The strangest Hadean world

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There are a number of firm indications that some form of crustal reservoir, enriched in incompatible elements, existed at the Earth's surface during the Hadean without being subducted, thus remaining relatively isolated during that time. These are (i) very ancient zircons up to 4.4 Ga in age, that show, on the whole, a slightly enriched source signarture in their Hf isotopes [1], (ii) a Pb isotope signature with enhanced $^{207}Pb/^{206}Pb$ in chemical sediments of the >3.7 Ga Isua Greenstone Belt, that is not seen in intracrustal rocks [2], and (iii) $^{142}Nd/^{144}Nd$ anomalies in Isua metasediments [3].

The apparent longevity of this vanished crust is surprising in the context of the commonly held view that the Hadean era was a time of much more active mantle convection than occurs today. To reconcile this paradox, a scenario is proposed that follows logically from the concept of a magma ocean generated in the aftermath of the Giant Impact that formed the Moon. Such a magma ocean could exist if blanketed by a thick atmosphere, which is however predicted to be dissipated rapidly [4]. Subsequently it solidified on a time scale of 10^4-10^5 years, from the bottom up. This solidification would result in a mantle geotherm determined by the solidus, and therefore highly superadiabatic.

This should lead to a mantle overturn, causing extensive remelting and thus producing a huge mafic crust, but also leading to a subadiabatic mantle geotherm. The causes of the latter are (i) the overturn itself, which brings cooler (lower-pressure solidus) material into the lower mantle, (ii) a newly solidus-determined upper mantle temperature, and (iii) blanketing by a thick crust that is enriched in incompatible, heat producing elements and therefore maintains a relatively high temperature at the top of the mantle.

Conditions for convection in the mantle are ultimately brought about by radioactive heating and core heat input in the lower mantle, as well as cooling at the top by conduction and a reduction of the ^{235}U component of heat production in the crust. It is shown that the required time scale is of the order of several hundred Ma, thus explaining the relatively long-term stable existence of the Hadean crust.

References

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