EXTRATERRESTRIAL SIDEROPHILES AND GEOLOGIC EXTINCTIONS
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Although evidence for an extraterrestrial event at the Cretaceous-Tertiary (KT) boundary is growing (1-4), there is insufficient evidence to choose among the various proposed mechanisms of this event and among those proposed to account for the terminal Cretaceous extinctions. Evidence for the extraterrestrial event include anomalously high siderophile concentrations with roughly chondritic abundances in KT boundary layer sediments on a world-wide basis. Kyte et al. (4) pointed out that Ir concentrations in boundary layers are too high to have been derived from the ejecta blanket produced by an impacting chondritic asteroid and have suggested 3 alternative mechanisms: 1) impact of a metal-sulfide projectile (i.e., an asteroidal core), 2) accretion from a dense interstellar cloud, and 3) a super-Tunguska event consisting of a massive shower of weak cometary material. The latter mechanism is favored but it is also the least constrained. Another possibility which seems unlikely but which cannot be entirely ruled out is that the siderophiles in the boundary layers are of terrestrial origin, and that they were precipitated from the oceans when the geochemical environment was severely altered by the massive extinctions of marine organisms.

There are at least 3 methods of further confirming the extraterrestrial nature of this event. One method would be discovery of geological field evidence for the event such as a crater or the effects of a blast wave or extremely large tidal waves. Another possibility would be the discovery of an Ir anomaly in a non-marine (e.g., lacustrine) section. Only an extraterrestrial event would be capable of producing such an anomaly. Unfortunately, however, nonmarine sections lack the fine stratigraphic control which micropaleontology provides in many deep-sea sediments. A third possibility (although not conclusive) would be to study the marine geochemistry of noble metals and to determine whether the modern oceans are capable of precipitating such a horizon under any reasonable circumstances. Unfortunately, at present the marine geochemistry of these elements is virtually unknown.

The siderophile abundances in 6 samples from Stevns Klint, Denmark, are only roughly chondritic and the abundance patterns are fractionated relative to known meteorite groups (4). Some fractionation is to be expected, however, if a large fraction of the extraterrestrial source goes into solution in the oceans. If the marine geochemistry is perturbed such that residence times of all siderophiles are short, the extraterrestrial siderophiles will not fractionate, but they will be accompanied by an enhanced deposition of terrestrial siderophiles. If the oceanic residence times remained comparable to the widely varying (factor of 1000) present day values, extraterrestrial siderophiles would be strongly fractionated during deposition. The ubiquitous pyrite...
in boundary layer sediments indicates that the oceans might have become reducing on a world-wide scale during the deposition of the KT horizon.

The addition of new data further illustrates the complexity of the problem. Preliminary RNAA data (work in progress) on 4 samples for which Ir, Fe, Ni, and Co concentrations have been reported (4) indicate significant differences from the abundance patterns of the 6 samples of the Stevns Klint fish clay from Denmark. The 2 additional Stevns Klint samples, FC6 and FC11 (12 and 16 ng/g Ir, respectively), generally have lower siderophile and chalcophile (Se, Sb, As) element concentrations than the other 6 samples for which data were reported. These preliminary data yield siderophile patterns significantly closer to chondritic with CI normalized element/Ir ratios within a factor of 1.3 for Re, Pt, Co, Fe, Pd and Au, the only exceptions being Re in FC11 (X1.5) and Pd in FC6 (X1.9). CI normalized Ir/Ni abundances are about 2.4. That these patterns become more nearly chondritic with decreasing siderophile and chalcophile concentrations may be related to the unusual depositional environment of the Stevns Klint horizon, which shows a broad siderophile peak rather than the sharp anomaly observed in the Caravaca, Spain section (2).

A very different trend is observed in the 2 Pacific core samples, 465A-1, and 465A-2 (16 and 13 ng/g Ir, respectively), obtained from a depth of ~2000 m in the central North Pacific. Both samples contain a portion of a thin, dark, pyrite-bearing horizon which constitutes most of 465A-1 and <10% of 465A-2. Sample 465A-1 contains more Fe, Ni, Co, Au, As and Sb than any of the Danish samples. This has resulted in siderophile enrichments with a distinctly different "roughly chondritic" abundance pattern. In sample 465A-2 siderophile abundances are lower and less chondritic, in contrast to the trend observed in the Danish samples. In this sample, the enhanced Ir and Pt levels are associated with Au and Pd essentially at expected background concentrations (5).

Although this problem appears to be growing in complexity, research is planned that should help constrain it. The possibility that deposition of the horizon may be associated with widespread anoxic water masses can perhaps be tested by sampling some extremely deep (5-6 km) marine sediments. Anoxic conditions are unlikely at this depth and discovery of a siderophile enrichment with or without enhanced chalcophiles would provide constraints on the relative importance of oceanic reduction versus detrital sedimentation. It would also be very important to discover Ir anomalies elsewhere in the stratigraphic record. These would be powerful time-stratigraphic tools as well as a basis for comparison to KT boundary sediments. Since microtektite horizons are likely the result of crater-producing impacts, horizons associated with such events are probably not highly enriched in siderophiles. In contrast, the superTunguska mechanism should produce horizons that are not associated with impact ejecta, but may generally be associated with paleoenvironmental catastrophes.
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References: