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# BROMELLITE FROM SYENITE PEGMATITE, SOUTHERN OSLO REGION, NORWAY

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## ABSTRACT

Bromellite has been found in a huge syenite pegmatite dyke in the Saga larvikite quarry, Mørje, Porsgrunn, in the southern Oslo region, Norway. The platy crystals, a few $\mu$m thick and up to 0.1 mm across, form intergrown aggregates. The color is white to creamy white; the mineral fluoresces yellowish white in both long-wave and short-wave UV light. Owing to the extremely thin crystals, only $\omega$ [1.705(5)] could be measured. The unit cell is hexagonal, $P6_3mc$, with $a$ 2.697(4), $c$ 4.372(4) Å and $V$ 27.54(6) Å$^3$. A chemical analysis gave (in wt.%) $SiO_2$ 0.7, $B_2O_3$ 1.4, $Al_2O_3$ 1.2, $Fe_2O_3$ 0.1, BeO 93.2, CaO 0.1, $H_2O$ 3.4, total 100.1. An infrared-absorption spectrum shows that water forms an integral part of the structure. This indicates that the Saga bromellite crystallized at about 200°C in vugs in coarsely crystalline natrolite, together with diaspore and chamosite, during the late-stage hydrothermal alteration of the primary minerals. Leucophanite and Be-substituted nepheline ($\sim$50 ppm Be) are possible sources for the beryllium in the residual hydrothermal fluids from which the bromellite crystallized.

*Keywords*: bromellite, chemical composition, physical properties, syenite pegmatite, Oslo region, Norway.

## SOMMAIRE

On trouve la bromellite dans un dyke immense de syénite pegmatitique dans la carrière de larvikite de Saga, Mørje, Porsgrunn, au sud d'Oslo, en Norvège. Les cristaux en plaquettes, d'une épaisseur de quelques micromètres et jusqu'à 0.1 mm de large, forment des agrégats en intercroissance. C'est un minéral blanc ou blanc crémeux qui donne une fluorescence blanc jaunâtre en lumière ultraviolette à onde courte ou longue. Vu la minceur des cristaux, seulement l'indice $\omega$ a pu être mesuré: 1.705(5). La maille est hexagonale, $P6_3mc$, $a$ 2.697(4), $c$ 4.372(4) Å, $V$ 27.54(6) Å$^3$. Une analyse chimique a donné (% pondéraux): $SiO_2$ 0.7, $B_2O_3$ 1.4, $Al_2O_3$ 1.2, $Fe_2O_3$ 0.1, BeO 93.2, CaO 0.1, $H_2O$ 3.4, total 100.1. Un spectre d'absorption infra-rouge prouve que l'eau fait partie intégrale de la structure. Ceci indique que la bromellite de Saga aurait cristallisé à environ 200°C avec diaspore et chamosite dans des vacuoles dans la natrolite à grains grossiers, au cours de l'altération hydrothermale tardive des minéraux primaires. Leucophanite et néphéline contenant environ 50 ppm de Be sont les sources possibles du beryllium dans les fluides résiduels qui ont produit la bromellite.

(Traduit par la Rédaction)

*Mots-clés*: bromellite, composition chimique, propriétés physiques, syénite pegmatitique, région d'Oslo, Norvège.

## INTRODUCTION

The minerals in the syenite pegmatite dykes in larvikite (monzonite) of the Langesundfjord district in the southern part of the Oslo region, Norway, became well known through the monograph of Brøgger (1890). An updated list of minerals and a brief review were published by Raade *et al.* (1980). In the last decade, a huge pegmatite dyke in the Saga larvikite quarry, situated on the mainland immediately east of the Langesundfjord, at Mørje, Porsgrunn, has yielded a large number of interesting minerals. Nearly 70 species, almost one half of all the minerals known from the syenite pegmatites in the Oslo region, have been identified from this dyke. Furthermore, the Saga pegmatite dyke shows a very interesting paragenesis of beryllium minerals; eleven beryllium minerals have been identified, among them the extremely rare species behoite, berborite, chiavennite and bromellite. The latter is the subject of this article.

## OCCURRENCE

Bromellite, BeO, was first described by Aminoff (1925) from Långban, Sweden. The mineral has been found in limited amounts in a few localities only, all of which are desilicated, skarn-like deposits (Kalenov 1959, Nefedov 1967, Klement'yeva 1969, Sergeyev 1973).

In 1984 a few samples of a fine-grained mineral in small vugs in natrolite were collected in the Saga larvikite quarry by one of the authors (SAB). It was subsequently identified at the Mineralogisk-Geologisk Museum in Oslo as bromellite.

The Saga bromellite occurs together with grey to green and violet crystals of diaspore (up to 2×0.5 mm in size) and pseudohexagonal prisms of green aluminian chamosite (up to 1×0.5 mm in size) in vugs of a coarsely crystalline, colorless to white natrolite. The bromellite-bearing natrolite is a result of hydrothermal alteration of nepheline. The zeoliti-

FIG. 1. A and B. Aggregates of bromellite crystals on natrolite, Saga quarry, Porsgrunn, Norway.

zation of nepheline in the Saga pegmatite dyke was briefly discussed by Larsen (1981).

## MORPHOLOGY, PHYSICAL AND OPTICAL PROPERTIES

The bromellite forms tiny tabular crystals in randomly intergrown aggregates, usually in complex rosettes (Fig. 1A, B). They are unevenly scattered throughout the vugs, which can be up to 5 cm in diameter. Smaller vugs may be completely filled with the aggregates of bromellite. The individual crystals are up to a few $\mu$m thick and up to 0.1 mm in diameter. The crystals are tabular parallel to *c*{0001}. At high SEM magnification, striated and irregularly developed pyramidal faces are seen. Tabular BeO crystals were described by Newkirk (1964) on synthetic material and by Sergeyev (1973) from a natural occurrence.

The Saga bromellite is vitreous and white to creamy white in color. The mineral fluoresces yellowish white in both long-wave and short-wave ultraviolet light.

The optical properties were difficult to obtain because of the small size and rough surface of the crystals. Only $\omega$ [1.705(5)] could be measured with some accuracy, by the immersion method using Na light. This value is slightly lower than expected for pure BeO ($\omega$ = 1.719) (Klement'yeva 1969), but distinctly higher than reported by Newkirk (1964) for hydrated BeO ($\omega$ = 1.628).

## X-RAY CRYSTALLOGRAPHY

Bromellite is hexagonal, space group $P6_3mc$, and has the wurtzite structure; it is isostructural with zincite (Sabine & Hogg 1969). The Saga bromellite was examined with a Philips PW 1700 powder diffractometer using Cu$K\alpha_1$ radiation, graphite monochromator and Si (NBS SRM 640a) as internal standard. The X-ray powder diffractogram matches that of synthetic BeO (PDF 4–843); the unit-cell dimensions obtained by least-squares refinement are *a* 2.697(4), *c* 4.372(4) Å, and *V* 27.54(6) Å$^3$. Chemical substitution to the extent found in the Saga bromellite has no significant effect on the unit-cell dimensions, but it may have some effect on the indices of refraction noted above.

## CHEMISTRY

Results of only two more or less complete analyses

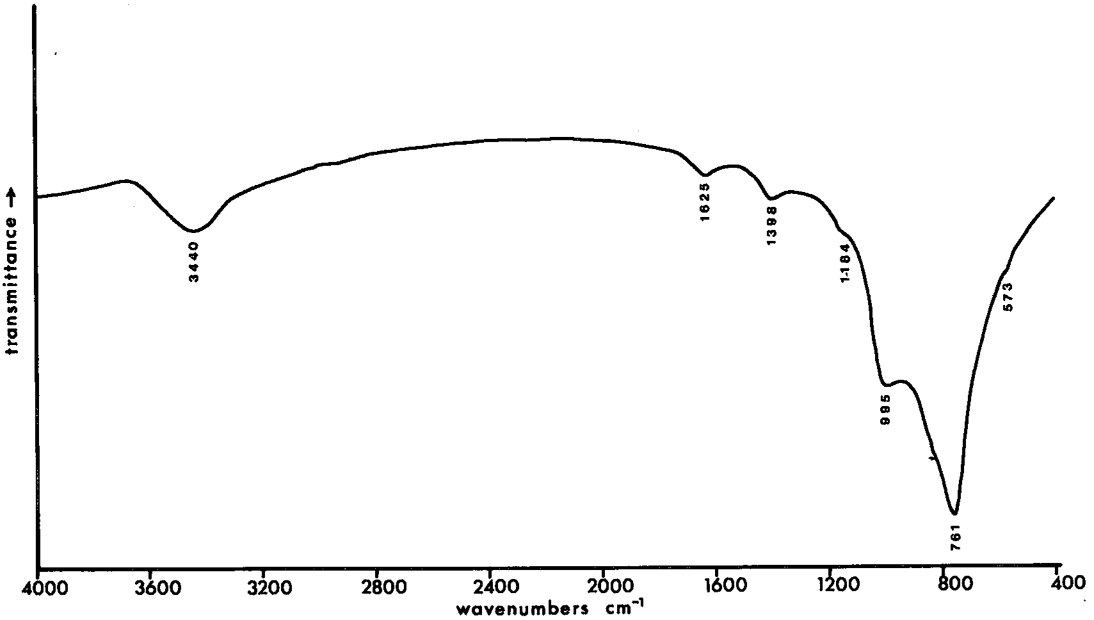

FIG. 2. Infrared-absorption spectrum of bromellite from the Saga quarry, Porsgrunn, Norway. The principal absorption bands are indicated.

of natural bromellite are reported in the literature (Aminoff 1925, Klement'yeva 1969). These show the mineral to be almost pure BeO (98.02 - 99.7 wt.% BeO). An analysis of the Saga bromellite, performed on carefully hand-picked grains under a binocular microscope, led to the following results (in wt.%): $SiO_2$ 0.7, $B_2O_3$ 1.4, $Al_2O_3$ 1.2, $Fe_2O_3$ 0.1, BeO 93.2, CaO 0.1, $H_2O$ 3.4, total 100.1 (analyst, A. Åsheim). Si, Al, Fe, Be and Ca were determined using atomic-absorption spectrometry after decomposition of the sample by potassium disulfate ($K_2S_2O_7$) melting flux and leaching with 2M $H_2SO_4$. Water was determined as loss on ignition at 950°C. B was determined using a Large Hilger quartz/glass spectrograph, DC arc (analyst, H.J. Bollingberg). The sample was mixed with Specpure $SiO_2$, $SrCO_3$ and carbon. Calibration was made against synthetic and natural B-Be-silicates. As in other samples of bromellite, beryllium is substituted to only a minor degree. The mineral is, however, slightly hydrated. This is in accordance with observations made by several authors; BeO formed at low temperatures may retain considerable amounts of water in the structure (Newkirk 1964, Bear *et al.* 1965). The latter authors reported up to 20% water below 200°C and 6% water at 300°C during recrystallization of BeO from dehydration of $Be(OH)_2$.

A sample of the Saga bromellite was stored at 110°C before it was pressed to a pellet with dry KBr and run in a Nicolet 5SX FTIR spectrometer. The infrared-absorption spectrum (Fig. 2) thus obtained indicates the presence of water of crystallization as a broad absorption band in the region 3200 - 3700 $cm^{-1}$ and a somewhat sharper peak at 1625 $cm^{-1}$. Residual water in the BeO structure has also been found using IR spectroscopy by Newkirk (1964) in his hydrothermal experiments. The absorption bands in the region 400 - 1500 $cm^{-1}$ are due to the Be - O stretching and bending vibrations.

## DISCUSSION

Certain areas in the Saga pegmatite dyke are heavily zeolitized. Nepheline, sodalite and cancrinite are completely altered to natrolite. The residual hydrothermal fluid is then enriched in aluminum, and forms gibbsite, diaspore and boehmite (Larsen 1981).

The beryllium responsible for the late-stage hydrothermal beryllium minerals may have two different sources. A primary beryllium mineral may have been altered at the zeolite stage of the pegmatite's evolution. The primary mineral probably is leucophanite, which has been found in other, less altered areas in the pegmatite dyke in masses of up to several kilograms. The same source for late-stage beryllium minerals in a zeolitized syenite pegmatite dyke at Langangen, 6 km northwest of the Saga quarry, has been proposed by Raade *et al.* (1983). Another source may be the beryllium content of the nepheline itself. This mineral is observed in unaltered parts of the pegmatite in masses up to several hundreds of kilograms. In two samples analyzed by us, 45 and 54 ppm Be were found. Beryllium may be liberated and leached out during the decomposition of nepheline, and subsequently concentrated in the latest hydrothermal fluid, from which the bromellite and other beryllium minerals crystallized.

From the samples collected, it is obvious that chlorite crystallized soon after natrolite, then diaspore and bromellite approximately simultaneously. This is consistent with the assumption by Burt (1978) that bromellite is presumably stable with diaspore in the system BeO - $Al_2O_3$ - $H_2O$. The hydrothermal experiments by Newkirk (1964) indicate that formation of bromellite is relatively pressure-insensitive, with a lower stability limit toward behoite $Be(OH)_2$ at 175 - 200°C. Newkirk found that the BeO crystallized close to this lower T limit is hydrated, with an enlarged unit-cell. However, he provided no data on the degree of hydration. The slightly hydrated Saga bromellite thus probably crystallized at a temperature of about 200°C or slightly below, but not as low as $\sim 135°C$, as this is approximately the boundary between diaspore + metastable boehmite and gibbsite (Ervin & Osborn 1951). Gibbsite is, however, locally abundant in the Saga pegmatite, but never coexists with beryllium minerals. Diaspore and boehmite are abundant in other areas of the pegmatite dyke; boehmite typically coexists with some of the low-temperature beryllium minerals (behoite, berborite).

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