KAŞ (TURKEY/GREECE) AND RUBIELOS DE LA CÉRIDA (SPAIN) METEORITE IMPACT STRUCTURES: COMPARATIVE INSIGHTS INTO PROMINENT SEDIMENTARY CARBONATE TARGETS.

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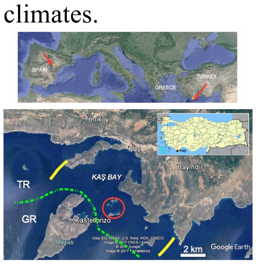
Introduction: After initial promising signs of a new large impact structure at the Turkish-Greek border (Fig. 1) [1] and a subsequent further verification [2], the Kaş structure began to crystallize in many ways as a faithful copy of the large Spanish Rubielos de la Cérida impact structure (Figs. 1, 2), and the extensive geological impact inventory of Rubielos de la Cérida became a helpful guideline in the terrain exploration of the new Kaş structure. What is special about this is that both structures are laid out in a purely sedimentary target, which is also largely formed in carbonate facies. While the products of meteorite impacts into dense, mostly crystalline and mixed targets are relatively well understood and macroscopic and microscopic deformations of these target rocks are the norm, the response of volatile-rich sedimentary rocks, in particular carbonate rocks, to impact, remains debated. Here we report on a selection of amazingly remarkable similarities in both impact structures as instructive illustrative material for impact terrain studies, especially as they are terrain with predominantly excellent field conditions and mostly easily accessible outcrops in pleasant climates.



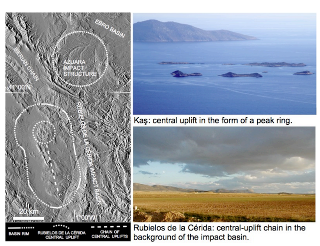


Fig. 1. The Kaş and Rubielos de la Cérida impacts in Spain and Turkey/Greece. - Location map for the Kaş structure at the Greek/Turkish boundary (green), the suggested extrapolation of the structure to the sea (yellow) and a distinct central uplift in the form of a peak ring (red; see Fig. 2). Google Earth. **Fig. 2.** The Azuara and Rubielos de la Cérida impacts in the digital map of Spain 1: 250,000 (courtesy M. Cabedo). Central uplifts (peak ring, Kaş, and chain, Rubielos de la Cérida).

The Kaş impact structure: Ure et al. [1, 2] have for the first time suggested a possible Kaş Bay impact structure based on preliminary geologic field evidence. New field studies and laboratory analyses further strengthen the impact hypothesis. With a diameter of about 10 km and a central uplift (Figs. 1, 2) Kaş Bay is classified as a complex impact structure. The local bedrock is Cretaceous neritic limestone. Based on stratigraphical evidence, uplift and subsidence rates, an age from the Pleistocene epoch is probable.

The Rubielos de la Cérida impact structure is an elongated impact basin with a central-uplift chain as part of the Mid-Tertiary Azuara multiple impact event (Fig. 2) [3, 4, and references therein]. The target is sedimentary with about 10 km thickness. Clear impact evidence, which is still doubted by some Spanish regional geologists, is given by geological and geophysical evidence like ubiquitous monomictic and polymictic breccias, large systems of monomictic and polymictic breccia dikes, enormous and extended megabreccias, shatter cones, extended impact ejecta, gravity and geo-magnetic anomalies, strong shock metamorphism like shock melt, planar deformation features (PDFs) and diaplectic glass in various minerals [3, 4].

Comparison: Although the impact basin of Rubielos de la Cérida is much more extensive than the Kaş basin and offers much more exploration possibilities, it is amazing how similar the effects of the impact are by and large. This applies to comparable structural conditions, rock types and deformations right down to the micro range, and it has not been difficult to compare findings of the most varied but impact-typical kind with each other, which is done below in a selection. In fact, comparable scenarios in the field and in the hand sample are much more extensive, which, however, forces a strong restriction here. It should first be noted that in the illustrations the letters K and R indicate the respective assignment to the two impact structures.

Megabreccias and scour planes: In general megabreccias are characterized by great extension and by large-sized components (megablocks), occur at best with gigantic landslides and otherwise are typical for larger impact structures. It is not surprising that with large impacts the enormous mass movements often lead to connections of megabreccias and impressive sliding surfaces, partly with mirror polish. Examples are shown in Figs. 3, 4.

Polymictic breccias and breccia dikes: Dike breccias are a prominent feature in impact structures frequently allowing detailed reconstruction of the cratering process [5]. Fig. 5 compiles a few examples of very characteristic polymictic dikes. In fact, the variability of the breccia dikes in the two structures is considerably greater and counts entire systems of dikes that can occur as generations of intersecting dikes. Especially the Rubielos de la Cérida structure is known for its enormous wealth of different breccia dikes [4].

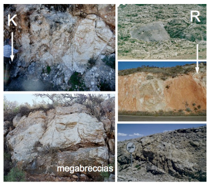


Fig. 3. Megabreccias. **Fig. 4**. Scour planes.

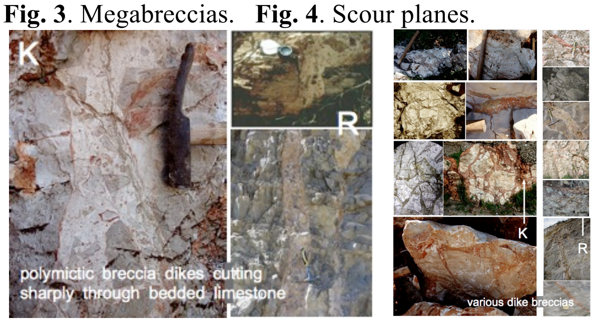


Fig. 5. Breccia dikes (dike breccias).

In impact stuctures monomictic and polymictic breccas in general characteristically originate in the rapidly proceeding stages of cratering - excavation, ejection, modification, landing of ejecta and their highly energetic mixing with the local target material. This is the reason for the formation of breccias-within-breccias right up to multiple breccia generations normally not observed in geological processes (Fig. 6).

Decarbonization/carbonate melt rock: In contrast to silicate rocks, carbonate rocks do not quench to form glass. Under impact high *PT* conditions, limestone can melt or decarbonize with subsequent, in part immediate, recrystallization. Like in other impact structures with a partial carbonate target (e.g. Haughton Dome, Canada [6]) such relics of carbonate melt/decarbonization are abundant in the investigated Kaş and Rubielos de la Cérida areas (Fig. 7).

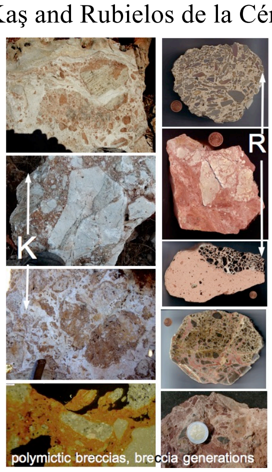


Fig. 6. Polymictic breccias and breccia generations.

Fig. 7. Decarbonization and carbonate melt rocks.

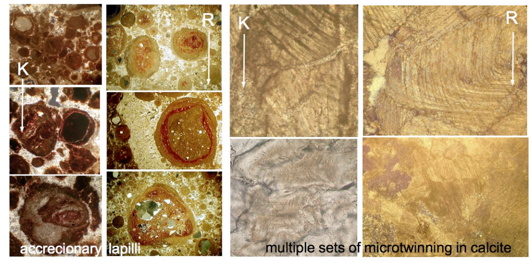


Fig. 8. Photomicrographs, crossed polarizers.

Petrographic thin section analyses: Unlike in the Rubielos de la Cérida structure, where the entire shock inventory of silicate rocks is abundantly represented [3,4], corresponding observations in the Kaş structure are inevitably limited to carbonate rocks. There we see, completely parallel to corresponding deformations in the Spanish structure abundant occurrences of multiple sets of microtwinning in calcite frequently in combination with kink banding (Fig. 8). Regularly the size of the twins is of the order of 1 µm which points to high-pressure deformation similar to the development of shock-produced PDF in quartz. Accrecionary lapilli usually associated with volcanic eruptions but also occurring in meteorite impacts add to geologicical conspicuousness (Fig. 8) and has nearly identical counterparts in the Rubielos de la Cérida structure (Fig. 8).

Conclusion: Very large impact structures in purely sedimentary, in particular predominantly carbonate targets, are rare and have not been much investigated to date. The comparison of two such big structures with an overabundant inventory of impact-typical formations, deformations and petrographic evidence, clearly shows that a considerable neglect of impact research can be observed here. Even in recent publications, e.g. in a review "of impact melt and breccia dikes in terrestrial impact structures" [7], sedimentary targets are mentioned only casually in a single sentence about lithic breccia dikes, apparently forgetting that such an inventory exists to a much greater extent and variability as exemplified here.

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References: [1] Ure, A. et al. (2017*) LPSC XLVIII,* Abstract #1144. [2] Ure, A. et al. (2018*) LPSC XLIX,* Abstract #1455.[3] Ernstson, K., et al. (2002). *Treballs del Museu de Geologia de Barcelona,* 11, 5-65. [4] Ernstson, K. and Claudin, F. http://www.impact-structures.com/accessed 14/12/18. [5] Lambert, P. (1981). *In: R.B. Merrill, R.B. and Schultz P.H. (eds.), Lunar Planet. Sci. Proc. 12A,* 59-78. [6] Osinski, G.R. et al. (2005) *Meteoritics Planet. Sci*., 40, 1759-1776. [7] Pilles, A. et al. (2018) *LPSC XLIX,* Abstract #1994.