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## **Geoarchaeological investigations in Dakhleh Oasis, Western Desert, Egypt: Did a meteorite strike Dakhleh during the time of Middle Stone Age occupations?**

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For Lech Krzyzaniak, whose investigations of the rock art in the 'South-east Basin' emphasized the importance of the geoarchaeological problems in the eastern Dakhleh palaeo-oasis, and the eastern Palaeolake Teneida Basin.

### **Abstract**

Geoarchaeological research in the Dakhleh Oasis region has led to the recognition of 'anomalies' in the prehistoric environmental setting. A natural glass (Dakhleh Glass) was discovered in the course of mapping and survey for archaeological and faunal remains associated with extensive Pleistocene palaeolake deposits. Other 'anomalies' in the geological settings appear to be related, and together with the glass pose the question of whether a meteorite, or a series of meteorite fragments, struck the Dakhleh region sometime between 100,000 and 200,000 years ago, during the time of Middle Stone Age occupations.

### **Introduction**

This paper reports on ongoing geoarchaeological research into an unusual heating event that occurred during end-Middle Pleistocene times in Dakhleh Oasis region, central Western Desert of Egypt (Fig. 1). 'Geoarchaeology' as a specialized subdiscipline has attained formal status in archaeology, geology, and other earth sciences only relatively recently. However, such investigations were pioneered in the Western Desert oases in the 1930's by Gertrude Caton-Thompson and Eleanor W. Gardner (e.g., Caton-Thompson 1935; Caton-Thompson 1952; Caton-Thompson & Gardner 1932, 1934; Gardner 1932, 1935). Similar in-

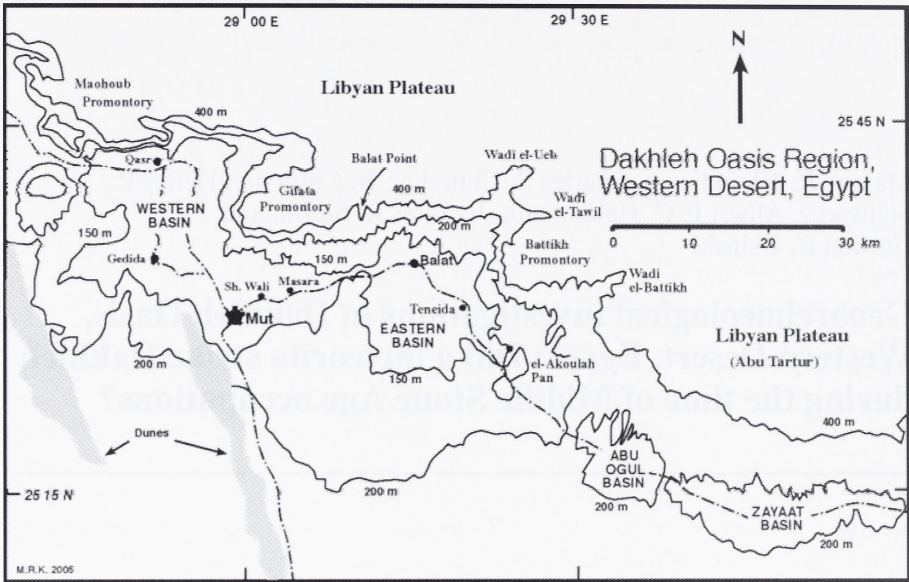


Fig. 1. Dakhleh Oasis Region, Egypt, showing main topographic features and towns, with contours at 150, 200 and 400 m above mean seal level. The 150 m contour encloses the modern Eastern and Western basins within the oasis, and el-Akoulah Pan to the southeast. Dune streaks stippled. hollower basins to the east of Dakhleh close within the 200 m contour.

terests in regional studies motivate the integration of environmental and archaeological research by the Dakhleh Oasis Project (DOP).

Usually, geoarchaeological research involves the study of relatively long-term processes that affect environments and their human inhabitants. Occasionally, one finds evidence of short-term, even instantaneous, catastrophic events (McGuire, et al. 2000; Nicoll 2003). Of these, the least common is probably evidence for meteorites striking the Earth in inhabited areas. Such observations have been limited to the Historic Period, or later prehistory (e.g., Rigby, et al. 2004; Santilli, et al. 2003; Veski, et al. 2001; Veski, et al. 2004). "Because meteorite falls are rare and unpredictable, any observation of them takes place quite by chance. However, accounts of spectacular events accompanying the falling of stones from the sky are to be found in the early histories of many regions. Such things must occasionally have been witnessed even in prehistoric times...." (Mark 1987: 1). To date, no studies of Pleistocene meteoritic events have integrated archaeological research with that of other sciences.

Even relatively small impact events would cause devastation in the



surrounding area, and have cultural as well as physical effects among humans. Myths from many areas suggest how humans have attempted to 'explain' the inexplicable (Cassidy and Renard 1995; n.a. 2004, 2005; Santilli, et al. 2003). Some idea of what happens can be gained from reconstructions of the Barringer (Meteor) event in Arizona, United States of America (1.2 km diameter crater), that occurred some 50,000 years ago (Kring 1997; Kring & Bailey n.d.); or the witnessed Tunguska airburst of 1908 in northern Russia (e.g., Andreev & Epikte-tova 1996; Bissell 2002; Bronshten 2000; Fast 1996; Hogg 1962; Kulik 1938). Vegetation and animal life is destroyed or heavily damaged for 10's of km around an impact or blast site. For the Barringer event, it is estimated that the blast would have produced winds of >1,000 km/hour, with changes in pressure and thermal emissions that would have destroyed vegetation over an area of 800-1,500 km<sup>2</sup> and damaged plant life over a further 200-600 km<sup>2</sup>. Animals, or humans, within 3-4 km would have died, and those within a radius up to 24 km would have been seriously injured (Kring & Bailey n.d.). Fortunately, the Tunguska explosion was above sparsely inhabited Siberian taiga. "Two thousand square kilometers of ancient forest were blown flat, men 60 km from the fall site were thrown down and seared by the heat" (Turco, et al. 1981: 19). "The blast flattened the forest to a radius of 15-35 km and damaged houses in Vanovara, 70 km away" (Trayner 1994: 227). Tungus camps were destroyed, artefacts were melted, and reindeer herds were killed (Bobrovnikoff 1928; Gallant 2002; Hogg 1962). The Tugus ascribed the event to the wrath of god (Gallant 1994).

### **Anomalies and Investigations**

Beginning in 1987, during surveys for archaeological and palaeoenvironmental evidence in Dakhleh Oasis region, members of DOP noted a number of puzzling anomalies. Kleindienst found dark coloured, slaggy material lagged on the surface of Pleistocene lacustrine deposits lacking cultural associations [Archaeological Locality (Loc.) 211]. This was identified as a natural glass<sup>1</sup> (Dakhleh Glass, DG) by Schwarcz in 1992, and subsequently analyzed (Schwarcz, et al. n.d.). The calcium-aluminum-silica glass has a unique composition, and represents sediments that melted at around 1100-1200 °C—either the lakebeds, soils, or the matrix of Pleistocene limestone gravels in the area. An averaged <sup>39</sup>Ar/<sup>40</sup>Ar determination for the glass at Loc. 211 is 122,000 ± 40,000 years (Schwarcz, et al. n.d.), recalculated as 129,000 ± 40,000 years (Kleindienst, et al. n.d.) Human actions, volcanic activity, forest or grass fires, and lightning strikes were ruled-out as formative causes; but a meteoritic event was considered unlikely. The origin of Dakhleh Glass remained a mystery.

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<sup>1</sup> DOP earth scientists regarded the material as anthropogenic slag. The absence of Historic Period cultural evidence made this identification unlikely.

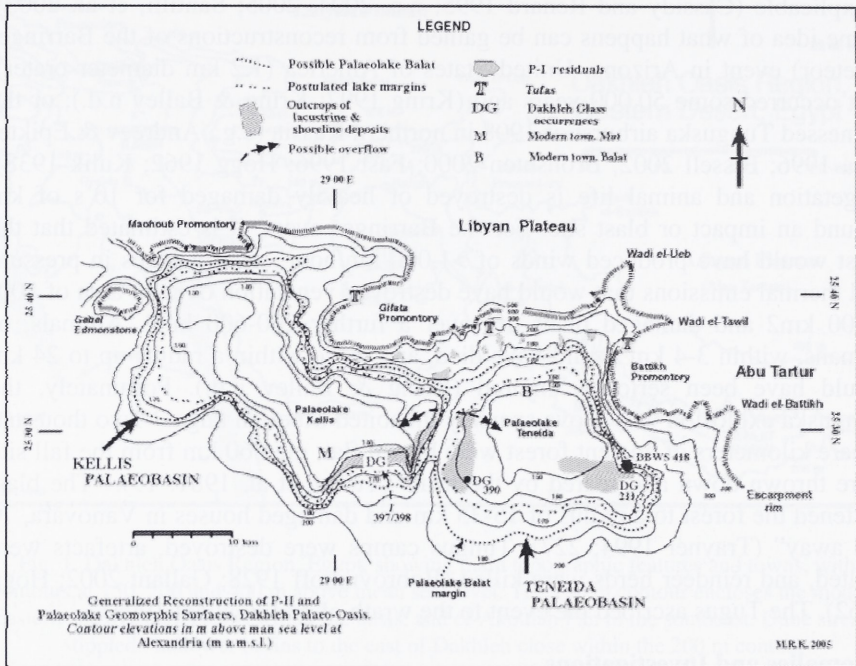


Fig. 2. Reconstruction of Dakhleh Oasis as it may have existed between 350,000 and 100,000 years ago, with large palaeolakes in the eastern Teneida Palaeobasin and the western Kellis Palaeobasin. Contouring based upon existing remnants of the P-II geomorphic surface with the addition of 20 m height to general modern grade elevations. Mapping of lacustrine outcrops as of 2003; later survey has located additional outcrops in the northeastern Kellis Palaeobasin. Map shows the locations of the Dakhleh Bow Wave Structure (DBWS 418), and occurrences of Dakhleh Glass (DG); see legend on figure.

Probable lacustrine deposits in Dakhleh were noted by Churcher in 1980 (Churcher 1981), but were only proved by finding faunal remains preserved in them in 1996 (Churcher, et al. 1999; Churcher, et al. n.d.). Subsequent mapping shows that long-lasting palaeolakes occupied two palaeobasins: Palaeolake Teneida on the east and Palaeolake Kellis on the west, reaching shoreline elevations of ~165 m. The lakes probably sometimes joined as Palaeolake Bahat, reaching highest shoreline elevations of >175 m (Fig. 2). The lakes were fed by groundwater from artesian springs, as well as by intermittent overland flow demonstrated by tufas preserved on the Libyan Escarpment face, allowing the



persistence of freshwater bodies even during drier climatic times. Geoarchaeological dating places the lakes between ~350,000 and 150,000 years ago, with associated terminal Earlier Stone Age through older Middle Stone Age occupations, although they may have persisted to the end of the Middle Pleistocene, ~135,000-125,000 yrs ago (younger Middle Stone Age occupations). The scattered faunal remains evidence an African savanna environment surrounding the lakes. Over 30 m of bedrock and lake deposits have since been removed by erosion over much of the palaeo-oasis area (Churcher and Kleindienst n.d.; Kleindienst, et al. 2004).

In the course of mapping the Pleistocene lake deposits, searching for fossils and artefacts, the Churchers and Kleindienst found two additional occurrences of Dakhleh Glass: one localized area on the southern margins of Palaeolake Teneida (Loc. 390); and a large area of surface finds, with some glass in situ within lake deposits of Palaeolake Kellis (Locs. 397 and 398) (Kleindienst, et al. n.d.; Mills 2003) (Figure 2). The mystery of how these glass 'splats' formed became more intriguing, given the relationship to the palaeolakes and to the time of Middle Stone Age occupations (see below).

While investigating the northern rim of Palaeolake Teneida, north of the areas with lagged Dakhleh Glass and the Holocene El-Akoulah Pan, Churcher and Kleindienst discovered an area of tectonically disturbed strata, where Duwi Formation (Fm.) beds were standing nearly vertical, inward dipping and surrounding an apparent 'teardrop' shape. Bee Churcher dubbed this the 'Bow Wave Structure' (Mills 2000). To the south, in wadis cutting the north rim of El-Akoulah Pan, were 'blobs' of apparent Mut and Duwi Fm. sediments, lying out of their normal stratigraphic positions and resting on eroded Taref Fm. sandstone surfaces. Duwi Fm. should conformably overlie Mut Fm., resting in turn on Taref Fm. sandstones, dipping northward at only 1-3° (Hermina 1990; Kleindienst et al. 1999). The reasons for these 'displaced sediments' also remained a mystery.

However, having ruled-out most of the usual causes for natural and human glass production, we applied the 'Sherlock Holmes' rule': that whatever explanation is left, however improbable, must be true. At least it becomes a working hypothesis: could Dakhleh Glass, in fact, be evidence of a meteorite impact? We began to think that the glass and the displaced sediments could be related to the 'Bow Wave' (Mills 2000). Haldemann noted features of interest on aerial photographs. Schwarcz obtained a high-resolution satellite image of the area west and northwest of El-Akoulah Pan (Loc. 211 and northward) that confirmed the aerial photographs. It showed a circular feature northeast of the 'Bow Wave', which is picked out by wadi channels, possibly an infilled crater in P-II limestone gravels ~300-400 m in diameter - three main geomorphic surfaces have been recognized; on these, soils and Pleistocene alluvial limestone gravels overly erosion surfaces,

or pediments. From earliest to youngest, these are termed P-I, P-II, and P-III. The older two are usually only preserved as elevated terraced remnants, while the P-III is more complex and extensive (see Kleindienst *et al.* 1999).

If so, both features might be evidence that a meteorite (or several pieces of one) hit the area. In 2004, Kleindienst obtained photographs of the eroded surface of the 'Bow Wave' that show light reflecting off a circular feature ~200-300 m in diameter, within the uptilted sediments; strangely, we have not 'seen' that before, and can only assume that on that day and at that time 'the light was right'—a phenomenon well known to desert explorers. Both P-II and P-III gravels lie on remnants of erosion surfaces within the feature, showing that it is older than the formation of the later Pleistocene P-III surface, and coeval with the now degraded P-II surface. We also observed tectonic disturbances over a wider area ~1.5 km across (Mills, et al. 2004). We now term the entire area the 'Dakhleh Bow Wave Structure' (DBWS) (Kleindienst, et al. n.d.). This has become a 'suspect' meteorite strike area, for detailed investigation by the planetary scientists.

However, there is a problem of whether masses of hot glass melt can be ejected from rather small (300-400 m diameter) impact craters for 10's of km. Vegetal impressions, vesicular structure and flow lines indicate that the glass was emplaced while viscous, and Osinski has found evidence comparable with known impactite from other meteorite craters (Haldemann et al. 2005a; Haldemann et al. 2005c).

Haldemann obtained SIR-C imaging for Dakhleh, and discovered that we have other intriguing anomalies which may relate to our problem (see Haldemann et al. 2005b; Haldemann et al. 2005a; Haldemann et al. 2005c). In particular, a 3 km diameter circular feature west of Balat shows only on radar imaging. Smith's ground transects in 2005 indicate that there is some puzzling geological evidence in that area. Sediments there are now mainly eroded to the level of the Taref Fm. sandstones. Only a few outcrops of lake deposits of the Lake Balat Fm. (western Palaeolake Teneida) overlying Mut Fm. mudstones are still preserved. This area, and others further west within the cultivated areas of the oasis, require investigation in order to account for the Dakhleh Glass emplacements at Loc. 390 and Locs. 397/398 (Kleindienst, et al. n.d.).

### **Conclusions from geoarchaeological research**

Geoarchaeology provides a framework for whatever heating event created Dakhleh Glass. Age ranges of Middle Stone Age units in Dakhleh are based upon geomorphic settings and correlations with chronometrically-dated tufas at Kharga Oasis that overlie sediments incorporating Middle Stone Age artefacts (Kleindienst 2003, 2005; Smith, et al. 2004). Lithic artefacts in the basal lake-



beds in the Loc. 211 area underlie the eroded surfaces with lagged glass by 3-4 m. They are assigned to the Teneida unit (provisionally, older Middle Stone Age developmental stage), possibly older than 150,000 years (Kleindienst 2003). On the surface of the P-III gravels within the DBWS only scattered, 'small-sized Middle Stone Age' pieces have been found (Loc. 418) which must be later Pleistocene in age, and which are likely to postdate the Dakhleh Unit (Aterian Complex). Isolated Dakhleh Unit tanged points have been found on surfaces to the south from which Lake Teneida Fm. beds were probably already eroded when these were dropped. The Dakhleh Unit is thought to be younger than ~70-90,000 years. Thus, although direct chronometric dating of archaeological units at Dakhleh is still unsatisfactory, the cultural evidence agrees with the broad-range  $^{39}\text{Ar}/^{40}\text{Ar}$  determination on Dakhleh Glass, and confirms that the heating event took place between ~100,000 and 200,000 years ago (Kleindienst, et al. n.d.).

Large-sized lithic raw materials are lacking in the general area of the DBWS and Loc. 211, and that of Locs. 397 and 398. The Tarawan cherts preferred by Middle Stone Age artisans are not found in those parts of the oasis (Hawkins and Kleindienst 2002). The Teneida unit associated with the Palaeolake Teneida deposits in the Loc. 211 area appears to represent occupation site aggregates, with some relatively large Levallois components made of Tarawan cherts that must have been imported for ~6-10 km (Kleindienst 2003). Artefacts are medium- to small-sized in the Middle Stone Age aggregates at Locs. 397/398. This may reflect the lack of large raw materials on the southern Palaeolake Kellis margins, and the distance to sources of Tarawan cherts below the Escarpment across a large lake. These aggregates may also be water-sorted. However, it is possible that they date to the end of the Middle Pleistocene, and are therefore younger than the Teneida unit. Their stratigraphic relationship to Dakhleh Glass has not yet been determined, and this Middle Stone Age material awaits detailed analyses.

Was it a meteorite impact event? If so, what would happen in Dakhleh? The evidence of Dakhleh Glass either lagged on, or in place within lacustrine deposits indicates that the heating event that produced the natural glass was related to the palaeolakes. Dakhleh Glass was certainly emplaced during the time of lake sedimentation in the Palaeolake Kellis basin. (As yet, none has been found in the Teneida Palaeobasin sediments.) The devastating palaeoenvironmental effects that would have occurred if meteorite(s) struck the shores, or the water bodies, of the Pleistocene palaeolakes are of concern for understanding the prehistoric archaeology and the Pleistocene environments of Dakhleh. If such a catastrophic event occurred during a drier period, the environment might take a long time to recover. The oasis area would cease to be a refugium for plants,

animals and humans, even with local water availability, because connections with other distant refugia that could repopulate the area would be problematic. Natural resource availability would be low or nonexistent. If the event occurred during a wetter period, recovery could be expected to have been faster, but still might take 100's to 1000's of years. Whatever the heating event was that produced Dakhleh Glass; there is a unique geoarchaeological problem under investigation in Dakhleh Oasis.

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