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Integrated potential-field and seismic constraints on the structure of the Archean metasedimentary English River belt, Western Superior craton, Canada

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Abstract

The English River Subprovince is a prominent belt of metasedimentary rocks in the Archean Western Superior Province. The structure of its western half was investigated by using techniques of enhancement and automatic interpretation of magnetic data, and integration of magnetic-derived information with seismic and gravity data. The results indicate that a suite of exposed felsic plutons that intruded the belt at ca. 2698 Ma extends under most of the metasedimentary rocks that are exposed at the surface. The thickness of the metasedimentary rocks is interpreted to be less than 1 km in areas where it is underlain by the members of this intrusive suite. In other areas, the metasedimentary rocks attain thicknesses of 3–4 km and appear to be underlain by rocks similar to the gneissic rocks that are exposed in the adjacent metaplutonic Winnipeg River Subprovince. The integration of enhanced magnetic data with gravity data indicates that the large gravity anomaly that extends along the English River belt correlates well spatially and morphologically with the extensive suite of felsic intrusions that underlies the belt, suggesting that the crustal component of the gravity anomaly is related to this suite of intrusions. We interpret the source of the gravity anomaly as a dense unit comprising anhydrous mineral assemblages that formed within these felsic intrusions in response to low-pressure, high-temperature metamorphism that affected the belt at ca. 2691 Ma. On the basis of geochronological, geological and geophysical constraints, we propose that this metamorphic episode is linked to the continuation of magmatism at depth after the emplacement of the ca. 2698 Ma felsic plutons, being ultimately related to the advection of mantle heat into the crust during a period of regional extension.

Keywords: Superior province; English River Subprovince; Metasedimentary rocks; Gravity data; Magnetic data; Seismic data

1. Introduction

The western part of the Archean Superior Province comprises a succession of east-trending belts (or subprovinces) of contrasting lithological, structural, metamorphic and geochronological characteristics (e.g. Card and Ciesielski, 1986). A distinct feature of this belt structure is the occurrence of prominent, linear regions of metamorphosed clastic sedimentary rocks (Fig. 1). In contrast to the adjacent granite-greenstone terrains, where metamorphic assemblages record subgreenschist to amphibolite facies conditions, these sedimentary belts experienced low-pressure, high-temperature metamorphism that locally reached granulite-facies conditions and led to widespread migmatization and formation of peraluminous granite (e.g. Ayres, 1978; Sawyer, 1984; Percival, 1989; Breaks, 1991).

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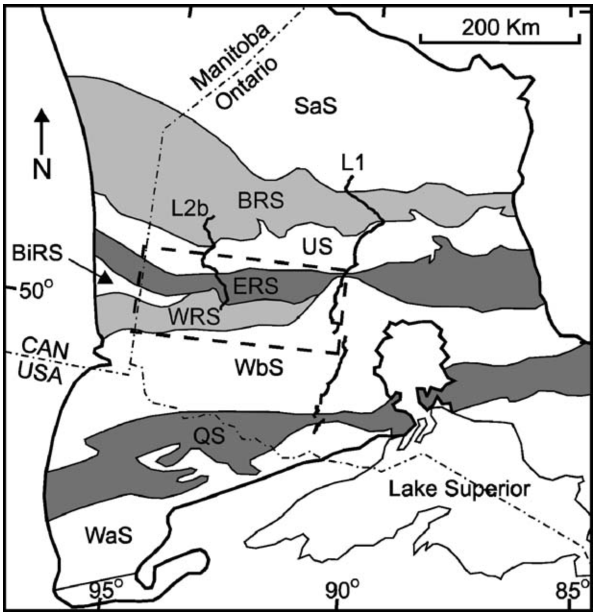

Fig. 1. Schematic map of the Western Superior Province showing its belt structure and the location of the map shown in Fig. 2 (thick dashed line). Lithoprobe seismic lines 1 and 2b are also indicated (thick continuous lines labelled L1 and L2b). The metasedimentary belts are represented with heavy shading, the metaplutonic belts are represented with light shading and the granite-greenstone belts are represented without any shading. SaS, Sachigo Subprovince; BRS, Berens River Subprovince; US, Uchi Subprovince; ERS, English River Subprovince; BiRS, Bird River Subprovince; WRS, Winnipeg River Subprovince; WbS, Wabigoon Subprovince; QS, Quetico Subprovince; WaS, Wawa Subprovince.

Given the scarcity of large, continuous, sediment-dominated belts in most Archean cratons, their presence in the Western Superior Province has been recognized as a potentially key element for understanding the development and evolution of the Superior craton (e.g. Williams, 1990). Within the past three decades, numerous geochronological determinations, geochemical studies, and field observations led to a widely accepted interpretation of the Superior Province belt structure as the result of a process of progressive growth from north to south by accretion of arc, oceanic, and continental fragments, which culminated at ca. 2720–2700 Ma with a major episode of crustal thickening, syn-tectonic magmatism and deformation known as the Kenoran orogeny (e.g. Langford and Morin, 1976; Card, 1990; Williams, 1990; Williams et al., 1992; Stott, 1997; Card and Poulsen, 1998). Among the essential elements in the development and refinement of this accretionary hypothesis have been structural, depositional and geochronological observations made in the metasedimentary Quetico Subprovince, which led to the interpretation of this belt as either an ancient accretionary complex (Percival, 1989; Percival and Williams, 1989; Williams, 1990, 1991), or a remnant of a syn-orogenic collisional sedimentary basin (Davis et al., 1990). Similarly, the metasedimentary English River belt, which in terms of setting, lithology, metamorphism and structural style closely resembles the Quetico belt has been interpreted as an accretionary prism (Hoffman, 1989; Breaks, 1991; Card and Poulsen, 1998), or as a syn-orogenic flysch deposit accumulated in a foreland basin (Corfu et al., 1995; Davis, 1998).

Most of the significant advances made toward understanding of the lithology, structure, metamorphic conditions, and tectonic evolution of the Western Superior Province metasedimentary belts are based on surface geological observations and related isotopic studies (e.g. Percival, 1989; Percival and Williams, 1989; Davis et al., 1990; Breaks, 1991; Williams, 1991; Corfu et al., 1995). Although these terrains have regional gravity and aeromagnetic coverage (e.g. Gupta, 1991a, b) and have also been probed seismically at the crustal scale (e.g. Hall and Hajnal, 1969, 1973; Cruden and Hynes, 1999; White et al., 2003; Calvert et al., 2004; Musacchio et al., 2004), the geophysical data have generally remained underused and not integrated with surface geological observations.

In the present study, we investigate the structure of the western half of the metasedimentary English River Subprovince (ERS), based on the enhancement and automatic interpretation of magnetic data, and the integration of the derived information with seismic and gravity data. Specifically, we attempt to constrain the distribution and extent of the intrusive bodies that occur within the metasediments, the source of the large gravity anomaly that extends along the belt, and the possible sources of heat that led to granulite-grade metamorphism. The implications of these results are then considered together with other geological and geophysical observations to propose a model for the evolution of this metasedimentary belt.

2. Geologic background

The western half of the ERS (Fig. 2) is bounded to the north by the granite-greenstone Uchi Subprovince, which contains volcano-plutonic complexes formed during a multistage evolution between 3000 and 2700 Ma (Corfu and Stott, 1993). The boundary with the Uchi Subprovince largely coincides with the Sydney Lake—Lake St. Joseph fault, which is a major late-Archean dextral strike-slip fault. However, occurrences of ERS-like metasedimentary rocks north of this fault