Structure and stratigraphy, Mount Bryant area, eastern Rocky Mountain Front Ranges, Alberta

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A.I. Zolnai[1] Institute of Sedimentary and Petroleum Geology, Calgary

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Abstract

In the eastern Front Ranges of the southern Rocky Mountains southwest of Calgary, Alberta, middle Cambrian, upper Devonian and Mississippian strata are imbricated and complexly folded in the McConnell, Kananaskis and Lac des Arcs thrust sheets (east to west in ascending order of structural stacking). The Fullerton Tear, south of Mount Bryant, cuts obliquely across the McConnell thrust sheet, within which it juxtaposes structures of contrasting complexity, and marks the southern termination of the Kananaskis thrust sheet, but does not appear to affect the overlying Lac des Arcs sheet or strata beneath the McConnell Thrust.

The role of the Fullerton Tear is interpreted as follows: the tear fault acted as an oblique ramp between the McConnell and Lac des Arcs thrusts; folds and faults north of it were accentuated as they were transported over a footwall ramp and anticlinorium-synclinorium pair located to the south of it. The tear fault also separates two structural levels; displacement of imbricate structures of the Kananaskis thrust sheet north of the tear is transferred to the Lac des Arcs Thrust. The duplex fault zone within Palliser strata to the south plunges underneath the tear, and connects with the McConnell Thrust to the east.

Résumé

Dans la partie est des Front Ranges du sud des Rocheuses, au sud-ouest de Calgary en Alberta, les strates du Cambrien moyen, du Dévonien supérieur et du Mississippien, sont imbriquées et plissées de façon complexe dans les nappes de charriage de McConnell, de Kananaskis et de Lac-des-Arcs (d'est en ouest suivant un ordre ascendant d'empilement structural). Au sud du mont Bryant, le décrochement de Fullerton traverse obliquement la nappe de charriage de McConnell, à l'intérieur de laquelle il juxtapose des structures de complexité contrastée, et marque la limite sud de la nappe de charriage de Kananaskis, et ne semble pas modifier la nappe sus-jacente de Lac-des-Arcs, ou les strates situées sous le charriage de McConnell.

On a interprité le rôle du décrochement de Fullerton de la façon suivante : la faille de déchirement s'est comportée comme une rampe oblique entre les charriages de McConnell et de Lac-des-Arcs; les plis et failles apparus au nord de celle-ci ont été accentués, lorsqu' ils ont été transportés par-dessus une rampe constituée par la lèvre inférieure de la faille, et un couple anticlinorium-synclinorium situé au sud de celle-ci. Le décrochement a aussi séparé deux niveaux structuraux; le mouvement des structures imbriquées de la nappe de charriage de Kananaskis, au nord de la faille de décrochement, a été transmis au charriage de Lac-des-Arcs. La zone faillie double située a Vintérieur des strates de Palliser au sud, plonge sous le décrochement et rejoint le charriage de McConnell à l'est.

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36 Ccdardale Mews S.W., Calgary, Alberta, T2W 5G4.

THANKS FOR YOUR CONTRIBUTION
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Chapter 16

Precambrian geology and tectonic history of North America

Paul F. Hoffman
Geological Survey of Canada, Ottawa, Ontario KIA 0E4, Canada

INTRODUCTION: TECTONIC ELEMENTS AND EVOLUTION

North America is an old continent. Whereas South America and Africa were not assembled until 0.7 Ga, and the assembly of Eurasia began at 0.3 Ga, most of the North American craton has been coherent since 1.7 Ga. This craton, known as Laurentia. included Greenland and northwest Scotland until their partial separation in the Late Cretaceous. This chapter describes the constituents of Laurentia, their aggregation in the Early Proterozoic (Table 1), and subsequent adventures of the craton until the rifting events at the end of the Proterozoic, which gave the continent approximately its present shape.

Radiogenic isotopic data from the Precambrian shield, and from inliers and subsurface samples on the platform indicate that about 55 percent of the area of the craton separated from the mantle in the Archean and about 45 percent in the Proterozoic (Fig. 1). In this regard, the shield is not representative of the craion as a whole, being strongly biased in favor of Archean crust (Fig. 2). Conversely, most of the Proterozoic crust underlies the Phanerozoic sedimentary veneer of the southern interior platform.

The Archean protocraton of Laurentia is an aggregate of seven former microcontinents (Fig. 1): the familiar Superior, Wyoming, Slave, and Nain (North Atlantic) provinces, and the newly recognized Hearne, Rae, and Burwell provinces (formerly parts of the composite Churchill province). The Rae province includes northern, southwestern, and southeastern prongs. Each province is a Late Archean crustal aggregate and contains variable proportions of Early and/or Middle Archean crust. Early Proterozoic rifting and subsequent collisional deformation govern the dimensions of the provinces. Some of the provinces may have had common ancestry prior to Early Proterozoic rifting, but this is speculative.

The Archean provinces are welded by Early Proterozoic collisional orogens (Fig. 3). The orogens are characterized by deformed passive-margin and foredeep sedimentary prisms, and foreland thrust-fold belts. Their hinterlands, bordered by Andean-type magmatic arcs, have regions of basement reactivation, thrusting, and transcurrent shearing accommodating collisional foreland indentation. Only the Trans-Hudson orogen, which separates the Superior province from the Wyoming and Hearne provinces, preserves a significant width (up to 400 km) of juvenile Proterozoic crust, including relics of island arcs and obducted oceanic crust. The Thelon orogen tightly welds the Slave and Rae provinces, the Snowbird orogen, the Hearne and Rae provinces, and the New Quebec orogen the Superior and Rae provinces. The Nain and Rae provinces are separated by a branching system of orogens (Torngat, Foxe, Rinkian, and Nagssugtoqidian orogens), which enclose the small Burwell province. The Wyoming and Hearne provinces are welded in the subsurface by the Great Falls orogen. U-Pb isotopic ages for the orogenic events show that the protocraton was assembled between 1.98 and 1.83 Ga (Fig. 4).

TABLE 1. GEOLOGIC TIME DIVISIONS

OGa	
	Phanerozoic
0.57 Ga	
	Late Proterozoic
0.90 Ga	
	Middle Proterozoic
1.60 Ga	
	Early Proterozoic
2.50 Ga	
	Late Arcchean
3.00 Ga	
	Middle Archean
3.40 Ga	
	Early Archean
3.80 Ga	
	Hadean
4.6 Ga	

The Archean protocraton is flanked to the west, south, and southeast by crust that was accreted in the Early Proterozoic and contains little or no Archean material (Fig. 1). In the Wopmay orogen and its subsurface extensions, terranes having apparent crust-formation ages of 2.4 to 2.1 Ga were accreted onto the western margin of the protocraton between 1.91 and about 1.7 Ga. Juvenile crust was accreted between about 1.86 and 1.80 Ga onto the southern and southeastern margins of the protocontinent in the Penokean and Ketilidian-Makkovik orogens respectively. Between 1.80 and 1.65 Ga, more than 1,200 km ofjuvenile crust was accreted in the southern and southwestern United States

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Evolution of the Boothia Uplift, arctic Canada

A. V. Okulitch, J. J. Packard, and A. I. Zolnai *Geological Survey of Canada, 3303 33rd Si. NW, Calgary, Alia., Canada T2L* 247

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The Boothia Uplift extends 1000 km northward from the northern Canadian Shield into the **Arctic** Archipelago. Consisting of a core of Arehean(?) to Aphcbian gneissic units and a cover of Protcrozoic to Devonian strata of the Arctic Platform and Franklinian Miogeocline**,** it formed during several minor pulses of uplift in the late Proterozoic and early Paleozoic and a major episode of tectonism during the Siluro-Devonian. Although it has long been regarded as a "horst" or vertical block uplift, compilation of new and previous data suggests that the uplift can be interpreted as a major, west-directed, imbricate mass of crystalline basement mantled by faulted and drape-folded cover. Details of the vertical component of movement have been provided by sedimentological and stratigraphic studies. Uplift increases northward from the craton to a maximum of 5 km. Estimates of horizontal movement, predicated on assumed fault dips, could be as much as 30 km.

Major tectonism of the Boothia Uplift was approximately coeval with uplift on southeastern Ellesmere Island and on northern Axel Heibcrg Island, folding and low-grade metamorphism on northernmost Ellesmere Island, and west-directed thrusting and folding on Greenland. The plate tectonic interactions responsible for these events remain obscure; a general regime ol west-directed compressive stresses associated with late stages of the Caledonian Orogeny may have been present.

Lc massif Boothia s'étend sur 1000 km, du nord du Bouclier canadien jusque dans l'Archipel arctique. I1 est constitué d'une zone interne gneissique d'unités archéennes (?) à aphébiennes et d'une zone externe de sediments précambriens à dévonins de la Plate-forme arctique et du Miogcoclinal franklinien. Ce massif s'est développé lors de phases mineurcs au Precambrien supérieur et Paléozoique inférieur et lors d'un episode tectonique majeure au Siluro-Dévonien. Longtemps considcré comme résultant d'un mouvement de socle vertical, ce massif est maintenant inierprcté comme un ensemble structural allochtonc. déformé par cisaillement dans la partie cristalline interne et par plissement-fracturation de la couverture sédimentaire. Les données stratigraphiques et sédimentologiques montrent que I'ampleur du soulèvement augmente du craton vers le nord, où il atteint un maximum de 5 km. Le déplacement horizontal, estimé à partir des rcjets sur les failles, pourrait attendre 30 km.

La tectonique majeure du massif Boothia est approximativement contemporaine du soulevement du sudde l'îlc Ellesmere et du nord de l'Île Axel Heibcrg, du plissement et métamorphisme de faible intensité du nord de 1'ile Ellesmere et des chevauchements vers l'ouest du Groënland. Le contexte globotectonique de ces déformations n'est pas connu. Elles semblent associées à un régime a vergence ouest tardi-calédonien.

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Introduction

The Boothia Uplift is a major positive cratonic and supracrustal structural feature that formed primarily during the Late Silurian to Early Devonian. It extends due north from Boothia Peninsula nearly 1000 km to Grinnell Peninsula (northwestern Devon Island; Fig. 1). The uplift is composed of two parts. A lower structural level, with an exposed width **of** 80 km, contains faulted, poly-deformed Aphebian or older metamorphic rocks of the Churchill Province **of** the Canadian Shield and crops out over the southern two thirds of the uplift. An upper structural level consists of Helikian and Cambrian to Lower Devonian strata of the Arctic Platform and Franklinian Miogeocline, which have been folded and faulted to form the Cornwallis Fold Belt. This upper level mantles the crystalline core and is preserved in the northern one third of the uplift over an exposed width of 150 km.

Study of structures of the uplift has been predominantly at a reconnaissance scale, and their geometry is thereby not fully understood. In contrast**,** stratigraphic, sedimentological, and paleontological investigations, although incomplete, have provided data of high resolution that document the timing, location, and magnitude of vertical components of tectonic pulses in considerable detail (e.g., Thorsteinsson and Uyeno 1980).

Such studies have indicated that the uplift is an asymmetric basement block bounded on the west by steeply to perhaps moderately east-dipping reverse faults and on the east by normal and reverse faults (Stewart and Kerr 1984) and segmented by northeast- to northwest-trending normal and reverse faults. Arctic Platform strata immediately west of the basement are steeply overturned, tightly folded, and overfhrust. To the east, they form west-verging folds and east-facing monoclines cut by steep normal and reverse faults. Within the thicker succession of the Franklinian Miogeocline to the north, structures at the surface are broad open synclines with tighter intervening anticlines and numerous steep faults of normal, and less commonly, reverse displacements. Although several weak pulses of uplift are documented in the tectonically sensitive platformal succession from the Helikian to the Late Devonian, the primary pulse that produced most of the structures and structural relief of the uplift occurred during the Late Silurian to Early Devonian epochs.

Early history of the Boothia Uplift

The crystalline core of the uplift is composed of Aphebian or older metasedimentary and metavolcanic gneissic units and granitoids that underwent polyphase deformation and uniform high-grade metamorphism prior to the Helikian (ca. 1600-1700 Ma) (Blackadar 1967: Brown *el al.* 1969). Predominant structural trends are north —south, changing to northeast—southwest at the southern end of Boothia Peninsula to parallel those typical of the main part of the Churchill Province. Diabase dykes, faults, and topographic lineaments generally trend northwest and northeast. In northern Boothia Peninsula and southern Somerset Island, northerly structural trends combine with east-west lineaments and faults to produce a reticulate pattern.

Regional cross section of the Southern Province adjacent to Lake Huron, Ontario: implications for the tectonic significance of the Murray Fault Zone

A. I. Zolnai,[1] R. A. Pricr, and H. Helmstaedt *Department of Geological Sciences, Queen's University, Kingston, Ont., Canada K7L 3N6*

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The Southern Province in the Lake Huron area of Ontario, and the Pcnokean Fold Belt of Minnesota. Wisconsin, and Michigan have Ihe earmarks of a collisional orogen. The Huronian Supergroup, a southerly lacing passive margin sequence, was deposited during early Aphebian (Early Protcrozoic) crustal stretching (and ocean basin formation?) along the southern margin of the Superior Province Archean craton. It accumulated as four unconformity-bounded, northerly tapering, onlapping clastic wedges (megacycles). The thickness and facies variations reflect syndepositional down-to-the-basin (south) normal faulting that controlled the accumulation and preservation of the lower three Huronian megacycles. These are overlapped northward by the youngest megacycle, an extensive sheet of elastic sediments recording post-stretching regional subsidence of the cratonic margin due to cooling and thermal contraction. Soft-sediment folds in the rocks of the youngest megacycle to the extreme south probably indicate southward slumping into an adjacent basin. Nipissing diabase instrusions, 2100 Ma old. cut Huronian strata and soft-sediment folds.

An enigmatic episode of compressional deformation is dated by 2333 Ma old plutons. During the first ductile (penetrative cleavage and peak mctamorphism phase of the Penokcan Orogeny (ca. 1900 Ma), the thicker part of the Huronian supracrustal wedge was overridden and depressed to mid-crustal levels, presumably because it was overridden by an allochthonous terranc. the remainder of which is postulated to lie south of the Manitoulin Island Discontinuity. The early down-to-thc-basin normal faults were reactivated and became the loci of north-verging, listric reverse faults. The thick wedge of Huronian rocks south of the Murray Fault Zone, which was deformed and metamorphosed as it was carried down to mid-crustal levels, subsequently was thrust northward over a thinner sequence of Huronian rocks that apparently was never deeply buried. Concurrently, the edge of the Superior craton and its cover of Huronian deposits were compressed as thrusting propagated northward and eventually deformed the 1850 Ma old Sudbury Nickel lrruptive. Structures that formed in the thick part of the wedge during the ductile deformation were rotated during the thrusting to their present near-vertical position. Lale or post-Penokean brittle deformation marked by conjugate small strike-slip faults reflects continued or renewed north—south compresssion in an isostatieally rising foldbelt, and post-Pcnokcan right-lateral strike slip along the Murray Fault Zone is probably related to northwestward compression during the Grcnvillc (approx. 1000 Ma) Orogeny.

La province Sud (région du Lac Huron. Ontario) et la chaîne plissée pénokéennc (Minnesota, Wisconsin et Michigan! sont caractéristiques d'une chaîne de collision. Le craton archéen de la province supérieure était bordé au sud par une marge continentale passive huronienne d'âge aphébien (protérozoïque inféricur) associée à un étircment crustal (avec formation de bassin océaniquc?). Quatre séries détritiques (mégacycles) s'épaississant vers le sud et séparées par des discontinuités se sont déposées sur cette marge. Le dépôt des trois premiers mégacycles s'est accompagné d'une tectonique syn-sédimentaire associée à 1'étirement crustal (failles normales à pendage sud), tandis que le dernier mégacycle (subsidence thermique) correspond au dépôt d'une couverture transgressive sur les mégacycles inférieurs et le socle archéen. Des plis effectués en sédiments non-consolidés du dernier mégacycle àa l'extrême sud attestent d'un possible écroulement dans le basins avoisinant. Les intrusions Nipissing de 2100 Ma recoupent les couches huroniennes et les plis en sédiments non-consolidés.

Un premier épisode compressif énigmatique est daté par des plutons de 2333 Ma. Durant la première phase ductile de 1'orogénèse pénokéenne (ca. 1900 Ma), la serie épaisse du prisme huronien au sud de l'accident Murray (Murray Fault Zone) fut enfouie à un niveau crustal intermédiaire à la suite du chevauchement postulé d'un terrain allochtone qui maintenant est présumé enfoui au sud de la discontinuité Manitoulin (Manitoulin Island Discontinuity). Les failles normales à pendage sud furent réactivées et devinrent le lieu de chevauchements listriques à vergence nord. L'épais prisme huronien au sud de l'accident Murray qui fut métamorphisé durant son éfondrement à niveau crustal intermédiairc et en phase ductile, fut ensuite chevauché vers le nord au dessus d'une mince série huronienne qui ne fut apparement pas enfouie très profondément. La bordure cratonique de la province supérieure ainsi que sa couverture détritique huronienne furent comprimées en même temps que les chevauchements furent propagés vers le nord et éventuellcment déformèrent l'irruptif nickelifèrc de Sudbury (Sudbury Nickel Irruptive) de 1850 Ma. Les structures, qui furent formées dans l'épais prisme huronien en tectonique ductile, furent soumis à une rotation en phase cassante de chevauchement vers leur préscnte position sub-verticale. La fin de cette orogénèse s'est accompagnée d'un tectonique cassante à décrochements conjugués nord-ouest et nord-est, tandis que dans un dernier stade, la réactivation de l'accident Murray est probablement liée à la compression grcnvillicnne nord-ouest—sud-est vers 1000 Ma.

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Introduction

The Southern Province of the Canadian Shield (Stoekwell *et al.* 1970) (Fig. 1) is underlain by the Huronian Supergroup (Fig. 2), a wedge of Early Proterozoic (Aphebian) clastic rocks that ontaps northward over the Archean Superior Province (>2500 Ma; Card *et al.* 1972) in four upward-fining megacycles (Fig. 3) (Card *et al.* 1972, Robertson 1973; Young 1983, which are cut by 2100 Ma old Nipissing diabase dykes (Card *et al.* 1972, Card, personal communication, 1982). The supracrustal wedge is overprinted to the southeast by (he Grenville Front, is overlain to the south by Paleozoic sediments, and is truncated to the west by the Mid Continent Rift. Within the Southern Province the Murray Fault Zone (MFZ) (Fig. 2) is the locus of conspicuous changes in the thickness and character of the Huronian Supergroup and of conspicuous changes in re-

[1]Present address; 36 Cedardale Mews SW, Calgary, Alta., Canada *T2W 5G4*

[2]Prcsent address:Geological Survey of Canada, 601 Boooth St., Ottawa, Ont., Canada K1A 0E8