$$\begin{vmatrix} u & v & w \\ u' & v' & w' \\ u'' & v'' & w'' \end{vmatrix} = 0.$$

The developments are the exact duplication of the above. They are omitted here for the sake of brevity.

Finally, one should not lose sight of the fact that the word "face" is here used in its broadest sense covering all planes (evidence of discontinuous vectorial properties) which obey Haüy's Law of Rationality: cleavage planes, twinning planes, gliding planes, x-ray "reflection" planes, as well as actual bounding faces. The meaning of the term "edge" is similarly extended: the intersection of two possible crystal planes, from the standpoint of rationality of indices.

NOTES AND NEWS

OCTAHEDRITE AS AN ALTERATION PRODUCT OF TITANITE

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In 1930 Dr. Hugh S. Spence of the Department of Mines of Canada described[1] a pegmatite rich in thucholite derived from uraninite from Henvey Township, Ontario. An important constituent of this pegmatite was an altered titanite intimately associated with thucholite. Dr. Spence submitted samples of this titanite to the Harvard Mineralogical Museum for examination as to the nature of its alteration, and the microscopic study of these specimens was entrusted to the author since the unusual type of alteration-product seemed to merit detailed description.

According to Dr. Spence the titanite is intimately associated with uraninite and thucholite in the centres of core-like masses of oligoclase which are distributed through the main mass of microcline. The titanite is in massive form, in aggregates of coarse crystals, pieces up to three pounds in weight having been found.

The specimens submitted are rough crystals or fragments bounded more or less by parting surfaces, the largest piece measuring 8 by 4 by 1.5 cms. They are dark green to yellowish green in color and none of them shows any of the original titanite substance. A clay-like substance not definitely determined is the main con-

[1] A remarkable occurrence of thucholite and oil in a pegmatite dyke, Parry Sound District, Ontario. *Am. Mineral.*, vol. **15**, pp. 499–520, 1930.

stituent of the exterior portion of the fragments and gives them their color. One fragment of the material, 4 by 3 by 1 cms. in size, is a nearly complete pseudomorph of a titanite crystal, showing the faces *c*(001), *n*(111), and *x*(102). The forms are all well developed and give excellent measurements with the contact goniometer.

The broken crystals reveal a cellular structure, consisting of a network of siliceous walls in a boxwork pattern with a distinct tendency to conform to the parting directions of the titanite. These siliceous bands are very thin, less than 1 mm., and are colored gray by intermixed clay. Upon the surfaces of these quartz septa are deposited myriads of minute black crystals of octahedrite.

The individual crystals of octahedrite are very minute, ranging from 0.16 mm. to 0.03 mm. in diameter. In ordinary light they appear quite black and lustrous, but in transmitted light they have a grayish blue color, the characteristic color of octahedrite. Several were measured on the goniometer and show only the unit bipyramid (111) in combination with the base (001). The signal from the base was poor and diffused, the face being much rounded and irregular. The pyramidal faces, though narrow, were, on the other hand, perfectly plane and gave excellent signals.

The more complete pseudomorph mentioned above was broken open to reveal its structure, and it was found that the internal appearance was somewhat different from the other specimens. Instead of having a boxwork structure, the interior was completely filled, and cleavage surfaces of calcite were noted. A fragment was allowed to stand in dilute HCl to remove the calcite, and then was found to have exactly the same appearance as the other specimens. Apparently calcite formerly filled the spaces now left as voids in most of the specimens. Within the drusy openings left after the removal of calcite, a few small, light brown, translucent, irregular crystalline fragments of rutile were found implanted on octahedrite. No rutile was found in any of the other specimens, from which the calcite was already removed naturally.

The question of the orientation of the octahedrite crystals in relation to the crystal or parting planes of the titanite was considered. It was noted that in turning the fragments so that reflections would be secured from a drusy surface, certain positions seemed to yield more brilliant reflections than the average. A study of the material under the binocular, however, failed to reveal any sort of recognizable orientation. The minute crystals of octahedrite were not confined to a single layer on the quartz septa nor were they attached in any systematic position, and it was concluded that the positions of maximum brightness were due merely to chance reflections from the multitude of tiny facets.

Although, as shown in the following summary of the literature, the formation of octahedrite as a product of the alteration of titanite has long been known, all of the previously described occurrences have been upon a microscopic scale, and in many cases the direct relationship was doubtful. In the specimens described here, this type of alteration has been observed in large titanite crystals for the first time.

The formation of octahedrite from titanite was first described by Diller[2] in 1883, who found small yellow-brown crystals of octahedrite in a hydrothermally altered granite. He assumed them to have been formed in this way because of the lack of titanite in the altered rock, although it was abundant in the original material.

The following year Thürach[3] showed more clearly that this was possible, when he found small crystals, seldom more than 0.15 mm. in diameter grown upon the walls and upon networks of limonite in spaces formerly occupied by titanite crystals. The forms observed were assumed to be a combination of the unit pyramid with the base.

Hamberg[4] infers the same origin for small crystals of octahedrite which he observed on the weathered surfaces of rutile from Kragerö. The weathering of the rutile was believed, in this case, to have resulted in the formation of titanite crystals, which, in turn, broke down to form octahedrite. He found a corroborative factor in the tendency of the octahedrite crystals to have grown on a limonitic mass, while the titanite rested directly upon the rutile. These crystals also showed a combination of the unit bipyramid with the base.

[2] Diller, J. S., Anatas als Umwandlungsprodukt von Titanit im Biotitamphibolgranit der Troas: *Neues Jahrb.*, vol. **1,** 1883, pp. 187–193.

[3] Thürach, H., Über das Vorkommen mikroskopische Zirkone und Titanmineralien in den Gesteinen: *Ver. der phys.-med. Gesell. zur Wurzburg,* N.F., vol. **18,** Sept. 1884, p. 32.

[4] Hamberg, A.,Anatas und Titanit auf Rutil von dem Apatitvorkommen bei Kragerö in Norwegen: *Geol. Fören. Förh.,* vol. **8,** 1886, p. 473. Abstr., *Zeit. Krist.,* vol. **15,** 1888–9, p. 430.

The observations of Doss[5] were most convincing. He described crystals 0.2 to 0.02 mm. in size occupying cavities formed by the replacement of titanite, but found many transitional stages with residues of titanite, and a few fresh unaltered titanite crystals. By measurements on the microscope stage, he claimed to have determined the bipyramid (334) in combination with (001).

Lacroix[6] mentions three occurrences of octahedrite resulting from the alteration of titanite. The first is that of Saint-Marie-aux-Mines, in Alsace in Vosges Mountains. This occurrence was originally described by Müller[7] as being one of brookite, but Lacroix found upon re-examination of the specimens that the crystals were actually octahedrite, showing the unit bipyramid in combination with the base. They occurred upon the surfaces and in crevices within strongly altered titanite crystals, associated with a yellow ochreous material. A second occurrence, similar to that described by Diller, is mentioned. The crystals were scattered through diorite at Eup, near Saint-Beat, in the Upper Garonne district of the Pyrenees. A third locality is that of Grand Clot in the Alps, where dark blue octahedrite crystals occur in the midst of quartz-calcite-ripidolite geodes associated with titanite and galena. They are described as often occurring in the centers of titanite crystals. Simple unit bipyramids were found, as well as combinations of this form with the base.

Another case in which the same origin for the octahedrite has been inferred is that described by Scrivenor[8] who remarks upon the abundance of well-formed crystals of similar habit in some of the English sandstones. From the evidence he decided that the colorless crystals measuring 0.025 to 0.17 mm. must have formed in place, largely from the alteration of ilmenite grains after the deposition of the sandstone. To account for the lack of titanite, despite its abundance in the source rocks, he suggests that it has been altered to octahedrite and leucoxene.

[5] Doss, B., Über Pseudomorphosen von Anatas nach Titanit im Syenit des Plauenschen Grundes: *Neues Jahrb.*, 1895, vol. **1**, pp. 128–138.

[6] Lacroix, A., *Miner. de France*, vol. **3**, pp. 115, 187 (1901).

[7] Müller, A., *Verh. der Naturforsch. Gesell.*, Basel, **1857**, p. 573.

[8] Scrivenor, J. B., Anatase in the Trias of Midlands: *Eng. Min. Mag.*, vol. **13**, pp. 348–351, 1903.