MAGNETIC Fe,Si,Al-RICH IMPACT SPHERULES FROM THE P-T BOUNDARY LAYER AT GRAPHITE PEAK, ANTARCTICA. M. I. Petaev[1,2] (mpetaev@cfa.harvard.edu), S. B. Jacobsen[1], A. R. Basu[3], and L. Becker[4]. [1]Department of Earth and Planetary Sciences, Harvard University, [2]Harvard-Smithsonian Center for Astrophysics, [3]Department of Earth and Environmental Sciences, University of Rochester, [4]Institute of Crustal Studies, Department of Geology, University of California, Santa Barbara.

Introduction: The geological boundary between Triassic and Permian strata coincides with the greatest life extinction in the Earth's history [1,2]. Although the cause of the extinction is still the subject of intense debates, recent discoveries in the P-T boundary layer of shocked quartz grains [3], fullerenes with the extra-terrestrial noble gases [4], Fe metal nuggets [5-7], and chondritic meteorite fragments [7] all point to a powerful collision of Earth with a celestial body in the late Permian. Here we report the discovery of magnetic Fe,Si,Al-rich impact spherules which accompany the chondritic meteorite fragments in some samples from the P-T boundary layer at Graphite Peak, Antarctica.

Samples and Analytical Techniques: The grain mounts of magnetic fractions from the samples #2060, #314, and #315 were studied in the BSE and SE images using a JEOL SuperProbe 733. The chemical compositions of bulk spherules and individual phases were measured at 15 kV and 30 nA using the DBA (10-50 μm) and FBA (1 μm), respectively. The standards were well-characterized minerals. A thorough description of the samples, their locations, and separation techniques used by us is given in [7]. Sample #2060 from the very base of the P-T boundary layer contains meteoritic fragments and Fe metal nuggets but no spherules. Magnetic spherules along with meteoritic fragments were found in samples #314 and #315 which come from the same layer but located ~23 cm above the base of the P-T boundary. Samples #314 and #315 contain no metal grains.

Petrography: Because of the small sizes and enrichment in opaque minerals, essentially all spherules are non-transparent in transmitted light, so the phase identification was based solely on their chemistry and behavior under the electron beam. Most spherules, with a few exceptions, have almost ideal spherical shapes and consist of mainly Si,Al-rich glass which often encloses magnetite and silica grains (Fig. 1). The FeO-rich spherules typically contain skeletal magnetite crystals (Fig. 1a) indicative of extremely high cooling rates of the spherules. Blocky or rounded crystals of silica (probably quartz with orange fluorescence under the electron beam) typically occur in the magnetite-depleted spherules (Fig. 1b).

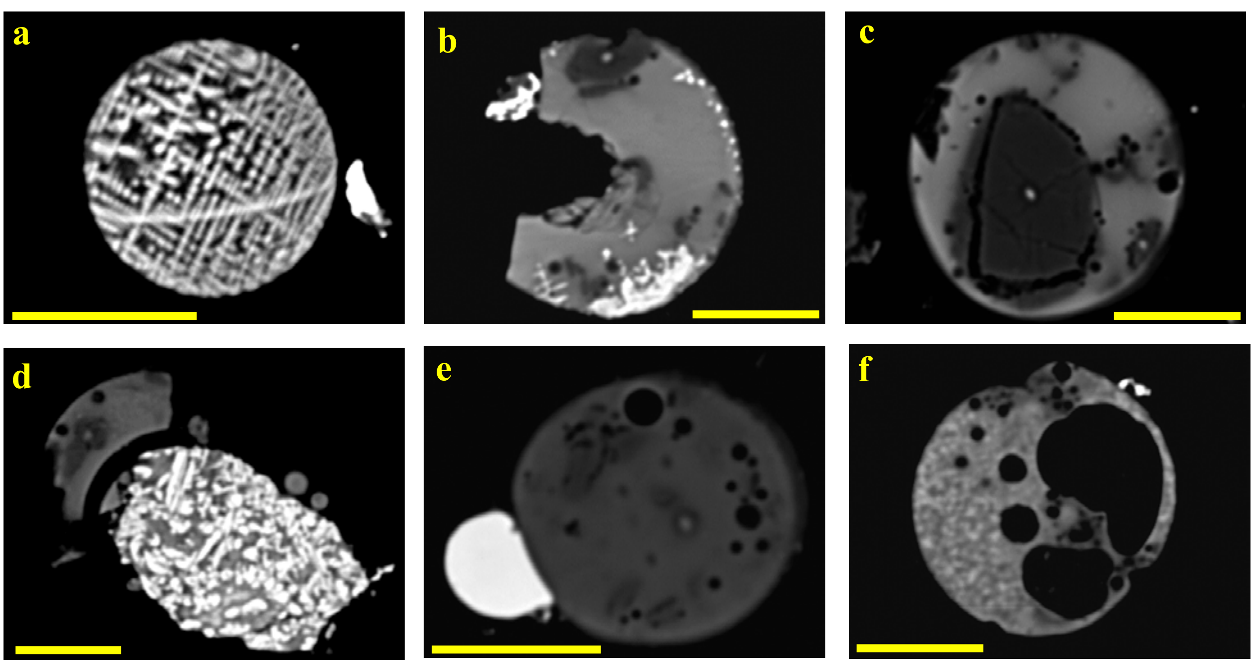

Fig. 1. BSE images of Fe,Si,Al-rich spherules. White – magnetite, intermediate gray – silicate glass (the lighter the color, the higher the FeO content), dark gray – silica (irregular or blocky regions, often with diffuse outlines), black – voids. Small bright dots within the gray phases are analytical spots. Scale bars are 20 μm.

A few spherules contain somewhat rounded remnants of the primary silica grains (Fig. 1c) providing clear evidence of incomplete melting of spherule precursors. Another common feature of the magnetite-depleted spherules is a high abundance of rounded vesicles (Fig. 1e,f) which apparently represent air bubbles trapped in silicate-melt during quenching. Some spherules show core-mantle textures, usually with a magnetite-rich core being surrounded by a FeO-depleted glassy mantle (Fig. 1d). We found several examples where two spherules display composite textures (Fig. 1e,f) reminiscent of those of compound chondrules. Such compound textures form when molten spherules suspended in a gaseous phase collide and stick together. Among known terrestrial processes only volcanic activity or impact melting can account for the observed petrographic characteristics of the spherules.

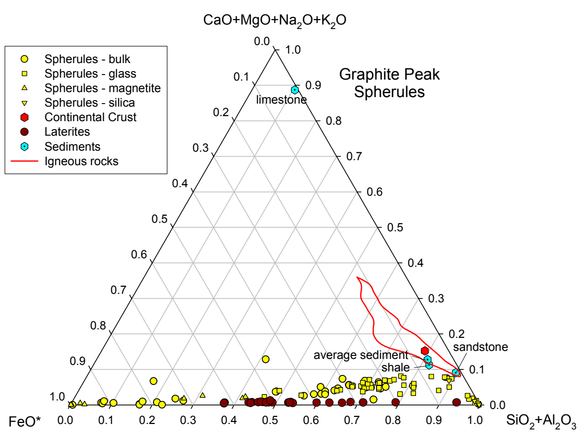

Fig. 2. Comparison of the chemical compositions of spherules with terrestrial igneous rocks (red line encloses >97% of 37,000 rock analyses from the Petros igneous rock database), sediments (average shale, sandstone, limestone and sediment [8]), the average composition of the continental crust [9] and lateritic soils [10].

Chemistry: The bulk compositions of the spherules as well as the compositions of their glasses (Fig. 2) display wide variations suggestive of the extremely heterogeneous nature of the precursor. Nevertheless, the generally high concentrations of TiO_2 (0 – 5.91 wt.%) and Al_2O_3 (2.01 – 33.86 wt.%), along with the lack of Cr_2O_3, MnO, and NiO, unequivocally point to an affinity of the spherule precursor to continental crustal materials. The depletion of the spherules in soluble elements such as Mg, Ca, Na, and K (Fig. 2) clearly separates them from the igneous rocks, ruling out a volcanic nature of the spherules. The same arguments rule out a cosmic origin of the spherules leaving impact as the only plausible mechanism of spherule formation. The compositional trend among the spherules is very close to that of laterites (tropical soils), except for somewhat higher concentrations of MgO, CaO, and K_2O in the spherules. This similarity implies that the late Permian impact responsible for the spherule formation should have occurred somewhere in the tropical region of the Pangea supercontinent. The minor compositional discrepancy between the spherules and laterites can be readily explained by a mixing of laterites and their felsic unaltered or partially altered precursors by the impact.

Spherules from Other Localities and the Scale of Late Permian Impact: The occurrence of meteoritic fragments, Fe metal nuggets, shocked quartz grains, and impact spherules in the P-T boundary layer at Graphite Peak provide strong evidence for a late Permian impact, but the scale of the impact is difficult to estimate based on a single P-T section. A wide distribution of Fe metal nuggets, from Antarctica to China and Japan, suggests that they were produced by a large scale event. There are also reports of spherules from several P-T boundary localities in China [e.g., 11,12], which are usually interpreted as volcanic, but their impact origin cannot be ruled out either [11,12]. Although the description of petrography and chemistry of those spherules is not detailed enough to facilitate direct comparison with the spherules described by us, there are striking similarities such as the magnetic nature of the spherules, their enrichment in Fe, Si, and Al and depletion in Cr, Ni, and K, the high abundance of vesicles, the composite textures of some spherules ('fused spheres'), etc. It appears that the spatial distribution of the spherules also points to a large scale event responsible for their origin, which is most likely an impact.

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