EJECTA FALLOUT AS A KILLING MECHANISM AT THE K-T BOUNDARY: EVIDENCE FROM A VOLCANIC ASH LAYER; I. Gilmour, Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637. Present address: Planetary Sciences Unit, Dept. of Earth Sciences, The Open University, Milton Keynes, MK7 6AA, U.K.

Studies of the possible environmental aftereffects of a large body impact at the K-T boundary have focussed on the consequences of dust and smoke in the atmosphere, such as global temperature change and the suppression of photosynthesis [1, 2, 3]. However, an additional factor is the effect of large quantities of ejecta fallout, particularly on the marine environment. Marine Cretaceous-Tertiary boundary clays apparently formed from rapidly deposited ejecta following the impact and are often enriched in organic matter over background values (by around 15× in organic carbon and 20× in nitrogen at Woodside Creek, New Zealand [3]). They therefore represent the accumulation of substantial quantities of organic material over a very short time scale. At Woodside Creek the total amount of organic carbon in the basal layer is comparable with the global average of particulate organic carbon in the present oceans. This has lead to the suggestion that the massive amounts of K-T ejecta settling rapidly through the water column would kill and sweep-out plankton and other particulate organic matter [3]. This scavenging hypothesis can be tested, and volcanic ash falls present a suitable analogue for this process.

A widespread volcanic ash layer, 2 to 40 cm thick, covering an area of 5×10^6 km^2 in the north-east Indian Ocean, was deposited around 75,000 years ago following the eruption of up to 2000 km^3 of magma from the Toba volcano on Sumatra. Interior portions of a piston core (Vema 29/3) containing a 9 cm thick primary air-fall layer with graded bedding on a millimetre scale that had not been reworked by slumping, currents or bioturbation was sampled in 5 to 10 mm intervals across the base of the ash layer. The duration of the eruption has been estimated at 9-14 days using the grain size distribution of feldspar crystals [4]. The coarsest grained material produced during the eruption would settle through the water column ≈64 hours. The finer material that remained in the atmosphere would continue to arrive after the eruption had ceased and would settle from the atmosphere relatively quickly and through the water column on a time scale of ≈3 months. To a first approximation, therefore, a mean sedimentation rate of around 40 cm/yr can be estimated.

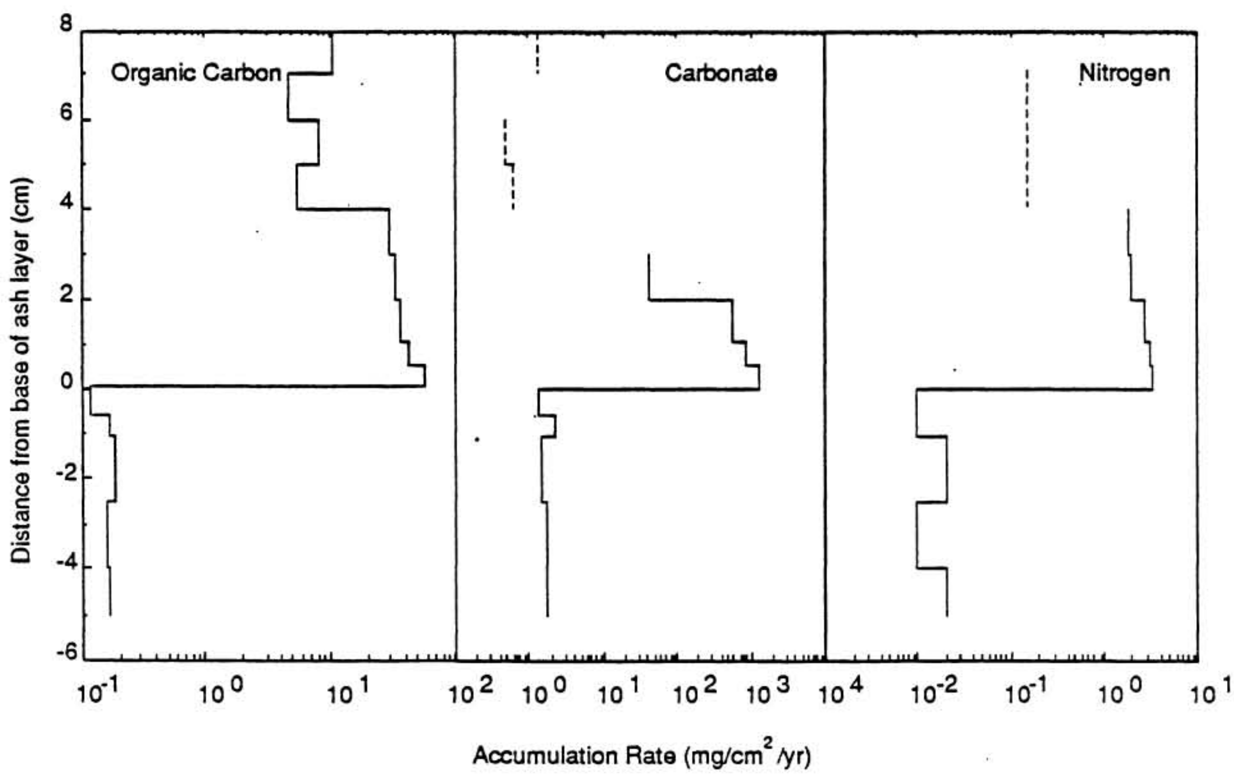

Table 1 Comparison of the integrated abundances of organic carbon, nitrogen and carbonate.

	Ocean mg/cm^2	Toba Ash mg/cm^2	Woodside Creek mg/cm^2
Organic Carbon	5.3	3.7	4.4
Nitrogen	0.13	0.24	0.83
Carbonate	≈20†	43.0	40.0

† Estimate from Atlantic Ocean

The extremely short deposition time of the ash layer is reflected by the ≈3 orders of magnitude increase in the accumulation rates of carbonate, organic carbon, and nitrogen (figure). Carbonate rises sharply (by >10^{2}x), declines over the next 3 cm, and then reverts to normal. Organic C also rises by >10^{2}x but stays higher for 4 cm then fluctuates at lower but still elevated values. The rise for N parallels those for carbonate and organic carbon, remaining high until 4 cm above the base of the ash layer. The integrated abundances of organic carbon, nitrogen and carbonate over the 0-4 cm interval and the average particulate organic carbon (POC) or nitrogen (PON) abundances throughout the water column for the Indian Ocean are given in Table 1. Evidently, the amounts of C and N buried with the ash layer approximate the estimated abundances of POC and PON in the oceans, give or take a factor of 2. The integrated calcium carbonate abundance over the 0-4 cm interval is higher most likely due to the survival of $CaCO_3$ down to the calcite compensation depth (CCD) in contrast to organic matter which is progressively oxidized as it settles through the water column. Apparently the Toba ash scavenged and buried particulate material in the ocean up to 2000 km from the site of the eruption. For C and N, it would seem that the fallout removed most of the POC and PON from the water column. For carbonate, the sharp decrease in accumulation rate at +3 cm, compared with +4 cm for organic C and N, implies that the majority of $CaCO_3$ was scavenged within this time interval possibly as a consequence of the coarser grain size of particulate $CaCO_3$ materials.

Comparing the Toba data with those for the K-T boundary reveals some remarkable similarities. In both cases the amounts of fall-out are roughly the same, around 4 g/cm^2 for Toba and between 2-5 g/cm^2 at the K-T, although the K-T ejecta was probably finer [5]. The integrated abundances at Toba and in the basal layer at Woodside Creek, New Zealand [3, 6] are remarkably similar. As the basal layer is believed to represent the primary fallout of ejecta following the impact, the good agreement between Woodside Creek and Toba reinforces the hypothesis that oceanic POC was scavenged and buried by impact ejecta at the K-T boundary. The oceanic environment following the K-T impact would clearly have been very different from that after the Toba eruption so that a number of additional factors such as widespread anoxicity and considerable mixing of surface and bottom waters could have played a role. Nevertheless, it would appear that the levels of fall-out from the Toba eruption were sufficient to scavenge the water column of much of its POC and PON, and most of its particulate carbonate thereby establishing "ground-truth" for the hypothesis that fall-out at the K-T boundary could scavenge and rapidly bury organic matter from the ocean.

One of the major mass extinctions observed at the K-T boundary is that of surface water planktonic species. In contrast benthic species and land plants suffered far fewer extinctions. Clearly, a reduction or elimination of photosynthesis due to reduced sunlight would impose extreme stresses on both marine plankton and land plants. However, the scavenging of the oceans by impact ejecta fall-out would effectively sweep clean the photic zone greatly reducing the chances of recovery for surface water species. In contrast land plants would be less affected by fall-out increasing their chances of recovery. Thus fall-out of the impact ejecta itself may account for some of the apparent selectivity of extinctions associated with the K-T boundary.

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