



Investigating a Possible Impact Structure in North-Central Oklahoma

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Abstract

Over time, geologic processes work to erode and fill impact craters, breaking down their shape and leaving ambiguous or nonexistent surface expressions. For this reason, surface expressions of impact craters are generally rare, and finding impact craters of any significant age is difficult.

The goal of this project is to investigate a possible impact crater in central Oklahoma near Ingalls, Oklahoma using ArcGIS. Previous study (Bermann 2011) has established the existence of a 2 km subcircular anomaly structure in the area. The study was unable to demonstrate conclusively that the structure was an impact crater; however, it did establish that the structure might be an Ordovician impact crater. Well logs within the structure differ markedly from the surrounding area, showing strata which are not present elsewhere. This observation is consistent with an impact crater which was later filled. The original study was unable to find the shocked quartz generally indicative of an impact, but rock samples were limited, and this failure is inconclusive.

We will attempt to constrain further the genesis of the crater by using the ArcGIS software suite to map the spatial distribution of a variety of features. We will set up a detailed elevation model, in hopes of detecting some surface expression of the feature too slight to be found using conventional methods. In addition, we will construct a model using well logs, to gain a better understanding of the structure's characteristics. Any additional data, particularly petrographic data, will also be mapped, and the resulting three-dimensional picture will be compared to known impact structures, such as the nearby impact crater near Ames, Oklahoma. Using these techniques, we hope to build a better understanding of the structure and its origins.

Background

Impact Craters:

Upon impact, meteorites transmit their momentum into the Earth. The velocity of incoming meteorites can be as high as 11 km/s (French 1998), so a large impactor will transmit a very large amount of energy, which is subsequently partially expended in deforming the surface. In large enough impacts, this deformation produces a crater, which may be either simple or complex. Simple craters follow the more widely known pattern, creating a bowl with an uplifted rim of detritus, but complex craters manifest concentric fault boundaries surrounding the crater and a central area where the underlying rock rebounded after impact (see figure below).

In addition to the crater itself, impacts may also leave evidence of shock metamorphism. This form of metamorphism requires much higher pressures than other forms of metamorphism, and can only be reached during an impact (French 1998), so it is conclusive evidence of an impact.

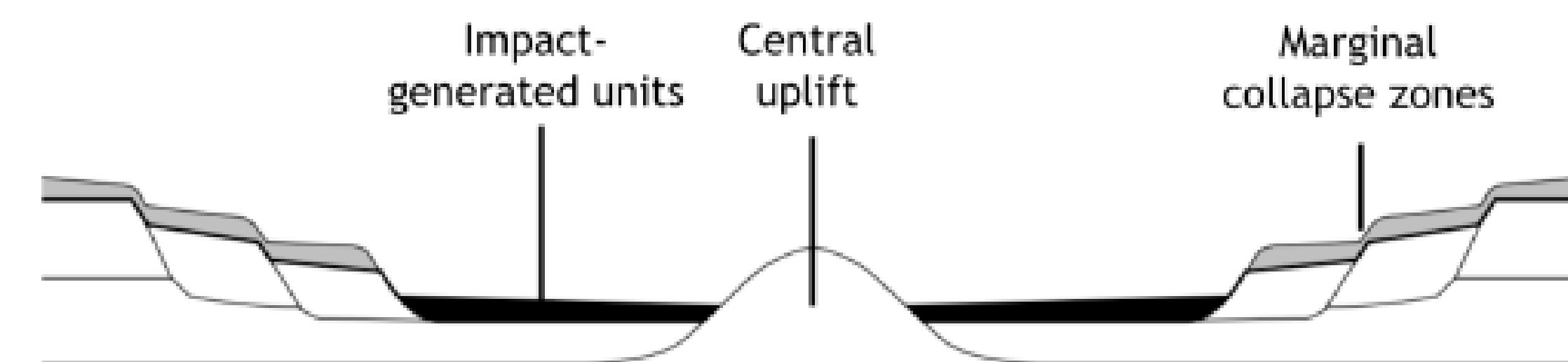


Figure 1: A cross section of a complex impact crater showing removed material, central uplift, and concentric faulting. From Hermann (2009).

Ames Crater:

In this study, we will use a confirmed impact structure in nearby Major County as an example of a structure of similar age and geologic history. The Ames structure contains significant numbers of grains containing evidence of shock metamorphism (Koeberl et al. 1997), and thus can be confirmed to be an impact crater.

The Ames Impact Crater is a complex impact crater, showing the distinctive faulted rim and central uplift characteristic of such craters, and, like the hypothesized Ingalls Crater, is of Ordovician age (Carpenter and Carlson 1994). Although the Ames Crater is larger, it is still reasonable to conclude that both craters would manifest similarly.

Study Area

The Ingalls structure is located in Payne County in central Oklahoma, near the town of Ingalls (see figure below). It includes parts of S21, 22, 27, and 28 in T19N R4E. The Ames Crater is in nearby Major County to the west, near the town of Ames.

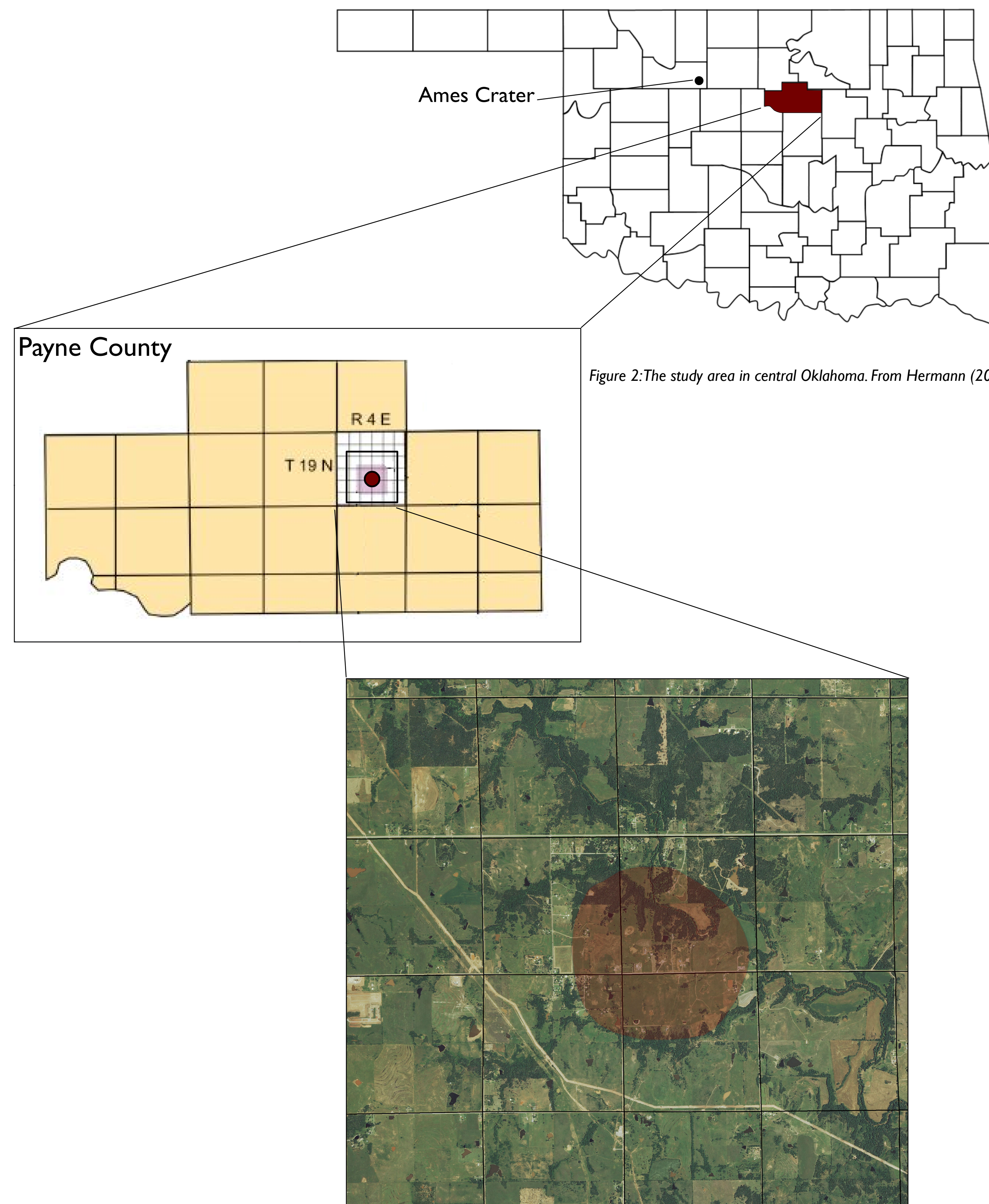


Figure 2: The study area in central Oklahoma. From Hermann (2009).

Method

The project took three distinct approaches. To find any surface expression of the structure - and thus better define the shape of the structure - we examined aerial photographs, drainage patterns, and a detailed elevation model. Each approach allows minute changes in elevation to be detected, increasing the probability that any surface manifestation of the structure will be detected.

In addition, a three-dimensional model was constructed using data from well logs. The Viola Formation represents the surface at the time of the proposed impact, so we used the top of Viola to approximate the structure.

Finally, gravity (specifically, Bouguer Anomaly) and magnetic maps were used to attempt to locate an anomaly consistent with an impact structure. Many impact structures show positive gravimetric anomalies, because of the introduction of denser material and the deformation of existing rock, and negative magnetic anomalies, possibly due to the disruption of the existing magnetic fields in the underlying rock. The presence of a gravity or magnetic anomaly corresponding with the structure would be very strong evidence of an impact.

Results

Surface Expression:

Given the age and depth of burial of the crater, a clear surface expression is unlikely, although not impossible - the analogous Ames Crater leaves a very vague surface impression. Similarly, the Ingalls Structure also leaves an indistinct and incomplete but still recognizable pattern on the surface. This is best seen in the southern rim of the crater, where a semi-circular ridge concentric to the proposed crater edge is visible in both topographic maps and aerial photos (see image at right). The northern edge is less developed, but faint concentric patterns in vegetation (which can reveal changes in elevation too faint for our elevation model to detect) also parallel the crater boundary.

Radial drainage patterns, which can also indicate a crater or other ovacular structures, are not immediately obvious outside the southern rim. Aerial photographs and our elevation model, then, are the best indicators of the surface expression of the crater, which, although indistinct, appears to be present.

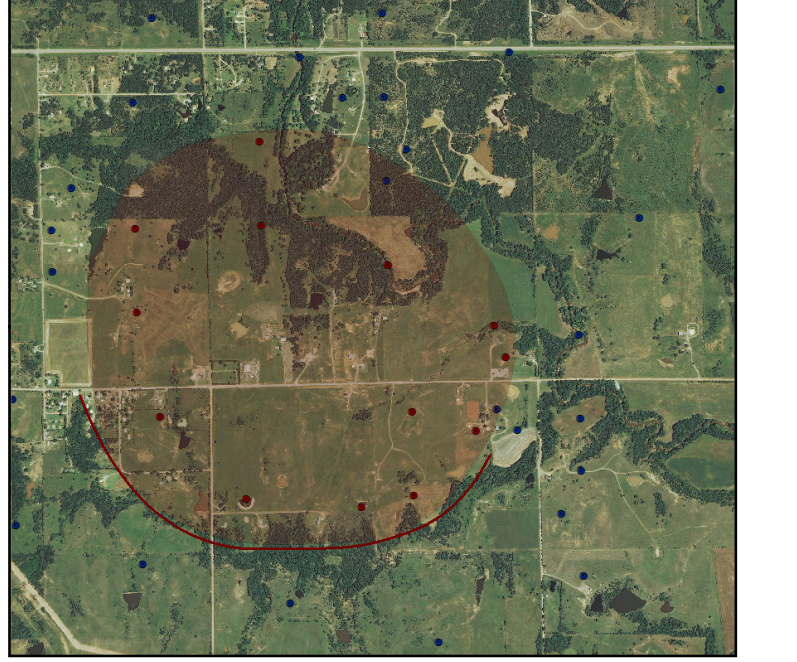
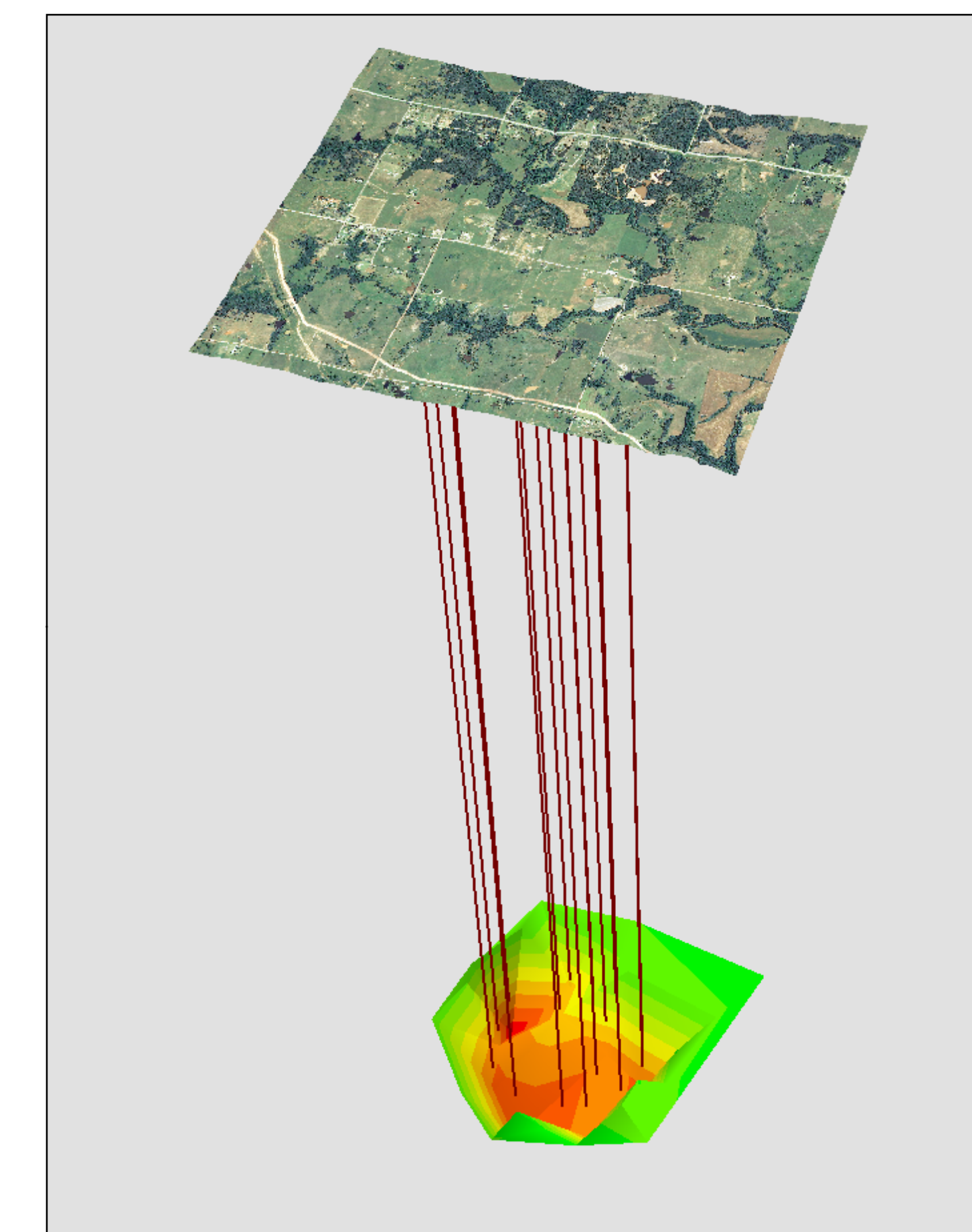


Figure 3: Overlay of the proposed crater boundaries with the concentric ridge to the south accentuated. Wells that encountered the Hunton Fm. are marked in red; others in blue.

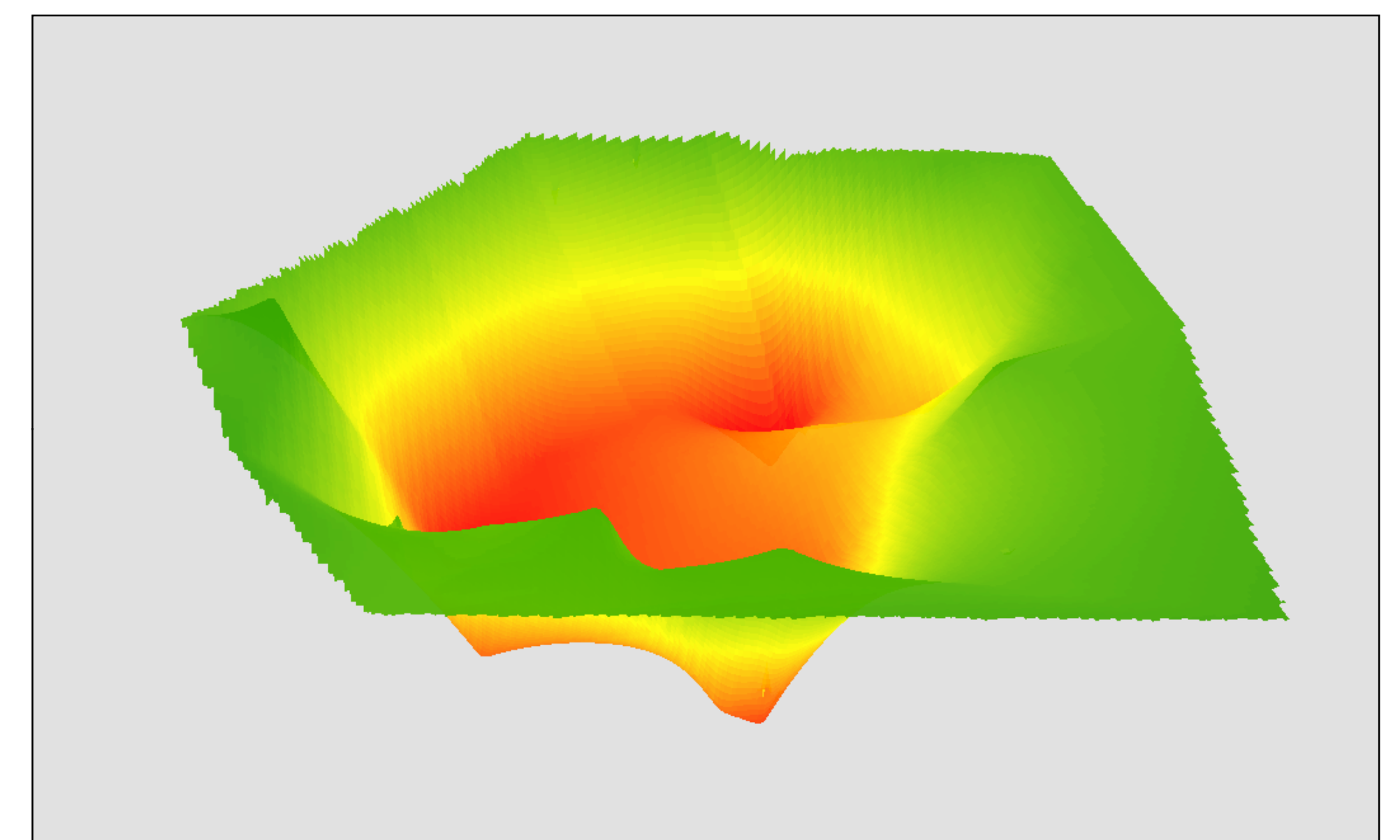
Three-Dimensional Model:



The structure can be seen primarily in its imprint in the stratigraphic column. Well logs show that the Sylvan Shale and the Viola Limestone, both Ordovician units, are offset by several hundred feet within the crater. This offset is largely due to the presence of the Hunton Formation in a ring within the crater. The Hunton Fm. is present in much of Oklahoma, but has been eroded away in the vicinity of the study area. This pattern is consistent with a complex impact crater - the Hunton Fm. would have been preserved within the depression formed by the impact, but eroded away like everywhere else in the area in the central uplift.

In order to understand the nature of the structure better, we produced a 3-Dimensional model (see figure at right). In this model, we took the top of the Viola Limestone, the formation corresponding with the age of the proposed impact, to be the profile of the crater. In addition, extruding the wells that encountered the Hunton to the top of the Hunton (see left) clearly shows the ring-like placement of the Hunton.

Figures 4 and 5: Figure 4 (left) shows the depth of the structure, along with the wells that encountered the Hunton Fm., extruded to the top of the Hunton. Figure 5 (right) shows the structure itself, modeled as the top of the Viola Ls. from well logs.



Gravity and Magnetic Data:

The gravity and magnetic anomalies often present in impact structures could not be conclusively located using data of the resolution available for the study area. A possible negative magnetic anomaly is apparent (see left), but the resolution of the magnetic maps for the area is simply too low to confirm this. No gravity anomaly is visible, although this is also inconclusive.

In addition, it is possible that no significant gravity anomaly is present. The impactor was relatively small compared to that at the Ames Crater - a full order of magnitude smaller, in fact - so it is conceivable that no anomaly was created. Without higher resolution data, though, it is impossible to say with certainty.

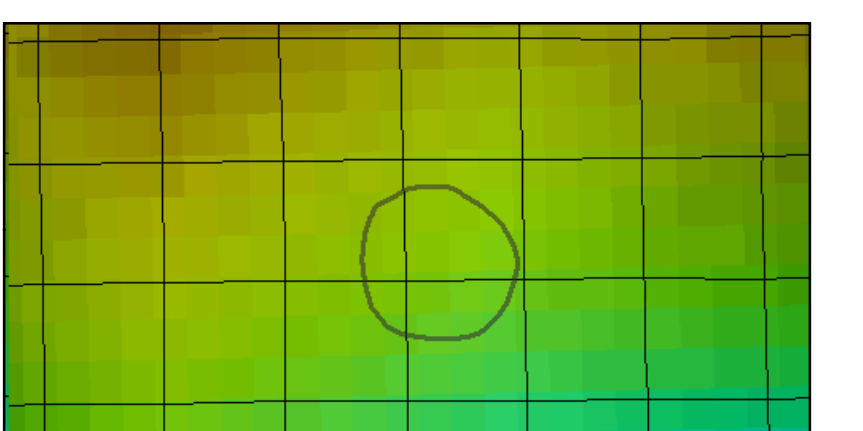


Figure 6: Magnetic map of the study area. The structure is marked with a gray circle.

Discussion

This project established the presence of a surface expression of the Ingalls Structure, and further constrained the three-dimensional characteristics of the structure. Gravity and magnetic data showing an anomaly in the vicinity of the crater would have left little doubt of the impact-related origin of the structure; however, the resolution of the gravity and magnetic maps available for the study area was too low to establish the presence of an anomaly with any degree of certainty.

Further study, particularly using better gravity and magnetic data, is still needed to determine the origin of the Ingalls Structure, but the structure's close resemblance to other complex craters, such as the Ames Crater, does much to confirm the proposed genesis of the structure.

References:

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