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BRECCIA DIKES FROM THE BEAVERHEAD IMPACT STRUCTURE, SOUTHWEST MONTANA. P. S. Fiske¹, S. B. Hougren², and R. B. Hargraves², ¹Department of Geology, Stanford University, Stanford CA 94305-2115, USA, ²Department of Geological and Geophysical Science, Princeton University, Princeton NJ 08544, USA.

While shatter cones are generally accepted as indicators of meteorite impact, other petrologic features are not widely recognized in the geologic community. Breccia dikes are one such feature: They are found in many large impact structures occurring over an area at least as extensively as shatter cones [1]. Breccia dikes will survive moderate degrees of metamorphism and tectonism, unlike many other microscopic features (shocked quartz grains, high-pressure polymorphs, etc.) and even large-scale features such as annular or bowl-shaped topographic features. Thus, they are important diagnostic criteria, especially for large, poorly preserved impact structures.

The Beaverhead Impact structure is a recently discovered, deeply eroded impact structure in southwestern Montana [2]. The remains of the structure are delineated by the occurrence of shatter cones, found in an area >200 km², occurring within the Cabin Thrust plate, part of the Cretaceous Sevier fold and thrust system. The distribution of shatter cones is further truncated by Tertiary normal faults (Fig. 1). The present remains represent an allochthonous fragment of a larger structure.

Enigmatic, fluidal-textured breccia dikes have been found in three localities in the area containing shatter cones. These rocks are characterized by rounded, highly deformed clasts of wall rock, suspended in a cryptocrystalline, flow-banded matrix. Two of these outcrops occur in sandstone (Proterozoic Gunsight Formation or Cambrian Wilbert Formation?) and the third is found in basement gneiss (Fig. 1). Breccia dikes of a different nature have been found 15 km south of the region containing shatter cones. Those breccia

dikes consist of angular, slightly deformed clasts in a fine matrix that lacks a fluidal texture.

Type A Breccia Dikes: The breccia dikes found in the northern three localities are all similar in texture and resemble type A breccia dikes described at Sudbury and elsewhere by Lambert [1]. The matrix of the dikes is greenish-gray at Island Butte, red to brown at Erickson Creek, and brown to black at Law Canyon, reflecting different compositions of the protolith and different degrees of postimpact alteration. Clasts in all samples are rounded, highly deformed, and represent local material only. In some clasts the deformation is most intense at the rims. In the central portion of these clasts, deformation is localized along small shear zones that contain an ultramylonitic material similar in texture to the dike matrix. Other clasts are completely pulverized and strung out into sinuous schlierenlike bands that fade into the matrix. Some of the material from Law Canyon contains vesicles, now filled with secondary quartz and calcite. Quartz, calcite, and chlorite also occur as secondary minerals in veins and in rims around some clasts. No unambiguous examples of shock lamellae (i.e., multiple sets of planar deformation features) have been found in any samples so far.

XRF and microprobe studies of the breccias of Island Butte show that the matrix is of similar composition to the wall rock, confirming previous studies [2], but depleted in Na by a factor of 5 and enriched in K, Fe, and Al. INAA analyses of the same pairs of samples also showed the matrix to be enriched in Sc, Co, Rb, and REE, indicating alteration of the fine-grained matrix material, possibly by postimpact hydrothermal activity [3]. ICP atomic emission analyses of clast and matrix samples from Law Canyon show a similar depletion in Na and enrichment in K. This trend is seen in impact melts from other impact structures [4]. In some samples from Law Canyon clasts have K-rich halos. XRF, INAA, and microprobe analyses are currently underway on samples from the other localities.

Despite the presence of vesicles in the samples from Law Canyon and the fluidal texture of the matrix and the schlierenlike deformation of the clasts, there is little textural evidence to suggest that these rocks were molten! The intense deformation of the clasts, the absence of any melt zones at dike borders, the cataclastic texture of the matrix, and the lack of any igneous textures in even the largest dikes suggests that these dikes were primarily the product of extreme cataclasis. Furthermore, cathodoluminescence studies of the material from Island Butte failed to reveal any evidence for melting [5].

Type B (?) Breccia Dikes: The breccia dikes in the south are very different in texture and composition from those in the north. The matrix is cryptocrystalline but does not show any fluidal texture. Clasts within the matrix are angular, slightly deformed, and represent the local lithologies in which these dikes are found, including pieces of brecciated material. Single sets of planar deformation features have been found in quartz grains from these breccia dikes.

These breccia dikes bear many similarities to type B breccia dikes of Lambert [1]. Their location near the Cabin Thrust fault has led regional geologists to conclude that these dikes are related to thrusting. Further work is needed to establish the age and origin of these breccia dikes. Confirmation of the impact nature of these breccias would double the size of the known Beaverhead impact structure.

References: [1] Lambert P. (1981) *Multi-Ring Basins* (P. H. Schultz and R. B. Merrill, eds.), 59-78. [2] Hargraves R. B. et al. (1990) *Geology*, 18, 832-834. [3] Koeberl C. and Fiske P. S. (1991) *Meteoritics*, 26, in press. [4] Dence M. R. (1971) *JGR*, 76, 5552-5565. [5] Ramseyer K., personal communication.

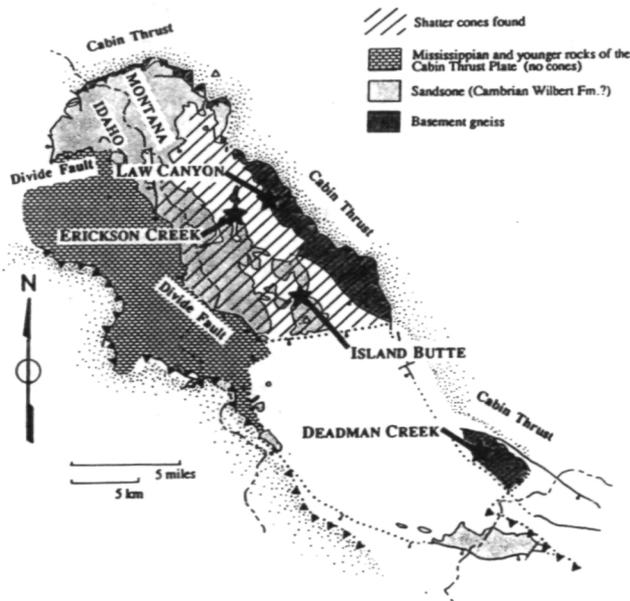


Fig. 1. Simplified map of the area of the Beaverhead Impact Structure, showing the distribution of shatter cones and the location of breccia dikes. Geologic map base is modified from [2].