

# Geotectonic evolution by asymmetric rifting of the Proterozoic Cape Smith Belt, New Quebec

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Article abstract

The tectonostratigraphic units of the Cape Smith Belt are interpreted as having accumulated in two distinct basins: (1) an older northern oceanic basin in which the Purtunigophiolite was formed; and (2) a younger southern Povungnituk - Chukotat basin. A comparison with present-day rifting processes suggests that the younger Povungnituk - Chukotat basin evolved as an asymmetric rift leading to the successive accumulation of the sediments of the Lamarche sub-group, the continental tholeiitic basalts of the Beauparlant subgroup, and the oceanic basalts of the Chukotat Group. In response to a north-south compression, the northern Chukotat Group basalts were probably subducted northward, thus initiating the development of a magmatic arc system (Parent Group).

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## Geotectonic evolution by asymmetric rifting of the Proterozoic Cape Smith Belt, New Quebec

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### Summary

The tectonostratigraphic units of the Cape Smith Belt are interpreted as having accumulated in two distinct basins: (1) an older northern oceanic basin in which the Purtuniqu ophiolite was formed; and (2) a younger southern Povungnituk - Chukotat basin. A comparison with present-day rifting processes suggests that the younger Povungnituk - Chukotat basin evolved as an asymmetric rift leading to the successive accumulation of the sediments of the Lamarche subgroup, the continental tholeiitic basalts of the Beauparlant subgroup, and the oceanic basalts of the Chukotat Group. In response to a north-south compression, the northern Chukotat Group basalts were probably subducted northward, thus initiating the development of a magmatic arc system (Parent Group).

### Résumé

La bande du Cap Smith correspond à l'évolution successive de deux bassins océaniques, chevauchés l'un sur l'autre lors de l'orogénèse trans-hudsonienne. Si nos données sur l'ophiolite de Purtuniqu sont encore insuffisantes pour établir un modèle précis de l'histoire du bassin océanique nord (le plus précoce), la comparaison des données obtenues sur le bassin méridional avec les modèles récents sur l'évolution des rifts, évoque pour ce dernier une évolution selon un mécanisme de "rifting" disymétrique avec

mise en place successive des sédiments du sous-groupe de Lamarche, des basaltes continentaux du sous-groupe de Beauparlant et des basaltes océaniques du Groupe de Chukotat. La présence des roches volcaniques calco-alcalines du Groupe de Parent à l'interface des deux domaines suggère que les laves océaniques du Groupe de Chukotat ont été subduites vers le nord, entraînant le développement d'un magmatisme d'arc.

### Introduction

The Cape Smith Belt in northern Quebec (Figure 1) contains two tectonostratigraphic domains separated by the east-west Bergeron fault (Bergeron, 1957, 1959; Hynes and Francis, 1982; St-Onge and Lucas, in press; Picard *et al.*, in prep.).

**Southern domain.** In the southern portion of the belt, the Povungnituk Group (Figure 1) comprises mostly sandstones, conglomerates, dolomites, quartzites and shales with a few ironstone formations (Lamarche subgroup, Lamothe, 1986). The sediments interfinger or are overlain by moderately LREE-enriched, massive and pillowed, tholeiitic, plagioclase-phyric basalts of continental affinity ( $MgO < 10\%$ ,  $TiO_2 = 1.2-3.6\%$ ; Hynes and Francis, 1982; Francis *et al.*, 1983; Picard, 1986, 1989a, b; Picard *et al.*, in prep.) which belong to the Beauparlant subgroup (Lamothe, 1986). The Beauparlant subgroup also includes ultramafic to mafic intrusions (Picard and Giovenazzo, in press), rhyolite domes and limited sequences of high-Ti basanites and phonolites (Picard, 1986, 1989a; Gaonac'h *et al.*, 1989 - this issue, p. 137-139) which locally overlie the pillowed basalts. The Chukotat Group (Figure 1) structurally overlies the Povungnituk Group. It includes several superposed sequences of slightly LREE-enriched, olivine-phyric komatiitic basalts ( $MgO = 19-11\%$ ,  $TiO_2 < 0.9\%$ ) and pyroxene-phyric tholeiitic basalts ( $MgO = 12.5-7\%$ ,  $TiO_2 = 0.8-1.1\%$ ; Picard, 1986, 1989a, b; Picard *et al.*, in prep.) which evolve, in its central part, to oceanic LREE-depleted olivine- and pyroxene-phyric basalts (Hynes and Francis, 1982; Francis *et al.*, 1981, 1983; Picard, 1986, 1989a, b; Picard *et al.*, in prep.). The upper section of the Chukotat Group comprises essentially LREE-depleted, pillowed and massive, plagioclase-phyric basalts ( $MgO < 8\%$ ,  $TiO_2 = 1.3-2.8\%$ ) typical of oceanic tholeiites. Local olivine-phyric or pyroxene-phyric basalt flows occur at the base of the latter sequence. In some locations, plagioclase, pyroxene and amphibole-porphyrific basalts and volcanoclastic rocks overlie the plagioclase-phyric basalts (Picard, 1989a).

**Northern domain.** The northern portion of the Cape Smith Belt contains a vast dismembered ophiolitic complex (Purtuniqu ophiolite, Figure 1, St-Onge *et al.*, 1987, 1988; St-Onge and Lucas, in press; Scott *et al.*, 1988, 1989 - this issue, p. 144-147; Picard *et al.*, in prep.).

In the lac Watts area (Figure 1), the ophiolite suite is composed of: (1) chromite rich, dunite peridotite and pyroxenite layered cumulates; (2) layered gabbros and anorthosites; (3) intrusive clinopyroxenites; and (4) slightly LREE-depleted tholeiitic diabase (in sheeted dykes) and massive or pillowed basalts ( $MgO = 9.80-5.76\%$ ,  $TiO_2 = 0.65-2.21\%$ ). In the rivière Déception area (Figure 1), the ophiolite includes (1) layered gabbros and anorthosites; (2) peridotitic and pyroxenitic layered cumulates; (3) gabbros and ferrogabbros; and (4) strongly LREE-depleted tholeiitic basalts ( $MgO = 8.91-5.55\%$ ,  $TiO_2 = 0.33-1.14\%$ ). The ophiolite structurally overlies a poorly documented sequence of greywackes and basalts to the north, and siltstones, sandstones and greywackes to the south (Figure 1). In the western part of the belt, the sediments are intercalated with basaltic to rhyolitic microporphyratic lavas and pyroclastic rocks (Parent Group, Lamothe, 1986) of calc-alkaline affinity (Picard *et al.*, in prep.). Finally, the northern domain is intruded by several massive to foliated felsic plutons ranging in age from about 1880 Ma to 1840 Ma (St-Onge and Lucas, in press; Parrish, 1989a, b - this issue, p. 126-130).

**Geotectonic Evolution**

Over the last twenty years, several magmatic and tectonic models have been proposed to integrate the structural, petrographic, and geochemical data for different portions of

the Cape Smith Belt. Gibb and Walcott (1971), Burke *et al.* (1977) and Thomas and Gibb (1977) proposed that the belt resulted from the collision of two continents. At the same time, Dimroth *et al.* (1970) and Baragar and Scoates (1981) interpreted the Cape Smith Belt as an autochthonous segment of the Circum-Superior Fold belt. Hoffman (1985) proposed that the belt is essentially a klippe, isolated from its root zone (geosuture) to the north by a post-thrusting basement antiform.

Hynes and Francis (1982), Francis *et al.* (1981, 1983) and later Picard (1986, 1989a, b) and Picard *et al.* (in prep.) have demonstrated that the southern Povungnituk and Chukotat Groups were the result of the progressive opening of an oceanic rift in four stages: (1) the creation of an ensialic fault basin into which were accumulated shallow water sediments of the Lamarche subgroup; (2) the formation of an ensialic proto-rift into which enriched plagioclase-phyric basalts of the Beauparlant subgroup were emplaced with local emission of peralkaline volcanic rocks; (3) the progressive opening of an oceanic rift and subsequent eruption of weakly enriched, then depleted, olivine- and pyroxene-phyric basalts of the Chukotat Group; and (4) the formation of an oceanic crust comprising the depleted plagioclase-phyric basalts of the Chukotat Group.

In the northern domain, Hynes and Francis (1982) interpreted the Watts Group as

the metamorphic equivalent of the southern Povungnituk Group. Nevertheless, St-Onge *et al.* (1987, 1988), St-Onge and Lucas (in press) and Scott *et al.* (1988, 1989 - this issue, p. 144-147) have shown that the northern domain is essentially composed of a vast ophiolitic complex (the Purtuniqu ophiolite). Scott *et al.* (1988, 1989 - this issue, p. 144-147) and Picard *et al.* (in prep.) have demonstrated that the tholeiitic diabase and basalts associated with the ophiolite are LREE-depleted, while the Povungnituk basalts are LREE-enriched (Picard *et al.*, in prep.).

U-Pb dating of zircon shows that the layered gabbros of the Purtuniqu ophiolite are older ( $1998 \pm 2$  Ma, Parrish, 1989a, b - this issue, p. 126-130) than the Povungnituk and Chukotat rocks which are bracketed in age between 1960 and 1920 Ma (Parrish, 1989a, b - this issue, p. 126-130). Thus, the geotectonic evolution of the Cape Smith Belt has to explain why the ophiolite is approximately 40 Ma older than the southern Povungnituk and Chukotat Groups. This dilemma may be resolved with the following scenario (Figure 2): (1) the opening of a northern basin with formation of ancient oceanic crust (the Purtuniqu basin); and (2) the opening of a second, younger southern basin (the Povungnituk - Chukotat basin). The Parent Group, interpreted as calc-alkaline deposits of an arc (Picard *et al.*, in prep.), appears to be the key to explaining the present relationships

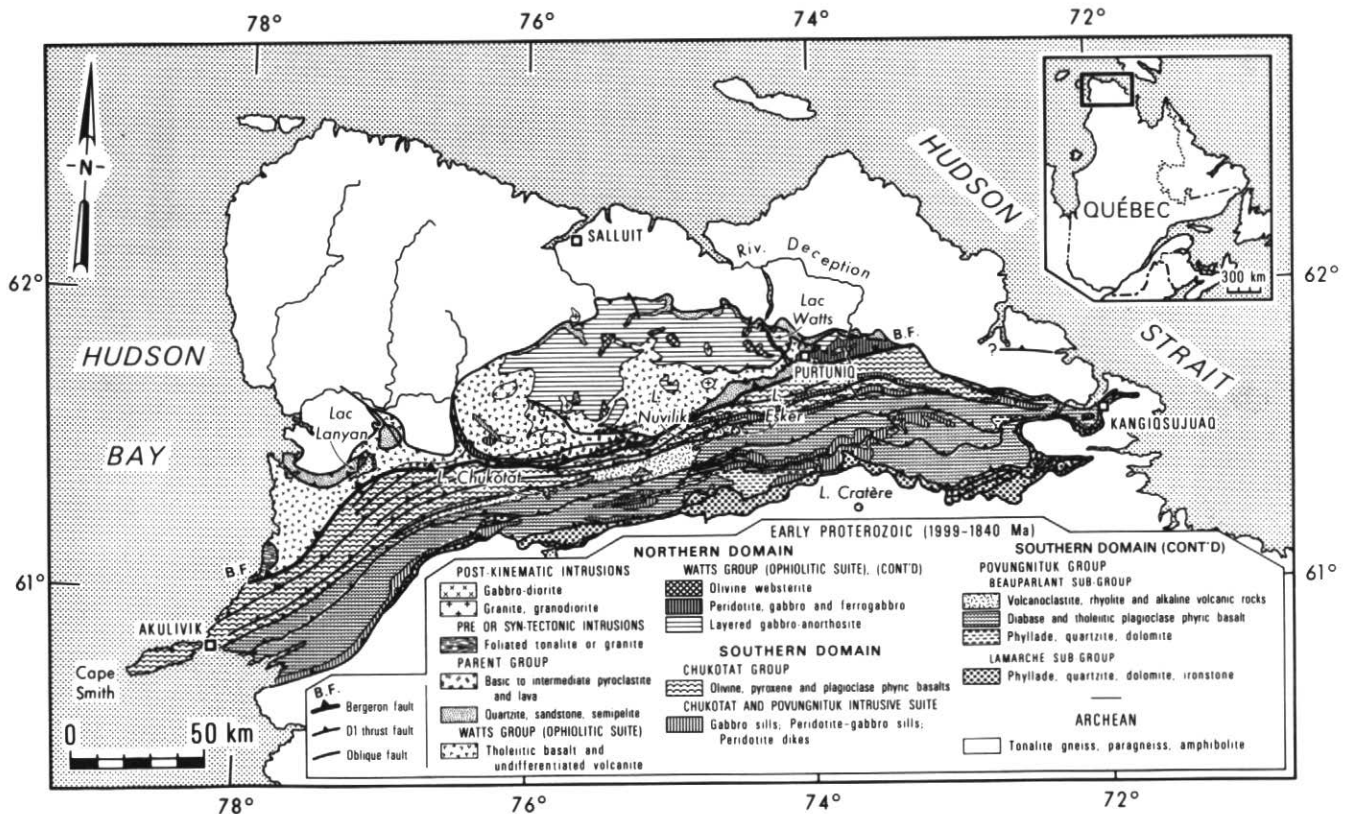


Figure 1 Geological map of the Cape Smith Belt. (Modified from Lamothe (1986) and St-Onge et al. (1988)).

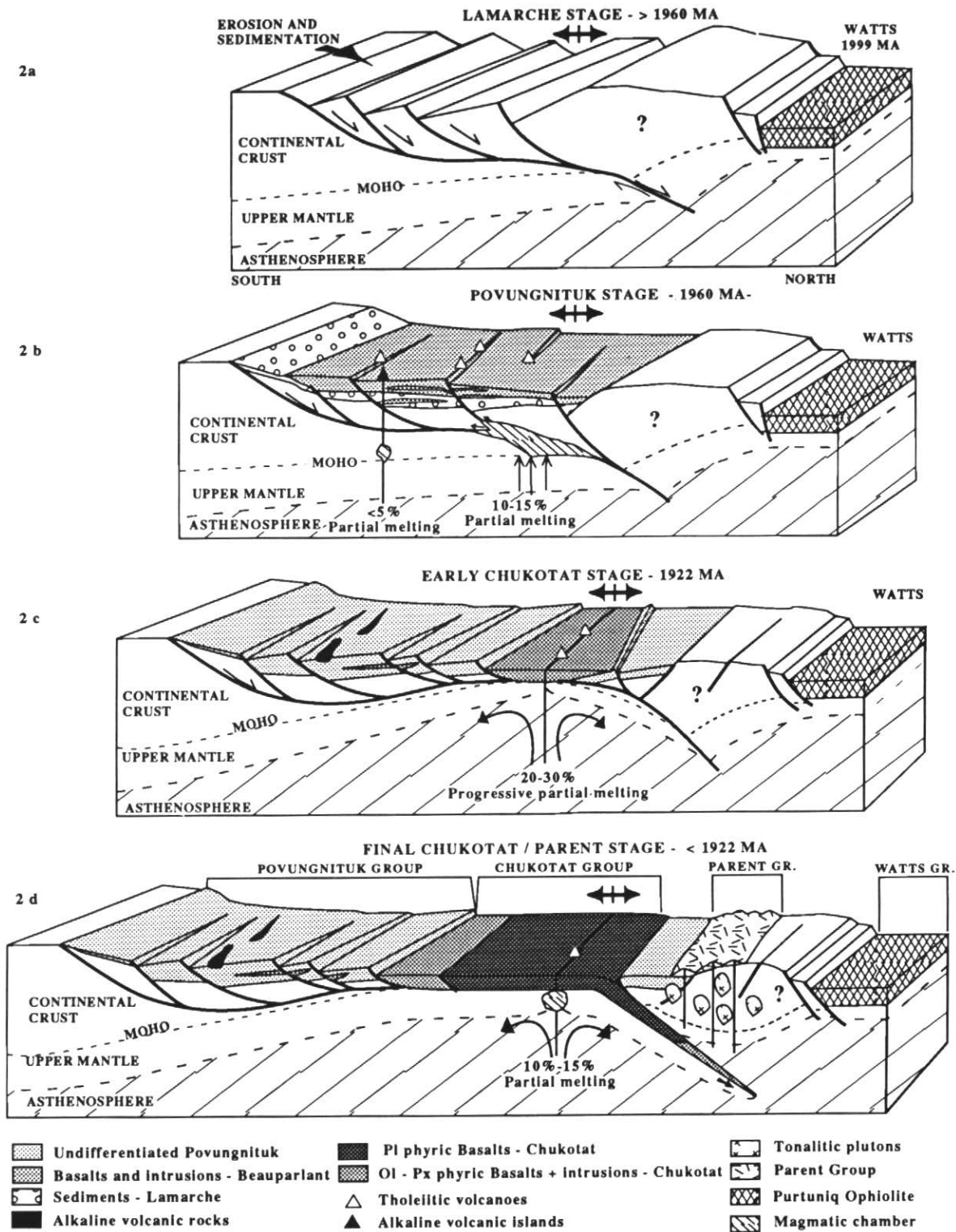


Figure 2 Proposed sequential evolution of the Cape Smith Belt.

between the two domains. The location of the Parent Group between the two domains (Figure 1), coupled with the structural work of St-Onge *et al.* (1987, 1988) and St-Onge and Lucas (in press), suggests that the Chukotat basalts were subducted below the northern domain forming a subduction-related magmatic arc on the overriding plate (Figure 2d). The hypothesis that the Parent Group represents a magmatic arc generated above a north-dipping subduction zone may provide a reasonable explanation for the post-rifting evolution of the continental margin system. This scenario appears to respect the chronology of the different events as revealed by the U-Pb ages (Parrish, 1989b - this issue, p. 126-130). It implies that a continental fragment separated the two oceanic domains prior to compressional deformation related to the Trans-Hudson Orogen (Figure 2a-d). However, no evidence for this crustal fragment is observed in the Cape Smith Belt, and in particular along the Parent Group. This missing fragment remains the biggest outstanding problem with the two-basin model. One possibility for explaining this missing fragment is that subduction of the southern crust occurred not directly below the continental crust, but in front of this crust, beneath a fragment of the Povungnituk crust (Povungnituk basalts and underlying continental crust, Figure 2d). The existence of low MgO and LREE-enriched tholeiitic basalts immediately to the north of the Bergeron fault in the region where we observe the Parent volcanics (Picard, 1989b) could argue for such a hypothesis. The absence of the continental crust could be also explained by obduction of the Purtuniqu ophiolite during the Trans-Hudson Orogen. Nevertheless, these two possibilities are speculative and more work is necessary in order to understand the relationships between southern and northern domains.

In the southern domain, it is clear that the Povungnituk and the Chukotat Groups have an asymmetric arrangement. If we apply the classic symmetric model for the formation of graben and rift, this implies that the subducted crust was equivalent in size and constitution to the Lamarche, Beauport and Chukotat units. Such a possibility is not out of the question, but the asymmetric arrangement of the Povungnituk and Chukotat Groups and the present structure of thrust faults invoke more an asymmetric model for rifting as proposed by Wernicke (1981), Wernicke and Burchfiel (1982) and Lister *et al.* (1986) as applied by Coleman and McGuire (1988) and Voggenreiter *et al.* (1988) to the Red Sea opening. Indeed, such a model implies an asymmetric distribution of the units, and favours a reduced size for the northern section of the crust, with subsequent subduction to the north.

### Conclusion

According to petrographic, geochemical, structural and geochronological data, the Cape Smith Belt appears to result from a double rifting process, affecting the ancient Archean Superior craton. The first event ( $1998 \pm 2$  Ma) was responsible for the formation of an oceanic crust (the Purtuniqu ophiolite) in the northern domain (Figure 2a, St-Onge *et al.*, 1987, 1988; St-Onge and Lucas, in press; Scott *et al.*, 1988; Picard *et al.*, in prep.). Later, crustal extension south of the northern basin opened a second rift basin (Povungnituk - Chukotat basin) on the Superior craton (Figure 2a). An asymmetric model is proposed to account for the apparent asymmetric distribution of rift margin deposits. Lamarche subgroup sedimentation was followed by continental basaltic volcanism (after fractionation in a magma chamber) of the Beauport subgroup with lateral and local emissions of peralkaline volcanic rocks at ca. 1959 Ma (Parrish, 1989a, b - this issue, p. 126-130; Figure 2b). Further extension of the rift margin along the presumed low-angle normal fault may have induced the uplift and partial melting of the asthenosphere. This resulted in the eruption of komatiitic olivine and tholeiitic pyroxene-phyric basalts in a transitional continental-oceanic setting at 1918 Ma (Parrish, 1989a, b - this issue, p. 126-130 Figure 2c) and finally in the eruption of tholeiitic plagioclase-phyric basalts in an oceanic setting (Figure 2d). Following development of this younger oceanic basin, the Chukotat Group was apparently subducted to the north below the continental fragment separating the two basins (Figure 2d). The sediments and calc-alkaline volcanic rocks of the Parent Group may represent the deposits of a magmatic arc related to subduction of the Chukotat Group oceanic crust. Obduction of the Purtuniqu ophiolite apparently occurred during this period of north-dipping subduction (St-Onge and Lucas, in press), with the ophiolite eventually being thrust onto the Parent Group rocks. However, the geometry of subduction, the location of the continental fragment separating the two basins, and the location of the remainder of the arc deposits remain outstanding problems not solved by this tectonic scenario. Hopefully, further integrated studies will allow these problems to be understood.

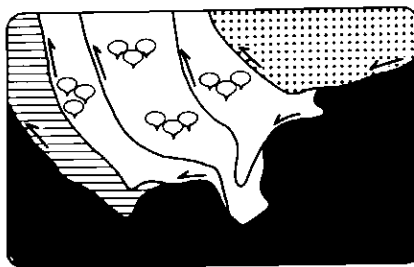
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## Tectonic setting of Ni-Cu-PGE deposits in the central part of the Cape Smith Belt

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### Summary

The Ni-Cu-PGE sulphide deposits in the central and eastern parts of the Cape Smith Belt are best developed near the contact between the Povungnituk and Chukotat Groups. The deposits are associated with differentiated sills and ultramafic intrusions forming part of the feeder system to the lower Chukotat Group which comprises alternating olivine and pyroxene-phyric basalts. The intrusions were emplaced near or at the axis of an oceanic proto-rift. The sulphide deposits are concentrated in two east-west trending horizons: (1) the Raglan horizon, containing deposits associated with sub-volcanic ultramafic intrusions (e.g., Lac Cross, Katinik and Donaldson sulphide deposits) and (2) the Delta horizon which contains deposits associated with differentiated sills (e.g., Delta region) and ultramafic intrusions (Méquillon dyke, Bravo Sills).

### Résumé

Les gîtes Ni-Cu-EGP de la partie centrale de la bande du Cap Smith sont abondants près de la limite supérieure du Groupe du Povungnituk, immédiatement sous les premières coulées de basaltes à olivine et pyroxène du Groupe de Chukotat. Ils sont associés aux intrusions différenciées et ultramafiques qui forment une partie du système nourricier des premières séquences de basalte komatiitique du Groupe de Chukotat. Ces intrusions se sont mises en place près de la zone axiale d'un proto-rift en

domaine océanique. Les gîtes se concentrent le long de deux horizons est-ouest: (1) l'horizon de Raglan qui comprend des gîtes associés à des conduits sub-volcaniques de composition ultramafique (ex. Lac Cross, Katinik et Donaldson) et (2) l'horizon de Delta, qui comprend des minéralisations associées à des intrusions ultramafiques (ex. dyke de Méquillon) et à des filons-couches ultramafiques à mafiques différenciés (ex. filon-couche Delta).

### Introduction

The geotectonic evolution of the southern part of the Cape Smith Belt (Povungnituk and Chukotat Groups, Figure 1) is described by the following sequence of events:

(1) Deposition of mainly shallow water sediments, followed by the extrusion of a volcanic sequence containing continental tholeiitic basalts with interdigitated clastic sediments and local rhyolites, basanites/nephelinites and phonolites (Picard *et al.*, 1989 - this issue, p. 130-134; Gaonac'h *et al.*, 1989 - this issue, p. 137-139). This environment is interpreted as a continental rift zone (Povungnituk Group; Francis *et al.*, 1981, 1983; Picard *et al.*, 1989 - this issue, p. 130-134).

(2) Eruption of komatiitic basalts that mark the beginning of the opening of a oceanic proto-rift (lower Chukotat Group; Picard *et al.*, 1989 - this issue, p. 130-134).

(3) Eruption of a monotonous plagioclase-phyric basalt sequence representing an oceanic floor (upper Chukotat Group; Francis *et al.*, 1983; Picard *et al.*, in press, 1989 - this issue, p. 130-134).

This sequence of events is recognized throughout the Cape Smith Belt, with the various tectonostratigraphic units preserved in east-west trending imbricated thrust-sheets (St-Onge and Lucas, in press).

**The Povungnituk Group.** The Povungnituk Group contains a lower, mostly sedimentary sequence of quartzites, shales, dolomites and a few iron formations structurally overlain by a volcanosedimentary package containing continental LREE-enriched tholeiitic basaltic sequences (Picard *et al.*, in press) with local alkali volcanic centres (Picard, 1986, in press; Gaonac'h *et al.*, 1989 - this issue, p. 137-139). A sedimentary unit terminates the Povungnituk Group and a local enrichment in LREE is observed (Giovenazzo *et al.*, in press). This transition zone between the Povungnituk and the Chukotat Groups is characterized by graphitic shales and siltstones, sulphidic shales, cherts and a few basaltic flows intruded by dioritic sills, differentiated sills and sub-volcanic ultramafic intrusions.

**The Chukotat Group.** This Group contains a volcanic sequence, with rare interflow sediments, composed of a basal series of alternating olivine and pyroxene-phyric basalts followed by an upper series composed of monotonous plagioclase-phyric