MANSON IMPACT STRUCTURE RESEARCH PROGRAM: SUMMARY THROUGH JANUARY 1995; D.J. Roddy and E.M. Shoemaker, U.S. Geological Survey, Flagstaff, AZ 86001; R.R. Anderson, Iowa Department of Natural Resources-Geological Survey Bureau, Iowa City, IA 52242

The Manson structure is a 74-m.y.-old eroded impact crater buried beneath glacial drift in western Iowa. This feature, about 36.5 km in diameter, was interpreted as an ancient "cryptovolcanic" feature [1], but identification of shock metamorphic features in core drilled in the central uplift led to the suggestion that Manson was instead formed by a large impact [2]. More recently, preliminary isotopic age studies indicate that the Manson event may have occurred at the time of the K-T boundary, i.e., 65 m.y. ago [3,4,5], suggesting that the Manson event could have contributed to the K-T impact event and its mass extinctions [6]. In 1991, the Manson Impact Structure (MIS) Research Program was initiated as a multi-year study to produce an integrated view of the cratering event, define its relation to the K-T boundary, and determine the effects on the environment [7,8]. These integrated studies, now reaching completion, confirm that the Manson structure is indeed an impact site but that the impact occurred prior to K-T boundary time by about 9 million years. More specifically, new isotopic age studies based on $^{40}Ar/^{39}Ar$ dating show (1) an impact age of 73.8 $\pm$ 0.3 Ma (relative to 513.9 Ma for MMhb-1 hornblende standard) or 74.9 $\pm$ 0.3 Ma (relative to 520.4 Ma for MMhb-1 hornblende standard), and (2) that far-field ejecta from the Manson crater are still preserved in Upper Cretaceous Pierre Shale over 240-500 km northwest of the impact site [9,10,11,12]. Today, the well-preserved Manson structure offers significant insight into large-body impact cratering processes and effects.

The integrated Manson results summarized here were derived mainly from the combined geologic and geophysical studies conducted in the MIS Research Program. During 1991-1992, 12 holes were drilled primarily along an E-W line through the east half of the structure and its rim, producing 1283 m of core. The Iowa Department of Natural Resources-Geological Survey Bureau (IDNR-GSB), as part of a MIS cooperative program with the USGS, conducted the drilling along an AMOCO seismic reflection line that extends from near the center of the MIS through the east rim. Two holes were drilled in the terraced section of the crater walls, three in the crater floor region, and seven in the central peak. Using these cores, research teams have been conducting detailed petrologic, stratigraphic, biostratigraphic, shock-metamorphic, isotopic dating, paleomagnetic, geochemical, and laboratory geophysical studies. Field geophysical studies, such as seismic reflection, down-hole logging, and gravity, were conducted to provide structural information. The IDNR-GSB is archiving part of the core at its core facility; the USGS is archiving half of other selected cores at its Core Research Center in Denver and has distributed extensive samples to the MIS research teams involved in the full range of cratering, geologic, and geophysical studies at Manson.

In summary, the most significant Manson findings include (a) a new $^{40}Ar/^{39}Ar$ isotopic age of about 74 Ma; (b) paleomagnetic analyses of core that show the impact occurred during normal geomagnetic polarity; (c) petrologic analyses of core that show vertical displacement of basement rock in central uplift was over 5 km; (d) identification of a complex melt unit overlying at least part of the central uplift; (e) recognition of overturned and stratigraphically inverted near-field ejecta deposits on terraced crater walls; (f) recognition of far-field ejecta with shock metamorphism, deposited in the Crow Creek Member of the Pierre Shale 240-500 km northwest, possibly during an impact-generated tsunami; (g) documentation of rim collapse using core and geophysical analyses; (h) recognition of partial filling of the crater by landslides and/or other possible flow-type deposits using core and geophysical analyses; (i) determination that crater erosion was only moderate, leaving central uplift and terraced crater walls (overlain by ejecta with inverted stratigraphy) still intact; and (j) recognition of long-term hydrothermal activity and alterations in crater-fill deposits.

THE MANSON IMPACT STRUCTURE RESEARCH PROGRAM; Roddy, D.J. et al.

The goal of the MIS Research Program is to combine the individual research studies into an integrated picture of the Manson event in order to understand its role in the continuum of large impacts and their effects on the Earth. In general, we conclude that about 74 m.y. ago, during normal geomagnetic polarity time, an asteroid or comet 1 to 3 km in diameter impacted into a low-relief coastal or shallow marine environment in central North America. The impacting body is estimated to have been moving at 20 to 60 km/sec with 3 to 10 x 10^5 Mt of kinetic energy [13]. A large flat-floored crater, about 21 km across, formed in seconds. Crystalline basement was abruptly uplifted over 5 km to form a massive central peak with a shallow central depression. A breccia lens formed in the crater and a complex melt unit was deposited on at least part of the central peak, and presumably part or all of the crater floor. The rim and shallow sea (if present) surrounding the crater are estimated to have been transiently uplifted over 5 km in height for seconds or more during the cratering process [14]. Terrace collapse of the rim, lasting minutes or more, continued to enlarged the crater until it was about 36.5 km across [13]. A continuous ejecta blanket was deposited on the rim surrounding the crater, but if the impact occurred in a shallow ocean environment, returning sea waters probably washed part of the ejecta back into the crater. If the impact did occur in an ocean, a tsunami also may have formed and swept outward during the time when shocked ejecta were being deposited from the air over part or all of the shallow floor of the Late Cretaceous seaway in central North America. Terrace collapse of the uplifted rim was followed by the formation of a complex sequence of landslide and flow-type deposits that appear to have swept inward over the crater floor; these deposits would also have covered much or all of the melt unit if it overlay the crater breccia lens and fallback. As the rim collapsed, weak Keweenawan shales appear to have shed off the developing crater-wall terraces and flowed inward toward the center. Later, regional erosion degraded the area and probably the upper part of the central peak, removed the surrounding ejecta blanket (except for that preserved on the down-dropped terraces), and lowered the rim by tens to hundreds of meters, or more if ejecta thicknesses are included. The entire Manson structure is now covered by about 30-70m of glacial drift.

These conclusions were drawn directly from the Manson Impact Structure Research Program which has been jointly sponsored by the U.S. Geological Survey (USGS), the Iowa Department of Natural Resources-Geological Survey Bureau (IDNR-GSB), the National Science Foundation (NSF), U.S. Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA). The USGS, DOE, and NSF joint sponsorship is part of the U.S. Continental Scientific Drilling Program.

REFERENCES: [1] Hoppin, R.A. and Dryden, J.E., 1958, *J. Geology 66*, 694-699; [2] Short, N.M., 1966, *J. Geol. Edu, 14*, 149-166; [3] Kunk et al., 1987, *Eos Trans.* AGU *68*, 1514; [4] Kunk et al., 1989, *Science 244*, 1565-1568; [5] Hartung et al., 1990, *GSA Special Paper 247*, 207-222; [6] Alvarez et al., 1980, *Science 208*,1095-1108; [7] Roddy, D.J. and Shoemaker, E.M., 1991, 2nd Forum Cont. Sci. Drilling, USGS and Geophy. Inst., 18-21; [8] Roddy, D.J. et al., 1994, VIIth International Symposium - DOSECC/U.S. Continental Sci. Drilling Program, 203-207; [9] Izett et al., 1993, *Science 262*, 729-732; [10] Izett et al, 1993, 24th *LPSC*, 705-706; [11] Dalrymple, G.B. and Izett, G.A., 1994, *GSA Abs.*, 1994 Ann. Meeting, A-337; [12] Izett, G.A. and Cobban, W.A., 1994, *GSA Abs*, 1994 Ann. Meeting, A-402; [13] Roddy et al., 1993, 24th *LPSC*, 1211-1212; [14] Roddy et al., 1987, *Int. J. Impact Engng. 5*, 525-541.