Early Archaean highly-depleted ultramafic boninitic lavas in the southern Kaapvaal Craton, South Africa

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This study reports on a suite of well preserved ultramafic lava flows in the c.3330 Ga Commondale area in the southern part of the Kaapvaal Craton. Olivine, orthopyroxene and clinoenstatite occur as granular crystals in the cumulate zones. Olivine has core compositions up to Fo96.6, and as they are strongly zoned, it is likely that original compositions were even more magnesium rich. These are the most magnesian olivines reported for any naturally occurring terrestrial igneous rock. An extremely fine grained rock-type is present in narrow units, commonly brecciated, and free of phenocrysts and is regarded as an aphyric chill phase closely representing liquid compositions. The determined liquid compositions range from 27 – 32 wt. % MgO with the olivine cumulate – enriched flow interiors having up to 44 wt. % MgO. Initial consideration may regard these lavas as unusually magnesium-rich komatiites.

Compared with Barberton komatiites liquid compositions are relatively enriched in SiO_2 (48.8 – 51.2 wt. %) but highly depleted in TiO_2 (0.08 – 0.12 wt. %) and enriched in Al_2O_3 (6.5 – 9 wt. %). A plot of TiO_2 versus Al_2O_3 shows liquid compositions to lie on a line which extends through the field of the most primitive modern-day boninites indicating a potential genetic link. Normalized trace element diagrams show these lavas to be highly depleted in incompatible elements (eg. Zr 3 – 4.5 ppm; La 0.03 – 0.05 ppm; Yb 0.6 – 0.9 ppm). The HREE are depleted relative to MORB (Ybn 0.27) and the LREE extremely depleted (Prn 0.015) yielding the ratio Ybn/Ndn 13 – 19. There is a slight up-turn of the MORB normalized REE pattern for La, Ce and slightly so for Pr, suggesting a similar control to that which gives the characteristic U-shaped REE patterns for boninite magmas.

These liquid compositions lie on extensions of experimentally determined H_2O-undersaturated boninite-harzburgite reactions at 2.0 to 2.5 GPa. Calculation of the olivine liquidus temperature with 2% dissolved H_2O reduces temperatures from the anhydrous range of 1616 – 1740° C to a more realistic temperature range of 1523 – 1618° C. These liquid relations indicate olivine compositions as high as Fo97.5 and are therefore consistent with the observed core compositions.

It is proposed that the Commondale ultramafic lavas represent a new class of Archaean-age igneous rock, strongly akin to boninites, and therefore originating in a subduction setting. These rocks are not komatiites but have similar highly magnesian compositions and are termed here, komatiitic boninites.

Chemical versus physical origins of rhyolite in a magma factory beneath Taupo volcano, New Zealand

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Taupo rhyolitic caldera volcano in New Zealand is highly productive and frequently active. Chemical and isotopic evidence (Sutton et al. 1995, 2000) shows that at >26.5 ka ≥2 magmatic systems were active (one climaxing in the ~530 km^3 26.5 ka Oruanui event) overlapping in time, but with geographically separated vent sites. After 26.5 ka, 3 subtly different rhyolite batches were erupted (the first preceded by dacites that are chemically linked to the following rhyolite). These three rhyolite batches were temporally distinct, but erupted from geographically overlapping groups of vents.

No mixing relationships are apparent within or between the post-26.5 ka magma batches, or between them and the Oruanui and other pre-26.5 ka magmas. U-Th disequilibrium dating shows the Oruanui contains zircons of variable ages; TIMS data are explicable by mixing or continuous growth (e.g. Charlier and Zellmer, 2000) and SHRIMP data by mixing of of 38 ka and 100 ka weighted-mean-age populations. The 3 post-26.5 ka rhyolite magma batches have zircon model ages that reflect differing amounts of post-26.5 ka overgrowth on >26.5 ka cores, the amount of overgrowth correlating with the degree of zircon-saturation in each batch. Although sharing broadly similar zircon core ages, the Oruanui and post-Oruanui magmas are otherwise distinct. Although chemical/isotopic evidence implies that the rhyolites are generated from arc basalts by AFC processes, we infer that the body of rhyolite erupted in any given event is largely generated by melting of pre-existing hot silicic (>70% SiO_2) intrusives beneath the volcano. We thus distinguish between a *chemical* origin for the rhyolite composition and the *physical* generation of a given body of rhyolite melt that erupts in any one event. We view the system below Taupo to be a magma factory, with mantle-derived mafic input as the feedstock, and undergoing AFC processing to yield silicic magmas. These silicic magmas are then stored in a hot but solid state, and are remobilised by back-melting to generate the melt bodies evacuated in individual eruptions.

References

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