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Minerals from the Apatite-bearing Veins at Noerestad near Risör on the S.E. Coast of Norway.

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(*With a note on their occurrence by* A. L. Collins.)

[Read November 10th, 1891.]

THE minerals described in this paper were obtained by Mr. Arthur L. Collins last summer, and their mode of occurrence is explained in the accompanying note by him. My description will deal in detail with their crystallographic characters.

Apatite.

Forms present; $a\{10\bar{1}\}$ $x\{210\}$ $o\{111\}$.

These crystals are more or less altered and often cavernous, of a light greyish-brown colour, partially coated by brown oxide of iron. Owing to this alteration the lustre, except on the prism faces, is very dull.

The crystals are grown together nearly parallel to the prism faces.

Many of the crystals were unsymmetrically developed, simulating oblique symmetry owing to the unequal development of the x and a faces, and they are nearly always curved.

They vary in size from 1 to 5 cm.

Some of the crystals have bright little crystals of sphene of a brown colour embedded in their basal planes.

Rutile.

Forms present; *a* {100} *s* {111} *e* {011} *m* {110}.

These are of a dull steel colour on the outside, are slightly iron-stained, and have a reddish brown colour on the broken surface.

They cleave very easily parallel to the *a* plane.

The *a* faces are large and deeply striated parallel to *m*; *m* very narrow; *e* well developed and striated parallel to *s*, which is always small.

The crystals are usually simple; when twinned the twin plane and composition face is (011).

Zircon.

Forms present; *p* {111} *x* {311} *v* {221} *m* {110} *a* {100}.

These crystals resemble in colour and development the crystals of zircon found in the zircon-syenite of South-west Norway.

The colour is dark reddish brown; lustre vitreous; *m* large, *p* small, *x v* and *a* very narrow.

They are sometimes curiously curved.

Scapolite.

Forms present; *a* {100} *m* {110} *f* {311} *r* {111}.

There are two distinct habits; to one belong large iron-stained crystals from 1 cm. to 30 cm. in length resembling the nuttalite from Arendal in Norway. Those of the other habit resemble the meionite from Monte Somma. These crystals are small, of a dirty white colour, often much altered at the surface, and slightly stained with iron oxide; they exhibit a very perfect cleavage parallel to the *a* faces; *a* large and very narrow; *m* and *f* well developed; *r* is usually unsymmetrically developed as in the crystals from Monte Somma.

Amphibole and Pyroxene.

This specimen is a very interesting one.

It consists of a number of well developed dark green oblique prisms terminated by the basal plane, from 0·5 cm. to 2 cm. in length, and less than 0·5 cm. in breadth.

These large green prisms are remarkable, as they have the form and angles of pyroxene, exhibiting *m* {110} large, *b* {010}, *a* {100} narrow, with a rough *c* {001} face.

On examining the crystals with a lens, the prisms are found to be more or less cavernous, being built up of a number of small crystals disposed nearly parallel to the intersection of the prism planes. They are almost invariably twinned about *a*, and have *m* large, *a* and *b* narrow. The measurement of a cleavage flake gave 55°30′ (55°49′ Descloizeaux). A thin cleavage flake was examined between crossed nicols in a polarising microscope, and the direction of extinction was found to make with the edge *m m*, an angle of 14°. This direction is that of maximum velocity in the plate, so there can be no doubt that these small crystals are amphibole. Many writers on petrology have described the alteration of pyroxene into amphibole by metamorphism ; but the uralitic aggregations of amphibole in the dolerites always contain magnetite and titaniferous iron and other alteration products and are embedded in the rock. The specimen to which Rose (*Pogg. Ann.* xxii. 322, 1831) gave the name uralite was from Mostovaja, Lake Baltym, near Katharinenburg in the Urals, and others since described resemble these crystals in being implanted, but they are much more altered.

This specimen differs, I believe, from those last described in being intimately associated with and apparently crystallised with black hornblende crystals which are often well developed, having the faces $a\{100\}$ $b\{010\}$ $m\{110\}$ $x\{1\bar{1}\bar{1}\}$; a cleavage plate gave a smaller extinction angle than the uralite, but otherwise the features are the same.

Sphene.

Forms present ; $c\{001\}$ $g\{101\}$ $r\{011\}$ $n\{123\}$ $\eta\{145\}$ $v\{\bar{1}01\}$ $t\{\bar{1}21\}$ $f\{\bar{2}33\}$; the last three forms are doubtful as the planes are rounded and dull.

The crystals are of a dark to light brown colour with vitreous to greasy lustre.

Some of the crystals attain a length of 12 cm. and a breadth of 5 cm.

The specific gravity of a fine large crystal was found to be 3·6.

The crystals are always twinned; twin plane and composition face $c(001)$.

All the large crystals consist of aggregations of twinned crystals grown parallel to the *c* face but inclined more or less to the edge *b c*, so that in an apparently simple crystal the edge *c r* is not parallel to the edge *r r* as would be the case in a simple crystal. This want of parallelism is well shown in some of the crystals where the angle between the zone axes [100] and [410] is 38° instead of 30°20′$\frac{1}{3}$, and the angle between *r* (011) and *η* (145) differs as much as 5° from the calculated value.

The crystals all possess a highly perfect and sometimes largely developed "face of union" (Absonderungsfläche) due to repeated twinning parallel to this face, and similar to that observed on sahlite, corundum, calcite and other minerals.

G. H. Williams (*Amer. Journ. Sci.* (1885) 29, 486) has described a "face of union" or "parting" on the sphenes from Pitcairn, St. Lawrence Co., New York. The face by which it is shown he describes as a small but very bright plane $\eta\{145\}$ lying in the zone [011,101], and, according to his drawing, holohedrally developed.

The angles I measured on the smaller crystals between the "face of union" and the other faces agree well with the calculated angles required for (145); but on the larger crystals, those described above, the angles agree much better for the form (134); in this case, however, the crystal not being a simple one, this "face of union," unlike the one described by Williams, is always hemimorphically developed.

In many of the crystals the η plane is ill developed, but the twin lamellæ appear in a striking manner on one-half of two of the r faces, giving to those parts a curious lustre, like that of bronzite or avanturine, and marking the twin junction of the two crystals and the hemimorphic development of the η face.

These crystals are modified by rounded planes of y v t and l.

On another crystal of a lighter colour the n plane is well developed with r and c, and has η large and hemimorphically developed.

Among the specimens of sphene were some small very brilliant simple crystals, having n large, r c and y small. They exhibit only in a slight degree the η twinning.

Appendix.

Note on the Mode of Occurrence of the above Minerals.

By A. L. Collins.

THE specimens described by Mr. Solly were found last summer during the course of mining operations upon some small apatite-bearing veins at Noerestad, near Risör, on the south-east coast of Norway. The whole district, from Laugesund on the east to near Arendal on the west, has been extensively worked for apatite and rutile for many years past; but this particular locality has never been described, or, so far as the writer is aware, even examined before.

The country rock is gneiss, often highly garnetiferous, with hornblende-schist, mica-schist, and occasionally quartzite; and it is pierced by large masses of a dioritic rock, consisting mainly of hypersthene and labradorite, the gabbro of Norwegian geologists. The schistose rocks are also pierced in places by dykes and irregular masses of a coarse-grained granite. The intrusive masses of gabbro generally stand out conspicuously as hills some hundreds of feet in height; and owing to the very extensive glaciation which this part of Norway has undergone, considerable areas of bare rock are almost everywhere available for examination.

The veins, which are generally small and irregular, occur in all these rocks, but most commonly in or near to the gabbro, which is altered in their neighbourhood to a characteristic white and black spotted rock, the scapolite-hornblende rock of Messrs. Brögger and Reusch.[1]

This altered gabbro often gives distinct indications of the presence of phosphoric acid by blowpipe tests.

The veins in the Noerestad district have the same general direction as the enclosing rocks; but in places they clearly cut across them, and even enclose angular fragments of the wall rock. The vein-filling is mostly hornblende, scapolite, apatite and calcite; but the following minerals, arranged roughly in order of frequency, were also observed:—

Albite (massive).
Titanic iron ,,
Rutile (crystals and massive)
Orthoclase (crystals and massive).
Augite.
Sphene (crystals and massive).
Magnetic pyrites.
Iron pyrites (crystals).
Hydrated oxide of iron (decomposition product).
Chalcopyrite.
Epidote.
Chlorite.
Mica (? Phlogopite).
Quartz.
Molybdenite.
Zircon (small brilliant crystal).

The veins often show a distinct combed structure—especially those passing through the schistose rocks: the opposite sides being a greenish-

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[1] W. C. Brögger and H. H. Reusch, *Norske apatitforekomster*, p. 268. *Nyt Magasin for Naturvidenskaberne*. Christiania, 1880.

black lustrous cleavable hornblende, passing gradually into the country-rock on the outside, but finely crystallised towards the centre: this consists in some cases of massive opaque grey apatite, and in others of coarsely crystalline sparry calcite, including crystals and masses of light green translucent apatite, and very perfect crystals of hornblende, scapolite, sphene and other minerals. This calcite is often dissolved away by the action of surface water, leaving irregular cavities, in places over 2 feet wide and many square yards in area; these are lined on each side with fine crystals of hornblende and scapolite, and contain all the formerly enclosed crystals in the earth and mud surrounding the large rounded blocks of calcite still left at the bottom. Some of these crystals were of considerable size: several crystals of sphene were found over 6 inches long; while one crystal of scapolite measured considerably over a foot in length, and 5 inches in diameter. The prism faces of the larger apatite crystals were commonly much curved: and the pyramid faces of the scapolite and rutile crystals were often very unequally developed, so as to give almost the appearance of oblique symmetry. Many specimens were curiously corroded and rounded at the edges; and most of the larger crystals of sphene and scapolite were broken or cracked partly through, and re-cemented with calcite or oxide of iron: these altered crystals being often found imbedded in apparently unaltered sparry calcite.

It will be seen that all the evidence—the common combed structure and bi-lateral symmetry of the vein filling—the frequency of drusy cavities lined with crystals—and of crystals included in massive calcite or apatite—goes to show that these deposits are segregation veins of ordinary type, whose fillings have been introduced solely by aqueous solutions; indeed, the extensive alteration of the enclosing rocks, and the corrosion of the crystals in the veins themselves, clearly point to former extensive hydro-thermal action. They seem to bear the closest analogy to some of the apatite deposits of Canada, and especially to certain veins in Renfrew Co., Ontario, described in the Report of the Royal Commission on the Mineral Resources of Ontario.[1]

Messrs. Brögger and Reusch, who made a detailed examination of all the then known apatite deposits of Norway in 1874, came to the conclusion that they were of eruptive origin; apparently including in the term, however, the action of deep-seated solutions, as well as of gaseous substances and of molten masses.[2] It is true that their attention seems

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[1] *Rep. Roy. Commission Min. Resources of Ontario*, p. 439. Toronto, 1890.

[2] W. C. Brögger and H. H. Reusch, *loc. cit.* p. 295.

to have been mainly directed to the deposits situated entirely in the gabbro, which in Norway are commercially the more important, and in which both well-developed crystals, and drusy cavitics, are of much rarer occurrence: but neither of the two latter theories seems to apply even to this class of vein, as seen at this locality.

As to the relative ages of the various minerals in the veins, an examination of some hundreds of specimens shows that hornblende and scapolite—the component minerals of the altered gabbro as frequently found in the neigbourhood of the veins—are the oldest vein-filling minerals: indeed, many of the smaller veins, and especially the lenticular masses common in the gabbro—consist of nothing else. These were succeeded by titanic iron and rutile, the two minerals being often found in large masses close together, and even gradually passing into one another: and these again by apatite. Sphene is clearly more recent than either apatite or rutile: while calcite would seem to be the most recent of all. The rarity of quartz in most of the veins was especially noticeable in a country like Norway, where it is usually so common: but one or two remarkable exceptions were observed—notably at Vaereland, a few miles south-west of Noerestad; where a vein was found consisting almost entirely of cellular sugary and ferruginous quartz, and rutile in brilliant red-brown crystals, varying in size from mere specks to stout prisms over an inch in length.