

Cover

The Serra da Cangalha astrobleme as revealed by ASTER and SRTM orbital data

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1. Introduction

Structural features caused by the impact of celestial bodies at the surface of the Earth always stir scientific interest. Different from natural geological processes like earthquakes and volcanic activities, these impacts instantaneously release huge quantities of kinetic energy that depends only on the mass and the velocity of the cosmic body. French (1998) postulates that the impact of a celestial body only a few kilometres in diameter can release more energy than the whole Earth releases in hundreds or thousands of years. Like a stone thrown at the surface of a pond, the impact of a cosmic body at the surface of the Earth radiates shock waves outward from the impact point. As a result, a crater is formed in a very short time, with rock being deformed, shattered, pulverized, and melted.

These ordinary cosmic events hold not only a geological interest. Scientists postulate that the shock of an asteroid or comet about 65 million years ago might have caused a dramatic change in the evolution of the terrestrial life. The Chicxulub crater in the Yucatán Peninsula, Mexico (Hildebrand *et al.* 1991, Morgan *et al.* 1997) is believed to be the site of that event. The impact would have released a large amount of dust as well as CO₂ and SO₂ gases from the melted sedimentary rocks. The resulting greenhouse effect suppressed photosynthesis and caused dramatic environmental changes at a global scale. The main consequence was the extinction of species, redirecting the biological evolution and favouring the subsequent domain of our ancestors, the mammals.

This cover shows the Serra da Cangalha astrobleme, the best preserved impact crater found in Brazil, as depicted by two modern sources of orbital remote sensing data: multispectral images acquired by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and terrain elevation data collected by the Shuttle Radar Topographic Mission (SRTM). As exemplified in the Serra da

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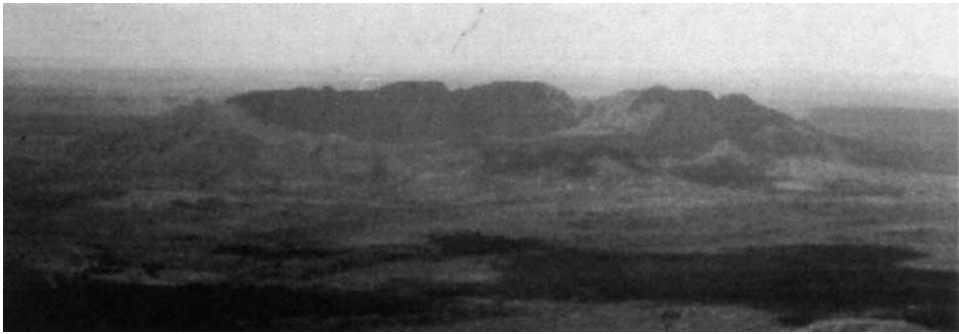


Figure1. Field photograph of the Serra da Cangalha astrobleme (source: Santos and McHone 1979).

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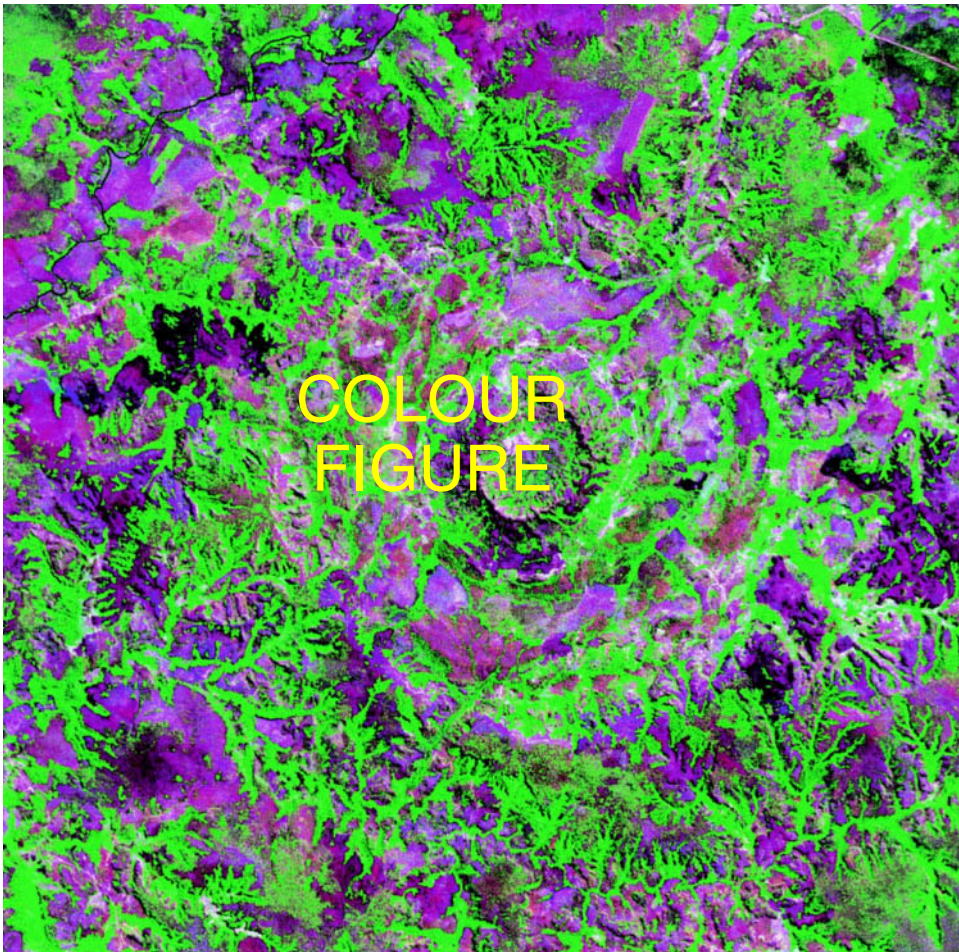


Figure2. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) colour composite (1B3G2R) of the Serra da Cangalha astrobleme (scene covers 24 km × 24 km; north is top).

Cangalha astrobleme, the use of multiple products generated from high-resolution remote sensing multispectral images and radar-derived digital elevation models (now available on a quasi-worldwide basis) can substantially improve structural interpretation of geologically complex terrain.

2. The Serra da Cangalha astrobleme

The impact crater of the Serra da Cangalha (Pack-Saddle Mountain) (figure 1) is located at the border of the Tocantins and Maranhão states, in northern Brazil with central coordinates of 46°51' west, and 8°04' south. The characteristic vegetation of this region is the Brazilian 'cerrado', a kind of savannah with riparian forests.

An outer ring of gentle hills (7 km radius) and an internal concentric bowl (2 km radius) rimmed by rock walls rising up to 420 m above the regional flatland, define the Serra da Cangalha structure. The presence of quartzite shatter cones near the centre of the site (Beatty 1980) indicates shock metamorphism and confirms an



Figure 3. Shuttle Radar Topographic Mission (SRTM) digital elevation model of the Serra da Cangalha astrobleme (heights vary from 235 m (black) to 655 m (white)). (Scene covers 24 km × 24 km; north is top).

impact origin to the structure. Blocks of fossil wood in the crest of the central uplift (mentioned by the same author) suggest that the impact occurred at the surface of the land.

The Serra da Cangalha impact scar is imprinted on undisturbed Permian sediments (Pedra de Fogo Formation) of the Parnaíba Palaeozoic sedimentary basin (Bruni *et al.* 1974). Within the central bowl occur deformed, steep dipping Carboniferous marine deposits of the Poti Formation. A similar structural pattern was also found in samples of Devonian shale of the Longá Formation in three 200-m deep holes drilled in this area by the Brazilian Geological Service (CPRM) (Dietz and French 1973). These findings indicate that high-pressure shock waves penetrated deep into the ground, putting large volumes of different sedimentary layers into motion, thus excavating the impact crater. These field evidences lead to an estimation that the impact would have occurred about 220 million years ago.

3. Remote sensing data and processing

The ASTER sensor aboard the TERRA platform was launched in December 1999. It is a high spatial resolution imager that collects data in three spectral regions: three bands in the visible/near-infrared, six bands in the short wavelength infrared, and five bands in the thermal infrared. The 15-m spatial resolution bands 1, 2 and 3 used here are centred at $560\ \mu\text{m}$ (green), $660\ \mu\text{m}$ (red), and $820\ \mu\text{m}$ (near-infrared) respectively (Abrams 2000). [1]

The other remote sensing data used were obtained by the SRTM, which collected elevation radar data to generate accurate digital elevation models (Rabus *et al.* 2003). A specially modified radar system flew onboard Space Shuttle Endeavour for 11 days in February 2000, covering most of Earth's land surface between the latitudes of 60° north and 56° south. To gather the topographic

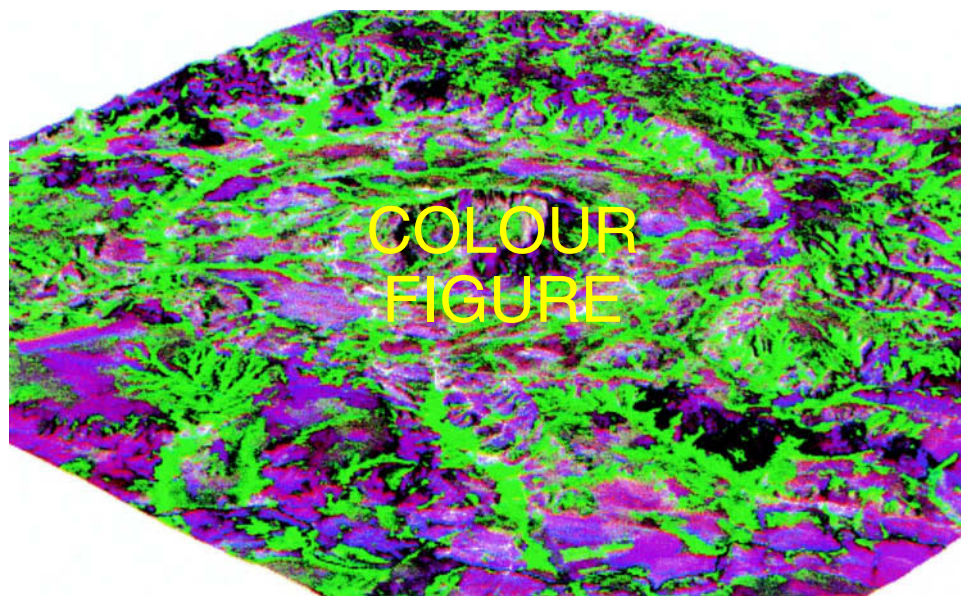


Figure 4. North-to-south perspective view of the Serra da Cangalha astrobleme obtained by merging an Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) colour composite (1B3G2R) and the Shuttle Radar Topographic Mission (SRTM) digital elevation model (diameter of the outer ring is approximately 14 km).

elevation data, the SRTM employed two interferometer systems in C- and X-bands. The technique of interferometry is based on the acquisition of two radar pulses from slightly different antenna locations. Two radar antennas were used: one was located in the shuttle's payload bay, and another at the end of a 60-m arm. Differences in time of the returning signal from a same area at the Earth's surface allow for calculating the relative height of the surface.

ASTER images acquired in September 2001 were geometrically converted to the Universal Transverse Mercator (UTM) coordinate system through a least squares first-degree polynomial rectification algorithm based on control points extracted from a topographic map at a scale of 1 : 100 000. After geometric correction, images were contrast stretched and combined into colour composites to enhance the main traces of the Serra da Cangalha astrobleme, as shown in figure 2.

National Aeronautic and Space Administration/Jet Propulsion Laboratory (NASA/JPL) produced the SRTM C-band elevation data at an approximately 90-m spatial resolution (<http://www.jpl.nasa.gov/srtm/>). In raster format data were co-registered to the ASTER images and resampled to 15-m spatial resolution. In the

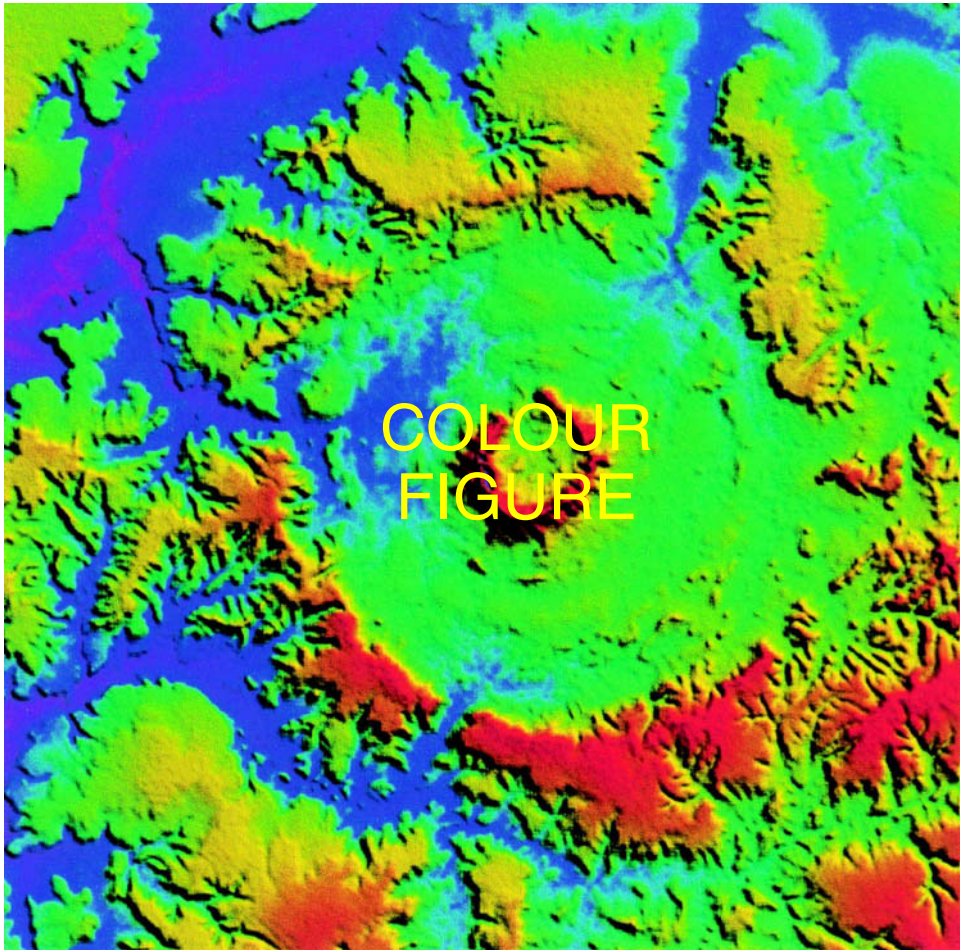


Figure 5. NE-SW shaded relief of the Serra da Cangalha astrobleme, with colour as height (scene covers 24 km × 24 km; north is top).

digital elevation model (figure 3) altitudes vary from 325 to 655 m, with lighter grey shades corresponding to higher altitudes (inner ring walls of the Serra da Cangalha structure). Different perspective views can also be created by merging ASTER images with the digital elevation model, as in the north-to-south view shown in figure 4 (also on the cover).

Shading and colour coding of topographic height were also used to enhance the Serra da Cangalha crater and its surroundings. The topographic slopes were computed to produce shaded digital elevation models as indicated in figure 5, which simulates the sun in northeast azimuth, resulting in bright northern slopes and shaded southern slopes. The colour coding follows the topographic heights, with magenta corresponding to the lowest elevations, changing to blue, green, yellow, and red as the topography elevates.

References

- ABRAMS, M., 2000, The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER): data products for the high spatial resolution image on NASA's Terra platform. *International Journal of Remote Sensing*, **21**, 847–859.
- BEATTY, J. K., 1980, Crater hunting in Brazil. *Sky and Telescope*, **59**, 464–467.
- BRUNI, M. A. L., ALMEIDA, J. T., and BRUNI, E. C., 1974, *Carta Geológica do Brasil ao Milionésimo-Folha Rio São Francisco (SC.23)*. Departamento Nacional da Produção Mineral, Brazil, 57 pp. [2]
- DIETZ, R. S., and FRENCH, B. M., 1973, Two probable astroblemes in Brazil. *Nature*, **244**, 561–562.
- FRENCH, B. M., 1998, *Traces of Catastrophe: A handbook on shock-metamorphosis effects in terrestrial meteorite impact structures*. LPI Contribution No.954, Lunar and Planetary Institute, Houston, TX, USA, 120 pp.
- HILDEBRAND, A. R., PENFIELD, G. T., KING, D. A., PILKINGTON, M., CAMARGO, A., JACOBSEN, B. S., and BOYNTON, W. V., 1991, Chicxulub crater: a possible Cretaceous/Tertiary boundary impact crater on the Yucatán Peninsula, Mexico. *Geology*, **19**, 867–871.
- MORGAN, J., WARNER, M., BRITTAN, J., BUFFLER, R., CAMARGO, A., CHRISSTESON, G., DENTON, P., HILDEBRAND, A. R., HOBIS, R., MANCINTYRE, H., MACKENZIE, G., MAGUIRE, P., MARIN, L., NAKAMURA, Y., PILKINGTON, M., SHARPTON, V., SNYDER, D., SUAREZ, G., and TREJO, A., 1997, Size and morphology of the Chicxulub impact crater. *Nature*, **390**, 472–476. [3]
- RABUS, B., EINEDER, M., ROTH, A., and BAMLER, R., 2003, The Shuttle radar topographic mission – a new class of digital elevation model acquired by spaceborne radar. *Journal of Photogrammetry and Remote Sensing*, **57**, 241–262.
- SANTOS, U. P., and MCHOME, J. F., 1979, Field report on Serra da Cangalha and Riachão circular features. INPE-1548-NTE/153, Internal Report, Instituto Nacional de Pesquisas Espaciais, São José dos Campos-SP, Brazil, 12 pp.

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