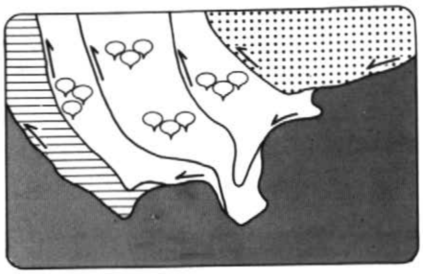

Evidence for the development of oceanic crust and for continental rifting in the tectonostratigraphy of the Early Proterozoic Cape Smith Belt [1]

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Summary

The Cape Smith Belt contains evidence for early Proterozoic plate tectonics in the form of a 1998 Ma ophiolite and a thrust belt which developed during northward underthrusting of a continental rift margin. Five tectonostratigraphic suites have been recognized from north to south in the eastern portion of the belt: (1) fluvio-deltaic sediments; (2) *ca.* 1960 Ma sediments and continental tholeiitic basalts; (3) *ca.* 1920 Ma transitional crust basalts; (4) deep-water sediments; and (5) basalts, sheeted dykes and mafic and ultramafic cumulates of a 1998 Ma ophiolite. Suites (1) to (3) reflect the development of a north-facing rift margin at the edge of the Superior Province. The older age of the ophiolite suggests that it developed in an earlier-rifted segment of the same basin, or it formed in a separate basin independent of the rift margin.

Résumé

La présence, dans la bande du Cap Smith, d'une ophiolite datée à 1998 Ma et d'une ceinture de chevauchement résultant de la subduction vers le nord d'une marge de rift continental sont autant d'évidences pour admettre l'existence d'une tectonique des plaques active pendant le Protérozoïque inférieur. Cinq suites tectonostratigraphiques sont reconnues du nord au sud dans la partie est da la bande: (1) sédiments fluviodeltaiques; (2) sédiments et basaltes tholéiitiques continentaux (*ca.* 1960 Ma); (3) basaltes de croûte transitionnelle (*ca.* 1920 Ma); (4) sédiments d'eau profonde; et (5) basaltes, dykes en feuillets et cumulats mafiques et ultramafiques d'une ophiolite datée à 1998 Ma. Les suites (1) à (3) documentent l'ouverture progressive d'un rift d'abord continental puis océanique sur la bordure nord de la province du lac Supérieur. L'âge de l'ophiolite indique que le domaine nord représente une portion plus ancienne du bassin océanique précité, ou un second bassin plus précose, développé de manière indépendante.

Introduction

Tectonostratigraphic studies in orogenic belts are the key to fully understanding the paleogeography and tectonic settings of deformed continental margins. Such studies provide an essential basis for eventually unravelling the structural and metamorphic histories of ancient (*e.g.*, Hoffman *et al.*, 1988) and more recent (*e.g.*, Ramos, 1988) mountain belts. In the Early Proterozoic Cape Smith Belt of northern Quebec, excellent exposure and >18 km of composite structural relief (Lucas, in press) has enabled the tectonostratigraphic components of both an old ophiolite and a younger rift margin to be studied.

The Cape Smith Belt is a thin-skinned thrust belt preserved in a doubly-plunging synclinorium as a stack of klippen. The southward-verging thrust belt developed during an episode of crustal thickening (D_1) (*ca.* 1920 to 1840 Ma; Parrish, 1989 - this issue, p. 126-130) during the Trans-Hudson Orogen (St-Onge and Lucas, in press). The belt formed in response to underthrusting of the northern Superior Province margin and obduction of an ophiolite, presumably from the overriding plate. Late D_1 out-of-sequence thrusts re-imbricated the thrust stack and were responsible for further southward translation of internal thrust sheets (Lucas, in press). The thrust belt and its footwall basement were deformed into regional-scale folds in two post-thrusting episodes (D_2: east-trending; D_3: northwest-trending). The principal consequences of D_2 and D_3 were to isolate the thrust belt from its proposed root zone by a basement antiform (Hoffman, 1985; St-Onge and Lucas, in press; Figure 1) and to generate an oblique cross-section of the belt.

In this paper, we first summarize the field and petrological characteristics of the principal tectonostratigraphic suites in the eastern portion of the Cape Smith Belt (Figure 2).

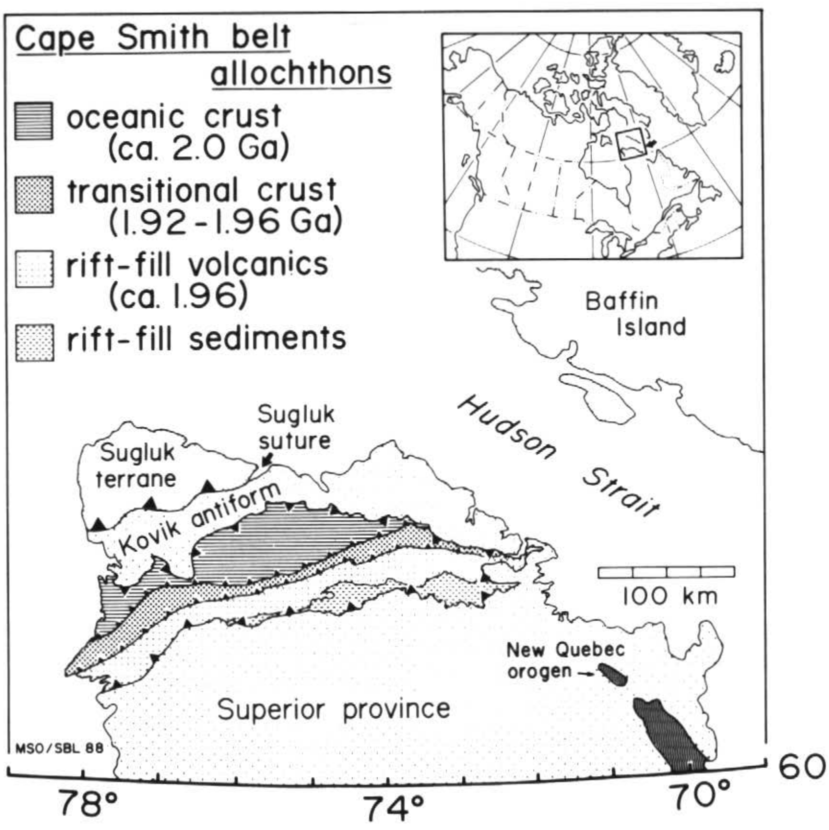

Figure 1 *Location map for the Cape Smith Belt (after Hoffman, 1985). The proposed suture between the underthrust Superior Province and the overriding Sugluk block is indicated as the "Sugluk suture".*

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These observations then form the basis for proposing that continental rift deposits, transitional crust basalts and oceanic crust units are preserved within the thrust belt as imbricate slices. Finally, two tectonic scenarios are considered (one *versus* two tectonostratigraphic basins) in order to account for the U/Pb geochronological data (Parrish, 1989 - this issue, p. 126-130) which suggest that the ophiolite is older than the rift margin sequence.

Tectonostratigraphy

Fieldwork in the eastern portion of the Cape Smith Belt (St-Onge *et al.*, 1986, 1987, 1988) has led to the recognition of distinct tectonostratigraphic units (Figure 2). Based on lithology, unit distribution, petrological characteristics, tectonostratigraphic affinities, and correlations with the western portion of the belt, five suites are recognized: (1) fluvio-deltaic sediments of the Povungnituk Group (St-Onge *et al.*, 1988); (2) rift-fill sediments and continental tholeiitic basalts of the Povungnituk Group (Hynes and Francis, 1982; Francis *et al.*, 1983; Picard, 1986, 1989a,b; Picard *et al.*, in prep.); (3) transitional crust basalts of the Chukotat Group (Francis *et al.*, 1981, 1983; Picard, 1986, 1989a,b; Picard *et al.*, in prep.); (4) deep-water sediments of the Spartan Group (Lamothe *et al.*, 1984; Lamothe, 1986); and (5) ophiolitic units of the Watts Group (Scott *et al.*, 1988, 1989 - this issue, p. 144-147; St-Onge *et al.*, 1988). The present distribution of units within the Cape Smith Belt is primarily a function of D_1 thrust imbrication. A discussion of the tectonostratigraphic record must therefore take into account the architecture of the thrust belt. The description of these tectonostratigraphic suites is thus presented in the order of their occurrence from the external (southern) to internal (northern) portions of the belt (Figure 2).

External outliers. Autochthonous arkosic sandstones of the Povungnituk Group are preserved in the Burgoyne Bay area (Figure 2: Formation 1) and are interpreted as the most proximal deposits of the rift margin sequence. Some of the beds display well-developed trough cross-bedding which is consistent with south to north channel flow in a fluvio-deltaic environment. The arkosic sandstones are deposited on demonstrably unstretched continental crust of the Archean Superior Province (St-Onge *et al.*, 1988).

External (southern) thrust sheets. Allochthonous Povungnituk Group sediments in thrust sheets A, B, C and D (Figure 2) comprise ironstones (Formation 2a) overlain by semipelites and arkosic sandstones (Formation 2b). The arkosic sandstones, interpreted as proximal fan deposits, commonly preserve graded bedding and tens-of-metre scale channel structures. Laterally, semipelites grade into ironstones and volcaniclastic sediments interlayered with metabasites. The proportions of semipelite, ironstone and sandstone within Formation 2 changes systematically with each more northerly (internal) thrust sheet. A northward increase in the semipelite to ironstone ratio coupled with a transition to more laterally discontinuous and thinner sandstone beds is interpreted as reflecting an overall northward increase in water depth.

Within thrust sheets A to H (Figure 2), micaceous sandstones (Formation 3) form a laterally extensive blanket. Unlike the sediments of Formation 2, the sandstones do not show south to north facies changes, and do not interfinger with volcanic rocks. Both the monotonous, homogeneous nature and the lack of interbedded volcanic material suggest that the micaceous sandstone accumulated in a basin isolated from volcanism. Within the more northerly Povungnituk Group thrust sheets (I to L, Figure 2), basalts (see below) rather than micaceous sandstone conformably overlie or interfinger with the sediments of Formation 2b. This dramatic change in rock type above Formation 2b emphasizes that a major south-to-north facies change occurs in the Povungnituk Group thrust sheets. The southern micaceous sandstones are interpreted to mark the shallowing of a more proximal (southern) basin, probably isolated from the main locus of crustal stretching and rift volcanism by syn-depositional normal faults.

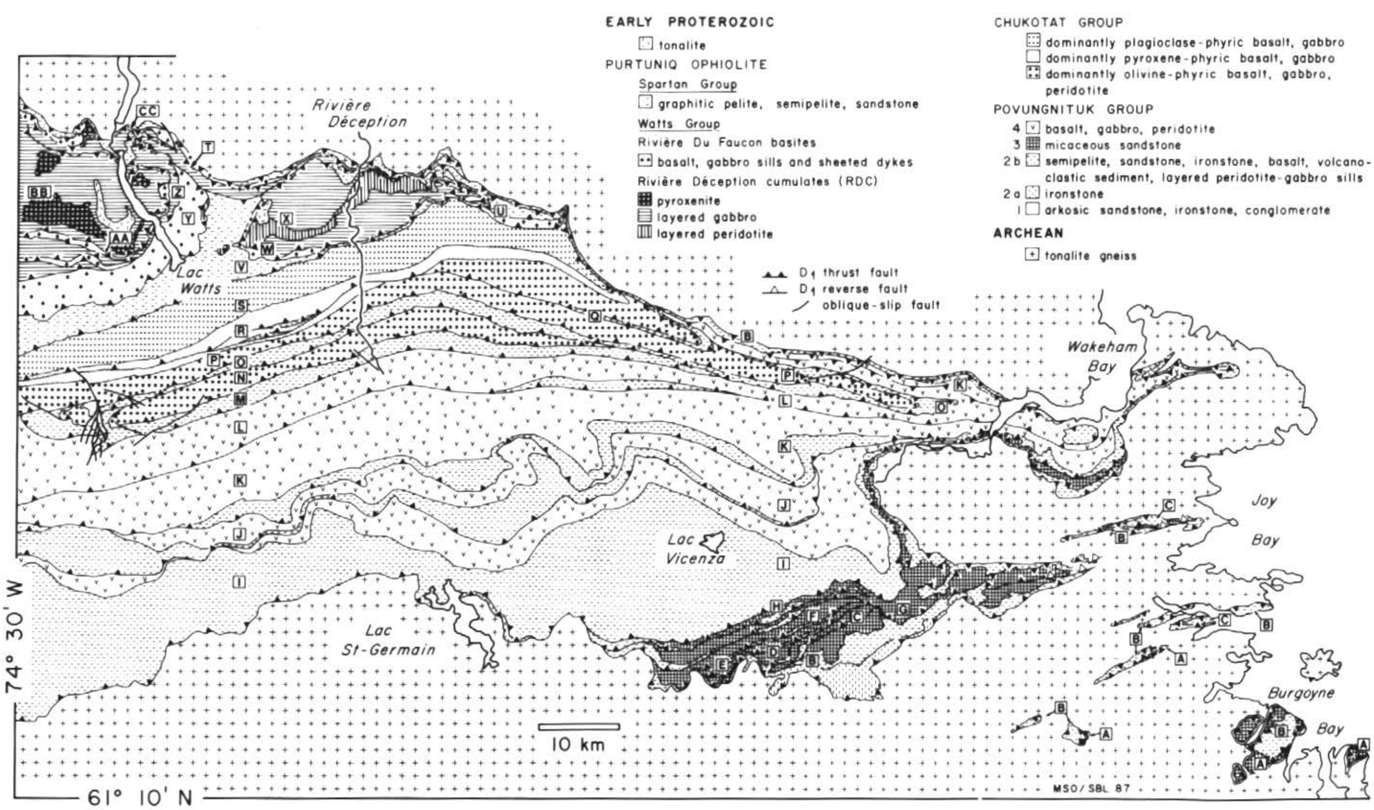

Figure 2 *Geological map of the eastern portion of the Cape Smith Belt. Boxed letters identify thrust sheets referred to in the text. Note that faults are named after the label of the overlying thrust sheet. Numbers 1 to 4 in the legend for the Povungnituk Group refer to informal formations discussed in the text.*

The basalts of Formation 4 (Figure 2) are characterized by thin, pillowed mafic flows and thicker, tabular flows. The Povungnituk Group basalts are described by Hynes and Francis (1982), Francis *et al.* (1983), Picard (1986, 1989a,b) as Fe- and Ti-rich, LREE-enriched continental tholeiites, with associated alkaline volcanic rocks (Gaonac'h *et al.*, 1989 - this issue, p. 137-139). Relatively rare, laterally discontinuous rhyolite bodies also occur within the mafic volcanic pile. One rhyolite has been dated (U/Pb on zircon) at 1959 Ma (Parrish, 1989 - this issue, p. 126-130).

Formation 4 also contains laterally discontinuous volcanic conglomerate units. These are typically composed of sub-rounded to angular blocks of basalt and gabbro which range in diameter from a few centimetres to several metres. The immature nature of the clasts, the presence of both basalt and gabbro clasts and the limited lateral extent of the volcanic conglomerate suggest that these units may be related to normal faulting during accumulation of the basalts.

Midbelt thrust sheets. In thrust sheets M, O and Q (Figure 2), the dominant sediments are semipelites interbedded with minor sandstones. Individual beds of sandstone are laterally very continuous and show no evidence of channel structures or cross-bedding, suggesting a distal fan environment. The sediments are interpreted as a deeper water (more outboard) facies of the Povungnituk Group.

Lower Povungnituk Group sediments occur within two fault-bound lozenges at the base of thrust sheet R (Figure 2). The lozenges contain spectacular polymictic conglomerate and local arkosic sandstone beds. The conglomerate is poorly sorted, with sub-angular to sub-rounded clasts of tonalite gneiss, basalt, gabbro and argillite (St-Onge *et al.*, 1987). The unsorted nature of the clasts, the presence of both basalt and gabbro clasts, and the similarity of the large granitoid boulders to the basement gneisses suggest that this unit is possibly a fault scarp deposit related to (normal?) faulting during accumulation of the Povungnituk Group.

Thrust sheets N, P and S (Figure 2) are host to dominantly pillowed basalt flows of the Chukotat Group. The volcanic rocks range from Mg-rich komatiitic basalts to low-Mg tholeiitic basalts with affinities to modern MORB (Francis and Hynes, 1979; Francis *et al.*, 1983). These authors, Picard (1986, 1989a, b) and Picard *et al.* (in prep.) interpret the Chukotat Group as documenting the transition from accumulation of transitional basalts slightly enriched in LREE to oceanic basalts depleted in LREE. A layered peridotite-gabbro sill emplaced in Povungnituk Group sediments and interpreted as a feeder to the lower Chukotat Group basalts (Thibert *et al.*, 1989 - this issue, p. 140-144) has been dated (U/Pb on baddeleyite) at 1918 Ma (Parrish, 1989 - this issue, p. 126-130).

Internal (northern) thrust sheets. Clastic sediments of the Spartan Group in thrust sheets V and U (Figure 2) comprise laminated graphitic pelites interbedded with semipelite and minor sandstone. The sequence is interpreted to coarsen upward from the deep water pelites at its base to the distal fan semipelites and sandstones near its top.

Thrust sheeet Y contains a sequence of mafic dykes, gabbro sills and pillowed tholeiitic basalts (Watts Group) that structurally overlies the Spartan Group sediments. The mafic dykes form a sheeted dyke complex, similar to those in Phanerozoic ophiolites, at the base of the thrust sheet (Scott *et al.*, 1988, 1989 - this issue, p. 144-147; St-Onge *et al.*, 1988). Gabbroic sills, and massive and pillowed basalt flows stratigraphically overlie the sheeted dykes.

Metapyroxenites, layered metaperidotites and layered metagabbros of the Watts Group are preserved within thrust sheets T, X, Z, BB and CC (Figure 2). The metagabbros and metaperidotites are thought to be part of a mafic to ultramafic cumulate sequence which has been interpreted as layer 3 of the oceanic crust (Scott *et al.*, 1988, 1989 - this issue, p. 144-147). U-Pb analyses of zircons from a layer of gabbroic composition have yielded an age of 1998 Ma (Parrish, 1989 - this issue, p. 126-130).

Discussion

The tectonostratigraphic record of (1) the autochthon, (2) external thrust sheets and (3) midbelt thrust sheets documents the evolution of an epicontinental rift which ultimately led to accumulation of oceanic basalts (Figure 3). Although normal faults have not been directly observed, the deposition of the continent-derived sediments of the Povungnituk Group on extended continental crust is suggested by the presence of volcanic conglomerates and fault scarp deposits. In addition, abrupt facies changes within the tectonostratigraphic sequence (micaceous sandstone to basalt) are interpreted to signal the accumulation of sediments and volcanic rocks in a series of rift basins separated by normal faults.

The basalts of the Chukotat Group document the transition from accumulation of continental rift-type volcanic rocks (*i.e.*, Povungnituk Group) to accumulation of transitional and then oceanic basalts (Hynes and Francis, 1982; Francis *et al.*, 1983; Picard, 1986, 1989a,b; Picard *et al.*, in prep.). As the Chukotat and Povungnituk Groups are mutually separated by major thrust faults (N, P and R on Figure 2), it will be important to successfully date the Chukotat Group in order to test proposed tectonic evolution models.

The most internal thrust sheets carry the mafic and ultramafic units of the Watts Group. The group has been interpreted by St-Onge *et al.* (1988) as early Proterozoic oceanic crust ("Purtuniq ophiolite"; Scott *et al.*, 1989 - this issue, p. 144-147). The composite thickness of the ophiolite complex (7-8 km) suggests that one or more slabs of immense size were obducted during the early Proterozoic thrusting event recorded in the Cape Smith Belt. The deep-water sediments of the Spartan Group are now structurally sandwiched between the obducted ophiolite and underlying Chukotat Group basalts. Whether the sediments were originally deposited on oceanic crust or transitional crust basalts cannot be resolved without further geochronological work on detrital zircon populations.

Existing U/Pb age determinations indicate that the Watts Group represents an older obducted oceanic domain (*ca.* 2000 Ma) juxtaposed against a younger, north-facing continental rift margin domain (*ca.* 1960-1920 Ma). Two potential tectonic scenarios are proposed to account for the two geochronologically distinct domains. The Purtuniq ophiolite may have formed along an earlier-rifted segment of the continental (Superior Province) margin domain. In this scenario, eventual juxtaposition of the two segments would have occurred during subsequent transpression. As an alternative, the two domains may have formed in two adjacent, but distinct, basins. One difficulty with this scenario is that there is no record of the crust that would have separated the older oceanic domain (Purtuniq ophiolite) from the younger continental rift margin domain. Continued field work and topical studies within the Cape Smith Belt and the hinterland to the north (Figure 1) will hopefully resolve these questions in the near future.

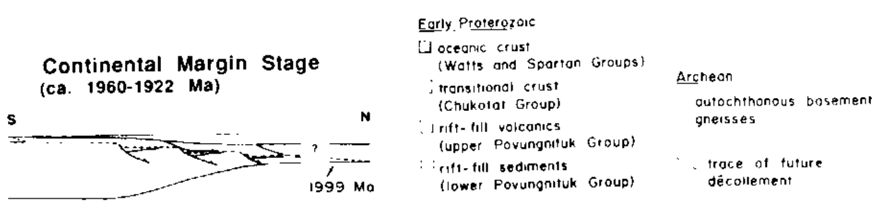

Figure 3 *Schematic representation of the inferred paleogeography of the north-facing continental margin of the Superior Province. Post-rift sediments are not illustrated. The future Purtuniq ophiolite is shown as a block of oceanic crust of unknown relation to the Superior Province margin*

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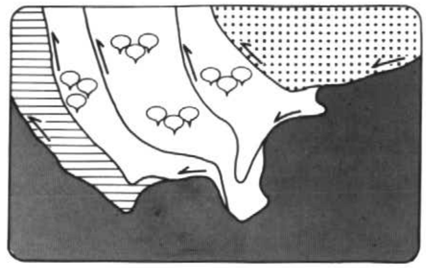

Structural evolution of the Cape Smith Belt from initial thrusting to basement-involved folding [1]

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Summary

Structures in the Cape Smith Belt record the transition during collisional deformation from (1) initial thin-skinned thrust belt growth, to (2) internal thickening of the thrust belt involving basement thrusting, and finally to (3) basement-involved, crustal-scale folding. Overprinting deformation-metamorphism relationships allow recognition of four principal stages in the history of the thrust belt. First, south-verging, regular (piggy-back)-sequence thrusts developed above a regional basal décollement which was localized at the basement-cover contact. Second, thermal equilibration of the thrust belt (20 to 30 km thick) resulted in metamorphism and the development of a ductile shear zone at its base. Third, major out-of-sequence thrust faults internally deformed the thrust belt from pre- to post-thermal peak conditions. Finally, thrust belt deformation (D_1) was followed by an episode of basement- (footwall-) involved folding (D_2) which continued to accommodate the north-south shortening.

Résumé

Les relations déformation-métamorphisme permettent de distinguer quatre stages dans l'histoire structurale de la bande du Cap Smith. Tout d'abord, des chevauchements en série (D_1) se sont développés du nord vers le sud au dessus d'un décollement de base entre le socle et la couverture. En second lieu, l'élévation des températures reliée à un processus de ré-équilibration thermique dans les nappes de chevauchement (épaisseur cumulée de 20 à 30 km) a

[1] Geological Survey of Canada Contribution No. 19189