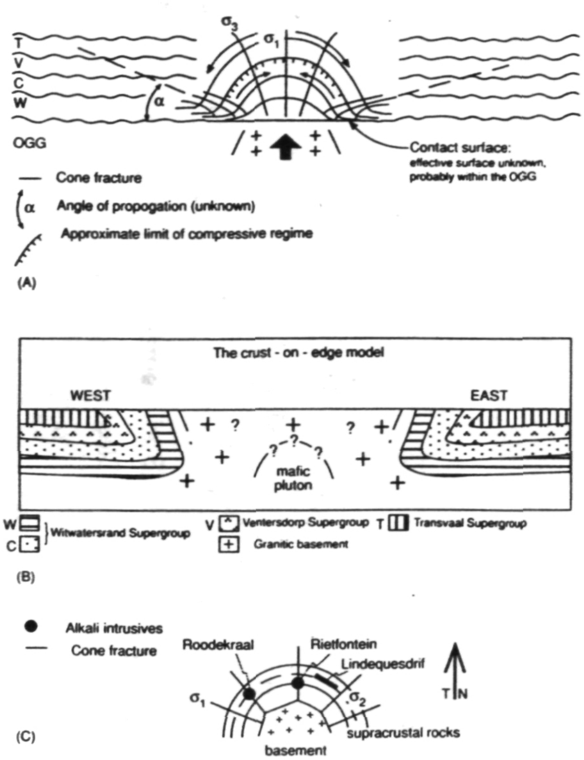

Fig. 1. Schematic illustrating a diapiric quasi-Hertzian stress field as a possible working model for the Vredefort structure: (**a**) predeformation cross section showing the quasi-Hertzian stress field, (**b**) postdeformation cross section (the crust-on-edge model), and (**c**) postdeformation plan view with superimposed stress field.

This structure consists of an Archean core of ca. 45 km in diameter, consisting largely of granitic gneiss, surrounded by a collar of metasedimentary and metavolcanic supracrustal rocks of the Dominian Group, Witwatersrand and Ventersdorp Supergroups, and Transvaal Sequence (for geological descriptions see, e.g., [1]).

The interpretation of images of the gravity and magnetic fields over Vredefort has permitted the delineation of several important features of the structure and of its immediate environment [2]. The polygonal, concentric outline of the collar strata is a prominent feature of both the gravity and the magnetic fields. The Vredefort structure shares this distinctive geometry with other structures (e.g., Manicouagan, Decaturville, Sierra Madera) of debated impact origin. In all these, successively older strata with steep outward dips are encountered while traversing inward to the center of the structure. A further attribute of these structures is the shortening of the outcrop of a particular stratigraphic unit compared to the original perimeter of that unit.

To account for the geometric attributes of the Vredefort structure a mechanical scheme is required where there is radial movement of horizontal strata toward, with uplift in, the center of the Vredefort structure. Two models can be proposed: (1) one in which there is a rapid rise and violent disruption of cover rocks in response to expansion of a fluid accumulation [3] and (2) one in which there is, in contrast, a nonexplosive, quasi-Hertzian stress field resulting from a diapiric process. Both models can accommodate the geometry and structural components of Vredefort. The proponents of the former model, for the Vredefort case, argue that it could provide a mechanism for deformation phenomena widely regarded as evidence of shock metamorphism (pseudotachylite, quartz with planar microdeformations, and shatter cones). Conversely, these same deformation phenomena are currently being debated [4,5] and it has been hypothesized that they could be formed by high-strain tectonic processes.

In Fig. 1, a Hertzian stress field is sketched (after [6]), both in plan- and cross-section. The stress component σ_3 is compressive, while σ_1, the principal component, is tensile and subparallel to the overlying strata. The trajectories of these stress fields can well account for overturning of collar stratigraphy and the subvertical attitude of the gneissic fabric in the core. In the collar rocks pseudotachylite veins generally occur along bedding plane faults, while in the core they are parallel to the principal shear directions [78]. In plan, σ_1 is tensile radially, whereas the intermediate σ_2 component is a "hoop stress." It is noteworthy that the lineaments of geophysical images comply with the σ_1 orientation and the triad of alkali granitic complexes (Roodekraal, Rietfontein, and Lindequesdrif), intruded into the collar, describe an arc similar to the σ_2 hoop stress. The location of these intrusives could be at the intersection of the σ_1, σ_2 tensile stress components.

This postulated quasi-Hertzian deformation model is dynamic, so the contact stress and resultant strain would be expected to be complex and to modify in time (see, e.g., [9]). Within the compressive regime (which may have a radius as much as the contact diameter of the indentor, in this case the diapir) [8,9] the σ_1 stress component is compressive and may account for the radial inward riding of sedimentary strata. The observed polygonal geometry results from the outward rupture and relative brittle strain of overlying strata outside the compressive regime (Fig. 1a).

In conclusion, the geometric and structural attributes of the Vredefort structure are consonant with a quasi-Hertzian stress field. In particular, it corroborates the many observations of ubiquitous subhorizontal structures that have led investigators to deduce that the Vredefort structure was produced by subhorizontal forces (see, e.g., [8,10]).

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SUDBURY PROJECT (UNIVERSITY OF MÜNSTER–ONTARIO GEOLOGICAL SURVEY): (6) ORIGIN OF THE POLYMICT, ALLOCHTHONOUS BRECCIAS OF THE ONAPING FORMATION. M. E. Avermann, Institute of Planetology, University of Münster, Wilhelm-Klemm-Str. 10, W-4400 Münster, Germany.

The Sudbury structure has been interpreted as a deeply eroded remnant of a peak-ring basin [1]. The polymict, allochthonous breccias of the Onaping Formation (OF) occur in the central part of the Sudbury structure, which is surrounded by the 1.85-Ga-old [2]

"Sudbury Igneous Complex" (SIC). From bottom to top the OF can be divided into Basal, Gray, Green, and lower and upper Black Members [3,4]. The breccias were mapped in detail in the east range of the structure. The SIC and the lower part of the OF (Basal Member) are interpreted as the impact melt system [1,3,5; compare also 6].

The *Basal Member* occurs as a fragment-laden polymict melt-breccia on top of the granophyre of the SIC and as isolated bodies (formerly called melt bodies [7]) in the Gray and Black Members. The Basal Member contains abundant rock fragments that consist of metasediments of the Huronian Supergroup and minor amounts of Archean crystalline basement. In the upper part of the granophyre a similar fragment population is observed. Therefore, these rocks must have been present in the target area at the time of the impact. Geochemical investigations of the main elements and rare earth elements underline the close genetic relationship of the SIC and the Basal Member and their formation of crustal rocks.

The overlying *Gray Member* is a breccia unit with a clastic matrix and has a sharp contact to the Basal Member. The polymict, allochthonous breccias of the Gray Member are characterized as a suevitic breccia by a high amount of melt particles and fragments with shock metamorphic features. Signs of multiple brecciation and internal contacts found during the mapping provide evidence for turbulent movements during the emplacement of the Gray Member [4,8]. Based on its petrographic character, the lower part of the Gray Member is interpreted as a ground-surge deposit, which grades into fall-back breccias.

The *Green Member* is considered as a continuous uniform breccia layer on top of the Gray Member and comprises the former "chlorite shard horizon" [7]. This breccia layer is characterized by a microcrystalline matrix, chloritized "glassy" particles, and a high content of small mineral clasts. The Green Member is regarded as gradational and fine-grained fall-back material, which was affected by high temperatures during the deposition. The Green Member and the chloritized particles originated by early excavation to high atmospheric regimes, condensation out of a vapor phase, and deposition with the final fall-back material.

The uppermost unit of the OF (*Black Member*) can be subdivided into a lower and an upper Black Member unit. The lower part (100–150 m thick) still shows petrographic features of suevitic breccias, small fragments of basement rocks, melt particles, chloritized particles, and breccia fragments in a dark, clastic matrix. These signs indicate that the lower unit has been transported from its original position outside the crater into the central depression of the crater. The upward increase of sedimentary features, signs of multiple brecciation in the upper part of the Black Member, and the gradational contact to the overlying Onwatin slates of the Whitewater Group indicate the subsequent change in the depositional environment. Investigations of the carbonaceous material in the matrix of the Black Members and the Onwatin slates suggest an origin by biogenetic material deposited at a slow rate lasting into a local, euxinic basin, which was created by the Sudbury event.

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SUDBURY PROJECT (UNIVERSITY OF MÜNSTER–ONTARIO GEOLOGICAL SURVEY): (1) SUMMARY OF RESULTS—AN UPDATED IMPACT MODEL. M. Avermann[1,2], L. Bischoff[2], P. Brockmeyer[1,2], D. Buhl[3], A. Deutsch[1], B. O. Dressler[4], R. Lakomy[1,2], V. Müller-Mohr[1,2], and D. Stöffler[1], [1]Institut für Planetologie and [2]Geologisch-Paläontologisches Institut, Universität Münster, Wilhelm-Klemm-Str. 10 and Corrensstr. 24, W-4400 Münster, Germany, [3]Institut für Geologie, Universität Bochum, W-4360 Bochum, Germany, [4]Ontario Geological Survey, 77 Grenville Street, Toronto, Ontario M7A 1W4, Canada.

In 1984 the Ontario Geological Survey initiated a research project on the Sudbury structure (SS) in cooperation with the University of Münster. The project included field mapping (1984–1989) and petrographic, chemical, and isotope analyses of the major stratigraphic units of the SS. Four diploma theses and four doctoral theses (Avermann, Brockmeyer, Lakomy, Müller-Mohr) were performed during the project (1984–1992). Specific results of the various investigations are reported in five accompanying abstracts [1–5]. As shown in Fig. 1 of [1], selected areas of the SS were mapped and sampled: Footwall rocks, Footwall Breccia and parts of the sublayer and lower section of the Sudbury Igneous Complex (SIC), Onaping Formation and the upper section of the SIC, and Sudbury breccia and adjacent Footwall rocks along extended profiles up to 55 km from the SIC. All these stratigraphic units of the SS had been studied in substantial detail by previous workers [6,7]. The most important characteristic of the previous research is that it was based either on a volcanic model or on a mixed volcanic-impact model for the origin of the SS. The present project has been clearly directed toward a test of the impact origin of the SS without invoking an endogenic component. In general, our results confirm the most widely accepted stratigraphic division [6] of the SS. However, our interpretation of some of the major stratigraphic units is different from most views expressed in [6]. The stratigraphy of the SS and its new interpretation is given in [3] as a basis for the following discussion.

The main conclusion to be drawn from our results is that (1) the SS is the erosional remnant of a peak- or multiring impact basin with an original diameter in the 200- to 240-km range and (2) the SIC is no endogenic intrusion but rather the main part of an impact melt sheet that occupies the central depression of the basin and has been produced by shock-induced total melting of crustal rocks [8–12]. Independently, R. A. F. Grieve of the Geological Survey of Canada has come to quite identical conclusions [9]. The individual stratigraphic units or impact-related rocks can be characterized and interpreted as follows.

Footwall Rocks and Related Breccias: The Archean and Proterozoic crystalline basement of the SIC displays impact-induced features up to a radial distance of at least 55 km, possibly 80 km [6], from the SIC. At the contact to the SIC it forms a (mega)breccia that is thermally metamorphosed and partially molten by the SIC (Footwall Breccia). This breccia grades into a weakly shocked (and, further out, into unshocked) brecciated basement. All basement units contain at least three generations of breccia dikes (Sudbury breccias) formed by frictional melting and shearing during the compression, excavation, and modification stages of the crater formation—a feature typical of all complex terrestrial craters (e.g., [13]).

SIC and Basal Member of the Onaping Formation: This unit represents a layered complex of rocks that crystallized from an impact melt. It comprises from bottom to top (1) the sublayer, including the offset dikes, a noritic to quartz-dioritic, clast-rich melt