

EXPLANATION OF PLATE XVI.

FIG. 1.—*Lindstromaster antiqua* (Hisinger), 1837.

„ 1a.—Outline of actinal surface of type-specimen, nat. size.

„ 1b.—The same magnified 4 diameters.

Bed C, corresponding to the Wenlock Shale, Gotland.

„ 2.—*Palæasterina Bonneyi*, sp. nov.

„ 2a.—Abactinal view of specimen, magnified 2 diameters.

„ 2b.—Actinal „ „ „ 3 diameters.

Ludlow Shales: Leintwardine, Shropshire.

III.—A DISCUSSION ON THE USE OF THE TERMS ROCK-WEATHERING, SERPENTINIZATION, AND HYDROMETAMORPHISM.

By GEORGE P. MERRILL,

Head Curator, Dept. of Geology, U.S. National Museum, Washington, D.C., U.S.A.

IN the abstract of a paper by Mr. Thomas H. Holland, read before the British Association, Section C (Geology), Bristol, 1898, printed in the January number of this Magazine,¹ on “The Comparative Actions of Subaërial and Submarine Agents in Rock Decomposition,” the author brings up again a question which the present writer has often had occasion to face, and has vainly tried to solve in a manner entirely satisfactory even to himself.

The question relates primarily to the limitation of the term weathering as applied to rocks, and indirectly to the general subject of hydrometamorphism and metasomatism as manifested in the production of serpentine.

In my work on “Rocks, Rock-weathering, and Soils” (p. 174), is made the following statement:—

“The term weathering, as here used, is applied only to those superficial changes in a rock-mass brought about through atmospheric agencies, and resulting in a more or less complete destruction of the rock as a geological body, as where granitic rocks are resolved into sand and kaolinic material, with liberation of carbonates of the alkalis and of lime, and oxides of iron. It does not include those deeper-seated changes taking place below the zone of oxidation and which result mainly in hydration and the production, it may be, of new mineral species, as chlorite, sericite, zeolites, etc., but during which the rock-mass as a whole retains its individuality and geological identity. The distinction is not one that has been sharply insisted upon, and, indeed, geologists and petrologists as a rule have been extremely careless in their use of such terms as *alteration*, *decomposition*, and *weathering*. The distinction drawn here is essentially that made by Roth (Allgemeine u. Chemische Geologie) between *Verwitterung* and *Complicirte Verwitterung*. For reasons above stated and others given on p. 161, it seems best to limit the terms weathering and decomposition to processes involving the destruction of the rock-mass as a geological body, and to designate the purely mineralogical, deeper-seated changes, as alteration, which may or may not be due wholly to hydrometamorphism.”

¹ GEOL. MAG., January, 1899, pp. 30-1.

This is essentially the ground taken by Lindgren also,¹ and while it may be open to criticism, nothing better, so far as the writer is aware, has been suggested.

Let us take for purposes of discussion the serpentinization of the mineral olivine, as mentioned in the abstract of Mr. Holland's paper. The author states (p. 31):—"In all these cases, however, although the action of the atmosphere is so striking, the results are purely superficial, and a specimen of rock taken from within a few inches of the clay products seldom shows a trace of hydrous decomposition, even in thin sections under the microscope. This is just as true for such delicate minerals as olivine and nepheline as for the commoner silicates. In many of the basic dykes, certainly pre-Cretaceous and probably Lower Palæozoic in age, the absence of serpentine is so complete that unusual precautions are often necessary for the determination of the olivine, whilst in the numerous occurrences of dunite throughout the Madras Presidency serpentine is extremely scarce."

Mr. Holland would account for this wide difference in the conduct of the olivine in Indian and European localities on the supposition that the European areas had, during the later geological periods, been submerged below the sea, while in southern India there are no evidences of any such depression since Lower Palæozoic time.

Just what would be the effect of prolonged submergence in seawater on a mass of olivine rock the writer is not prepared to say, but he does express the doubt if simple weathering of the mineral is ever productive of serpentine. Has there been ever advanced any proof that serpentinization is a superficial phenomenon? If due to weathering we ought somewhere to meet with masses which are superficially converted into serpentine and gradually resume their normal character at greater depths.

So far as is to be judged from available literature the olivine granules in any mass of rock, however dense, show no greater degree of hydration (serpentinization) near the surface or along contacts where surface waters would most readily permeate, than in the interior of the mass. Further than this, serpentinization is as common, so far as the United States is concerned, in the arid portions of the West as in the humid East. In fact, this phenomenon is apparently entirely independent of climatic conditions. Is not the inference, then, fair that the process has gone on entirely independent of surface waters?

Although convinced that excepting in the purely physical weathering of arid regions hydration is a most important factor,² the absence of any but a very narrow zone of hydration products between the residual clay and fresh rock is not at all strange. Much depends on the texture of the rock and its mineral composition. In cases where the weathering is largely in the nature of solution and oxidization such abrupt changes are to be expected. The Fourche Mt. syenite, of Arkansas, an almost purely feldspathic

¹ 17th Ann. Rep. U.S.G.S., 1895-6, pt. ii, pp. 90-6.

² "Rocks and Rock-weathering," pp. 188, 234, etc.

rock, passes within the space of 2 cm. from a fine red-brown unctuous clay to a massive fresh unchanged feldspar: the nepheline of the nepheline syenite of Mias in the Urals is eaten out below the surface of the more refractory feldspar, mica, zircons, etc., but gives in the closed tube only traces of water and shows under the microscope only incipient stages of hydration.

My own view of the case is, that the two phenomena are due to widely different causes; that serpentinization is a deep-seated process due to waters or vapours coming from considerable depths, and it may be even constituents of the magmas at the time of their intrusion. The almost complete absence of oxidation products in fresh serpentine is indicative of this. Again, serpentinization is a process involving a greater degree of hydration than is weathering. The serpentinized olivine rock of the Nijni Tagilsk platinum district yields 14.21 per cent. of water, while the brown crust which results from its weathering yields but 11.74 per cent. The serpentine of Harford County, Maryland, further, shows a loss on ignition of 18.15 per cent.,¹ while the hard red-brown crust produced on the immediate surface, through weathering, loses but 11.82 per cent. and the residual soil but 7.89 per cent. In the same manner soils derived by weathering from other highly hydrated magnesian rocks, as the so-called soapstone (altered pyroxenites), show a very considerable loss of water, even though the actual loss on ignition in the resultant soil may be a trifle greater than in the fresh rock.

These facts are mentioned in detail here since they do not seem to have been before noted, or at least their significance not realized. If serpentinization were a product of weathering, a shorter exposure to atmospheric influences, as in India, ought to result in merely a thinner coating of serpentine over the altered material. Were it a result of subaerial agencies, certainly the superficial alteration of olivine into serpentine ought to be more nearly universal. Yet, in several instances, as notably in the corundum areas of western North Carolina, the olivine is almost perfectly fresh, but on the immediate surface rotted away to a ferruginous clay.

That this process of hydration, hydrometamorphism, or alteration, whichever term may be used, is quite distinct from true weathering, is further shown by the corundum crystals of this same region. These are often superficially or quite altered to damourite. Yet both the corundum and the alteration products are so resistant to weathering, that they remain among the residues in the clays resulting from the decomposition (weathering) of the mother rock, whatever that may have been. Serpentine pseudomorphs after pyroxene are sometimes more refractory than the rock in which they are formed, and may be found with well-preserved crystal outlines in the débris resulting from its breaking down.² When rocks like

¹ In part due to CO, though the amount of this constituent cannot be over 3 or 4 per cent.

² J. Smith, "Crystals from Decomposed Trap": *GEOL. MAG.*, Dec. IV, Vol. VI (1899), p. 93.

the Nijni Tagilsk peridotites, which are largely serpentinized but still contain residuary olivines, undergo actual weathering, the olivines do not yield serpentine, but break up, as does the serpentine itself into free iron oxides, free silica, carbonates of magnesia, and unrecognizable earthy products.

The ideas put forward in this paper are not altogether new, and are in part in harmony and in part in conflict with those advanced by others.

Thus Bischoff says: ¹ "The decomposition of a rock takes place only when it is exposed to the undisturbed action of atmospheric agents; while alteration, on the contrary, takes place when the rock is more or less beyond the reach of this action." On the other hand, Roth,² to whom we owe so much, speaks of both serpentine and zeolites as products of weathering (*Verwitterung*), but in his latest work³ he so far changes his views or mode of expressing them as to call the deep-seated process *Complicirte Verwitterung*, in distinction from the purely superficial *Verwitterung*, due to atmospheric action. Moreover, in the paper "Ueber den Serpentin," to which reference is made above, he describes the processes and results incidental to the *Verwitterung* of the serpentine quite independently of those incidental to its first production.

Teall⁴ apparently accepts unhesitatingly ideas contrary to those expressed by myself, for he says: "The alteration of olivine by surface agencies—water, carbonic acid, and oxygen—gives rise to serpentinous and other pseudomorphs."

Consideration along these lines led the present writer in the work to which reference has been made to attempt making a distinction between true weathering and the more deep-seated process which he called hydrometamorphism. Surely processes so widely different as those resulting in the production of a serpentine from a peridotite and the final destruction through oxidation, carbonization, and partial dehydration of this same serpentine, should not be confounded under the same name. The distinction, it is true, is not one that can at all times be readily made. As the petrologist finds difficulty in separating his plutonic from the effusive rocks, so here are no hard and fast lines, and it is often impossible to state at just what point one shall assume that superficial processes cease and the deep-seated begin. The writer's conclusions are to the effect that the zone of oxidation forms the natural and easiest recognizable limit. The processes within this zone are those of weathering; those below, whether brought about by superficial waters deprived of their free oxygen and carbonic acid, or by deep-seated waters welling upwards, are those of hydrometamorphism, metasomatism, alteration, or whatever suitable name may be adopted.

¹ "Chemical and Physical Geology," Paul & Drummond's English translation, 1854, vol. iii, p. 86.

² "Über den Serpentin, etc.": Abhandl. der K. Akademie der Wiss. zu Berlin, ii (1869), p. 42.

³ "Allgemeine u. Chemische Geologie," 1893.

⁴ "British Petrography," p. 85.

In conclusion, one might urge the necessity of closer observations regarding the formation of serpentine from olivine or other anhydrous magnesian silicates. That it is through a process of hydration is self-evident, but as to the conditions under which it goes on literature is strangely silent. Is the process still going on in the exposed masses now open to our inspection, or is it at a standstill? The writer is of the present opinion that both this process and that resulting in the formation of zeolites and chlorites have ceased, so far as material available for study is concerned. They are due to conditions which do not exist on the immediate surface, except it may be in such sporadic and unusual occurrences as those of Plombieres, or those more recently described by F. Gounard¹ and by Lacroix.² This paper is, however, written more for the purpose of eliciting the opinions of others than of expressing those of the writer.

IV.—WOODWARDIAN MUSEUM NOTES: A NEW TRILOBITE FROM MOUNT STEPHEN, FIELD, B.C.

By F. R. COWPER REED, M.A., F.G.S.

A REPRESENTATIVE collection of fossils from the Middle Cambrian beds of Mount Stephen, Field, British Columbia, has recently been brought back by Mr. S. H. Reynolds, M.A., F.G.S., and presented to the Woodwardian Museum. The fauna has been described by Rominger³ and Walcott⁴; and the latter⁵ has compared it to that from the Highland range, near Pioche, Nevada, and from near Antelope Spring, Western Utah. The section at Field has been described by Mr. R. G. McConnell.⁶

The collection made by Mr. Reynolds contains the following species:—

- Ogygopsis Klotzi* (Rominger).
- Ogygopsis*, sp.
- Bathyriscus Howelli* (Walcott).
- Olenoides nevadensis* (Meek).⁷
- Olenoides* cf. *quadriiceps* (Hall & Whitfield).
- Ptychoparia Cordilleræ* (Rominger).
- Ptychoparia*, sp.

¹ Bull. de la Société Minéralogique de France, vol. v (1882), p. 268.

² Comptes Rendus Paris Acad. Sci., vol. xxiii (1896), p. 761.

³ C. Rominger, "Description of Primordial Fossils from Mount Stephens, North-West Territory of Canada": Proc. Acad. Nat. Sci. Philadelphia (1887), p. 12, pl. i.

⁴ C. D. Walcott, "Cambrian Fossils from Mount Stephens, North-West Territory of Canada": Amer. Journ. Sci., ser. iii, vol. xxxvi (1888), p. 163. "Descriptions of New Genera and Species of Fossils from the Middle Cambrian": Proc. U.S. Nat. Mus., vol. ii (1889), p. 441.

⁵ Correlation Papers, Cambrian: Bull. U.S. Geol. Surv., No. 81 (1891), pp. 170-1, 326-7, 360-1, 366, and pl. ii.

⁶ Geol. Surv. Canada, new ser., vol. ii (1886-7), pp. 24d-30d.

⁷ Matthew (Trans. Roy. Soc. Canada, ser. ii, vol. iii (1897), sect. iv, No. 7, p. 186) contends that Dames' name *Dorypyge* (Dames in Richthofen's "China," iv: Beitr. z. Paläont., 1883, p. 23, t. i, figs. 1-6) has the priority of *Olenoides*. Matthew here describes a variety of *Olenoides* (*Dorypyge*) *quadriiceps* from the St. John Group of Hastings Cove.