The granite, which is shocked to stage I, often shows in its upper part *in situ* melting, which gradually increases toward the top. This partly molten granite is not part of the allochthonous coherent melt sheet [3] that covered the granite and induced its melting. Except for some relics this layer of molten target rock was eroded like most of the ground-surge and fall-back breccias.

The original bedding of the Paleozoic formations is deformed by impact-induced fracturing and folding. The concentric arrangement with increasing younger formations from the center to the margin of the structure give the structure the apparent domelike appearence. This is due to the combination of a central uplift and the peripheral graben structure. But, in fact, most contacts between the different formations are of tectonic origin and each ring consists of a multitude of fault blocks. Bedding in these blocks has a steep dipping in the central ring, but has moderate to gentle dipping in the outer parts of the structure. Folds are best developed in the sandstones of the Devonian Furnas Formation of the interior hills. The axis of the steeply outward plunging open folds scatter remarkably in different directions. They are sometimes arranged in a complex fanlike pattern. From the analysis of the fault pattern and the geometry of the folds, the principal stress components can roughly be estimated with $\sigma_1$ radial to the center.

Pebbles of some target rocks are heavily sheared. Shear plane analysis may be used to reconstruct stress distribution during the cratering process if the original position of the pebble-containing beds is known.

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**SUDBURY PROJECT (UNIVERSITY OF MÜNSTER–ONTARIO GEOLOGICAL SURVEY): (2) FIELD STUDIES 1984–1989—SUMMARY OF RESULTS.** L. Bischoff[1], B. O. Dressler[2], M. E. Avermann[1,3], P. Brockmeyer[1,3], R. Lakomy[1,3], and V. Müller-Mohr[1,3], [1]Geologisch-Paläontologisches Institut, University of Münster, Corrensstr. 24, W-4400 Münster, Germany, [2]Ontario Geological Survey, 77 Grenville Street, Toronto, Ontario, M7A 1W4, Canada, [3]Institut für Planetologie, University of Münster, WilhelmKlemm-Str. 10, W-4400 Münster, Germany.

In cooperation between the Ontario Geological Survey (B. O. Dressler) and the Institute of Geology and Institute of Planetology, both of Westfälische Wilhelms-Universität, Münster, geological, petrological, and geochemical studies were carried out on impact-related phenomena of the Sudbury structure during the last decade. The main results of the field studies are briefly reviewed (see also [1–5]). As shown in Fig. 1, Footwall rocks, sublayer, and lower sections of the Sudbury Igneous Complex (SIC) were mainly mapped and sampled in the northern (Levack Township) and western (Trillabelle and Sultana Properties) parts of the north range. Within these mapping areas Sudbury Breccias (SB) and Footwall Breccias (FB) have been studied; SB have also been investigated along extended profiles beyond the north and south ranges up to 55 km from the SIC [5]. The Onaping Formation (OF) and the upper section of the SIC were studied both in the north range (Morgan and Dowling Townships) and in the southern east range (Capreol and McLennan Townships) (see Fig. 1).

The Footwall rocks [6–12] exhibit shock metamorphic phenomena of shock stage I, which is characteristic of an impact crater floor. Shock metamorphism, including especially planar elements in quartz and shatter cones, can be observed up to a radial distance of 9 km from the lower SIC contact or up to 17 km (shatter cones). The Footwall rocks were subjected to a thermal overprint by the SIC up to a distance of 1 km [8,12].



The FB [3,6,10,12,13] is the remnant of a clastic matrix crater floor breccia. It occurs as irregularly or lenticularly shaped bodies at the contact between the Footwall and the SIC. Further on FB dikes intrude into the brecciated crystalline basement rocks up to 250 m away from the FB layer [10,12,13]. The contacts between FB and the underlying Footwall rocks are always sharp, even on a microscale. The fragment content reflects a local origin. Fragments of FB occur enclosed in the sublayer and norite. The crystalline matrix was formed after localized melting of the originally clastic matrix due to the thermal overprint by the SIC. Locally megaclasts (>25 m) adjacent to the country rock are embedded in huge intercalations of FB matrix.

The SB [5,7,9,11,12,14] occur as various types of clastic or crystalline matrix breccia forming irregular dikes whose orientations appear not to be controlled by the geometry of the Sudbury structure. In the north range dikes have been observed up to a distance of at least 55 km from the lower contact of the SIC, but are abundant within a zone of 10 km adjacent to the SIC and a second zone located approximately between 20 and 33 km north of the SIC. The thickness of the dikes ranges from centimeters to several hundred meters. Most of the dikes exhibit sharp contacts to the wall rock. Several phases of brecciation can be distinguished by breccia fragments in SB, whereas crosscutting of different breccia types is extremely rare. Most of the fragments of the SB are directly derived from the country rock, but in large dikes relative movements of clasts over several hundred meters can be found. The SB were formed by shearing and friction of Footwall rocks.

The breccias of the OF [4,15–17] can be divided from bottom to top into Basal Member, Gray Member, Green Member, and lower and upper Black Member according to their lithological composition, matrix, clast population, contacts, and texture. The term "Basal Member" comprises a clast-rich melt breccia on top of the SIC and the "melt bodies" [18], as they were formerly called, whereas the term "Green Member" implies the former "chlorite shard horizon" [18]. The Black Member was subdivided due to obvious changes upward in fragment content, size, matrix texture, grade of foliation, and occurrence of both carbonaceous material and sedimentary features. The lower part of the polymict allochthonous breccias of the OF are interpreted as impact-melt breccias, the overlying breccias as ground-surge breccias, and the uppermost as original or resedimented fall-back breccias [see 1,2,4].

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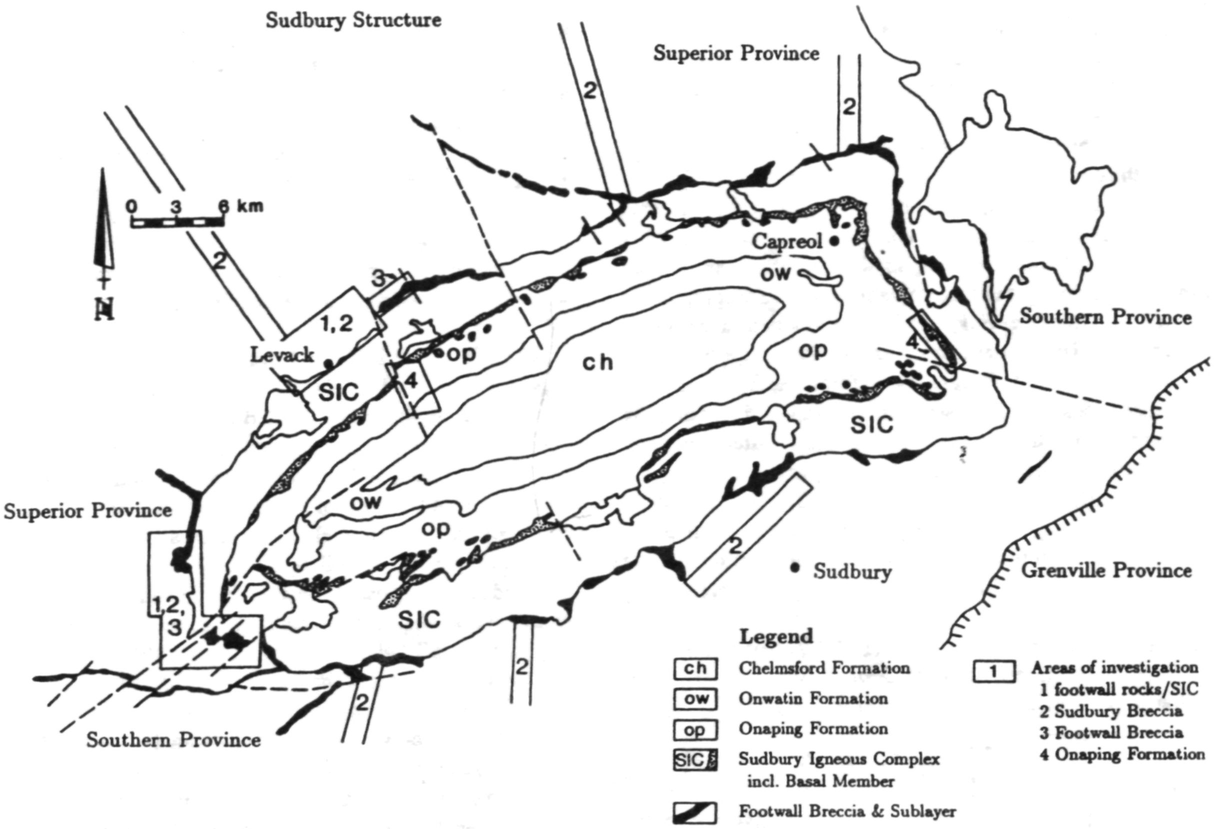




**Fig. 1.** Sketch map of the Sudbury structure showing the areas of investigation.



**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