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Anomalous Paleozoic outliers near Limestone Mountain, Michigan

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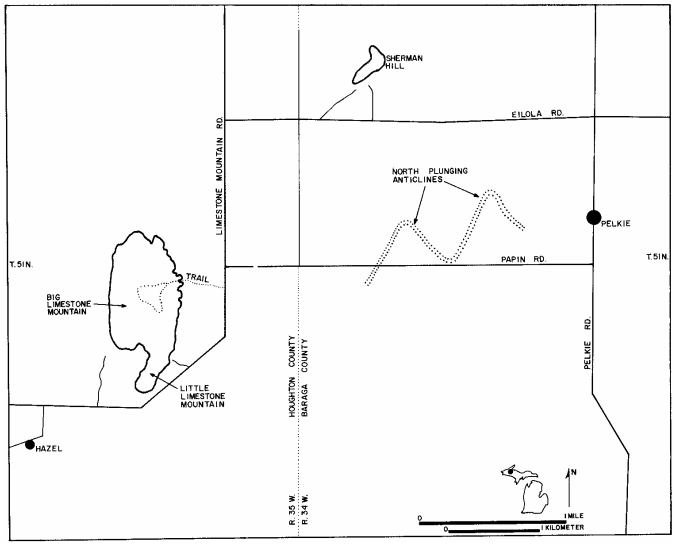

Figure 1. Location of Limestone Mountain, Sherman Hill, and two plunging anticlines near Pelkie, Michigan.

LOCATION

Limestone Mountain, Sec.`3,14,23,24,T.51W.,R.35W., Houghton County, Michigan; Pelkie, Michigan, 7½-minute Quadrangle. Limestone Mountain is located 1 mi (1.6 km) northeast of Hazel, Michigan (Fig. 1). Access to Limestone Mountain is by private road or foot trail. The trail head is located on the west side of Limestone Mountain Road, 800 ft (244 m) south of this road's intersection with Papin Road (Fig. 1). Limestone Mountain is located on privately owned wilderness land, and permission should be obtained prior to entry.

SIGNIFICANCE

Limestone Mountain rises more than 300 ft (90 m) above the surrounding regional topography and consists of Ordovician, Silurian, and Devonian carbonates overlying Precambrian sandstone deposits. Considerable deformation is evident at the structure and in smaller, isolated outcrops in the vicinity. Deformation involves major and minor faulting, folding, shearing, missing stratigraphic units, brecciated dolomite, and beds with varied strikes and dips, with some of these beds being pitched near vertical. Structural irregularities also include deformation microstructures in quartz and feldspar grains from the sandstone units.

Limestone Mountain is the westernmost identified outlier of Paleozoic rock in Michigan's Northern Peninsula. The Devonian strata identified at Limestone Mountain are found nowhere else in Michigan's northern peninsula. The nearest outcrops of equivalent-aged rocks are almost 200 mi (320 km) to the southeast.

The Limestone Mountain structure and its surrounding region have been the subject of geologic investigations for nearly 140 years. To date, no positive hypothesis has been presented to account for the preservation of these outliers, or to explain the cause and extent of structural deformation associated with them.

GEOLOGICAL SETTING

The geology of the Keweenaw Peninsula, as shown in Figure 2, has been well defined due to the intense prospecting for copper in the region. A good general outline of the regional geology has been presented by Halls (1966).

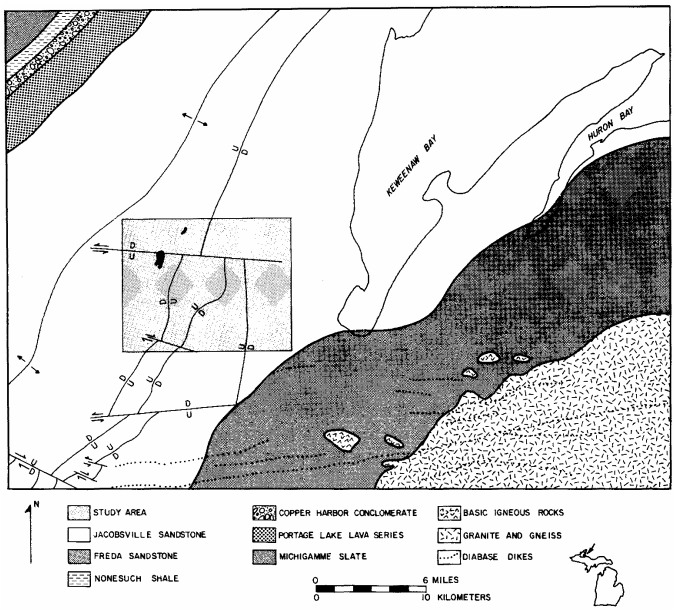

Figure 2. The general geology of southeastern Keweenaw Peninsula, Michigan. Map indicates the location of Limestone Mountain and Sherman Hill. Interpretation of bedrock and structural geology modified from Meshref and Hinze (1970, Plate 2).

The Limestone Mountain region of the Keweenaw Peninsula consists of a fairly flat plain with a few prominent hills rising to a maximum of 1,133 ft (345 m) above mean sea level. The area was glaciated by the southerly movement of the Pleistocene Keweenaw sublobe of the Superior lobe. Pleistocene drift deposits vary in thickness from 0 to 300 ft (90 m).

The Limestone Mountain region is drained northeasterly by the Otter, Silver, and Sturgeon rivers. Hoehl (1981) reports that the Otter River north of Sherman Hill is apparently structurally controlled, whereas there is no evidence of such control influencing the other two rivers.

Most regional streams cut sharp-sided valleys into the clayey to silty soil.

The stratigraphy of Limestone Mountain is shown in Figure 3 and is revised from the paleontological work of Case and Robinson (1914).

Outcrops and water-well drilling records establish the Jacobsville Sandstone as bedrock in the area surrounding Limestone Mountain.

Regionally the Jacobsville Sandstone overlies the Powder Mill Group of lavas (Fig. 3) and in turn is overlain unconformably by the Munising Formation of Upper Cambrian age. In the Limestone Mountain area the Cambrian rocks are overlain by dolomites ranging from Middle Ordovician to Middle Devonian in age.

Hoehl (1981) notes one water-well record from an area southeast of Limestone Mountain identifying limestone as bedrock. Hoehl was uncertain if the limestone was float or bedrock, but seismic tests established a buried high-velocity zone in the area, suggesting the possibility of limestone bedrock.

While Limestone Mountain is the largest and most complex of the Paleozoic outliers in the Pelkie area, it is best to consider all the outliers in the nearby region when considering Limestone Mountain. A summary of the major structural features of the area follows. (1) On the west side of Limestone Mountain, the basal Cambrian sandstone and overlying dolomites are moderately sheared and dip steeply. (2) There is highly disturbed Cambrian sandstone on the southwestern side of Big Limestone Mountain. This may represent soft-sediment deformation during a time of faulting. (3) On the eastern side of Little Limestone Mountain at the top of the Limestone Mountain Quarry, dolomite dips vertically and consists of brecciated dolomite that is healed. (4) At the south end of Little Limestone Mountain, there is an east-west fault along which the strata on the north side have dropped 20 ft (6 m) with reference to those of the south. (5) Sherman Hill northeast of Limestone Mountain is tilted slightly west. (6) Regionally the Jacobsville Sandstone is flat lying and known to be disturbed structurally in very few places. One mile (1.6 km) west of Pelkie a cluster of Jacobsville Sandstone outcrops shows divergent dips but generally northeasterly strikes. The structure resembles that of Limestone Mountain, but lacks dolomite in the vicinity. (7) Geophysical data indicate a thickening of glacial overburden east of Limestone Mountain. (8) Geophysical data suggests a graben or down warping of near-surface basement rock east of Limestone Mountain. (9) Gravity and magnetic lows form a partial ring encompassing the Limestone Mountain region. (10) Deformation microstructures have been identified in outcrops of the Jacobsville Sandstone at Limestone Mountain. (11) A fault exists at the south end of Big Limestone Mountain that separates it from Little Limestone Mountain. (12) The stratigraphic sequence of Paleozoic rock units found at Limestone Mountain includes a number of unexplained missing units. (13) Two mi (3 km) to the east of Limestone Mountain a pair of compressed anticlines plunging slightly to the east of north are clearly visible on air photographs. The ridge formed by the anticlines is not more than 6 ft (2 m) high and appears in an M-shaped pattern.

DESCRIPTION

Previous work involving the Limestone Mountain region is extensive. The following is a selected listing and summary of studies pertaining to the Limestone Mountain region.

Jackson (1849) first assessed the Limestone Mountain structure and assigned it a Silurian age based on paleontological evidence. The following year, Foster and Whitney (1850) offered the first explanation for the disturbed structures in the Limestone Mountain area. Their conclusion attributes noted structural deformation to core uplifting from some unknown volcanic process (cryptovolcanic).

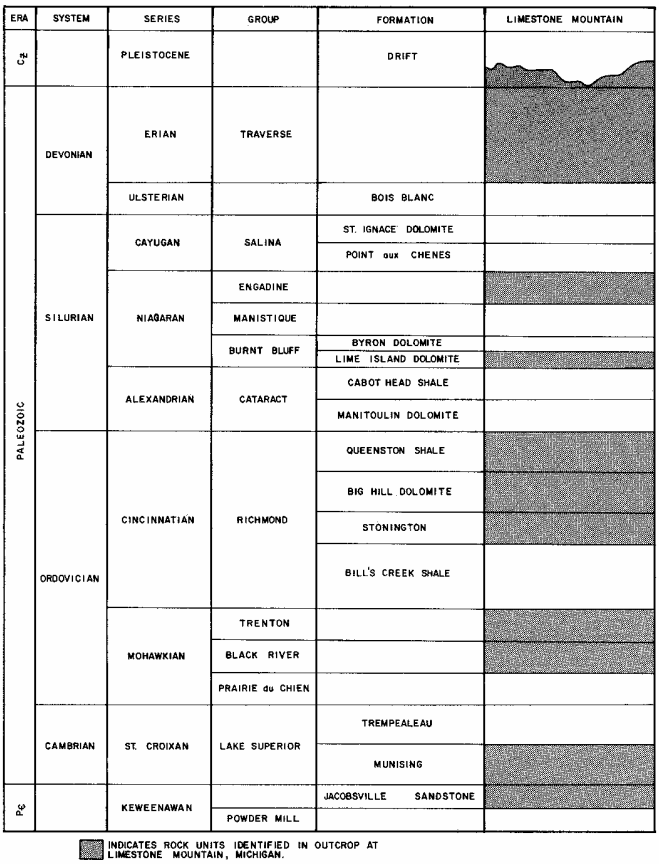

Figure 3. Stratigraphic column indicating rock units both missing and identified in outcrop at Limestone Mountain, Michigan.

Rominger (1873) states he could find no positive facts explaining the causes that produced the inclined position of the carbonate beds at Limestone Mountain. Rominger concludes that the structural irregularities are due to underwashing and the subsequent sinking of Paleozoic strata during glaciation, and are unrelated to upheaval at an earlier date.

Wadsworth (1891) reported extensively on the unpublished paleontological and cross-section work done on Limestone Mountain by W. L. Honnold of the Michigan Geological Survey. Based on this earlier work, Wadsworth theorized in 1897 that Limestone Mountain is the remnant of a synclinal or oblong basin-shaped fold.

Lane (1905) reports identifying a four-tiered surface expression on Limestone Mountain and attributed this to wave action from the ancient Great Lakes. Further paleontological investigations of the site were carried out and reported by Lane (1911). Lane's findings agreed with Jackson's earlier work that Limestone Mountain was of Silurian age.

A major investigation by Case and Robinson (1914) included palentological studies along with structural and stratigraphic interpretations. In this study the authors were unable to propose any hypothesis for the preservation of the Paleozoic outliers. They concluded that the upper layers of Paleozoic rocks showed no peculiar hardness or consistency which would have enabled them to resist erosion and that faulting does not account for their preservation. Case and Robinson speculated that the structural deformation noted is best attributed to landslides or slumps due to undercutting by surface or underground waters in comparatively recent times. Their investigation further suggested the presence of numerous faults associated with the structure at Limestone Mountain. The largest fault is believed to be located between Big and Little Limestone mountains and may be responsible for 80 ft (24 m) of offset in the top of the Jacobsville Sandstone between the two structures (Fig. 4). The major contribution of Case and Robinson's investigation is the exhaustive description and identification of Paleozoic rocks noted at Limestone Mountain. Their findings show that rocks of not only Pre-cambrian age, but those of Cambrian through Middle Devonian age are present and involved in the structural deformation at Limestone Mountain (Fig. 3). This is of great significance as no other rocks of Middle Devonian age appear in outcrop in Michigan's Northern Peninsula. The nearest outcropping of Middle Devonian rocks occur in Michigan's Southern Peninsula west of the Straits of Mackinac on Beaver Island, 175 mi (280 km) to the southeast.

Roberts (1940) concludes that Limestone Mountain is a syncline with a northerly strike and a shallow plunge toward the north. While Roberts defines an easterly striking fault between Big and Little Limestone mountains, with a minimum of 150 ft (46 m) displacement, he is unable to conclude the exact direction of movement. Further, Roberts does not speculate as to whether faulting or folding is the most important factor in creating the structure, though he states that faulting is the most plausible.

Thwaites (1943) speculates that Limestone Mountain may be caused by a major fault on the east side of the structure. As evidence, Thwaites notes vertical bedding and brecciated but healed dolomite on the eastern side of Little Limestone Mountain. Inclined bedding noted at the southeastern corner of Big Limestone Mountain is attributed to drag along the projected fault.

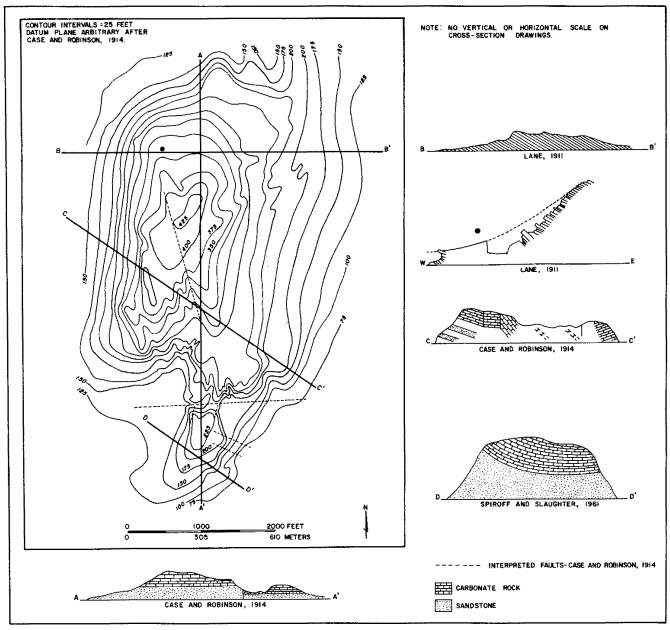

Figure 4. Cross-section interpretations through Limestone Mountain, Michigan, 1911 to 1961.

Spiroff (1952) concludes that Limestone Mountain is the remnant of a graben structure and the Paleozoic rocks found there were preserved by some uncommon glacial movements.

Hamblin (1958) suggests that Limestone Mountain is the remnant of a major regional structure related to compressional forces that caused the Keweenaw fault. He further suggests that Limestone Mountain is a syncline flanked to the west by an anticline of equal or greater magnitude and to the east by an anticline, monocline, or fault.

Based on geophysical data, Aho (1969) suggests Limestone Mountain is the result of basement faults that existed prior to deposition of the Jacobsville Sandstone, and were reactivated during subsequent regional events.

Read (1970) finds that thin sections of quartz and feldspar from the disturbed Jacobsville Sandstone at Limestone Mountain exhibit microstructures similar to those found in quartz and feldspar from generally accepted astroblemes. While not concluding that the Jacobsville Sandstone is “shocked,” Read suggests that Limestone Mountain and its accompanying outliers represent the remnants of an encircling graben or downwarp associated with an Ordovician astrobleme.

In a report concerning the potential for diamond-bearing kimberlites in Northern Michigan and Wisconsin, Cannon and Mudrey (1981) speculate that Limestone Mountain and the adjacent Sherman Hill are cryptovolcanic structures formed as the result of collapse over deeper-seated kimberlite pipes. Based on fragments of Early Devonian rocks found at Limestone Mountain, Cannon and Mudrey assign a Devonian or later age to the structures.

In a geophysical investigation of the Limestone Mountain area, Hoehl (1981) concludes that Limestone Mountain is a fault-controlled, north-south striking, synclinal structure flanked on the west by a monocline, with the latest faulting and folding in the area occurring during Late Mississippian time in conjunction with movements in the Michigan Basin. Hoehl's geophysical data indicates that there is no evidence to suggest the existence of a kimberlite pipe or any other high-density, magnetic, near-surface body of igneous rock associated either locally or regionally to the Limestone Mountain-Sherman Hill area.

Additional work by Read (written communication to R. C. Reed, Michigan Geological Survey, 1984) implies the existence of a partial ring of gravity and magnetic lows associated with the Limestone Mountain region (Fig. 5). Read asserts that both anomalies are consistent with a model for a ring graben in which high density and high magnetic basement rock has been dropped down. He maintains, in this instance, the down-dropped rock is basalt of the Powder Mill Group. Read's work further identifies a pair of compressed north-plunging anticlines slightly to the east of north of Limestone Mountain. Read states that the type and pattern of these folded anticlines does not fit with a pattern commonly identified with normal faulting alone. He feels they do, however, compare favorably with the complex combination of faults and folds that are often identified in conjunction with astroblemes found in areas of flay-lying sedimentary rocks.

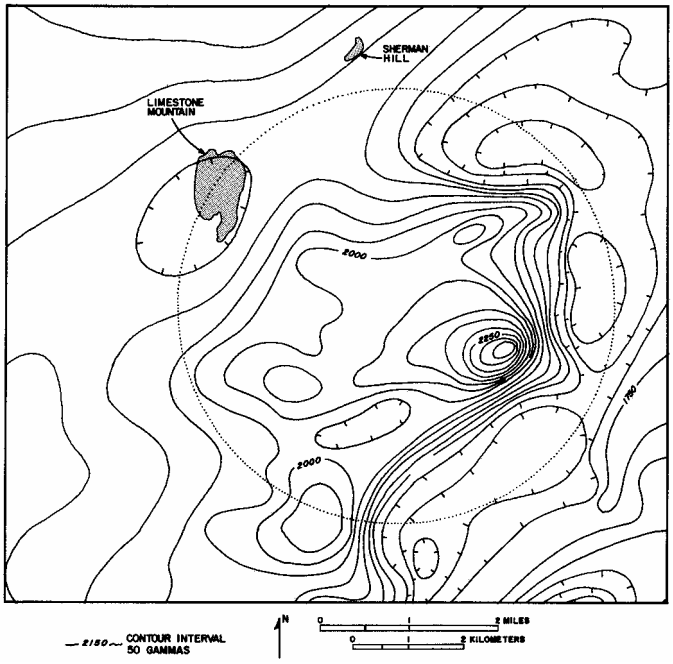

Figure 5. Aeromagnetic map of the Limestone Mountain region. Dotted circle indicating partial ring of magnetic lows (modified from Read, 1984).

Milstein (1986), in reviewing structures of a cryptoexplosive nature found in the Michigan Basin, concludes that Limestone Mountain, Sherman Hill, and similar disturbed outcrops of Paleozoic rock found near Pelkie, Michigan, should be classified as cryptoexplosive disturbances. Milstein further states that while no solid evidence implicating impact origin for the structures exists, a large body of interpretive data suggests the possibility that the cryptoexplosive disturbances in the Limestone Mountain area are remnants of an impact structure as defined by Grieve and others (1981).

As can be noted, the Limestone Mountain area has been the subject of numerous investigations. To date, no consensus has been reached to explain these interesting outliers or their accompanying structure. Visitors to Limestone Mountain are reminded that they will be in a rural/wilderness area and that proper precautions and preparations should be taken. Rugged clothing, boots, compass, and insect repellent are essential. Due to the unique nature of these outliers, the taking of samples is discouraged.

SITE DESCRIPTIONS

A series of stops has been outlined to acquaint the visitor with the structure and stratigraphy of the Limestone Mountain outliers.

Stop 1. Sherman Hill. To reach Sherman Hill, proceed north from Pelkie, Michigan, on Pelkie Road 0.5 mi (0.8 km) to the intersection of Eiloca Road. Turn west and continue 1.5 mi (2.4 km). Sherman Hill and a small quarry operation located at the site will be visible on the north side of the road. Sherman Hill is located on private property, and permission to enter the grounds must be obtained from Mr. Reuben Turunen.

While no fault is visible at the surface in the area, at the southwest end of the quarry, fault breccia and fracture surfaces suggest the existence of a major fault striking to the northwest.

Stop 2: Big Limestone Mountain. To reach Big Limestone Mountain from Pelkie, go south on Pelkie Road 0.5 mi (0.8 km) to the intersection of Papin Road. Proceed west on Papin Road 2.5 mi (4 km) to the junction of Limestone Mountain Road. Turn south and continue 0.75 mi (1.2 km). The entrance to Limestone Mountain Quarry is marked by a pair of large gateposts.

This quarry is owned by the Limestone Mountain Company, but there are no local offices. There is no barrier at the entrance to the access road and presumably no objection to visitors. One may drive straight into the quarry.

Active quarry operations have not taken place for more than 15 years, and exposed dolomite beds appear somewhat discolored by weathering.

This quarry is the only locality among the anomalous Paleozoic outliers where a large mass of rock with steep dips can be seen. Dips throughout most of the quarry are in excess of 45°, but at the quarry's north-end beds dip nearly vertical.

By returning to Limestone Mountain Road and continuing south 0.7 mi (1 km), an access road on the north side will lead to the western flank of Limestone Mountain. On this western flank, large dolomite ledges are exposed. Permission to enter this part of Limestone Mountain must be obtained from Mr. Raymond Clark whose house is located on the access road.

The exposed ledges suggest dolomite reaches a thickness of more than 180 ft (55 m) at this outcrop. The dolomite ledges are continuous all the way to the north end of the mountain, and their continuity is only occasionally broken by beds of buff-colored deformed sandstone.

Stop 3: Little Limestone Mountain. Permission to enter Little Limestone Mountain must be obtained from Mr. Raymond Clark. Little Limestone Mountain is reached by travelling 0.4 mi (0.6 km) on Limestone Mountain Road from the Clark access road. On the north side of the road a north-south section-line fence can be seen. This fence runs to the top of Little Limestone Mountain.

About 500 ft (152 m) in from the road, the ground begins to rise steeply and moss-covered ledges of dolomite can be seen to the northeast. These dolomite beds are similar to those seen in the Big Limestone Mountain Quarry, except the dips are less steep (northwestward).

By following the fence up the slope, the visitor will eventually encounter a small, nearly vertical fault, striking 70° east of north. South of the fault, bedding dips steeply northeast; north of the fault, bedding is nearly vertical.

Eventually the section fence will turn, and at this point the visitor should continue in a north line rather than follow the fence. At a distance of 250 ft (76 m) a small prospect pit can be found. A similar pit can be found about 125 ft (38 m) to the northwest. In both pits, the dip of the bedding is approximately 30° northeast.

Stop 4: Pair of plunging anticlines. To reach the anticlines from Pelkie, travel south 0.25 mi (0.5 km) to the intersection of Papin Road. Turn west on Papin Road and proceed 1 mi (1.6 km) to Marshall Road. At this location the visitor will be at the middle portion of a pair of north-plunging anticlines composed of Jacobsville Sandstone. The anticlines lie on the north side of Papin Road. The folds accompanying these anticlines are greatly eroded and easily escape notice at ground level but are clearly visible in air photos. What is visible at ground level is a low ridge of outcrop whose structure resembles the letter “M” (Fig. 1). It is easier to follow the structure on the eastern anticline. Permission to traverse this property must be obtained from Mr. George Maki, whose house is located on the north side of Papin Road.

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