Fluorine and the emplacement of extensive felsic lavas (flood rhyolites)

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Volatile components are known to fundamentally affect the eruption behaviour of magmas. The melt viscosity, a parameter that affects magma ascent through the crust and its extrusion, is primarily controlled by the amount of H2O and F dissolved, as well as temperature and bulk composition of the magma (1). Further, decompression-driven saturation and exsolution of volatile components (H2O, Cl, H2S...) can cause vesiculation and trigger explosive eruptions. However, because of their very nature, volatile components tend to be lost during degassing and subsequent alteration and weathering, leaving little or no evidence in the rock record. Thus their importance on the eruption behaviour can be easily overlooked when studying ancient volcanic successions.

The ca. 1590 Ma old Gawler Range Volcanics (GRV) and the ca. 2060 Ma Rooiberg Group are part of intracratonic silicic large igneous provinces that include extensive (several tens to a few hundred km) felsic lava units (2, 3). The two igneous provinces share similar anhydrous parageneses, and several lines of evidence indicate that in both cases, magmas had relatively high F contents and high temperatures. Evidence includes melt inclusion analyses (F up to 1.3 wt.pc, Cl up to 0.3 wt.pc, EPMA tot 98 wt.pc for the GRV), water content estimates based on paragenesis (H2O = 1 - 2 wt.pc (4)), and thermometric estimates based on two-pyroxene thermometry and zircon and apatite saturation (new data and (4)). We propose that high concentrations of de-polymerising F, coupled with large magma volume, created favourable conditions for the eruption of extensive, large-volume felsic lavas. The low water contents caused low degrees of vesiculation, precluding explosivity during eruption.

These characteristics are dictated by the tectonic setting in which these magmas were produced and erupted. In an intraplate setting, melting is believed to occur because of mantle rise and decompression. These mantle movements cause a geotherm uprise, and as a consequence, the decompression-triggered melts have high temperatures (5). Intraplate magmas have generally lower total volatile compositions in comparison to magmas produced at convergent margins, and tend to have higher F/Cl and F/H2O (6). Similar combinations of high F, water-undersaturated compositions and high magmatic temperatures might have been important in the emplacement of other extensive felsic lavas and strongly rheomorphic ignimbrites in similar tectonic environments (Snake River Plain-Yellowstone, Keweenawan Midcontinent Rift volcanic units, Etendeka Igneous Province).

References

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