FORMATION OF IMPACT BRECCIAS AT THE SLATE ISLANDS STRUCTURE, NORTHERN LAKE SUPERIOR, ONTARIO, CANADA;

B.O.Dressler and V.L.Sharpton, Lunar and Planetary Institute, Houston TX, 77058; B.Schnieders and J. Scott, Ontario Geological Survey, Thunder Bay, Ontario, Canada, P7E 6E3.

Various types of breccias, shatter cones, impact melts and microscopic shock metamorphic features are common on the Slate Islands (48° 40' N; 87° 00' W) and provide convincing evidence that the structure was formed as the result of comet or asteroid impact (1, 2). Target rocks consist of three main groups of Archean and Proterozoic supracrustal and intrusive rocks, about 2.7 Ga and 1.8 Ga and 1.1 Ga old respectively. The structure is about 32 km in diameter. Its age is as yet not very well constrained (3). A large portion of the island group appears to represent the partially eroded central uplift of a complex impact crater. Here we relate specific breccia types in the target rocks to the various phases of the impact process, namely compression (Type A pseudotachylites), central uplift and excavation (clastic matrix breccias), and crater modification (monomict, parautochthonous breccias). Type B pseudotachylites may have formed during the excavation and late crater modification stages. Bunte Breccia and suevite deposits occur on the flanks of the central uplift or on the inner flanks of the annular trough.

Breccias in Target Rocks

Compression: High confining pressures and frictional movement during the compression stage are conducive to the formation of pseudotachylite veinlets (pseudotachylite Type A, (4, 5)) with commonly straight and more or less parallel boundaries with the host rock and anastomosing veinlets branching off them. The dikes and veins develop commonly along pre-existing fractures, rock contacts, and other zones of weakness. At the Slate Islands structure the matrix of these veinlets is devitrified glass, containing few host rock inclusions. Quartz in these inclusions exhibits planar deformation features. The pseudotachylite veinlets are chemically similar to the host rock and, assuming that their assignment to the compression phase of the impact process is correct, their formation is a very rapid process. This process, however, is not "instantaneous" and simple, but surprisingly very complex. We have observed up to three pseudotachylite melt "phases" in one pseudotachylite veinlet of which inclusions of the earliest-formed phases are observed in later phases. Tiny apophyses of thethird melt phase intrude the host rock of the pseudotachylite vein but only where the host rock is cataclasticly deformed. The apophyses are connected with the central part of the third phase pseudotachylite and cut across the chilled border zone of this third phase. The various pseudotachylite melt phases observed by us may not all represent friction melts produced during the compression stage only but also slightly later decompression melts localized where early friction melts formed.

Excavation and Central Uplift: Following the passage of a hypersonic shock wave, rarefaction, decompression, and central uplift affect the target rocks, again leading to brecciation of target rocks and of earlier-formed breccias. Decompression allows for the opening of fractures and for the formation of large breccia bodies and anastomosing breccia dikes in the target rocks. It also makes possible the movement and mixing of breccia components over considerable distances. At the Slate Islands structure we noted shocked clasts in breccias contained in unshocked hostrocks indicating a horizontal component of clast movement of about 2 km away from the center of the structure. Downward clast movement over considerable distances (>100m to possibly >5km) is indicated by the presence of siltstone clasts, interpreted to be derived from either the Proterozoic Animikie Group or Jacobsville Formation, in breccias hosted in Archean target rocks. - The breccias formed during the central uplift and excavation stage are clastic matrix breccias containing a wide variety of clasts supporting our view that the breccias were formed by a process allowing wide-range fragment mixing. Up to seven clast types were observed by us in one breccia dike. In places, the breccia bodies contain altered glass fragments probably derived from the expanding transient crater cavity. Shock metamorphic features in breccia components are common. We have also noted clastic matrix breccias that cut across earlier formed pseudotachylite Type A veins and contain fragments of this pseudotachylite type.

This is further evidence for the formation of these breccias during a later stage of the impact process. Most clastic matrix breccias have a fine-grained, greenish or red matrix. Type B pseudotachylite (4) with an aphanitic, dark gray or black matrix and abundant fragments are also present on the islands but are much less common than the greenish or red breccias. They are larger in size than Type A pseudotachylites and may also have formed during the excavation and the crater modification stages.

Crater Modification: Monomict, probably parautochthonous breccias are common on the islands away from the center of the structure, in a zone which we believe to represent the heavily eroded inner flanks of the annular trough (3). Within the monomict breccias there are clastic matrix dikes containing a substantial variety of fragments. The dikes themselves are fragmented; however, large, angular dike fragments are still aligned in one direction within the monomict breccia. This observation is an indication that the formation of the monomict breccias, at least in part, is related to a relatively late modification stage of the impact process.

Allogenic Breccia Deposits

Pseudotachylites, clastic matrix breccias and monomict, parautochthonous breccias occur in the rocks of the central uplift and probably also in the crater basement rocks around the central uplift. Breccias ejected from the crater have not been observed on the mainland about ten kilometers to the north of the islands group, probably because of post-impact erosion. They are assumed to be present in the waters of Lake Superior around the islands. There are, however, a small number of suevite and Bunte Breccia-like deposits on the flanks of the central uplift or in what we tentatively interpret as the inner flanks of an annular trough of the structure (3). Suevite and Bunte Breccia make up the ejecta at the Ries crater in southern Germany but also occur in the crater cavity (crater suevite) and in the "megablock zone" (suevite and Bunte Breccia) (6). The Slate Islands crater suevite contains millimeter-to-meter-scale Archean and Proterozoic target rock fragments, some of which contain quartz with up to five sets of planar deformation features. Shard-like glass fragments, up to 5 cm across, are common and are altered to smectite and chlorite. They are not aerodynamically shaped. A Bunte Breccia deposit close to a suevite outcrop consists of shatter-coned fragments derived from upper, Proterozoic siltstones and sandstones. The fragments do not show evidence of strong shock metamorphic overprint, a characteristic of sedimentary target rock fragments of Bunte Breccia of the type location of the Ries crater (6).

Conclusions: It is customary to depict the planetary impact process in various stages. Here we adhere to this custom being aware, however, that this step-by-step depiction of a continuous process is a convenient simplification only. Our assignment of the Slate Islands breccias to these stages is based on detailed field and laboratory work, however, really diagnostic observations are small in number. Type A pseudotachylites formed in the compression stage, however, friction also may lead to melting during a later stage. Type B pseudotachylite formed during the decompression and impact crater modification stages. Similarly, monomict brecciation of target rocks seems to have accompanied crater modification but formation may have begun earlier. Heterolithic clastic matrix breccias in the rocks of the central uplift and crater basement are specifically assigned to the crater excavation and central uplift stage.

References: **(1)** - Halls H.C. and Grieve R.A.F. (1976) *Can. Jour. Earth Sci.*, 13, 1301. **(2)** - Dressler B.O., et al. (1995) *Ontario Geological Survey. MP.*, 164, 54. **(3)** - Sharpton V.L. and Dressler B.O. (1996) *(this volume).* **(4)** - Martini J.E.J. (1991) *Earth and Planet. Let.*, 103, 285. **(5)** - Fiske P.S. et al. (1995) *Science*, 270, 28. **(6)** - Engelhardt W.v. (1990 *Tectonophysics*, 171, 259.