The Chicxulub impact and the Cretaceous-Paleogene (K-Pg) boundary: Current status and pending issues

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About 30 years ago, it was proposed that a large asteroid impact (now identified as the Chicxulub impact event) hit the Earth at the end of the Cretaceous (~65 m.yrs. ago), thereby causing the dramatic mass extinction at the K-Pg (formerly "K-T") boundary (e.g., Alvarez et al., 1980). Meanwhile, many details of the impact event and the associated mass extinctions have been revealed, though the causative link is still unanswered. We will discuss examples for (A) the general evidence for the Chicxulub impact event and its link to the ejecta deposits at the K-Pg boundary, and (B) lines of research useful to further clarify impact-induced effects in the aftermath of the Chicxulub event.

(A) Evidence for the Chicxulub impact and the mm- to m-thick deposits at the K-Pg boundary being its world-wide ejecta is provided mainly by the presence of (a) shocked minerals and ejected lithic clasts with shock features, (b) glass spherules of in part exotic composition, (c) microkrystites, (d) Ni-rich spinels with a high ratio of ferric/ferrous iron, and (e) specific geochemical signatures (e.g., Smit, 1999). These geochemical signatures include (i) tracers for the projectile (e.g., Cr isotope ratios, high concentrations of platinum group elements and their inter-element ratios), (ii) stable isotope excursions that indicate a sudden productivity and temperature drop following the impact event, and (iii) an abrupt increase of element concentrations, change in elemental ratios, and a spike in the $^{87}Sr/^{86}Sr$ isotope ratio, all seen as indicator for a high flux of material from the continents and the surrounding shelf in the pelagic realm. Slumping and mass wasting at the Gulf of Mexico and the Atlantic continental slope may be evidence for the seismic effects of the Chicxulub impact in proximal regions (see Schulte and Deutsch, this volume). In addition, these mass flows may be responsible for the occasional occurrence of multiple Chicxulub ejecta deposits in northeastern Mexico (Schulte et al., 2003). However, all boundary layers that are generally agreed to be stratigraphically complete contain only one horizon rich in impact debris and that layer is intimately associated with faunal and floral evidence for the mass extinction at the K-Pg boundary. Moreover, the excellent correlation of the Chicxulub impact with ejecta found in the K-Pg boundary layer worldwide provide no support for multiple large impact events at the End of the Cretaceous.

(B) Any approach to better understand the impact event and related environmental perturbations must be centered on the fact that impact of a chondritic projectile with a diameter of 10 km is a high-energetic event, releasing energy on the order of $1.5e+21 \times 10^2$ Joules. Second important fact is the extreme short time-scale causing "sudden" changes, followed by more long-lasting effects. Environmental effects of the Chicxulub impact event range from multiple tsunamis to a short heat pulse, acid rain, and – more importantly – a short period of global cooling due to injection of vapor, dust, and formation of sulfate aerosols in the stratosphere (e.g., Pierazzo et al., 2003; Kring, 2007). Translating these various hazards to the biosphere into the ultimate cause for the extinction of certain species is a difficult task due to the short timescale of the processes and the usually condensed sedimentation recorded in the K-Pg boundary clay. Moreover, published results on the amount of dissociated carbonates and evaporites differ by several orders of magnitude (Ivanov and Deutsch 2002). Therefore, experimental observations (e.g., Agrinier et el., 2001) as well as ejecta investigations (e.g., Schulte et al., 2009) both provide further clues on the dissociation of carbonate and sulfate-bearing target rocks. Additional investigation of the K-Pg boundary clay and earliest Danian on a sub-mm scale, e.g., by LA-ICP-MS, may then give further records of the immediate environmental effects of the Chicxulub impact event (see Deutsch et al., this volume). Finally we want to point out that only few geological processes are understood that well as impact cratering. This is due to the fact that the basis of knowledge covers very different fields, ranging from “real-time” observations (e.g., impact of comet SL-9 on planet Jupiter in 1994; nuclear tests; cratering and shock experiments) over data collection in 3D (field work and drilling on Earth; remote sensing on other bodies in the solar system), analyses in the lab to modeling. Modeling is a very effective tool to check if proposed processes are compatible with the laws of physics, and modeling results may help to understand observations, whereas observations help to refine models!

Alvarez, L.W., Alvarez, W., Asaro, F., and Michel, H.V. (1980): Extraterrestrial cause for the Cretaceous-Tertiary extinction. Science, 208, 1095-1108.

Agrinier, P., Deutsch, A., Schärer, U., and Martinez, I. (2001): Fast back-reactions of shock-released CO2 from carbonates: An experimental approach. Geochimica et Cosmochimica Acta 65, 2615-2632.

Ivanov, B.A., and Deutsch, A. (2002): The phase diagram of CaCO3 in relation to shock compression and decomposition. Physics of The Earth and Planetary Interiors, 129, 131-143.

Kring, D.A. (2007): The Chicxulub impact event and its environmental consequences at the Cretaceous-Tertiary boundary. Palaeogeography, Palaeoclimatology, Palaeoecology, 255, 4-21.

Pierazzo, E., Hahmann, A.N., and Sloan, L.C. (2003): Chicxulub and climate: Radiative perturbations of impact-produced S-bearing gases. Astrobiology, 3, 99-118.

Schulte, P., Stinnesbeck, W., Stüben, D., Kramar, U., Berner, Z., Keller, G., and Adatte, T. (2003): Fe-rich and K-rich mafic spherules from slumped and channelized Chicxulub ejecta deposits at the northern La Sierrita area, NE Mexico. International Journal of Earth Sciences, 92, 114-142.

Schulte, P., Deutsch, A., Salge, T., MacLeod, K.G., Neuser, R.D., Kontny, A., and Krumm, S. (2009): A dual-layer Chicxulub ejecta sequence with shocked carbonates from the Cretaceous-Paleogene (K-Pg) boundary, ODP Leg 207, Demerara Rise, western Atlantic. Geochimica et Cosmochimica Acta, 73, 1180-1204.

Smit, J. (1999): The global stratigraphy of the Cretaceous-Tertiary boundary impact ejecta. Annual Review of Earth and Planetary Sciences, 27, 75-113.