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The Sudbury Igneous Complex: A Differentiated Impact Melt Sheet*

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Abstract

The Sudbury structure, Ontario, is the remnant of a 1.85 Ga old impact crater, which originally had a diameter of 200 to 250 km. The Sudbury Igneous Complex occurs within the Sudbury structure. The Sudbury Igneous Complex is a 2.5- to 3.0-km-thick, ~60- × 27-km elliptical igneous-rock body, which consists of four major lithologies (from top to bottom) traditionally termed "granophyre," "quartz gabbro," "norite," and "contact sublayer" (sulfide- and inclusion-bearing noritic rock). With the exception of the latter, all these lithologies are continuous across the structure. Modal analyses reveal that, following the IUGS system of nomenclature, quartz gabbro samples are in fact quartz monzogabbros, a few of the norite samples are quartz gabbros, and most norite samples are quartz monzogabbros. In view of these observations, and in order to clarify the nomenclature, an updated terminology is proposed (from top to bottom): upper unit, middle unit, lower unit, and contact sublayer.

The bulk composition of the Sudbury Igneous Complex, from North Range data, is granodioritic. Continuous and gradational mineralogical and geochemical variations between the lithological units are evidence that the Complex behaved as a single melt system. All the Sudbury Igneous Complex lithologies have the same light to heavy rare earth element (REE) ratio and an overall pattern of increased light REE and depleted heavy REE. The occurrence of primary hydrous minerals (hornblende and biotite), deuteric alteration, and abundant micrographic and granophyric intergrowths demonstrate that the melt was rich in H_2O. Moreover, the granophyric and other far-from-equilibrium textures are most likely due to rapid crystallization triggered by exsolution of a volatile phase.

The Sudbury Igneous Complex differs from traditional layered mafic complexes in the following aspects. It has an overall intermediate composition, a hydrous nature, a crustal isotopic signature, normative corundum, and an unusually large volume of granophyre. The Sudbury Complex differs from known terrestrial impact melt sheets only by its great thickness and the presence of chemical, and therefore, mineralogical layering. Reported here for the first time, and similar to those found in impact melt rocks elsewhere, are the occurrences of plagioclase xenocrysts with complex twinning and zoning patterns and planar deformation features in quartz xenocrysts. The well-known ore deposits of the Sudbury region are directly related to the genesis of the Sudbury Igneous Complex. Some ores precipitated from the Sudbury melt, whereas others were concentrated by hydrothermal fluids that percolated through the crystallized complex. It is concluded that the Sudbury Igneous Complex is the best exposed and only well-documented, to date, terrestrial impact melt sheet to have differentiated.

Introduction

THE SUDBURY STRUCTURE (N 46°36', W 81°11'), Ontario, is renowned for its very large ore deposits; it encompasses an area >15,000 km^2 (Fig. 1). It consists of fractured and brecciated Archean metavolcanic, metasedimentary, and granitic rocks, emplaced more than 2,600 m.y. ago, and Proterozoic metasedimentary and metavolcanic rocks of the Huronian Supergroup, deposited and folded between 2500 and 2219 Ma (Card et al., 1977; Card, 1978). These basement rocks are crosscut by quartz diorite dikes (ten, presently known as "offset dikes"; e.g., Wood and Spray, 1998; Scott and Spray, 1999) and by multiple veins and lenses of pseudotachylyte and clastic matrix breccias (locally referred to as "Sudbury breccia"; e.g., Thompson et al., 1998). The Sudbury Igneous Complex occurs in the center of the Sudbury structure. It overlies brecciated basement rocks, including a thermally metamorphosed zone of heterolithic (mega) breccia (locally referred to as "footwall breccia"; e.g., Dressler, 1982, 1984; Dressler et al., 1992). The Sudbury basin, which is filled in by the Onaping, Onwatin, and Chelmsford Formations, overlies the Sudbury Igneous Complex. In the last two decades, considerable advances have been made in understanding the character of large impact structures and impact processes. These have led to a generalized working hypothesis for the origin of the Sudbury structure (e.g., Grieve et al., 1991; Deutsch and Grieve, 1994; Stöffler et al., 1994; Deutsch et al., 1995). Although initially highly controversial, the impact origin of many of the geologic features at Sudbury, as first suggested by Dietz (1964) and later confirmed by the work of Dietz and Butler (1964), Bray et al. (1966), French (1970), and others, is now broadly accepted and the Sudbury structure is regarded as

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