Upward transport of S, Cu and Au in magmas by flotation of sulphide melt on vapour bubbles

J. E. MUNGALL[1], J. M. BRENAN[1], B. GODEL[2], S. J. BARNES[2] AND F. GAILLARD[3]

[1]Dept. of Earth Sciences, University of Toronto, 22 Russell St, Toronto, ON, M5S 3B1 (correspondance: mungall@es.utoronto.ca, brenan@es.utoronto.ca

[2]CSIRO, 26 Dick Perry Ave., Kensington, WA, Australia 6151 (Belinda.Godel@csiro.au, Steve.Barnes@csiro.au)

[3]CNRS-Université d'Orléans-BRGM, UMR 7327, 1A, rue de la Férollerie, 41071 Orléans, France fabrice.gaillard@cnrs-orleans.fr

Emissions of sulphur and transition metals from felsic magmas in the shallow crust have global impacts on human society by affecting climate after volcanic eruptions and by forming giant Cu and Au ore deposits. These emissions vastly exceed the amounts that could have been derived from the felsic magmas themselves. Magmatic underplating by vapour- and sulphide-saturated mafic magma is the most probable source of the excess sulphur and metals in felsic eruptive or hydrothermal systems. However, the mechanism for the selective upward tranfer of sulphur and metals remains poorly understood. We have conducted experiments in which sulphide melt was equilibrated with vapour and silicate melt under a variety of conditions and find that, to minimize surface energy, the sulphide melt hangs at the silicate melt-vapour interface, despite being denser than silicate melt. Sulphide droplets will adhere to vapour bubbles during vesiculation of sulphide-saturated basalt, providing a simple physical mechanism for the upward transfer of sulphide melt from basalt into overlying felsic magma bodies in the shallow crust, providing S and metals to erupting or ore-forming felsic magmatic systems. Models of speciation in vapour combined with mass balance between vapour, silicate melt, and sulphide melt show that as compound drops comprising vapour and sulphide melt re-equilibrate during magma ascent and decompression the sulphide melt is consumed by hydration reactions like:

$$H_2O_{(\text{silicate melt})} + FeS_{(\text{sulphide melt})} = FeO_{(\text{silicate melt})} + H_2S_{(\text{vapour})}$$

During this process the metals and sulphur are transferred to the growing vapour bubble, producing a S- and metal-rich volatile phase that has composition closely resembling that of ore-forming fluids in pophyry Cu-Au deposits. The rise of compound vapour-sulphide drops into shallow crust or eruptive products is a highly effective vector for the transfer of sulphur and metals to either ore-forming systems or to eruptions.