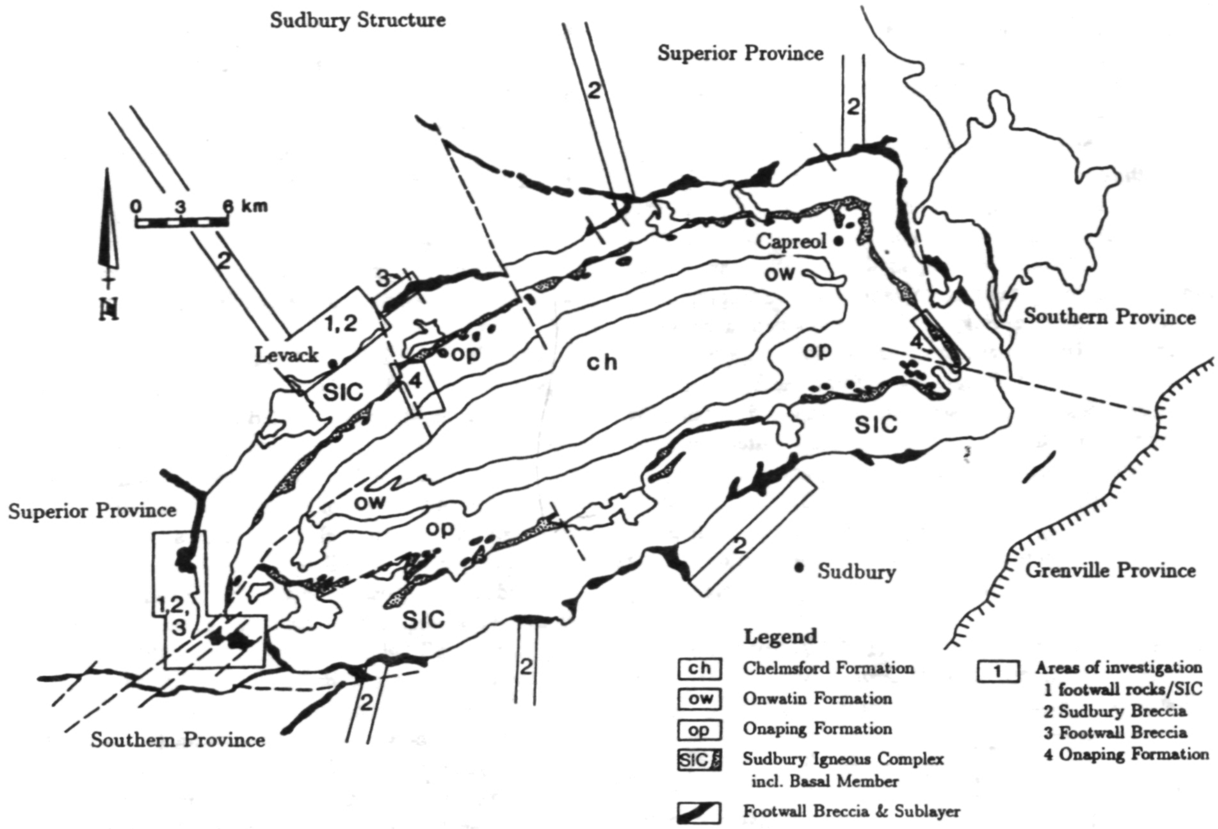

Fig. 1. Sketch map of the Sudbury structure showing the areas of investigation.

LARGE METEORITE IMPACTS: THE K/T MODEL. B. F. Bohor, U.S. Geological Survey, Box 25046, MS 972, Denver CO 80225, USA.

The Cretaceous/Tertiary (K/T) boundary event represents probably the largest meteorite impact known on Earth. It is the only impact event conclusively linked to a worldwide mass extinction, a reflection of its gigantic scale and global influence. Until recently, the impact crater had not been definitively located and only the distal ejecta of this impact was available for study. However, detailed investigations of this ejecta's mineralogy, geochemistry, microstratigraphy, and textures have allowed its modes of ejection and dispersal to be modeled without benefit of a source crater of known size and location [1,2].

Initially, only K/T boundary sites in marine rocks with a single, thin (~3–5 mm) layer of Ir-rich ejecta were known. Subsequently, nonmarine sites were discovered in the western interior of North America with thicker (~3 cm) boundary claystone units composed of two distinct layers [3]. The uppermost of these two layers, which I have called the "fireball" layer, contains a substantial Ir anomaly, skeletal Ni-rich magnesioferrite crystals, and a large population of shocked minerals in the nonclay fraction. The maximum grain size of these shocked minerals decreases regularly away from the site of the putative crater, both in the western interior [4] and on a global basis [5]. Geochemically, the fireball layer has a basaltic signature and is mainly composed of laminated smectitic clay. It immediately overlies the lower layer with a sharp textural contact. This lower layer, which I have named the "melt ejecta" layer, has a very subdued Ir anomaly, contains only a small amount of shocked minerals and no magnesioferrite, has a silicic geochemical signature, and displays a turbated texture of unsorted, altered, imbricate shards [6], vitric clasts [7], and microtektites [8] in a microspherulitic kaolinite matrix [6]. The melt ejecta layer thins radially away from the putative crater location in the Caribbean region and cannot be identified beyond ~4000 km of the crater. Both the fireball and melt ejecta layers contain a similar suite of trace minerals [9], which argues for a mutual origin from a single impact.

The partitioning of these impact components and signatures between the two layers supports a dual-phase model of ejection and dispersal from a single impact [2]. Moreover, the distinctive clay minerals formed from the vitric components in each of these two layers in the western interior lends further support to the dual-phase model [10]. In this model, the fireball layer represents sedimentation from a radially expanding cloud of vaporized bolide and entrained target material dispersed above the atmosphere. The melt ejecta layer represents melted target rock ejected from the crater and

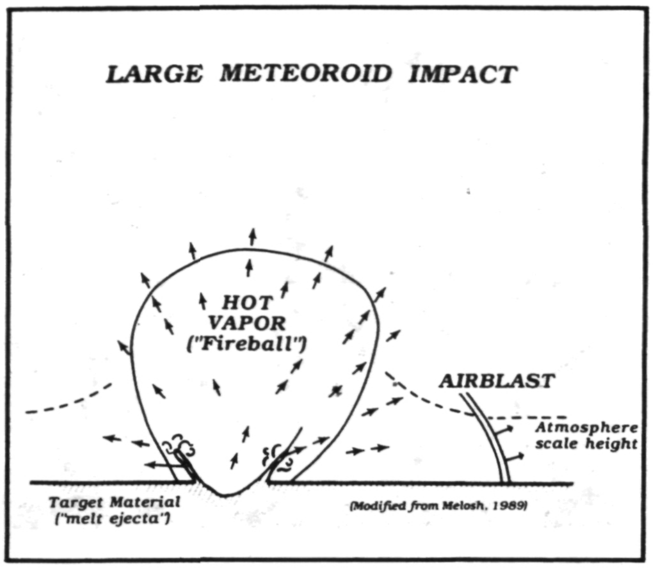

Fig. 1. Vapor plume cloud (fireball) exceeds the scale height of atmosphere and expands globally above it.

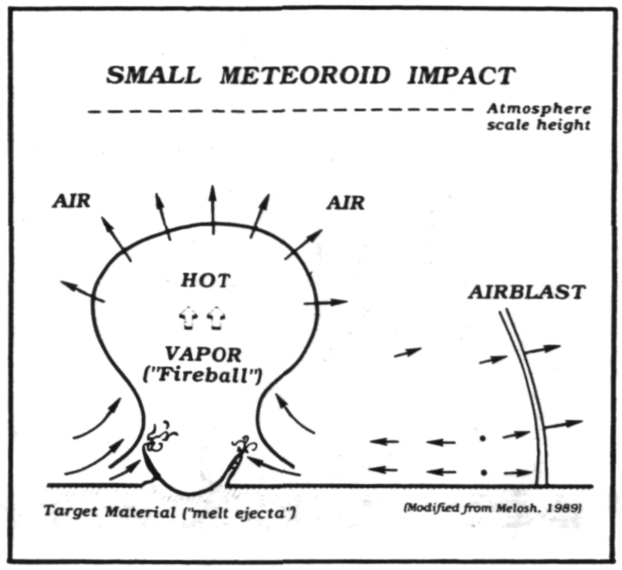

Fig. 2. Vapor plume cloud (fireball) contained and dispersed within scale height of the atmosphere.

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.

Acknowledgments: This work was partially supported by NASA Grant T5715P. W. J. Betterton provided valuable technical support.

References: [1] Bohor B. F. (1990) In *GSA Spec. Pap. 247*, 335–342. [2] Bohor B. F and Betterton W. J. (1992) *LPSC XXIII*, 135–136. [3] Izett G. A. and Bohor B. F. (1986) *GSA Abst. with Prog., 19*, 644. [4] Bohor B. F. and Betterton W. J. (1991) *Meteoritics, 26*, 321. [5] Bohor B. F. and Izett G. A. (1986) *LPSC XVIII*, 6869. [6] Pollastro R. M. and Pillmore C. L. (1987) *J. Sed. Petrol., 54*, 456–466. [7] Bohor B. F. (1988) *Meteoritics, 23*, 258–259. [8] Bohor B. F. and Betterton W. J. (1991) *Meteoritics, 26*, 320. [9] Bohor B. F. et al. (1989) *Meteoritics, 24*, 253. [10] Pollastro R. M. and Bohor B. F. (1991) *Clay Min. Soc. Prog. and Abst.*, 129, LPI Contrib. No. 773 [11] Barnouin O. and Schultz P. H. (1992) *LPSC XXIII*, 65–66. [12] Melosh H. J. (1989) *Impact Cratering*, Oxford, New York. [13] Lowe D. R. et al. (1989) *Science, 245*, 959–962.

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