What have we learned from pre-4 Ga zircons?

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Detrital or xenocrystic zircons with concordant U-Pb ages older than 4 Ga have been identified from at least 5 localities in the Yilgarn craton; one 4.2 Ga zircon is reported from Acasta. These crystals are the only known relicts of the first 500 myr of Earth history (several are 4.4-4.35 Ga). Many pre-4 Ga zircons have been analyzed for U-Pb age; trace elements including REE, Th/U and Ti; O and Hf isotopes; mineral inclusions including quartz; radiation damage; and imaged for patterns of growth zoning, inheritance, and disturbance. Various hypotheses based on these data include the extreme proposal that modern style plate tectonics started at 4.5 to 4.4 Ga (Harrison et al. 2005, Science) and alternatively that most pre-4 Ga zircons are altered and ambiguous (Nemchin et al. 2006 EPSL).

We have presented U-Pb and oxygen isotope data that support a more moderate proposal that some granitic crust (sensu lato) formed by 4.4 Ga and that liquid water oceans existed by 4.2 Ga (Cavosie et al. 2005 EPSL). Our in situ analyses closely correlate CL zoning and coincident ion probe pits for U-Pb, O, and trace elements. These results show that most zircons are igneous in origin and that most have domains preserving magmatic composition. Undamaged domains are found on ~90% of analyzed zircons and are recognized by U-Pb, $\delta^{18}O$, trace elements, and CL (Cavosie et al. 2006, Goldschmidt). Mildly enriched values of $\delta^{18}O(Zc)$ = 6.3 to 7.5‰ are found in undamaged igneous zircons and are higher than in zircons in equilibrium with mantle-derived magmas (5.3±0.6). No zircons in young ocean crust or on the Moon are known above 6.3‰. Values above 6.3‰ form by low temperature alteration or weathering in the presence of liquid water. The burial and melting of such altered protoliths created high $\delta^{18}O$ magmas and zircons.

We consider plate tectonic intrepretations of granite (sensu stricto) based on Ti-in-zircon thermometry questionable because Ti temperatures overlap for zircons from felsic and mafic rocks (Valley et al. 2006 Science). Likewise, large variations of εHf, up to ± 9, could be generated if the age assigned for Hf is in error by 400 myr and thus the conclusion that crustal differentiation began at 4.5 Ga is premature for zircons of undocumented complexity where Hf isotopes have been measured by laser from volumes of zircon that are >100 times larger than corresponding SHRIMP pits. All pre-4 Ga zircons, but especially the few that yield extreme values, should be fully documented for zoning and heterogeneity before extreme conclusions are based on them. Strong conclusions require strong evidence.