VESICULATION AND VESICLE LOSS IN NORMAL RIDGE MAGMAS TRACED BY He-Ne-Ar
CONCENTRATIONS AND PRESSURE INFLUENCE ON RARE GAS SOLUBILITIES

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Introduction: We still have a poor understanding of rare gas concentrations in MORB. Although elemental ratios like 4He/40Ar are known to be commonly fractionated (1.5 to more than 100), no satisfactory interpretation of both rare gas concentrations and elemental ratios has ever been proposed.

Expected Effects: Vesiculation is expected to produce two phases, a rare gas depleted melt with highly fractionated abundance ratios, and a gas phase, in the form of vesicles, having most of the rare gas inventory and abundance ratios close to those in the melt before vesiculation. If vesicles are lost after vesiculation, one expects total gas data (i.e. melt + vesicles) to follow binary mixing systematics, for example a negative correlation between He concentration and the He/Ar ratio, because total concentration must act as a proxy for vesicle abundance. Such systematics have never been found.

Abundance Ratios and Concentrations Negatively Correlated: We show that, using Ar or Ne instead of He, the expected binary mixing curves are indeed present, where the smaller the Ar or Ne concentration the most elevated the He/Ar or He/Ne ratio. These negative correlations hold for published MORB data from any laboratory (Fig. 1) provided samples with a deep-plume influence are eliminated on the basis of their 3He/4He ratio [1]. Therefore, He is not a good proxy for vesicle abundance, certainly because its solubility in melt is too high.

Modeling Equilibrium Vesiculation and Vesicle Loss: We use the classical vesicle-melt budget together with Henry’s law to describe equilibrium vesiculation as a function of vesicularity. We do not use distillation as samples are not plume–influenced [1]. We then simply describe vesicle loss by a mixing equation between depleted melt and vesicles. This model fits the data when vesicularities are set between 5 and 20 % and vesicle loss is higher than 90 %. This is in perfect agreement with current observations of MORB vesicularities and with the idea that most MORB are highly degassed lavas.

However, the model only works if the solubility ratios SHe/SAr and SHe/SNe are higher by a factor of 4-10 than predicted based on laboratory measurements. We propose that this is a pressure effect, since laboratory measurements of rare gas solubilities in tholeiite melt have always been performed at 1 atm. This is consistent with estimates of CO2 vesicles growth rate, which show that large, millimeter-sized vesicles must have nucleated at depth in the mantle.

Pressure Influence on Rare Gas Solubilities: A total pressure increase is likely to decrease ionic porosity, thus decreasing rare gas solubility in melt, but this was never quantified. We attempt an approach using the works of Carrol and Stolper [2], who deal with various silicate melts at 1 atm, and of Chamorro-Pérez et al. [3] who study olivine melt at high pressure and 2000-2500°C. We obtain a linear relationship between pressure and ionic porosity for olivine melt. Assuming a parallel line for tholeiite melt, we estimate that vesiculation starts at about 30 km depth in the mantle (1Gpa, Fig. 2). This is reasonable compared to melting depth estimates. However, the behavior of He versus Ne and Ar is not explained well. This points to the need of high pressure rare gas solubility data.

References: