AOROUNGA AND GWENI FADA IMPACT STRUCTURES, CHAD, CENTRAL AFRICA: PETROLOGY AND GEOCHEMISTRY OF TARGET ROCKS.

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Summary: Rocks - mainly sandstones - from two impact structures in Chad, Aorounga and Gweni Fada, were studied for their petrographical, geochemical, and isotopic characteristics. The rocks have chemical and isotopic compositions that are typical of the upper continental crust. No clear signature for the presence of a meteoritic component was found in any of the samples. In rocks from both craters, abundant evidence for shock metamorphism was found in the form of multiple sets of planar deformation features in quartz, confirming the impact origin for both structures. Their crystallographic orientations indicate a fairly high shock level and are characteristic for the orientations observed in sandstones, with the higher frequencies being fairly abundant.

Introduction and Geology: In 1994, only 15 confirmed impact structures were known in Africa [1]; since that time, three new African impact structures have been identified: the small 220 m diameter Sinamwenda crater in Zimbabwe, the 14 km diameter Gweni-Fada complex crater in Chad (see below), and the large (200 km diameter) Morokweng impact structure in South Africa (e.g., [2]). While detailed geological mapping and sampling expeditions have not yet been done at the two craters in Chad (the only ones known so far in an area of about 1.28 million km^2), we are using the existing sample suite to provide a more detailed understanding of the petrological and geochemical variation of the crater rocks.

The circular depression of Aorounga (Fig. 1), which is included on some geological maps, has a diameter of 12.6 km and is situated in Northern Chad, about 110 km southeast of the Emi Koussi volcano in the Tibesti Massif. French researchers have collected a few samples from the structure, which show evidence of shock metamorphism [3]. The host rock of the crater is a fine-grained, well-sorted, carbonate-bearing sandstone of probably Upper Devonian age. However, the structure was described in an earlier photogeological study by Roland [4], who concluded that it is a diapir. The structure has an outer and an inner ring wall, which both rise about 100 m above the mean level of the surrounding plain. The two rings are separated from each other by a depression of uniform width. A central uplift is located near the center of the central depression. The sandstones forming the outer ring dip steeply towards the depression. No age information is available for Aorounga.

The second impact crater in Chad, the 14 km diameter Gweni Fada structure, was first noted on Landsat images and aerial photography, and later visited on the ground by a French team, who reported that preliminary petrographic studies showed the presence of shock metamorphic effects in quartz grains from sandstones [5]. The structure is asymmetric and appears deeply eroded. An external depression, with a diameter of 12 km, forms a crescent around two thirds of the inner disturbed zone. The external limit of the depression is pronounced and marked by steeply dipping sandstones. The depression is surrounded on the north side by an elevated outer ring of outward dipping sandstones. On the south side the external depression is absent, but tilted or folded sandstones are present [5]. The inner zone, with a diameter of about 10 km, consists of a rugged terrain with hills of several hundred meters elevation. Sandstones show no uniform dip direction. The structure is exposed within Upper Devonian sandstones; the Precambrian basement was not found to be exposed in the central uplift.

Samples and Methods: We obtained 15 samples from the Aorounga impact structure and 6 samples from the Gweni Fada impact structure. Petrographic thin sections of these samples were studied by optical microscopy to classify the rock type and to study any evidence of shock metamorphism, if present. In addition, major and trace element analyses were done on powdered samples by standard X-ray fluorescence (XRF) and instrumental neutron activation analysis (INAA) procedures. Crystallographic orientations of the planar deformation features (PDFs) were measured on the optical microscope using a universal stage with 4 axes. Rb-Sr and Sm-Nd isotopic compositions of some samples were determined by mass spectrometry.

Results: Our samples from the Aorounga structure are derived from the top or outer slope of the inner ring structure (cf. Fig. 1). We conclude from our petrographic studies that all these samples represent normal quartzite or sandstone without any unusual properties. Lithologically, a number of rock types have been sampled, including pure orthoquartzite, quartzites and sandstones of variable grain size and grain shape distributions, hematite-cemented sandstone, as well as arenites of variable degrees of recrystallization. These samples are shock metamorphosed to variable degrees. This ranges from unshocked rocks to evidence of low (short microfractures are present in quartz), moderate (single sets to PDFs in only a few quartz grains per thin section), to high degree of shock metamorphism. In the latter case, nearly every quartz grain shows at least one, but frequently up to five sets of different crystallographic orientations. Two to three sets of PDFs are most abundant. In a few barely deformed samples, no shock-characteristic deformation effects were found, but indications of compression, such as short fractures emanating from a contact point between two quartz crystals, were observed. The results of the orientation measurements show clearly that the shock-characteristic orientations (0001), {1013}, {1012}, {1122}, {1011}, and {2131} are present. A histogram showing the orientation of the poles of the PDF planes relative to the c-axis of the quartz grains is given in Fig. 2.

Unfortunately only a limited number of samples from Gweni Fada was available for our study. These samples also represent a suite of arenitic lithologies, including quartzite, hematite-stained sandstone, a pebbly sandstone, and a quartz conglomerate. They are derived from various locations of the central disturbed area, as well as from the outer margin of the ring depression. Some samples are apparently unshocked, but display minor evidence of compressional deformation. Others contain few to abundant grains with single or multiple sets of PDFs, with two sets of PDFs being most common. Fig. 3 shows the orientations of PDFs in quartz from Gweni Fada. In addition, local brecciation in the form of micro-veins of cataclastic material or off more pervasive brecciation was noted in individual specimens. It appears as if the presence of cataclastic zones is limited to samples that have very few or no PDFs (i.e., shock pressure < 15 GPa).

In terms of chemistry, the major element abundances show no surprises. All samples are silica rich and of typical sandstone composition. With the exception of some samples that show hematite-staining, the SiO_2 contents range from about 88.4 to 97.7 wt%. Other major elements show a somewhat wider range in abundance, which is mainly due to the presence of variable amounts of hematite and alteration products in the matrix. The limited variation is reflected also by the trace element compositions, which are typical of crustal rocks. The chondrite-normalized rare earth element patterns are also typical for upper crustal rocks, with La_N/Yb_N ratios of about 10 and minor to moderate negative Eu anomalies. A crustal source of distinct composition is also evident from the isotopic composition (presently available values are: ε_{Sr} +177 to +222, ε_{Nd} -6.4 to -13.9). No obvious siderophile element anomalies have been observed in any of the samples. Only one sample from Aorounga (a highly shocked rock, possibly a breccia) shows an Ir concentration barely above the detection limit at about 0.25 ppb, with somewhat elevated Ni values. No clear evidence for the presence of an extraterrestrial component was found in any of the samples.

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Fig. 1. Space Shuttle image of the Aorounga impact structure. North is up.

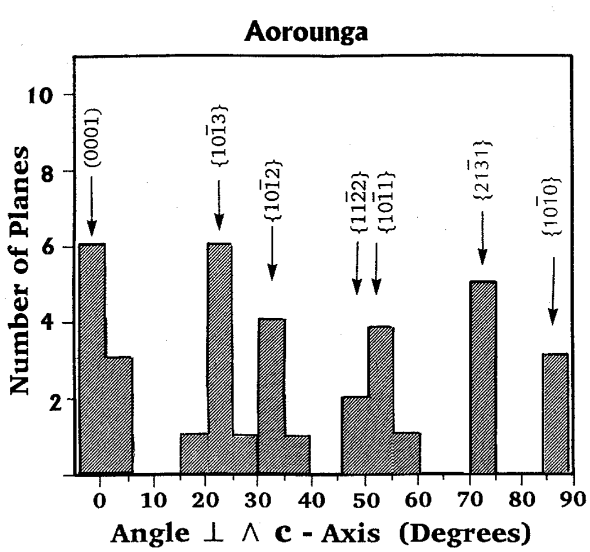

Fig. 2. Crystallographic orientation of PDFs in quartz from the Aorounga structure; 38 planes in 22 grains.

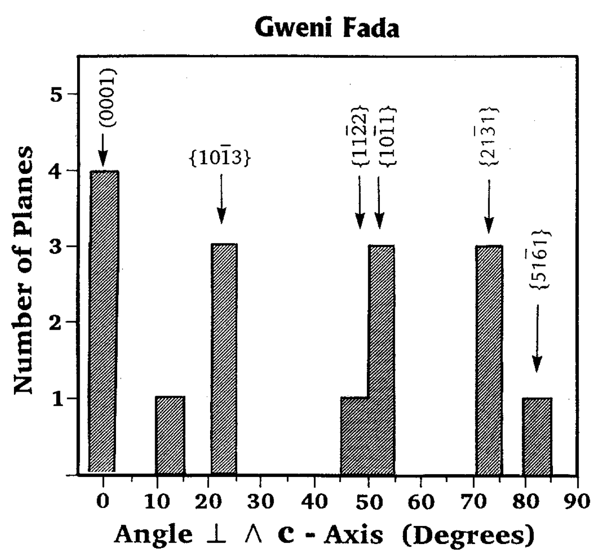

Fig. 3. Crystallographic orientation of PDFs in quartz from the Gweni Fada structure; 16 planes in 10 grains.