

## THE GEOLOGY OF THE MANSON IMPACT STRUCTURE: SAMPLE STUDIES REVEAL A WELL PRESERVED COMPLEX IMPACT CRATER

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The Manson Impact Structure (MIS) in north central Iowa is the largest impact structure in the United States, and with an age of 65.7 Ma is, within experimental uncertainty, the same age as the Cretaceous-Tertiary boundary (1), one of the greatest periods of species extinctions known. An on-going study of water well cuttings has refined our models of the structure, produced by the interpretation of seismic and other geophysical data. These studies have defined the following terranes; a central peak of uplifted crystalline rocks, a crater moat filled with ejecta and related material mobilized by the impact and overlain by post-impact Tertiary(?) lake deposits, and a ring graben, a region of down-dropped blocks locally capped by ejecta material

1) The **central peak** region includes a central area of ejecta material, with polymictic breccia including impact-shocked quartz grains, surrounded by an area of crystalline rocks. This central peak configuration has been observed in extraterrestrial craters and is interpreted as produced when the evolving central peak "over shoots" its ultimate height and collapses into the crater moat producing a central peak crater (2).

2) The **crater moat**, the area between the central peak and the rim of the transient crater, appears to be mostly filled with ejecta material and debris that slumped off the central peak and the edge of the transient crater, and includes mixtures composed of polymictic breccia including shock deformed quartz, feldspar grains, and rare glass fragments mixed with grains to blocks of all strata disturbed by the impact (Cretaceous, Paleozoic, and Proterozoic sediments and Proterozoic crystalline rocks). The ejecta and related materials are overlain in many areas of the moat by apparently intact sequences of shale, siltstone, and sandstone that may have been deposited in a **lake** that formed after the crater stabilized. Analysis of spores and pollen from these strata show ferns to be the dominant floral element, similar to the fern spike reported for the earliest Tertiary (3).

3) The **ring graben** lies between the limits of the transient crater and the apparent crater. In this region large blocks of dominantly intact strata subsided as underlying material moved into the transient crater shortly after crater formation. This subsidence structurally preserved an estimated 330 m of Cretaceous strata (4) that were present in the area at the time of impact. To date, wells with a maximum of 190 m of this structurally preserved Cretaceous strata have been identified. Since the present erosional edge of Cretaceous rocks passes through the MIS, this provides a good estimate of the depth of MIS erosion, a minimum of 190 m and probably about 330 m, plus overlying ejecta material. In some areas of the ring graben these Cretaceous rocks are overlain by polymictic breccias interpreted as ejecta material. This ejecta should preserve a complete Cretaceous section as well as the impact surface, which must have been buried almost instantaneously by the ejecta.

The excellent state of preservation of the MIS and the good understanding of the strata disrupted by the impact, has allowed detailed modeling of the sequence of events that formed the structure and the materials involved. The impact of a 2 km diameter

bolide would have produced a hemispherical "vapor crater" with a diameter of 3.0 km (volume 7.1 km<sup>3</sup>) which, when combined with the bolide, yielded a total of 11 km<sup>3</sup> of vaporized material. The hemispherical "melt crater" had an estimated diameter of about 5.5 km (volume 43 km<sup>3</sup>). The parabolic "excavation crater" had a diameter of 21 km and a depth of about 3.8 km (volume 660 km<sup>3</sup>). Table 1 shows estimates of the volumes of various Earth materials that were blown out of the MIS assuming the model above. The final depth of the transient crater was estimated to be about 6 km (volume 1050 km<sup>3</sup>). The volume of material in the transient crater that was depressed rather than ejected was calculated by using the seismic controlled crater model to estimate the volume of the central peak and the volume of subsidence of the ring graben; detailed structural mapping of a shallow Paleozoic datum outside of the crater provided an estimate of the remnant rim uplift. Adding the central peak volume to the rim uplift and subtracting the ring graben subsidence yielded an estimate of the material displaced, 390 km<sup>3</sup> (or 37% of the volume of the transient crater). The remaining 660 km<sup>3</sup> of the transient crater represents the excavation crater and can be modelled by a parabolic crater 3.8 km deep (or 63% of the depth of the transient crater), with only 2.2 km (27%) of the transient crater depth produced by depressed target materials.

The high quality of the seismic data over the MIS and good control by well data reveal the excellent preservation of the structure. The resulting model gives us an opportunity to begin to understand the sequence of events that formed the structure, the materials involved, and provide a basis for modeling the effects of the impact on the environment at the end of the Cretaceous. It also will serve as a base for the design of future research drilling projects, which promise to produce a wealth of information on the MIS and large terrestrial impacts in general.

Table 1. Earth Materials Displaced from the Manson Impact Structure.

Rock Materials	Vaporized (km <sup>3</sup> )	Melted (km <sup>3</sup> )	Ejected (km <sup>3</sup> )
Carbonate	3.0	9.6	151.0
Sandstone	1.4	13.1	191.4
Siltstone	0.5	4.8	72.0
Shale	2.1	7.7	131.8
Chert	0.1	0.3	4.9
Coal and Lignite	<0.1	0.1	2.0
Igneous and Metamorphic	<u>0.0</u>	<u>0.6</u>	<u>63.8</u>
	7.1	36.2	616.9

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