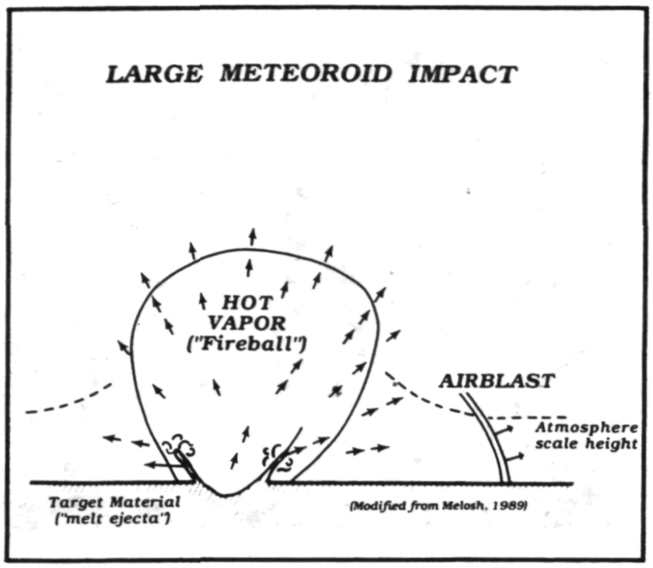

Fig. 1. Vapor plume cloud (fireball) exceeds the scale height of atmosphere and expands globally above it.

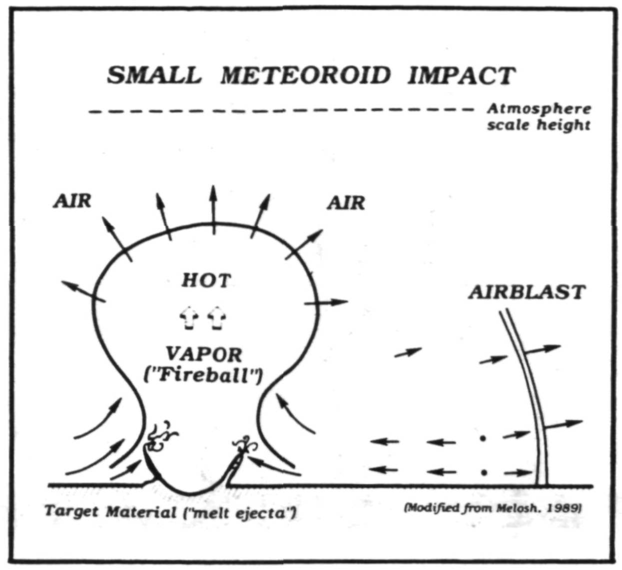

Fig. 2. Vapor plume cloud (fireball) contained and dispersed within scale height of the atmosphere.

transported both ballistically and in a detached ejecta curtain within the atmosphere [11], forming an areally limited, continuous ejecta blanket. This dual-phase impact model applies only on planets with atmospheres when the size of the stabilized vapor plume exceeds the scale height of the atmosphere (Fig. 1) [12]. In this case, the cloud of vaporized bolide penetrates above the atmosphere and is dispersed globally, resulting in two-layer deposition within the limits of the continuous ejecta blanket. Only a single layer (fireball) is present elsewhere beyond the bounds of the basal melt ejecta blanket. This pattern of ejecta dispersal explains many of the early misconceptions about the nature of the K/T target rocks and impact site that were based on geochemical analyses of far-field ejecta comprised solely of the fireball layer.

Distal ejecta from other large terrestrial impacts should resemble this dual-phase K/T model. Thus, if distal ejecta from the Sudbury structure can be located, it would be expected to be composed of two layers within the extent of the continuous ejecta blanket and single-layered beyond this limit. However, analyses of ejecta deposits from Archean impacts in South Africa and Australia [13] indicate that most of these thick spherulitic beds are comprised of both fireball (Ni-spinels and high Ir) and melt ejecta (microtektites) components. This comingling of components suggests either lack of a significant atmosphere during the late bombardment period, or small-scale impacts where the fireball is contained within the atmosphere (Fig. 2) [12]. Other planets with atmospheres, such as Venus and Mars, may also show a dual-phase distribution of ejecta for large impacts.

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SHOCKED ZIRCONS IN THE ONAPING FORMATION: FURTHER PROOF OF IMPACT ORIGIN. B. F. Bohor and W. J. Betterton, U.S. Geological Survey, Box 25046, MS 972, Denver CO 80225, USA.

The Onaping Formation fills the structural basin at Sudbury, Ontario, Canada. This formation is composed of three members: a basal, coarse, mainly quartzitic breccia (Basal Member), a light-colored, heavily included, polymict middle unit (Gray Member), and a similar but dark-colored upper unit (Black Member). Two different origins have been proposed for the Onaping: (1) volcanic ash-flow sheet and (2) impact fall-back ejecta. These origins are critically discussed in a review paper coauthored by proponents of each view [1].

French [2] identified multiple sets of shock lamellae in quartz and feldspar grains from the Onaping Formation at Sudbury. We have also identified sets of shock lamellae (called planar deformation features, or PDF) in a single quartz grain from a thin section of the Black Member. These PDF usually consist of "decorated" lamellae that are much less distinct than those in younger impacted rocks and ejecta, such as the K/T, because of annealing by subsequent metamorphic events.

Because it is more refractory than quartz and feldspar, zircon should resist annealing by thermal metamorphism. We have already shown that some zircons from K/T distal ejecta display PDF when

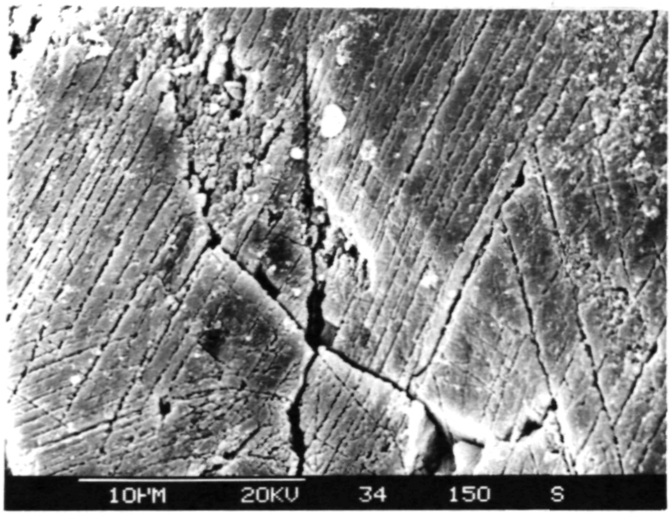

Fig. 1. PDF (4 sets).

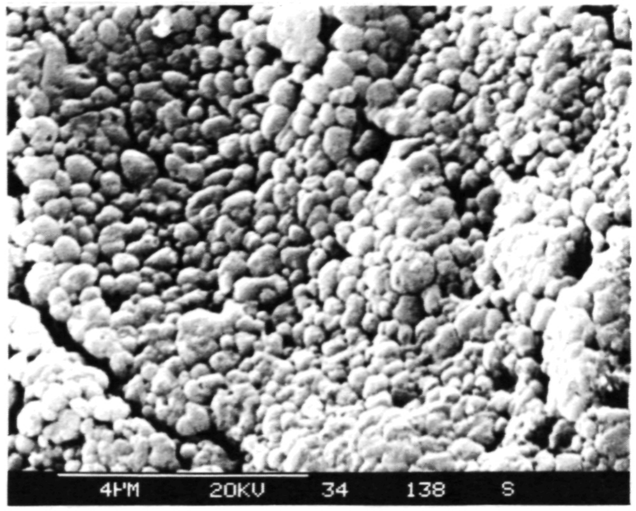

Fig. 2. Granular texture.

subjected to an alkaline etch [3]. We dissolved samples of both the Gray and Black Members of the Onaping with acids to free the contained zircons, which were then etched in alkaline solutions to reveal any PDF. These samples were collected from outcrops of the Onaping along Highway 144 south of Levack and west of the High Falls on the Onaping River. In the process of separating the zircons, we also recovered other resistant trace minerals indicative of target rock lithologies. These include tourmaline, garnet, kyanite, rutile, staurolite, chromite, pyrite, and pyrrhotite.

Many of the etched zircons from both the Gray and Black Members display PDF when viewed in an SEM. Figure 1 shows an area of a shocked zircon from the Black Member that displays at least four sets of PDF. These shock lamellae in zircon are much narrower than those in quartz and do not etch as deeply, probably because they contain less glass within them. Precession X-ray photos of zircons from K/T ejecta with PDF show extreme broadening and streaking (asterism) of diffraction maxima, confirming that they have been highly shocked [3].

Krogh et al. [4] reported zircons from the Onaping Formation at Sudbury that show linear, crystallographically oriented fracturing. They ascribed these features to shock caused by impact, and this conclusion is supported by U-Pb data. The discordance of these zircons is crudely proportional to the amount of fracturing they display, caused by the Sudbury event dated from a lower intercept age of ~1836 Ma. We have also observed both linear and irregular fractures in our Onaping zircons, but the finer-scale PDF probably indicate a significantly higher level of shock than do these coarse, open features.

In addition to fractures and PDF, Onaping zircons also show another type of textural feature that indicates exposure to a high level of shock. We have called this texture, first noted in zircons from K/T ejecta [3], "granular" or polycrystalline (Fig. 2). Often, zircons displaying this texture are idiomorphic with some of the original crystal surfaces still visible. This indicates that the zircons have not melted, but instead have been recrystallized due to shock. Thus, these granular zircon grains can be considered to be diaplectic—that is, shock-converted by solid-state transformation into polycrystalline zircon below their fusion temperature. On the other hand, zircons also can be melted by impacts, as shown by fused grains partially or completely converted to baddeleyite in high-temperature impact glasses [5]. The granular zircons in K/T ejecta and from the Onaping show no phase or compositional changes by X-ray analyses, in either diffraction or energy-dispersive modes. This is another indication that their texture is due to solid-state transformation induced by shock, and not thermal melting.

It is instructive that these granular-textured zircons have been found only in ejected material, and not in shocked, *in situ* target rocks around craters. However, zircons bearing impact-generated PDF have been identified from three types of sites and materials: K/T distal ejecta, Sudbury fall-back ejecta (Onaping), and Manicouagan target rocks. More importantly, PDF and granular textures have never been seen in volcanic zircons. Therefore, zircons can provide corroborating evidence of impact-generated shock; this discovery could prove very useful in evaluating the metamorphic histories of quartz-poor lunar rocks and meteorites.

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SUEVITE SUPERPOSITION ON THE BUNTE BRECCIA IN NÖRDLINGER RIES/GERMANY: NEW FINDINGS ON THE TRANSPORT MECHANISM OF IMPACTITES. D. Bringemeier, Marie-Hedwig-Str. 15, W-3392 Clausthal-Z., Germany.

Research undertaken in the last decades in Nördlinger Ries, Germany, has repeatedly emphasized the sharp contact between Bunte breccia and suevite. However, extensive investigations into this layer boundary have not yet been possible due to insufficient outcrop ratios.

New outcrops enabled an in-depth investigation into the superposition of suevite on the Bunte breccia, which is assigned a key role in interpreting the transport mechanisms of ejecta of large impact.