SEARCH FOR A GEOCHEMICAL RECORD OF THE LATE HEAVY BOMBARDMENT ON EARTH.
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Introduction: If a late heavy bombardment during the time period of about 3.8 to 4 billion years ago occurred on the Moon, the Earth must have been subjected to an impact flux somewhat more intense as that recorded on the Moon. The consequences for the Earth must have been devastating, although the exact consequences – such as a total remelting of the crust – are still unclear. So far, no unequivocal record of a late heavy bombardment on the early Earth has been found. The earliest rocks on Earth date back to slightly after the end of the heavy bombardment, although there are relict zircons that have ages of up to 4.4 Ga (in which no impact-characteristic shock features have yet been found). In terms of evidence for impact on Earth, the first solid evidence exists in the form of various spherule layers found in South Africa and Australia with ages between about 3.4 and 2.5 Ga; these layers represent several (the exact number is still unknown) large-scale impact events. The oldest documented (and preserved) impact craters on Earth have ages of 2.02 and 1.86 billion years. Thus, the impact record for more than half of the geological history of the Earth is incomplete and not well preserved, and we mostly have only indirect evidence regarding the impact record and its effects during the first 2.5 billion years of Earth history.

Early Impact Evidence: As there are no rock preserved on Earth that exceed an age of 4 billion years, and the rock record covering the pre-3.5 billion year range is extremely sparse, it is very difficult to search for terrestrial evidence of a late heavy bombardment, which is indicated in lunar rocks for the period 3.8 to 4 Ga. Detrital minerals, especially zircons, with ages beyond 4 billion years exist, but none have been shown any clear evidence of shock features. Part of the problem might be the extreme heat associated with early impacts that could have erased any shock features. Besides the search for shock features in minerals and rocks, another important line of evidence for impact processes comes from geochemical indications of the presence of an extraterrestrial component. Only elements that have high abundances in meteorites, but low abundances in terrestrial crustal rocks are useful for such studies – for example, the siderophile platinum-group elements (PGEs: Ru, Rh, Pd, Os, Ir, and Pt) and other siderophile elements (e.g., Co, Ni). Elevated abundances of siderophile elements in impact melt rocks or breccias (and impact ejecta), compared to target rock abundances, can be indicative of the presence of either a chondritic or an iron meteoritic component. There are, however, cases in which the PGE interelement abundances might be fractionated.

These problems can, in part, be overcome by the use of isotopic tracers for extraterrestrial components. Most prominent among those are the Os and Cr isotopic methods. The Os isotopic method, which is based on the decay of Re-187 to Os-187, is very sensitive and can detect sub-percent levels of extraterrestrial components in impact breccias and melt rocks, but it is not possible to determine the meteorite type.

In contrast, the Cr isotopic method relies on the fact that all terrestrial rocks have a uniform Cr isotopic composition, whereas different meteorite types have different isotopic anomalies. The Cr isotopic method is, thus, selective not only regarding the Cr source (terrestrial vs. extraterrestrial), but also regarding the meteorite type..

Tungsten Isotopes: Another isotope recently suggested as a tracer for a meteoritic component in terrestrial material is ^{182}W, which has been produced by the decay of now extinct ^{182}Hf ($T_{1/2}$=8.9 Ma). Each group of meteorites and the terrestrial crust have distinct W isotopic compositions. There have been suggestions that W isotope analyses supposedly indicate a evidence of the late heavy bombardment on Earth by a W isotope anomaly in early Archean (3.8 Ga) metasedimentary rocks [1]. However, W isotope analyses in a variety of impactites and ejecta from confirmed impact deposits, which had unequivocally been identified by other geochemical proxies, the isotopic composition of W was identical with analytical error to that of the Earth's continental crust, and no ^{182}W anomalies are present, even in the samples containing a significant (percent level) meteoritic component [2]. Any W isotope anomalies rather have a terrestrial origin. Therefore, W isotopes cannot provide proper evidence of a meteoritic component or confirm a LHB on Earth, and still other methods for such a search must be employed.

References: [1] Schoenberg R. et al. (2002) *Nature* 418, 403–405. [2] Moynier F. et al. (2009) *Earth Planet Sci. Lett.* 286, 35–40