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Assemblages with titanite ($CaTiOSiO_4$), Ca-Mg-Fe olivine and pyroxenes, Fe-Mg-Ti oxides, and quartz: Part II. Application

DIMITRIOS XIROUCHAKIS,[1,]* DONALD H. LINDSLEY,[2] AND B. RONALD FROST[3]

[1]Earth Sciences and Solar System Exploration Division, NASA Lyndon B. Johnson Space Center, Mail Code SN2, Houston, Texas 77058, U.S.A.

[2]Department of Geosciences and Center for High Pressure Research, State University of New York at Stony Brook, Stony Brook, New York 11794-2100, U.S.A.

[3]Department of Geology and Geophysics, University of Wyoming, Laramie, Wyoming 82071, U.S.A.

ABSTRACT

In the system CaO-MgO-FeO-Fe_2O_3-TiO_2-SiO_2, equilibria among titanite, pyroxene(s), olivine, spinel phase, ilmenite, and quartz constrain f_{O_2}, T, a_{SiO_2}, a_{TiO_2}, a_{Fe}, and the compositional variables, $\mu TiFe^{2+}Fe^{3+}_{-2}$, $\mu Ca(Mg,Fe)_{-1}$, and consequently $\mu Mg,Fe_{-1}$ among the silicate and oxide phases. These equilibria can provide the framework for a better understanding of relevant titanite-bearing natural assemblages. In addition, such equilibria can constrain the variables that operate during crystallization of igneous and metamorphic rocks. Titanite-bearing assemblages with pyroxene(s), Fe-Mg-Ti ilmenite and spinel, olivine, and quartz are rare in metamorphic rocks but are common in igneous rocks where they are more commonly reported in plutonic than in volcanic rocks. Probably because, at high temperatures, titanite cannot coexist with the relative common in volcanic rocks sub-assemblage augite + orthopyroxene + olivine + spinel phase + ilmenite. Moreover, decreasing pressure and temperature conditions appear to favor titanite. Thus, it is not surprising that titanite is commonly observed in slowly cooled rocks, albeit, most typically in association with amphibole. We argue that the titanite + amphibole association is favored by high a_{H_2O} and, because a_{H_2O} typically increases during crystallization of a pluton, titanite + amphibole (and consequently titanite) is more common in plutonic than in volcanic rocks.

We have used a modified version of the program QUILF that includes our thermodynamic data for titanite and appropriate titanite-bearing assemblages to estimate the equilibrium crystallization conditions of samples from: (1) a tonalite from the Myoken-Zan granitic complex in Japan; (2) the Sandwich Horizon in the Skaergaard intrusion in Greenland; (3) rhyodacites, dacites, and andesites from the Sajama, Porquesa, and Parinacota volcanoes in the Andes; (4) the Fish Canyon Tuff in Colorado; and (5) a quartz-rich, calc-silicate gneiss adjacent to the Horse Creek Anorthosite Complex in Wyoming. The calculations suggest that: (1) these titanite-bearing assemblages crystallized at values of f_{O_2} that ranged from slightly below FMQ to more than 3 $\log f_{O_2}$ units above FMQ at 500–800 °C; and (2) the stability of titanite is controlled by T, f_{O_2}, a_{SiO_2}, and the compositions of the coexisting oxides and silicates.