New perspectives from old spherules - Archean impact layers and the early meteorite bombardment of the Earth

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Introduction: Large asteroids have hit the Earth during and in the wake of accretion and during the (somewhat debated) late heavy bombardment, but the scars of these impact events have long since been obliterated. Extensive spherule deposits, rarely observed in relationship to post-Archean impact events, provide (due to their preservation over extremely long periods of time) the only accessible tracers of the Archean impact record. The oldest impact layers identified so far range in age from 3.4 to 3.2 Ga and are found in the Pilbara craton in Australia and the Barberton Greenstone Belt (BGB) in South Africa; some of them these probably correlated [1]. After decades of debate about the nature of the enormous, up to slightly superchondritic, platinum group element (PGE) enrichments in some of these spherule layers [2,3], convincing evidence for an impact origin in the form of carbonaceous chondritic Cr isotope signatures in most of the analyzed spherule layers was provided [4,5].

Initially four, later possibly up to eight Archean spherule layers were identified [6-8], and it was speculated about the corresponding impactor sizes (up to ~60 km) and effects it had on the planet, including earthquakes, large-scale tectonic rearrangements, and tsunamis [9].

However, the discovery of up to 21 new spherule layers (representing an unknown, but smaller number of impact events) in two recently drilled cores (Barb5 and CT3) from the BGB will help to better understand impactor types and impact effects. Here we review the evidence for chondritic impactors proposed in three recent studies [10-12], using highly siderophile element abundances and ^{187}Os isotope signatures.

Results and Discussion: Barb-5 spherule horizons exhibit up to chondrite-like highly siderophile element (HSE) abundances and ^{187}Os signatures [11], whereas [12] found up to four times chondritic HSE concentrations (always associated with chondrite-like ^{187}Os) in the CT3 core. Back-calculated (to an age of ~3.2 Ga) ^{187}Os/^{188}Os ratios always plot above or on the chondritic ^{187}Os isotope evolution line. Based on in-situ measurements of Ni-rich chromium spinels (suspected carrier phases of the HSE) in Barb-5 spherule layers [13] and data for whole rock analyses of Barb-5 spherule-groundmass assemblages [11], modal abundances of up to 1 wt.% of spinels would be necessary to explain chondritic concentrations in the spherule layers. However, this is not observed.

Conclusions: The current dataset for both drill cores points toward the following observations: (i) spherule layer samples and lithologies intercalating the spherule layers (mostly shales and cherts from the Fig Tree Group) both exhibit HSE concentrations ranging from sub- to chondritic (and in the case of CT3 also superchondritic) values, (ii) the maximum concentrations reported by [10] represent the highest abundances ever reported for Archean spherule layers, (iii) most samples exhibit rough trends toward chondrite-like HSE ratios with increasing total Ir content, suggesting various meteoritic admixtures to the samples, (iv) samples from both drill cores define rough linear mixing trends connecting impact-unrelated Fig Tree Group sediments with chondrites in HS interelement diagrams, and (v) initial ^{187}Os isotope signatures further strengthen the proposition of chondritic impactors.

The existence of superchondritic HSE abundances might best be explained to result from fractionation processes within the impact plume, syn- or post impact hydrothermal activity, or post-impact mechanical enrichment of HSE carrier phases. However, chondritic admixtures of up to, and above 100% in some of the spherule layers from the Barberton area, are orders of magnitude higher compared to any such values reported for other (post-Archean) impact ejecta and deposits. The accumulated evidence from all analyzed Archean spherule layers supports that these magnitudes of meteoritic admixtures might be a general feature, possibly related to the enormous impactor sizes, or potentially indicating impactor compositions that are not represented in the present-day meteorite collections.

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