A PIECE OF THE KT BOLIDE? Frank T. Kyte, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567.

A heavily altered lithic fragment of probable meteoritic origin has been recovered from sediments of the Cretaceous/Tertiary (KT) boundary from Deep Sea Drilling Project (DSDP) Site 576. DSDP Site 576 is located in the western North Pacific (32°21.4'N, 164°16.5'E) and sediments recovered at this site record a nearly complete sequence of pelagic clay sedimentation from Late Cretaceous to Recent. At 65 Ma this site was located in the central region of the ancestral Pacific basin approximately 9,000 km due west of the Chicxulub impact structure in the Yucatán. The KT boundary has now been identified in two cores at this site [1] recovered from Holes 576 and 576B. The KT boundary is characterized by anomalous Ir concentrations, as high as 13 ng/g, coincident with a trace mineral assemblage dominated by shocked quartz and Ni-rich magnesioferrite spinel. At Site 576, anomalous Ir (>1 ng/g) occurs across nearly 100 cm of section, but a sharp peak with the trace minerals is more localized. In Hole 576, FWHM for the Ir anomaly is ~10 cm. The breadth of the Ir anomaly has been attributed to bioturbation and possibly chemical diffusion within these homogenous pelagic clays.

In one sample of dark brown clay, a light brown, ~5 mm inclusion was observed and removed. This sample (576-8-1, 50-52 cm) was later found to be at the base of the Ir anomaly; a split of this sample contained 2.6 ng/g Ir. The inclusion was observed to be very fine-grained clay with a slick, waxy texture. It was allowed to air dry and was then broken open with a stainless steel probe. The interior contained a darker brown, more coarse-grained clast, ~2.5 mm in length. Optically this clast appeared to be an altered lithic fragment. It was peppered with numerous small (<50 μm) opaque grains. Its silicate matrix contained various rounded and angular inclusions of different colors.

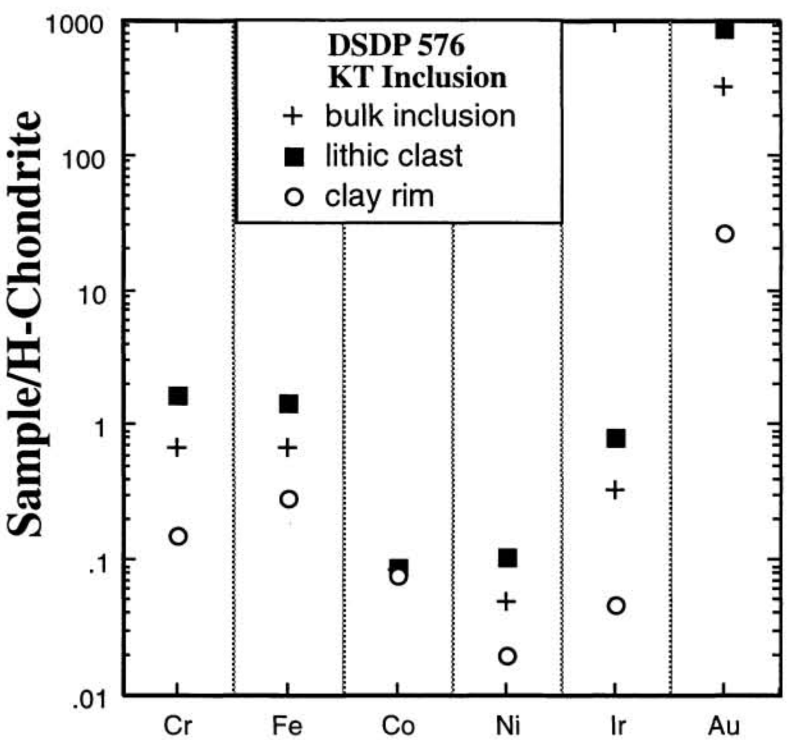
The entire inclusion was irradiated for instrumental neutron activation analysis (INAA). The relative abundances of Cr, Fe, Co, Ni, Ir and Au in the bulk inclusion, the clay rim, and the lithic core, plotted relative to H chondrites [2], are illustrated in Figure 1. An important note is that the rim sample is impure, containing traces of pelagic clay and small portions of the lithic core. The bulk Cr, Fe and Ir concentrations are close to those in chondritic meteorites, whereas Co and Ni are highly depleted and Au shows an extraordinary enrichment (up to 1000 times H chondrite in the lithic core).

A few small chips from the lithic core and the light brown rim were mounted in polished section for electron microprobe analyses. The remainder has been preserved for subsequent INAA analyses to determine whether Au is dispersed throughout the lithic clast or concentrated in one or more mineral grains. Approximately 3 mm^2 of polished section of the lithic core have been examined petrographically and by backscatter electron imaging. This object consists mainly of Fe-rich oxides in a hydrated, silicate matrix. The Fe-oxides are finely dispersed throughout most of the sample with grain sizes ranging from submicron up to ~100 μm. Microprobe analyses indicate that they are probably principally hematite. NiO concentrations are typically <1.0%, with only two exceptions observed. Three of the larger (40 to 100 μm) hematite grains contain traces of micron-sized inclusions. Qualitative analyses indicate that these are probably Ni-Fe metal and sulfides. One of these larger oxide grains consistently yielded NiO concentrations of ~2.0 %. Another yielded NiO concentrations ranging from 4 to 7 %. In this oxide, on one metal grain a quantitative composition of $Ni_{87}Fe_{13}$ was obtained. Analyses of the silicate groundmass, as well as the light brown clay rim are consistent with mixed-layer smectite/illite clays of variable composition. Texturally the interior of the lithic clast appears to be a breccia, with clay pseudomorphs after mineral and lithic fragments. The hematite grains have a modal abundance of about 30%. Their distribution is uneven - concentrated in some regions and nearly absent in others.

DISCUSSION. The high siderophile content of the lithic clast, as well as traces of NiFe- metal and sulfides in Ni-rich oxides, are strongly suggestive that this may be a highly weathered fragment of meteoritic material. This would be consistent with the large size (5 mm) of the inclusion which could not have been transported to this site by any terrestrial process. The best documented occurrence of a "fossil" meteorite is that of Brunflo, a 10 cm chondritic clast recovered from an Ordovician limestone

[3,4]. Brunflo is almost entirely replaced by calcite, barite, clays, and a host of secondary minerals that may be consistent with recrystallization in a relatively reducing environment. In contrast, the environment in DSDP Site 596 is relatively oxidizing and silicate-rich. Under these conditions FeNi metal (and sulfides?) will oxidize and mafic silicates should alter to smectites.

The low abundances of Ni and Co are readily explained by diagenetic loss. For example, heavily weathered samples of the Maralinga (CK) chondrite have suffered 70% loss of Ni and 40% loss of Co [5]. Complete oxidation of metal and replacement of silicates as in the KT inclusion should result in more extreme fractionation. The apparent thousand-fold enrichment of Au is a more difficult problem to explain. Conceivably this could be contamination, but this is considered unlikely. Planned experiments will attempt to examine the actual distribution of Au within the lithic clast. One possible source of Au enrichment could be the KT boundary itself which may have contained a considerable amount of Au (e.g., 35 ng Au deposited per cm^2, assuming H-chondrite Ir/Au ratios). Alteration of the KT boundary may have mobilized much of its Au, and perhaps it could have precipitated onto metal grains still present in the lithic clast. However, this mechanism may be unsatisfactory, as it would have to be very efficient and may require concentration of all the Au deposited over an area of ~30 cm^2.



In conclusion, the lithic fragment appears to be the heavily altered and replaced "fossil" of a metal-rich meteorite. The smectite rim may have initially been composed of glass, perhaps a fusion crust of some kind, although the portion examined appears structureless. Based on an estimated modal abundance of ~30% hematite in the lithic clast, the precursor metal may have had a modal abundance on the order of 15%. Among the known meteorite groups, this would rule out nearly all groups of carbonaceous chondrites, L and LL chondrites, pallasites, and irons as potential precursors. Potential precursors do include CR, H, EH, EL chondrites, mesosiderites, and acapulcoites. Of course, the precursor could have been from an unknown meteorite group.

The most reasonable source for a meteorite fragment within the KT boundary is, of course, from the KT projectile itself. Small meteorite fragments may survive even the largest impacts; low-angle impact should increase the odds of this [6]. Other possible sources could include fragments of a comet that disrupted prior to impact, or the inevitable tail of dust that would accompany a large, long-period comet.

[1]Kyte F.T., et al. (1995) Proc. ODP. Sci. Res., 145, 427-433. [2]Kallemeyn G.W. et al., (1989) Geochim. Cos. Acta, 53, 2747-2767. [3]Thorslund P., et al. (1984) Lithos, 17, 87-100. [4]Nystrom J.O. and Wickman F.E. (1991) Lithos, 27, 167-185. [5]Kallemeyn G.W. et al., (1991) Geochim. Cos. Acta, 55, 881-892. [6]Schultz P.H. and Gault D.E. (1990) Geol. Soc. Amer. Spec. Pap. 247, 239-261.