

Titanium in biotite from metapelitic rocks: Temperature effects, crystal-chemical controls, and petrologic applications

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ABSTRACT

An extensive natural biotite data set from western Maine constrains the temperature and crystal-chemical controls on the saturation Ti levels in biotites from metapelites. The geologically and petrologically well-characterized metamorphic terrain associated with the M3 metamorphism of the Acadian Orogeny of western Maine is ideal for this approach in that metamorphism occurred at roughly isobaric conditions of 3.3 kbar, and chemical equilibrium was closely approached. The data set from these metapelites exhibits systematic variations in Ti contents over a continuum of metamorphic grades (garnet through sillimanite-K-feldspar zones), mineral assemblages, and bulk compositional ranges. Samples were selected so that competing substitutions are restricted to those in metapelites with quartz, aluminous phases (chlorite, staurolite, or sillimanite), Ti phases (ilmenite or rutile), and graphite. Due to crystal-chemical factors, in any given metamorphic zone, an inverse linear relationship exists between Ti and Mg contents. Decreasing octahedral Ti and increasing tetrahedral Si in Mg-rich biotite helps alleviate size disparity between octahedral and tetrahedral sheets. For a biotite with a given Mg content, Ti most dramatically increases above staurolite zone conditions. Our constrained data set allows us to calculate a Ti saturation surface for natural biotite as a function of temperature and Mg content at 3.3 kbar. The Ti saturation surface can be used to establish several important metamorphic features in similar metamorphic settings. These include a general approach to equilibrium, local and/or subtle departures from equilibrium due to minor alteration to chlorite, and relative and absolute geothermometry based on Ti in biotite inclusions in refractory minerals and in matrix biotite.