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Petrographic Investigation of Ejecta from the Tenoumer Impact Crater, Mauritania

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TEMOUMER IMPACT STRUCTURE

The Tenoumer impact crater (22° 55'N, 10° 24'W) is a 1.9 km diameter crater within the Paleoproterozoic and Archean rock of the Reguibat Shield in Mauritania (Figure 1). Tenoumer has a well preserved circular rim, overturned sections, exterior outcrops of dark, vesicular melt rocks, and a blocky ejecta unit [2]. Visible microscopic shock indicators (PDF's) have been identified within the melt rocks [1-3]. Presently, there are two different proposed ages of the impact. K/Ar dating established a 2.5 +/- 0.5 Ma age, whereas fission track analysis of apatite has suggested an age of 21.4 +/- 9.7 Ka [2, 4].

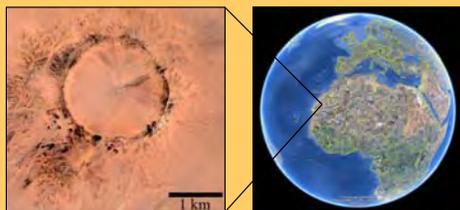


Figure 1. The Tenoumer Impact Crater, Reguibat Shield, Mauritania.

HYPOTHESIS

Impact cratering theory and modeling demands (Fig 2a and b):

- 1) pressures decrease rapidly with depth during impact, and
- 2) material from the greatest depth is deposited closest to the impact

This material that is found closest to the rim should have been located originally at greatest pre-impact depths, and thus experiences the lowest shock pressures. Likewise, material farther away from the crater rim, should have had shallower pre-impact depths and should have experienced the greatest shock pressures.

The goal of this study is to examine the microscopic grain-scale deformation to trace the vertical pressure gradient of the impact in the deposited ejecta unit.

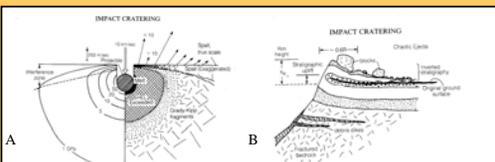


Figure 2: Schematic diagrams showing a) the pressure gradient with depth and b) the inverted stratigraphy after impact (from [12])

DETERMINATION OF SHOCK PRESSURES

Within impact rocks, observable textures can be used as evidence for deformation by a hypervelocity impact and as general gauges of impact pressures as certain textures can only be formed above characteristic pressures [5-8]. More narrowed estimates can be obtained by detailed measurements of planar features in Quartz. Shock deformation in quartz is highly orientation dependent, and thus the angle of shock fabrics with respect to the primary crystal axis can more narrowly constrain shock pressures (table 1) [8].

Table 1. Shock Deformation Levels in Quartz

Deformation Type	Characteristic Index	Mean Pressure (GPa)
A	c{0001}	8.8
B	ω{101̄3}	12
C	{2241}, r{101̄1} z{011̄1}, ζ{1122}	15
D	{1012}	23

PETROGRAPHY OF TENOUMER MELT ROCKS

Tenoumer melt rocks (Fig. 3) are melt-matrix breccias primarily composed of a glassy, fine-grained plagioclase matrix with embedded clasts of quartz and granitic rock fragments. Shocked quartz (PDF's) are found within granitic clasts (exception: NMNH 113029-15). Orientations of PDF's were measured on a universal stage [5, 7, 8] and were found to follow the characteristic shock indices. Shock barometries based on PDF orientations within melt rock clasts were then calculated to be 18 +/- 2 GPa.



Figure 3: Typical melt rock from Tenoumer, NMNH 113029-15. A) Shocked quartz in a granitic clast embedded in the matrix. B) Flow textures seen in the glassy matrix.

PETROGRAPHY OF CRYSTALLINE EJECTA

The crystalline samples contain no melt or glass, and consist of amphibolite to greenschist facies metamorphic rocks that are identical in both hand sample and thin section to basement rocks collected from the crater floor [2, 3]. No shocked quartz was found in any of these samples (neither the near-rim nor the more distant material). However, other minerals, particularly feldspars, show deformation that may be due to low-level shock.

Rim and near-rim samples are thus interpreted to be ejecta which was initially too deep to experience the minimum pressures necessary for petrographically recognized features of shock metamorphism. This is consistent with studies of the basement rocks which also lack diagnostic shock features.

The distant samples show textures and grain-scale deformation features that suggest low level shock, below the pressures required to form PDF's in quartz. Sample TAU, from the upper ejecta blanket, shows PF's in quartz which parallel the {1013} and {5161} planes (figure 4a). The more distant TAL shows feldspar textures similar to those described in other impact structures [9-10]. Deformation lamellae in alternating albite twin planes (figure 4b, 4c) and offset twin planes ("ladder texture," figure 4d) are common and are interpreted to be the result of low pressure deformation due to the impact. Additionally, these feldspar grains contain microcline inclusions which do not appear to be in equilibrium contact with the host grain and be the product of recrystallization from a (diaplectic?) glass (figure 4e, f). Micro-Raman spectra of the feldspars show a broadened peak at 1110 and 514 cm⁻¹, and a loss of the peak at 576 and 454 cm⁻¹, consistent with observed shocked feldspars elsewhere [11] (figure 5).

CONCLUSION AND DISCUSSION

This study highlights one of the continuing struggles in understanding the impact cratering process. The majority of shock deformation studies and shock barometry calibrations have focused on PDF's in quartz, which limits our ability to detect low shock pressures. The rocks from the Tenoumer impact crater demonstrate the need for additional calibration at lower pressures using a combination of quartz and other minerals, such as feldspar. Such calibration will allow us to expand the use of petrography in understanding the distribution of shock in both target rocks and impact ejecta, and will lead to a greater understanding of the impact process.

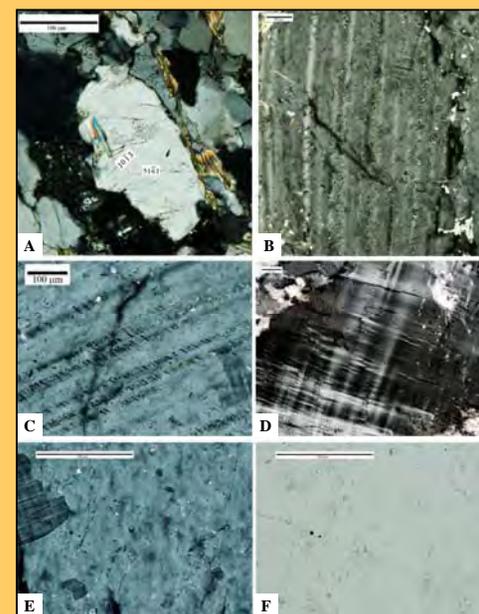


Figure 4: Shock features in distant ejecta. A) PF's in quartz, TAU; B and C), deformation lamellae in alternating albite twins, TAL; D) offset twin planes, E) microcline inclusions in feldspar XPL; F) microcline inclusions seen in (E), PPL.

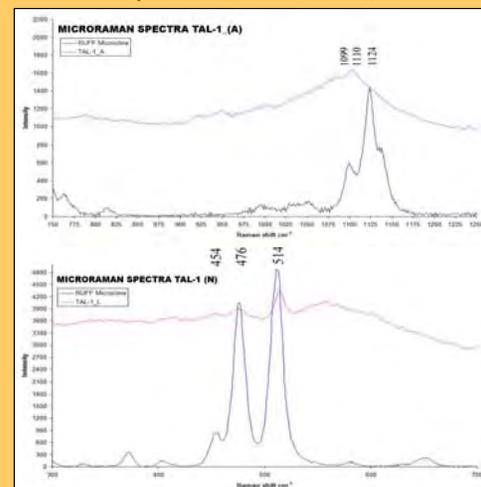


Figure 5. Micro-Raman spectra of microcline in TAL-1 (distant ejecta) showing broadening of 1110 and 514 peaks and loss of peaks at 454 that are characteristic of shock.

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