# THE IMPACT CRATER JEBEL WAQF AS SUWWAN IN JORDAN: EFFECTS OF TARGET HETEROGENEITY AND IMPACT OBLIQUITY ON CENTRAL UPLIFT FORMATION.

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**Introduction:** A 6 km diameter impact structure, named Jebel Waqf as Suwwan (N31°02.9'E36° 48.4') has recently been discovered in Jordan [1,2] (Fig. 1). Previously a crypovolcanic origin had been assumed for this prominent crater structure [3]. The impact origin has been confirmed based on abundant occurrences of shatter cones [1]. The circular structure has a distinct uplifted rim, and a well exposed central uplift of ~1000 m diameter, which provides a section through the entire sedimentary target. Here we present results of a joint field campaign in spring 2008, between researchers from the University of Jordan and the Museum für Naturkunde Berlin

**Geology:** The strata in eastern Jordan near Waqf as Suwwan are usually flat lying or very gently inclined. The oldest exposed rocks are Cretaceous sandstones that are exposed in the core of the Waqf as Suwwan structure. They are overlain by upper Cretaceous limestones, marls, and cherts. Within the ring syncline and along the crater rim white marls and chert beds of Eocene age outcrop (Fig. 2). Landsat images indicate NW-SE (dominant), NE-SW, E-W, and N-S lineaments in the region of Waqf as Suwwan. The age of the crater is unknown but is younger than the Eocene.

**Central uplift**: *Morphology:* The dominant morphological feature of the central uplift is a triangular-shaped collar of hills, which surrounds an inner depressed region with a hummocky relief. This triangle has a S, a NW, and a NE facing side. The collar is built up by chert layers of uppermost Cretaceous strata. The hummocky relief of the core is caused by a complicated block structure of the interior of the uplift.

*Stratigraphy and structure*: The innermost area exposes the oldest strata (Cenomanian sst., green). Variegated limestones with good marker beds surround the core of the central uplift in a complex manner and allow to map blocks of a few tens of meters size (Fig.3). Strata above the colored limestone sequence comprise more uniform limestones. Several competent limestone beds form the crests of hills and are useful marker horizons. The sequence is dismembered into blocks of 50-200 m size. Within blocks strata are folded. In four blocks open synclines with radial fold axes are developed (Fig. 4). Overturned blocks occur in the NE. The limestone blocks are surrounded by a sequence of incompetent marls of Campanian age (yellow). This layer forms a continuous ring but its thickness shows strong variations, as it apparently accommodates space incompatibilities that arose from block deformation of the limestone beds beneath, and chert beds above, the marls. The chert layer of uppermost Cretaceous age (purple) is the prominent collar builder of the central uplift. Folding and faulting is widespread. In the more massive SW part of the collar normal layering dominates, whereas overturning is the rule in the NE part (Fig. 5). Radial folding is the most conspicuous structural attribute of the chert sequence (Fig. 4). Fold axes in the SW part plunge outward. In this sector anticlines and synclines are tight to isoclinal, and amplitudes are larger than wavelengths. In the NE part of the collar only synclines are developed with overturned, steeply inward plunging fold axes and overturned strata. Adjacent synclines are separated by radial faults. The weak footwall strata are squeezed into the narrow anticlinal hinge zones between the synclines. The periphery of the central uplift is formed by Paleogene beds. This is a succession of beige, white, and yellowish marls, with some chert beds and concretions.

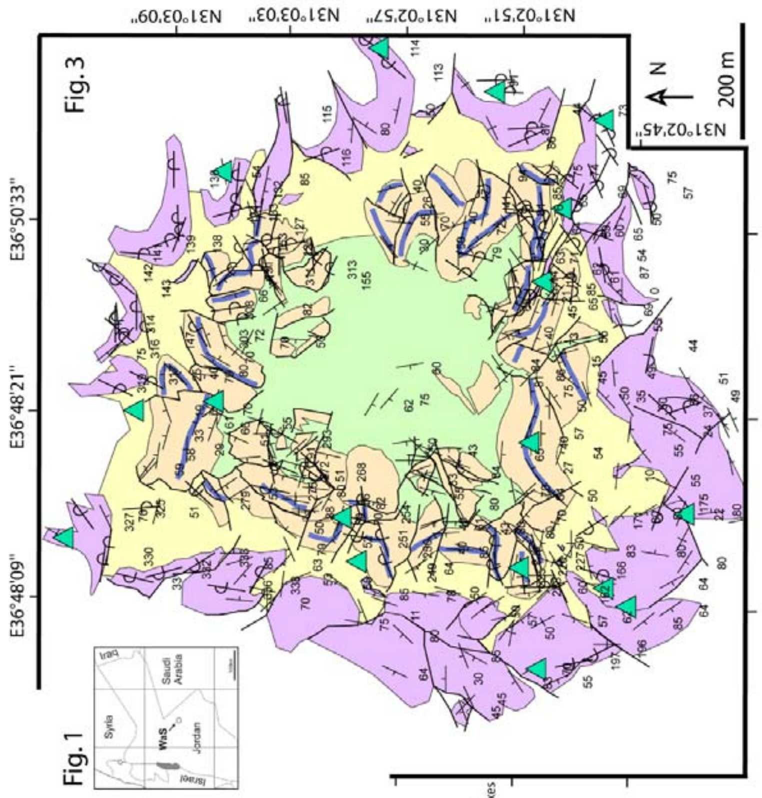
*Shock features:* Shatter cones are abundant at Waqf as Suwwan. They occur all along the periphery of the central uplift and are formed in siltstones, limestones, and cherts. The target is mainly composed of limestone, for which definite shock features are lacking. Chert is also devoid of shock features due to its fine grain size. Some Cenomanian sandst. show PFs and feather textures. A single observation of PDFs was reported by [1,2].

*Block size:* Block sizes could be determined in the Cretaceous limestone sequence and in the uppermost Cretaceous chert sequence of the central uplift (Fig. 6). In less competent sequences blocks could not be mapped due to the limited exposure and the more pervasive and small-scale deformation. Although scatter is large, there is a trend of increasing block size with increasing radial range. In the limestone sequence blocks increase in size from 30 m at 100 m distance to 60 m at 300 m distance. Chert blocks increase to 120 m size at 600 m distance from the crater center.

*Heterogeneous target:* Waqf as Suwwan has been formed in a layered sedimentary target. Considerable competence contrasts occur between incompetent marl beds interlayered with competent limestone beds and chert beds. This layering caused a substantial strength anisotropy during impact with preferential bedding-parallel movements along marly interbeds. The weak marl beds of the central uplift were thick enough so that the competent beds beneath and above could deform almost independently from each other. Wavelength, amplitude, and shape of folds are different in both competent sequences, and the geometry of folds depends mainly on strength properties and thickness of the layers, and the amount of strain.

*Asymmetry of the central uplift:* The central uplift has an axis of symmetry that trends SW-NE (Fig. 4). The SW and NE sectors of the central uplift show remarkable anisotropies. Whereas layering and folding in the SW sector is normal, overturning characterizes the NE sector suggesting top-to-NE shearing. We explain the structural pattern of the central uplift with an oblique impact scenario with an impact from SW.

**References**: [1] Salameh, E. et al. 2006, Z. Dtsch. Ges. Geowiss., 157, 319-325. [2] Salameh, E. et al. [2008] MAPS, v. 43, No.10. [3] Heimbach, W., 1969: Beih. Geol. Jb.,81,149-160.



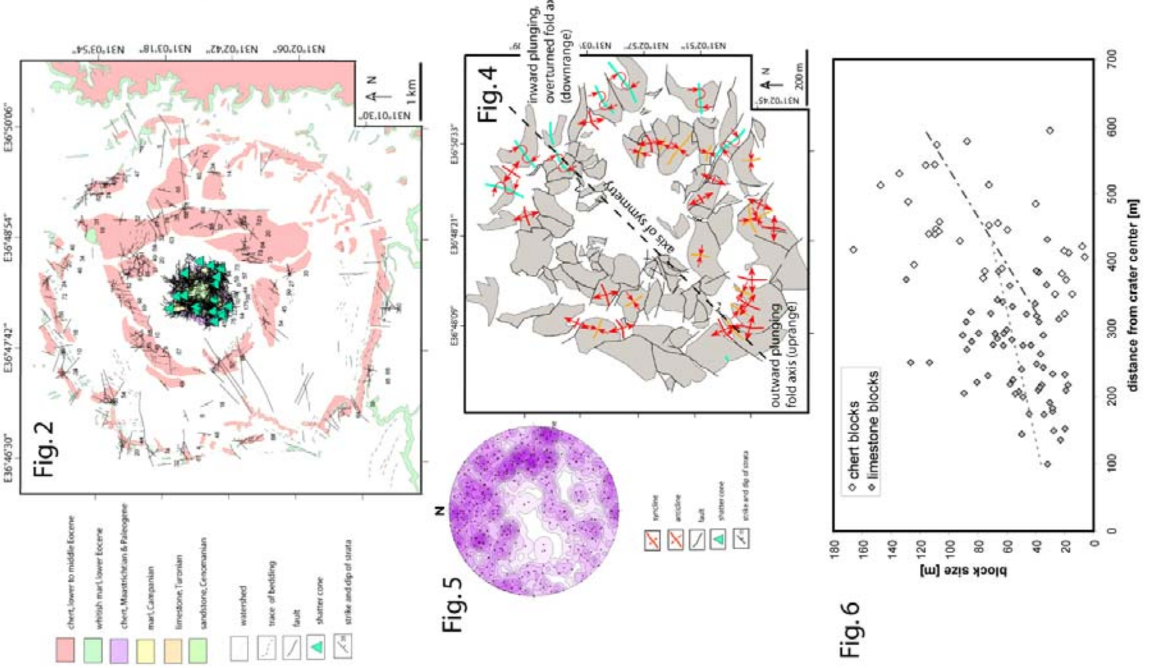


Fig. 1 Location of the Jebel Waqf as Suwwan impact crater in Jordan.
Fig. 2 Geologic map of the impact crater.
Fig. 3 Geologic Map of the central uplift.
Fig. 4 Folds within the central uplift.
Fig. 5 Stereoplot of strata orientation within the central uplift.
Fig. 6 Sizes of limestone and chert blocks within the central uplift as a function of their radial distance to the crater center.