ANOMALOUS IRIDIUM AT THE PALYNOLOGICAL TRIASSIC-JURASSIC BOUNDARY IN THE FUNDY BASIN, PARTRIDGE ISLAND, NOVA SCOTIA. Frank T. Kyte[1], Lawrence H. Tanner[2], and Anne E. Walker[2], [1]Center for Astrobiology, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567 USA (kyte@igpp.ucla.edu), [2]Department of Biological Sciences, Le Moyne College, Syracuse, NY 13204 USA

Introduction: It has long been argued that the Triassic-Jurassic (T/J) boundary coincided with a single, catastrophic extinction making it one of the "big five" extinction events of the Phanerozoic [1-13]. More recently, however, some workers have interpreted the latest Triassic as an interval of accelerated turnover and decreasing diversity, punctuated by discrete extinction events [14-16]. In either case, a major biotic event occurred at this system boundary that severely reduced some faunal groups, and eliminated others that were already in serious decline.

Olsen et al. [6] first proposed a bolide impact to explain extinctions at the T/J boundary, citing evidence of a Late Triassic age for the Manicouagan impact structure. However, precise dating of Manicouagan at 214 $\pm$ 1 Ma [17] showed that this impact was substantially older than the currently accepted age of the Triassic-Jurassic boundary of 199.6 $\pm$ 0.4 Ma [18]. Also, shocked-metamorphosed quartz grains were reported from a section in northern Italy [19], but no subsequent work has confirmed this. More recently, Olsen et al. [7,8] published data that showed elevated levels of Ir (up to 285 pg/g) in four correlative non-marine sections from the Newark basin at a stratigraphic level interpreted as the T/J boundary from palynological data. The Ir anomalies coincide stratigraphically with high concentrations (up to 80%) of "fern-like" (i.e. trilete) spores, drawing comparisons to the K-T impact scenario.

In this study, we report concentrations of Ir, organic carbon, and several trace elements from a non-marine palynological T/J boundary from the Fundy basin, Nova Scotia. This locality is stratigraphically similar to the sections studied by Olsen et al. [7,8], but ~1000 km further north. The Blomindon Formation, in the Fundy Group, comprises 200 to 300 m of Late Triassic to Early Jurassic sandstone and mudstone overlain by the North Mountain Basalt, dated at 201.3 $\pm$ 0.3 Ma. [20]. The palynological turnover at this site marking the probable T/J boundary is 20-30 cm from the top of the Blomindon Formation at Partridge Island, but no "fern spike" is found here. Earlier work by Orth et al.[21] found an Ir concentration of 150 pg/g in a single sample from this locality, and Mossman et al. [22] reported Ir levels of 100 and 200 pg/g in a few samples, but lacked the precision to demonstrate a convincing Ir anomaly. Conversely, Tanner [23] reported that Ir levels at the base of the formation are below detection limits. These studies, however, lacked close sampling resolution, and were not constrained by palynostratigraphic placement of the Triassic-Jurassic boundary. Tanner and Kyte [24] first showed that an Ir enrichment (up to 310 pg/g) in the Fundy basin occurs at a similar stratigraphic level as in the Newark basin and this low-resolution study suggested that this Ir anomaly might occur at multiple levels in the section.

This Study. In this study we resampled the Blomindon formation and analyzed a suite of 45 samples including most of a 100 cm interval from the top of the section. Where possible, some samples were examined in thin section. Iridium and several trace elements (Sc, Cr, Fe, Co, Ni, Zn, Cs, Ce, Eu, Tb, Yb, Hf, Ta, and Th) were measured by neutron activation analysis in splits from 1-2 gram powders, and organic carbon (C_{org}) by combustion analysis (Leco Truspec C/N) in separate samples from the same stratigraphic intervals. The uppermost meter of the formation comprises beds of red mudstone that are 2 cm to 15 cm thick and gray mudstones that vary from light greenish-gray beds 2 cm to 5 cm in thickness to finely laminated beds. Laminated mudstones contain fine (mm-scale or finer) dark gray to black organic-rich laminae, interlayered with light gray to red mudstone laminae.

Concentrations of Ir vary by more than an order of magnitude from a minimum of 24 pg/g at the base of the analyzed section (150 cm below the formation top) to a peak concentration of 449 pg/g at 42 cm. Secondary peaks occur at 72 cm (320 pg/g) and 16 cm (273 pg/g), and lower levels of enrichment (above 100 pg/g but less than one order of magnitude above background) occur at 6 cm, 23 cm, 48 cm and 52 cm. Concentrations of C_{org} in the section also vary by over an order of magnitude, from a minimum of 0.2 mg/g to approximately 5 mg/g. In general, the C_{org} concentration corresponds to the rock color, with the highest concentrations occurring in dark gray mudstone or reddish mudstone that contain kerogen laminae. Of all the elements measured, only Zn is moderately correlated with Ir ($r^2 = 0.4$). The samples with the highest Ir concentrations also have relatively high Zn (150 to 600 μg/g), but not all high Zn samples have high Ir. The other elements measured including C_{org}, exhibit no significant corellation with Ir, however, due to an analytical malfunction we currently lack C_{org} data on the sample with the highest Ir, which has adjacent samples above and below with high Ir, Zn, and C_{org}. High C_{org} in this sample would result in a correlation similar to that with Zn. Zinc concentrations are also somewhat correlated to C_{org} ($r^2 = 0.3$), showing the strongest correlation to bulk organic carbon of any element measured. In general, the distribution of Ir, Zn, and C_{org} are similar across the section.

Although the concentrations of the Ir anomalies are small, they are comparable to anomalies at some sites known

to contain impact ejecta – the late Eocene clinopyroxene (cpx) spherule deposits. At several localities where cpx-spherule deposits have been positively identified, peak Ir concentrations are ≤250 pg/g (e.g., [25,26]). Often a better measure of an Ir anomaly is the fluence, or the total mass of excess Ir deposited per cm^2. If we assume an average background Ir concentration of 80 pg/g, and a dry bulk density of 2 g/cm^3, then the excess Ir in the eight samples with Ir concentrations >150 pg/g is 3.7 ng/cm^{-2}. This is a non-trivial value and corresponds to about 8 mg cm^{-2} of chondritic matter (based on 465 ng/g Ir in CI chondrites). By comparison, estimates of the Ir fluences for the global impact deposits recognized for the late Eocene cpx-spherule layer and the K/T boundary are about 11 and 55 ng/cm^{-2}, respectively [27,28]. Clearly the Fundy basin Ir anomalies are significant and not typical of non-marine sediments. These anomalies require an external source for the Ir, other than typical detrital sediment.

At this time, we cannot exclude an extraterrestrial source for the Ir anomalies, but neither can we present any strong evidence to support such a hypothesis. We find no direct evidence of impact spherules, a common component in known impact deposits (e.g., [29]). A study of quartz grains in this section [22], failed to find shocked quartz, but the presence of detrital quartz in these sediments would make a search for traces of shocked quartz an impossible task. Further, at such low Ir concentrations, equivalent to 0.1% of CI chondrite, application of chemical ratios (e.g., Ir/Cr, Ir/Pd) as a tracer for extraterrestrial matter in these sediments, can't work. The problem with this is that the estimated meteoritic component, based on Ir concentrations, is too small and elements that might be diagnostic for more concentrated impact deposits, such as Ni, Cr, and Pd are overwhelmed by terrestrial contributions at such low Ir concentrations. Only Os might also be expected to exhibit a similarly small anomaly. Since the Cr in these sediments is clearly dominated by detrital sources, an attempt to measure a Cr-isotopic anomaly [30] would likely fail. Perhaps if enough Os could be extracted from these sediments, one might find an Os-isotopic anomaly, but this would not be suitable for distinguishing between an extraterrestrial vs. mantle source for Os [31]. Perhaps if there were evidence that this Ir anomaly was global in extent, an impact hypothsis might have some credibility. However, at this point, attempts to find a global anomaly have failed [32], and the occurrence of this anomaly is currently restricted to the localities within the Newark and Fundy basins, separated by only ~1000 km, and closely situated relative to the coeval Central Atlantic magmatic province (CAMP) volcanics.

Conclusions: We find Ir anomalies at multiple levels near the palynological T/J boundary in the Fundy Basin. These anomalies are significant, at 3.7 ng/cm^{-2}. Although not strongly correlated, Ir, Zn, and C_{org} enrichments occur at similar levels, within dark-colored sediment layers containing kerogen-rich laminae, suggesting that their distributions are controlled by redox boundaries during early diagensis. However, the high levels of Ir require a significant external source. We cannot exclude an extraterrestrial source, but the fact that this anomaly is known only regionally, and in proximity to the CAMP volcanics, requires us to suggest volcanic aerosols [33] as an equally plausible source.

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