Generation of moderately to very alkalic young Honolulu Series lavas from Th-U-Os-Pb-Nd-Sr isotopes

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The Honolulu Series volcanics on the Hawaiian Island of Oahu, are a type locality of alkalic ocean island rejuvenation stage magmatism. They have been studied by multiple researchers over the past several decades. Rejuvenation volcanism episodically spanned nearly 1 Myr. Our study focuses on the last two groups of eruptions (at ca 80 Kyr, Rubin et al., unpub.), which are known to represent the compositional extremes of the series. Lavas and pyroclasts of the Koko (subaerial/submarine) and Tantalus (subaerial) rift zones are mildly to highly silica undersaturated and alkalic (45-47 and 37-41wt% SiO2; 3.5-5 and 5.5-7 wt% tot. alkalis, respectively), and thought to be derived by small degrees of melting of one or two oceanic mantle source(s), perhaps containing exotic residual mineralogy (multiple authors, too numerous to cite).

We find highly correlated variations in Th/U and age-corrected ($^{230}Th/^{238}U$) in both lava groups, ranging to extreme disequilibria of >50%. Very small degree melts are likely involved. Both groups span the same U-series range, with no correlation to alkali content or other major element indicators of rock composition (e.g., SiO_2, MgO, TiO_2). Disequilibria are not correlated with trace element indicators of residual garnet (e.g., La/Yb). Relationships to tracers that would be sensitive to a Cretaceous lithosphere influence (e.g., $^{187}Os/^{186}Os$) are weak to non-existent. Sr-Nd-Pb isotopic variations are smaller in our sample set than the extant literature. Ratios are nearly constant in the Tantalus samples; Koko lavas display small but significant Pb and more subtle Nd isotopic variations, indicating variable or mixed source chemistry. Pb and Nd isotopes are correlated with U-series signatures on the Koko rift zone. We use these data to discuss the petrogenenis of these magmas and to evaluate both previously proposed and new models for their generation in the asthenosphere, lithosphere or both. The U-series disequilibria appear to require a magmatic phase that can strongly enrich Th relative to U without a strong effect on most LIL or REE.

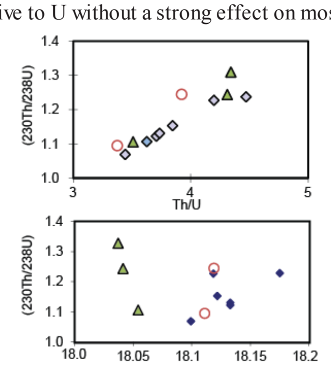

Figure #1: ($^{230}Th/^{238}U)_{meas.}$ verus Th/U and $^{206}Pb/^{204}Pb$ in Koko (diamonds), submarine Koko (circles) and Tantalus (triangles) lavas.

Craton formation

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Archean cratons throughout the world share key features indicating a commonality of processes in their formation and modification. These features include: a) a thick (110 to 220 km) keel of refractory peridotite (typical Fo of 92-93), b) generally increasing fertility of peridotites in the lowermost sections of keels, c) rhenium-depletion model ages of cratonic peridotites that are similar to the age of the overlying crust, d) presence of lithospheric diamonds, as well as diamonds with lower mantle mineral inclusions, now described from most cratons, e) low surface heat flow, averaging 40 mWm^{-2}, f) a ~40 km thick crust composed of granites and greenstone belts at the surface, with increasing seismic velocities with depth, but average intermediate to felsic bulk crustal compositions.

The two classes of competing hypotheses for formation of Archean cratons: plume subcretion vs. stacking and accretion of subducted oceanic lithosphere, do not account for all of the above features, particularly the presence of evolved continental crust overlying refractory mantle peridotite (whose complementary melt must be high Mg-Fe basalt, picrite, or komatiite, -- rare lithologies in cratons). If cratonic peridotite forms via melt extraction at Archean oceanic spreading centers [e.g., 1], and assuming that the density of the Fe-rich basaltic crust is sufficient to cause the lithosphere to founder (subduct?), then cratonic mantle may form from buoyant diapirs of harzburgite mechanically segregated from downgoing lithosphere in the transition zone or deep mantle (where some diamonds grow?) that underplate nacsent cratonic crust formed during partial melting of the downgoing basaltic/picritic crust. Rare eclogites found within cratonic mantle lithosphere may be fragments of the (residual?) oceanic crust that were entrained in the buoyant harzburgite diapirs. Assuming the buoyant tonalitic melts that formed by partial melting of foundering oceanic crust intrude and rise to the top of pre-existing picritic crust, there is still a need to remove picritic material from the deep crust. This could be accomplished by delamination [2] or overturn of lithospheric mantle [3], followed by recycling of eclogitic material. The latter hypothesis has the added attraction of explaining the late granite blooms that occur in most cratons well after their original formation and stabilization. The common occurrence of more fertile peridotite near the base of cratonic keels likely reflects refertilization associated with intrusion of basaltic magmas over the long history of the cratons as they move about the surface of the Earth.

[1] Herzberg et al., (2010) *Earth and Planetary Science Letters* **292**, 79-88. [2] Bedard, J.H. (2006) *Geochimica et Cosmochimica Acta* **70**, 1188-1214. [3] Percival, J.A. and Pysklywec, R.N. (2007) *Earth and Planetary Science Letters* **254**, 393-403.