Contemporary High-Resolution LiDAR Derived Digital Elevation Models Could Inspire Developments in the Study of Impact Structures

Michael P. Finn[a], Gary W. Krizanich[a], Kevin R. Evans[b] and E. Lynn Usery[a]

Key Words: Impact Structure, Crater, DEM, Meteorite, Elevation Model, LiDAR, Light Detection and Ranging, GIScience

Introduction:

In the middle of the United States there is an alignment of several anomalous geological features that alternately have been interpreted as crypto-explosive structures or meteorite impacts (fig. 1). Crypto-explosive structures generally are regarded to have a volcanic origin. Viewed from a meteorite impact perspective, the nearly linear arrangement of the features is an argument for serial impact, comparable to the Shoemaker-Levy 9 impacts on Jupiter in 1994. Evidence suggests that both hypotheses may be partly correct. We have used a primary Geographic Information Science (GIScience) technique of creating a digital elevation model (DEM) of two of these features that both occur in Missouri: the Crooked Creek and Weaubleau structures.

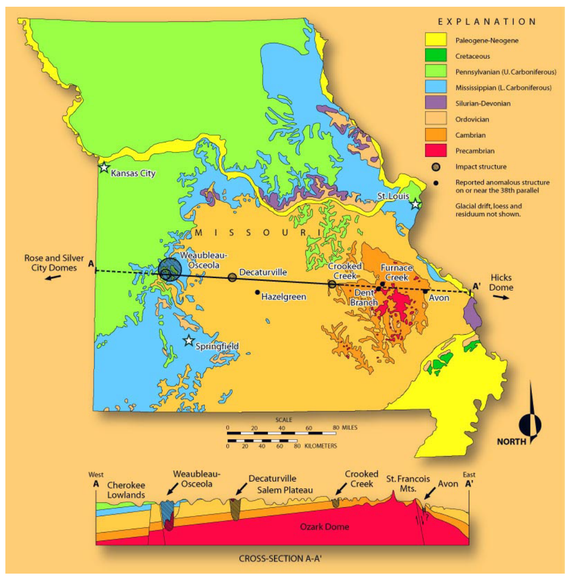

Figure 1. Generalized geologic map of Missouri showing structures aligned along the 38th parallel.

Results:

High resolution LiDAR DEMs provide a level of detail not achievable with standard elevation data. They are accurate enough to allow for precise measurements and better interpretations of geological structures such as shape and extent (fig. 4), particularly jointing in the carbonate rocks and ultimately stimulating advancements in knowledge of these meteorite impact structures. The results show elevations varying between 276 and 348 meters for Crooked Creek and 220 and 290 meters for Weaubleau. Round hay bales and berms from terraced agricultural fields are clearly visible in the data from the Weaubleau structure (fig. 5) and vertical beds bordering the central uplift are clearly visible in the Crooked Creek DEM (fig. 6).

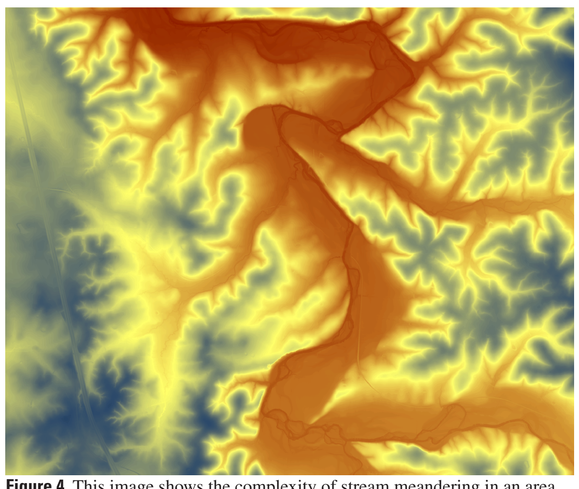

Figure 4. This image shows the complexity of stream meandering in an area that has extensive fracture control. Amstutz (1965) recognized the polygonal nature of these sorts of features.

Study Area:

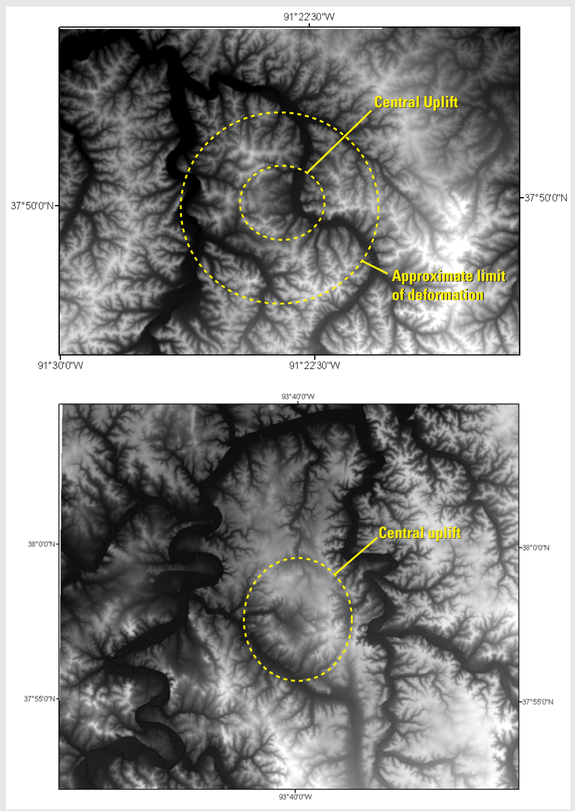

Figure 2. (a) LiDAR DEM image of Crooked Creek structure in southern Crawford County and **(b)** Weaubleau structure in southeastern St.Clair County, Missouri.

Crooked Creek structure (fig. 2a) is approximately 7 km in diameter and has a ring-like morphology; the exposed target material in the structure includes Cambrian and Ordovician strata. It is located in southern Crawford County, Missouri, approximately five kilometers northeast of Cook Station on Missouri State Highway VV and is centered at approximately 37° 50' N and 91° 23' W. The Crooked Creek structure has an intensely deformed central uplift area that includes displaced blocks of sandstone, dolomite, and bedded chert. The central uplift exposes formations approximately 300 meters higher than their regular stratigraphic position and is surrounded by peripheral normal faults.

The Weaubleau structure (fig. 2b) is approximately 18 km in diameter; the structure comprises deformed Mississippian limestones and breccia that partially are buried below undeformed Pennsylvanian strata. The Weaubleau structure is located in southeastern St. Clair County, Missouri, approximately centered 3 km south of Vista, Missouri at 38° 07'N and 93° 35' W.

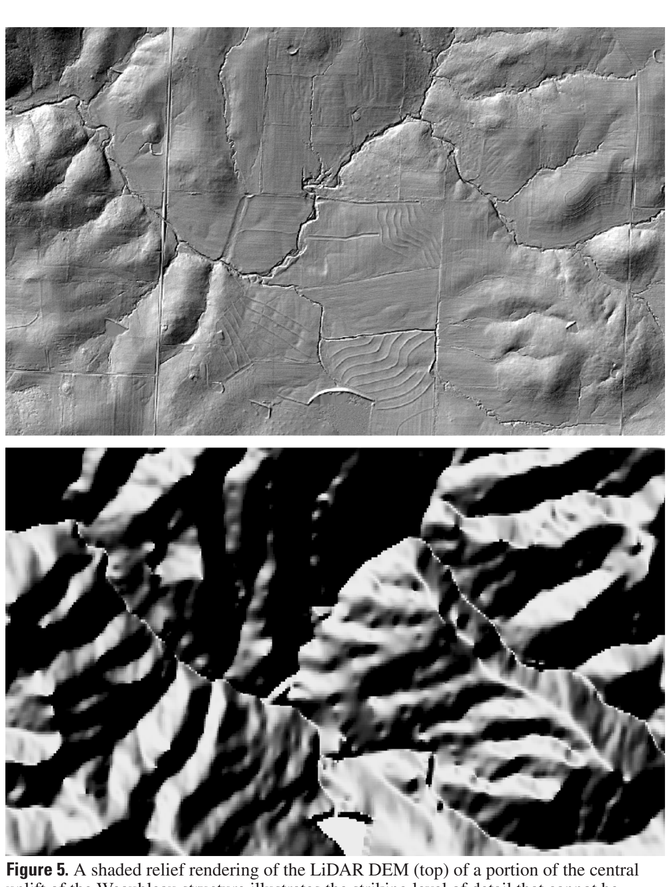

Figure 5. A shaded relief rendering of the LiDAR DEM (top) of a portion of the central uplift of the Weaubleau structure illustrates the striking level of detail that cannot be achieved with the standard 30 meter DEM (bottom). Round hay bales and berms from terraced agricultural fields are clearly visible.

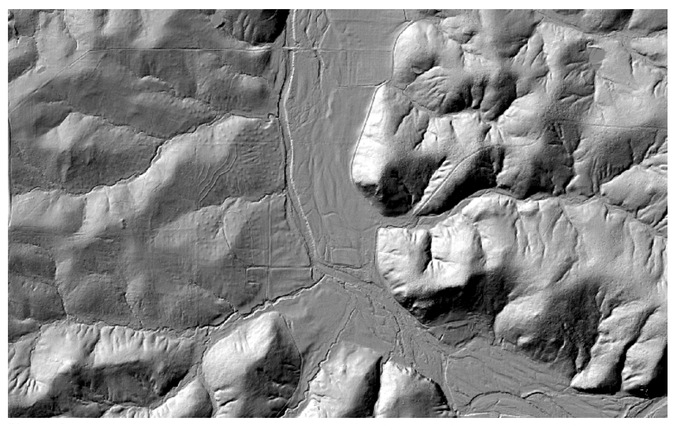

Figure 6. A shaded relief image of a portion of the Crooked Creek structure. Vertical beds bordering the central uplift are visible near the center of the image.

Data/Methods:

The interpretation of high-resolution DEMs derived from airborne light detection and ranging, or LiDAR, can potentially contribute to the study of impacts as well as other enigmatic circular structures and benefit scientists who study them. For the United States, the nominal, publicly available DEM is based on 1 arc second latitude and longitude posting with varying higher resolution DEMs available at 1/3 arc second and a few at 1/9 arc second. These DEMs have nominal postings of 30-meter, 10-meter, and 3-meter, respectively. The hypothesis is that a very high resolution DEM derived from airborne LiDAR would allow GIScience to somehow contribute to the study of these structures, and also be of benefit to scientists in other disciplines studying them. Through contracts, airborne LiDAR data have been acquired at nominal 1.4 meter pulses (ground sample distance) and these data have been processed to a bare earth DEM of 1.6 meter posting, representing a statistically rigid solution based on samples collected at 90 percent, in two directions, of the final post spacing. From this we manipulated and analyzed the DEMs themselves and in conjunction with other digital geospatial datasets such as raster topographic maps and geologic maps (fig. 3).

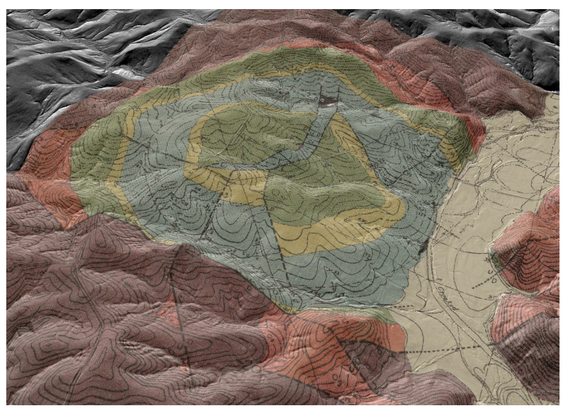

Figure 3. Geologic map of the Crooked Creek structure combined with a shaded relief dataset derived from the LiDAR data.

Approaches similar to ours, yet with coarse resolution data, have been used before. For example, Mahmood and others (2001) generated a 10-m resolution DEM from the RADARSAT-1 Fine-beam data to generate accurate topographic information of the Haughton impact crater site on Devon Island in Canada's Nunavut Territory. In addition to laser ranging done on Earth, the most detailed topographic survey of Mars used a non-imaging laser-ranging device called the Mars Observer Laser Altimeter or MOLA (Zuber and others 1992, Mahmood and others, 2003).

Conclusions:

- High resolution LiDAR DEMs are accurate enough to allow for precise measurements of geological structures.
- LiDAR shows greater definition of the central uplift area in the Weaubleau structure than DEMs.
- High spatial resolution LiDAR data can be used to identify areas of interest for field mapping.
- LiDAR alone cannot be used to positively identify impact structures. This still requires identification of shock metamorphic features or trace evidence from impactors.

Contact Information:

[a] U.S. Geological Survey (USGS), 1400 Independence Road, Rolla, Missouri 65401, mfinn@usgs.gov, gkrizanich@usgs.gov, usery@usgs.gov

[b] Missouri State University, Department of Geography, Geology, and Planning, 901 S. National Avenue, Springfield, Missouri 65897, kevinevans@missouristate.edu