GEOPHYSICAL SIGNATURES OF THE RIACHÃO IMPACT STRUCTURE, BRAZIL. M.A.R. Vasconcelos[1], A.P. Crósta[1], M.V. Maziviero[1], E.C. Molina[2], and W.U. Reimold[3]. [1]Institute of Geosciences, University of Campinas, Campinas, SP, Brazil (vasconcelos@ige.unicamp.br,); [2]Astronomical and Geophysical Institute, University of São Paulo, SP, Brazil; [3]Museum für Naturkunde, Leibniz Institute at the Humboldt-Universität Berlin, Berlin, Germany.

Introduction: The Riachão impact structure, centered at 7°42'S/46°38'W, is a complex impact structure of ~4 km diameter with a 1.4 km wide central uplift that is located in Maranhão State, northeastern Brazil. It was formed in Phanerozoic sedimentary rocks of the Parnaíba Basin, which was developed over a Cambro-Ordovician rift system. Its sedimentary record comprises Silurian, Devonian and Carboniferous-Triassic sequences. Riachão was discovered by NASA astronauts during the 1975 Apollo-Soyuz Test Project. It is thought to have been substantially eroded, resulting in limited exposures of deformed bedrock (mostly sandstones). In the 1980s Riachão was studied by [1], but no clear impact evidence was found. Recent studies by the authors uncovered evidence that Riachão is indeed an impact crater, in the form of a rare PDF set in a quartz grain. Here, we present the geophysical signatures of Riachão based on gamma-ray spectrometric, magnetic and gravity studies. Gamma-ray spectrometry is usually not employed in the geophysical analysis of impact structures. However, cratering processes cause a number of physical/chemical changes in the bedrocks, including the remobilization of hydrothermal fluids, which may directly modify the composition of target rocks and, consequently, of the soils related to these rocks.

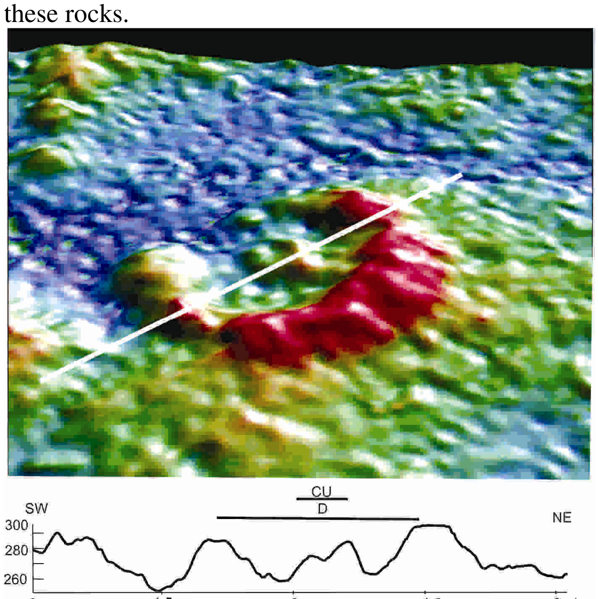

Figure 1- Topography derived from ASTER GDEM- Global Digital Elevation Model- over the Riachão impact structure and an elevation profile along the NE-SW direction (white line) indicating the structure's diameter (D) of ~4 km and central uplift (CU). Warm colors in the upper figure represent relatively higher elevations.

Magnetic data are frequently used to characterize impact craters, as they typically present a dominant, low magnetic anomaly that truncates the regional magnetic fabric [2]. These data are also used to characterize other shallow and thin magnetic sources that may occur in the annular basin of an impact structure. Gravity data can be used to define the limit of deformation in eroded craters, as in the case of Riachão.

Geological setting: Riachão crater has a slightly elliptical shape, with the major elliptical axis trending in NW-SE direction, as well as the central elevation with a diameter of 1.5 km. There is a regional trend of lineaments along NW-SE, a direction that coincides with the major elliptical axis. Based on limited bedrock exposures at the structure, the dominant stratigraphic unit in the outer parts of the crater seems to be the Permian Pedra de Fogo Fm. The outermost, horseshoe-shaped elevation comprises pre-impact brecciated sandstones, whereas the central elevation exposes outcrops of the Carboniferous Piauí Formation. This elevation is part of the eroded crater rim, which rises 30 m above the surrounding terrain. The rim exhibits a depressed sector in the northeast (Fig.1). Based on the target rock geology, the age of the structure can be stratigraphically constrained as <240 Ma.

Data processing: Data acquisition, sensor calibration and data processing were carried out in 2004-2006 by staff from the University of São Paulo (USP) and AGP-LA, contracted by the Brazilian National Petroleum Agency (ANP) [3,4] to a broad airbone survey. After the processing of the raw magnetic data we applied an upward continuation filter, ranging from 100 to 150 meters, in order to remove the remaining noise along the flight lines regional anomaly. Additionally, ground magnetic data were acquired by the authors along a 3 km long WNW-ESE transect crossing the eastern rim and passing through the annular basin. Data collection points were spaced at 50 m. On average, 3 measurements were collected at each point. The data were corrected for the diurnal variation, and the regional field was estimated as a constant value of 25023.1 nT, originating the residual magnetic anomaly pattern. The Bouguer gravity anomaly was obtained by applying the free-air, Bouguer, and terrain corrections, with the removal of the regional field following the robust polynomial technique [5].

Results: Gamma spectrometric data show low concentrations of K, Th and U along the crater rim in comparison with the other parts of the crater. Whereas the crater rim signatures correspond to about 0.3 wt%

K, 2.8 ppm Th and 0.6 ppm U the signatures over the surrounding areas correspond to approximatelly 1.6 wt%, 11.8 ppm and 2.3 ppm, respectively. The central uplift of Riachão also shows a strong gamma-ray sinature. A RGB image showing the combined distribution of these elements is shown in Fig. 2. The low quantity of radioactive elements is likely related to the strong weathering both within and outside of the strructure. This weathering process may have carried the elements into topographically lower areas in the neighborhood of the crater.

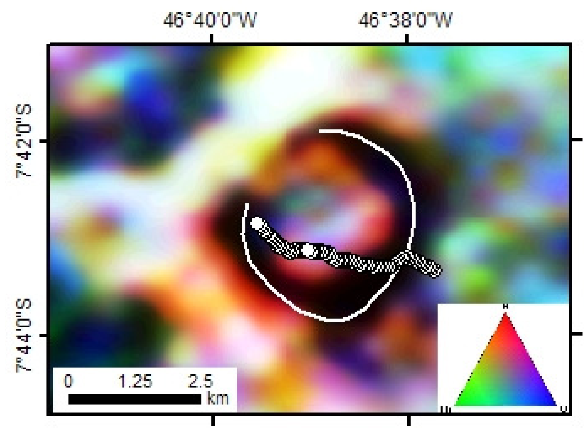

Figure 2- Concentrations of K, Th and U, shown as RGB ternary composition map. The white circles represent the points where magnetic data were acquired.

Magnetic data show a slight increase of values towards the east (Fig. 3) and there is a low magnetic anomaly at the crater rim in the east. The annular basin presents 3 positive peaks with short wavelenghts that are not obvious along the remaining profile. They certainly represent shallow and thin sources beneath the crater floor, and we consider that they may be related to magnetized bodies embedded during the modification stage, maybe representing impact breccia. Although Riachão is deeply eroded, these bodies may still represent remnants of breccia.

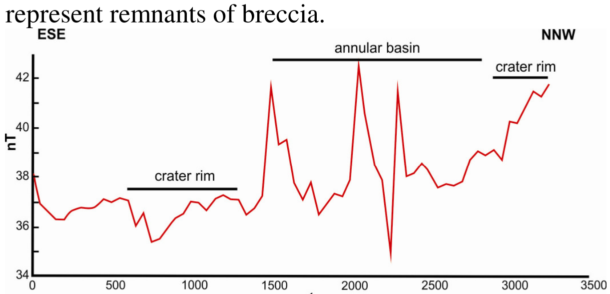

Figure 3- Magnetic profile across Riachão impact crater acquired along the WNW-ESE direction (compare with Fig. 2).

Concerning the gravity signature, Riachão is located within a regional negative anomaly (~-0.3 mGal). A unexpected positive and large wavelength anomaly is located in the region of the annular basin (Fig. 4) with peak value of ~0.3 mGal near the central uplift. It is known that usually many impact structures have residual negative Bouguer anomalies, the amplitudes of which are directly correlated with the crater diameter [2]. However, Riachão does not exhibit this typical gravity signature, possibly because of significant erosion. The positive anomalies observed could be related to relatively denser bodies in the target rock.

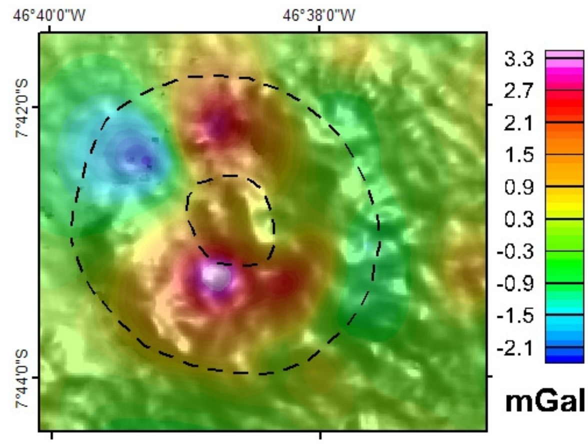

Figure 4- Gravity map of the Riachão impact structure superimposed onto topographic image. Dashed lines represent the outermost boundary of the structure and the outer limit of the central uplift.

Conclusions: Our geophysical analysis shows that gamma-ray spectrometry is a promising method to map impact structures. In this case, the rim and the central uplift of the Riachão structure were quite well delineated. The crater rim exhibits low concentrations of the three radiometric elements, whereas the interior of Riachão structure and the crater environs show relatively higher levels. Ground magnetic data allowed differentiating the rim from the annular basin that is characterized by the occurrence of short wavelength anomalies related to yet unknown shallow and thin sources. Finally, the gravity signature of Riachão shows two localized positive anomalies in the annular basin that do not have equivalents in the region around the crater. They may be related to the impact event, although further studies are necessary to prove it.

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] Pilkington M. and Grieve R.A.F. (1992) *Rev. Geophys.* 30, 161-181. [3] Horsfall K.R. (1997) *J. Austral. Geol. Geophys*. 17, 23-30. [4] Minty B.R.S., Luyendyk A.P.J. and Brodie R.C. (1997) *J. Austral. Geol. Geophys*. 17, 51-62. [5] Beltrão, J.F., Silva, J.B.C. and Costa, J.C. (1991) *Geophys.* 56, 80-89.