic characteristics of both these minerals. The red tints often seen in the ferruginous cuirass of laterites are regarded as undoubtedly due to the dissociation of the yellow hydrate under the influence of the sun's rays. But Professor Lacroix regards the product as a mixture of *hematite* with the initial limonite or *stilpnosiderite*, and not as a special hydrate of formula $2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$, to which the name *hydrohematite* or *turgite* has been attached. He has never detected the presence of *goethite* in the laterites of Guinea, although it has been reported as existing in some of the laterites of that country.

The *silicates of aluminium* exist in two forms, crystalline (*kaolinite*) and *colloidal*, and of the latter the author detects two varieties, one of them cryptocrystalline, which is regarded as *halloysite*, and the other isotropic, which is supposed to possess a composition near to that of *halloysite*. From the fact that hydrochloric acid never breaks up more than a very small portion of the clays, he judges that there cannot be present any important quantity of silicates more basic than *halloysite*, such as *allophane*. Attempts made in Professor Lacroix's laboratory to repeat the distinction of silicates from hydrates by staining, as announced by Dittler and Doelter, gave such irregular results that they were discontinued.

It has not proved possible to detect mineralogically the presence of *titanium compounds* in laterite. But it is supposed that the portion of the titania of laterites that is soluble in hydrochloric acid exists as orthotitanic acid, $\text{TiO}_2 \cdot 2\text{H}_2\text{O}$, whilst the idea of Arsandaux that the portion of the titania of laterites that is soluble only in sulphuric acid, which is the greater part, exists as metatitanic acid, $\text{TiO}_2 \cdot \text{H}_2\text{O}$, is accepted as probable. For these titanic hydrates Lacroix proposes the name *doelterites*, in honour of C. Doelter, who has done so much work on colloid minerals.

It is supposed that the small quantities of chromic oxide detected in some laterites exist as a hydrate of Cr_2O_3 , probably in the colloidal form. The only *manganiferous* product in the Guinea laterites consists of a mixture of *stilpnosiderite* and *psilomelane*, and was found in Los Isles.

IV. THE PROCESSES AND PRODUCTS OF LATERITIZATION.

In chapter v of his memoir, the author first states the *chemical result* of the formation of laterite, namely, the elimination of the alkalis, alkaline earths, and silica of the original rock, and the persistence of hydrated oxides of aluminium and iron with a little titanic acid, noticing that in different cases the rock is formed in different ways, which lead to important *mineralogical and structural variations* in the final product.

Starting from the intact rock Professor Lacroix has been led to distinguish two superposed zones, the *zone de départ*, which we may translate as the *zone of leaching*, and the *zone de concrétion*. Between the two zones there is perfect continuity, their separation being arbitrary, and necessary only for the sake of a clearer exposition of the problem; the point chosen is that where the original structure of

the rock, still evident in the zone of leaching, ceases to be perceptible. More exactly the lower zone would be spoken of as the zone of maximum departure or leaching.

In the preceding chapters Professor Lacroix has discussed the products of alteration of three distinct groups of rocks, there being distinct types of laterite corresponding to each. These three groups are: (1) nepheline-syenites, gabbros, diabases,¹ and peridotites; (2) micaceous schists and granites; (3) alluvium composed of debris of non-lateritic origin. In this final chapter the author compares the three.

IV (a). *Zone of Leaching (départ).*

This zone is characterized by the elimination of the greater part of the constituents, the disappearance of which characterizes the phenomenon of lateritization; three cases can be distinguished, marked by the formation of gibbsitic laterites, ferruginous laterites, and bauxitic laterites, respectively.

Gibbsitic Laterites.—In the first case, namely that predominating in the alteration of gabbros, diabases, and nepheline-syenites, the transformation is *abrupt* without transition, the same thin slice showing the contact of the absolutely fresh rock with the portion in which there is no longer any unaltered mineral, and where the leaching of constituents destined to elimination is often almost complete.

In such rocks, the ratios of TiO_2 , Fe_2O_3 , and Al_2O_3 are at first sensibly the same as in the fresh rock, but as one rises in the section the proportion of iron diminishes very rapidly in consequence of its removal to the higher levels, and later the amount of Al_2O_3 increases with reference to that of the TiO_2 .

From the mineralogical point of view the essential feature is the transformation of the feldspars into gibbsite, which occupies the body of the destroyed mineral, the composition of the original feldspar having no influence on the result; at the same time colloidal products take the place of the other minerals. The transformed rock, with the original structure still visible, is porous and light in weight, with a very characteristic variegated aspect, which to Professor Lacroix suggests *pain d'épices*. This laterite is more or less rich in aluminium silicate, concentrated in the skeletons of the ferro-magnesian minerals, and in the examples represented by analyses Nos. 2, 6, 9, given in Part II, the quantity of silica ranges from 2.21 to 12.67 per cent, corresponding to 5 to 30 per cent of silicate of composition corresponding to the formula $2\text{H}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot n\text{SiO}_2$.²

In Los Archipelago where the nepheline-syenites occur, the alteration normally corresponds with that above described, but at

¹ I have retained the term *diabase* throughout this article, although personally I think it an unnecessary term, the word *dolerite* being the more desirable.

² In a footnote Lacroix remarks that the essentially kaolinic transformation of a diabase is an exceptional case that he has not himself observed. Such cases occur, however, in India: cf. Mem. Geol. Surv. Ind., xxxvii, p. 376, 1909, where is described the occurrence at Yeruli of a zone of variegated argillaceous material intervening between the underlying basaltic rock and overlying laterite.

certain points in these islands it has locally pursued a totally different course, with formation of a plastic clay (see analysis No. 4, Part II). The association of these two different types of alteration is so intimate that Professor Lacroix has no explanation to offer of their coexistence at the same point (p. 281). It impels the question whether, in the normal case, gibbsite, instead of being the first secondary product formed from the feldspars, may not itself have been derived from the destruction of an aluminium silicate. Judging from the examination of a considerable number of specimens in which the type of transformation is always the same, Professor Lacroix answers this question in the negative, thinking it likely that the decomposition has been from the beginning a hydrolysis of the original silicates.¹

Ferruginous Laterites.—Ferruginous laterites in the zone of leaching result from the alteration of peridotites, owing to the poverty of these rocks in aluminiferous silicates. The ferro-magnesian silicates decompose in the same manner as in the gabbros, furnishing colloidal ferric products, containing some alumina (see analysis No. 9, Part II). The rock is porous, ochreous, light, and friable.

Kaolinic and Argillaceous Decomposition.—This, the third form of alteration in the zone of leaching, characterizes the mica-schists, gneisses, and granites. It is clearly distinguishable from the first case, because, instead of an abrupt alteration without intermediate phase, there is a *progressive change*, so gradual and extending to such a depth that the unaltered rock is seldom seen. In the mica-schists of Fatoya, borings pushed to a depth of 60 metres have not reached the fresh rock, probably because the vertical disposition of the schists has facilitated their alteration. Consequently, in contrast to the rocks considered above, in which the original structure persists for only a few metres above the original fresh rock, the *initial structure*

¹ Mr. E. S. Simpson (GEOL. MAG., 1912, p. 401) has criticized adversely my postulation (GEOL. MAG., 1911, p. 459) of two distinct modes of decomposition of rocks resulting respectively in the formation of clay and laterite, apparently because in Western Australia primary laterite is always found to overlie an almost pure pipeclay and this in turn a crystalline rock. From the work of Lacroix it is seen that the feldspar in a crystalline rock, such as nepheline-syenite, may alter *directly into gibbsite or directly into a hydrous aluminium silicate*. When the latter forms, a chemical change may cease at this stage, as in Los Archipelago, or it may proceed further, as in the case of the mica-schists noticed on a later page in this paper. With reference to Mr. Simpson's comparison of lateritization with the formation of saline efflorescences, Lacroix' work indicates a marked distinction. A saline efflorescence is deposited *on* the surface of the ground; the constituents of a lateritic crust, on the other hand, are partly *residual* (although recrystallized), formed approximately in their present place from the once fresh primary rock, at the time when the zone of leaching was at this level; and have partly been brought up from the zone of leaching and added to the residual portions: in any case these constituents were deposited *inside* the crust and not *on* the surface, except perhaps to a very minor degree. In the following paragraph Mr. Simpson gives a curious definition of a *replacement of a rock*, namely, "a deposit accumulating in the actual space originally occupied by the solid rock which has yielded the materials which compose the laterite." Surely the essential feature of replacement is that the replacing mineral has been brought from elsewhere, and has been deposited in the place of another mineral removed in solution.

is here preserved through a very great thickness of altered rock; but the degree of cohesion of the rock is profoundly modified, the rock being unctuous to the touch and friable when dry. The micas are progressively deprived of their alkalis concurrently with the fixation of a larger and larger quantity of water (see analysis on p. 306 of Lacroix' memoir). From this results kaolinite or colloidal silicates of aluminium, mixed with a greater and greater quantity of aluminium hydrate. This mode of alteration also characterizes certain granites and gneisses in Guinea. None of these products of alteration in the zone of leaching would be designated laterite; they are fundamentally *kaolins* or *clays*, passing upwards into *lateritic clays*.

The type of alteration is not characteristic of a given rock.—Judging from the results given above, one might think that in the Tropics the mode of alteration of the rocks is always determined by the mineralogical and chemical composition of the original rock. Such a generalization would be inexact, as is shown by observations made in Madagascar, where the gabbros, diabases, and nepheline-syenites behave as in Guinea, but where the granites and gneisses give rise not only to a great development of argillaceous alteration products, as in Guinea, but also in places give rise to gibbsitic laterites, often quite free from iron.

(To be continued.)

REVIEWS.

I.—WATER REPTILES OF THE PAST AND PRESENT. By Professor S. W. WILLISTON. pp. 251, with 131 text-figures. Published by the University of Chicago Press: Agents in Great Britain, the Cambridge University Press, Fetter Lane, London. Price 12s. net.

IN this volume Professor Williston has endeavoured to give a popular account of the various groups of reptiles which have become more or less adapted to an aquatic life, and to a great extent he has succeeded in this difficult task. At the same time it is not easy to tell how far a work of this kind will appeal to the general reader, since much that is highly technical and unfamiliar necessarily remains. In any case, the book is a valuable one because it brings together in a compact form a large amount of information hitherto widely scattered and often not easily accessible.

In the earlier chapters the author gives a general account of the mode of occurrence of fossil reptiles, of their classification and their osteology. The chapter dealing with the last-mentioned subject might perhaps have been extended with advantage, and, indeed, if so good an authority as Professor Williston would publish a volume on the osteology of the class, it would fill one of the most notable gaps in palæontological literature. The subject essentially is one for the palæontologist, since in perhaps no other group of the Vertebrata are the fossil forms of such preponderating importance. This will be understood when it is realized that out of the fifteen