COMPARISON OF DISTAL IMPACT SPHERULES FROM KT BOUNDARY AND LATE EOCENE DEPOSITS. Frank T. Kyte, Center for Astrobiology, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, USA (kyte@igpp.ucla.edu).

Distal impact spherules provide information about impact processes that cannot be perceived by analyses of impact craters or numerical models. Two rather well-studied impact spherule deposits which are also relatively well preserved are the KT boundary and the late Eocene deposit containing clinopyroxene-bearing (cpx) spherules. The KT boundary spherules are almost certainly directly related to the Chicxulub impact event, and the late Eocene cpx spherule deposit is commonly believed to be derived from the Popigai event. These are the two largest impact structures in the last 100 Ma. These deposits have several common features, which may reflect processes common to large-body impacts as well as significant differences. I will concentrate on data from the KT boundary at DSDP Site 577, western N. Pacific and Eocene ejecta from ODP Site 709, western Indian Ocean.

The KT boundary is known to have at least two distinct spherule deposits [e.g., 1]. Large glass spherules are found beneath impact wave deposits of the Gulf of Mexico and are commonly attributed to impact melt from low-velocity ejecta that has a very low extraterrestrial component (i.e., low Ir content). These are probably distributed regionally, and not globally. They form the lower layer of the KT boundary couplet in the Western Interior, N. America and traces of large, hollow spherules found in N. Pacific sites GPC3 and DSDP 577 may also be from this source. The Ir-rich global fallout is also composed mostly of spherules. It's origin is probably largely from the impact plume [2], but may also contain materials derived directly from meteoritic materials [3]. The KT boundary is known at well over 100 sites; the mean amount of Ir deposited is on the order of 55 ng/cm^2 [4].

The KT boundary at DSDP 577 probably has the best preserved spherules of any site. However, in nearly all cases, most of the silicates have been replaced by clay minerals, so bulk chemical analyses of the original major element chemistry are impossible. The high degree of preservation is probably related to shallow burial at Site 577 (109 m) and oxidizing, rather than reducing conditions following burial. Three high-temperature minerals have been identified at this site. Clinopyroxene (cpx), found only at Site 577 may be the precursor to diagenetic sanidine in some European sites [5]. Magnesioferrite spinel [6] has the highest Fe_2O_3/FeO of any KT locality [2] and can have trace inclusions of Ni-rich magnesiowustite [7], which is known at only one other site (Site 596, S. Pacific). Other debris described includes shocked quartz grains >200 µm [8], hollow spherules possibly related to regional glass deposits [1,5], and irregular Ir-rich particles that may be unmelted meteoritic materials [9]. The latter may be related to the fossil meteorite found at DSDP Site 576, just 500 km to the east [10].

A large-volume (~10 cc) sample from DSDP 577 provided a 44 mg carbonate-free residue (>60 µm) composed nearly entirely of impact debris. Nearly 2700 particles >100 µm were classificatied based on color, shape, and morphology. Although they form a rather complex assemblage of spherules and other particles, they gan be generally described as ~60% light colored spherules and ~40% dark colored spherules. The light-colored spherules are mostly white, but can contain dark inclusions, and several percent of the total include green, cpx-bearing spherules and fragments of large, hollow spherules.These have generally low siderophile element concentrations (Fe, Cr, Ni, Co, Ir) and are probably derived from a target-rich portion of the impact plume. Many were found to have pseudomorphic textures similar to the dendritic textures of cpx spherules, so it's likely that many, if not all of these are altered from hi-Ca pyroxene (±glass?). The dark colored particles have a broad range of siderophile element concentrations, but are generally more enriched in the meteoritic component than the light spherules. As noted by [3] some of these particles have Ir concentrations comparable to those found in chondritic meteorites. The dark particles invariably contain magnesioferrite spinels, but the spinel content is quite variable, ranging from trace concentrations to perhaps 50% by volume of some spherules. A small fraction with high Ir have irregular outlines, and no obvious melt textures; these are the possible unmelted meteorite particles described by Robin et al. [3]. Hypotheses for origin of the spinel bearing spherules include origin in the projectile-rich portion of the impact plume [2] or as a form of ablation debris derived directly from meteoritic material [3]. Possibly, both are important sources of these particles. We have found several light-colored spherules with dark inclusions that are a mixture of the two main spherule types, with one or more inclusions of spinel-bearing material. We believe that this indicates that both types of material were coexisted as liquids, strongly supporting a plume origin for at least some fraction of the spinel-bearing spherules.

The late Eocene cpx spherule deposits contain a similar mix of particles to those in the KT boundary. They are much better preserved, commonly containing glass and unaltered cpx, so it is possible to determine bulk major element chemistry of the precursor materials. As with the KT boundary, there are two distinct components, a glassy microtektite that may be equivalent to the impact melt glasses of regional KT deposits, and the cpx spherules that are distributed globally [11,12]. Isotopic analyses of these components have shown that the microtektites and cpx spherules are from the same source [13] and this is consistent with the Popogai crater [14]. Ir analyses have been reported for 12 sites and the mean Ir deposited in the late Eocene was on the order of 9 ng/cm^2, or about 16% of the KT value [15].

A large-volume sample from ODP Site 709 has yielded more than 17,000 cpx spherules, and several hundred microtektites (>125 µm), as well as shocked quartz and coesite [16]. The microtektites have a very low siderophile content (<100 pg/g Ir), while a bulk sample of the cpx spherules has ~1 ng/g (analyses in progress). As with the KT boundary, there are both light and dark-colored cpx spherules. Microprobe analyses of these spherules indicate that the main difference is that the light spherules have generally high CaO (12% vs. 6%, on average) and lower FeO (3.6% vs. 7.5%), and probably also lower Cr (but Cr data are near detection limits and imprecise). In general, this is consistent with a model in which the cpx spherules are from the impact plume, with the darker spherules from the more projectile-rich portion of the plume. Unlike the KT boundary spherules, spinels are never more than a trace phase in the cpx spherules, but they are clearly more common in the darker spherules.

Compared to the KT boundary, a significant component appears to be missing in the late Eocene deposits [15]. The coarse fraction of KT deposits holds the majority of the Ir and other siderophiles in well preserved deposits like DSDP 577. But in the Eocene sediments, the Ir in the cpx spherules can only account for a small fraction, at most a few per cent of Ir in the bulk sediment. Whether the principal Ir carrier is an ejecta component in the fine fraction, or some larger Ir component that is not preserved in sediments has yet to be determined.

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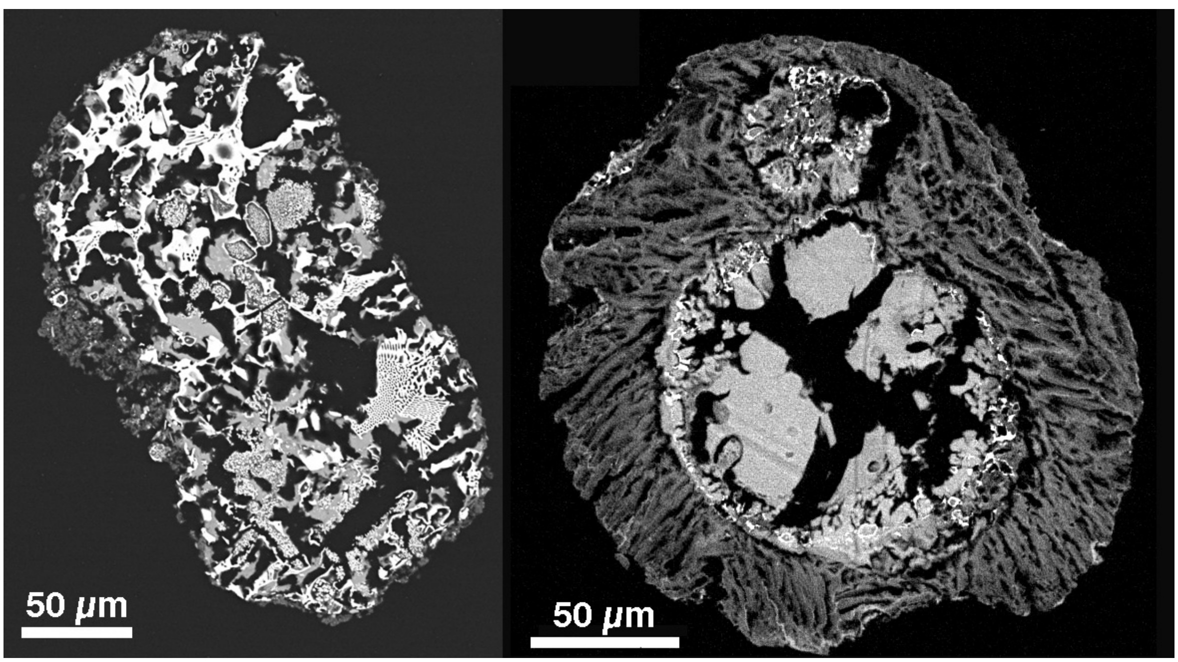

Figure. BSE images of polished sections of two KT boundary impact spherules. **Left**: very spinel-rich spherule. Nearly all the bright phases are anhedral, commonly porous, spinel. It's difficult to estimate the original proportion of spinel vs. silicates. During drying, clays shrink and separate. Dark voids are epoxy that has intruded the spherule during mounting. This spherule was probably at least 50% spinel by volume. **Right**: This is a typical light colored spherule, without spinel, that has inclusions of spinel-bearing material. Clearly these two components were both liquid at about the same time. They probably mixed together inside the impact plume.