Global Evidence for a Permian-Triassic Impact Event Robert J. Poreda[1] Asish Basu[1], Luann Becker[2], Craig Nicholson[2], Adriana Ocampo[3], [1]Department of Earth & Environmental Sciences, Rochester University, Rochester, NY 14626; [2]Department of Geology, University of California, Santa Barbara, 1140 Girvetz Hall, Santa Barbara, CA 93106; [3]ESTEC Planetary Division, SCI-SB Keplerlaan 1 2200 AG Netherlands

Introduction: Several studies of the possible role of bolide (asteroidal or cometary) impact at the PTB were carried out through chemical and mineralogical characterization of boundary sediments. Although shocked quartz, microspherules and iridium anomalies have been detected (Xu and Yan, 1993; Holser and Margaritz 1992; Retallack et al., 1998; Kaiho et al., 2001 Olsen et al., 2002) the abundances of these impact tracers are some 10 to 100-fold lower than those reported at the 65 million year old KTB. Moreover, previous investigations of impact tracers (e.g. iridium) in some PTB locations (e.g. Meishan, China) have produced negative results (Zhao and Kyte, 1988; although the boundary layer for Meishan in this work was located in the middle of Bed 27 rather than the base of Bed 25; see also Xu and Yan, 1993) and no attempt was made to identify shocked metamorphosed grains. Another problem is that the present boundary for Meishan (base of Bed 25) is discontinuous and not present at all outcrop locations further highlighting the difficulties in identifying the PTB and detecting impact tracers in older sediments (Erwin, pers. comm.).

Last year, we presented a new tracer, fullerenes with trapped extraterrestrial noble gases at the Meishan, China and Sasayama, Japan PTB sites (Becker et al., 2001). The Meishan fullerene tracer is coincident with changes in the $\delta^{13}C$ carbonate carbon that appear to signal an abrupt productivity collapse in marine ecosystems (Jin et al., 2000) and shocked metamorphosed Fe-Si-Ni grains (Kaiho et al, 2001) that are also consistent with impact origin. At Sasayama, fullerenes occur in the siliceous claystone layer (Becker et al., 2001) where both microspherules (Miono et al., 1996) and Fe-Si-Ni bearing grains or "iron nuggets" (Miono et al., 1999) have previously been reported. No fullerenes were found in sediments above and below the PTB, consistent with our results on other known impact-related boundaries like the KTB (Becker et al., 2000).

The only plausible mechanism for the presence of these unique carbon molecules in a discrete boundary layer is that a bolide delivered the fullerenes 'intact' to the Earth, triggering a series of catastrophic (massive volcanism) and environmental perturbations and severe mass extinction. We proposed that fullerene with ET noble gases (like shocked quartz) represents a discrete "event marker" in contrast to other chemo-indicators such as $\delta^{13}C$, bulk ^{3}He or iridium that are controlled either by changing climatic conditions or sedimentation processes, respectively.

To expand on our initial investigation of the PTB sites at Meishan, China and Sasayama, Japan and to sort out some of the questions raised (Farley and Mukhopadhyay, 2001), we examined the continental PTB section from Graphite Peak, Antarctica (Poreda and Becker,2003). This well-studied sequence of paleosols has measurements of Ir, $\delta^{13}C$ organic carbon, shocked quartz, biostratigraphy, grain size and mineralogy (Retallack et al., 1998; Retallack and Krull, 1999). The region of interest (~ 2-meter interval from a 200-meter section) brackets the last "Gondwana" coal occurrence that ended the Permian Era. Below this "last" coal seam is a moderate Ir increase (late Permian) that coincides with the last occurrence of the Glossopteris flora while just above this coal shocked quartz within the PTB "claystone-breccia" ushers in a new Triassic fauna. Both the lower Ir spike and the upper "shocked quartz" layer have anomalous $\delta^{13}C$ (~ -40‰) that suggests a severe disruption to the normal plant biomass (~ -27‰) (Krull and Retallack, 2000). Based on the presence of shocked quartz and biostratigraphy, Krull and Retallack (2000) identified the upper layer as the PTB and confirmed this interpretation with similar evidence from sections at Mt. Crean, Antarctica and Wybung Head, NSW, Australia (Retallack and Krull, 1999).

One of our goals is to sort out the effects of continuous flux monitors (Ir and ^{3}He) from those that may represent a boundary or "event" marker". Noble gas investigations have shown that interplanetary dust contains predominantly solar gases (e.g. Nier et al., 1990). This solar signature contrasts with the "planetary signature" observed in carbonaceous chondrites and the fullerene isolates (Becker et al 2000). Specifically we examined the $^{3}He/^{4}He$, $^{20}Ne/^{22}Ne$ and $^{3}He/^{36}Ar$ ratios as these indicators display the greatest difference between solar and planetary signatures.

Results: Following our standard Soxhlet extraction with organic solvents (Becker et al., 2000), we separated a fullerene component (20 μg) from the acid resistant residue (100 mg) of the Graphite Peak boundary breccia. The fullerene yield for Graphite Peak is 20 μg out of a bulk 40-gram rock sample, similar to other PTB sites (~10-20 μg in 40g.) and a ^{3}He concentration of some 40 times above the background signal. The $^{3}He/^{4}He$ ratios of 30 to 80 x 10^{-6} are about one half the planetary ratio seen in fullerenes extracted from carbonaceous chondrites and consistent with an ET signature. This result is expected because of the degradation of fullerene with time in a surface (terrestrial) environment and the possible exchange of ET with air helium. Sub air $^{40}Ar/^{36}Ar$ serves to confirm the presence of ET gases and the ratio of $^{3}He/^{36}Ar$ falls close to the value for planetary gas. Interestingly, this ET fullerene signal occurs only at the "upper" boundary breccia layer (above the last Gondwana coal) (~65cm.) coincident with the shocked quartz and not with the Ir peak that occurs below the coal (~145 cm.). The fullerene content at ~145 cm., based on both LDMS and ^{3}He concentration, is at background levels or about 50 ng (~40 grams of sediment or ~1ppb).

In contrast to the low fullerene abundance, the ^{3}He content of the bulk sediment is amongst the highest values measured in sedimentary environments (e.g. GPC-3; Farley, 1995). The ^{3}He ranges from 1-250 pico-cc/g in the bulk sediment with a $^{3}He/^{4}He$ ratio up to 1.7 $X10^{-4}$ with the highest abundances (and ratios) corresponding to both the Ir-rich layer and the impact layer.

In an attempt to identify the carrier phase for the ^{3}He and to determine if the high ^{3}He at the boundary reflects an impact marker, we isolated ~ 1 mg of a strongly magnetic fraction from three samples of bulk Graphite Peak sediment. The ^{3}He concentration of these 1-20 μm sized grains was 4-14 ncc/g or ~100-500X higher than the bulk and is about 10% of the total helium^{-3} in the bulk material. Because this magnetic fraction represents < 0.1% of the total sediment mass yet contains about 10% of the helium, it is reasonable to assume that this component is the major carrier of the ^{3}He (many small, < 5μm sized opaque grains, remain in the "non-magnetic" fraction and contribute to the residual ^{3}He signal). The ^{3}He is also a minimum concentration estimate because this fraction may include terrestrial magnetic grains or IDP grains that have degassed during atmospheric entry.

The neon isotopic composition of the magnetic fraction is non-atmospheric in both $^{20}Ne/^{22}Ne$ and $^{21}Ne/^{22}Ne$. The $^{20}Ne/^{22}Ne$ ratio is a mix of air and solar gas while ^{21}Ne excess reflects nuclear production of ^{21}Ne by (α,n) reactions on ^{18}O in 250 Ma sediments (e.g. Ozima and Podosek, 1984).

We compared the helium and neon results for the Graphite Peak magnetic fraction to an isolated IDP component collected and separated by Don Brownlee (U. Washington, Seattle) from zero-age deep-sea sediments of the central Pacific (e.g. Nier et al., 1990). Although somewhat variable, the magnetic fractions from Graphite Peak throughout the section have similar $^{3}He/^{4}He$ ratios to the zero age IDP grains, isolated from the deep-sea sediments. The zero age IDP grains reflect a pure SEP (Solar Energetic Particle) neon signal as observed in lunar fines and stratospheric IDP collections (Nier and Schlutter 1990).

These new results coupled to previous studies of fullerenes with trapped noble gases and other impact tracers point to an end-Permian impact(s) event in the offshore Tethys and Circum-Pacific regions. The Bedout High, located offshore Canning basin, northwestern Australia, is an unusual structure and its origin remains problematic. K-Ar dating of volcanic samples from the Lagrange-1 exploration well indicated an age of about 253 +/− 5 Ma consistent with the Permian-Triassic boundary event. Gorter (1996) speculates that the Bedout High is the uplifted core (30 km) of a circular feature, some 220 km across, formed by the impact of a large bolide (cometary or asteroid) with the earth near the end-Permian. Accepting a possible impact origin for the Bedout structure, with the indicated dimensions, would have had profound effects on global climate and significant changes in lithotratigraphic, biostratigraphic and chemo-stratigraphic indicators as seen in several Permian-Triassic boundary locations worldwide.

We will present the global evidence for a Permian-Triassic impact event and re-examine some of the structural data previously presented by Gorter (1996) as well as additional seismic lines and gravity. Evidence for an impact of extraterrestrial origin is based upon several impact tracers including shocked metamorphosed grains, productivity collapse, helium-3, Mossbauer spectroscopy on nanophase Fe material, noble gases in magnetic fines and fullerenes with trapped noble gases from some Permian-Triassic boundary sites. Our findings suggest that the Bedout structure and a possible newly discovered (~100 km) secondary crater may be good candidates for an oceanic/continental impact(s) at the end Permian, triggering the most severe mass extinction in the history of life on the Earth.

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