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Emplacement of the megablock zone in the Chicxulub crater, Yucatan, Mexico.

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Abstract

Strontium isotope stratigraphy applied to the Cretaceous sequence present in the Yaxcopoil core drilled in 2002 in the Chicxulub crater (Yucatan) demonstrates that the megablocks preserved their original pre-impact orientation. No overturned unit has been identified at the level of resolution, setting constraints on the emplacement mechanisms taking place in this part of the megablock zone during the cratering process 65 million years ago.

1. Introduction

The ~ 180 to 200 km Chicxulub impact structure in Yucatan is the largest Phanerozoic crater and the cause of the Cretaceous-Tertiary boundary mass extinction, 65 Ma ago (Schulte et al. 2010). The structure lies buried under ~ 1km of Cenozoic sediments under the Yucatan Peninsula (Mexico), half-onshore and half-offshore. Because of rapid burial the crater morphology appears well preserved. Consequently, its study documents the formation process large complex craters on terrestrial planets, in particular the poorly understood multi-ring structures as suggested for Chicxulub. In 2002, the "Chicxulub Scientific Drilling Project (CSDP)" supported by the International Continental Scientific Drilling Project (ICDP) drilled the structure to a depth of 1500m [Urrutia et al. 2004].

The Yaxcopoil-1 (Yax-1) well is located in the ~ 65 km to the southwest of the center, in the depression zone forming the annular trough between the inner-peak ring and the crater rim. At the bottom of the well, 616m (from 895m to 1511m) of cores encountered displaced Cretaceous target rock. This sequence consists of alternating limestone, anhydrite and dolomite. This sequence interpreted as part of the crater megablock zone, is cut at several levels by suevitic (909m & 916m), impact-melt (1347m & 1348m) and polymict (1314.7m & 1374m) dikes (Kenkmann et al. 2004; Wittmann et al. 2004). The dip of the bedding planes changes throughout the sequence, indicating a displacement towards the center of the structure [3]. The essentially micro- and macrofossils free lithologies hamper biostratigraphic correlations. The only marker identified in the whole sequence is the presence of the Bonarelli event (Event OAE2), at the Cenomanian-Turonian boundary, close to the bottom of the Yax-1 (at 1452 to 1495m) (Stinnesbeck et al. 2004)

2. Formation of the megablock zone

Two mechanisms have been proposed to account for the emplacement of the Cretaceous sequence constituting the megablock zone. 1) The sequence is para-autochtonous and originated from the external zone located near the rim. It moved inward and slightly downward along normal faults during the crater modification phase (Kenkmann et al. 2004). 2) The megablock sequence forms part of the excavated or pushed away components during the evolution of the transient cavity. The sequence has moved horizontally outward into the annular through, from the more central part of the crater, as the transient cavity collapsed at the end of the excavation phase (Stöffler et al. 2004). The megablock sequence is allochtonous and stratigraphic inversion is expected, in analogy with observation of overturned blocks at smaller craters such as the Ries (Germany).

At this stage, mathematical modeling of the cratering process cannot precisely document the evolution of the target material forming the megablock zone. To test if the Cretaceous sequence preserved its original stratigraphy (hypothesis 1) or is overturned (hypothesis 2) strontium isotopes were measured across the 616m of sequence and compared to the established Late Cretaceous seawater Sr-isotope curve (Howarth and McArthur, 1997).

3. Results

More than fifty $^{87}Sr/^{86}Sr$ data points (including a number of duplicate analyses) were obtained across the 616m of displaced Cretaceous sequence. The OAE2 event, located near the base of the core forms a stratigraphic anchor point. From this point upward to ~ 1050m depth, the $^{87}Sr/^{86}Sr$ trend shows small undulations, ranging between 0.7074 and 0.7073, characteristic of Cenomanian to Santonian values. It is followed around 1000m by a sharp increase to 0.7078, very similar to the one showed by the seawater strontium curve between the Santonian and Late Maastrichtian (Howarth and McArthur, 1997).

4. Conclusion

Based on these results, the displaced Cretaceous sequence in Yax-1 appear to have preserved its stratigraphic coherence. This observation favors an emplacement inward along normal (possibly listric) faults from the crater rim zone, during the crater modification stage. The mechanical decoupling resulted in separation of the target-rock sequence into blocks that were somewhat tilted against each other. It is too early to generalize this to the whole ~ 200 km sized crater. However, the megablock material encountered at Yax-1 should be considered para-authochtonous. It most likely originated in the zone near the crater rim and travelled some considerable distance (>20km?) inward towards the inner through zone, at the base of the central peak-ring.

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