**THE OASIS STRUCTURE, SOUTHEASTERN LIBYA – NEW CONSTRAINTS ON SIZE, AGE AND MECHANISM OF FORMATION.**
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**Introduction:** The Oasis Structure, centered at 24° 35'N, 24° 24'E, was identified by French et al. [1] as an impact structure based on the presence of PDF and intense planar fracturing in quartz grains, and microscopic glass fragments in a microbreccia sample. They suggested an eroded morphology with a diameter between 5.1 and 11.5 km wide, with the most prominent feature being a 5.1 km-diameter ring of hills, up to 100 m high, in which they noted outward dipping strata. A limited remote sensing analysis and very brief field visit led [2] to propose a larger, 18 km, diameter for the Structure and to speculate that the inner ring of hills might represent an eroded central peak or peak-ring. Their upper size limit was based on the apparent truncation of a set of NW-trending regional lineaments observed on satellite images by arcuate features centered on the Structure. Both groups inferred that the Structure is located in Jurassic to Lower Cretaceous Nubia Formation sandstones and conglomeratic sandstones, which would place an upper age of ca. 90-120 Ma on the Structure. Both speculated on a possible link to the Libyan Desert Glass found 150 km to the east in Egypt.

Here we report the first results of a recent reconnaissance field mapping and remote sensing study of the Oasis Structure that casts new light on its size, age and mechanism of formation.

**Lithological mapping:** Field studies revealed that the Structure affects both the 'Nubia Formation' siliceous sandstones and conglomerates and underlying sandstones, siltstones and claystones of Upper Carboniferous age that contain *Lepidodendron* casts and trace fossils. It is unclear at this stage whether older Carboniferous strata might also be involved.

Within the inner ring, several breccia types are found, although the relation of most of these to the target rocks is unclear owing to lack of exposure of contacts. The most common breccia type is a white, massive, fine-grained sandstone containing rare, subrounded to rounded, grit-sized quartz pebbles and spherical iron concretions usually < 5 mm in size. We suggest that this lithology could correspond to the 'shattered sandstone/allochthonous microbreccia' described by [1]; however, confirmation awaits further petrographic study. A more siliceous breccia is more prominently exposed on the inner flanks of the hilly ring. It is gray-white, coarser-grained, and contains more abundant grit-sized quartz pebbles, as well as sandstone and claystone clasts up to several centimeters in size. Outcrops have a porous appearance owing to the preferential weathering of lithic clasts. Volumetrically smaller dark gray and red breccias occur in the southeastern- and eastern-central sectors. Both show extensive hematitic alteration, and the red breccia contains highly irregular, altered, mm-scale fragments that may be glass particles.

The remaining breccia type found within the core of the Structure is a fine-grained, pink-white sandstone with rare grit-sized pebbles and local vertical flow banding that occurs in subvertical dikes up to 1 m wide and several tens of meters long. These dikes cut the Carboniferous beds and lack some of the deformation structures seen in the target rocks, indicating a post-impact emplacement.

The annular topographic variation is a direct reflection of the underlying lithology, with the highest hills in the inner parts of the Structure capped by the more resistant, highly siliceous Lower Cretaceous sandstones. The plain surrounding these hills is underlain by less resistant Carboniferous beds, with only local Cretaceous sandstone outliers related to synformal folds (see next section). Carboniferous strata also underlie the central depression and the lower hills in the northern and eastern sectors of the inner ring.

Rocks in the central parts of the structure are highly kaolinitized and contain iron and manganese nodules, zones of iron impregnation and, locally, chert, all of which signifies extensive fluid movement. Much of the fracture-controlled alteration here appears to postdate the impact-related structures, and decreases in intensity outwards, suggesting that it could be linked to an impact-induced hydrothermal system. However, nodules, chert, and iron and manganese impregnation are also locally common in the outer parts of the Structure and beyond, suggesting that at least some of the alteration is unrelated to the impact.

**Structural geology:** The regional stratigraphy comprises horizontal to very gently dipping (< 5°) strata, but Oasis is a locus of intense and complex folding, with strata locally rotated to vertical, and even overturned, orientations. [1] and [2] noted that the strata in the central hills are folded, but suggested that they are mostly outward-dipping, implying a dome structure. Our study has revealed, however, that both the hilly terrain and the surrounding plains are underlain by intensely folded rocks. Tangential folds extend up to at least 12.5 km, and possibly as much as 18 km, from the center. These vary from upright to reclined, outward-verging folds ranging from meters up to 500 to 1000 m in wavelength and up to 50 m in amplitude. A second set of upright, radial, folds displays a similar range of wavelengths up to 500 m and indicates constrictional strain that increases in intensity towards the center of the Structure.

The folded strata are also intensely faulted, with both shallow and steeply inward-dipping tangential faults and radial faults in the central hills. Faults are highly sinuous on a meter-scale, and the discontinuous nature of the outcrop may imply a similar sinuosity on a larger scale as well. They are typically associated with Fe impregnation with or without silicification, and locally contain ferruginous-matrix breccias with angular clasts. Commonly faulted tangential fold hinges suggest that at least some of the tangential-striking faults formed in association with the tangential folds.

These faults and the folds are, in turn, cut by a younger generation of regional, generally NW-trending, predominantly normal dip-slip, faults that we correlate with the 'clastic dikes' described by [2].

No impact-diagnostic fractures such as shatter cones were found. However, one of the distinctive features of the central parts of the Structure is single or conjugate sets of cm- to dm-spaced fracture cleavage that show normal-slip displacements of up to 10 cm. Their geometry indicates a subvertical $\sigma_1$, consistent with an origin by vertical collapse.

**Petrography:** Preliminary petrographic analysis of samples collected from within 3 km of the center has identified abundant PDF and planar fractures in quartz, with up to 4 PDF sets (but mostly only one or two sets) per grain. This confirms the impact origin of the Oasis Structure, first proposed by [1]. Shock microdeformation features are consistent with shock pressures ranging from 5-15 GPa. Quartz grains may also contain mosaicism. One breccia sample contains highly altered suspected melt fragments, but no glass similar to that described by [1] has yet been found.

**Discussion:** The Oasis Structure is a locus of complex folding and faulting, both of which decrease in intensity and complexity outwards, consistent with a point-source origin for the deformation such as that produced during an impact. This deformation postdates the >90 Ma Lower Cretaceous 'Nubia Formation' sandstones. However, folds are cut by the regional NW-trending, normal faults that are believed to be Tertiary (ca. 39 Ma; M. Baegi, unpubl. work) in age. This would rule out an association with the 28.5 ± 0.8 Ma [3] Libyan Desert Glass, speculated on by [1,2].

The increasingly gentle folding and the limited outcrop away from the center of the Structure make it difficult to precisely define the limits of the Structure. Our preliminary survey suggests a diameter of between 25 and 36 km, somewhat larger than the 5-11.5 to 18 km estimates of [1,2]. Given the poor outcrop, it is too early to speculate on whether the variable diameter may reflect an asymmetric structure formed by a low-angle impact, however, the inner hills also show a slight, NW-SE, elongation. Reconstruction is also complicated by the post-impact Tertiary faulting.

At present, it is unclear whether the tangential folds formed before, simultaneous with, or possibly even after, the radial folds. The most appropriate explanantion of the upright to outward-verging tangential folds is that they formed during collapse of the transient cavity as centripetally-driven blocks converged and some reverse upwards-and-outwards flow occurred in the central region. The extent of this folding might imply an originally much wider, but comparatively shallow, crater, which would be consistent with the similar stratigraphic levels exposed across the entire diameter of the Structure. An unpublished abstract by [4], quoted in [2], suggests that the Oasis Structure has been exhumed by about 400 m since its formation.

The fold-dominated response may be peculiar to low-strength, layered, porous sedimentary targets, or a target in which weaker (Carboniferous) layers underlie a more competent unit (the siliceous Nubia sandstones). The Oasis Structure provides excellent potential to investigate the structural effects of a moderately large impact formed without any detectable influence of crystalline rocks. This aspect will be examined during further fieldwork in 2011.

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