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U-Pb geochronology of the Cape Smith Belt and Sugluk block, northern Quebec

Randall R. Parrish

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Article abstract

The Cape Smith Belt is a multiply-deformed thrust belt containing metamorphosed basaltic volcanic, mafic intrusive, and sedimentary rocks. It lies south of the Kovikanti form and the Sugluk block; together, these constitute the Ungava segment of theTrans-Hudson Orogen. U-Pb dating of representative units reveals that Archean rocks of the Superior craton which underlie the belt are ca. 2780-2880 Ma old, and that theoldest rocks in the belt proper are those of the Purtuniq ophiolite at 1998 ± 2 Ma. The belt evolved between ca. 2000 Ma (oceanic crust generation) and about 1830 Ma, the age of the later part of the belt's south-directed structural translation and subsequent thick-skinned deformation. The Po-vungnituk Group (the structurally lowest assemblage of sedimentary and volcanic rocks) was deposited ca. 1960 Ma, and being younger than the ophiolite, cannot be the rift assemblage which led to creation of oceanic crust of the Purtuniq ophiolite. Ages of intrusions and sedimentary rocks within the Sugluk block are as young as 1830 Ma,and they were metamorphosed and deformed at granulite faciès at 1830-1820 Ma, prior to a period of slow cooling.

expanded into the thrust belt and its underlying footwall basement. The basal shear zone became inactive at syn-thermal peak conditions after it was overridden by out-of-sequence thrust faults. Its demise is attributed to (1) strain hardening of the shear zone during prograde metamorphism resulting from the emplacement of the out-of-sequence thrust stack; and (2) decrease in the shear zone strain rate as a result of the development of major (overlying) out-of-sequence décollements (Lucas, in press).

D_2 basement-involved folding is interpreted to be the final stage of deformation associated with the collisional orogeny which was responsible for D_1 deformation. The P-T estimates for D_2 (St-Onge and Lucas, in press) suggest that folding of the underthrust basement and the thrust belt followed relatively shortly after D_1. In total, an evolution is observed in the nature of basement-involvement during the D_1-D_2 collisional orogeny. Initially, crustal shortening during D_1 was accomplished by the development of the thrust belt and by bulk underthrusting of the Superior Province basement (Figures 3a,b). Next, slices of underthrust basement were accreted to the thrust belt along out-of-sequence thrusts (Figure 3c) relatively late in the D_1 thrusting episode (see Lucas, in press). Finally, the footwall basement and thrust belt deformed together by folding in order to accomplish crustal shortening during D_2.

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Dave Scott and Normand Bégin (both at Queen's University, Kingston) are gratefully acknowledged for their assistance both with mapping in eastern Cape Smith Belt (1985-87) and with discussions on the structural history of the belt. Tim Byrne (Brown University) is acknowledged for many beneficial discussions and comments on the ideas presented in this paper. Christian Picard (Mineral Exploration Research Institute in Montréal) is thanked for a helpful review.

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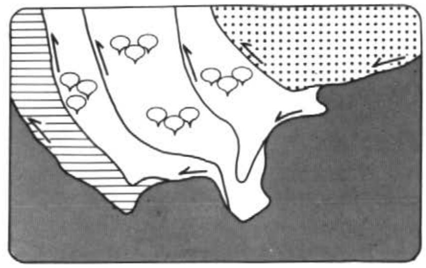

U-Pb geochronology of the Cape Smith Belt and Sugluk block, northern Quebec [1]

Randall R. Parrish
Lithosphere and Canadian Shield Division
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

Summary

The Cape Smith Belt is a multiply-deformed thrust belt containing metamorphosed basaltic volcanic, mafic intrusive, and sedimentary rocks. It lies south of the Kovik antiform and the Sugluk block; together, these constitute the Ungava segment of the Trans-Hudson Orogen. U-Pb dating of representative units reveals that Archean rocks of the Superior craton which underlie the belt are *ca.* 2780-2880 Ma old, and that the oldest rocks in the belt proper are those of the Purtuniq ophiolite at 1998 ± 2 Ma. The belt evolved between *ca.* 2000 Ma (oceanic crust generation) and about 1830 Ma, the age of the later part of the belt's south-directed structural translation and subsequent thick-skinned deformation. The Povungnituk Group (the structurally lowest assemblage of sedimentary and volcanic rocks) was deposited *ca.* 1960 Ma, and being younger than the ophiolite, cannot be the rift assemblage which led to creation of oceanic crust of the Purtuniq ophiolite. Ages of intrusions and sedimentary rocks within the Sugluk block are as young as 1830 Ma, and they were metamorphosed and deformed at granulite facies at 1830-1820 Ma, prior to a period of slow cooling.

Résumé

La bande du Cap Smith est une ceinture de chevauchement qui est caractérisée par une tectonique polyphasée et qui comprend des basaltes, intrusions mafiques et sédiments métamorphosés. La ceinture se trouve au sud de l'antiforme Kovik et du bloc de Sugluk; cet ensemble constitue le segment Ungava de l'orogène Trans-Hudsonienne. La datation

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par U-Pb d'unités représentatives révèle que les roches archéennes du craton du lac Supérieur, sous-jacentes à la bande du Cap Smith, ont des âges qui varient entre *ca.* 2780-2880 Ma. Dans la ceinture de chevauchement, les unités les plus anciennes (datées à 1998 ± 2 Ma) sont celles de l'ophiolite Purtuniq. L'évolution de la bande du Cap Smith s'est donc faite entre *ca.* 2000 Ma (formation de la croûte océanique) et approximativement 1830 Ma, l'âge du stage final de transport à direction sud dans la ceinture de chevauchement et de la déformation du socle et de la couverture. Le Groupe de Povungnituk (ensemble de roches sédimentaires et volcaniques avec une position structurale basse) s'est accumulé *ca.* 1960 Ma bien après la formation de l'ophiolite. Etant donné que l'âge du Groupe de Povungnituk est plus jeune que celui de l'ophiolite, ce dernier ne peut pas être le rif qui a éventuellement donné lieu à la formation de la croûte océanique préservée dans l'ophiolite Purtuniq. Les âges des intrusions et des roches sédimentaires dans le bloc de Sugluk sont aussi jeunes de 1830 Ma. Ces unités furent métamorphosées et déformées au faciès métamorphique granulite entre 1830 et 1820 Ma, suivit d'une période de refroidissement lent.

Introduction

The Cape Smith Belt (Bergeron, 1957, 1959; Taylor, 1982; Hynes and Francis, 1982; Hoffman, 1985; St-Onge and Lucas, in press) is a structurally complex belt of marine sedimentary rocks and predominantly mafic volcanic rocks disposed in a major synclinorium in northernmost Quebec (Figure 1). The belt experienced south-verging thrusting and considerable southerly translation on a basal décollement prior to thick-skinned buckling into an east-west synclinorium (Lucas, in press; St-Onge and Lucas, in press). The belt has been interpreted as a structural klippe, isolated from its root zone to the north by the intervening Kovik antiform (Hoffman, 1985) composed of Archean Superior Province basement rocks. Rocks of Sugluk block (*i.e.*, rocks northwest of Sugluk Inlet, Figure 1) include abundant granulite-grade orthogneisses and supracrustal rocks (Taylor, 1982; Doig, 1987) and have been interpreted as the hinterland of the belt. Hoffman (1985) suggested that the root zone for the Cape Smith Belt allochthons is located at Sugluk Inlet, and that the Sugluk block to the north constituted a different Archean craton which collided with the northern Superior Province during the Early Proterozoic.

A reconnaissance program of U-Pb geochronology was undertaken as part of the Geological Survey of Canada's mapping project in eastern Cape Smith Belt. These data provide a temporal framework for the belt.

U-Pb methods and results

This paper summarizes the results of U-Pb zircon, baddeleyite, and monazite results from 17 rocks from the Cape Smith Belt, Superior Province basement, and Sugluk block (Figure 1, Table 1). Presentation of the data and a discussion of their tectonic implications will be presented in a subsequent publication elsewhere. Analytical methods are those summarized in Parrish *et al.* (1987), incorporating error propagation as outlined by Roddick (1987) and Parrish *et al.* (1987).

Archean basement of the Superior Province. Rocks within Kovik antiform on the north side of the eastern Cape Smith Belt have been interpreted as part of the autochthonous Superior Province basement. One of these, a tonalite, (D244A-86) has an age of 2882 +44/−28 Ma with relatively poor quality zircons. A sheared tonalite (D245-86) from a thin slice of basement incorporated into the basal décollement zone (Lucas, in press) during thrusting is 2780 ± 4 Ma old. These ages are similar to those near the northern New Quebec Orogen (Figure 1) where basement rocks are 2720 to 2880 Ma old (Machado *et al.*, 1989).

Oceanic crust of northern Cape Smith Belt. Much of the northern part of the belt comprises metamorphosed basaltic flows and dykes, and mafic to ultramafic cumulate rocks of the Watts Group, and metamorphosed sedimentary rocks of the Spartan Group (St-Onge *et al.*, 1988). This assemblage has been interpreted as an ophiolite, but it could represent either a mid-ocean, back arc, or even island arc tectonic setting. Two samples of Watts Group mafic cumulates were dated using zircons. In a metagabbro (L284-87), zircons are 1998 ± 2 Ma, whereas in a metamorphosed anorthositic layered gabbro (L283-87), two types of zircons are present. Igneous cloudy grains are 1995-2000 Ma whereas clearer overgrowths are 1977 ± 3 Ma, perhaps related to seafloor metamorphism. This suite of rocks is thus 1998 ± 2 Ma old, representing one of oldest ophiolite suites yet documented.

Chukotat and Povungnituk Groups. To the south of the Watts and Spartan Groups is a thick sequence of basalts, termed the Chukotat Group, which chemically resemble modern MORB (Hynes and Francis, 1982).

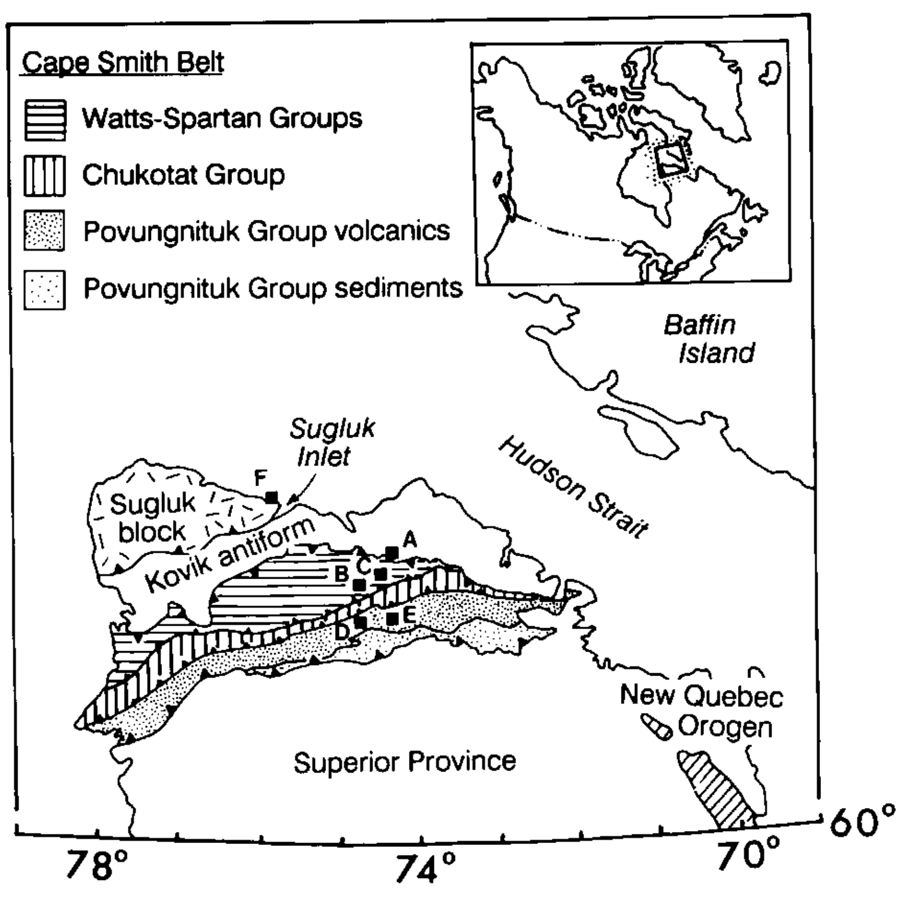

Figure 1 *Map of the northern Ungava Peninsula, including the Cape Smith Belt and Sugluk block The main tectonostratigraphic packages of the Cape Smith Belt are outlined, as are areas from which samples were collected Sample localities are* ***A****, D244A-86 and D245-86;* ***B****, Z2-84, Z3-84, Z4-84, and Z5-84;* ***C****, P23-87, L283-87, L284-87, and S162A-86;* ***D****, Z1-84;* ***E****, D237-86;* ***F****, Sugluk-1-87, 2-87, 3-87, 4-87 and 5-87; see Table 1 for a summary of localities and ages of samples*

Table 1 Summary of U-Pb ages, Cape Smith Belt and Sugluk block.

Sample Number	Lithology	Latitude	Longitude	U-Pb age (Ma)
Archean basement				
D244A-86	tonalite gneiss	61°55'	74°03'	2882 +44/-28 (Z)
D245-86	tonalite gneiss	61°52'	74°02'	2780 +/- 4 (Z)
Watts Group, Purtuniq ophiolite				
L283-87	anorthositic gabbro	61°54'	74°17'	1995-2000 (Z)
L284-87	metagabbro	61°51'	74°12'	1998 +/- 2 (Z)
Povungnituk Group				
Z1-84	rhyolite	61°28'	74°47'	1958.6 +3.1/-2.7 (Z)
D237-86	ferrogabbro (sill)	61°35'	74°17'	1918 +9/-7 (B,Z)
Granitic intrusive rocks				
Z2-84	granite	61°50'	74°43'	1848 +6/-5 (Z)
				1839 +/- 3 (S)
Z3-84	foliated tonalite	61°38'	75°02'	1898 +12/-9 (Z)
Z4-84	quartz diorite	61°42'	74°41'	ca.1840 (Z)
				1836 +/- 3 (S)
Z5-84	tonalite	61°45'	75°02'	>1850 (Z)
P23-87	2-mica tonalite	61°49'	74°15'	1870-1880 (Z)
S162A-86	tonalite	61°47'	73°57'	1876.1 +/- 1.5 (Z)
Sugluk Block				
Sugluk-1-87	X-C granitic dyke	62°19'	75°52'	1758.2 +/- 1.2 (Z,M)
Sugluk-2-87	granitic orthogneiss	62°19'	75°52'	1835 +/- 1 (Z,M)
Sugluk-3-87	gnt-bi orthogneiss	62°19'	75°52'	1825 +/-3, (Z)
				1815-1820, (M)
				1792 +/- 1 (X)
Sugluk-4-87	quartzite	62°17'	75°37'	1830-1833*
	igneous grain			1833 +/- 6 (Z)
	igneous grain			1838 +/- 1 (Z)
	igneous grain			1863 +/- 3 (Z)
	igneous grain			1830 +/- 3 (Z)
	igneous grain			>2525 (Z)
	core of metamorphic grain			>2545 (Z)
	round monazite grain			1835 +/- 2 (M)
	round monazite grain			1836 +/- 2 (M)
Sugluk-5-87	2-pyx. orthogneiss (igneous and metamorphic zircons)	62°17'	75°37'	1830 +/- 2 (Z)

Notes: ***Z***, zircon; ***B***, baddeleyite; ***S***, sphene; ***M***, monazite; ***X***, xenotime; ***X-C***, cross-cutting; ***gnt***, garnet; ***bi***, biotite; * age of quartzite is inferred to be younger than the age of the youngest detrital grains and older than its granulite facies metamorphism, which is dated at 1830 ± 2 Ma from data of Sugluk 5.

There are no direct, reliable age determinations for these rocks at the present time. They could be younger or older than the Povungnituk Group, described below. Hynes and Francis (1982) interpreted the chemistry of these basalts as representing the change from continental rift-type volcanism to the formation of transitional oceanic crust.

Structurally, the Povungnituk Group lies beneath the Chukotat Group. It comprises marine, generally fine-grained sedimentary rocks overlain by tholeiitic basaltic rocks of continental affinity with minor rhyolite. The group has been interpreted by St-Onge and Lucas (in press) as a rift sequence built upon the northern Superior Province continental margin. The sequence, and that of the Chukotat Group is intruded by both gabbroic and ultramafic sills. A rhyolite located within the upper volcanic sequence (Z1-84) is 1958.6 $+3.1/-2.7$ Ma old. One of the differentiated ultramafic sills intruded into lower Povungnituk Group sediments (D237-86) in a mid-belt thrust sheet (St-Onge *et al.*, 1989 - this issue, p. 119-122), has baddeleyite and zircon which yield an age of 1918 $+9/-7$ Ma. Thus, mafic igneous activity occurred at least from 1960 to 1920 Ma, although these two age determinations can hardly be considered adequate to fully constrain the age range of the whole of the Povungnituk Group. Nevertheless, the mafic igneous activity which has been inferred to be related to rifting (Hynes and Francis, 1982; St-Onge and Lucas, in press) is distinctly younger than that of the Watts Group.

Granitic intrusive rocks. Granitic intrusions form a minor component of the igneous rocks of the belt, but they provide the essential constraints on the timing of deformation. Four granitic samples from locality B, Figure 1, range from 1840 to about 1880 Ma, with limited evidence of older zircon inheritance in some samples. The younger samples are massive and the older ones generally more foliated.

Two samples of tonalite plutons interpreted to cut early thrust faults but which are carried by later thrust faults (P23-87 and S162A-86) are about 1876-1880 Ma, with evidence of older inheritance in P23-87. Therefore, deformation of the belt was underway by 1880 Ma. Clear constraints on the maximum age for termination of deformation in the Cape Smith Belt are not available since none of the 1840 Ma plutons cut either later thrust faults or can be demonstrated to have post-dated thick-skinned folding of the belt. Therefore, south-verging displacement and deformation of the belt may have continued past 1840 Ma.

Sugluk block northwest of Sugluk Inlet. The abundance of granulites with a magnetic signature different than the Superior province suggested to Hoffman (1985) that the Sugluk block represented an exotic Archean block which collided with the northern margin of the Superior Province and resulted in the deformation of Cape Smith Belt. Reconnaissance Rb-Sr geochronology on rocks north of Cape Smith Belt by Doig (1987) identified the presence of older Archean (*ca.* 3000-3200 Ma) rocks as well as clear evidence of Proterozoic (1830 Ma) intrusions and reworking of older rocks. During the course of this study, 3 granulite grade orthogneisses (Sugluk 2-87, 3-87, and 5-87), one cross-cutting pegmatite (Sugluk 1-87), and a quartzite (Sugluk 4-87) were sampled for U-Pb dating. All but one sample (Sugluk 1-87) are very strongly deformed, with a northwest-dipping, in part mylonitic, foliation.

Seven detrital grains of zircon and monazite from the quartzite are concordant to $<0.8\%$ discordant, and range in age from 1830 $\pm$ 3 Ma to 1863 $\pm$ 3 Ma; the monazite grains are 1835 $\pm$ 2 Ma. Two additional grains are Archean with Proterozoic metamorphic overgrowths. Morphologies of the detrital grains imply that some were shed from a high-grade igneous and metamorphic terrane 1860-1830 Ma old which included reworked Archean rocks. This implies that the quartzite cannot be older than 1830 Ma.

A nearby two-pyroxene orthogneiss (Sugluk 5-87) has clear igneous zircons and clear round (probably metamorphic) zircons, both of which are 1830 $\pm$ 2 Ma old. Another garnet-bearing orthogneiss (Sugluk 3-87) has granulite-grade metamorphic overgrowths 1825-1829 Ma with zircon cores >2230 Ma. Monazite and xenotime are 1815-1820 Ma and 1792 $\pm$ 1 Ma, respectively. A leucocratic, probably granulite-grade concordant intrusion (Sugluk 2-87) has igneous zircons 1835 $\pm$ 1 Ma with metamorphic zircons 1825-1830 Ma old. Though the closure temperatures of monazite and xenotime are not precisely known, they are probably in the range of 700°C and 600-650°C, respectively (R. Parrish, unpublished data, 1988), suggesting relatively slow cooling from high metamorphic grade. Finally, a cross-cutting granitic dyke with an amphibolite facies hydrated aureole has igneous zircons 1758.2 $\pm$ 1.2 Ma old and inherited monazites <1900 Ma old.

Sugluk block north of Sugluk Inlet, in addition to having older Archean components (Doig, 1987), contains sediments 1830 Ma old, major igneous intrusions 1835-1830 Ma old, and a well-developed granulite facies metamorphism accompanied by strong deformation 1830-1820 Ma old. The deformation of the block may have continued later, and it appears to have remained at elevated temperatures during a protracted period of slow cooling to at least 1758 Ma.

Implications for existing tectonic models

Purtuniq ophiolite, the Povungnituk Group, and Cape Smith Belt. The Purtuniq ophiolite at 1998 Ma is the oldest rock thus far dated in the Cape Smith Belt, and it appears significantly older than Povungnituk Group basalts and sediments interpreted by Hynes and Francis (1982) and St-Onge and Lucas (in press) to be related to initial rifting of the northern Superior craton. This age relationship is not consistent with the view that the ophiolite and related oceanic crust were generated during a progressive evolution from Povungnituk Group rifting to Chukotat Group transitional crust to Watts Group oceanic crust generation. Instead it implies that Watts Group oceanic crust was generated in a basin prior to that of Povungnituk Group (St-Onge and Lucas, in press). If the Povungnituk Group is a rift-related assemblage of rocks, then this basin must have evolved separately. Such a scenario would imply more than one period of rifting and separation of crustal fragments once attached or adjacent to the northern margin of the Superior Province. Such fragments, however, have yet to be identified in Cape Smith Belt.

Although the rift model for Povungnituk Group remains appealing, two aspects of the tectonic evolution remain unclear: (1) the above mentioned age complexities which require separate evolution of assemblages (Povungnituk-Chukotat-Watts Groups) which have chemical and lithological similarities and are adjacent, and (2) the lack of a continental margin sediment wedge which would be expected to have developed subsequently to rifting and oceanic crust generation. Other alternate models for the tectonic setting of the Povungnituk Group could include a marine foreland basin sequence with (albeit voluminous) foredeep magmatism (Hoffman, 1987) or a hot spot-related centre of extension and volcanism developed near a pre-existing rift margin or back-arc basin setting.

Sugluk block and its deformation. Strong deformation and granulite facies metamorphism within the Sugluk block at 1830-1820 Ma implies that some of the deformation of the Cape Smith Belt, Kovik antiform, and Sugluk block postdated the younger 1840 Ma granitic intrusions of the belt. Part of Sugluk block may have been thrust southward over the northern part of Cape Smith Belt during the later stages of deformation, presumably representing the terminal collision of the major crustal block north of Sugluk Inlet.

The Sugluk block cannot simply be an exotic Archean block which collided with the northern Superior craton since it contains quartzose sediments 1830 Ma old shed from a metamorphic-plutonic source not much older. The relationship of Cape Smith Belt to the Sugluk block and to the Proterozoic supracrustal rocks and granulite facies metamorphic belts of southern Baffin Island is an outstanding problem in the context of the tectonics of the eastern Trans-Hudson Orogen.

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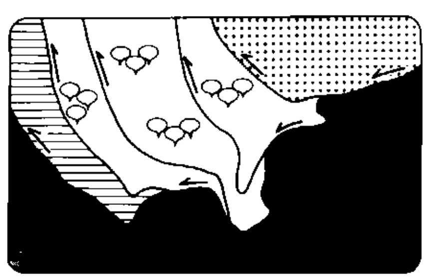

Geotectonic evolution by asymmetric rifting of the Proterozoic Cape Smith Belt, New Quebec

Christian Picard
Mineral Exploration Research Institute
Succ. A., CP 6079
Montréal, Québec H3C 3A7

Danièle Giovenazzo
Département des Sciences de la Terre
Université du Québec à Chicoutimi
Chicoutimi, Québec G7H 2B1

Daniel Lamothe
Ministère de l'Énergie et des Ressources du Québec
Québec, Québec G1S 4N6

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 Purtuniq 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 Purtuniq 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-group de Lamarche, des basaltes continentaux du sous-group 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 subductées vers le nord, entrainant 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-porphyritic basalts and volcaniclastic rocks overlie the plagioclase-phyric basalts (Picard, 1989a).

Northern domain. The northern portion of the Cape Smith Belt contains a vast dismembered ophiolitic complex (Purtuniq 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.).