Mineralogical Magazine, June 1998, Vol. 62(3), pp. 325–332

A corundum-quartz assemblage in altered volcanic rocks, Bond Range, Tasmania

R. S. BOTTRILL

Mineral Resources Tasmania, P.O. Box 56, Rosny Park, Tasmania, Australia

ABSTRACT

Unusual corundum-bearing rocks occur in the Bond Range, northern Tasmania, in a hydrothermally altered Cambrian quartz porphyry. The assemblage exhibits quartz and corundum in mutual contact, a rare phenomenon, in association with andalusite, pyrophyllite, diaspore and other minerals. This metastable assemblage apparently resulted from advanced argillic alteration at moderate temperature and low pressure, followed by rapid depressurisation accompanying boiling of hydrothermal, granite-derived fluids. This corundum occurrence appears to be unrelated to the sapphires in placer deposits in Tasmania.

KEYWORDS: Corundum, quartz, diaspore, pyrophyllite, andalusite, Tasmania, advanced argillic alteration.

Introduction

CORUNDUM usually occurs in silica-undersaturated rocks such as nepheline syenites, various aluminous rocks which have been thermally metamorphosed and desilicated by basic to ultrabasic intrusives, and some rare silica-poor metamorphic rocks (Deer *et al.*, 1962; Hughes, 1990). The assemblage quartz–corundum is rare and is not considered to be thermodynamically stable (Motoyoshi *et al.*, 1990). Such an assemblage, however, occurs in several small outcrops at the northern end of Bond Range, one km west of the Lea River/Fall River Junction (40° 30′ S, 145° 58’ E), near Moina, northern Tasmania (Fig. 1), and is described herein, with suggestions on its genesis.

Geological setting

Dyke-like corundum-diaspore-andalusite bearing bodies (~3 m wide by ~100 m long) occur within the Bond Range Porphyry and Back Creek Beds, in the Mid-Late Cambrian Mt Read Volcanics, and appear to cross-cut the stratigraphy (Pemberton and Vicary, 1989). The Bond Range Porphyry is a quartz–plagioclase–hornblende–biotite phyric shallow intrusive body, and the Back Creek Beds are tuffaceous, quartz- and feldspar-rich sandstones and siltstones, formed in an Island-Arc setting (Corbett, 1992). These rocks have been metamorphosed to lower greenschist facies and are intruded by widespread Late Devonian granitoids (Fig. 1), which are locally associated with major tin and tungsten deposits (Green, 1990). Several porphyry and corundum-bearing samples collected by John Pemberton were examined for this study.

Description

The corundum-bearing rocks in the dyke-like bodies exhibit a range of assemblages and textures indicating a complex history and a general lack of mineralogical equilibrium. The least altered rocks examined (V604, V605) around the dykes are quartz-phyric dacitic porphyries, with phenocrysts (up to ~ 15 mm) of rounded to skeletal quartz (~ 10–20% of the rocks), ?altered plagioclase phenocrysts (sericitic aggregates < 2mm, ~ 5–10% of the rocks), and clots of opaques, quartz and sericite pseudomorphing mafic minerals (~ 10–20% of the rocks) in a fine grained, sericitised quartzo-feldspathic matrix. Less altered samples contain approximately 10% each of quartz, plagioclase, hornblende, biotite and clinopyroxene, all ~1–6 mm in size. The dyke samples, however, show more extensive alteration, and as

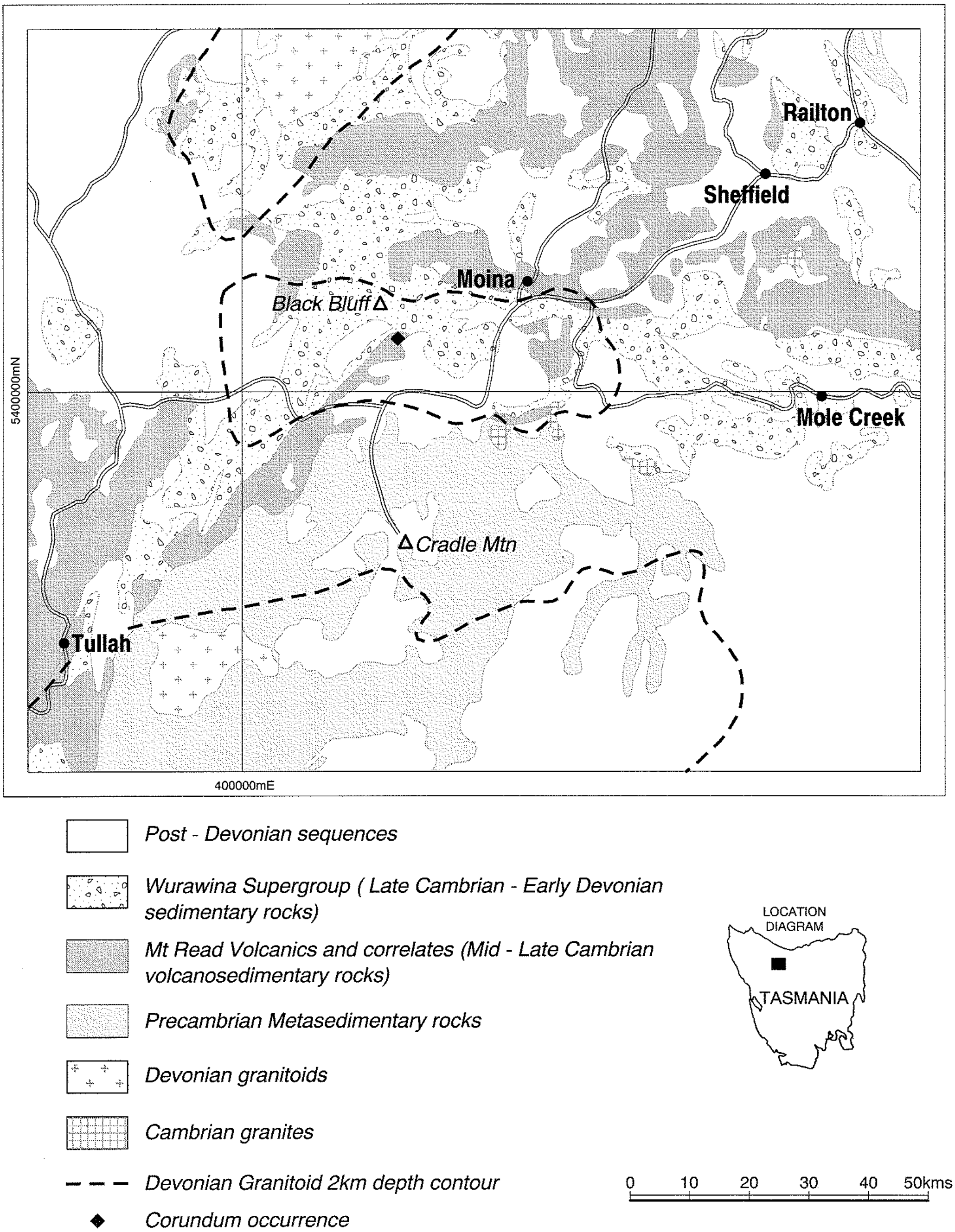

FIG. 1. Location and geological map of the Granite Tor–Black Buff areas.

well as fine grained sericite ± pyrophyllite clots replacing feldspar and mafic minerals, also contain aggregates and crystals of diaspore, corundum and andalusite.

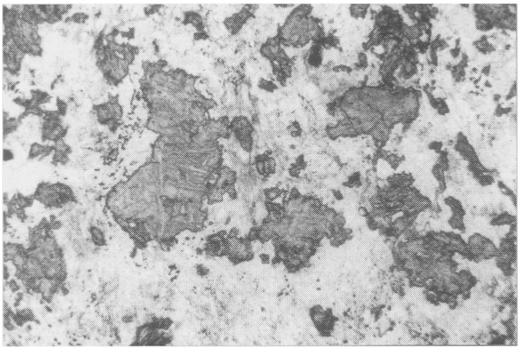

FIG. 2: Corundum grains (grey, high relief) showing lamellar textures and ragged nature. Sample V609, plain polarised light, field of view: 4.3 × 2.8 mm.

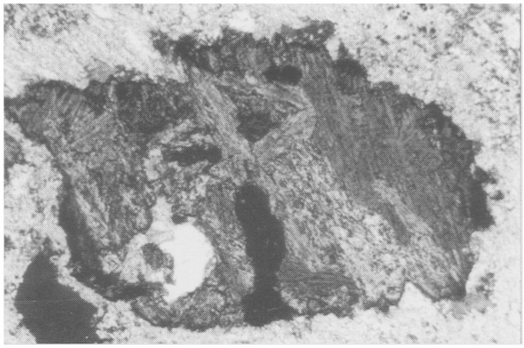

FIG. 3. Corundum grain (high relief) showing lamellar textures and a quartz inclusion. Sample V611, cross polarised light, field of view: 4.3 × 2.8 mm.

Corundum occurs as ragged grey-blue aggregates up to ~2 mm in grainsize, and may comprise up to ~30 % of the rock (Fig. 2). Remarkably, the corundum is in contact with quartz in some instances (Fig. 3). Some corundum contains inclusion-rich areas resembling the fibrous diaspore in size and shape (Fig. 2). Andalusite occurs as well-formed, poikiloblastic crystals to ~2 mm, and may also comprise up to ~10 % of the rock. The andalusite commonly has an alteration rim of kaolinite, a result of late-stage hydrothermal alteration or weathering. Some andalusite also contains inclusion-rich areas resembling the fibrous diaspore in size and shape. Small prismatic crystals and fibrous aggregates of diaspore (<1mm, up to 5 % of the rock) occur in some highly sericitic samples; other samples exhibit micaceous pseudomorphs resembling the diaspore crystals in form. Relatively coarse grained diaspore overgrows some andalusite, and fine-grained diaspore replaces corundum in some samples.

The pyrophyllite and muscovite are fine grained (<0.1 mm), with muscovite mostly disseminated, and pyrophyllite mostly in patchy aggregates or clots. In corundum-rich rocks fine grained muscovite and pyrophyllite partly replace quartz (Fig. 4). In some samples the micaceous clots are variously recrystallised and/or largely replaced by fibrous diaspore, anhedral to poikiloblastic andalusite and ragged grey-blue corundum aggregates. Kaolinite may make up to 5% of the rocks, as clots and veins, partly replacing andalusite and other minerals, and minor albitic(?) feldspar is also present (X-ray diffraction). Electron microprobe analyses of some minerals are listed in Table 1.

Genesis

The mineral assemblage in these rocks is in thermodynamic disequilibrium; corundum and quartz, in particular, are rarely found together (Hemley *et al.*, 1980; see Fig. 5), and their coexistence has been attributed to sluggish dissolution and nucleation rates (Tracey and McLellan, 1985). Another report of corundum and quartz coexisting is in a granulite facies, spinel-bearing quartzite, where corundum formed metastably, probably due to fluid-absent retrograde metamorphism (Motoyoshi *et al.*,1990).

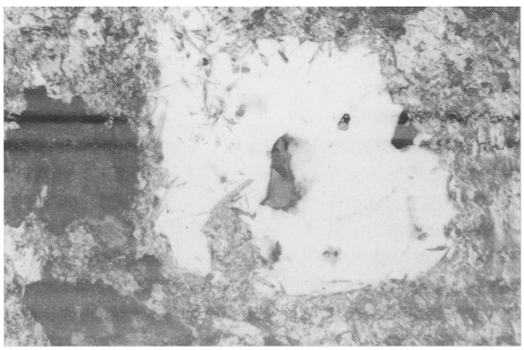

FIG. 4. Quartz phenocryst (colourless) showing partial replacement by muscovite and pyrophyllite. Sample V611, cross polarised light, field of view: 1.7 × 1.1 mm.

TABLE 1. Selected mineral analyses, by electron microprobe (wt.%)

Sample No. Description	V609 Corundum	V609 Mica 1	V609 Mica 2	V609 Diaspore	V609 Pyrophyllite 1	V609 Pyrophyllite 2
SiO_2	0.52	46.11	46.08	1.89	65.83	64.35
TiO_2	0.26	0.01	0.04	0.22	0.00	0.03
Al_2O_3	97.43	35.13	34.45	94.04	27.60	29.62
Cr_2O_3			0.03	0.15	0.03	
FeO(tot)	0.34	0.65	0.85	0.38	0.18	0.14
MnO	0.01	0.00	0.00	0.00	0.01	0.00
MgO	0.00	0.04	0.08	0.00	0.01	0.02
CaO	0.01	0.06	0.01	0.01	0.03	0.03
Na_2O	0.03	0.23	0.36	0.02	0.05	0.13
K_2O	0.00	8.93	8.48	0.03	0.00	0.62
F	0.00	0.10				0.00
Total	98.60	91.26	90.38	96.74	93.74	94.94
−O=F	0.00	0.04	0.00	0.00	0.00	0.00
Total	98.60	91.22	90.38	96.74	93.74	94.94
No. oxygens	3	22	22	3	22	22
Si	0.009	6.311	6.346	0.033	8.014	7.787
Ti	0.003	0.001	0.004	0.003	0.000	0.003
Al	1.980	5.665	5.590	1.946	3.959	4.223
Cr			0.003	0.002	0.003	
Fe	0.005	0.074	0.098	0.006	0.018	0.014
Mg	0.000	0.008	0.016	0.000	0.002	0.004
Ca	0.000	0.009	0.001	0.000	0.004	0.004
Mn	0.000	0.000	0.000	0.000	0.001	0.000
Na	0.001	0.061	0.096	0.001	0.012	0.031
K	0.000	1.559	1.490	0.001	0.000	0.096
Total cations	1.998	13.688	13.646	1.991	12.012	12.161
F	0.000	0.043				0.000

The presence of diaspore in an alunite-quartzite may be related in origin, but forms at lower temperature (Astashenko, 1940).

Two possible modes of origin for the Tasmanian rock are suggested: rapid prograde desilicification and cation-stripping of aluminous rocks, or a rapid decrease in fluid pressure at relatively constant temperature, of rocks that had previously undergone advanced argillic alteration. The first model is less likely because silica needs to be heavily stripped from phyllosilicates and alumino-silicates whilst quartz is retained. However it may apply to the quartz–diaspore rocks (Astashenko, 1940), and andalusite ± corundum-bearing rocks formed in deep-seated porphyry copper deposits and greisens as a locally important advanced argillic alteration style. Under the second model, a decrease in fluid pressure may slow down reaction rates. Andalusite is typically difficult to nucleate and thus other aluminosilicates may persist metastably into its stability field (Hemley *et al.*, 1980).

Advanced argillic alteration is a common form of alteration accompanying many ore deposits. Vigorous acid attack (commonly by sulphatic, acid rich waters) on silicate rocks will produce an assemblage of quartz (or opal at low temperature) - pyrophyllite or kaolinite + illite or muscovite ± alunite ± pyrite ± tourmaline ± topaz ± diaspore ± dickite and other clay minerals (Evans, 1980). Diaspore and pyrophyllite are favoured by increasing temperature, although diaspore is unlikely in equilibrium with quartz. Dissolution of quartz and the removal of silica under these conditions may stabilise diaspore locally under rapidly changing temperatures.

The assemblage appears to have evolved from low to moderate temperature and the suggested principal reactions shown below are mostly derived from Hemley *et al.* (1980; Figs. 6,7).

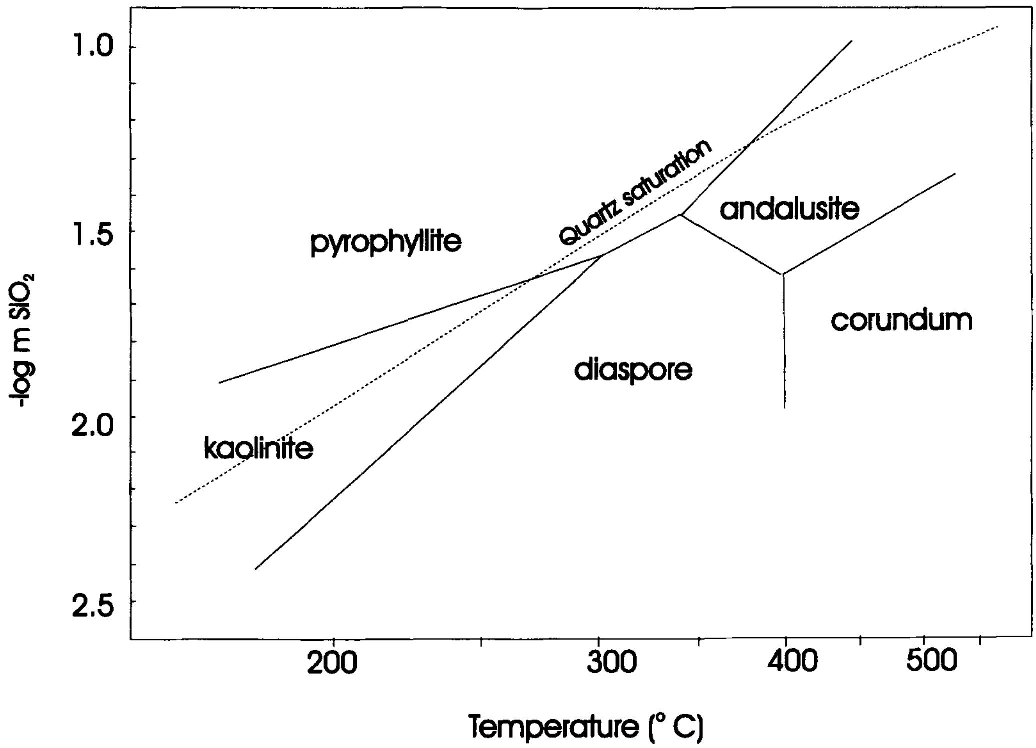

FIG. 5. Stability relations in the system Al_2O_3–SiO_2–H_2O at 1 kbar H_2O. Adapted from Hemley *et al.* (1980).

Alteration probably began at low temperature with:

$3NaAlSi_3O_8 + K^+ + 2H^+ \rightarrow KAl_3Si_3O_{10}(OH)_2 + 6SiO_2 + 3Na^+$

Plagioclase → Muscovite + Quartz

The main reactions under more acid conditions would be:

$2NaAlSi_3O_8 + H_2O + 2H^+ \rightarrow Al_2Si_2O_5(OH)_4 + 4SiO_2 + 2Na^+$

Plagioclase + Water → Kaolinite + Quartz

$2KAl_3Si_3O_{10}(OH)_2 + 3H_2O + 2H^+ \rightarrow 3Al_2Si_2O_5(OH)_4 + 2K^+$

Muscovite + Water → Kaolinite

At higher temperatures:

$Al_2Si_2O_5(OH)_4 + 2SiO_2 \rightarrow Al_2Si_4O_{10}(OH)_2 + H_2O$

Kaolinite + Quartz → Pyrophyllite + Water

$2KAl_3Si_3O_{10}(OH)_2 + 6SiO_2 + 2H^+ \rightarrow 3Al_2Si_4O_{10}(OH)_2 + 2K^+$

Muscovite + Quartz → Pyrophyllite

Under very acid conditions silica may be removed significantly from the system, by the reactions:

$2Al_2Si_2O_5(OH)_4 \rightarrow 4SiO_2\,(aq) + 4AlO(OH) + 2H_2O$

Kaolinite → Quartz + Diaspore + Water

$Al_2Si_4O_{10}(OH)_2 \rightarrow 2AlO(OH) + 4SiO_2(aq)$

Pyrophyllite → Diaspore + Quartz

When the temperature reached about 300–320°C, the fluid probably lost pressure dramatically, perhaps due to hydrofracturing and loss of confining pressure, causing boiling. Pressures could have dropped rapidly from about 1 kbar to less than 0.2 kbar (similar to that postulated at Mt Bischoff: Kwak, 1987). This would have initiated rapid dehydration of the assemblage on dropping below the liquid-vapour curve, (Figs. 6,7, Hemley *et al.*, 1980) with the following probable reactions:

$Al_2Si_4O_{10}(OH)_2 + 6AlO(OH) \rightarrow 4Al_2SiO_5 + 4H_2O$

Pyrophyllite + Diaspore → Andalusite + Water

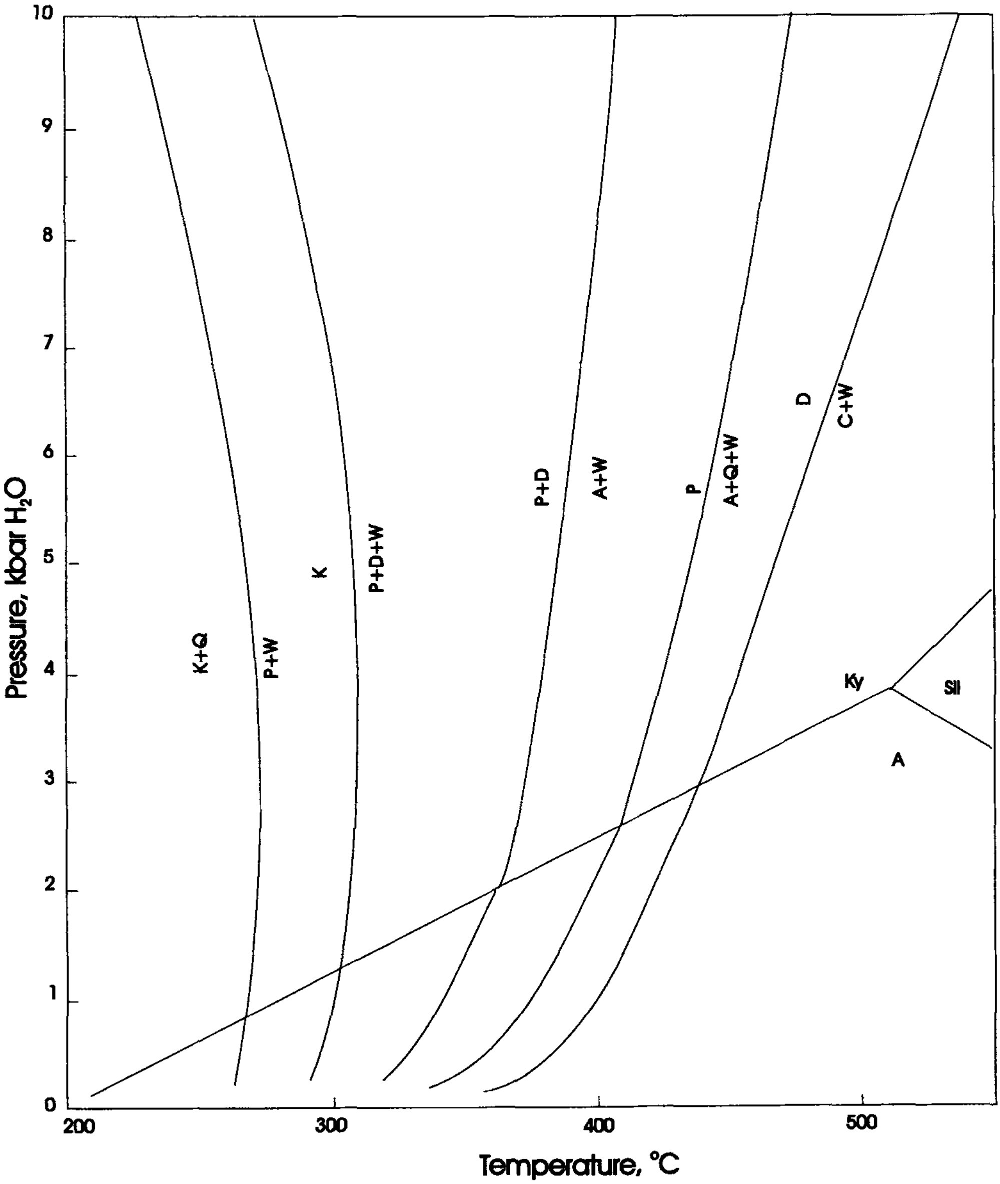

FIG. 6. Calculated *P–T* curves in the system Al_2O_3–SiO_2–H_2O, <10 kbar. Adapted from Hemley *et al.* (1980). Abbreviations: Q: quartz, K: kaolinite, W: water, P: pyrophyllite, D: diaspore, C: corundum, A: andalusite, Ky: kyanite, Si: sillimanite.

$$Al_2Si_4O_{10}(OH)_2 \rightarrow Al_2SiO_5 + 3SiO_2 + H_2O$$
Pyrophyllite → Andalusite + Quartz + Water

and

$$2AlO(OH) \rightarrow Al_2O_3 + H_2O$$
Diaspore → Corundum + Water

Illite or muscovite present in the rock may dehydrate to feldspar and andalusite in a similar manner (Althaus *et al.*, 1970):

$$KAl_3Si_3O_{10}(OH)_2 + SiO_2 \rightarrow KAlSi_3O_8 + Al_2SiO_5 + H_2O$$
Muscovite + Quartz → K-feldspar + Andalusite + Water

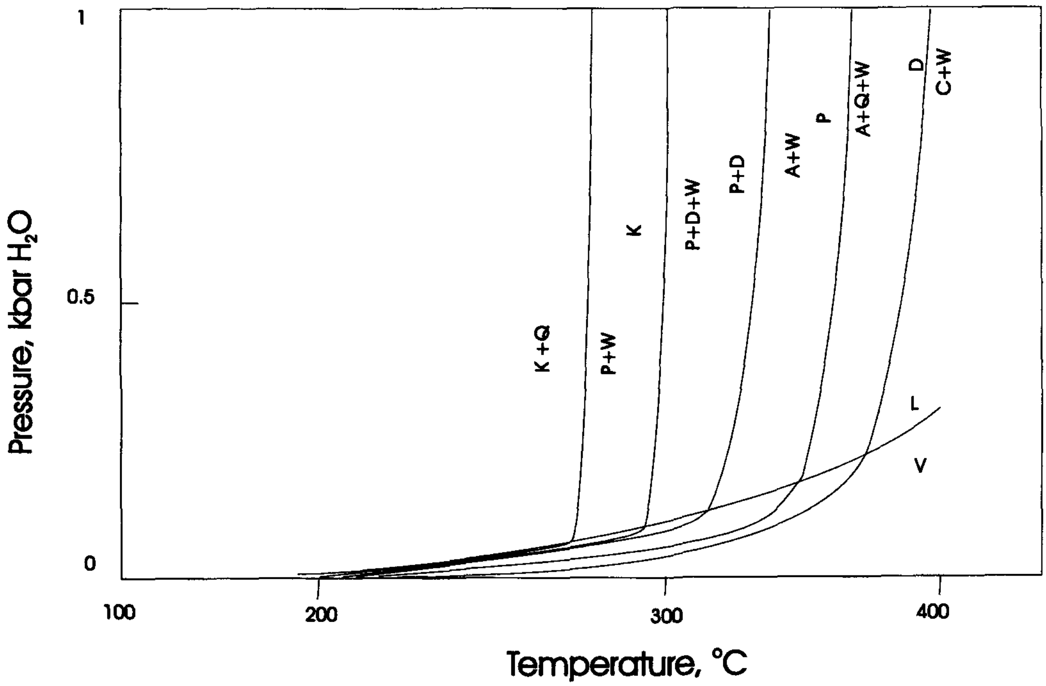

FIG. 7. Calculated $P-T$ curves in the system Al_2O_3–SiO_2–H_2O, <1 kbar. Adapted from Hemley *et al.* (1980). Abbreviations as in Fig. 6.

Other corundum occurrences in Tasmania

Gem corundum (mostly sapphires) occurs in sporadic placer deposits in many parts of Tasmania (Matthews and Bottrill, 1993; Bottrill, 1996), particularly in the northeastern tinfields, usually associated with relatively coarse grained red-brown zircon and black pleonaste spinel, plus rare chrysoberyl, as well as more typical granitic minerals (quartz, cassiterite, topaz, etc.). The sapphires may be well crystallised and gemmy, and are typically a dark blue, but grade into yellow to green and purple; some are parti-coloured (two or more colours in the one stone) and rare ruby has been reported. Most of these sapphires were found associated with Tertiary basalts, and may have a pyroclastic origin and a deep source (nepheline syenite?) as postulated for similar occurrences in eastern Australia and South East Asia (Stone, 1976; Coenraads *et al.*, 1990; Sutherland, 1994, Guo *et al.*, 1996). These sapphire grains are quite different to the corundum in the Bond Range, and are probably not related.

A mafic, mica- and hornblende-bearing dyke cutting granodiorite in the Lisle valley was described as corundum-bearing by Thureau (1882) and probably represents one of the widespread Devonian and Cretaceous lamprophyres in Tasmania. Corundum is also a probable constituent of skarn (magnesite–serpentine–pyrrhotite) assemblages in altered dolomites intruded by Devonian tin-bearing porphyries and greisens in the Mt Bischoff Tin Mines (Groves *et al.*, 1973; Kwak, 1987). Thus the Bond Range corundum association appears to be unique in Tasmania.

Acknowledgements

This paper is published with the permission of the Director of Mines, Tasmania. Drs Geoff Green, Tony Brown, Jafar Taheri and Ben Goscombe, all of Mineral Resources Tasmania, improved the manuscript. John Pemberton is thanked for providing samples and information on the occurrences.

References

Althaus, E., Nitsch, K.M., Karothe, E. and Winkler, H.G.F. (1970) An experimental re-examination of the upper stability limit of muscovite plus quartz. *Neues Jahrb. Mineral. Mh.*, 1970, 325–36.

Astashenko, K.I. (1940) Alunite-bearing secondary quartzites in the Central Balkash region. *Doklady Acad. Sci. USSR.*, **27**, 142, 477.

Bottrill, R.S. (1996) *Corundum and sapphire in Tasmania*. Tasmanian Geological Survey, Record 1996/05.

Coenraads, R.R., Sutherland, F.L. and Kinny, P.D. (1990) The origin of sapphires: U-Pb dating of zircon inclusions sheds new light. *Mineral. Mag.*, **54**, 113–22.

Corbett, K.D. (1992) Stratigraphic-volcanic setting of massive sulphide deposits in the Cambrian Mount Read Volcanics, Tasmania. *Econ. Geol.*, **87**, 564–86.

Deer, W.A., Howie, R.A. and Zussman, J. (1962) *Rock Forming Minerals*, Vol. 5: *Nonsilicates*. Wiley & Sons, New York.

Evans, A.M. (1980) *An Introduction to Ore Geology*. Blackwell. Oxford.

Green, G.R. (1990) Palaeozoic Geology and Mineral deposits of Tasmania. In: *Geology of the Mineral Deposits of Australia and Papua New Guinea* (F.E. Hughes, ed.). 1207–23 (The Australasian Institute of Mining and Metallurgy, Melbourne).

Groves, D.I., Martin, E.L., Murchie, H. and Wellington, H.K. (1973) A century of tin mining at Mt Bischoff, 1871–971. *Geol. Survey Tasm., Bull* . **54**.

Guo, J., O'Rielly, S.Y. and Griffin, W.L. (1996) Corundum from basaltic terrains: a mineral inclusion approach to the enigma. *Contrib. Mineral. Petrol.*, **122**, 368–86.

Hemley, J.J., Montoya, J.W., Marinenko, J.W. and Luce, R.W. (1980) Equilibria in the system Al_2O_3–SiO_2–H_2O and some general implications for alteration/mineralisation processes. *Econ. Geol.*, **75**, 210–28.

Hughes, R.W. (1990) *Corundum*. Butterworth-Heinemann, London.

Kwak, T.A.P. (1987) *W-Sn skarn deposits and related metamorphic skarns and granitoids*. Developments in economic geology, **24**, Elsevier, Amsterdam.

Matthews, W.L. and Bottrill, R.S. (1993) *Occurrences of Gemstone Minerals in Tasmania*. 7th edition. Mineral Resources Tasmania, Hobart.

Motoyoshi , Y., Hensen, B.J. and Matsueda, H. (1990) Metastable growth of corundum adjacent to quartz in a spinel-bearing quartzite from the Archaean Napier Complex, Antarctica. *J. Metam. Geol.*, **8**, 125–30.

Pemberton, J. and Vicary, M.J. (1989) *Geology of the Winterbrook-Moina area*. 1:25,000 Mt Read Volcanics map series. Geol. Surv. Tasmania.

Sutherland, F.L. (1996) Alkaline rocks and gemstones, Australia: a review and synthesis. *Austral. J. Earth Sci.*, **43**, 323–43.

Stone, D.M. (1976) Gemstones. In: *Geology of Victoria*. Geological Society of Australia, Special Publication **5**, Melbourne.

Thureau, G. (1882) Report on the Mineral Resources and permanancy of the Lisle goldfield. *House of Assembly Paper Tasmania*, 46.

Tracey, R.J. and McLellan, E.L. (1985) A natural example of the kinetic controls of compositional and textural equilibration. In: *Metamorphic Reactions: Kinetics, Textures and Deformation*. (A.B. Thompson and D.C. Rubie, eds). 118–37. Springer, New York.

[*Manuscript received 5 August 1997: revised 23 October 1997*]