Tasmanian Geological Survey
Record 1996/05

Corundum and sapphire in Tasmania

by R. S. Bottrill

INTRODUCTION

Two principal types of corundum occurrence are known in Tasmania; gem sapphires in various alluvial deposits, and finer grained rock-forming corundum *in situ* in granite-related deposits in the Mt Read Volcanics. These occurrences (fig. 1) are described below.

SAPPHIRES AND RUBIES

Sapphires are a gem variety of corundum (Al_2O_3). The name was originally intended only for stones with a blue colour, but is now used for stones of any colour except red (which is usually designated as the variety ruby), and including green, yellow and purple. The colours are mostly due to varying proportions of iron and titanium or, in the case of ruby, traces of chromium, in the crystal lattice. Gems with the most common colour, dark blue, are rich in titanium and iron; with decreasing titanium the colours tend towards green and yellow (Deer *et al.*, 1962). During cooling, excess amounts of titanium may exsolve as very fine, orientated needles of rutile, producing an attractive asterism known as 'star sapphire', usually in dark blue stones.

Sapphires are widely distributed throughout eastern Australia and South East Asia, in a belt extending from Tasmania through central and eastern Victoria, northeastern NSW, eastern Queensland, Thailand, Kampuchea, Vietnam and southern China (Tasmania Department of Mines, 1970; Stone, 1976; Coenraads *et al.*, 1990; Robertson and Sutherland, 1992; Guo *et al.*, 1996). Most of the stones have been recovered from alluvial sediments, usually associated with zircon, pleonaste spinel and ilmenite.

The sapphires are usually closely associated with Tertiary alkaline basalt (basanite, nephelinite, etc.) which occurs as flows, plugs and pyroclastics. Sapphire has been found as corroded megacrysts in these basalts, along with numerous xenoliths (including metasediments, granulite, granite, anorthosite, pyroxenite, lherzolite, etc.) and other xenocrysts (including zircon, spinel and anorthoclase) (Coenraads *et al.*, 1990; Robertson and Sutherland, 1992). The major primary host rock in central Queensland is thought to be the associated pyroclastic rocks, indicating that volatile-rich magmas may have brought corundum and other phases rapidly to the surface, possibly from a nepheline syenite source rock at pressures of greater than 10 kbar (>35 km depth; Robertson and Sutherland, 1992). Guo *et al.* (1996) found evidence, in the mineral inclusions in corundum, that there were at least two stages of genesis, related to carbonatitic and basaltic magmas. Intrusion of CO_2-bearing ultrabasic magmas deep in the crust may have evolved carbonatitic fluids, which would have reacted with overlying silicic rocks, forming corundum and other minerals in syenitic and granitic pegmatites. Later volatile-rich mafic magmas may have intruded and brecciated these corundum-bearing rocks and carried the minerals as megacrysts rapidly to the surface.

Diamond is a rarer associate and may have the same source, but be somewhat earlier in age than the sapphires (Robertson and Sutherland, 1992).

SAPPHIRES AND RUBIES IN TASMANIA

Sapphires occur in many areas of Tasmania (fig. 1), particularly the northeastern tinfields, and are usually associated with relatively coarse-grained red-brown zircon and black pleonaste spinel. Other areas include Boat Harbour–Sisters Creek, Blythe River, Table Cape, Bell Mount, Lisle, Stanley River, Adamsfield, Coles Bay and Launceston (Tasmania Department of Mines, 1970; W. L. Matthews, pers. comm.). The stones are typically a dark blue colour, but range from yellow to green and purple, and some are parti-coloured (two or more colours in the one stone). Star sapphires have been recorded in several areas.

The largest recorded stone was a 52.8 g (264 carats) parti-coloured stone from the Weld River area, but most are much smaller (Tasmania Department of

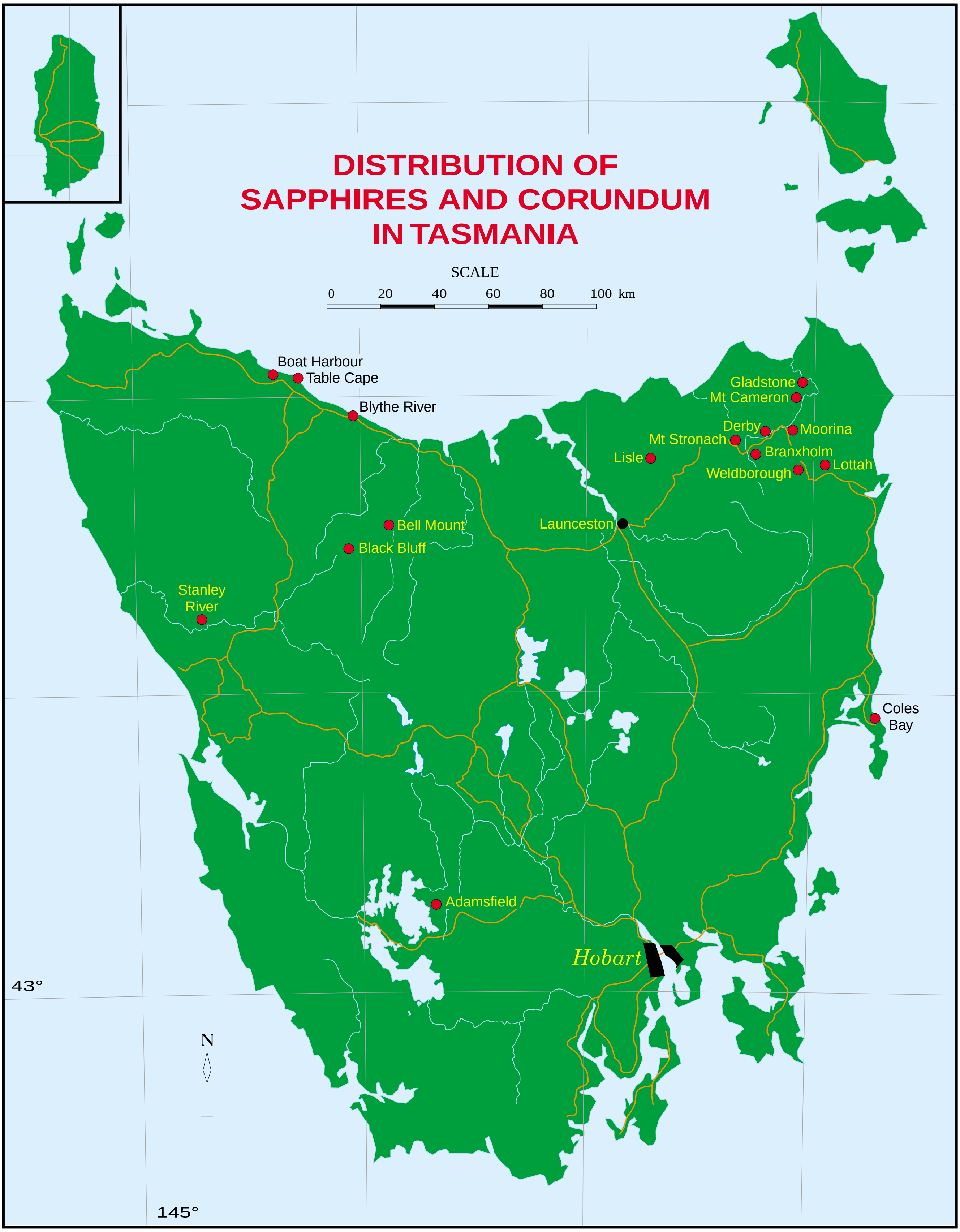
DISTRIBUTION OF
SAPPHIRES AND CORUNDUM
IN TASMANIA
SCALE
0 20 40 60 80 100 km
Boat Harbour
Table Cape
Blythe River
Gladstone
Mt Cameron
Derby
Moorina
Mt Stronach
Branxholm
Lisle
Lottah
Weldborough
Bell Mount
Launceston
Black Bluff
Stanley River
Coles Bay
Adamsfield
Hobart
43°
N
145°

Figure 1

Mines, 1970; W. L. Matthews, pers. comm.). Most of the stones were found in sediments that originate in areas of Tertiary basalt, with the exception of the Adamsfield and Stanley River occurrences. In these areas much of the country is highly eroded and dissected, and basalts may not have survived. Alternatively, small plugs may not have been recognised in these relatively inaccessible areas. The Launceston occurrence is relatively recent, and is in Tertiary gravel underlying basalt near St Leonards (W. L. Matthews, pers. comm.).

In the northeastern tinfields the main occurrences are at Branxholm, Derby, Gladstone, Lottah, Main Creek, Moorina, Mt Stronach, Mt Cameron, Thomas Plain, and in particular the Weldborough–Weld River area (Tasmania Department of Mines, 1970; W. L. Matthews, pers. comm., Figure 1). Topaz, cassiterite, zircon and spinel are typically associated; topaz and cassiterite are unlikely to have the same source but the spinel and much of the coarser zircon are probably derived from basalt (Yim *et al.*, 1985). Minor chrysoberyl, almandine, monazite and gold also occur in association. Tertiary basalt is present in the Ringarooma River valley and as isolated remnants at higher levels, such as the Weldborough Pass, at the headwaters of the Weld River, and Grays Hill near Branxholm. A pumiceous breccia dome, suggestive of an eruptive centre, occurs within the Weldborough Pass basaltic remnant, and is overlain by massive basalt flows containing xenoliths of anorthoclasite and sanidinite. These rocks suggest a deep source (syenite?) and may relate to similar xenoliths found at the sapphire occurrences in Queensland (Robertson and Sutherland, 1992).

Ruby has also been reported rarely from the tin workings in northeastern Tasmania, but has not been confirmed chemically or mineralogically (Tasmania Department of Mines, 1970). These stones may actually be red zircons (W. L. Matthews, pers. comm.), although Boyd Sweeney, a gemmologist, has stated that he has received a positive response to a Chelsea Filter optical test for ruby on one pale pink stone.

CORUNDUM-BEARING ROCKS

Unusual corundum-bearing rocks have been identified in several small outcrops at the northern end of Bonds Range, one kilometre southwest of the Lea River/Fall River Junction, near Moina, Tasmania (the AMG reference is about 414 300 mE, 5 404 700 mN). The dyke-like bodies (~3 m wide by ~100 m long) occur within the Bonds Range porphyry and Back Peak Beds of the Cambrian Mt Read Volcanics, and cross-cut the stratigraphy (Pemberton, 1982; Pemberton, 1983; Roberts, 1986; Pemberton and Vicary, 1989). The rock contains up to ~30% corundum, plus quartz, mica, kaolinite, pyrophyllite, feldspar and andalusite, and are probably granite-related, high temperature, metasomatic replacement bodies. They are described and discussed further in Appendix 1.

A mafic, mica-hornblende bearing (lamprophyric?) dyke cutting granodiorite in the Lisle valley was described as corundum bearing (Thureau, 1882), and may be the source of sapphire in that valley.

Groves *et al.* (1973) and Kwak (1987) mention corundum as a probable constituent of skarn (magnesite-serpentine-pyrrhotite) assemblages in altered dolomite in the Mt Bischoff workings.

RESOURCE POTENTIAL

The potential for economic sapphire in Tasmania is uncertain; the deposits have probably not been tested for size or grade in any area. Compared with stones from New South Wales, Queensland and South East Asia, the Tasmanian stones are mostly small and dark, although some fine stones do occur (especially star sapphires). Most of the known deposits appear to be small and restricted, although they occur over a wide area and are probably present in many deep leads.

The resource potential of the corundum-bearing rocks from the northern end of Bonds Range is also uncertain. The bodies appear small and the samples examined have a small to moderate corundum content (<30 %), but have not been the subject of any serious exploration, despite recording by exploration companies (Pemberton, 1982; Pemberton, 1983; Roberts, 1986).

SUMMARY

Corundum is widespread in Tasmania, mostly in the form of small sapphire grains in alluvial deposits. These are probably related to the occurrence of similar material throughout eastern Australia and South East Asia. The sapphire is thought to have been formed in syenite or similar rocks at great depth, and rapidly brought to the surface in pyroclastic eruptions of alkaline basalts, which are usually closely spatially associated. No resource estimates have been conducted.

Another type of occurrence in Tasmania (in the Bonds Range) is non-gemmy, black material in argillised silicic volcanic rocks, probably formed by rapid dehydration accompanying boiling, acidic, granitic fluids.

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[27 May 1996]

Appendix 1

Petrography and interpretation of corundum-bearing rocks from Bonds Range

INTRODUCTION

Unusual corundum-bearing rocks have been identified in several small outcrops at the northern end of Bonds Range, one kilometre west of the Lea River/Fall River Junction, near Moina, Tasmania (414 300 mE, 5 404 700 mN). The dyke-like bodies (~3 m wide by ~100 m long) occur within the Bonds Range porphyry and Back Creek Beds, of the Cambrian Mt Read Volcanics, and appear to cross-cut the stratigraphy (Pemberton, 1982; Pemberton, 1983; Roberts, 1986; Pemberton and Vicary, 1989). Several samples, collected by J. Pemberton, were examined for this study.

DESCRIPTION

The corundum-bearing rocks exhibit a range of assemblages and textures, indicating a complex history and a general lack of equilibrium.

The least altered are quartz-phyric volcanic or shallow intrusive rocks, with phenocrysts of plagioclase, rounded to skeletal quartz, and mafic minerals (originally hornblende, biotite and/or pyroxenes) in a fine-grained quartzo-feldspathic matrix. Most samples show moderate to extensive sericitisation, with sericitic clots replacing feldspars and mafic minerals. Pyrophyllite and muscovite are difficult to distinguish, but muscovite appears more disseminated, and pyrophyllite occurs more as aggregates. Small prismatic crystals of diaspore occur in some highly sericitic samples; other samples have micaceous pseudomorphs resembling the diaspore crystals in form. In some samples the micaceous clots are recrystallised and/or largely replaced by fibrous diaspore, anhedral poikiloblastic andalusite, and ragged grey-blue corundum aggregates.

The andalusite rarely contains inclusion-rich 'shadows' resembling the fibrous diaspore in shape; this texture is much more obvious in the corundum (fig. 2, 3). Relatively coarse-grained diaspore may also rarely overgrow andalusite, and fine-grained diaspore replaces corundum in some samples. Remarkably, the quartz and corundum are in contact in many instances (fig. 3). In the most corundum-rich rocks (<30% corundum), fine-grained muscovite and pyrophyllite partly replace quartz (fig. 4). The andalusite commonly has an alteration rim of kaolinite, a result of late-stage hydrothermal alteration or weathering.

X-ray diffraction of one of the most altered samples (V609) confirms the presence of quartz, corundum, mica, kaolinite, pyrophyllite, feldspar and andalusite. The feldspar is probably albite but could not be confirmed in either optical or microprobe analysis of the polished thin sections.

GENESIS

The mineral assemblage in this rock is not in thermodynamic equilibrium. Corundum and quartz, in particular, are rarely found in the same rock (Hemley *et al.*, 1980), and are unlikely to have a coexisting stability field under crustal conditions (Motoyoshi *et al.*,1990; fig. 5). One of the few examples 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). In another example, sluggish dissolution and nucleation rates caused the appearance of a quartz-corundum assemblage (Tracy and McLellan, 1985). The presence of diaspore in an alunite-quartzite may be related in origin (Astashenko, 1940).

There are two possible modes of origin for the rock described above;

- 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.

In the first model it is difficult to envisage a situation where silica is being heavily stripped from phyllosilicates and alumino-silicates whilst quartz is retained. Quartz-diaspore and andalusite ± corundum-bearing rocks found in many areas may, however, have been formed by this process, which probably is important in the deep levels of some porphyry copper deposits and greisens. Under the second scenario, a decrease in fluid pressure will tend to 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).

Contact metamorphism by intrusive mafic to ultramafic rocks can also cause the formation of corundum by desilicification, but there is no evidence for such rocks at this location.

Advanced argillic alteration is a common form of alteration accompanying many ore deposits. Vigorous acid attack (commonly by sulphuric acid rich waters) on silicate rocks will produce an assemblage of quartz (or opal at low temperature)-pyrophyllite-kaolinite ± illite ± 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 silica removal under these conditions may result in local stability under rapidly changing temperatures.

The assemblage probably evolved from low to moderate temperature. The probable main reactions used below are mostly derived from Hemley *et al.* (1980; Figure 6).

Alteration probably began at low temperature with:

$$3NaAlSi_3O_8 + K^+ + 2H_3O^+ \rightarrow KAl_3Si_3O_{10}(OH)^2 + 6SiO_2 + 2H_2O + 3Na^+$$

plagioclase → muscovite + quartz

The main reactions under more acid conditions would be:

$$2NaAlSi_3O_8 + 2H_3O^+ \rightarrow Al_2Si_2O_5(OH)_4 + 2Na^+$$

plagioclase + water → kaolinite

$$2KAl_3Si_3O_{10}(OH)_2 + H_2O + 2H_3O^+ \rightarrow 3Al_2Si_2O_5(OH)_4 + 2K^+$$

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

$$2KAl_3Si_3O_{10}(OH)_2 + 6SiO_2 + 2H_3O^+ \rightarrow 3Al_2Si_4O_{10}(OH)_2 + 2K^+ + 2H_2O$$

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. This could have caused the pressures to drop rapidly from about 1 kb to less than 0.2 kb (similar to that postulated at Mt Bischoff; Kwak, 1987). This would, in turn, have initiated rapid dehydration of the assemblage on dropping below the liquid-vapour curve (Fig. 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

$$Al_2Si_4O_{10}(OH)_2 \rightarrow Al_2SiO_5 + 3SiO_2 + H_2O$$

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 → Kspar + andalusite + water

CONCLUSIONS

The corundum-bearing rock was probably originally an intermediate to acid volcanic rock rich in quartz, plagioclase and mafic minerals. Advanced argillic alteration probably converted the assemblage to quartz-kaolinite-illite (with most ferro-magnesian material removed) at low temperature, changing to quartz-muscovite-pyrophyllite-diaspore at higher temperature. Rapid dehydration (accompanying boiling granitic fluids) could partly convert this assemblage to quartz-andalusite-feldspar-corundum, a metastable assemblage but one consistent with the known sluggish dissolution and nucleation of some of the reactant phases, as discussed early in the previous section. There is minor retrogression of corundum, feldspar and andalusite to fine-grained phyllosilicates due to late-stage fluid movement.

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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

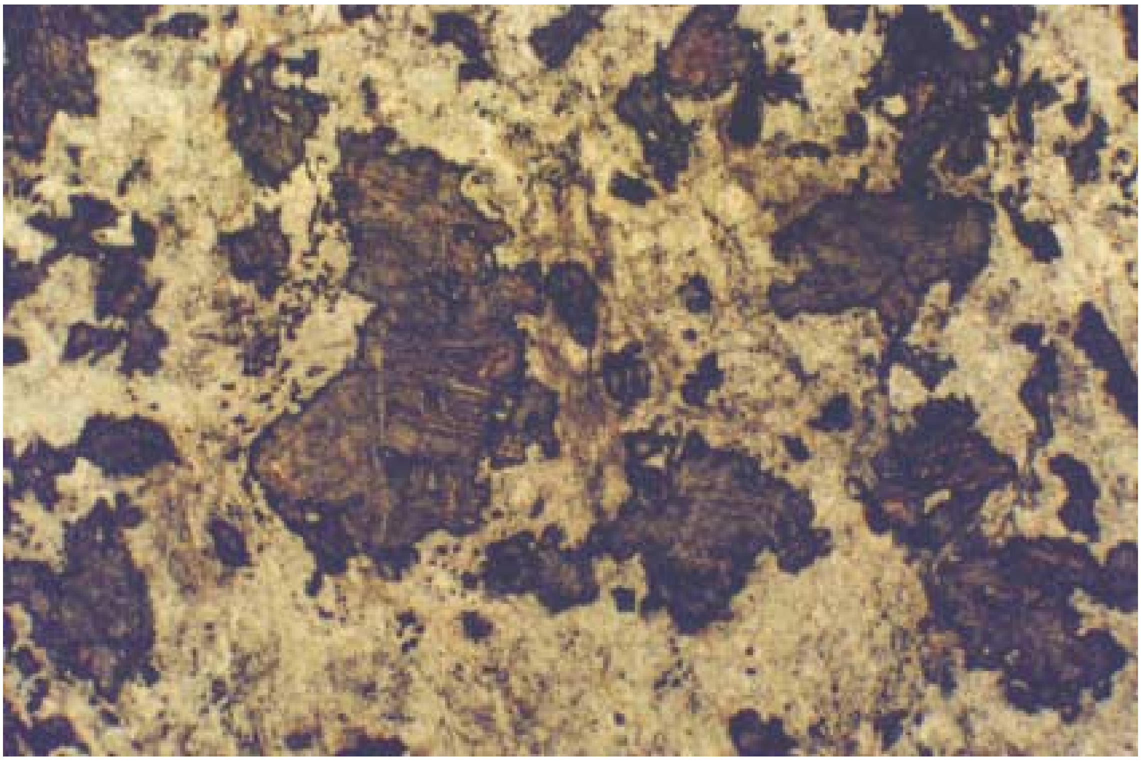

Figure 2

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

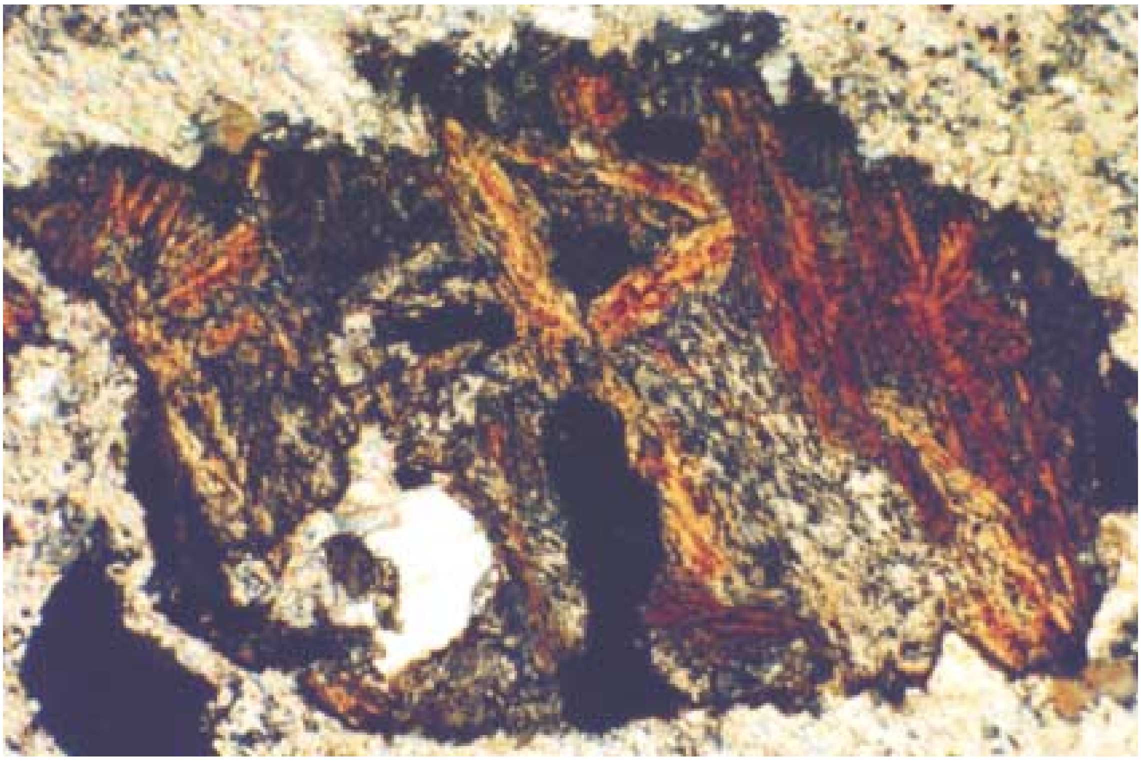

Figure 3

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

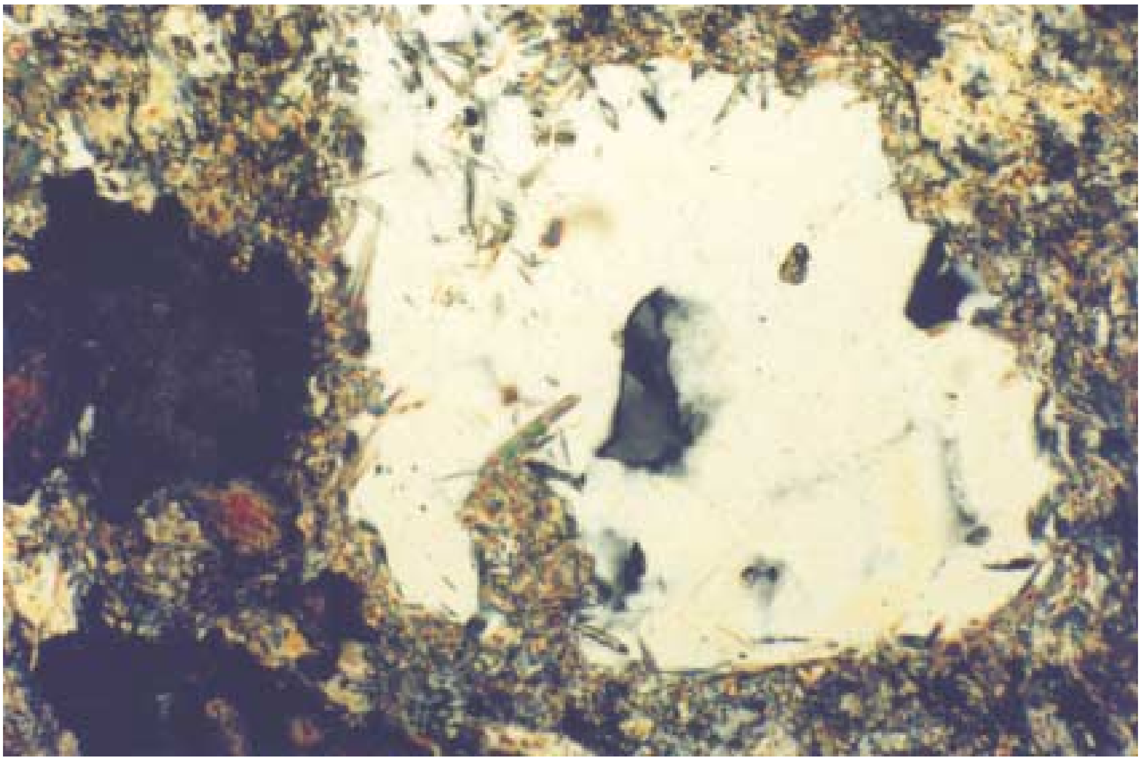

Figure 4

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

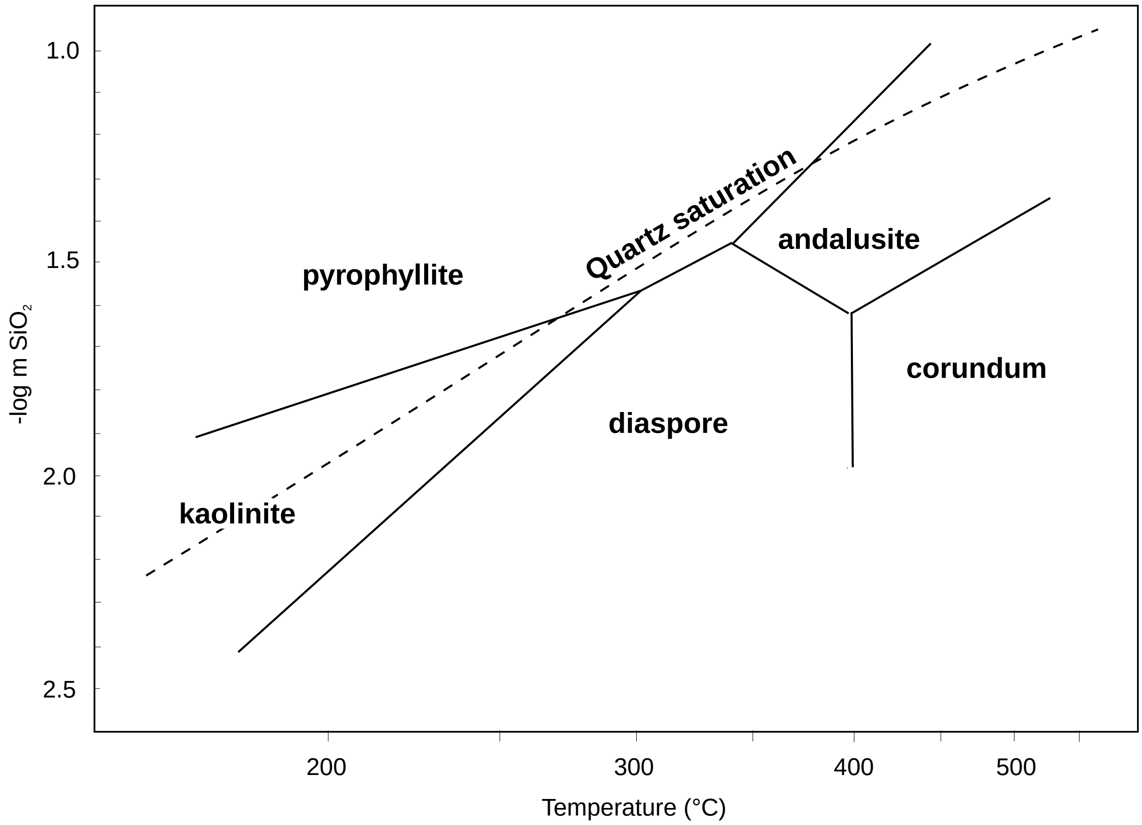

Figure 5

Stability relationships in the system Al_2O_3-SiO_2-H_2O (adapted from Hemley et al., 1980).

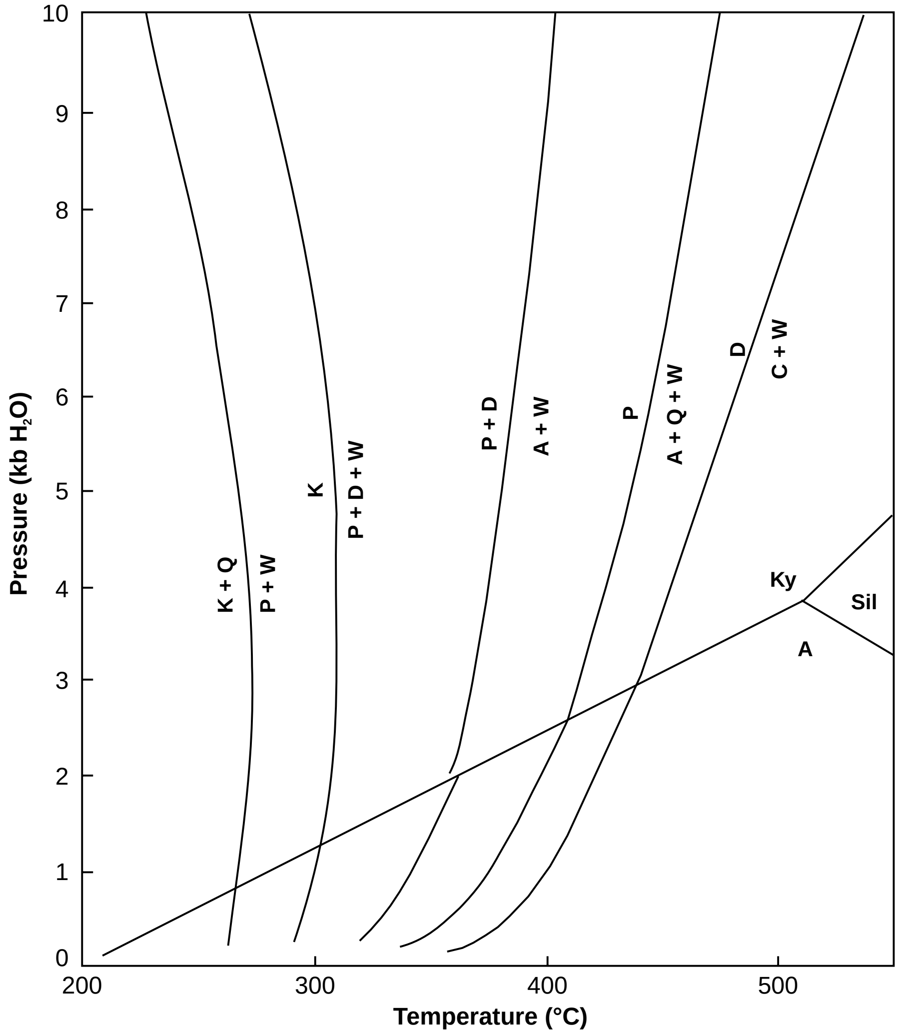

Figure 6

Calculated P-T curves in the system Al_2O_3-SiO_2-H_2O. Adapted from Hemley et al. (1980)

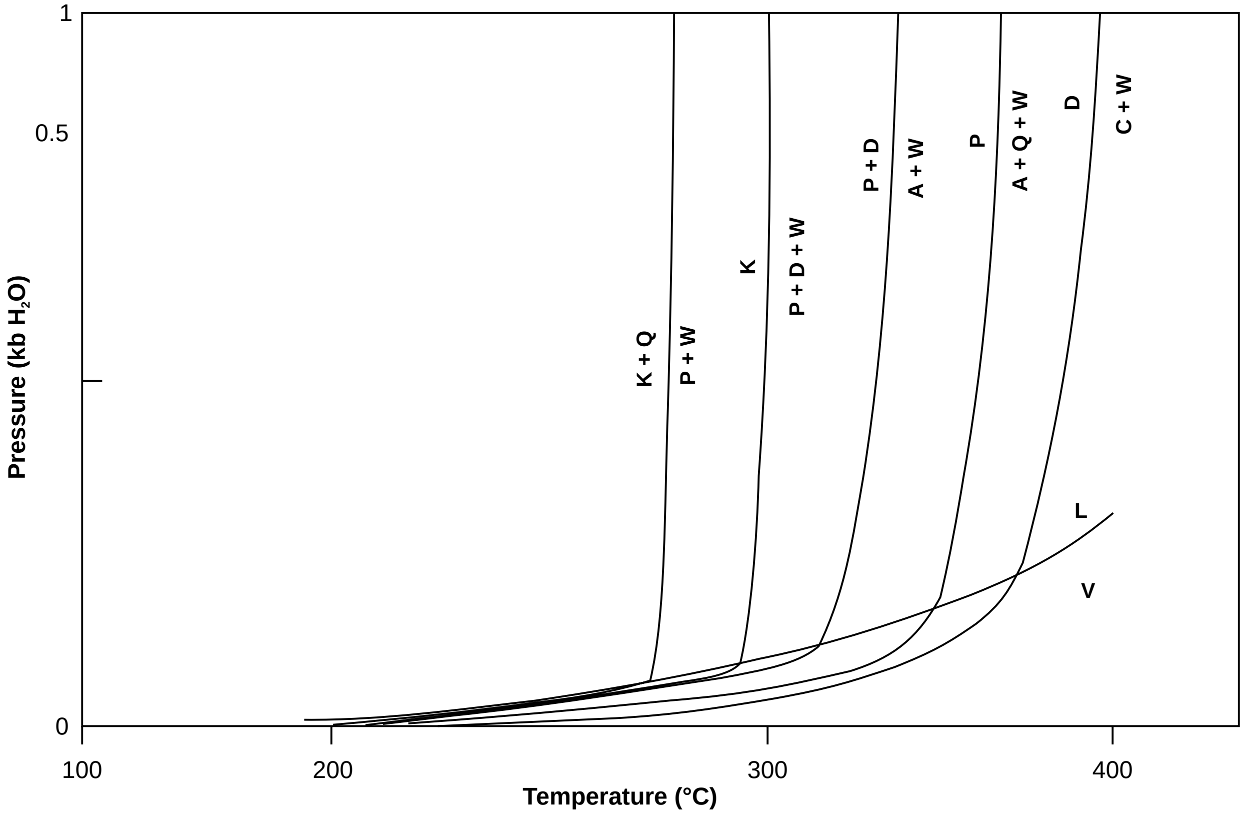

Figure 7

Calculated P-T curves in the system Al_2O_3-SiO_2-H_2O. Adapted from Hemley et al. (1980)