PALEOMAGNETISM AT SERPENT MOUND

A Thesis

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by

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Abstract

Eight hand samples, three from the Brassfield Formation (Lower Silurian), five from the Tymochtee Formation (Middle Silurian) were collected from the core and flanks of the Serpent Mound cryptoexplosion structure in southwestern Ohio. The magnetic moment of over sixty cores were measured in a Superconducting Cryogenic Magnetometer. By determining the paleomagnetic age of one of the episodes of iron and zinc mineralization, it is concluded that Serpent Mound has been active at least twice. The first time was in the Carboniferous when the structure formed. The second was the inflowing of iron and zinc bearing fluids in the Upper Triassic. This is strong evidence for including Serpent Mound in a group of thirteen similar structures which suggest partial development of a rift valley tectonic structure during Middle Paleozoic through Early Mesozoic time.

Introduction

Serpent Mound is located in southwestern Ohio at the common boundaries of Adams, Highland, and Pike counties (Figure 1). The Serpent Mound Indian Site is located on the west flank of the topographic feature, giving rise to the geographical name. The Serpent Mound structure stands as a topographic high on the extreme eastern edge of the Interior Plateau Physiographic Province. It is nearly circular in plan view with a diameter between 4.5 and 5 miles. The structure is slightly elongated in a north-south direction and has an area of approximately 16 square miles.

The disturbance was first mentioned by Locke of the Geologic Survey of Ohio in 1836. In 1921, Bucher published the first reconnaissance map of the structure calling it a "cryptovolcanic structure". He ascribed its origin to deep seated explosive volcanic processes because of its resemblance to the Steinhem cryptovolcanic structure in Germany. In 1947, Dietz suggested the term "cryptoexplosion structure", and related it to a meteorite impact event, similar to lunar impact structures.

The structural map by Bucher indicates intense deformation in a small central area with intensity decreasing concentrically outward. In the central area, the Ordovician shales and limestones have uplifted at least 350 feet above their normal position and in one instance, Bucher found evidence of perhaps 950 feet of uplift (Bucher, 1936).

The central area, or core, has an angular polygonal pattern structure consisting of seven radiating anticlines. The joint system in the area has a northeast and northwest strike. Steep dips and folds surround the central uplifted block. Normal faults with nearly vertical planes of displacement separate the uplifted block from the surrounding area. There are several low displacement faults, some overturning, and some minor overthrusting, but they are local and negligible.

As indicated by Bucher, the large blocks surrounding the central area dip inward and form a ring depression. Faults generally define the boundaries of the blocks except where there is a sharp flexure. Several marginal anticlines lie outside the peripheral area: the largest is on the northeast side.

Detailed mapping by Reidel (1975) has shown structures caused by a force directed upward and to the east or southeast. Most of the folds are formed by a combination of shear folding and rotation of the limbs. Grabens formed between the anticlines on the east and south sides in response to lateral forces. Faults formed between the anticlines on the north and west sides where there were no lateral forces acting on them.

Both regional and local geophysical studies indicate a specialized environment for Serpent Mound. Regional geophysical evidence indicates the structure lies in an area of positive magnetic anomalies (Zeitz, 1969) and within a regional negative free-air gravity anomaly along the eastern flank of the Cincinnati Arch. On a local scale, the gravity and magnetic trends have the same axis as the greatest fault frequency class found in the structure.

Serpent Mound was formed just before the youngest sediments, which lie over the top of the structure, were deposited. These sediments are the Cuyahoga, Sunbury, and Bedford shales and the Berea Sandstone of the Late Devonian and Early Carboniferous. The formations exposed range from the Late Ordovician to Early Mississippian. The absolute age of the Serpent Mound deformation cannot be determined by normal geochemical methods because of the absence of igneous material.

Heyl and Brock (1962) first reported an occurance of the mineral sphalerite (zinc sulfide) in the Serpent Mound structure. Additional work has shown that this mineral and related zinc and lead minerals occur throughout the structure. The sphalerite is clear to yellow and purple in color and occurs primarily along fault zones. The most favorable host rocks for sphalerite mineralization are the Brassfield Limestone of Early Silurian and the Tymochtee, Greenfield, and Peebles Dolomites of Late Silurian. Paragenesis of the mineralization indicates that there have been two and possibly three different periods of zinc mineralization (Reidel, 1975), but the ages of the mineralizing events are unknown, save that they were Post-Mississippian.

Proceedure

My research bears upon the time of origin of the Serpent Mound mineralization. In order to determine the age of these events, oriented hand samples were collected from the core and flanks of the disturbance. Where the rocks were sampled was dependent on surface exposure, but all were located in proximity to a site where Reidel (1975) had determined the presence of zinc geochemically. A total of eight samples were collected; three from the Brassfield Formation (Early Silurian) and five from the Tymochtee Formation (Late Silurian). Each sample was drilled perpendicular to bedding and sliced to produce a suite of over sixty cores of approximately uniform volume. Each core was marked with the strike and dip direction and labeled with a core name. For example, Sb-3D represents the fourth core from the third hand sample from the Silurian Brass-Field Formation.

The magnetic moment of each core was measured in a Superconducting Cryogenic Magnetometer (SCM). Each core was measured initially to determine the natural remanent magnetization (NRM) and following a series of magnetic cleanings in a peak AF field of 100, 200, 300, 400, 500, 600, and 700 Oersteds. The samples were demagnetized along three mutually perpendicular axes (X,Y, and Z) in a single axis Schonstedt GSD-1 AC Geophysical Specimen Demagnetizer. This cleaning is essential as it randomizes the less stable magnetic moments acquired in the ambient (Recent) geomagnetic field, leaving an ordered magnetization which the minerals acquired when they were formed.

Other factors may contribute to the magnetization measured in the sample if the samples have a weak magnetic moment. These factors include a weak magnetic moment contributed by steel contamination during the coring process and contamination by dirt on the surgical paper tape used to hold the samples in the sample tube of the SCM. If the rock contains a mineral with low coercive fields, storage in the laboratory will permit the soft component to rotate into alignment with the laboratory field. Thus once AF cleaning has begun, the samples are stored in zero field.

The Tymochtee samples were stored in the laboratory for a period which varied from several weeks to several months before initial measurements were made. It is possible that the NRM directions recorded contain some response of the soft component to the laboratory field.

The SCM measures magnetic directions and intensities along three orthogonal axes (X,Y, and Z). This data along with the strike, dip, and geographic coordinates of the sample is analyzed by a computer program. The program calculates the magnetic moment of the sample and mean location of the ancient geomagnetic pole (paleopole), along with statistics about the data, distribution (Fisher Statistics), and plots the individual core results on a stereo net projection for each stage of demagnetization.

During analysis, the data was grouped according to formation. Further segregation of samples from the Tymochtee Formation was made. The cores from the first, second, and third hand samples (Group 1) with declinations near 350 degrees were treated separately from the fourth and fifth sample cores (Group 2) with declinations around 280 degrees. The cores from the Brassfield Formation (Group 3) with declinations of less than 10 degrees were in good agreement with the cores from Group 1.

Paleomagnetic dating is made possible by the existance of well documented positions for the geomagnetic dipole axis throughout Geologic time (McElhinny, 1973). This data for the Northern Hemisphere is shown in Figure 2. Superimposed on this figure are the paleopole positions calculated for my samples.

Since the computer program calculates eight paleopole positions, one for each stage of demagnetization, only a portion of the results were plotted in Figure 3. The three pole positions which had the largest precision parameters, K, were plotted for each group. Table 1 summarized my experimental results in tabular form. The explanation for the anomalous behavior of Group 2 is unclear. This group shows inclinations approximately 90 degrees away from Groups 1 and 3. That the magnetization of the 13 cores of this group agree well rules out error in measurement. Contamination of the cores or errors in core labeling would show more random a pattern. It is possible that this group acquired its magnetization during a reversal of the geomagnetic field.

None of the Silurian limestones which I sampled exhibited a Silurian magnetization. Instead, Groups 1 and 3 recorded a paleopole position which is Late Triassic in age. This is strong evidence that these rocks recorded a chemical remnant magnetization (CRM) due to the invasion of iron and zinc bearing fluids in Mesozoic time. This resulted in a much younger pole position as the iron minerals interacted with the ambient geomagnetic field. A Late Triassic pole position makes it apparent that the mineralization was not derived from the Early Carboniferous event which produced the mound structure.

Johnson (1973) conducted a paleomagnetic investigation of the Tymochtee Formation at Plum Run Quarry in southcentral Ohio. The Plum Run Quarry is 15 miles (S 25° E) of Serpent Mound and contains faults which could possibly join the NW-SE fault system that predates the Serpent Mound deformation. She calculated a paleomagnetic pole position at a latitude of 36.6° N and a longitude of 108.8° E. This paleomagnetic pole position is not significantly different from the Silurian paleopole of Figure 2.

The work of Johnson is important to this study for two reasons. First, she independently confirms that the Tymochtee Dolomites are carriers of a valid paleomagnetic record. Second, the existance of a Silurian magnetization in the same formation 15 miles away from the site of the disturbance indicates a post-depositional magnetization (CRM) for the Silurian sediments in the region of the disturbance. This mineralization is not a likely consequence of meteorite impact, but is a likely consequence of iron and zinc bearing fluids invading the crust and derived from the mantle.

Conclusion

Both the explosive gas expulsion and meteorite impact hypotheses can account for the general features of Serpent Mound; a central uplift and a ring graben. Both can easily generate the needed energy.

The geophysical evidence, although not conclusive, closely fits the mapped geology. This tends to indicate continuation of the structure at depth. However, the gravity relationships between Serpent Mound and so called "proven" meteorite craters are dissimilar. Meteorite craters such as Grosse Bluff (Milton et al., 1972), Bent Crater (Millman et al., 1960), Holleford Crater (Beale et al., 1956), and Deep Bay (Innes, 1961) all show concentric gravity contours with only a single center of symmetry in the central area. The work of Zahn (1969) and others has shown that Serpent Mound is different, exhibiting a bilateral symmetry.

The lack of detailed geological information involving explosions at depth has resulted in limited explanations of the mechanics that would produce a cryptovolcanic structure. However, the association of two prominent geophysical anomalies and two structural anomalies (Reidel 1975, p. 106) could be more easily explained with the gas driven explosion hypothesis.

Zinc mineralization has been found at several other cryptovolcanic structures: Jeptha Knob (Reidel, 1975), Decaturville (Offield, 1971), Hicks Dome (Snyder, 1968), and others. By determining the paleomagnetic age of the zinc mineralization in the core of Serpent Mound, I have demonstrated that this structure has been active at least twice. The first time was in the Carboniferous when the structure formed. The second was with the inflowing of iron and zinc bearing fluids along existing fault planes.

It is difficult to imagine a meteorite striking Southwestern Ohio twice in the same spot. If the structure is indeed of cryptovolcanic origin as suggested by Bucher, Serpent Mound is on of a group of 13 similar structures distributed in a pair of belt-like patterns along the 38th parallel in the Midcontinent. This pair of belt-like patterns of cryptovolcanic structures straddles a region of uplifted basement rocks which may be the result of partial development of a rift valley tectonic structure during Middle Paleozoic through Early Mesozoic time. Recently, Myers and Noltimier (1978) have reported paleomagnetic anomalies in the region of Lake Erie, lying at the northern end of the Cincinnati Arch, one arm of the uplifted basement complex in the Midcontinent. These anomalies are most easily accounted for if they are the result of Mesozoic intrusives of ultrabasic nature.

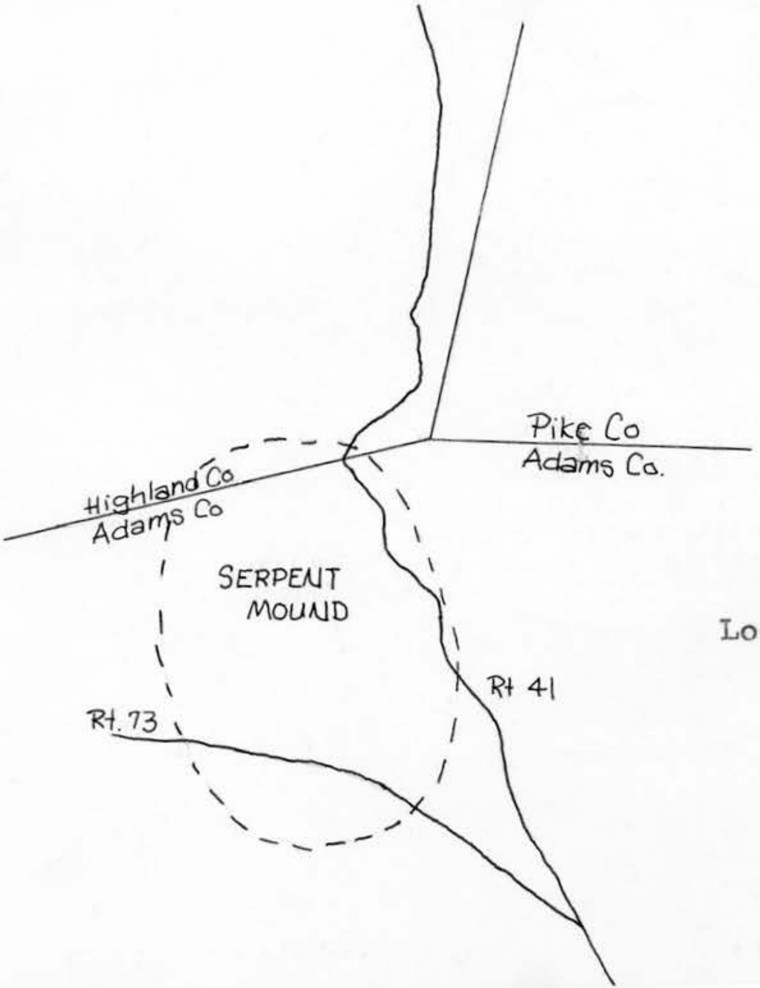

Figure 1:

Location of Serpent Mound

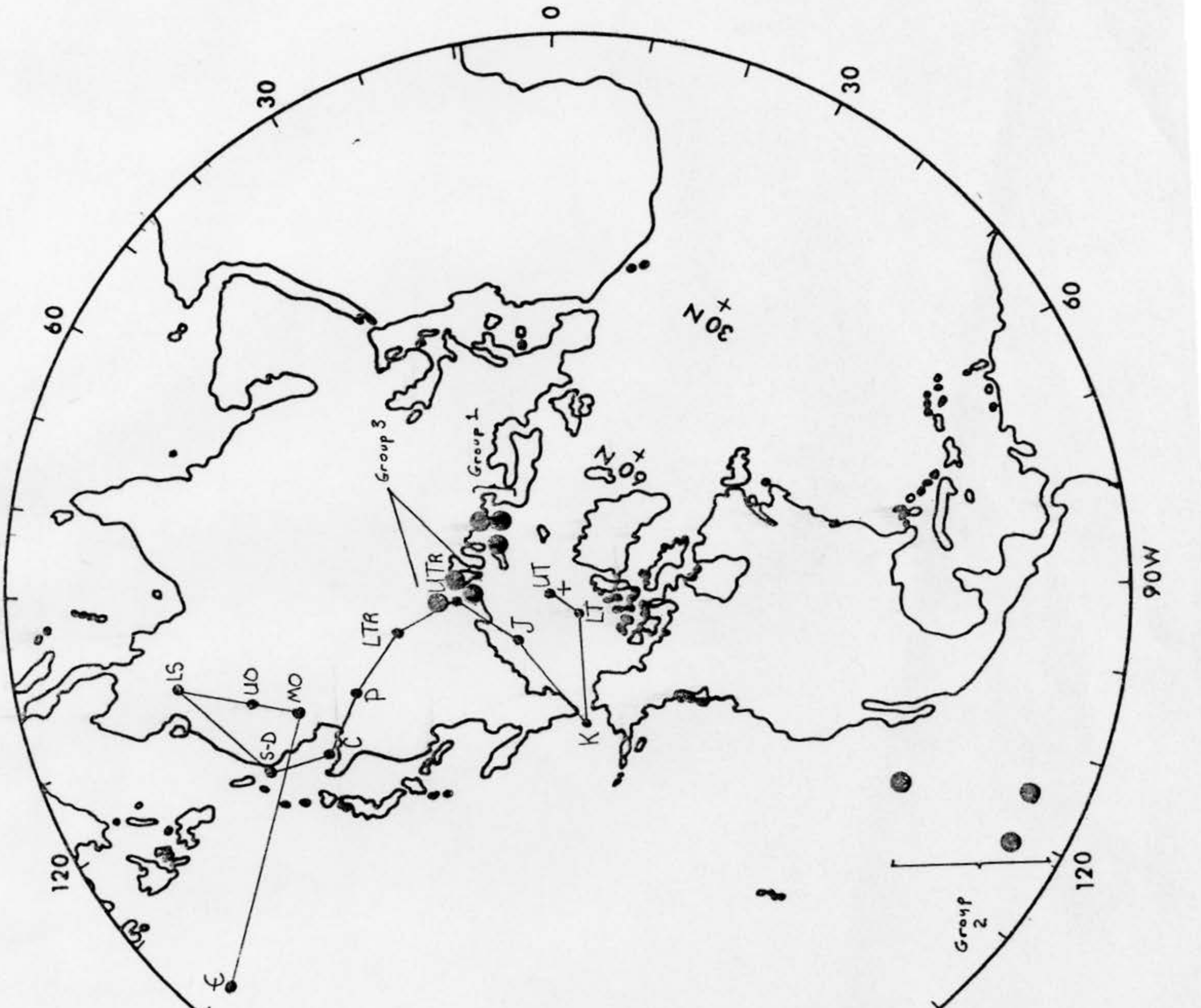

Figure 2. Paleomagnetic results.

GROUP	NO. OF CORES	K	ALPHA-95	LOCATION OF PALEOPOLE LATITUDE	LONGITUDE
1	19	24	4°	70°N	44°E
2	12	13	6°	6°N	114°W
3	13	6	11°	64°N	95°E

Table 1. Paleomagnetic results.

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