Fullerenes and Interplanetary Dust (IDPs) in the Phanerozoic

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The flux of extraterrestrial material to the surface of the earth has important implications for the changes observed in life during the Phanerozoic. Recently we have shown that a new tracer of giant impact, fullerene, is associated with two of the most severe mass extinctions recorded in the rock record, the end-Cretaceous and the end-Permian events (1). Recently Mukhopadhyay et al., (2) have suggested that asteroidal or cometary impacts can be determined by measuring the flux of helium-3 in bulk sediments (a proxy for the accretion of interplanetary dust or IDPs) over geologic time. Measurement of a near constant flux of helium-3 (^{3}He) in sediments associated with a discrete boundary event, like the KTB, would be consistent with an asteroidal impact (2) while an enhanced signature for IDPs coupled with multiple impacts, like those during the Eocene (3), is consistent with a cometary event.

In contrast, a separate study by Farley and Mukhopadhyay, of ^{3}He in volcanic ash layers across the Meishan and Shangshi PTB, indicated no signal for ^{3}He leading them to suggest that a large impact did not accompany the extinction at the PTB (4). However, as pointed out in (5) the differences in bulk ^{3}He concentrations reported in (4) appear to be directly attributed to sample heterogeneity. Moreover, subsequent studies of deep-sea sediments over time show high ^{3}He and ^{4}He concentrations and low ^{3}He/^{4}He ratios consistent with sediment focusing, or lateral advection, and to the mixing of similar IDPs but different terriginous sources (6).

One of the difficulties in assessing the true nature of ^{3}He (e.g. terr. vs. ET) in bulk sediments is that, unlike fullerene, the ‘carrier’ of the ET helium in IDPs has not been properly identified. Thus, it is crucial to look for the IDP-carrier in sediments to establish whether or not ^{3}He is truly a proxy of asteroidal or cometary impact or is simply a result of sediment focusing (i.e. terrestrial). In this work we will present data on the IDP-carrier and their associated trapped noble gas compositions in some deep-sea and impact-related sediments. We will also show that the abundances of IDPs are strongly dependent upon sedimentation rates and lithology. Moreover, the IDP noble gas signature can be uniquely de-coupled from fullerene demonstrating that two separate tracers are present (direct flux of IDPs for ^{3}He vs. giant impact for fullerene).

References

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Lu-Hf isotope geochemistry of garnet-peridotite xenoliths from the Kaapvaal craton and the thermal regime of the lithosphere

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We carried out Lu-Hf and Sm-Nd isotope measurements by MC-ICP-MS for clinopyroxene (cpx), garnet and whole-rock powders from five coarse-granular garnet-peridotite xenoliths from the Kaapvaal craton (South Africa). Hf and Nd isotope compositions span a wide range, significantly larger than that observed for present-day oceanic basalts. In particular, they differ from both MORB and OIB by very high ^{176}Hf/^{177}Hf (ε_{Hf} up to 70 in cpx and up to 2500 in garnet) and low ^{143}Nd/^{144}Nd (ε_{Nd} down to –12 in cpx).

The isotopic disequilibrium between ^{176}Hf/^{177}Hf and ^{143}Nd/^{144}Nd of garnet and cpx exceeds radiogenic ingrowth since the time at which the xenolith host was erupted (ca. 90 Ma). This implies that the Lu-Hf isotope system remained only partially closed during the residence of the sample in the cratonic lithosphere. Two garnet-cpx pairs yield Sm-Nd ages of about 300 Ma while five Lu-Hf garnet-cpx ages range from 190 to 1250 Ma. The initial ^{176}Hf/^{177}Hf ratios are positive and strongly heterogeneous ($\varepsilon_{Hf}(t)$ = +12 to +86) while $\varepsilon_{Nd}(t)$ are negative. The Lu-Hf ages are related to the equilibrium temperatures (T) and pressures (P) of the xenoliths such that the low-T (T≤950°C), shallower (P<40 Kbar), samples provide relatively old ages whereas the youngest ages are found in higher-T, deeper samples (T>1000°C; P≥50 Kbar). If the T and P estimates reflect a modern lithospheric geotherm, the Lu-Hf closure temperature for the garnet-cpx pair must be in excess of 1000°C and the isochron ages provide only minimum ages for lithospheric accretion. Whether the partial Hf isotopic disequilibrium reflects a continuous exchange mechanism between garnet and cpx within a thermally zoned lithosphere or the effect of multiple events of thermal erosion by mantle plumes since the accretion is unclear. Alternatively, the T and P recorded at different localities may be those of fossil geotherms. In such a case, the T, P estimates reflect the conditions prevailing during those multiple events whose ages are frozen into the Lu-Hf isochrons and should not be combined, even locally, into a single geotherm. The significant discordance between the Lu-Hf and Sm-Nd ages and the unusual initial isotopic compositions, however, do not favour this second interpretation. Admitting that the Hf and Nd isotopic compositions of the cpx represent a reasonable approximation of the host peridotite, the Kaapvaal subcontinental lithosphere represents an unsuitable mantle source for any known type of basalt.