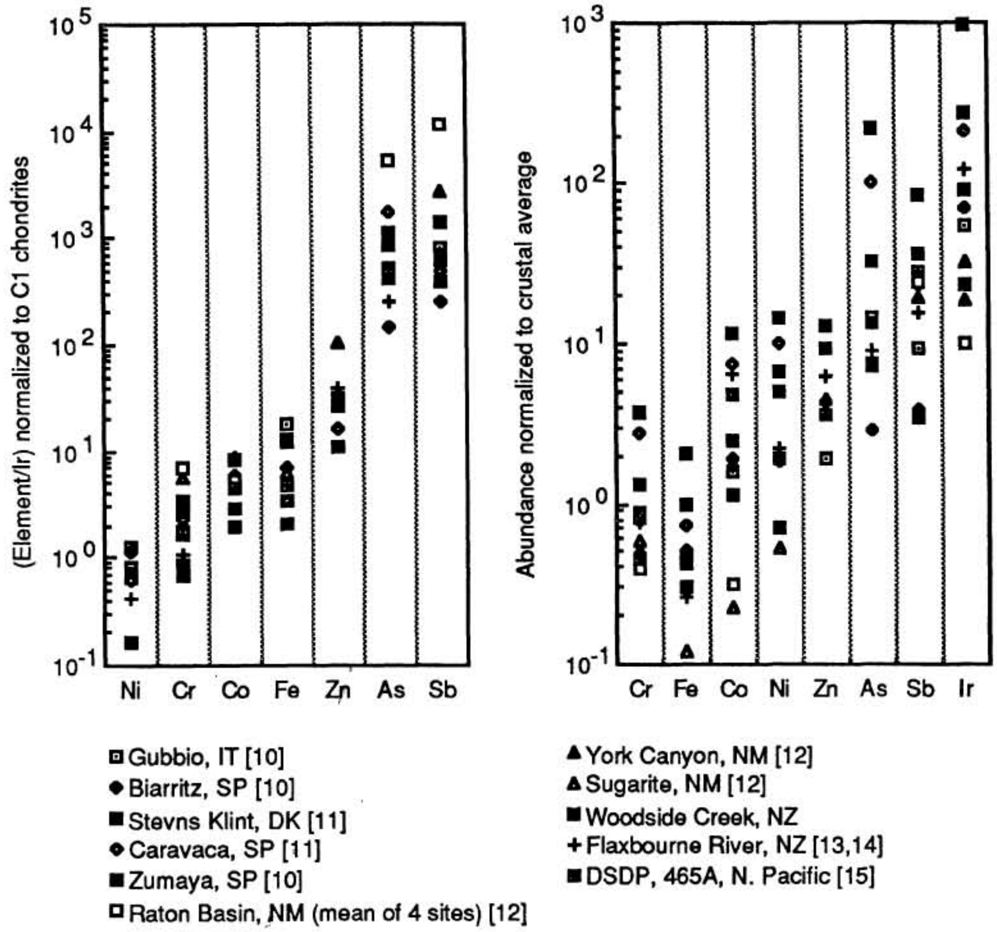
TRACE ELEMENTS AT THE K-T BOUNDARY: EVIDENCE FOR A SINGLE IMPACT?; Iain Gilmour* and Edward Anders†, *Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637; †and Physikalisches Institut der Universität, University of Bern, Bern, Switzerland.

Not only meteoritic elements (Ir, Ni, Au, Pt metals), but also some patently non-meteoritic elements (As,Sb) are enriched at the K-T boundary. Strong *et al.* [1] compared 8 enriched elements at 7 K-T sites and found that: (i) All have fairly constant proportions to Ir (within <10x) and (ii) Kilauea — invoked as an example of a volcanic source of Ir by opponents of the impact theory — has too little of 7 of these 8 elements to account for the boundary enrichments. We have reexamined the distribution of trace elements at the K-T boundary using a more comprehensive set of data and 4 additional localities.



To assess the meteoritic component, the abundances of 7 elements enriched in boundary clay are normalized first to Ir, the most obviously extraterrestrial element, and then to C1 chondrites (see figure). Of these 7 elements only Cr and Ni approach unity, indicating near chondritic Cr/Ir and Ni/Ir ratios. For Cr, a mean ratio of 2.8 (±2.0) is obtained using data from all 11 sites. For Ni, the mean ratio is 0.8 (±0.5) based on data from 9 sites (the only published Ni data for a continental sequence is from the Sugarite site in the Raton Basin, New Mexico). The crustal and mantle ratios for these elements are much higher (180x and 100x chondritic for Cr; 24x and 20x chondritic for Ni [2, 3]).

The remaining elements all have higher ratios to Ir, suggesting that they have only minor meteoritic components. This includes Co, which though siderophilic and enriched by up to 10x over average crustal abundances, has high ratios to both Ir and Ni, suggesting it is largely terrestrial in origin. Sb and As, and to a lesser extent Zn, are also enriched over typical crustal abundances by up to 100x. Clearly the source of the boundary clay is atypical with respect to these elements. Sb/Ir and As/Ir ratios are ~700x chondritic and ~660x chondritic respectively for the marine sites, while Zn/Ir ratios are ~25x chondritic, based on data published for 6 of the marine sites. It is remarkable that despite the wide geographic distribution of these sites, the ratios of these elements show such a close grouping.The continental sites of the Raton Basin, including York Canyon and Sugarite in New Mexico, show more variation in chalcophile abundance pattern, though some have only a marginal enrichment in chalcophiles over Upper Cretaceous values for these sequences. Examination of the distribution of chalcophiles across the boundary at Caravaca, Spain, and at Flaxbourne River and Woodside Creek in New Zealand (among the most complete sequences so far found) show them to be well correlated with Ir (r=0.945 to 0.997).

The apparent correlation of chalcophile element abundances with Ir, the grouping of chalcophile/Ir ratios, and the enrichment over the typical crustal abundances of these elements may imply a single unique source. In terms of the impact theory there are some interesting possibilities.The decrease in primary production following the mass extinction of plankton, as suggested by changes in carbon isotope ratios [5], could lead to anoxic oceans. Mass balance calculations have shown that scavenging of the ocean alone could account for the enrichment in Sb and As [1] though tremendous depths of water would be required for Zn, implying another source. A possible candidate is crustal or mantle rock (as impact ejecta), which could supplement an oceanic contribution or, if the impact site consisted of an enriched source rock, provide all of the enrichment. Evidence for the latter may come from the presence of elemental carbon, primarily soot, which is enriched in sediments from the boundary and is apparently derived from fires triggered by the impact [6]. Combustion of fossil fuels such as coal, oil shales or petroleum has been proposed as the source of this carbon and Cisowski [7,8] has suggested that microspherules found in the boundary clay represent fossil fuel fly ash. Organic rich shales are known to lose chalcophile elements during combustion [9] and the soot and Ir at Woodside Creek correlate across the boundary implying that the two fell out together. If this is indeed the case, it would tend to exclude multiple impacts as they are unlikely to have repeatedly hit As,Sb-enriched terranes.

Volcanic emissions such as those from Kilauea Vent 3 [10] do not readily account for the abundance patterns observed [1], as the ratios to Ir of all but As are considerably lower than in the boundary clay.

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