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A DISCONTINUOUS MELT SHEET IN THE MANSON IMPACT STRUCTURE

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Petrologic studies of core recovered from holes drilled in the Manson, Iowa, buried impact structure may unravel the thermal history of the crater-fill debris. We made a cursory examination of about 200 m of core recovered from the M-1 bore hole, which was the first of 12 holes drilled as part of a cooperative drilling program between the U.S. Geological Survey and the Iowa Geological Survey Bureau [1]. The M-1 core hole is about 6 km northeast of the center of the impact structure, apparently on the flank of its central peak [1]. We developed a working hypothesis that a 30-m-thick breccia unit within a 53-m-thick unit previously termed the "crystalline clast breccia with glassy matrix" [1] is part of a discontinuous melt sheet in the crater-fill impact debris. The 30-m-thick breccia unit reached temperatures sufficient to partially melt some small breccia clasts and convert the fine-grained breccia matrix into a silicate melt that cooled to a greenish-black, flinty, microcrystalline rock.

Large clasts in the 30-m-thick breccia unit consist of Precambrian crystalline rocks (granite, gneiss, and mafic rocks), most of which are 5-10 cm long. Smaller clasts 0.5-1.0 cm include quartz, quartzite, and feldspar. Microcline clasts are pink and fresh appearing from the bottom of the core (~700 ft depth) up to ~500 ft depth. Above this level, especially in the 30-m-thick breccia unit, microcline and other feldpsar clasts are chalky white and show various effects of melting or partial melting, including feldspar masses consisting of radially oriented crystals and sheaf-like masses (spinifex? texture). Some microcline clasts, which contain shock lamellae, were thermally converted to potassium feldspar (sanidine?) having a very small optic angle ($2V_X$). A conspicuous type of small clast consists of yellowish-brown dusty-appearing quartz cores containing shock lamellae surrounded by haloes of quartz that are in optical continuity with the shocked quartz cores (fig. 1). Coronas of clinopyroxene crystals (<40 μm) are concentrated near the margins of the quartz haloes with the surrounding matrix. The former presence of shocked quartz clasts is indicated by centimeter size polycrystalline quartz masses surrounded by coronas of clinopyroxene crystals. EDS-SEM analysis of the clinopyroxene crystals shows that they are augite ($Mg_{48}Ca_{37}Fe_{15}$). Biotite (100 μm), skeletal ilmenite (fig. 2), and titanomagnetite crystals (<50 μm) also occur in the quartz coronas. The above described mineralogic relations suggest to us that the small shocked quartz clasts were partly to wholly melted and that clinopyroxene, biotite, titanomagnetite, and ilmenite crystallized in the associated quartz coronas.

Optical microscopic and SEM study of the matrix of the 30-m-thick breccia unit shows that it is composed of a microcrystalline intergrowth of quartz and feldspar. Previously, the matrix was thought to be glassy[1], but we found no mineralogic evidence to support this idea. The matrix contains conspicuous amounts of disseminated titanomagnetite and ilmenite crystals, and shocked zircon and apatite crystals were recovered from the matrix using standard mineral separation methods.

Measurements of the intact M-1 core showed that a 30-m-thick interval from 380 to 480 ft depth (116-146 m) is characterized by high magnetic susceptibility (fig. 3). Microscopic and thermomagnetic study of a few samples (421 and 423 ft depths) in the core revealed that the source of the high magnetic susceptibility is disseminated 5-50 μm euhedral crystals of unaltered titanomagnetite. In addition, the breccia matrix contains unaltered ilmenite crystals 10-100 μm in diameter. An important morphological feature of some ilmenite crystals is their skeletal habit typical of crystals whose growth in a liquid has been arrested (fig. 2). Another crucial observation is that the ilmenite and titanomagnetite crystals are in some places intimately associated. Small areas of titanomagnetite within, or adjacent to, large ilmenite crystals were observed with an SEM. EDS-SEM analyses of 10 spots within 10 crystals of titanomagnetite and ilmenite in the breccia matrix show that the crystals are fairly uniform in composition. The titanomagnetite (Usp 30%) has the following average weight % composition: Fe as FeO, 84.7; TiO_2, 10.6; Al_2O_3, 2.7; MgO, O.2; and MnO, 1.0. The ilmenite (Hm 13%) has the following average weight % composition: Fe as FeO, 50.5; TiO_2, 46.6; Al_2O_3, 0.5; MgO, 1.4; and MnO, 0.8.

Assuming that (1) our observational and chemical data for titanomagnetite and ilmenite are representative of the 30-m-thick breccia interval and (2) the titanomagnetite and ilmenite are an equilibrium pair, the temperature and oxygen fugacity can be estimated using the computer program of Andersen et al. [2]. Application of their computer program indicates that the titanomagnetite and ilmenite crystallized at about 760° C at an oxygen fugacity of log fo_2 -10^{14}. It should be stressed that the above observational and chemical data for the 30-m-thick breccia unit are based on only a few samples and confirmation of our preliminary results awaits complete characterization of the core.

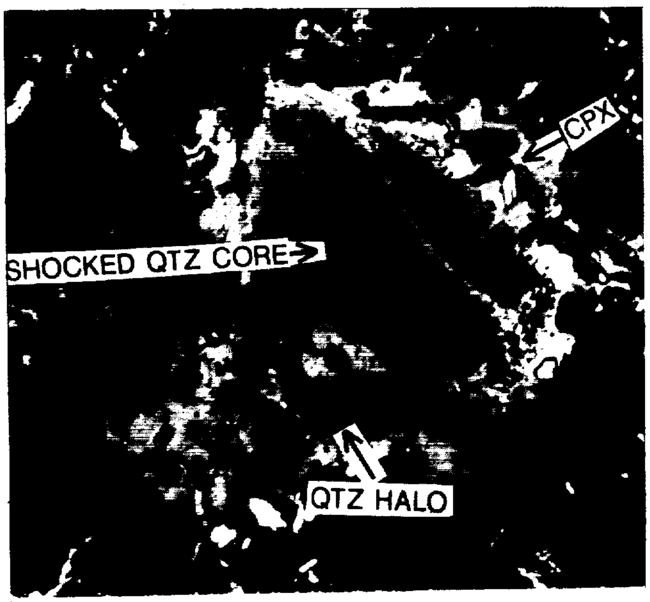

Figure 1

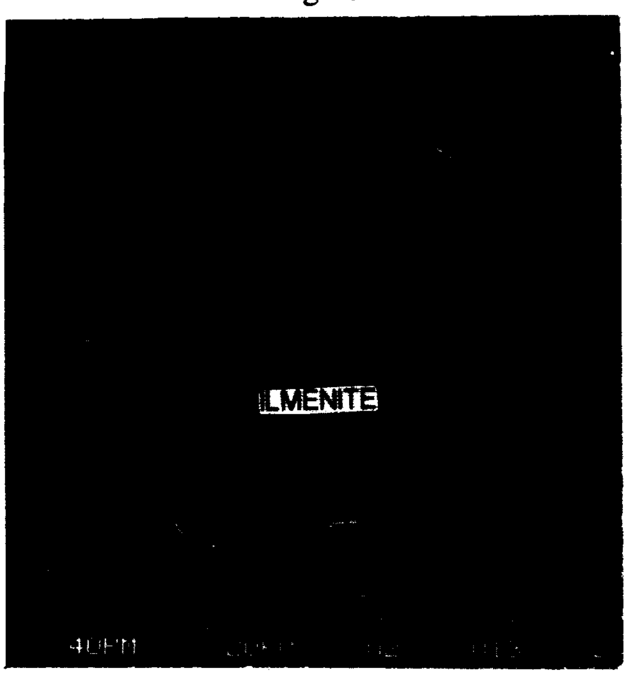

Figure 2

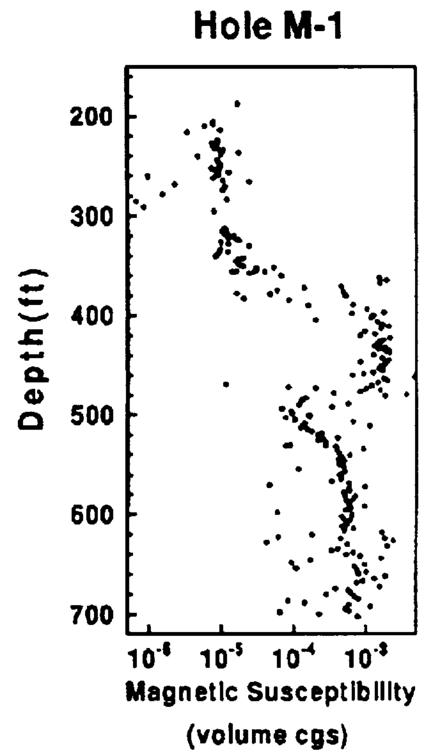

Figure 3

References: [1] Anderson, R.R., Hartung, J.B., Roddy, D.J., and Shoemaker, E.M., 1992, LPI Contribution 790, 2-3; [2] Andersen, D.J., Lindsley, D.H., and Davidson, P.M., 1992, QUILF: A Pascal program to assess equilibria among Fe-Mg-Ti oxides, pyroxenes, olivine, and quartz [In Press}.