A STRUCTURAL STUDY OF THE KENTLAND, INDIANA IMPACT SITE.
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This report deals with one of the approximately fifteen cryptoexplosion or meteorite impact structures which occur in the east-central United States. The Kentland, Indiana impact site is located in the north-east corner of Indiana about 4 km. east of the town of Kentland (see insert, Figure 1). Although most of the region is veneered with glacial till, a large stone quarry exposes a portion of the central uplift of this impact site. A 700 meter thick sequence of Ordovician through Pennsylvanian limestones, dolomites, sandstones and shales were disrupted by the impact which produced the Kentland structure.

Recent geophysical and drilling information have outlined the major features of the structure (1). The central uplift consists of Ordovician and Silurian strata that have been uplifted over 550 meters above their normal stratigraphic position. The 4 km. diameter central uplift is coincident with a +3.5 milligal gravity anomaly due to the uplift of the dense Ordovician carbonates. A ring syncline or structural depression at a radii of 3.2 km. from the center of the structure is expressed as a -1 milligal anomaly. At a radii of 6.4 km., a +0.5 milligal anomaly having approximately 15 meters of structural relief defines a ring anticline. This ring anticline is the approximate limit to the disturbance, thus the Kentland impact site is about 13 km. in diameter.

Structural complexity increases from the flanks of the central uplift inward. Dips on the outer Silurian strata are generally 20-30 and increase to 75-90 for the Ordovician rocks. Exposures in the 80 meter deep stone quarry, which is situated on the northern flank of the uplift, show complex folding, faulting and brecciation involving both Ordovician and Silurian rocks. Both normal and reverse faulting have occured with most of the fault planes dipping steeply. Monolithologic and mixed breccias are well developed in the quarry, with all gradations existing between breccias composed of shattered clasts of a single lithology to complex megabreccias composed of blocks up to 100 meters across. Most of the mixed breccias are irregular, tabular bodies emplaced along faults and bedding planes and consist of clasts derived from all lithologies present in the quarry. Some mixed breccias show flow foliation of the groundmass and preferred orientation of elongate clasts.

Quartz grains in the mixed breccias commonly show irregular fractures, cleavage, microfaulting and development of basal deformation lamellae. Planar features in the quartz grains appear to be absent. The presence of abundant shatterconing and the apparent absence of high pressure mineral phases suggest

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that shock pressures did not exceed 75 kb. and probably did not get above 50 kb. (2). This evidence supports the contention that relatively deep, sub-crater floor material is being sampled.

Figure 1 is a preliminary bedrock geology map based on quarry exposures and recent drilling information. The center of the uplift is interpreted to be composed of Lower Ordovician blocks in a chaotic arrangement surrounded by Middle Ordovician and Silurian carbonates that are folded and cut by circumferential and radial faults but are still structurally coherent. There appears to be a relation between lithology and deformational style, with the more competent carbonates deforming as blocks from 400-800 meters in length, while the more mobile shale and sandstone units are caught up in complex faulting between these large blocks. Major circumferential faulting is believed to occur as dip slip or at low angle to bedding surfaces.

Structural response of the rocks to the impact appears to involve several steps. After the passage of the initial compressional shock wave, some type of rebound mechanism is postulated to have operated. Material which formed the central uplift moved both inward and upward, with the most intense deformation confined to an area in the center of the structure approximately 2 km. in diameter. Deep drilling in the quarry has indicated that at least some of the near vertical fault planes extend to a depth of at least 300 meters. Steep normal faulting appears to be one of the earliest structural responses during central uplift formation at the Kentland site. During this faulting, dilation of the strata occured, probably mainly along bedding surfaces. During this time some mixing of the various lithologies took place and produced the material of the mixed breccias. Gravitational settling and compression of the uplifted material squeezed the trapped mixed breccia into available fissures and openings. This late stage settling would account for the reverse faulting relationships seen in the quarry. Erosion has since destroyed the upper portions of the original crater and has exposed material from the root zone of the central uplift.

Recent numerical simulations of high-explosive cratering experiments have indicated that volumetric rebound of material and the collapse of the crater walls are two probable mechanisms operating during central uplift formation (3). The results of of this study indicate that at least for the Kentland site, the structural relationships and large displacements along steep faults are most consistent with some type of rebound mechanism.

REFERENCES. (1) Tudor, D.S. (1971) Ph.D Thesis, Indiana Univ. (2) Carter, N.L. (1968) Shock Metamorphism of Natural Materials, p. 453-474. (3) Ullrich, G.W., Roddy, D.J. and Simmons, G. (1977) The Moon, in press.

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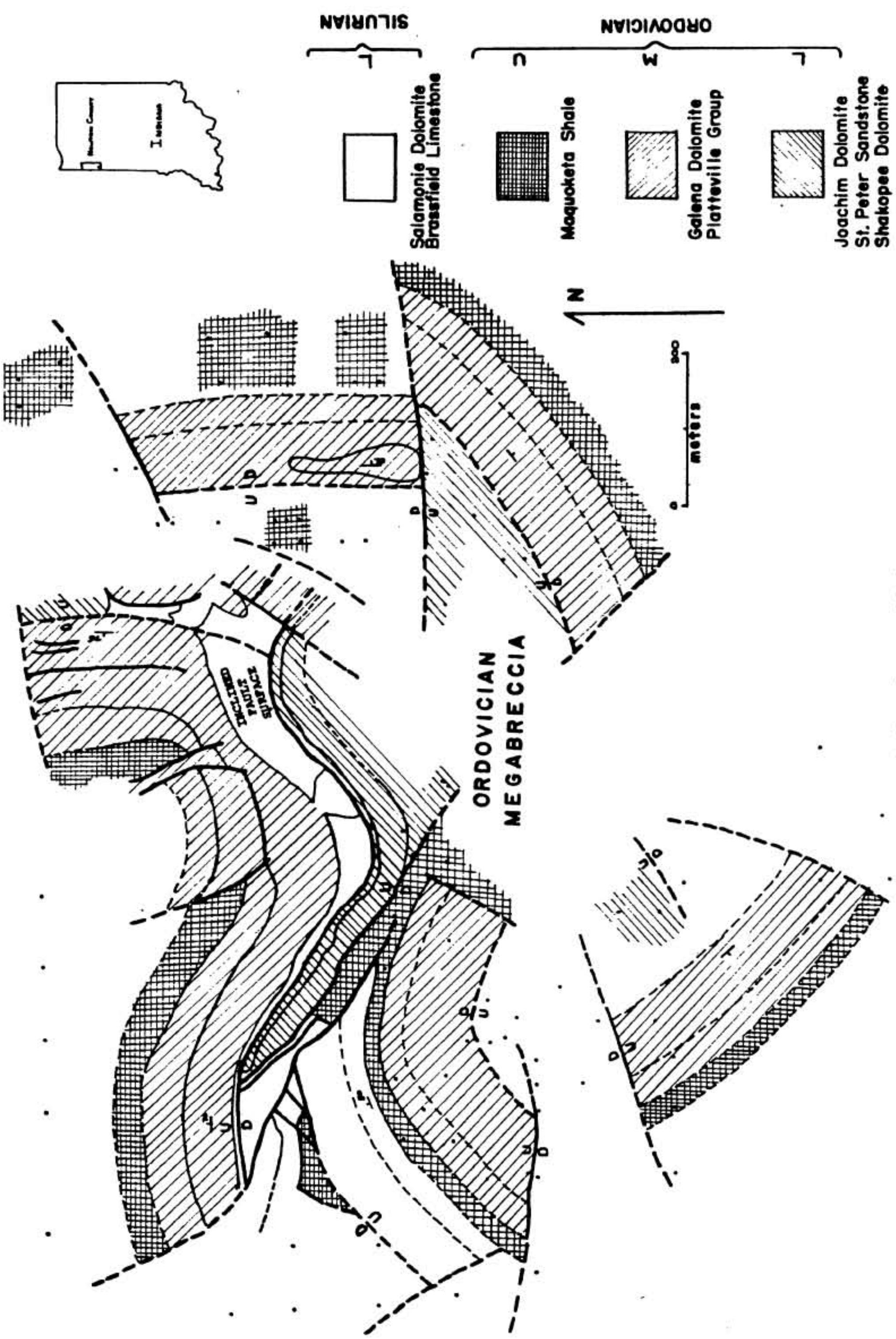

FIGURE 1. Preliminary bedrock geology map of the central uplift of the Kentland, Indiana impact structure.