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LiDAR Views of the Serpent Mound Impact Crater

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There are 28 known meteorite impact craters in the United States (Earth Impact Database 2011). Of these craters, one is located in southwestern Ohio. Known as the Serpent Mound Impact Crater,[1] the center of this feature is at 39º.0356 N, 83º.4039 W, near the intersection of Adams, Highland, and Pike counties. In this brief article, LiDAR technology is used to generate perspectives of the crater that have not been seen before. From this, perhaps some insight can be gained as to why the Serpent Mound effigy is located where it is.

The Serpent Mound Impact Crater is named after Serpent Mound - a prehistoric Native American effigy mound shaped like a snake. Serpent Mound is situated in the southwest quadrant of the impact crater. The serpent effigy is about 424 m (1,388 ft) in total length, 0.9 - 1.5 m (3 - 5 ft) in height, and 2.6 - 6.2 m (8.5 - 20.5 ft) wide. The head of the serpent appears turned on its side, with open jaws. Situated partially within the jaws is an oval-shaped embankment variously interpreted as a sun symbol, egg, or eye of the snake. The serpent effigy has seven body convolutions and terminates in a three-coil tail. Two radiocarbon dates suggest the effigy dates to about A.D. 1070 (Fletcher, et al. 1996). However, since the charcoal that was dated did not come from a foundation feature or event, the A.D. 1070 date may not reflect when the effigy was actually constructed.[2]

In any case, recent thought is that the Serpent Mound Impact Crater was caused by meteorite impact between 256 and 330 million years ago (Baranoski et al. 2003:37). Milam (2010) suggests that the crater rim was originally about 14 km in diameter.[3] A meteorite impact of that magnitude would have devastated most life within a radius of 7 kilometers (4.3 miles), or 154 square kilometers (58 square miles).

Figure 1 shows a LiDAR image of the Serpent Mound Impact Crater.[4] Several structural features are visible: 1) a central peak or uplift area; 2) a transition area; and 3) a circular ring graben. New research by Milam (2010) suggests that remnants of the crater's east rim may also be visible.

Briefly described, the central peak or uplift area consists of Ordovician and Silurian-age rock. The area has been uplifted a minimum of 122 meters (400 ft) and possible maximum of 275 meters (900 feet) (Baranoski et al. 2003:3) and it is severely faulted and folded. Seven anticlines radiate outward from the center of the uplift area (Reidel et al. 1982:1349).

The transition zone is the area between the radial features of the central uplift area and the concentric faults of the outer ring graben. Topographically the region is lower relative to the two zones that surround it. The area is mostly Silurian rock.

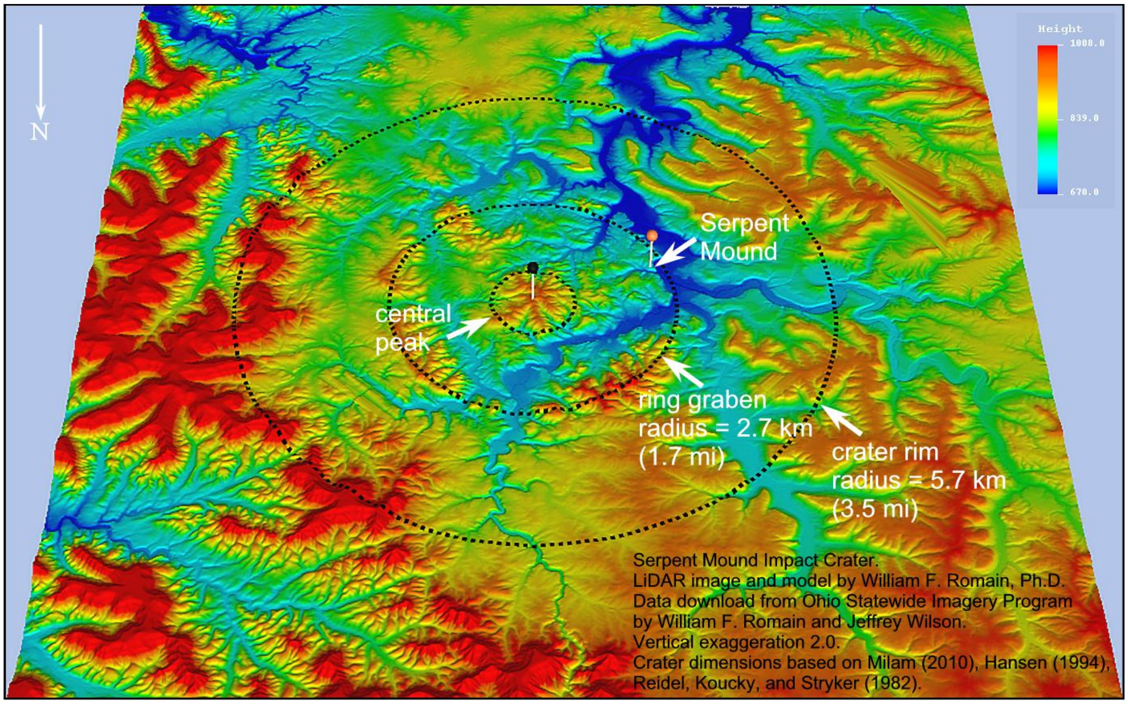

Figure 1. LiDAR view of the Serpent Mound Impact Crater. LiDAR image and model by William F. Romain. Data download from Ohio Statewide Imagery Program by William F. Romain and Jeffrey Wilson, accessed 12-2011. Vertical exaggeration 2.0. Crater dimensions based on Milam (2010), Hansen (1994), Reidel, et al. (1982).

The circular ring graben consists of Silurian to Mississippian-age rock (Reidel, et al. 1982). It is characterized by concentric faults. The center of the ring graben appears topographically elevated due to the erosional resistance of the Mississippian-age rock as compared to the less-resistant surrounding rock (see Hansen 1994:4 for an illustration of the phenomenon).

It is well-known that craters of this size exhibit not only a central uplift area and depressed floor, or ring graben, but also an outer rim. Prior to Milam's (2010) work, however, the rim of the Serpent Mound Impact Crater had not been definitively identified. Milam (2010:34) suggests that earlier identification of the crater's rim was hampered by the severely eroded nature of the rim on its west and southwest sides and glacial activity and deposition on the rim's northwest side.

In search of the crater rim, Milam utilized three approaches. First he made morphometric estimates for the size of the crater rim based on known ratios of central peak-to-rim distances. Next, he analyzed subsurface data from hundreds of logs for gas, water, and oil wells across the crater area. Using these data, he constructed a subsurface contour map showing the lateral extent of the structural deformation of the Devonian-age rocks across the area. Lastly, he examined dozens of topographic DEM profiles for traces of the crater. What he found was that a series of hills to the east match the modeled location for the crater rim. These hills conform to an arc that appears to represent the crater's rim. Considered together, these three lines of evidence led to one conclusion:

> The consistency of modeled crater diameter ranges using multiple techniques, the circularity of the eastern ridge and its conformity to the interior portions of the crater and the lateral extent and circularity of structural deformation all suggest that the maximum diameter of the Serpent Mound impact crater is approximately 14 km and that the circular ridge east of the disturbed area...represents the eroded remnant of the crater rim (Milam 2010:42-43).

Figure 2 shows a LiDAR profile through the impact crater. Visible in this figure are the central peak, ring graben, and posited crater rim.

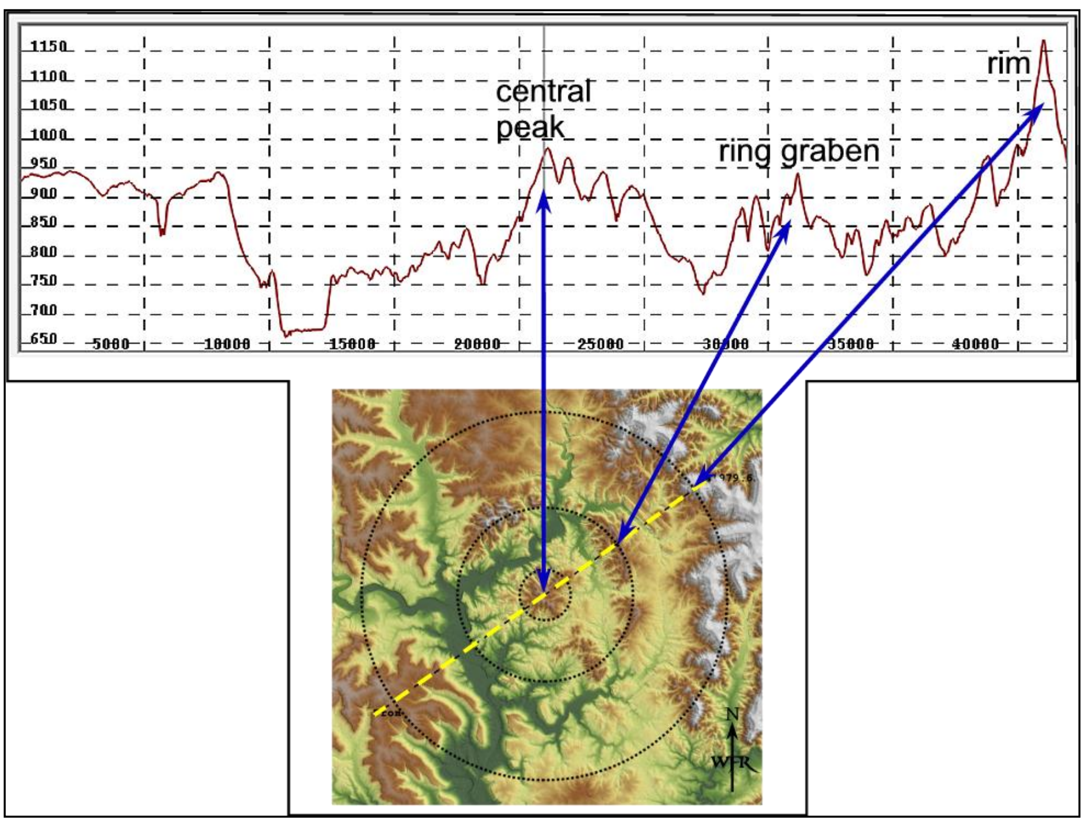

Figure 2. LiDAR profile across the Serpent Mound Impact Crater. Image and analysis by the author.

Discussion

Milam's work is a significant contribution to our understanding of the morphology of the Serpent Mound Impact Crater. Specifically, it demarcates the extent of a rare landscape feature. Although it is not known if early Native Americans - including the Serpent Mound builders, surmised that a meteorite impacted the area, it seems likely that, at minimum, the nature of the landscape within the impact zone would have been recognized as unusual. The uplifted, vertically-tilted, and down-dropped rock formations representing deviations exceeding 100 meters within the crater are impressive. Indeed the peculiar nature of the area led John Locke in 1838 to observe:

> ...it became evident that a region of no small extent had sunken down several hundred feet, producing faults, dislocations and upturning of the layers of the rocks....On traveling from Locust Grove to Sinking Spring, I found that a tract large enough for a township, reaching within a mile of Sinking Spring and extending several miles up Straight Creek, was in the same manner dislocated and sunken about four hundred feet....it is evident that this mountain at some remote period of time, has sunk down from its original place, and I venture to call it the 'Sunken Mountain' (Locke 1838:266-267).

If the jumbled landscape of the Serpent Mound Impact Crater was evident to John Locke in the 1800s, then, I would propose, it may also have been noticed by the builders of Serpent Mound - whomever they were. Given that, we can speculate that perhaps the unusual nature of the area contributed to selection of the present location for Serpent Mound. As such, the serpent effigy is appropriately situated in an area of highly disturbed rock formations on a grand scale - suitable evidence to mark the occasion, perhaps, when the Great Horned Serpent of Native American legend, rose from the depths of the Lowerworld and for a time, moved across the landscape - in this world.

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[1] Several theories have been proposed for the origin of the Serpent Mound disturbance feature. This has resulted in different names for the feature to include: Serpent Mound Cryptovolcanic Structure (Bucher 1936), Serpent Mound Disturbance (Reidel et al. 1982), Serpent Mound Cryptoexplosion Structure (Reidel 1975, Hansen 1994), and Serpent Mound Impact Crater (Milam 2010). Today, the preponderance of evidence (e.g., bedrock geology, planar deformed quartz, shatter cones, presence of iridium) suggests that the feature is the result of meteorite impact (Dietz 1960, Cohen et al. 1961, Carlton et al. 1998, Baranoski et al. 2003).

[2] The question of when the Serpent Mound was built is one of the questions currently being investigated by The Serpent Mound Project. Comprised of experts from a variety of fields, The Serpent Mound Project has been conducting Geoprobe coring, hand coring, magnetic gradiometer, electric resistivity, and other non- and minimally invasive techniques at Serpent Mound to learn more about the effigy (Romain 2011).

[3] Diameters for the central uplift, ring graben, and outer rim vary - depending on what methods are used to assess those variables (see e.g., Milam 2010:Table 1). For example, if the presence of shatter cones is used to estimate the extent of the central uplift, then the diameter of that feature is about 2.6 km. If, however, slope profiles are used, then the diameter ranges from ~ 4.6 to 5 km (Milam 2010:35). Complicating the matter is that the impact crater does not describe a perfect circle; rather, it is slightly elongated along its north-south axis.

In Figure 1, the drawn radius for the crater rim is a best fit approximation to prominent features visible in the LiDAR imagery and that are proposed by Milam (2010) as surviving traces of the crater's rim. As a result, the dimension for the crater rim provided in Figure 1 differs from the maximum value of 14 km provided by Milam (2010:43). Again, however, the dimension provided in Figure 1 is not intended as a maximum dimension. Moreover, the Figure 1 dimension falls within Milam's maximum and minimum diameter estimates for the rim.

[4] LiDAR is an acronym for Light Detection and Ranging. LiDAR directs a beam of near-infrared laser light to a target. The reflected light is then used to determine the distance to the target. In the case of aerial LiDAR, this distance information is combined with GPS (Global Positioning System) data. The result is a precise set of three-dimensional coordinates for a targeted point on the ground. Typically, thousands, or even millions of coordinate data points are next integrated by computer, with the result being a three-dimensional model of the ground terrain. For further discussion of what LiDAR is and how it works, see Romain and Burks 2008a, 2008b, 2008c.

Several small glitches appear in the Figure 1 LiDAR image. In these areas, the terrain appears flattened. This unfortunate result sometimes occurs when very large models are created. It appears that in these areas, the computer program is not able to link successfully the underlying LAS files.