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Fold origin of the NE-lobe of the Sudbury Basin, Canada: Evidence from heterogeneous fabric development in the Onaping Formation and the Sudbury Igneous Complex

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Abstract

Structural analysis of the Onaping Formation, a heterolithic impact melt breccia, and the Granophyre in the NE-lobe of the 1.85 Ga Sudbury Igneous Complex (SIC) assist in understanding the formation of the Sudbury Basin. Previously, the lack of mesoscopic strain fabrics in the SIC, in contrast to pervasive fabrics in the Onaping Formation of the NE-lobe, led to interpretations of the shape of the NE-lobe as primary. We demonstrate that the structures of the Onaping Formation are consistent with deformation in a fold core controlled by the mechanically stronger Granophyre of the NE-lobe. Evidence for this interpretation includes the (1) presence of open structural domes and basins, (2) geometry of planar mineral shape fabrics, (3) variation in shape fabric intensity, and (4) kinematics of prominent faults. Folding of the Onaping Formation affected the SIC because fold geometry is based on dip data in the SIC and fold-related faults cut both the Onaping Formation and Granophyre. Microstructural observations point to different temperatures during deformation in both units that are consistent with initiation of folding during cooling of the SIC upon reaching middle greenschist-facies metamorphic conditions.

Keywords: Sudbury Basin; Heterogeneous deformation; Folds; Faults; Mineral fabrics

1. Introduction

With an estimated diameter of 200–250 km, the Sudbury impact structure, in the southern Canadian Precambrian Shield (Fig. 1), is the second largest impact structure known on Earth (Grieve et al., 1991; Deutsch et al., 1995; Spray et al., 2004). The central portion of the impact structure is marked by the synformal and layered Main Mass of the Sudbury Igneous Complex (henceforth called SIC) that is 1.85 Ga in age (Krogh et al., 1982, 1984). Along with the overlying Onaping Formation, a heterolithic impact melt breccia, and post-impact sedimentary rocks, the SIC forms the 60 km by 30 km Sudbury Basin (Brocoum and Dalziel, 1974). To the north and east, the SIC rests on granitoid, gneissic and granulite rocks, notably the Levack Gneiss Complex, of the Archean Superior Province (Fig. 1). To the south, it overlies steeply northward-dipping and overturned metasedimentary and metavolcanic strata of the Paleoproterozoic Huronian Supergroup. These rocks were deformed by the ca. 2.4–2.2 Ga Blezardian and ca. 1.9–1.8 Ga Penokean episodes of orogenic deformation (Riller and Schwerdtner, 1997; Riller et al., 1999), the latter one of which affected also the SIC and its overlying rocks.

The SIC is widely accepted to be the relic of a solidified impact melt sheet (Grieve et al., 1991; Deutsch et al., 1995) formed by shock-induced fusion of Archean and Paleoproterozoic target rocks based on the presence of massive pseudotachylitic breccia, shatter cones and planar deformation features (e.g., Bray et al., 1966; Dressler, 1984b; Spray and Thompson, 1995). Upon cooling, the melt sheet differentiated into, what is traditionally known as, the Norite, Quartz-gabbro and

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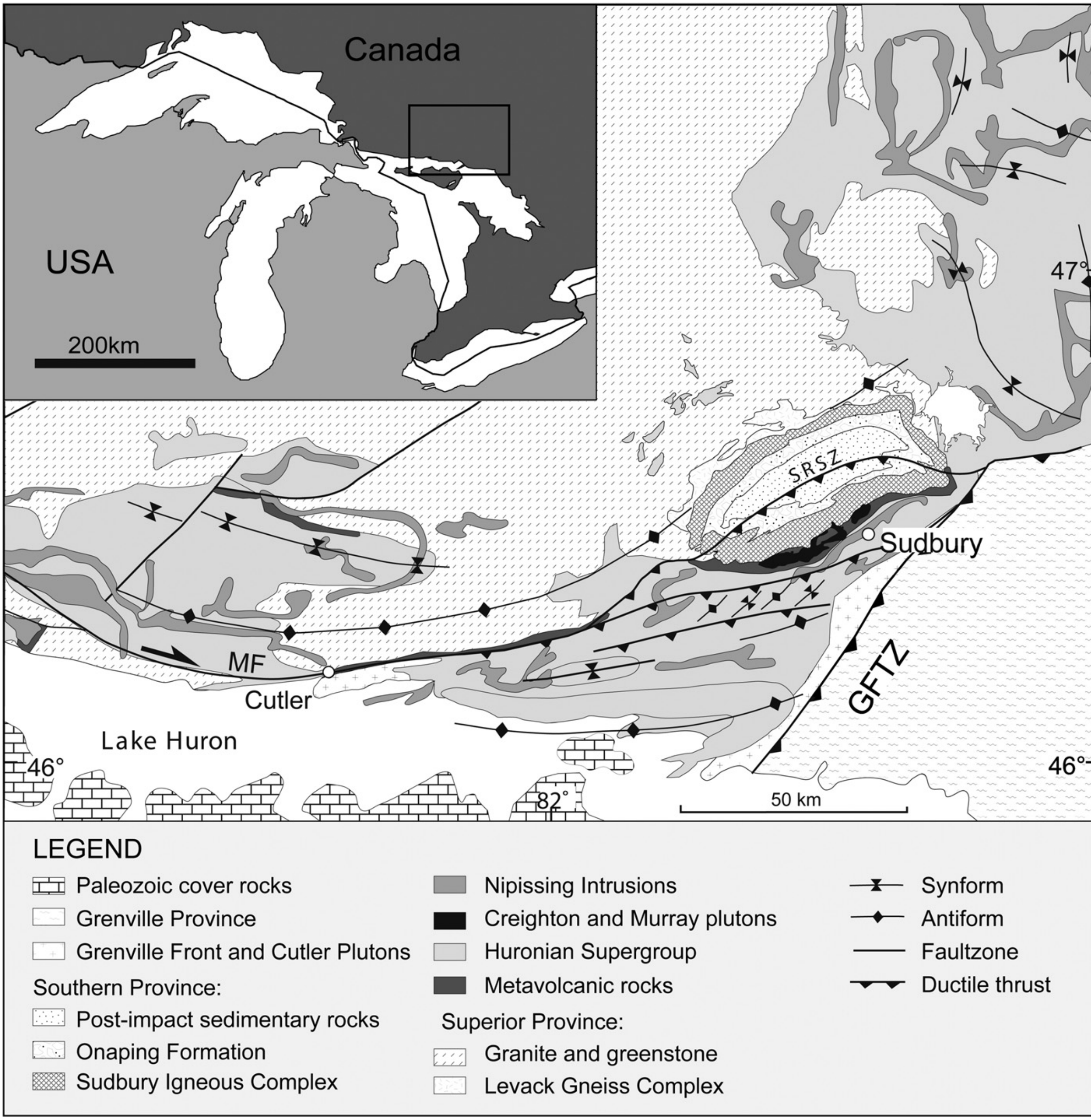

Fig. 1. Simplified tectonic map, modified from Card et al. (1984), showing the relics of the central Sudbury impact structure as part of the Eastern Penokean Orogen in the southern Canadian Shield. The Sudbury Igneous Complex rests on Archean rocks, notably granulites of the 2.7 Ga Levack Gneiss Complex in the north, and Paleoproterozoic rocks of the Huronian Supergroup in the south. SRSZ: South Range Shear Zone, GFTZ: Grenville Front Tectonic Zone, MF: Murray Fault.

Granophyre layers (Fig. 2: Grieve et al., 1991; Deutsch et al., 1995; Therriault et al., 2002), likely within about 10,000 years (Prevec and Cawthorn, 2002; Zieg and Marsh, 2005).

Based on impact models, the SIC formed in a large impact basin with a flat crater floor (e.g., Grieve et al., 1991; Deutsch et al., 1995; Ivanov and Deutsch, 1999). Its elliptical outline (Fig. 2), dip of lower contact toward the centre of the Sudbury Basin (Dressler, 1984a) and asymmetric deep structure (Milkereit et al., 1992) point to a synformal geometry of the melt sheet (Coleman, 1905, 1907; Collins and Kindle, 1935). The asymmetry of the SIC is attributed to northwest-directed displacement of the South Range on the South Range Shear Zone (Fig. 2), a prominent ductile thrust characterized by asymmetric mineral fabrics (Shanks and Schwerdtner, 1991). In reflection seismic profiles, the thrust is evident by imbricated contacts of the SIC and by southward inclined,