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Fe-Ti-P Oxide Melts Generated through Magma Mixing in the Antauta Subvolcanic Center, Peru: Implications for the Origin of Nelsonite and Iron Oxide-Dominated Hydrothermal Deposits

ALAN H. CLARK†

Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Ontario, Canada K7L 3N6

AND DANIEL J. KONTAK

Nova Scotia Department of Natural Resources, P.O. Box 698, Halifax, Nova Scotia, Canada B3J 2T9

Abstract

Commingling and mixing of K-rich basaltic (absarokitic) and partially crystallized, strongly peraluminous, S-type monzogranitic-rhyodacitic magmas have been documented in the 23.8 Ma Antauta hypabyssal complex of the Picotani Group, Puno, southeastern Peru. Magma mixing generated intermediate, andesitic rocks hosting small volumes of SiO_2-poor (≥8.4 wt %), Fe oxide-rich melt, with TiO_2 (≥30 wt %) and P_2O_5 (≥23 wt %) contents corresponding to those of the genetically problematic nelsonite ore type. Microscopic spheres of this composition are embedded in rhyolitic glass surrounding both extensively melted, sieve-textured plagioclase xenocrysts derived from the rhyodacitic magma and cognate orthopyroxene phenocrysts exhibiting replacive Fe-rich mantles. The andesites also contain up to 15 modal percent of strongly resorbed, granite-derived, quartz xenocrysts with glass-orthopyroxene-clinopyroxene coronas. Intense, quasipervasive silicification of the fractionating mafic magma is inferred to have displaced the hybridized melt composition into the stable liquid immiscibility region of the $Na_2O+K_2O+MgO+Al_2O_3$-$FeO+TiO_2+MnO+CaO+P_2O_5$ - SiO_2 - H_2O system. Some Fe-Ti-P–rich bodies have 30 to ca. 55 wt percent SiO_2 and exhibit broadly linear trends of major oxides versus SiO_2, but the more SiO_2-deficient spheres exhibit extreme compositional scatter, implying the existence of complex immiscibility fields within the parental, protonelsonitic melt domain. In contrast, the predominant, apparently conjugate, silicate glass (70–78 wt % SiO_2) is relatively consistent in composition and equivalent to a syenogranite and/or rhyolite. The extreme local variability in the composition of the oxide-rich melt bodies may directly reflect their formation in a magma-mixing environment in which temperature varied over at least 200° to 300°C. Such a compositional range, also apparent in large-scale nelsonite occurrences, indicates that strong fractionation of mafic melts under conditions precluding ferroan spinel crystallization may not be a prerequisite for oxide-silicate immiscibility, and hence nelsonite formation.

Specular hematite is widely disseminated in the glassy andesites, commonly clustered around resorbed quartz xenocrysts, and microscopic bodies of illite-montmorillonite-chlorite occur in contact with unaltered glass in unveined andesites, implying endogenous sources of, respectively, iron and hydrothermal fluid. Moreover, the Upper Paleozoic clastic sedimentary envelope of the Antauta center at Pucacancha hosts hydrothermal breccias and veins rich in hematite, barite, quartz, chalcedony, and epidote, with lesser anhydrite and traces of U-, Th-, REE-rich allanite, chalcopyrite, and molybdenian scheelite. This unambiguously hydrothermal mineralization is analogous to that of the iron oxide-copper-gold clan, and we propose that the development of some deposits of this type may have been triggered by the formation and subsequent vesiculation of immiscible Fe-rich oxide melt during the mixing of mafic and felsic magmas.

† Corresponding author: e-mail, charbon@geol.queensu.ca

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