Geological Vignettes of Nunavut: Setting the Stage for Change

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SUMMARY

In the coming years significant political, economic and environmental changes are likely to sweep across Nunavut. Many of these changes will either have their origins in the geology, geochemistry and resource potential of this region, or will be affected and moderated by the physical structure of the area. A model of the geological architecture of Nunavut sketching the building of Nunavut — from its Archean basement through the Proterozoic, the Lower and Middle Paleozoic, and the Upper Paleozoic, Mesozoic and Cenozoic — outlines regions where specific kinds of natural and anthropogenetic change can be expected. The regional bedrock geology and chemistry have an impact on the economy, vegetation and water in distinctive ways (*i.e.*, Archean gold and soapstone; Mesozoic hydrocarbons; calcophile plants on Proterozoic and Paleozoic carbonates; and local U, Pb, Zn and Cu anomalies in water and soils). In addition, the relief of Proterozoic and younger tectonic structures broadly moderates climate and weather fronts to influence the position of the tree line and the varieties of tundra seen in the north. Global change as well as local change due to natural and anthropogenic processes will variably have an impact on the different regions of Nunavut. Whatever the future has in store for Nunavut, a broad understanding of the geologic architecture sets the stage for determining the geographic limits, and the rate and extent of natural and anthropogenic change.

RÉSUMÉ

Dans les années qui viennent, le Nunavut connaîtra probablement de grands changements de nature politique, économique et environnementale. Parmi ces changements, un bon nombre seront directement reliés aux caractéristiques géologiques, géochimiques ainsi qu'au potentiel en ressources naturelles de cette région et, leur réalisation sera fonction des conditions physiques particulières de ce milieu. Un modèle abrégé esquissant l'architecture géologique du Nunavut — du socle archéen jusqu'au Cénozoïque, en passant par le Paléozoïque inférieur à moyen, le Paléozoïque supérieur et le Mésozoïque — permet d'identifier certaines des zones susceptibles de connaître des changements naturels ou anthropogéniques particuliers. La nature géologique et chimique du substratum de la région se répercute de diverses façons sur son économie, sa végétation et ses eaux (par ex. les gisements archéen d'or et de saponite, les gisements d'hydrocarbures mésozoïques, les exploitations de carbonates protérozoïques et paléozoïques et, la présence de zones d'anomalies en U, Pb, Zn et Cu dans les eaux et les sols). On constate également que les éléments topographiques protérozoïques ou plus récents ont suffisamment d'effet sur le climat et les fronts météorologiques pour changer la position de la limite forestière et les types de toundra qui y croissent. Les changements naturels ou anthropogéniques, qu'ils soient à l'échelle de la région ou du globe, auront des répercussions diverses sur les différentes régions du Nunavut. Il est certain qu'une bonne compréhension du cadre géologique permettra de mieux définir les limites géographiques, le rythme et l'étendue de tout changement naturel ou anthropogénique à venir dans le Nunavut.

INTRODUCTION

In 1993 there were two bills passed in the House of Commons which fundamentally changed how we view the Canadian dominion. With Federal Cabinet approval, on 1 April 1999 the Northwest Territories will be officially divided into territories that are more in keeping with the peoples encompassed within them. One bill proclaims the Final Land Claims with the Inuit of the eastern Arctic, the other bill creates a new territory called Nunavut (Nunavut Tunngavik Inc., 1993).

At approximately 1,900,000 km^2, Nunavut occupies about one-fifth of the land mass of Canada (Fig. 1); this is more than five times larger than Germany and about the same size as continental Europe (Nunavut Tunngavik Inc., 1993). The region, measuring more than 2,500 km in length and width, is largely unarable mountains, icefields, polar deserts, and tundra. There are few roads and oftentimes unpredictable weather. Distances between settlements still form significant obstacles to travel and communication.

The population of about 20,000 is largely Inuit, spread among fewer than 30 predominantly coastal settlements (Environment Canada, 1994). Population density, among the lowest in the world (0.01 persons·km^{-2}), is about 30 times less than the Canadian average and 22,000 times less than Germany (Nunavut Tunngavik Inc., 1993). In contrast, population growth, at 300% in the last 30 years (Table 1), is many times higher than the rest of Canada.

In isolation, local initiatives such as hunting, fishing, trapping and crafts are the major components of a domestic subsistence economy. Wildlife, harvested primarily for domestic use, is one of the mainstays of the local diet (Government of Canada, 1991). Other foods, domestic products, modular homes and other buildings (*i.e.*, offices and shops), and vehicles (*i.e.*, snow machines, boats, cars, trucks, and tractors) are pre-packaged products ordered weeks or months in advance and shipped by water or air at significant expense. Government and government-promoted activities (*i.e.*, teaching, research and tourism) create opportunities for significant monetary transfers from the south. Although considered important to Canada's national security, non-renewable resources of ores and energy fuels are not widely used in Nunavut; exploration and development of mining and manufacturing industries in this huge area is still in its infancy. In total, little is known about the limits to sustainable growth in this area and in particular in these times when significant global change is predicted.

Given this brief background to Nunavut and its burgeoning population, it is clear that the development of non-renewable mineral and oil resources will have to play a significant role in its growth and success. So too, the geology of Nunavut determines other aspects of territorial integrity, including such important environmental concerns as the climate and local weather, water quality, wildlife and plant distribution, and migration routes.

The purpose of this review is to outline a general pattern for the origin and distribution of the landforms, rocks and minerals in Nunavut, and to discuss their general influence on physiography (Fig. 2) and ecozones (Fig. 3). By understanding the physical setting of Nunavut and the regional distribution of its various mineral resources, studies of the water and air may be put in context, the changing biology of the landscape may be better understood, and naturally produced toxins in the environment may be separated from pollution produced by local and extra-regional anthropogenic activities. With this knowledge, the impact of change in Nunavut can be assessed in a realistic manner and, if necessary, accommodated by careful planning for site protection or development.

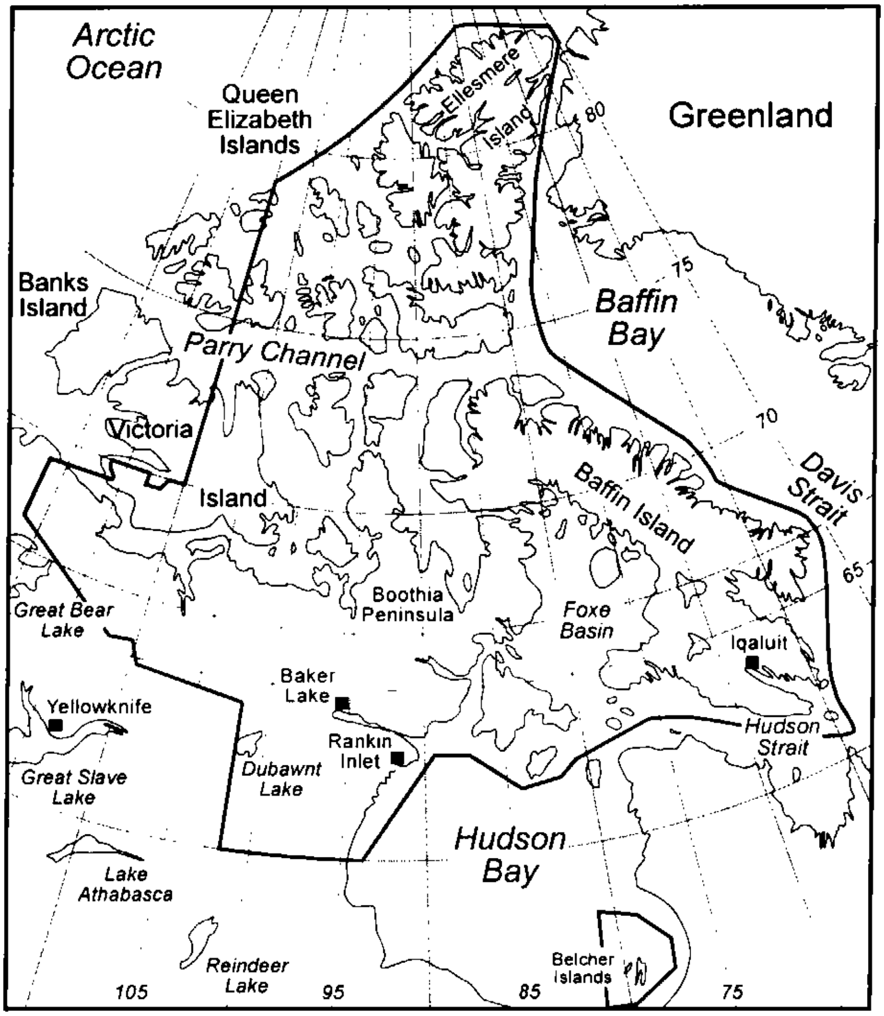

Figure 1 *Location map for Nunavut.*

GEOLOGIC SETTING

Nunavut is a very old and geologically complex region with origins extending 4000 million years (m.y.) ago to the beginning of the Precambrian. Throughout this long history there are multiple episodes of mountain building and erosion manifested by distinctive belts of rock which: 1) host significant and regionally unique deposits of ore, petroleum and coal; 2) differentially affect water quality and biology through dissolution of minerals, releasing major and trace elements to watersheds; and, 3) influence local climate and biology by deflecting the air, plants and animals along paths of least resistance, and attracting humans to sites where significant mineral resources (*i.e.*, soapstone or gold) can be developed.

Pragmatically, and based on long-recognized precepts of lithology, structural evolution and paleontology, the geological development of Nunavut is conveniently divided into four distinctive episodes: the Archean, from 4000 Ma to 2500 Ma; the Proterozoic, from 2500 Ma to 560 Ma; the early and middle Paleozoic, from 560 Ma to 360 Ma; and the late Paleozoic, Mesozoic, and Cenozoic, from 360 Ma to 0 Ma (the present).

Paradoxically, the oldest, most highly metamorphosed and deformed rocks of Nunavut are also the most widespread and best exposed in the region. Since their origin more than 560 m.y. ago, Archean and Proterozoic strata of the Precambrian have been largely emergent and eroding. Studies of stratigraphy, structure, peneplains, and ancient landscapes, combined with radiometric dating, serve to separate the various Precambrian rock units from one another and to establish a chronology for the physical evolution of Nunavut's most ancient mountains and seas.

Younger, predominantly clastic and calcareous strata of the Paleozoic, Mesozoic and Cenozoic of Nunavut tend to be restricted to: 1) the Queen Elizabeth Islands on the northwestern edge of the North American continent; 2) a small number of relatively thin deposits in broad, shallow, sedimentary basins lying on Precambrian crust, and; 3) recently formed offshore basins in Baffin Bay and the Arctic Ocean. These rocks chronicle cycles of rifting, passive margin shelf development, collapse, and orogenesis for the opening, closing and opening of seas which face the modern Arctic and Atlantic oceans.

Archean Microcontinents

The bedrock core of Nunavut, the north-

Table 1 Growth of Nunavut and Canada in the last 30 years (statistics from Dominion Bureau of Statistics, 1963; Statistics Canada, 1992, 1994).

	1961	1991	Change (%)
Canada	18,238,247	27,296,859	49.6
Nunavut[1]	5,000	20,000	300.0

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[1] Statistics based on Nunavut communities in the present Northwest Territories

ern edge of the Canadian Shield (the North American craton Laurentia), is formed of four irregular belts of Archean rocks known as the Slave, Rae, Hearne, and Burwell provinces (Fig. 4). Typically more than 2500 m.y. old, and differing from one another in age, structure and internal composition, each of the Archean provinces is thought to be a microcontinent formed from accretion of one or more mountainous volcanic island arcs (Hoffman, 1989).

In the far west of Nunavut, the Slave province is well exposed in the uplands east of Great Bear Lake and north of Great Slave Lake. Farther north on Banks and Victoria islands, the Slave province probably lies beneath deeply buried and mildly deformed Proterozoic strata. To the east, the Rae province is a broad area of Archean crust extending across most of the barrens west of Hudson Bay, into the eastern Arctic Islands, and including Baffin, Ellesmere and part of Greenland. The south part of Nunavut west of Hudson Bay is identified as the Hearne province, the youngest of the Archean microcontinents. Lastly, the Burwell province, the smallest of the Archean microcontinental blocks, is recognized as a fault-bounded block of high-grade, granitic and mafic gneiss occurring on the eastern margin of Nunavut on southern Baffin Island.

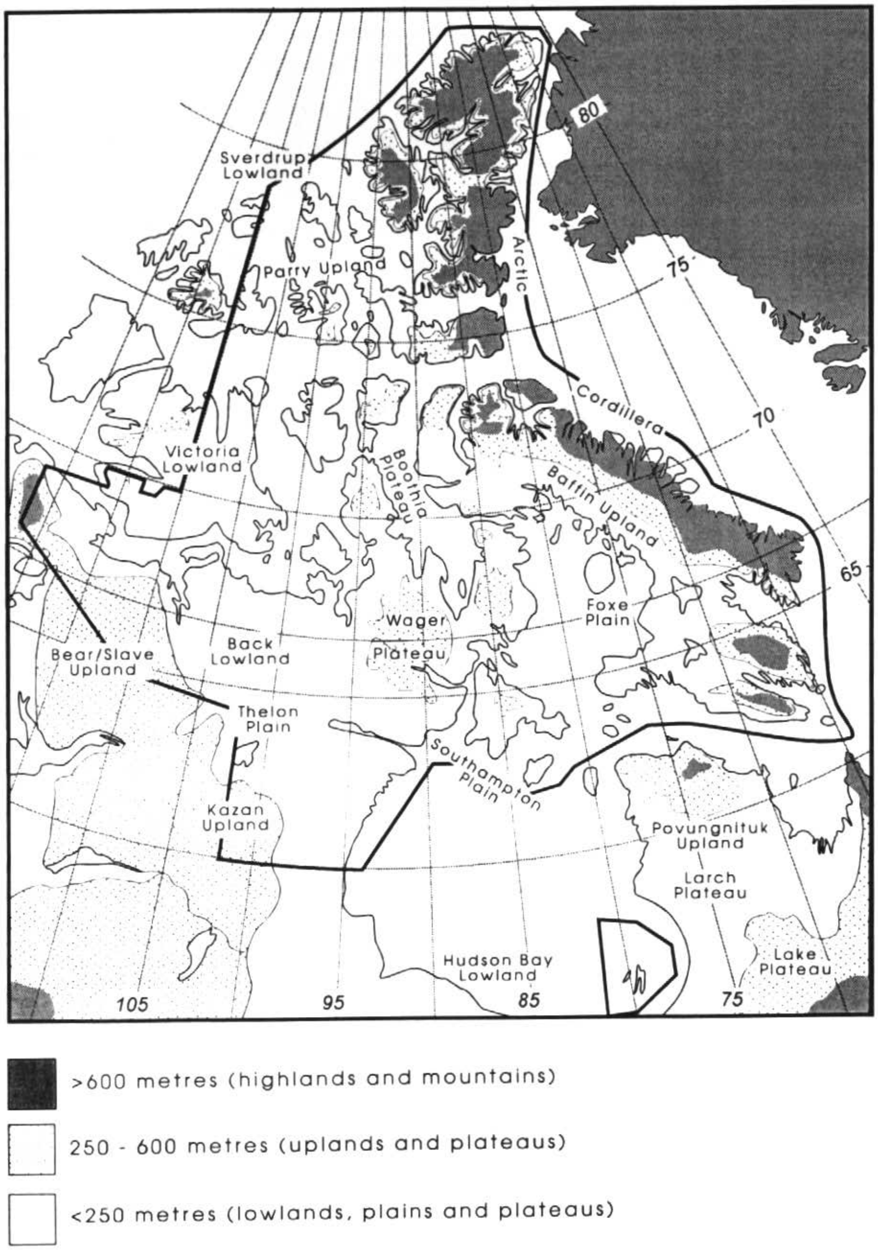

Figure 2 *Regional physiography and relief of Nunavut (after Dyke* et al., *1989; Hodgson, 1991).*

A model for accretion of microcontinents, and using the Slave Provice as an example, shows that most of the exposed strata are plutonic and metamorphic rocks 2700 Ma to 2500 Ma in age derived from turbidites which formed in back-arc basins and were mixed with lesser amounts of intermediate and felsic volcanics from adjacent island arc and back-arc sources (Lambert, 1978; Padgham, 1985). Prominent tectonic signatures and structural terranes are thought to show subduction and fusion of older gneisses of the western part of the Slave provice beneath a volcanic island arc complex in the east (Fig. 5). More thorough discussions of the regional lithology, structure, origin and ages of these provinces may be found in McCulloch and Wasserburg (1978), Fraser and Heywood (1978), Frisch (1982), Fahrig and West (1986), Kalsbeek *et al.*, (1988), and Hoffman (1989).

Archean igneous and metamorphic activity resulted in the formation of regionally distinctive mineral suites that have been used by humans for thousands of years. Gold showings are widespread in the volcanogenic and sedimentary Archean rocks of Nunavut. Gold is presently mined at several localities in the Slave province near Great Slave Lake but only one mine, Lupin, falls within the southwestern boundary of Nunavut. Soapstone, other sulfide deposits, and showings of Au, Ag, Cu, Zn, Ni and platinum group elements occur in volcanogenic strata from various localities in Nunavut, including the abandoned Ni deposit at Rankin Inlet on Hudson Bay and soapstone from Mary River on Baffin Island (Gibbins, 1982). Metamorphosed Archean sedimentary rocks from Baffin Island and from west of Hudson Bay contain significant deposits of Fe which may one day be economic (Jackson and Sangster, 1987). Diamond deposits (technically much younger deposits but uniquely associated with Archean rocks; pers comm., Wilton, 1996) located west of Hudson Bay are in the final stages of economic and environmental review before mining starts.

Proterozoic Orogens

Suturing of the Archean microcontinents across orogenic zones, including the Thelon, Snowbird, Trans–Hudson and Foxe–Dorset, took place early in the Proterozoic, between 2000 Ma and 1750 Ma. At this time the Archean microcontinents were welded together along distinctive orogenic fronts to form a significant mountainous terrain extending northeast across all of Nunavut (Fig. 6). In formation, the Superior and Slave provinces were subducted forelands with passive margin sedimentary prisms (the Wopmay orogen north of Great Bear Lake and the Penokean orogen far to the south in the Great Lakes region) on the trailing edge, and foreland fold and thrust belts on the leading edge. In contrast, the trapped Rae, Hearne and Burwell provinces were hinterlands subjected to significant tectonic deformation along reactivated Archean structures (Thomas and Gibb, 1985; Hoffman, 1989). Hinterlands, now very deeply eroded to reveal the core of ancient mountains, contain geologic records for major episodes of shearing, thrusting and igneous intrusion. To this day, these features influence the local topography, water flow and quality, and have a direct impact on other broad environmental concerns of Nunavut. In many places where Early Proterozoic strata lie upon the edges of Archean microcontinents, the younger rocks were also folded, metamorphosed, and intruded by plutons as the microcontinents were sutured together to form the present Canadian Shield.

The Thelon orogen, the westernmost hinterland, is a narrow, elongate zone of tectonism extending from the subsurface of southwestern Canada, across the East Arm of Great Slave Lake, and north across Ellesmere Island (Fig. 4). Farther east, the Snowbird Tectonic Zone is a prominent geophysical line trending from southern Canada northeast and east across southern Nunavut and terminating in Hudson Strait, north of Quebec. Where geological data are available, the thrusts, sinistral(?) faults, granulites and mylonites along this line indicate deep crustal burial and suturing of the Hearne and Rae provinces.

The Trans–Hudson orogen is a large, high-grade metamorphic complex formed from the oblique, sinistral collision of the Superior province with Archean provinces located to the north (Hoffman, 1989). Most of the Trans–Hudson orogen is located outside Nunavut, but there are two small areas west of Hudson Bay and in the Belcher Islands where Trans–Hudson strata are identified.

Proterozoic orogenic activity in the eastern reaches of Nunavut on Baffin Island is complicated by branching of the Foxe–Dorset orogens around Archean microcontinents and intrusion of the massive Cumberland granite. Metamorphic strata in this area are quartzite or marble, overlain by thick deposits of lithic sandstones and shales with mafic volcanics near the base. More detailed accounts of the genesis of these Early Proterozoic terrains may be found in van Breemen *et al.* (1987), Hoffman (1989), Jackson *et al.* (1990), and Ross *et al.* (1991).

Inasmuch as the Archean terranes record the collision of microcontinents, the Wopmay orogen on the trailing edge of the Slave province and in the far west of Nunavut preserves one of the oldest records for a complete cycle of sea-floor spreading and orogenesis. Here, rocks formed between 2400 Ma and 2000 Ma show evidence of rifting and marine transgression, with shelf and ocean basin development (Fig. 7). In the later stages of the cycle, between 1900 Ma and 1700 Ma (Bowring and Podosek, 1989), shelf and basin deposits were telescoped together through thrust faulting and intruded with subducted island arc volcanics.

Middle and Upper Proterozoic cratonic sequences round out the remainder of the picture for the Precambrian. Following the Early Proterozoic accretion of Archean microcontinents, the newly formed Canadian Shield was deeply eroded, exposing the roots of its ancient mountain systems. Over the next 1000 m.y. a broad and probably fault-bounded

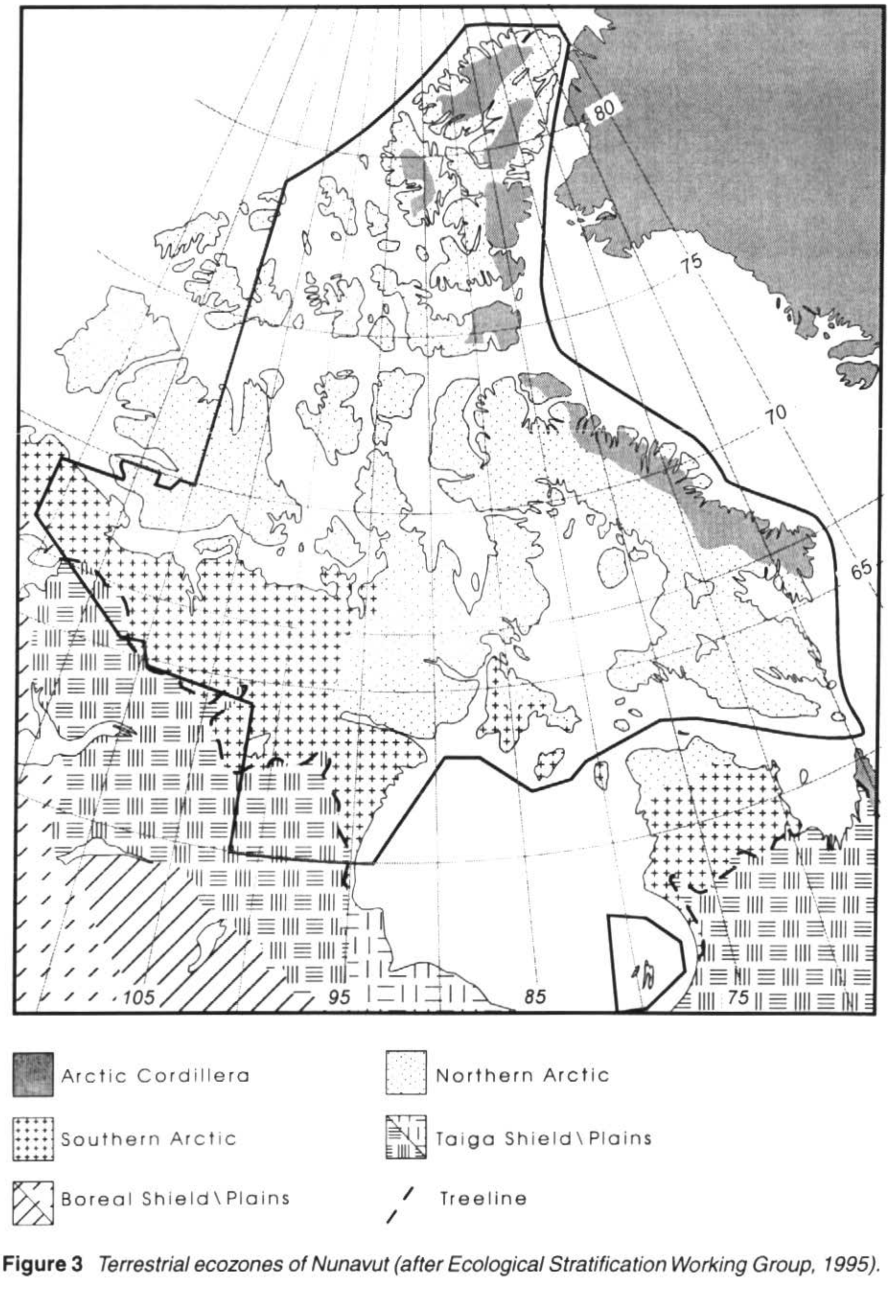

Figure 3 *Terrestrial ecozones of Nunavut (after Ecological Stratification Working Group, 1995).*

flexure, known as the Boothia Uplift, developed along the Boothia Peninsula, swinging south across Southhampton Island and into northern Quebec. Crustal downwarping adjacent to this flexure left rifts and basins filled with several kilometres of terrestrial and marginal marine carbonates, evaporites and clastics. Tholeiitic plateau basalts (Fahrig, 1987), mafic intrusions, and widespread radiating dike swarms are associated with the basins containing the thickest middle and upper Precambrian sedimentary deposits. As a result of this complex geologic heritage, the largest of these basins — the Amundsen, Thelon, Baker and Borden in Nunavut and the Athabasca in Saskatchewan — are important sites for mineralization.

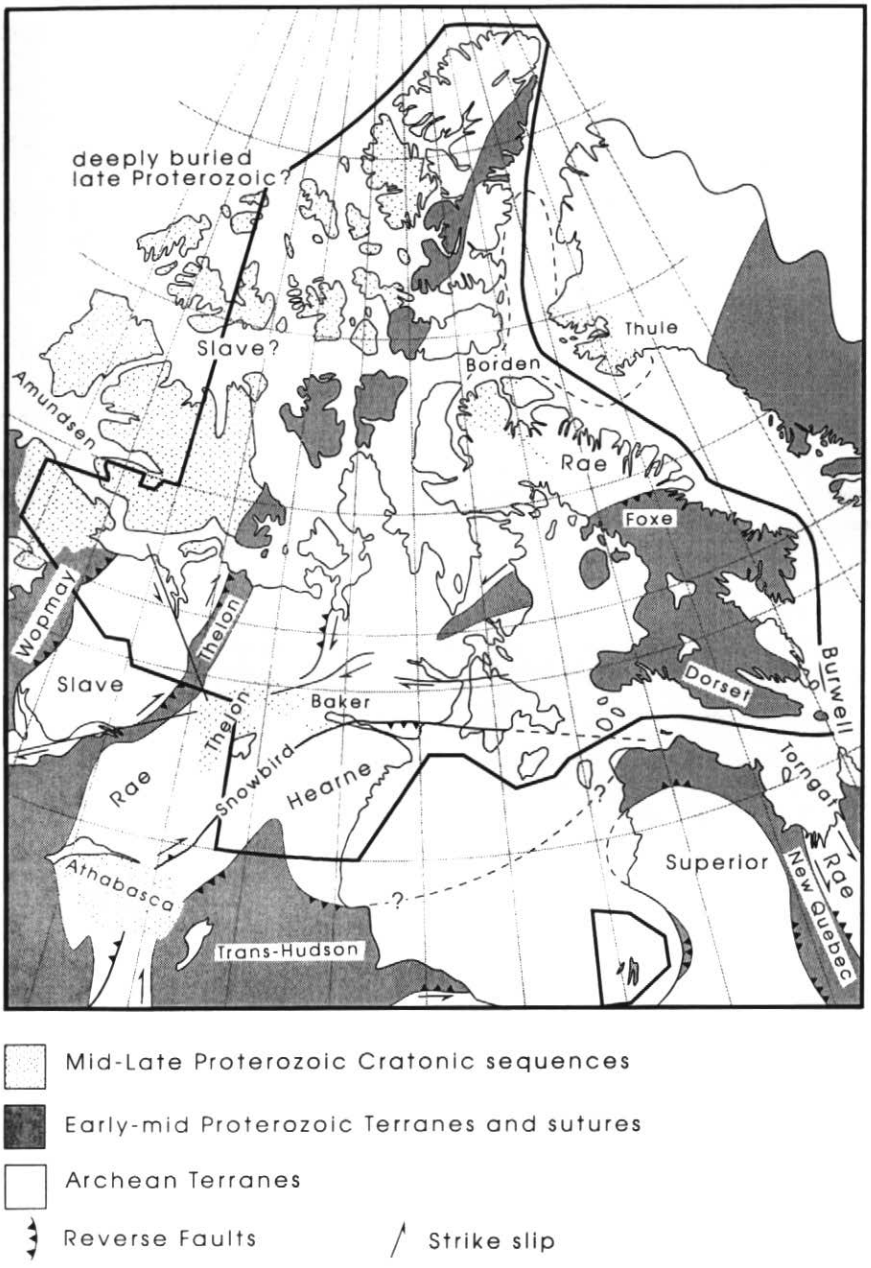

Figure 4 *Regional geology and structure of Precambrian rocks of Nunavut (after Gibb, 1983; Hoffman, 1989).*

Significant U, Cu and Fe occurrences are found throughout the Proterozoic strata of Nunavut. In particular, large Cu and U showings are known from upper Proterozoic volcanigenic rocks lying in the region of Great Bear Lake. Uranium mineralization, frequently identified by surveys of radioactive isotopes naturally occurring in soil and water, raises a host of social issues and questions. Historically, uranium mining has been conducted just outside Nunavut, near Great Bear Lake and near Lake Athabasca in Saskatchewan. A uranium mine proposed for the Baker Lake area west of Hudson Bay has been put on hold until economic and environmental concerns have been adequately addressed. Inasmuch as significant areas of Proterozoic rock on Baffin Island and elsewhere in Nunavut contain very high values of naturally occurring Ni, Cu, Pb, Zn and As in the soil and water (Cameron, 1986), exploration for new deposits is an ongoing process subject to the whims of the economy. At present, there is only one mine in Nunavut that actively exploits Proterozoic mineralization. This is the Nanisivik Mine on northern Baffin Island, a Zn/Pb deposit hosted by Late Proterozoic carbonates (Gibbins, 1991).

Early and Middle Paleozoic Platforms, Basins and Mountains

Following the events of the Precambrian, Paleozoic seas, less than 550 m.y. old, and teaming with macroscopic life, slowly transgressed from the northwest to the southeast across Nunavut where they merged with other seas flooding the Canadian Shield from the St Lawrence Platform on the east, and the Western Can-

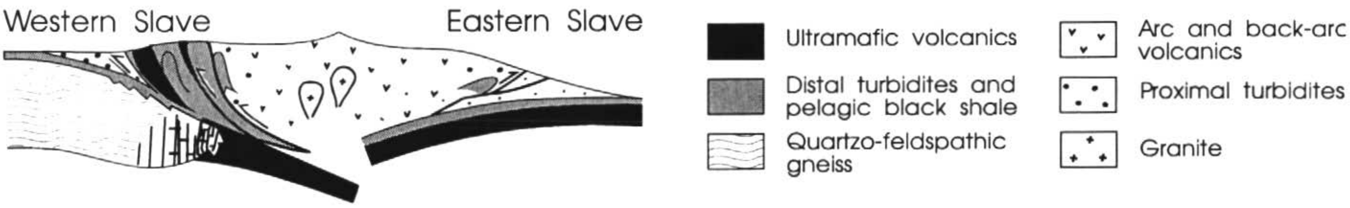

Figure 5 *Tectonic assembly of the Slave Province as a subducted volcanic island arc complex about 2670 Ma (after Kusky, 1990).*

ada Sedimentary Basin on the west.

Two significant lower Paleozoic depositional facies belts, overlain by a widespread middle Paleozoic clastic-dominated foreland succession, are recognized (Fig. 8). In the north on the Queen Elizabeth Islands, lower Paleozoic strata tend to be deep-water open marine deposits and include submarine volcanics. In the south, carbonate and clastic strata are shallow marine shelf and terrestrial deposits. The early Paleozoic shelf edge break varies through time, but was located generally in the southern islands of the Queen Elizabeth Islands along the edge of the Parry Channel (Trettin, 1991a). There, stratigraphic relationships in the transition from shallow water to deep water deposits are further complicated by tectonic deformation within the Franklinian Mobile Belt.

Paleozoic Platforms

At one time or another in the Paleozoic, virtually all of Nunavut was underwater. In the far south of Nunavut, and west of Hudson Bay, thin deposits of marine shelf carbonates are preserved in low-lying depressions on the Canadian Shield. In Hudson Bay, lower and middle Paleozoic shallow marine carbonates and clastics of the Hudson Platform are rarely more than 1500 m thick (Norris, 1993). In the Arctic Islands, the platform rocks are collectively known as the Arctic Platform and include the Foxe Basin west of Baffin Island (Trettin, 1991a). Here, lower Paleozoic shallow marine carbonates about 1000 m thick (Fig. 9), thicken to several thousand metres at the shelf edge to the north and west of Nunavut. In the middle Paleozoic, during and after the Franklinian orogeny, a foreland developed on the shelf edge and platform. In the northern and far western regions, the lower Paleozoic carbonates may be overlain by as much as 4000 m of middle Paleozoic shallow marine shale and terrestrial and marginal marine clastics.

Some of the thickest Paleozoic sections of the Arctic Platform tend to be located on or about the site of the mid- and Late Proterozoic Amundsen Basin, implying continued subsidence in the area. Supporting, if also contrasting, evidence is found on the Boothia Peninsula where the nearby Paleozoic strata contain sedimentary lithologies, facies and tectonic structures which show continued uplift and erosion on this arch (Trettin, 1991a; Okulitch *et al.*, 1991).

The resource potential for Arctic and Hudson platform rocks is largely unknown. In those areas where the rocks have been deeply buried, the rocks may have become thermally overmature and the potential for hydrocarbon production may be lost (Embry *et al.*, 1991). However, on the Hudson Platform, Paleozoic oil shale (Sanford *et al.*, 1993) suggests a potentially mineable resource and a potential source rock for conventional hydrocarbons elsewhere.

Franklinian Basin

In the transition from the shallow marine Arctic Platform to deep marine environments in the Franklinian Basin (Fig. 8), the lower Paleozoic strata of the southern margin of the Queen Elizabeth Islands become clastic-dominated successions, often more than 8000 m thick (Fig. 9). Farther out into the basin, the deep marine successions of pelagic shale, limestone and chert typically are less than 3000 m thick. In many parts of the Franklinian Basin, lower Paleozoic rocks may be overlain by as many as 5000 m of shallow marine and terrestrial clastic sediments, part of a middle Paleozoic tectonic foreland succession.

Far to the north, on northern Ellesmere Island, thrusted slices of volcanic and volcaniclastic strata, suggestive of an island arc origin (Trettin, 1991c) and located well beyond the North American craton, form the northern edge of the Franklinian Basin and the leading edge of an exotic Precambrian crustal block known as Pearya (Fig. 8). The Pearya terrane is not considered to be North American crust; its origins may lie in the European Caledonides (Trettin, 1991c).

With the exception of a small pool of light hydrocarbons in the Bent Horn Field of the Queen Elizabeth Islands (Procter *et al.*, 1984), many of the shelf edge rocks may have been too deeply buried to produce liquid hydrocarbons. Instead, the tendency is for shelf edge carbonates, along the southern edge of the Queen Elizabeth Islands and across Ellesmere Island, to contain Pb/Zn showings (Gibbins, 1991); one mine, the Polaris Mine of Little Cornwallis Island (immediately west of Cornwallis Island; Figs. 8, 9) contains significant Zn reserves in Paleozoic carbonates (Gibbins, 1991). Farther north on Ellesmere Island and Greenland, the distal sedimentary facies and volcanics contain Ba and Cu show-

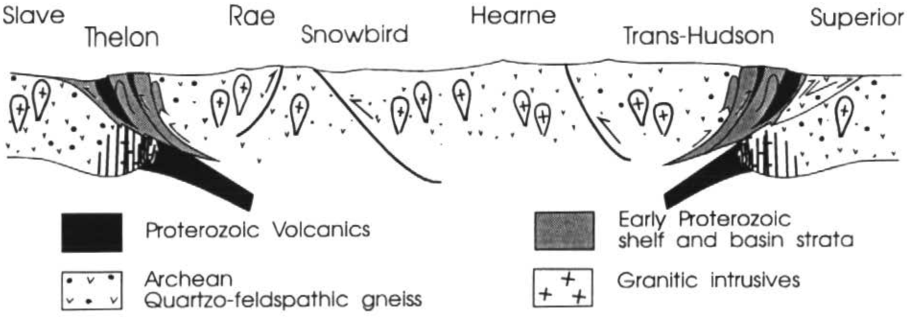

Figure 6 *Schematic cross-section of the assembly of Archean terrains in the Proterozoic.*

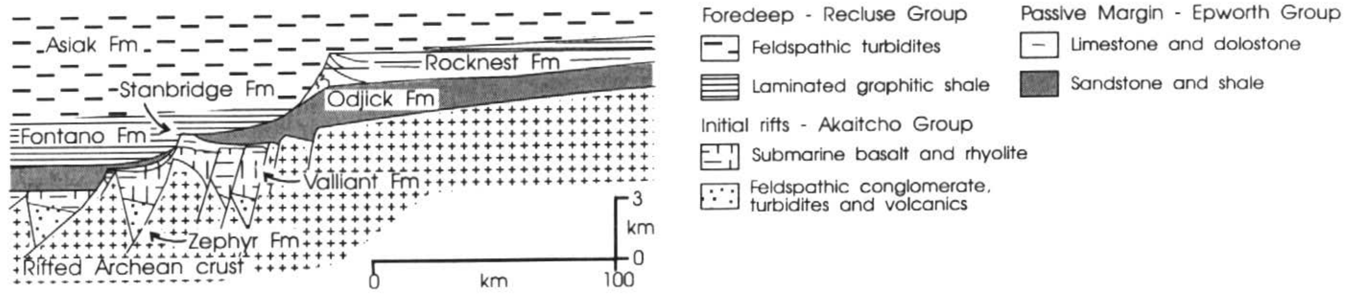

Figure 7 *Restored cross-section of the eastern Wopmay orogen showing rifting, marine transgression and passive margin development about 2000 Ma (after Hoffman, 1989).*

ings (Gibbins, 1991; Steenfelt, 1991).

Franklinian Mobile Belt

At the end of the early Paleozoic and continuing through middle Paleozoic time, a wave of compressional tectonic activity, creating mountains and foreland basins, spread south and west across the Queen Elizabeth Islands and onto the Boothia Peninsula. The ultimate source for this tectonism is still largely unknown, but evidence points to collision and suturing of Arctic Canada with parts of western Siberia (Embry, 1990).

Early in this tectonic history, the exotic Pearya terrane was obliquely and sinistrally sutured to the North American craton (Trettin, 1991c). Granitic plutonism into the newly formed Ellesmerian mountains is not well understood; outcrops of plutonic rocks are only seen on the far northern reaches of Ellesmere and Axel Heiberg islands (Trettin, 1991c).

As orogenic activity continued through the middle Paleozoic, a major foreland basin complex developed on the edge of the southward migrating thrust front. By the end of the middle Paleozoic when Franklinian orogenesis ended, as many as 5000 m of foreland basin clastics of terrestrial and marginal marine origin were deposited over the Queen Elizabeth Islands (Fig. 9).

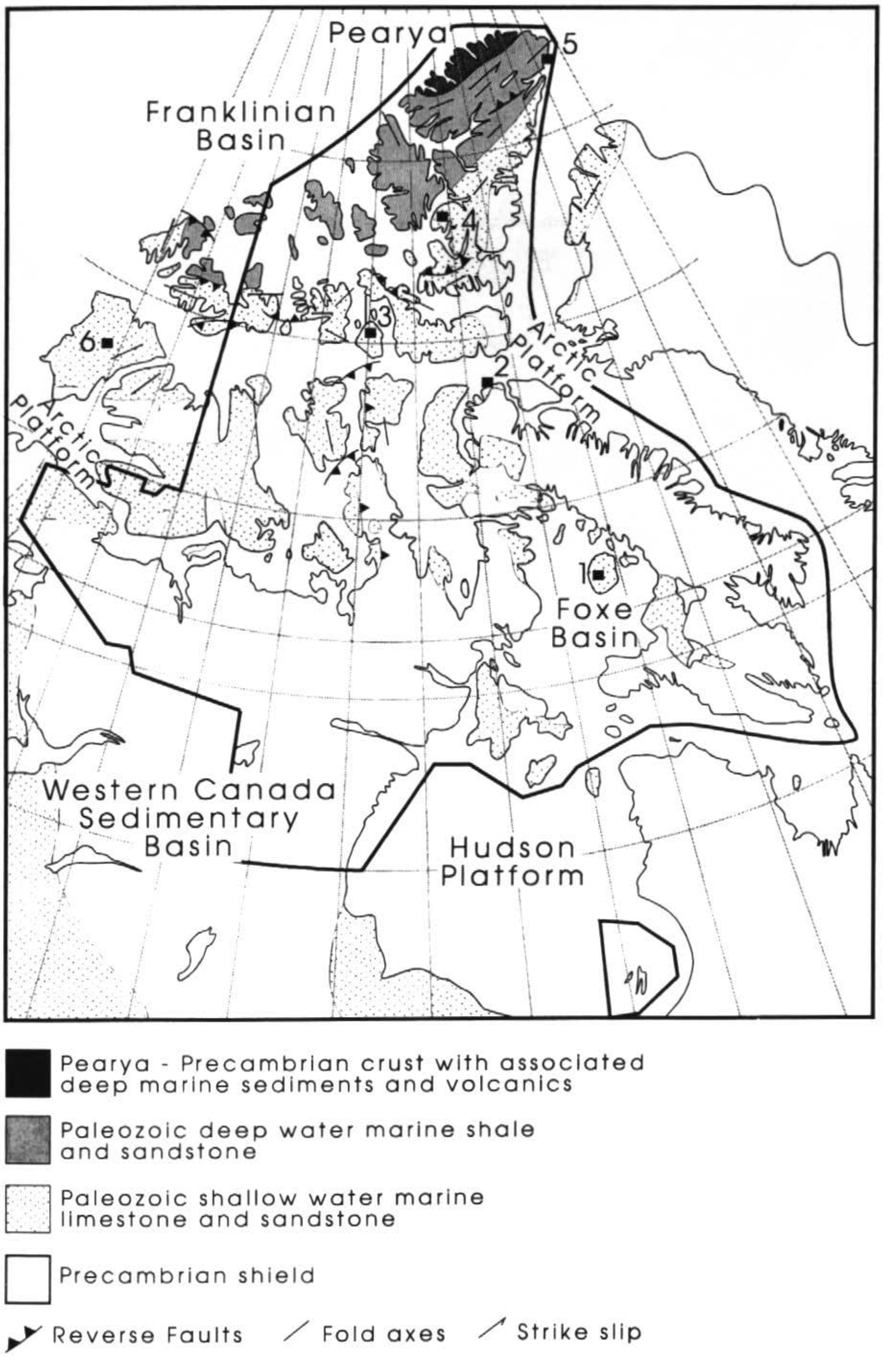

Figure 8 *Regional geology and structure of Paleozoic rocks of Nunavut (modified after Okulitch, 1991; Norris, 1993). Numbers refer to localities identified in Figure 9.*

Late Paleozoic, Mesozoic and Cenozoic Rifting, Mountains and Basins

Following the mid-Paleozoic compressional tectonism which spread across the Franklinian mobile belt on the Queen Elizabeth Islands, rifting, crustal subsidence and extension of the late Paleozoic, Mesozoic and Cenozoic rocks began. Elsewhere in Nunavut, the late Paleozoic and younger eras were characterized by episodes of uplift and erosion in which lower and middle Paleozoic cover was stripped from the continent, leaving conditions much as they were at the beginning of the Paleozoic. Sedimentation was restricted to the Sverdrup Basin on the Queen Elizabeth Islands and later, in the newly formed basins of the Arctic Ocean and Baffin Bay and vicinity.

Sverdrup Basin

Extending in a broad belt from north-central Ellesmere Island across the Queen Elizabeth Islands and onto Banks Island, the Sverdrup Basin and its extension, the Banks Basin, formed a major upper Paleozoic, Mesozoic and Cenozoic depositional site in northern Nunavut. In outline (Fig. 10), this basin is rimmed on the south and southeast by the edge of the Franklinian mobile belt. The northwestern edge, known as the Sverdrup Rim, is an uplifted region on the edge of the Queen Elizabeth Islands and likely represents a remnant of an unknown, and perhaps Siberian, continental plate (Embry, 1990).

Where best developed, the centre of the basin contains more than 12,000 m of strata (Fig. 11). Typically, these deposits are marine and marginal marine shales and sandstones which record numerous marine transgressions and regressions since late Paleozoic time (Embry, 1991). Paleogeography and sediment provenence indicate that, throughout much of the late Paleozoic and Mesozoic, the region was a narrow sea or gulf that opened either to the northeast beyond Ellesmere Island or to the southwest beyond Banks and Prince Patrick islands.

Toward the end of the Mesozoic, the Sverdrup Rim subsided and marine incursions approached from the northwest. In addition, an episode of volcanic activity on northern Ellesmere Island indicates rifting and separation of the Siberian(?) plate along transform faults which end in northwestern Nunavut. Anticlockwise movement on these faults in the Mesozoic and Tertiary created the Arctic Ocean (Embry, 1990).

Cenozoic plate motions associated with the opening of the Arctic and Atlantic oceans led to compression and uplift of the Sverdrup Basin, leaving mildly folded and faulted fluvial and deltaic strata on Banks Island and the Sverdrup Lowland (Fig. 2). The most intensively deformed region lies on Ellesmere Island. Here, complex structures formed by compression which was related to the rotation of Greenland away from Baffin Island and shearing past Ellesmere Island. These structures are attributed to the Eurekan Orogeny (Okulitch and Trettin, 1991).

Significant coal and hydrocarbon deposits, forming upwards of 20% of Canada's national reserves, are regionally extensive in the Queen Elizabeth Islands. Where analyses have been completed, the coal is predominantly high-quality, low-sulphur, low-ash, bituminous and lignitic humic coal (Bustin and Miall, 1991). Hydrocarbon deposits of oil and gas, located both onshore and offshore in the Queen Elizabeth Islands (Embry *et al.*, 1991) pose special problems owing to ice and frigid temperatures. Significant economic and environmental concerns must be addressed before any large-scale developments of these resources will take place.

Baffin Bay and Vicinity

Extensional tectonism, tied to the opening of the North Atlantic in the late Mesozoic, caused rifting in what is now the Baffin Bay region (Fig. 10). In total, more than 14,000 m of fluvial and marginal marine sandstones and marine siltstones and shales were deposited in fault-bounded grabens as the crust was stretched and broken, and Greenland drifted away from Baffin Island (Balkwill *et al.*, 1990). In the south of Baffin Island the Mesozoic and lower Cenozoic strata are covered with more than 1000 m of lower Cenozoic basalt (Burden and Langille, 1990). Farther north, in some of the larger sedimentary basins on and around the shores of Baffin, Bylot and Ellesmere islands, an additional several thousand metres of Cenozoic clastic sediments were deposited in grabens, first as a function of rifting and later as erosion from adjacent horsts as they rebounded to form coastal highlands and mountains (Fig. 11).

The non-renewable resource potential of this area is largely unknown. Small, perhaps locally significant deposits of coal occur in some of the grabens which are found onshore (Bustin and Miall, 1991). Offshore, the sedimentary strata are deeply buried beneath water and glacial deposits and are generally inaccessable. Seismic imaging indicates strata have some potential as hydrocarbon reservoirs (Balkwill *et al.*, 1990) and natural oil seeps found along the coast of Baffin Island indicate petroleum has been produced (Levy and MacLean, 1981). Exploration and development in these ecologically sensitive, frigid, iceberg-infested waters is clearly many years away.

DISCUSSION: SETTING THE STAGE FOR CHANGE

The close correlation between the geology of the region and its present relief, physiography and biogeography is one of the most interesting aspects of Nunavut. Here, many relatively recent geologic events and some very ancient ones remain visible through the limited vegetation and soil which covers the region.

Four distinctive belts of elevated plateaus, highlands and mountains separating three distinctive lowland regions (Fig. 2), and with origins extending well into the Precambrian, exert a basic and yet profound influence on the climate, the flora, and the fauna of Nunavut (Fig. 3). Broadly defined environment change in Nunavut is locally controlled by geological conditions and is predictable.

In the far southwest of Nunavut, the Bear–Slave Upland and the Kazan Upland are Archean terrains located on the southern edge of low-lying Proterozoic terrains known geographically as the Thelon Plain, Back Lowland, and Victoria Lowland. Lowland terrains tend to support more calcophile plants growing on Proterozoic and Paleozoic platform carbonates. However, the most obvious difference lies in the position of the tree line on these southern uplands.

The tree line separating forested regions from the subeconomic shrubby and herbaceous tundra plants is well

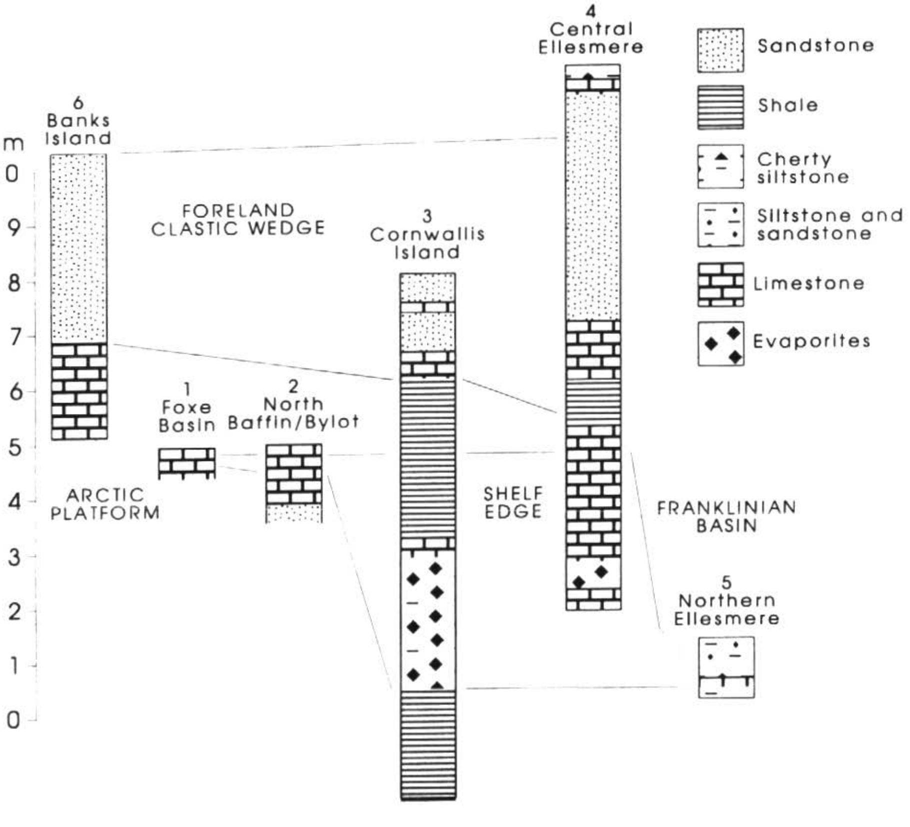

Figure 9 *Generalized stratigraphic columns showing thickness variations and geologic correlations of early Paleozoic strata across the Arctic Platform and into the Franklinian Basin. A thick foreland wedge of late Paleozoic age covers most of the northern Arctic Islands. Lines of correlation are time lines derived from biostratigraphy (after Trettin, 1991b).*

defined both physically and climatically. In a general sense, winter temperatures have little to do with the survival of spruce trees on the tree line; they are well adapted to extreme cold conditions. Instead, it is summer conditions governing growth and reproduction strategies which play a significant role in survival. Simply stated, for spruce to survive, the growing season must exceed 500 growing degree days above 5°C (Wiken, 1986). This corresponds in a general way with the 10°C summer isotherm (Gullett and Skinner, 1992) and the southern limit of the Arctic Front (Edlund, 1987). The fact that the tree line lies on uplands suggests that the summer position of the Arctic Front is confined to open lowland areas. A weakening of the Arctic Front might result in a rapid and significant northward advance of tree line species across the lowlands west of Hudson Bay to the base of the next upland region, defined by the Proterozoic and younger structures which form the Wager Plateau and the Boothia Plateau.

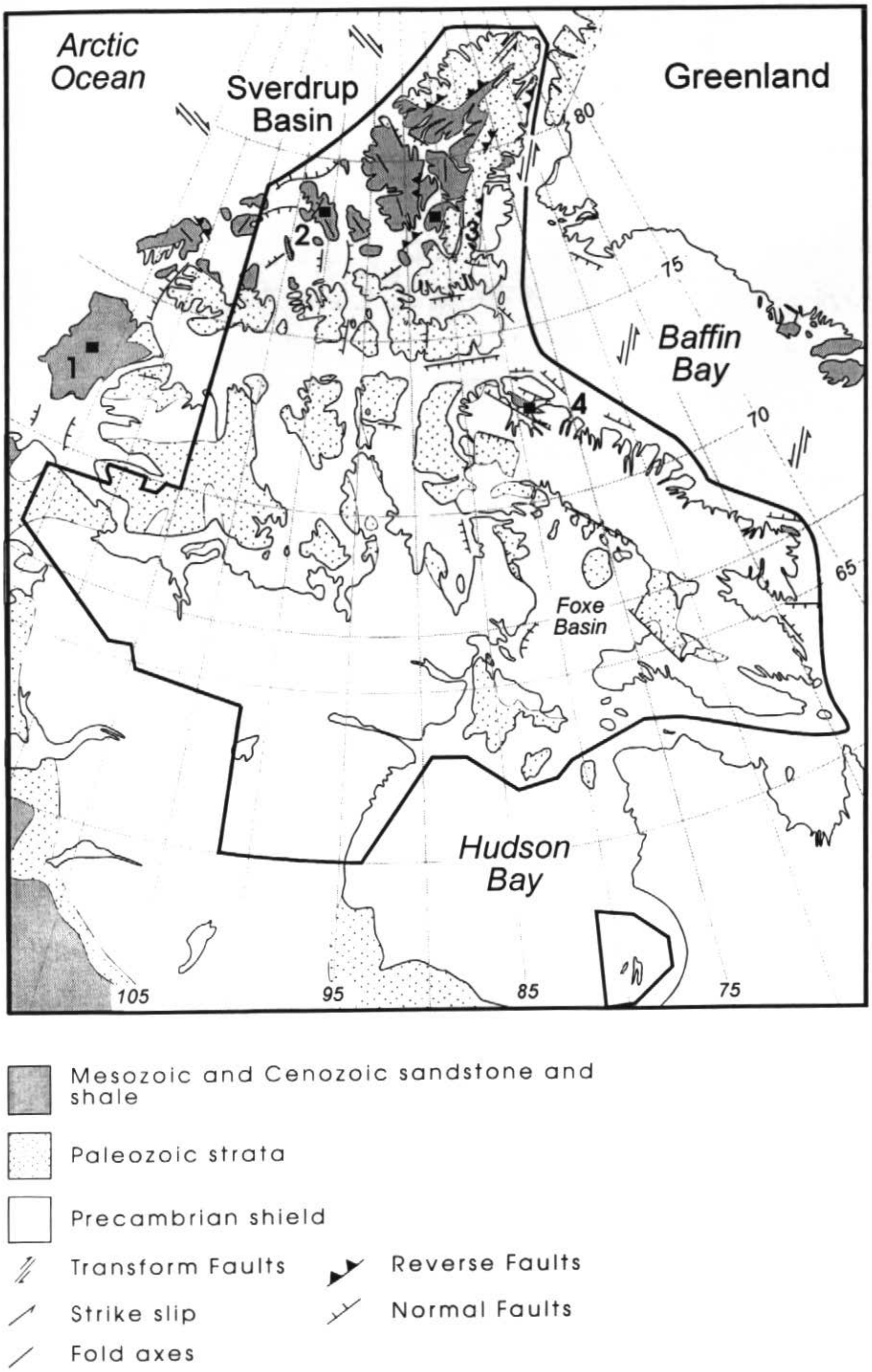

Figure 10 *Regional geology and structure of Mesozoic rocks of Nunavut (modified after Trettin, 1991a; Okulitch and Trettin, 1991). Numbers refer to localities identified in Figure 11.*

Beyond the present tree line the tundra ecozone vegetation is dominated by lichens, sedges, mosses and grasses. Specific ecozones are identified by the occurrence of erect and prostrate shrubs and herbs (Wiken, 1986; Ecological Stratification Working Group, 1995). In addition, given thin or nonexistant soils, subtle differences in the flora occur in regions where calcareous strata form the uplands and plateaus, and significant areas may be essentially unvegetated. With thin soils and little buffering capacity, changes in atmospheric fallout from anthropogenic activities will have various impacts on the region according to its geology.

The tundra flora of the Southern Arctic Ecozone is widely distributed across the exhumed Proterozoic terrains of the Back Lowland and Thelon Plain of southern and southwestern Nunavut. Here, the summer temperatures over a broad area leading up to the arctic coast, the Wager Plateau, and the Boothia Plateau, are normally above 7°C (Edlund, 1987) and an average year might have 40-80 frost-free days (Wiken, 1986). Summer conditions over this broad area are only just below the survival limits for spruce forest. The area is very sensitive to minor temperature fluctuations and the tree line has, in the past, been located farther north (Nichols, 1975).

Typical sites from the Southern Arctic Ecozone contain a flora that is much richer in taxa and more robust than anything the northern tundra has to offer. Diverse species of shrub willow and dwarf birch have erect stems, and may, under certain favorable circumstances, attain heights of 3-6 m (Edlund, 1987). So too, many other species of commonly erect herbs and shrubs of the Ericaceae are widespread in this region (Porsild, 1957). Terrestrial wildlife on this southern tundra is dominated by very large herds of caribou, smaller herds of muskox and, in areas near the tree line, moose. Carnivores include the wolf and barren ground grizzly bear. Coastal regions along the shore of Hudson Bay contain significant numbers of marine mammals and polar bears (Wiken, 1986).

With the possible exception of parts of the Victoria Lowland, where temperature gradients are moderated, there is a sharp contrast between the Southern Arctic Ecozone and the Northern Arctic Ecozone. In general, the Northern Arctic Ecozone is distributed across all of the lowlands and uplands of the Arctic islands and extends onto the mainland along a line of Proterozoic uplands identified as the Boothia Plateau, the Wager Plateau, and the Povungnituk Upland. North of this line temperatures are significantly influenced by polar conditions; summer temperatures average 0-5°C (Gullett and Skinner, 1992) and there are fewer than 20 frost-free days (Wiken, 1986). Birch and other temperature-sensitive herbs do not extend far into this ecozone (Porsild, 1957). Willow and other cold-tolerant plants take on a low stature on the southern Arctic islands. In the region of the Parry Upland on the southern margin of the Queen Elizabeth Islands, willow becomes prostrate and finally disappears on the Sverdrup Lowlands north of the Parry Upland (Edlund, 1987). The Sverdrup Lowlands is an ancient Cenozoic coastal plain where, today, cold, moist air, sourced in the polar ice packs of the Arctic Ocean, spreads across low-lying islands to the base of the Parry Uplands and the Arctic Cordillera. Plants in this area are few in number and diversity; less than 5% of the ground is covered (Edlund, 1987). Terrestrial mammalian wildlife of the Northern Arctic Ecozone is comprised of large and small herds of caribou and muskox widely dispersed across many of the Arctic islands and preyed upon by polar bear, wolves and humans. These animals range widely and some (*i.e.,* the Peary caribou) are distinctive sub-species adapted to high-Arctic conditions. Any lessening of the cold polar conditions present on the Sverdrup Lowlands should have an obvious impact on the flora and fauna of this, and other parts of the, Northern Arctic Ecozone.

The relatively young rifted mountains of the Arctic Cordillera contain the Arctic Cordillera Ecozone. Flora is largely a mixture of lichens, sedges and grasses, with other secondary and normally prostrate herbs. Few calcophile plants occupy these elevated Archean and Proterozoic terrains, and there is little buffering capacity from atmospheric fallout. Plant distribution patterns vary in large part according to moisture availability and temperature, with moisture coming from North Atlantic air and water circulation into Baffin Bay. The average annual growing season is typically less than 125 growing-degree days above 5°C (Wiken, 1986) and bare rock is common. In areas where plants grow, the cooler, drier areas contain more lichens and prostrate herbs; warmer, wetter areas contain more sedges, grasses and erect herbs. Wildlife is largely absent from the rugged, windswept and ice-covered mountains. Fiords and other nearby coastal areas are home to a variety of seabird colonies and are the feeding and calving areas for large marine mammals and polar bears.

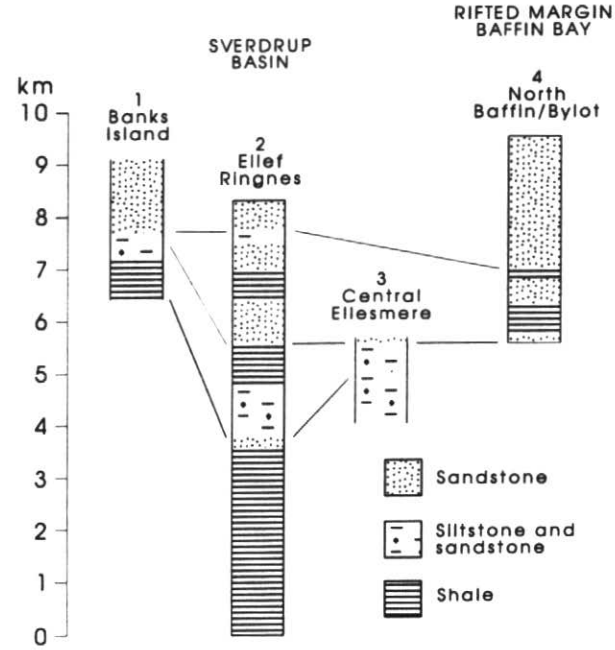

Figure 11 *Generalized stratigraphic columns showing thickness variations and geologic correlations of Mesozoic and Cenozoic strata across the Arctic Platform and into the Sverdrup Basin. Crustal subsidence is most pronounced in the Mesozoic rocks of the Sverdrup Basin. Cenozoic rocks are thickest in grabens in Baffin Bay and vicinity. Lines of correlation are time lines derived from biostratigraphy (after Trettin, 1991b; Burden, unpublished).*

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Accepted as revised 10 January 1997.