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Chicxulub impact, climate changes and mass-extinctions

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The mass-extinctions at the Cretaceous-Paleogene boundary (K/PgB) are probably caused by environmental changes induced by the Chicxulub impact on the Yucatan peninsula. Even so, at least three other impacts of similar size must have taken place in the Phanerozoic. Yet after 30 years of intensive search, the connection between impact and extinction has remained largely speculative. What is so special about the Chicxulub impact? Or are the mass-extinctions due to a fortuitous concurrence of Deccan traps volcanism, sealevel changes and multiple impacts?

We explore the last, complex, scenario first. The exact stratigraphic succession across K/PgB must be known in detail before the role of each of the components can be assessed. The Deccan traps began to extrude about 0.6-0.7My before K/Pg, based on marine Os isotopes (Ravizza, 2003). The Deccan traps may have led to a temperature increase in the deep south Atlantic, but surface waters were unaffected. In the last 3.8myr of the Maastrichtian, planktic foraminiferal faunas remain extremely diverse (>70 species). Only one species disappears and two appear. If ocean surface temperatures in this period had changed as consequence of the Deccan trap extrusions, it should have been visible as a change in diversity of planktic species. None has been observed before the K/PgB.

Sealevel changes have been invoked (Gale, 2008) as cause for mass-extinctions at K/Pg. The sedimentology of the late Maastrichtian in shallow marine sequences in the US Gulf coast, Denmark, Holland and Spain, provides conflicting sequence stratigraphic interpretations. In the Maastrichtian type section in the ENCI quarry and Denmark (Stevns) a pronounced shallowing is documented in the last 0.3ma of the Maastrichtian, while in the Zumaya section the temporary disappearance of ammonite shells suggests the opposite: a deepening at 0.25ma followed by shallowing at 40ky before K/PgB. A well defined Sequence Boundary occurs about 0.1 my after the K/PgB, in the sections mentioned above. At the K/Pg itself, no unambiguous indications for a sealevel change have been documented anywhere, although in the Gulf sometimes a tsunami or gravity flow deposit with Chicxulub ejecta has been mistaken for a transgressive sequence. Therefore, there is no obvious connection between any sealevel change and climate changes around K/PgB.

The impact ejecta (Ir, shocked qz) are global and occur exactly at K/PgB. Thus far, only one impact, the Chicxulub impact has been identified. However, the occurrence of multiple impacts remains a distinct possibility, as double craters exist, and a shower of impacts, possibly as result of a breakup event (Baptistina, Bottke, 2007) in the asteroid belt is possible. However, such hypothesis requires extraordinary evidence because of the extremely small probability!

Thus far, the evidence for an impact after K/PgB is based on ambiguous evidence in reworked sediments in Beloc, Haiti and Coxquihui, Mexico, but nowhere outside the Gulf of Mexico.

Evidence for a Chicxulub impact about 0.3 Ma before another, equally large, impact at K/PgB likewise has been interpreted from disturbed sediments in the Gulf, and is therefore highly suspect (Keller, 2009).

Widespread evidence from the double K/PgB ejecta layer in coal-swamp deposits in the US western interior demonstrates that the K/PgB impact and the Chicxulub impact are the same. This leaves the Chicxulub impact as the only agent that can be held responsible for the mass-extinctions. The question is, what environmental or climate changes were induced by the impact, and on what timescales?

Pre-impact signals for change (diversity, stable isotope shifts) are influenced by leaching or bioturbation of the uppermost 10 cm of the Cretaceous. He-isotopes do not support a scenario where the Chicxulub impact occurs within a pedestal of cometary debris, the arrival of which could lead to environmental stress.

The effects of the Chicxulub impact must have been almost immediate. Even in complete sections (Kef, Brazos) the first sediments on top of the ejecta layer are highly depleted in calcareous planktic fossils. The dust-cloud

darkness scenario would have decimated photosynthetic primary producers within weeks, consistent with the record. However, if this would be the only effect, more of such extinctions should have been found in the geological record. The dinoflagellate record adds a shortterm (<50yrs) clobal cooling to this scenario, which is consistent with the vaporization of large amount of SOx aerosols from the anhydrite bearing impact target rocks.
The 2-23 cm thick boundary clay directly on the ejecta further provides some clues. Stable isotope shifts demonstrate a crash of primary production (∂13C), but also a global warming (∂18O) over some 2-5 kyrs, which may have prevented an immediate recovery of biota. Vaporized CO2 and H20 and destruction of biomass have probably led to such prolonged greenhouse warming, and ultimately to the mass-extinctions observed.