CERRO DO JARAU AND SÃO MIGUEL DO TAPUIO: TWO NEWLY CONFIRMED, LARGE IMPACT STRUCTURES IN BRAZIL. A. P. Crósta[1], W. U. Reimold[2] and M. A. R. Vasconcelos[3]
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Introduction: Cerro do Jarau (CdJ) and São Miguel do Tapuio (SMT) are two large circular structures that have been suggested [1,2,3,4] for some time to be formed by meteorite impact events. CdJ is located in Rio Grande do Sul State, southern Brazil, near the border between Brazil and Uruguay, centered at 30º12´S and 56º32´W. It has a diameter of ca. 13.5 km (Fig. 1a). SMT is located in Piauí State, northeastern Brazil, centered at 5°37.6′ S, 41°23.3′ W, and has a diameter of 20 km (Fig. 1b). Limited evidence for impact origin has been provided for CdJ and none for SMT. We present the results of detailed optical microscopic analysis of sandstone samples from both these structures that unveiled, for the first time, such evidence, in the form of shock deformation features in quartz grains.

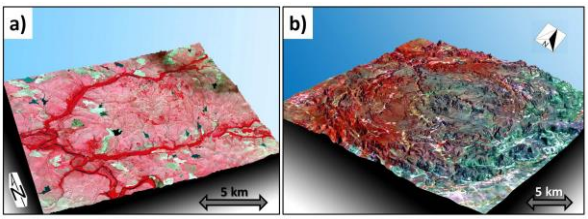

Figure 1 Perspective views of the Cerro do Jarau (a) and São Miguel do Tapuio (b) impact structures generated from ASTER satellite images and GDEM digital elevation data.

Geological background: CdJ represents a conspicuous circular feature in the otherwise flat "pampas" terrain typical of the regional landscape of the borders between Brazil, Uruguay and Argentina. The structure was formed in target rocks comprising basaltic flows of the Jurassic-Cretaceous Serra Geral Fm., which is part of the Paraná-Etendeka Large Igneous Province, as well as regionally underlying sandstones of the Botucatu and Guará formations. These stratigraphic units are part of the Phanerozoic Paraná Sedimentary Basin and are undeformed outside the CdJ structure. Sandstones from the Botucatu and Guará units are exposed at the center of the structure, in a ring of hills which rise up to 200 m above the surrounding terrain, comprising deformed and recrystallized quartzose rocks.

SMT forms an equally remarkable circular structure formed in sedimentary strata of the Phanerozoic Parnaíba Basin, mostly sandstones of the Devonian Pimenteiras and Cabeças formations. Likewise, these stratigraphic units exhibit virtually no deformation outside the structure, whereas in its interior they show different degrees of deformation, mostly characterized by fracturing.

Searching for shock deformation: A number of studies have been conducted over the years at these two structures in order to investigate their nature and origin. Although the results have mostly pointed at an impact origin, no robust and conclusive evidence in the form of diagnostic shock deformation features has been produced to date. Therefore, the impact origin postulations have been based on the occurrence of anomalous deformation of the otherwise undeformed sedimentary and volcanic (in CdJ), and sedimentary (in SMT) rocks, as well as interpretation of geophysical data. The latter comprise geophysical signatures similar to impact structures elsewhere, as well as indication of absence of endogenous geological processes that might have formed these large structures [4]. We have recently conducted field surveys at CdJ and SMT, and thin sections of samples have been extensively analyzed using optical microscopy. This revealed conclusive evidence of high-pressure (>7 GPa) shock features in the form planar deformation features (PDF) in quartz grains from CdJ and SMT, as well as other microdeformation features formed at lower shock pressures, such as feather features (FF) and planar fractures (PF). At CdJ, a relatively extensive set of about 250 samples could be analyzed [5]. For SMT only a dozen samples showing notable deformation could be found and examined in thin sections, of which only a few provided positive results.

Results: At Cerro do Jarau deformation includes all three types of planar features (PDF, FF and PF) (Fig. 2), together with non-planar ones, and appears to be spatially distributed in a heterogeneous way. Even in the innermost part of the structure, unshocked and significantly shocked samples may occur at the same site, or at least in close vicinity, and PDF have been detected in samples from the presumed edge of the central uplift. Different categories of deformation degree do not appear to form a regular pattern. Rather the various categories are found scattered over the entire area. The outermost shock deformed samples come from about 3.5 km from the apparent center of the structure. PDFs were detected mostly but not exclusively in samples from up to ca. 2 km from the center. The furthest oc-

currence away from the center lies at about 3.5 km distance. All the PDFs observed are generally short and mostly occur at host grain edges [6].

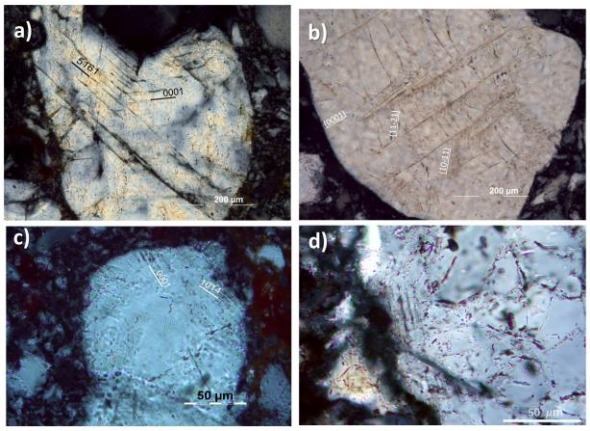

Figure 2 a) Quartz grain exhibiting Planar Fractures (PF) oriented along (0001) and $(51\bar{6}1)$. b) Quartz grain exhibiting PF and Feather Features (FF); PFs are oriented along the basal plane (0001) and the microfractures formed from them are oriented at $\{11\bar{2}1\}$ and $\{10\bar{1}1\}$. c) Two sets of short PDFs near the border of a small quartz grain; the sets are oriented parallel to (0001) and the $\{10\bar{1}3\}$. d) Other sets of PDF also near the border of a quartz grain.

The thin sections from SMT that were analyzed are from sandstone and monomict sandstone breccia collected at ca. 1 km from the center of the structure. The sandstones revealed mostly non-shock features, such as extensive but irregular, non-planar fracturing. The breccia unveiled both low-pressure shock features (FF and PF), as well as higher pressure PDF (Fig. 3). However, there are admittedly just a few samples, collected at nearby locations, that did reveal bona fide shock features, whereas the majority of samples at hand only showed non-shock deformation. Difficulties in collecting samples at the central portion of SMT include, first, the lack of access (there are no tracks or trails) to a very rugged terrain, which is covered by dense thorny vegetation, and, second, the pronounced degree of erosion and laterization of the local rocks, which make it very difficult to find adequate rock samples for further analysis. However, based on the positive results achieved so far, future field campaigns are planned for an in-depth analysis of the geology and shock deformation of the sandstones at SMT.

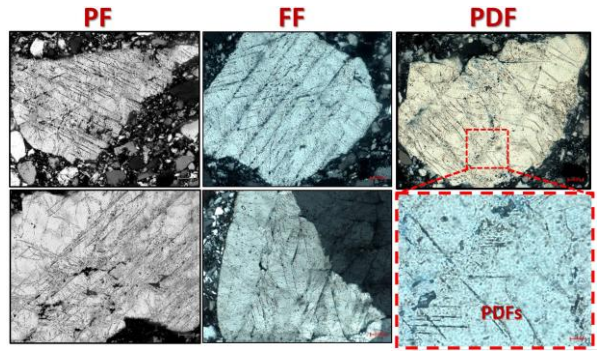

Figure 3 Shock deformation features identified in the monomict impact breccia of São Miguel do Tapuio. Planar Fractures (PF – left), Feather Features (FF – center) and Planar Deformation Features (PDF – right).

Conclusions: As PDF are exclusively formed at shock pressures above ca. 7 GPa, its occurrence in supracrustal rocks such as the sandstones at CdJ and SMT is diagnostic of meteorite impact deformation. As a consequence of the identification of shock features in quartz grains from arenites of Cerro do Jarau and São Miguel do Tapuio, these two structures have been conclusively demonstrated to be the result of meteorite impact events. They are, respectively, the 7th and 8th confirmed impact structures in Brazil. São Miguel do Tapuio, at 20 km diameter, is the second largest impact structure known in South America.

References:

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