Archean geodynamics and the onset of plate tectonics

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Since the Archean (between 4 to 2.5 Gyr ago) was much hotter than the present time because of higher rates of internal heat production, it is traditionally accepted that the mantle was convecting faster, resulting in faster mixing time and also plates at the surface of the Earth moving faster. Short-lived isotope systems are particularly adapted to understand the geological processes that occurred during the Archean because their production stopped at some point in the past and only mixing can subsequently modify them. As such, the system ^{146}Sm-^{142}Nd where ^{146}Sm was extinct ~0.5 Gyr after the formation of the solar system is particularly useful to investigate the Earth's early geodynamics.

By using this system, we found a resolvable positive anomaly of $\mu^{142}Nd$ = + 7 ± 3 ppm in a 2.7 Gyr old tholeiitic lava flow from the Abitibi Greenstone Belt indicating that early mantle heterogeneities formed between 4 and 4.5 Gyr persisted ~1.8 Gyr after Earth's formation [1]. This result contradicts the expected rapid early (~0.1 Gyr) [2, 3], as well as the slower recent (~1 Gyr) mixing rates in the convecting mantle [3-5]. We developed a numerical modelling [1, 6] which suggests that inefficient convective mixing can occur even in a highly convective mantle in absence of plate tectonics, i.e. in a stagnant-lid regime. Our model allows only sporadic and short subduction episodes throughout the Hadean and Archean in order to explain the long-term preservation of chemical anomalies in a highly convective mantle. Modern subduction is characterized by (U)HP-LT metamorphism resulting eclogite-facies rocks. Eclogites are absent from the Archean record, hence corroborating the absence of modern-style subduction zones. On the other hand, we will also present the oldest evidence of HP-LT eclogite at 2.1 Gyr from the Congo craton, which is a clear indicator that the 2.7-2.1 Gyr period was a turning point for the onset of modern plate tectonics on Earth [7].

References:

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