THE INFLUENCE OF THE DEEP STRUCTURE OF THE GLENNIE DOMAIN ON THE DIAMONDS IN SASKATCHEWAN KIMBERLITES

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Diamondiferous kimberlites are typically located in stable, cratonic (Archean) regions of the earth (Clifford's Rule). This is reflected in the Nitrogen-aggregation characteristics of the diamonds[1]. Recently discovered kimberlites at Fort a la Corne (FALC)[3-5], near Prince Albert, Saskatchewan, and Sloan[6], in northern Colorado (see Fig.1), show some Proterozoic N-aggregation characteristics. These features are attributed to a Proterozoic continent-continent collision, leading to crustal and lithospheric thickening, and a subsequent period of diamond growth. Heavy minerals have been separated from 320kg of FALC kimberlites (as part of the Operation Fish Scale[2] investigating core from FALC), including garnets, micro and macrodiamonds. All the diamonds (30) have been analysed for their N-aggregation state, plus three for carbon isotope values (D. Mattey in ref [2]). Garnets (105 grains) have been commercially analysed with proton-probe Ni-thermobarometry (W.L. Griffin in ref [2]).

Evidence from seismic reflection east-west profiling (LITHOPROBE at 55°N and COCORP at 49°N) confirms that the Trans-Hudson orogen (THO) is a broadly anticlinal structure[7-9]. The central region, called the Glennie Domain (GD), comprises tectonically emplaced (aged 1.83-1.79 Ga) arc volcanics and arc sediments bordered by foreland shelf sediments associated with the Hearne/Wyoming craton in the west and Superior craton to the east. The entire THO is tectonised by transpressional structures, including thrusts and strike-slip faults, some of which extend into the lower crust. Broad tectonic structures indicate a collision of the GD from the NW to SE (in current orientations)[8]. In an analogous situation further south, in northern Colorado, the THO wraps around the south-western borders of the Wyoming craton. Final subduction polarity of the GD is postulated to have been north-westwards, under the Hearne/Wyoming craton. However, the deep structure of the GD consists of two lower crustal wedges, under both the eastern (Superior) and north-western boundaries (Hearne/Wyoming); i.e. GD underlies both cratons. In Saskatchewan the anticlinal core of the GD is composed of Archean mylonitic and gneissic rocks, with scattered windows outcropping at surface along minor anticlinorial and thrust axes in the north (around 57°). The arch crest in the COCORP profile (49°N) is at 20km depth, and may be related, if not directly connected, to the anticlinal core in central Saskatchewan. The GD imaged by LITHOPROBE includes a 48km crustal root, a significant Moho topography of about 12km over 60km (½-wavelength). This root is situated in the western half of the GD, and corresponds to the postulated crust-thick thrust system (GD down to the west) that is the boundary between the GD and craton to the west. When correlated to the current topography the root zone occurs below Prince Albert. Work in progress suggests that the root zone may not be present in a linear fashion along the entire north-south strike of the THO western boundary[11].

The FALC kimberlite cluster is composed of over seventy Cretaceous volcanic centres[3,5], located on the eastern slope of the root zone. Other kimberlites in the THO are further to the north and east, away from this deep root structure. The Sloan kimberlites are located in a similar tectonic setting; a Proterozoic orogenic belt, near to an Archean block. Kimberlites occurring here, including the Sloan 1 and 2 diatremes[6], contain Proterozoic high temperature eclogitic diamonds - 'Sloan'-types[10].

Garnets from the FALC kimberlites indicate a T_{MAX} 1250°C for the lherzolitic and harzburgitic garnets. Cr_2O_5 in these garnets indicates a source at approximately 180km depth for the deepest xenoliths that the kimberlites sample. N-aggregation analysis of FALC diamonds produced six populations, suggesting a complex growth history. These populations include peridotitic diamonds of Archean age, eclogitic diamonds of undetermined age and a Sloan-type diamond of Proterozoic age. Carbon isotope analysis indicated two diamonds of eclogitic origin (δ^{13}C-11.8, -12.1‰PDB), and one probably peridotitic (δ^{13}C-5‰PDB)[12]

The pre-collisional Glennie Domain had a width of at least 400km (determined from the extent of Archean wedges imaged by LITHOPROBE), and probably existed as an Archean microcontinent[7]. This has a lithosphere of at least 150km as evidenced by the populations of diamonds of Archean age, determined by their N-aggregation characteristics. An alternative to this model is that the GD did not have a well developed lithosphere, and inherited the Archean-type lithosphere and diamonds from the Superior craton to the east during Proterozoic docking or continental collision. However, this seems unlikely given the static nature (a defining characteristic) of cratonic lithosphere. The presence of the Sloan-type diamond is consistent with diamond growth in the Proterozoic. Great crustal thickening occurred during the Proterozoic continent-continent collision, the crust having had about 10km removed by erosion since the orogeny[7]. This would have produced a crust at least 55km thick immediately after collision, an increase of about 20km over the regional average. A crustal thickening event on the scale of continent-continent collision should also thicken any underlying lithosphere. Simple Airy-type isostatic modelling verifies this concept. The lithosphere will downwarp by about 30km, depressing more of the mantle below the graphite-diamond isograd (at approximately 150km) - leading to a period of (Sloan-type) diamond growth (see Fig.3). This model assumes a stability of the lithosphere, allowing a small increase in thickness (of about 10-20%) without significant melting or catastrophic delamination. In support of this, there is no evidence for widespread alkaline magmatism in the post-collisional THO, until the Cretaceous kimberlite emplacement, some 1.6Ga later. This indicates no major lithospheric melting occurred associated with the Proterozoic thickening event and subsequent period of diamond growth.

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FIGURE 1 - CRATONIC LOCATION MAP

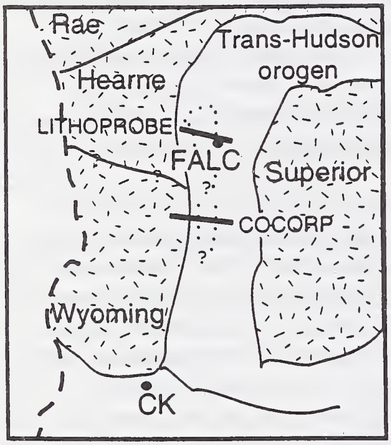


Diagram showing the cratonic provinces of the central North American Plate. Superior, Rae, Hearne and Wyoming (stippled) are all Archean cratonic blocks (aged between 3.0 and 2.5Gyr.) The Trans Hudsonian is a Proterozoic mobile belt (aged about 1.9-1.8Gyr.) underlain by an Archean microcontinent (dotted lines). Thick dashed line represents the edge of the Cordillera FALC and CK are kimberlite clusters in the mobile belts; Fort a la Corne (near Prince Albert, Sask.) and the Colorado Kimberlites (on the Colorado-Wyoming state line). Seismic reflection profiles shown with thick lines. Scale approximately 1cm = 500km.

FIGURE 2 - COMPARISON OF ARCHEAN AND SLOAN TYPE DIAMOND SPECTRA

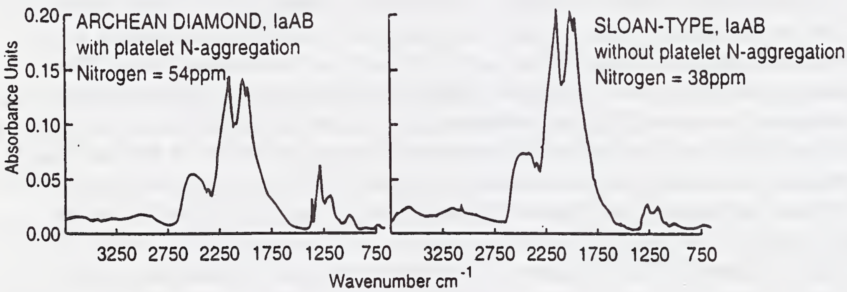
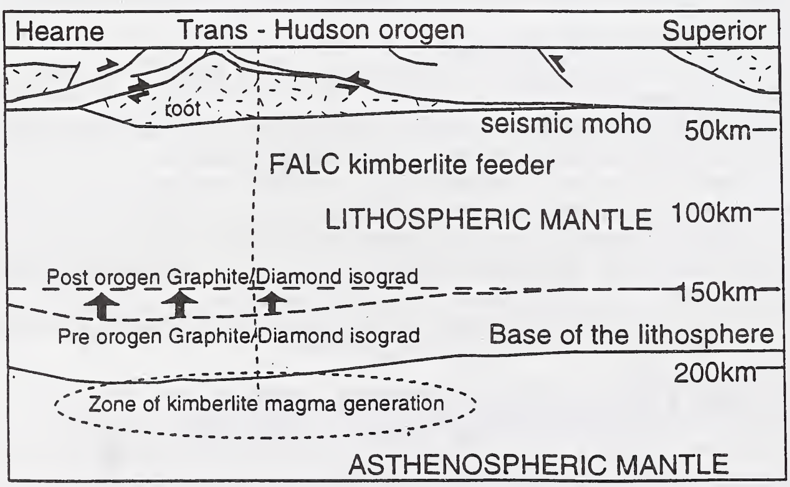


FIGURE 3 - LITHOSPHERIC SECTION OF THO - MECHANISM FOR SECOND GROWTH PERIOD OF DIAMONDS.



N.B. Crustal section adapted from seismic interpretation in Lewry etal 1994. (Ref 1.)