Natrophosphate from the Ilímaussaq alkaline complex, South Greenland

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The rare mineral natrophosphate has been identified for the first time in the Ilímaussaq alkaline complex in a drill core from the Kvanefjeld area. It occurs sparsely in zoned veinlets with cores of natrophosphate and borders of fibrous trona. The natrophosphate is more or less smoky, transparent and unaltered. The refractive index n = 1.448 ± 0.005 is low compared to that given for the material from the type locality, Khibina alkaline complex, Kola Peninsula; the unit cell parameter a = 27.76 ± 0.05 Å is in excellent agreement with that given for the material from the type locality. The veins occur in hyper-agpaitic naujakasite lujavrite; villiaumite is an associated mineral. Only a few water-soluble minerals have so far been found in the Ilímaussaq alkaline complex compared to the wealth of such minerals in the Khibina and Lovozero alkaline complexes. This is possibly at least partly due to lack of necessary precautions during sampling.

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Natrophosphate, $Na_7(PO_4)_2F{\cdot}19H_2O$, is a rare mineral, first described by Kapustin *et al.* (1972) from Yukspor Mountain, Khibina alkaline complex, Kola Peninsula, Russia, and subsequently from the nearby Lovozero alkaline complex (Khomyakov & Bykova 1980). The first well-formed crystals were reported from Mont Saint-Hilaire, Quebec, Canada, by Mandarino & Anderson (1989) and Horvath & Gault (1990). Recently, natrophosphate has been described from the Aris phonolites, Windhoek, Namibia (Petersen *et al.* 1997).

In 1993 a search for water-soluble minerals was carried out on some 1000 m of drill core from the Ilímaussaq alkaline complex. Natrophosphate, associated with a carbonate, was optically identified in a small number of very thin parallel veins in drill core 49. The present report is a documentation of the Ilímaussaq occurrence.

Occurrence and general description

The Ilímaussaq natrophosphate occurs in a small number of less than 1 mm wide, fairly regular, parallel veins in drill core 49 at a depth of approximately 71.5 m. The veins are symmetrically zoned, with a core of natrophosphate constituting up to half of the vein, and with borders of fibrous trona, identified from a Gandolfi type X-ray diagram. Trona has previously been described as forming crusts in cavities in ussingite, from drill cores from the same area (Sørensen *et al.* 1970). The natrophosphate is colourless or more often smoky, transparent and, though exposed to air for quite some time, remarkably unaltered. The snow-white trona bordering the veins forms dense fibrous aggregates with the fibres oriented perpendicular to the walls of the veins (Fig. 1). In thin section the parallel fractures containing the natrophosphate veins are closely spaced.

The veins occur in a naujakasite lujavrite containing about 50% naujakasite and a substantial amount of villiaumite (Fig. 1). Parallel arranged laths of microcline and small prismatic grains of arfvedsonite give the rock a distinct igneous lamination. The rock also contains small prismatic grains of aegirine, altered grains of eudialyte, and minor interstitial albite. Sphalerite and an opaque mineral are associated with the albite.

The natrophosphate cores of the veins are associa-

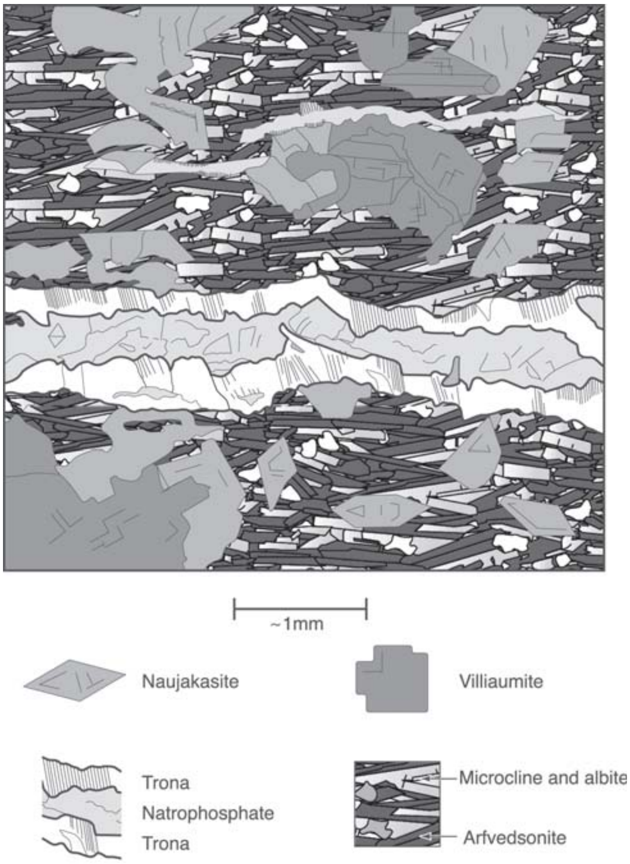

Fig. 1. Sketch showing a typical, symmetrically zoned vein of natrophosphate and trona in naujakasite-bearing arfvedsonite lujavrite. Drill core 49, depth approximately 71.5 m, Kvanefjeld, Ilímaussaq alkaline complex, South Greenland.

ted with a few small irregular grains of villiaumite; the marginal zones consist entirely of fibrous trona. The rusty colour of the trona in thin section in transmitted light is ascribed to scattering of light, probably by micro-inclusions, and the apparently low birefringence to the very fine fibrous nature of the trona.

The veins are discontinuous and branching and can, for instance, penetrate the grains of naujakasite along their cleavage planes. The branches between the rock-forming minerals and along the naujakasite cleavages only consist of trona.

Optical properties, X-ray diffraction and chemistry

The refractive index of the natrophosphate from Ilímaussaq is 1.448 ± 0.005, which is low compared to the values given by Kapustin *et al.* (1972): 1.460–1.462 for the material from the type locality. The low refractive index is believed to be due to the unaltered state of the Ilímaussaq natrophosphate, i.e. the mineral has a high content of H_2O compared to the partly dehydrated natrophosphate from the type locality. The refractive index is close to the value of 1.450 for the natrophosphate from Aris, Namibia (Petersen *et al.* 1997).

The unit cell parameter refined from Gandolfi type powder pattern, Cu$K\alpha$ radiation, λ = 1.54178 Å, of the natrophosphate from Ilímaussaq was found to be a = 27.76 ± 0.05 Å, in excellent agreement with the a = 27.79 Å given by Kapustin *et al.* (1972) for the type material from Yukspor Mountain, Khibina alkaline complex, Kola Peninsula, Russia.

The correct chemical formula of natrophosphate, $Na_7(PO_4)_2F{\bullet}19H_2O$, was first suggested by Khomyakov & Bykova (1980), and finally established by Genkina & Khomyakov (1992) when refining the structure of natural natrophosphate from the Lovozero alkaline complex. The small amount of material available of the Ilímaussaq natrophosphate, together with the extreme amount of H_2O in natrophosphate, precluded a full quantitative analysis.

Discussion

Only a few water-soluble minerals have so far been found in the Ilímaussaq alkaline complex. Villiaumite is of widespread occurrence in drill cores, though only exceptionally at depths less than 50 m below the present surface. Trona and thermonatrite have been found in drill core 6 at 109.74 m (Sørensen *et al.* 1970), and dorfmanite in a single hand specimen from the exploration adit in the Kvanefjeld area (Petersen *et al.* 1993). By comparison with the wealth of water-soluble minerals in the Khibina and Lovozero alkaline complexes (Khomyakov 1995), such minerals should also be expected to be common late-stage minerals in the Ilímaussaq alkaline complex. The presence of such minerals may be inferred from numerous cavities in the rocks of the complex and from chemical analyses of water flowing out of the Kvanefjeld adit. The pH of this water is 11, and the dissolved material consists of 7.7 kg/t NaF, 3.0 kg/t Na_2O and 6.9 kg/t SiO_2, corresponding to a mixture of villiaumite and natrosilite (Sørensen 1982). Furthermore, the walls and roof of the Kvanefjeld adit, and also the drill cores, are covered with white encrustations of thermonatrite and sodium acetate. This encrustation takes place within a few days of exposure to the atmosphere. The source of the Na must be villiaumite and other water-soluble Na minerals whereas the source of the carbon may be the carbon dioxide of the atmosphere and especially the methane and other hydrocarbons from fluid inclusions in many of the minerals. Natrosilite and other water-soluble minerals must be collected immediately after blasting and fracturing of rocks and drill cores and must be protected from contact with the atmosphere (Khomyakov 1995). This precaution was not taken during the construction of the Kvanefjeld adit and the drilling programmes in the 1960s and 1970s because the possibility of the presence of water-soluble minerals was not appreciated at the time. It is therefore of great satisfaction that natrophosphate has been preserved in drill core 49.

Not surprisingly, the natrophosphate in Ilímaussaq has been found in the hyper-agpaitic naujakasite lujavrite, which is unique to the complex (Sørensen 1997). In the Khibina and Lovozero alkaline complexes of the Kola peninsula, natrophosphate also occurs in hyper-agpaitic pegmatites and veinlets where it is associated with ussingite, natrosilite, analcime, natrolite, villiaumite, thermonatrite, etc. (Khomyakov 1995).

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