WHEN CLASSIFICATION GETS COMPLICATED: THE INGALLS "IMPACT-LIKE" STRUCTURE

R. G. Mayne[1] S. J. Jaret[2] and B. C. Herrmann[1,3]

[1]Monnig Meteorite Collection, School of Geology, Energy, and the Environment, 2950 West Bowie SWR 207, Texas Christian University, Fort Worth, TX 76109, [2]Department of Geosciences, Earth and Space Science Building, Stony Brook, NY 11794, [3]Devon Energy, 333 W Sheridan Avenue, Oklahoma City, OK 73102.

Classification is a complex process and some rigor is always necessary. The Ingalls Structure does not meet the current specifications to be classified *senso-stricto* as an impact-crater; however, taking into account the geologic history of the area in which it is found, it is hard to imagine what else it could be. It is not possible to gather more data on this subsurface feature and gain the data necessary to "prove" its origin. Perhaps, it deserves some leniency, perhaps not, but we do think it deserves some discussion.

Classification of Impact Craters:

Currently, acceptance (read that as "classification") of geologic structures formed by hyper-velocity impacts are governed by a rigorous and straightforward set of criteria [3]. A specific set of identifiable damage imparted by shock associated with impacts is unique to shock events and cannot be produced by other endogenic means (e.g. [2,4,5,6]). Accepted criteria for identification of terrestrial meteorite impact structures include [3]:

1) Meteorite fragments,
2) Chemical and isotopic traces of the impactor
3) Shatter cones,
4) Diaplectic glasses,
5) High pressure minerals* (typically silica polymorphs, coesite and stishovite)
6) High temperature glasses and melts*
7) Planar Fractures (PFs) in quartz*
8) Planar Deformation Features (PDFs) in quartz

* indicates that these are widely known to also occur in non-impact settings.

In the case of an impact crater, *high-pressure minerals are not enough to confirm a structure, nor should they be, because they could be formed by other processes, completely unrelated to impacts.*
There are also factors, not included above, that are best described as only "suggestive" of an impact crater origin. These are not part of the accepted criteria for a reason and are considered complementary observations to the above list. They include:

1) Circular shape,
2) "Odd" brecciation,
3) Spherules of glass fragments,
4) Geophysical anomalies
5) irregular stream drainage patterns.

Unless accompanied by shock deformation, *these are not considered definitive proof of impact*, because they are not unique to impacts and are actually more commonly formed from non-impact means.

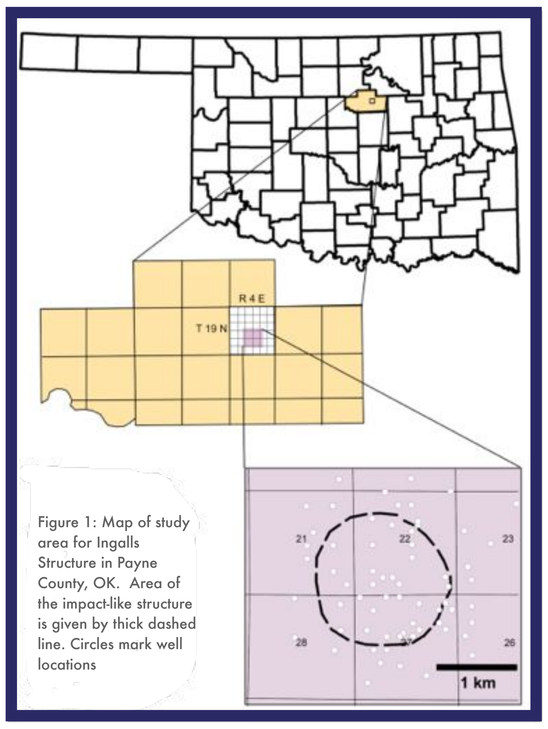

Figure 1: Map of study area for Ingalls Structure in Payne County, OK. Area of the impact-like structure is given by thick dashed line. Circles mark well locations

Classification IS complicated:

What do we do when an object is found that does not fit current classification criteria, but cannot really be described as something else?

The Ingalls Structure is a roughly 2km diameter circular feature found in the subsurface of north-central Oklahoma [7](Figure 1). It was discovered by a group of petroleum geologists, who noticed that the well-logs in this area were very uncharacteristic of the regional stratigraphy. Despite being located in an active oil and gas area with over 200 wells present, only 20 wells have been drilled deep enough to encounter the structure and have data that can be correlated. No detailed cores are available from any of these wells. Some well cuttings were available and analyzed; however, it is hard to establish which cuttings may come from relevant stratigraphic intervals and, despite detailed investigations, no shock features were found in any of the grains analyzed.

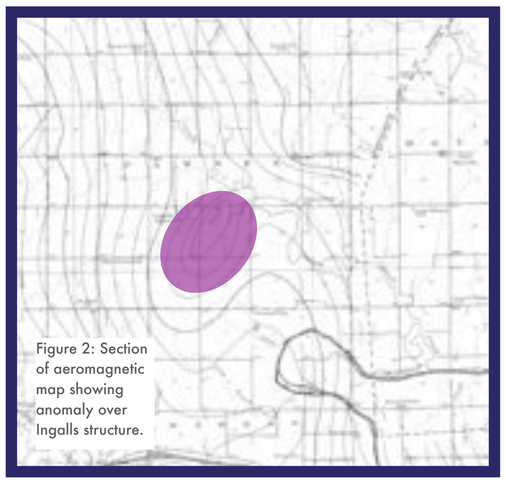

Figure 2: Section of aeromagnetic map showing anomaly over Ingalls structure.

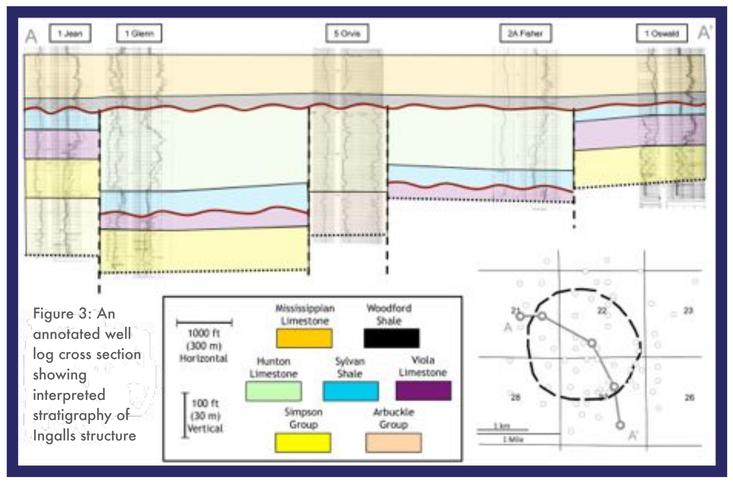

Figure 3: An annotated well log cross section showing interpreted stratigraphy of Ingalls structure

Suggestive Features of the Ingalls Structure:

The Ingalls Structure is definitely "impact-like." It has a circular shape and a geophysical anomaly can be seen above it in the aeromagnetic map of the Payne County, Oklahoma region (Figure 2). However, perhaps the most "suggestive" qualities that Ingalls has are the geologic history of the area in which it is found and the unusual stratigraphy seen in the structure itself. Geologically, in Oklahoma, this is a very well understood time period.

There is no regional tectonism or igneous activity that could explain this structure.

Cross sections of the area constructed from well logs show that the feature has very abrupt boundaries (Figures 3-5), which are accompanied by drastic changes in lithology indicative of fault planes not in keeping with the area's geologic history [7], such as:

1) None of the units in the structure correlate precisely with the units outside of the structure. There are varying bed thicknesses and some units not present outside the structure are present within it.
2) A large thickness (up to 60m) of Hunton limestone is found within the structure, but regionally this unit has been truncated out over 20km to the west of the structure.
3) The Simpson group is present in the center of the crater in a large spire-like unit, suggestive of a central uplift. This unit is older than all the rocks surrounding it and has been uplifted approximately 150m above the equivalent unit in the surrounding area.

This leaves us with an area with regionally undisturbed rocks containing a circular suite of younger strata, surrounding an uplifted older section of rocks. Any non-impact explanation would require both extension and compression at the same time.

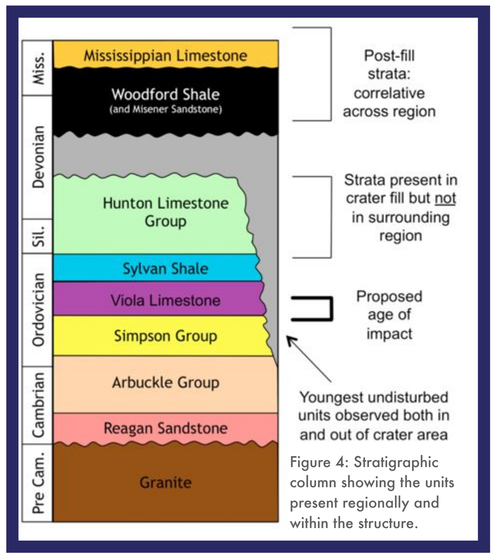

Figure 4: Stratigraphic column showing the units present regionally and within the structure.

With no other geological explanation, the evidence at Ingalls seems more than "suggestive" of an impact crater.

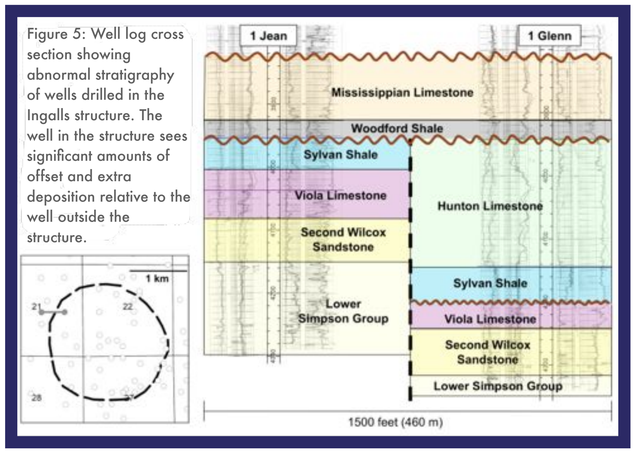

Figure 5: Well log cross section showing abnormal stratigraphy of wells drilled in the Ingalls structure. The well in the structure sees significant amounts of offset and extra deposition relative to the well outside the structure.

References:
[1] Melosh H.J. (1989) Impact Cratering. A Geologic Process. [2] Kieffer S.W. and Simonda C.H. (2010) Rev. Geophys., 18, 143-181. [3] French B.M. and Koeberl C. (2010) Earth Sci. Rev., 98, 123-170. [4] Alexopoulos J.S. et al. Geology, 16, 796-799. [5] French B.M. and Short N.M. Shock Metamorphism of Natural Materials [6] Shoemaker E.M. (1960) Impact Mechanics In: The Moon, Meteorite, and Comets. [7] Herrmann B and Mayne R.G. (2011) LPSCXXXII Abstract #1032.