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Iridium and Osmium as Tracers of Extraterrestrial Matter in Marine Sediments

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ABSTRACT

Platinum group elements, specifically iridium and osmium, are the most sensitive non-volatile elemental tracers of extraterrestrial (meteoritic) matter in marine sediments. The budget of these elements in sediments can be considered a mixture of extraterrestrial, eolian (i.e., wind-blown dust), and hydrogenous (i.e., seawater-derived) sources. Differences in the osmium isotopic composition between these three sources allow quantification of the amount of extraterrestrial osmium in sediments. Osmium isotope data for about 30 pelagic sediments from the Atlantic and Pacific oceans, spanning the past 80 Myr, yield an average annual flux of extraterrestrial matter of 30,000 ± 15,000 metric tons. The only clear exception is the large impact at the Cretaceous-Tertiary boundary. Temporal resolution of these flux estimates is limited to at least several thousand years by the need to obtain statistically representative samples. The scatter in the flux estimates is large and secular variations in the flux of less than a factor of about three cannot be excluded. However, samples from individual cores indicate that the flux of extraterrestrial matter has varied by less than a factor of two, if the flux is averaged over the scale of temporal resolution in marine sediment samples.

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INTRODUCTION

The two-step chemical differentiation of Earth—core formation and formation of continental crust—has lead to marked chemical differences between undifferentiated (primitive) extraterrestrial (ET) matter and the Earth's crust. Iridium (Ir) and osmium (Os) are highly siderophile (iron-loving) and chalcophile (sulfur-loving) elements. Consequently more than 99.5% of the terrestrial Ir and Os is incorporated in the Earth's core. The continental crust, formed primarily through melts extracted from the mantle during the first 3 billion years of Earth's history, is strongly depleted in Ir and Os relative to the mantle, because both elements are compatible in mantle mineral phases. Most of the remaining <0.5% of the terrestrial Ir and Os therefore remain in the Earth's mantle and only a minute fraction, less than one part per million, resides in the crust. Of all non-volatile elements, Ir and Os are thus the elements most strongly enriched (factor 10^3–10^4) in primitive meteoritic ET matter compared to typical crustal rocks and marine sediments (Fig. 1).

FUNDAMENTALS

Several benchmark studies led to the development of platinum group element (PGE) analysis as a means of quantifying the amount of ET matter in marine sediments. The potential of this approach had been recognized by Petterson and Rotschi (1952) and Goldschmidt (1954), but analytical difficulties in the detection of PGE had to be overcome. In the 1960s and 1970s neutron activation analysis was developed into a very sensitive analytical method for Ir, and early studies focus primarily on this element. Using this method Barker and Anders (1968) pioneered the application of Ir and Os analysis in deep-sea sediments to calculate the flux of ET matter to Earth. Based on

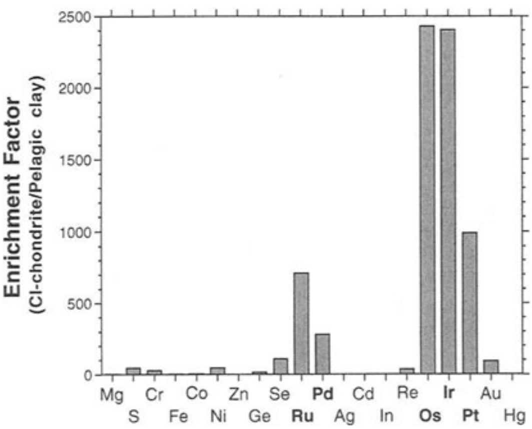

Figure 1. Enrichment factors of elements enriched in CI-chondrites (Anders and Grevesse, 1989) relative to average pelagic clay (Taylor and McLennan, 1995, with PGE concentrations modified using unpublished data). Platinum group elements in bold show highest enrichment factors.