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# DIOMIGNITE: NATURAL $Li_2B_4O_7$ FROM THE TANCO PEGMATITE, BERNIC LAKE, MANITOBA

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## ABSTRACT

Diomignite, $Li_2B_4O_7$, occurs as a clear, colorless, tetragonal daughter mineral (30 $\mu$m in maximum dimension) in fluid inclusions in spodumene from the Tanco pegmatite, Bernic Lake, Manitoba. Its identity was established by several analytical techniques, and confirmed by the identical Gandolfi X-ray-diffraction pattern for diomignite and synthetic $Li_2B_4O_7$. Optical properties are: uniaxial (-) for diomignite and synthetic $Li_2B_4O_7$; $\omega = 1.612(2)$, $\epsilon = 1.554(2)$, $\delta = 0.058(4)$ for synthetic $Li_2B_4O_7$. Geometrical properties are: $a$ 9.470(4), $c$ 10.279(5) Å, refined in the space group $I4_1cd$; $V$(cell) = 921.83(5) Å$^3$, $Z = 8$, $V$(mole) = 69.397 cm$^3$, $D$(calc) = 2.437 g/cm$^3$. The strongest five X-ray lines [$d$ in Å(I, $hkl$)] are: 4.07(100,112), 2.662(60,123), 3.495(50,022), 2.587(40,132), and 2.045(40,332). Natural diomignite and $Li_2B_4O_7$ synthesized at high $P$ and $T$ commonly appear trigonal or cubic in form. The rhombohedral or cubic appearance can be reconciled with the tetragonal space-group by the pseudocubic shape of the diomignite cell ($c/a \simeq 1$), by the generation of 2 pseudomirrors with rotation about a three-fold pseudoaxis, and by angular intersections of $[0k0] \wedge [hkl]$ of approximately 60°. The $Li_2B_4O_7$ component (as diomignite) served as a flux to depress solidus temperatures, to increase silicate - $H_2O$ miscibility, and to enhance the solubilities of ore-forming incompatible lithophile elements in late-stage pegmatitic fluids at Tanco.

*Keywords:* fluid inclusions, lithium, boron, alkali tetraborate, granite, pegmatite, melt properties, volatile components, rare elements, Tanco, Manitoba.

## SOMMAIRE

La diomignite, $Li_2B_4O_7$, espèce minérale tétragonale dite "fille", se présente en petits cristaux (30 $\mu$m au maximum) incolores et limpides; on les trouve dans les inclusions fluides du spodumène de la pegmatite de Tanco, au lac Bernic, Manitoba. On a établi son identité par différentes méthodes analytiques; l'identification a été confirmée aux rayons X lorsque le cliché Gandolfi s'est avéré identique à celui du $Li_2B_4O_7$ synthétique. Propriétés optiques: uniaxe négatif, tel qu'observé sur cristaux naturels et synthétiques; $\omega = 1.612(2)$, $\epsilon = 1.554(2)$, $\delta = 0.058(4)$ (synthétique). Propriétés géométriques: les dimensions de la maille, $a$ 9.470(4), $c$ 10.279(5) Å, obtenues sur diomignite, ont été affinées dans le groupe (connu) $I4_1cd$; $V$ (maille) 921.83(1) Å$^3$, $Z = 8$, $V$ (mole) = 69.397 cm$^3$, densité calculée 2.437. Les cinq raies les plus intenses du cliché de poudre [$d$ en Å(I) ($hkl$)] sont: 4.07(100)(112), 2.662(60)(123), 3.495(50)(022), 2.587(40)(132), 2.045(40)(332). La diomignite, tout comme le $Li_2B_4O_7$ synthétisé à hautes T et P, présente des formes pseudo-rhomboédriques et pseudo-cubiques. L'apparition d'un axe pseudo-ternaire s'explique par la forme pseudo-cubique de la maille ($c/a \simeq 1$), par la génération de deux pseudo-mirroirs de rotation, et par une intersection de $0k0$ et de $hkl$ d'environ 60°. Le composant $Li_2B_4O_7$ a agi comme fondant pour abaisser la température du solidus; il a de plus augmenté la miscibilité entre silicates et phase fluide, et la solubilité, dans les fluides pegmatitiques tardifs à Tanco, des éléments lithophiles incompatibles susceptibles de former des zones minéralisées.

(Traduit par la Rédaction)

*Mots-clés:* inclusions fluides, lithium, bore, tétraborate alcalin, granite, pegmatite, propriétés du bain, composants volatils, éléments rares, Tanco, Manitoba.

## INTRODUCTION

A study of fluid inclusions in spodumene from the Tanco pegmatite, Bernic Lake, Manitoba, has revealed the presence of a complex assemblage of daughter minerals (London 1982, 1983, 1984b, 1986a, London *et al.* 1982). This crystalline assemblage includes a highly birefringent, colorless phase that has subsequently been identified as the new mineral species *diomignite,* natural $Li_2B_4O_7$. The name *diomignite* stems from Homeric Greek *dios mignen* (divine mix), in allusion to the pronounced fluxing effects of $Li_2B_4O_7$ on the hydrous pegmatite magma. Type samples have been deposited in the Smithsonian Institution, National Museum of Natural History (USNM 164236), Washington, D.C., and the American Museum of Natural History (AMNH

98089), New York, N.Y., in the form of doubly polished chips of spodumene that contain diomignite-bearing inclusions. The mineral name and species have received approval by the IMA Commission on New Minerals and Mineral Names. Diomignite is the first new mineral species to be described solely as a daughter mineral in fluid inclusions.

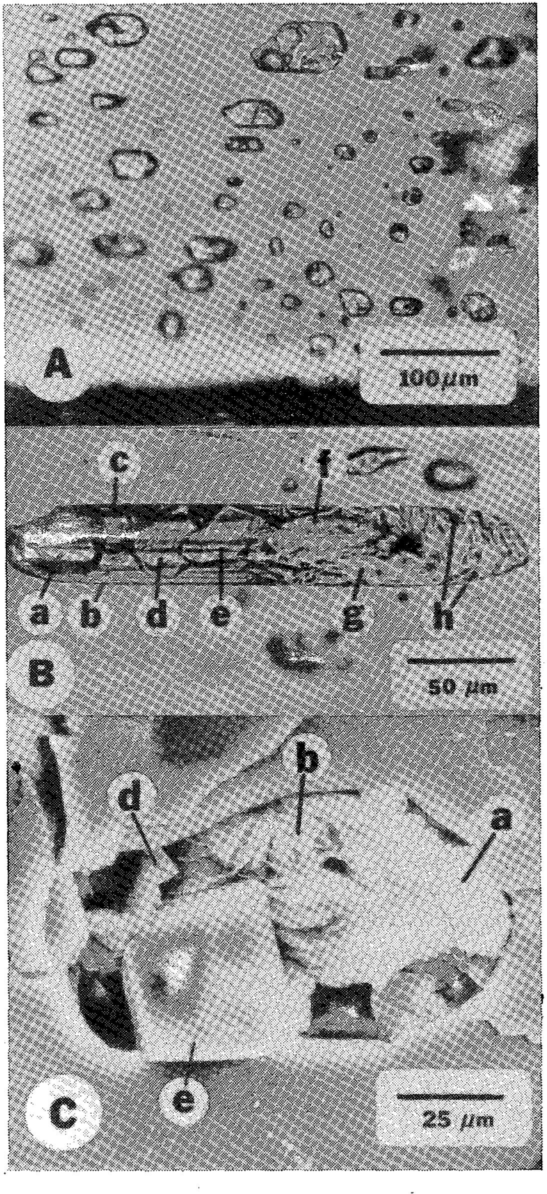

FIG. 1. (A) Doubly polished chip of spodumene (partly crossed polars) from Tanco, illustrating the size, distribution and contents of crystal-rich, diomignite-bearing inclusions. (B) Photomicrograph (partly crossed polars) of a diomignite-bearing inclusion in coarse-grained spodumene from Tanco. Included phases are aqueous vapor (a), aqueous liquid (b), an unidentified rhombohedral carbonate (c), diomignite (d), albite or pollucite (e), albite (f), cookeite (g), and an oxide (h) that, from EDS analyses, appears to be microlite. Photographs (A) and (B) reprinted from London (1986a). (C) SEM image of a diomignite-bearing inclusion. In addition to diomignite (e) the inclusion contains albite (a), cookeite (b), and quartz (d). Photograph (C) reprinted from London *et al.* (1982).

## OCCURRENCE

Diomignite has been observed only as small (≤ 30 µm) anhedral to euhedral crystals in fluid inclusions in spodumene, and tentatively in fluid inclusions in the petalite from which most of the spodumene formed. In these associations, diomignite is an abundant and widely distributed phase; it occurs in virtually every crystal-rich inclusion in spodumene (Fig. 1A). Diomignite is a component of an assemblage of daughter minerals that includes albite, cookeite, quartz, pollucite–analcime solid solution, microlite, and an unidentified carbonate (Fig. 1B). Diomignite and associated daughter minerals are entirely absent from the abundant fluid inclusions in the quartz that formed contemporaneously with the spodumene (as spodumene + quartz pseudomorphs after petalite: Černý & Ferguson 1972). Evidence cited in London (1985) shows that the inclusions in quartz are secondary and are not contemporaneous with those in spodumene.

## IDENTIFICATION

The fine grain-size of diomignite, its location in fluid inclusions as loosely attached crystals, and its composition make the characterization difficult and incomplete in that no definitive chemical analysis could have been performed. The data presented below, however, are sufficiently diagnostic that little doubt remains as to the identity or composition of the phase.

In doubly polished plates of spodumene, diomignite can be readily recognized by its high birefringence (Table 1). Euhedral crystals commonly appear pseudorhombohedral or pseudocubic in form. Cleavage and twinning have not been observed in diomignite.

Diomignite crystals on spodumene cleavage surfaces were examined by scanning and point-mode electron microscopy (SEM) and energy-dispersion spectroscopic (EDS) analysis at an accelerating voltage of 15 keV, condenser current of 2.0 amps, and 100 seconds of live count-time on an Si(Li) detector crystal (Fig. 1C). The EDS analyses of carbon-coated diomignite crystals show no detectable major or minor elements in any of several orientations with respect to the electron-beam and detector-crystal geometries, thus providing confirmation that diomignite consists wholly of elements with an atomic num-

TABLE 1. OPTICAL AND PHYSICAL PROPERTIES OF TANCO DIOMIGNITE AND SYNTHETIC $Li_2B_4O_7$

| | diomignite | synthetic $Li_2B_4O_7$ | | |
|---|---|---|---|---|
| | | Sastry and Hummel (1958) | Krogh-Moe (1962) | London* |
| Optics: | | | | |
| Indicatrix | uniaxial (-) | uniaxial (-) | | uniaxial (-) |
| R.I. | high ($\bar{n}$ ∿ 1.6) | $\omega$ = 1.605(2)**<br>$\varepsilon$ = 1.560(2) | | $\omega$ = 1.612(1)<br>$\varepsilon$ = 1.554(2) |
| Birefringence | high ($\delta$ ∿ 0.05) | $\delta$ = 0.045(4) | | $\delta$ = 0.058(4) |
| Unit Cell: | | | | |
| Space Group | $I4_1cd$ | $I4_1cd$ | $I4_1cd$*** | $I4_1cd$ |
| Cell Parameters | $a$ = 9.470(4) Å<br>$c$ = 10.279(5) Å | $a$ = 9.470 Å<br>$c$ = 10.278 Å | $a$ = 9.477(3) Å<br>$c$ = 10.286(4) Å | $a$ = 9.464(3) Å<br>$c$ = 10.275(4) Å |
| V(cell) | 921.83(1) $Å^3$ | 921.7 $Å^3$ | 923.82(1) $Å^3$ | 920.30(1) $Å^3$ |
| Z | 8 | 8 | 8 | 8 |
| Physical Properties: | | | | |
| Molar Volume | 69.397 $cm^3$ | 69.387 $cm^3$ | 69.546 $cm^3$ | 69.281 $cm^3$ |
| Density (calc) | 2.437 $g/cm^3$ | 2.437 $g/cm^3$ | 2.432 $g/cm^3$ | 2.441 $g/cm^3$ |
| Crystal Forms | pyramid {111}<br>prism {100} | hexagonal | | pyramid {111}<br>prism {100} |

*This report; see Figure 2
**Standard deviation to last significant figure
***tetragonal space-group assigned by Krogh-Moe (1962)

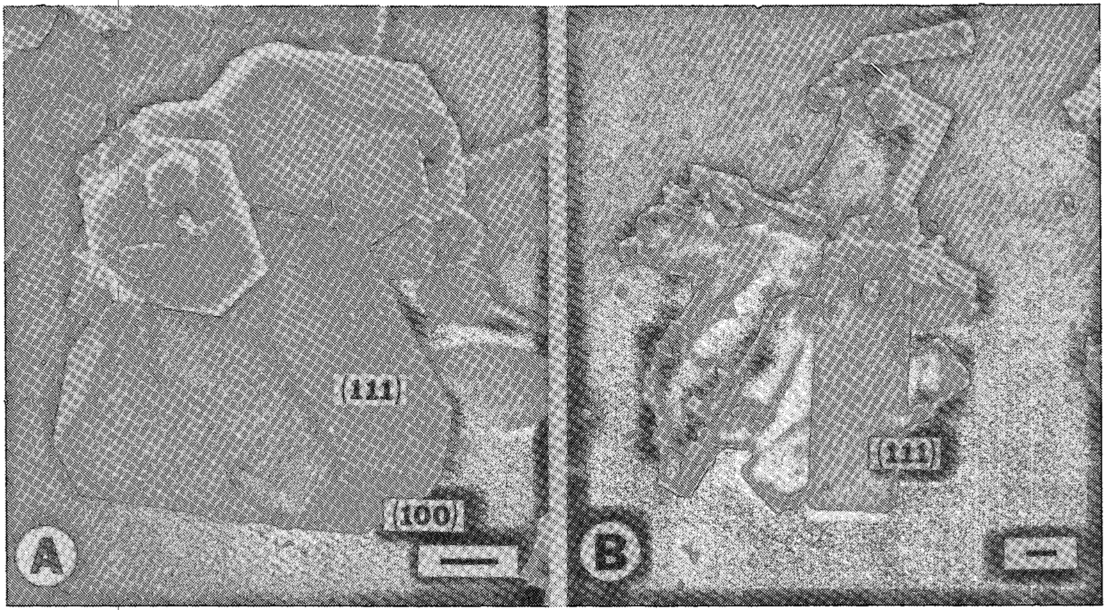

FIG. 2. SEM images of synthetic $Li_2B_4O_7$ crystallized at 600°C and $P(H_2O)$ = 200 MPa (A) and at room temperature and pressure (B). Apparent tetragonal forms are prism {100} and pyramid {111}. Although the crystals in (B) appear orthorhombic in symmetry, they have the same X-ray powder-diffraction pattern (tetragonal) as reported by Krogh-Moe (1962). Projection gives diomignite and high-temperature synthetic $Li_2B_4O_7$ a pseudotrigonal or pseudocubic appearance in some orientations. The {100} prism is rarely developed or absent in $Li_2B_4O_7$ crystals synthesized at room temperature and pressure. Scale bar in both photos is 10 $\mu$m.

ber less than 11. Additional delimiting information on the composition of diomignite was obtained from microthermometric measurements of solubility in unopened fluid inclusions (London 1986a). The observed depression in the freezing point of the aqueous fluid that surrounds the diomignite crystals is indicative of a low-salinity solution (*cf.* a solubility for $Li_2B_4O_7$ of 2.98 g/100 cm$^3$ cold water: Weast 1974; see London 1986a). Although complex and incomplete, the measured thermometric properties for synthetic $Li_2B_4O_7$–$H_2O$ solutions also show a relatively small depression in the freezing point [-1.6(0.1)°C] that is consistent with the microthermometric data on the aqueous phase in inclusions in the spodumene. Heating the inclusions to 350°C showed little rounding of the corners or edges of diomignite crystals over the duration of the experiments (up to 30 minutes). The combined results of freezing and heating data show that diomignite, like $Li_2B_4O_7$, is sparingly soluble in an aqueous fluid medium. The diomignite daughter crystals are stable to a $T$ in excess of 375°C, which precludes sassolite $H_3BO_3$ as a possible candidate. Sassolite decomposes incongruently above 170°C (Weast 1974). The aqueous fluids in the inclusions are saturated with respect to diomignite to approximately 420°C, the temperature of final disappearance of diomignite crystals. In the system $Li_2B_4O_7$–$H_2O$, lithium tetraborate melts congruently at 700°C and $P_{\text{fluid}} = 200$ MPa (London 1983, 1986a).

In hydrothermal experiments in which diomignite dissolved and reacted with aluminosilicate phases to form glass on the quench, no $CO_2$-rich fluid was evolved; thus diomignite was shown not to be a carbonate. Fluid inclusions near the tips of large laths of primary spodumene do contain a carbonate in addition to diomignite (Fig. 1B). Where the two phases coexist, the carbonate usually can be distinguished from diomignite by its higher birefringence. In addition, the carbonate dissolves completely between 275 and 300°C, and yields a small amount of liquid $CO_2$ upon subsequent quench of the hydrothermal experiments.

A search for a highly birefringent non-carbonate phase that is slightly soluble in water, is stable to a temperature above 375°C, and is composed wholly of elements lighter than sodium, yielded very few possibilities among known inorganic compounds. Among these compounds, only $Li_2B_4O_7$ satisfies all of the available data on the optical and physical–

TABLE 2. X-RAY POWDER-DIFFRACTION DATA FOR TANCO DIOMIGNITE AND SYNTHETIC $Li_2B_4O_7$

| | | diomignite | | synthetic $Li_2B_4O_7$ | | | |
|---|---|---|---|---|---|---|---|
| hkl | $d_{\text{calc}}$(Å)* | $d_{\text{obs}}$(Å) | $I/I_0$ | $d_{\text{obs}}$(Å)+ | $I/I_0$+ | $d_{\text{obs}}$(Å)** | $I/I_0$** |
| 020 | 4.735 | 4.73 | 10 | 4.74 | 8 | 4.72 | 8 |
| 012 | 4.517 | 4.51 | 10 | -- | -- | 4.51 | 1 |
| 112 | 4.077 | 4.07 | 100 | 4.08 | 100 | 4.07 | 100 |
| 121 | 3.916 | 3.908 | 20 | 3.918 | 18 | 3.914 | 18 |
| 022 | 3.482 | 3.495 | 50 | 3.485 | 40 | 3.486 | 40 |
| 130 | 2.995 | -- | -- | 2.997 | 2 | 2.995 | 2 |
| 123 | 2.664 | 2.662 | 60 | 2.665 | 40 | 2.662 | 40 |
| 132 | 2.588 | 2.587 | 40 | 2.589 | 55 | 2.587 | 55 |
| 004 | 2.570 | -- | -- | 2.571 | 6 | 2.568 | 6 |
| 231 | 2.545 | 2.545 | 10 | 2.547 | 8 | 2.545 | 8 |
| 040 | 2.368 | 2.370 | 5 | 2.369 | 6 | 2.360 | 6 |
| 024 | 2.259 | -- | -- | 2.261 | 2 | -- | -- |
| 141 | 2.242 | 2.240 | 20 | 2.243 | 14 | 2.240 | 14 |
| 042 | 2.150 | -- | -- | 2.152 | 4 | 2.152 | 4 |
| 240 | 2.118 | -- | -- | 2.119 | 4 | 2.117 | 4 |
| 233 | 2.085 | 2.085 | 20 | 2.086 | 10 | 2.084 | 10 |
| 332 | 2.047 | 2.045 | 40 | 2.049 | 25 | 2.047 | 25 |
| 224 | 2.039 | -- | -- | 2.040 | 12 | 2.039 | 12 |
| 242 | 1.958 | 1.957 | 20 | 1.959 | 10 | 1.954 | 10 |
| 134 | 1.950 | 1.952 | 10 | 1.951 | 8 | 1.950 | 8 |
| 143 | 1.908 | 1.910 | 10 | 1.909 | 10 | 1.903 | 10 |
| 341 | 1.863 | -- | -- | 1.864 | 2 | 1.862 | 2 |
| 150 | 1.857 | 1.852 | 5 | 1.858 | 2 | 1.856 | 2 |
| 125 | 1.849 | -- | -- | 1.851 | 4 | 1.850 | 4 |
| 152 | 1.747 | -- | -- | 1.748 | 2 | 1.749 | 2 |
| 044 | 1.741 | -- | -- | 1.742 | 4 | 1.745 | 4 |
| 251 | 1.733 | 1.734 | 10 | 1.734 | 8 | 1.731 | 8 |
| 116 | 1.660 | 1.657 | 5 | 1.660 | 8 | 1.658 | 8 |
| | | | | plus 13 more lines | | plus additional lines | |

* indexed using the program Unit Cell (Appleman and Evans, 1973).

\+ Krogh-Moe, 1962.

** synthesis at 600°C, 2 kbar P($H_2O$); see Figure 2.

chemical properties of diomignite. Confirmation of the identity of diomignite was obtained by Gandolfi X-ray-diffraction patterns of single crystals. Diomignite crystals were extracted from fluid inclusions by the method described by Zolensky & Bodnar (1982). Single crystals were X-rayed in a Gandolfi camera 57.3 mm in diameter using Cu$K\alpha$ radiation generated at 40 kV and 20 mA, with a Ni foil filter, and a graphite monochromator. A single crystal of diomignite mounted on a glass whisker was run for three days under vacuum. (Because of the length of exposure and the faintness of the lines, the pattern for diomignite does not copy well. The original film pattern may be borrowed from the first author.) A crystalline Si standard was used to determine the camera constant. Corrections for film shrinkage proved to be unnecessary. The observed X-ray-diffraction pattern (Table 2) is virtually identical to the powder patterns reported for synthetic $Li_2B_4O_7$ by Sastry & Hummel (1958) and Krogh-Moe (1962; PDF 18–717) (Fig. 2, Table 2). Intensities of individual reflections differ from those of synthetic $Li_2B_4O_7$ because the present study relied on single crystals of diomignite mounted in a Gandolfi camera. The X-ray data for synthetic $Li_2B_4O_7$ were obtained from powder patterns.

The space group of synthetic $Li_2B_4O_7$ is $I4_1cd$, and its cell parameters are $a$ 9.477(5), $c$ 10.286(6) Å (Krogh-Moe 1962, Natarajan *et al.* 1979). A least-squares refinement of the Gandolfi camera data for diomignite using the program of Appleman & Evans (1973) yielded refined cell-parameters that are in close agreement with those of Krogh-Moe (1962) for synthetic $Li_2B_4O_7$ (Table 1). The tetragonal space-group and symmetry proposed by Krogh-Moe (1962) for synthetic $Li_2B_4O_7$, however, are inconsistent with the apparent trigonal and cubic forms displayed by diomignite and by synthethic $Li_2B_4O_7$ (*e.g.*, Sastry & Hummel 1958) (Fig. 2A). The space-group assignment is unequivocal, and diomignite necessarily resides in the crystal class $4mm$. The three-fold pseudo-axis can be explained by noting the pseudocubic shape of the diomignite cell ($c/a \simeq 1$). This three-fold pseudo-axis, combined with one of the mirrors of $4mm$ (the true symmetry), creates two pseudomirrors and yields $3m$ pseudosymmetry. In addition, diomignite and $Li_2B_4O_7$ crystals synthesized at hydrothermal conditions possess a short tetragonal {100} prism, and angular intersections of {100} prism and {111} pyramid faces at approximately 60°. The columnar crystals of Figure 2B are elongate parallel to [101], presumably as a result of external effects on their growth.

We attempted in vain to obtain ion-microprobe data for diomignite (with Dr. Erik Steele, analyst, National Bureau of Standards, Gaithersburg, Maryland). The crystals originally X-rayed by M.E.Z., however, had popped off their whisker mounts and were lost. Efforts to locate diomignite crystals by ion microscopy in grain mounts were hampered by two factors: (1) the crushed host spodumene diluted the abundance of diomignite crystals by a factor of approximately $10^5$, and (2) with the limited $Z$-direction focus on the Cameca IMS–3F ion probe, the topography of the grain-mount surface was found to be too great for secondary-ion imaging. We subsequently attempted to use an Ar ion mill to expose a diomignite-bearing inclusion near a polished surface of spodumene. Even the botryoidal surface produced by ion milling produced some dispersion of the secondary ion beam, and the dispersion and sample charging around inclusion walls precluded any focusing of the secondary beam. Further Ar-ion milling to minimize the relief of inclusion walls demonstrated that diomignite is more volatile in a charged Ar beam than is spodumene, and diomignite crystals were quickly cratered to oblivion.

## SIGNIFICANCE OF NATURAL $Li_2B_4O_7$ IN PEGMATITE SYSTEMS

Diomignite and the associated aluminosilicate daughter minerals represent the crystallization products of a late-stage hydrous borosilicate fluid that was entrapped principally by spodumene that formed as a result of the breakdown of petalite to spodumene + quartz. This reaction relationship was recognized at Tanco by Černý & Ferguson (1972) and has been confirmed experimentally by Stewart (1963, 1978), Munoz (1971), and London (1984a). The results of fluid-inclusion microthermometry and other experimental data place entrapment conditions at 470–500°C and 270–290 MPa, the $P$–$T$ interval over which spodumene crystallized at Tanco (London 1986a). The $Li_2B_4O_7$ component of the natural fluid at Tanco apparently was responsible for substantial depression of solidus temperatures and for the increased reciprocal miscibility of silicate liquid and $H_2O$ (London 1983, 1984b, 1986a). Hydrothermal phase-equilibrium experiments in the analogous synthetic system $LiAlSiO_4$–$NaAlSi_3O_8$–$SiO_2$–$Li_2B_4O_7$–$H_2O$ show that $Li_2B_4O_7$ concentrations comparable to those of the inclusions in Tanco spodumene (see Table 2 in London 1986a) promote rapid rates of crystallization and significant reductions in fluid viscosity through depolymerization of residual silicate fluids (London 1986a). The combined effects of Li and B on solidus depression and silicate–$H_2O$ miscibility appear to be far greater than that of either component by itself (*cf.* Chorlton & Martin 1978, Stewart 1978, Pichavant 1981, 1983, Martin 1983, Martin & Henderson 1984).

NMR spectroscopic studies of crystalline and amorphous borate compounds have shown a close correlation between the co-ordination of boron in crystals and in compositionally similar glasses (quenched melts) (*e.g.*, Bray 1978). There are two $BO_3^{3-}$ and two $BO_4^{5-}$ clusters per formula unit of crystalline $Li_2B_4O_7$ (Krogh-Moe 1962, Natarajan *et al.* 1979). The presence of two $BO_4^{5-}$ clusters per formula unit of $Li_2B_4O_7$ may be taken as an additional indication of the peralkaline composition of the late-stage fluids at Tanco (fluid-inclusion contents have an agpaitic index of approximately 1.3: London 1986a). The proportion of $[BO_4^{5-}]$ to $[BO_3^{3-}]$ should increase with increasing alkalinity of the fluid (Pichavant 1983, London 1986a), as reflected by the following acid–base hydrolysis reactions:

$$^{III}BO_3^{3-} + OH^- = {}^{IV}BO_3(OH)^{4-} \qquad (1)$$

$$H^+ + {}^{IV}B(OH)_4^- = {}^{III}B(OH)_3 + H_2O \qquad (2)$$

and by the fact that tetrahedral $BO_4^{5-}$ oxyanions are stronger Lewis bases than are triangular $BO_3^{3-}$ clusters. Borosilicate minerals are monitors of alkalinity. Tourmaline, which may be stable with micas and topaz in comparatively acidic conditions, contains only triangular $BO_3^{3-}$ clusters. Reedmergnerite $NaBSi_3O_8$ has been reported only from peralkaline igneous rocks (Pichavant *et al.* 1984) and contains only tetrahedral $BO_4^{5-}$ oxyanions (Appleman & Clark 1965). Recently, Foord *et al.* (1986) have reported feldspars from tourmaline-rich pockets in granitic pegmatites from San Diego County, California, that contain approximately 50 mol % reedmergnerite. This association of B-rich feldspars with late-stage tourmaline-rich zones is a further indication of the presence of boron-rich peralkaline fluids in the final stages of consolidation of complex rare-element pegmatites.

The volumetric proportion of diomignite to other crystalline and fluid phases in the inclusions in spodumene at Tanco (approximately 10 vol. %) provides an indication of the boron contents that are obtainable through fractional crystallization of natural pegmatite magmas. The boron content of the Tanco inclusions is far in excess of that needed to produce Fe-rich tourmaline (schorl) in granitic systems (Pichavant 1981). The presence of diomignite in the Tanco inclusions bears evidence of high Li and B contents of late-stage fluids. It has been suggested that when tourmaline crystallized at Tanco, the diomignite component was extracted from the hydrous silicate fluid (London & Morgan 1985, Morgan & London 1985, London 1986a). As a result, albite, micas, and other aluminosilicate and oxide-forming ores were deposited, leaving a comparatively low-density residual aqueous phase (London 1986a). The crystallization products of the hydrous borosilicate fluid at Tanco are represented by the saccharoidal albite unit that contains economic concentrations of Ta–Sn oxides and beryl in the eastern ore-zone (Černý 1982).

These observations from Tanco should be applicable to Li- and B-rich rare-element pegmatites elsewhere. The concentration of tourmaline in late-stage internal and wall-rock assemblages in many massive and miarolitic pegmatites manifests the instability of tourmaline throughout much of the history of primary crystallization. In Li- and B-rich miarolitic pegmatites, unusually high concentrations of tourmaline and boron-rich feldspars (*e.g.*, 2-3 wt. % B in Na-feldspar: Foord *et al.* 1986) are found in gem-bearing pockets, which are the latest primary units to form (*e.g.*, Foord 1977, London 1986b). Late-stage albite–mica–tourmaline zones contain most deposits of rare metals and gem minerals in pegmatites throughout the world. The enrichment of incompatible elements in such units may stem partly from high concentrations of the borate component and peralkalinity of the parent fluid (melt or silicate-rich vapor) (*e.g.*, Hess 1980, Kawamoto *et al.* 1981, Ryerson 1985, London 1986a). Loss of this fluxing component through crystallization of tourmaline or boron loss to wall rocks would promote the deposition of incompatible elements along with typical aluminosilicate components of rock-forming minerals (London 1986a).

Diomignite may be found in assemblages of daughter minerals (probably hosted by spodumene, topaz and, possibly, beryl, all of which tend to trap crystal-rich inclusions) in other Li- and B-rich pegmatites where the crystallization of tourmaline was a late-stage phenomenon. Diomignite, however, has not been (and probably will not be) identified as a constituent of tourmaline-rich pockets. The crystallization of Li-tourmaline consumes the diomignite component of late-stage fluids (London 1986b). The precipitation of comparatively insoluble borates such as hambergite (*e.g.*, in tourmaline-rich pockets of the Himalaya dyke system, California: Foord 1977) would further reduce the activity of boron in late-stage fluids. Any excess $Li_2B_4O_7$ probably would be lost to wall rocks during pocket rupture or subsequently dissolved from pockets by the influx of externally derived fluids (*e.g.*, Foord *et al.* 1986, Morgan & London 1985, 1986, London & Morgan 1985).

To a large extent, the diomignite component ($Li_2B_4O_7$) in Li- and B-rich rare-element pegmatites may control the physicochemical properties of highly fractionated, late-stage fluids, and may be partly responsible for the accumulation and ultimate precipitation of rare-metal ores and gem minerals. The recognition of diomignite as a component of late-stage fluids has important implications for the genesis of Li- and B-rich rare-element pegmatites.

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