be essentially that of the host rock. It is apparent from grain deformation that transport distances were on the order of millimeters to centimeters along the veins.

The textures of flädle, quartz breccia, and pseudotachylite are fundamentally different when viewed petrographically. Although each of the rock types appears darkly opaque (dark gray or black) in hand specimen, the only sample with a matrix that is truly opaque in thin section is the flädle. No clasts representing compositions and textures of the other impactites have been observed in the pseudotachylite thus far. Present work is directed at determining what textural and compositional changes were involved during formation and whether the pseudotachylite represents material comparable to associated impactites.

References: [1] Schwarzman E. C. et al. (1983) *GSA Bull., 94,* 926–935. [2] Wenk H. R. (1978) *Geology, 6,* 509–511. [3] Koeberl C. et al. (1989) *GCA, 53,* 2113–2118. [4] Hartung J. et al. (1991) *54th Annu. Met. Soc. Mtg.,* Monterey, CA. [5] Fudali R. F. (1973) *Meteoritics, 8,* 245–257. [6] Reimold W. U. and Miller R. McG. (1989) *Proc. LPSC, Vol. 21,* 711–732.

SUDBURY PROJECT (UNIVERSITY OF MÜNSTER-ONTARIO GEOLOGICAL SURVEY): (4) ISOTOPE SYSTEMATICS SUPPORT THE IMPACT ORIGIN.

A. Deutsch[1], D. Buhl[2], P. Brockmeyer[1], R. Lakomy[1], and M. Flucks[1], [1]Institute for Planetology, University of Münster, Wilhelm-Klemm-Str. 10, D-4400, Münster, Germany, [2]Institute for Geology, RU Bochum, Postfach 10 21 48, D-4630 Bochum 1, Germany.

Introduction: Within the framework of the Sudbury project [1–3] a considerable number of Sr-Nd isotope analyses were carried out on petrographically well-defined samples of different breccia units [4–7]. Together with isotope data from the literature these data are reviewed in this abstract under the aspect of a self-consistent impact model [5,8–10]. The crucial point of this model is that the Sudbury Igneous Complex (SIC) is interpreted as differentiated impact melt sheet [5,8–11] without any need for an endogenic "magmatic" component such as "impact-triggered" magmatism or "partial" impact melting of the crust and mixing with a mantle-derived magma [e.g., 12]. For the terminology used here we refer to the companion abstracts in this volume [1–3].

Strontium and Neodymium Isotopes: Impact melt rocks such as the sublayer [12], the SIC [11,12], and the clast-rich melt breccia on its top [5,6], as well as melt breccia bodies, matrix, and melt particles from the Onaping breccias [5,6], are characterized by ε_{Nd} between -5 and -12 with Onaping lithologies tending toward lower ε_{Nd} values (Fig. 1). Their Nd-model ages TDM relative to a depleted mantle [13] cluster around 2.7 Ga, which agrees well with the time of the last major crust-forming event in the Archean Superior Province northwest of the Sudbury structure [e.g., 14,15]. It is important to note that ultramafic inclusions in the sublayer plot among other SIC rocks with negative ε_{Nd} and positive ε_{Sr} [12]. Figure 1 shows that the SIC has highly radiogenic and variable I_{Sr}. All those findings fit with the proposed total melting of the crust in the Sudbury region by the impact event that leads to $\sim 1.5 \times 10^4$ km^3 of impact melt [10], namely the SIC and the melt breccia, and the melt in the suevitic Onaping breccias [3]. In contrast, the data are incompatible with the input of fresh mantle magma as up to 75% contamination by upper crustal material would be required [12] to explain the Nd-Sr isotope systematics of these units, but an endogenic melt cannot assimilate such a high fraction of relatively cold material.

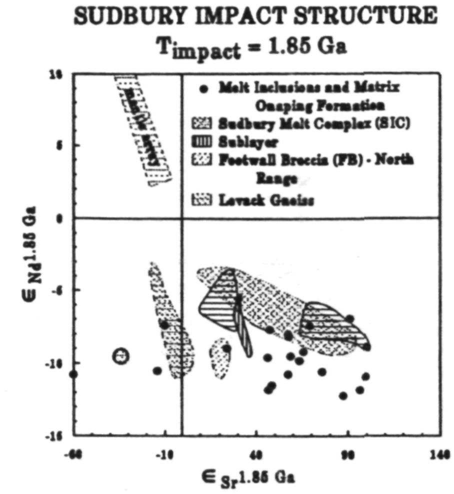

Fig. 1. ε_{Nd}-ε_{Sr} diagram for different lithologies of the structure with data recalculated to 1.85 Ga, the time of the impact event [14]; data sources [4–6,11,12,15–17,19].

Neodymium isotope ratios of the impact melt concur with Nd characteristics of the target lithologies in the Sudbury region, for example, the Levack gneiss [12]. The observed spread in ε_{Sr} reflects the widely varying $(^{87}Sr/^{86}Sr)^{T = 1.85\ Ga}$ for the Archean basement [4,15], Proterozoic Intrusives [16,17], and the Huronian Supergroup [16,18] that were mixed into the melt. Distinct fields for the sublayer from different localities [12,19] in Fig. 1 show that the impact melt sheet (SIC) assimilated local bedrocks after its emplacement in the final modified crater. Strongly deviating Sr isotope ratios for some Onaping rocks in Fig. 1 with $(^{87}Sr/^{86}Sr)^{T = 1.85\ Ga}$ as low as 0.700 [6,7] or 0.67 [20] are due to a reopening of the Rb-Sr system during the Penokean orogeny [4, see also 7]. This is demonstrated with selected growth curves in Fig. 2: Some recrystallized melt particles and devitrified glass have enhanced Rb/Sr ratios but the majority of the material has I_{Sr} identical to the granophyre. Together with their ε_{Nd}, this fact supports our view that the melt-breccia on top of the granophyre and the melt material in the suevitic Onaping breccias and in the Green Member originated from the same source as the SIC, namely impact-melted crustal material.

Oxygen isotope data [21] support our findings. The norite, the granophyre, and the matrix of Onaping breccias all show a considerable spread in $\delta^{18}O$, but typical trends as known from differentiated layered intrusions are absent. The $\delta^{18}O$ values of these lithologies are bracketed by oxygen isotopic compositions observed for local Archean and Proterozoic bedrocks with the Onaping breccias reflecting a higher input of Huronian greywackes. To explain the Os isotope ratios for the Sudbury ores [22] by mixing between a mantle magma and crust would need up to 90% crustal material. Therefore these data are also in line with a derivation of the ores exclusively from ancient crustal sources by impact melting followed by segregation of a sulfide liquid out of the melt sheet.

Summary and Outlook: While in the original contributions SIC isotope systematics were discussed preferentially in terms of a possible mixing between a hypothetical mantle component with up to 75% crustal material, the impact melt model does not have any problem explaining the crustal signatures of the SIC, the Onaping breccias, and the Sudbury ores—total melting of basement and supracrustal lithologies can only produce crustal signatures. Future studies on Sudbury should concentrate on combined analyses of

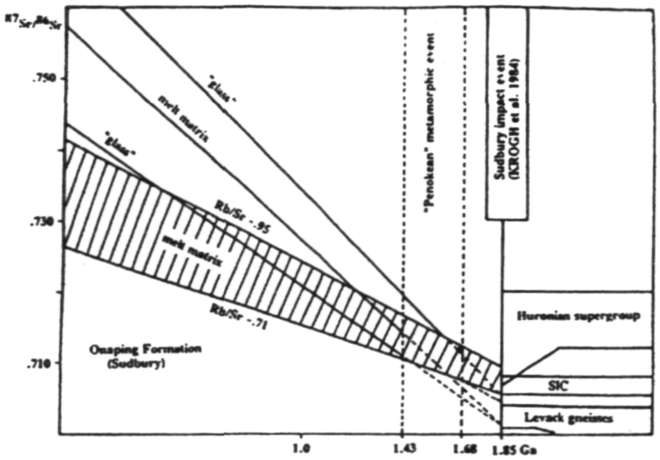

Fig. 2. Selected Sr growth curves for recrystallized Sudbury melt particles and devitrified glass from the Gray and Green Member of the Onaping Formation [3], and the matrix of the melt breccias topping the granophyre; data sources [5,6].

stable and radiogenic isotopes on petrographically defined samples in order to understand the mixing process in impact melts in more detail. Isotope data could also help to decipher the complex process of assimilation by a large hot impact melt sheet for both lithic fragments and crater floor lithologies.

References: [1] Avermann M. et al., this volume. [2] Bischoff L. et al., this volume. [3] Stöffler et al., this volume. [4] Deutsch A. et al. (1989) *EPSL, 93*, 359. [5] Deutsch A. et al. (1990) *LPSC XXI*, 282. [6] Brockmeyer P. and Deutsch A. (1989) *LPSC XX*, 113. [7] Buhl D. et al., this volume. [8] Stöffler D. et al. (1989) *Meteoritics, 24*, 328. [9] Lakomy R. (1990) *Meteoritics, 25*, 195. [10] Grieve R. A. F. et al. (1991) *JGR, 96*, 22753–22764. [11] Faggart B. E. Jr. et al. (1985) *Science, 230*, 436–439. [12] Naldrett A. J. et al. (1986) In *Metallogeny of Basic and Ultrabasic Rocks*, 75–91, Inst. of Mining Metallurgy, London. [13] DePaolo D. J. (1981) *JGR, 86*, 10470. [14] Krogh T. E. et al. (1984) In *The Geology and Ore Deposits of the Sudbury Structure* (E. G. Pye et al., eds.), 431–446, Toronto. [15] Hurst R. W. and Fahart J. (1977) *GCA, 41*, 1803–1815. [16] Fairbairn H. W. et al. (1969) *Can. J. Earth Sci., 6*, 489. [17] Gibbins W. A. and McNutt R. H. (1975) *Can. J. Earth Sci., 12*, 1970. [18] Fairbairn H. W. et al. (1967) *15th Annu. Rept M.I.T.*, 1381. [19] Rao B. V. et al. (1984) *Misc. Pap. Ontario Geol. Surv. 121*, 128. [20] Fullagar P. D. et al. (1971) *Can. J. Earth Sci., 8*, 435. [21] Ding T. P. and Schwarcz H. P. (1984) *Can. J. Earth Sci., 21*, 305. [22] Walker R. J. et al. (1991) *EPSL, 105*, 416.

NORIL'SK/SIBERIAN PLATEAU BASALTS AND BAHAMA HOT SPOT: IMPACT TRIGGERED?

R. S. Deitz and J. F. McHone, Department of Geology, Arizona State University, Tempe AZ 85287, USA.

Twenty-eight years after one of us [1] argued that Sudbury was an astrobleme, this interpretation has only recently attained wide acceptance; not so for his view that the Sudbury Cu/Ni sulfide ores are cosmogenic [2,3]. Papers such as by Alt et al. [4] have provided the triggering of plateau basalts by super-large impacts a modicum of respectability. Also, the recent apparent successful tying in of the K/T extinctions to the Chicxulub astrobleme in Yucatan encourages the search for an impact event that may have caused the other two major post-Paleozoic extinctions (P/Tr, Tr/J). This gives us heart to offer two further outrageous hypotheses.

Noril'sk Ores/Siberian Basalts: The cosmogenic concept for the Sudbury ore deposit remains viable because it is giant, nonultramafic, and unique (except for Noril'sk). It also has telling geologic relationships; for example, the ore-hosting sublayer appears to be a splash-emplaced target/bolide melt lining the Sudbury Basin cavity like spackle on a bowl that was also injected centrifugally into tensional cracks (offsets) (see [3] for further evidence). At Sudbury, endogenic scenarios usually have been assumed, especially the concept of the ring-dike sublayer fed from a deep magma reservoir [5]. This view has recently been seriously challenged by Grieve and Stöffler [6], who explain the Sudbury Intrusive Complex as an impact melt sheet. Although the geologic relationships between the ore and the country rock at Noril'sk remain enigmatic, it seems a remarkable Sudbury look-alike. Their ore mineralogy is similar, including platimum group metals, and they are both large scale (one Noril'sk sulfide body covers 2 sq km and is 20 m thick.) Naldrett et al. [7] believe that the Noril'sk ores and adjacent Siberian plateau basalts are intimately related and consanguineous. A similar view was offered by several other authors at the 1991 American Geophysical Union Fall Meeting symposium (Noril'sk Siberia: Basalts, Intrusions, and Ores). Using argon/argon laser fusions, Dalrymple et al. [8] assigned a date for the ores and flood basalt of 249 ± 1 Ma, indistinguishable from the Permian/Triassic boundary. We therefore suggest that the Noril'sk ores may be of cosmogenic parenthood and that this impact also triggered the Siberian plateau basalts. An associated event then might be the great extinction of life forms at the P/Tr boundary, all tied together as an event horizon.

Bahama Nexxus: Olsen [9] has attributed the Triassic/Jurassic boundary catastrophic extinctions to the Manicouagan asteroidal impact, but recent radiometric dating [10] indicates these events are diachronous (Manicouagan astrobleme 212 ± 2 Ma and Tr/J boundary 200 Ma). This boundary is also marked by extensive tholeiitic basalts (flows, sills, and dikes) of the rapidly extruded Newark Supergroup. Radially emplaced dikes on Pangaea (now broken up into Africa, North America, and South America) focus toward the Bahamas [11]. Dietz [12] has previously termed this presumed hidden hot spot (now buried beneath 6 km of shallow water coral reef limestone) as the Bahama Nexxus (a great triple junction connection) that marked the birth of the Atlantic rift ocean. The Bahama Platform might then be a mega coral reef laid down ensimatically on a subsiding plateau basalt. The floor spreading process calls for symmetrical repaving of the ocean floor by dike splitting. This clearly applies to the North Atlantic continental drift (North America/Africa) from Nova Scotia southward until the Bahama platform is reached. Then the conjugate point between North America and Africa jumps to the eastern tip of the Bahama cresentic platform rather than being at the tip of Florida. Clearly the seafloor spreading (dikesplitting) was overprinted by the hot spot, causing newly fragmented Gondwana (Africa/South America) to remain fixed (relative to the Earth's spin axis) while North America drifted away. (We can observe a modern example by the eastward offsetting of the Mid-Atlantic ridge as it transects Iceland hot spot.) Eventual death of the hot spot allowed the Mid-Atlantic Ridge to pave the ocean floor symmetrically. Thus almost the entire Bahama platform was stranded on the North American plate, leaving but a very small conjugate volcanic excrescence attached to Africa—the Bijagos Plateau off Portuguese Guinea. This great magmatic event