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Spinels and other oxides in Mn-rich rocks from the Hutter Mine, Pittsylvania County, Virginia, U.S.A.: Implications for miscibility and solvus relations among jacobsite, galaxite, and magnetite

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ABSTRACT

The Hutter Mine locality, Pittsylvania County, Virginia, is a metamorphosed magnetite deposit, with substantial development of subsidiary manganoan marble, that occurs within Latest Precambrian or Early Paleozoic sillimanite-grade pelitic schists. Manganese oxides and spinels at the Hutter Mine include manganosite (MnO) (coexisting with hausmannite and jacobsite) as well as spinels rich in jacobsite ($FeMn_2O_4$), magnetite (Fe_3O_4), and galaxite ($MnAl_2O_4$), and a variety of intermediate solid solutions between these three end-members. Several samples contain spinels that exhibit substantial miscibility along the jacobsite-galaxite and jacobsite-magnetite joins. Magnetite-galaxite solid solution is, by comparison, very limited. Coexisting manganoan spinels within the jacobsite-galaxite-magnetite ternary system include jacobsite-rich varieties with galaxite <65 (normalized to glx + mag + jac = 100) that coexist with Mg-Zn-bearing galaxite-rich spinel with galaxite >75. However, the wide range of spinel compositions at the Hutter Mine largely reflects compositional variability in the host rock. In a skarn reaction zone between Fe-rich, quartz-bearing amphibolites and Si-poor, Mn-rich marbles, the galaxite content of spinel drops from 60% to near zero as silica activity increases over a 5 mm interval. In this same reaction zone, magnetite content of spinel increases from about 10 to 95%, but over a narrower interval (about 2 mm). Total variation in spinel composition in this reaction zone is nearly the same as that seen over the entire suite of Hutter Mine samples.

Both regional metamorphic geology and thermobarometry on local pelite samples indicates that T_{max} at the Hutter Mine was 550–600 °C. Manganosite formed by the decarbonation of Mn-rich carbonate in the presence of a CO_2-poor ($X_{CO_2} \leq 0.01$) fluid having $\log a_{SiO_2} < -3.0$. Oxygen fugacity in the manganosite-bearing sample was buffered by coexisting manganosite and hausmannite, placing f_{O_2} within the magnetite stability field at peak T. This result is consistent with the occurrence of magnetite as the principal ore at Hutter.

The extensive miscibility observed along the jacobsite-galaxite join requires reexamination of miscibility gaps proposed in previous studies. We suggest that the wide compositional gaps found in previous studies reflect a variety of chemical factors of which silica activity is the most critical. In particular, the large range of silica activities observed in Hutter Mine rocks stabilizes spinels with a wide range in galaxite content. The crests of both the jacobsite-galaxite and jacobsite-magnetite two-phase regions appear to occur at relatively low temperatures, probably below 600 °C.