Sulfur-rich primitive arc magmas and possible sulfur recycling beneath volcano

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Tephra of high-Mg basalts (8.9 wt% MgO) from the 1941 lateral eruption of Plosky Tolbachik volcano (Kamchatka) contains olivine and chrome-spinel phenocrysts with numerous naturally quenched melt inclusions (MI) 20–100 μm, sometimes up to 350 μm in size. Volatile contents in such inclusions measured by the electron and ion microprobes vary from near zero to exceptionally high values, containing up to 5.1 wt% H_2O, 1200 ppm CO_2, 0.30–0.35 wt% S and 0.28 wt% Cl. This includes the most primitive MI in Cr-spinel (15.6 wt% MgO in the melt) with ~0.3 wt% S. The original CO_2 content was possibly 3–4 times higher because the majority of the original CO_2 can be lost to a shrinkage bubble (e.g., Wallace, 2015). The $d^{34}S$ of the inclusion glasses vary strongly, ranging from +6 to +11‰ and show positive correlation with S contents. Meanwhile, there is a population of MI with anomalously high sulfur (0.5 –1.08 wt% S), which is close to the maximum sulfur abundance measured in island arc magmas (Wallace and Edmonds, 2011). The origin of anomalous sulfur was attributed to wall rock assimilation, which is supported by positive correlation between $\delta^{34}S$ and total S. Considering the volcanic environment, assimilation of hydrothermally altered rocks rich in pyrite, gypsum, alunite and native sulfur seems plausible. High total sulfur suggests that a major fraction of sulfur in the magma was dissolved as sulfate, whereas S^{2-} contents were just below or slightly above the level of sulfide saturation. The latter was surpassed in some volumes of magma, resulting in segregation of Ni-rich sulfide melt, droplets of which were also trapped in olivine phenocrysts. At the same time, some melt inclusions contain crystals and aggregates of anhydrite $CaSO_4$. The origin of anhydrite is controversial. Some large aggregates of anhydrite could have been trapped from the melt. On the other hand, subaerial oxidation of melt inclusions containing large sulfide droplets could produce enough sulfate to form anhydrite in situ. In summary, primitive arc magma from Tolbachik demonstrates high volatile contents close to or exceeding the highest ever measured in an arc setting. Additional sulfur was possibly recycled from hydrothermally altered wall rocks and gave rise to sulfide saturation of magma. The presence of anhydrite in primitive melt inclusions requires further investigations.

References:

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