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THE CALVIN 28 CRYPTOEXPLOSIVE DISTURBANCE, CASS COUNTY, MICHIGAN: EVIDENCE FOR IMPACT ORIGIN.

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ABSTRACT. The Calvin 28 cryptoexplosive disturbance is an isolated, nearly circular subsurface structure of Late Ordovician age in southwestern Michigan. The structure is defined by 107 wells, is about 7.24km in diameter and consists of a central dome, an annular depression and an encircling anticlinal rim. Seismic and geophysical well log data confirm that an intricate system of faults and structural derangement exists within the structure. Deformation decreases with depth and distance from the structure. U.S.G.S. topographic maps and aerial imagery show the structure is reflected as a subtle surface topographic rise controlling local drainage. Igneous or diapiric intrusion and solution collapse are rejected as possible origins for Calvin 28 on the basis of stratigraphic, structural and geophysical evidence. A volcanic origin is inconsistent with calculated energy requirements and an absence of igneous material. Although shock-metamorphic features are unidentified, microbreccias occur in deep wells that penetrate the structure. Morphology and structural parameters support an impact origin.

INTRODUCTION. Geophysical data, geologic mapping, and drilling have delineated a subsurface structure in Calvin Township, Cass County, Michigan, centered 1.4km southwest of the village of Calvin Center. The structure consists of a central domal uplift bounded by an annular depression and an encircling anticline. The structure has a diameter of 7.24km. Surface topography is gently rolling glacial terrain with 30 to 133m of drift. The underlying Paleozoic strata are 1333m in thickness and dip northeastward at 5 to 11m/km. Three Devonian oil fields are associated with this structure. Two are located in conjunction with the anticlinal rim and one in conjunction with the central uplift.

STRUCTURAL CHARACTERISTICS. RIM ZONE: Middle and Late Devonian formations in the outer rim are 1.5 to 9m higher than their equivalents in the annular depression. The rim has a maximum width of 1.5km.

In the Smith #1-20 test well rock units below the Middle Silurian Clinton have anomalous thickness. For example, the local thickness of the St. Peter Sandstone is about 7m: the St. Peter in the Smith #1-20 is over 172m thick. The Ordovician Prairie du Chien Group is absent and the Cambrian Trempealeau Formation is greatly reduced in thickness.

ANNULAR DEPRESSION: An inner annular depression about 1km wide separates the outer rim zone from the central uplift. Devonian strata lie 28m below their regional level and 41m below equivalent strata in the central uplift. Within the annular depression, no test wells have been drilled to targets older than Devonian age. Seismic data confirm the presence of the depression at depth.

CENTRAL UPLIFT: The extent of structural uplift exhibited by the central dome is 415.5m. Geophysical well logs, and well cuttings show the absence or anomalous thickness of many regionally distinct stratigraphic units in wells drilled into the central uplift. For example, in the Hawkes-Adams #1-28 test well a thinned section of the Late Ordovician Cincinnatian Series rests directly on the Late Cambrian Trempealeau. The Lawson #1 test well while showing a full complement of regional strata, exhibits extreme variations in their thicknesses, especially the Middle and Late Ordovician sequences.

Geophysical well logs show both well bores to be intersected by several faults. Dipmeter readings taken in the Lawson #1 show random dips throughout the disrupted section, with readings as high as 78°. In the lower 160m of the well bore, the dip decreases, from top to bottom, from near 70° to roughly 5° with a persistent dip to the northeast, suggesting a waning of deformation at depth.

AGE OF THE STRUCTURE. Cincinnatian rocks of the Late Ordovician age (Richmond Group) are involved in the deformation, so the Calvin 28 structure is clearly older than Early Silurian. Lithologic units within the Cincinnatian are readily correlatable and when combined with accurate descriptive logs and well samples, correlation between subsurface points is quite reliable.

Data indicate rocks of Late Cincinnatian age are present in all control points both on and off structure. Control points on structure display a lack of Early and Middle Cincinnatian stratigraphy. Correlating away from the structure, Early and Middle Cincinnatian lithology becomes evident. Rocks of the Middle Ordovician age, (Trenton and Black River Groups) are involved in the deformation, and appear faulted and abnormally thick on the flank of the central uplift, and in the peripheral anticline. These rocks were deposited prior to the structure's formation. The age of the event responsible for the formation of Calvin 28 has been placed prior to Early Silurian time, but after deposition of the Early Cincinnatian age rocks of the Utica Shale.

SHOCK-METAMORPHIC EFFECTS. A microscopic investigation for shock-metamorphic features was done on samples from three deep wells. Because rocks older that Devonian were not cored in these wells, the search for shock-related deformation features was limited to thin sections prepared from well cuttings.

The examinations showed no evidence of high pressure, high strain-rate or high temperature shock effects, however the limited availability and small size of samples for inspection was a major restriction. A thorough microscopic search for shock metamorphism would have to involve cores and the less restricted use of well cuttings.

MICROBRECCIA. A microbreccia was identified in thin sections of rocks of Late Ordovician through Late Cambrian age from deep test wells drilled into the structure. The breccia is composed of both fractured and unfractured, subrounded to rounded floating quartz grains imbedded in a carbonate matrix.

The occurrence of the microbreccia at different stratigraphic intervals and at multiple locations about the structure, suggests that it is not the result of up-hole cavings. In addition, despite the small portion of well cuttings used to make each thin section, the microbreccia is apparent in each thin section. The lithology of the microbreccia is the same regardless of the unit in which it occurs and contrasts markedly with the normal lithology of the units. The variation of quartz grain morphology, in combination with the carbonate matrix, suggests the need for distinctly different depositional environments if the breccia is to be attributed to normal sedimentary processes. The characteristics of the microbreccia are consistent with those noted in macro and micro breccias associated with cryptoexplosive structures and impact craters (1).

ENERGY REQUIREMENT. The energy required to form the Calvin 28 structure can be estimated by using the empirical scaling law, D=cfKnE**1/3.4, derived from the effects of nuclear explosions on sedimentary targets (2). The calculated energy required to form the 7.24km diameter Calvin 28 structure is 1 x 10**26 ergs. While this value exceeds energy estimates for known singular explosive endogenetic events, it would be considered a conservative value for energy released by a hypervelocity impact (2).

EVALUATION OF POSSIBLE ORIGINS. No volcanic material has been identified in association with the Calvin 28 structure. Mineralization attributable to hydrothermal or known volcanic processes has not been recognized in well samples. Microbreccia associated with the structure contains no volcanic material. If igneous material had been present at the site, even in small amounts, it would be difficult to explain it's absence by weathering processes. The absence of significant carbonate and evaporite deposits in the Cambrian and Ordovician rocks underlying the structure, effectively eliminates a solution subsidence-collapse origin. Seismic profiles indicate no intrusive body beneath the structure. A geophysical investigation by Ghatge (3) showed no gravity or magnetic anomalies to one milligal or gamma associated with the structure.

Structures exhibiting similar characteristics to Calvin 28 are limited to impact craters and cryptoexplosion structures. The Calvin 28 structure exhibits many of the megascopic features of the cryptoexplosion structure of Dietz (4). Most significant are the structure's size, subcircular nature, as well as its intense, localized stratigraphic deformation. Lastly, this feature has no obvious relation to known volcanic or tectonic activity.

Throughtout the region surrounding the Michigan Basin a number of cryptoexplosion structures have been identified in the surface and subsurface. Cryptoexplosives located in Kentland, Indiana, Glasford, Illinois, Flynn Creek, Tennessee and Rock Elm, Wisconsin have been compared to Calvin 28 based on specific characteristics (5 and 6). Results of the comparison indicate that similarities in structure and morphology exist between the features.

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Structures now identified as terrestrial impact scars appear in two forms, simple and complex craters (7). The board characteristics for complex crater forms compare favorably with features identified in the Calvin 28 structure.

Pike (8) and Grieve and others (7) state that impact craters exhibit specific characteristics and that these can be calculated based on relationships between the crater's observable depth, diameter and structural uplift. Grieve and others (6) suggest a final complex crater form will exhibit an apparent diameter (Da), which can be considered approximately equivalent to the observed distance from rim to rim, a true depth (dt), which can be determined only by extensive drilling, and an amount of structural uplift (SU), calculated by the measurable uplift of the deepest in place marker horizon.

Only three deep test wells have been drilled into the disrupted sections of Calvin 28 and no reliable estimate of dt is available. Based on measurments made from structure contour maps, the Da of Calvin 28 is estimated a 7.24km. This estimate may be considered the maximum, observable value for Da. Geophysical well logs give a minimum estimate of SU for Calvin 28 of 415.5m. This is based on comparitive measurments of the lowest, observable in place marker bed, the Cambrian Mt. Simon Sandstone, between the on structure Hawkes-Adams #1-28 and the off structure Wooden #1.

By studying the relationships between stratigraphic uplift and the apparent diameter of accepted terrestrial complex craters, (7) find, SU = 0.06Da**1.1. By solving for SU and Da with the observed values, a calculated SU of 529m and a calculated Da of 6.93km are found. The author believes minor disagreements between calculated results and observed values are acceptable given the maximum and minimum limitations placed on the observed values. Calvin 28 is considered to exhibit a recognized relationship between stratigraphic displacement in the central uplift and its present form and dimension.

While the identification of shock metamorphic features. a macrobreccia, or chemical anomalies would lend stronger support to an impact origin, seven characteristics of the Calvin 28 structure strongly support origin by impact: 1. The structure is circular, with a central uplift, surrounding annular depression and a peripheral anticline. 2. Calvin 28 is an isolated structure involving intense, large-scale deformation in otherwise flat-lying strata. 3. Deformation decreases with depth beneath and distance away from the structure. 4. Calvin 28 exhibits a recognized relationship between stratigraphic displacement in the uplift and crater form. 5. The occurence of a microbreccia. 6. No igneous material is associated with the structure. 7. The event responsible for the structure's origin is estimated to have released at least 1 x 10**26 ergs of energy, without the development of magma.

CONCLUSION. Comparison of the Calvin 28 cryptoexplosive disturbance with known endogenetic structures shows a notable lack of analogs. A yet unidentified endogenetic mechanism may be responsible for its origin, but the available evidence makes this unlikely. Comparison of Calvin 28 to structures of known or suspected exogenetic origin suggest consistent structural and physical analogs. While a considerable body of interpretive data favors an impact origin for the structure, specific physical data indicative of impact cratering events is not available. Based on the available data it is concluded that the Calvin 28 cryptoexplosive disturbance is the result of a near-surface, high energy shock event, and that the event can best be attributed to hypervelocity impact.

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GENERAL CHARACTERISTICS - CALVIN 28 CRYPTOEXPLOSIVE DISTURBANCE

Subsurface Structure		Microbreccia.	Yes	Circular Shape
Crater Diameter	7.24km	Volcanic Material.	None Identified	Central Domal Uplift
Structural Uplift.	415.5m	Mineralization.	None Identified	Encircling Annular Depression
Bedding Dips.	5° - 78°	Microstructures.	None Identified	Anticlinal Rim
Estimated Age.	Late Ordovician	Gravity Anomaly.	None	Intense Faulting
Deformation Decreases with Depth		Magnetic Anomaly.	None	Anomalous Bedding Thicknesses