MAPPING THE OUTER MARGINS OF THE SERPENT MOUND IMPACT STRUCTURE TO ASSESS THE LATERAL EXTENT OF DEFORMATION, ADAMS, HIGHLAND, AND PIKE COUNTIES, OHIO

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The Serpent Mound Impact Structure

The Serpent Mound Impact Structure is a heavily eroded complex impact structure that occurred between the Upper Devonian and Late Permian (Baranoski and others, 2003; Milam and others, 2010). It is located within Adam's, Highland, and Pike counties immediatley to the west of the Appalachian escarpment (Bucher, 1933, Reidel and others, 1982). It is named after a prehistoric effigy mound; The Great Serpent Mound, which sits on the western flank of the impact structure. The disturbance was first recognized in 1838 by John Locke who called it the "Sunken Mountain" because some of the hills inside the crater are comprised of downfaulted strata. Since then the origin of the structure was hypothesized have been caused by an explosive release of hydrothermal or volcanic gas but there is no evidence to support that interpretation. In 1961 the discovery of coesite bearing shatter cones by R.S. Dietz and A.J. Cohen Confirmed an impact origin.

Until recently the lateral extent of deformation associated with the impact was estimated to be 8 km in diameter (figure 1) (Reidel, and others 1982). That estimate corresponds to the extent of concentric normal faulting which is the most diagnostic feature of a crater rim (Kenkmann and others, 2014). Beyond 4 km from the crater center there is no clear evidence of a crater rim, but the annular morphology of the landscape suggests that it is associated with the impact structure.

Recent Investigations

In 2010 Dr. Keith Milam of Ohio University applied complex crater morphometery, morphologic analyses, and contact elevation to delineate the location or existence of rim features.

Findings

-Using the morphometric ratio where:

Central uplift diameter = (0.23 ± 0.03) final rim to rim diameter (Pike, 1985)

the crater is at least 10 km in diameter but no greater than 25 km.

-Basal Ordovician contact data compiled from other studies, well logs, and field work show that the base of the Ordovician is displaced downward up to 7 km away from the crater center.

-The average distance from the crater center to the highest point on a particular circular ridge surrounding the structure was found to be 6.01 km with a standard deviation of 0.455 km. This would give the topographic rim a diameter of 12 km

Purpose

The purpose of this study is to asses the lateral extent of deformation associated with the impact event by testing the hypotheses that the true crater rim diameter of the Serpent Mound structure is between 10 and 25 km, proposed by Milam (2010), and that evidence of a crater rim exists and has not been removed by erosion.

Figure 1

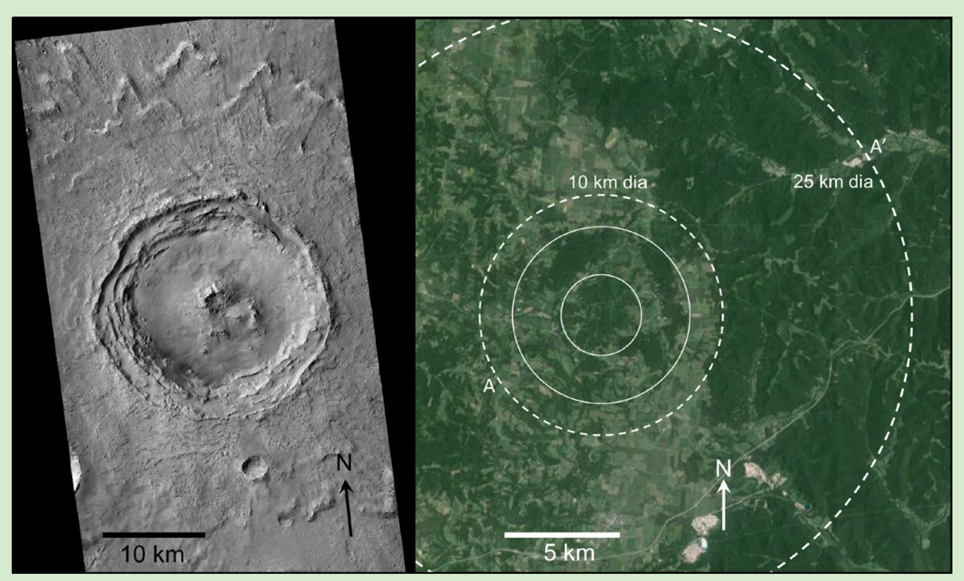


Figure 1. On the left is a visible gray-scale image of a well preserved complex impact crater on Mars from the Mars Reconnaissance Orbiter's Context Camera at 19.43° latitude and 312.07° longitude. The pronounced central peak and terraced rim show that this crater has undergone very little erosion compared to the Serpent Mound impact structure. On the right is a visible aerial image of the Serpent Mound impact structure courtesy of Google Earth, downloaded 2016. The inner solid ring approximately encompasses the central uplift, the outer solid ring represents the extent of the ring graben, and the two dashed circles represent upper and lower limits of the proposed rim to rim diameter (Reidel, 1975; Milam, 2010).

Methods

Field Work

Field work for this study was completed during June and July 2016 and some time spent again in January 2017. Data collected during field work included lithologic descriptions, geospatial data, and structural measurements. Data was collected from the outer margin of the impact structure approximately 5 km to 12.5 km away from the crater center based on the extent of deformation proposed by Reidel (1975) and Milam's (2010) largest proposed rim to rim diameter. Areas affected by glaciation were avoided because it is likely that the related erosion has removed rim structures. The area affected by glaciation is the northwest, west, and south of the impact structure so the study area was confined to the east.

Data Collection

Wherever there was outcrop with exposed bedding surfaces multiple strike and dip measurements were taken and averaged to reduce measurement error. Depending on the quality of the outcrop, between three and six measurements were taken at each site. It was important to distinguish between beds which have been mass wasted locally and those that have been tilted but remain intact due to the impact. Slump blocks of the Ohio Shale approximately 5 – 15 feet across were common throughout the field area. There were no exposures of the Bedford shale fit to measure strike and dip with, but the attitude can be inferred from those measurements taken from the overlying Berea sandstone. Bedding surfaces of the Peebles dolomite were often very vuggy and irregular so special care was taken to measure strike and dip by place a large flat object on the bedding surface to avoid letting the vugs influence the strike and dip measurement. Whenever measuring strike and dip of the vuggy Peebles dolomite and the laminated, fissile Ohio Shale, extra strike and dip measurements were taken to ensure accuracy.

The geographic positions of field sites were recorded using a Global Positioning System (GPS) and by triangulation on USGS quadrangle maps with a compass when possible. The GPS used was a handheld Garmin Colorado model 400t. A Brunton compass with an inclinometer was used to measure the strike and dip of bedding surfaces.

Cartography

The geologic map and cross sections were drawn using adobe illustrator. Basemaps are USGS 7.5 minute topographic maps. The map and cross sections were formatted using the Federal Geographic Data Commitee's digital cartographic standards for geologic maps.

Results

The amount of offset recorded in the contacts never exceeded nor approached the maximum amount of relief of the undisturbed strata, so no faulting could be reported. However, the average dip of the undisturbed rocks in the region is approximatley 2° to the east. Some of the dips recorded during this study were found to stray quite considerably from that average. Additionally bedding strike varied across the mapping area.

Conclusion

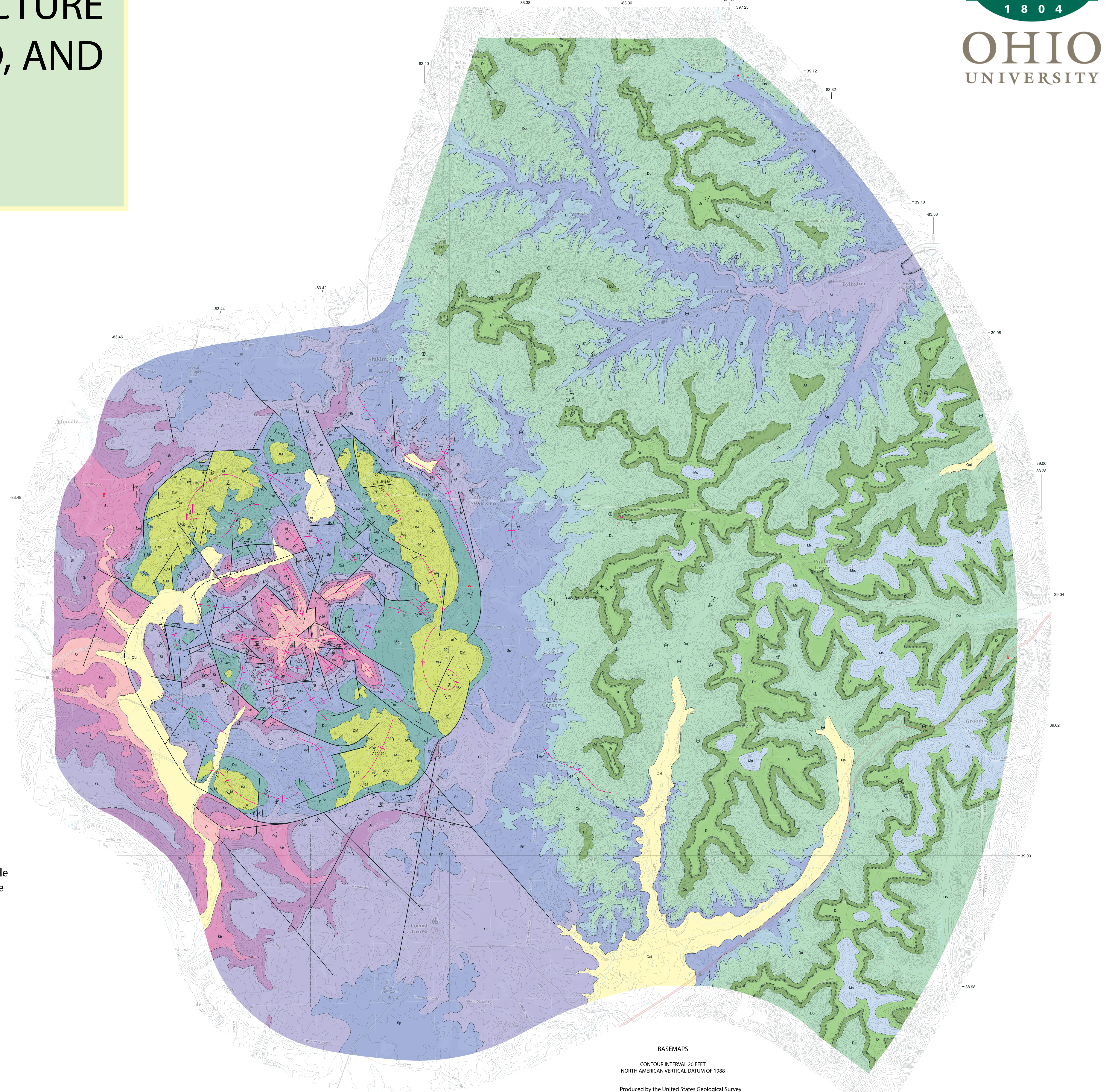
Based on contact elevations, there is no faulting, therefore erosion has removed the crater rim faults. The local variations in dips extend to approximatley 6.6 mi (10.5 km) from the crater center. They stray quite considerably from the regional dip which strongly suggests that they are associated with the impact. Listric normal faults are the primary structures that facilitates crater rim collapse (Kenkmann and others 2014).The crater has been extensively eroded so the present ground surface may be in close proximity to the base of listric normal rim faults. At the base of listric normal faults the primary component of displacement is heave rather than throw. The variable dips may be caused by heave induced compression at the base of rim faults causing minor folds to from. Another interpretation is that the minor folds are Radial compressional structures that form due to constriction of material as it is displaced downward and closer to the crater center (Kenkmann et al., 2014; Kenkmann et al., 2000). If either of those interpretations are true then the extent of lateral deformatoin associated with the impact event is approximatley 10 km from the crater center which confirms the hypotheses that the true crater rim diameter of the Serpent Mound structure is between 10 and 25 km, proposed by Milam (2010), and that evidence of a crater rim exists and has not been removed by erosion.

Key

- Contact
- Contact - location approximate
- Contact - location inferred
- Gradational contact
- Fault
- Fault - location inferred
- Sense of motion indicator
- Anticline
- Anticline - location approximate
- Anticline - Identity questionable
- Monocline - Identity questionable
- Monocline - location inferred
- Monocline - Identity questionable location inferred
- Syncline
- Syncline - location approximate
- Overturned anticline
- Quarry Boundary
- Geologic unit label
- Strike and dip of bedding
- Horizontal Bedding
- Core location
- A A′ Ends of cross section line

Geologic Units

- Qal — Quaternary Alluvium
- Ms — Missippian combined
- Mc — Cuyahoga Formation, Sunbury Shale Berea Sandstone and Bedford Shale
- Dr — Berea Sandstone
- Dd — Bedford Shale
- Dol — Ohio and Olentangy Shales
- Do — Ohio Shale
- Dl — Olentangy Shale
- Sp — Tymochtee Formation, Greenfield Dolomite, and Peebles Dolomite
- Sl — Lilley and Bisher Formations
- Sr — Rochester Shale
- Sb — Brassfield Limestone
- O — Ordovician



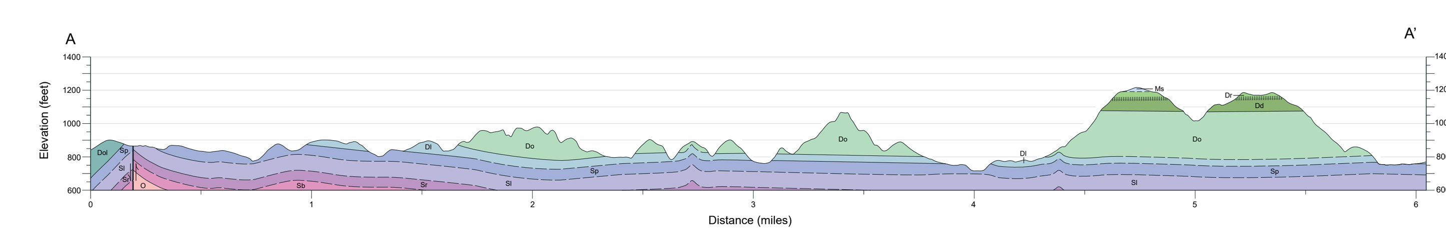
BASEMAPS

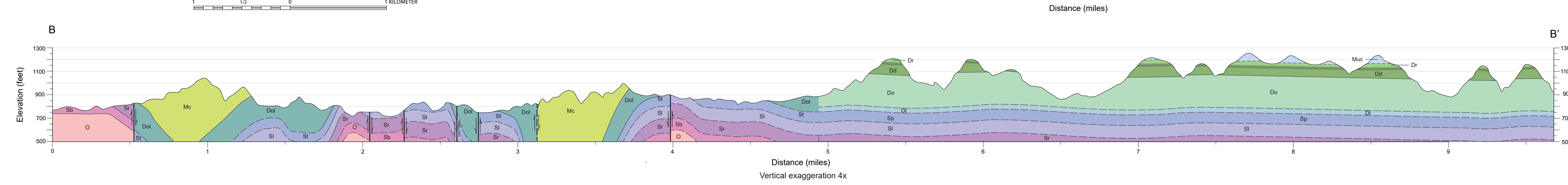
CONTOUR INTERVAL 20 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

Produced by the United States Geological Survey

North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and 1,000-meter grid: Universal Transverse Mercator, Zone 17S
Produced by the United States Geological Survey
10,000-foot ticks: Ohio Coordinate System of 1983 (south zone)

Data presented in map compiled from Reidel (1975), Swinford (1985), Galbraith (1968), Trygstad (2014), and from field work completed during this study.





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