

Magmatic Degassing of Volatiles and Ore Metals into a Hydrothermal System on the Modern Sea Floor of the Eastern Manus Back-Arc Basin, Western Pacific

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Abstract

Magmatic fluids were degassed before and during the eruption of vesicular volcanic rocks that host the actively forming massive sulfides at the PACMANUS hydrothermal field in the eastern Manus back-arc basin, western Pacific. The dredged samples of fresh lavas, ranging in composition from basalt to rhyolite, define a calc-alkalic trend that is thought to have resulted from fractionation in a common magma chamber. These rocks have variable vesicularity and vesicle size distributions that record the degassing history of the magma. The highly vesicular basalt and basaltic andesite are the least fractionated melt and experienced preeruptive, syneruptive, and posteruptive degassing. The weakly vesicular felsic rocks formed from an evolved magma that was largely degassed before its eruption. Vesicularity tends to decrease with Si, K, Ba, and Zr and to increase with Ca, Mg, Fe, and Sc in bulk samples, suggesting that the degassing of volatiles was linked to crystal fractionation of the magma.

A volatile-rich magma is indicated by high concentrations of H₂O (0.9–2.5%) and Cl (to 0.45%) in mafic melt inclusions in phenocrysts of the basaltic andesite. A fluid phase in the melt inclusions indicates that the magma was saturated with volatiles in the magma chamber. Volatiles exsolve as an immiscible fluid with increasing crystal fractionation, and the composition of the degassed magmatic fluid changes with the evolving magma. The fluid is CO₂-dominated during the degassing of weakly fractionated mafic magma and becomes a mixture of CO₂ and H₂O as H₂O is increasingly exsolved from the highly fractionated felsic magma. The ore metals in the degassed fluid, as inferred from the compositions of the metallic precipitates found in the vesicles of melt inclusions and matrix glass, progressively change from Ni + Cu + Zn + Fe in basalt and basaltic andesite, to Cu + Zn + Fe in andesite, to Cu + Fe in dacite, to Fe in rhyodacite, and to Fe + Zn (+ Pb?) in rhyolite. This trend suggests that magmatic fluids, released from a fractionating magma, could be a source of metal for various types of ore deposits and mineral occurrences.

Significant amounts of magmatic fluid can be degassed during the fractionation of a shallow magma chamber. At least 1.7 percent H₂O is estimated to have exsolved from the magma at PACMANUS. If a fluid is concentrated in a shallow magma chamber and is discharged along a favorable structural zone that extends to the sea floor, it will contribute large quantities of volatiles and ore metals directly to a sea-floor hydrothermal system, a process demonstrated for the geothermal systems of subareal volcanoes. The focused discharge of a magmatic fluid as a result of preeruptive degassing, particularly in a fractionated felsic magma, could be responsible for the Fe, Cu, Zn, and Pb metals in the sulfide chimneys at PACMANUS. By analogy, a magmatic fluid can provide a major source of ore metals for large or super-large volcanogenic massive sulfide deposits in the geologic record.