The Effects of Water in Nominally Anhydrous Minerals on Anatexis of Lower Crustal Granitoids

Sheila Seaman, Michael Williams, Christopher Koteas
Department of Geosciences, University of Massachusetts, Amherst, Massachusetts, USA

Granitoids of the lowest crust are commonly dominated by anhydrous minerals such as alkali feldspar, plagioclase feldspar, and quartz. Sparser hydrous minerals such as muscovite, biotite, and hornblende can facilitate melting through dehydration melting reactions. Eutectic melting is aided by the relatively high ambient temperature of the lowermost crust and by partial melts of mantle rocks heating the lower crust. Free water is the most typical flux for lowering the eutectic temperature of the crystalline rocks of the lowermost crust, and subduction is the most commonly cited mechanism for delivering water to this setting. However, water in nominally anhydrous minerals such as quartz and feldspar is an additional flux for partial melting of granitoid source rocks. Water occurs both in structural sites in the host minerals and in fluid inclusions (Johnson, 2006). Although water occurs in low concentrations (300-5000 ppm is typical; Kronenberg and Wolf, 1990; this study), the abundance of these minerals in granitoids makes the effect of the water significant in terms of slightly lowering the solidus and initiating partial melting. Following the work of Aubaud et al. (2004), who did similar calculations on the effect of water in nominally anhydrous minerals of the mantle on the mantle solidus, 500 ppm water in minerals that make up large volumes of crustal rocks (alkali feldspar, plagioclase feldspar, quartz) would lower the dry solidus of granite by 24^{o}C at 1 GPa and, because of the small bulk distribution coefficient likely for water in these minerals, would produce a near-solidus melt with X_{H20} ~= 0.248, corresponding to 8.3 weight percent water in the partial melt. Water must be liberated from intracrystalline sites to be an effective flux. It is likely that deformation of lower crustal minerals by hydrolytic weakening mobilizes water from mineral interiors and transports it to sites of cotectic or eutectic mineral assemblages. Water in mineral structures is likely to weaken nominally anhydrous minerals, making them susceptible to deformation by dislocation creep (Kohlstedt, 2006). The positive feedback between structural weakening, enhancement of deformation, and liberation of water culminates in melt production and further ductility of the lowermost crust.

References:
Aubaud, C., Hauri, E.H., and Hirschmann, M.M. (2004), Geophysical Research Letters, 31, L20611.
Johnson, E.A. (2006), Reviews in Mineralogy and Geochemistry, 62, 117-154.
Kohlstedt, D.L. (2006), Reviews in Mineralogy and Geochemistry, 62, 377-396.
Kronenberg, A.K and Wolf, G.H. (1990), Tectonophysics, 172, 255-271.