Evidence of the earliest crust on Earth

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Understanding the earliest crust on Earth has long been considered the relm of planetary geology. Since all crust older than 4 Ga was apparently destroyed on Earth, older mafic to ultramafic rocks from Mars and the moon provided analogs. However, growing evidence from zircons is finally providing direct testimony of the first 500 myr on Earth.

Detrital and xenocrystic zircons older than 4.0 Ga, without identified parent rocks, are found in highly mature conglomerates and sandstones, and occasionally in granites, almost exclusively from the northern Yilgarn of Western Australia. The oldest grains cluster at 4.35 to 4.4 Ga and are among the most intensely studied samples on Earth. Compositions and ages are variable within single grains and careful study involves imaging and in situ analysis correlated to textures [1]. Many zircons have younger overgrowths or altered domains, and bulk ages should be interpreted with caution. Some zircons are actually small "rocks", containing a granitic suite of inclusions including: quartz, K-feldspar, and plagioclase [2]. No evidence of shocked zircon (planar elements, reidite) has yet been reported inspite of careful examination by optics and SEM. Mildly elevated $\delta^{18}O$(Zc) indicates that low temperature processes involving liquid water altered protoliths of parent magmas. Equally high $\delta^{18}O$ is not found in zircons from mafic rocks in young ocean crust [3] or from the moon [4]. A number of tests support these results as primary including: magmatic zoning, U-Pb concordance, Th/U, type 1 REE profiles [1], and slow diffusion rates in zircon [5]. The picture emerges of an early Earth with differentiated buoyant crust, cool (perhaps cold) surface temperatures, and oceans, which was hospitable for the emergence of life by 4.2 Ga and perhaps earlier.

The composition of the earliest crust and its tectonic setting are less constrained. Nd, Hf, and Pb isotopes have long pointed to early formed protocrust. Recently, $^{176}Hf/^{177}Hf$ ratios and low Ti in zircons were interpreted to indicate the existence of wet S-type granites, continental crust, and plate tectonics before 4.4 Ga [6], but questions remain [7].

Why are rocks older than 4.0 Ga preserved on Mars and the moon, but not Earth? Impacts and melting, commonly cited culprits, were important on all bodies. Plate tectonics, if a factor on early Earth, would have subducted zircons along with rocks. Perhaps surface rocks on Earth merely weathered away in an early low pH atmosphere and zircons are the only recognizable relicts. If so, deeper rocks should have escaped and may still await discovery.

References

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Fractionated HSE in suboceanic mantle: Assessing the influence of refertilization processes on upper mantle peridotites

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The Totalp ultramafic massif in Eastern Switzerland consists of peridotites interlayered with pyroxenites, that have been exposed on the seafloor of the Jurassic Ligurian ocean. Petrographic observations, whole rock major element and Re-Os data in peridotites from the Totalp massif suggest refertilization of the peridotites by percolating melt parental to the associated pyroxenites. Here, we examine the behaviour of other highly siderophile elements (HSE).

Peridotites from the Totalp massif have Ir contents between 1.7 and 4.3 ppb, typical for mantle-derived lherzolites. Osmium abundances range from 2.7 to 5.2 ppb, Ru abundances range from 4.8 to 12.7 ppb, both within the range previously reported for mantle peridotites. Os/Ir_N and Ru/Ir_N are broadly chondritic to slightly suprachondritic within a range of 1.0 to 1.9 and 1.3 to 1.9, respectively. Platinum abundances range from 2 to 7 ppb; Pt/Ir_N varies from subchondritic to slightly suprachondritic within a range from 0.72 to 1.19. Palladium abundances range between 4 and 15 ppb, Re abundances between 0.21 and 0.76 ppb. In a few samples, Pd/Ir_N and Re/Ir_N are enriched by factors of up to 4 and 5, respectively, compared to typical upper mantle lherzolites.

Associated pyroxenites are enriched in incompatible PPGE while compatible IPGE have slightly lower abundances compared to the peridotites. Websterite layers display Pd/Ir_N as high as 40 and Re/Ir_N of up to 9; Pt/Ir_N and Ru/Ir_N are only slightly elevated, to factors of up to 3.8 and 2.1, respectively.

Single grain in situ analyses of Ni-Fe-sulfides (pentlandite, pyrite, godlevskite; alondside native copper) in pyroxenites by LA-ICP-MS yield roughly chondritic Os/Ir and chondritic to suprachondritic Ru/Ir and Pd/Ir of up to 23 and 50, respectively. Re/Ir is subchondritic to slightly suprachondritic by a factor of 2. Both HSE abundances and inter-element HSE ratios vary significantly within one sample, indicating heterogeneous distribution of HSE on grain to thin section scale.

In summary, whole rock and in situ single grain HSE data indicate that melt migration by mafic mantle derived melts produced suprachondritic Pd/Ir and Re/Ir and negligibly affected Pt and more compatible HSE.