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Chicxulub impact event is Cretaceous/Paleogene boundary in age: New micropaleontological evidence

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Abstract

High-resolution and quantitative planktic foraminiferal biostratigraphy from two SE Mexico stratigraphic sections (Bochil, Guayal) shows that the Chicxulub-related Complex Clastic Unit (CCU) is synchronous with the ejecta-rich airfall layer and the Cretaceous/Paleogene (K/Pg) catastrophic mass extinction horizon in the El Kef (Tunisia) and Caravaca (Spain) sections. The lowermost Danian *H. holmdelensis* subzone (=Biozone P0) was identified in both sections in a thin dark clay bed just above the CCU, proving that such bed is chronostratigraphically equivalent to the K/Pg boundary clay of the El Kef stratotype. These new micropaleontogical data confirm that the K/Pg impact event and the Chicxulub impact event are the same one. This contradicts the suggestion by others that the Chicxulub impact predated the K/Pg boundary by about 300 ka.

Keywords: Planktic foraminifera; Biochronology; Acme stages; K/Pg clay; Impact crater

1. Introduction

The 65 Ma-old Cretaceous/Paleogene (K/Pg) mass extinction appears to have been a catastrophic event related to the aftermaths of a ~10 km-diameter asteroid impact [1,2]. Dust and fine ejecta covered the atmosphere and were deposited slowly, probably over months or a few years, forming a millimeter-thick airfall layer worldwide [3,4]. This layer contains evidence of the meteoritic impact including: an iridium anomaly, siderophile trace elements in chondritic proportions, osmium and chromium isotope anomalies, microdiamonds, nickel-rich spinels, shocked quartz, and altered microtektites [5–8]. It is placed at the basal part of a dark clay bed commonly called the "K/Pg boundary clay", which was deposited during a global decrease in ocean productivity after the meteorite impact [9]. The K/Pg boundary was formally defined at the base of this dark clay in the K/Pg Global Stratotype Section and Point at

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El Kef (Tunisia), i.e., at the base of the airfall layer containing the impact material [10,11], and coincides with the planktic foraminiferal catastrophic mass extinction [5,12]. According to that definition, all the impact material overlies the K/Pg boundary and the lithological unit containing this material is consequently Danian in age.

The K/Pg boundary impact site was located in the northern Yucatan Peninsula (Mexico) [13] after recognition of a ~180 km-wide crater, whose center lies below the small town of Puerto Chicxulub [14]. Impact sequences in boreholes drilled within the Chicxulub crater are characterized by impact melt and suevite breccias. Those were dated with the ^{40}argon/^{39}argon method to be approximately 65 Ma [15,16], supporting a genetic link between the Chicxulub impact and the K/Pg boundary. The genetic links between the ejecta and the crater are also indicated by the isotopic compositions of the glass [17] or shocked zircons dating [18]. In Gulf of Mexico and Caribbean sections, the K/Pg sequence outside the crater is represented by a characteristic impact material-rich Complex Clastic Unit (CCU). The chemical composition of fresh impact glass fragments from the CCU at Beloc (Haiti) and El Mimbral (NE Mexico) is similar to that of the Chicxulub melt rock, indicating that the three sequences are genetically related [19]. Those impact glasses were also dated as 65.07±0.1 Ma, based on the ^{40}Ar/^{39}Ar method [16]. However, isotopic dating commonly has a margin of error which does not provide enough resolution to test whether there is an exact coincidence in time between the Chicxulub impact and the K/Pg extinction event.

As a result, the high resolution of planktic foraminiferal biozones has been used to pinpoint the age of the Chicxulub impact. Based on this method, some scientists have argued that the Chicxulub impact occurred about 300 ka before the K/Pg boundary [20]. According to their "ultraimpactist" scenario, the K/Pg crater has yet to be found, and Chicxulub is just one of the several impact events that arose across the K/Pg boundary over a period of 400 ka. This controversial hypothesis contradicts the detailed Ir profile for 10 Ma across the K/Pg boundary performed at Gubbio (Italy), where only one Ir anomaly was identified right at the boundary [21], in addition to micropaleontological and sedimentological evidence from most continuous Tethyan sections, such as Caravaca (Spain) and El Kef, which indicate only one impact event [5,12,22].

Much research has shown that Chicxulub has an age corresponding to the K/Pg boundary, including multidisciplinary studies in Mexican and Caribbean CCUs [11,23–27]. Nevertheless, no continuous K/Pg sections have been discovered yet in those areas. Based on high-resolution planktic foraminiferal biostratigraphy, two recognizable hiatuses were identified in sections from northern Mexico and Cuba, at the uppermost Cretaceous and the lowermost Paleocene [28–30]. Recently, the Yaxcopoil-1 well was drilled within the Chicxulub crater to determine its role in the K/Pg event. However, the presence of two similar hiatuses (affecting the upper part of the Maastrichtian and the lower part of the Danian) has raised a debate, since some researchers continue claiming that Chicxulub is not K/Pg in age [31], in disagreement with other investigators [32,33]. Detailed analysis of continuous marine K/Pg sections rich in planktic foraminifera near the impact site will help to resolve the controversy.

In this study, a micropaleontological and sedimentological analysis to establish if the Chicxulub event coincides with the planktic foraminiferal mass extinction and the K/Pg boundary is conducted. A high-resolution planktic foraminiferal biostratigraphical analysis at the K/Pg Bochil and Guayal sections was performed for the first time, and correlated to those obtained from the El Kef and Caravaca sections.

2. Location and sedimentological setting

The studied sections in this work are located in southeastern Mexico. The Bochil section (17°00′43" N, 92°56′50" W) is located in the State of Chiapas, about 9 km northeast from the town of Bochil, whereas the Guayal section (17°32′39" N, 92°36′80" W) is located in the State of Tabasco, about 60 km southeast of the City of Villahermosa. Both outcrops provide good exposures across more than 100 m and are two of the most representative southern Mexican K/Pg sections, relatively close to the Chicxulub crater (Fig. 1). There, the CCU is sandwiched between two pelagic formations rich in planktic foraminifera: the underlying Jolpabuchil Formation (Campanian–Maastrichtian) and the overlying Soyaló Formation (Paleocene).

The Chicxulub impact influenced strongly the sedimentary processes across the Gulf of Mexico and Caribbean regions. That event triggered intensive seismic activity and giant tsunamis that destabilized the continental margins and deposited CCUs in deep-water environments [11,27,30,34,35]. The thickness, lithology and sedimentology of those clastic deposits depend on their distance from the Chicxulub crater, their depositional environment (depth of deposition), and the origin of their allochthonous material (from the shelf and upper slope). Stratigraphic data from numerous southern Mexican sections and wells indicate that the local CCU has a