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SUDBURY PROJECT (UNIVERSITY OF MÜNSTER–ONTARIO GEOLOGICAL SURVEY): (3) PETROLOGY, CHEMISTRY, AND ORIGIN OF BRECCIA FORMATIONS.

D. Stöffler[1], A. Deutsch[1], M. Avermann[1,2], P. Brockmeyer[1,2], R. Lakomy[1,2], and V. Müller-Mohr[1,2], [1]Institut für Planetologie and [2]Geologisch-Paläontologisches Institut, Universität Münster, Wilhelm-Klemm-Str. 10 and Correnstr. 24, W-4400 Münster, Germany.

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Within the Sudbury Project of the University of Münster and the Ontario Geological Survey [1] special emphasis has been put on the breccia formations exposed at the Sudbury structure (SS) because of their crucial role for the impact hypothesis [2]. They were mapped and sampled in selected areas of the North, East, and South Ranges of the SS ([3] and Fig. 1 of [2]). The relative stratigraphic positions of these units are summarized in Fig. 1. Selected samples were analyzed by optical microscopy, SEM, microprobe, XRF and INAA, Rb-Sr and Sm-Nd-isotope geochemistry [4], and carbon isotope analysis.

This abstract summarizes the results of petrographic and chemical analyses for those stratigraphic units that were considered the main structural elements of a large impact basin (see [1]).

Basement and Related Breccias (Fig. 1): The crystalline rocks underlying the Sudbury Igneous Complex (SIC), collectively called footwall rocks [5], display three types of impact-induced effects: (1) An 8–10-km-wide zone with planar deformation features in quartz immediately below the SIC indicating peak shock pressure up to about 20 GPa [6]. (2) An irregular, mostly lens-shaped, discontinuous heterolithic breccia zone along the contact of the SIC (Footwall Breccia = FB) that occasionally occurs in dikelike "intrusions" in the footwall rocks. The breccia matrix is crystalline with a dioritic composition and intersertal texture in an upper zone near to the SIC and a tonalitic-to-granitic composition and poikilitic to granular texture in a lower zone. The matrix texture is caused by thermal annealing and partial melting due to the overlying melt complex [7–9]. The clast lithologies in this breccia and its chemical

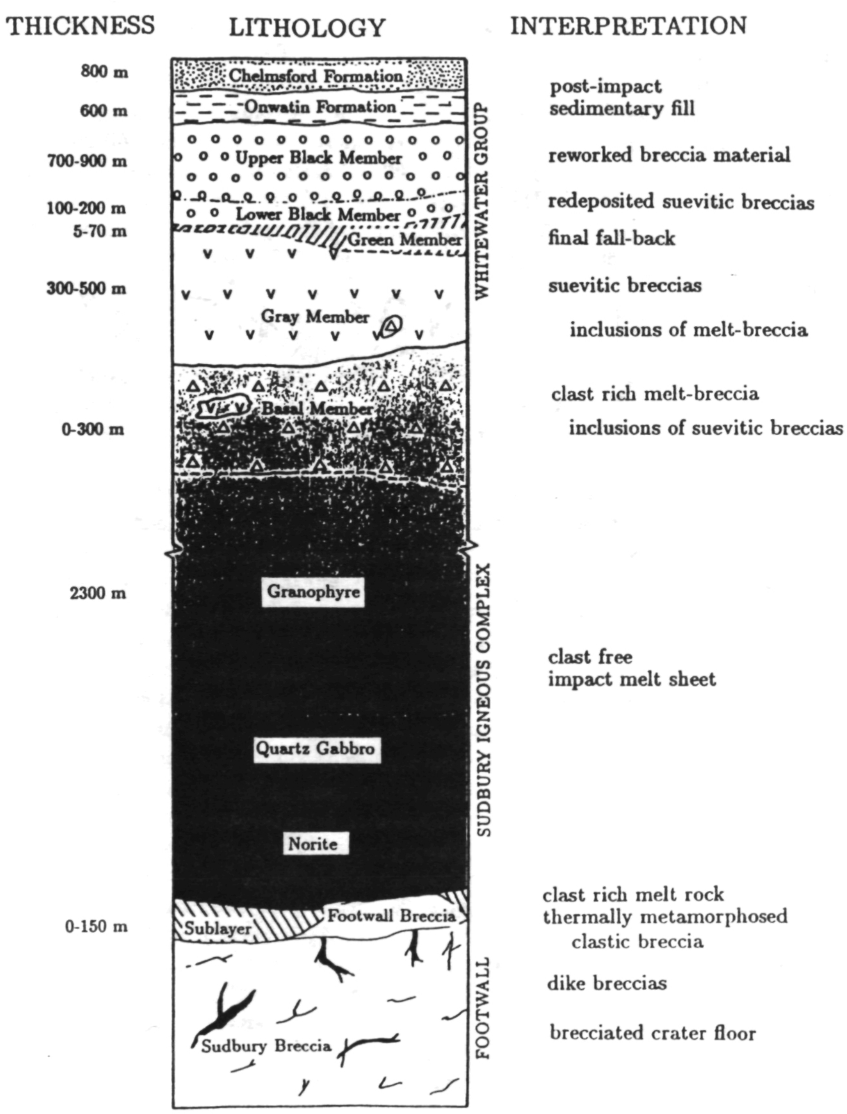

Fig. 1. Stratigraphic sequence at the Sudbury structure with the present genetic interpretation of the lithological units (modified from [12]).

characteristics indicate that it is derived almost exclusively from the local Levack gneisses [7,8]. (3) Breccia dikes, collectively named Sudbury Breccia, which are irregularly distributed in the basement up to a radial distance of at least 55 km from the SIC [6]. They have a random orientation and range in thickness from millimeters to some 300 m. Four generations of dikes have been identified [6] that differ in matrix characteristics (crystalline to clastic), thickness, clast content, and contact relationships. The composition of the matrix typically resembles the composition of the country rock and the clasts are derived from the local rocks except for very large dikes where clasts were moved over distances of up to 800 m. Shocked clasts (stage I) within the dikes occur only up to a radial distance of 10 km from the SIC.

SIC and Basal Member of Onaping (Fig. 1): The SIC has been studied only in its contact zones to the Basal Member and to the Footwall Breccia. The Sublayer is a heterolithic breccia with a crystalline melt matrix of mafic composition and abundant mafic to ultramafic lithic clasts. It contains also clasts of FB as the latter carries clasts of the norite and Sublayer. The contacts of the FB to the norite are sharp whereas to the Sublayer they are either sharp or gradational [8,9]. Similarly, the uppermost section of the SIC (granophyre) shows sharp and gradational transitions to the Basal Member, which is a clast-rich impact melt breccia. Abundant clasts (up to 80 vol%), mainly from the Proterozoic Huronian metasediments, are embedded in a crystalline matrix with granophyric to variolitic texture [10]. There is a chemical similarity between the SIC, especially the granophyre, and the melt breccia of the Basal Member confirming that both units represent a whole rock melt of Precambrian target rocks. There is some indication for an increasing proportion of Proterozoic Huronian rocks toward the top of the melt system [4].

Gray, Green, and Black Members of Onaping (Fig. 1) [10,11]: The Gray Member is a polymict clastic matrix breccia composed of lithic clasts of variable degree of shock and irregularly shaped melt inclusions that have a fine-grained crystalline texture and show flow structures. Texturally, this breccia layer is similar to the suevitic breccias found in the crater fill of many complex impact craters. The clastic breccia constituents are derived predominantly from rocks of the Huronian Supergroup and, more rarely, from Archean basement rocks. The Gray Member is covered by a thin layer of a rather uniform, strongly chloritized breccia (Green Member, formerly called chloritized shard horizon). The contact varies from sharp to gradational. This breccia contains relatively fine-grained clastic material in a microcrystalline matrix characterized by concavely shaped vugs filled with chlorite. Green Member is topped by the clastic matrix breccia layer of the Black Member, which, as a whole, is characterized by a carbonaceous matrix. In its lower unit it shows similarities to the Gray Member. The upper unit displays textural features of reworking and sedimentation under aquatic conditions. A major fraction of the carbon is derived from organic matter and formed under euxinic conditions. The bulk chemical composition of the whole sequence of clastic matrix breccias (Gray Member to Black Member) is less siliceous and richer in Fe, Mg, K, and Na than the melt breccia of the Black Member [10,11]. It is not clear whether this is due to secondary alteration processes or whether it reflects a primary change in the composition of the source rocks of the clastic matrix breccias. The REE patterns of all breccia units of the Onaping Formation are quite similar and are well within the range of the potential source rocks from the Proterozoic and Archean basement.

The data obtained from the petrographic and chemical investigations of the breccia formations at the SS are compatible with the impact basin model summarized in [2]. The interpretation of our results with regard to the origin and emplacement of these formations are therefore different from most of the previous views as expressed mainly in [5]. The present interpretation is as follows: The Sudbury Breccias (dike compression of the crater basement by *in situ* frictional melting and by shearing processes during the gravity-induced breccias) were formed during shock collapse of the transient cavity. The Footwall and Sublayer Breccias including the offset dikes were formed in the late stage of the transient cavity (TC) formation as crater floor breccias before the collapse of the cavity. This holds also for the impact melt system and the suevitic breccias of the Gray Member that covered the central part and the upper walls of the TC. As a consequence of its collapse the innermost, clast-free part of the melt layer within the TC pooled to a melt sheet filling the central depression as well as the depressions outside the now eroded peak ring and, immediately afterward, became covered by clast-rich melt slumping in from higher regions of the TC wall. Similarly, the suevitic material slumped into the depression from even higher portions of the TC wall. It was then covered by airborne fallback material (Green Member) deposited from the ejecta plume. The Black Member breccias are interpreted as material that was transported into the central depression by turbulent slumping from the walls of the peak ring and by aquatic sedimentation of ejecta material covering the ring region.

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"BRONZITE" GRANOPHYRE: NEW INSIGHT ON VREDEFORT. A. M. Therriault and A. M Reid, University of Houston, Department of Geosciences, Houston TX 77204, USA.

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The Vredefort Dome is located near the center of the Witwatersrand Basin, about 120 km southeast of Johannesburg, South Africa. Its origin is enigmatic, ranging from a major impact event [1–3] to endogenous processes, either igneous [4–6] or tectonic [7]. A unique melt rock, the "Bronzite" Granophyr, occurs in the Vredefort structure as vertical ring dikes along the contact between sedimentary collar and core of Archaean granites, and as vertical dikes extending northwest-southeast and northeast-southwest in the granitic core. The granophyre rocks have an unusual composition and high content of recrystallized sedimentary inclusions compared to common intrusive igneous rocks with similar SiO_2 content (61 to 70% by weight). The unique nature of the granophyre has been underlined in previous studies and origin hypotheses as an impact melt or as a highly contaminated intrusive mafic magma have also been discussed [e.g., 8–10]. We present new results obtained from a recent detailed petrographic and geochemical study of a very large and texturally diverse suite of "Bronzite" Granophyre, representing all dikes occurring at Vredefort.

Petrography: The major mineral phases observed in the granophyre are hypersthene, plagioclase, orthoclase, quartz, pigeonite, augite, biotite, magnetite, and ilmenite. Only rare bronzite grains