Direct observation of low temperature melting in the system petalite-quarltz-H_2O using a hydrothermal diamond-anvil cell: Methods and geological implications

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An unexpected low-temperature immiscible melt phase in the ternary petalite ($LiAlSi_4O_{10}$)-quartz (SiO_2)-H_2O was observed in a hydrothermal diamond-anvil cell (HDAC). The melt phase was positively identified *in situ* at temperatures below 527°C near 290 MPa, and the initial melting may have occurred at temperatures as low as 400°C near 142 MPa. These new results are relevant to our understanding of the late evolutionary stages in lithium-rich rare element pegmatite formation.

Experimental procedures and results

Small chips of natural colourless petalite (from Minas Gerias, Brazil) and quartz were loaded together with distilled deionized H_2O in a sample chamber of the HDAC (Bassett *et al.*, 1993); the chamber was a 0.5 mm-diameter hole in a 0.12 mm-thick Re gasket, sandwiched between

two diamond anvil faces. The air/water ratio in the chamber was adjusted before sealing, such that the desired sample pressures can be generated during heating. Sample pressures at measured temperatures were approximated by using the equation of state of H_2O (Haar *et al.*, 1984), neglecting the effect of mineral dissolution. Sample temperatures were measured by two K-type thermocouples which were in direct contact with the two diamonds (one each), and were accurate to ± 2°C. The bulk density of H_2O (ρ) was determined by the liquid-vapour homogenization temperature (*Th*; precise to $\pm$ 0.5°C). Samples were observed under a microscope, and the images together with time and temperature information were recorded continuously on videotapes (Haselton and Chou, 1994).

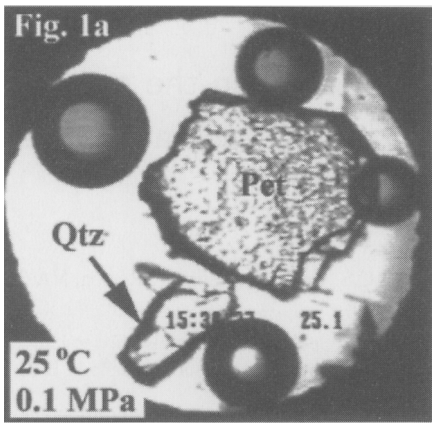
Two experimental runs were performed in this study, one was petalite dominant (Figs. 1a-c) and the other, quartz dominant (Figs. 2a-b). Heating to a desired sample temperature was controlled automatically by a computer with a preset ramp rate (normally 70°C/min.), and the temperature increments ranged from one to few tens of degrees. In the petalite-dominant run, *Th* = 284°C (ρ = 0.743 g/cm^3), and quartz became opaque at 370°C (*P* = 106 MPa). Initial rounding of the quartz grain occurred at 412°C (*P* = 156 MPa) and significant rounding was observed at 483°C (*P* = 240 MPa; Fig. 1b). Abundant immiscible melt spheres were observed at 527°C (*P* = 290 MPa; Fig. 1c), however the melting certainly occurred at much lower temperatures. In the quartz-dominant run, *Th* = 231°C (ρ = 0.826 g/cm^3), and well developed melt spheres were abundant at 550°C (*P* = 468 MPa; Fig. 2b); again we suggest that the initial melting occurred at much lower temperatures.

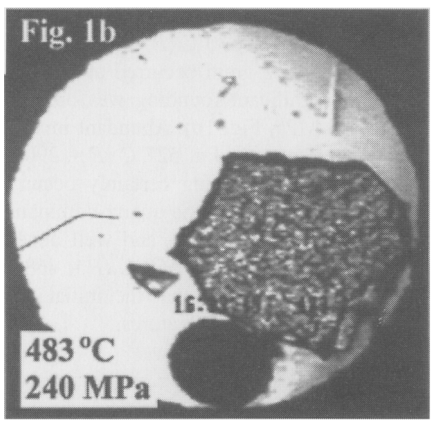
Discussion

The solidus temperatures reported previously (e.g. Stewart, 1978, his Fig. 3) for the system petalite-quartz-H_2O are well above 800°C at 200 MPa. The much lower solidus temperatures observed in this study may result from the use of considerably higher H_2O/minerals ratios in our experiments. These observations suggest that in some rare element pegmatites the late stage lithium aluminosilicate- and quartz-rich units may have formed at low temperatures without requiring elevated concentrations of elemental fluxes such as B, F and P. Also, this study demonstrates the utility of the HDAC for *in situ* visual observation and VCR documentation. Other advantages of the HDAC include its: (1) large applicable *P-T* region, (2) simple construction, (3) inexpensiveness relative to other types of high *P-T* facilities, (4) safety, and (5) amenability to *in-situ* sample characterizations.

References

Bassett, W.A., Shen, A.H., Bucknum, M., and Chou I-Ming (1993) *Rev. Sci. Instru.*, **64**, 2340–5.





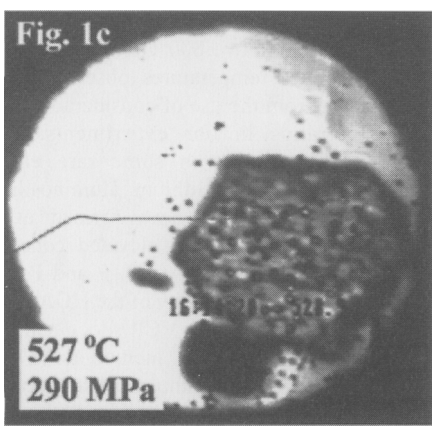
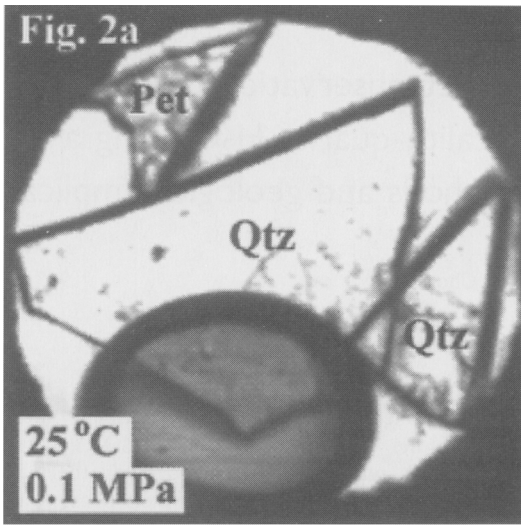


FIG. 1. Images of the petalite-dominant run. (a) shows petalite (Pet) and quartz (Qtz) fragments immersed in water with four air bubbles, (b) shows the rounding of the quartz grain, and (c) shows spheres of melt accumulated near the top sample chamber. The diamond anvil sample chamber is about 0.5 mm in diameter.



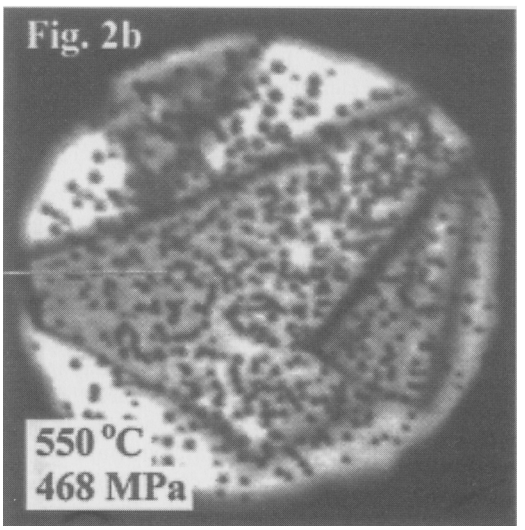


FIG. 2. Images of the quartz-dominant run. (a) shows petalite (Pet) and quartz (Qtz) fragments immersed in water with one air bubble, (b) shows numerous immiscible melt spheres. The sample chamber is about 0.5 mm in diameter.

Haar, L., Gallagher, J.S., and Kell, G.S. (1984) *NBS/NRC Steam Tables*. 320 p. Hemisphere, Washington, D.C.

Haselton, H.T., Jr. and Chou, I-Ming (1994) *U.S. Geol. Surv. Open-File Rep.* **94-703**, 24 p.

Stewart, D.B. (1978) *Amer. Mineral.*, **63**, 970–80.