CONSTRAINTS ON THE ORIGIN OF THE OFFSET DIKES (SUDBURY IMPACT STRUCTURE, CANADA) FROM U-Pb DATA

M. Ostermann[1,2], U.Schärer[2], and A. Deutsch[1]; [1]Institut für Planetologie, Wilhelm-Klemm-Str. 10, D-48149 Münster, Germany; [2]Univ. Paris 7 and IPG, 2 place Jussieu, F-75251 Paris Cedex 05, France

The 1.85 Ga old [1] Sudbury Structure (Ontario, Canada) represents a tectonically deformed peak-ring or multi-ring impact structure with an original rim to rim diameter of up to 250 km [2-7]. Within the frame of this model, and supported by geochemical analyses [8, 9] and recent LITHOPROBE data [10], the Main Mass of the Sudbury Igneous Complex (SIC) is interpreted as the clast-free, differentiated central part of a coherent impact melt sheet, consisting of remolten crustal material only. At its base, a crystalline melt breccia, the Sublayer, forms a discontinuous thin layer.

A unique feature of the Sudbury Structure is the occurence of Offset Dikes. The term "offset" was introduced by [11] for up to 1500 m wide dikes, which radiate outward from the Main Mass of the SIC, and which are related to the SIC. Several economic important sulphide ore deposits are concentrated along these dikes [12, 13]. According to the most concise description on geological setting and petrography by [13], three types of Offsets can be distinguished: dikes occuring (*i*) perpendicular, or (*ii*) parallel to the outer margin of the SIC, or (*iii*) discontinous bodies. Dikes of type (*i*) can be traced for up to 28 km into the country rocks. The main lithology of the Offset Dikes is a quartz diorite with either hypersthene, clinopyroxene or amphibole as the dominant mafic mineral. Proximal to the contact with the SIC, the dikes show a greater compositional variety with norites, Sublayer lithologies and bodies of the Footwall Breccia. Most common are xenoliths of local country rocks as well as mafic to ultramafic clasts [14], which are probably derived from unexposed pre-Sudbury magmatic bodies. Geochemical data suggest different degrees of country rock assimilation after emplacement of the dikes. Their contacts are always sharp; they lack chilled margins, and contact metamorphic overprint in adjacent rocks is totally absent implying that country rock material was at elevated temperatures during dike intrusion.

It is generally assumed that the Sublayer and the Offset dikes are genetically related. Several models with up to four intrusion phases over an extended period of time have been proposed to explain chemical variations and complex internal contact relationships in the Sublayer [e.g., 15], as well as the origin of the Offset Dikes with their associated ore deposits [e.g., 12, 16, 17]. In all these endogenic or endogenic-exogenic models, however, age relationships between SIC, Sublayer, and Offsets remain unclear due to the lack of radiometric age data for the Offset dikes.

To bracket the age of the Offset Dikes, zircons were separated from the Foy Offset (north of the SIC), and small abraded fractions were analyzed for U and Pb. The three small to medium-grained quartz-dioritic Offset Dike samples are free of clasts and they have SiO_2 contents of 50.9, 57.3, and 58.7 wt.-%; they show various degrees of alteration. The zircons have a magmatic appearance, based on their morphology and internal structure with a total absence of inherited cores. In the concordia diagram of Figure 1, the zircon data plot slightly discordant and colinear on a trajectory intersecting the concordia line near 1850 Ma, which is the age of the SIC [1]. The U-Pb data also imply that the zircons were newly grown in the melt now forming the Offset Dikes. Moreover, on the basis of known U-Pb systematics in zircon, it can be concluded that very high temperatures were reached in this melt, causing total resetting and eventual dissolution of any older zircons present. Only impact melts can reach such high temperatures.

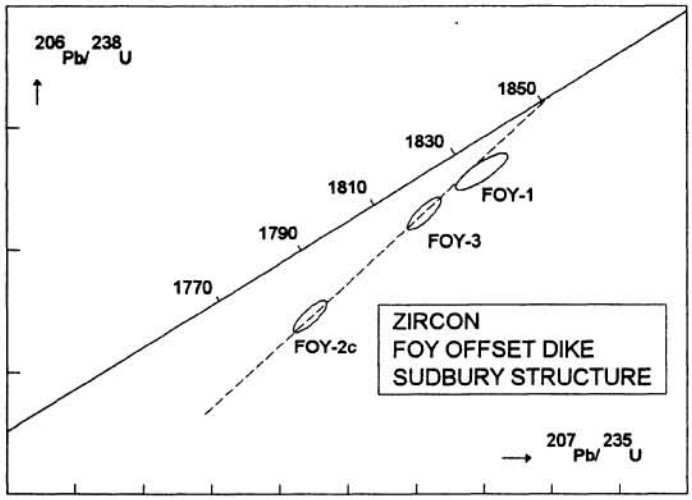

Figure 1. Concordia diagram with zircon data for the Foy Offset Dike. Sample locations: FOY 1, half distance between the outer rim of the SIC and Nickel Lake; FOY 2, Nickel Lake; FOY 3, North of Nickel Lake. 1850 ± 1 Ma (2σ) is the age of the SIC, defined by data for zircon and baddeleyite from the norite and the granophyre of the SIC [1].

On the basis of these preliminary U-Pb geochronological data, the Foy Offset Dike and the SIC show an identical age. In addition, U-Pb systematics of the zircons indicate that the Offset Dikes are also part of the impact melt system at Sudbury, consisting of re-melted crustal material. This view is supported by relatively radiogenic osmium isotope compositions in the main mass of the Cu-Ni ores and in the Offset Dikes [18, 19], which are incompatible with an mantle origin of the platinum group metals. The Cu-Ni ores must have formed by immiscibility [20] relatively early in the differentiation of the SIC. They are concentrated in the basal layer of the melt sheet, the Sublayer, and were transported along with xenoliths of basal SIC rocks into the Offset Dikes. It is proposed that the major period of their extrusion from the SIC was after the crater had formed and the ores had segregated but prior to Footwall Rock cooling. Presumably, Offset Dike emplacement was during late-stage topographic and isostatic adjustments. The spatial distribution of Offset Dikes suggests that they intruded zones of impact-induced fractures and pre-existing faults in the crater basement.

ACKNOWLEDGEMENTS. We thank Dr. B.O.Dressler (Ontario Geol. Survey) for providing the samples. Analytical work was supported by PROCOPE and by the INSU-D.B.T. grant 1991-4.17 to U.Schärer.

REFERENCES. [1] Krogh, T.E. et al. (1984) *Ontario Geological Survey, Spec. Vol.1*, 431-446; [2] Brockmeyer, P. (1990) *unpub. Ph.D. thesis* University of Münster; [3] Lakomy, R. (1990) *Meteoritics, 25*, 195-207; [4] Grieve, R.A.F.et al. (1991) *JGR, 96*, E5, .22,753-22,764; [5] Avermann, M. et al. (1994) *GRL* i.p.; [6] Stöffler, D. et al. (1994) *Geol. Soc. Am. Spec. Vol.* i.p.; [7] Grieve, R.A.F. and Deutsch, A. (1994) *this volume*; [8] Faggart, B.E. et al. (1985) *Science, 230*, 436-439; [9] Deutsch, A. (1994) *Geol. Soc. Am. Spec. Vol.* i.p.; [10] *GRL Spec. Vol.* i.p.(1994); [11] Coleman, A.P. (1905) *Ontario Bureau of Mines, 4*, Part 3, 188; [12] Souch, B.E. et al. (1969) *Economic Geology Monograph 4*, 252-261; [13] Grant, R.W. and Bite, A. (1984) *Ontario Geol. Surv., Spec. Vol.1*, 275-300; [14] Scribbins, B.T. et al. (1984) *Can. Mineral.*, 22, 67; [15] Dressler, B.O. et al. (1987) in *Research in Terrestrial Impact Structures* (Pohl, J. ed.) 39-68 (Vieweg, Braunschweig); [16] Naldrett, A.J. et al. (1972) *Intern. Geol. Congress 24th, 4*, 206-214; [17] Pattison, E.F. (1979) *Can. Mineral., 17*, 257-274; [18] Walker, R.J. et al. (1991) *EPSL, 105*, 416-429; [19] Dickin, A.P. et al. (1992) *GCA, 56*, 3531-3537; [20] Naldrett, A.J. et al. (1986) in *Metallogeny of Basic and Ultrabasic Rocks*, 75-91, Inst. of Mining Metallurgy, London, U.K.