Geological Society of America Centennial Field Guide—
North-Central Section, 1987

The Calvin 28 cryptoexplosive disturbance, Cass County, Michigan

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LOCATION

Geophysical data, geologic mapping, and the extensive drilling of oil and gas test wells have delineated a subsurface structure in Calvin Township, Cass County, Michigan, T.7S.,R.14W.; Adamsville, Michigan, 7½-minute Quadrangle. The center of the structure is approximately 1 mi (1.4 km) southwest of the village of Calvin Center (Fig. 1). The feature maintains a surface topographic expression and a partially encircling drainage pattern, but its major structural complexity is concealed by drift and Paleozoic rock.

The location of the Calvin 28 cryptoexplosive disturbance is shown in Figure 1, which uses an idealized geologic map as a base and to which road numbers have been added. The Calvin 28 cryptoexplosive disturbance can be reached by driving 4 mi (6.4 km) east on Michigan 60 from Cassopolis until encountering the intersection of Calvin Center Road. A right (south) turn on Calvin Center Road will take the visitor toward the structure. After travelling 4.2 mi (6.8 km) on Calvin Center Road, the visitor will cross over the outer encircling rim of the structure. The outer edge of this rim is delineated by a chain of lakes connected by Christiana Creek (Fig. 2). Continuing south on Calvin Center Road 0.5 mi (0.8 km), one encounters the village of Calvin Center. The village is located, subtly, within the annular depression surrounding the central uplift of the structure. Continue south an additional 1 mi (1.6 km) to the junction of Calvin Hill Stree and turn right (west). By traveling 0.5 mi (0.8 km), turning left (south) on an unnamed light-duty road, and following it to its end, the visitor will arrive at the center of the central domal uplift of the structure. By returning to Calvin Center Road and turning right (south) and proceeding for an additional 2 mi (3.2 km) to the intersection of Mason Street, the visitor again enters the annular depression. This time the depressed area is more evident and is seen reflected in the course taken by streams that drain the depression and flow into Lafferty Lake (Fig. 2). By either continuing south on Calvin Center Road or turning right (west) on Mason Street, the visitor will cross the south edge of the encircling anticlinal rim. These high and low areas are evident in the surface topography illustrated in Figure 2. A northwest-southeast geologic section is shown in Figure 3. This section depicts the massive structural upheaval displayed beneath the surface expressions. Although the visible geology at the Calvin 28 cryptoexplosive disturbance is subtle and not particularly exciting, the subsurface geology is of much interest; many researchers consider the structure to be the most anamolous geologic feature in the Michigan Basin.

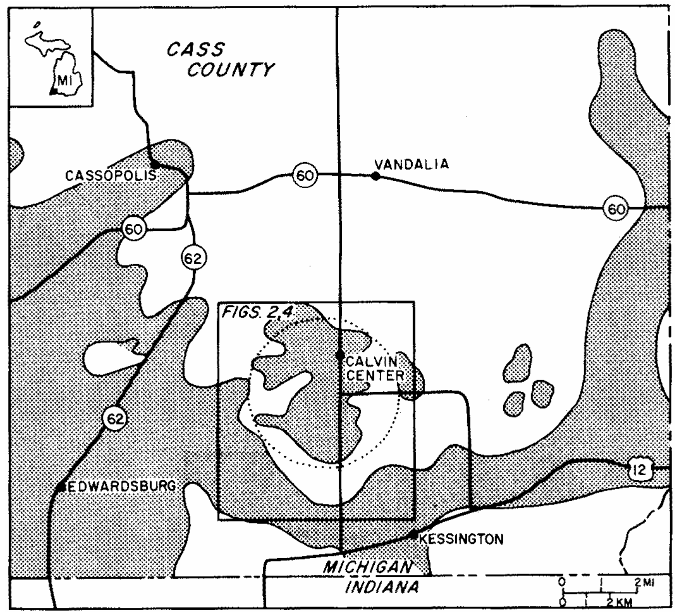

Figure 1. Map of the southeastern part of Cass County, Michigan, showing location of the Calvin 28 cryptoexplosive disturbance (dotted circle). Shaded area, Ellsworth Shale; unshaded area, Coldwater Shale.

DESCRIPTION

In 1982, an exploratory well, the Halwell, Incorporated, Hawkes-Adams #1-28, was drilled through the central domal structure in Section 28 of Calvin Township, Cass County, Michigan. The well penetrated 1,591 ft (485 m) of regional, although thinned, Paleozoic strata down to the Late Ordovician Cincinnatian Series. Instead of encountering the expected Middle and Lower Ordovician stratigraphic sequence, the well bore entered into a shortened section of the Lower Ordovician Prairie du Chien (Fig. 3). The base of the Prairie du Chien and the top of the Late Cambrian Trempealeau Formation were 1,243 ft (379 m) above normal regional levels. Continued drilling revealed the upper half of the Munising Formation to be absent down to its Eau Claire Member. The Mount Simon Sandstone Member, lying in its proper stratigraphic position below the Eau Claire, showed a vertical displacement of 1,363 ft (415.5 m). Geophysical well logs run on the test well revealed complex faulting in addition to steep and varied dips within the well bore. Continued drilling of more than 100 Devonian test wells in the area has defined the structure as an isolated, nearly circular predominantly subsurface feature with a diameter of 4.5 mi (7.25 km) and consisting of a central dome, an annular depression, and an encircling anticlinal rim. The heavily drilled Devonian horizon reflects the general structural characteristics of the feature, defined by limited deep test wells and seismic profiling (Fig. 4).

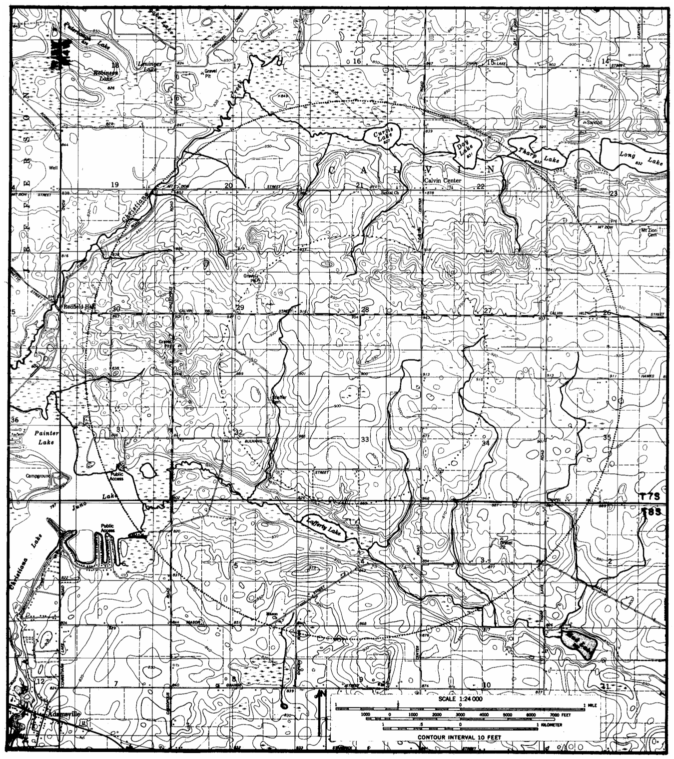

Figure 2. Map of part of the Adamsville 7½-minute Quadrangle showing the surface expression of the Calvin 28 cryptoexplosive disturbance. Circles indicate known subsurface limits of the central uplift and anticlinal rim structures. Structurally related drainage patterns are enhanced.

Previous work involving the Calvin Township structure is limited. R. J. DeHaas (written communication, 1983), in a presentation to the Michigan Basin Geological Society, provided evidence of dramatic structural uplift associated with a dome beneath the Calvin 28 oil field. He suggested the “cryptoexplosive” nature of the domal feature based on superficial comparisons to other Midwestern and European cryptoexplosive disturbances, and first brought attention to the surface topographic expression of the structure.

Mata and Myles (1985) interpret the feature to be the result of basement faulting in a technically “tight” and compressed corner of the Michigan Basin. The southwestern portion of the Michigan Basin, which includes Cass County, is interpreted as a region of compression and stress due to its close proximity to the Illinois Basin. The ensuing room problem caused fault blocks to pop up and fold over.

A geophysical investigation of the structure by Ghatge (1984) indicates no gravity anomalies or magnetic anomalies to 1 milligal associated with the structure. Ghatge concluded that any interpretation of the structure based on its gravity and magnetic surveys would not be able to explain the intense uplift or missing Cambrian and Ordovician sediments. While Ghatge favored origin by impact, he felt his evidence was insufficient to categorize the feature as anything but a “crypto-explosion structure.”

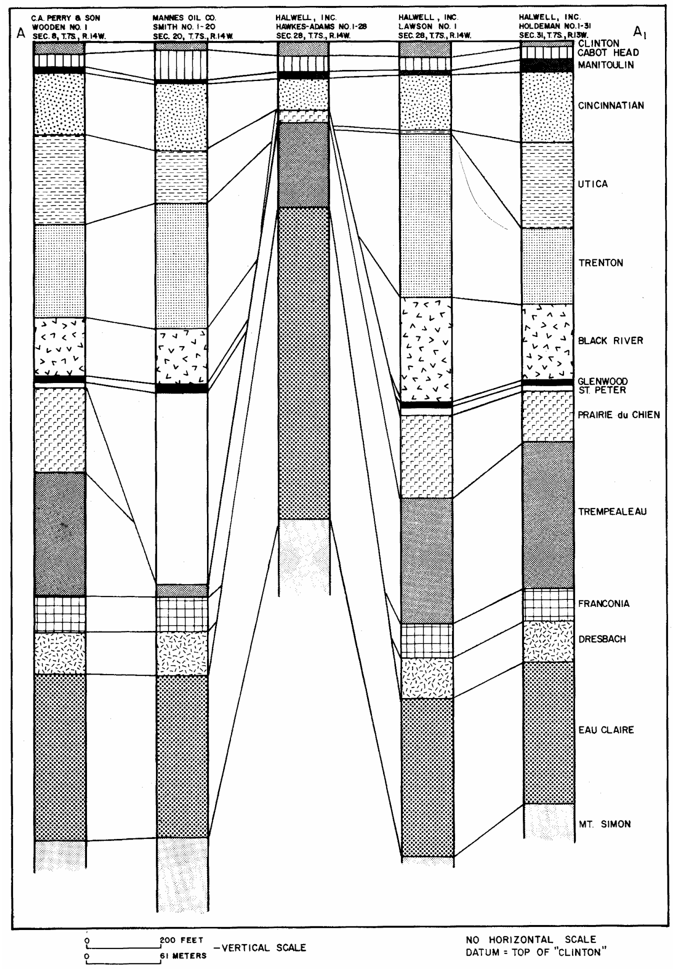

Figure 3. Northwest-southeast cross section indicating stratigraphic uplift and missing lithology associated with the Calvin 28 cryptoexplosive disturbance. Line of section shown on Figure 4.

In an extensive study, Milstein (1986) defines the complete cryptoexplosive nature of the structure and identifies the feature as the Calvin 28 cryptoexplosive disturbance.

Milstein calculates the age of the event responsible for the formation of Calvin 28 to be prior to Early Silurian time, but after deposition of the Early Cincinnatian Upper Richmond Group. Milstein also suggests that the present surface topographic expression of the feature is due to either slumping and settling of unstable sediments related to complex faulting, the periodic reactivation of faults resulting in the further upward movement of disrupted strata, or continuous rebound action from the initial event forming the structure.

Milstein (1986) finds that the Calvin 28 structure consists of a centrally located uplift 2 mi (3.25 km) in diameter, with structural closure on the Devonian Traverse Limestone of 135 ft (41 m), a surrounding annular depression about 3,280 ft (1 km) wide, and an outer encircling aniclinal feature or rim, roughly 3,280 ft (1 km) wide with a structural relief of 112 ft (34 m) on the Traverse Limestone.

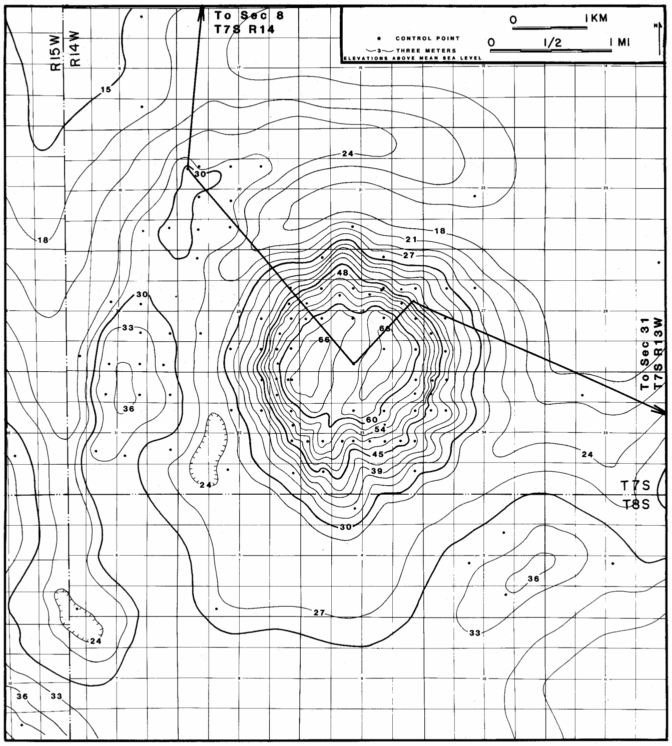

Figure 4. Structure contour map of the Calvin 28 cryptoexplosive disturbance as expressed on the top of the Devonian Traverse Limestone (from Milstein, 1986).

Milstein (1986) concludes that any explanation for the origin of the Calvin 28 structure must accommodate the following observations. (1) The structure is circular, containing a central uplift, surrounding annular depression, and a peripheral anticline. (2) Structural deformation is intense, involving large-scale faulting and upward movements of strata. (3) More than 906 feet (276 m) of strata is missing in portions of the structure, while other locations show highly anomalous thicknesses of units. (4) Deformation wanes with depth beneath, and distance away from, the structure. (5) The structure exists as an isolated feature. (6) No volcanic material is identified in association with the structure. (7) A microbreccia consisting of fractured and unfractured floating quartz grains in a carbonate matrix is identified in deep well samples. (8) The event responsible for the structure's origin is estimated to have released at least 1 x 10^{26} ergs of energy, nearly instantaneously, without the development of magma.

Possible origins for such large-scale cryptoexplosive structures as Calvin 28, involve both endogenetic and exogenetic processes. Excellent summaries of both arguments for the origin of cryptoexplosive structures have been given by French (1968) and McCall (1979).

Milstein (1986) compares the Calvin 28 cryptoexplosive disturbance with both endogenetic and exogenetic structures that exhibit similar characteristics. Endogenetic structures that exhibit characteristics consistent with structural patterns identified in the Calvin 28 feature include: maars, diatremes, calderas, kimberlite pipes, igneous intrusives, diapirs, and solution subsidence structures. Exogenetic structures exhibiting similar characteristics are limited to cryptoexplosive/astroblemes and impact craters.

In comparing endogenetic structures to the Calvin 28 feature, Milstein (1986) finds no significant evidence to suggest that volcanic eruption, igneous intrusion, solution subsidence, or a diapiric mass of sedimentary material is responsible for the structure's origin. No igneous material occurs in association with the structure. If igneous material had been present at the structure, even in small amounts, it would be difficult to explain its absence by weathering processes. Diapirism is ruled out by a stratigraphic configuration that would not allow the significant density inversion necessary for flowage. The structural pattern of the feature and lack of soluble strata below the structure rule out the possibility of solution subsidence.

Milstein (1986) identifies eight characteristics of the Calvin 28 cryptoexplosive disturbance that strongly favor origin by impact. (1) Terrestrial surface impact structures with central uplifts (complex craters) show a modelable relationship between stratigraphic displacement in the uplift and the crater form (Grieve and others, 1981). The Calvin 28 structure exhibits this relationship. (2) The waning of structural deformation beneath Calvin 28 is indicated by seismic profiles and dipmeter readings from deep test wells. The lessening of derangement with depth would not be expected from a tectonic or volcanic origin, but would be consistent for structural deformation incurred from a downward-projected shock envelope (Shoemaker, 1960; Lindsay, 1976). (3) The structural pattern of Calvin 28 indicates that a large amount of near-surface energy was involved in the formation of the structure and that the energy was released as a single nearly instantaneous event. (4) No igneous material has been recovered from well cuttings or identified in petrographic studies involving the structure. (5) Calvin 28 is an apparently isolated circular structure of intense deformation in otherwise flay-lying strata. (6) The lack of any magnetic or gravity anomalies associated with the circular structural pattern is a trait commonly identified with impact craters in sedimentary targets. (7) The presence of a microbreccia consisting of fractured and unfractured floating quartz grains in a carbonate matrix is similar to microbreccia associated with impact craters in sedimentary targets (Short and Bunch, 1968). (8) The energy required to produce the 4.5 mi (7.24 km) diameter structure, the apparent structural relief, the missing strata, and the intense structural deformation is at least 1 x 1026 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 in a sedimentary target (Shoemaker and Wolfe, 1982).

These eight characteristics would account for all major features listed earlier and considered essential in the evaluation of Calvin 28's origin.

While an endogenetic origin for most cryptoexplosive structures is disputed (French, 1968; McCall, 1979), the possibility exists that a yet unidentified endogenetic process may have formed Calvin 28. It is unlikely though that such an event could generate the tremendous energy required to form Calvin 28, without the presence of magma.

While not ruling out an endogenetic origin, Milstein (1986) concludes that the Calvin 28 cryptoexplosive disturbance is the result of a nearly instantaneous shock event, and that the event can best be attributed to hypervelocity impact.

REFERENCES CITED

French, B. M., 1968, Shock metamorphism as a geological process, *in* French, B. M., and Short, N. M, eds., Shock metamorphism of natural materials: Baltimore, Maryland, Mono Book Corporation, p. 1-17.

Ghatge, S. L., 1984, A geophysical investigation of a possible astrobleme in southwestern Michigan [M.S. thesis]: Kalamazoo, Western Michigan University, 41 p.

Grieve, R.A.F., Robertson, P. B., and Dence, M. R., 1981, Constraints on the formation of ring impact structures, based on terrestrial data, *in* Schultz, P. H., and Merrill, R. B., eds., Multi-ring basins, Lunar and Planetary Science Conference, 12th, Houston, 1980: New York, Pergamon Press, p. 37-57.

Lindsay, J. F., 1976, Lunar stratigraphy and sedimentology; Developments in solar systems and space science, 3: New York, Elsevier Scientific Publishing Company, p. 65-79.

Mata, F., and Myles, J., 1985, Geology, geophysics must be combined for basin exploration: Michigan Oil and Gas News, v. 91, no. 12, p. 65.

McCall, G.J.H., ed., 1979, Astrobleme-cryptoexplosion structures: Stroudsburg, Pennsylvania, Dowden, Hutchinson and Ross, Incorporated, Benchmark papers in geology, v. 50, p. 1-4, p. 4-20.

Milstein, R. L., 1986, Impact origin of the Calvin 28 cryptoexplosive disturbance, Cass County, Michigan [M.S. thesis]: Greeley, University of Northern Colorado, 87 p.

Shoemaker, E. M., 1960, Penetraion mechanics of high velocity meteorites, illustrated by Meteor Crater, Arizona, *in* McCall, G.J.H., ed., Meteorite craters: Stroudsburg, Pennsylvania, Dowden, Hutchinson and Ross, Incorporated, p. 170-186.

Shoemaker, E. M., and Wolfe, R. F., 1982, Cratering time scale for the Galilean satellites, *in* Morrison, D., ed., The satellites of Jupiter: Tuscon, University of Arizona Press, p. 277-339.