

# SHORT COMMUNICATIONS

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## Occurrences of boron-free and boron-poor kornerpupine

In a recent paper Vry (1994) described under the title 'Boron-free kornerpupine from the Reynolds Range, Arunta Block, central Australia' the discovery of 'nearly boron-free kornerpupine...' (Vry, 1994, p. 27) as the third occurrence, world-wide, of boron-free kornerpupine. This assertion is in error. The two localities referred to by Vry (1994) where boron-free kornerpupine had earlier been reported were first, at Fiskeneset in southern West Greenland (Herd, 1973) and second, in the Limpopo Belt at Beit Bridge, Zimbabwe (Schreyer and Abraham, 1976). The occurrence of boron-free kornerpupine from Fiskeneset harbour was initially reported by Herd (1973), samples from the type locality being described as not containing boron on the basis of the element being sought, but not detected, by laser probe. This occurrence was referred to by Schreyer and Abraham (1976) when describing the Limpopo locality, as the first naturally-occurring example.

Subsequently, Ackermann *et al.* (1984) described kornerpupine from Sarfaq (some 25 km south-east of Fiskeneset) involved in breakdown reactions which included tourmaline and thus was assumed to contain boron. Because of the importance of boron-free kornerpupine to  $P-T$  estimates (e.g. Siefert, 1975; Schreyer and Abraham, 1976), samples of kornerpupine from the type locality at Fiskeneset were subsequently re-examined using an ion-probe mass analyser by Grew *et al.* (1987). All of the three samples they analysed, including a repeat of the sample first analysed by Herd (1973), were found to contain boron. This re-examination of the Fiskeneset material by Grew *et al.* (1987) effectively reduced the known occurrences of natural, boron-free kornerpupine to one, that of the Limpopo Belt. Within the Limpopo Belt more localities with examples of mineral assemblages containing boron-free kornerpupine have sub-

sequently been found (Windley *et al.* 1984; Droop, 1989).

Both the type locality for kornerpupine, at Fiskeneset harbour, and that at Sarfaq were metamorphosed to granulite-facies conditions and subsequently underwent some retrogression under hydrous, amphibolite-facies conditions. To the east of the type locality, there are several other known occurrences of kornerpupine in the Fiskeneset region which span the prograde amphibolite- to granulite-facies boundary (see McGregor and Friend, 1992, Fig. 2). To investigate the possibility that there may yet be boron-free kornerpupine in this region, two examples from an area of amphibolite facies rocks near the Inland Ice some 50 km east of Fiskeneset were examined. The samples were analysed using ICP-AES by the Analytical Laboratory of the Institut für Mineralogie, Ruhr-Universität.

The two samples came from enclaves of ultrabasic rocks which have reacted due to their engulfment by the parent magmas of the Fiskeneset anorthosite complex and are associated with the Cr-rich sapphirine described by Friend (1982). The two samples differ considerably in their appearance. Kornerpupine in GGU 183393 has a deep, sea-green colour and is associated with calcic plagioclase and minor phlogopite. Sample GGU 183514 has pale, cream-coloured kornerpupine associated with calcic plagioclase. This kornerpupine contains inclusions of corundum along the contacts of which reactions have formed the magnesian chlorite sheridanite. Representative analyses of the cream-coloured kornerpupine and associated minerals from GGU183514 are given in Table 1. The kornerpupine data plot just to the aluminous side of the point  $\text{SiO}_2:\text{RO}:\text{R}_2\text{O}_3 = 1:1:1$  in a ternary diagram (Fig. 1) in which compositions of the associated phases are also given. The kornerpupine is very magnesian with

TABLE 1. Microprobe analyses of kornepupine and associated chlorite (sheridanite) from GGU 183514/1

|                                | 1       |               | 2           |               |
|--------------------------------|---------|---------------|-------------|---------------|
|                                | korn    | range         | sheridanite | range         |
| SiO <sub>2</sub>               | 29.03   | (28.28–29.31) | 28.24       | (28.15–30.50) |
| TiO <sub>2</sub>               | 0.07    | (0.06–0.09)   | 0.06        | (0.04–0.06)   |
| Al <sub>2</sub> O <sub>3</sub> | 48.86   | (48.52–49.84) | 23.32       | (22.79–23.32) |
| Cr <sub>2</sub> O <sub>3</sub> | 0.03    | (0.02–0.05)   | 0.03        | (0.02–0.05)   |
| FeO                            | 1.36    | (1.28–1.43)   | 1.42        | (1.35–1.46)   |
| MnO                            | 0.01    | (0.01–0.05)   | 0.01        | (0.01–0.03)   |
| MgO                            | 18.07   | (17.50–18.07) | 31.80       | (31.30–31.85) |
| CaO                            | 0.07    | (0.06–0.07)   | 0.03        | (0.00–0.07)   |
| Na <sub>2</sub> O              | 0.05    | (0.05–0.06)   | 0.01        | (0.01–0.03)   |
| K <sub>2</sub>                 | 0.04    | (0.02–0.04)   | 0.04        | (0.02–0.04)   |
| *B <sub>2</sub> O <sub>3</sub> | (0.38)  |               | na          |               |
| *H <sub>2</sub> O <sup>+</sup> | (1.20)  |               | na          |               |
| Total                          | 99.17   |               | 84.96       |               |
| Cations                        | 21.5(O) |               | 28(O)       |               |
| Si                             | 3.592   |               | Si          | 6.447         |
| Al                             | 1.327   |               | Al          | 1.553         |
| B                              | 0.081   |               | t           | 8.000         |
| t                              | 5.000   |               | Al          | 4.723         |
| Al                             | 5.798   |               | Ti          | 0.010         |
| Cr                             | 0.003   |               | Cr          | 0.017         |
| Ti                             | 0.007   |               | Fe          | 0.275         |
| Fe                             | 0.141   |               | Mn          | 0.003         |
| Mn                             | 0.001   |               | Mg          | 5.360         |
| Mg                             | 3.333   |               | Ca          | 0.007         |
| t                              | 9.282   |               | Na          | 0.004         |
| Ca                             | 0.009   |               | K           | 0.012         |
| Na                             | 0.012   |               | t           | 10.411        |
| K                              | 0.006   |               |             |               |
| t                              | 0.028   |               |             |               |
| Total cations                  | 14.310  |               |             |               |
| anions                         |         |               |             |               |
| OH                             | 0.990   |               |             |               |

\*B and H<sub>2</sub>O were analysed on a bulk mineral separate.  
na, not analysed

$X_{Mg}$  in excess of 0.96, which is a similar value to those reported by Grew *et al.* (1987), but higher than those reported by both Ackermann *et al.* (1984) at  $X_{Mg}$  0.74–0.77 and Vry (1994) at *c.* 0.85. The B<sub>2</sub>O<sub>3</sub> contents of the two samples varies considerably, the cream-coloured GGU 183514 contained 0.38% B<sub>2</sub>O<sub>3</sub> (Table 1) whilst the sea-green GGU183393 contained 1.97% B<sub>2</sub>O<sub>3</sub>. This latter sample is rather more boron-rich than any of those from Fiskensættet reported by Grew *et al.* (1987). Water (as H<sub>2</sub>O<sup>+</sup>) was less variable, having 1.2% and 1.80% respectively. There appears to be no negative correlation between B<sub>2</sub>O<sub>3</sub> and water as was suggested might occur by Werding and Schreyer (1978).

A problem now arises as to what is intended by the term 'boron-free' kornepupine. The literature (e.g. Grew *et al.*, 1990) contains an increasing number of kornepupine analyses which include B. When B vs. Al<sup>iv</sup> is plotted, a clear linear correlation emerges (Fig. 2) and, apart from the truly B-free samples, the kornepupine from GGU183514 has the lowest reported B when compared with other high-quality data. From this diagram it may be anticipated that potentially there should be a complete substitution with no obvious gaps. It then becomes debatable as to whether a term is needed to describe those kornepupine analyses which have very low contents of boron and, as contended by Vry (1994), may act as

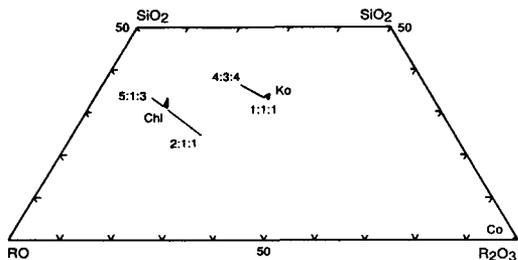


FIG. 1. Ternary diagram of the plane  $\text{SiO}_2$ – $(\text{Mg,Fe,Mn})\text{O}$ – $(\text{Al,Cr,B})_2\text{O}_3$  (molecular proportions), showing the compositions of the phases kornerupine (Ko), sheridanitic chlorite (Chl) and corundum (Co) in GGU 183514. The accepted solid-solution ranges for kornerupine (4:3:4–1:1:1) and chlorite (5:1:3–2:1:1) are indicated.

a  $P$ – $T$  indicator. In consequence it is recommended that the term 'boron-free' is specifically not used unless boron has been adequately analysed for and not detected (e.g. Droop, 1989; Grew *et al.*, 1990). When considering the designation of trace elements in a mineral, weights of less than 0.1 wt.% are

sometimes used, but because boron is a light element 0.5 wt.%  $\text{B}_2\text{O}_3$  converts to approximately 0.1 atoms per formula unit. It is suggested, therefore, that a new term 'boron-poor' kornerupine be introduced to cover those examples that have  $\leq 0.2$  B atoms p.f.u.

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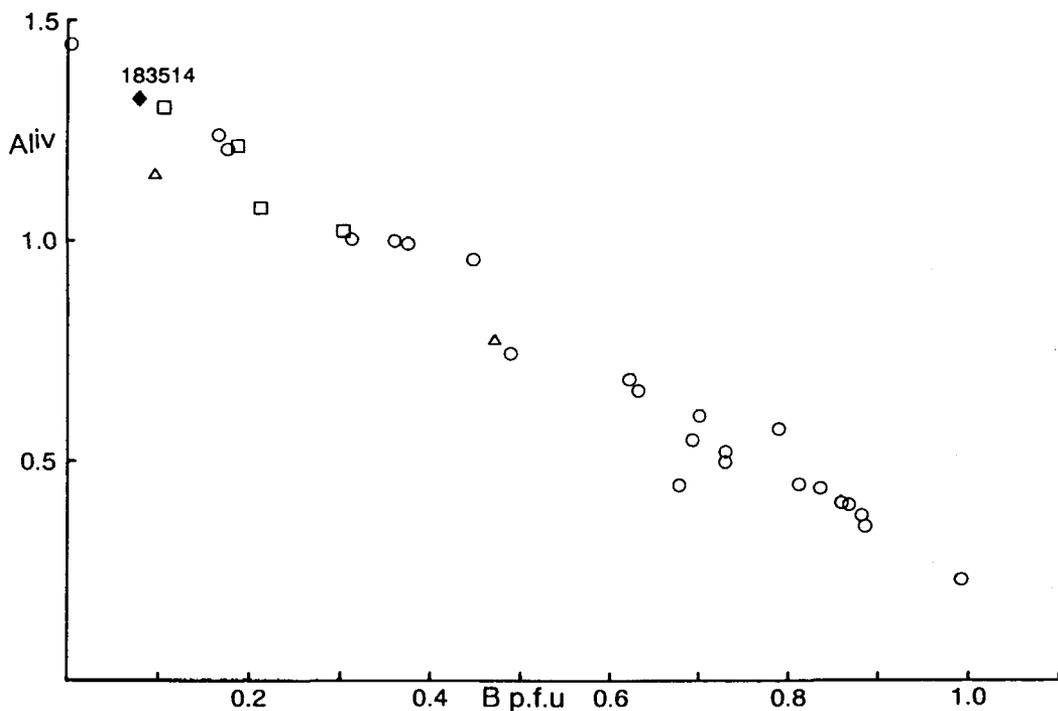


FIG. 2. Plot of  $\text{Al}^{\text{IV}}$  vs. B atoms per formula unit showing a linear correlation and the position of GGU 183514 (solid diamond). Other data from: boxes, Grew *et al.* (1987); circles, Grew *et al.* (1990); open triangles, Vry (1994).

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## A second occurrence of mahlmoodite, from Cornwall, England

MAHLMOODITE, FeZr(PO<sub>4</sub>)<sub>2</sub>·4H<sub>2</sub>O, is a rare mineral, hitherto known only from its type locality, the Union Carbide Vanadium mine, Wilson Springs, Garland County, Arkansas, USA. Although illustrated, and correctly formulated by Hey *et al.* (1982) as a new Fe–Zr–Sc phosphate, it has only recently been formally described and named (Milton *et al.*, 1993). Mahlmooodite is very scarce at Wilson Springs and occurs as tiny cream spherules in vugs in vanadium ore. Hey *et al.* (1982) illustrate mahlmooodite spherules on crystals of kolbeckite; more commonly they occur on crystals of sodic pyroxene.

Mahlmooodite has now been identified on a number of specimens from a coastal exposure of Zn-Fe

mineralization at Kerriack Cove, between Porthtowan and Portreath, near Redruth, Cornwall, England (NGR SW678470).

Kerriack Cove is situated in Devonian sandstones and slates of the Falmouth and Portscatho series. At the northern end of the cove, an E–W lode bearing quartz, sphalerite, chalcopyrite and galena was worked, principally for zinc, as part of the Wheal Lushington sett (Dines, 1956; Dewey, 1921). Towards the middle of the cove, an E–W trending mineralized fissure vein crops out in a shelf of rock at the base of the cliff. This vein, up to 4 cm wide, carries mainly sphalerite, pyrite, green chlorite and quartz, with minor galena and chalcopyrite, and