DARKNESS AFTER THE K-T IMPACT: EFFECTS OF SOOT

Wendy S. Wolbach*, Edward Anders*, Charles J. Orth†
**Enrico Fermi Institute & Dept. of Chem., Univ. of Chicago, Chicago, IL 60637-1433, USA*
†Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Dust from the K-T impact apparently settled from the atmosphere in <6 months, restoring sunlight to minimum photosynthesis levels in ~4 months (1). However, the discovery of a global soot component in the boundary clay (2) makes it necessary to reconsider the problem, as soot particles not only are smaller (0.1 vs ~0.5 µm) and thus settle more slowly, but also are better light absorbers (optical depth of 13 mg soot cm^{-2} ~1800; 3), and are more resistant to rainout. Still, the darkness cannot have lasted very much longer than 6 months, else no larger animals would have survived. Perhaps the soot coagulated with the rock dust and fell out with it?

Evidence on this point may be sought at a relatively undisturbed K-T boundary site, such as Woodside Creek, N.Z. There the boundary clay and lowermost Tertiary strata are finely laminated and show large chemical and isotopic differences on a millimeter scale, apparently representing a detailed time sequence. We have studied a 3 m section across the boundary at this site, analyzing the principal forms of carbon (soot, elemental C, kerogen, and carbonate) as well as 33 elements (3). Let us look for correlations among the elements to see what fell out together.

Impact Ejecta. A curious feature of boundary clays is that they are enriched not only in meteoritic elements (Ir, Ni, Cr, etc.) but also in certain non-meteoritic elements (Sb,As; 5). Both groups of elements occur in characteristic, uniform proportions at 11 sites worldwide, which suggests that they represent a uniform mixture of meteorite and target rock ejected from a single impact crater (5) and distributed globally. At Woodside Creek, these uniform proportions persist not only in 3 layers of the boundary clay -- representing primary ejecta deposited in <1 year -- but also in the first 2 m of the Tertiary, representing secondary, redeposited material that was moved around by lateral transport. The figure shows that correlations with Ir -- a meteoritic element par excellence -- continue well into the Tertiary not only for elements that have appreciable meteoritic components (Cr, Fe) but also for those that are almost entirely terrestrial (Sb, Zn).

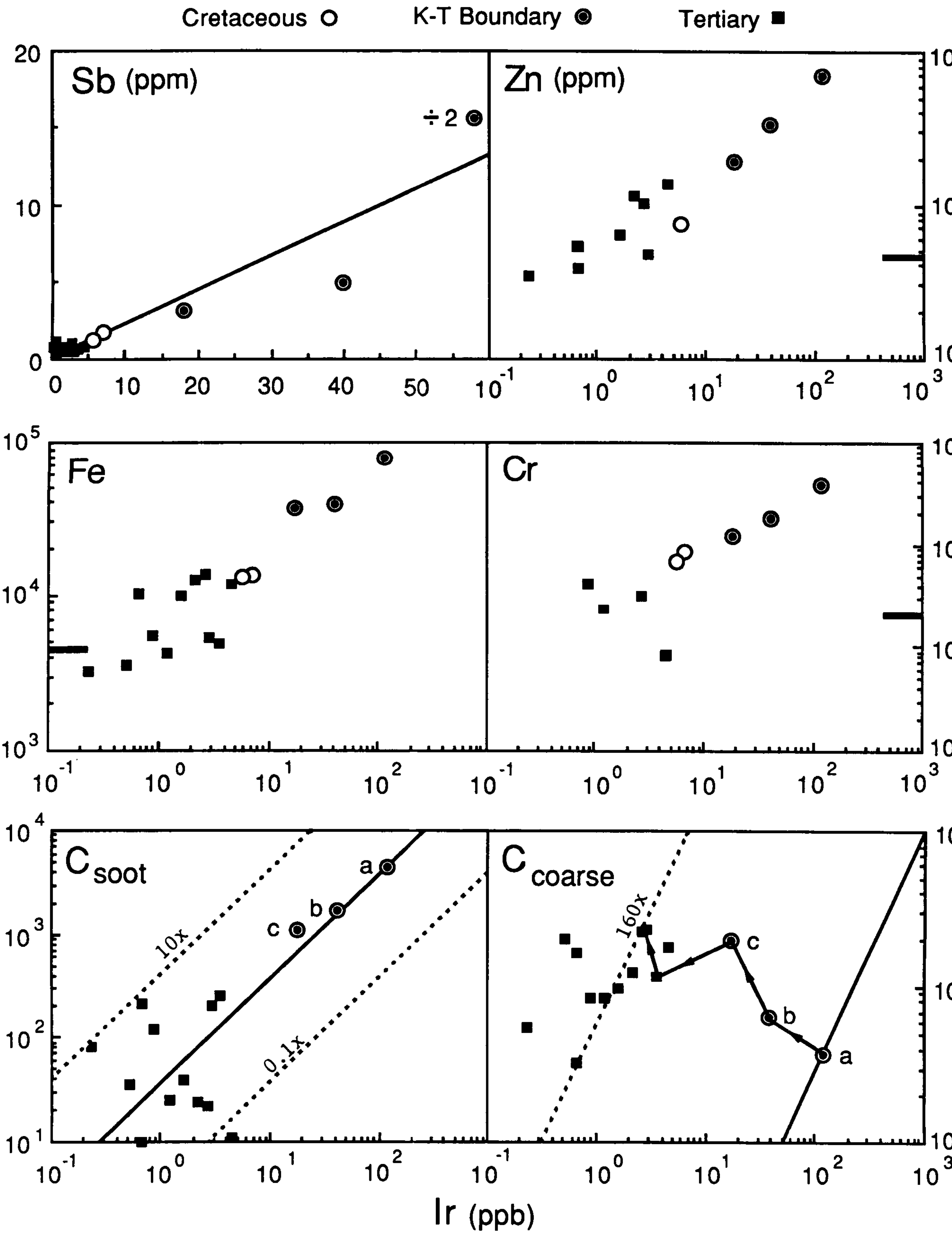
On linear plots (shown only for Sb), the slope and intercept represent "impact" and "background" components. The background components thus determined are indicated by tick marks on the log-log plots. Each element correlates with Ir until it has dropped to near background levels, at 1-2 m above the boundary (~10^5 yr). Apparently meteorite and target rock were thoroughly mixed in the molten ejecta, and therefore remained tightly coupled throughout ejection, fallout, sedimentation, and redeposition.

Carbon. Soot correlates nicely with Ir in the 3 layers of the boundary clay (a to c) and the next two samples (0.6-5.8 cm), but then goes its own way, first dropping ~10^{-1} below the correlation line and then rising above it at 90-170 cm. Coarse C, on the other hand, shows a very different pattern. It rises rather than falls from bottom to top of the boundary clay (a to c), then peaks at 11 cm and stays at ~200x the initial C/Ir ratio to 170 cm.

Apparently soot came early and coagulated with the ejecta, staying with them for the primary fallout and in the next 5 cm, but then parting company, perhaps due to size sorting. Coarse C, on the other hand, appeared later and began to coagulate with Ir only in the secondary fallout, just when the soot-Ir correlation began to break down. Several factors may be responsible for these differences: soot forms only in flames and may have been lofted into the stratosphere, where its high surface/volume and charge/mass ratios may have helped it coagulate with ejecta. Coarse C, on the other hand, forms by charring and largely stays on the ground, thus having no chance to coagulate with ejecta. It probably reached the sea by a different, slower route.

Anyhow, since soot apparently coagulated with ejecta, it could lengthen the darkness stage only by its greater optical depth, not by its slower settling time. This result has implications for nuclear winter, where coagulation of soot is a major issue.

(1) Toon, O.B. *et al.* (1982) *Geol. Soc. Am. Spec. Pap.* **190**, 187-200 ; (2) Wolbach, W.S. *et al.* (1985) *Science* **230**, 167-170; (3) Wolbach *et al.* (1988) *Nature*, in press; (4) Alvarez *et al.* (1980) *Science* **208**, 1095-1108; Gilmour, I. and Anders, E. (1988), this conference.


Cretaceous
K-T Boundary
Tertiary
Sb (ppm)
÷2
Zn (ppm)
Fe
Cr
C soot
10x
0.1x
a
b
c
C coarse
160x
Ir (ppb)