The Chicxulub ejecta blanket and its bearing on sample return missions to Mars

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Evolutionary Transformation and Mass Extinction

Introduction: The ejecta blanket of the Chicxulub impact crater (Ø 180 km, 65 Ma) was discovered in several wells close to the crater (UNAM 5, 6, and 7 [1]) and mapped over a large area on the southern Yucatán Peninsula, where it covers a preexisting Upper Cretaceous Karst topography [2, 3]. It is one of the few examples for a well preserved ejecta blanket of large impact structures on Earth and extends up to 5 crater radii from the center [3,4]. Due to this large runout it has been considered since its recognition as a primary example for comparative studies with Martian impact craters [3, 5, 6]. Similar to the fluidized ejecta on Mars, where beside single layered craters (SLE) ejecta blankets with two or multiple ejecta layers could be identified („Double Layer Ejecta" - DLE and „Multiple Layer Ejecta" - MLE - craters respectively), the Chicxulub ejecta blanket can be subdivided into three radial zones, which will be discussed herein.

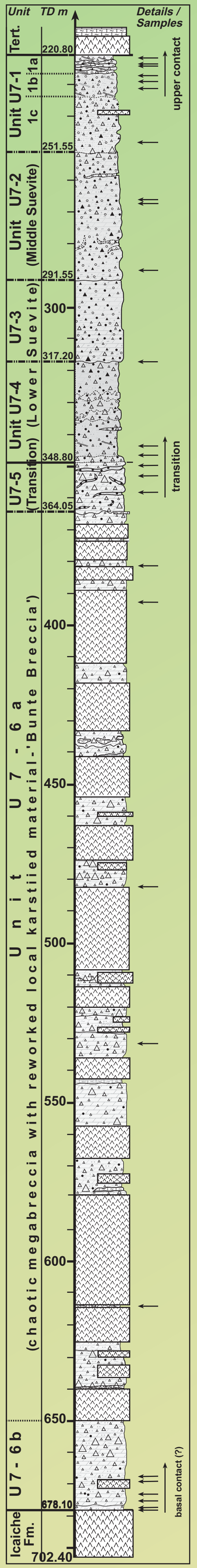


Fig. 2 (left): Stratigraphy and petrography of the succession of impactites recovered from the UNAM 7 drill core, below: legend.

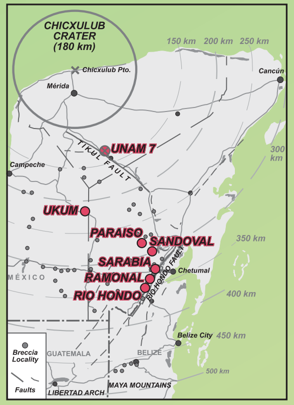


Fig. 1: Location of the discussed localities on the Yucatán Peninsula

Fig. 3: Indicators of ejecta movement on the southern Yucatán Peninsula, a) measurements from the intermediate ejecta blanket show a clear radial movement away from the impact center, b) measurements from the outer ejecta blanket instead displays a significant deviation around topographic obstacles (localities see Fig. 1)

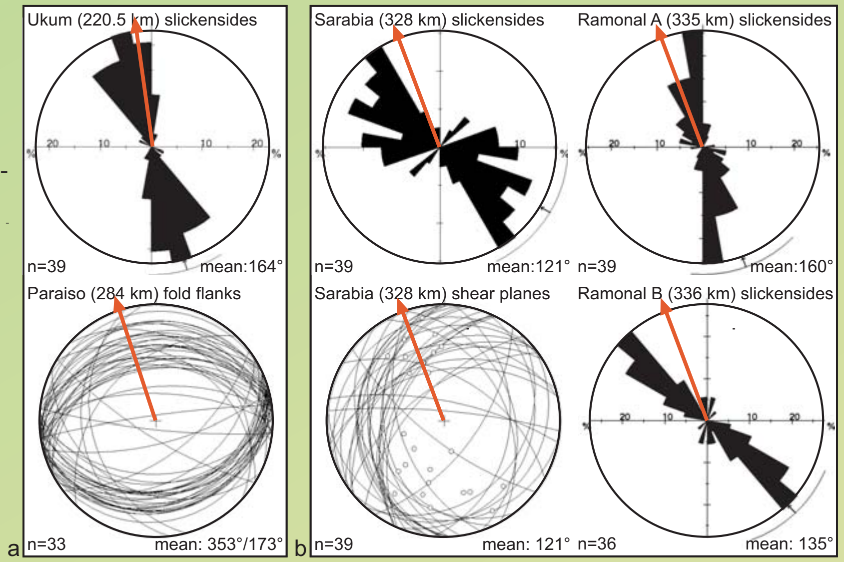
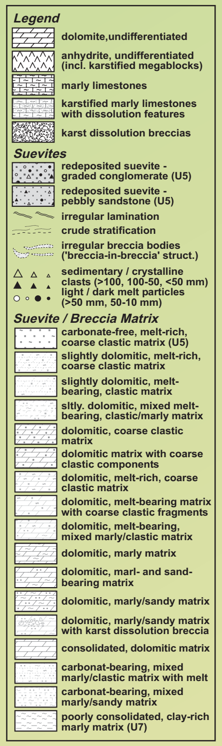


Fig. 4: a) Lower contact of the ejecta blanket at Paraiso, showing deformation of the underlying marls and clays, b) clay particles within the matrix are here eroded from the subsurface, c) melt-poor breccia at the Sandoval locality.

Fig. 5: a) Basal pocket of melt-rich primary ejecta that was deformed by the overriding bulk ejecta material at Sarabia, b) large melt clast and c) shocked granite clast derived from the same basal pocket, d) multiple sets of pdf in quartz.



The inner ejecta blanket: This zone is represented by breccias from the UNAM 7 drill core, 105 km (1.4 crater radii) from the impact center (Fig. 1, Fig. 6). These impactites comprise a lower dolomitic megabreccia with anhydrite megablocks and an upper unit of suevites (Fig. 2, [7]). The thick megabreccia sequence (unit U7-6) does not contain crystalline basement clasts but has an amount of 1-3% of black or bottle-green melt fragments. The contact with the overlying melt-rich suevites is transitional [7]. In unit U7-5 the first larger melt clasts >3 cm occur well below the base of the lower suevite. The upper part of this unit is an alternating succession of irregular suevitic lenses and the dolomitic, sedimentary breccia. Large melt clasts are present in the lowermost suevites, but dolomitic portions do occur up to 327 m. The suevites have a variable but high content of melt clasts (20-40%) and contain abundant shocked crystalline fragments (Fig. 2).

The intermediate ejecta blanket: Outcrops of the ejecta blanket on the central Yucatán Peninsula are rare. The closest unequivocal exposure of the Chicxulub ejecta is a quarry near the village of Ukum in Campeche at 2.45 cr from the impact center (220.5 km, Fig. 1, Fig 3a, Fig. 6). Other important outcrops can be found at distances between 3.15 cr (284 km, Paraiso roadcut) and 3.32 cr (298 km, Sandoval quarry). Measurements of motion indicators like slickensided shear planes and fold flanks of subsurface deformation features indicate a strict radial movement away from the center (Fig. 3a, cf. Fig. 4a). The polymict breccias are to a large extent composed of sedimentary clasts which were eroded from the subsurface (Fig. 4). Clay particles that can be interpreted as altered melt fragments are either absent (Ukum and Paraiso) or very rare (less than 1-2 %, Sandoval, Fig. 4c). No crystalline basement clasts could be found.

The outer ejecta blanket: Beyond 300 km from the impact center (3.33 cr) the Chicxulub ejecta blanket is widely distributed across the southern Yucatán Peninsula. The best examples are the Sarabia quarry near Chetumal (328 km, 3.6 cr), the Ramonal roadcut (335 km, 3.73 cr) and several outcrops in the Rio-Hondo-area along the border between Mexico and Belize (3.7-3.86 cr, Fig. 1, Fig. 5, Fig. 6). Slickensided shear planes display a significant deviation from a radial movement around obstacles from the underlying karst topography (Fig. 3b). Clay particles are dispersed at variable amounts of 5-20% throughout the matrix of the ejecta blanket (in local pockets up to 40-50 %). They can at least in part be interpreted as altered impact melt. Larger melt fragments, shocked crystalline clasts and vesiculated glass shards were found occasionally (Fig. 5). They occur preferably in pockets or layers close to the base of the ejecta, thus representing an „inverse stratigraphy" compared to the U7 drill core. Rarely they were also observed within the well consolidated dolomitic matrix of the upper bulk ejecta material.

Discussion: The characteristics of the distribution of melt and crystalline basment clasts have been explained by a combination of the two processes involved in the ejecta emplacement on planets with an atmosphere and subsurface volatiles: The lower inner and the intermediate ejecta were deposited by *Ballistic Sedimentation*, while in the outer part *Atmospheric Ring Vortices* overrode the ejecta curtain and deposited crater material that later became eroded by the secondary ejecta flow (Fig. 6, [7]).
The observed motion indicators can best be compared to Martian DLE craters, where the inner layer like the intermediate Chicxulub ejecta blanket shows radial movement, whereas the outer layer is characterized by a flow that is deviated around obstacles (Fig. 7). In order to assess the processes of ejecta emplacement on Mars a DLE or MLE crater preferably on sedimentary terrain should be sampled from its proximal to its distal ejecta blanket and tested for the presence of abrasion features and the distribution of crater-derived material (cf. Fig. 7).

Fig. 6: Model of the final stage of ejecta emplacement on the Yucatán Peninsula, showing the three „layers" of the Chicxulub ejecta blanket.

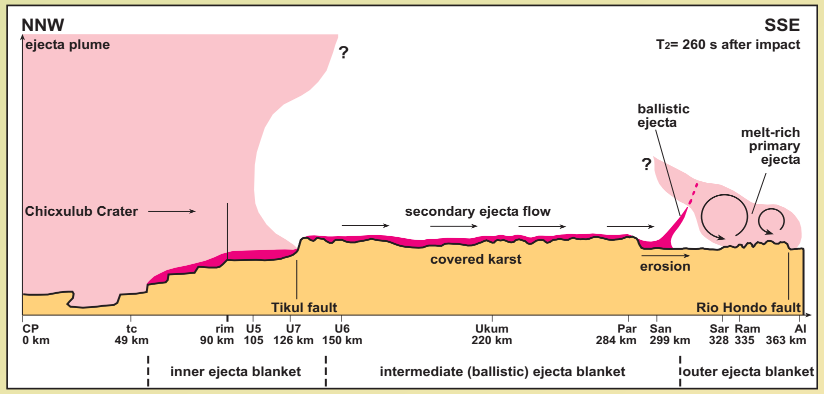
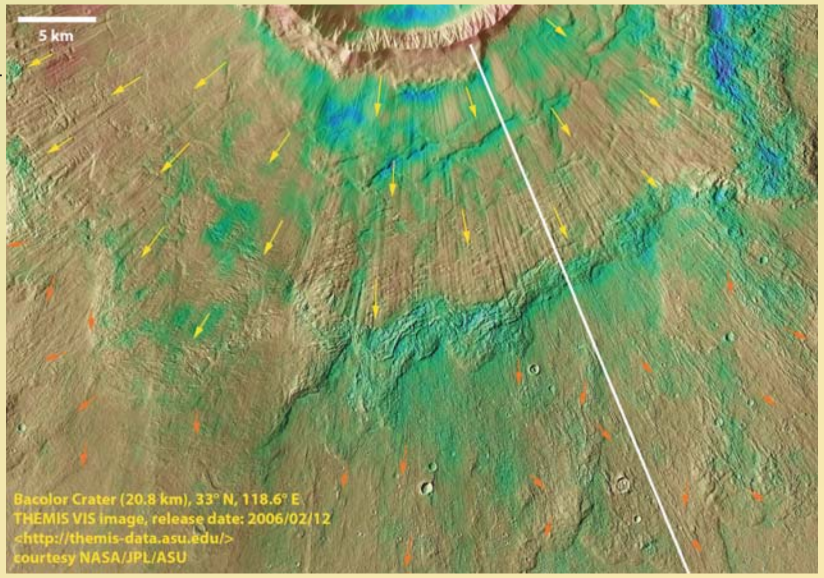


Fig. 7: THEMIS image of the ejecta blanket of the DLE Bacolor Crater on Mars, note that the inner layer displays a radial movement, whereas the flow of the outer ejecta layer is, as in the case of Chicxulub, deviated around obstacles.



References: [1] Urrutia-Fucugauchi J. et al. (1996) Geoph. Res. Let. 23(13), 1565-1568. [2] Pope K. O. et al. (2005) GSA Spec. Pap. 384, 171–190. [3] Kenkmann T. and Schönian F. (2006) MAPS 41(10), 1587-1603. [4] Ocampo A. C. et al. (1997) LPS XXVII, Abstract #1861. [5] Pope, K. O. and Ocampo A. C. (1999) LPS XXX, Abstract #1380. [6] Schönian F. et al. (2004) LPS XXXV, Abstract 1848. [7] Schönian F. et al. (2008) LMI IV, Abstract 3100.