

**IMPACT-WAVE EFFECTS AT THE CRETACEOUS-TERTIARY BOUNDARY IN GULF OF MEXICO DSDP CORES** W. Alvarez<sup>1</sup>, J. Smit<sup>2</sup>, M. H. Anders<sup>3</sup>, F. Asaro<sup>4</sup>, F. J.-M. R. Maurrasse<sup>5</sup>, M. Kastner<sup>6</sup>, W. Lowrie<sup>7</sup>. <sup>1</sup>Dept. Geology & Geophysics, Univ. Calif., Berkeley 94720; <sup>2</sup>Dept. Sediment. Geol., Free Univ. Amsterdam; <sup>3</sup>Lamont-Doherty Geol. Obs., Columbia Univ., Palisades, NY 10964; <sup>4</sup>Lawrence Berkeley Lab., Univ. Calif., Berkeley 94720; <sup>5</sup>Dept. Phys. Sci., Florida International Univ., Miami 33119; <sup>6</sup>Scripps Inst. Oceanogr., La Jolla CA 92093; <sup>7</sup>Inst. Geophysik, ETH Hönggerberg, CH-8093 Zürich.

For many years, search for a large Cretaceous-Tertiary (KT) boundary impact crater was unsuccessful, suggesting the possibility that the impact might have been on oceanic crust that was subsequently subducted <sup>1, 2</sup>. This was an attractive possibility in light of the interpretation of KT impact spherules as having originally been of basaltic composition <sup>3, 4</sup>. A major oceanic impact would produce a very large wave that would erode nearby ocean floor and continental margins and redeposit the eroded material. We therefore carried out a search through the records of the Deep-Sea Drilling Project (DSDP) for sites in which an arbitrary amount of the Cretaceous was missing, and the hiatus was overlain by basal Paleocene sediment, with or without redeposited material below the basal Paleocene. Oceanic sediments deposited below the carbonate compensation depth are difficult to evaluate because of the rarity of fossils, but fossil control is generally adequate in continental-margin sites. Despite uncertainties due to discontinuous coring, it was evident that sites with Paleocene over a Late Cretaceous hiatus are largely confined to the Gulf of Mexico. This supports the other arguments now pointing toward impact in the Gulf of Mexico-Caribbean area <sup>5-12</sup>. The useful sites are (located between the Yucatan and Florida platforms) are DSDP 94 and 95 (Leg 10) and 536, 537, 538A, and 540 (Leg 77). We concentrate here on sites 536 and 540.

Site 536 recovered an apparently continuous, conformable KT boundary in core 9, section 5, 70-71 cm (Initial Reports, DSDP, v. 77) <sup>13</sup>, and it was puzzling that there is no trace of the worldwide KT boundary clay layer. However, re-examination shows that ooze with lowermost Paleocene planktic forams rests on a 112-cm thick graded, current-bedded unit which contains mixed early Maastrichtian (G. "tricarinata" zone) and late Maastrichtian (A. mayaroensis zone) planktic faunas, with no Paleocene forams. We tentatively interpret this unit as the top of a KT boundary clastic unit resulting from impact disturbance of the water in the Gulf. This explains the absence of KT ejecta deposits, which would have fallen out before the wave reworking ceased. An iridium anomaly is present at or near the top of the graded, current-bedded unit, with the maximum Ir value observed so far being  $704 \pm 91$  ppt. This pattern, with an Ir anomaly at the top of a redeposited KT bed) agrees with observations at Beloc (Haiti) and Brazos River (Texas), and suggests that the Ir was dominantly in high-speed ejecta which settled only after calming of impact-disturbed water which had reworked proximal ejecta. Because of poor recovery, it is not possible to determine what lay immediately below the ripple-laminated unit.

In DSDP 540, the lowest recovered Tertiary (core 30) is of middle Paleocene age (foram

zone P4; coccolith zone CP8); however, because of incomplete core recovery, there is a missing interval of as much as 13.5 m in which basal Paleocene (and/or uppermost Maastrichtian) could be present. Underlying core 31 recovered a current-bedded sand which is a mixture of grains of white carbonate, dark-grey clay, and pyrite. The clay is a smectite, probably representing altered glass. The smectite was interpreted in vol. 77 as altered volcanic glass, but the smectite could instead be altered impact glass, an interpretation strengthened by the complete absence of the crystal grains expected in pyroclastic deposits. This unit contains Maastrichtian planktic forams and coccoliths, with no Paleocene microfossils yet observed. This is compatible with origin of the core-31 current-bedded sand as proximal KT impact ejecta reworked by disturbed water in the Gulf. Below the current-bedded sand is an interval of pebbly mudstones about 45 m thick. The mud matrix contains Cenomanian forams exclusively, and was interpreted as a series of mud flows of that age. Alternatively this interval may represent a KT impact-triggered event. The former predicts that the matrix will have normal magnetic polarity, while the latter predicts reversed polarity; this is currently being tested.

From DSDP Sites 540 and 536 we infer the presence of a unit that can reasonably be interpreted as impact ejecta reworked by water set in motion by the impact wave, with an extraterrestrial iridium anomaly in the uppermost part, and overlain by basal-Paleocene pelagic ooze. This interpretation is compatible either with a nearby oceanic impact (for example, on Atlantic Ocean crust subsequently subducted beneath the Caribbean plate), or with an impact that could have produced the Chicxulub structure <sup>7</sup> in Yucatan, or with impact on the proto-Caribbean island arc between Cuba and Hispaniola <sup>12</sup>. Only redrilling with improved recovery can reveal the full KT record in this critical area.

1. Alvarez, W., Alvarez, L.W., Asaro, F. & Michel, H.V. *Geological Society of America Special Paper* **190**, 305-315 (1982).
2. Alvarez, W. & Asaro, F. *Scientific American* **263**, 78-84 (1990).
3. Smit, J. & ten Kate, W.G.H.Z. *Cretaceous Research* **3**, 307-332 (1982).
4. Montanari, A., et al. *Geology* **11**, 668-671 (1983).
5. Bourgeois, J., Hansen, T.A., Wiberg, P.L. & Kauffman, E.G. *Science* **241**, 567-570 (1988).
6. Hildebrand, A.R. & Boynton, W.V. *Science* **248**, 843-846 (1990).
7. Hildebrand, A.R. & Penfield, G.T. *Eos* **71**, 1425 (1990).
8. Bohor, B.F. & Seitz, R. *Nature* **344**, 593 (1990).
9. Izett, G.A., Maurrasse, F.J.-M.R., Lichte, F.E., Meeker, G.P. & Bates, R. *U. S. Geological Survey Open-File Report* **90-635**, 1-31 (1990).
10. Sigurdsson, H., et al. *Nature* (in press).
11. Smit, J. *Nature* (in press).
12. Maurrasse, F. J.-M. R., *Geol. Soc. Amer. Abs. Progr.* **22**, 77 (1990).
13. Buffler, R.T., Schlager, W. & others. *Initial Reports, Deep-Sea Drilling Project* (U. S. Government Printing Office, Washington, 1984).