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Crust–mantle coupling revisited: The Archean Slave craton, NWT, Canada

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ABSTRACT

Lithospheric domains in the Slave Province, inferred from regional variations in chemistry of mantle-derived garnets, are parallel with northeasterly structural trends in Neoarchean surface rocks and were used previously to infer Late Neoarchean crust–mantle coupling and argue against the presence of diamondiferous Mesoarchean lithosphere under the western Slave craton prior to its late Neoarchean orogenic climax. A review of more recent evidence does not support this view but concludes that a Mesoarchean lithospheric root was coupled to Mesoarchean crust of the Central Slave superterrane (CSST) prior to accretion of adjacent juvenile Neoarchean terranes. A significant part of this root survived the Neoarchean break-up of the CSST, Neoarchean terrane accretion and a complex sequence of post-accretion deformation, granitoid plutonism and metamorphism. It was least modified in the ultra-depleted harzburgitic layer (UDL) under the central part of the Contwoyto terrane, where it is trapped above the deepest part of an underplated Paleoproterozoic slab which stabilized the remnants of the Archean root and caused downward younging of the lithosphere. Upper mantle domains recognized on the basis of the distribution of peridotitic garnets are not primary Neoarchean features but were either inherited from the original Mesoarchean root or resulted from Neoarchean and Paleoproterozoic tectonic erosion and/or metasomatism of this root. The Slave Province resembles other diamondiferous cratons in that its diamond endowment consists of both Mesoarchean and Paleoproterozoic stones.

1. Introduction

Following the discovery of diamondiferous kimberlites on the Archean Slave craton, their upper mantle sample was studied extensively to determine composition and structure of the lithosphere as well as to establish ages of diamond formation and crust–mantle coupling. Based on regional variations in the chemistry of mantle-derived garnet xenocrysts from till samples, Grütter et al. (1999) inferred the existence of three ENE-trending lithospheric domains with marked differences in depletion of peridotite bulk compositions. A central domain, characterized by an abundance of ultra-depleted garnets, includes the Lac de Gras kimberlite field, under which the presence of an ultra-depleted harzburgite layer (UDL) was recognized from studies of xenoliths and garnet concentrates from kimberlites (Griffin et al., 1999b; Pearson et al., 1999). This domain coincides with a zone of enhanced electrical conductivity, referred to as Central Slave Mantle Conductor (CSMC) (Jones et al., 2001; Jones et al., 2003). A northern domain is indicated by a sharp drop in abundance of G-10 garnets and an increase in the number of eclogitic garnets (Grütter et al., 1999). The boundary with the central and southern domains is less sharp, but also marked by a significant decrease in G-10 garnets and an increase in eclogitic garnets. Some extremely high-Cr garnets occurring in exploration sample in the southern domain are found also in the Snap Lake and CL-25 kimberlites (Pokhilenko et al., 1997; McLean et al., 2001). Because a N–S cross-section through the Slave Province lithosphere constructed from upper mantle xenoliths and xenocrysts of widely distributed kimberlites (Kopylova and Caro, 2004) is broadly compatible with the observations of Grütter et al. (1999), the notion of a north-northeast trending mantle-domain structure has become widely accepted (see also Davis et al., 2003a).

As the inferred central, ENE trending, ultra-depleted mantle domain sits astride the Neoarchean, N–S trending tectonic terrane boundaries but is sub-parallel to "D1" structural trends and the regional distribution of Defeat-age (~2630–2620 Ma) arc-like plutonic rocks in the southern Slave Province (Davis and Bleeker, 1999), Grütter et al. (1999) concluded that the crust and underlying lithospheric mantle were coupled in the late Neoarchean along northeast-trending zones. After the first Mesoarchean Re–Os model ages were presented from Slave peridotite xenoliths (e.g., Aulbach et al., 2001), Davis et al. (2003a) considered it a paradox that extensive Neoarchean plutonism and low-P, high-T metamorphism in the crust of the Slave Province should have developed above a previously stabilized, thick Mesoarchean lithospheric root (see also Canil, 2008). They suggested that the ENE mantle domain structure developed late in the Neoarchean orogenic cycle, probably by northwest-directed subduction related to the Defeat arc, and that significantly older mantle components (>2750 Ma) may be accounted for by tectonic underplating of more ancient lithospheric fragments during Neoarchean

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collisional events. A corollary of the inferred late crust–mantle coupling is that diamond formation is thought to have occurred at the earliest in the latest Archean, within only slightly older lithosphere (Davis et al., 2003a).

Current isotopic evidence does not support the model of Davis et al. (2003a). Of the two periods of diamond growth recognized, one is Mesoarchean, the other Paleoproterozoic (Westerlund et al., 2006; Aulbach et al., this issue), and Neoarchean diamond ages have not been identified to date. In the present paper, an alternative tectonic model is proposed, therefore, that attempts to reconcile the presence of Mesoarchean peridotitic and Paleoproterozoic eclogitic diamonds with geophysical evidence for a thick cratonic keel and the available information on the tectonothermal evolution of the Slave craton.

2. Geological setting

The Slave Province is located in the north-western part of the Canadian Shield, between Great Slave Lake and Coronation Gulf (Fig. 1), and represents the exposed part of the Slave craton, one of the Archean building blocks of the Precambrian core of North America, also referred to as Laurentia (Hoffman, 1989). Crystalline basement of the Slave Province consists of ca. 4.0 to 2.58 Ga crust that cratonized between 2.58 and 2.51 Ga (Fig. 3). The main part of the province comprises ca. 172,500 km^2 (Padgham, 1991) and has an elliptical shape, measuring 680 km in the long (along an approx. NNE trending line from Gros Cap, on Great Slave Lake, to Cape Barrow, on Coronation Gulf) and 460 km in the short (E–W, along Latitude 64°N) dimensions (Figs. 1 and 2). A north-eastern segment, the Bathurst or Hope Bay Block, comprises ca. 16,250 km^2 and is separated from the main part by the Bathurst fault zone and gently to moderately folded Paleoproterozoic rocks of the Goulburn Supergroup. An even smaller segment, the Eokuk uplift, lies to the west of the main part of the Slave Province, along the coast of Coronation Gulf. It comprises 1250 km^2 and forms an inlier within the autochthonous part of the Paleoproterozoic Coronation Supergroup.

Archean rocks of the Slave Province are framed by Paleoproterozoic orogenic belts (Fig. 1) inferred to be suture zones which developed near passive margins along which a larger Archean land mass had drifted apart in the Early Paleoproterozoic (Hoffman, 1989). In the east, the Thelon orogen resulted from oblique collision between the Slave (foreland) and the Rae (hinterland) provinces (Hoffman, 1989). The 2020 to 1910 Ma Thelon magmatic zone is an arc that developed on Archean basement of the adjacent Rae Province. Slave basement shows an increase in metamorphic grade and mylonitization towards the Thelon Front (Henderson and van Breemen, 1991), suggesting that it occupied a lower plate position during collision. Towards the Thelon Front, the characteristic pattern of bulbous plutons and irregular areas of supracrustal rocks changes into a NNE trending, steeply dipping zone of straight gneisses in which Slave Province rocks become involved in the Paleoproterozoic deformation front (Henderson and

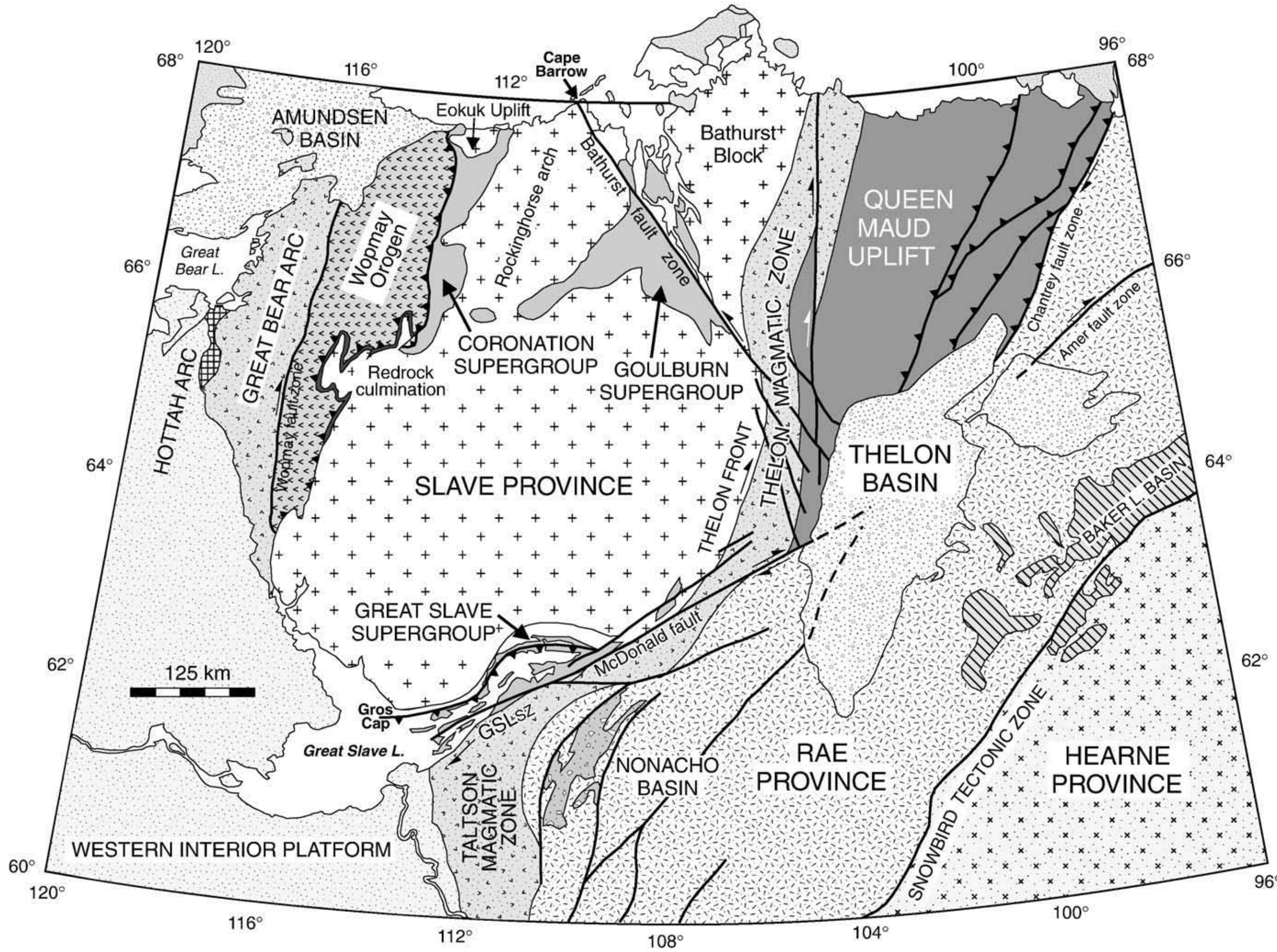

Fig. 1. Tectonic setting of Slave Province within northwestern part of Canadian Shield (after Hoffman, 1989). Archean rocks of province (crosses) are bordered by Paleoproterozoic Thelon–Taltson orogen and Wopmay orogen in east and west, respectively, and remnants of relatively little deformed Paleoproterozoic cover rocks (Goulburn and Coronation supergroups) are preserved in northern part of the province. Southwestern part of province is overlapped by Paleozoic rocks of the western Interior Platform. GSLSZ — Great Slave Lake shear zone linking magmatic zones of Thelon–Taltson orogen.