THE RIACHÃO RING IMPACT STRUCTURE, NORTHEASTERN BRAZIL: RE-EVALUATION OF ITS STRATIGRAPHY AND EVIDENCE FOR IMPACT. M. V. Maziviero[1], M. A. R. Vasconcelos[1], A. M. Góes[2], A. P. Crósta[1], and W. U. Reimold[3]. [1]Institute of Geosciences, University of Campinas, Brazil, (mariana.maziviero@ige.unicamp.br), [2]Institute of Geosciences, University of São Paulo, Brazil, [3]Museum für Naturkunde, Leibniz Institute at Humboldt Universität Berlin, Germany.

Introduction: The Riachão impact structure, located in Maranhão State of northeastern Brazil (S7º42', W46º38'), is a 4.2 km diameter, semi-circular complex structure, which was formed in a target consisting of Pennsylvanian (Upper Carboniferous) to Permian sedimentary rocks of the Parnaíba Basin. A hypervelocity impact origin of the Riachão structure was already suggested in the 1980s by McHone [1]. He published the first geological map of the Riachão structure and documented the presence of breccia on the rim and reported on quartz grains with sets of planar fractures parallel to $(10\bar{1}3)$, $(51\bar{6}1)$ and $(10\bar{1}2)$ .However, he did not present definite evidence for an impact origin of the structure. Through remote sensing datasets (ASTER DEM and CBERS-2B/HRC), we identified that the Riachão structure rises to a maximum of 50 m above the surrounding terrain, whereas the central uplift rises about 30 m above the floor of the structure. Based on field work and petrographic analysis we studied the sedimentary units present at the structure and compared the local stratigraphy against the one previously reported for the structure [1]. Moreover, we found microscopic shock-diagnostic evidence in samples from the central uplift.

Geological Setting: The region containing the Riachão structure is located in the Parnaíba Basin. The strata in the Riachão area are part of the depositional sequence of the Balsas Group. The Balsas Group is composed of the Piauí, Pedra de Fogo, Motuca and Sambaíba formations. Regional stratigraphic surveys were carried out in the Parnaiba Basin in the early 1950's as part of petroleum exploration efforts. One stratigraphic borehole was drilled 35 km to the north of Riachão (1VG-0001R-MA, 2887 meters deep), providing information about the thickness of the formations addressed in this work: Piauí, Pedra de Fogo and Motuca. The Pennsylvanian Piauí Fm. consists of a sequence of sandstones interbedded with shales deposited in a fluvial-eolian environment. The total thickness does not exceed 300 m in this region. The Early Permian Pedra de Fogo Fm. is characterized by sandstones, siltstones and calciferous shales alternating with chert; its depositional environment is interpreted as near-shore marine, with warm, arid or semi-arid conditions. This formation has a maximum thickness of 150 m. The Middle to Late Permian Motuca Fm. is characterized by brick-red fluvial sandstones with some limestones, dolomites and anhydrite, deposited in a dry environment, with a maximum thickness of 120 m. The Sambaíba Fm. forms the youngest lithostratigraphic unit of the Balsas Group and was deposited during the Early Triassic. It comprises well sorted sandstones with typical sedimentary structures including large high-angle sets of cross-beds. This formation was deposited in a dry climate and contains eolian sand dunes, and its maximum thickness is 200 m [2].

The rocks of the Balsas Group are not affected by any tectonic or local deformation events elsewhere in this portion of the Parnaíba Basin. Deformation is limited to occasional gentle warping at large amplitudes of tens of meters.

Geology of the Riachão Structure: We analyzed the structure combining remote sensing data and geological field observation (~120 reference points), and with petrographic examination of rock samples. Based on morphologic characteristics of the Riachão structure, it was subdivided, from the periphery to the center of the structure, into: (1) an elevated rim; (2) an annular depression; and (3) a central uplift.

(1) The current geometry of Riachão's rim is similar to that of a horseshoe, with an opening in its northwestern part. The top of the crater rim comprises sedimentary breccias and lithic sandstones. These breccias are massive, poorly sorted, and matrix-supported, with 20-30% subangular clasts (0.2-10 cm) of sandstone similar to the sandy quartz matrix of the breccia. The lithic sandstone exhibits small-scale cross-bedding, is composed of quartz with characteristics similar to the matrix of the breccias, and local concentrations of sandstone clasts (0.2 – 3 cm). Both the breccias and the lithic sandstones are tilted with dip angles > 40º and dip direction usually towards the opening of the crater rim in the northwest (Fig. 1).

(2) The annular depression is floored by laminated siltstones and calcilutites, with dip angles of up to 10-20º in ENE-WSW or NW-SE directions. At the transition from the annular depression to the central uplift and along the rising slope of the central uplift, we observed brecciated cherts.

(3) The central uplift exhibits a slightly elliptical shape with a NW-SE diameter of 1.5 km and a maximum width of 1.1 km in the perpendicular direction. The central uplift mainly exposes fine- to medium-grained sandstones with dip angles of up to 55-80º in

all possible directions. In thin sections, this sandstone shows a high proportion of comminuted and sharp-edged quartz grains, mixed with rounded grains.

Microscopic Features of Shock Origin: Petrographic analysis provided evidence of shock-diagnostic planar deformation features (PDF) only found in a single sample of sandstone from the central uplift (Fig. 2). In addition, planar fractures (PF) and feather features (FF) were observed regularly in samples from the central uplift. The fragmentation to angular "shards" after rounded quartz grains is also designated as likely impact-related deformation

Discussion: Our main findings are:

(1) The rim of Riachão is formed by breccias and lithic sandstones that lack clasts from a variety of lithologies. These rocks exhibit sedimentary features and lack shock deformation. This suggests that there is no accumulation of ejected material, as previously interpreted by [1]. The evidence suggests that breccias and lithic sandstones were deposited by high-energy flow and were lithified before the impact event, which was responsible for the tilting of the layers. Furthermore, [1] interpreted the rim as made up of erosional remnants of cross-bedded Sambaíba sandstone. However, our regional field data suggest that the Sambaíba Fm. does not outcrop in this portion of the basin. Our stratigraphic and sedimentary analysis indicates that Pedra de Fogo Fm. constitutes the youngest sediments affected by the impact event that occur in the outer parts of the Riachão structure. Although there is no radiometric age for this formation, preliminary palynological analyses indicate a minimum age of 260 – 251 Ma (Upper Permian) [3] – thus, giving a maximum age for the impact event.

(2) The annular depression exposes rocks typical of the Pedra de Fogo Fm., in contrast to the interpretation by [1], who thought that this terrane contained rocks of the Motuca Fm. The in situ brecciation of the rocks may be due to the impact.

(3) The central uplift is probably formed by chaotic blocks and folded beds of Piauí sandstone - although we did not find contact relationships in the field, nor diagnostic sedimentary features for this formation. However, the stratigraphic uplift, estimated by the relationship [4] proportional to the diameter of the structure, is consistent with outcrop of Piauí Fm. Unlike the proposal by [1], the Motuca Fm. does not outcrop on the central uplift.

Conclusion: We propose changes in the stratigraphy of the Riachão impact structure and present new shock deformation evidence. However, it should be noted that the advanced degree of erosion of the Riachão structure limits its geological characterization due to the limited exposure of shock affected rock. Severe erosion also explains the absence of the original crater rim, the remnants of ejecta on top of the rim and outside the structure, shatter cones in the exposed sandstones, and of crater-fill impact breccia, as well as the seriously restricted evidence of microscopic shock effects.

References: [1] McHone J. F. (1986) Terrestrial impact structures: Their detection and verification with two new examples from Brasil. Ph.D. thesis. University of Illinois, USA, 210 p. [2] Lima, E. de A. M. and Leite, J. F. (1978) Projeto estudo global dos recursos minerais da bacia sedimentar do Parnaíba. Final report of phase III, DNPM-CPRM, v.1., 115-149 p. [3] Souza, P. A., (2011) pers. commun. [4] Grieve R. A. F. et al (1996) *Meteoritics & Planet. Sci., 31,* 6-35.

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Figure 1. Field photograph of lithic sandstone tilted and located at the Riachão rim.

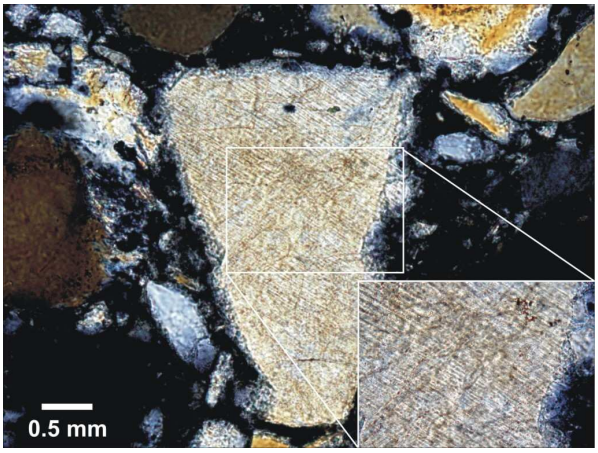

Figure 2. Photomicrograph of sample collected from central uplift. Shocked Piauí sandstone with quartz containing one set of PDF.