AN EXTENDED FIELD OF CRATER STRUCTURES IN EGYPT: OBSERVATIONS AND HYPOTHESES.

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Introduction: Using orbital imaging data, we detected more than one thousand structures in the Western Egyptian Desert. They are crater-shaped, often quite circular, and are distributed over an area of 40,000 km^2 East of the Gilf Kebir plateau. We studied 62 of these structures during two expeditions in February and December 2004. Two hypotheses are proposed to explain the origin of the structures: hydrothermal vent complexes, produced by fluid seeps in a volcanic-sedimentary basin, or the impact of numerous fragments generated in the break-up of a rubble-pile asteroid.

Satellite Image Analysis: Having initially located a possible crater field in southwestern Egypt using JERS-1 radar images [1], we then acquired 10m-resolution scenes of the French SPOT 4 satellite. Our region of interest, 225 × 215 km in size, is located in Southwest Egypt, in the vicinity of the Gilf Kebir plateau (Figure 1). We manually processed the SPOT 4 mosaic in order to mark all crater-shape structures: 1312 such structures were identified this way, occurring over more than 40,000 km^2 in three main clusters (cf. red circles in Figure 1). The diameter of the smallest structure that could be detected in the SPOT 4 images is 50 m but we observed several smaller ones on the field. Most of the structures have a diameter of the order of 150 m, the structure-size distribution presenting a typical exponential decrease. In the dataset of 1312 structures, 42 are doublets, and the mean distance between two neighboring structures is 1330 m. Also, a great number of structures are not perfectly circular, but the general shape is more likely a circle than an ellipse (cf. Figure 2).

Field Observations: We visited 62 structures over 5 sites (cf. green boxes on Figure 1) during two expeditions in February and December 2004. Their diameters range from 10 to 2120 m. Except for a couple of small structures covered by the Quaternary sand sheet, most of them present well-defined rims, with heights ranging from a couple of meters to more than 80 m. Most structures are more or less filled with Quaternary aeolian deposits, their center being in general higher than the surroundings. The height/diameter ratio of the visited structures ranges from 0.05 to 0.1. Rims are made of tilted sandstone layers of the Sabaya Formation (Albian age, around 110 Ma) covered by breccia, sometimes also covered by paleo-soils.

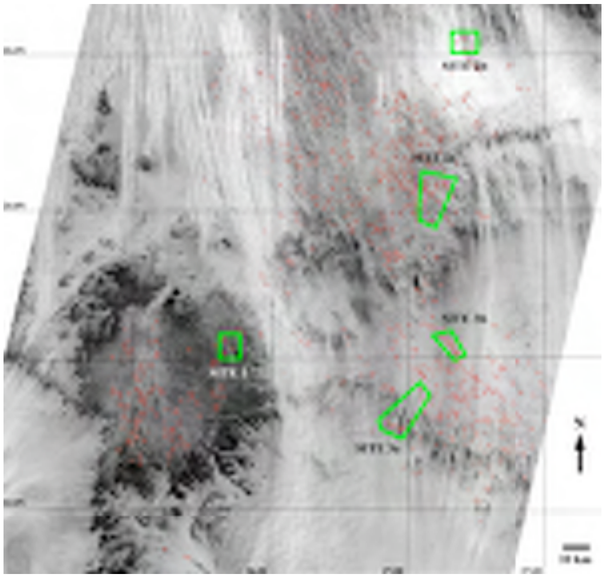

Figure 1. SPOT4 mosaic of the study region (source CNES).

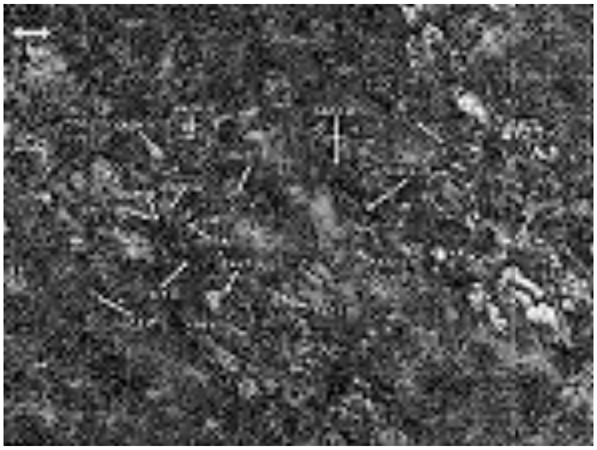

Figure 2. SPOT4 scene of site 2a north (source CNES).

Some structures are cross-cut by basalt dykes, indicating that volcanism took place after their formation. Since basalts in the region are of Lutetian age (46 Ma [2]), we can conclude that the structures certainly formed before this time. Shatter-cone-like features were found along the rim of several crater structures (Figure 3a). However, wind erosion of exposed rocks can produce such features, and we could not clearly observe the typical striation patterns of shatter cones [3]. Abundant occurrences of breccias were observed along the rim of numerous structures, forming pluri-decimetric to metric beds, sometimes interbedded with sandstones or covered by paleo-soils (Figure 3b). Such breccia formations can be produced by classical geological processes such as tectonics and rock falls, but they do also occur in and around impact structures. Optical microscopic analysis of thin sections of breccia and sandstone samples collected on the rims of several structures have shown that quartz is the predominant mineral component of all samples; minor components include phyllosilicates, iron oxides, and some accessory minerals such as zircon. Many quartz grain in these samples contain planar and sub-planar microdeformations (Figure 3c), strongly reminiscent of planar fractures (PFs), known from weakly shocked quartz of many impact structures [4], but also from tectonic settings. GPR soundings were performed on 10 of the visited structures and on some areas between these structures. The collected data showed the occurrence of faulting, fractures and chaotic buried terrains in the quasi totality of the radar transects. All GPR profiles reveal the same subsurface morphology: a perturbed paraboloid structure buried under sediments [5]. In terms of lack of stratigraphy and scattering phenomena, they are quite different from typical profiles observed for volcanic craters for instance.

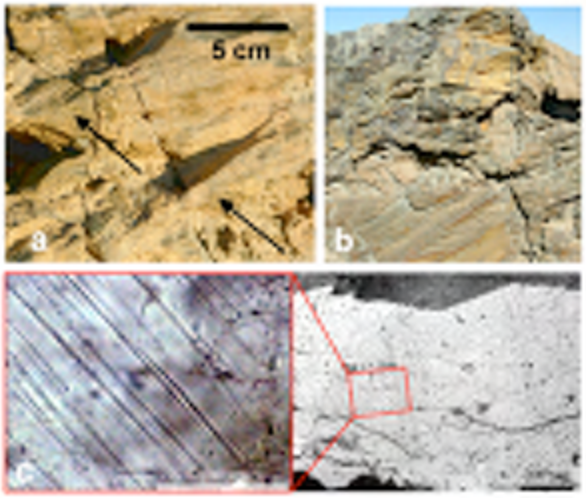

Figure 3. Shatter cone-like feature (a), breccia (b) and sub-planar deformations in quartz grain (c).

Possible Origin of the Structures: In large igneous provinces, such as the Siberian traps, the Karoo Province in South Africa, and the North Atlantic, fluid seeps in volcanic sedimentary basins can produce extensive magmatic complexes: for example, more than 700 hydrothermal vent complexes spread over 85,000 km^2 have been observed in the More and Voring basins, offshore in the Norwegian Sea [6]. Tips of transgressive sills can produce vertical structures reaching the surface, where they terminate in eye-shaped structures, with abundant sediment dykes cutting dolerite sills and large volumes of brecciated sediments. The typical size (about 150 m) and number (more than 1300) of the structures in the Gilf Kebir region are compatible with the hydrothermal vent hypothesis and the brecciated sediments found around most of the structures that were visited could have been produced by fluidized sediments reaching the surface. However, southwestern Egypt is not known as part of a large igneous province, it is thus required to discover a major (and still unknown) hydrothermal event there that could have produced such vent complexes. GPR sounding performed on several structures revealed a flat floor covered by sedimentary deposits: hydrothermal vents should show tracks of a vertical structure, the conduit zone connecting to the tip of a sill intrusion. Also, we could not find evidence of sediment dykes and pipes in the 62 structures we visited, even though they should be abundant in the case of hydrothermal vents.

An alternative to the hydrothermal hypothesis could be cratering as a consequence of meteorite impacts. The paraboloid morphology of the structures confirmed by GPR sounding, the observation of shatter-cone-like fracturing phenomena, the abundant occurrence of breccias, and the presence of PFs in quartz grains could be indications of the presence of impact structures in the Gilf Kebir crater field. However, “classical” strewn fields on Earth result from meteorite showers that typically produce a few meter to kilometer-sized impact craters in a single event, covering at most a hundred square kilometers [7] (all the known impact strewn fields on Earth do not extend over more than 80 km^2). Clearly, the dimensions of the study area are greater than the maximum possible based on the mechanism of single meteorite breakup. Nevertheless, recent numerical simulations of large asteroid breakups have shown that rubble-pile asteroids, consisting of weak aggregates of gravel-sized to boulder-sized components held together by gravity, are produced by collisions that continuously take place in the asteroid belt [8]. If such a rubble-pile asteroid can break up into several fragments of kilometer-size when approaching the Earth-Moon system, each fragment can again be divided into smaller pieces by atmospheric breakup: the impact of all these fragments with the Earth’s surface could theoretically result in an extended impact field covering several thousands of km^2.

References: [1] Paillou Ph. et al. (2004) *CRAS Geoscience, 336,* p. 1491. [2] Meneisy M. Y. (1990) in The Geology of Egypt, Bakelma, p. 113. [3] Sagy A. et al. (2004) *JGR,* 109, B10209. [4] Stöffler D. and Lagenhorst F. (1994) *Meteoritics,* 29, p. 155. [5] Heggy E. and Paillou Ph. (2006) *GRL*, in press. [6] Svensen H. S. et al. (2003) *Geo-Mar Lett.*, 23, p. 351. [7] Passey Q. R. and Melosh H. J. (1980) *Icarus*, 42, p. 211. [8] Michel P. et al. (2003) *Nature*, 421, p. 608.