Petrographic Investigation of Ejecta from the Tenoumer Impact Crater, Mauritania.

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Introduction: The identification and study of small (<2 km) meteorite impact craters is often problematic because of burial, erosion, or the absence of distinctive shock metamorphic features or significant impact melt units in craters formed in sedimentary target rocks [1]. To improve our understanding of the excavation, shock metamorphism, and impact melting in such small structures, we undertook a mineralogical and petrological study of ejecta and impact melt samples from the well-established but little studied, Tenoumer impact crater, Mauritania [2,3,4].

The Tenoumer impact crater (22°55'N, 10°24'W) is a 1.9 km diameter simple crater within the paleoproterozoic and Archean rocks of the Reguibat Shield in Mauritania. Tenoumer has a well preserved circular rim with displaced material, overturned sections, and exterior outcrops of dark vesicular melt rocks. A blocky, ejecta layer has been recently identified [4]. The impact origin for Tenoumer was confirmed by the presence of planar deformation features (PDF's) in clasts within melt rocks [2]. Chronologic studies of the Tenoumer event differ in both methodology and results. K/Ar dating [2] established an age of 2.5 +/- 0.5 Ma, whereas fission track analysis of apatite in melt rocks yielded an age of 21.4 +/- 9.7 Ka [5]. No structural mapping, or analysis of impact associated material other than the melt rocks exists in the literature.

In 2003, a suite of 8 crystalline rocks was collected from Tenoumer ejecta. Specifically, the suite includes 4 samples collected from the crater rim, 2 samples from immediately outside the crater rim, 1 sample from the upper ejecta blanket (1-1.5 radii outward), and 1 sample from the lower ejecta blanket (2-2.5 radii outward). These samples, as well as six melt rocks (NMNH 113027-41, NMNH 113029-15, TM-1, TM-3, 13029-61, ATD-68-1) [2,3] were examined petrographically and minteralogically in an attempt to use shock features to quantify pressure conditions at the time of impact. Modeling and theory of impact cratering suggest that shock pressures rapidly decrease with depth and that ejected material from greatest depth is deposited closest to the crater rim after excavation [6,7]. In this study we attempt to use shock indicators to trace the stratigraphic inversion of target rocks within the ejecta blanket.

Petrography of the Near-Crater Ejecta: Rim and near rim ejecta samples (TR-1, TR-2, TR-3, TR-4, TO, and TO-1) show no evidence of shock metamorphism (i.e., shocked quartz) and are indistinguishable in both hand sample and thin section from basement samples collected inside the crater [3,4].

The crystalline samples are amphibolite to greenschist facies metamorphosed granitic geneisses. Major minerals include K-feldspar, plagioclase, quartz, and biotite, with minor amounts of amphibole, apatite, and opaque minerals. Pre-impact dynamic recrystallization fabrics dominate the rocks. Quartz forms clean, small smooth crystals in narrow bands between larger feldspar grains indicating metamorphic conditions between the melting points of quartz and feldspars.

Petrography of Distant Ejecta and Melt Rocks: Shock indicators occur primarily in the more distant ejecta samples (TAL and TAU) and the melt rocks. Tenoumer melt rocks can be described as vesicular melt-matrix breccias, containing clasts of granitic basement in a plagioclase microlitic glassy matrix. Chemical compositions of melt rocks have been well documented [2,3,4]. Within the melt rocks, PDF's occur primarily within granitic clasts entrained in the matrix (samples TM-1, TM-3, NMNH 113027-41, ATD-68-1) and rarely within individual quartz grains (NMNH 113029-15). Additional shock related features found include PDF's in feldspars, lechatelierite, and ballen textures.

Flow structures within melt phases (NMNH 113029-15) indicate rapid movement during molten stage, consistent with either airfall or injection dike emplacement [3]. Within the shocked quartz grains, up to 5 sets of PDF's were found, but grains most commonly exhibited 2-3 sets. Decorated PDF's and heavily toasted quartz [10] in the majority of samples (exception: NMNH 113029-15 which has clear, pristine PDF's) indicates at least minor post shock alteration. Measurements of clasts within the melt rocks using shock barometry methods [6,8,9] yielded mean pressure vales of 19.9, 19.4, 18.1 and 16.4 GPa.

Ballen quartz and lechatelierite are extremely common in the melt rocks and often occur together. Similar associations have been reported in Chesapeake Bay and Bahía Blanca ejecta units [11], and may suggest genesis at higher shock pressures [6-9]. However, the mean shock pressures of the Tenoumer melt rocks was found to be much lower than that required to melt quartz, supporting the notion of preferential melting of grains (or parts of grains) resulting from heterogeneities within the host rock [11].

Discussion and Conclusions: Impact ejecta from the Tenoumer impact crater show a rich array of shock features. In a reappraisal of melt rock samples and the first analysis of non-melt ejecta, it is clear that the Tenoumer ejecta preserves the stratigraphic inversion expected with impact cratering. Samples collected from the rim and the closest ejecta blanket are interpreted to be the most deeply excavated material. They contain no shock indicators and both texturally and are compositionally identical to target rocks preserved on the crater floor [3,4]. Samples collected more distally from the rim, show no PDF's in quartz, but do contain grain scale deformation features (e.g., PF's) in both quartz and feldspars that suggest lower shock pressures (<10 GPa). In these samples, deformation lamellae within albite twins are similar to those described in other impact structures [12,13] (figure 1). These samples also contain anhedral microcline inclusions within feldspar which do not appear to be in equilibrium with the host grain and are interpreted to be recrystallized from (diaplectic?) glass. Additionally, these samples contain quartz grains that show Planar Fractures parallel to the $\{10\bar{1}3\}$ and $\{51\bar{6}1\}$ planes (figure 2). Combined features in both feldspars and quartz are consistent with low level shock.

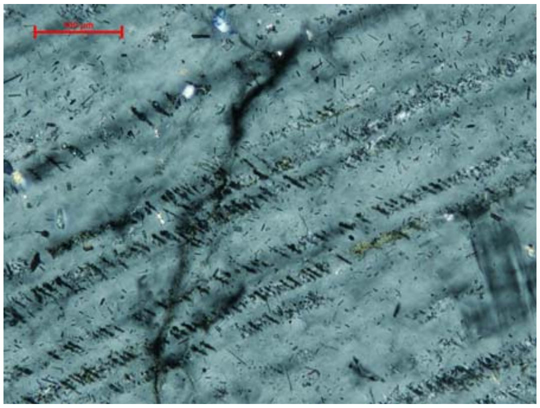

Figure 1: Feldspar grain from a sample of crystalline ejecta (TAL) showing parallel lamellae occurring in albite twins, which are interpreted as possible low level shock features.

This study highlights one of the continuing struggles in understanding impact cratering, particularly that of small simple craters. The majority of shock deformation studies have focused exclusively on quartz deformation fabrics, and shock barometry methods are calibrated to PDF's in quartz. The absence, therefore, of PDF's in quartz in ejected material makes it impossible to detail the full range of shock pressures represented in the ejecta blanket.

The impact process, however, also preserves other petrographically traceable effects on material ejected at lower pressures than those required to form PDF's in quartz. The lower pressure deformation in the Tenoumer samples demonstrate the need for additional calibration at the low-end of impact barometry, using quartz as well as other minerals (e.g., feldspars). Such calibration will expand the utility of petrography in constraining shock pressures during impacts. Ultimately, spatial investigations of shock pressures will provide greater understanding on the distribution and attenuation of shock during the impact of a wide range of lithologies.

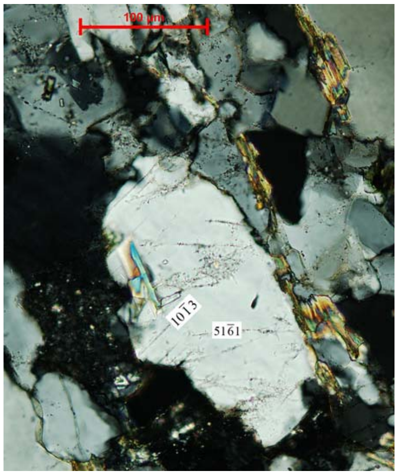

Figure 2: Planar Fractures (PF's) in quartz from the crystalline sample (TAU) parallel to the $\{10\bar{1}3\}$ and $\{51\bar{6}1\}$ crystallographic planes.

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