Proterozoic (1.85-1.7 Ga) Igneous Suites of the Western Churchill Province: Constraints on Tectonic Assembly and Crust-Mantle Dynamics

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Summary

Igneous suites of the lower and middle Dubawnt Supergroup (DSG) are a unique record of the tectonic setting of the Western Churchill Province during a crucial phase in the formation of Laurentia. Granitic, basaltic, and ultrapotassic rocks indicate that some or all of the following occurred in the latter stages of accretion and cratonization between *ca*. 1.9 and 1.7 Ga: crustal thickening and upper mantle/lower crustal imbrication (1.9 Ga); widespread lithosphere extension and rising isotherms (1.85 Ga); and possible mantle delamination (1.75 Ga). The spatial distribution of the suites reflects the boundaries of accreted blocks and of mechanically resistant Archean mantle. The presence of identical suites in other Archean cratons formerly connected to Laurentia in the supercontinent *Nuna* indicate that a specific tectonic regime and style of crust-mantle interaction characterized its amalgamation.

Petrogenetic Constraints on the Igneous Suites

The three igneous suites are (Fig. 1): (1) the Hudson granitoid suite (dominantly granodiorite and quartz monzonite, ca. 1.85-1.8 Ga); (2) the Dubawnt minette suite, which includes the volcanic Christopher Island Formation (lower DSG) and the plutonic Martell Syenite, and was contemporaneous with the Hudson suite; (3) the Nueltin Suite (ca. 1.76-1.72 Ga), a bimodal basalt-rapakivi granite suite with extrusive equivalents in the volcanic Pitz Formation (middle DSG).

Hudson Suite Granitoids Hudson suite granitoids between Hudson Bay and the Thelon Basin are restricted to a mid-crust zone; geochemical/petrographic characteristics and field relations indicate they are sill-like intrusions of minimum-melt magmas which froze nearly in place, typically near extensional shear zones. There is no evidence for triggering by mafic magmas, and they are interpreted as a product of rising isotherms in the middle crust, probably as a result of widespread extension superimposed on crust previously thickened at ca. 1.9 Ga.

Dubawnt Minettes Primary magmas of the Dubawnt suite are hi-Mg ultrapotassic rocks with characteristics of both minettes and lamproites. Enriched Nd and LILE element compositions are very similar to Hudson granitoids, but high Mg numbers and entrained mantle xenoliths/xenocrysts require the magmas to originate in metasomatized mantle. The timing of metasomatism is undetermined: competing models are Archean or Proterozoic subduction enrichment, or mixed upper mantle/lower crust. The margins of the extent of the dyke swarm correspond well with important tectonic boundaries: the southern margin with the northern edge of the central Hearne domain, the northern margin with a high- strain zone along Chesterfield Inlet, and the western margin is near the south/north Rae contact. The absence of high-K rocks in the southern Hearne indicates that metasomatism related to trans-Hudson north-dipping subduction is not involved. The Nd isotopic composition of the ultrapotassics is remarkably similar to that of surrounding crustal rocks (Fig. 2). We propose that these magmas were

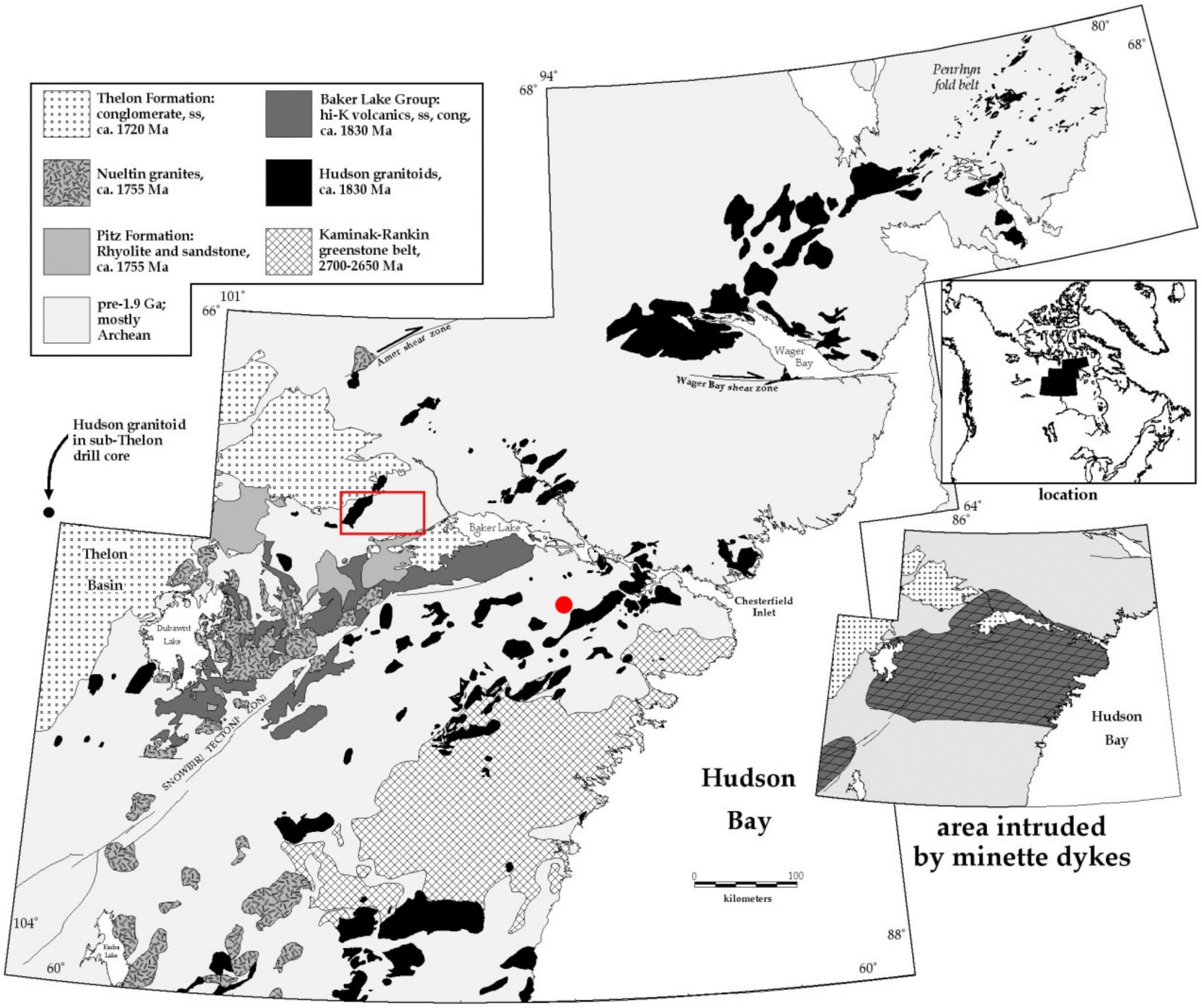

Figure 1. *Distribution of 1.85-1.7 Ga igneous rocks in the Western Churchill Province. Red circle: P-rich, diamond-bearing Akluilak dyke; red box: area with mixed minette-granitoid plutons. After Peterson et al. (2002).*

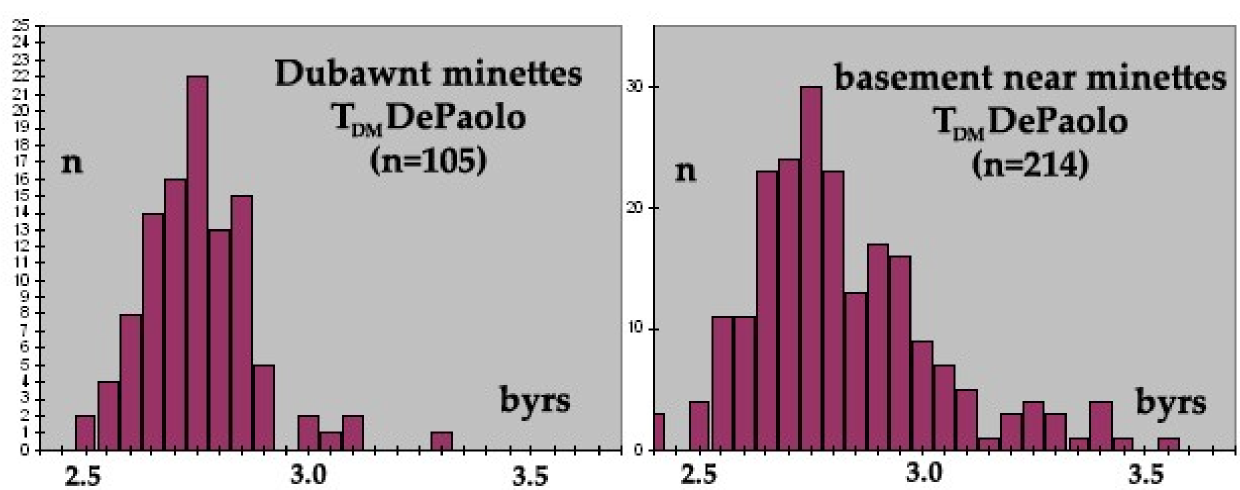

Figure 2: *Histograms of Nd model ages of ultrapotassic Dubawnt minettes, and older crustal rocks immediately within or adjacent to their basins and dyke swarms. Data from Peterson and Pehrsson (2010).*

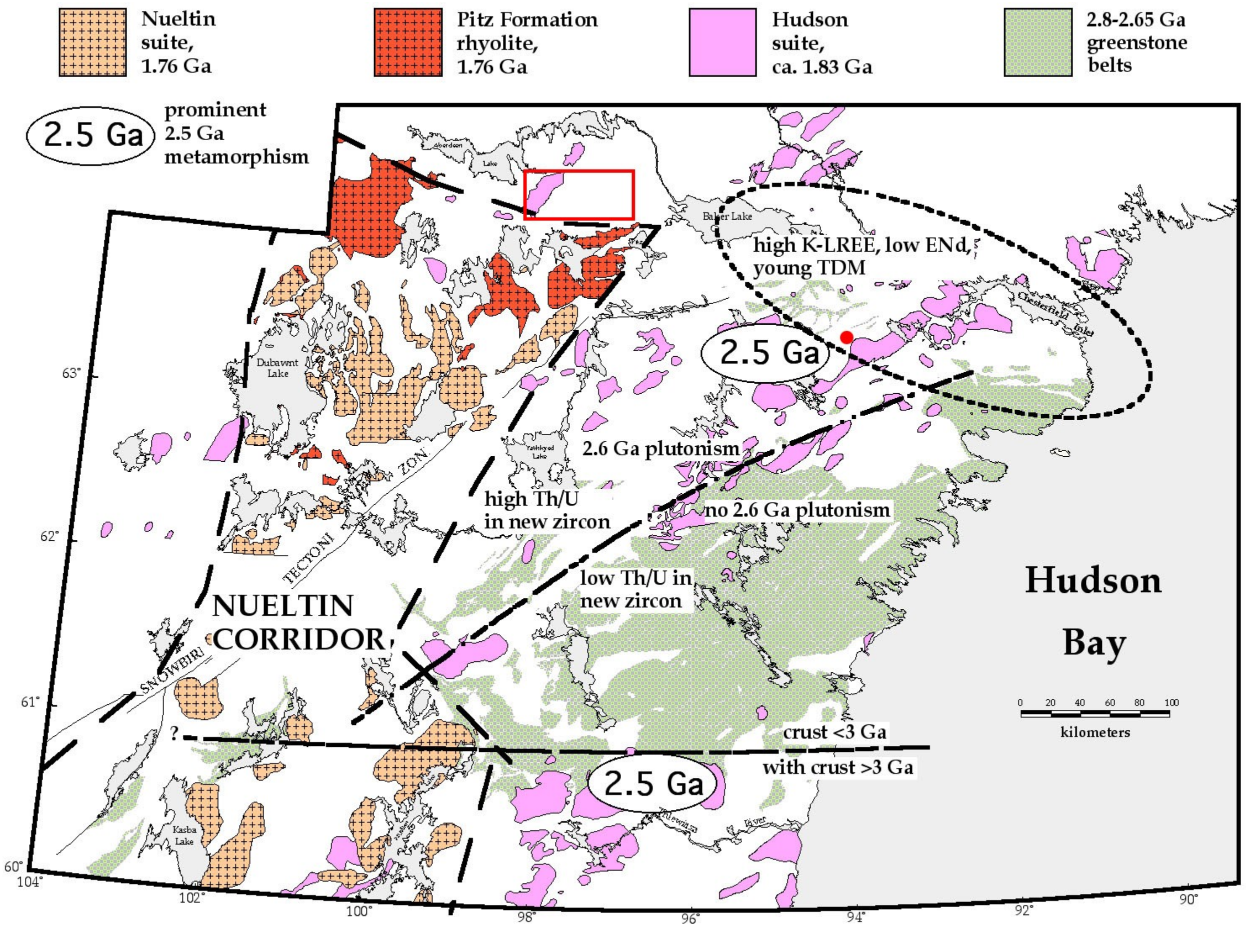

Figure 3: *Crustal domains determined, in part, from studies of Proterozoic granites (see Berman et al, 2007, for other data). Note the high K-LREE anomaly zone in Hudson granitoids along Chesterfield Inlet, and the high angle of the Nueltin corridor relative to the NE Proterozoic structural grain of the region. Red circle: Akluilak dyke; red box: area with mixed minette-granitoid plutons.*

sourced from a zone of imbricated lower crust (source of K, LILE, enriched Nd) and depleted upper mantle, with the extent of the dyke swarm delineating the zone of imbrication caused by crustal shortening during amalgamation of the Rae and Hearne domains at ca. 1.9 Ga. This was a time of crustal thickening and medium to high pressure metamorphism along the Snowbird tectonic Zone (STZ) (Berman et al., 2007).This model is consistent with the presence of young microdiamonds in the P-rich Akluilak dyke, which resemble diamonds in ultrahigh-grade metamorphic terranes such as the Kokchetav massif. Fluid inclusion studies of the Kokchetav diamonds show enrichment in K, P, and others (Dobrzhinetskaya and Wirth, 2008), and ultrapotassic melts have been implicated in their formation (Hwang et al., 2005).

The Dubawnt minettes and Hudson granitoids overlapped in space and time, but there are few recorded instances of mixing of the magmas, probably because the minettes ascended in dykes utilizing brittle fractures, which may not have penetrated the partially molten zones near the granites. The exception is west of Baker Lake, where plutons show abundant mixing. Such mixing may have been locally promoted by extreme crustal extension, to bring the upper mantle source region of the minettes near to the mid-crustal zone of Hudson emplacement.

Nueltin Granites The Nueltin suite is a bimodal basalt-rapakivi granite/rhyolite suite, exposed in an approximately N-S corridor where the mid-crustal Hudson suite is absent. The corridor, at a high angle to the dominant NE Proterozoic structural grain, is interpreted as a subsided block. Its north end corresponds to a cryptic extension of the Chesterfield high-strain zone and zone of anomalous Hudson granitoids, on strike with the impingement apex of the Slave craton. The E and W margins do not correspond to any known crustal structures. However, recent S-wave velocity data (Bedle and van der Lee, 2009) indicate the N and E margins correspond to the limit of a block of high-velocity mantle at 120 km; at 160 km, the W margin is delineated by the N-S trending limit of high-V mantle to the west. We suggest that the Nueltin corridor reflects upper mantle, not crustal features. Basaltic magmas, which triggered crustal melting to form the silicic magmas, may have resulted from localized mantle delamination.

Interpretation

The petrogenetic variations and distribution of these Proterozoic magmas are best explained by convergent tectonics at ca. 1.9-1.85 Ga that produced, first, thickening of the lithosphere and imbrication of lower crustal rocks with depleted sublithospheric upper mantle. Continued shortening and subsequent extension at ca. 1.83 Ga decoupled the crust and mantle, so that a ENE-trending Trans-Hudson structural grain at crustal levels was at high angle to a more N-S fabric locally preserved in underlying Archean mantle. Extension at ca. 1.75 Ga, triggered by a sub-lithospheric event (delamination?) occurred along this fabric to produce the Nueltin corridor. Anomalous Hudson granitoids along the high-strain Chesterfield Inlet, now known to extend as far as Aberdeen Lake, and the abrupt northern termination of the Nueltin corridor, indicate a fundamental lithospheric boundary. At its east end, it reflects the former site of Chesterfield block-Rae accretion and lithosphere amalgamation. West of Baker Lake, accretion of the Hottah terrane which drove Slave indentation may have created a secondary high-strain zone which linked with the east end.

Analogous suites of similar age are present in other Laurentia/Nuna cratons, such as Sao Francisco and Kimberley (summarized in Peterson et al., 2002). We therefore reject unique causes for DSG magmatism such as plumes and Archean subduction metasomatism.The global record of ultrapotassic, DSG-type magmatism, formed during late stages of *Nuna* amalgamation may, herald a fundamental change in lithospheric processes. We speculate that where Archean lithosphere was involved in accretion, the less robust Paleoproterozoic lithosphere was displaced and imbricated, allowing the first bloom of such magmatism in Earth's history.

Acknowledgements

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