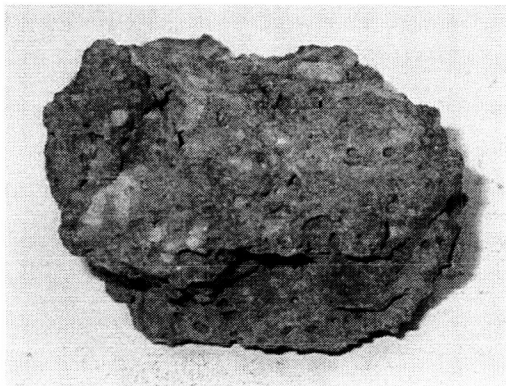


**Volatiles in the Desert: Subtle Remote-Sensing Signatures of the Dakhleh Oasis Catastrophic Event, Western Desert, Egypt.** A.F.C. Haldemann<sup>1</sup>, M.R. Kleindienst<sup>2</sup>, C.S. Churcher<sup>3</sup>, J.R. Smith<sup>4</sup>, H.P. Schwarcz, and G. Osinski, <sup>1</sup>Jet Propulsion Laboratory, California Institute of Technology, Mail-Stop 238-420, 4800 Oak Grove Dr., Pasadena, CA 91109, USA, [albert.f.haldemann@jpl.nasa.gov](mailto:albert.f.haldemann@jpl.nasa.gov); <sup>2</sup>Department of Anthropology, Univ of Toronto, 3359 Mississauga Road North, Mississauga, ON L5L 1C6, Canada, [maxine.kleindienst@utoronto.ca](mailto:maxine.kleindienst@utoronto.ca); <sup>3</sup> Department of Zoology, Univ of Toronto, Toronto, ON M5S 3G5, Canada, [rchurcher@shaw.ca](mailto:rchurcher@shaw.ca); <sup>4</sup>Earth and Planetary Sciences, Washington Univ in St Louis, Campus Box 1169, One Brookings Drive, St Louis, MO 63130; <sup>5</sup>School of Geography and Geology, McMaster Univ, Hamilton, ON L8S 4L8, Canada; <sup>6</sup>Agence Spatiale Canadienne/Canadian Space Agency, 6767 Route de l'Aéroport, Saint-Hubert, Quebec, J3Y 8Y9, CANADA, [gordon.osinski@space.gc.ca](mailto:gordon.osinski@space.gc.ca).

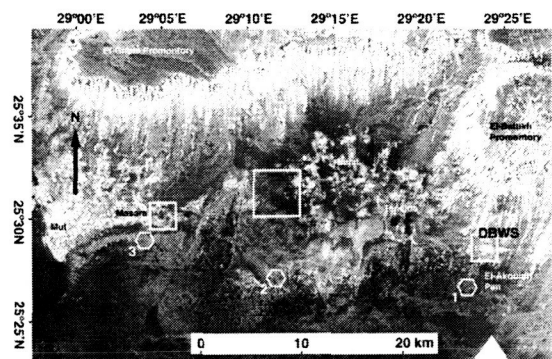
**Introduction:** Over the past decade members of the Dakhleh Oasis Project have studied enigmatic signatures in the Pleistocene geologic record of portions of the Dakhleh oasis and palaeo-oasis in Egypt's Western Desert [1,2]. In particular, Si-Ca-Al rich glass melt (Dakhleh Glass, Fig. 1) points to a catastrophic event between c.100,000-200,000 years ago [3] in this well-studied African savannah and freshwater lake Middle Stone Age environment [4,5].



**Figure 1.** A typical piece of Dakhleh Glass, 4 cm across, from site 397.

The wide extent of glass deposits, over tens of kilometers, may suggest multiple, co-eval impacts or airbursts, or perhaps a record of "high-speed molten ejecta decoupled from the later stages of crater excavation" [6]. Here we report on mapping of remote sensing data (visible, infrared and radar) that is being used to guide wider reconnaissance of the Dakhleh Glass deposits (Fig 2). The remote sensing is anchored on the best-studied element, the Dakhleh Bow Wave Structure (DBWS), where structural elements of a ~400 m cratering event are preserved. These structures are nevertheless highly degraded, and not directly apparent in the remote sensing data. The Dakhleh Glass, while chemically quite unique, is nowhere very extensive, and is thus only a minor constituent in each remote sensing pixel; we attempt to identify its presence by calibrating to the known occurrence locations near the DBWS. Clearly, these subtle remote-sensing signatures of the relatively

recent impact(s) into a sedimentary target at Dakhleh, where the erosion rate is estimated at 0.1 mm/yr, underscore the difficulty in accumulating a clear characterization of the range of sedimentary target modifications associated with smaller (100 m - 1 km) terrestrial craters.



**Figure 2.** Composite 5-cm wavelength radar image of the Dakhleh Oasis Region, showing the area of Dakhleh Glass at (1) Loc. 211 and the Dakhleh Bow Wave Structure (DBWS) southeast of the oasis. The proposed circular features or 'virtual craters' in the unlabeled boxes located within the oasis proper, and north-east of the Dakhleh Glass occurrences at (2) Loc. 390, and (3) Locs. 397-398, are visible only on the radar imaging. These features may result from meteorite impacts or airbursts, and account for the formation of the glass at these other locations. Images from Shuttle Imaging Radar, SIR-C processing runs 16113 (left) and 16095 (right).

**Multiple-impacts or fast glass ejecta:** Results from the most recent field season (Smith, 2005, personal communication) tend to discount the idea that the circular feature west of the village of Balat (largest box in Fig. 2, "Balat Bullseye") is a second impact remnant, however new Dakhleh Glass deposits were discovered in the south-west quadrant of the Balat Bullseye. This has led us to consider whether what we are exploring is a remnant of high-speed molten ejecta early in the cratering process when the impactor is obliquely incident (~30°), as reported by [6]. Impact glasses recovered from the Argentine loessoid deposits [7,8] are interpreted to have been generated by this process, and we note the

similar mesoscopic aspect of the Dakhleh Glass (Fig. 1) to those samples.

**Relevance to Mars:** (1) To better understand the role of cratering in the Martian sedimentary record, considering that the study of a new terrestrial crater into a sedimentary target, in particular one with glass ejecta because examples of this are so rare [7], adds a significant increment to the terrestrial analog dataset. This will refine our understanding and expectations for the occurrence of glass among Martian ejecta. (2) the DBWS and associated Dakhleh Glass may be a mappable instance of early molten ejecta, where the relationship of that process to volatiles can be reconstructed from the paleoenvironmental record. (3) The Dakhleh Glass deposits, while apparently widespread are not readily apparent in any remote sensing data down to a resolution of 10 m per pixel, suggesting that studies of the cratering process on Mars will also profit from both higher resolution orbital data as well as future *in situ* studies. (4) Some Dakhleh Glass fragments engulfed extant life at the time of formation, which suggests a tantalizing exobiological possibility for martian glass ejecta.

**Discussion:** The subtlety of the remnant traces of catastrophe in Dakhleh Oasis need to be explored on the ground; remote sensing can at best serve to guide the exploration. In the Dakhleh Oasis area, which is well-studied by an ongoing multi-disciplinary team

we anticipate being able to make a reasonable taphonomic survey of the Dakhleh Glass and thereby reconstruct the ejecta pattern of what may be a unique example of impact process in a sedimentary environment. But to reiterate, the traces on the ground are subtle (Fig. 3), and careful field exploration will be required to tease out the answer to this mystery.

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**Figure 3.** from [1]. West to east composite view of the Dakhleh Bow Wave Structure 'upthrust' feature, as seen from the P-III limestone gravel-capped ridge to the south. Note circular aspect within the veined green shales inside the upthrust (black arrow), which is picked-out by morning light, suggesting that the feature is an eroded impact crater (photo: Kleindienst, Feb., 2004, 11:00 a.m., yellow filter).