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Olivine enters largely, or as a predominant constituent, into the composition of several rocks of frequent occurrence in Europe, viz.—

EULYSYTE, consisting of the iron-olivine, fayalite, garnet and augite;

LHERZOLYTE, consisting of olivine, enstatite, diopside, and picotite; and

PICRYTE, made up of olivine crystals in a matrix of hornblende, diallage, or biotite, with magnetite and calcite.

Dunyte, however, the only rock which, when unaltered, consists entirely of olivine, with a little chromite or magnetite, is said to occur in the South of Spain, in Norway, and in several other European localities, of which little is known. The largest outcrop occurs at the Dun Mountain in New Zealand; of this Hochstetter has given a description in considerable detail.

On this continent the same rock has been also found in North Carolina, Georgia and Alabama, as well as more recently in Canada.[1] It is there found in important rock-masses in the immediate vicinity of the serpentines of Mt. Albert, North Ham, in the Province of Quebec. It is finely granular, slightly friable, yellowish to grayish-green in color, and contains a little chromite and perhaps enstatite.

In the western part of North Carolina, the chief outcrops of this interesting rock occupy mainly a zone in the mountain-plateau, between the Blue Ridge and the Great Smoky Range, about 250 kilometers long, and from 15 to 30 kilometers wide, from the Rich Mt. in Watauga County, to the State line at Shooting Creek in Clay County, and so on through South Carolina and Georgia into Alabama. The beds are everywhere and exclusively found enclosed in a stratum of hornblende-gneiss, black and slaty. This forms the upper layer, and largely occupies the central zone of the mass of gneisses and schists, entirely of types identical with those found in the White Mountains of New Hampshire, which make up the mountain plateau.

Many facts in regard to the general features, lithological characteristics and mode of occurrence of this rock have been already published: in the paper by Prof. C. U. Shepard on Corundum;[2] in the detailed description given in the Geological Report by Prof. W. C. Kerr,[3] and the paper by C. D. Smith in the appendix

[1] B. J. Harrington, Can. Nat., 1881, IX, 254.

[2] Am. Jour. Science, 1872, (III) IV, 109, 175.

[3] Geol. of N. C., 1875, I, 129, 130, 293, 298, 299.

to the same volume; by Dr. F. A. Genth of the University of Pennsylvania, in his excellent papers on Corundum;[1] and by R. W. Raymond, in a short report on a survey of the Corundum veins near Franklin. In the present brief sketch it is proposed merely to offer some additional facts to which there has been little or no reference, the general results of my study for several years, both in the field and on a large collection of specimens and thin sections.

FORM. As the beds are always highly tilted, they are seen always in cross-section, and their tracts generally present irregularly oval or elliptical outlines, or, in the smaller masses, those of decidedly lenticular layers. The major axis of such a mass reaches the length of about 1.5 kilometers in the largest bed, that of Cullakenee (Buck Creek) in Clay County, and the width of about 200 meters, the creek having cut its way through the length of the deposit and affording a good section of the layers upon its bare, sloping banks.

LAMINATION. The rock always possesses a marked slaty lamination, exactly like that of the slaty hornblende-gneisses surrounding it, the distinct laminae usually varying from ½ to 1 cm. That these laminae really indicate the bedding planes of a mechanical sediment, and not the characteristics of a chemical deposit, is shown by three facts,—

1st. On microscopic examination of thin sections, transverse to the lamination, there is always shown an alternation of coarser and finer irregular grains, the certain mark of a sorting out of sediments deposited in water.

2d. The chromite-grains are not only dispersed through the dunyte, in exactly the same way as those of iron-ore through the siliceous sands on a sea-coast; but are often concentrated in laminae about a centimeter in thickness, alternating with those of olivine, or even in coarser layers of a chromite-breccia, with kaemmererite-scales acting as a cement. These coarser layers are often spoken of as "veins," but always lie in the plane of stratification, and often show the sorting process among their own grains.

3d. At a few localities, near the margin of a huge mass of dunyte, this rock is found to be interbedded with the hornblened-

[1] Am. Phil. Soc., Sept. 19, 1873, and July 17, 1874.

gneiss, in layers 1 to 6 meters in thickness. This was shown by a cross-section of the beds on the north side of the dunyte deposit at the Jenks Mine, near Franklin, in Macon County. Although the dunyte is thus enclosed in, or interbedded with the hornblende-gneiss, the latter was never observed to be enveloped by the dunyte.

STRIKE. The strike, as shown by the lamination, coincides generally, but by no means always, with that of the associated gneisses. Though often attended by slight curves and even small faults, the plane of lamination usually extends straight and uninterrupted throughout the mass of dunyte. Along the margin of the mass, however, at the ends of the layers wherever visible, a sharp break seems to occur between the dunyte and the gneiss, sometimes with a deviation of the strike of the former, amounting to 20° to 30°. To this fact and to the many flexures naturally occurring near the centre of the anticlinal in which the dunyte-beds lie, may be attributed the idea sometimes advanced, that the dunyte is found in erupted dykes. All its characteristics, on the contrary, are simply those of a chrysolite-sandstone, which, wherever unaltered, and thus without accessory fibrous constituents as a cement or binding-material, is pulverulent and friable. The explanation of these differences in the strike is founded, I think, on the difference in specific gravity of the olivine-mass (3.3) and of the gneiss (2.6), and, it may be, on the greater rigidity of the former. Thus in the course of the plication and contortion of the mass of the gneiss, during its ancient plastic condition, the small enclosed dunyte-masses have sometimes been moved in some degree independently, and their strike slightly disturbed.

WEATHERING. The weathering of dunyte everywhere presents very interesting features: not only in its naked surface and dun color, which render an outcrop of dunyte distinct and desolate to the eye, as far as it can be seen, among the forest-clad mountains of North Carolina, as well as of New Zealand: but also in an extreme ruggedness, due to the irregular projection of laminae and of rough, jagged points — the pitted and honeycombed surface being often similar to the fretting of a coral-reef by the surf of a tropical sea. The chemical decomposition, however, is generally more rapid than the disintegration, the resulting ochreous mass being bound together by a network of plates of quartz or fibres of actinolite. Still there are localities where the upper surface of a dunyte outcrop in North Carolina is clothed with forest. Here the aluminous content of the soil, shown by its analysis, indicates an increment of foreign material in some way, perhaps by sand or dust blown by the wind.

ALTERATION.

The various processes of alteration, which have attacked and modified the lithological character of dunyte, are as important as they are novel and interesting. Although substantially the same reactions and results are involved, the discussion of these processes may be separately considered, with reference to that which took place in fissures, and to those which progressed throughout the rock, within its interstices. The respective results were, from the first process, the formation of *veins* — from the others, the conversion of the dunyte, partially or completely, into different rocks.

VEINS. These vary in form, from vertical sheets, intersecting the rock to unknown depths, to elliptical or lenticular pockets with vertical axes; in thickness, from mere films to a width of two meters. In the veins of ordinary type, which are very common, the walls are lined with successive laminae of actinolite in transversely fibrous crusts, sometimes partially or wholly altered into talc, and the interior is occupied by ripidolite. The latter mineral almost invariably serves as the matrix of the corundum, with its associated minerals, these corundum veins being particularly abundant and large in the southern part of the dunyte-belt. In regard to the varied series of minerals which are found in association with the corundum, and in regard to their paragenetic relations, it will suffice for the present purpose to refer to Dr. Genth's valuable paper, the general accuracy of which on these points my field-observations everywhere confirm. It may be added that brownish-green enstatite is a common member of the vein-series; sometimes occurring in huge masses, nearly a meter in diameter, lined with actinolite; sometimes in minute disseminated granules; and less commonly in brilliant bronze-colored scales, to which the name bronzite is more pertinent.

INDIGENOUS ALTERATION. Four common modes of alteration may be observed throughout the dunyte-belt, in all stages of each process.

1. Chalcedonic. In this process all the constituent silicates of the rock are decomposed, the bases sometimes remaining as reddish brown, soft ochreous grains, and sometimes completely removed. The silica entirely remains, generally as a white or yellowish chalcedony, passing into white, yellowish or reddish chert. When all the bases have disappeared, and the chalcedony remains as an exceedingly cellular mass of thin scales and plates, parallel or anastomosing with the greatest irregularity, a chalcedonic schist, or siliceous sinter is the result, often bearing some resemblance to a buhrstone.

2. Hornblendic. In this process, microscopic spicules of greenish actinolite first become more or less abundantly interspersed among the olivine-grains. Other varieties present actinolite-grains visible to the eye; and these may predominate until the alteration becomes complete. The final result is a green actinolyte-rock or schist, or grayish-white amphibolyte or tremolyte-schist, which may be fine grained or very coarse, consisting of huge fibrous masses of grayish-white amphibole, 2 to 3 decimeters in length, crossing each other in the greatest confusion. Even among these coarse masses, where the conversion and disappearance of the dunyte seems complete, a few grains or small bunches of unaltered olivine may be sometimes found in the interstices, on a fresh fracture of the rock.

3. Talcose. The development of the talc-scales throughout a dunyte is brought about in two ways: by the conversion of the olivine-grains, partially or completely, into talc, which either envelopes them as a microscopic crust, with an ochreous core (*i. e.* the separated iron-oxide), or has crystallized out in scales among the interstices of the olivine-granules; or again, by the alteration of the actinolite-fibres and grains into talc, which is then seen as fibrous pseudomorphous films or scales within the cleavage-planes of the actinolite, or entirely replacing it. The process has often attacked the rock in both ways in the same mass, and has resulted in the production of talcose dunyte, talcose actinolitic dunyte, talcose amphibolytes and actinolitic steatyte and talc-schists. One novel variety is a white granular steatyte, in which the granules are pseudomorphous after those of the original olivine, a rock often denominated a "white serpentine."

4. Ophiolitic. In this common process, well shown near Bakersville, Webster, etc., the olivine has suffered alteration in

exactly the same way as that fully studied and described by Zirkel and others in the chrysolitic lavas, etc., cf numerous foreign localities. All the transition-varieties occur in abundance, from that in which the serpentine is diffused among the olivine-granules, merely as a minute fibrous network, or as films enveloping olivinec-ores — to that in which only minute particles of olivine survive as the nuclei of the granules — and to the final result of a true and complete serpentine, always, however, granular in structure, and often retaining the original lamination. The serpentine is also generally found in such localities as a vein-deposit, *i. e.*, white or greenish marmolite, filling or lining the fissures of the rock, or occupying branching contraction-cracks throughout the mass. The talcose alteration has generally progressed more or less in association with the ophiolitic, and then a talcose serpentine has resulted, rich in disseminated scales of talc and hematite (göthite?). It is in such serpentines that bronzite is found, in brilliant bronze-colored scales, two to three mm. in diameter.

5. DIORITIC. The last and perhaps most interesting alteration of all, confined to a single locality, consists of an internal conversion of the olivine into amphibole (a bright, grass-green variety which Dr. Genth has identified as smaragdite or kokscharoffite) and albite, sometimes with abundantly disseminated particles of ruby red corundum, producing a peculiar variety of dioryte or gabbro.

Again, this very rock has been subsequently attacked by a secondary process of alteration, the albite-grains being enveloped by an alteration-crust of margarite, and the condition of the hornblende modified. The result of this action is a coarse margaritic gabbro, whose weathered surface is peculiarly rough and warty.

On the whole, it appears that the view which has been suggested,[1] founded on certain phenomena observed in the corundum veins, that these secondary rocks and many schists have been mainly derived from the alteration of corundum, finds not the least confirmation from my studies, and is, indeed, strongly contradicted by facts observed in the field. The corundum itself is in all cases, both in the veins and the particles found in the gabbro, a secondary or alteration product. All the phenomena of altera-

[1] F. A. Genth, loc. cit., 31, 45.

tion, both in the veins and rock-masses, absolutely require, and can be simply explained by the introduction of a solution of soda and alumina into the fissures and interstices, during the period of alteration and metamorphism. The combination of soda with silicates of aluminum and iron, perhaps previously formed, has produced all the minerals of the vein-series; while the precipitation of the alumina naturally ensued from the separation of its alkaline solvent. The question then presents itself of the evidence of the introduction of such a solution. This is found in the strata of hornblende-gneiss, which everywhere surround the dunyte-beds, and are abundantly traversed, all along the dunyte-belt, by the huge veins of endogenous granyte, now largely exploited to supply mica for commercial purposes. Into these there has certainly been an introduction, by subterranean thermal solutions, of soda and alumina, as shown both by the development of a long series of crystallized mineral-silicates, containing those with other elements, and elsewhere even by the precipitation of corundum itself (in association with muscovite, margarite and albite), in a certain class of small veins in the gneiss, of limited occurrence but great interest.

It is a natural enquiry, whether there is any evidence of the former occurrence of dunyte at other points along the Appalachian belt between North Carolina and Canada? Of this I have no doubt. The actinolytes, amphibolytes and hornblende-schists, as well as many of the steatytes, talc-schists and serpentines, which occur all along to the northward throughout these Montalban rocks, are in many cases, I believe, the equivalents, usually more crystalline, of their southern congeners.

The question of the origin of the olivine in this concentrated form has been met by three hypotheses:

First, that the material is of an eruptive origin.

Secondly, that it is a chemical precipitate.

Thirdly, that it is a mechanical accumulation, in the form of ancient olivine-sand.

It has already been briefly indicated that both the petrographical and lithological phenomena observed present, in my opinion, insurmountable objections to the first two hypotheses. It remains then to suggest the source from which such olivine-sands have been derived. Doubtless from some ancient terrane, perhaps of lower Laurentian age, of chrysolitic lavas or gabbros, now worn down and buried beneath the later sediments, beyond our view. Olivine-sands, it is true, are of rather rare occurrence at the present time, but only because the chrysolitic rocks are rarely found on the present seacoasts. Such sands do occur in abundance, however, at the Hawaiian Islands, at the foot of the congealed streams of chrysolitic lava which have flowed down to the seashore. Aside from the dunytes, there are few rocks, capable of yielding olivine-sands, which now happen to be exposed over the territory east of the Mississippi River. However, the number of these, constantly increasing with closer observation (*e. g.*, the huge, erupted masses of chrysolitic rocks near Montreal, and elsewhere in the Province of Quebec, the chrysolitic iron ore of Rhode Island, the chrysolitic hornblende and pyroxene rocks of Cortlandt, New York, the olivine-gabbros of Wisconsin, etc.), all imply that olivine formed by no means an unimportant constituent in the rocks of Archean Age and therefore in the beach-sands of those ancient shores.