Bollide, Flood Basalt, or Artifact, Ir and Nd-Sm clues to the Climatic Catastrophe at the Triassic Jurassic Boundary

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Introduction: The three largest Phanerozoic mass extinctions, the Permo-Triassic, the Triassic-Jurassic (Tr-J), and the Cretaceous-Tertiary (K-T) are very close in time or overlap with the 3 largest flood basalt eruptions, the Siberian Traps, the Central Atlantic Magmatic Province (CAMP), and the Deccan Traps, the K-T also being the only confirmed coincidence of a bolide impact and an major extinction event *(1)*. This apparent correlation (Fig. 1), extending to less important extinction events and smaller igneous provinces, between basalts and mass extinctions has naturally given rise to the hypothesis that mass extinctions are, on general, caused by the climatic catastrophes caused by giant flood basalt eruptions *(2)*. The deleterious effects of such eruption could include sulfate aerosols producing severe global cooling, CO_2 emissions resulting in severe global warming, perhaps leading to methane release from clathrates, and halide release resulting in large scale poisoning, as well as the "local" effects from the lava and ash themselves *(3)*.

Of the three largest mass extinctions, the Tr-J is unique in geologic context with direct evidence of the extinction event co-occurring in the same continental and marine stratigraphic sequences with both flood basalts (CAMP) and high-resolution geochronologic control in a high-accumulation rate setting. The CAMP is the Earth's largest flood basalt in area covering about 11 x 10^6 km^2 *(3)*. Hence, it offers perhaps the most natural laboratory for investigating the links between flood basalts, climatic catastrophes, and mass extinctions.

Previous work on the Tr-J has documented a 50% drop in pollen and spore diversity over an interval of less than 30 ky *(4,5)*, a fern spore spike (*4,5*), the base of a global, negative $\delta^{13}C$ excursion *(6,7,8,9,10)* (Fig. 2), a CO_2 spike (based on stomatal density data from Greenland: *11*), a ^3He anomaly potentially of extraterrestrial origin (in fullarenes?: J. H. Whiteside and K. Farley, pers. comm., 2005), and modest Ir anomaly, known from North America (*5, 12,* Tanner, pers. comm., 2007). While the observations, especially Ir anomaly, parallel those associated with the K-T boundary bolide impact (reviewed in *7*), no shocked quartz or impact-diagnostic evidence has been found to date at the Tr-J boundary. In fact, the observations are equally condign with flood basalt eruptions.

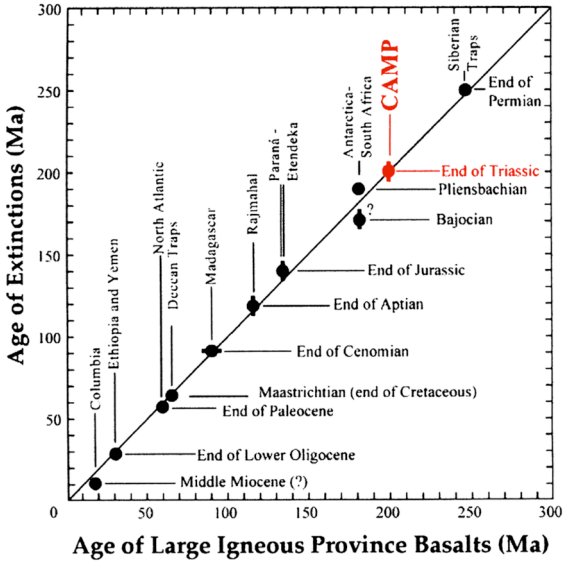

Figure 1: Correlation between ages of large basaltic igneous provinces and mass-extinctions (from ref. *2*).

Proposed Work: In order to lay the groundwork for an appropriately extensive investigation of the climatic catastrophe(s) at the Tr-J mass extinction, we propose a test of concept in strata around the Tr-J in eastern North America using analyses for PGE (Ir, Pt, etc.) anomalies (by ICP-MS) and the Nd-Sm system (using conventional techniques) to:

1) determine the frequency of PGE anomalies and attempt to discriminate between primary or diagenetic sources of these anomalies.
2) determine the frequency and magnitude of basaltic input to the sediments, particularly in cryptic tuffs with PGE anomalies using the Nd, Sm/Nd, and Sr isotope ratios and rare earth element

proportions taking advantage of the large differences between the crystalline basement and CAMP basalt end members that could have provided potential terrestrial inputs.

We propose to analyze 60 samples for PGEs from a broader stratigraphic range at Jacksonwald (Fig. 2) and sections in Holyoke, MA, Berlin, CT, and the Fundy basin to establish if is there is a correlation between redox boundaries and Ir anomalies in general in these sections, or whether there are unique to the narrow extinction interval with its other associated phenomena. These samples are in hand at Lamont and include the same samples used for $\delta^{13}C$ and ^{3}He by Whiteside and Farley. We will run the Jacksonwald samples (30 samples) at an external lab (Geoscience Laboratories, Sudbury, Ontario; a division of the Ontario Geological Survey) using nickel-sulfide fusion assay technique with ICP-MS (*13*) to provide a baseline for in house work and to conform to the time frame of participation of a high school student (see below), and we will run some of the Jacksonwald samples and the rest of the samples from the other sections in our effort to develop the nickel-fusion preconcentration ICP-MS method at Lamont, for routine analyses (see below). If Ir anomalies prove to be present at multiple levels at redox boundaries, we will be forced to conclude they are diagenetic origin and not from extraterrestrial or basaltic terrestrial sources.

The same samples run for PGEs will be run for Nd, Sm/Nd, and Sr isotope ratios and rare earth element proportions, here at Lamont by Hemming. While non-diagenetic Ir anomalies are usually thought of as indicators of extraterrestrial input, and all of the Phanerozoic distal impact ejecta other than that at the K-T boundary have Ir anomalies comparable to that at the Tr-J (e.g., the two Eocene examples: *14*), basaltic tuffs can routinely have Ir concentrations comparable to those of non-K-T, distal ejecta. This was most clearly shown by Schmitz and Asaro's *(15)* study of the Paleocene-Eocene Fur Formation basaltic tuffs derived from the initial eruptions of the North Atlantic igneous province, and coincident with the PETM. Many of these tuffs range from 200 to 680 ppt, overlapping values from the Tr-J anomalies and the Eocene impact layers. The Nd, Sm/Nd, and Sr isotope ratios and rare earth element analyses should allow for the identification cryptic (completely devitrified) basaltic tuffs within these sections and of multiple levels with basaltic Nd, Sm/Nd, and Sr isotope ratios and high PGEs might well indicate that there was considerable explosive volcanism associated with the initiation of the CAMP, and that could be the origin of both the Tr-J anomaly and perhaps a significant killing mechanism for the extinctions as well. Preliminary work indicates that most sedimentary strata around the CAMP basalts have virtually no CAMP contribution *(16)*, and therefore cryptic tuffs rich in CAMP products should be distinctive.

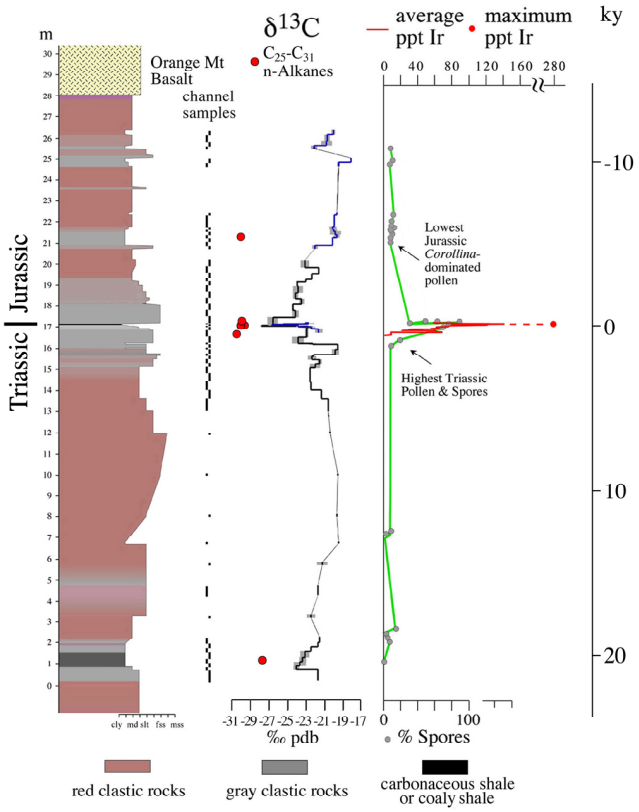

Figure 2: Triassic-Jurassic Boundary in the Jacksonwald Syncline (from *17*).

Role of Students: An exceptional high school student Nirmal Nair (Eastchester High School: Edward Gruber Science Research Coordinator/Physics Teacher) initiated this effort as part of the initial stages of national Science competitions. In addition to providing the motivation for a reexamination of the Tr-J Ir

anomalies, he has prepared the relevant samples for analysis. The samples run by Geoscience Laboratories will be used by Nair in his project on the Tr-J boundary in the upcoming Intel science competition. In addition we would like to involve at least 1 Columbia undergraduate in this work (TBD)

Potential to develop system at Lamont: While we do analyses of PGEs by ICP-MS here at Lamont (Chillrud lab) no preconcentration step is used. Tanner and Kyte *(12)* used both neutron activation and Ni-fusion ICP-MS and obtained results indistinguishable from neutron activation on the same samples from the Partridge Island section, and we are therefore confident this method could be developed here for routine PGE determinations.

Potential for leveraging other projects: This project is a test of concept for full NSF proposals to look systematically at long geological records, especially, although not exclusively as seen in core, especially around the Triassic-Jurassic boundary. For our purposes this will include not only standard NSF proposals, but also larger scale ones such as the Colorado Plateau Coring Project, a workshop for which will be held Nov. 13-16 (P.E. Olsen, D.V. Kent, J. Geissman, PIs: http://www.ldeo.columbia.edu/~polsen/cpcp/CPCP_home_page.html), and a possible Large Igneous Province IODP mission-oriented drilling project including the CAMP and seaward-dipping reflectors (C. Herzberg, pers. comm., 2007). Development of the nickel-sulfide fusion assay technique at Lamont will almost certainly catalyze other projects as well.

Budget:

PGE analysis: nickel-sulfide fusion with ICP-MS: 30 samples* @ 140 per sample (Geoscience Laboratories, Sudbury, Ontario; a division of the Ontario Geological Survey)	$4200.00
PGE set up at Lamont (expendable materials)†	$600.00
Nd, Sm/Nd, and Sr isotope ratios and rare earth element proportion†	$1200.00
Total requested	**$6000.00**

*The other 30 samples will be run in-house
†Additional funds will be used from other sources, including for the ICP-MS time at Lamont

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