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Melt inclusion evidence for magmatic fluids as a source for metals in seafloor hydrothermal systems

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Magmatic fluids may provide a major source of Fe, Cu, Zn, Pb, Ag, Au and S for seafloor hydrothermal systems and their ancient analogous ore deposits in volcanic terrains now on land. Evidence is found in melt inclusions in phenocrysts and in vesicles of volcanic rocks from the eastern Manus back-arc basin in the Bismarck Sea and the Ordovician-age "giant" (134 million metric tons) Brunswick #12 back-arc volcanogenic massive sulfide ore deposit in Canada. A fluid phase is typically observed in cavities within melt inclusions, indicating that the magma was saturated with volatiles prior to its eruption. The fluid is CO_2-dominated with lesser H_2O and CH_4 in melt inclusions of mafic volcanics and is H_2O-rich in felsic volcanics. Tiny crystals and amorphous precipitates (recrystallized at Brunswick #12) of Fe, Ni, Zn, Cu and Mn chlorides, sulfides and oxides coat the walls of the vapor cavities. Ag and Au are detected by TOF-SIMS. At Manus, the compositions of the precipitates of melt inclusions are similar to those found in the vesicles in the matrix glass of the same sample. The ore metals in the volatile phases changed from Ni+Zn+Cu+Fe ♢ Cu+Zn+Fe ♢ Fe+Zn (+Pb?) as the magma evolved from basalt through intermediate compositions to rhyolite. Glass of the melt inclusions compared to that of the matrix of the rocks from Manus have significantly higher concentrations of H_2O (av. 1.64 vs 0.7 wt%), Cl (av. 2500 vs 1300 ppm) and S (av. 900 vs 100 ppm) demonstrating that these volatiles were extensively exsolved from the magma during or after formation of the melt inclusions and prior to eruption. A minimum of 1.0 to 1.7 wt% of magmatic volatiles is estimated to have been degassed before and during the eruptions. Image analyses of melt inclusions from Manus demonstrate that the volume of vapor in many inclusions greatly exceeds that expected from shrinkage of the trapped magma or exsolution of its

volatiles on cooling. This requires a separate vapor phase to have formed from vigorous exsolution of volatiles ("boiling") of magma in the crystallizing magma chamber. The ratios of vapor to melt in the inclusions show distinct distribution patterns in the phenocryst minerals, indicating that there was more than one vesiculation event in the magma chamber. This means that the magma could continuously provide large quantities of ore metals and volatiles to a hydrothermal system over a long period of time to form a large massive sulfide deposit on the sea floor. Only a small amount (1 wt%) of metal-rich magmatic fluid would contribute over 85% of the total metals to form an ore body. Such magmatic fluids are most likely to be formed from volatile-rich felsic magmas that are prevalent at convergent plate margins such as Manus and, if sufficiently long-lived and added to the normal hydrothermal circulation system, could be responsible for the formation of "giant" volcanogenic massive sulfide deposits such as Brunswick #12.