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THE GEOLOGY OF MELVILLE ISLAND, ARCTIC CANADA

Editors
R.L. Christie and N.J. McMillan

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Naturally carved head of Hecla Bay sandstone,

Robertson Anticline locality, eastern Melville Island.

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PREFACE

The earliest geological observations of Melville Island were made between 1819 and 1820, during the search for a northwest passage, by members of Captain Parry's crew. It was concluded correctly that most of the rocks were coaly sandstones. During searches for John Franklin and his crew, several more geological discoveries were made in the mid-1800s. In 1908 and 1909 the Canadian Government sent three expeditions to undertake mapping and to attempt to unravel the geology of parts of the Arctic Archipelago.

The Geological Survey of Canada initiated systematic surveys in 1952 in the Arctic. The Survey quickly moved to Melville Island in 1954 to lay the groundwork of stratigraphy and structure as a basis for finding resources. These studies were the geological foundation for oil company exploration. The first wildcat was drilled in 1961 and 1962. This venture was followed by 45 more wells, which resulted in the discovery of three gas fields onshore and offshore Melville Island.

This bulletin encompasses stratigraphic, paleontological, structural and seismic studies and melds them with industry interpretations. The objective is to consolidate scientific knowledge so that the search for more natural resources in the future can proceed with greater success.

Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

PRÉFACE

Les premières observations géologiques de l'île Melville ont été faites en 1819-1820 par des membres de l'équipage du capitaine W.E. Parry qui étaient à la recherche du passage du Nord-Ouest. Ils ont conclu correctement que la plupart des roches étaient des grès charbonneux. Plusieurs autres découvertes géologiques ont été faites durant les années 1850, au cours des recherches effectuées dans l'espoir de retrouver Sir John Franklin. En 1908 et 1909, l'expédition du gouvernement canadien menée par le capitaine J.E. Bernier passait l'hiver sur l'île Melville, profitant de l'occasion pour ajouter au fonds de connaissances géologiques de la région.

Les premiers levés systématiques dans l'Arctique ont été entrepris par la Commission géologique du Canada en 1952. La CGC s'est rendue dans l'île Melville en 1954 afin d'y étudier la stratigraphie et la structure en vue de la prospection des ressources pétrolières et minérales. Ces études ont servi à jeter les bases sur lesquelles se sont par la suite érigées les sociétés pétrolières. On y a foré le premier puits d'exploration entre 1961 et 1962. Par la suite, 45 autres puits ont été forés, ce qui a mené à la découverte de trois champs de gaz dans l'île Melville et au large de ses côtes.

Le présent bulletin regroupe des données d'études stratigraphiques, paléontologiques, structurales et sismiques et des interprétations de l'industrie. Son objectif est de réunir les connaissances géoscientifiques actuelles afin de contribuer au travaux futurs de prospection des ressources naturelles.

Elkanah A. Babcock
Sous-ministre adjoint
Commission géologique du Canada

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Summary

Melville Island was the scene of some of the earliest geographical exploration in the Arctic Islands. The island is, however, remote, and the surrounding channels are usually heavily ice-laden, so that few visitors had touched its shores since its discovery by Europeans in 1819. Air photographs were taken in 1950 and subsequently revealed numerous geological features, including complex fold structures. Reconnaissance field work to study these features was begun soon after by the Geological Survey of Canada. Petroleum exploration began in 1960 with geophysical techniques including seismic, closely followed by the drilling of wells. Geological studies in the sixties and seventies by Survey, oil company, and university field parties improved the understanding of the stratigraphy and structure of the island and surrounding area. A reappraisal of the island was begun by the Geological Survey in 1984, and a new geological map is now available (GSC Open File 2335, 1991).

This bulletin contains descriptions of the structural features and stratigraphy of Melville Island, which have emerged from the recent studies of the island. A summary of the stratigraphy of the island is given by Goodbody and Christie, data being gleaned both from the accompanying papers of this volume and (where appropriate) from earlier reports.

Goodbody then describes in detail the lower Paleozoic strata exposed on Melville Island, with reference to subsurface data from approximately 45 wells drilled on the island and close offshore. Strata of Early Ordovician to Late Devonian age are exposed. From the Early Ordovician to early Middle Devonian, the island region was dominated by a carbonate sedimentary regime succeeded by clastic deposition until at least Late Devonian, when the area underwent folding, uplift and erosion.

Depositional environments for the many units and facies, interpreted from observation of the sedimentary structures and styles, range from fluviodeltaic coastal plain (e.g., Hecla Bay Formation), to submarine fan-continental slope (Blackley Formation) and marine basin (Ibbett Bay and Cape Phillips formations).

Lenz and Borré have included a note on graptolites in the Canrobert and Ibbett Bay formations, which documents the age assignments published in an earlier account of these Lower Ordovician units.

McGregor describes spore-based correlations of Middle and Upper Devonian rocks of Melville Island. Spore assemblages from 41 measured outcrop sections were used. Some of the conclusions from the palynological study are: the Cape de Bray and Weatherall formations are diachronous (as suggested from earlier field work), the contact between the units being of mid-Eifelian age in the eastern part of the island and early Givetian in the west; the Weatherall–Hecla Bay boundary is early Givetian in the east and late Givetian in the west; the Hecla Bay–Beverley Inlet contact is approximately isochronous; and the Parry Islands Formation of eastern Melville Island is late Frasnian to early late Famennian, with no palynological evidence for a disconformity at its base.

The Upper Carboniferous to Lower Permian Canyon Fiord Formation, which forms the base of the post-Ellesmerian, Sverdrup Basin succession is documented by Riediger and Harrison. Canyon Fiord strata are clastics that can be assigned to several facies associations. The characteristics of the associations, from paleocurrent data, suggest initial basin-fill, alluvial fan deposits overlain successively by thick deposits representing alluvial fan, braided stream, tidal flat, and shallow marine conditions. Canyon Fiord beds were deposited both in the Sverdrup Basin and in fault-bounded basins south of the margin of the Sverdrup Basin.

In Embry's review of Triassic-lowermost Cretaceous beds, the account is mainly of units exposed on the island, but it is also based on subsurface data of units truncated at depth. The

Jurassic–lowermost Cretaceous succession is divided into eleven formations, which in turn are grouped in five sequences separated by unconformities. A major unconformity separates the succession from underlying Triassic beds. The sedimentary features suggest offshore marine shelf to nearshore and strandline conditions.

Poulton has provided an extensive biostratigraphic and lithostratigraphic account of Jurassic beds of Melville and nearby Prince Patrick and Borden islands. The beds are discussed stage by stage, with every stage of the Jurassic except the Hettangian (earliest Jurassic) represented by marine fossils. Unconformity-bounded sequences can be recognized. These are thin remnants of thicker units deeper in the Sverdrup Basin. Sea level fluctuations can be interpreted, which hold implications for paleogeographic models of Arctic Canada and northern Alaska. Faunal studies suggest that a landmass separated the two regions in the Jurassic.

Vertebrate remains discovered in 1984 were re-examined and collected in 1985. Russell documents this in a paper describing a plesiosaur (cf. *Cryptoclidus richardsoni*) and an ichthyosaur (*Ophthalmosaurus chrisorum* n. sp.), which are considered to be closely related to taxa in the United Kingdom and the United States.

Goodarzi, Gentzis and Harrison describe the petrography of coals collected from the Upper Devonian Hecla Bay, Beverley Inlet and Parry Islands formations. The coals evidently were of forest swamp type, deposited in a deltaic interdistributary channel setting. Reflectance data indicate a shallower depth of burial than that for Devonian coals of western Melville Island.

Data from a reflection microscopy study of core and cutting samples from wells on Melville Island are given by Goodarzi and Gentzis. The samples represent both lower Paleozoic and Mesozoic strata, and several types of organic matter found in the sample material were used. A wide range of reflectance values indicate mature and overmature stages of hydrocarbon generation.

Coal samples from Lower Cretaceous beds of southeastern Melville Island were studied as polished sections under reflected light, and the results are reported by Goodarzi, Harrison and Wall. The coal, lignite to sub-bituminous in grade, occurs in beds up to 1 m thick. They are liptinite-rich and include a "needle" coal. The coal beds are enclosed in fault bounded outliers of silt, sand, gravel and shale beds of the Isachsen Formation. Deposition in a wet environment, either in a reed marsh or under water, is indicated by the coal components. The sedimentary character of the enclosing beds indicates a variety of nonmarine settings, including point bar, overbank and delta plain conditions. Marine conditions in one section, however (not common in the Isachsen Formation) are indicated by agglutinated Foraminifera typical of brackish marine sites such as back barrier lagoons or estuaries.

Edlund documents the nature and distribution of present day plant communities on Melville Island. The distribution of vascular plants is controlled mainly by the lithological (chemical) nature of the surficial materials and by the intensity and duration of the summer thaw period. The surficial materials consist of in situ weathered bedrock, a feature revealed as uniform banding in satellite imagery. Major changes in vegetation patterns usually coincide with lithological boundaries. Other surface materials that affect vegetation include a veneer of reworked material with additional nutrients due to post-glacial marine submergence, and heavy, blanketing glacial (morainic) deposits on southern Melville Island that mark northward incursions of Laurentide ice.

Plant diversity and abundance vary considerably on the island, exhibiting sensitivity to a complex of climatic factors such as elevation, topographic shelter, inter-island channels, radiation regime, and atmospheric circulation patterns. Five bioclimatic zones were mapped, the vegetation types varying from "unvegetated" (recently emerged from ice or snow) to "woody species and sedges dominant; greatest diversity" (coastal, protected areas with mean July temperatures 5°C or above).

Harrison provides a structural analysis of Melville Island based on surface observations and on well and seismic data. The island is divided into four areas of contrasting structural style: 1) southwest, an area of flat-lying, block-faulted, and homoclinal strata; 2) northwest (Canrobert Hills), an area of tightly folded basinal rocks evidently detached at two levels — a lower detachment in pre-Ordovician rocks (not exposed) and an upper one in the shaly Cape de Bray Formation; 3) central and northeast, an area of open folding in which one to three detachment levels are evident — Cape de Bray shales, evaporites of the Bay Fiord Formation, and a Cambrian or Precambrian stratigraphic level (the last two levels not exposed); and 4) north (Sverdrup Basin), a basin margin homoclinal regional with northern regional dips and some broad, open folds.

The oldest structural elements, deeply buried, are presumed Precambrian open folds apparently truncated by an angular unconformity, evident on seismic records, at a depth of about 9 km. The broad belt of conspicuous folds of northeastern Melville Island — the Parry Islands Fold Belt — was deformed by south-directed compression (Ellesmerian Orogeny) prior to middle Early Carboniferous time. This fold belt is characterized by the classic features of a foreland fold and thrust belt developed on a weak basal detachment.

The Melvillian disturbance took place after the deposition of the basal unit of the Sverdrup Basin, the Upper Carboniferous Canyon Fiord Formation, but pre-dates the Upper Permian Assistance Formation. Deformation during this disturbance, perhaps influenced by the presence of "sub-basins" of deposition (beyond the margin of the Sverdrup Basin) was characterized by the transport of basin fill along thrust faults to overlie, with tectonic contact, adjacent older terranes.

Extensional faults of Cretaceous or younger age intersect the island and are parallel to, or coincident with, linear aeromagnetic anomalies believed to be caused by a swarm of gabbro dykes and sills. Evaporitic intrusions and some faults have been active in Tertiary and even in Recent times.

Sommaire

Certains des premiers travaux d'exploration géographique des îles arctiques ont été menés dans l'île Melville. Toutefois, l'île est éloignée, et les passages qui l'entourent sont souvent englacés; elle avait donc été peu visitée depuis sa découverte par les Européens en 1819. Des photographies aériennes prises en 1950 et après révèlent la présence de nombreuses caractéristiques géologiques, y compris des structures complexes formées par plissement. Peu de temps après, la Commission géologique du Canada (CGC) a entrepris des travaux de reconnaissance en vue d'étudier ces caractéristiques. L'exploration pétrolière a commencé en 1960; on a eu recours d'abord à des méthodes géophysiques, notamment des méthodes sismiques, puis, peu après, au forage de puits. Durant les années 1960 et 1970, la CGC, les sociétés pétrolières et des équipes universitaires ont effectué des études géologiques en vue d'améliorer les connaissances de la stratigraphie et de la structure de l'île et des environs. La CGC a entrepris une réévaluation de l'île en 1984, et on peut maintenant se procurer une nouvelle carte géologique (CGC, Dossier public 2335, 1991).

Le présent bulletin se fonde sur des travaux récents pour décrire les phénomènes structuraux et la stratigraphie de l'île Melville. Un résumé de la stratigraphie de l'île est presenté par Goodbody et Christie; elle se fonde sur des données tirées des autres études de ce volume et, le cas échéant, d'études antérieures.

Par la suite, Goodbody décrit en détail les strates du Paléozoïque inférieur qui affleurent dans l'île Melville; l'étude se fonde sur des données souterraines recueillies dans environ 45 puits forés dans l'île et immédiatement au large de ses côtes. Les strates qui affleurent dans l'île s'échelonnent de l'Ordovicien précoce au Dévonien tardif. À partir de l'Ordovicien précoce jusqu'au début du

Dévonien moyen, un régime sédimentaire carbonaté a prédominé dans la région de l'île; par la suite, la sédimentation clastique a prédominé au moins jusqu'au Dévonien tardif, lorsque la région a été plissée, soulevée et érodée.

Les milieux sédimentaires des nombreuses unités et des nombreux faciès sont interprétés à partir des structures et des styles sédimentaires. Ces milieux englobent une plaine côtière fluviodeltaïque (p. ex., Formation de Hecla Bay), un cône sous-marin/talus continental (Formation de Blackley) et un bassin marin (formations d'Ibbett Bay et de Cape Phillips).

Lenz et Borré ont inclus une étude sur les graptolites des formations de Canrobert et d'Ibbett Bay; elle présente les âges publiés dans une description antérieure de ces unités de l'Ordovicien inférieur.

McGregor décrit la corrélation, fondée sur des spores, des roches du Dévonien moyen et supérieur dans l'île Melville. On a examiné des associations de spores provenant de 41 coupes d'affleurement mesurées. Voici certaines des conclusions découlant de cette étude palynologique : les formations de Cape de Bray et de Weatherall sont diachrones (ce que portent à croire des études antérieures), le contact entre les unités remontant à l'Eifélien moyen dans l'est de l'île et au Givétien précoce dans l'ouest; la limite des formations de Weatherall et de Hecla Bay date du Givétien précoce dans l'est et du Givétien tardif dans l'ouest; le contact entre les formations de Hecla Bay et de Beverley Inlet est approximativement isochrone; la Formation de Parry Islands dans l'est de l'île Melville s'échelonne du Frasnien tardif au début du Famennien tardif, et il n'existe aucun indice palynologique d'une discordance érosionnelle à sa base.

La Formation de Canyon Fiord (Carbonifère supérieur-Permien inférieur), qui constitue la base de la succession post-ellesmérienne du bassin de Sverdrup est décripte par Riediger et Harrison. Les strates de la formation sont de nature clastique et appartiennent à plusieurs associations de faciès. À en juger par des données sur les paléocourants, les caractéristiques des associations portent à croire que les sédiments sont des dépôts de cône alluvial comblant des bassins, que recouvrent successivement des dépôts épais de cône alluvial, de cours d'eau anastomosé, de wadden et de mer peu profonde. Les lits de Canyon Fiord se sont accumulés dans le bassin de Sverdrup et dans des bassins limités par des failles qui se trouvaient au sud de la marge du bassin de Sverdrup.

Embry examine les lits du Jurassique et du Crétacé basal. L'étude décrit principalement les unités qui affleurent dans l'île, mais elle présente aussi des données souterraines sur les unités tronquées en profondeur. La succession du Jurassique-Crétacé basal comporte onze formations qui se groupent en cinq séquences séparées par des discordances. Une discordance majeure sépare la succession et les lits triasiques sous-jacents. Les caractéristiques sédimentaires semblent indiquer que le milieu de sédimentation a varié d'une plate-forme extracôtière à un littoral et à une ligne de rivage.

Poulton a préparé un exposé approfondi de la biostratigraphie et de la lithostratigraphie des lits jurassiques de l'île Melville et des îles Prince Patrick et Borden voisines. Les lits sont examinés étage par étage, chaque étage du Jurassique, sauf l'Hettangien (Jurassique initial), étant représenté par des fossiles marins. On y reconnaît des séquences limitées par des discordances : ce sont des restes peu épais d'unités plus épaisses situées à plus grande profondeur dans le bassin de Sverdrup. On peut interpréter les fluctuations du niveau marin, et ces interprétations influeront sur les modèles paléogéographiques de l'Arctique canadien et du nord de l'Alaska. Les études fauniques portent à croire qu'une masse continentale séparaient les deux régions au Jurassique.

Des restes de vertébrés découverts en 1984 ont été examinés à nouveau et recueillis en 1985. Russell examine ces travaux, et décrit un plésiosaure (cf. *Cryptoclidus richardsoni*) et un ichthyosaure (*Ophthalmosaurus chrisorum* n. sp.), qui sont considérés comme étroitement apparentés à des taxons trouvés au Royaume-Uni et aux États-Unis.

Goodarzi, Gentzis et Harrison décrit la pétrographie de charbons prélevés dans les formations de Hecla Bay, de Beverley Inlet et de Parry Islands, du Dévonien supérieur. Les charbons sont manifestement du type «marécage forestier» et se sont accumulés dans un chenal entre des défluents d'un delta. Les données sur la réflectance indiquent que leur profondeur d'enfouissement est inférieure à celle des charbons dévoniens dans l'ouest de l'île Melville.

Les résultats de l'examen, au microscope à lumière réfléchie, de carottes et de déblais de forage provenant de l'île Melville sont donnés par Goodarzi et Gentzis. Les échantillons représentent des strates du Paléozoïque inférieur et du Mésozoïque, et on a utilisé plusieurs des types de matières organiques qu'ils contiennent. Le vaste intervalle des chiffres de réflectance indique que la génération d'hydrocarbures a atteint les stades de maturité et de maturité avancée.

On a examiné en lumière réfléchie des sections polies d'échantillons de charbon provenant de lits du Crétacé inférieur dans le sud-est de l'île Melville. Les résultats sont donnés par Goodarzi, Harrison et Wall. Le charbon, qui va d'une lignite à un charbon subbitumineux, se présente dans des lits dont l'épaisseur peut atteindre 1 m. Ils sont riches en liptinite et comprennent un charbon «en aiguille». Les lits de charbon sont encaissés dans des buttes-témoins qui se composent de couches de silt, de sable, de gravier et de shale de la Formation d'Isachsen; ces buttes-témoins sont limitées par des failles. Les composantes du charbon témoignent d'une accumulation dans un milieu humide, soit une roseraie ou un milieu subaquatique. La nature sédimentaire des lits encaissants indique une gamme de milieux non marins, y compris des bancs arqués, des lits majeurs et des plaines deltaïques. Toutefois, la présence, dans une coupe, de foraminifères agglutinants typiques de milieux marins saumâtres comme des lagunes d'arrière cordon ou des estuaires, atteste de conditions marines (d'ailleurs peu fréquentes dans la Formation d'Isachsen).

Edlund décrit la nature et la distribution des phytocénoses modernes dans l'île Melville. La distribution des plantes vasculaires est contrôlée principalement par la nature lithologique (chimique) des matériaux en surface et par l'intensité et la durée du dégel estival. Les matériaux en surface se composent de substratum rocheux altéré *in situ*, qui dessine des bandes uniformes dans les images satellites. En général, les changements majeurs dans la végétation concident avec les limites lithologiques. D'autres matériaux en surface influent sur la végétation, notamment un placage de matériaux remaniés enrichis en éléments nutritifs par suite d'une submersion marine post-glaciaire, et des nappes épaisses de dépôts glaciaires (morainiques) dans le sud de l'ile Melville qui marquent l'incursion vers le nord des glaces laurentidiennes.

La diversité et l'abondance des végétaux varient considérablement dans l'île et sont sensibles à une série de facteurs climatiques comme l'altitude, les abris topographiques, les chenaux entre les îles, le régime de rayonnement et la circulation atmosphérique. Cinq zones bioclimatiques sont cartographiées; les types de végétation vont de «non végétalisé» (récemment déneigé ou déglacé) à «predominance d'espèces ligneuses et de carex; diversité maximale» (zones côtières abritées ayant une température moyenne de 5 C ou plus en juillet).

Harrison presente une analyse structurale de l'île Melville fondée sur des observations en surface, sur des données de forage et sur des données sismiques. L'île comporte quatre zones aux styles structuraux variés : 1) au sud-ouest, une zone composée de strates planes, morcellées par failles et homoclinales; 2) au nord-ouest (collines Canrobert), une zone comportant des roches de bassin déformées en plis très fermés qui présentent deux niveaux de décollement, soit un décollement inférieur dans des roches pré-ordoviciennes (qui n'affleurent pas) et un décollement supérieur dans la formation shaleuse de Cape de Bray; 3) au centre et au nord-est, une zone caractérisée par des plis ouverts, où l'on reconnaît entre un et trois niveaux de décollement - les shales de la Formation de Cape de Bray, les évaporites de la Formation de Bay Fiord, et un niveau stratigraphique cambrien ou précambrien (les deux derniers niveaux n'affleurent pas); et 4) au nord (bassin de Sverdrup), une marge de bassin homoclinale caractérisée par des pendages régionaux nord et quelques grands plis ouverts.

Les phénomènes structuraux les plus anciens, profondément enfouis, sont vraisemblablement des plis ouverts précambriens que semble tronquer une discordance angulaire, visible sur les enregistrements sismiques, à une profondeur d'environ 9 km. La vaste zone de plis bien en vue dans le nord-est de l'île Melville - la zone de plissement de Parry Islands - a été déformée par compression vers le sud (orogenèse ellesmérienne) avant le milieu du Carbonifère précoce. Cette zone de plissement présente les éléments classiques d'une zone de plissement et de chevauchement de l'avant-pays formée sur un faible décollement basal.

L'accident du Melvillien a eu lieu après l'accumulation de l'unité de base du bassin de Sverdrup, soit la Formation de Canyon Fiord du Carbonifère supérieur, mais avant le dépôt de la Formation d'Assistance du Permien supérieur. La déformation qui a eu lieu au cours de l'accident, possiblement influencée par la présence de «sous-bassins» de sédimentation (au-delà de la marge du bassin de Sverdrup), a été caractérisée par le transport de sédiments de remplissage de bassin le long de failles de chevauchement jusqu'à des terranes adjacents plus anciens. Les sédiments reposent sur ces terranes avec un contact tectonique.

Des failles de distension d'âge crétacé ou plus jeunes croisent l'île et coïncident avec des anomalies aéromagnétiques linéaires ou en sont parallèles. Ces anomalies sont attribuées à un essaim de dykes et de filons-couches de gabbro. Des évaporites, des intrusions et certaines failles ont été actives au Tertiaire et même au Récent.

INTRODUCTION

R.L. Christie[1]

Christie, R.L., 1993. Introduction; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 7–11.

A field study of Melville Island, Canadian Arctic islands, was begun in 1984 and completed in 1985. Data from the study, with earlier surface and subsurface information (both from wells and geophysical surveys) were obtained with a view to providing information useful in future re-evaluations of the resource potential of Melville Island and environs (Fig. 1). Also, the geological mapping was part of the Geological Survey's ongoing program to map all parts of Canada at a scale of 1:250,000. This bulletin is an account of the stratigraphy and structure of Melville Island. One paper describes the plant communities of the island.

Apparently the first visitors to Melville Island were Dorset and pre-Dorset culture people. This is tentatively established because of the presence of stone tent rings indicative of summer occupation sites in the vicinity of Bridport Inlet and Liddon Gulf. The Bridport Inlet region is also known to possess Thule culture temporary sites. From this scant evidence it can be concluded that between 3000 and 500 years ago the island was periodically visited by hunting parties venturing outward from villages located in the eastern and southern Arctic islands (Schledermann, 1981).

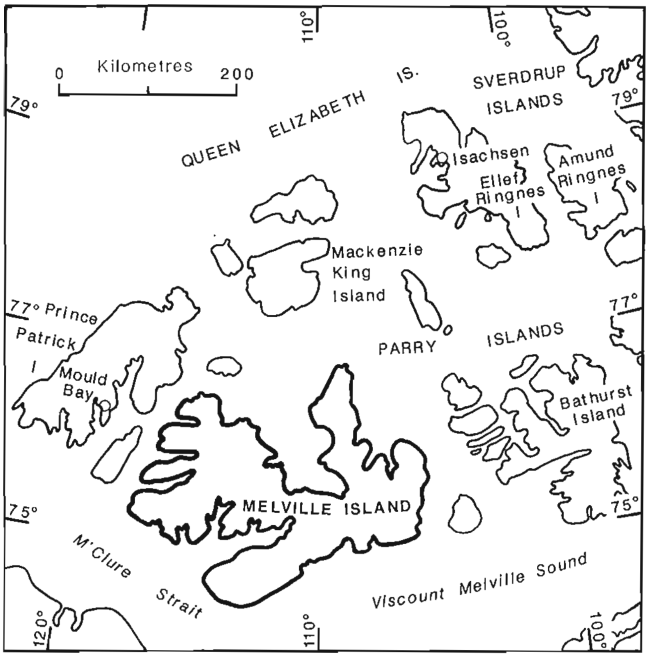

***Figure 1.** Index map, Canadian Arctic Archipelago, showing location of Melville Island.*

Nineteenth century geological discoveries[2]

The earliest geological observations of Melville Island were made during Captain W.E. Parry's search for a northwest passage in 1819–20. Rocks, mostly "being chiefly rolled pieces, or casual fragments", were described by Charles Konig (1824). He correctly stated that most of Melville Island is "fletz" sandstone (evenly flat bedded sandstone) with lesser amounts of limestone. He identified the lustreless coal associated with the sandstone. He made some tentative fossil identifications and concluded that the limestone is the oldest fletz or transition formation. Presumably, he meant the Ordovician.

Later, in the period 1848 to 1859, Captain F.L. M'Clintock made four expeditions to the Arctic islands in the search for Sir John Franklin and his crew. During these voyages some rock samples and fossils were collected. They were later studied by Rev. Samuel Haughton (1857, 1859). Haughton identified Silurian, Carboniferous, and Lias rocks and fossils on Melville Island. Most of the rocks are coal-bearing sandstones referred to the Carboniferous by Haughton because "I do not believe in the lapse of a long interval of time between the Silurian and Carboniferous deposits — in fact in a Devonian period" (1859). Haughton dwelt on the problem of temperature and the availability of light during the Carboniferous and the Lias to produce coal and allow flourishing ammonites.

Fossil plants from the "Carboniferous" sandstones were described by Oswald Heer in 1868.

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[1] RR5, Madoc, Ontario K0K 2K0.

[2] Geological exploration of the Canadian Arctic islands was outlined by Christie and Kerr, 1981.

Twentieth century geological discoveries

It was not until 1908–09 that the Canadian Government made efforts to map and understand the geology of the Arctic islands. J.E. Bernier made three expeditions between 1906 and 1910 to the Arctic in D.G.S. *Arctic*. During the 1908–09 cruise, the geologist J.G. McMillan (1910) made a visit to the southern coast of Melville Island. He collected fossils that were later classed as Carboniferous. This repeated the error made by Samuel Haughton (1857), because we now know the rocks are Devonian.

W.W. Heywood (1955, 1957) of the Geological Survey of Canada, working from the Isachsen weather station on Ellef Ringnes Island in 1952, was the first to establish that the circular features seen on aerial photos are gypsum domes. By extrapolation, the same conclusion held for Sabine Peninsula, Melville Island. Heywood also established names for some of the formations on Ellef Ringnes Island, and these units extend to northern Melville Island.

Systematic study of the Melville Island region by the Geological Survey of Canada (GSC) began in 1954, when E.T. Tozer (1956) carried out geological reconnaissance by dog team from Mould Bay Weather Station on Prince Patrick Island. Tozer mapped part of Sabine Peninsula in 1955, during the helicopter-supported Operation Franklin. In 1958, using a Piper Super-Cub on oversize wheels, he and R. Thorsteinsson completed a reconnaissance stratigraphic study and geological map of the island (and other islands of the Western Queen Elizabeth Group) (Tozer, 1956, 1963; Tozer and Thorsteinsson, 1964).

Applications for permits for petroleum exploration were accepted by the Canadian Government in 1959, and although regulations had not yet been drafted, the applicants were allowed to designate areas of interest and to carry out fieldwork. Several Canadian and multinational groups immediately applied and began both photo-geological and field studies. Notable in 1959 and 1960 were field parties under A. McNair, W. Gallup, and J.C. Sproule, all of Calgary. Arctic Canada's first wildcat well, Dome et al. Winter Harbour No. 1, was spudded in 1961 (completed 1962), and a show of gas was obtained from the Upper Devonian Hecla Bay sandstone.

The United States Geological Survey installed a cable allowing temperature readings. Depth of permafrost was established at 535 m (Taylor and Judge, 1974). The Barrow and Colquhoun gypsum domes of northern Sabine Peninsula were visited and ammonoid fossils obtained in 1961 by J.C. Sproule and Associates. Oil sands were discovered on northern Melville Island in 1962 by A. Spector, then Dominion Observatories Branch, and, later the same year but independently, by H.L. Stephens, a member of a Sproule party. The sands were studied in detail by H.P. Trettin in 1964. W.W. Nassichuk collected ammonoids from Permian beds in 1964 and 1967 and, with collections donated by the exploration companies, he refined the correlation of Permian formations of the island. Stratigraphic sections of Middle Devonian beds (Cape De Bray, Weatherall, and Hecla Bay formations) were measured in 1968 by D.C. McGregor and T.T. Uyeno, at which time palynological and microfossil collections were obtained (Trettin and Hills, 1966, 1967; Nassichuk, 1975; Jones, 1981; McGregor and Camfield, 1982).

The Arctic islands in the 1960s saw geological field work by parties under Texaco, B.P., Elf (Petropar), and Mobil petroleum companies, and some of this work extended to Melville Island.

Panarctic Oils Limited, an industry-government consortium, was formed in 1967, some years after the initial proposals of J.C. Sproule and others. The company inherited Sproule's geological database, and Dome Exploration became the initial operator. Seismic exploration began on Melville Island in 1968, and five wells were drilled on the island in 1969 and 1970. Completion of the successsful Drake Point well in Jurassic sandstone in 1970 marked the discovery of the giant Drake Point gas field (Jones, 1981). Seismic surveys were extended to offshore areas near Melville Island in the early 1970s; some elements of the subsurface structure of these areas were reported and illustrated by Fox (1983, 1985) and by Texaco Canada Resources Limited (1983).

A.F. Embry studied the Devonian "clastic wedge" of Melville and other islands between 1972 and 1975, and in recent years has directed his attention to the subsurface data available from the many wells drilled in strata of the Sverdrup Basin. Q.H. Goodbody measured and sampled stratigraphic sections on Melville Island in the course of a university supported study of Devonian clastic and carbonate formations (Embry and Klovan, 1976; Embry, 1983, 1984a, b, c, 1985a; Goodbody, 1985).

Atlantic Richfield Company carried out stratigraphic studies on the island in 1971 and 1972. In 1973, B.P. Minerals Limited carried out an aerial and ground evaluation of the uranium potential, acting on advice from V. Ruzicka, Geological Survey of Canada. Gamma spectrometry was measured from the air over the entire island, and ground checks were made, mainly in the southeastern parts (R.N. Aitken, pers. comm., 1986).

Fieldwork, 1984-1985

Fieldwork for the Melville project occupied two seven-week summer field seasons, (each commencing in late June and ending mid-August). Field studies were helicopter-supported, based in 1984 at Nias Point, on the south shore of Hecla and Griper Bay, and in 1985 near the head of Ibbett Bay, in the northwestern part of the island. The Panarctic Oils Limited base camp at Rea Point served as a shipping point and, for short periods, as a base for fieldwork. Areal mapping and spot checks of geology were carried out by helicopter reconnaissance. Stratigraphic sections were measured by parties of two, usually setting out by helicopter with a light camp.

The basic field parties had 13 to 15 members, with visiting specialists for short periods each season.

Stratigraphic studies were carried out by Q.H. Goodbody (University of Alberta) and by Jennifer Robson (University of Western Ontario) in both 1984 and 1985, and by Cindy Riediger (University of British Columbia) in 1985. J.C. Harrison [Institute of Sedimentary and Petroleum Geology (ISPG)] was responsible for structural-stratigraphic mapping. Other fieldwork supported by the project included: Jurassic biostratigraphy, T. Poulton (ISPG); Pennsylvanian-Permian biostratigraphy, J. Utting, A.C. Higgins (both ISPG) and P. von Bitter (Royal Ontario Museum) in 1984; collection of plesiosaur and other vertebrate remains, D.A. Russell and C. Kennedy (Canadian Museum of Nature, Ottawa) in 1985; and Lower Paleozoic graptolites, A.C. Lenz (University of Western Ontario). S.A. Edlund (GSC, Ottawa) completed geobotanical studies begun on the island in earlier years. D.A. Hodgson (GSC, Ottawa) and L. Dyke (Queen's University) studied aspects of surficial and glacial geology in 1985, with Gary Parkin and Suzanne Szojka as assistants. Field assistance for the project was provided in 1984 by Jane Bracken, Todd Cross, Sabine Feulgen, and Kathi Higgins; in 1985 by David Christensen, Sabine Feulgen, Linda Haid, Ben Lawson, and Rory McIntosh.

The project was visited in the field by Hans Avé Lallement and John Oldow (Rice University), D.G. Cook and D.K. Norris (both ISPG), Boris Lopatin and Michael Kosko (from the USSR), J. Podruski (ISPG), Susan Aiken (Canadian Museum of Nature), Randall Stevenson (ISPG), R. Thorsteinsson (ISPG), and D. Benson (GSC, Ottawa). H.P. Trettin (ISPG), with Greg Stewart, assistant, visited the field in 1984 to aid in the study of the Franklinian basinal sediments.

A visit to the Ibbett Bay camp was made in 1985 by a "headquarters party" comprising R. Price, Pierre Perron, W.W. Hutchison, G.D. Hobson, and S. Hawkins. A guided geological tour of part of the island was provided for some members of the party.

Camp management and radio operation in 1984 were carried out by David Christensen, and in 1985 by David Diduck.

More detailed accounts of the field operations were included in earlier reports (Harrison et al., 1985; Christie, 1986).

ACKNOWLEDGMENTS

Panarctic Oils Limited provided moral and considerable logistical support for the project. Field operations out of Rea Point (where Bill Jehlke and Truls Lund were camp managers) were aided by Panarctic's equipment operators and by staff of Hofam Catering. The efficiency and helpfulness of the Rea Point personnel were much appreciated; their support contributed in no small way to the success of the fieldwork, which was completed in spite of the disadvantages of short field seasons, great distances, and, in both seasons, numerous periods of foul weather.

Quasar Helicopters pilots Gerry Dionne (1984), Marc Hutchinson, James Clancy, and Endel Sutt (1985) provided transport under variable, often adverse conditions, and engineers Kevin Mahoney (1984, 1985), Shawn Long, Dave Tranelis (1984), Larry Nelson, and C. Arnott (1985) kept the machines in good condition. The virtually trouble-free air support was much appreciated.

Bradley Air Services, from a base at Resolute Bay, provided reliable, regular air freight support for the operation. The ability of pilots Carl Zberg, Duncan Grant, Russ Blomberry, Doug McLeod, Joe McGrath, and Jim Merritt to find the base camps and to land on the improvised airstrips, on occasion in deteriorating weather, provided the potential for legends.

The field parties also acknowledge logistical and radio support by the Polar Continental Shelf Project, based at Resolute.

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SUMMARY OF STRATIGRAPHY OF MELVILLE ISLAND, ARCTIC CANADA

Q.H. Goodbody[1] and R.L. Christie[2]

Goodbody, Q.H. and Christie, R.L., 1993. Summary of stratigraphy of Melville Island, Arctic Canada; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 13–22.

Abstract

The sedimentary rocks of Melville Island can be grouped into three sedimentary successions that were controlled by regional tectonics. The groups are: 1) Infill of the Franklinian Geosyncline (now called the Franklinian Mobile Belt): the rocks are upper Precambrian to Upper Devonian carbonates succeeded by evaporites and black shales. These rocks are overlain by Devonian clastic rocks. The clastic rocks dominated the basin fill from the Middle Devonian until the Ellesmerian Orogeny (Famennian to Viséan). An angular unconformity separates the rocks from the Sverdrup Basin fill above. 2) Sverdrup Basin rocks ranging from Pennsylvanian to early Tertiary. Carboniferous rocks are mainly sandstone, conglomerate and minor limestone. Anhydrite of Pennsylvanian age is exposed in two domes in Sabine Peninsula. Bitumen-bearing Triassic rocks are found on northwestern Melville Island. The youngest rocks of the Sverdrup succession are the Maastrichtian and Paleocene strata of the Eureka Sound Group. 3) Beaufort Formation strata, consisting of gravel and sand containing wood, discontinuously overlie older rocks. They are assigned to the Upper Tertiary — probably Pliocene-Miocene.

Résumé

Les roches sédimentaires de l'île Melville se divisent en trois successions sédimentaires qu'a contrôlé la tectonique régionale. (1) Le remplissage du géosynclinal franklinien (maintenant appelé ceinture mobile franklinienne) : les roches sont des roches carbonatées du Précambrien supérieur-Dévonien supérieur, puis des évaporites et des schistes noirs. Elles sont recouvertes de roches clastiques dévoniennes. Les roches clastiques ont dominé le remplissage du bassin du Dévonien moyen jusqu'à l'orogenèse ellesmérienne (du Famennien au Viséen). Une discordance angulaire sépare les roches des sédiments sus-jacents du remplissage du bassin de Sverdrup. (2) Les roches du bassin de Sverdrup s'échelonnent du Pennsylvanien au Tertiaire précoce. Les sédiments du Carbonifère se composent principalement de grès, de conglomérat et de quantités mineures de calcaire. Des affleurements d'anhydrite du Pennsylvanien se rencontrent dans deux dômes dans la presqu'île Sabine. Des roches bitumineuses du Tertiaire se trouvent dans le nord-ouest de l'île Melville. Les roches les plus jeunes de la succession de Sverdrup sont les strates maastrichtiennes et paléocènes du Groupe d'Eureka Sound. (3) Les strates de la Formation de Beaufort, composées de gravier et de sable contenant du bois, reposent en discontinuité sur des roches plus anciennes. Elles s'échelonnent du Tertiaire supérieur vraisemblablement jusqu'au Pliocène-Miocène.

INTRODUCTION

The papers in this volume describe much of the sedimentary column and tectonic history of Melville Island. A brief overview of the known stratigraphic section will provide a framework for the readers unfamiliar with the geology of the area.

Sedimentary rocks known from outcrop or intersected in wells on Melville Island range from

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[2] RR5, Madoc, Ontario K0K 2K0.

Ordovician to Tertiary. Three sedimentary successions are present. The oldest succession, of late Precambrian to Late Devonian age, forms part of the infill of the Franklinian Geosyncline (now termed the Franklinian Mobile Belt). A younger Carboniferous to Tertiary succession sits with angular unconformity on the Franklinian rocks and infills the Sverdrup Basin. Igneous dykes and sills intrude these deposits. The youngest succession, consisting of outliers of semiconsolidated sand and gravel, and which lies unconformably on Franklinian and Sverdrup rocks, is assigned to the upper Cenozoic Beaufort Formation.

The distribution of the Franklinian and Sverdrup successions of Melville Island is shown in Figure 1. Franklinian deposits lie in open folds throughout much of the island; the folding lessens toward the southwest, where the beds assume a gently dipping or essentially flat-lying attitude. More tightly compressed folds occur in the Canrobert Hills, northwestern Melville Island. The Sverdrup succession forms a gently north-dipping homocline with some slight undulations, which result in flat beds or local southerly dips. Pennsylvanian rocks in northwestern parts of the island are locally warped, the folds in the younger beds parallelling more tightly compressed structures in the unconformably underlying Franklinian succession (see Harrison, *this volume*).

STRATIGRAPHIC AND TECTONIC UNITS

Franklinian successions

Strata of the Franklinian Mobile Belt are widely exposed on Melville Island and occur extensively also in the subsurface (Fig. 1). Seismic evidence indicates limestone, dolostone, evaporites and black shale of

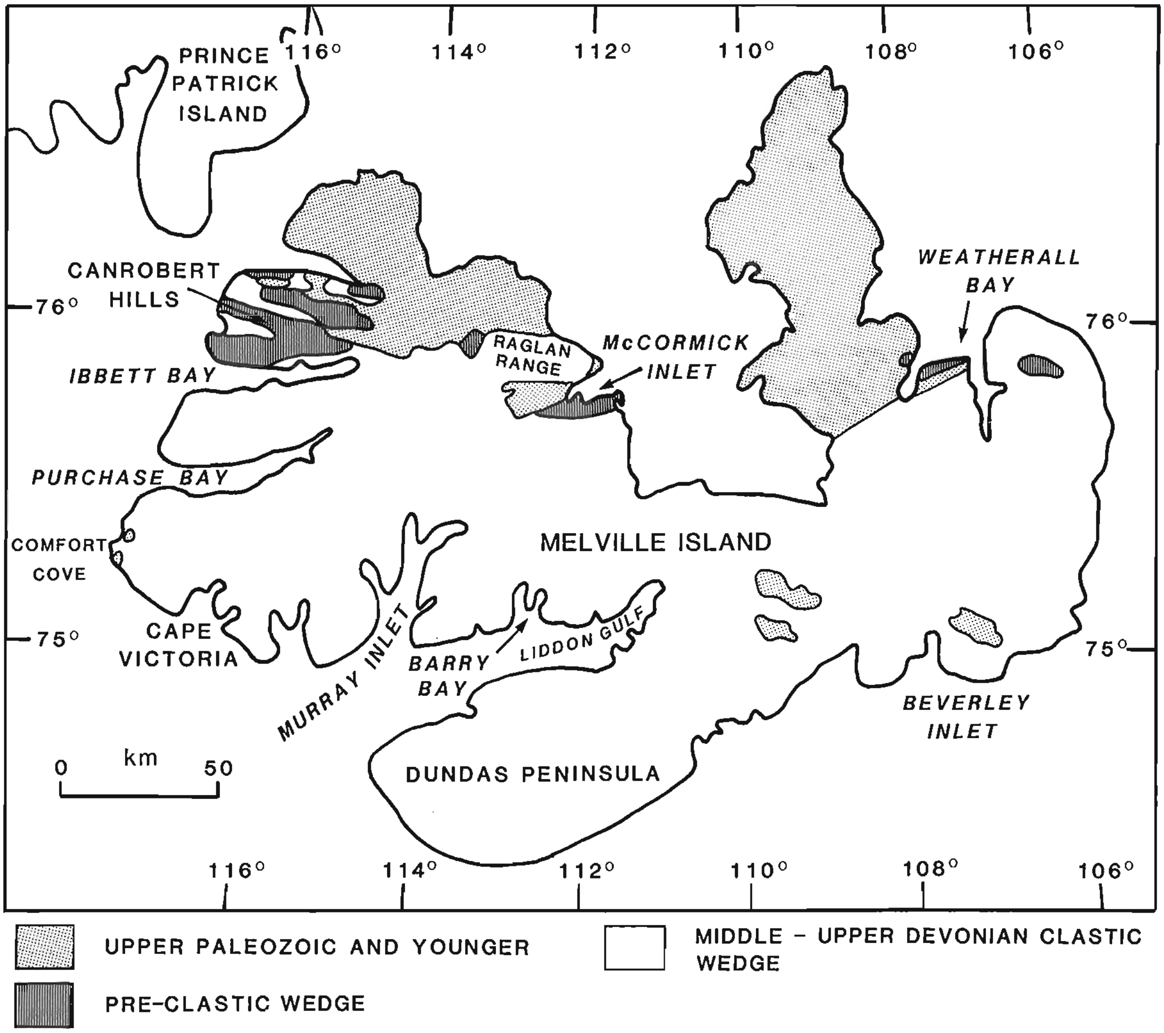

Figure 1. Structural and stratigraphic provinces of Melville Island. (After Harrison et al., 1985.)

Ordovician to lower Middle Devonian age are overlain by a thick succession of clastic rocks of Middle to Late Devonian age. The complete succession is in the order of 7000 m thick.

The Cambrian to Mid-Devonian lower carbonate and black shale part of the Franklinian succession may be divided into three superposed divisions, each of which represents a platform-basin couplet (Figs. 2–4). The oldest division, of pre-late Ashgillian age, comprises surface and subsurface units assigned to the Eleanor River, Bay Fiord, Thumb Mountain and Irene Bay formations, the Canrobert Formation, units 1, 2 and lower portion of unit 3 of the Ibbett Bay Formation, and units 1, 2 and part of unit 3 (as yet unnamed) of a carbonate inlier at the west end of the Raglan Range. The Eleanor River to Irene Bay formations were deposited on a carbonate/evaporite platform that extended over all of eastern and southwestern Melville Island; the platform margin lay in the vicinity of the Canrobert Hills (Figs. 2, 4).

The second division, above the oldest division, includes the upper part of unit 3, all of unit 4, and half

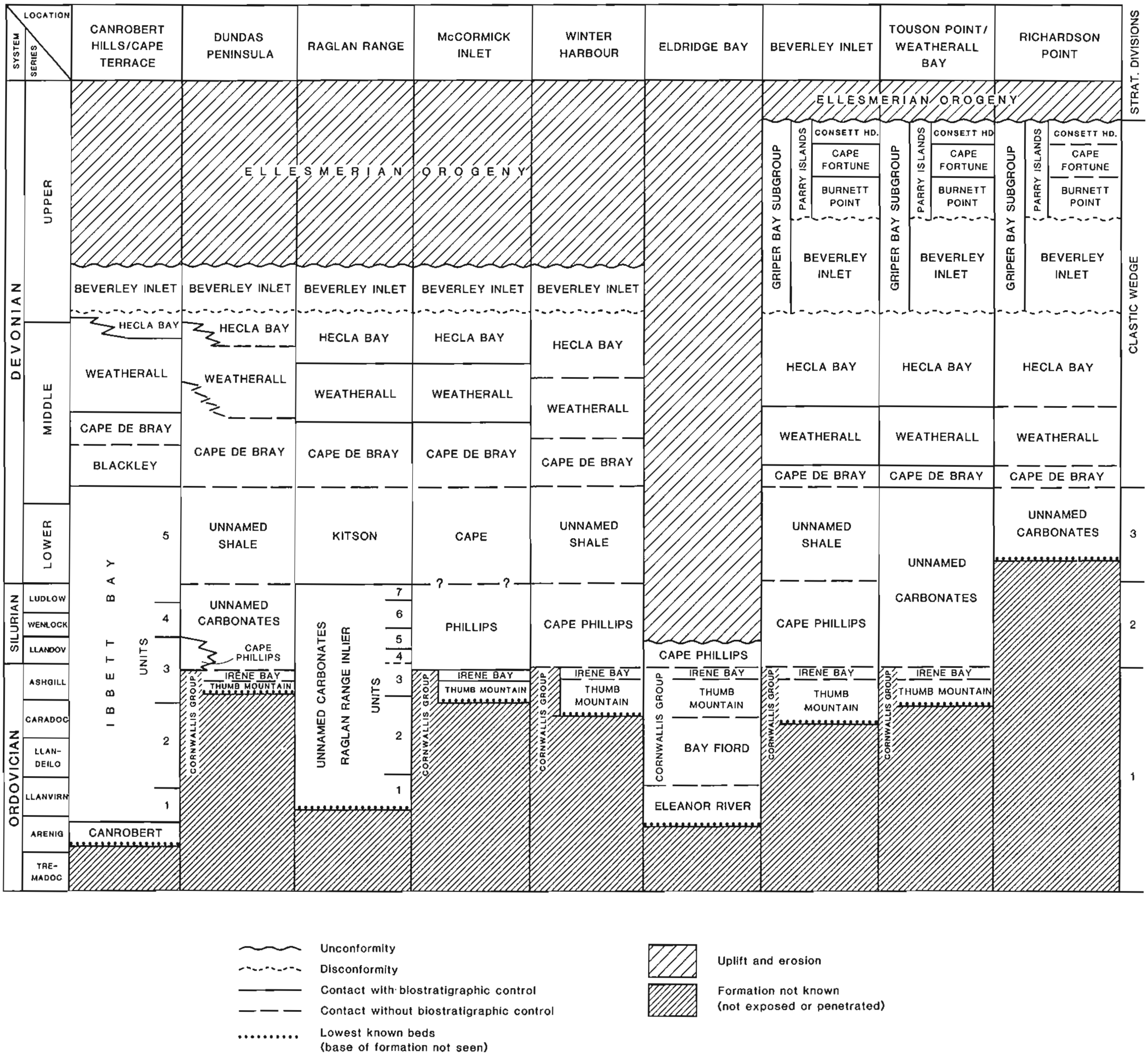

Figure 2. Table of lower and middle Paleozoic formations, Melville Island.

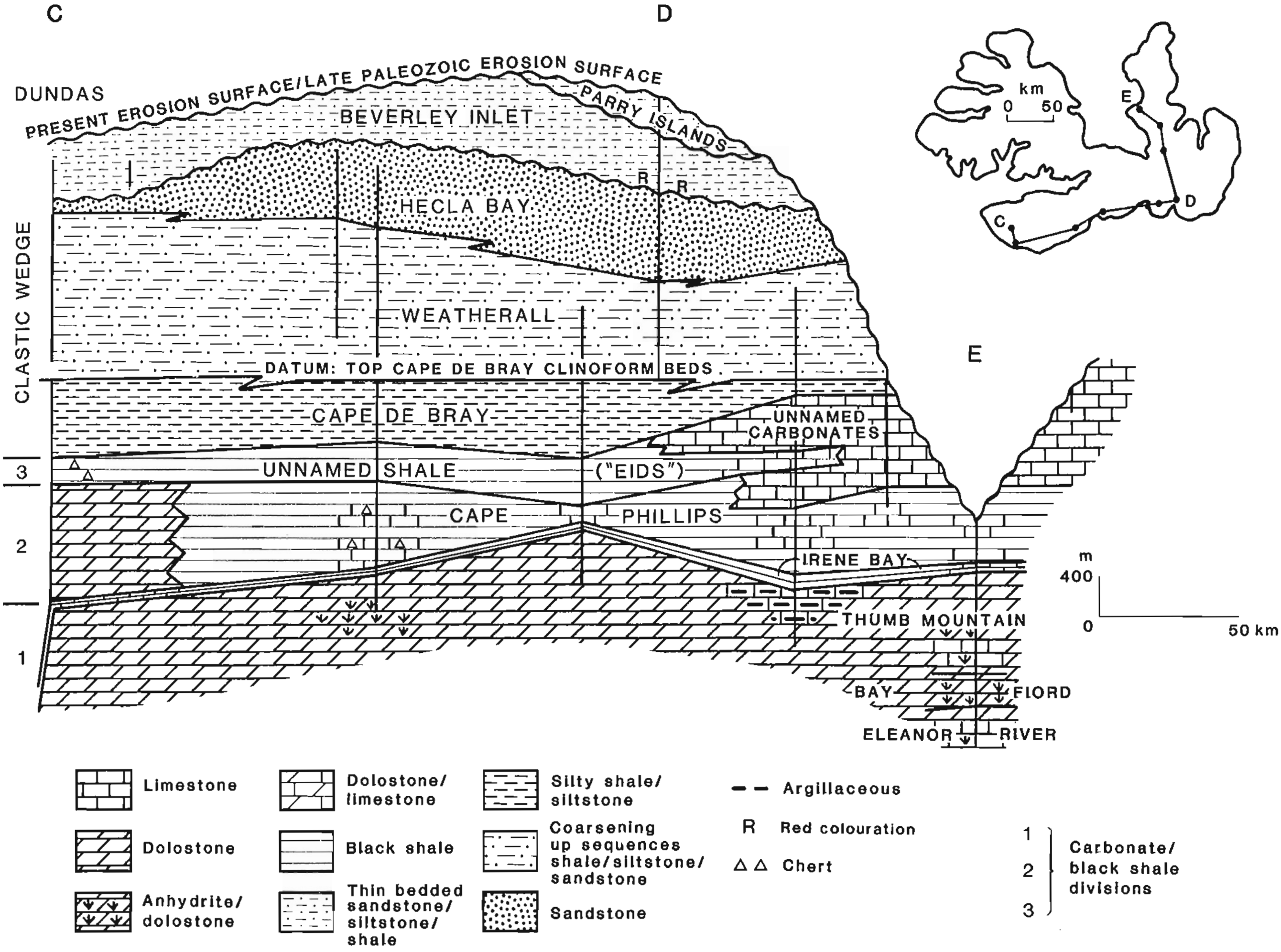

Figure 3. Stratigraphic cross-section, lower and middle Paleozoic of southern and eastern Melville Island.

of unit 5 of the Ibbett Bay Formation, all but the uppermost shales of the Cape Phillips Formation, unnamed carbonates in the subsurface of Dundas Peninsula and exposed carbonates in the vicinity of Tingmisut Lake on northeastern Melville Island, and part of unit 3 and units 4 to 7 of the Raglan Range carbonate inlier. This division is characterized by widespread shale with isolated carbonate buildups in the areas of Dundas Peninsula, the Raglan Range, and northeastern Melville Island (Figs. 2, 3). Deposition of this division extended from latest Ordovician (Ashgill) to latest Silurian (Pridolian) time.

The third division consists of shales in the upper half of unit 5 of the Ibbett Bay Formation, the Kitson Formation, and the upper part of the Cape Phillips Formation in the McCormick Inlet area of west-central Melville Island. Shales of division 3 are more widespread than those of division 2; carbonate platform deposits are confined to northeastern Melville Island, where unnamed limestones and dolostones occur in the vicinity of Weatherall Bay. The third division is mainly Early Devonian in age.

The Devonian clastic rocks that overlie the carbonate and shale sequences (divisions 1-3) form a distinctive succession that has been described as a "clastic wedge" (Tozer and Thorsteinsson, 1964). This clastic wedge reflects a dramatic change in tectonic and sedimentary conditions in the Franklinian Mobile Belt; clastic influx commenced in the early Middle Devonian and the sedimentological regime was dominated by clastic material for the remainder of the basin's history.

The clastic wedge is made up of three sequences (Embry and Klovan, 1976; Embry, 1988a, b). The oldest of these, the Hecla Bay sequence, is composed

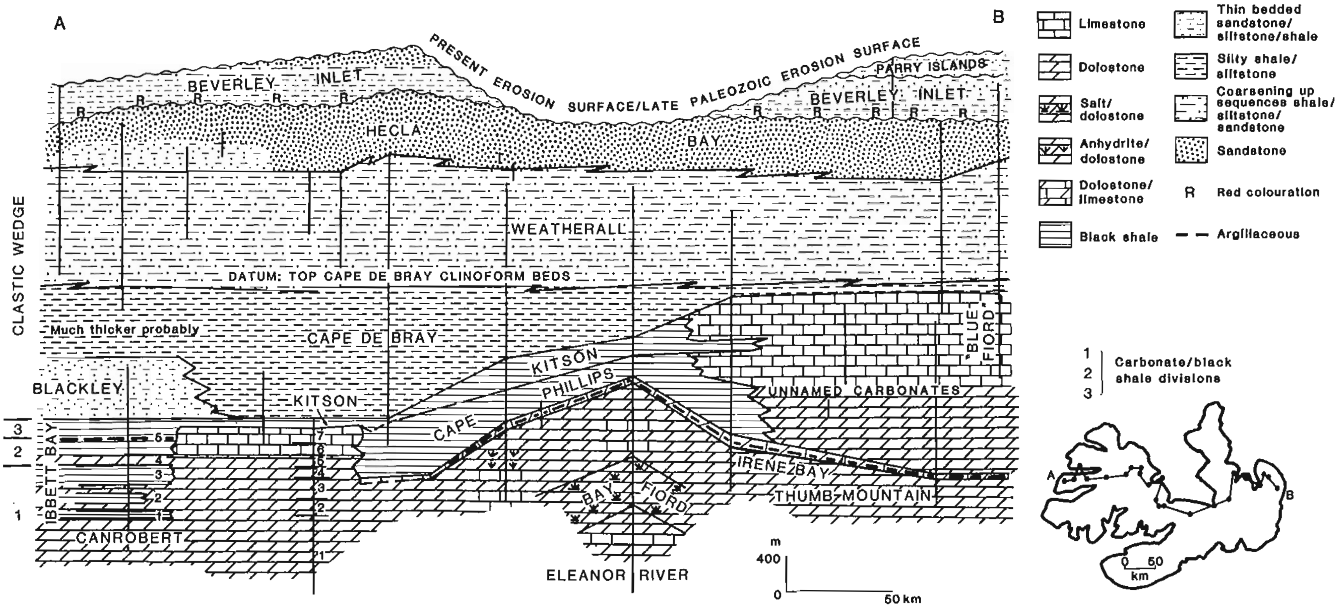

Figure 4. Stratigraphic cross-section, lower and middle Paleozoic of northern Melville Island.

of the Blackley, Cape de Bray, Weatherall, and Hecla Bay formations. A regional disconformity near the Frasnian–Givetian boundary separates the Hecla Bay sequence from the succeeding Beverley Inlet sequence, which is named after its constituent formation. A second disconformity in the upper Frasnian separates the uppermost, or Parry Islands sequence, from the underlying rocks. The youngest preserved rocks of this sequence are mid-Famennian in age (McGregor, *this volume*).

An episode of uplift and folding termed the "Ellesmerian Orogeny" (Thorsteinsson and Tozer, 1960) occurred between Famennian and Viséan times (Harrison, *this volume*). This event terminated deposition in the Franklinian Mobile Belt and resulted in a major angular unconformity between Franklinian rocks and the succeeding deposits of the Sverdrup Basin.

Sverdrup successions

Sedimentary rocks of the Sverdrup Basin in the Melville Island region range in age from Pennsylvanian to early Tertiary and rest with profound unconformity on the Paleozoic Franklinian rocks. The axis of the Sverdrup Basin lay north of present-day Melville Island, which was a basin-margin region. Sedimentary units tend to thicken north- or basinward, where the stratigraphic sections intersected by wells are also more complete. Many units are truncated to the south by unconformities. The exposed section on northern Melville Island is therefore relatively thin and incomplete. The mainly clastic rocks, with some substantial limestone and evaporitic units, have been assigned to 17 formations (Fig. 5) in numerous "sequences" that are bounded by disconformities (see Embry, *this volume*; Poulton, *this volume*).

The exposed basal beds of the Sverdrup Basin succession on Melville Island include up to 830 m of sandstone, conglomerate, and minor limestones of the Upper Carboniferous Canyon Fiord Formation. The formation is mainly Moscovian in age. However, Bashkirian strata are locally preserved at the base and Kasimovian through Sakmarian rocks may be present at the top. The formation has been divided into three members; a lower member composed mainly of coarse breccia, conglomerate, and sandstone; an intermediate member of limestone and marine sandstone; and an upper member comprising sandstone, siltstone and conglomerate. Alluvial fan, lacustrine, shoreface, tidal flat, and shallow marine environments of deposition are represented by various facies (Riediger and Harrison, *this volume*).

Anhydrite occurs in two conspicuous piercement structures on northern Sabine Peninsula: the Barrow and Colquhoun domes. These evaporites, tectonically displaced upward, have been assigned to the Pennsylvanian Otto Fiord Formation by Thorsteinsson (1974). The age was determined from ammonoids collected and studied by Nassichuk (1968).

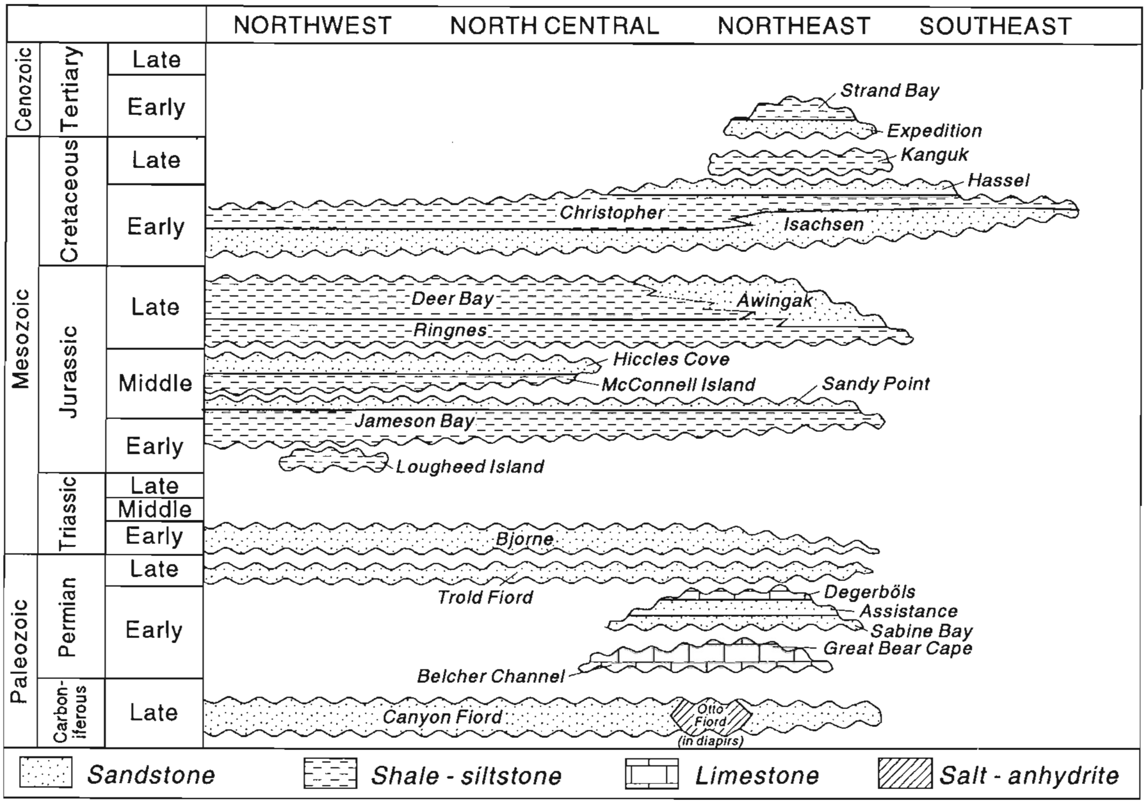

Figure 5. *Table of Carboniferous to Tertiary formations at the surface, Melville Island. (Adapted from Harrison, 1991.)*

In the outcrop belt on southern Sabine Peninsula, the Canyon Fiord Formation is overlain by a succession of Permian beds that includes the Great Bear Cape, Sabine Bay, Assistance, Degerböls, and Trold Fiord formations (Nassichuk, 1965). In the adjacent subsurface, the Belcher Channel Formation occurs between the Canyon Fiord and Great Bear Cape formations. All of these strata consist primarily of limestone, quartz sandstone and glauconitic sandstone of shallow shelf origin that together grade northward in the subsurface to basin facies mudrocks, chert, siltstone, and dark carbonate rocks of the Hare Fiord, Trappers Cove, and Van Hauen formations. The total thickness of this structurally conformable Permian succession is about 700 m on northern Sabine Peninsula and the succession is progressively truncated by Lower Triassic strata across northwestern Melville Island.

The lowest Permian unit exposed at the surface, the Great Bear Cape Formation, comprises about 10 to 90 m of limestone (variably quartzose, coquinoid, and fossiliferous) and calcareous sandstone. The basal contact is interpreted as representing a marine flooding surface. The Sabine Bay Formation, light-coloured, shallow water marine sandstone with lesser chert-pebble conglomerate, disconformably overlies the Great Bear Cape Formation. The unit is generally pale orange (weathering to pale reddish brown), medium grained, thin to thick bedded, commonly crossbedded, and contains layers of detrital coal up to 5 cm thick. Thickness measurements of 6 to 122 m have been obtained on Sabine Peninsula (Tozer and Thorsteinsson, 1964, p. 101; Nassichuk, 1965, p. 10; Thorsteinsson, 1974, p. 51).

The Assistance Formation, 15 to 50 m of mostly dark grey, medium to coarse grained sandstone, rests with presumed disconformity on the Sabine Bay Formation on Sabine Peninsula. Studies of ammonoids indicate a late Early Permian (late Artinskian) age for the unit (Nassichuk, 1965, 1970). The provisional name, "Unit A" was used by Nassichuk for about 90 m of bioclastic limestone that disconformably overlie the Assistance Formation. These strata are assigned to the Degerböls Formation. The Trold Fiord Formation, which gradationally overlies the Degerböls Formation, comprises about 230 m of dark greenish grey glauconitic sandstone and lesser spiculitic chert. Brachiopods collected on Melville Island were assigned a Late Permian (Guadalupian) age (Thorsteinsson, 1974). Trold Fiord beds rest locally with angular unconformity on folded beds of the Canyon Fiord Formation on northwestern Melville Island, and the episode of folding and faulting pre-dating the Trold Fiord Formation has been named the Melvillian Disturbance (Tozer and Thorsteinsson, 1964, p. 209; Thorsteinsson and Tozer, 1970, p. 572).

The Lower Triassic Bjorne Formation rests unconformably on the Trold Fiord Formation. The Bjorne Formation comprises sandstone and lesser conglomerate with minor amounts of red shale; the unit is up to 460 m thick in the west but, together with the correlative Blind Fiord Formation (mudrock) is over 1300 m thick to the northeast in the subsurface. The lower part of the Bjorne Formation weathers to a distinctive and conspicuous red colour that contrasts with the underlying drab Permian beds. The upper, and thicker, part of the Bjorne Formation consists of quartzose sandstone that weathers grey, white, or yellowish brown (Tozer and Thorsteinsson, 1964).

Bitumen deposits were discovered in 1962 in the Bjorne Formation north of Marie Bay, northwestern Melville Island (Fig. 1), and field studies to evaluate the economic petroleum potential were carried out in 1963 and 1964 (see Sproule and Associates, 1964; Trettin and Hills, 1966, 1967). The bitumen occurs in the upper part of otherwise relatively uncemented upper, sandy beds of the formation. The formation forms a wedge, dipping gently northward and bounded both below and above by erosion surfaces. The Bjorne Formation is capped by impermeable Jurassic strata and the oil evidently was trapped in the tilted "pinchout" (Trettin and Hills, 1966).

The Middle and Upper Triassic Schei Point Group is up to 750 m thick in the subsurface (intersected in wells on Sabine Peninsula), but is truncated toward the southern margin of the Sverdrup Basin and does not appear at the surface on Melville Island. The Schei Point Group comprises shale, siltstone, and sandstone representing marine slope and shallow water marine shelf environments (Embry, 1984a, b).

Overlying the Bjorne Formation and separated from it by an erosion surface of marked relief (see Poulton, *this volume*) are four sequences of shale, siltstone, and sandstone formations of Early Jurassic through mid-Early Cretaceous ages (Embry, *this volume*). The sequences provide a record of numerous transgressive-regressive cycles of sedimentation, with the locus of basinal deposition lying north of Melville Island. Sandy, basin-margin facies of the Melville Island region tend to grade laterally into silty and shaly, marine-shelf facies northward, in the subsurface.

The oldest of the Jurassic formations are the Grosvenor Island and the Maclean Strait, Lougheed Island, and King Christian formations, which consist of shale, siltstone, and sandstone. The combined units are in the order of 100 m thick in the subsurface (basinward), but thin southward due to Jurassic erosion so that only a thin and irregular erosional remnant of the Lougheed Island Formation is known in outcrop in northwestern Melville Island.

The overlying sequence consists of a shale–siltstone unit, the Jameson Bay Formation, and a conformably overlying arenaceous unit, the Sandy Point Formation. This sequence attains a thickness near 300 m in the subsurface and thins to 50 m in exposed sections in northern Melville Island. The base of the Jameson Bay Formation rests, toward the basin margin, on an erosion surface (Fig. 5). The upper contact of the Sandy Point is also an erosion surface. This second shale–sandstone sequence ranges in age from late Early to early Middle Jurassic.

A third shale–sandstone sequence comprises the McConnell Island Formation (lower) and the lower part of the Hiccles Cove Formation (upper). The McConnell Island strata overlie an unconformity and the lower Hiccles Cove Formation in turn is truncated southeastward by another unconformity, so that the two units pinch out in that direction. A combined thickness for the two units of 110 m has been measured in the subsurface. The McConnell Island and Hiccles Cove formations are considered to be of late Middle Jurassic age. Plesiosaur and ichthyosaur remains in the Hiccles Cove Formation were collected in 1985 and studied by Russell (*this volume*).

A fourth, and uppermost, Jurassic sequence comprises the argillaceous Ringnes Formation, the sandstone-dominated Awingak, and the cyclical shale, siltstone and sandstone beds of the Deer Bay Formation. A maximum thickness of about 550 m is known in the subsurface and the sequence thins toward the basin margin due to onlap and later erosion, so that only about 300 m are exposed in northwestern Melville Island and about half that on Sabine Peninsula. Sequence 4 beds are of Late Jurassic and Early Cretaceous ages (Embry, *this volume*).

The youngest clastic rocks of the Sverdrup Basin include 6 units: 1) the basal Isachsen, 2) Christopher, 3) Hassel, 4) Kanguk, 5) Expedition and 6) Strand Bay, all of which are formations. The last two formations are part of the Eureka Sound Group. These strata rest on a surface that is an important disconformity. The Isachsen and Christopher beds overstep older units at the margin of the Sverdrup Basin to rest directly on folded Devonian rocks on southeastern Melville Island (Fig. 5; see Goodarzi, Harrison, and Wall, *this volume*). The succession ranges from mid-Early Cretaceous (Barremian) to early Tertiary (Paleocene), based on fossils from Melville and other islands. The Isachsen Formation, a mainly nonmarine sandstone unit that is widespread in the Sverdrup Basin, is represented on Melville Island by 30 to 200 m of weakly consolidated white to grey sandstone that overlies Deer Bay or Awingak beds with an abrupt contact. A lower, coarse grained sandstone, a middle shale-siltstone, and an upper, fine grained sandstone belonging to the Isachsen have been recognized, with coal seams and coal fragments present in the upper member (Tozer and Thorsteinsson, 1964; Embry, 1985). The Christopher Formation, marine grey silty shale with thin interbeds of soft sandstone conformably overlies the Isachsen Formation. The unit ranges from 660 m at surface to over 950 m in the northern subsurface. Eighty to 220 m of unfossiliferous yellow sandstone and lesser shale of the Hassel Formation gradationally overlie the Christopher. Light and dark marine shales, up to 370 m thick, unconformably overlie the Hassel Formation and are assigned to the Kanguk Formation. Fragmentary fish remains are common in this usually poorly exposed unit (Tozer and Thorsteinsson, 1964; Thorsteinsson and Tozer, 1970).

The youngest units of the Sverdrup Basin succession are assigned to the Eureka Sound Group (Ricketts, 1986). At the base is the Expedition Formation, which consists of Maastrichtian and Paleocene, fine to medium grained crossbedded quartz sandstones up to 230 m thick. The upper unit, the Strand Bay Formation, includes up to 50 m of upper Paleocene shale.

Gabbroic dykes intrude the Canyon Fiord Formation on eastern Melville Island; masses or blocks of gabbro, some tabular or arcuate and measuring up to 150 m thick, occur in the evaporites of the piercement structures of Sabine Peninsula (see Tozer and Thorsteinsson, 1964, p. 173). Also, gabbro sheets in Lower Permian strata were intersected in four deep wells on Sabine Peninsula. The dykes and sills appear to be broadly contemporaneous with the pre-Isachsen unconformity (Balkwill and Haimila, 1978). A much wider ditribution of subsurface dykes and sheets is indicated throughout central and eastern Melville Island on aeromagnetic surveys and seismic reflection profiles (Balkwill and Fox, 1982; Harrison, *this volume*).

Deposits of gravel and sand with rare twigs of unaltered to slightly compressed wood have been noted in parts of central Melville Island (see Hodgson, Vincent, and Fyles, 1984) and have been assigned to the late Tertiary Beaufort Formation. The occurrence of marine shell fragments and far-travelled igneous and metamorphic clasts in many of these deposits has, however, introduced uncertainty to the assignment (Harrison, Goodbody, and Christie, 1985, p. 633; Harrison, 1991), and it is unclear to what extent these gravels may include Quaternary glacial outwash.

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LOWER AND MIDDLE PALEOZOIC STRATIGRAPHY OF MELVILLE ISLAND

Q.H. Goodbody[1]

Goodbody, Q.H., 1993. Lower and middle Paleozoic stratigraphy of Melville Island; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 23–103.

Abstract

The stratigraphy of Lower Ordovician to Upper Devonian rocks on Melville Island is divisible into a lower carbonate-dominated portion and an upper clastic portion.

The Lower Ordovician to lower Middle Devonian carbonate-dominated succession consists of three successive shale basin/carbonate platform sequences, each with a distinct distribution pattern for the two megafacies. Platformal carbonates were most widespread in the stratigraphically lowest Sequence A (Lower Ordovician to Upper Ordovician), becoming progressively more restricted to eastern Melville Island through Sequences B (Upper Ordovician to lowermost Devonian) and C (lower Middle Devonian to Upper Devonian).

Middle to Upper Devonian clastic strata abruptly but conformably overlie carbonate Sequence C, and were deposited in a foreland basin, in front of the southwestward advancing Ellesmerian orogenic belt. Three tectonostratigraphic sequences make up this clastic wedge.

The oldest sequence, the Hecla Bay Wedge, is made up of two distinct pulses of sediment influx. Pulse 1 consists of submarine fan/slope turbidites in the extreme western portion of Melville Island, which are coeval with a southwestward prograding shelf system in the eastern portion of the island. Pulse 2 contains slope/outer shelf, mid- to inner-shelf and fluviodeltaic deposits; rocks of this pulse are widely distributed on Melville Island and exhibit southwestward progradation of proximal over distal facies.

The overlying sequence, the Beverley Inlet Wedge, occurs across Melville Island and contains rocks deposited in source-proximal shelf and fluviodeltaic settings. The youngest preserved sequence, the Parry Islands Wedge, is only locally preserved on eastern Melville Island and consists of fluviodeltaic and source-proximal shelf deposits.

A profound angular unconformity, indicating Ellesmerian uplift and erosion, separates deposits of the Franklinian Mobile Belt from succeeding deposits of the Sverdrup Basin.

Résumé

La stratigraphie des roches de l'Ordovicien inférieur-Dévonien supérieur de l'île Melville comporte une partie inférieure, à prédominance de roches carbonatées, et une partie supérieure, clastique.

La succession à prédominance de roches carbonatées, qui s'échelonne de l'Ordovicien inférieur à la base du Dévonien moyen, se compose de trois séquences successives de shales de bassin et de roches carbonatées néritiques, chacune ayant une distribution distincte des deux mégafaciès. Les roches carbonatées néritiques sont le plus étendues dans la Séquence A, soit la séquence stratigraphiquement inférieure (Ordovicien inférieur-supérieur), et sont de plus en plus limitées à

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l'est de l'île Melville dans la Séquence B (Ordovicien supérieur-Dévonien basal) et la Séquence C (base du Dévonien moyen-Dévonien supérieur).

Les strates clastiques du Dévonien moyen-supérieur reposent nettement, mais en concordance, sur la Séquence C de roches carbonatées; elles se sont accumulées dans un bassin d'avant-pays, devant la ceinture orogénique ellesmérienne en progression vers le sud-ouest. Ce biseau clastique se compose de trois séquences tectonostratigraphiques.

La séquence la plus ancienne, le Biseau de Hecla Bay, est le résultat de deux impulsions distinctes d'apports sédimentaires. Dans l'extrême ouest de l'île Melville, l'impulsion 1 se compose de turbidites de cône sous-marin/talus qui sont contemporaines d'une plate-forme en progradation vers le sud-ouest dans l'est de l'île. L'impulsion 2 contient des dépôts de talus/plate-forme externe, des dépôts de plate-forme moyenne-interne et des dépôts fluviodeltaïques; les roches sont très étendues dans l'île et témoignent de la progradation sud-ouest de faciès proximaux sur des faciès distaux.

Le biseau sus-jacent de Beverley Inlet se rencontre partout dans l'île Melville; il contient des roches néritiques déposées près de leur source et des roches fluviodeltaïques. La séquence la plus jeune qui soit conservée, le Biseau de Parry Islands, ne se rencontre que par endroits dans l'est de l'île Melville et se compose de dépôts néritiques accumulés près de leur source et de dépôts fluviodeltaïques.

Une discordance angulaire marquée, qui témoigne de soulèvement et d'érosion ellesmériens, sépare les dépôts de la ceinture mobile franklinienne des dépôts successifs du bassin de Sverdrup.

INTRODUCTION

Sedimentary rocks known from outcrop or intersected in wells on Melville Island range in age from Ordovician to Cenozoic. A summary description of the stratigraphy of these rocks is presented in Goodbody and Christie (*this volume*). This paper describes in more detail the stratigraphy of the Franklinian Mobile Belt, as seen from surface exposures on Melville Island. The reader is referred to Fox and Densmore, 1992; Harrison (*this volume*; Harrison, 1991) for a discussion of the subsurface geology of Ordovician to Devonian beds of the region.

The stratigraphy of the Ordovician to Upper Devonian rocks on Melville Island can be divided into a lower carbonate portion and an upper clastic portion. From Early Ordovician to early Middle Devonian time, the Melville Island area was dominated by a carbonate sedimentary regime. Significant clastic influx commenced in the early Middle Devonian and resulted in a change from a carbonate- to a clastic-dominated sedimentary regime. Clastic sedimentation continued at least until the Late Devonian, following which the area underwent uplift and erosion. This paper is accordingly divided into two parts. The first part is concerned with the Lower Ordovician to lower Middle Devonian carbonates and shales. In the second part, the Middle to Upper Devonian clastic formations are described and discussed.

Acknowledgments

Biostratigraphic determinations were provided by the following Geological Survey of Canada personnel: A.D. McCracken and G.S. Nowlan — Ordovician and Silurian conodonts; T.T. Uyeno — Devonian conodonts; D.C. McGregor — palynology; B.S. Norford — graptolites; A.W. Norris — brachiopods. Age assignments in this paper are not referred in the text to individual paleontologists, but relevant Geological Survey of Canada internal paleontological reports are listed in the bibliography. A.C. Lenz, University of Western Ontario, provided additional biostratigraphic information based on graptolites.

STRATIGRAPHY

Ordovician to lower Middle Devonian carbonates and shales

Carbonate and shale formations on Melville Island belong to three successive shale basin/carbonate platform packages, or sequences, in the Lower and

Middle Paleozoic rocks (Fig. 1). The stratigraphic units included in these sequences are as follows:

Sequence A: the Canrobert, (?)Eleanor River, Bay Fiord, and Thumb Mountain formations, units 1, 2 and part of unit 3 of unnamed carbonates[1] in the Raglan Range Inlier, and members 1, 2 and the lower part of member 3 of the Ibbett Bay Formation.

Sequence B: the upper part of member 3 and member 4 of the Ibbett Bay Formation, the upper part of unit 3 and units 4-7 of the Raglan Range carbonate inlier, the Irene Bay Formation, unnamed carbonates in the Tingmisut Lake Inlier, and the Cape Phillips Formation.

Sequence C: Lower to Middle Devonian unnamed carbonates (earlier assigned to the Blue Fiord Formation by Tozer and Thorsteinsson, 1964), the upper part of the Ibbett Bay Formation, the Kitson Formation, and the upper part of the Cape Phillips Formation of Thorsteinsson and Tozer, 1964.

On account of the considerable regional variation, the stratigraphy and sedimentology of these rocks are described below for five areas on northern Melville Island: the Canrobert Hills, Raglan Range, McCormick Inlet, Tingmisut Lake, and Weatherall Bay (Spencer Range and Towson Point Anticline) areas.

Sequences A and B: Lower Ordovician to Upper Silurian or lowermost Devonian carbonates and shales

Canrobert Hills

The Canrobert Formation and the overlying Ibbett Bay Formation are widely exposed in the Canrobert Hills, northwestern Melville Island. These formations were examined at six localities (Fig. 2).

Canrobert Formation

Description. The Canrobert Formation (>390 m) was named by Tozer (1956) and has since been described by Tozer and Thorsteinsson (1964), and by Robson (1985). It is the oldest formation exposed on Melville Island. The unit is composed of cliff- and felsenmeer-forming, well bedded, light grey dolostones and light to dark grey, variably impure dolostones and dolobreccias (Plate 1a). The formation was examined at localities 2 and 3 (Fig. 2). The base is not exposed. The Canrobert Formation is gradationally overlain by interbedded shales and dolostones of the Ibbett Bay Formation. To distinguish the Canrobert Formation from the lithologically similar member 2 of the Ibbett Bay Formation for mapping purposes, colour was used as the distinguishing characteristic. The Canrobert is yellowish grey on weathered surfaces, whereas the Ibbett Bay is medium brownish grey. Three styles of facies association were observed in the Canrobert Formation, occurring in the following order: 1) breccia beds and interbedded dolostones; 2) laminated argillaceous dolostone; and 3) cyclic repetition of argillaceous dolostone and quartzose dolostone.

1. Breccia beds, up to 57 m thick but generally 0.5 to 4.0 m thick, are the most striking feature of the Canrobert Formation (Plate 1b, c). The interbedding of the breccia bodies with thin and medium bedded dolostones gives the formation a banded appearance (Plate 1a). Breccia clasts are of pebble to boulder grade, angular to subrounded, and consist of light grey dolostone, medium to dark grey argillaceous dolostone, light to medium grey quartzose dolostone and light grey to black chert. The matrix consists of variably silty, micritic dolostone. The breccias are clast- to matrix-supported. A complete range in breccia texture is present, from slight boundinage in the planar bedded dolostone, through "edgewise conglomerates", to chaotic textures and fining-upward trends.

2. Intervals 30-50 m thick of thin bedded, planar to slightly wavy laminated, light and dark grey banded, argillaceous dolostones (Plate 1e) with interbedded arenaceous dolostone turbidites occur between the breccia beds and the hemicyclic facies of 3.

3. A hemicyclic facies repetition, with each hemicycle approximately 6 m thick (Plate 1e, f) is locally apparent. Thin bedded, medium grey, laminated, argillaceous dolostones at the base of each hemicycle grade upward into thicker bedded, light grey, less argillaceous dolostones that locally have boudinage due to soft friable sediment and semiconsolidated sediment disturbance. Above this there is a gradation into ripple and wavy laminated, light grey quartzose dolostones that are abruptly overlain by edgewise conglomerate and breccia beds. Grain size in many cases decreases

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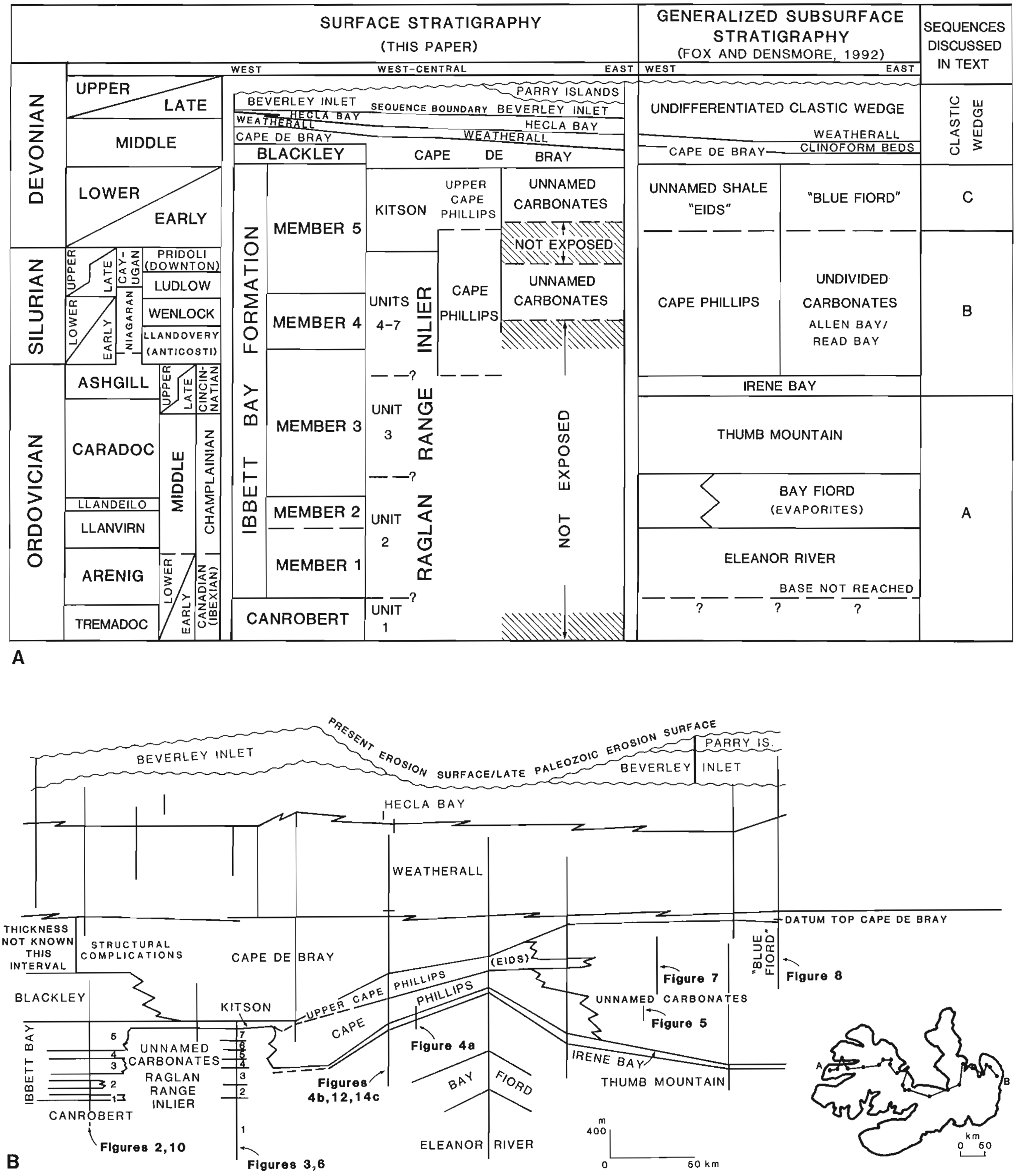
[1] These are unnamed, problematic units, in about the same stratigraphic position as the Cornwallis Group, that require further stratigraphic and biostratigraphic study.



A

B

Figure 1. A. Generalized surface and subsurface stratigraphy and nomenclature of Melville Island. B. Simplified stratigraphic cross-section, Melville Island. Positions of carbonate sections figured in this paper are marked.

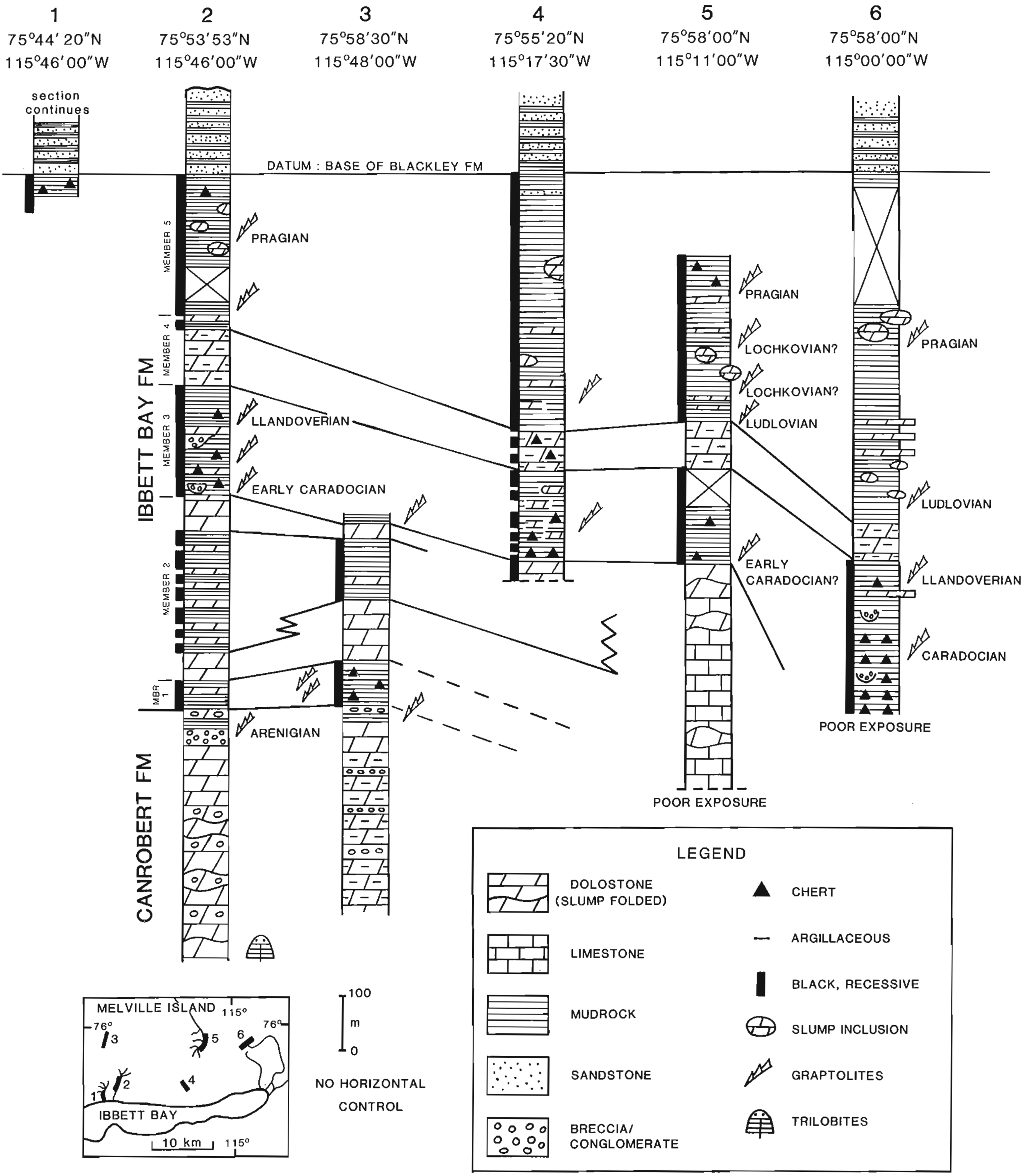


Figure 2. Diagrammatic representation of measured sections of the Canrobert and Ibbett Bay formations, Canrobert Hills, western Melville Island (incorporating the work of Robson, 1985).

upward in the uppermost beds, and the breccia passes into ripple laminated quartzose dolostone. The upper surfaces of the hemicycles are commonly hummocky. Indeterminate bioclastic hash occurs locally in some beds, and a single inarticulate brachiopod was recovered from the basal portion of one such bed. The boundary with the overlying bedded argillaceous dolostones of the basal portion of the succeeding hemicycle is abrupt.

Important bedding features in the formation include synsedimentary slumps on both micro and macro scales (Plate 1d).

Age and correlation. Trilobites from near the base of exposure indicate an Ordovician (Arenigian or Tremadocian) age; conodonts and graptolites taken from the uppermost beds of the formation are Arenigian.

No other units equivalent in age to the Canrobert Formation are exposed on Melville Island. However, probable age-equivalent limestones and evaporites, assigned to the (?)Eleanor River Formation, were penetrated by the Sun KR Panarctic Kitson River C-71, Panarctic et al. Sabine A-07, and Panarctic Eldridge Bay E-79 wells (Goodbody and Christie, *this volume*, Fig. 2).

Environment of deposition. The Canrobert Formation is interpreted as representing sedimentation in the transition between a carbonate platform and a deep-water shale basin.

Ibbett Bay Formation

Description. The Ibbett Bay Formation (1200 m) was named by Tozer (1956) and described by Tozer and Thorsteinsson (1964) (and see Robson, 1985). It is dominated by black shale with subordinate amounts of light grey- to buff-weathering dolostone, dolobreccia, and chert.

A five-fold division of the formation into informal members (Fig. 2) was proposed by Robson (1985).

The contact with the underlying Canrobert Formation is gradational, and is placed at the top of the highest breccia bed underlying the 60–92 m of dark grey-brown to black, thin bedded chert and shale with cherty concretions that constitute member 1 of the Ibbett Bay Formation (Plate 2a). The contact between members 1 and 2 is gradational, the transitional beds consisting of planar laminated and thin bedded, medium to dark grey argillaceous dolostone.

Member 2 (380–460 m) is characterized by light-grey-weathering, variably argillaceous and silty dolostone with minor amounts of interbedded breccia, as in the Canrobert Formation. As previously stated, weathering colour is a reliable mapping criterion to distinguish between the otherwise similar Canrobert Formation and member 2. Slump structures are common (Plate 2b). A three-fold division of the member into basal and capping dolostone units with a medial black shale unit is apparent in the western Canrobert Hills (sections 5, 3 and 2, Fig. 2).

Above a sharp contact (Plate 2b), member 3 (191–300 m) consists of thin bedded (1–5 cm), variably siliceous black shales and cherts. Interbeds, 5–50 cm thick, of light-grey-weathering, variably fossiliferous and impure dolostone (Plate 2c) are commonly graded. Burrowing is locally discernible in the argillaceous chert.

Member 4 (75–110 m) consists of thinly interbedded (3–10 cm) black shales, brown-weathering cherty shales, light grey and greenish grey dolomitic cherts and dark grey to black, variably fossiliferous argillaceous and silty dolostone. The upper and lower boundaries of this member are abrupt. Planar lamination within beds is locally disrupted by subhorizontal bioturbation. Lateral accretion bedding occurs in a cliff section east of section 5 (Fig. 2, Plate 2d). Member 4 is readily recognizable in the field because of its distinctive brown colouring.

Member 5, by far the thickest of the members (325–730 m), is a recessive, black-weathering interval composed mainly of black siliceous and pyritic shales. Variably continuous interbeds of silty, locally pyritic, light-grey-weathering dolostone are common, and large olistoliths of this lithotype (Plate 2e) occur at some horizons.

The top of the Ibbett Bay Formation lies within a 10 m interval of gradational colour and composition change from black shale of the Ibbett Bay Formation to dark brown sandstone, siltstone and shale of the Blackley Formation.

Age and correlation. Graptolites and conodonts in member 1 indicate an Arenigian to Llandeilan/Caradocian age. Conodonts from the lower carbonate unit of member 2 indicate a Llanvirnian/Llandeilan age. Graptolites at the base of member 3 are of early Caradocian age, whereas those collected from the top of the member are of Llandoverian age. Data from conodont studies indicate an age of early Wenlockian (early Late Silurian) to Early Devonian for member 4. Graptolites from 8–20 m above the base of member 4 near Nisbet Point are dated as Ludlovian. Graptolites and conodonts recovered from the base of member 5 are indicative of a Ludlovian age; conodonts 30 m from the top of this member are late Emsian in age.

Members 1 and 2 are approximately age equivalent to units 1 and 2 of the Raglan Range Inlier (described below) and apparently are equivalent to part of the Eleanor River Formation, the Bay Fiord Formation, and part of the Thumb Mountain Formation encountered in the Sun KR Panarctic Kitson River C-71, Panarctic Apollo C-73, Panarctic et al. Sabine Bay A-07, and Panarctic Eldridge Bay E-79 wells (Goodbody and Christie, *this volume*, Fig. 2).

Surface equivalents to member 3 include units 3, 4, and part of unit 5 of the Raglan Range Inlier, and the lower part of the Cape Phillips Formation. Subsurface equivalents include the lower part of the Cape Phillips shales, the lower part of the unnamed carbonates, and carbonates and shales assigned to the Irene Bay Formation and the upper part of the Thumb Mountain Formation encountered in the Sun KR Panarctic Kitson River C-71, Dome Panarctic N. Dundas N-82, Panarctic Dome Dundas C-80, Dome et al. Winter Harbour No. 1, Panarctic Apollo C-73, Panarctic et al. Sabine Bay A-07, Texex King Point West B-53, Panarctic Eldridge Bay E-79, Panarctic et al. Beverley Inlet G-13, and Panarctic Towson Point F-63 wells.

Member 4 has surface age-equivalents in units 5 (in part), 6 and 7 of the Raglan Range Inlier. Subsurface equivalents include part of the unnamed carbonates and Cape Phillips Formation in the above named wells.

Member 5 is possibly partly age equivalent to unit 7 and is definitely age equivalent to the Kitson Formation, as exposed in the Raglan Range Inlier. It is also age equivalent to the uppermost part of the Cape Phillips Formation and unnamed Devonian carbonates in the Spencer Range and Towson Point inliers. Subsurface equivalents include shale and chert in the upper part of the Cape Phillips Formation, and the upper part of unnamed carbonates encountered in the Panarctic Dome et al. Sherard Bay F-14, Dome Panarctic Texex Weatherall O-10, Texex King Point West B-53, Panarctic Towson Point F-63, and Panarctic et al. Richardson Point G-12 wells.

Environment of deposition. The alternation of black shale- and dolostone-dominated members of the Ibbett Bay Formation is taken to represent lateral oscillations between a platform-margin setting (carbonate members) and a basin-margin setting (shale members) in response to carbonate progradation and to changes in sea level.

Raglan Range

Raglan Range carbonates

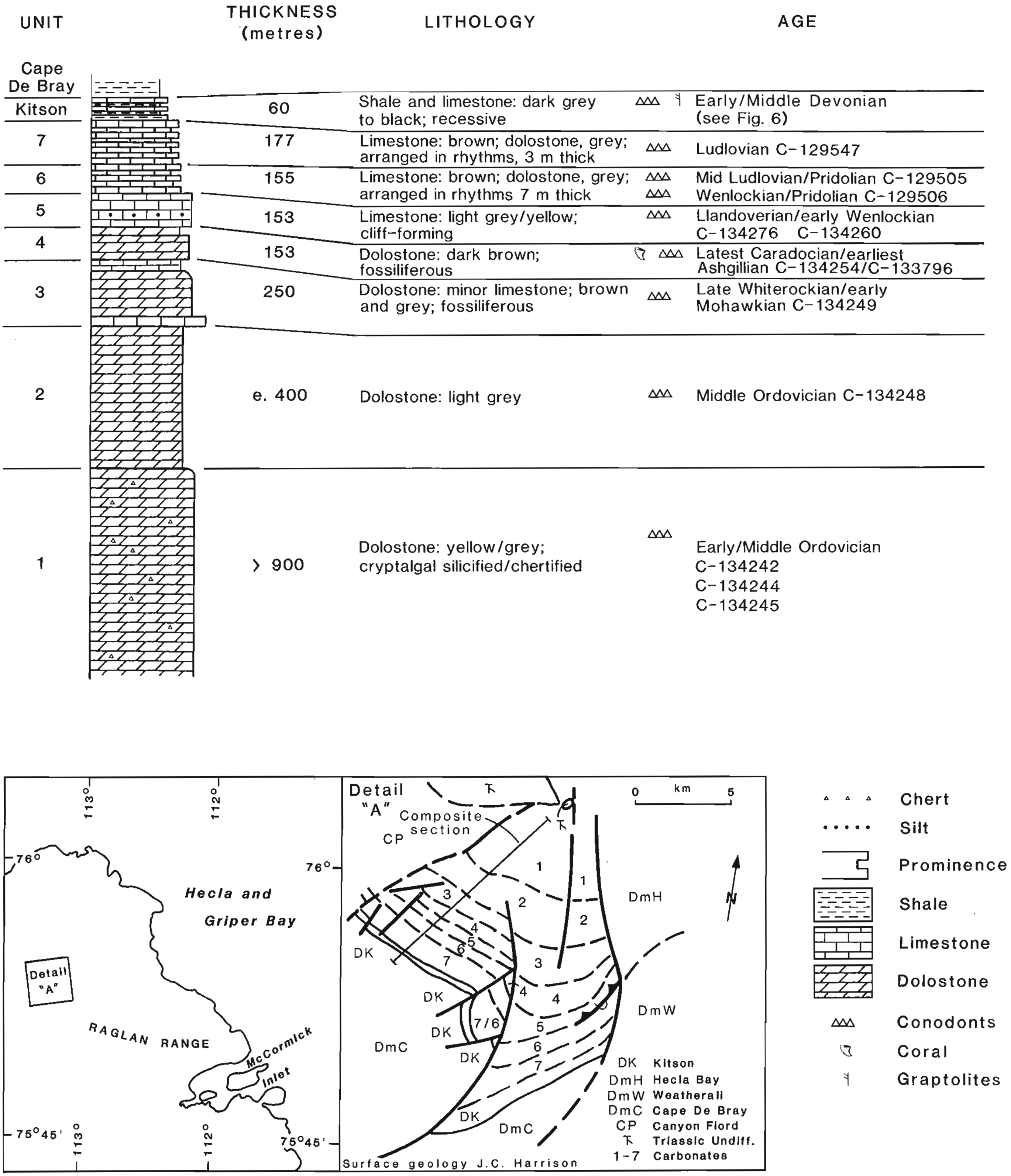
Description. An isolated carbonate inlier on the extreme western edge of the Raglan Range, west-central Melville Island (Plate 3a), exposes 2200 m of Ordovician to Lower Devonian carbonates. The unnamed carbonates of this inlier are herein divided into seven informal rock units based on lithotype and style of facies repetition (Fig. 3, Plate 3b–f). The carbonates are overlain by shales of the Kitson Formation.

Unit 1 (>900 m thick), the lowest in the inlier, consists of cherty, sucrosic, light grey to buff dolostone containing cryptalgal mounds and small-scale slump structures. Shallowing-upward rhythms are locally evident. Unit 2 (about 400 m thick) is composed of light- to dark-grey-weathering, medium bedded, locally stromatoporoidal dolostone that, in places, is almost totally recrystallized, chert veined, and iron stained. Unit 3 (250 m) consists of alternating dark and light grey dolostone and dolomitic limestone containing silicified faunas of halysitid corals, solitary rugose corals, crinoid ossicles, gastropods, bryozoans and receptaculitids. Unit 4 (153 m) comprises dark grey-brown to black, stromatoporoidal dolostone at the base; the unit becomes lighter coloured, more calcareous, and less fossiliferous higher in the section.

The four oldest units are profusely fractured; silicified boxwork fabrics and ochre coloured staining along fault traces are common.

Unit 5 (153 m) is composed of well bedded limestone, locally arenaceous, with massive, laminated, burrowed, fenestral and intraclastic textures. Oolites constitute a minor component. Stromatoporoids, corals, crinoid ossicles and brachiopods are present, but rare. Units 6 and 7 (155 and 177 m thick, respectively) consist of rubbly bedded, dark coloured limestone and light grey to buff dolostone arranged in shallowing-upward hemicycles. Rhythm thickness decreases from an average of 7 m in unit 6 to 3 m in unit 7. Variably rich faunas of stromatoporoids, corals, gastropods and brachiopods are present.

Unit 7 grades abruptly into the overlying, recessive-weathering Kitson Formation.



UNIT	THICKNESS (metres)	LITHOLOGY		AGE
Cape De Bray				
Kitson	60	Shale and limestone: dark grey to black; recessive	ΔΔΔ	Early/Middle Devonian (see Fig. 6)
7	177	Limestone: brown; dolostone, grey; arranged in rhythms, 3 m thick	ΔΔΔ	Ludlovian C-129547
6	155	Limestone: brown; dolostone, grey; arranged in rhythms 7 m thick	ΔΔΔ ΔΔΔ	Mid Ludlovian/Pridolian C-129505 Wenlockian/Pridolian C-129506
5	153	Limestone: light grey/yellow; cliff-forming	ΔΔΔ	Llandoverian/early Wenlockian C-134276 C-134260
4	153	Dolostone: dark brown; fossiliferous	ΔΔΔ	Latest Caradocian/earliest Ashgillian C-134254/C-133796
3	250	Dolostone: minor limestone; brown and grey; fossiliferous	ΔΔΔ	Late Whiterockian/early Mohawkian C-134249
2	e. 400	Dolostone: light grey	ΔΔΔ	Middle Ordovician C-134248
1	> 900	Dolostone: yellow/grey; cryptalgal silicified/chertified	ΔΔΔ	Early/Middle Ordovician C-134242 C-134244 C-134245

Figure 3. Diagrammatic section through the Raglan Range Inlier, north-central Melville Island, showing internal stratigraphy and attributes of the seven composite units. (Incorporating the work of C. Riediger, J.C. Harrison and Q. Goodbody.)

Age and correlation. Units 1 and 2 are assigned a Middle Ordovician age on the basis of conodonts. Corals at the base of unit 3 are of latest Caradocian to earliest Ashgillian age. Conodont samples from the base of unit 4 are of Llandoverian/Wenlockian age. This indicates that the Ordovician/Silurian boundary lies within unit 3. The uppermost beds of the carbonate inlier (unit 7) are apparently Ludlovian.

Surface and subsurface equivalents of these units were discussed above, in the account of the Ibbett Bay Formation (also, see Goodbody and Christie, *this volume*, Fig. 2).

Environment of deposition. With the exception of unit 3, the carbonates in this inlier indicate shallow water, lagoonal to intertidal depositional settings. Unit 3 represents open shelf deposition. The Raglan Range Inlier consists of platform carbonates that are age equivalent to platform margin and basinal deposits exposed in the Canrobert Hills (the Canrobert and Ibbett Bay formations).

McCormick Inlet

Tozer and Thorsteinsson (1964) assigned carbonates and shales exposed on Middle Island, McCormick Inlet, to the Cornwallis and Cape Phillips formations. The Cornwallis Formation was later raised to group status by Kerr (1967).

Cornwallis Group

Description, correlation and age. The Cornwallis Group consists of the Bay Fiord, Thumb Mountain and Irene Bay formations (these units are typified by evaporite, cherty dolostone and limestone, respectively). On Melville Island, evaporites assigned to the Bay Fiord Formation were encountered below 3270 m in the Panarctic et al. Sabine Bay A-07 wildcat well, southeast of McCormick Inlet. Carbonates of the Cornwallis Group exposed on Middle Island are divided into two units (Fig. 4): a lower unit, in excess of 40 m thick, composed of cherty dolostone, and an upper unit, 35 m thick, of variably argillaceous, thin to rubbly bedded, dark coloured limestone (Plate 4c). These two units are tentatively assigned to the Thumb Mountain and Irene Bay formations of other islands, and may correlate with units 2 and 3 of the Raglan Range Inlier. Conodonts indicate a Late Ordovician (Edenian to Gamachian) age for these carbonates. These beds are overlain by a third unit: argillaceous limestone and shale of the Cape Phillips Formation.

Cape Phillips Formation

Description. Thorsteinsson (1958) erected the term "Cape Phillips Formation" for shales, calcareous shales and argillaceous limestones that overlie the Irene Bay Formation on northeastern Cornwallis Island. Shales assigned to this formation in the Panarctic Apollo C-73 well south of McCormick Inlet are 355 m thick. The original sedimentary thickness is uncertain and obscured, because of structural complications. The basal beds of the Cape Phillips Formation are exposed on Middle Island, and the upper part of the formation may be seen in a stream exposure 5 km to the south of McCormick Inlet (Fig. 4).

Dark grey to black argillaceous limestone, in places cherty, which is assigned to the base of the Cape Phillips Formation, overlies medium grey limestone of the Cornwallis Group on Middle Island. The limestones grade, 35 m above the contact, into black, thin bedded shale containing limestone concretions. Beds higher in the formation are covered at this locality.

South of McCormick Inlet (locality 19 of Tozer and Thorsteinsson, 1964), the upper portion of the Cape Phillips Formation is exposed. The unconformable contact between the Cape Phillips Formation and the overlying Canyon Fiord Formation (Carboniferous-Permian) is well exposed here, but beds lower in the Cape Phillips Formation are obscured.

The 134 m of exposed Cape Phillips Formation at this locality consist of light grey-weathering, calcareous, fissile shale, dark grey/brown to black when fresh, containing calcareous concretions. Alteration of this shale to white has occurred beneath the sub-Canyon Fiord Formation unconformity (Plate 4a).

Conformably overlying the calcareous fissile shales within the Cape Phillips Formation is a 110 m thick unit of thinly bedded black chert separated by thinner shale partings (Plate 4b). This unit is interpreted as belonging to carbonate/shale sequence C, and is termed the "Upper Cape Phillips Formation." It is more fully described later in this paper under Sequence C.

Age and correlation. Conodonts from 10 m above the base of the Cape Phillips Formation on Middle Island are of probable Late Ordovician age, and a sample from 20 m above the base of the formation yielded conodonts indicative of a late Llandoverian to earliest Wenlockian age. Graptolites from 25-45 m above the base of the formation at the same locality are indicative of the late Llandovery. Monograptids,

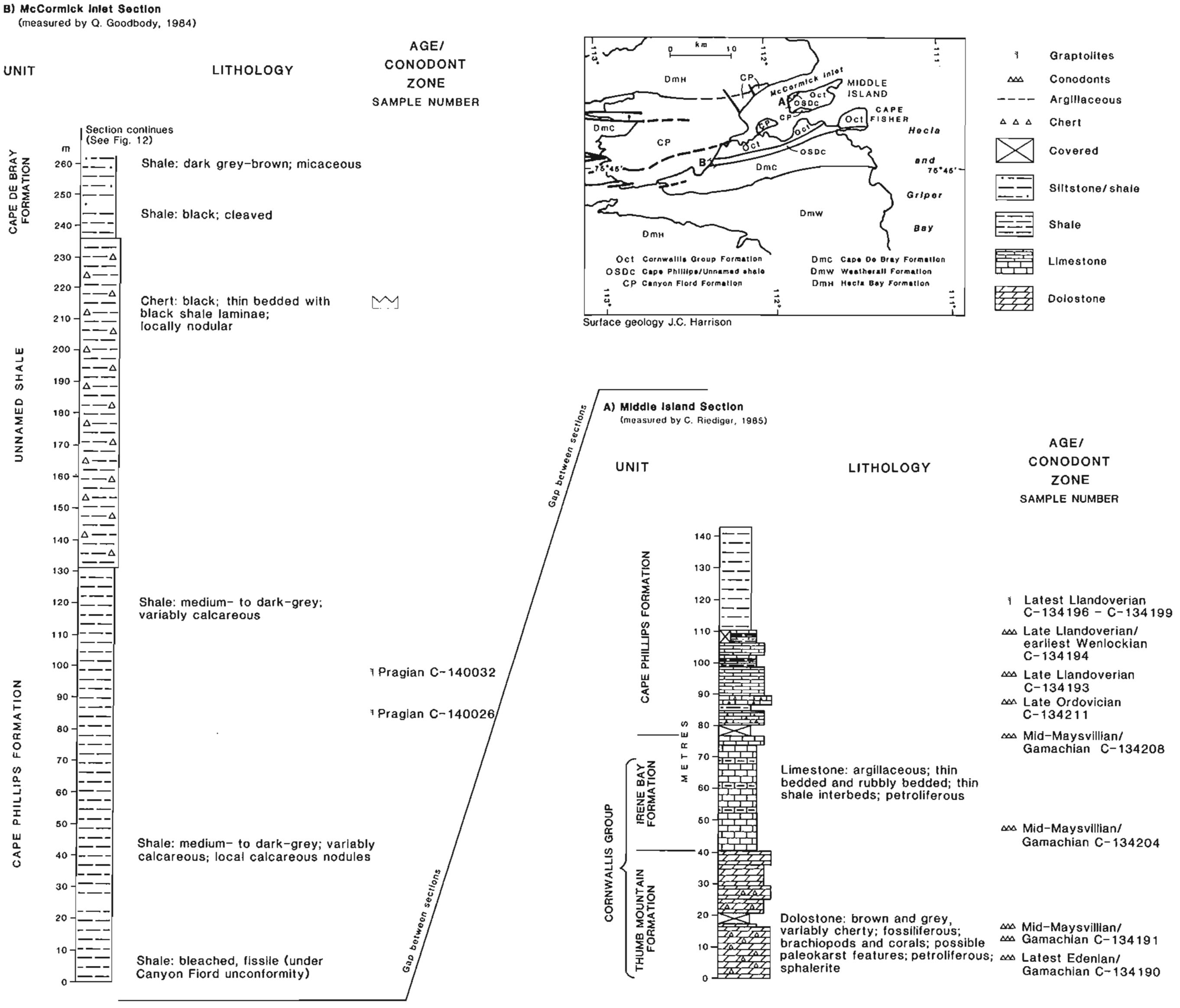


Figure 4. *Composite section of the Middle Island and south McCormick Inlet exposures of the Cornwallis Group, Cape Phillips Formation and unnamed shale unit. The gap between sections is estimated. Measured by C. Riediger and Q. Goodbody.*

tentaculitids and conulariids indicative of an Early Devonian (Pragian) age were collected from beds 55-65 m below the top of the formation at the locality south of McCormick Inlet. The age equivalence of these basinal shales to parts of the Ibbett Bay Formation was described earlier.

Tingmisut Lake, Weatherall Bay

Unnamed carbonates

Description. A small carbonate inlier, assigned a Silurian age by Tozer and Thorsteinsson (1964), outcrops as a conspicuous topographic feature 4 km to the southeast of Tingmisut Lake, northeastern Melville Island. Approximately 200 m of carbonates are exposed (Fig. 5). The base of this sequence is not exposed; the upper contact is a paraconformity with the red-coloured Canyon Fiord Formation (Carboniferous/Permian). The inlier consists of light grey to buff-coloured, sucrosic dolostone, locally containing poorly preserved brachiopods, gastropods and crinoid ossicles. Both sedimentary and tectonic brecciation is common. There are sporadic shows of galena.

Age and correlation. The inlier was sampled for conodonts. Only one sample, from scree below the

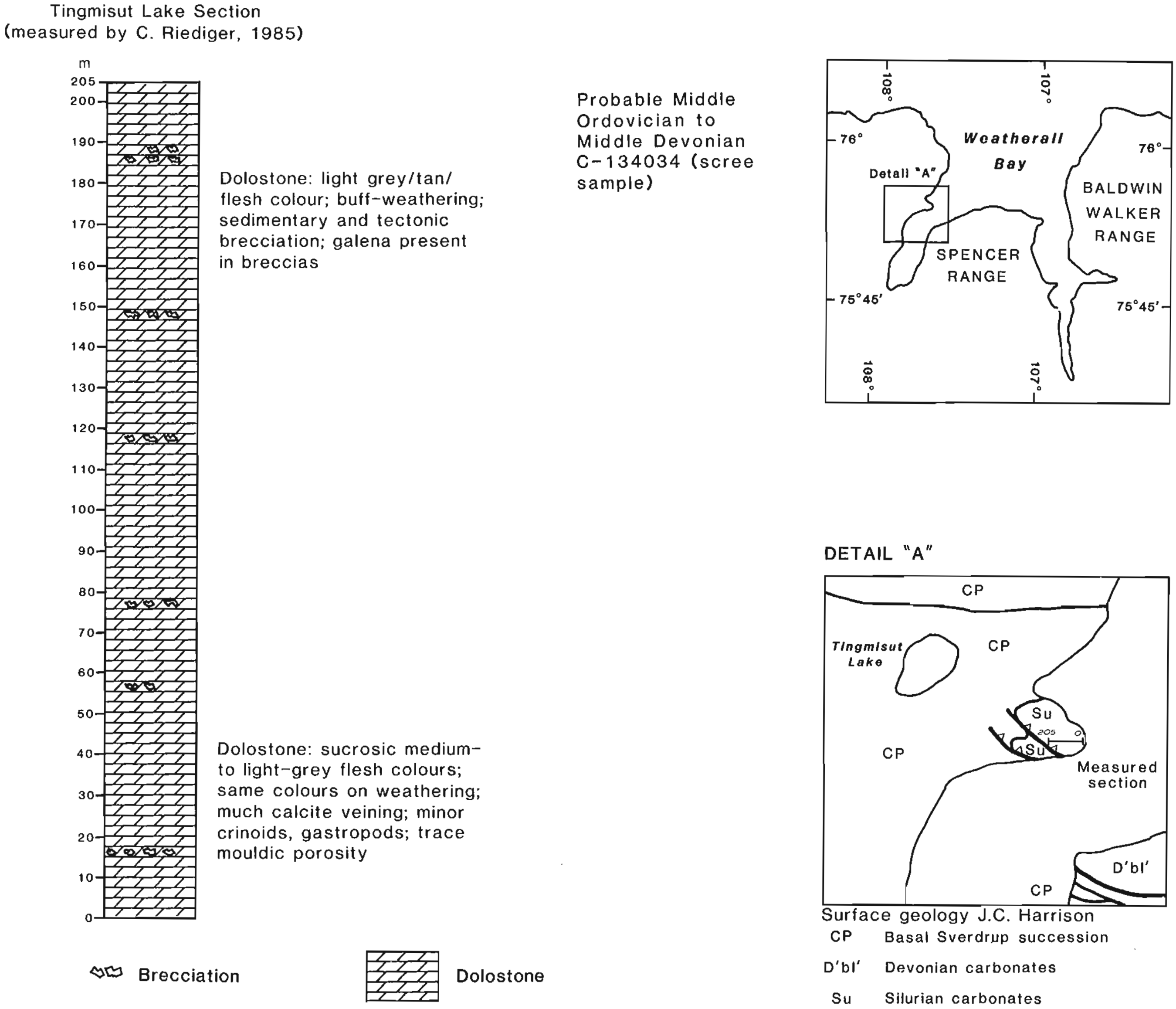


Figure 5. Section through Tingmisut Lake carbonate inlier. Measured by C. Riediger.

uppermost beds provided an inconclusive, probable Middle Ordovician–Silurian age. Tozer and Thorsteinsson (1964) assigned a Silurian age to this inlier on the basis of brachiopods taken from scree. The Tingmisut Lake beds are probably equivalent to the carbonates of the Raglan Range Inlier and to shale and carbonate of the Ibbett Bay Formation; subsurface equivalents include shale of the Cape Phillips Formation, unnamed carbonates in the Panarctic Dome Dundas C-80 and Dome Panarctic N. Dundas N-82 wells and possibly in the Texex King Point West B-53 well, and the lower part of unnamed carbonates in the Sun KR Panarctic Kitson River C-71 and Panarctic Towson Point F-63 wells.

Sequence C: Lower to Middle Devonian carbonates and shales

Canrobert Hills

Member 5, Ibbett Bay Formation

Description/Age/Correlation/Environment of deposition. Described previously.

Eastern and east-central Melville Island

Upper Cape Phillips Formation

Description. A shale unit with a distinctive signature in seismic records in the subsurface of eastern and east-central Melville Island overlies somewhat similar shale of the Cape Phillips Formation (Fox and Densmore, 1992). This unit, termed an "unnamed shale" by Fox and Densmore, was originally included in the Cape Phillips Formation of Tozer and Thorsteinsson (1964). In the subsurface it is composed mainly of shale and siltstone; chert and thin limestone beds constitute a minor part of the succession in some wells, the limestone increasing in proportion with proximity to age-equivalent carbonate buildups.

A chert and shale section 122 m thick overlies shale confidently assigned to the Cape Phillips Formation south of McCormick Inlet (Fig. 4), and is tentatively considered equivalent to the unnamed shale of Fox and Densmore. This unit is herein referred to as the Upper Cape Phillips Formation. At this locality, 110 m of thinly bedded (beds 4 cm thick) black chert with shale partings, which appear to represent C-D-E Bouma sequences (Plate 4b), overlie variably calcareous, graptolitic shale confidently assigned to the Cape Phillips Formation. Cherty concretions are locally present. These beds are capped by a poorly exposed interval, 12 m thick, of recessive, very black, fissile shale (Fig. 4). The contact with the overlying silty micaceous shale of the Cape De Bray Formation is placed where there is a distinct colour change from black to grey-brown. No biostratigraphically useful fossils were recovered.

Correlation. The upper Cape Phillips Formation is stratigraphically equivalent to Lower and Middle Devonian carbonates exposed in inliers on eastern Melville Island. It is possibly equivalent to unit 7 and is definitely equivalent to the Kitson Formation of the Raglan Range carbonate inlier (see Goodbody and Christie, *this volume*, Fig. 2). Age- and facies-equivalents to this shale unit on Bathurst Island were assigned to the Eids Formation by Kerr (1974) and by Mayr (1980), but the validity of this nomenclature is now considered uncertain (Thorsteinsson, pers. comm., 1987). Equivalents in the subsurface of Banks Island have been assigned to the Orksut Formation and to part of the Nanuk Formation (Miall, 1976), and to the Kitson Formation (Embry and Klovan, 1976).

Environment of deposition. These shales and cherts are interpreted as having been deposited in a deep water, basinal setting.

Kitson Formation

Description. The Kitson Formation (defined by Tozer and Thorsteinsson, 1964) is a 55 m thick succession of petroliferous, thinly interbedded black shale and very dark grey to black, bioclastic limestone. This poorly exposed unit caps the previously described Raglan Range carbonate inlier (Fig. 3). The section described here (Fig. 6) was obtained by combining partial sections from the south and southwest sides of the inlier. Limestone dominates at the base, but grades upward into black shale with interlayered, thin bedded limestone. Possible slump folding is present (Plate 3g).

Age. Macrofossils include graptolites, tentaculitids, brachiopods, crinoid ossicles and rare bryozoans. Graptolites from basal shales indicate a Late Silurian to Early Devonian age. Conodonts from the basal limestones indicate a late Pridolian to early Lochkovian age (*hesperius* to *delta* zones). Beds high in the formation yielded lower Middle Eifelian (*patulus* to *costatus* zones) conodonts.

Correlation and environment. The Kitson Formation is apparently a condensed sequence that was deposited in marginal to distal basin settings. It is time equivalent to the unnamed shale of Fox and Densmore, to that part of the Cape Phillips Formation exposed south of McCormick Inlet, and to the more than 500 m of carbonates exposed in the Spencer Range and Towson Point inliers (described below).

Spencer Range

Unnamed carbonates

Description. The Spencer Range, at the north end of the headland separating the two arms of Weatherall Bay, is a distinctive light grey range of hills constituting a carbonate inlier. The southern boundary of the inlier is marked by east-west trending faults. No contact with an overlying rock unit was observed. A series of sections measured across the geographic centre of the inlier provides an adequate description of the exposed beds (Fig. 7), which form an 820 m thick, monotonous succession of light to dark grey, variably silty, micritic dolostone and limestone that are more prevalent upward in the section. The lower 350 m of exposed carbonates consist of disturbed, vuggy in part, interbedded light to medium grey, micritic limestone, light grey silty dolomicrite, and dark grey to black, finely crystalline dolostone. Sedimentary structures include planar and wavy lamination, fenestral fabrics,

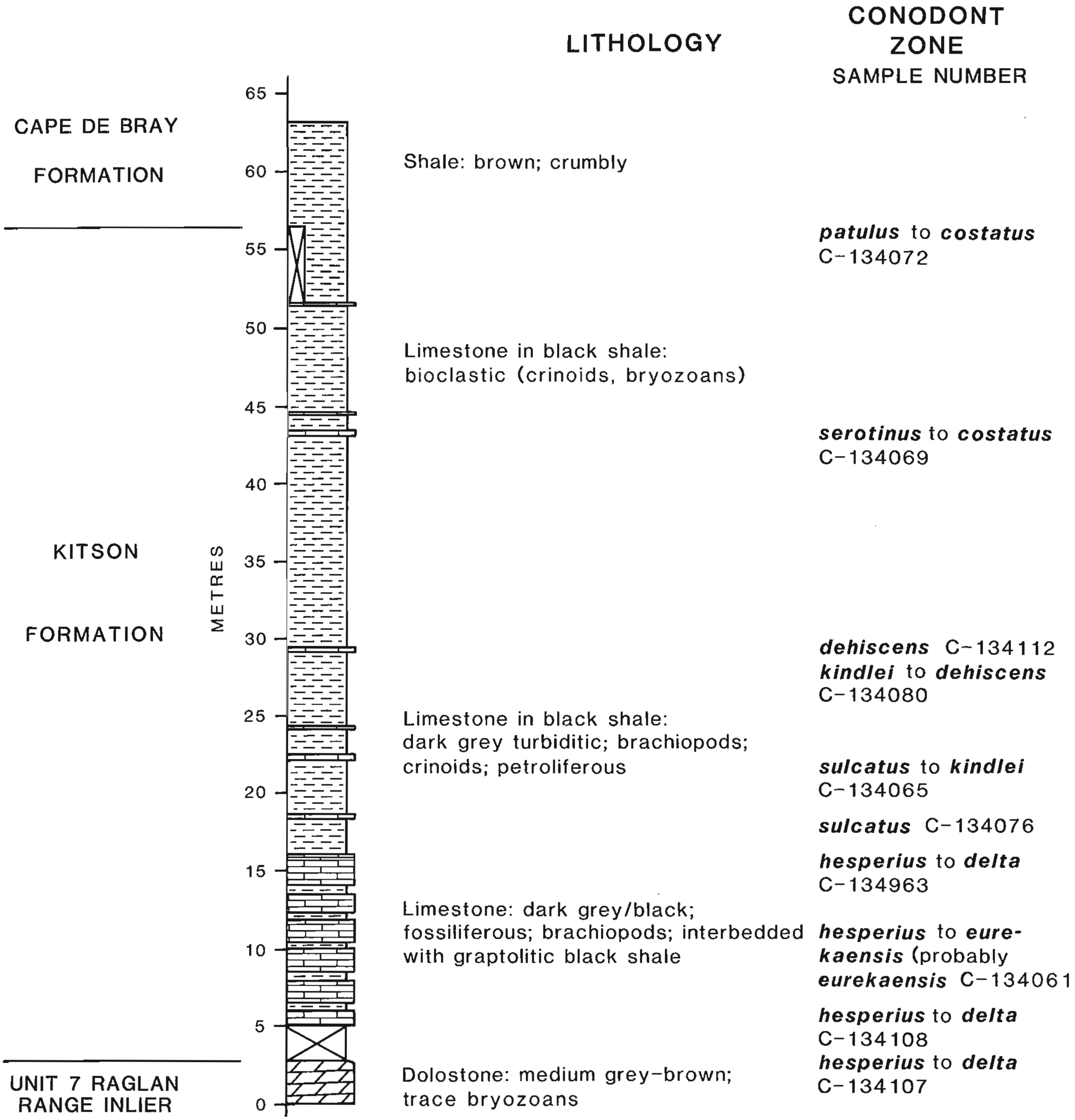


Figure 6. Composite section through the Kitson Formation, Raglan Range Inlier, north central Melville Island. (See Figure 3 for distribution of Kitson Formation in this area.) Incorporating fieldwork by C. Riediger and Q. Goodbody.

and intraclastic layers. Fossils, although rare, occur in localized horizons and include gastropods and thamnoporoid corals. Pyrobitumen is present as a partial infill to some vugs; the crystalline dolostone intervals emit a pungent bituminous odour on breaking. Fluorspar, galena and pyrite are present in small amounts in fault breccias.

The remaining 470 m of the inlier is characterized by repetition of hemicyclic facies sequences. In the

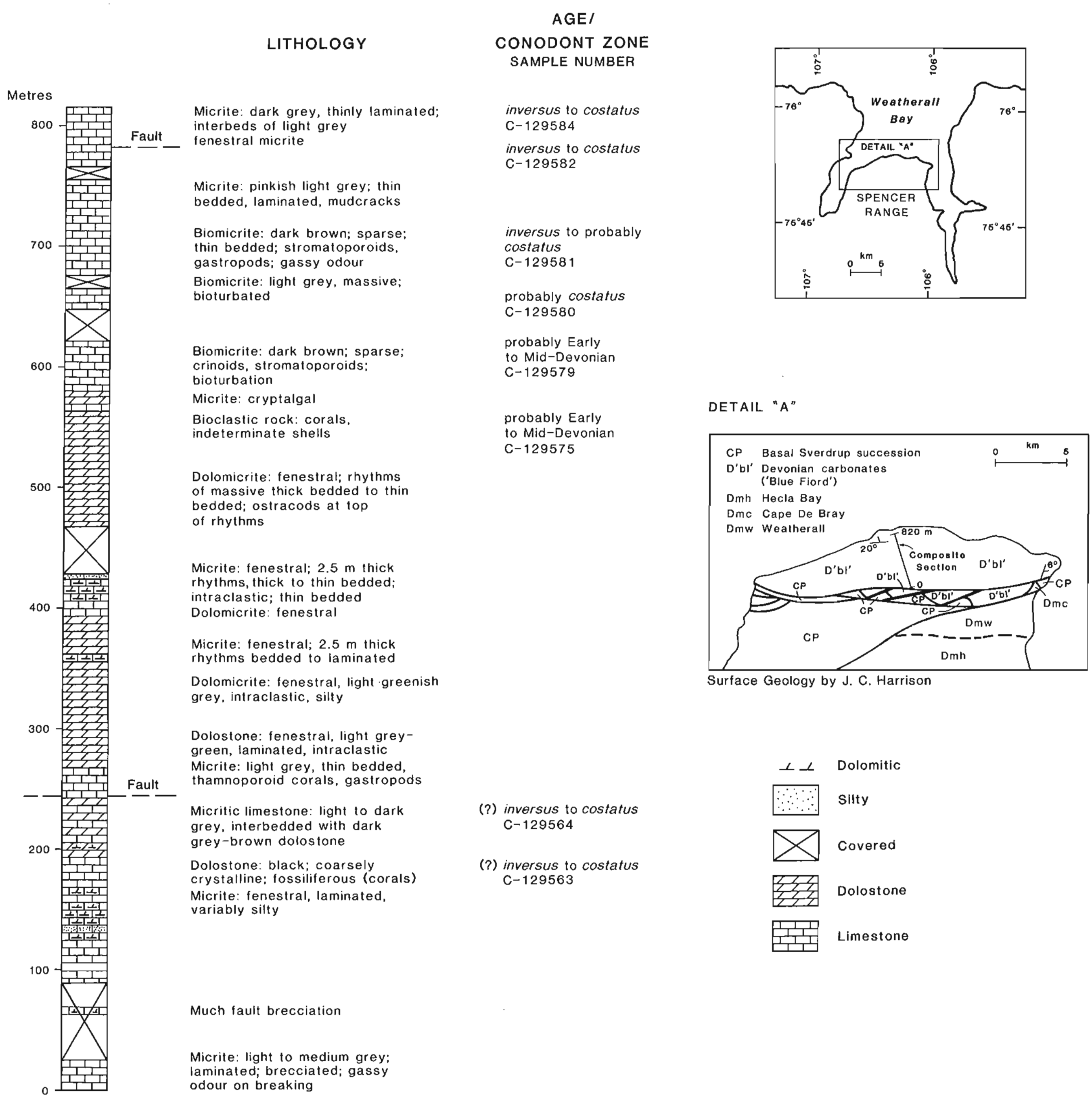


Figure 7. Composite section through the Spencer Range carbonate inlier, northeastern Melville Island. Measured by Q. Goodbody.

interval between 350 and 550 m above the base of the section these hemicycles, 2-5 m thick, consist of thick bedded, indistinctly laminated, light grey micrites that grade upward into thin bedded, evenly laminated, fenestral, silty, light grey micrites. Ostracodes occur locally. Above 550 m there is a marked increase in dark grey micrite at the base of the hemicycles. This change in lithotype is accompanied by an increase in fossil content: there are gastropods, stromatoporoids, and crinoid ossicles. In this part of the inlier, the hemicycles are dark, fossiliferous micrite at the base that grades upward into light grey, cryptalgal (laminated and fenestral), locally mudcracked, micritic limestone. The dark brown limestone emits a strong bituminous odour when broken.

Age. Conodont faunas, sparse both in number and diversity, have been recovered from the Spencer Range carbonates. The entire succession appears to be Early to Middle Devonian age (*inversus* to *costatus* zones).

Environment of depositon. Sedimentological features within the carbonates of this inlier generally indicate shallow water deposition. The lowest 350 m was deposited in very shallow water (fenestral and intraclastic micrites); an increase in marine circulation and/or water depth are indicated by the dark, sucrosic, bioclastic dolostone interlayers. The pattern of repeated hemicyclic facies sequences observed in the upper 470 m is characteristic of sedimentation in platformal areas. The thicker bedded, generally darker limestone at the base of the sequences was probably deposited in a subtidal lagoon to shallow shelf setting, whereas the thinner bedded, lighter coloured, fenestral micrite capping the hemicycles indicates an intertidal to supratidal setting. Toward the top of the inlier, the appearance of darker coloured micrite at the base of the sequences, coupled with an increase in the fossil faunas, indicates more open marine circulation than that indicated by beds lower in the section.

Correlation. The Spencer Range carbonates are time equivalent to the upper part of member 5 of the Ibbett Bay Formation, the Kitson Formation, and the upper part of the Cape Phillips Formation (Goodbody and Christie, *this volume*, Fig. 2). The black dolostones 200 m above the base of exposure are tentatively correlated with a tongue of the Eids Formation occurring between the Disappointment Bay and Blue Fiord formations in the Panarctic Tenn et al. Bent Horn N-72 well on Cameron Island (see Mayr, 1980).

Towson Point

Unnamed carbonates

Description. The Towson Point Inlier is a range of hills situated east of Weatherall Bay that are composed of Devonian carbonate (Plate 4g). The sedimentological base of the carbonate section is not exposed. Dark brown siltstone at the base of the section appears to be beds of the Cape De Bray Formation, upon which the older carbonate has been overthrust. The contact between these units is covered. The upper contact with shale and calcareous siltstone of the Cape De Bray Formation is best exposed where a stream breaches the southern limb of a complex anticline (the Towson Point Anticline) approximately 4.5 km from its eastern end (Plate 4f). Despite the structural complications, locally excellent exposures allow detailed examination of sedimentary features and the construction of a stratigraphic column. The total thickness of Devonian carbonates exposed is 325 m, but thrust repetition occurs in the upper central part of the section, rendering the true thickness of the succession 247 m (as shown in Fig. 8).

The carbonates of the Towson Point Inlier can be divided into three units: the lowest 65 m (unit 1) consist of bluff-forming, variably silty, rubbly and massively bedded light to medium grey biomicrite[1].

Unit 1 grades upward into unit 2 (112 m, exclusive of thrust repetition), which consists of repeated hemicycles (1.5–3.0 m thick) of brown to dark grey, rubbly bedded, fossiliferous micrite grading to thin, planar bedded, planar and wavy laminated, light grey and greenish grey dolomicrite (Plate 4f) and silty shale. These carbonates are variably silty. Intraclastic lags are locally present at the base of the hemicyclic sequences. The capping dolostone contains shallow water depositional features, including patterning, fenestral fabrics (vugs and well developed bird's eye textures), cryptalgal and stromatolitic lamination and mudcracks. Bulbous stromatoporoids are the most important faunal element in the brown micrites, with lesser amounts of gastropods, crinoid ossicles, corals and brachiopods.

The upper part of the carbonate inlier, unit 3, forms bluffs similar to unit 1 (Plate 4f). Unit 3 comprises shallowing-upward sequences of very rubbly bedded, locally abundantly fossiliferous, dark brown to grey micrite to light grey to pinkish-brown massive and fenestral micrites. Solitary corals, thamnoporoid corals, crinoid ossicles, bulbous stromatoporoids, brachiopods and rare trilobites are present in the darker micrite. Rugose corals occur in profusion near the base of the unit. A measured thickness of 70 m may be somewhat too great due to minor, but undetermined, thrust repetition.

The contact between these carbonates and the overlying clastic rocks of the Cape De Bray Formation is abrupt.

Age. McGregor and Camfield (1982) reported on age determinations from conodonts and palynological study for samples collected from the inlier. Conodonts from 297.2 and 45.7 m (measured positions, ignoring certain structural complications) below the top of the carbonates yielded conodonts of middle Emsian to early Eifelian age (*inversus* to *costatus* zones). According to Pedder (*in* Uyeno and Mason, 1975), corals from about midway in the carbonates are not

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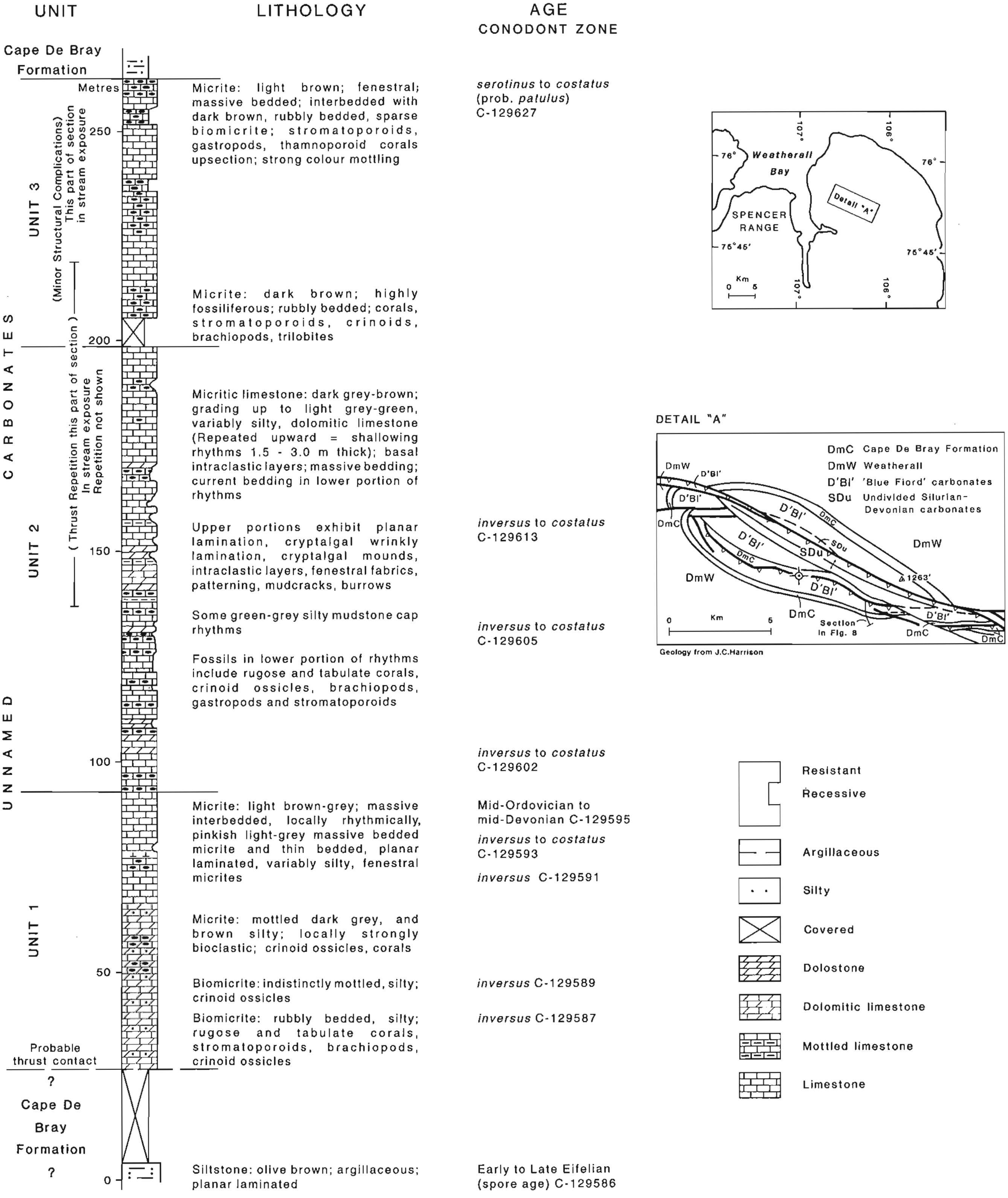
[1] Hemicyclic micritic limestone and dolomitic limstone (Plate 4c) at the base of structurally more complex section 8 km to the west may be stratigraphically below unit 1, but the relationship is uncertain.



Micrite: light brown; fenestral; massive bedded; interbedded with dark brown, rubbly bedded, sparse biomicrite; stromatoporoids, gastropods, thamnoporoid corals upsection; strong colour mottling

Micrite: dark brown; highly fossiliferous; rubbly bedded; corals, stromatoporoids, crinoids, brachiopods, trilobites

Micritic limestone: dark grey-brown; grading up to light grey-green, variably silty, dolomitic limestone (Repeated upward = shallowing rhythms 1.5 - 3.0 m thick); basal intraclastic layers; massive bedding; current bedding in lower portion of rhythms

Upper portions exhibit planar lamination, cryptalgal wrinkly lamination, cryptalgal mounds, intraclastic layers, fenestral fabrics, patterning, mudcracks, burrows

Some green-grey silty mudstone cap rhythms

Fossils in lower portion of rhythms include rugose and tabulate corals, crinoid ossicles, brachiopods, gastropods and stromatoporoids

Micrite: light brown-grey; massive interbedded, locally rhythmically, pinkish light-grey massive bedded micrite and thin bedded, planar laminated, variably silty, fenestral micrites

Micrite: mottled dark grey, and brown silty; locally strongly bioclastic; crinoid ossicles, corals

Biomicrite: indistinctly mottled, silty; crinoid ossicles

Biomicrite: rubbly bedded, silty; rugose and tabulate corals, stromatoporoids, brachiopods, crinoid ossicles

Siltstone: olive brown; argillaceous; planar laminated

serotinus to *costatus* (prob. *patulus*) C-129627

inversus to *costatus* C-129613

inversus to *costatus* C-129605

inversus to *costatus* C-129602

Mid-Ordovician to mid-Devonian C-129595

inversus to *costatus* C-129593

inversus C-129591

inversus C-129589

inversus C-129587

Early to Late Eifelian (spore age) C-129586

Figure 8. Location and measured section, Towson Point Inlier, eastern Melville Island. Measured by Q. Goodbody.

known from rocks older than Eifelian. Conodonts obtained from this study indicate an *inversus* Zone age for unit 1, *inversus* to *costatus* zones age for unit 2, and a *serotinus* to *costatus* (possibly *patulus*) zones age for the uppermost beds of unit 3.

Environment of deposition. Units 1 and 3 are interpreted as open marine shelf deposits. Unit 2 was deposited in a variably restricted, shallow water, intertidal, and possibly separated, setting.

Middle to Upper Devonian clastic units

Tozer and Thorsteinsson (1964) recognized that the Devonian clastic beds on Melville Island form part of a thick clastic wedge that extends across the Canadian Arctic Islands. Embry and Klovan (1976) studied these rocks and revised the stratigraphic nomenclature, naming several new formations (Table 1). They also proposed an interpretation of the gross environments of deposition, and, in association with Chi and Hills (1976), elucidated the time relationships of the facies packages. The Devonian clastic sequence was divided into three constituent wedges; these, termed the Hecla Bay, Beverley Inlet and Parry Islands wedges, contain rocks deposited in a variety of shelf and deltaic environments that record a southwesterly progression of nonmarine over marine deposits.

The three wedges recognized by Embry and Klovan (1976) occur on Melville Island (Fig. 9), and their stratigraphic nomenclature has been followed in this study. Stratigraphic and sedimentological data from wells drilled subsequent to that work and from sections measured during fieldwork associated with the present study, have provided a basis for an improved understanding of the sedimentology and stratigraphy of the Devonian clastic complex. The three wedges are described under separate headings below.

TABLE 1

Development of stratigraphic nomenclature of Devonian clastic rocks of Melville Island

Tozer, 1956	Tozer and Thorsteinsson, 1964		Embry and Klovan, 1976; this paper		
MELVILLE ISLAND FORMATION	MELVILLE ISLAND GROUP	GRIPER BAY FORMATION	PARRY ISLANDS FORMATION	GRIPER BAY SUBGROUP	MELVILLE ISLAND GROUP
			BEVERLEY INLET FORMATION		
		HECLA BAY FORMATION	HECLA BAY FORMATION		
		WEATHERALL FORMATION	WEATHERALL FORMATION		
		Cape De Bray Member	CAPE DE BRAY FORMATION		
		Blackley Member	BLACKLEY FORMATION		

Hecla Bay wedge

The Hecla Bay wedge (Embry and Klovan, 1976) extends across the Arctic Islands from Prince Patrick Island to central Ellesmere Island. Four formations constitute the wedge on Melville Island (Fig. 9), where a maximum thickness of approximately 3700 m is attained (determined from seismic information by J.C. Harrison in the Blue Hills Syncline). Embry and Klovan interpreted the Hecla Bay wedge on Melville Island as containing rocks deposited in environments ranging through submarine fan, marine slope, shelf, and deltaic settings (the Blackley, Cape De Bray, Weatherall, and Hecla Bay formations respectively — see Fig. 9). Nonmarine deposits of the Hecla Bay Formation were recognized to thin and grade laterally into marine deposits of the Weatherall Formation in the southwestern part of the island. With the exception of the Blackley Formation, for which a northern source was proposed, all the formations making up the wedge become younger to the west and indicate a generally westward advance with time of a succession of progressively shallowing facies belts, the sediments of which were derived from the northeast and east.

Blackley Formation

Description. The Blackley Formation was originally described by Tozer and Thorsteinsson (1964) as a member of the Weatherall Formation, with the type locality 6.5 km northeast of the northeast corner of Blackely Haven, west of the Canrobert Hills. The unit was redescribed and raised to formation status by Embry and Klovan (1976), and was further described by Robson (1985).

Exposure of the Blackley Formation is confined to northwestern Melville Island, where the formation comprises interbedded sandstone, siltstone, and shale. The alternation of hard and soft layers gives the formation a banded appearance from the air (Plate 5a). Good exposures are rare. The Blackley Formation conformably overlies black shale of the Ibbett Bay Formation (Plate 5a), and is overlain by shale and siltstone of the Cape De Bray Formation. The formation is known in the subsurface of Banks and Prince Patrick islands (Embry and Klovan, 1976; Miall, 1976). It is absent to the north due to post-Devonian erosion, and to the east due to a facies change (Fig. 9).

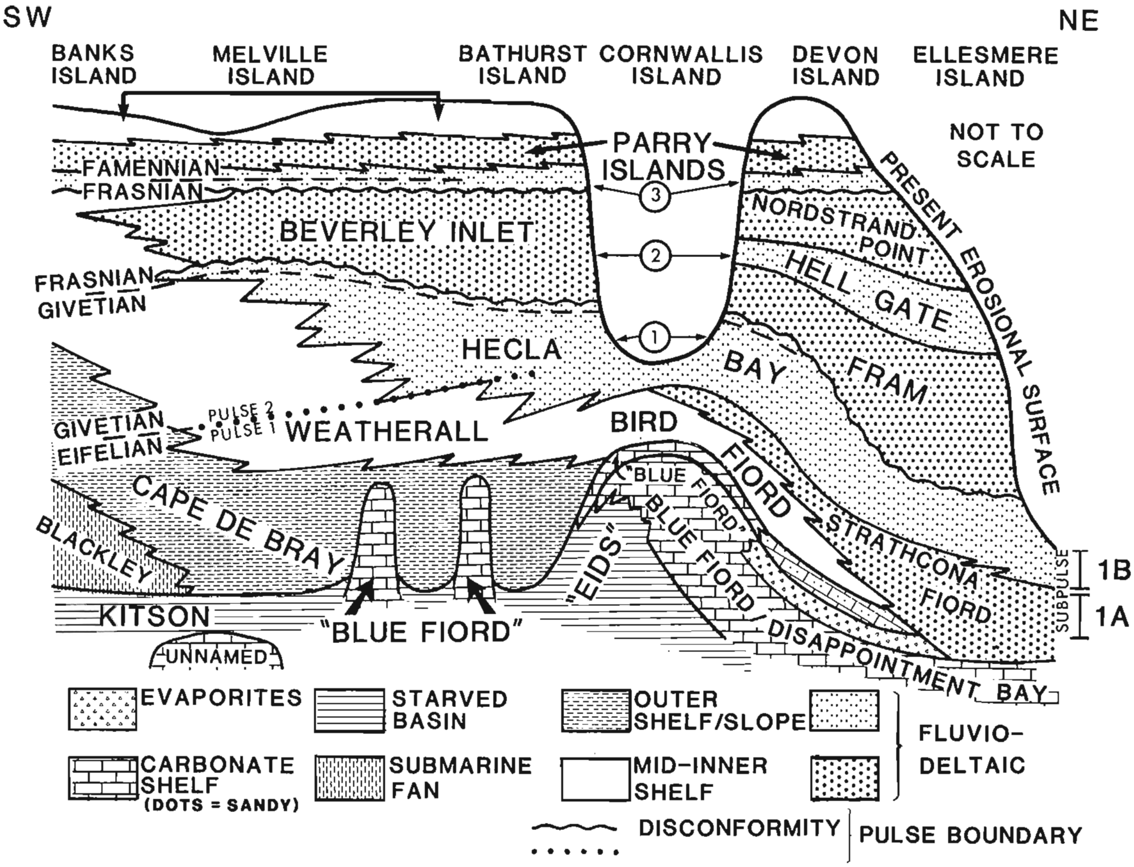
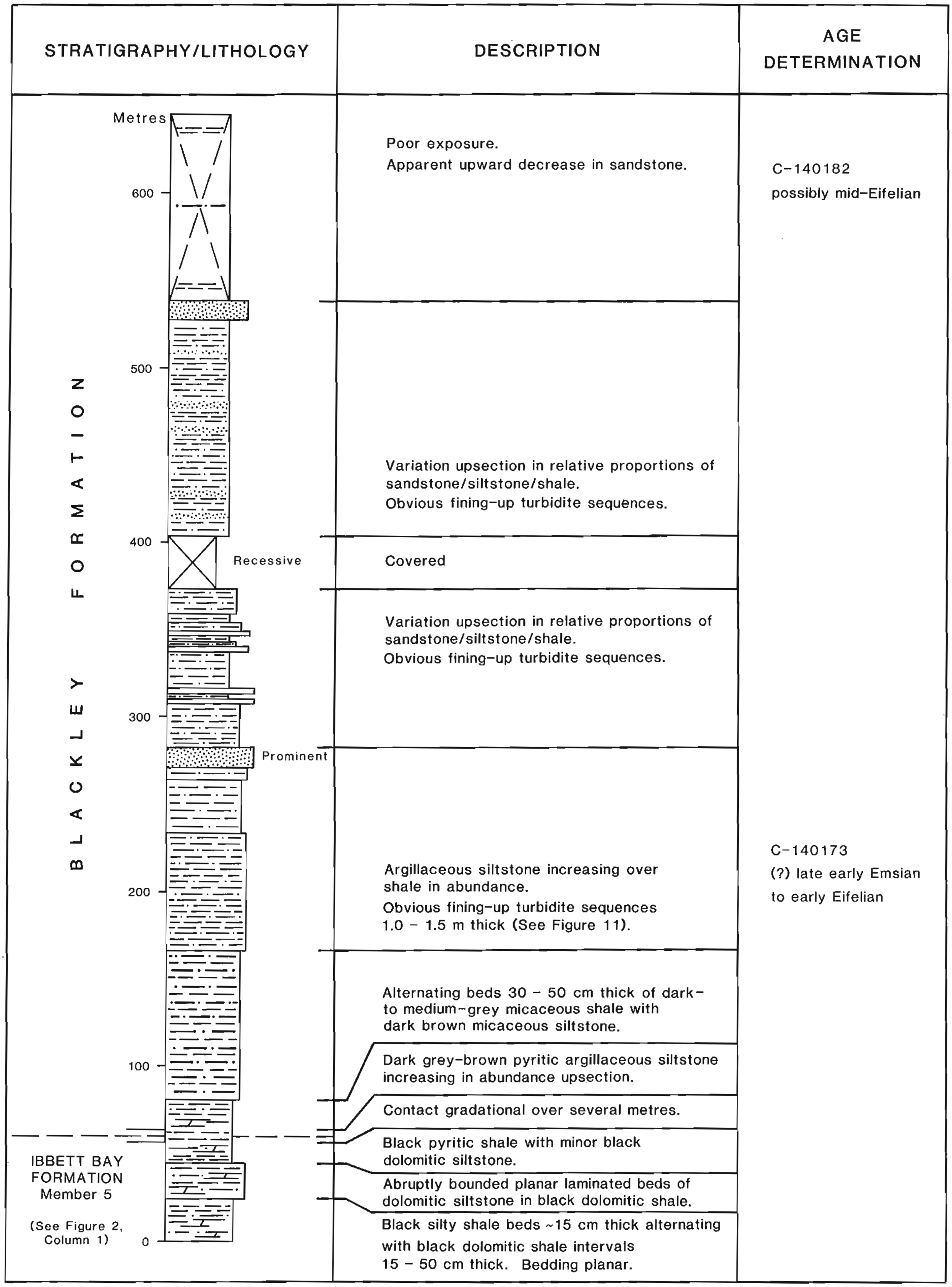


Figure 9. Diagrammatic cross-section of the Devonian clastic wedge, Canadian Arctic Islands, showing facies trends and stratigraphic relationships. Constituent wedges are numbered. 1 = Hecla Bay Wedge; 2 = Beverley Inlet Wedge; 3 = Parry Islands Wedge. (Modified from Embry and Klovan, 1976.)

The lower 600 m of the Blackley Formation, and its contact with the Ibbett Bay Formation, are exposed in a stream section south of the central Canrobert Hills (Fig. 10). The formation is approximately 700 m thick at this locality. Fine grained, light to medium brown sandstone and siltstone, and dark grey to brown micaceous shales are commonly arranged in distinct fining-upward sequences that closely resemble the classic Bouma B-C-D-E and C-D-E sequences (Plate 5b, c, Fig. 11). Sandstones are sharp-based; the undersurfaces of the thicker beds are characterized by groove casts, tool marks and slide marks (Plate 5d, e). Each sequence fines upward from massive bedded or planar laminated sandstone at the base, through cross laminated and ripple laminated silty sandstone to planar laminated siltstone, and finally to shale at the top. The shale dominates the section. The frequency and thickness of sandstone beds varies through the section (Fig. 10), and the sandstone content is much reduced in the upper part.

Good exposure of the contact with the overlying Cape De Bray Formation was not found. This contact can be recognized on air photographs by a change from fine sandstone and shale banding characteristic of the Blackley Formation, to the relatively featureless silty shale and siltstone of the Cape De Bray Formation.

Age and correlation. No megafossils have been reported from the Blackley Formation. Most samples taken for palynological study have proved barren, but a few samples have yielded dark, poorly preserved palynomorphs. Spores tentatively interpreted as late Emsian in age were obtained 56 m above the base of the formation, and a spore sample from approximately 170 m above the base suggests a late early Emsian to early Eifelian age. Another poorly preserved spore sample 537 m above the base was dated as possibly mid-Eifelian. A sample 22.7 m below the top of the Blackley Formation was tentatively dated as Eifelian to early Givetian.



Poor exposure.
Apparent upward decrease in sandstone.

Variation upsection in relative proportions of sandstone/siltstone/shale.
Obvious fining-up turbidite sequences.

Covered

Variation upsection in relative proportions of sandstone/siltstone/shale.
Obvious fining-up turbidite sequences.

Argillaceous siltstone increasing over shale in abundance.
Obvious fining-up turbidite sequences 1.0 – 1.5 m thick (See Figure 11).

Alternating beds 30 – 50 cm thick of dark- to medium-grey micaceous shale with dark brown micaceous siltstone.

Dark grey-brown pyritic argillaceous siltstone increasing in abundance upsection.

Contact gradational over several metres.

Black pyritic shale with minor black dolomitic siltstone.

Abruptly bounded planar laminated beds of dolomitic siltstone in black dolomitic shale.

Black silty shale beds ~15 cm thick alternating with black dolomitic shale intervals 15 – 50 cm thick. Bedding planar.

C-140182
possibly mid-Eifelian

C-140173
(?) late early Emsian to early Eifelian

Reference section: Blackley Formation, north-central Ibbett Bay, Canrobert Hills (75°44′20″ N, 115°46′ W)

Figure 10. *Location and measured section of the Blackley Formation, south-central Canrobert Hills, northwestern Melville Island. Measured by Q. Goodbody. See Figure 2 for legend.*

The youngest paleontological date for beds beneath the Blackley, from a horizon 210 m below the base of the Blackley in the Ibbett Bay Formation, is Emsian (Tozer and Thorsteinsson, 1964). Robson (1985) reported graptolites of Pragian age 120 m below this contact (Fig. 2).

Poorly preserved spores 24 m above the base of the overlying Cape De Bray Formation are tentatively interpreted as late Emsian or early Eifelian in age.

Miall compared the Blackley Formation on Melville Island and the sandy upper beds of the Nanuk Formation (in the Elf et al. Storkerson Bay A-15 well) on Banks Island. He reported a late Eifelian age for the Nanuk Formation. Embry and Klovan (1976) considered these beds in the A-15 well, and the whole of Miall's (1976) Nanuk Formation in the Elf Nanuk D-76 well to belong to the Blackley Formation.

Provenance. Numerous current features have been observed at the bases of the sandstone beds, but conflicting orientations of scour and tool marks on single bedding planes, coupled with the intense structural deformation in the area, hamper paleocurrent analysis. The Blackley Formation apparently was derived from a northerly source. This is indicated by its apparent eastward equivalence to the uppermost part of the upper portion of the Cape Phillips Formation and the lower part of the Cape De Bray Formation (described below) at McCormick Inlet. This conclusion is in agreement with Embry and Klovan (1976). Miall (1976), commenting on the source of sandstone at the top of the Nanuk Formation on Banks Island (as noted, correlable with the Blackley Formation on Melville Island) considered a northerly source probable on account of time equivalent strata to the south containing virtually no clastic material other than scattered silt grade quartz grains.

Environment of deposition. The Blackley Formation, basically a unit of turbidites, evidently represents deposition in a mid- to outer submarine fan setting.

Cape De Bray Formation

Description. Tozer and Thorsteinsson (1964) designated 600 m (2000 ft.) of argillaceous siltstone and silty shale overlying their Blackley Member on western Melville Island as the Cape De Bray Member of the Weatherall Formation. Embry and Klovan (1976) raised the Cape De Bray (as with the Blackley) to formation status. They also recognized the Cape De Bray Formation between Devonian carbonates and the Weatherall Formation on eastern Melville Island.

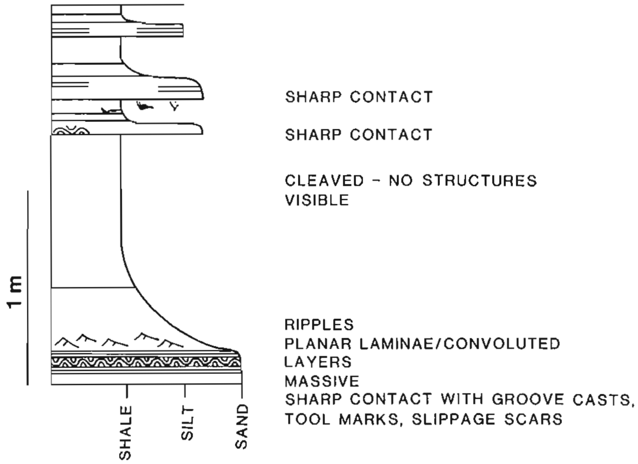


Figure 11. Diagrammatic representation of typical facies sequences within the Blackley Formation.

On northwestern Melville Island, the Cape De Bray Formation outcrops as a recessive, featureless, dark brown to grey micaceous silty shale. The lack of banding distinguishes it from the underlying Blackley Formation. An indistinct cyclicity of coarsening-upward sequences of shale to silt to sand is apparent within the formation. The boundary between the Cape De Bray Formation and the overlying Weatherall Formation is drawn where these cycles become thinner and more distinct, and where there is a marked increase in the abundance of sand, ironstone, and megafossils. This boundary is readily recognizable in air photographs.

Poor surface exposures and the presence of structural complications lead to difficulty in measuring the true thickness of the Cape De Bray Formation. A complete section, designated a reference section by Embry and Klovan (1976), occurs 5 km south of McCormick Inlet, north-central Melville Island (Fig. 12). At this locality, 1200 ± 300 m of dark grey to brown, micaceous silty shale with scattered calcareous siltstone and fine sandstone beds overlie the black shale and chert of the upper part of the Cape Phillips Formation. Sharp-based, fine-grained sandstone beds, locally with flute casts and tool marks, are present in the basal, shale-dominated 200 m of the formation. These beds are apparently of turbiditic origin and occur at the interdigitation between facies of the Blackley and Cape De Bray formations. Much of the remainder of the Cape De Bray Formation is composed of vaguely discernible shale-dominated parasequences, 50–75 m thick, of shale to siltstone, the upper 5–10 m of which locally coarsen into light brown, calcareous, silty sandstone (Fig. 13, Plate 6a,

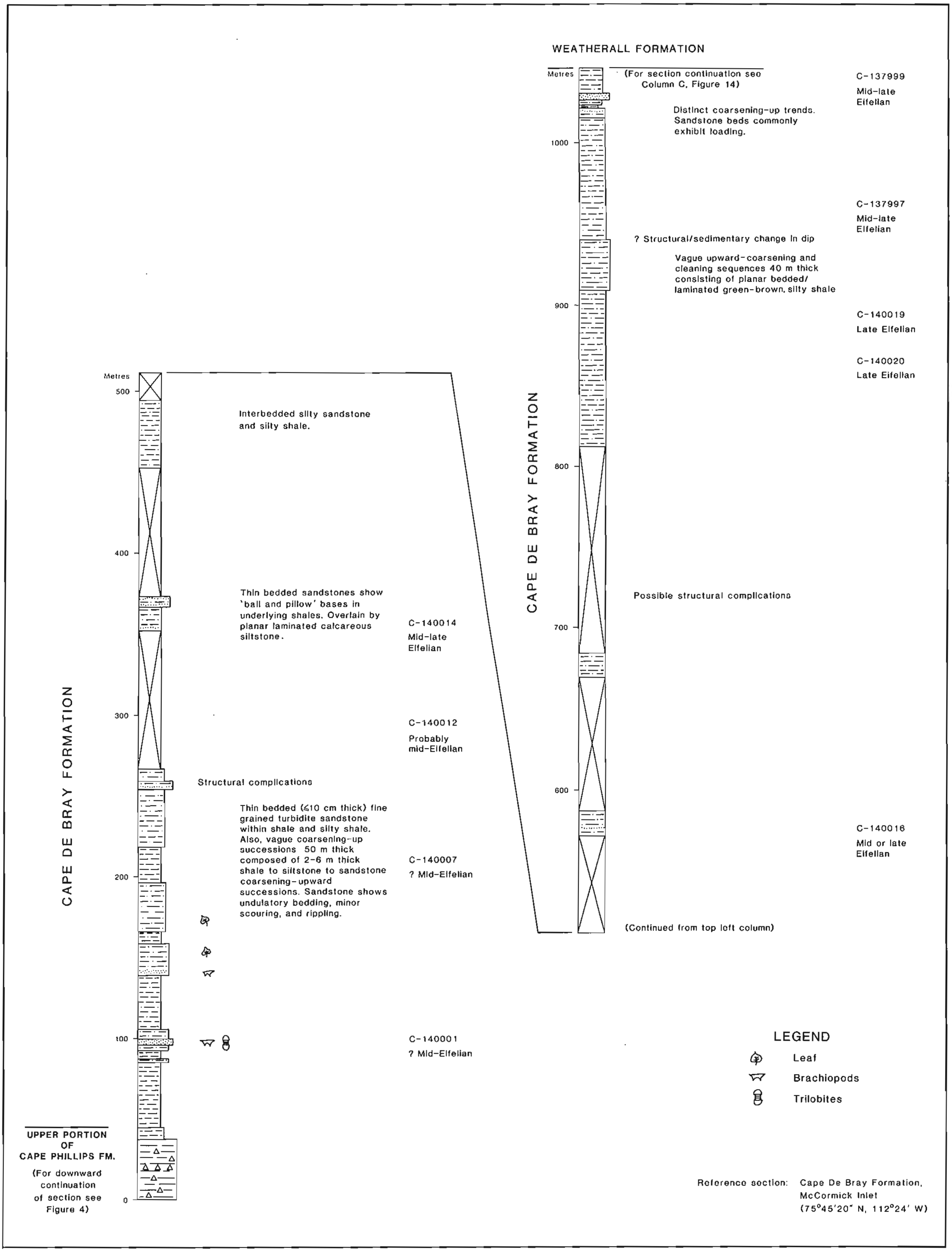


Figure 12. *Measured section of the Cape De Bray Formation, 6 km south of McCormick Inlet, central Melville Island. Note the structural complications. Measured by Q. Goodbody. See Figure 4 for legend.*

b, c). These capping sandstones exhibit loading structures, ripple cross-lamination, and bioturbation features (Plate 6d). Brachiopods and trilobites are present at some horizons; carbonized plant fragments are common throughout.

The Cape De Bray Formation, where it overlies Lower to Middle Devonian carbonates in eastern Melville Island (Fig. 1b), is much reduced in thickness. It is 80 m thick where it overlies carbonates of the Towson Point Inlier. The basal contact with the carbonates is abrupt. At this location, silty shale and siltstone of the Cape De Bray Formation weather recessively to form a virtual moat around the perimeter of the carbonate inlier (Plate 4g). The upper contact, with the Weatherall Formation, is drawn at the appearance of calcareous sandstone. The Cape De Bray beds thus make up the lower part of a thick shale–siltstone–sandstone coarsening-upward sequence, the sandy, calcareous fossiliferous top of which forms the base of the Weatherall Formation.

The Cape De Bray Formation also outcrops along the axes of anticlines in the southeast and south-central parts of Melville Island, where, however, exposures are invariably poor.

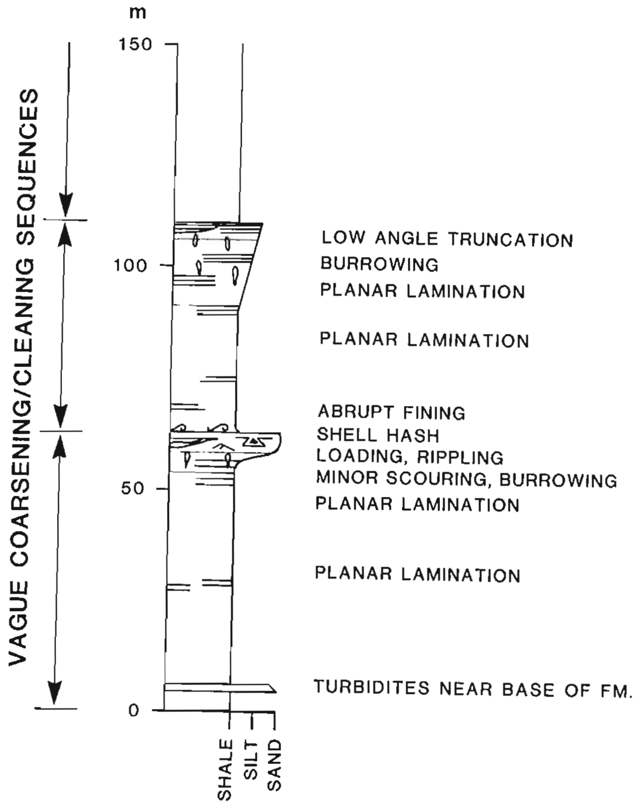


Figure 13. Diagrammatic representation of a typical facies sequence of the Cape De Bray Formation.

Age. Samples taken for palynological dating from the base of the Cape De Bray Formation in central and western Melville Island have invariably proven to be barren. The base of the Cape De Bray Formation, where it forms the base of the clastic wedge on Melville Island, is approximately early Eifelian, probably diachronous, being younger to the west, as is the base of the clastic wedge elsewhere in the Arctic Islands (Goodbody, 1985; Goodbody, 1989).

Conodonts have been obtained from the top of carbonate underlying the Cape De Bray Formation and from calcareous sandstone at the base of the Weatherall Formation in the Towson Point Inlier; these indicate an early Eifelian age. The top of the Cape De Bray Formation becomes younger westward. This is evident from age determinations (see McGregor, *this volume*). Brachiopods and spores from the top of the formation east of Liddon Gulf, south-central Melville Island, indicate a probable late Eifelian age. Miospores from the top of the formation near the mouth of Ibbett Bay, western Melville Island, indicate a late early Givetian age. Tozer and Thorsteinsson (1964) collected Givetian fossils from the lower part of the formation at the type section on western Melville Island.

Environment of depositon. The Cape De Bray Formation was evidently deposited in a variety of outer shelf, slope, and basinal settings. The sedimentology of the formation is described later in a discussion of the Cape De Bray, Weatherall, and Hecla Bay sedimentary complex (Hecla Bay wedge).

Weatherall Formation

Description. The term "Weatherall Formation" was introduced by Tozer and Thorsteinsson (1964) for interbedded sandstone, siltstone and shale, with marine fossils, that overlie Devonian limestone, and that underlie sandstone of the Hecla Bay Formation. On western Melville Island, in the vicinity of the Canrobert Hills, Tozer and Thorsteinsson (1964) recognized a tripartite division of the Weatherall Formation. Embry and Klovan (1976) raised the three divisions to formational rank as the Blackley and Cape De Bray formations, and a revised Weatherall Formation (Table 1).

Tozer and Thorsteinsson (1964) chose a type section for the Weatherall Formation (stated as approximately 1400 m thick) along a southerly flowing stream 15 km east of Weatherall Bay (the same stream that exposes the unnamed carbonates and the Cape De Bray

Formation in the Towson Point Inlier). Exposure is poor at this location. They recognized a two-fold division of the Weatherall Formation on eastern Melville Island; a lower member consisting of drab-coloured, thin bedded sandstone, siltstone and shale with marine fossils, and an upper member containing relatively thick units of light coloured sandstone. The lowest 80 m of the lower member of the Weatherall Formation of Tozer and Thorsteinsson (1964) at the type locality are now assigned to the Cape De Bray Formation (Embry and Klovan, 1976). The transitional interval between the Weatherall Formation and an overlying massive sequence of light coloured sandstone (the Hecla Bay Formation) represents the upper member of the Weatherall of Tozer and Thorsteinsson. The upper boundary of the Weatherall is now taken "at the horizon above which white, fine grained sandstone becomes common in the section" (Embry and Klovan, 1976, see their Fig. 6).

A well exposed section of the Weatherall Formation occurs along a stream that cuts through an anticline 25 km southeast of the head of Beverley Inlet. The Weatherall Formation, 1000 m thick at this locality, consists of repeated shale-siltstone-sandstone coarsening-upward parasequences (Column D in Fig. 14). A hierarchy of these parasequences is discernible: large-scale coarsening-upward successions >50 m thick (Plate 7a) are composed of increasingly sandy, 3–8 m thick shale–siltstone–sandstone rhythms (Plate 7b, d, e; Plate 8a, c, d). The large-scale parasequences become less correlable and less distinct upsection in the formation. Abundant trace fossils are present in the siltstone and fine sandstone that cap the small-scale rhythms. There are also brachiopods, bivalves, and trilobite fragments. As noted by Tozer and Thorsteinsson, noncalcareous sandstone interbeds increase in importance upsection. An 80 m thick interval that is dominated by yellow, noncalcareous sandstone intercalated with dark grey-brown siltstone and shale (Plate 7g) marks the relatively abrupt transition into white- to yellow-weathering sandstone of the Hecla Bay Formation on eastern Melville Island (Plate 7f).

A well exposed and easily accessible section through the entire Weatherall Formation is present 13 km southwest of McCormick Inlet, north-central Melville Island (Column C, Fig. 14). The formation is 1350 m thick at this locality. The basal contact with the Cape De Bray Formation in this area has already been described. Both large- and small-scale cyclicity within the formation is readily apparent. This section is shale-rich, and ironstone is abundant. Rich brachiopod and bivalve faunas are present in the upper parts of the small-scale rhythms. The transition into sandstone of the Hecla Bay Formation is fairly abrupt, both at this location and at exposures along the East Kitson River, 30 km to the northwest (Plate 8b, e).

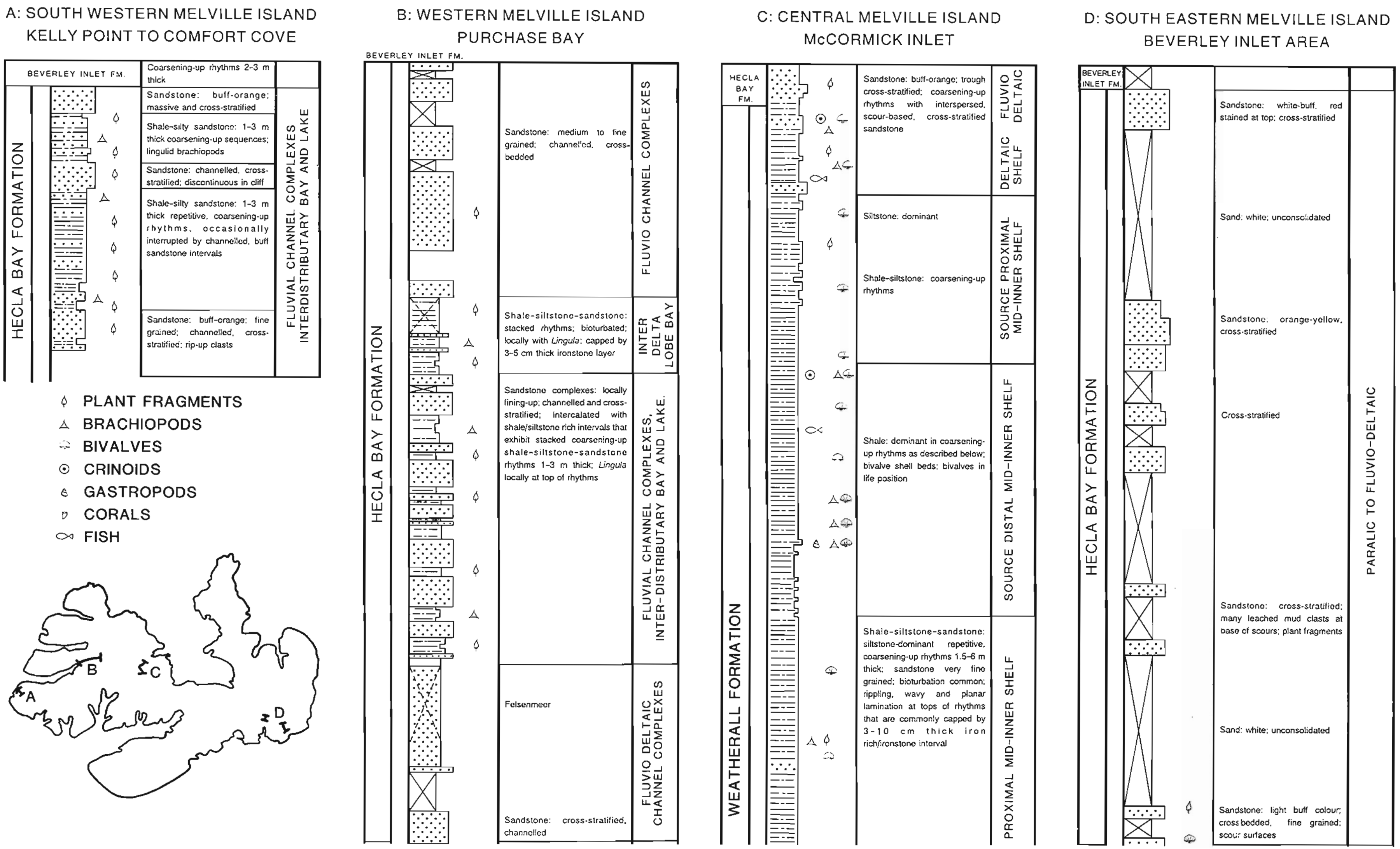
Extensive interdigitation of orange-buff-weathering, noncalcareous sandstone (i.e., Hecla Bay lithology according to Tozer and Thorsteinsson, 1964) and dark brown to grey shale, siltstone, and silty sandstone (Weatherall lithology of the same authors) occurs in cliff exposures between Barry Bay and Ibbett Bay (Plate 9b, 10). The boundary between the Weatherall and Hecla Bay formations in this area was described as "ill defined", and the Hecla Bay sandstone was noted as shaling out southwestward into Weatherall type assemblages (Tozer and Thorsteinsson, 1964). The boundary is arbitrarily placed where the orange-buff-weathering sandstone characteristic of the Hecla Bay Formation first becomes common upward in the section. In sections along the southern shore of Ibbett Bay, the lower part of the Weatherall Formation is made up of shale to siltstone to calcareous, variably fossiliferous, fine grained sandstone coarsening-upward successions 3 to 8 m thick. This sedimentological pattern resembles that of the formation in eastern and central Melville Island. The upper part of the formation in westernmost Melville Island, as seen in sections south of Humphries Head and Kelly Point, consists of repeated, 1 to 3 m thick, coarsening-upward rhythms of dark grey, silty shale grading to brown and buff, sparsely fossiliferous, variably calcareous siltstone and silty sandstone. The regularity of these rhythms is locally disrupted by light yellow to orange coloured splay and channel sandstones (Plate 11).

The age of the Weatherall Formation is discussed later, in conjunction with that of the Hecla Bay Formation.

Environment of deposition. The variation in the type and scale of coarsening-upward successions within the Weatherall Formation reflects deposition in a variety of environments, ranging from mid-shelf to inner shelf settings (discussed further below).

Hecla Bay Formation

Description. The Hecla Bay Formation in eastern Melville Island was defined as "a massive sequence of light grey to white sandstone lying between the Weatherall Formation, below, and the Griper Bay Formation, above" (Tozer and Thorsteinsson, 1964). The type section was chosen on the south limb of the Robertson Point Anticline, along stream exposures 11.2 km northeast of the head of Beverley Inlet. Embry


A: SOUTH WESTERN MELVILLE ISLAND
KELLY POINT TO COMFORT COVE
BEVERLEY INLET FM.
HECLA BAY FORMATION
Coarsening-up rhythms 2-3 m thick
Sandstone: buff-orange; massive and cross-stratified
Shale-silty sandstone: 1-3 m thick coarsening-up sequences; lingulid brachiopods
Sandstone: channelled, cross-stratified; discontinuous in cliff
Shale-silty sandstone: 1-3 m thick repetitive, coarsening-up rhythms, occasionally interrupted by channelled, buff sandstone intervals
Sandstone: buff-orange; fine grained; channelled, cross-stratified; rip-up clasts
FLUVIAL CHANNEL COMPLEXES
INTERDISTRIBUTARY BAY AND LAKE
B: WESTERN MELVILLE ISLAND
PURCHASE BAY
BEVERLEY INLET FM.
HECLA BAY FORMATION
Sandstone: medium to fine grained; channelled, cross-bedded
FLUVIO CHANNEL COMPLEXES
Shale-siltstone-sandstone: stacked rhythms; bioturbated; locally with Lingula; capped by 3-5 cm thick ironstone layer
INTER DELTA LOBE BAY
Sandstone complexes: locally fining-up; channelled and cross-stratified; intercalated with shale/siltstone rich intervals that exhibit stacked coarsening-up shale-siltstone-sandstone rhythms 1-3 m thick; Lingula locally at top of rhythms
FLUVIAL CHANNEL COMPLEXES, INTER-DISTRIBUTARY BAY AND LAKE.
Felsenmeer
Sandstone: cross-stratified, channelled
FLUVIO DELTAIC CHANNEL COMPLEXES
C: CENTRAL MELVILLE ISLAND
McCORMICK INLET
HECLA BAY FM.
WEATHERALL FORMATION
Sandstone: buff-orange; trough cross-stratified; coarsening-up rhythms with interspersed, scour-based, cross-stratified sandstone
FLUVIO DELTAIC
DELTAIC SHELF
Siltstone: dominant
Shale-siltstone: coarsening-up rhythms
SOURCE PROXIMAL MID-INNER SHELF
Shale: dominant in coarsening-up rhythms as described below; bivalve shell beds; bivalves in life position
SOURCE DISTAL MID-INNER SHELF
Shale-siltstone-sandstone: siltstone-dominant repetitive, coarsening-up rhythms 1.5-6 m thick; sandstone very fine grained; bioturbation common; rippling, wavy and planar lamination at tops of rhythms that are commonly capped by 3-10 cm thick iron rich/ironstone interval
PROXIMAL MID-INNER SHELF
D: SOUTH EASTERN MELVILLE ISLAND
BEVERLEY INLET AREA
BEVERLEY INLET FM.
HECLA BAY FORMATION
Sandstone: white-buff, red stained at top; cross-stratified
Sand: white; unconsolidated
Sandstone: orange-yellow, cross-stratified
Cross-stratified
Sandstone: cross-stratified; many leached mud clasts at base of scours; plant fragments
Sand: white; unconsolidated
Sandstone: light buff colour; cross bedded, fine grained; scour surfaces
PARALIC TO FLUVIO-DELTAIC
PLANT FRAGMENTS
BRACHIOPODS
BIVALVES
CRINOIDS
GASTROPODS
CORALS
FISH
A
B
C
D

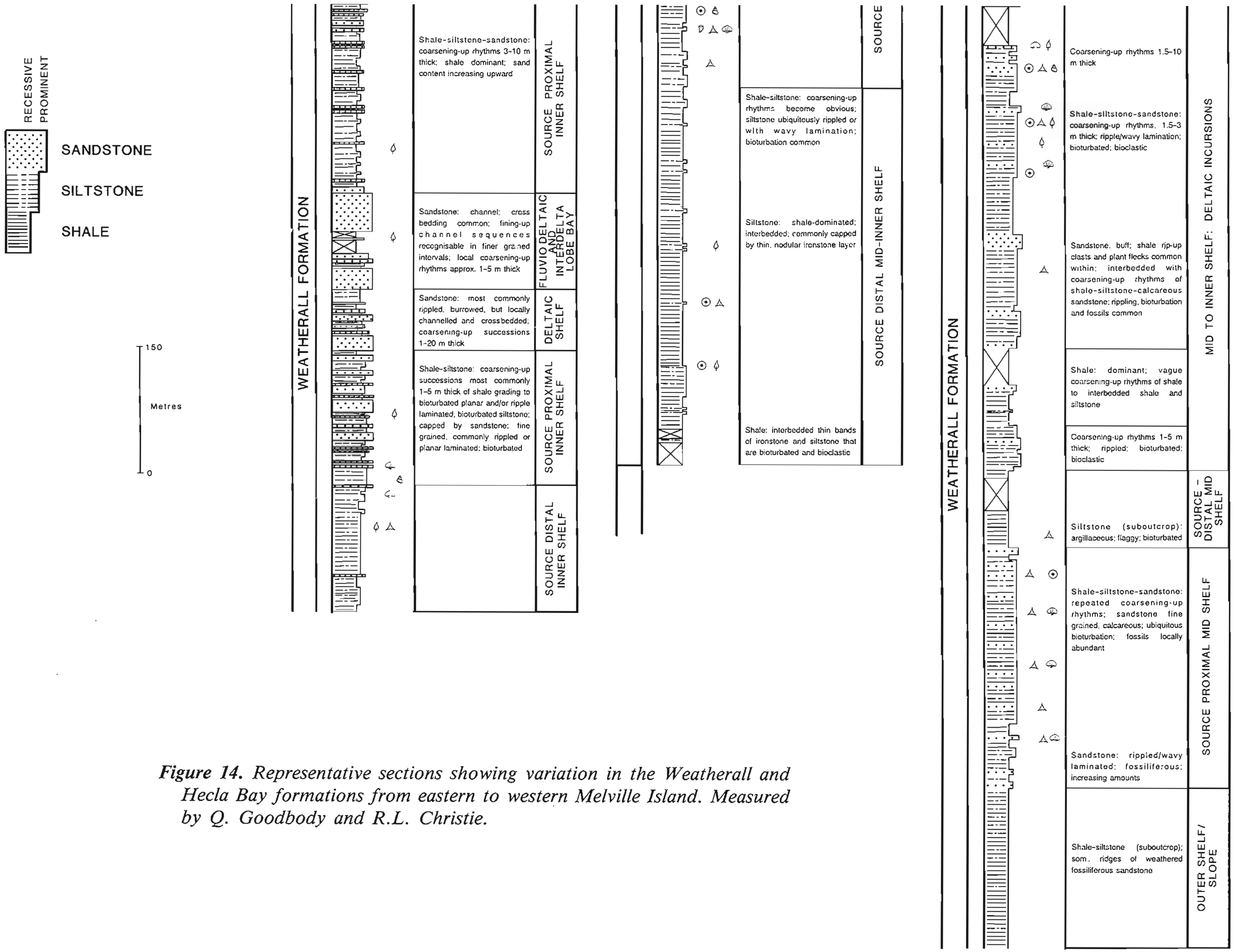


Figure 14. *Representative sections showing variation in the Weatherall and Hecla Bay formations from eastern to western Melville Island. Measured by Q. Goodbody and R.L. Christie.*

and Klovan (1976) measured and published this section (their Fig. 5).

In eastern Melville Island, the Hecla Bay Formation (750–1050 m thick) is composed of variably cemented, fine to medium grained quartzose sandstone with a subordinate amount of dark siltstone. Exposures commonly consist of recessive, unconsolidated white to cream coloured sand with isolated bluffs of cemented, yellow sandstone with ubiquitous cross-stratification (Column D, Fig. 14, Plate 12d). Some very large channel scours and infills can be seen where plant debris and mud chips line the scour surfaces (Plate 12a, b, c, e). Body fossils are absent, and trace fossils exceedingly rare.

Cementation in the sandstone increases westward. The overwhelming dominance of sandstone in eastern Melville Island persists as far west as McCormick Inlet and in the Raglan Range. Chert-pebble conglomerate is present within the formation in the Raglan Range (Harrison, pers. comm., 1985).

To the southwest, in the Barry Bay and Murray Inlet areas, the Hecla Bay Formation (~670 m thick) comprises bluff-forming orange-yellow-weathering sandstone with semiprominent to recessive-weathering, dark coloured shale and siltstone interbeds, and intervals of 1–3 m thick shale-siltstone-sandstone coarsening-upward sequences. The alternation of these rock types and facies succession patterns produces a distinct banding or striping in cliff exposures (Plate 9).

The massive, sandy "Hecla Bay lithology" grades southwestward into shale- and siltstone-dominated "Weatherall lithologies". The boundary between the Weatherall and Hecla Bay formations is taken, as elsewhere, where light coloured, noncalcareous sandstones (Hecla Bay lithology) first become common upward in the section. In the Purchase Bay and Ibbett Bay areas the Hecla Bay Formation is made up of a lower sandstone-dominated interval 250 m thick, a 220 m thick central interval consisting of stacked 1–2 m thick shale to sandstone coarsening-upward successions, and an upper sandstone-dominated interval approximately 800 m thick (Fig. 14, Column B). Twelve kilometres south of Cape Terrace, the Hecla Bay Formation is 515 m thick and is made up of a lower sandstone interval (110 m), a central shale–siltstone–sandstone rhythmic interval (215 m), and an upper sandstone-dominated interval (190 m). Thirty kilometres to the south of this section, between Kelly Point and Comfort Cove, the Hecla Bay Formation is a 30 m thick, continuous sandstone sheet. All stratigraphically lower sandstones have pinched out, or are reduced to channel fills interrupting the regularity of the stacked 1–2 m thick shale to silty sandstone coarsening-upward rhythms of the Weatherall Formation (Column A, Figs. 14, 16, 17; Plate 11).

The Hecla Bay Formation is overlain by recessive, green-grey and maroon shale, siltstone and sandstone of the Beverley Inlet Formation (Fig. 9). The contact between the units is generally abrupt, except at the Cape Terrace section, where the boundary is gradational over several metres. The usually abrupt change in lithology, with the presence of reworked spores in the lowest Beverley Inlet beds (derived from Cape De Bray and Weatherall age terranes; McGregor, pers. comm., 1985) suggests a marked change in sedimentary regime. The contact between the two formations is taken to be the sequence boundary between the Hecla Bay and Beverley Inlet wedges, and appears to be at least a disconformity over much of Melville Island, grading to a conformable relationship toward the southwesternmost parts of the island.

Environment of depositon. The Hecla Bay Formation was deposited in a variety of paralic and deltaic environments (see discussion of environment of deposition in the Hecla Bay Wedge).

Age of Weatherall and Hecla Bay formations. Palynological study (McGregor, 1985a-f, 1986, *this volume*) has confirmed previous work by Chi and Hills, which indicated that the Weatherall Formation becomes younger toward the west.

The base of the Weatherall Formation is early Eifelian in age (Uyeno *in* McGregor and Camfield, 1982) near Weatherall Bay, eastern Melville Island, and the formation ranges to the lowest Givetian (McGregor, *this volume*; McGregor and Camfield, 1982). At Barry Bay, south-central Melville Island, Weatherall beds lying beneath an interdigitation of Hecla Bay and Weatherall facies are dated as early to mid-Givetian. The zone of interdigitation ranges into the late Givetian or early Frasnian. The top of the Cape De Bray Formation is late early to mid-Givetian in age south of Ibbett Bay, but the Cape De Bray–Weatherall boundary is structurally complicated at this location. At Ibbett Bay and at Purchase Bay the lower sandstone unit of the Hecla Bay Formation is mid-Givetian in age. The base of the upper Hecla Bay sandstone interval is dated as mid- to late Givetian; the uppermost beds are early Frasnian in age everywhere on the island.

Sedimentology and environments of deposition of the Cape De Bray, Weatherall, and Hecla Bay formations. Grouping the Cape De Bray, Weatherall, and Hecla Bay formations as a "complex" — in effect a single genetic unit or sequence — aids in describing the geometry of the formations, and certain sedimentological trends and events can be more easily distinguished. The three formations constitute a large, coarsening-upward succession, reflecting the southwestward advance of a clastic wedge into a pre-existing basin, with successive overstepping within the wedge of proximal facies (upper part of the Weatherall Formation and the Hecla Bay Formation) over fine grained distal facies (Cape De Bray Formation and lower part of the Weatherall Formation). Sedimentological descriptions and interpretations of the facies associations within this sequence are presented. Elucidation of the lateral relationships of these facies associations enables construction of a regional depositional model.

The Cape De Bray Formation at its base is silty shale; siltstone and silty sandstone increase in content upsection. In the McCormick Inlet section, coarsening-upward parasequences 50–75 m thick are discernible (Plate 6a, b; Fig. 13). The basal two-thirds to three-quarters of each parasequence is made up of silty shale; this is succeeded gradationally by an increase of thinly planar laminated siltstone within the shale (Plate 6c). Some parasequences are capped by thin bedded, calcareous, silty sandstone with climbing ripples, planar and wavy to parallel lamination, and, locally, by loading structures (Plate 6d). Brachiopods are present, but are not common. Evidence of bioturbation is sparse.

Thin turbidite beds of silty sandstone are present within the coarsening-upward parasequences in the lower 150 m of the formation at the McCormick Inlet section.

The small grain size, the preponderance of planar lamination, and the lack of oscillatory bedforms and crossbedding in the formation indicate source-distal, deep water deposition below both storm and fairweather wave bases. The general lack of shelly benthic faunas and of bioturbation may be related to water depth, or to rate of sedimentation. Load structures at the base of sandstone beds near the top of some parasequences are indicative of high rates of sedimentation.

The Cape De Bray Formation is made up of two divisions in seismic sections: a lower, reflection-free unit, and an upper, clinoformal unit (Fig. 15). Sigmoidal and oblique reflection patterns can be recognized within the clinoforms (terminology of Mitchum et al., 1977), which prograde toward the southwest and exhibit depositional dips as high as 15 degrees. Topset reflections in sigmoidal clinoforms merge, toward the source, with (depositionally) horizontal reflectors in the Weatherall Formation (J.C. Harrison, pers. comm.). Clinoforms near the top of the Cape De Bray Formation are exposed on the southern shore of Ibbett Bay (Plate 6e, f).

The Cape De Bray Formation is interpreted as reflecting source-distal, deep water deposition in three distinct settings (Figs. 15, 16):

1. Basin (the lower, monotonous seismic reflection-free unit and the bottom sets of the clinoforms).
2. Basin-margin step or slope (foresets of clinoforms). Maximum relief on these clinoforms is about 700 m (J.C.Harrison, pers. comm.).
3. Platform (topsets of the clinoforms); the platform region is here termed the "outer shelf".

The Weatherall Formation in eastern and central Melville Island contains coarsening-upward successions at two contrasting scales, or orders of magnitude, one within the other. The largest, in excess of 50 m thick (Plate 7a; Fig. 14 sections C, D; Fig. 18) are composed of a multitude of coarsening-upward rhythms or smaller parasequences 1 to 8 m thick (Fig. 18; Plates 7, 8). The sand content increases upward in the large-scale parasequence (Fig. 17).

The common presence of bioturbation structures, shelly fossils, and current and wave ripples in the Weatherall Formation point to deposition in shallow marine settings. The evident lateral continuity of beds within the formation is indicative of a high degree of homogeneity on the sea bottom. The Weatherall Formation was apparently deposited on an almost flat marine platform or shelf. Lateral and vertical variations within the formation reflect differences in water depth and proximity to sediment sources (Fig. 16).

Very thick, large-scale coarsening-upward parasequences in the lower part of the Weatherall Formation are interpreted as reflecting regressive shelf advances, in response either to eustatic changes in sea level or to influxes of sediment due to Ellesmerian

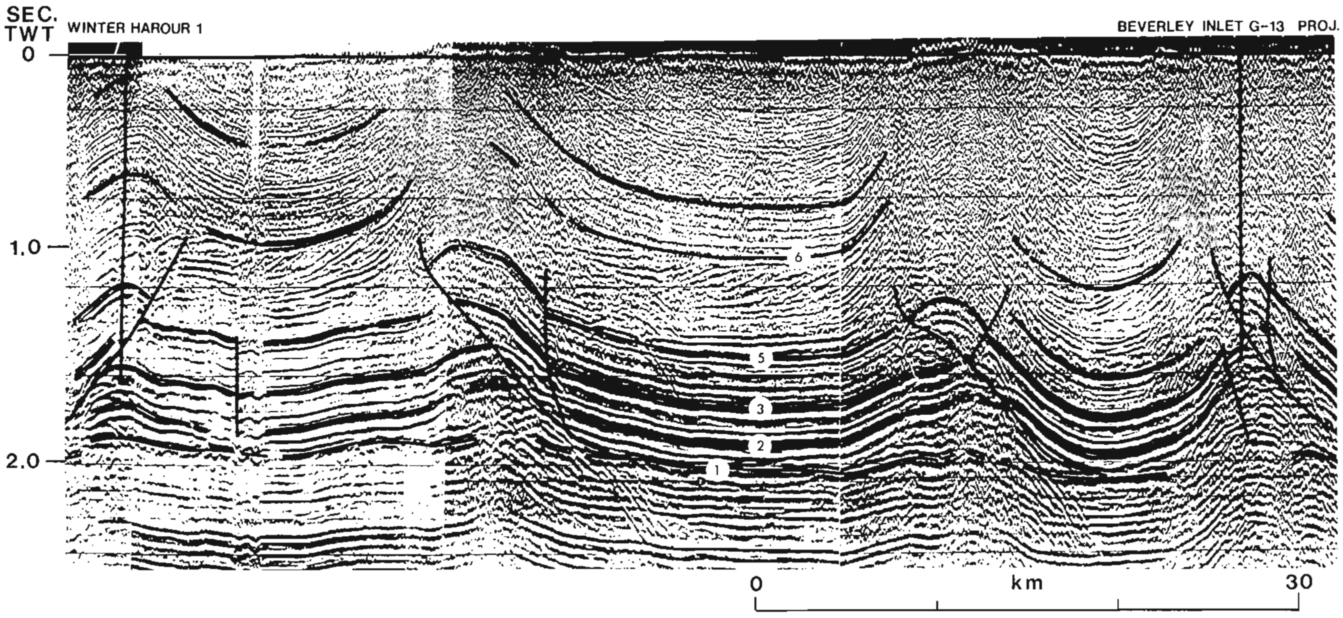


Figure 15. *Seismic profile, Beverley Inlet area. Interval between 5 and 6 is the Cape De Bray Formation. Note parallel planar reflections in basal portion of this interval, and clinoforms in upper portion. Boundary between Cape De Bray Formation and overlying Weatherall Formation is marked by 6. (From Fox, 1983.)*

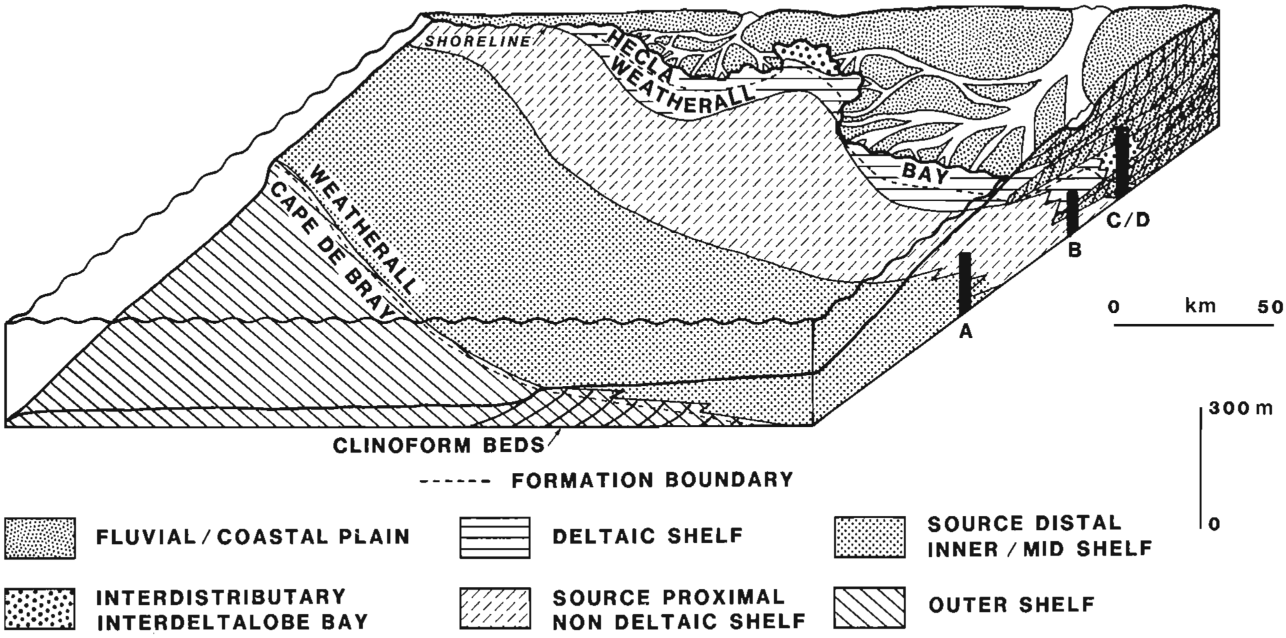


Figure 16. *Model illustrating the relative positions of the different formations forming the Hecla Bay wedge, and their sedimentary environments. Columns A, B, C/D indicate the relative positions of columns illustrated in Figures 17, 18, 19, and 20, respectively.*

tectonic pulses. The upward coarsening reflects the transition from a mid- to an inner-shelf setting. Silt-rich, sand-poor rhythms or small-scale parasequences at the base of the large-scale coarsening-upward parasequences represent source-distal shelf deposition (source-distal mid-inner shelf). Sand-rich, shale-poor rhythms in the upper portion of the coarsening-upward parasequences represent source-proximal deposition (source-proximal, nondeltaic inner shelf; Fig. 17).

The large-scale coarsening-upward parasequences become thinner, and are less readily distinguishable between sections of the upper part of the formation, where they probably represent local cones of sediment from discrete deltaic centres emptying onto a generally source-proximal shelf.

In some large-scale coarsening-upward parasequences, especially toward the top of the Weatherall Formation, the rhythmic, coarsening-upward style is not evident. Coarsening-upward rhythms may have anomalously thick, noncalcareous, nonfossiliferous sands at their tops (representing shoreline and deltaic advance onto the shelf) and the rhythmic style of facies

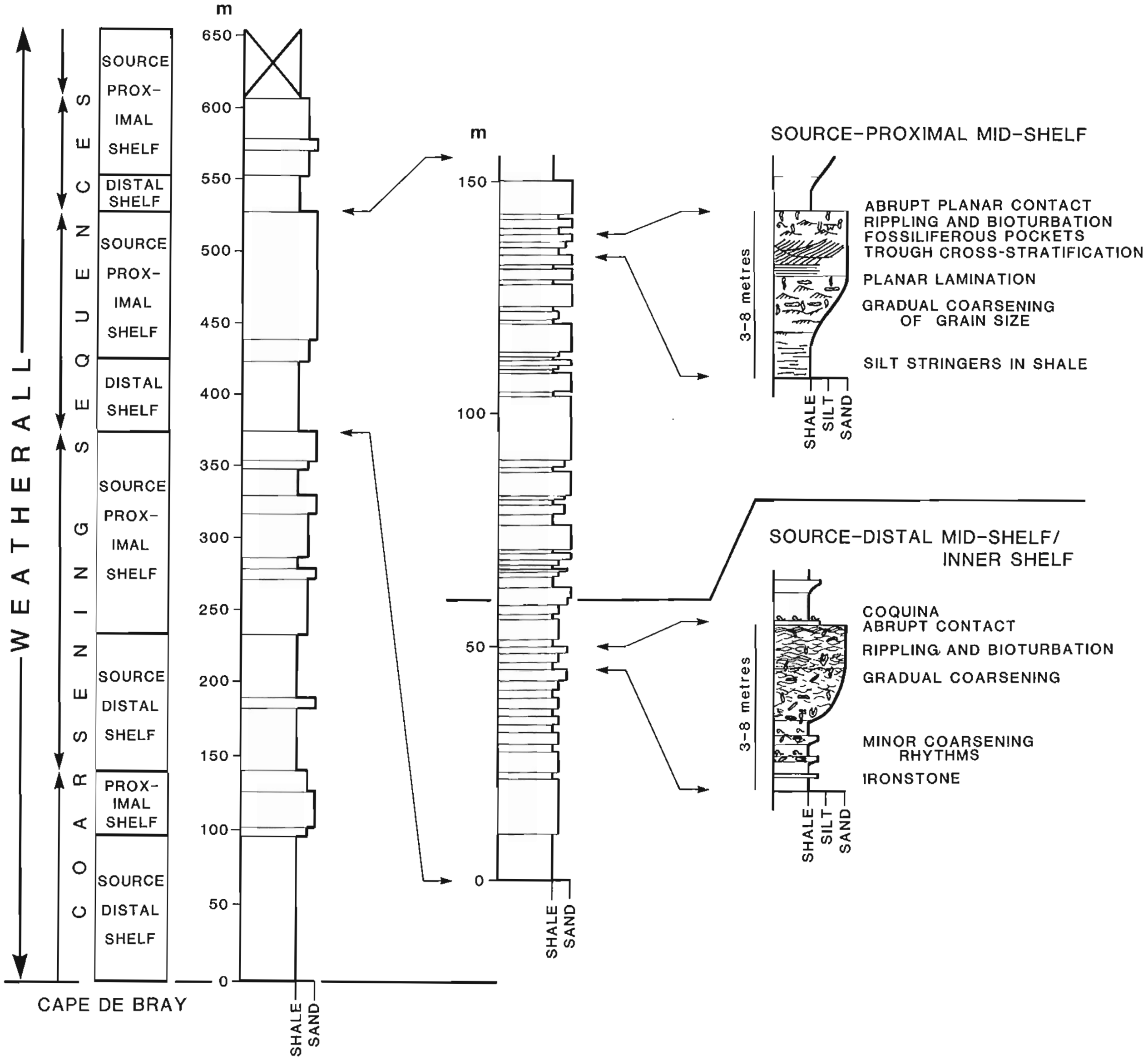


Figure 17. Diagrammatic representation of facies sequence style in nondeltaic shelf settings, Weatherall Formation. (Column A in Fig. 16.) Note the difference between source-distal and source-proximal shelf settings.

succession is locally disrupted by channel sandstones (distributary channels in shelf deposits). These hybrid, source-proximal shelf and deltaic deposits are classified as "deltaic inner-shelf" deposits (Figs. 16, 18).

The Weatherall Formation of westernmost Melville Island is characterized by a multiplicity of laterally discontinuous, repeated, 1.5–3.0 m thick, coarsening-upward, shale to fine grained sandstone rhythms (parasequences) with little bioturbation and few shelly fossils. Loading features are common in the upper portion of the rhythms (Fig. 19). The regular stacking of the rhythms is interrupted by thick, laterally discontinuous, orange, channel sandstone (Plate 10a,

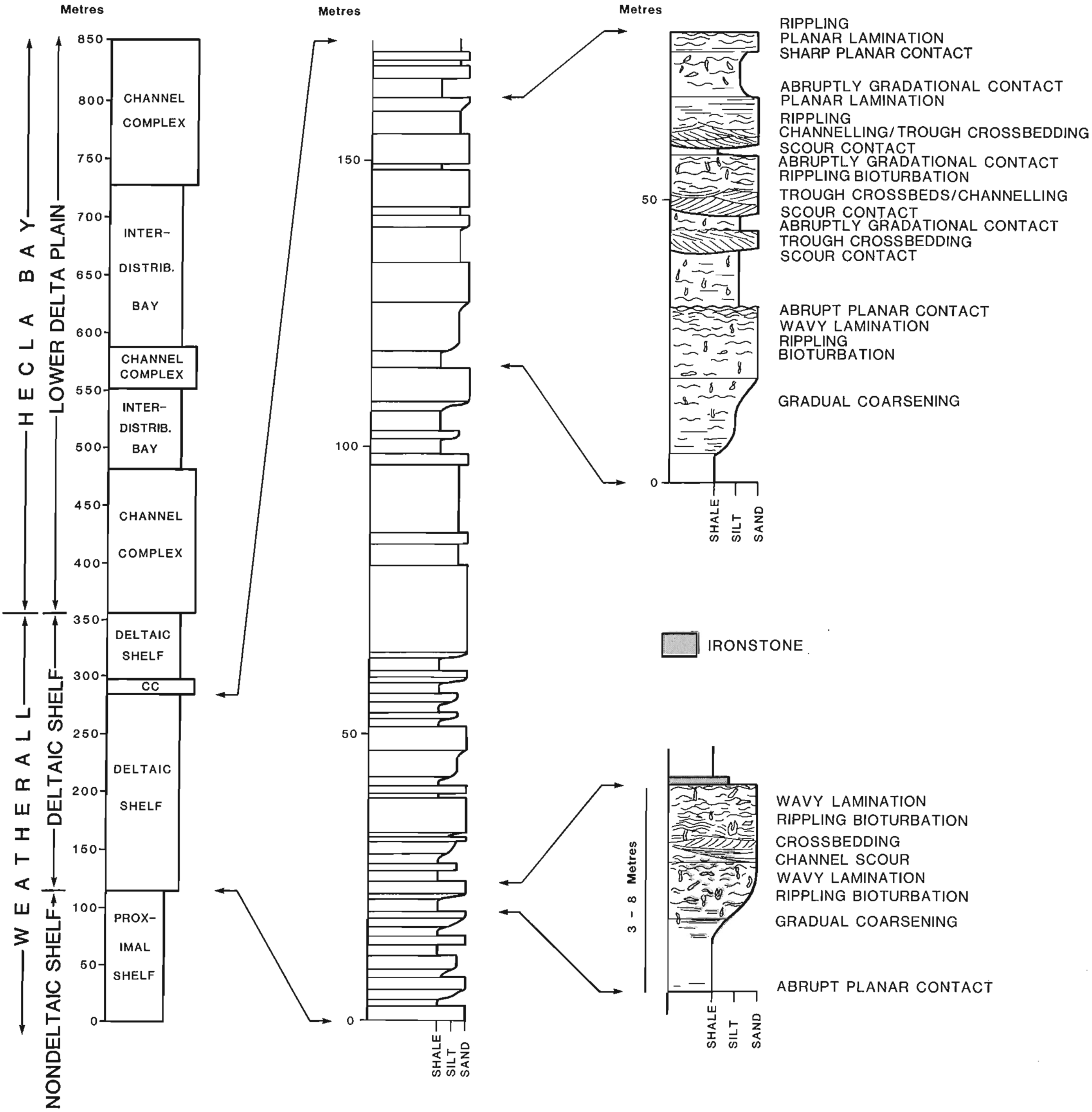


Figure 18. Diagrammatic representation of facies sequence style in the deltaic-shelf setting, Weatherall Formation. (Column B in Fig. 16.)

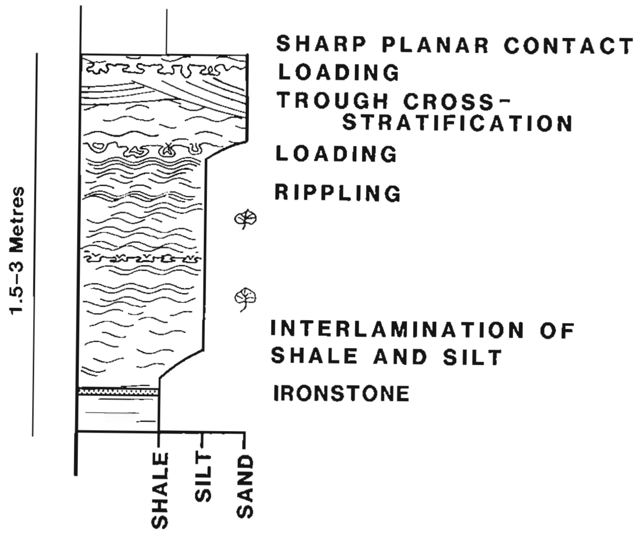


Figure 19. Diagrammatic representation of facies sequence style of typical interdistributary/interdeltalobe bay coarsening-upward rhythms, Weatherall Formation, southwestern Melville Island. (Column C/D in Fig. 16.)

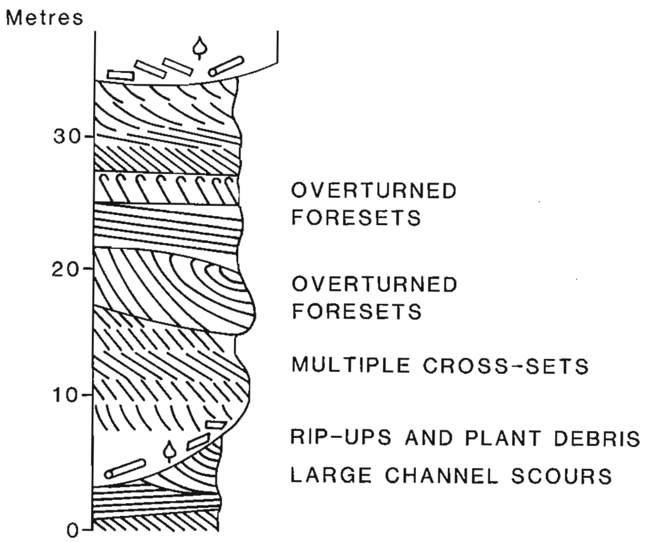


Figure 20. Diagrammatic representation of facies sequence style in the paralic/coastal plain Hecla Bay Formation, eastern Melville Island. (Column C/D in Fig. 16.)

b, c). These features suggest brackish water bayfill successions in inner-shelf interdistributary bay and interdeltalobe bay settings (Fig. 16).

The Hecla Bay Formation in eastern Melville Island is weakly consolidated and poorly exposed. The unit is overwhelmingly sand dominated in this region. Broad, shallow channels are locally discernible (Plate 12). Cross-stratification is ubiquitous, and overturning of foresets is common (Fig. 20; Plate 12). Siltstone and shale intercalations are rare. Trace fossils are extremely rare, and megafossils consist solely of plant debris. The formation in this area is tentatively interpreted as a paralic, coastal plain deposit.

The Hecla Bay Formation of western Melville Island includes both sandstone-dominated intervals and invervals of interbedded shale, siltstone, and sandstone. Within the sandstone-dominated intervals occur erosive-based, tabular, laterally continuous sand bodies (Plate 10), internally channelled and trough cross-stratified, which fine upward through rippled sandstone to siltstone and shale (Fig. 21). Thin beds of spore coal occur locally with finer grained rocks (Goodarzi, Goodbody, and Gentzis, 1990). These Hecla Bay successions are interpreted as channel-fill sequences. The significant lateral extent of each sand body, coupled with variation in both lateral and vertical definition of channel form within the bodies, indicates a combination of meandering and braided streams in an upper to lower delta plain setting (Fig. 16).

The interbedded shale, siltstone, and sandstone intervals are formed of stacked coarsening-upward rhythms 1-3 m thick (Fig. 22) similar to those described in the Weatherall Formation of westernmost Melville Island (Fig. 19). A similar environment of deposition is interpreted for them (interdistributary/interdeltalobe bay fill; Fig. 16).

A model of the Cape De Bray-Weatherall-Hecla Bay sedimentary complex is given in Figure 16. The three formations together are a complete shelf system that advanced across earlier basinal deposits on Melville Island. Regional correlation within the system indicates both regressive and transgressive episodes within a general southwestward advance of nonmarine over marine deposits during Givetian and earliest Frasnian times (Figs. 23, 24, 25).

A stepwise southwesterly migration of proximal over distal facies is illustrated in Figure 23. A major advance of source-proximal shelf deposits occurred in the late Eifelian (pulse 1). The top of this advance is interpreted as approximating a time-line, and acts as the datum for this cross section. It appears to record a sea level rise. Fluviodeltaic environments had not advanced into the area at this time. A second major regressive pulse (pulse 2) resulted in the advance of

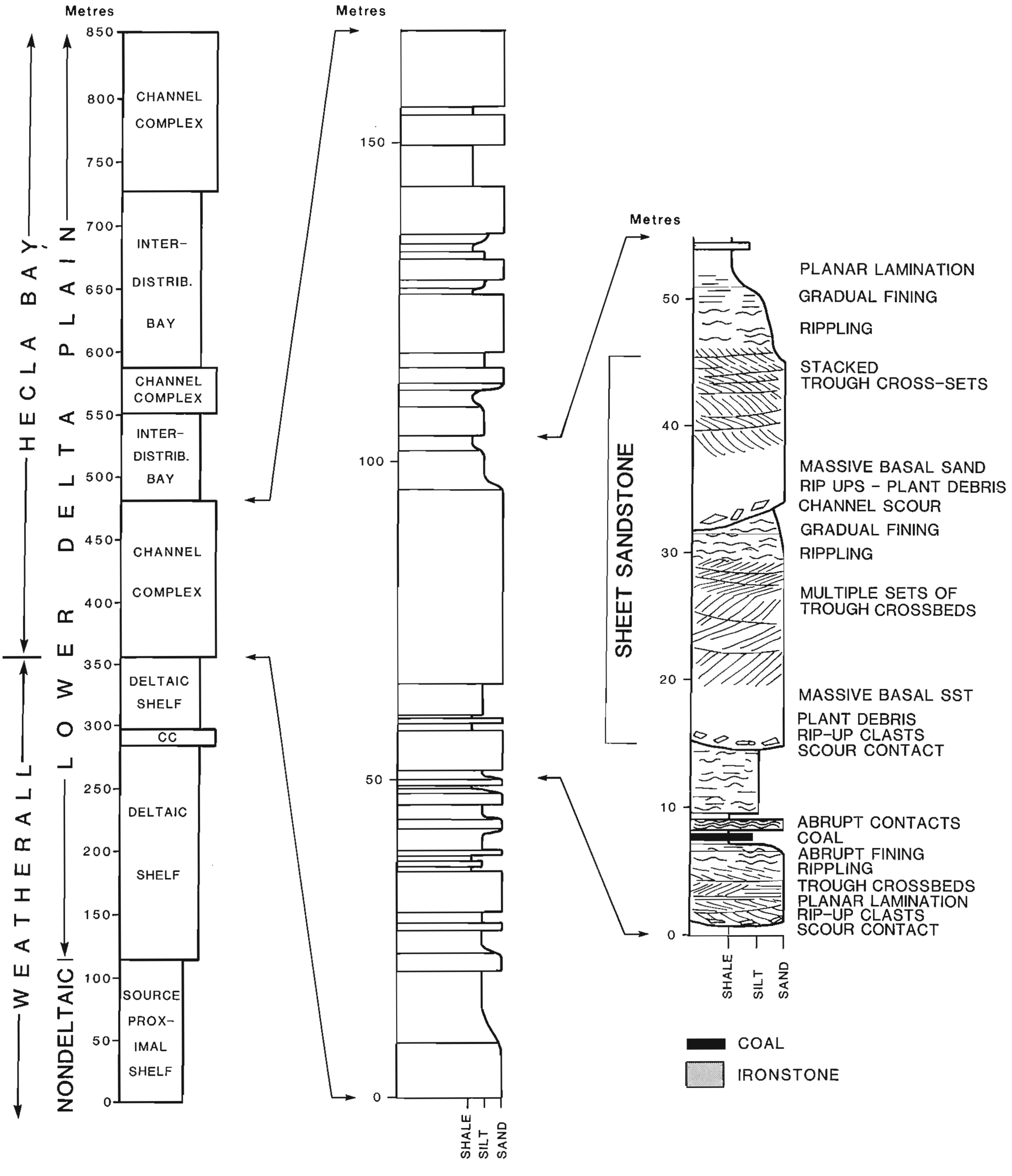


Figure 21. Diagrammatic representation of facies successions in the fluviodeltaic setting, Hecla Bay Formation, western Melville Island. CC, channel complex.

fluviodeltaic deposits to a position between the Dome Panarctic et al. Hearne F-85 and Panarctic Dome Dundas C-80 and Dome Panarctic N. Dundas N-82 wells on Dundas Peninsula. Three regressive subpulses are discernable in pulse 2; subpulse 2b apparently extends to western Melville Island (see Figs. 24, 25).

A stepwise westward advance of deltaic deposits of the Hecla Bay Formation, with the deltaic facies pinching out into shelf facies, is apparent in Figure 24. A mid-late Givetian transgressive episode can apparently be correlated with the top of subpulse 2b of Figure 23. The much greater thickness of the Givetian

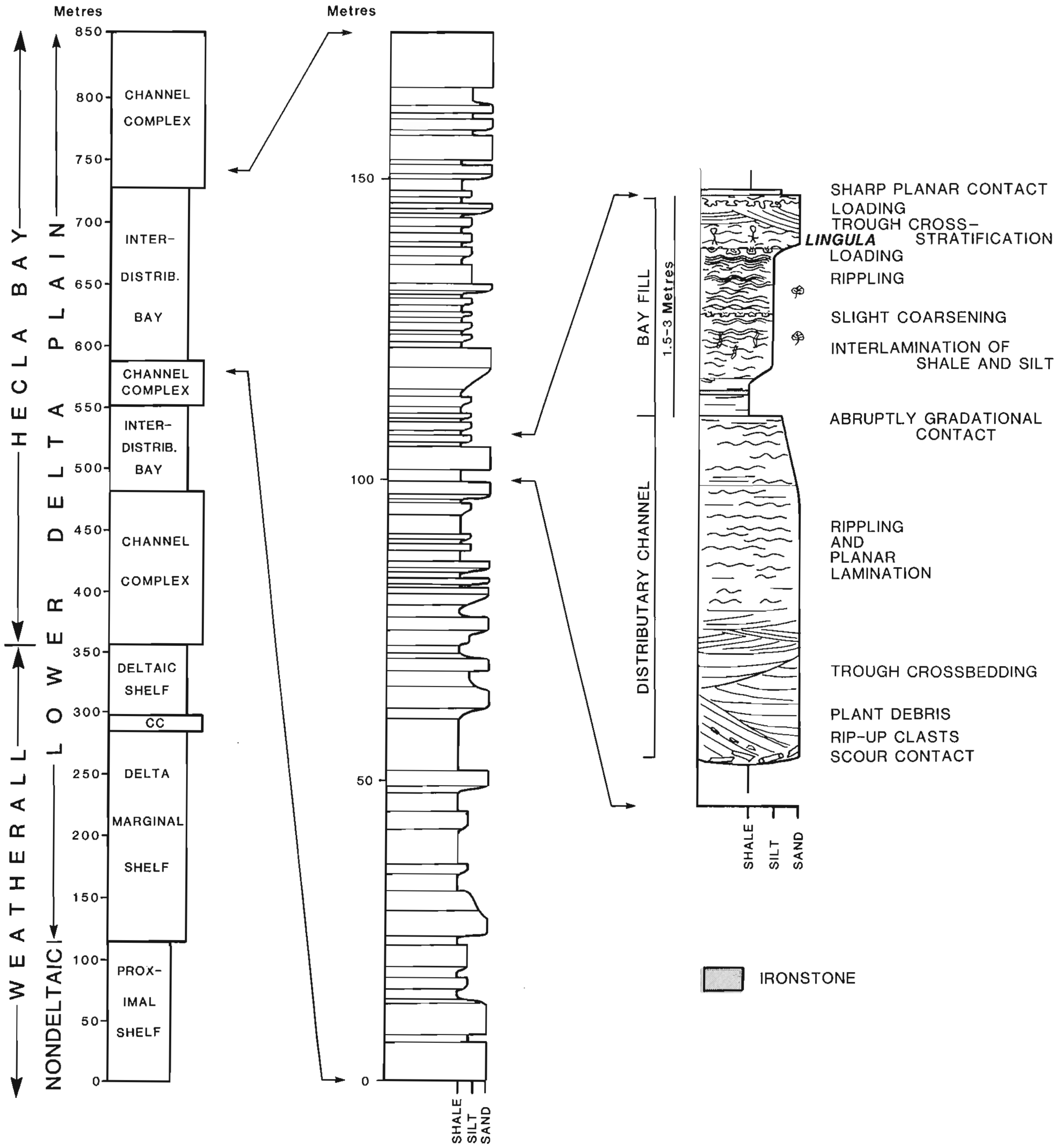


Figure 22. Diagrammatic representation of facies sequence style in the interdeltaic/interdelta-lobe setting, Hecla Bay Formation, Western Melville Island. CC, channel complex.

section in western compared to eastern Melville Island suggests that western Melville Island at this time was a main depocentre. The abrupt lateral transition between the fluviodeltaic deposits of the Hecla Bay Formation and shelf deposits of the Weatherall Formation is notable, and may be an expression of basement control. The area of transition may be a favourable one for Devonian stratigraphic traps for hydrocarbons.

The intertonguing of fluvial sandy facies of the Hecla Bay Formation with intervals of shelf sandstones, siltstones, and shales on western Melville Island

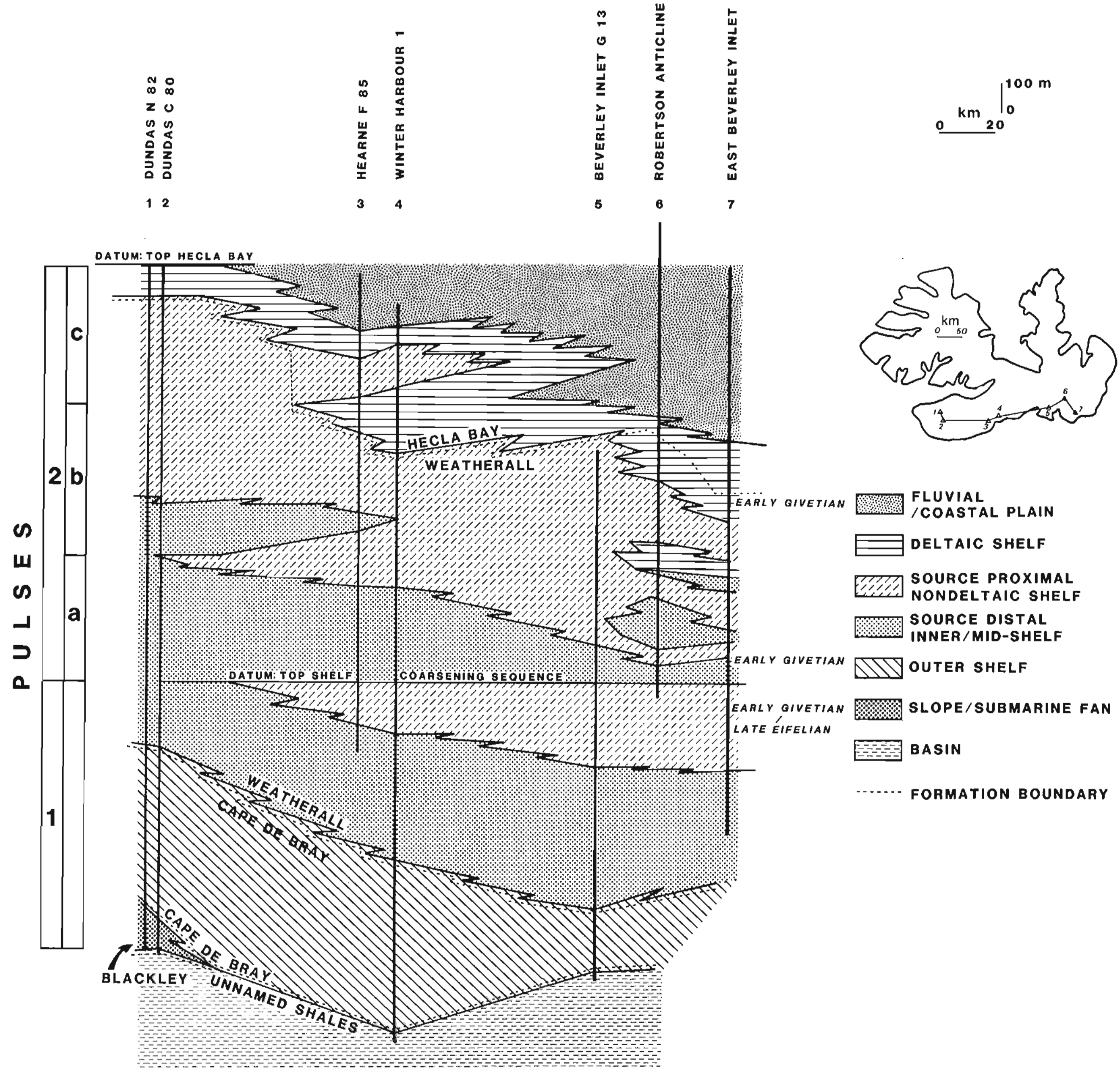


Figure 23. Cross-section through the Hecla Bay wedge, southeastern Melville Island.

is evident in Figures 24 and 25. The lower, sandy Hecla Bay tongue is thickest in the central Ibbett Bay–Purchase Bay area, but pinches out between shelf deposits to the south and west. This tongue apparently correlates with subpulse 2b of Figure 23. Extensive interdistributary or interdeltalobe, bayfill deposits occur within the Hecla Bay Formation. These deposits form the central interval that separates two sand tongues; similar deposits also occur within the upper, sandstone-dominated part of the formation.

Further investigation of the Barry Bay sections might show that much of the Hecla Bay Formation is of paralic origin, rather than fluviodeltaic as indicated (Fig. 25). If this were the case, the transition into shelf Hecla Bay deposits in the wells of Dundas Peninsula, 70 km to the south, would be less abrupt than shown.

Beverley Inlet wedge

Deposits of the Beverley Inlet wedge (Embry and Klovan, 1976) occur throughout the area south of the

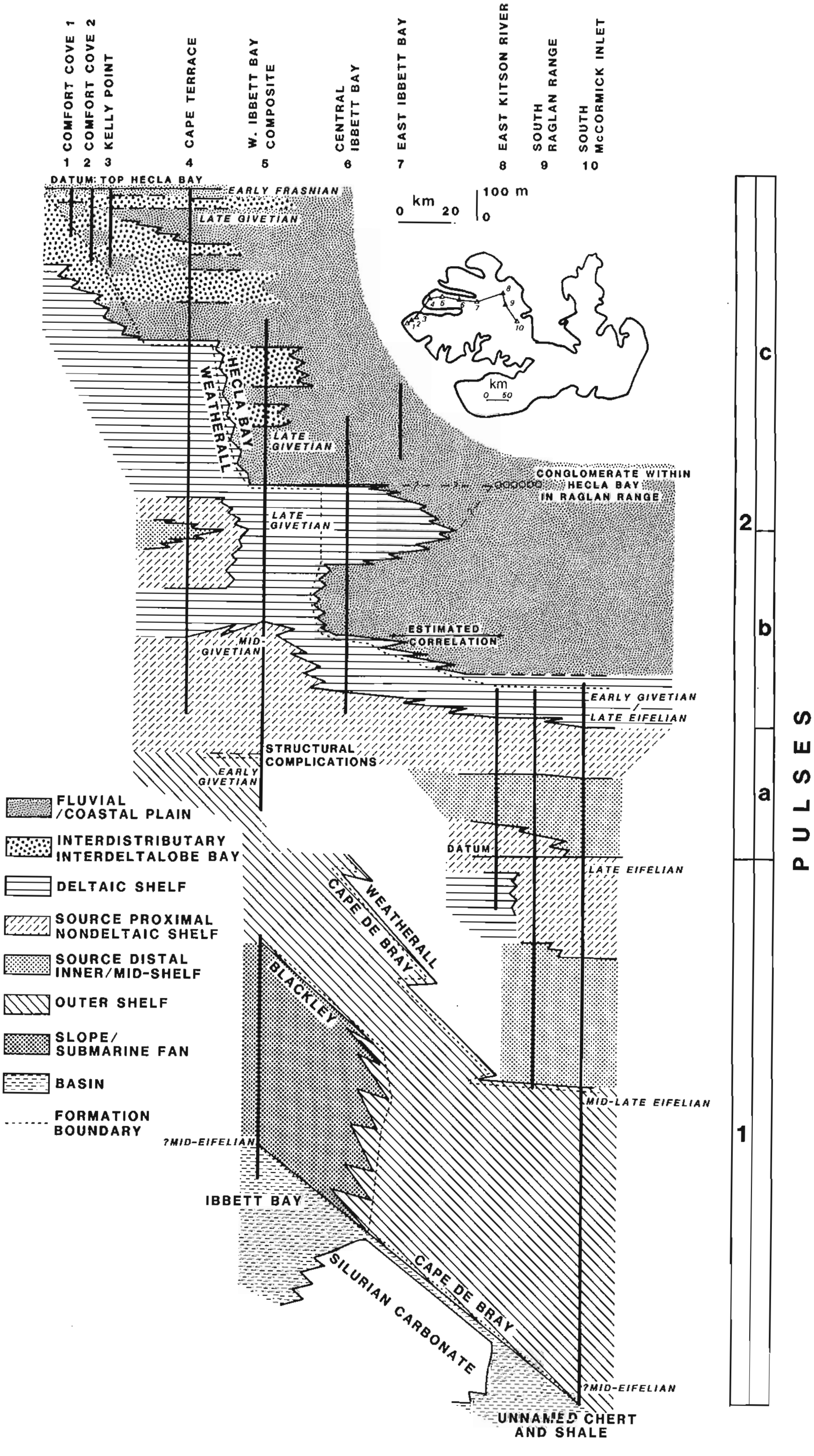


Figure 24. Cross-section through the Hecla Bay wedge, northwestern and western Melville Island.

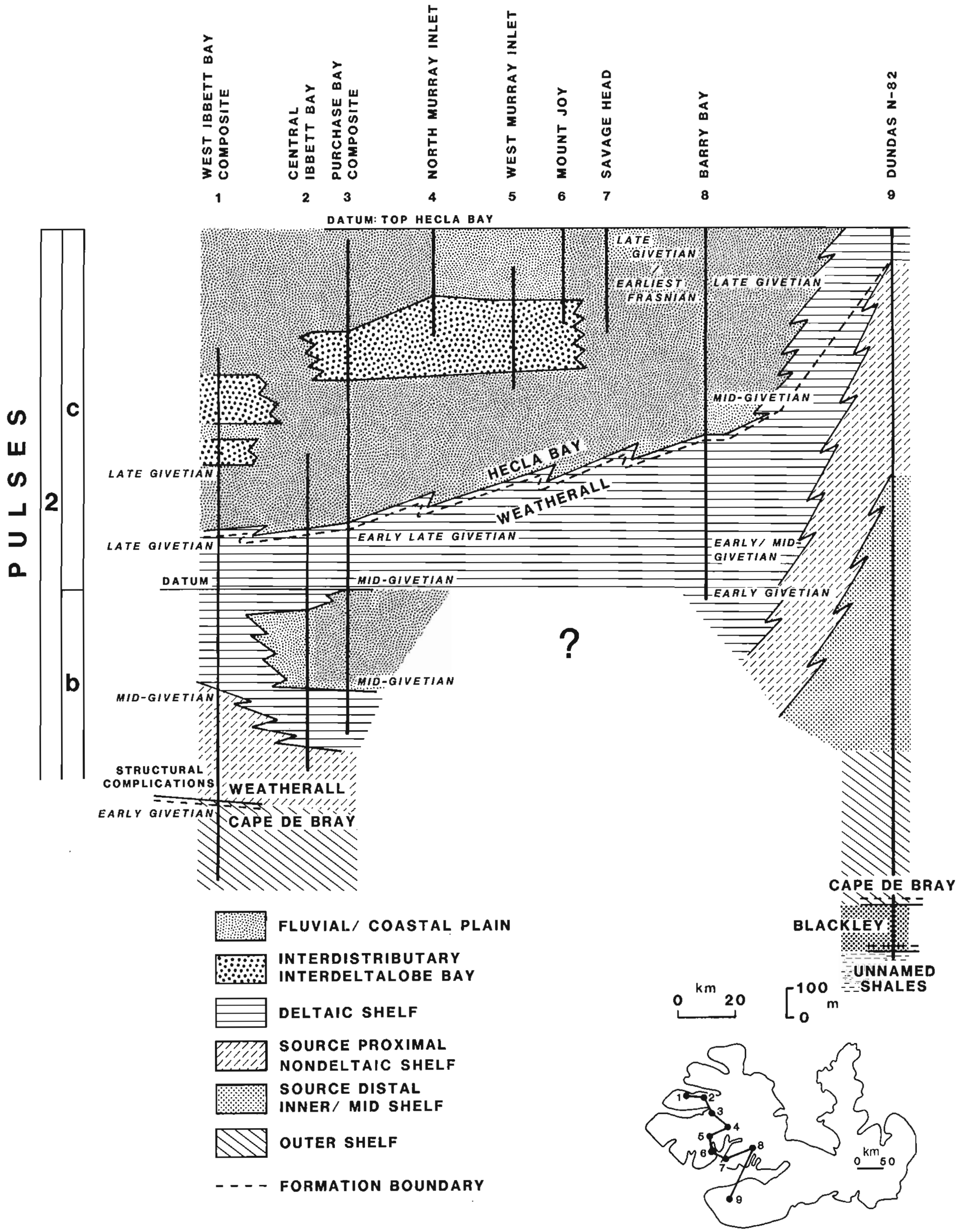


Figure 25. Cross-section through the Hecla Bay wedge, southwestern Melville Island.

margin of the Sverdrup Basin on Melville Island. In this area the wedge is made up only of the Beverley Inlet Formation. The total thickness of the unit in eastern Melville Island is 510 m (Embry and Klovan, 1976); to the southwest the wedge is truncated by the present erosion surface and an incomplete thickness of 750 m is present.

Beverley Inlet Formation

Strata now assigned to the Beverley Inlet Formation were originally mapped by Tozer and Thorsteinsson (1964) as part of the Griper Bay Formation (Table 1). The Griper Bay Formation was subsequently raised to subgroup status by Embry and Klovan (1976), who defined the Beverley Inlet Formation as consisting of interbedded fine to medium grained sandstone, siltstone and shale, with minor pebbly sandstone and coal. The type section is on the south limb of the Robertson Anticline, 12 km northeast of the head of Beverley Inlet, southeastern Melville Island.

Stratigraphic relationships. The basal contact with the Hecla Bay Formation is abrupt (Plate 13a) and apparently a disconformity in eastern and central Melville Island. Very slight angular discordance between beds above and below the boundary is apparent in cliffs on the west side of Murray Inlet; however, this is interpreted as reflecting depositional dip within the Hecla Bay Formation rather than pre-Beverley Inlet tilting of the Hecla Bay beds. The Beverley Inlet Formation is paraconformably overlain by the Parry Islands Formation on eastern Melville Island. On western Melville Island, the Beverley Inlet Formation, widely exposed at the present erosion surface, is overlain unconformably by Jurassic sandstones in down-faulted blocks (as at Comfort Cove).

Description—Eastern Melville Island. The Beverley Inlet Formation is generally recessive and, in eastern Melville Island, poor exposure inhibits a thorough understanding of the internal facies relationships. Sections measured earlier by Embry and Klovan (1976) were briefly examined at Weatherall Bay and Beverley Inlet, where the formation is 450 and 513 m thick, respectively. Thinly interbedded maroon- and green-weathering mudstone, shale and siltstone with minor amounts of grey-green sandstone abruptly overlie sandstone of the Hecla Bay Formation. The thickness of this interval varies considerably even between nearby sections (44 m in the Robertson Anticline section compared to approximately 300 m at the East Beverley Inlet locality; see Fig. 26).

The recessive, argillaceous basal portion of the formation is overlain by interbedded shale, siltstone and sandstone variably arranged in coarsening- and fining-upward sequences, buff to white channelled sandstone, coaly sandstone, and occasional coals. These beds are well exposed at the Robertson Inlet locality (470 m thick), and in cliffs on the east side of Weatherall Bay (>200 m thick) (Plates 13b, 15a).

Description—Western Melville Island. The Beverley Inlet Formation is well exposed on west-central and southwestern Melville Island. Four sections were measured in this region (Figs. 27, 28).

1. At the head of the northwest arm of Murray Inlet (Fig. 27, section C) the basal 140 m of the formation consist of a succession of variably complete fining-upward sequences. These sequences are 2 to 4 m thick, with brown and grey-green cross-bedded sandstone at their base grading upward into variably light grey-green to maroon-weathering siltstone and shale (Plate 13c, d). Fine grained lithologies predominate. The succeeding 130 m consist of a basal bluff-forming sandstone, a central argillaceous coaly interval, and a capping, bluff-forming sandstone, which is cross-stratified and in places discontinuous due to channelling; outcrops locally exhibit spectacular channel migration sequences (Plate 13e). The upper sandstone is overlain by 185 m of recessive, very dark shale with minor amounts of interbedded sandstone, siltstone and coal. In excess of 175 m of bluff-forming, yellow- and orange-weathering, crossbedded sandstone with lesser amounts of intercalated shale and siltstone form the top of the measured section.

2. Another composite section (B, Fig. 27) illustrates the stratigraphy within the formation between Cape Smith and Cape Russell. In shoreline cliffs near Cape Victoria (Plate 14a), the upper part of the Hecla Bay Formation and the basal 275 m of the Beverley Inlet Formation are exposed. At this locality, the basal 80 m of the Beverley Inlet Formation consists of green- and maroon-weathering shale and siltstone with intercalated light brown, sharp-based channel sandstone (generally 0.5–1.5 m thick, with a few beds up to 4.5 m). Fining-upward channel sequences contain root casts. The succeeding 64 m consist of greenish brown shale and siltstone with intercalated, discontinuous greenish brown channel sandstone up to 7.5 m thick (Fig. 14b). This is overlain by 36 m of dark green-grey, recessive-weathering shale. Very thin, dark green, silty sandstone layers

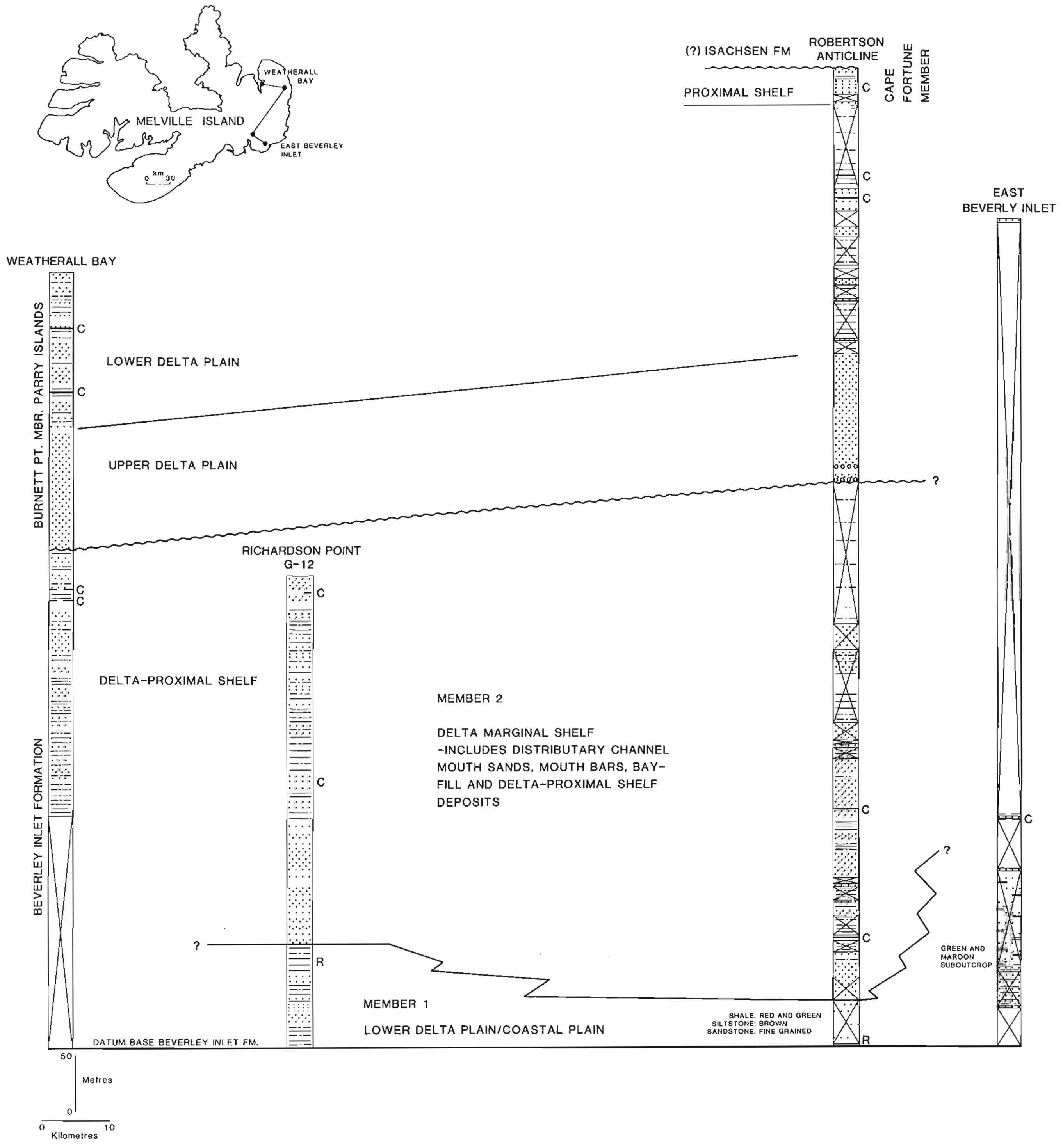


Figure 26. Stratigraphy of the Beverley Inlet Formation (Upper Devonian), eastern Melville Island. C = coal; R = red.

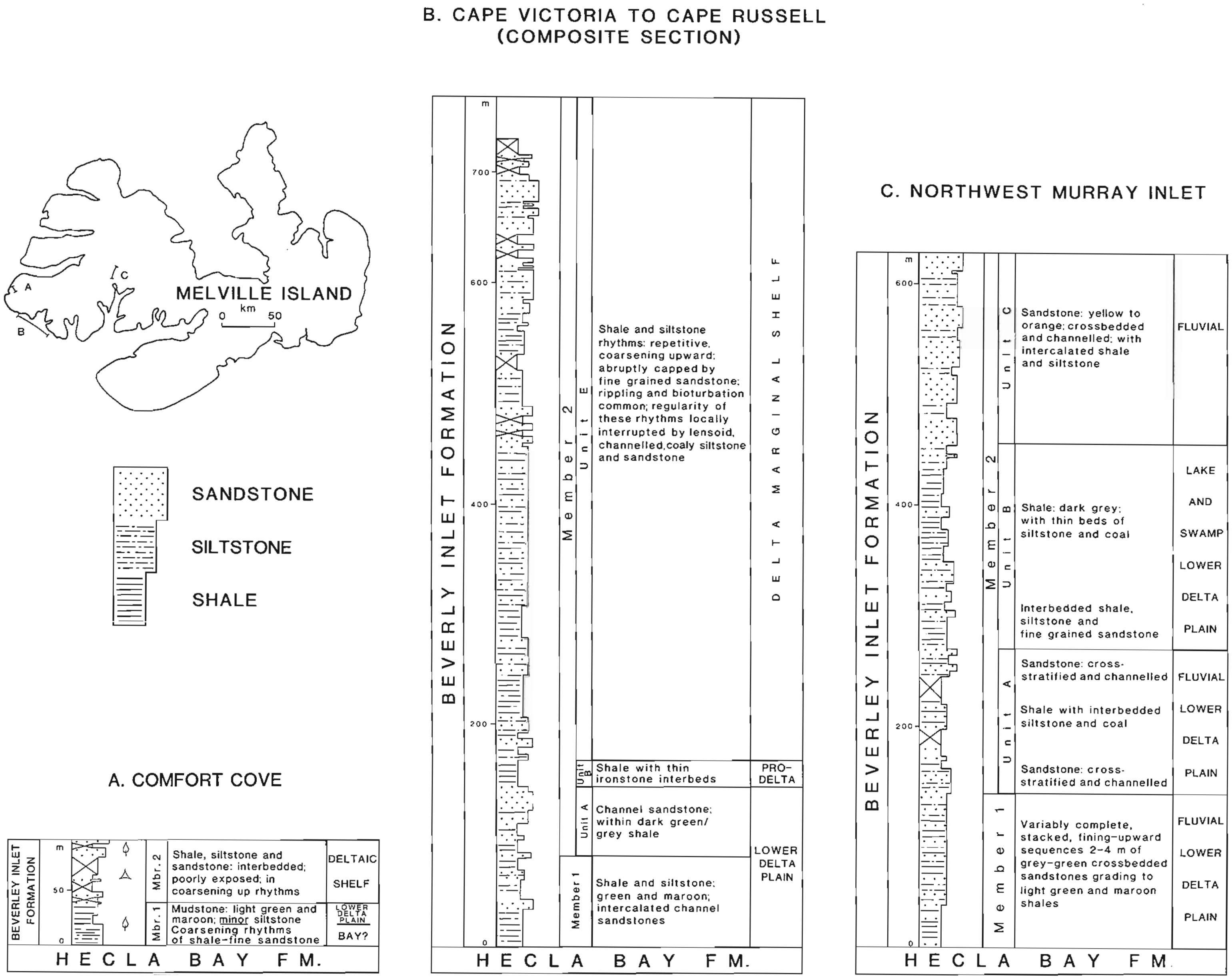


Figure 27. *Representative composite measured sections of the Beverley Inlet Formation, south-central and southwestern Melville Island. Measured by Q. Goodbody and R.L. Christie. See Figure 14 for legend.*

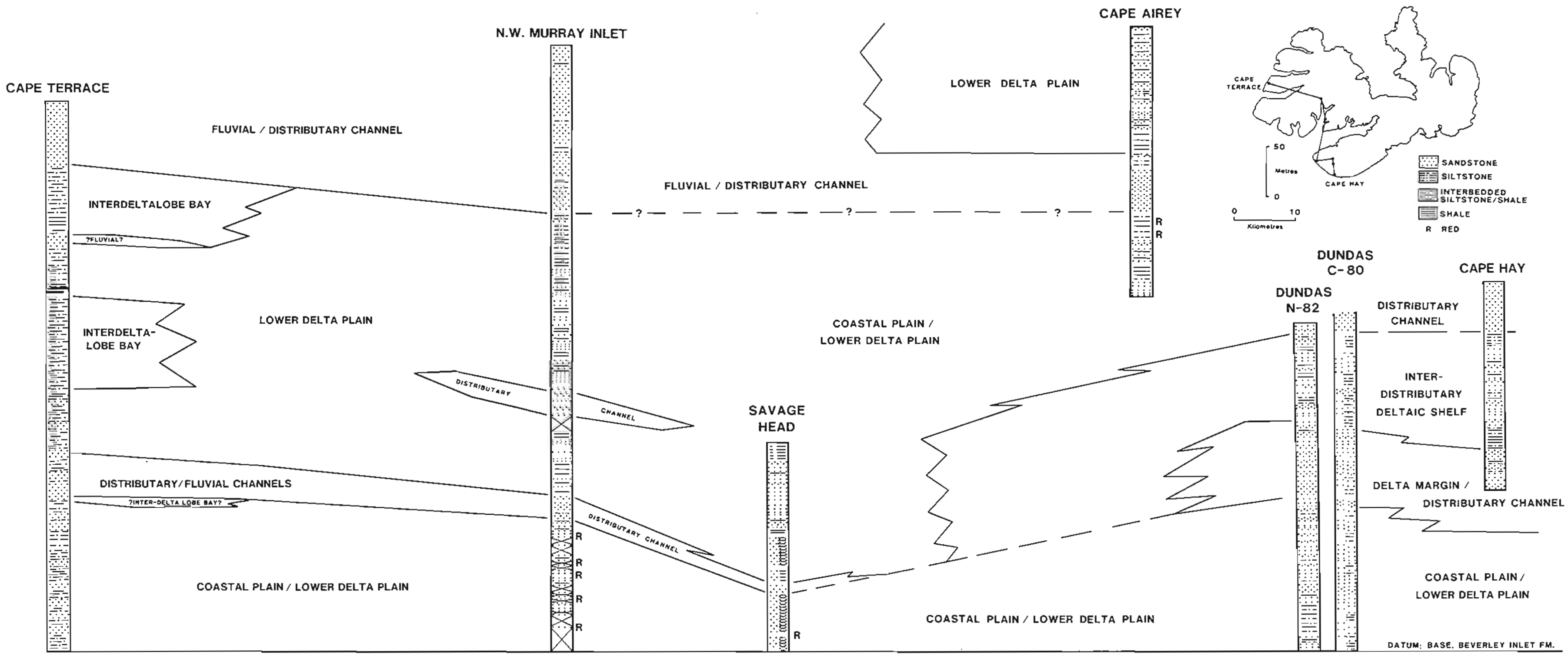


Figure 28. *Cross-section of the Beverley Inlet Formation, south-central to western Melville Island showing stratigraphic relation of measured sections, and distribution of interpreted environments of deposition. Sections measured by Q. Goodbody and R.L. Christie.*

are present at scattered horizons; planar bands of continuous and nodular ironstones, approximately 15 cm thick, are common. This shale interval is succeeded by more than 550 m (thickness obtained from combined sections) of interbedded shale, siltstone, and sandstone arranged in coarsening-upward rhythms (parasequences) 1.5 to 3.0 m thick. The beds forming these rhythms give the cliffs between Cape Smith and Comfort Cove a banded appearance (Plate 14d). Bedding is generally horizontal but indistinct. Low angle clinoforms are discernible in some exposures. The regular stacking of these parasequences is interrrupted at various levels by lensoid intervals of brown-weathering siltstone and shale with minor coal locally asociated with crossbedded yellow- to orange-weathering sandstone (Plate 14d, e).

3. At Comfort Cove, southwesternmost Melville Island, the basal 10 m of the formation consists of repeated coarsening-upward rhythms (Plate 14c) of shale to fine grained sandstone (Fig. 27, Column A). This is overlain by 30 m of recessive, light green- and maroon-weathering mudstone, siltstone and minor sandstone. This interval is, in turn, succeeded by a very poorly exposed, sparsely fossiliferous sequence of interbedded shale, siltstone and sandstone.

4. At Stevens Head, prominent yellow-orange sandstone of the Hecla Bay Formation are gradationally overlain by 25 m of interbedded sandstone and grey-green siltstone that in turn grade upward into the maroon and grey-green shale- and siltstone-dominated basal portion of the Beverley Inlet Formation. The succeeding 125 m of the Beverly Inlet Formation consist of variably maroon, light grey, grey-green, and grey-brown siltstone and shale with minor sandstone. This is overlain by a ridge-forming interval 95 m thick, which consists of three distinct ribs of internally crossbedded and channelled sandstone units separated by recessive shale and siltstone. The remainder of the section (225 m) is shale dominated, but contains interbedded sandstone and siltstone at various levels. Sandstone in this part of the section is generally sheet-like, bioturbated, and commonly caps coarsening-upward rhythms; however, distinctly channelled sandstone is present near the base and top of this interval. Crossbedded sandstone, more than 50 m thick and apparently of the Beverley Inlet Formation [(?)possibly Parry Islands], are in faulted contact with the top of the measured section.

Dundas Peninsula. The Beverley Inlet Formation forms much of the surface of Dundas Peninsula; exposure is generally poor inland, but is excellent along sea cliffs on the south coast. Two partial sections of the formation were measured on these cliffs (Fig. 28); in addition, two incomplete subsurface sections are available from exploration wells. The formation in this region is in excess of 365 m (penetrated in the Panarctic Dome Dundas C-80 well). Correlation between sections is hampered by apparent variability in internal stratigraphy, but some similarities can be seen between the stratigraphy of this area and that at the head of Murray Inlet and near Cape Victoria (Fig. 28). Red- and green-weathering mudstone, siltstone and minor sandstone form the lowest beds in the formation. No exposed sections were measured through this unit, but it is easily recognized by its distinctive red- and green-weathering colours in aerial traverses of southeastern Dundas Peninsula. Above this interval, the formation consists of thinly interbedded shale, siltstone and sandstone with intercalated thick intervals of channelled orange-weathering sandstone. Some redbeds were noted within this upper unit at Cape Airey.

Age. Palynological data indicate a range in age from lowest to upper Frasnian for the Beverley Inlet Formation on eastern Melville Island. The base of the formation, of early Frasnian age, appears to approximate a time line across the island. Dating of this boundary is complicated by a lack of well preserved spores in the basal beds of the formation, and by the presence of reworked spores. The youngest beds preserved in southwestern Melville Island are mid-Frasnian.

Environment of deposition. Embry and Klovan (1976) noted a transition from nonmarine beds of the Beverley Inlet Formation in eastern Melville Island to marine beds in southwestern Melville Island. In eastern Melville Island, poor exposure hampers environmental interpretation. The lithology, colours and lack of trace or body fossils in the lower, argillaceous part of the formation suggest a meandering stream, lower delta plain environment of deposition. The admixture of coarsening-upward and fining-upward successions in the upper, sandier part of the formation, combined with the presence of thin coals, suggests interdigitating delta-marginal (lower delta plain, distributary channel and mouthbar) and deltaic inner-shelf settings (Fig. 26).

Six facies associations were recognized in western Melville Island. They are as follows:

Facies association 1 (Fig. 29A): fining-upward sequences 2–4 m thick of sandstone to shale within a shale-dominated succession. The base of each sequence is abrupt, commonly exhibiting erosion of the underlying shale. A lower intraclastic lag may be overlain by crossbedded sandstone, grading through rippled siltstone to shale. This style of facies sequence, the associated sedimentary structures, and the lack of marine fossils indicate a meandering fluvial, possibly lower delta plain depositional setting.

Facies association 2 (Fig. 29B): shale-dominated succession containing coarsening-upward parasequences, 1–2 m thick, of shale to silty sandstone. Sharp based, rippled siltstone and fine grained sandstone intervals of similar thickness, some fining-upward, also occur within the shale. Thin spore coals are locally present. This depositional style represents either an interdistributary bay or a deltaic shelf setting. The coarsening-upward rhythms (parasequences) are bayfill or lake-infill parasequences, and the variably loaded, fining-upward sequences are distributary channel scour-and-fill deposits and proximal to distal splay sandstones. The thin coals record the settling of spores in shallow backwater areas.

Facies association 3 (Fig. 30A): sandstone-dominated, with successive, variably complete, fining-upward sequences of crossbedded sandstone grading through rippled siltstone to shale. The sequences may be several metres thick. These rocks were probably deposited in fluvial, lower delta plain settings as the result of migration and infill of meandering to braided channels.

Facies association 4 (Fig. 30B): dark grey-brown shale within which thin planar and lensoid beds and laminae of rippled siltstone and sandstone occur. Thin beds of coal and nodular ironstone are also present within the shale. A quiet water, lower delta flood plain setting is indicated for these deposits, which occur between intervals of facies association 3.

Facies association 5 (Fig. 31A): shale-dominated, as association 4, but without coal and with less ironstone. This facies association is found below facies

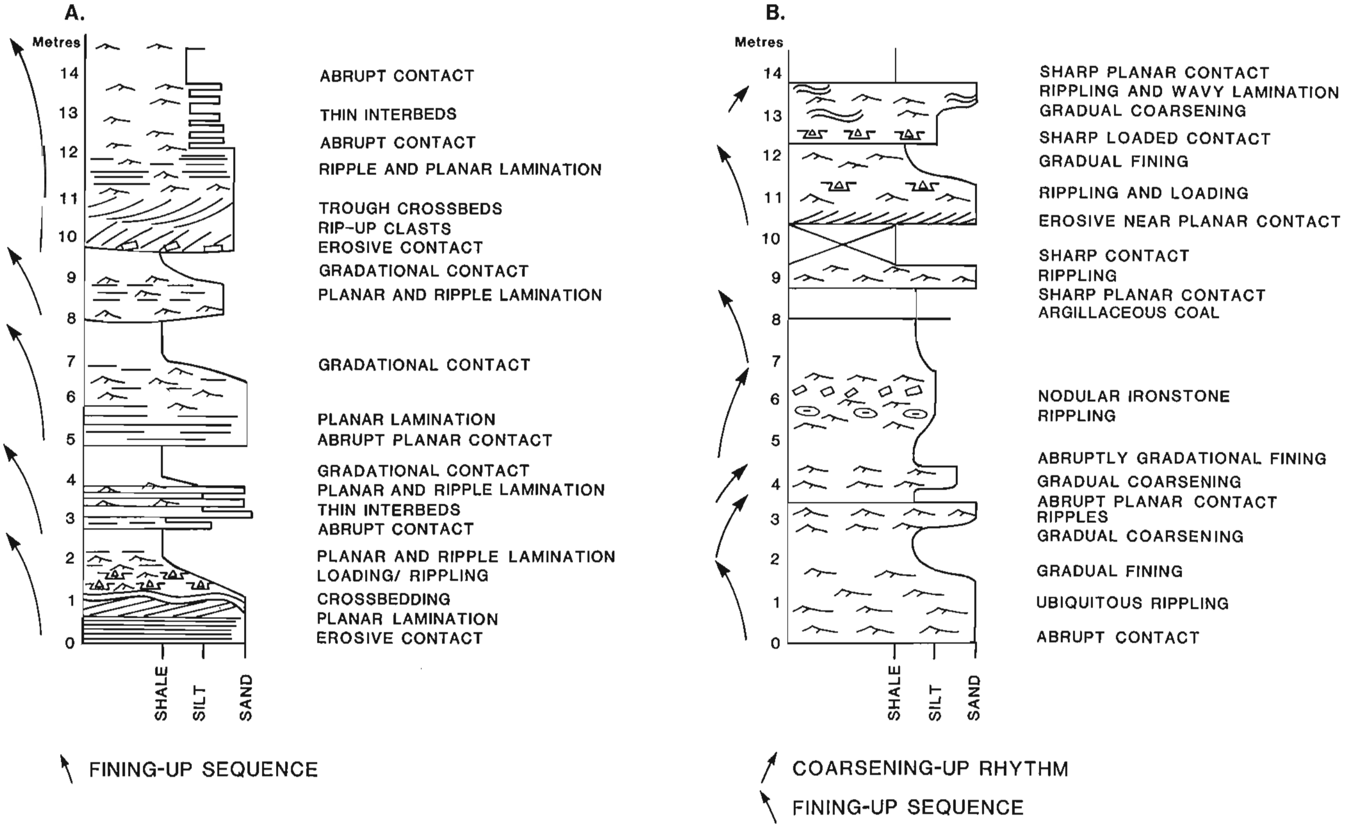


Figure 29. *A. Facies association 1, meandering fluvial.* ***B.*** *Facies association 2, interdistributary bay/deltaic shelf, Beverley Inlet Formation.*

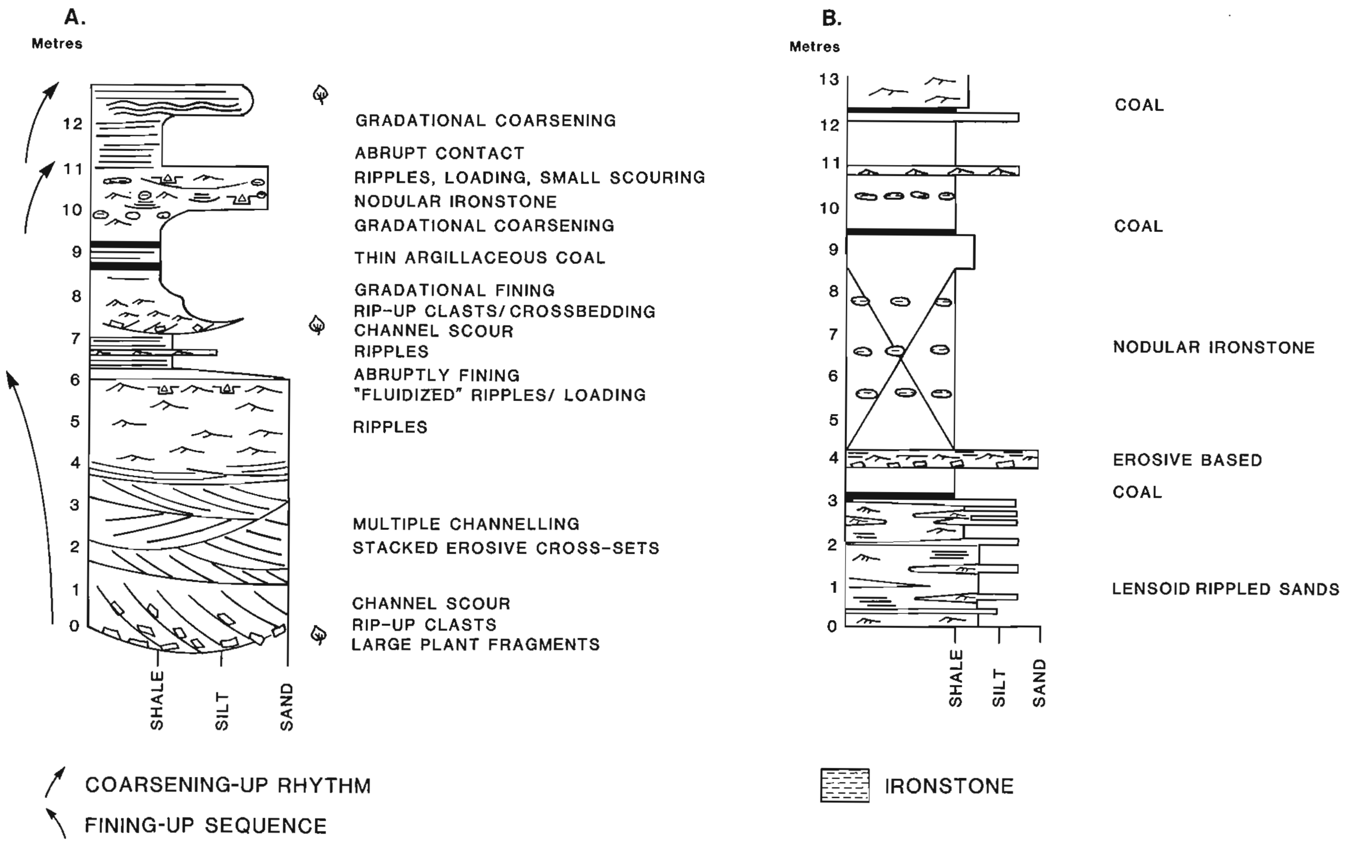


Figure 30. A. Facies association 3, fluvial-meandering to braided. B. Facies association 4, lower delta floodplain, Beverley Inlet Formation.

association 6 (source-proximal inner shelf). The absence of coal is interpreted as reflecting distance from feeder streams for spore input rather than being due to a possible increase in the rate of sedimentation. A prodeltaic to delta marginal setting is envisaged.

Facies association 6 (Fig. 31B): stacked, coarsening-upward parasequences 1.5 to 3.0 m thick of shale to siltstone to fine-grained sandstone. Planar layers of nodular ironstone are present in the basal shales, and increased rippling, scouring, and bioturbation are evident higher in the parasequences. Rarely, cross-bedding can be observed in the sandy tops. Shells (brachiopods, crinoid ossicles and fish plates) and ironstone pebble lags cap some parasequences. This facies association is taken to represent a deltaic–shelf setting.

Comparison of measured sections in western Melville Island shows a high degree of lateral variation in the Beverley Inlet Formation in this region. The environmental setting for this formation in southwestern Melville Island appears to have been one of repeated, generally southwesterly directed advances of fluviodeltaic deposits onto a shallow marine shelf (Figs. 28, 32, 33).

Parry Islands wedge. The Parry Islands wedge (Embry and Klovan, 1976) (made up of the Parry Islands Formation) is recognized with certainty only in eastern Melville Island. This wedge, about 700 m thick (Embry and Klovan, 1976), is well exposed in cliffs that form the shores of Weatherall Bay, northeastern Melville Island. Elsewhere, these deposits are preserved in the cores of synclines and form low, undulating terrain. The basal contact with the Beverley Inlet Formation is interpreted as a regional unconformity (Embry and Klovan, 1976). The stratigraphic top of the formation is not preserved. No new sections were measured in the present study.

Parry Islands Formation

Description. Embry and Klovan (1976) defined the Parry Islands Formation as a heterogeneous unit composed of white to orange, medium to coarse

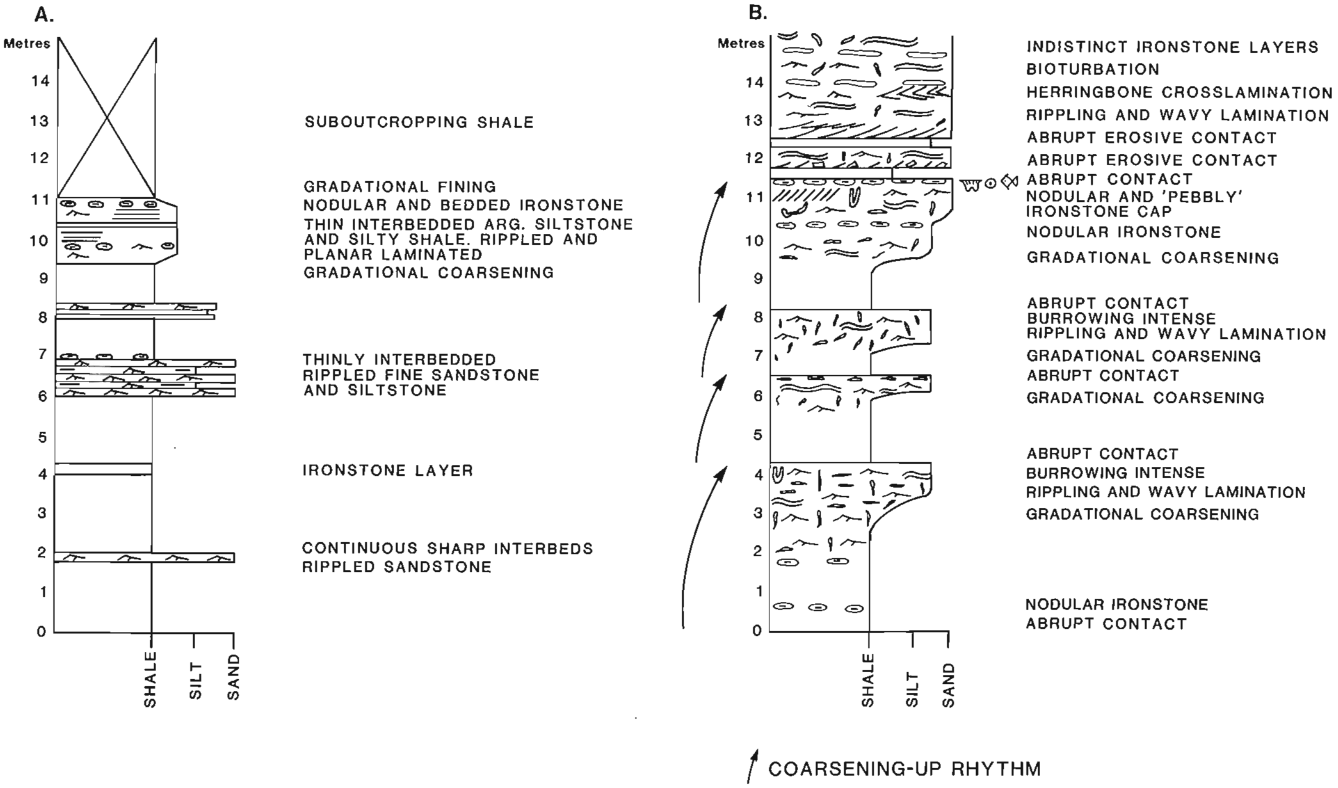


*Figure 31. A. Facies association 5, prodelta to delta margin, Member 2, unit D. **B.** Facies association 6, deltaic shelf, Member 2, unit E, Beverley Inlet Formation.*

grained sandstone, green, very fine to fine grained sandstone, siltstone, shale and coal. They recognized three members: the Burnett Point, the Cape Fortune, and the Consett Head members. The Cape Fortune Member was defined by Greiner (1963) on Cameron Island.

The Parry Islands Formation is recognized, in the present study, only in east-central and eastern Melville Island. Scattered outliers of the formation in western Melville Island were indicated by Embry and Klovan (1976, their Fig. 36); however, without biostratigraphic control, correlation between these outliers and the Parry Islands Formation is, at best, tenuous. Significant sandstone units are now known to be present in the Beverley Inlet Formation of west-central and western Melville Island, and it is likely that these sandstones were assigned by Embry and Klovan (1976) to the Parry Islands Formation.

The Burnett Point Member (275–365 m), the lowest unit, is characterized by orange to white, fine to coarse grained sandstone; shale and siltstone occur throughout and are most abundant in the upper part of the member. The Cape Fortune Member (180–250 m) is characterized by shale and siltstone with marine fossils. White, fine grained sandstone units are rare within this member. The Consett Head Member (150 m) consists of orange to white fine to medium grained sandstone. Interbeds of shale, siltstone and coal are present, but are not common.

The light yellow to light buff coloured conglomeratic sandstones of the basal Parry Islands Formation (Burnett Point Member) contrast sharply with the grey-green colour of the uppermost Beverley Inlet Formation in eastern Melville Island. The basal contact with the underlying Beverley Inlet Formation is sharp. Well exposed cliff sections on the east side of Weatherall Bay were chosen as the type section of the Burnett Point Member (Embry and Klovan, 1976). Chert and siltstone pebbles and ironstone intraclasts are present within the lowermost sandstone horizons. Considerable crossbedding and large scale channelling characterize the member (Plate 15b, c).

The Cape Fortune Member, at the Robertson anticline locality 7.5 km northeast of Beverley Inlet, is exposed as a ridged weathered exposure of ruddy brown shales and grey-brown and grey-green, locally

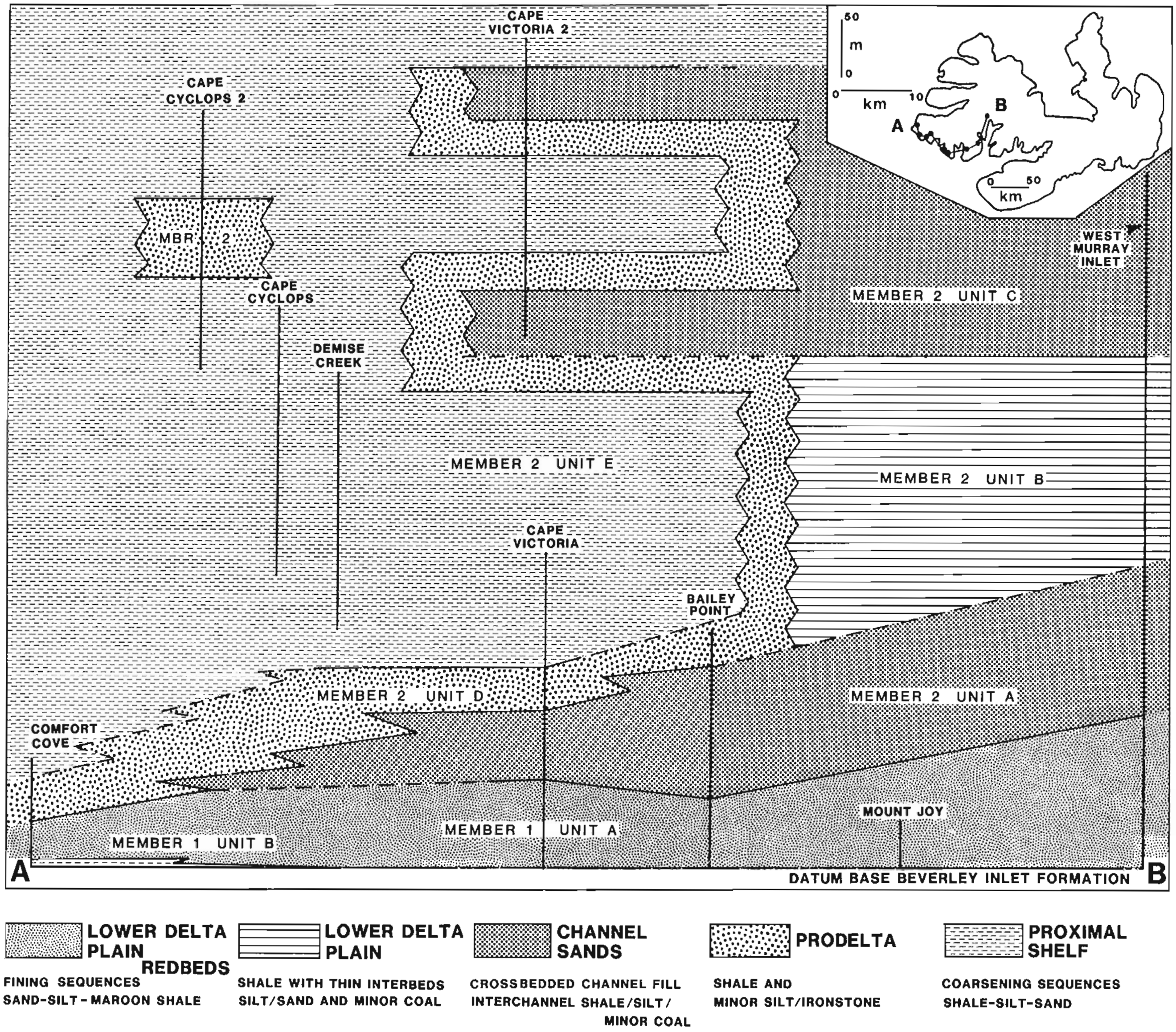


Figure 32. Cross-section, Beverley Inlet Formation, southwestern Melville Island showing relation between measured sections, and distribution of interpreted depositional environments.

iron stained, fine grained sandstones. The type section of the Consett Head Member was designated at the core of the syncline between Consett Head and Robertson Point, where, as elsewhere, this member is poorly exposed. A three-fold division of the Consett Head Member is recognized (Harrison, pers. comm.): a lower sandstone, a medial shale, and an upper, sandstone-dominated interval with significant coal content.

Age. Spores from 2.3 m above the base of the Burnett Point Member are late, but not latest, Frasnian (*ovalis-bulliferus* Zone). The lower beds of the Cape Fortune Member contain spores of the *torquata-gracilis* Zone of early, but not earliest, Famennian age. Conodonts of the Lower to Middle *crepida* Zone, of Lower Famennian age, were obtained 60 m above the base of this member. The Consett Head Member is mid to late (not latest) Famennian (Upper *torquata-gracilis* Zone) in age (McGregor, *this volume*).

Environment of deposition. Embry and Klovan (1976) interpreted the Parry Islands Formation as representing an oscillating delta plain and marine shelf. Depositional environments of the members are assigned as follows: Burnett Point Member, braided

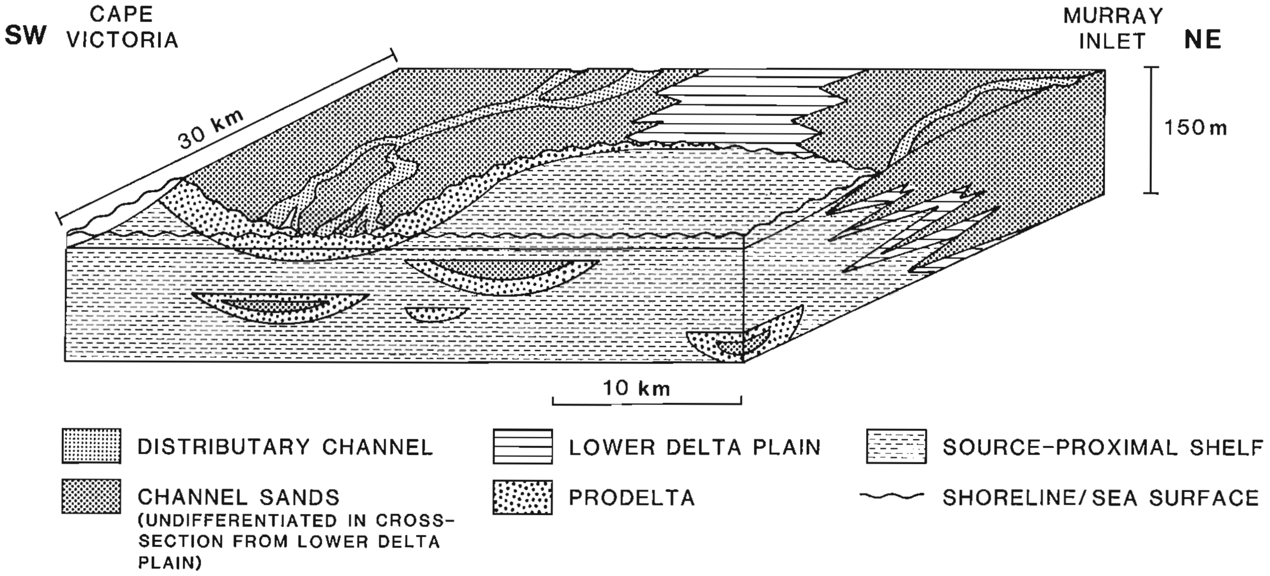


***Figure 33.** Model showing spatial relationships of sedimentary environments, Beverley Inlet wedge, southwestern Melville Island.*

stream to meandering stream; Cape Fortune Member, delta plain and marine shelf; Consett Head Member, fluvial (lower sand unit), marine or lacustrine (medial shale), and fluvial-deltaic (upper sand and coal unit).

Middle to Upper Devonian tectono-stratigraphic setting

The Middle to Upper Devonian clastic succession described above was deposited in a foreland basin that lay in front of the southward-advancing Ellesmerian Orogenic Belt (Embry, 1988). The three constituent wedges are interpreted as stratigraphic sequences (sensu Mitchum et al., 1977), which resulted from intermittent thrusting in the northern and eastern hinterland region. The action of tectonism, eustacy, and autocyclic sedimentary processes (such as delta switching) are evident within each of these sequences in the guise of the many smaller scale sequences and parasequence sets that constitute them.

A profound unconformity separates these deposits from the overlying basal clastics of the Sverdrup Basin (Canyon Fiord Formation). The angularity of this unconformity indicates a period of folding, uplift, and erosion, which occurred between the Famennian and the Viséan (Harrison, 1991, *this volume*; Embry, 1988). Embry (1988) considered that between 2500 and 3000 m of Clastic Wedge strata, which originally overlay the Parry Islands Formation, were eroded from the Melville Island area during this orogenic episode.

SUMMARY

Deposits of the Franklinian Mobile Belt (Upper Precambrian to upper Devonian) are widely exposed and occur extensively in the subsurface of Melville Island. Limestones, dolostones, evaporites and black shales of Cambrian to lower Middle Devonian age are overlain by a thick succession of clastic rocks of Middle and Upper Devonian age.

The lower carbonate-shale portion of the Franklinian succession is divisible into three superposed sequences, each representing a carbonate platform-shale basin couplet (Fig. 1; also Goodbody and Christie, *this volume*) with its own distinct distribution of platformal and basinal facies.

The abrupt change to clastic deposition that occurred in the Middle Devonian reflects a dramatic change in the tectonic setting of the Franklinian Mobile Belt. The Melville Island area was directly experiencing the effects of the advancing Ellesmerian orogenic front in the form of receiving clastic sediments eroded from uplifted areas to the north and east (Embry and Klovan, 1976; Embry, 1988). The resulting "Clastic Wedge" is made up of three tectonostratigraphic sequences, the origins of which lie in intermittent thrusting, erosion and crustal loading within the orogen. The advance of Ellesmerian orogenesis into the Melville Island area in the Late Devonian is indicated by a profound angular unconformity, which separates these Franklinian rocks from the succeeding deposits of the Sverdrup Basin.

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PLATES 1–15

PLATE 1

Canrobert Formation

a. General view of Canrobert Formation, near section Robson 2, south-central Canrobert Hills. Approximately 350 m of section shown. (GSC photo no. 2533-17.)

b. Conglomerate. Note lack of sorting of clasts in silty dolostone matrix; also draping of breccia by light grey, laminated, silty dolostone (at extreme top of bed). (GSC photo no. 2444-329.)

c. Turbidite bed, showing distinct upward fining. (GSC photo no. 2444-79.)

d. Large-scale slump fold within thin bedded argillaceous dolostone. (GSC photo no. 2444-344.)

e, f. Cleaning/coarsening-upward sequences of argillaceous to less argillaceous dolostone. Note change from thin bedded argillaceous dolostone (facies 2) to thicker bedded, less argillaceous dolostone upsection. Conglomerate beds locally occur in the more prominent-weathering, upper portions of these sequences. (GSC photo nos. 2444-349, 2444-341.)

PLATE 1

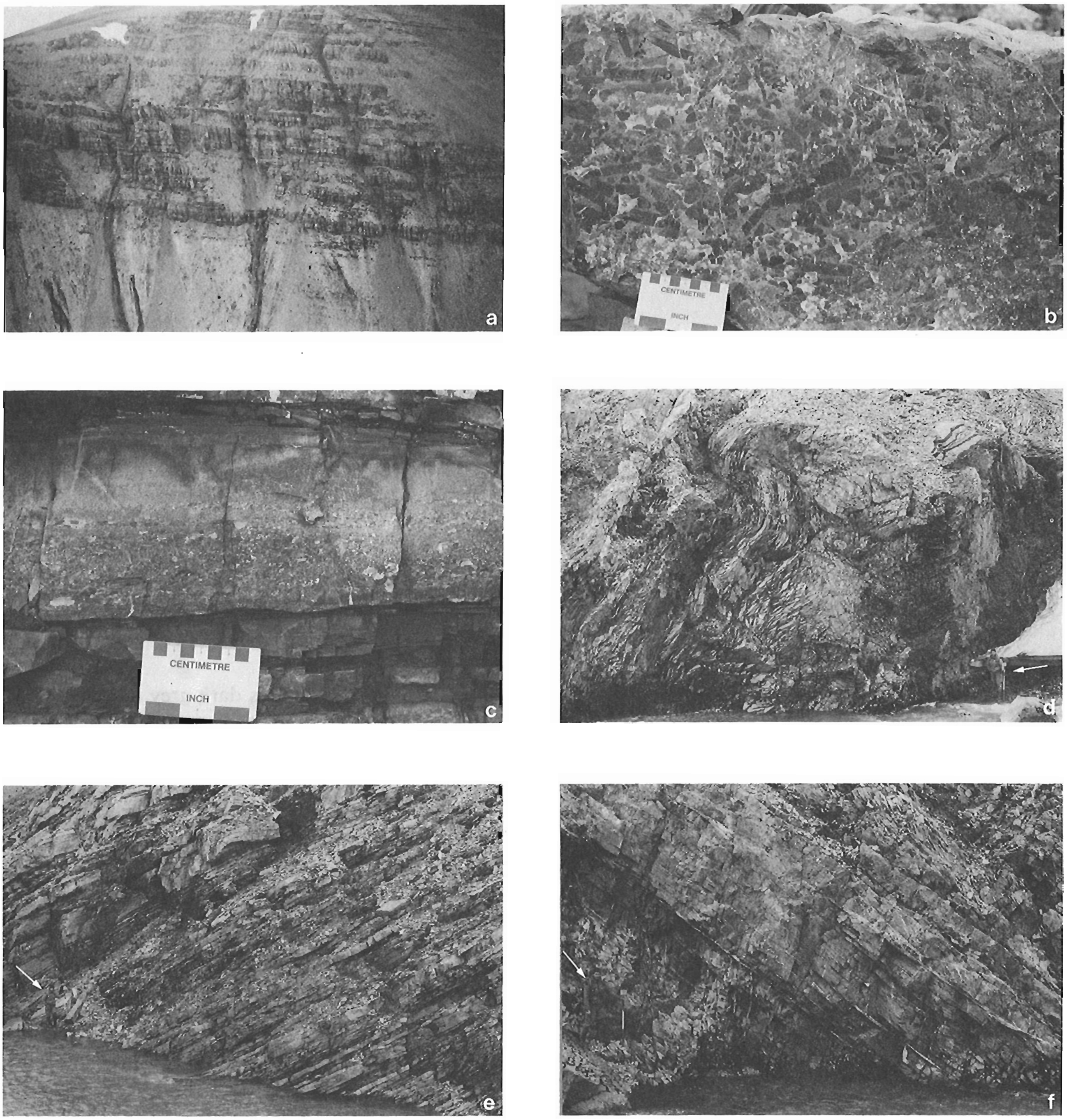


PLATE 2

Ibbett Bay Formation

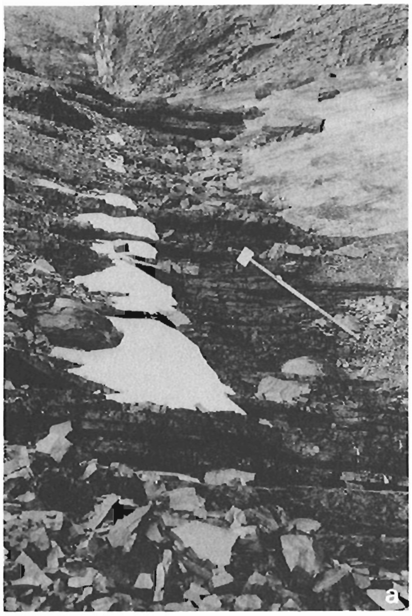
a. Member 1. Thin bedded, dark grey to black chert, (?)dolostone and shale. Note concretions. (GSC photo no. 2444-350.)

b. Contact between members 2 and 3, section 4, Figure 2. Note thin planar bedded and slump contorted, light grey dolostone capping member 2; abrupt contact with black shale and dark grey to black impure dolostone of member 3. (GSC photo no. 2444-76.)

c. Member 3, section 4, Figure 2. Interbedded, variably continuous dark grey to black impure dolostone and shale; approximately 100 m of section is shown. (GSC photo no. 2444-85.)

d. Contact between members 3 and 4, west-central Canrobert Hills. Black shale and dolostone of member 3 are overlain by buff-weathering thin bedded siltstone, chert and impure dolostone of member 4. Note lateral accretion surfaces in member 4. Approximately 50 m of section is shown. (GSC photo no. 2533-13.)

e. Member 5, section 4, Figure 2. Olistoliths (slump inclusions) of medium to dark grey, impure dolostone in thin bedded, black, cherty and silty shale. (GSC photo no. 2425-79.)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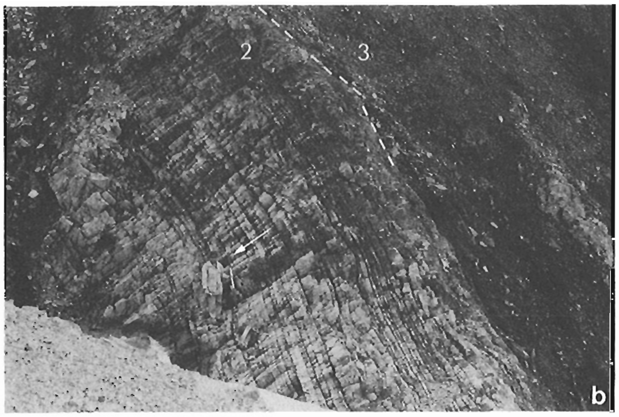
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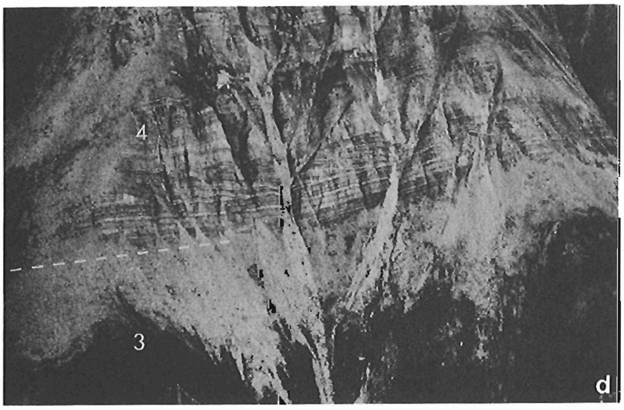
3
b


c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3
d

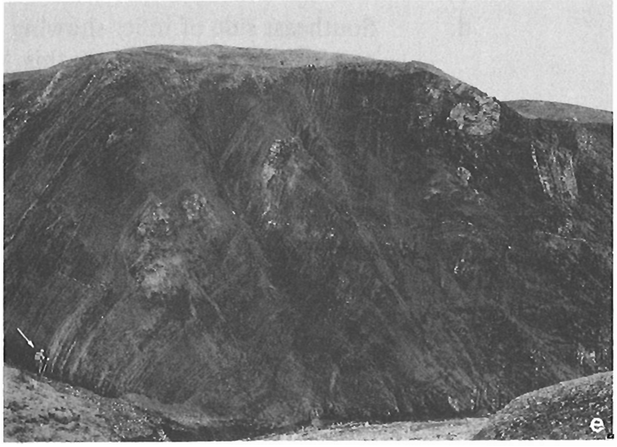
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PLATE 3

Raglan Range carbonate inlier

a. Looking eastward toward southern end of inlier. Prominent light coloured Raglan Range carbonates (RRC) contrast sharply with recessive, dark shale of the Kitson Formation (K), and siltstone of the Cape De Bray (CDB) Formation. (GSC photo no. 2533-39.)

b. Aerial view of northern part of inlier showing stratigraphic divisions 2–6 and faulted contact with Canyon Fiord Formation (CF). (GSC photo no. 2562-5.)

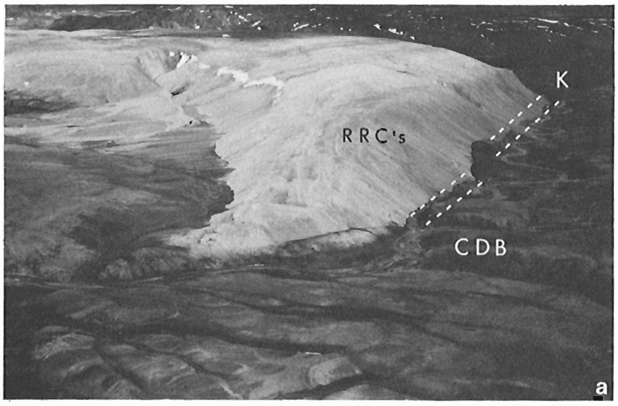
c. Panorama (looking north) of northern end of inlier showing character of units 4 and 5. Overlying Sverdrup Basin deposits (S) are visible in the background. (GSC photo nos. 2562-9, 2562-12.)

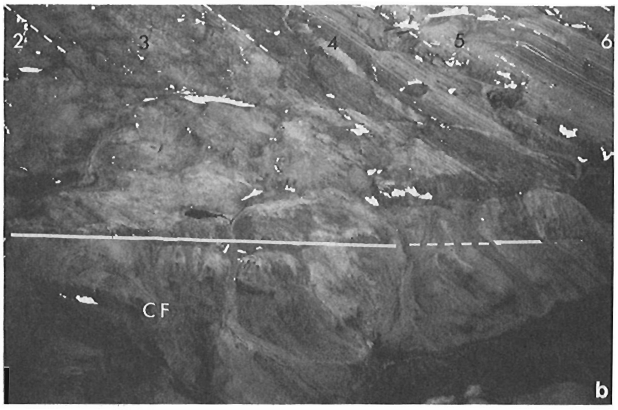
d. Southeast side of inlier showing possible thrusted contact between units 5 and 6. Beds are locally overturned at this location. (GSC photo no. 2533-41.)

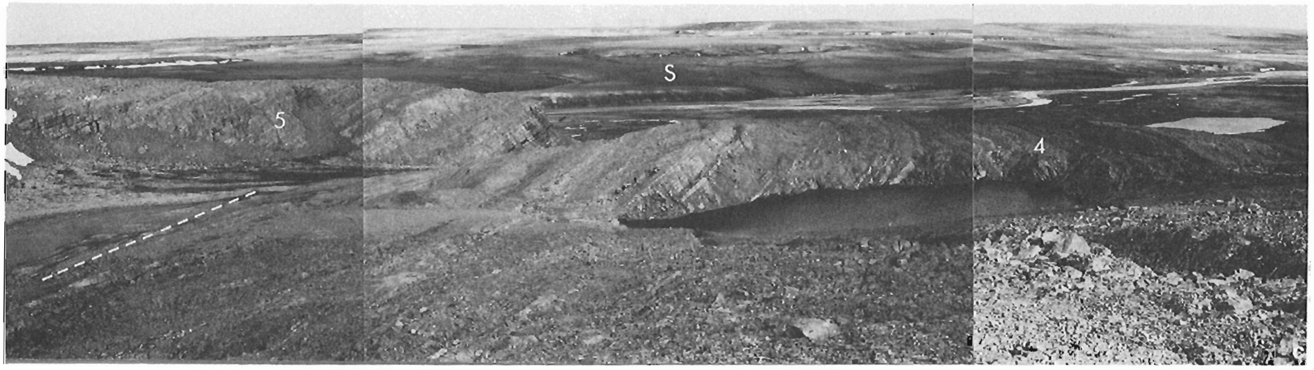
e. Looking west along the southern margin of the inlier showing stratigraphic units: Cape De Bray (CDB); Kitson (K); Raglan Range carbonate units 5, 6, 7 (RRC). (GSC photo no. 2562-6.)

f. Southeast tip of inlier; man standing at top of an approximately 5 m thick "shallowing-upward" parasequence in unit 7.

g. West flank of inlier; slump-folding or Ellesmerian deformation feature in interbedded dark grey to black limestone and shale of the Kitson Formation. 5 m of section shown. (GSC photo no. 2562-2.)


K
RRC's
CDB
a


2
3
4
5
6
CF
b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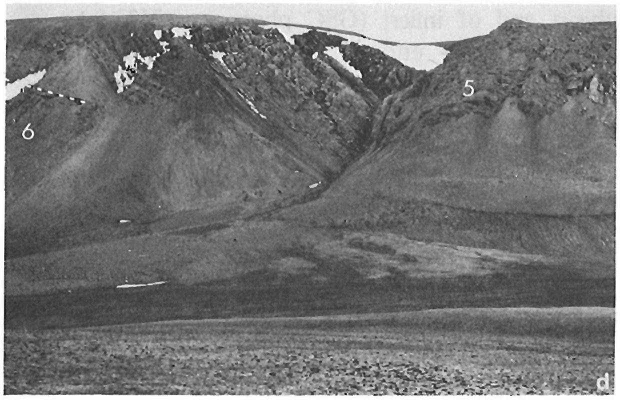
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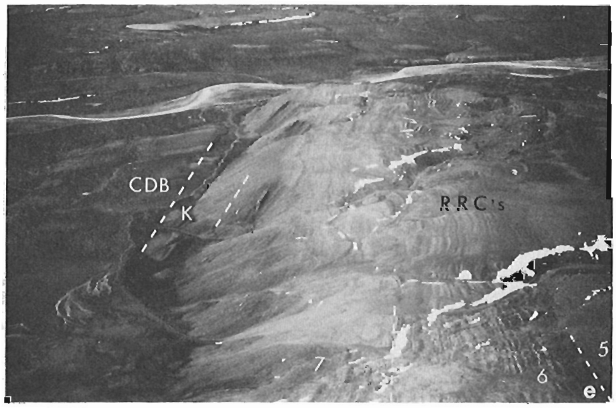
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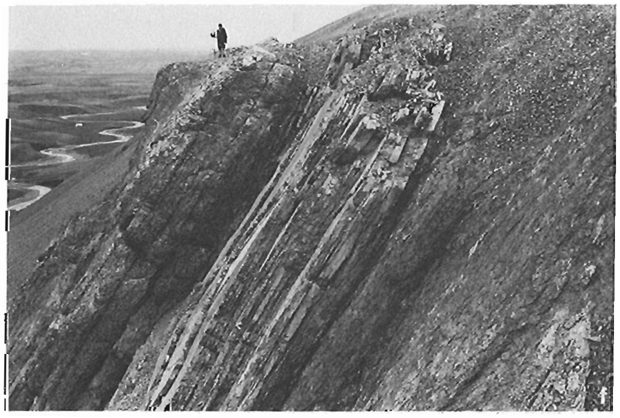
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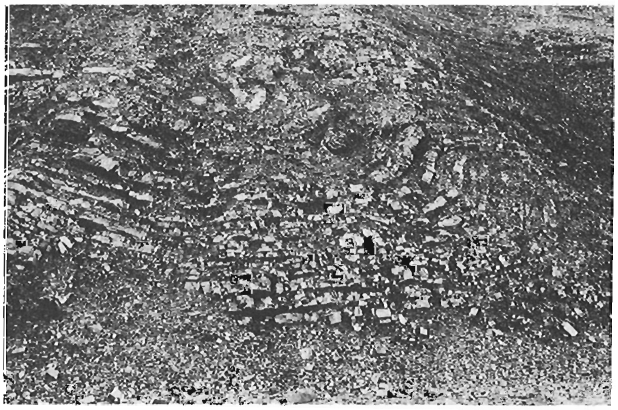


PLATE 4

a. Panorama, south McCormick Inlet section, 6 km southwest of McCormick Inlet. Altered shale of the Cape Phillips Formation (CP) are unconformably overlain by conglomerates of the Canyon Fiord Formation (CF). Note man at lower left centre, for scale.

b. Thin bedded, dark grey to black chert and shale of the upper portion of the Cape Phillips Formation, south McCormick Inlet section.

c. Thin bedded, nodular dolostone beds transitional between Irene Bay and Cape Phillips formations, Middle Island. Note barite veins top left of scale bar. Scale bar = 15 cm. (GSC photo no. 2562-4.)

d–g. Towson Point Inlier, 15 km east of Weatherall Bay, northeastern Melville Island: d. upright tight folding in unit 2, southeast end of inlier; (GSC photo no. 2533-5.) e. contact between units 1 and 2, southeastern end of inlier; (GSC photo no. 2533-10.) f. contact between carbonate units 2 (Cii) and 3 (Ciii), top of section in Figure 8, south-central part of inlier (in centre of figure g). CDB = Cape De Bray, W = Weatherall, looking south, section shown; g. aerial view looking east-northeast downsection from over the Weatherall Formation (W), across the recessive Cape De Bray Formation (CDB) to the prominent light-grey-weathering carbonates of the inlier itself (C). Section in Figure 8 is marked by an arrow. (GSC photo no. 2533-4.)

PLATE 4

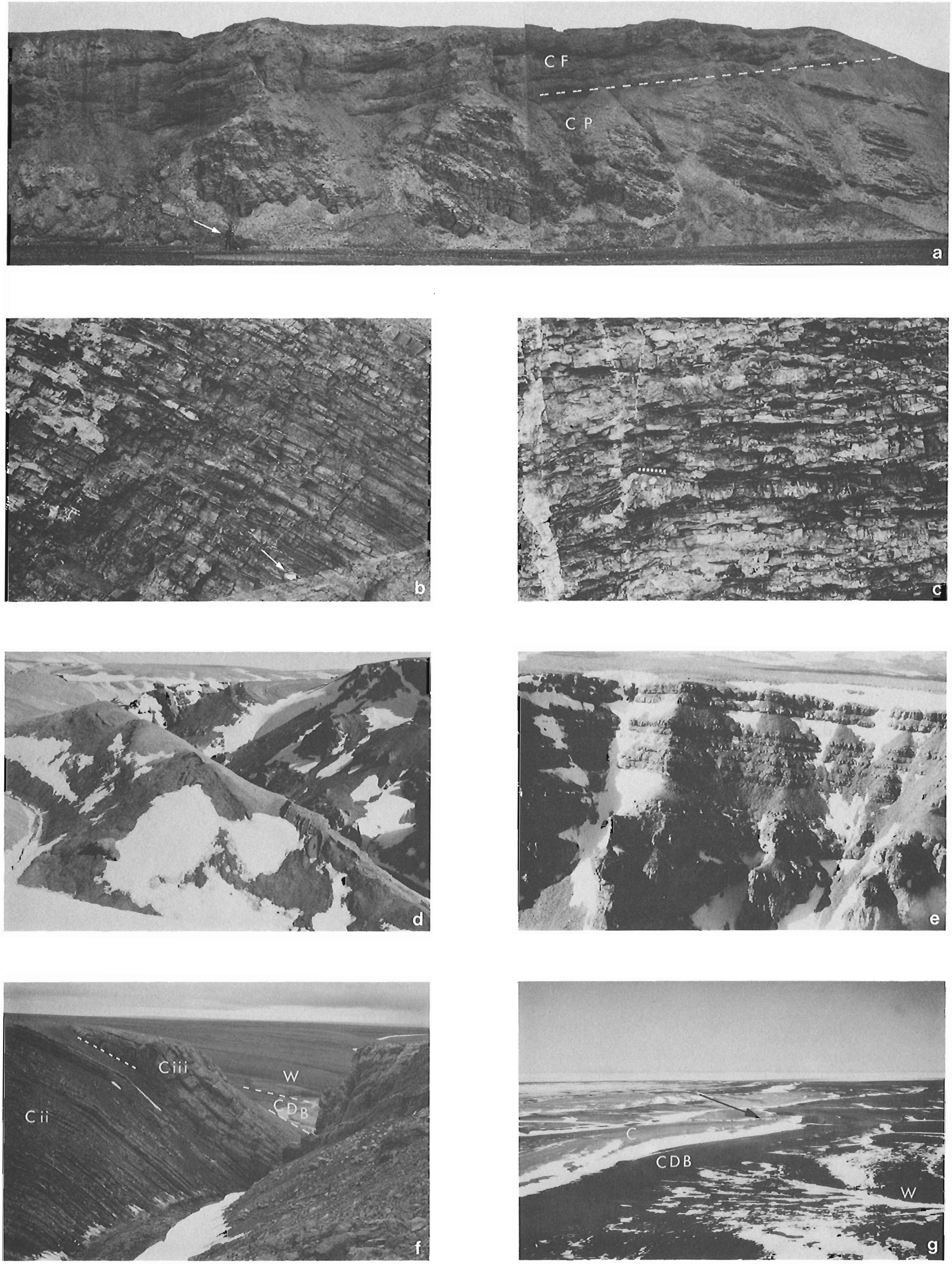


PLATE 5

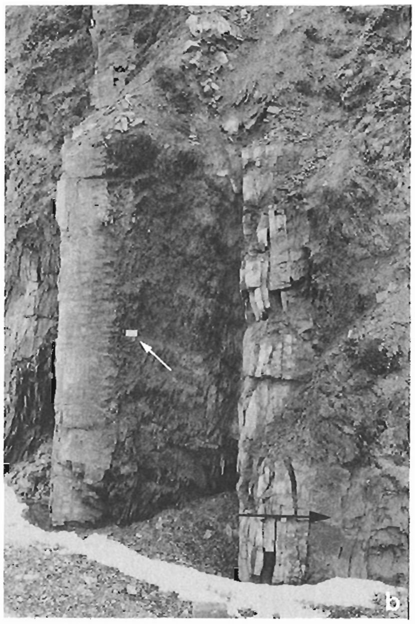
Blackley Formation

a. Aerial view looking east, east-central Canrobert Hills. The sharp contact between member 5 of the Ibbett Bay Formation (IB) and the Blackley Formation (B) is highlighted by an abrupt change in colour (from black to brown) and bedding style ("massive" to prominently bedded). Contortions in the bedding of the Blackley Formation may be due to either synsedimentary slumping or to postsedimentary tectonic deformation. (GSC photo no. 2533-11.)

b, c. Close-up of bedding in the Blackley Formation; b. (top of sequence to right) sharp-based fining-upward Bouma sequences, one of which is marked by a black arrow, of sandstone to shale; scale card 9 cm long (GSC photo no. 2444-150.) c. (top of intervals to left) abrupt interbedding of shale and siltstone in intervals lacking sandstone beds. (GSC photo no. 2444-153.)

d, e. Slide, scour and tool marks on bases of sandstone beds. (GSC photo nos. 2444-363, 2444-148.)

PLATE 5



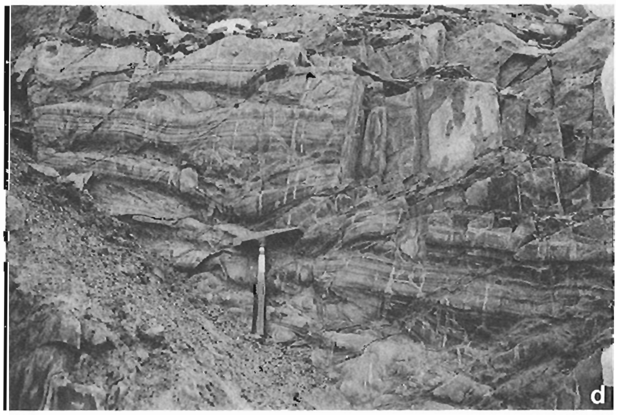


PLATE 6

Cape De Bray Formation

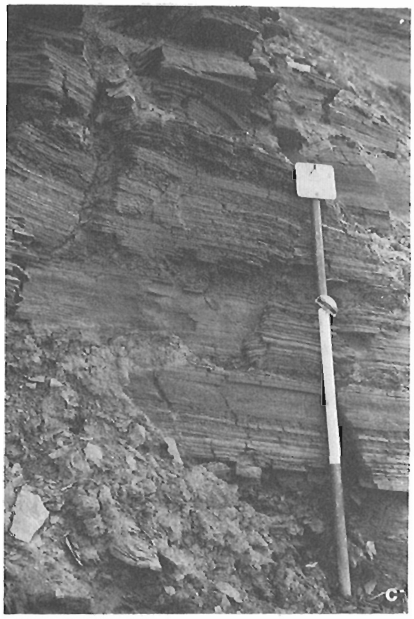
a. Indistinct, large-scale coarsening-upward parasequences (arrows) in lower part of formation (see Fig. 13); section in Figure 12, 6 km southwest of McCormick Inlet. (GSC photo no. 2444-178.)

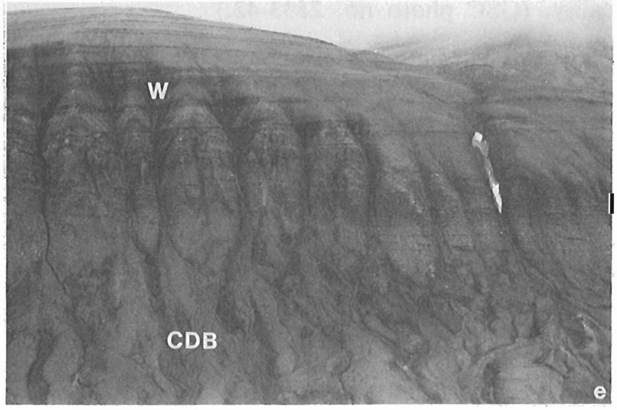
b, c. Typical bedding in coarsening-upward parasequence — planar lamination and thin bedding of shale and argillaceous siltstone. Note man in lower left of b, for scale. (GSC photo nos. 2444-182, 2444-180.)

d. Fine grained sandstone forming top of coarsening-upward parasequence. Note climbing ripples and planar/wavy parallel lamination. (GSC photo no. 2444-179.)

e, f. Transition between Cape De Bray (CDB)and Weatherall (W) formations, south shore near head of Ibbett Bay; interpreted as clinoforms at the mid-shelf - outer-shelf transition. West is to the right. Approximately 70 m of section is shown in each photograph. (GSC photo nos. 2444-14, 2444-12.)

PLATE 6





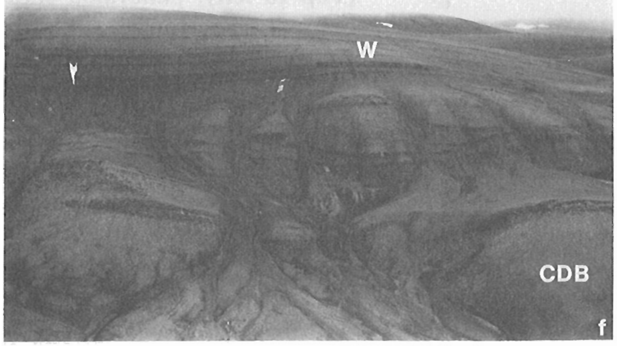


PLATE 7

Weatherall Formation, Eastern Melville Island

a. (Top of sequence to right, as shown by arrow); large-scale coarsening-upward parasequence set in the upper part of the Weatherall Formation, East Beverley Inlet. Section D in Figure 14. Note tents for scale, left centre. (GSC photo no. 2657-6.)

b. (Top of rhythm to left); small-scale thickening- and coarsening-upward rhythm (arrow), lower Weatherall Formation, in the lower part of a large-scale coarsening-upward parasequence set. Section D, Figure 14, East Beverley Inlet.

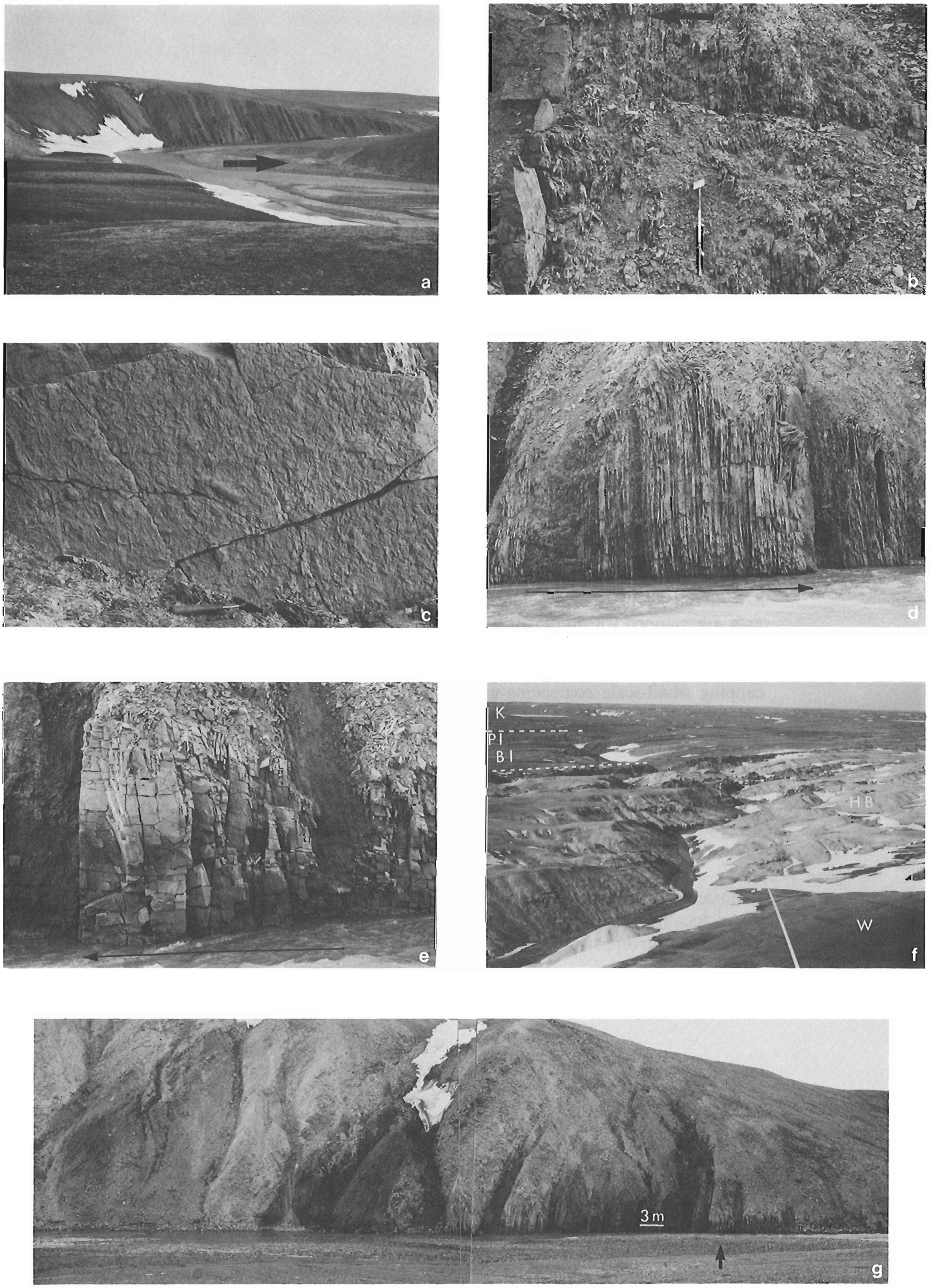
c. Base of sandstone bed capping small-scale coarsening-upward rhythm, lower Weatherall Formation. Section D, Figure 14, East Beverley Inlet.

d. (Top of rhythm to right); small-scale coarsening-upward rhythm, mid-Weatherall Formation. Section D, Figure 14, East Beverley Inlet.

e. (Top of rhythm to left); small-scale coarsening-upward rhythm (arrow) near the contact between the Weatherall and Hecla Bay formations (location marked in g). The rhythm is approximately 5 m thick.

f. Aerial view to south-southwest at top of Weatherall Formation (W), type Hecla Bay Formation (HB), with Beverley Inlet to Parry Islands formations in background (BI, PI). The skyline is made up of unconformable Mesozoic and/or Tertiary sedimentary formations (K). Robertson Anticline locality. (GSC photo no. 2533-42.)

g. (Top to left); panorama showing the Weatherall Formation–Hecla Bay Formation contact. Section D, Figure 14, East Beverley Inlet. The location of the coarsening-upward rhythm in figure e. is marked by an arrow.


a
b
c
d
e
K
P
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HB
W
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3 m
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PLATE 8

Weatherall Formation, central and western Melville Island

a. Sandy, upper portion of penultimate large-scale coarsening-upward parasequence set in Weatherall Formation, East Kitson River section. The parasequence is made up of bundles of coarsening-upward rhythms separated by recessive, silty shale intervals.

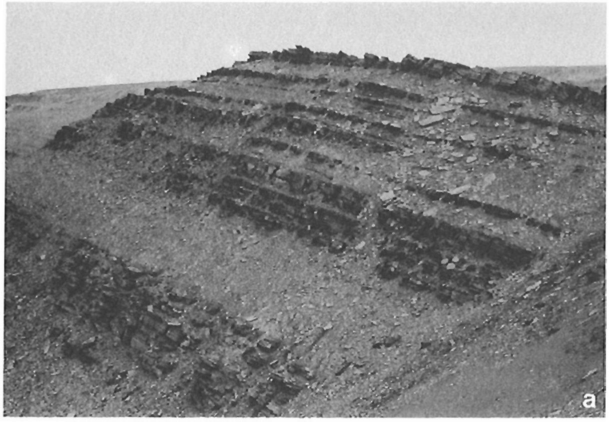
b. Upper Weatherall Formation, east Kitson River section. Note increase of sandstone interbeds within shale background upsection toward contact with Hecla Bay Formation (on skyline). (GSC photo no. 2657-5.)

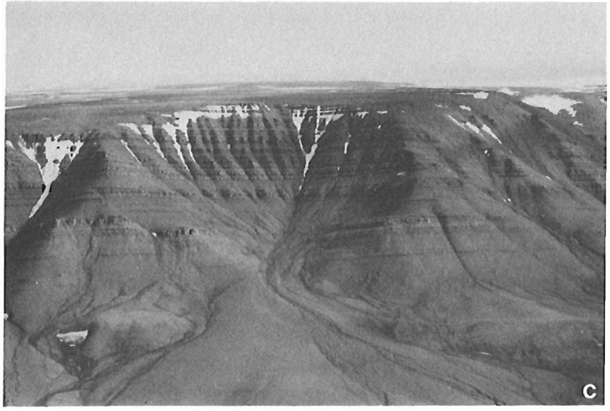
c. South shore of Ibbett Bay; top of the penultimate large-scale coarsening-upward parasequence set in the Weatherall Formation. (These beds are included in the Weatherall Formation in geological mapping; correlative beds in the Purchase Bay area are mapped within the Hecla Bay Formation due to an increase in sand content — see note on map). Lowlands at the base of the photograph are composed of silty shale and siltstone. Upsection, an increase in sheet sandstone (shelf and deltaic origin) capping small-scale coarsening-upward rhythms results in cliff exposures in which individual beds can be traced for tens of kilometres. Note pinchout to right (west) of deltaic/nearshore sandstone in lower part of cliff face. (GSC photo no. 2425-30.)

d. Stacked, coarsening-upward rhythms; lower, fine grained part of a large-scale coarsening-upward parasequence set in the Weatherall Formation, 15 km east of the head of Purchase Bay. These beds are equivalent to beds at the base of the cliff shown in figure c. Note geologist at lower left, for scale.

e. Panorama of Weatherall Formation/Hecla Bay Formation transition, East Kitson River locality. Coarsening-upward deltaic/shoreface regressive parasequences are marked by arrows.

PLATE 8





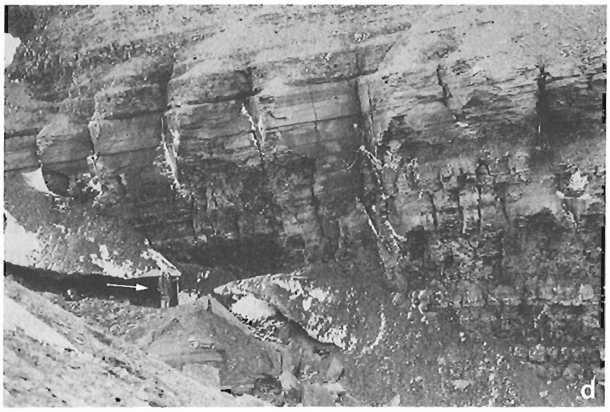


PLATE 9

a. Cliff section of Hecla Bay Formation, head of northeast arm of Murray Inlet, south-central Melville Island, showing typical character of this formation in the central and western part of the island. Note interlayering of prominent, light coloured, well cemented sandstone with more recessive, dark coloured siltstone and shale. This interlayering gives the formation a distinctly banded appearance in cliff sections. Cliff height approximately 400 m.

b. Panorama of west side of Barry Bay, south-central Melville Island, showing extensive interdigitation of "Weatherall facies" (small-scale, coarsening-upward parasequences) and "Hecla Bay facies" (prominent light coloured sandstone) in the transition between the two formations. Cliff height 300 m. (GSC photo nos. 2533-51, 2533-50, 2533-49, 2533-48.)

PLATE 9

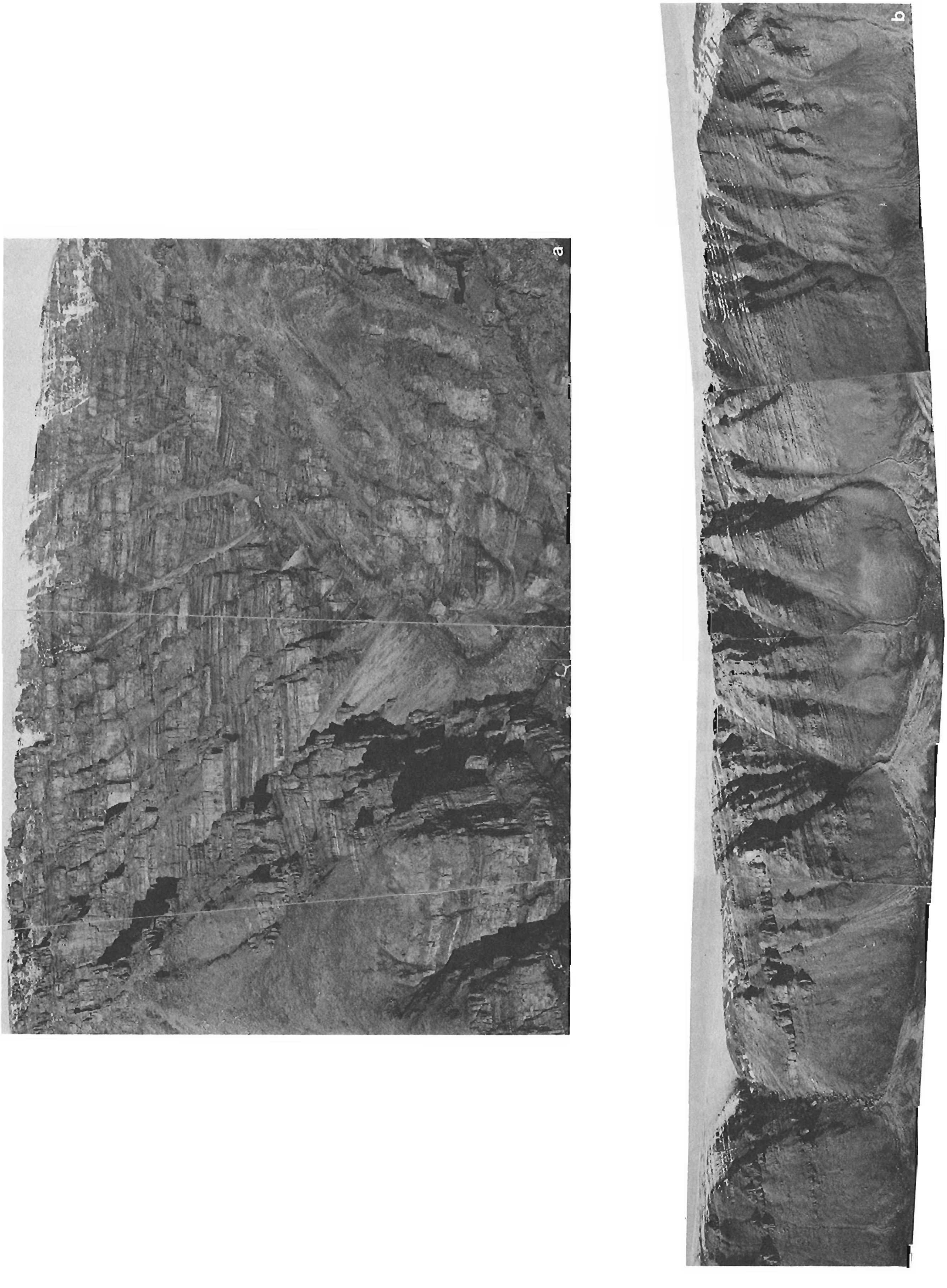


PLATE 10

Hecla Bay Formation, central and western Melville Island

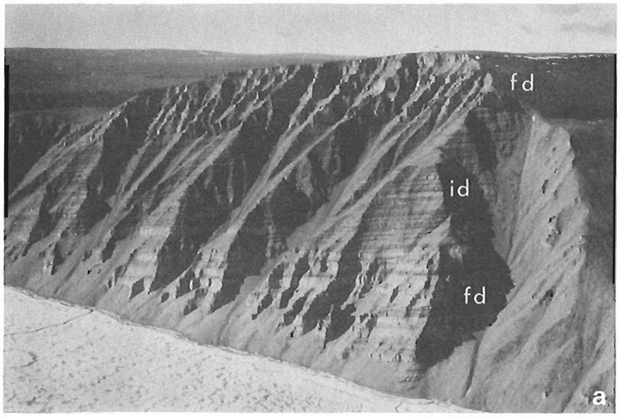
a. Stratigraphic features visible include distinct fluviodeltaic sand tongues (fd) and interbedded, darker coloured interdeltaic shale and silt-rich interval (id) comprising many stacked, small-scale, coarsening-upward rhythms; 9 km south of Mount Joy, west shore of Murray Inlet, southwest-central Melville Island. (GSC photo no. 2657-4.)

b, c. Details of central (id) interval in figure a, showing stacked, laterally persistent coarsening-upward rhythms with intercalated, laterally impersistent channel sandstone bodies (one just above centre in figure b).

d. Lower Hecla Bay Formation, west side of Murray Inlet; note interbedding of sandstone (light) with siltstone and shale (dark), and large-scale crossbedding in lower left-centre. (GSC photo nos. 2250-68, 2250-6.)

e. Sheet sandstone in fluviodeltaic Hecla Bay Formation; complex channelled and cross-stratified sandstone in lower 80 per cent, and abrupt fining upward to siltstone and shale in upper 20 per cent of unit, west arm of Murray Inlet.

f. Sheet sandstone in fluvial upper Hecla Bay Formation, 10 km east of Cape Victoria. (Same section as Plate 13, figure a). Note man at left-centre for scale. Multiple channels and planar cross-sets are evident. (GSC photo nos. 2444-273, 2444-274, 2444-275.)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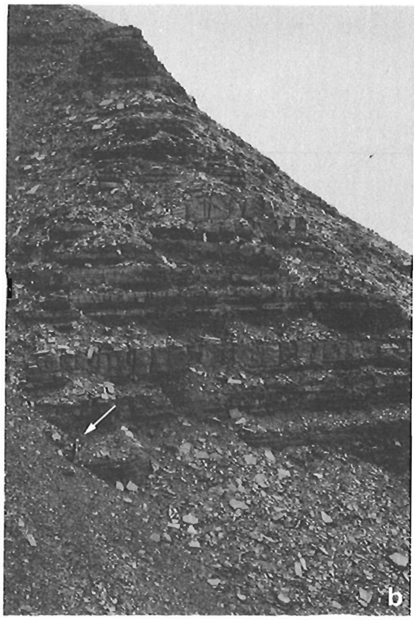
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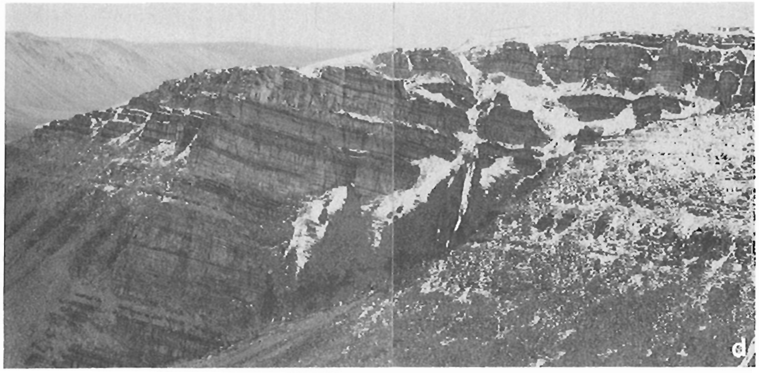
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f

PLATE 11

Pinchout of Hecla Bay sandstone facies into Weatherall facies between Comfort Cove and Kelly Point, southwestern Melville Island.

a, b. Distributary channel sandstone lense encapsulated within stacked shale and siltstone-dominated, deltaic shelf, coarsening-upward parasequences. Cliff height approximately 250 m.

PLATE 11

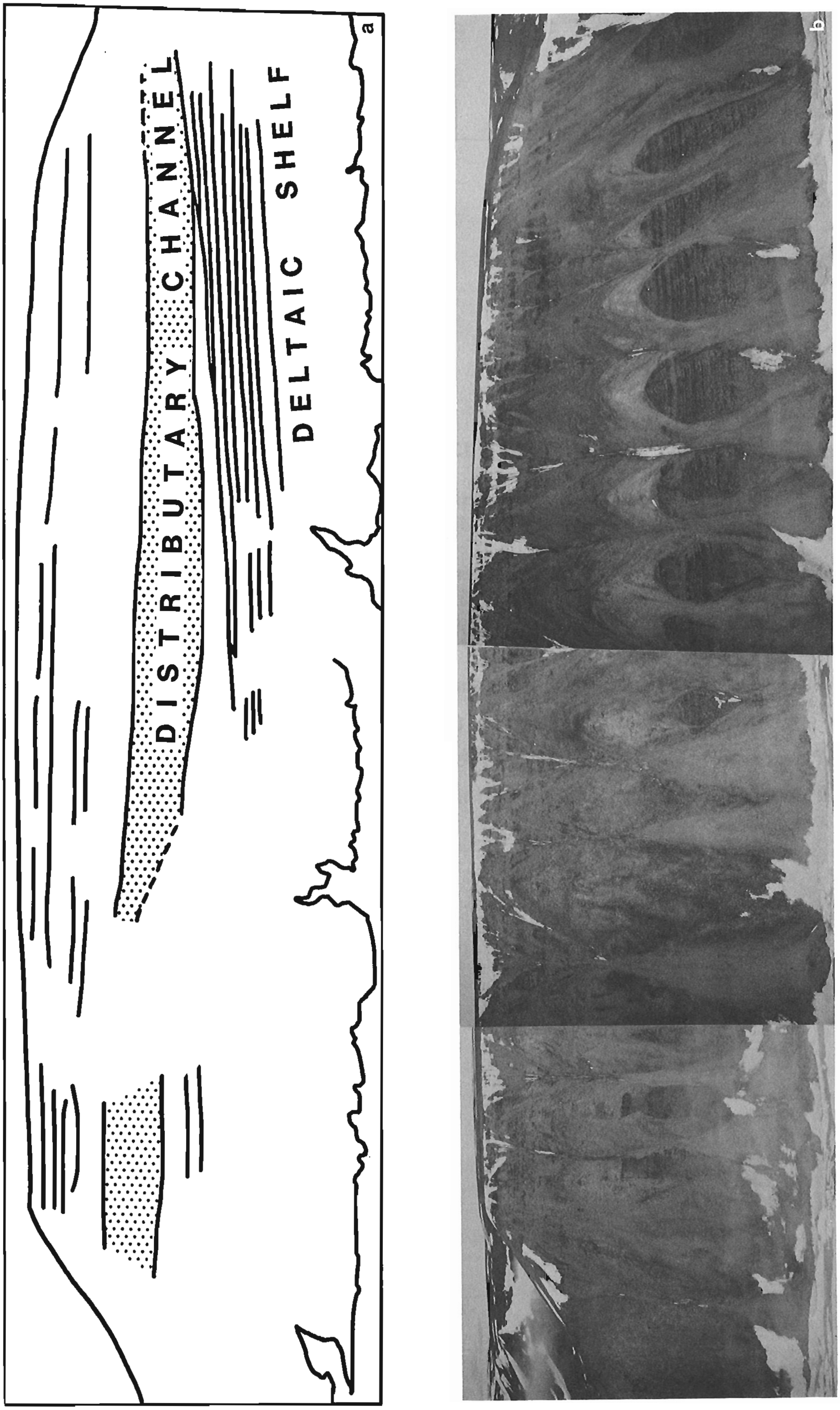


PLATE 12

Hecla Bay Formation at type section, Robertson Anticline, southeastern Melville Island

a. Panorama showing bluff-forming, cemented white sandstones alternating with recessive, loosely cemented sandstone intervals. Note lack of siltstones and shales, and the channelled contact (arrows) between prominent sandstone beds in centre of the photograph. Height from stream to bluff top is 50 m. (GSC photo no. 2250-5.)

b. Steep edge to channel with crossbedded infill. (GSC photo no. 2533-33.)

c. Overturned tops to trough crossbeds. (GSC photo no. 2533-34.)

d. Planar-tabular cross-sets within bluff-forming sandstone. (GSC photo no. 2657-1.)

e. Plant debris in crossbedded sandstones near the base of a channel scour. (GSC photo no. 2533-32.)

PLATE 12

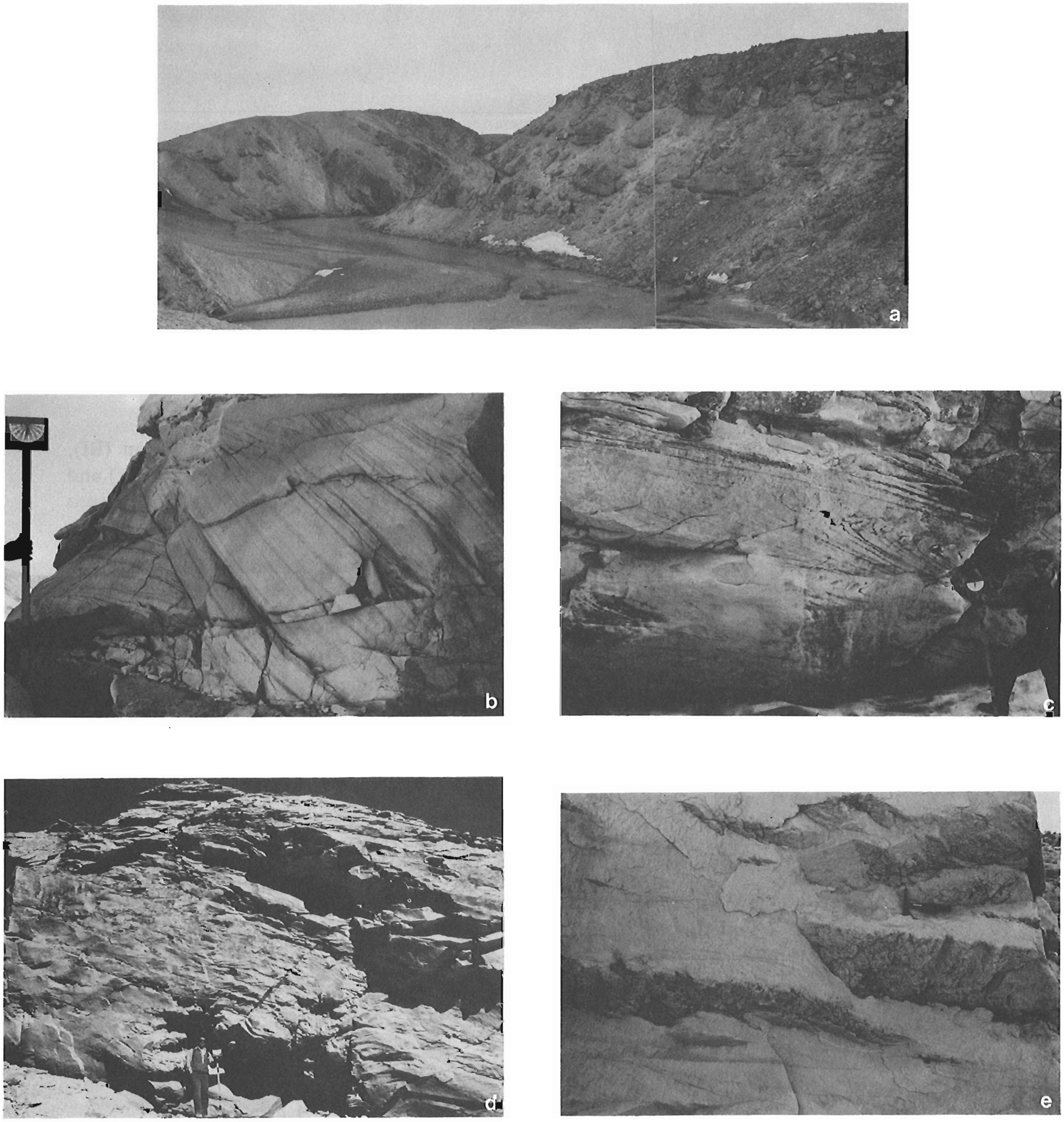


PLATE 13

a. Contact between Hecla Bay Formation (HB) and Beverley Inlet Formation (BI), Robertson Anticline, southeastern Melville Island. Parry Islands Formation (PI) and unconformable Mesozoic and younger cover (K) in background. (GSC photo no. 2533-43.)

b. Contact between Beverley Inlet Formation (BI) and Parry Islands Formation (PI — Burnett Point Member), east side of Weatherall Bay, northeastern Melville Island.

c. Panorama of Beverley Inlet Formation, head of northwest arm of Murray Inlet, west-central Melville Island. Contact with sandstones of Hecla Bay Formation is 1 km downvalley of left edge of photo. Stratigraphic divisions, as described in the text: 1a = Member 1a; 2a, b, c = Member 2, units a, b, c. (GSC photo nos. 2444-135–138.)

d. Fining-upward sequence of sandstone–siltstone–shale in Beverley Inlet Formation, Member 1, northwest Murray Inlet. Staff = 1.5 m.

e. Lateral accretion within channel sandstones at the base of Member 2, 0.5 km to left of panorama in figure c. (GSC photo no. 2444-141.)

f. Heavily loaded sandstone bed within rippled shales, siltstones and fine sandstones. Member 2, unit b, northwest Murray Inlet.

PLATE 13

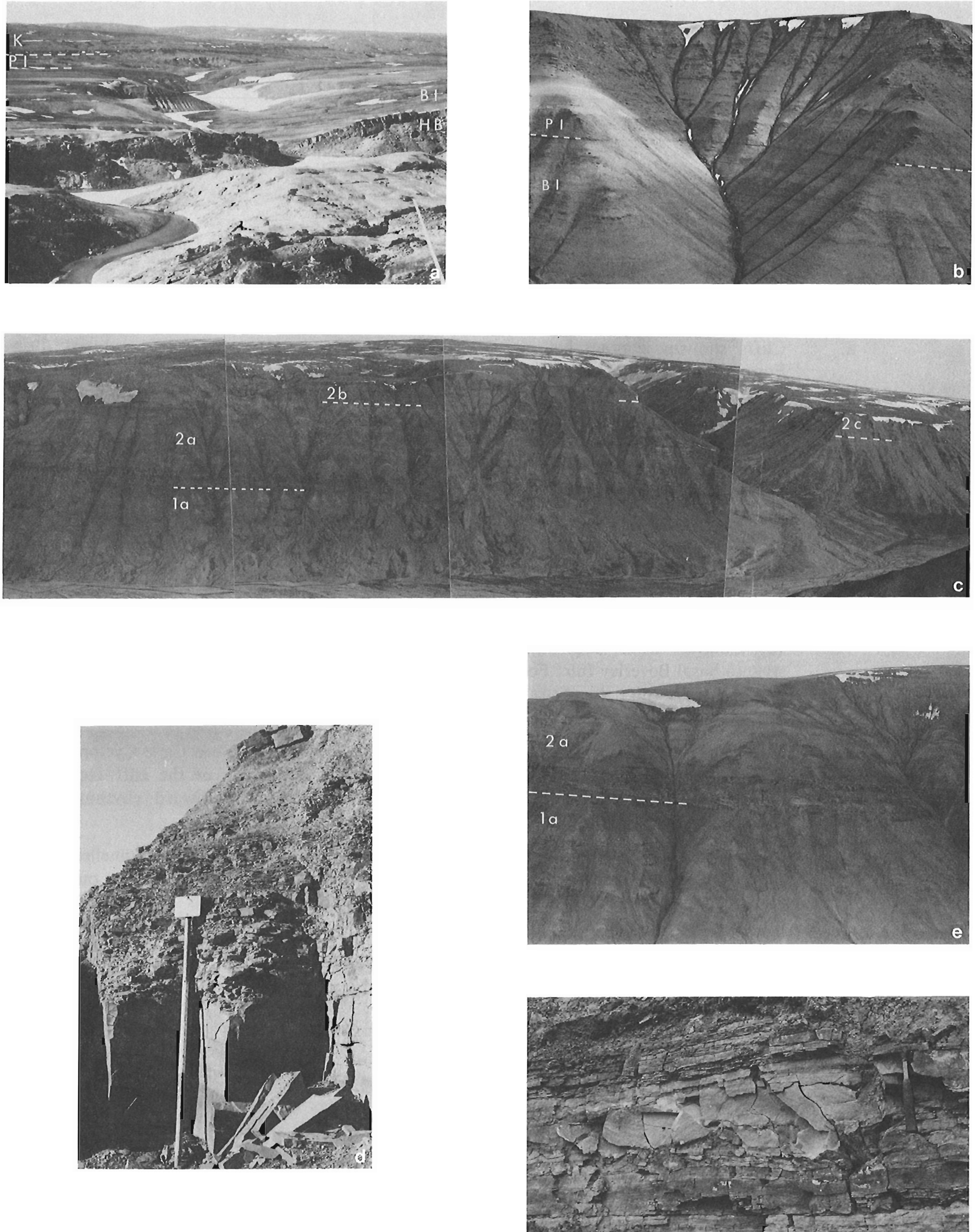


PLATE 14

a. Cliffs showing contact between Hecla Bay Formation (HB) and Beverley Inlet Formation (BI), 10 km east of Cape Victoria, southwestern Melville Island. Lower 230 m of section A, Figure 25 measured from off left, up to and along ridge with unit markings. Note difference in internal stratigraphy of Beverley Inlet Formation between this section and the panorama taken of the formation at northwest Murray Inlet, 80 km to the northeast (Plate 13c). Cliff height 570 m. (GSC photo no. 2533-19.)

b. Laterally variable channel sandstones within a sequence of shales containing thin beds of siltstones and sandstones; Member 2, unit a, Beverley Inlet Formation, Cape Victoria section. (GSC photo no. 2444-289.)

c. Contact between Hecla Bay Formation (prominent sandstones — HB) and Beverley Inlet Formation (stacked, coarsening-upward rhythms — BI, Member 1, units 1b and 1a), Comfort Cove, southwestern Melville Island. Note difference in sedimentary style to basal Beverley Inlet Formation at this locality compared to the Cape Victoria and Murray Inlet localities. Man on skyline serves as scale. (GSC photo no. 2444-374.)

d. Member 2, unit e, Beverley Inlet Formation, in coastal cliffs between Cape Cyclops and Comfort Cove, southwestern Melville Island. Striped nature of the cliff face (250 m high) is due to stacking of small-scale, coarsening-upward rhythms (parasequences). (GSC photo no. 2533-27.)

e. Member 2, unit e, Beverley Inlet Formation; complexly crossbedded and channelled sandstones intertonguing with stacked, coarsening-upward rhythms. Note shaling out to left of lower part of sandstone bluffs. Top of section 5, Fig. 32a, 7 km east of Cape Victoria. (GSC photo no. 2533-3.)

PLATE 14

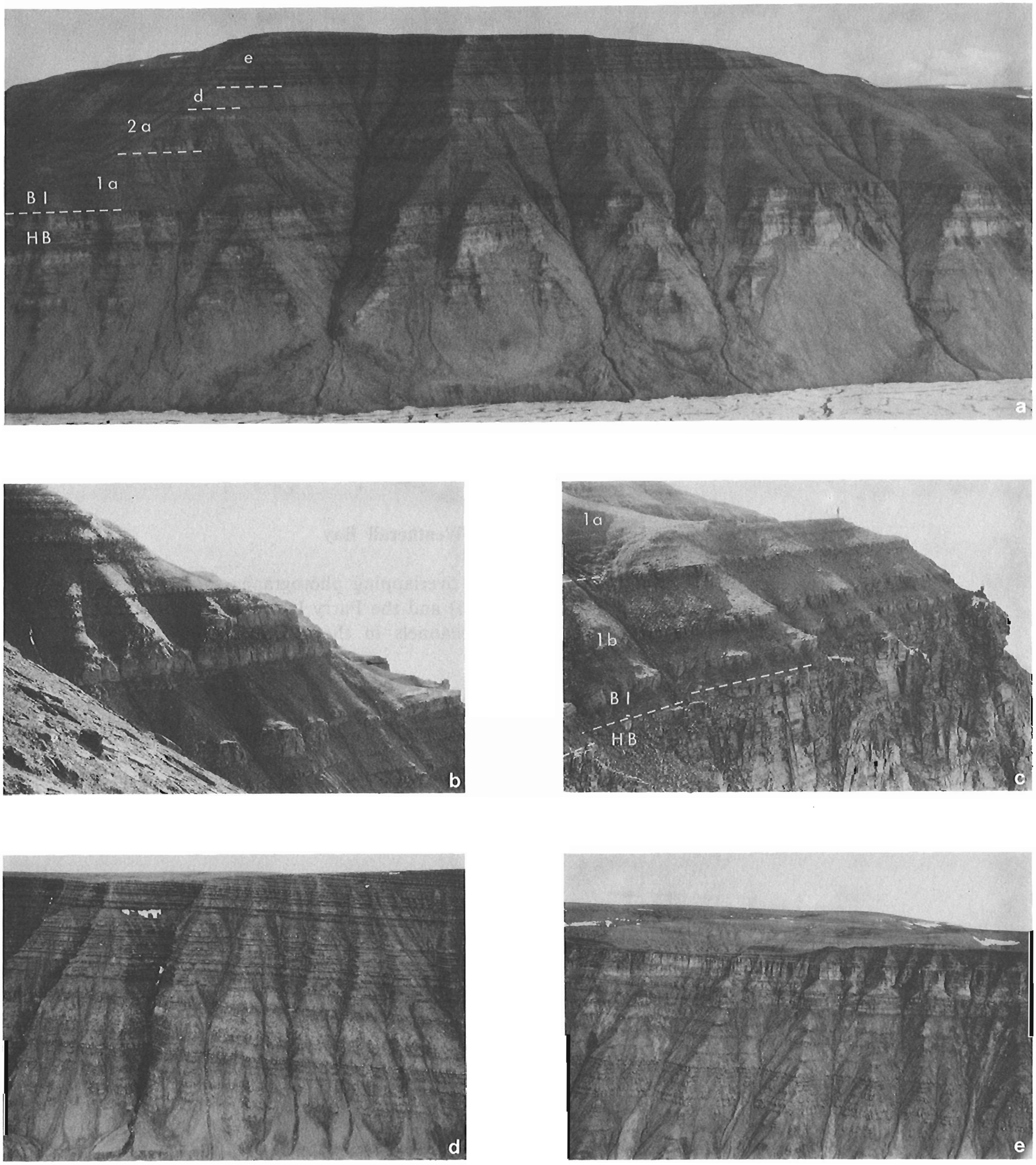


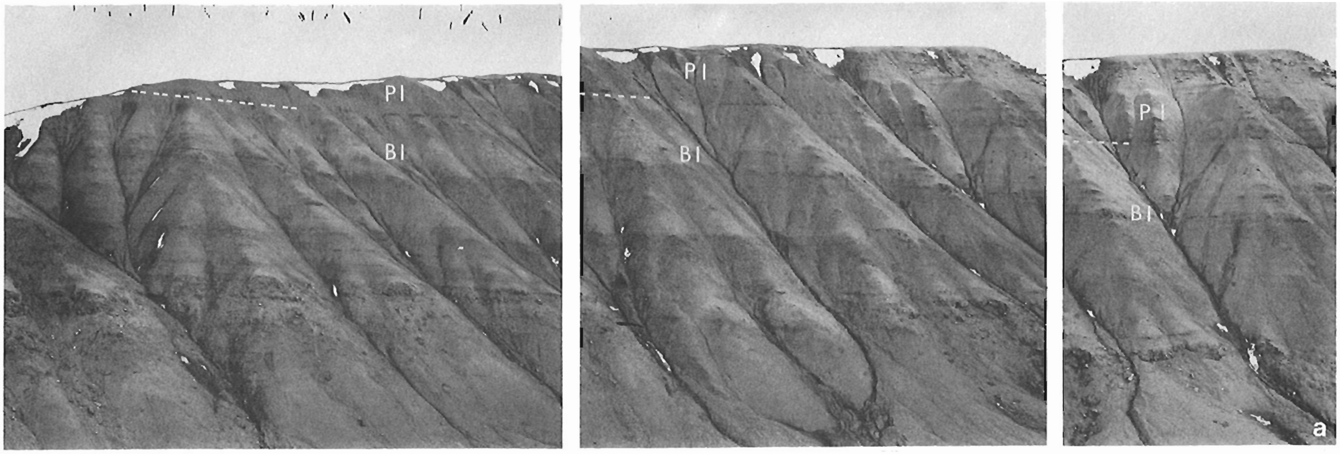
PLATE 15

Parry Islands Formation, Weatherall Bay

a. East shore of Weatherall Bay; partially overlapping photographs showing contact between the Beverley Inlet Formation (BI) and the Parry Islands Formation (PI — Burnett Point Member). Note broad channels in the uppermost Beverley Inlet Formation.

b. Crossbedding in Burnett Point Member. (GSC photo no. 2250-12.)

c. Coal rip-up clasts in conglomeratic lower part of Burnett Point Member. (GSC photo no. 2250-18.)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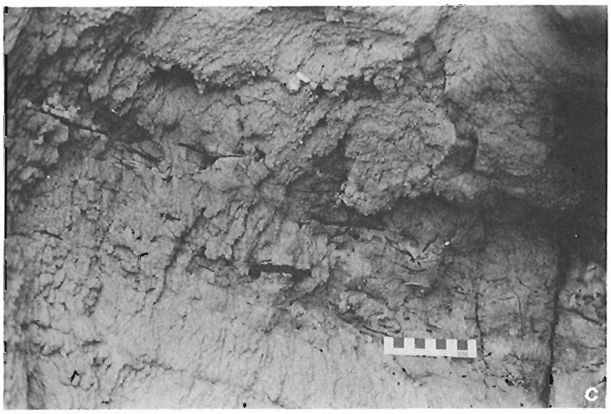
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A NOTE ON GRAPTOLITE CORRELATION OF THE CANROBERT AND IBBETT BAY FORMATION BOUNDARY (ORDOVICIAN) NISBET POINT, NORTHWESTERN MELVILLE ISLAND, ARCTIC CANADA

A.C. Lenz[1] and D.J. Borré[1]

Lenz, A.C. and Borré, D.J., 1993. A note on graptolite correlation of the Canrobert and Ibbett Bay formation boundary (Ordovician) Nisbet Point, northwestern Melville Island; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 105–109.

Abstract

Graptolites are common in the uppermost shales of the Canrobert Formation and the lowest Ibbett Bay Formation of the Nisbet Point section. The Canrobert graptolites probably correlate with the *Oncograptus* Zone (Upper Arenig) of the northern Cordillera, whereas those of the Ibbett Bay appear coeval with the *Paraglossograptus tentaculatus* Zone, or possibly with the *Oncograptus* and lower *tentaculatus* zones of latest Arenig and early Llanvirn age.

Résumé

Les graptolites sont fréquents dans les shales sommitaux de la Formation de Canrobert et dans la partie inférieure de la Formation d'Ibbet Bay de la coupe de la pointe Nisbet. Il existe vraisemblablement une corrélation entre les graptolites de la Formation de Canrobert et la Zone à *Oncograptus* (Arénigien supérieur) de la Cordillère du Nord; en revanche, les graptolites de la Formation d'Ibbet Bay semblent être contemporains de la Zone à *Paraglossograptus tentaculatus* ou possiblement de la Zone à *Oncograptus* et de la partie basale de la Zone à *tentaculus* de l'Arénigien terminal et du Llanvirnien précoce.

INTRODUCTION

Graptolites collected from the Canbrobert and Ibbett Bay formations in the Canrobert Hills of northwestern Melville Island were tentatively identified and age dated by Lenz (*in* Robson, 1985). That study showed that graptolites ranging from low in the Arenig to Lower Devonian (Pragian) are present in the region. The age of the boundary between the Canrobert and overlying Ibbett Bay formations was, however, only crudely positioned. During the summer of 1985, two large grab-sample collections of graptolites from the upper 3 m of shale of the Canrobert and lowermost 8 to 10 m of shale and siliceous shale of the Ibbett Bay were collected from a creek section (75°55″W, 116°34″W), on Nisbet Point, Ibbett Bay. A part of the 1985 collections was studied by Borré (1986).

The collections made in this study were of a reconnaissance nature only, were not tightly controlled stratigraphically and, particularly in the case of the Ibbett Bay Formation, were mainly talus collections. Clearly, further careful stratigraphically controlled collecting is warranted, although remoteness of the area makes this difficult. Nevertheless, this study is of value, because it shows that for one section, an interformational boundary can be restricted to almost a single graptolite zone.

Acknowledgments

Appreciation is expressed to M.J. Robson and S. Feulgen for assistance in collecting, and to R.L. Christie, Geological Survey of Canada, for generous field support.

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STRATIGRAPHY

The lithological characteristics of the Canrobert and Ibbett Bay formations have been described in general terms by Robson (1985), who considered the two stratigraphic units to be in conformable contact. The graptolite-bearing shale of the upper Canrobert consists of evenly and thinly laminated, light to medium-grey dolomitic shale that weathers to a yellowish brown colour. Graptolites are relatively common and are well preserved. The overlying Ibbett Bay, the base of which is drawn at the top of the highest conglomerate of the Canrobert (Robson, 1985), consists of dark grey shale, siliceous shale and chert. Graptolites are uncommon, but are moderately well preserved.

GRAPTOLITE FAUNAS

The highest graptolite-bearing shale of the Canrobert Formation (GSC loc. C-131009) contains the following species, with those of particular biostratigraphic value being marked by an asterisk: **Didymograptus v-deflexus* Harris, *D. extensus* (Hall) (sensu lato), *Tetragraptus quadribrachiatus* (Hall), *T. serra* (Brogniart), *T.* cf. *T. bigsbyi* (Hall), *T.* cf. *T. taraxacum* Ruedemann, *Isograptus* sp., **I. caduceus australis* Cooper, **I. victoriae maximodivergens* Harris, **Pseudisograptus dumosus* Harris, **P. manubriatus* (T.S. Hall) (sensu lato), *?*Pseudotrigonograptus ensiformis, Dichograptus octobrachiatus* (Hall), *?*Cardiograptus morsus* Harris and Keble, *Phyllograptus* sp., **Skiagraptus gnomonicus* Harris and Keble, *Kinnegraptus* sp., and ?*Kinnegraptus* cf. ?*K. gracilis* Chen. The genera *Isograptus, Pseudisograptus* and *Tetragraptus* are very common and make up more than 50 per cent of the fauna.

The Ibbett Bay Formation (GSC loc. C-131010) yields the following species: *Loganograptus logani* Hall, ?*Dichograptus* sp., **Cardiograptus crawfordi* Harris, *Phyllograptus* sp., *?*Tylograptus* sp., **Undulograptus austrodentatus* (Harris and Keble), **Amplexograptus* cf. *coelatus* Lapworth, **Paraglossograptus* aff. *P. tentaculatus* (Hall), *Glossograptus hincksii* (Hopkinson), *Tetragraptus* cf. *T. acanthonotus* Gurley, *T.* cf. *T. pendens* Elles, **Isograptus caduceus australis* Cooper and *Isograptus caduceus* (Salter) (sensu lato). No taxa dominate the fauna.

AGE AND CORRELATION

Correlation of the graptolite faunas is achieved through comparison with the Lower Ordovician zonal schemes of Australasia (see Thomas, 1960; Cooper, 1973, 1979; Cooper and Lindholm, 1990; and especially Vandenberg, 1981), and with the Canadian Cordillera (Lenz and Jackson, 1986). The Canadian Cordilleran Lower Ordovician graptolite sequences can be compared almost zone by zone with those of Australasia, and the biostratigraphic scheme of Lenz and Jackson (1986) is employed in this study.

Canrobert Formation

Isograptus victoriae maximodivergens and *Pseudisograptus dumosus* appear in the *maximodivergens* Zone of the Cordillera and its equivalent, the *maximus* Zone of Australia (see Vandenberg, 1981). *Isograptus caduceus australis* and *Didymograptus v-deflexus* occur first in the *Oncograptus* Zone of Australia, whereas they are already present in the *maximodivergens* Zone of the Cordillera. *Pseudotrigonograptus ensiformis* begins in the basal *Oncograptus* zones of both realms. *Cardiograptus morsus* and *Skiagraptus gnomonicus* first appear in the lower *Oncograptus* Zone of the Cordillera, but make their first occurrence in the slightly younger *Cardiograptus* Zone of Australia.

The uppermost Canrobert strata can, therefore, most likely be correlated with the *Oncograptus* Zone of the Cordillera and Australasia, or possibly with the upper part of the *maximodivergens* Zone and the lower part of the *Oncograptus* Zone; that is, with strata of high, or possibly highest, Arenig.

Ibbett Bay Formation

Taxa of this unit are, for the most part, typical of, and restricted to, the *Paraglossograptus tentaculatus* Zone of the Cordillera (Lenz and Jackson, 1986). The fauna does, however, include some longer ranging or earlier appearing species, particularly *Loganograptus logani*, several species of *Tetragraptus* and, above all, *Isograptus caduceus australis*. In both the Cordillera, and Australasia, the last named species is confined to pre-*tentaculatus* strata. The appearance of biserials such as *Undulograptus, Amplexograptus* and *Paraglossograptus* is, however, particularly important, and clearly indicative of an assignment to the *tentaculatus* Zone; that is, uppermost Arenig and lower Llanvirn. However, in view of the occurrence of *I. caduceus australis*, and that the collection is a talus sample gathered from about a ten metre interval, it is quite feasible that part, at least, of the *Oncograptus* Zone is also represented.

CONCLUSIONS

The faunal evidence supports the suggestion of Robson (1985) that the Canrobert and Ibbett Bay formational contact is conformable, at least in the Nisbet Point section. The boundary coincides approximately with the contact between the *Oncograptus* and *tentaculatus* zones; that is, close to the Arenig-Llanvirn boundary or the Yapeenian–Darriwilian boundary of Australasia.

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PLATE 1

All specimens are from GSC locality C-131009

Figures 1-4. *Isograptus victoriae maximodivergens* Harris

1, 2. GSC 82973 and GSC 82974, x2.7.
3, 4. GSC 82975 and GSC 82976, x1.9.

Figures 5-7. *Pseudisograptus dumosus* Harris

GSC 82977, 82978 and 82979, x7.

Figures 8-12. *Pseudisograptus manubriatus* (T.S. Hall) (sensu lato)

8. GSC 82980, x3.1.
9. GSC 82981, x3.8.
10. GSC 82982, x3.6.
11. GSC 82983, x3.4.
12. GSC 82984, x3.3.

Figures 13, 14. *Isograptus caduceus australis* Cooper

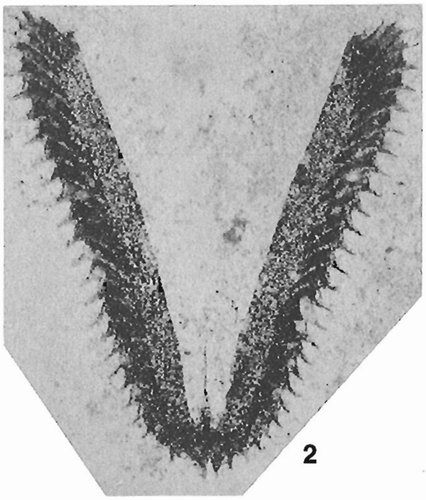
13. GSC 82985, x2.3.
14. GSC 82986, x2.7.

Figure 15. *Didymograptus v-deflexus* Harris

GSC 82987, x3.4.

PLATE 1


1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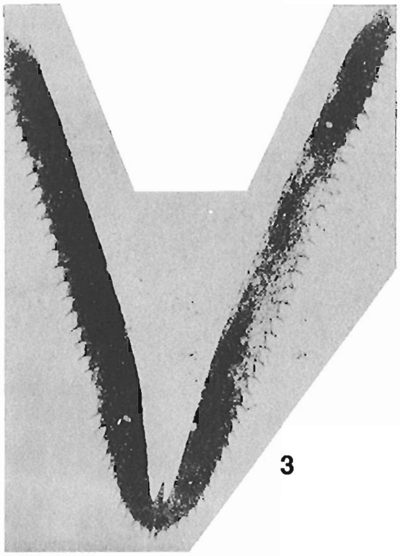
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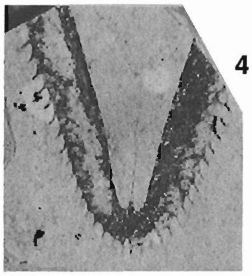
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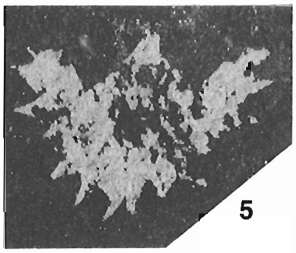
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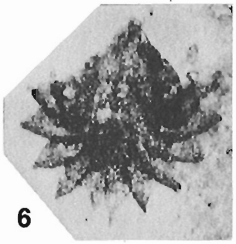
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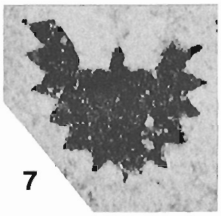
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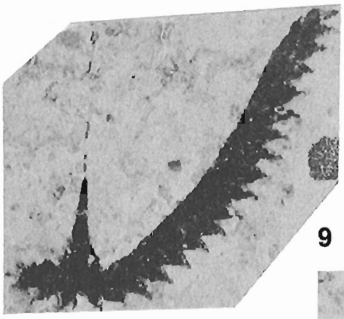
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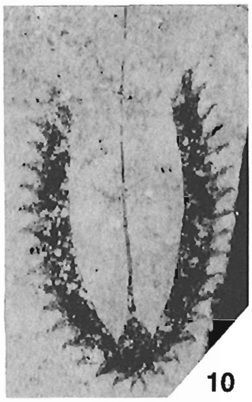
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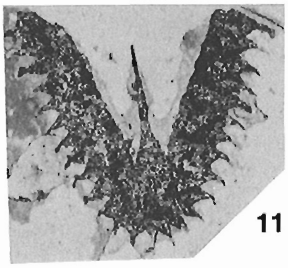
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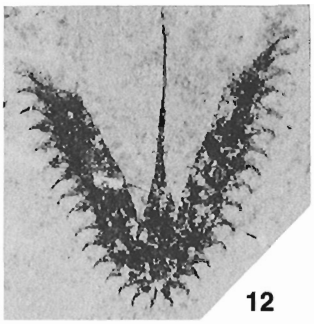
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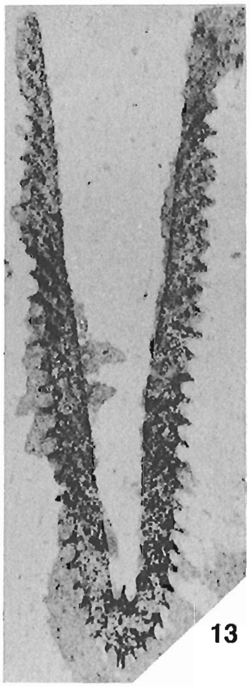
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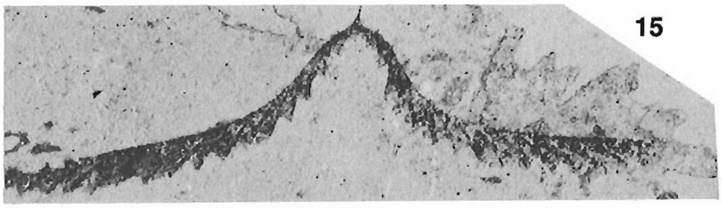
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PALYNOLOGICAL CORRELATION OF MIDDLE AND UPPER DEVONIAN ROCKS OF MELVILLE ISLAND, ARCTIC CANADA

D.C. McGregor[1]

McGregor, D.C., 1993. Palynological correlation of Middle and Upper Devonian rocks of Melville Island, Arctic Canada; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 111-120.

Abstract

Spore assemblages from 41 measured outcrop sections have been used to correlate, and determine the age of, Middle and Upper Devonian rocks of Melville Island. The Cape De Bray and Weatherall formations are diachronous; the Cape De Bray-Weatherall contact is mid-Eifelian in the eastern part of the island and early Givetian in the west. The Weatherall-Hecla Bay boundary is early Givetian in the east and late Givetian in the west. The Hecla Bay-Beverley Inlet contact is approximately isochronous. The Parry Islands Formation of eastern Melville Island is upper Frasnian to lower upper Famennian with no palynological evidence for a disconformity at its base. Strata close to the Frasnian-Famennian boundary, in the Burnett Point Member of the Parry Islands Formation, do not contain either spores or marine fossils. Eifelian and lower Givetian sediments were redeposited during much of later Devonian time, but most abundantly in the late Givetian and early Frasnian. Marine faunas useful for age determination occur with spores in some sections, particularly in rocks of Eifelian-early Givetian and Famennian age, and in Frasnian strata on western Melville Island.

Résumé

Des assemblages de spores provenant de 41 coupes d'affleurement mesurées ont été utilisés pour mettre en corrélation et dater les roches du Dévonien moyen et du Dévonien supérieur de l'île Melville. Les formations de Cape De Bray et de Weatherall sont diachrones, le contact entre les deux datant de l'Eifélien moyen dans l'est de l'île et du Givétien précoce dans l'ouest. La limite Weatherall-Hecla Bay date du Givétien précoce dans l'est et du Givétien tardif dans l'ouest. Le contact Hecla Bay-Beverley Inlet est approximativement isochrone. Dans l'est de l'île Melville, la Formation de Parry Islands s'échelonne du Frasnien supérieur à la base du Famennien supérieur; il n'existe aucun indice palynologique d'une discordance érosionnelle à sa base. Des strates trouvées près de la limite Frasnien-Famennien dans le Membre de Burnett Point de la Formation de Parry Islands, sont dépourvues de spores et de fossiles marins. Des sédiments de l'Eifélien et du Givétien inférieur ont été resédimentés au cours d'une grande partie du Dévonien plus tardif, mais plus abondamment au Givétien tardif et au Frasnien précoce. Des fossiles marins stratigraphiques se rencontrent avec les spores dans certaines coupes, notamment dans des roches de l'Eifélien-Givétien précoce et du Famennien et dans des strates du Frasnien dans l'ouest de l'île Melville.

INTRODUCTION

Temporal correlation of the strata of the Middle and Upper Devonian clastic wedge of Melville Island has been impeded because of the rarity of diagnostic marine fossils, and often complex lithofacies variations within the beds. In recent years, however, some success has been achieved in correlation of these beds using spores.

Spores are present in all of the Middle and Upper Devonian formations of Melville Island, and in some strata they occur in enormous numbers. Derived from plants that grew on land, the spores were carried by

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wind and especially by water into the various sedimentary environments of the clastic wedge, from fluvial to marine slope. In the more distal depositional environments, they occur with marine faunas. Where spores are present in the same strata as marine zonal fossils, biozones based on spores may be correlated directly with marine biozones (Richardson and McGregor, 1986).

This report is a preliminary account of the stratigraphic significance of spore assemblages from the Cape De Bray, Weatherall, Hecla Bay, Beverley Inlet, and Parry Islands formations. The spores were obtained from 41 measured outcrop sections at 20 locations distributed across Melville Island (Fig. 1). The samples were collected in 1968 (McGregor and Uyeno, 1969, their locations 1 and 2), in 1971 and 1972 (Chi and Hills, 1976, p. 646 and Fig. 3), and in 1984 and 1985 (during the field phase of the Melville Project) (see Table 1).

PREVIOUS WORK

Tozer and Thorsteinsson (1964), Embry and Klovan (1976), Harrison et al. (1985), Christie (*this volume*)

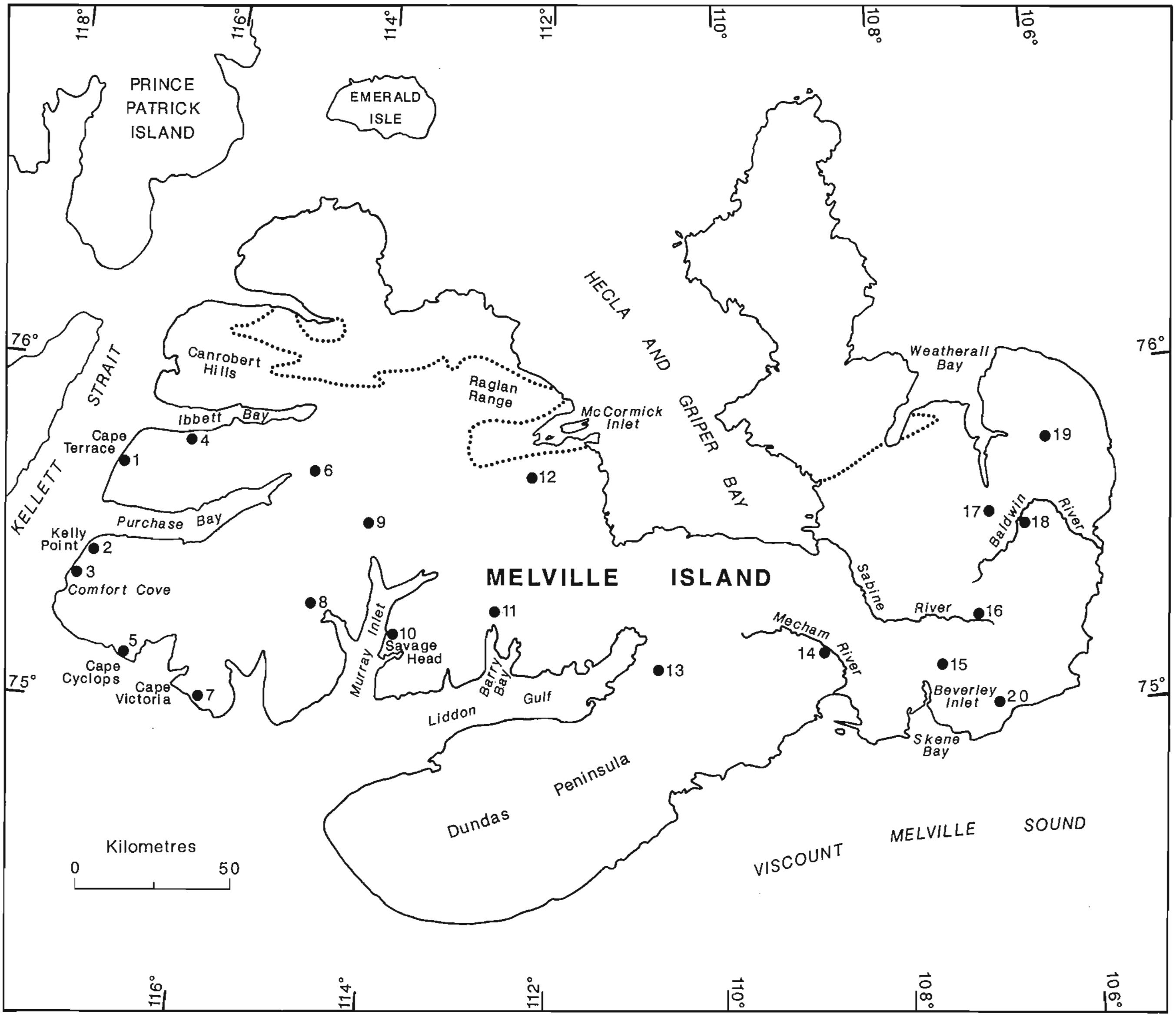

Figure 1. Geographical location of numbered sections shown in Figures 2-4. Dotted line shows approximate northern limit of outcrop of Devonian rocks (after Harrison et al., 1985).

TABLE 1

Summary of sample collections for sections in Figures 2-4

Field no or name	Location (Fig. 1)	Sample collector	Year	Latitute/longitude of base of section
Cape Terrace	1	McGregor and Chi	1971	75°47′25″N, 116°52′00″W
Cape Terrace	1	Chi and Embry	1972	75°48′12″N, 116°36′30″W
85CB-QG-KP	2	Goodbody	1985	75°24′00″N, 117°20′00″W
85CB-QG-COC	3	Goodbody	1985	75°22′30″N, 117°31′30″W
85CB-QG-COC2	3	Goodbody	1985	75°21′30″N, 117°34′00″W
84CB-QG-IB	4	Goodbody	1984	75°47′30″N, 116°13′00″W
84CB-QG-IB2	4	Goodbody	1984	75°46′40″N, 116°11′00″W
85CB-QG-CC	5	Goodbody	1985	75°07′30″N, 116°46′30″W
85CB-QG-CC2	5	Goodbody	1985	75°09′30″N, 117°09′30″W
84CB-QG-PB	6	Goodbody	1984	75°45′30″N, 114°30′00″W
84CB-QG-PB5	6	Goodbody	1984	75°48′58″N, 114°35′30″W
84CB-QG-PB6	6	Goodbody	1984	75°44′40″N, 114°37′30″W
85CB-QG-CV	7	Goodbody	1985	75°01′30″N, 115°59′00″W
84CB-QG-WMI	9	Goodbody	1984	75°29′50″N, 114°03′00″W
84CB-QG-WMI2	9	Goodbody	1984	75°31′30″N, 114°05′00″W
84CB-QG-WMI3	9	Goodbody	1984	75°31′00″N, 114°05′00″W
84CB-QG-WMI5	9	Goodbody	1984	75°33′00″N, 114°04′00″W
84CB-QG-WMI6	8	Goodbody	1984	75°21′30″N, 114°45′00″W
84CB-QG-WMI7	8	Goodbody	1984	75°21′30″N, 114°43′00″W
84CB-SH	10	Christie	1984	75°10′50″N, 113°55′W
84CB-BB1	11	Christie	1984	75°18′45″N, 112°45′W
84CB-BB2	11	Christie	1984	75°18′00″N, 112°44′W
84CB-BB3	11	Christie	1984	75°17′50″N, 112°44′W
84CB-BB4	11	Christie	1984	75°17′10″N, 112°43′W
84CB-BB5	11	Christie	1984	75°16′50″N, 112°43′W
84CB-BB6	11	Christie	1984	75°16′20″N, 112°42′W
85CB-QG-MCI	12	Goodbody	1985	75°46′00″N, 112°19′00″W
85CB-QG-MCI2	12	Goodbody	1985	75°45′20″N, 112°24′00″W
84HBB-145	13	Harrison	1984	75°07′46″N, 110°44′55″W
84CB-ELG	13	Christie	1984	75°07′30″N, 110°45′W
Beverley Inlet	15	McGregor and Uyeno	1968	75°12′N, 107°23′W
84HBB-94	17	Harrison	1984	75°36′24″N, 106°55′16″W
84HBB-116	15	Harrison	1984	75°08′40″N, 107°31′12″W
84HBB-117	15	Harrison	1984	75°08′47″N, 107°30′35″W
84HBB-174	14	Harrison	1984	75°13′36″N, 108°53′56″W
84HBB-177	14	Harrison	1984	75°11′39″N, 108°47′02″W
84HBB-178	18	Harrison	1984	75°33′11″N, 106°31′34″W
84HBB-179	18	Harrison	1984	75°32′54″N, 106°33′16″W
85HBB-224	16	Harrison	1985	75°15′16″N, 107°10′57″W
84CB-QG-EWB	19	Goodbody	1984	75°52′00″N, 106°18′00″W
Weatherall Bay	19	McGregor and Uyeno	1968	75°51′00″N, 106°15′11″W
84CB-QG-EBI	20	Goodbody	1984	75°01′00″N, 106°53′00″W
84CB-QG-EBI2	20	Goodbody	1984	75°00′00″N, 106°53′00″W

and others have given accounts of the history of geological work on Melville Island up to the present. Some of these authors (e.g., Tozer and Thorsteinsson, 1964, p. 87; Embry and Klovan, 1976) referred briefly to the results of palynological work on Devonian rocks of the region. More detailed references to palynological studies were given in the publications cited below.

McGregor and Camfield (1982, p. 2, 3) outlined the history of study of Devonian spores from the Queen Elizabeth Islands up to 1980. They also described 116 taxa of spores from the Cape De Bray, Weatherall, and Hecla Bay formations east of Weatherall Bay (Fig. 1, location 19). McGregor (1981) plotted the stratigraphic ranges of selected species of spores from Givetian-Frasnian boundary beds north of Beverley Inlet (Fig. 1, location 15). More recently, McGregor et al. (1985, p. 169) summarized faunal and palynological evidence from the Beverley Inlet section with respect to the definition of the Middle-Upper Devonian boundary.

The results of several years' work on Devonian spores of the Canadian Arctic and elsewhere in the Northern Hemisphere have been integrated into the spore zonation of the Silurian and Devonian described by Richardson and McGregor (1986). The primary reference sections for three of their nineteen assemblage zones, the *Densosporites devonicus-Grandispora naumovae* Zone (mid-Eifelian to early Givetian), the *Geminospora lemurata-Cymbosporites magnificus* Zone (mid-Givetian), and the *Contagisporites optivus* var. *optivus-Cristatisporites triangulatus* Zone (late Givetian and early Fasnian), are on Melville Island.

AGE AND CORRELATION

Spores

Spore-based correlations of the Cape De Bray, Weatherall, Hecla Bay, Beverley Inlet, and Parry Islands formations are shown in Figures 2-4. For convenience, the sections are grouped into three geographical regions: western (Ibbett Bay-Cape Victoria), central (Raglan Range-Liddon Gulf), and eastern (Weatherall Bay-Beverley Inlet). In Figure 1, these regions include locations 1-7, 8-13, and 14-20, respectively. The generalized temporal correlation of the rocks of the three regions is shown in Figure 5.

The correlations shown here are based on the method described by Richardson and McGregor (1986, p. 3): that of comparing i) whole assemblages that have a number of key species in common, and ii) the oldest occurrences of some commonly occurring key species that have intercontinental distribution. Some of the key species found on Melville Island are listed below. The ages of the oldest known records of their occurrence are given in brackets: *Densosporites devonicus* (mid-Eifelian); *Cymbosporites magnificus* followed by *Geminospora lemurata* (early Givetian); *Chelinospora concinna* followed by *Cristatisporites triangulatus* and *Contagisporites optivus* var. *optivus* (late Givetian); *Archaeoperisaccus timanicus* and multifurcate-spined spores (very late Givetian); *Archaeoperisaccus opiparus* followed by *A. ovalis* (early Frasnian); *Hymenozonotriletes deliquescens* (late early Frasnian); *Cyrtospora cristifera* (very late Frasnian); and *Cornispora varicornata* (early Famennian).

Detailed lists of the taxa recovered, and their stratigraphic ranges on Melville Island, as well as comparison of the assemblages with those that occur in Middle and Upper Devonian rocks elsewhere, are omitted from this preliminary account.

The lower contacts of the Weatherall and Hecla Bay formations are diachronous, being significantly younger toward the west. This observation supports the similar conclusion reached by Embry and Klovan (1976, Fig. 37). The actual ages of the Cape De Bray-Weatherall and Weatherall-Hecla Bay contacts, however, are about one third to one half a stage older than reported by Embry and Klovan (1976) on the basis of the sparse paleontological data available to them.

The Hecla Bay-Beverley Inlet contact, on the other hand, appears to be of about the same age wherever it has been investigated on Melville Island. Embry and Klovan (1976) and Goodbody (*this volume*) reached the same conclusion from their sedimentological studies. The age of this contact is very early Frasnian, near the top of the spore *optivus-triangulatus* Zone.

The youngest Devonian strata on Melville Island, those of the Parry Islands Formation, occur only in the eastern region. The lower beds, at the base of the Burnett Point Member, are late, but not latest, Frasnian (upper *ovalis-bulliferus* Zone). The highest unit of the Parry Islands Formation, the Consett Head Member, is mid- to late Famennian (upper *torquata-gracilis* Zone).

A disconformity between the Beverley Inlet and Parry Islands formations was proposed by Embry and Klovan (1976), mainly on the basis of the abruptness of the contact between the two formations on Banks Island. The presence of such a break is not supported by the distribution of the spores across this contact on eastern Melville Island. Spore assemblages above and below the contact contain virtually the same species, of late, but not latest, Frasnian age.

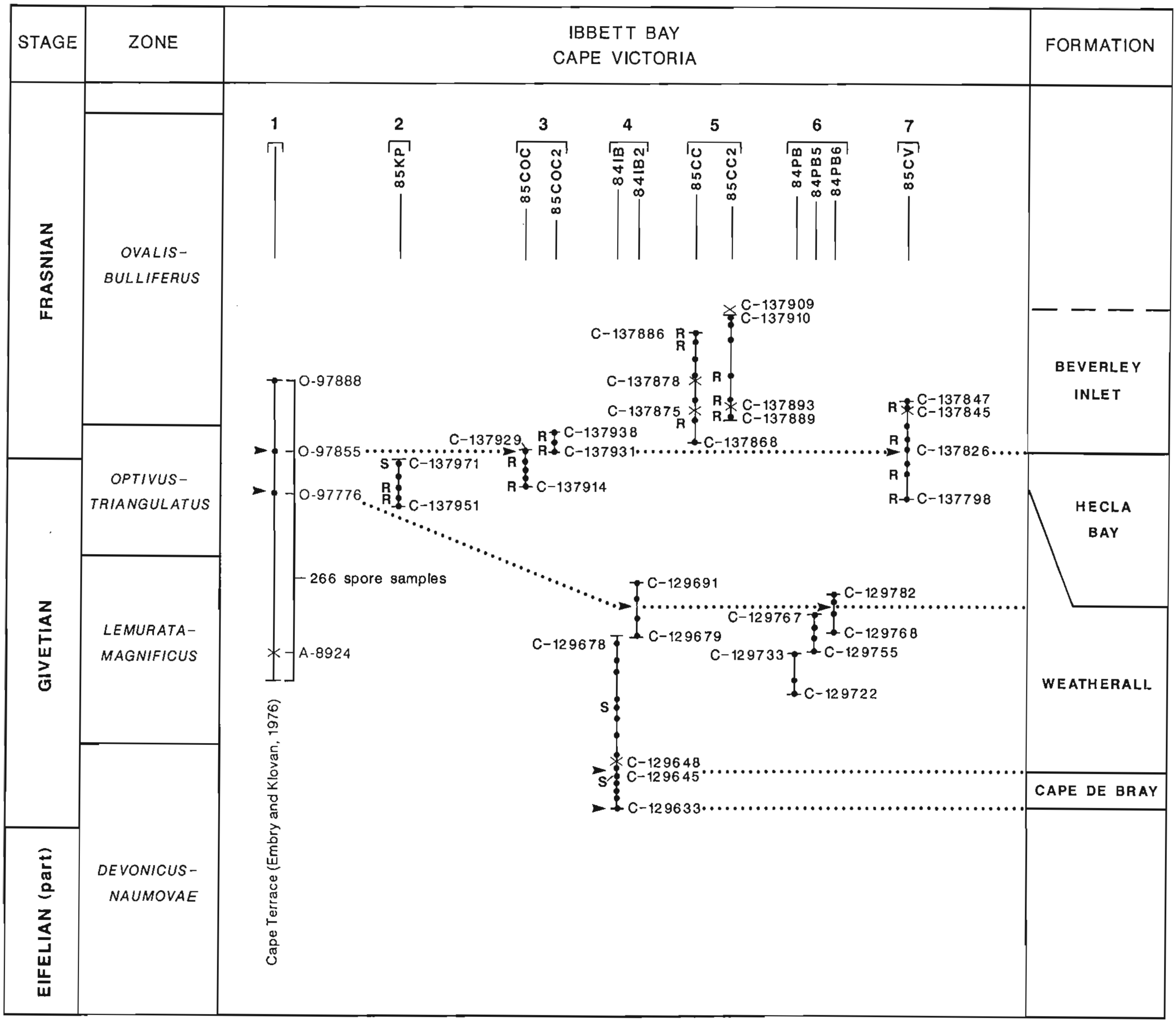

Figure 2. Correlation and age of Middle and Upper Devonian formations of western Melville Island, based on spore assemblages. ● = spores; × = marine faunas; S = scolecodonts; R = redeposited upper Eifelian/lower Givetian spores. GSC locality numbers are shown for the highest and lowest fossiliferous samples in each section, for samples with age-diagnostic faunas, and for samples close to formational boundaries. For approximate geographical locations of sections, see Figure 1.

The Frasnian-Famennian boundary probably occurs between GSC locs. A-8285 and A-8288 in the section north of Beverley Inlet (location 15, Fig. 4). This stratigraphic interval is in the lower part of the Burnett Point Member of the Parry Islands Formation. It consists predominantly of fine to coarse grained sandstone unsuitable for palynomorph preservation. The sample from GSC loc. A-8285 contains late Frasnian spores (*ovalis-bulliferus* Zone) and that from GSC loc. A-8288 contains a different assemblage, belonging to the latest Frasnian to early Famennian *torquata-gracilis* Zone. The base of the latter zone is very late Frasnian (Richardson and McGregor, 1986). Two palynological samples taken between GSC locs. A-8285 and A-8288, probably close to the Frasnian-Fammennian boundary, were barren.

The ages of the Ibbett Bay and Blackley formations could not be determined because the palynomorphs that were recovered are unidentifiable owing to

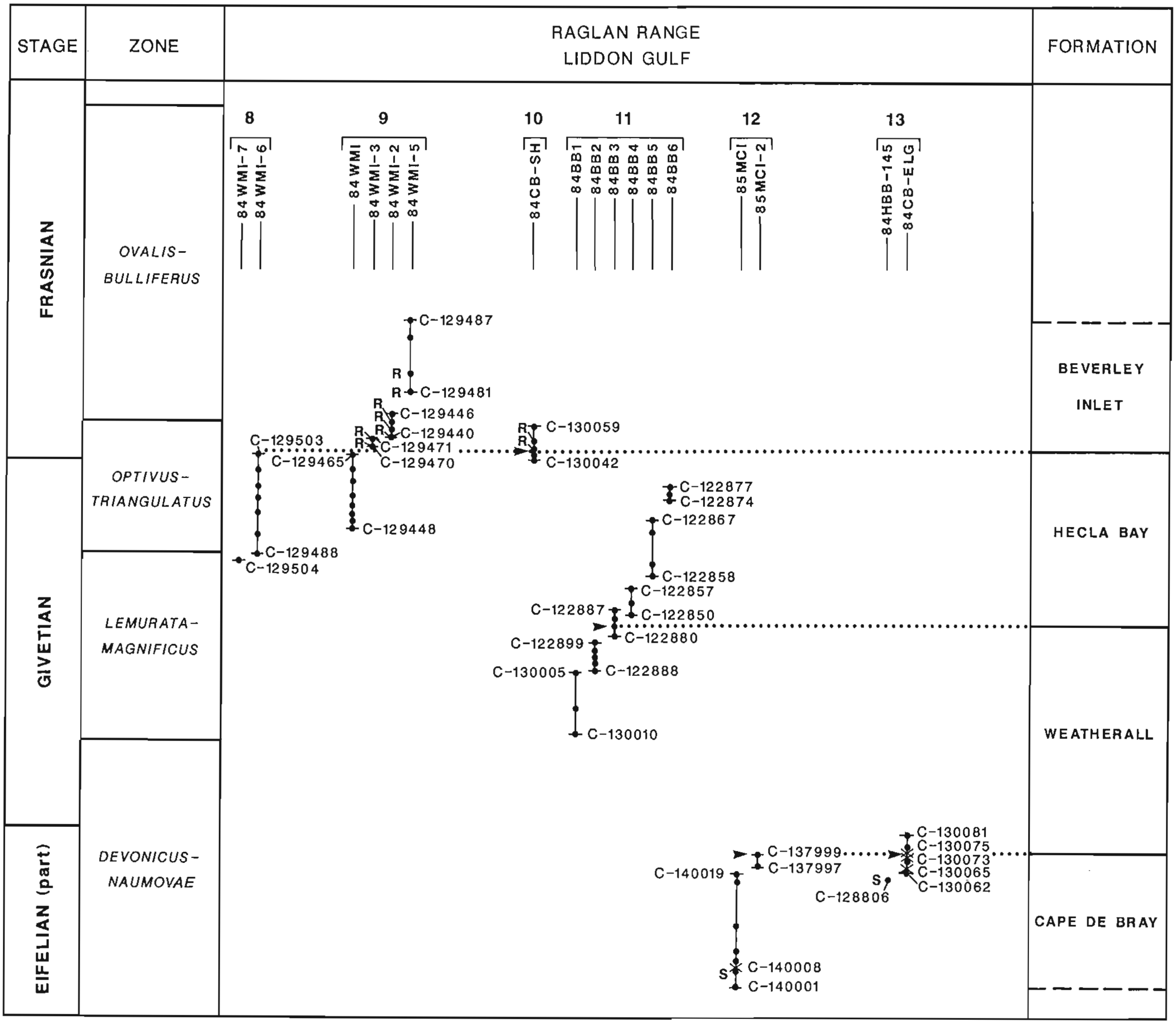

Figure 3. Correlation and age of Middle and Upper Devonian formations of central Melville Island, based on spore assemblages. For further explanation, see caption of Figure 2.

carbonization and corrosion. As these formations cannot be dated palynologically, they are not included in Figures 1 to 5.

Recycled spores are common in all of the formations of the clastic wedge. The most abundant reworked spores are those of early Eifelian to early Givetian age. Specimens with this age range are particularly numerous in the upper Hecla Bay Formation and the Beverley Inlet Formation (Figs. 2, 3). In colour (thermal alteration index of 2+; J. Utting, pers. comm., 1986) and quality of preservation they resemble the younger, in situ spores with which they occur. Because of this, and because the upper limits of the life-ranges of some of the reworked species are not well defined, the full scope of the recycling is difficult to determine. Nevertheless, it is clear that Eifelian and early Givetian terranes of the clastic wedge, and to a lesser extent younger deposits of the wedge, were being eroded and redeposited extensively during most of later Devonian time.

Marine fossils

Most of the palynologically productive samples of Middle and Late Devonian age from Melville Island contain only nonmarine palynomorphs (spores and/or

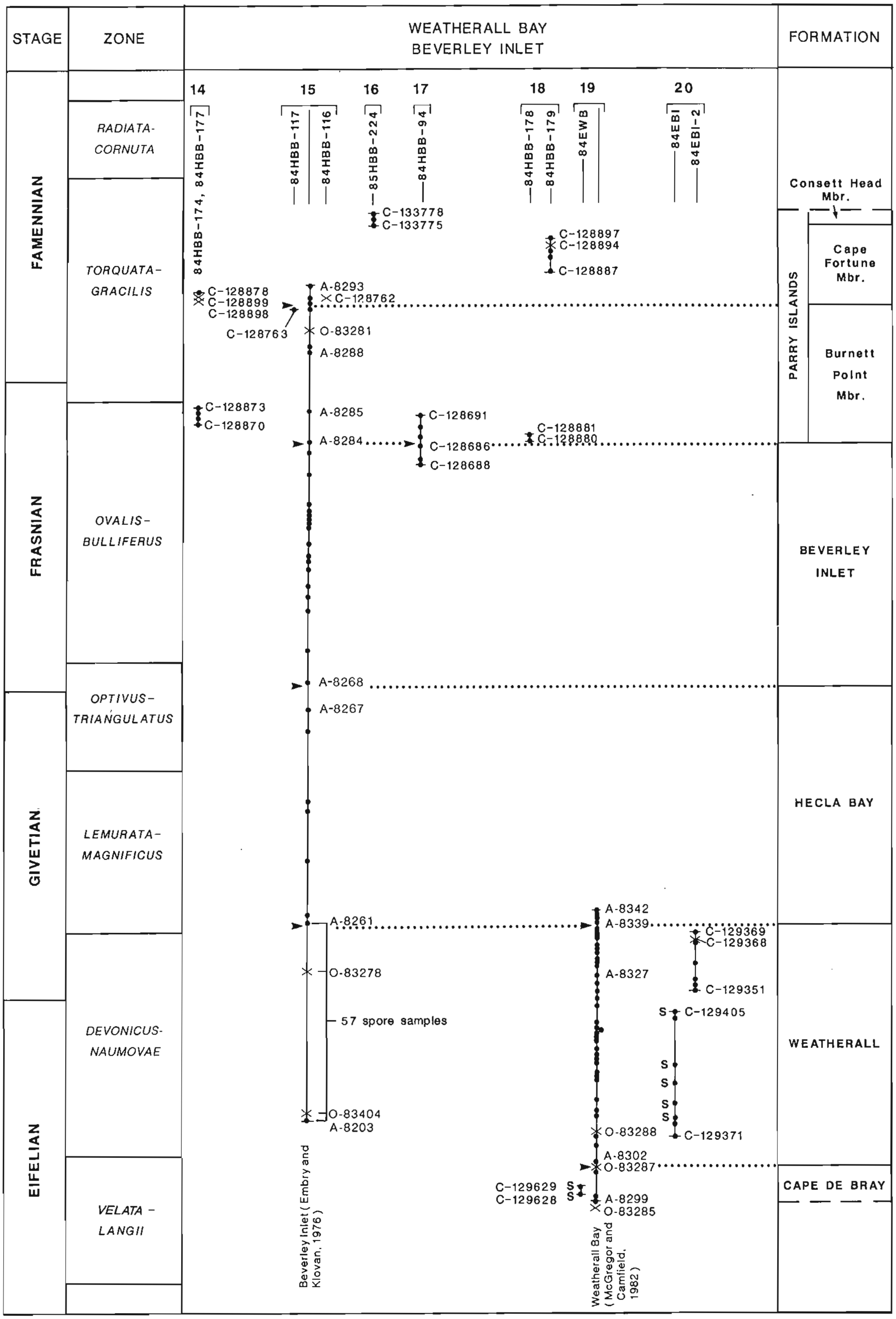

Figure 4. Correlation and age of Middle and Upper Devonian formations of eastern Melville Island, based on spore assemblages. The base of the Hecla Bay Formation according to Embry and Klovan (1976) and McGregor and Camfield (1982) is below GSC loc. A-8327 in the Weatherall Bay section (location 19). For further explanation, see caption of Figure 2.

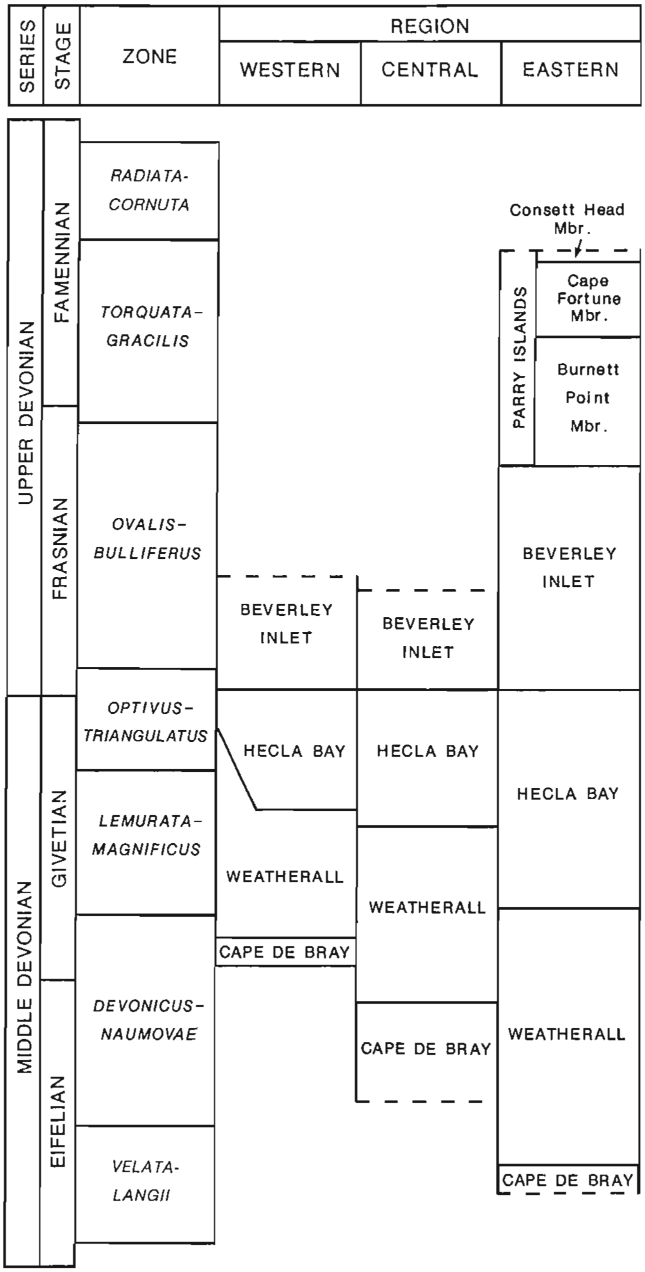

Figure 5. Biostratigraphic correlation of Middle and Upper Devonian formations across Melville Island, based on Figures 2–4. Broken lines indicate limits of data in sections.

fragments of land plants). A few of the samples from the Cape De Bray Formation and the lower Weatherall Formation, however, yielded scolecodonts, commonly believed to be jaw apparatuses of polychaete worms that lived in shallow marine environments (Figs. 2, 3, 4). No acritarchs or chitinozoans (indicative of holomarine conditions) were found among the several hundred thousand palynomorphs recovered. Neither scolecodonts nor other marine palynomorphs were found in the Beverley Inlet Formation of western Melville Island, or in the Parry Islands Formation of the northeastern region. Both of these formations contain marine faunas (indicated in Figs. 2, 4), and their depositional environments were therefore apparently, at least in part, appropriate for the occurrence of scolecodonts, and perhaps acritarchs. The most reasonable explanation for the apparent lack of scolecodonts and acritarchs in these beds may be that the numbers of marine palynomorphs, if present, were greatly diluted by influxes of terrigenous spore-bearing sediments.

Marine faunas useful for age determination have been found together with (or bracketed by) spores in the Cape De Bray Formation, in the lower and higher parts of the Weatherall Formation, in marine facies of the Beverley Inlet Formation on the west side of the island, and in the Cape Fortune Member and upper Burnett Point Member of the Parry Islands Formation. Their stratigraphic positions are shown in Figures 2, 3, and 4. Their ages are summarized in Table 2. In most cases the ages determined from the faunas agree fully with the ages independently assigned on the basis of the spore record. A few do not, and they are noted and discussed below.

Beds about 70 m below the top of the Weatherall Formation at section 84EBI-2 (location 20, Fig. 4) are "probably Eifelian" according to data from faunas at GSC loc. C-129368 (Norris, 1986a, p. 5). More recently however, A.W. Norris (pers. comm., 1986) commented that the *Echinocoelia* sp. in the sample from GSC loc. C-129368 could be Givetian, judging by its occurrence in Devonian strata of the mainland of northwestern Canada. A spore assemblage 16.8 m higher stratigraphically in the same section (GSC loc. C-129369) contains *Archaeozonotriletes timanicus, Perotrilites heclaensis*, and cf. *Geminospora lemurata*, which are regarded as early Givetian precursors of the *lemurata-magnificus* Zone.

In section 84IB a marine fauna at locality C-129648 (location 4, Fig. 2), in the Weatherall Formation about 56 m above its base, is "late Eifelian (possibly *kockelianus* Zone)" (Norris, 1986a, p. 5). Spores from section 84IB, both above and below the fauna at GSC loc. C-129648, suggest a slightly younger, early Givetian age. GSC loc. C-130116, from an isolated outcrop of the Weatherall Formation close to location 4, contains a very late Givetian fauna correlated with the conodont Lowermost *asymmetricus* Zone (Norris, 1986b, p. 1, 2). Therefore, in the region south of Ibbett Bay, the minimum age span of the Weatherall Formation, according to marine animal fossil data, is

TABLE 2

Location and age of marine faunas

GSC loc.*	Section	Identified by	Year	Age
A-8924	Cape Terrace	A.W. Norris	1984	About mid-Givetian
O-83278	Beverley Inlet	T.T. Uyeno	1980	Mid-Eifelian–Eifelian/Givetian boundary, *australis* to *ensensis* zones
O-83281	Beverley Inlet	T.T. Uyeno	1982	Famennian, *crepida* to *L. velifer* zones
		A.W. Norris	1982	Early to mid-Famennian
O-83285	Weatherall Bay	T.T. Uyeno	1981	About mid-Emsian–early Eifelian *inversus* to *c. costatus* zones
O-83287	Weatherall Bay	T.T. Uyeno	1979	Probably early Middle Devonian *c. costatus* Zone
O-83288	Weatherall Bay	T.T. Uyeno	1979	Middle Devonian, *australis* Zone to Lower *varcus* Subzone
O-83404	Beverley Inlet	A.W. Norris	1985	Late Eifelian
C-128762	85HBB-116	A.W. Norris	1986	Famennian
C-128894	84HBB-179	A.W. Norris	1986	Famennian
C-128898	84HBB-177	A.W. Norris	1986	Early late Famennian
C-128899	84HBB-177	A.W. Norris	1986	Famennian
C-129368	84CB-QG-EBI2	A.W. Norris	1986	Probably Eifelian
C-129648	84CB-QG-IB	A.W. Norris	1986	Late Eifelian (possibly *kockelianus* Zone)
C-130065	84CB-ELG	A.W. Norris	1986	Late Eifelian, *dysmorphostrota* Zone
C-130073	84CB-ELG	A.W. Norris	1986	Late Eifelian, *dysmorphostrota* Zone
C-130075	84CB-ELG	A.W. Norris	1986	Late Eifelian, *dysmorphostrota* Zone
C-137845	85CB-QG-CV	A.W. Norris	1986	Late Givetian, *impennis* Zone (=Lowermost *asymmetricus* Zone)
C-137875	85CB-QG-CC	A.W. Norris	1986	Late Givetian, *impennis* Zone (=Lowermost *asymmetricus* Zone)
C-137878	85-CB-QG-CC	A.W. Norris	1986	Early Frasnian, *A. allani* Zone (in Middle *asymmetricus* Zone)
C-137893	85CB-QG-CC2	A.W. Norris	1986	Probably late Givetian
C-137909	85CB-QG-CC2	A.W. Norris	1986	Early Frasnian, *A. allani* Zone (in Middle *asymmetricus* Zone)
C-140008	85CB-QG-MCI	A.W. Norris	1986	Eifelian

*GSC localities are designated with prefixes as follows: A- plant locality, C- locality number curated at I.S.P.G., Calgary; O- locality number curated at GSC, Ottawa.

late Eifelian to latest Givetian. However, the spore evidence from section 84IB and 84IB-2 suggests a shorter age range for the Weatherall Formation in that region, i.e. early Givetian to early late Givetian (see Figure 2, location 4).

Faunas low in the Beverley Inlet Formation, at GSC loc. C-137875 in section 85CC and GSC loc. C-137845 in section 85CV (locations 5, 7, Fig. 2) are very late Givetian, in the Lowermost *asymmetricus* Zone, and those at GSC loc. C-137893 in section 85CC2 (location 5, Fig. 2) are probably late Givetian (Norris, 1986a, p. 3, 4). In contrast, spore assemblages bracketing these fossils in all three sections contain *Archaeoperisaccus* spp. and other species that strongly suggest an early Frasnian age. On the other hand, higher in the Beverley Inlet Formation in sections 85CC and 85CC2, age assignments based on the spores and faunas are in close agreement. Shelly fossils at GSC loc. C-137878 (51.2 m above GSC loc. C-137875) and at GSC loc. C-137909 (170.9 m above GSC loc. C-137893) are within the Middle *asymmetricus* Zone, i.e. early but not earliest Frasnian (Norris, 1986a, p. 2, 3). Early (not earliest) Frasnian spores occur a few metres below and above these faunas in both sections.

The few apparent differences between the ages deduced from the marine faunas and those concluded from the spores span only half a stage or less. These differences may be ascribed to the preliminary nature of the evidence relating the stratigraphic ranges of some of both kinds of fossils to their ranges in stratotype sections. The two lines of evidence, gathered and interpreted independently, are based on organisms that lived and evolved separately from one another, in continental and benthonic marine environments, respectively. Zonal schemes based on fossils from these two magnafacies are still being calibrated with one another, through interdisciplinary studies such as the Melville Project. The minor discrepancies in the age determinations noted above will be resolved as work progresses, resulting in improved precision in the zonation schemes of both kinds of fossils.

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STRATIGRAPHY AND SEDIMENTOLOGY OF THE CANYON FIORD FORMATION, MELVILLE ISLAND

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Abstract

The Upper Carboniferous and Lower Permian Canyon Fiord Formation on Melville Island comprises up to 1800 m of predominantly quartzose sandstone and pebble conglomerate, with lesser amounts of siltstone, mudstone, and sandy bioclastic limestone. Outliers of the Canyon Fiord Formation occur in an east-west trending belt across northern Melville Island.

The Canyon Fiord Formation on Melville Island is made up of several facies associations. They are:

1. A1, A2, A3 talus slope and proximal alluvial fan
2. B distal alluvial fan
3. C tidal flat and alluvial floodplain
4. D foreshore and upper shoreface
5. E1, E2 shallow marine environments.

The Canyon Fiord Formation is subdivided on a broader scale into three members. These units provide a record of facies variations and the dominant depositional environments through time in response to tectonic activity and sea level changes. In ascending stratigraphic order they are:

The lower clastic member, consisting mainly of coarse grained clastic deposits of facies associations A1, A2, A3, and B (Bashkirian/Moscovian); **the middle limestone member**, dominated by shallow marine sandstone and limestone of facies association E (Moscovian); **the upper clastic member**, mainly alluvial plain, tidal flat, and proximal marine sediments (Moscovian to Sakmarian).

Although local variations can be observed, the lower clastic member and middle limestone member generally weather yellow to light grey, in contrast to the distinctive red or variegated colouration of the upper sediments.

Résumé

Dans l'île Melville, la Formation de Canyon Fiord du Carbonifère supérieur et du Permien inférieur se compose principalement d'un maximum de 2 150 m de grès quartzeux et de conglomérat à cailloux, avec des quantités moindres de siltstone, de mudstone et de calcaire bioclastique sableux. Des buttes-témoins de la Formation de Canyon Fiord se rencontrent dans une ceinture à orientation est-ouest dans le nord de l'île Melville.

La Formation de Canyon Fiord de l'île Melville comporte les associations suivantes de faciès :

1. A1, A2, A3, tablier d'éboulis et cône alluvial proximal

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2. B cône alluvial distal
3. C wadden et plaine d'inondation alluviale
4. D estran et avant-plage supérieure
5. E1, E2 milieux marins peu profonds.

La Formation de Canyon Fiord se subdivise en trois grands membres. Ces unités témoignent de la variation dans le temps, en réponse à l'activité tectonique et aux fluctuations du niveau marin, des faciès et des principaux milieux de sédimentation. Ces membres sont les suivants, donnés en ordre stratigraphique croissant :

Le **membre clastique inférieur**, qui se compose principalement de dépôts clastiques à grain grossier des associations de faciès A1, A2, A3 et B (Bashkirien/Moscovien); le **membre calcaire intermédiaire**, dans lequel prédomine des grès et calcaires épicontinentaux de l'association de faciès E (Moscovien); et le **membre clastique supérieur**, qui se compose principalement de sédiments de plaine alluviale, de sédiments de wadden et de sédiments marins proximaux (Moscovien-Sakmarien).

Bien qu'il existe des variations locales, en général, les surfaces altérées du membre clastique inférieur et du membre calcaire intermédiaire ont une couleur jaune ou gris pâle qui fait nettement contraste à la couleur rouge ou bariolée caractéristique des sédiments supérieurs.

INTRODUCTION

The Canyon Fiord Formation, comprising Upper Carboniferous to Lower Permian strata, is a syntectonic deposit that occurs as scattered outliers on northern Melville Island (Fig. 1). Canyon Fiord strata represent the earliest deposition within the Sverdrup Basin in the Melville Island area. Very fine and fine grained quartzose sandstone and conglomerate are dominant. Minor coarse grained sandstone, siltstone, mudstone, and sandy bioclastic limestone are also present.

Thicknesses of up to 1220 m were estimated by Tozer and Thorsteinsson (1964). However, Canyon Fiord strata are commonly repeated by faults, and these are difficult to delineate due to poor outcrop exposure, abrupt facies changes, and inadequate internal markers, so that it is easy to overestimate thickness. The longest stratigraphic section was measured northeast of the head of Ibbett Bay, and contains about 830 m of strata. However, composite sections indicate thicknesses of up to 1800 m, and seismic profiles indicate up to 3200 m (Harrison, 1991).

In this paper, descriptions of the five facies of the Canyon Fiord Formation are given, and a discussion of stratigraphy and age. Local variations in syndepositional structural style have profoundly influenced the Canyon Fiord Formation in the Melville Island region so that a wide spectrum of sedimentary patterns is now exhibited.

PREVIOUS WORK

The Canyon Fiord Formation was first named by Troelsen (1950) for about 122 m of limestone at Canyon Fiord, western Ellesmere Island. Upper Carboniferous (Moscovian) fossils were collected at that locality. In an unpublished manuscript, Troelsen (1954) also included conglomerate, sandstone, and impure limestone in the formation. Thorsteinsson (1974) amended the definition of the Canyon Fiord Formation to encompass about 1680 m of red-weathering quartzose sandstone with minor amounts of conglomerate and limestone, and demonstrated that Troelsen's (1950) type section is a middle member of the amended Canyon Fiord Formation. Thorsteinsson and Tozer (1963), Tozer and Thorsteinsson (1964), Nassichuk (1965, 1975), and Thorsteinsson and Tozer (1970) have provided additional information on Canyon Fiord strata in the type area and elsewhere in the Canadian Arctic Archipelago.

Beauchamp (1987) subdivided the Canyon Fiord Formation into three members at Raanes Peninsula on Ellesmere Island. Beauchamp's lower clastic member consists mainly of red-weathering conglomerate and lesser amounts of sandstone and limestone; the overlying middle limestone member is characterized by ledge-forming fossiliferous limestone with interbedded, more recessive, fine grained argillaceous clastics and argillaceous limestone; and the upper clastic member comprises mainly sandstone and minor limestone.

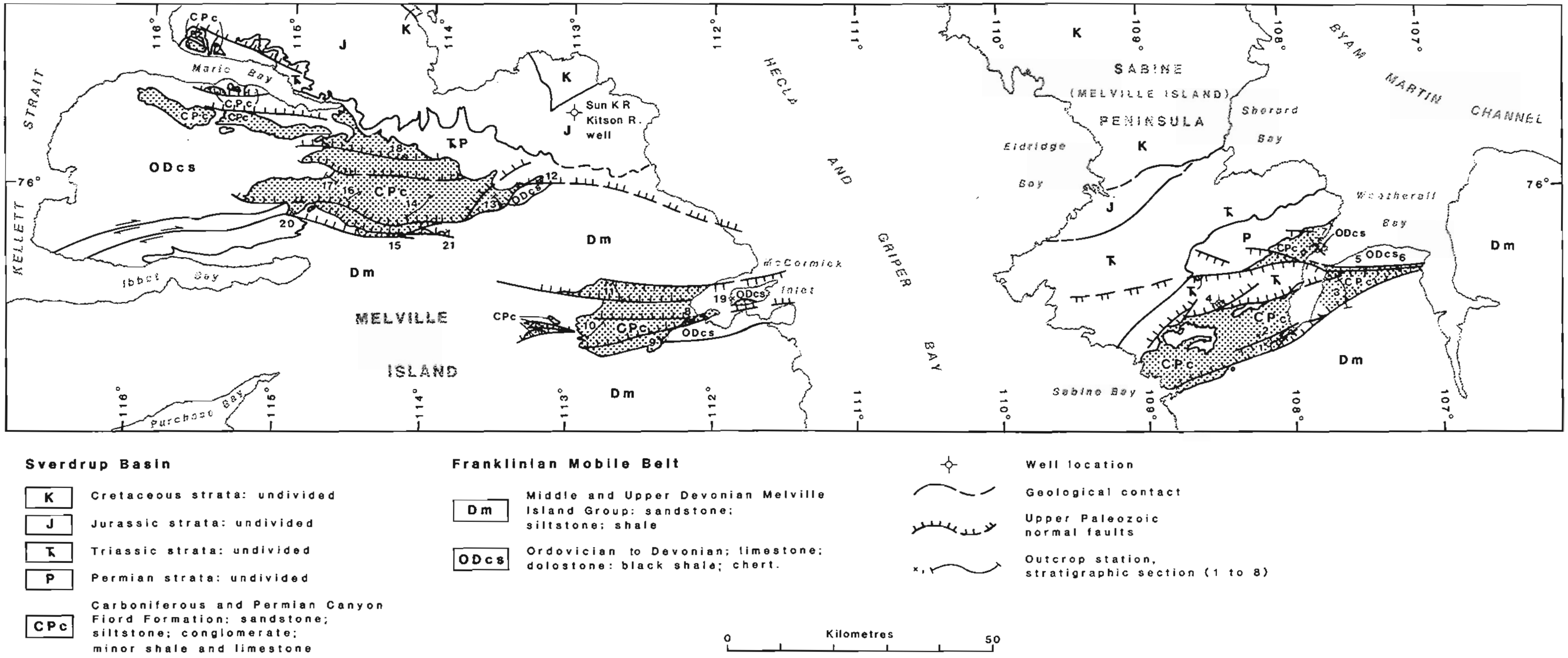


Figure 1. *Map showing Canyon Fiord outliers on Melville Island. Lines of stratigraphic section, and isolated outcrop station locations are also shown.*

These three members are recognized on Melville Island; this nomenclature is therefore also used here.

Beauchamp et al. (1989a, b) provided a regional synthesis of Upper Paleozoic stratigraphy and basin analysis for the Sverdrup Basin. These papers also contain an excellent summary of the tectonic and depositional setting for Canyon Fiord deposition on Melville Island. Specific structures relating to Carboniferous and Permian deformation on Melville Island are described by Harrison (1991, *this volume*).

Facies analysis

Five facies associations, A to E, are recognized in the Canyon Fiord Formation based on data obtained from measured stratigraphic sections and from isolated outcrops. A detailed description and interpretation of each facies association is given in the text, and summarized in Table 1. Representative stratigraphic sections for each facies association are presented in Figures 2 to 9.

Facies association A

Facies association A consists of matrix- and clast-supported pebble to cobble conglomerate and breccia, with associated granule conglomerate and red sandstone. Three types of coarse clastic deposits representing different environments of deposition are recognized. They are: A1, yellow- or red-weathering breccia; A2, massive, poorly sorted breccia; and A3, red-weathering conglomerate.

A1: Yellow- or red-weathering, calcite-cemented, pebble- to cobble-sized breccia, which is generally clast-supported and monomictic or oligomictic (Fig. 2). Framework clasts are commonly very angular, ranging in size up to 30 cm in diameter, with an open matrix cemented by calcite spar or a very poorly sorted very fine to coarse grained sand. The breccias are unsorted and free of any obvious grading or internal stratification, and frequently occur adjacent to, and in the hanging wall of, steeply dipping or gently dipping normal faults.

Clast composition reflects the lithology of adjacent source rocks, including argillaceous limestone, bioclastic limestone, cryptalgal limestone, dolostone, and minor grey to black chert.

A2: Massive, matrix-supported, poorly sorted polymictic breccia (Fig. 3). The matrix consists of fine

TABLE 1

Summary of facies associations, Canyon Fiord Formation, Melville Island

FACIES ASSOCIATION	FIGURE REFERENCE	LITHOLOGY	SEDIMENTARY STRUCTURES	INTERPRETATION
A1	Figure 2	Clast-supported, pebble- to cobble-sized, monomictic or oligomictic breccia	Massive bedding; open (calcite cemented) or sparse sand matrix; scour and fill; thin sand lenses	Scree breccias and (?)debris flows; fan apex, scarp and fault-line deposits
A2	Figure 3	Matrix-supported, pebble-sized polymictic or oligomictic breccia; laminar caliche hardpan	Massive bedding; vertically oriented clasts; argillaceous sand matrix	Subaerial debris flows; proximal alluvial fan
A3	Figure 4	Clast-supported chert pebble conglomerate; sandstone cobble conglomerate	Massive bedding; trough crossbedding or horizontal stratification; scour and fill; sole markings; small-scale fining-upward sequences; normally graded beds; imbricated clasts	Braided stream; channel fill and sieve deposits; proximal alluvial fan
B	Figure 5	Coarse grained sandstone and interbedded pebble conglomerate	Trough and planar crossbedding; parallel stratification; local channelling; small-scale, fining-upward sequences	Streamflow and sheetflood deposits; medial to distal alluvial fan
C	Figure 6	Fine and very fine grained sandstone; siltstone; mudstone	Fining-upward sequences; massive bedding; bioturbation; low angle, bimodal ripple and cross lamination; flaser bedding	Tidal flat and alluvial floodplain deposits; minor lagoonal and lacustrine deposits
D	Figure 7	Fine and medium grained sandstone; scattered pebbles and pebble bands	Coarsening-upward sequences; planar bedding; subparallel to low-angle planar lamination; low-angle bimodal crossbedding; trough crossbedding; symmetric and asymmetric ripple cross lamination; bioturbation; burrows	Foreshore and upper shoreface deposits
E1	Figure 8	Fine and very fine grained sandstone; calcareous; bioclastic; oolitic	Hummocky and swaley cross-stratification; ripple cross lamination; burrows; bioturbation	Lower shoreface and shallow siliciclastic shelf deposits
E2	Figure 9	Bioclastic limestone, variably quartzose; minor encrinite	Wave-ripple cross-stratification	Shallow offshore organic shelf deposits

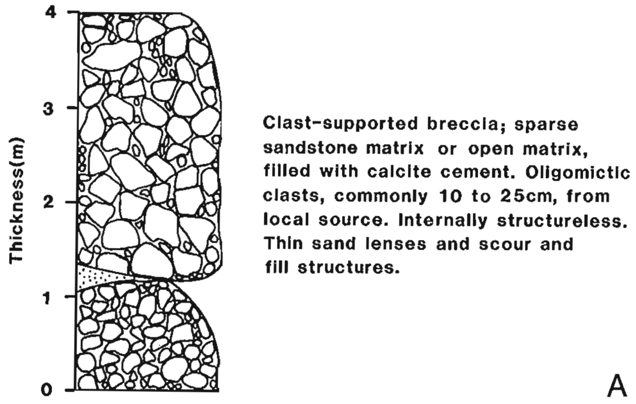
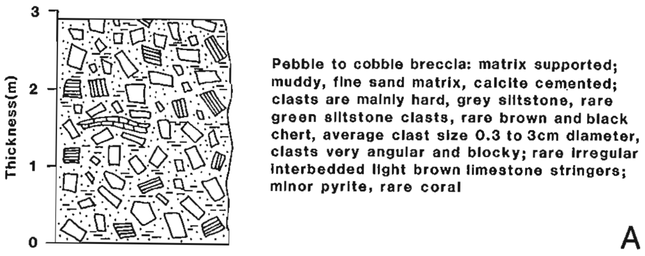


Figure 2. Facies association A1. A. Schematic section; B. Representative exposure; hammer, 30 cm. (GSC photo no. 2899-4.)



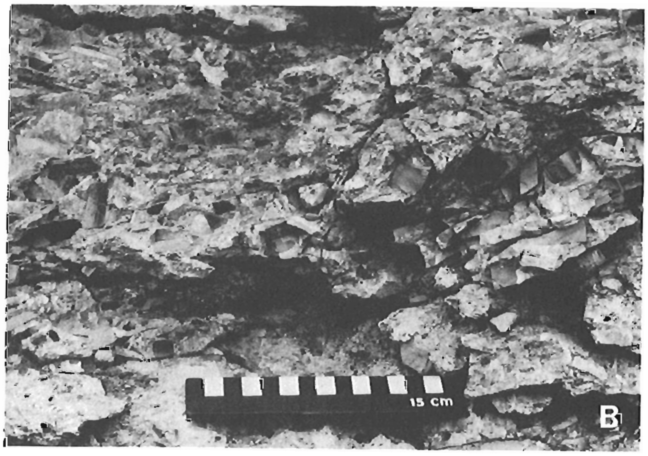


Figure 3. Facies association A2. A. Schematic section; B. Representative outcrop. (GSC photo no. 2899-5.)

grained sandstone and mudstone. Calcite is the dominant cement type, with local hematite-stained zones. The clasts include very angular, blocky, well indurated grey siltstone, mudstone, and limestone, with an average diameter of 1 to 3 cm. Rare clasts of brown and black chert and green siltstone average 0.5 cm in diameter. Clasts up to 10 cm are also encountered in some exposures and can be dominant in other exposures. In such places the deposits may superficially resemble strata of facies association A1, but are distinguished by the matrix-supported character of A2. Light brown, laminated micrite occurs in facies association A2 as rare, irregular stringers, 2 to 3 cm thick and 5 to 7 cm long.

A3: Red-weathering, clast-supported, chert pebble and sandstone cobble conglomerate (Fig. 4). The conglomerate is locally clast imbricated. Rounded to well rounded clasts, predominantly of variegated chert, range in diameter from 1 to 2 cm with a few exceeding 5 cm. Rounded clasts of white, fine grained sandstone and light brown limestone are less common, but tend to be larger on average than the chert pebbles and cobbles, with sandstone cobbles and boulders from 10 to 70 cm in diameter, and limestone cobbles ranging up to 15 cm in diameter (Fig. 4B, C, D). Clasts of hematite-cemented chert pebble conglomerate also occur, and range up to 15 cm in diameter.

The matrix of facies association A3 conglomerate most commonly consists of coarse grained, cherty sandstone, although some conglomerate has a fine or medium grained sandstone matrix. These clast-supported conglomerates are cemented by calcite, or more rarely by hematite. Open framework, variably

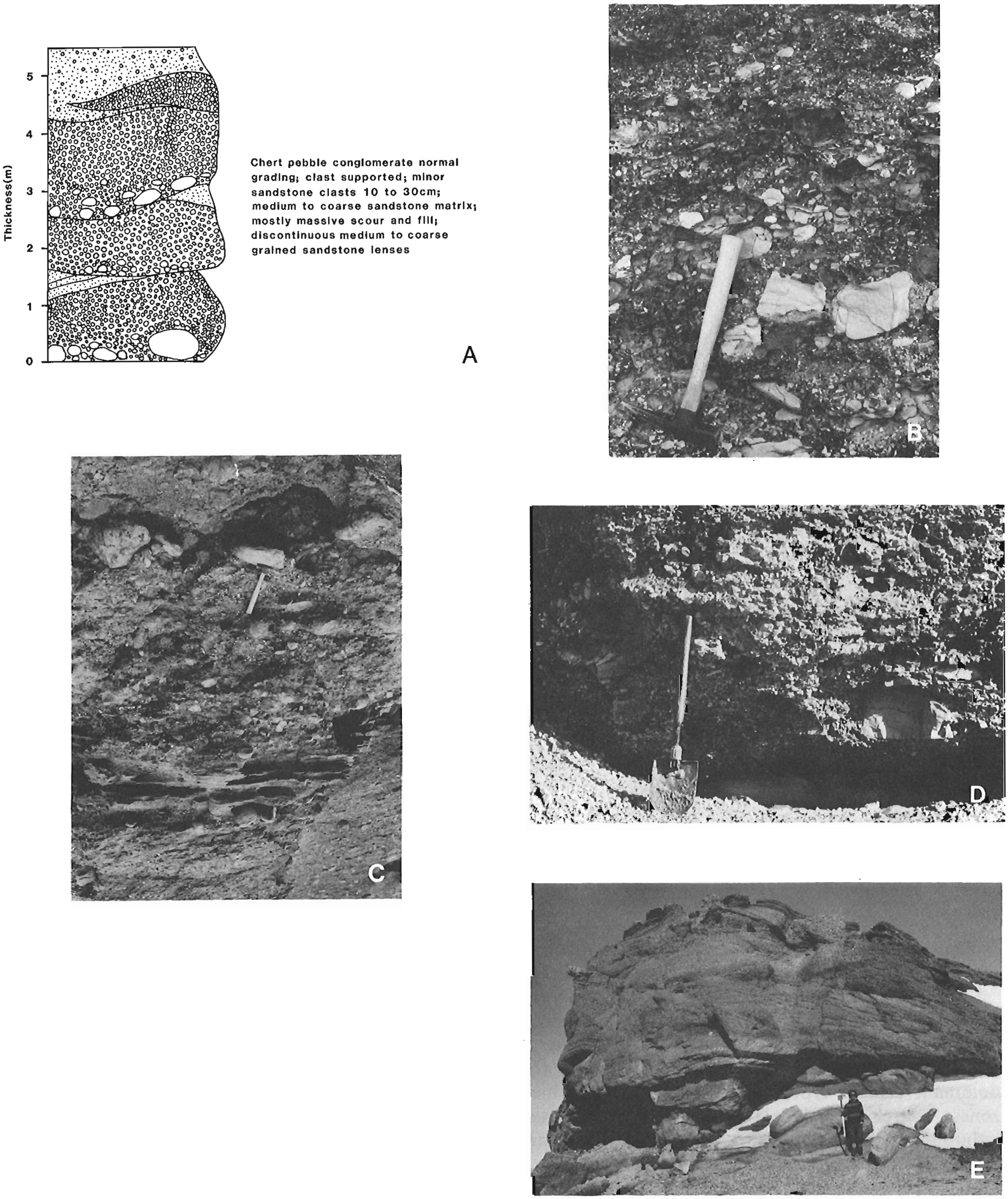


Figure 4. *Facies association A3.* ***A.*** *Schematic section;* ***B, C, D*** *(GSC photo nos. 2912-10, 2912-13, 2899-3). Characteristic appearance of conglomerates in outcrop;* ***E.*** *Typical outcrop section (GSC photo no. 2899-1). Hammer, 30 cm, shovel, 70 cm, Jacob's staff, 1.5 m.*

calcite-cemented conglomerate in discontinuous lenses, is also typical of facies association A3.

Sedimentary structures include massive bedding, trough cross-stratification, or crude horizontal stratification. Scour and fill structures as well as rare basal sole markings also occur. Small-scale, fining-upward rhythms are present, indicating local fluctuations in flow velocity. Granule conglomerate and pebbly, coarse grained sandstone occur as lenses interbedded with the pebble to cobble conglomerate. Figure 4D illustrates a typical outcrop of facies association A3.

Interpretation of facies association A

The breccias of facies association A1 are interpreted as fan apex and fault line scree or paleotalus deposits. They are similar to paleotalus deposits described by Crowell (1982), Nilsen (1982), and Ballance (1984). Rare basal scour and fill structures beneath some thick beds indicate that mass flow processes were locally operative.

The vertical orientation of some clasts (Fig. 3), the fine grained matrix, and the matrix-supported fabric of facies association A2 suggest a debris flow origin for these conglomerates. The texture of A2 breccias is much like textures of modern debris flows as described by Nilsen (1982). Rust (1979) detailed similar massive breccias with a high angle (subvertical) clast fabric from the Cannes de Roche Formation (eastern Gaspé), which he interpreted as debris flows. The laminated micritic limestone stringers are intepreted as caliche hardpan deposits, similar to the laminar caliche hardpan beds described by Esteban and Klappa (1983).

The coarse grained deposits of facies association A3 are interpreted as braided stream and channel fill deposits in a proximal alluvial fan environment. These deposits interfinger downfan with deposits of facies association B. The conglomerates compare favourably to recent streamflow deposits of Furnace Creek Wash, Death Valley, California (Nilsen, 1982), to the ancient proximal conglomeratic alluvium described by Steel and Aasheim (1978) from the Devonian of Norway, and to the coarse grained sequences of the Ridge Route Formation of southern California, also interpreted as alluvial fan deposits by Link and Osborne (1982). The open framework conglomerates of facies association A3 are interpreted as sieve deposits, similar to those described by Gloppen and Steel (1981) from Devonian strata in Norway, and by Ballance (1984) for the Simmler Formation of southern California.

Facies association B

Facies association B consists mainly of parallel-stratified and cross-stratified, coarse grained sandstone with interbedded pebble conglomerate (Fig. 5B). Coarse to medium grained sandstone, locally containing pebble- and cobble-sized clasts of chert and sandstone (Fig. 5C), is characterized by trough and planar crossbedding and parallel stratification with interbedded conglomerate. Local, vertically stacked channels up to 9 m in total thickness cut the sandstone, and are filled with chert-pebble conglomerate. Small-scale, fining-upward sequences, an example of which is shown in Figure 5D, are present. The cement is most commonly calcite, although hematite cementation occurs locally. Pyrite occurs in places as framboids or disseminated grains.

A sequence of grey, grey-khaki, and purplish shales is exposed at one locality, where it is interbedded with the sandstone described above. Utting (1985) recovered a nonmarine palynomorph assemblage from these shales, and suggested a lacustrine environment of deposition.

Interpretation of facies association B

The sandstone and conglomerate of facies association B are clearly waterlain, and are comparable to stream channel and sheetflood deposits described by Gloppen and Steel (1981), Nilsen (1982), and Ballance (1984). The Melville Island beds represent medial to distal alluvial fan environments, and they presumably interfinger landward with coarser deposits of facies association A3, and basinward with facies association C. The interbedded lacustrine shales indicate the occurrence of small lakes in the distal fan environment.

Facies association C

Facies association C comprises unconsolidated, fine grained clastics that are arranged in fining-upward cycles. Because the rocks are weakly cemented, outcrop typically is poor, and sedimentary structures, biogenic features, and lateral and vertical stratigraphic relationships are commonly obscured. Several well exposed intervals provide the basis for defining this facies association.

The base of each cycle is marked by fine or very fine grained, white to light grey quartzose sandstone that is clean and well sorted and appears to have a sheet-like geometry. A few horizontal trace fossils can be seen,

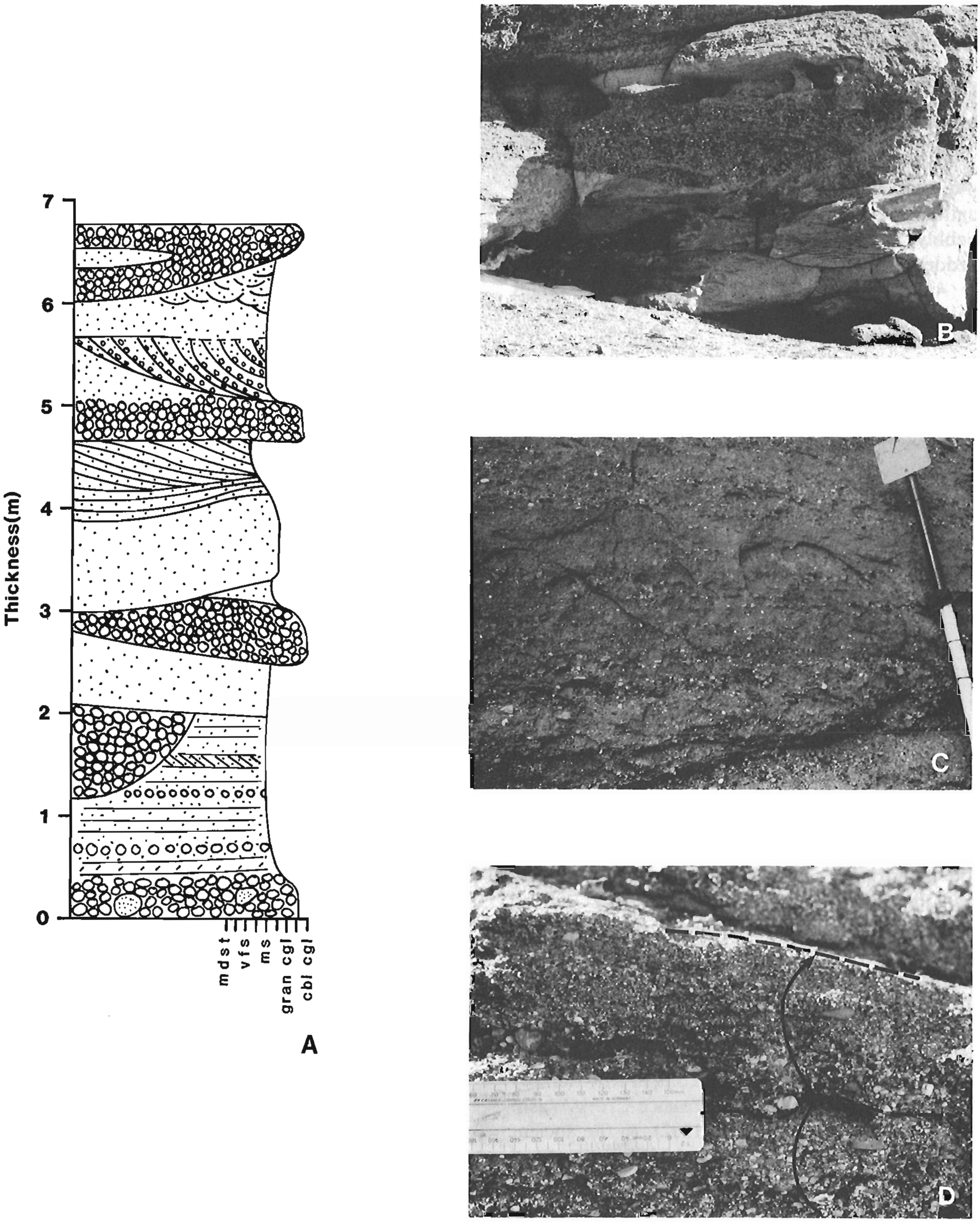


Figure 5. Facies association B. A. Schematic section; B. Crossbedded sandstone and conglomerate (GSC photo no. 2899-7); C. Pebble bands in sandstone (GSC photo no. 2899-12); D. Small-scale, fining-upward cycles (GSC photo no. 2899-11). Shovel, 70 cm, Jacob's staff, 1.5 m. mdst = mudstone; vfs = very fine grained sandstone; ms = medium grained sandstone; gran cgl = granule conglomerate; cbl cgl = cobble conglomerate.

but it is suspected that the generally massive character of the sandstone is due to intense bioturbation. Rare, low-angle, bidirectional ripple crosslamination and trough crosslamination are present [Fig. 6A(i)]. Laminae are from 0.3 to 0.8 cm thick. Sandstone pebbles and pyrite are present locally. The basal sandstone grades upward to massive, red, commonly argillaceous siltstone and greenish grey mudstone [Fig. 6A(ii)]. The red colouration, typical of the Canyon Fiord Formation, is largely attributed to red siltstone beds within this facies association.

Interpretation of facies association C

The sandstone at the base of the facies association C fining-upward sequence is considered to represent lower intertidal sand flat sedimentation. The occurrence of trace fossils suggests marine or restricted marine conditions, and bidirectional crosslaminated sequences were probably generated by tidal action. The overlying red and green siltstone and mudstone are interpreted as mixed intertidal flat and supratidal mudflat sequences. Acritarchs recovered from some beds indicate a marine influence. Similar cycles from the Middle Carboniferous of Svalbard were described and interpreted as representing a tidal flat setting by Gjelberg and Steel (1983). However, an alluvial plain interpretation cannot be entirely discounted. The tidal flat and alluvial plain deposits of Melville Island are closely associated with strata of facies associations D and E in a basinward direction, and landward, closer to paleotopographic highs, commonly interfinger with distal alluvial fan deposits of facies association B.

Figure 6B(i) shows a sequence of thinly interbedded light coloured sandstone and darker siltstone and mudstone. The dark colour of the fine grained deposits suggests a local reducing environment, in contrast to the predominantly oxidizing conditions that produced the ubiquitous red of the enclosing strata. The association of these deposits with underlying shoreline sediments of facies association D [Fig. 6B(ii)] and overlying transgressive marine sandstone of facies association E implies deposition in a lagoonal environment; the light and dark beds represent uppermost strata of a single, high frequency transgressive-regressive cycle typical of facies association C. The occurrence of flaser bedding (Fig. 6), rare coalified fragments, calcareous concretions, and marine palynomorphs (J. Utting, pers. comm., 1986) is consistent with this interpretation, and it can be suggested that barrier islands were present locally.

Facies association D

Fine and medium grained sandstones with isolated pebbles and pebble layers, which are commonly arranged in high frequency, coarsening-upward sequences, are characteristic of facies association D. The sandstones are commonly friable and weakly consolidated, so that exposures tend to be poor; however, some calcite-cemented units have been preserved. Plant fragments, mudstone rip-up clasts, and glauconite are present in minor amounts. Pyrite commonly occurs along bedding planes, as burrow linings, in fractures and as concretions and framboids. Thin calcarenites, in which the allochems are mainly crinoids, brachiopods, gastropods, corals, and bryozoa, are locally interbedded with the sandstones. Trace fossils, including (?)*Ophiomorpha* occur in some beds. Sedimentary structures include planar bedding, wedge-shaped sets of subparallel to low angle planar lamination (Fig. 7A), low angle, commonly bidirectional (herringbone) cross-stratification (Fig. 7B), trough crossbedding, and symmetric and asymmetric ripple crosslamination. Thin beds (less than 5 cm) of granule to cobble conglomerate and very coarse grained sandstone are rare.

Interpretation of facies association D

The mineralogy, macrofossil and trace fossil content, and sedimentary structures of facies association D show marked similarity to foreshore and upper shoreface deposits described by Gjelberg and Steel (1983) and Reinson (1984). The coarsening-upward sequences and sedimentary structures are typical of shoreline progradation following periods of marine onlap. The occurrence of *Ophiomorpha* supports a foreshore and upper shoreface interpretation (Frey and Pemberton, 1984). Facies association D strata interfinger with tidal flat-alluvial plain and lagoonal sequences of facies association C, and with deeper marine shelf deposits of facies association E.

Facies association E

Facies association E is represented by two distinct lithofacies deposited in similar marine environments:

E1: Planar and cross-stratified, fine grained sandstone with intercalated very fine grained sandstone is typical of facies association E1. Patches of shell debris are common. Sedimentary structures include planar lamination, and hummocky and/or swaley cross-stratification (Fig. 8B). The rock is intensely

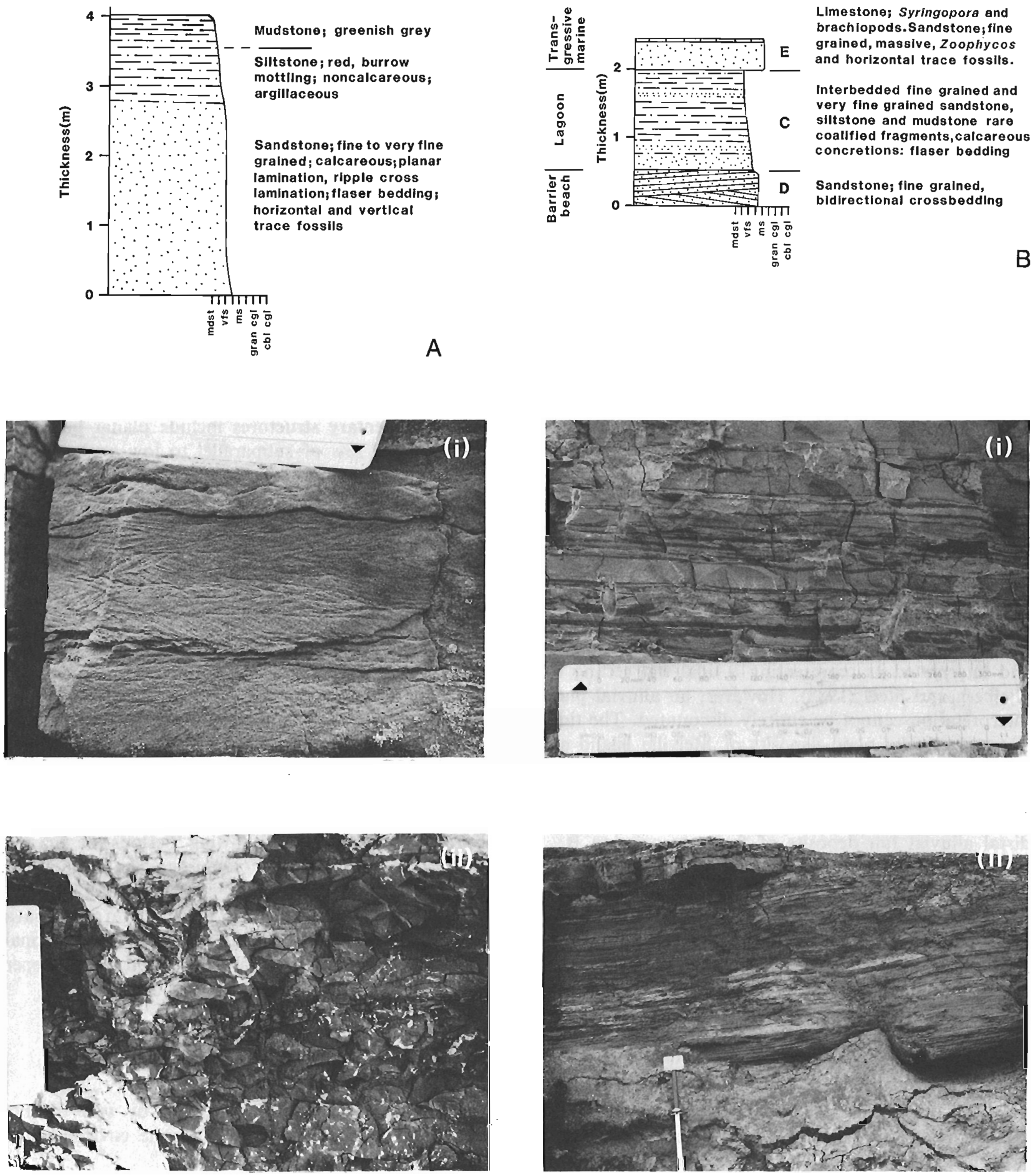


Figure 6. *Facies association C.* ***A.*** *Tidal flat sequence with (i) ripple crosslamination, and (ii) interbedded red siltstone and green mudstone (GSC photo nos. 2899-16, 2899-17);* ***B.*** *Lagoonal sequence showing (i) flaser bedding and (ii) typical outcrop (GSC photo nos. 2899-13, 2899-14). Jacob's staff, 1.5 m. mdst = mudstone; vfs = very fine grained sandstone; ms = medium grained sandstone; gran cgl = granule conglomerate; cbl cgl = cobble conglomerate.*

bioturbated and is usually completely homogenized, although rare horizontal traces, vertical tubes (*Skolithos*) and feeding traces (*Zoophycos*) are present (Fig. 8C). Isolated outcrops contain bryozoans, crinoids, solitary corals, and large colonial corals (*Syringopora, Favosites*).

E2: Sandy, bioclastic limestone. Rare occurrences of sandy, bioclastic limestone of facies association E2 suggest intervals of lower clastic input. The medium to light grey limestone (Fig. 9) typical of the facies is a biosparite containing crinoids, brachiopod spines, bryozoans, echinoderm plates, and coral fragments in a sparry matrix, and occurs as 10 to 40 cm thick beds. Encrinite beds at one locality exhibit wave ripple cross-stratification (Fig. 9).

Interpretation of facies association E

The sandstone of facies association E1 exhibits sedimentary structures, macrofossils, and trace fossils that are typical of middle and lower shoreface sands (Reinson, 1984; Walker, 1984). The presence of macrofossils, particularly corals, in the sandstone may indicate local carbonate banks in the lower shoreface environment, similar to those described by Ginsburg and James (1974) from recent sediments in the eastern Gulf of Mexico.

Facies association E2 limestones are interpreted as shallow marine shelf deposits, resulting from occasional extensive marine transgressions. The encrinite beds also associated with this facies (Fig. 9)

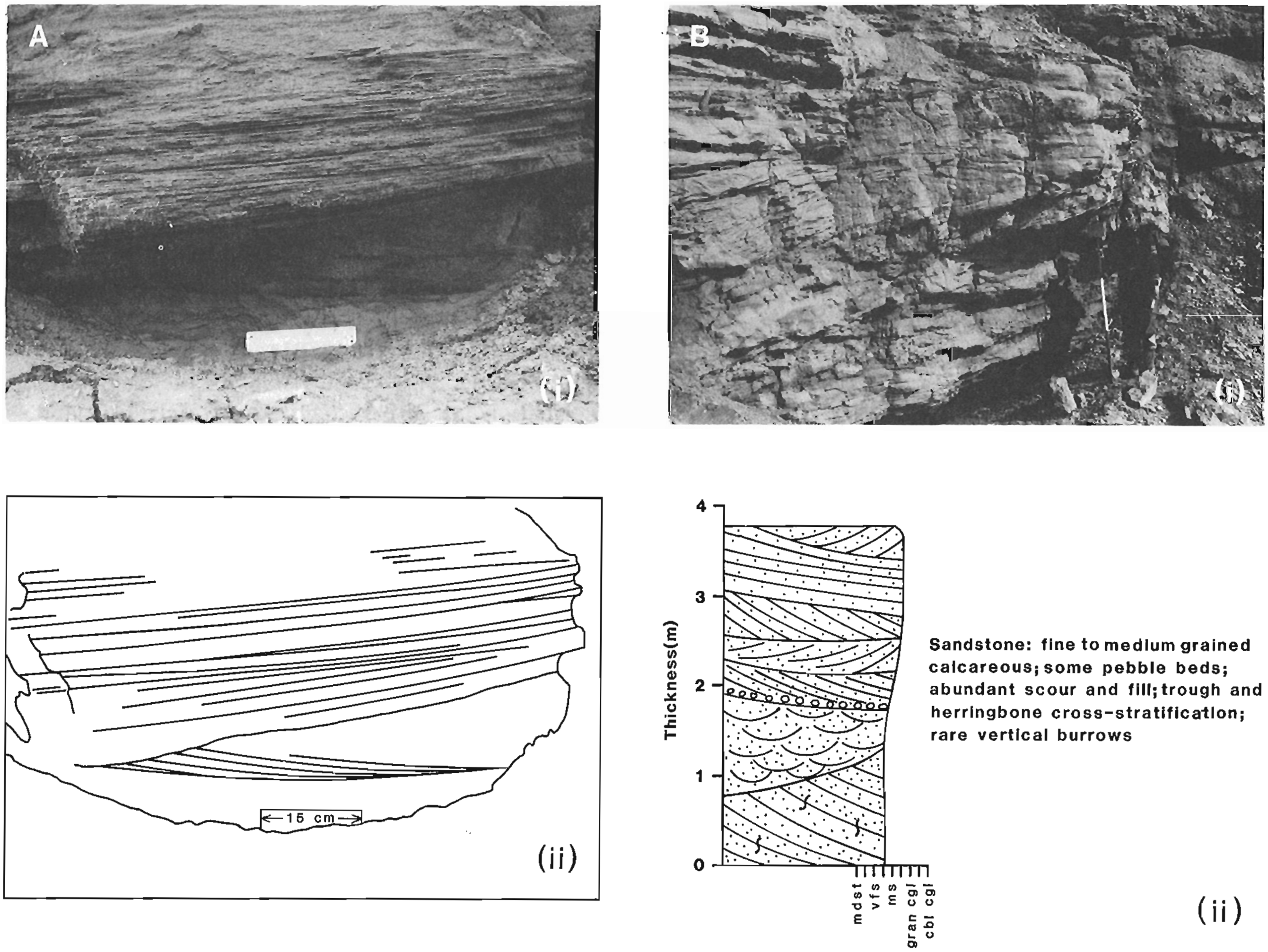


Figure 7. *Facies association D.* ***A.*** *Low angle planar cross-stratification (i) in outcrop (GSC photo no. 2899-15); (ii) schematic of structures in (i);* ***B.*** *Bidirectional (herringbone) crossbedding (i) in outcrop (GSC photo no. 2899-10); (ii) schematic section. Jacob's staff, 1.5 m. mdst = mudstone; vfs = very fine grained sandstone; ms = medium grained sandstone; gran cgl = granule conglomerate; cbl cgl = cobble conglomerate.*

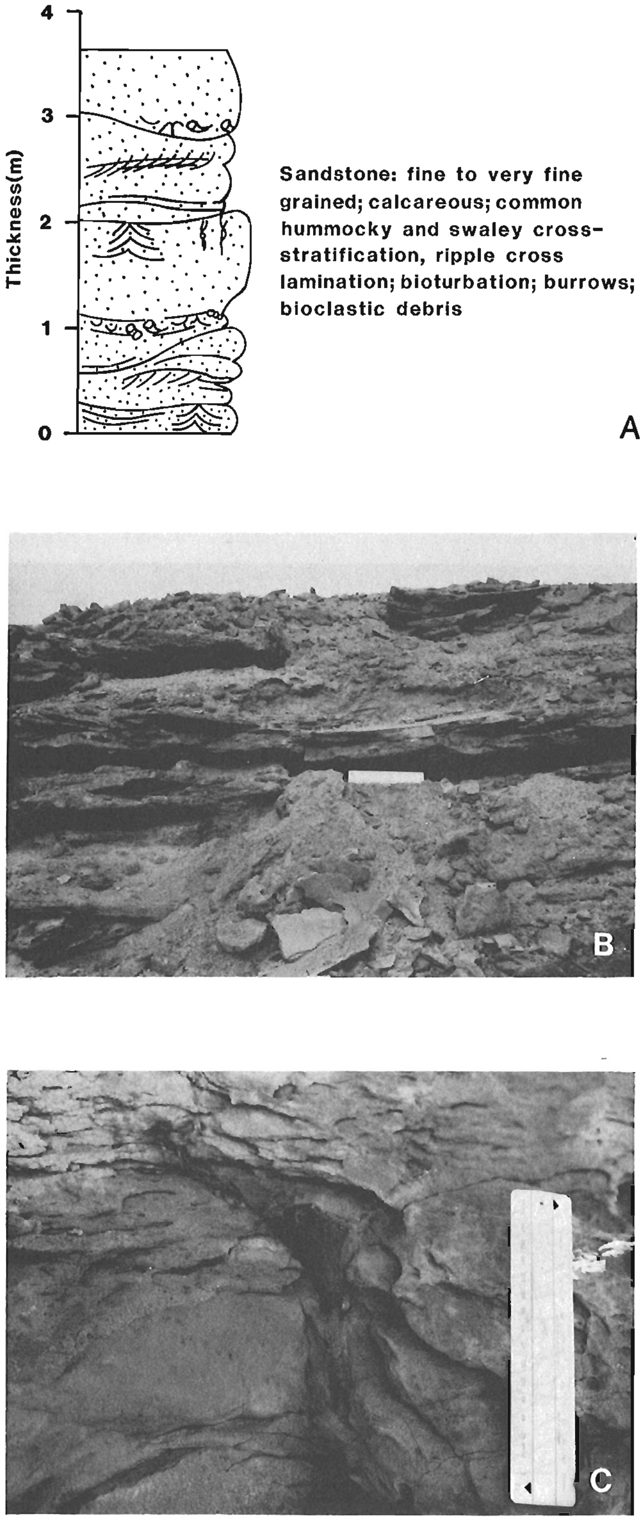


Figure 8. Facies association E1. ***A.*** *Schematic section;* ***B.*** *Hummocky cross-stratification (GSC photo no. 2997-4);* ***C. Zoophycos*** *burrow (GSC photo no. 2997-6).*

probably represent an offshore marine bar sequence. Deposits of facies association E are most commonly preserved in abrupt or erosional contact with underlying units of various facies associations, and thus are considered to mark an episode of marine transgression in which the sea extended far inland.

STRATIGRAPHY AND AGE

The facies associations described previously can be considered as stratigraphic building blocks, juxtaposed in time and space in response to tectonic movements and sea level fluctuations. In the following discussion of lithostratigraphy, the three members of the Canyon Fiord Formation are described in terms of their constituent facies associations. The age of the Canyon Fiord Formation is provided in the discussion of biostratigraphy. In Figure 10, Canyon Fiord deposition in a half-graben setting is schematically illustrated, and the relationships between the five facies associations and the three members (upper and lower clastic members and middle limestone member) of the Canyon Fiord Formation are demonstrated.

LITHOSTRATIGRAPHY

Beauchamp (1987) subdivided the Canyon Fiord Formation on Raanes Peninsula, Ellesmere Island, into three members: lower clastic, middle limestone, and upper clastic. These subdivisions of the Canyon Fiord Formation are also recognized on Melville Island.

The **lower clastic member** of the Canyon Fiord Formation of Melville Island commonly includes 100 to 120 m of coarse grained quartzose and cherty sandstone, calcareous sandstone, conglomerate, and breccia of facies associations A1, A2, A3, and B (Fig. 10A). Three hundred metres of the lower clastic member strata are present at one locality near McCormick Inlet (Section 10, Fig. 1).

It is gradationally overlain by the **middle limestone member**, which consists of bioclastic limestone, sandy limestone, and lesser marine quartzose sandstone (facies associations E1 and E2, Fig. 10B). E2 limestones range up to 90 m in thickness. However, in many exposures, the middle limestone member is absent or so thin, that for mapping purposes it is more conveniently included with the lower clastic member. Absence of the middle limestone member is thought to be most likely due to a shoreward facies change to marine sandstone, although tilting and erosion of some

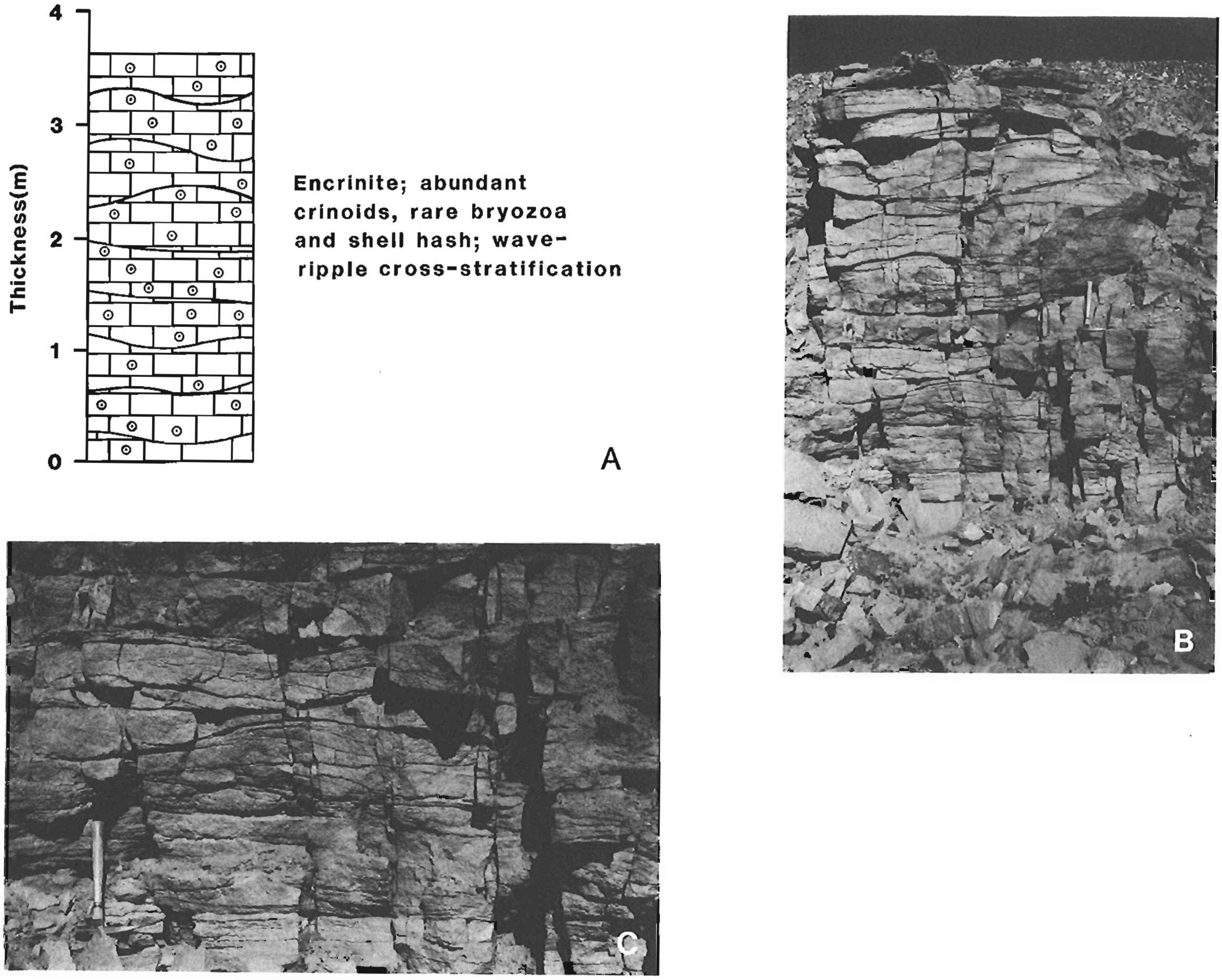


Figure 9. Facies association E2. A. Schematic section; B; and C. Crossbedded encrinite units (GSC photo nos. 2899-8, 2899-9). Hammer, 30 cm.

middle limestone member and the upper beds of the lower clastic member prior to deposition of the upper clastic member may have occurred in some areas.

The **upper clastic member** appears to range up to at least 1670 m of sandstone, siltstone, conglomerate, and minor impure limestone, and includes mainly facies associations B, C, and D (Fig. 10C, D). The estimate of thickness for the upper clastic member is based on geometric calculations and composite sections.

Yellow-weathering colours are common in the lower two members of the Canyon Fiord Formation, which are dominated by facies associations A1, A2, A3, B, E1, and E2. These colours can usually be used as a guide to distinguish the lower two members from the upper member, which is invariably dominated by red, orange, or light green surface colouration (facies association C). However, in many parts of the Canrobert Hills and, locally, north and south of the Raglan Range, the lower member is also stained red. Nevertheless, the characteristic facies associations outlined above can still be used to identify the contacts between the units.

BIOSTRATIGRAPHY

Age determinations for the Canyon Fiord Formation of Melville Island area have been reported by Tozer and Thorsteinsson (1964), Utting (1985, 1989), and Beauchamp (1987). The age of the conglomerates at the base of the lower clastic member is unknown. The conglomerate could conceivably have been deposited any time between the Famennian and the Moscovian, although an age in the Late Carboniferous (Bashkirian to early Moscovian) seems most likely. East of Tingmisut Lake on Sabine Peninsula (Fig. 1), Tozer

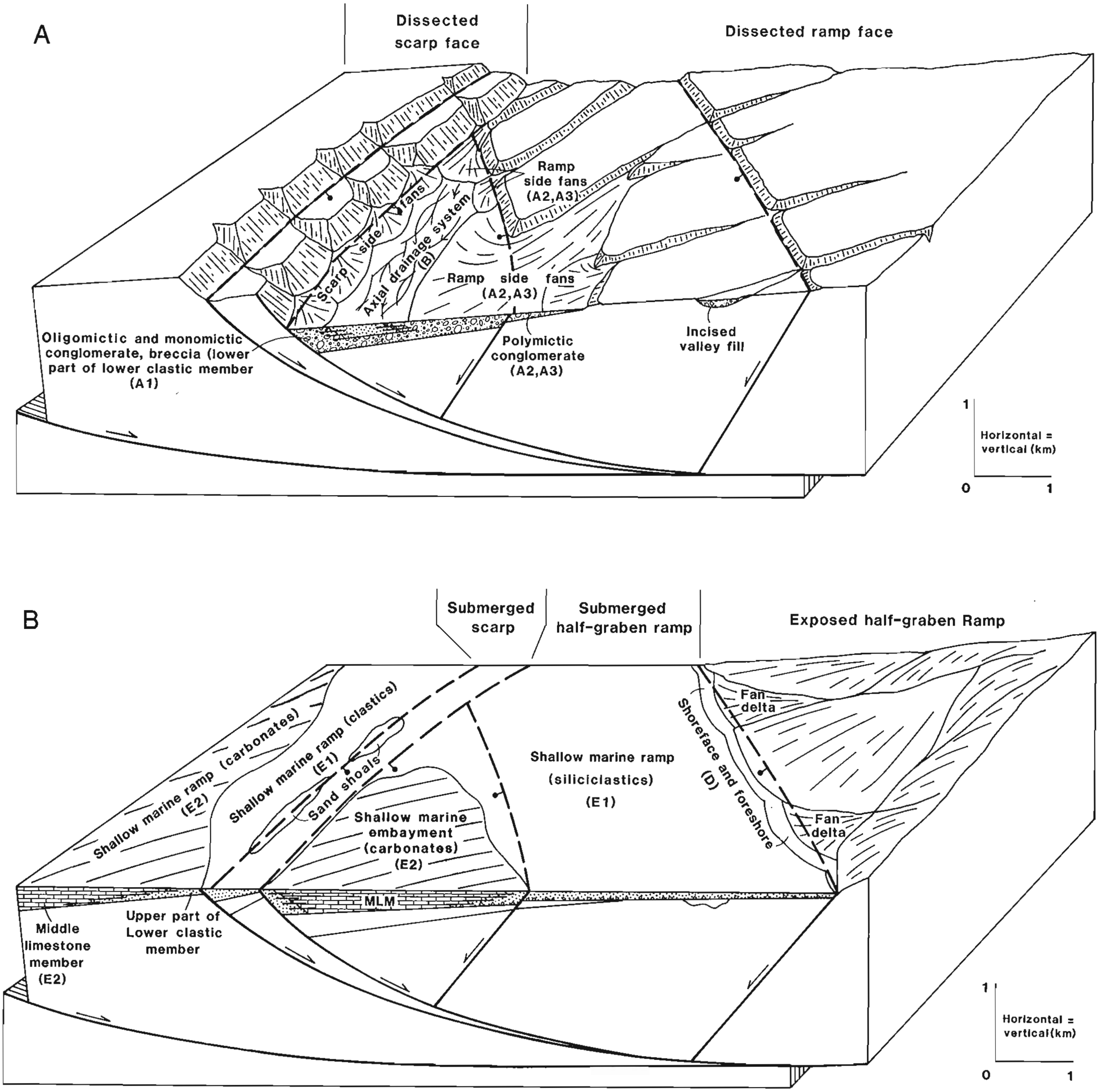


Figure 10. Schematic model of half-graben evolution, illustrating the vertical and aereal distribution of the five facies associations, and the three members of the Canyon Fiord Formation. ***A.*** *Lower clastic member (LCM) (Bashkirian/Moscovian);* ***B.*** *Lower clastic (LCM) and middle limestone (MLM) members (Moscovian);* ***C.*** *Early deposits of the upper clastic member (UCM) (Kasimovian-Gzhelian);* ***D.*** *Late deposits of the upper clastic member (Asselian-Sakmarian).*

and Thorsteinsson (1964) reported a well preserved brachiopod fauna that yielded a Middle Pennsylvanian (Moscovian) age for marine sandstone of the lower clastic member. B.L. Mamet (pers. comm., 1985, 1988) found Bashkirian foraminifers at 134 m above the base of the formation in the Sherard F-34 well, and upper Bashkirian to lower Moscovian foraminifers near the top of the lower clastic member west of Raglan Range (Station 13, Fig. 1). Conodonts at 29.8 m above the base of the lower clastic member are upper Moscovian at section 17 (Fig. 1) in eastern Canrobert Hills (C.M. Henderson, pers. comm., 1989).

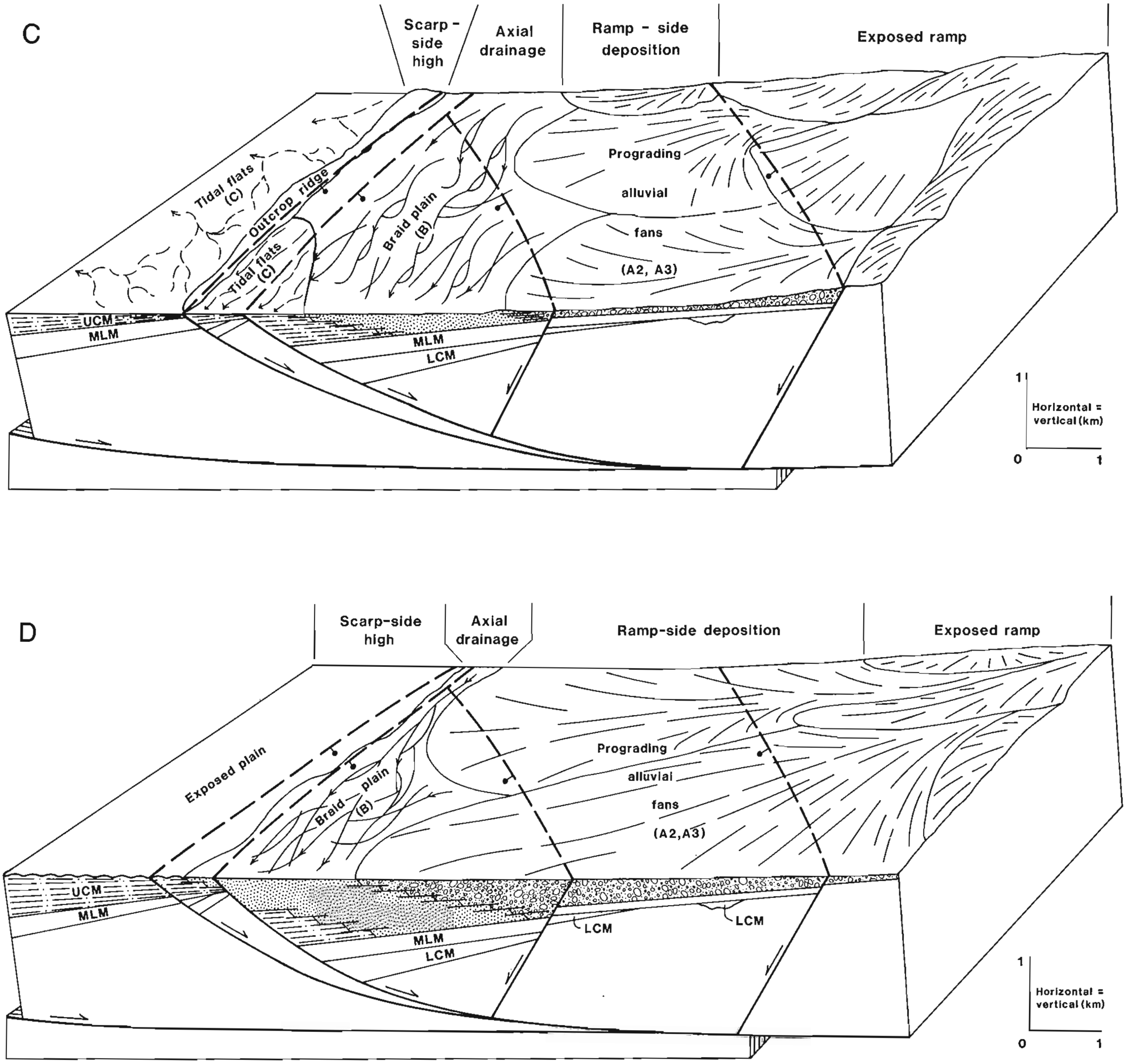


Figure 10. (cont'd)

On western Ellesmere Island, Beauchamp (1987) reports that transgressive marine sandstones from the upper part of the lower clastic member contain Bashkirian to lower Moscovian fusulinids and algae.

Thin limestones assigned to the middle limestone member south of Raglan Range and at two localities in the Canrobert Hills also contain Moscovian fusulinids of the genus *Profusulinella* (Tozer and Thorsteinsson, 1964; R. Thorsteinsson, pers. comm., 1986). On Ellesmere Island, conodonts from the middle limestone member range from early to late Moscovian in age. The top of the member is diachronous and younger toward the basin (Beauchamp, 1987).

Conodonts obtained from the upper clastic member at section 16 (Fig. 1) in the eastern Canrobert Hills range from Moscovian to possibly Gzhelian or lower Asselian in age (C.M. Henderson, pers. comm., 1989), whereas a large colonial coral collected from an outlier in the same area (near station 21, Fig. 1), and identified by E.W. Bamber (pers. comm., 1987), has a late Sakmarian to Artinskian range elsewhere in the Arctic Islands. Preliminary palynological results from four samples collected from the lower part of the upper clastic member northeast of the head of Ibbett Bay (eastern Canrobert Hills, stations 22 and 23, Fig. 1) indicate that these beds may be of Kasimovian-Gzhelian to Asselian age, and the presence of acritarchs suggests a marine influence (J. Utting, pers. comm., 1986). In northwestern Melville Island, an unknown thickness of the upper clastic member has been removed by erosion or nondeposition as a result of uplift associated with the Melvillian Disturbance. The youngest post-tectonic deposits are assigned to the Assistance Formation (Roadian). Thus, the missing stratigraphic interval probably spans some part of the Lower Permian (Asselian/Sakmarian and Artinskian).

On Sabine Peninsula, the Canyon Fiord Formation is gradationally and transgressively overlain by marine sandstone and, above that, Artinskian marine limestone assigned to an unnamed formation. Utting (1985) reported that a poorly to fairly well preserved palynomorph assemblage recovered from uppermost strata of the upper clastic member north of Tingmisut Lake is likely Early Permian (Asselian or Sakmarian). A similar palynomorph assemblage was recovered 18.5 m from the top of the Canyon Fiord Formation on the east side of the west arm of Weatherall Bay, and is tentatively assigned a late Asselian to Sakmarian age (J. Utting, pers. comm., 1986).

SUMMARY AND CONCLUSIONS

1. Five facies associations are recognized within the Canyon Fiord Formation on Melville Island. They are as follows:

   Facies association A: matrix- and clast-supported pebble to cobble conglomerate and breccia (further subdivided into facies associations A1, A2, and A3) representing proximal alluvial fan and paleotalus deposits.

   Facies association B: parallel-stratified and cross-stratified, coarse grained sandstone with interbedded pebble conglomerate deposited by streamflow and sheetflow in a medial to distal alluvial fan environment.

   Facies association C: fining-upward sequences of fine grained clastics with trace fossils and bidirectional crosslamination, which are variably interpreted as shallow subtidal to intertidal deposits of a tidal flat environment or as alluvial plain sediments.

   Facies association D: fine and medium grained, locally glauconitic and pyritic sandstone with herringbone and trough cross-stratification and ripple crosslamination representing barrier beach, foreshore, and upper shoreface sedimentation.

   Facies association E: planar and hummocky cross-stratified sandstone (E1), and sandy bioclastic limestone and encrinite beds (E2), deposited in lower shoreface and shallow marine shelf environments.

2. The lower clastic, middle limestone, and upper clastic members of the Canyon Fiord Formation described by Beauchamp (1987) on Ellesmere Island are also recognized on Melville Island. On Melville Island, the lower clastic member comprises mainly coarse clastics (facies associations A1, A2, A3, and B), the middle limestone member consists of facies associations E1 and E2 sandstone and limestone, and the upper clastic member comprises shallow marine to upper shoreface and tidal flat sediments (facies associations B, C, and D).

3. The lower clastic member on Melville Island is Bashkirian to approximately Moscovian in age, the middle limestone member is Moscovian, and the upper clastic member is Moscovian to Sakmarian.

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UPPERMOST TRIASSIC, JURASSIC, AND LOWERMOST CRETACEOUS STRATIGRAPHY, MELVILLE ISLAND AREA, ARCTIC CANADA

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Embry, A.F., 1993. Uppermost Triassic, Jurassic, and lowermost Cretaceous stratigraphy, Melville Island area, Arctic Canada; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 139-159.

Abstract

The uppermost Triassic, Jurassic, and lowermost Cretaceous succession of the northern Melville Island area is divided into eleven formations on the basis of lithology, and into four sequences on the basis of two major unconformities that bound the succession and three significant unconformities that lie within it. The sequences are dated as 1) Rhaetian-Sinemurian; 2) Pliensbachian-Aalenian; 3) Bajocian-Callovian; 4) Oxfordian-Valanginian.

The Rhaetian-Sinemurian sequence consists of the Grosvenor Island, Maclean Strait, Lougheed Island, and King Christian formations of the Heiberg Group. The strata record two cycles of transgression followed by regression and marginal uplift. The Pliensbachian to Aalenian sequence contains the argillaceous Jameson Bay Formation and the arenaceous Sandy Point Formation. Two transgressive-regressive cycles, of Pliensbachian-Toarcian and Aalenian age, occur in these strata.

The McConnell Island Formation (shale-siltstone) and Hiccles Cove Formation (sandstone) make up the Bajocian-Callovian sequence and record transgression in the Bajocian-early Bathonian, followed by regression in the late Bathonian and Callovian.

The uppermost sequence, Oxfordian-Valanginian in age, encompasses the Ringnes (shale-siltstone), Awingak (sandstone), and Deer Bay (shale-siltstone) formations. Transgression occurred in earliest Oxfordian, followed by regression in the Oxfordian and early Kimmeridgian. Transgression in earliest Volgian was followed by numerous small transgressive-regressive cycles in Volgian and Berriasian time, when sandstones were restricted mainly to the southeastern portion of the study area. A large trangression occurred in the early Valanginian and this was followed by regression and uplift of the entire study area in the late Valanginian to Hauterivian.

Résumé

La succession du Trias sommital, du Jurassique et du Crétacé basal du nord de l'île Melville se divise en onze formations d'après la lithologie, et en quatre séquences d'après deux discordances majeures qui limitent la succession et trois discordances significatives qui y sont contenues. Les séquences remontent (1) au Rhétien-Sinémurien, (2) au Pliensbachien-Aalénien; (3) au Bajocien-Callovien; (4) à l'Oxfordien-Valanginien.

La séquence du Rhétien-Sinémurien comprend les formations de Grosvenor Island, de Maclean Strait, de Lougheed Island et de King Christian du Groupe de Heiberg. Les strates témoignent de deux cycles de transgression suivis d'une régression et d'un soulèvement marginal. La séquence du Pliensbachien-Aalénien contient la formation argileuse de Jameson Bay et la formation arénacée de Sandy Point. On y trouve deux cycles de transgression-régression qui remontent au Pliensbachien-Toarcien et à l'Aalénien.

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La séquence du Bajocien-Callovien comprend la Formation de McConnell Island (shale-siltstone) et la Formation de Hiccles Cove (grès), qui témoignent d'une transgression au Bajocien-Bathonien précoce et d'une régression au Bathonien tardif et au Callovien.

La séquence sommitale, oxfordienne-valanginienne, englobe les formations de Ringnes (shale-siltstone), d'Awingak (grès) et de Deer Bay (shale-siltstone). Il y a eu transgression à l'Oxfordien initial, puis régression à l'Oxfordien et au Kimméridgien précoce. La transgression au Volgien initial a été suivie de nombreux petits cycles de transgression-régression au Volgien et au Berriasien, lorsque les grès se rencontraient principalement dans la partie sud-est de la zone à l'étude. Une importante transgression a eu lieu au Valanginien précoce et a été suivie d'une régression et d'un soulèvement dans l'ensemble de la zone à l'étude au Valanginien tardif-Hauterivien.

INTRODUCTION

Jurassic strata outcrop along an east-west belt across northern Melville Island from southern Sabine Peninsula in the east to southern Sproule Peninsula in the west (Fig. 1). The strata dip gently northward as part of the Sverdrup Basin succession, and have been penetrated by numerous wells (Fig. 1). Uppermost Triassic, basal Jurassic, and lowermost Cretaceous strata, which are also considered in this report, occur only in the subsurface. Generally, the uppermost Triassic-lowermost Cretaceous strata consist of interbedded sandstone, siltstone, and shale units. Two major gas fields, Drake Point and Hecla (see Goodbody and Christie, *this volume*), contain large reserves in sandstones in the lower part of the succession. These fields were discovered in 1969 and 1972, respectively, and greatly stimulated exploration within the Jurassic succession of the Melville Island area.

The uppermost Triassic-lowermost Cretaceous succession in the study area is bounded by regional unconformities and also harbours three widespread unconformities within it (Fig. 2). These unconformities, which are recognizable both on the surface and in the subsurface, allow the succession to be divided into four sequences, which are currently dated as: 1) Rhaetian-Sinemurian, 2) Pliensbachian-Aalenian, 3) Bajocian-Callovian, and 4) Oxfordian-Valanginian. Other unconformities are present in the succession, but in general they are more local in extent and are not used as sequence boundaries for this study. In this paper the stratigraphy of each sequence is

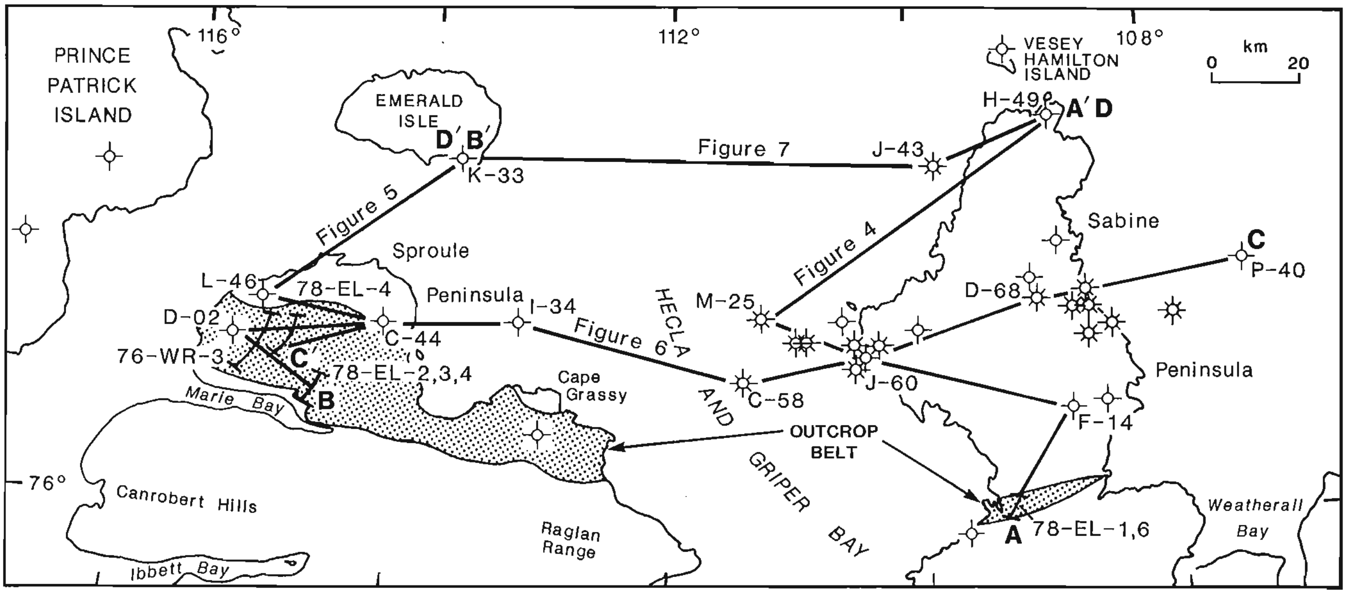

Figure 1. Location of study area showing wells, surface sections, and lines of cross-section for Figures 4, 5, 6, 7. Jurassic outcrop area (stippled) from Tozer and Thorsteinsson (1964).

described, and the historical geology for northern Melville Island during Jurassic and earliest Cretaceous time is interpreted.

Previous work

The outcropping Jurassic to lowermost Cretaceous succession of Melville Island was studied and described by Tozer and Thorsteinsson (1964), who also provided a full account of the earlier geographic and geological exploration of the region. They divided the succession into three formations — Borden Island, Wilkie Point, and Mould Bay — all of which had been defined on nearby islands. The Borden Island Formation on Melville Island was described as "40 feet of . . . green sand, red and green, ferruginous sandstone and grey phosphatic nodules" and was recognized only on Sproule Peninsula. The formation rests unconformably on the Lower Triassic Bjorne Formation and yielded an early Sinemurian ammonite.

The overlying Wilkie Point Formation was delineated along the entire outcrop belt and was said to thin from 135 m in the west to 90 m in the east. Two informal members were recognized: a lower marine unit of green to grey, in part glauconitic, sandstone with ironstone beds; and an upper, light grey-white, carbonaceous sandstone. Pelecypods and ammonites of Aalenian and Bajocian age were found in the lower member.

The youngest formation of the succession, the Mould Bay Formation, was also mapped along the entire outcrop belt and it too was found to thin from west to east, from 140 to 60 m. Two informal members were recognized on Melville Island: a lower, dark grey shale and an upper sandstone. Pelecypods of Upper

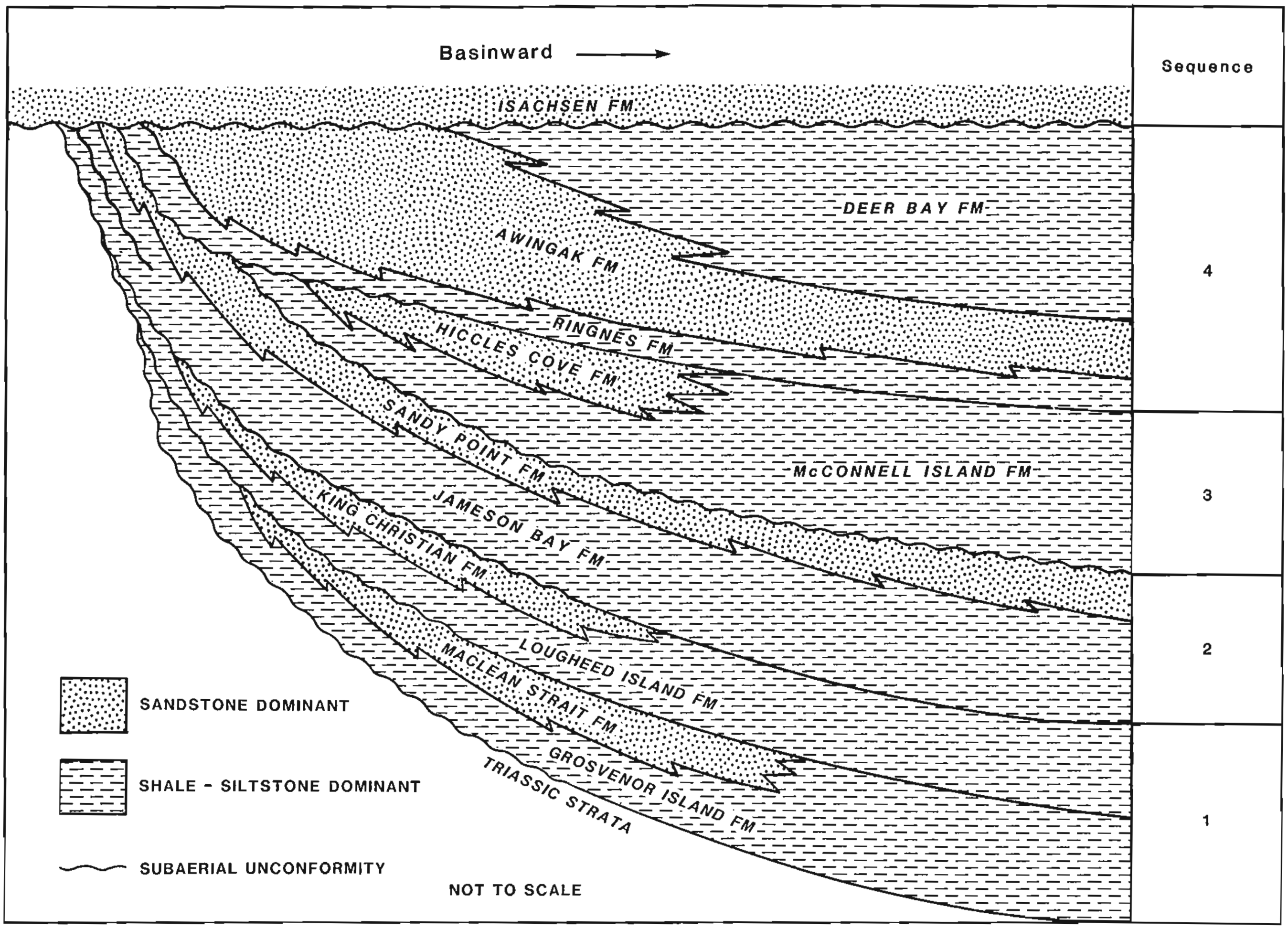

Figure 2. Schematic cross-section illustrating generalized uppermost Triassic-lowermost Cretaceous lithostratigraphy of the Melville Island area.

Jurassic age were found in the formation, which is unconformably overlain by the Barremian-Aptian Isachsen Formation.

Fieldwork has been carried out by D.G. Wilson, A.F. Embry, and T.P. Poulton, all of the Geological Survey of Canada. Wilson measured a section through the succession on Sproule Peninsula in 1976 and Tan (1979) used samples from this section for a dinoflagellate study in the western Sverdrup Basin. Embry measured sections on both Sproule and Sabine peninsulas in 1978, and these data are incorporated into this paper. In 1984, Poulton (*this volume*) measured a number of sections on Sproule Peninsula and south of Cape Grassy. These sections were briefly revisited by Poulton and Embry in 1987.

Subsurface studies, mainly of Lower Jurassic sandstones of Sabine Peninsula (which contain large gas reserves in the Drake Point and Hecla fields), have been carried out. Reinson (1975), Meneley (1977), and Douglas and Oliver (1979) all described subsurface sections of the Borden Island Formation and interpreted the sandstones as being of beach to shallow water marine origin. Crain (1977) described the petrophysical characteristics of these gas-bearing strata. Henao-Londoño (1977) correlated the Jurassic strata of Melville Island with those of Lougheed Island, as did Balkwill et al. (1982).

Present work

The stratigraphic nomenclature for the uppermost Triassic to lowermost Cretaceous succession has been extensively revised in the course of a study that has extended over the past fourteen years (Embry, 1982, 1983, 1984, 1985, 1986, 1991; Embry and Johannessen, 1992). Eleven formal formations are recognized in the succession on Melville Island (Fig. 2). The new nomenclature is compared with that of Tozer and Thorsteinsson (1964) in Figure 3. Four stratigraphic cross-sections encompassing both surface and subsurface sections have been constructed to display the stratigraphy of the succession in the Melville Island area (Figs. 4-7).

Macrofossils (pelecypods, ammonites, belemnites) from outcropping strata were identified by T.P. Poulton, J.A. Jeletzky, and H. Frebold (Poulton, *this volume*). Micropaleontological and palynological studies of material from both surface and subsurface sections are reported in unpublished G.S.C. paleontological reports (and see Tan, 1979).

STRATIGRAPHY

Sequence 1. Rhaetian-Sinemurian

The basal sequence in the succession consists of four formations that comprise two transgressive-regressive cycles. The lower cycle consists of the argillaceous Grosvenor Island Formation and the arenaceous Maclean Strait Formation, and the upper cycle is composed of the Lougheed Island (shale-siltstone) and King Christian (sandstone) formations. These four formations are part of the Heiberg Group, which occurs throughout the western Sverdrup Basin (Embry, 1983, 1991). The correlation of these strata with thicker, equivalent successions in the Lougheed Island and Ellef Ringnes Island areas to the northeast has been problematic, although recent paleontological (T.P. Poulton, pers. comm., 1987; L. Suneby, pers. comm., 1987) and sedimentological data (Embry and Johannessen, 1992) have allowed regional correlations to be made with reasonable confidence. The correlations used in this paper are those presented in Embry and Johannessen (1992), and supercede those in Embry (1982, 1991).

On Melville Island, the strata are confined almost exclusively to the subsurface, with only a thin, erosional remnant of Lougheed Island Formation known from outcrop on southern Sproule Peninsula. The thickness of the sequence increases northward to a maximum thickness of 138 m in the Emerald K-33 well (Fig. 8).

The lowermost formation of the sequence, the Grosvenor Island, everywhere rests unconformably on Triassic strata. An oolitic ironstone unit occurs at the base of the formation. Reddish brown shale overlies the basal oolite, with grey-green, silty shale, siltstone, and very fine grained argillaceous sandstone usually forming the upper part of the formation. These strata coarsen upward and are gradually replaced by sandstone at the base of the Maclean Strait Formation. Beds of the Grosvenor Island Formation are rarely bioturbated and such strata are interpreted as estuarine to restricted marine shelf in origin. The basal oolitic ironstone is not burrowed and does not contain macrofossils, and is judged to represent a transgressive deposit of a restricted sea.

The sandstone-dominant Maclean Strait Formation on Sabine Peninsula has been described in detail by Reinson (1975) and by Douglas and Oliver (1979). These authors demonstrated that the formation consists of two shallowing-upward successions of very fine to medium grained sandstone of shoreface to

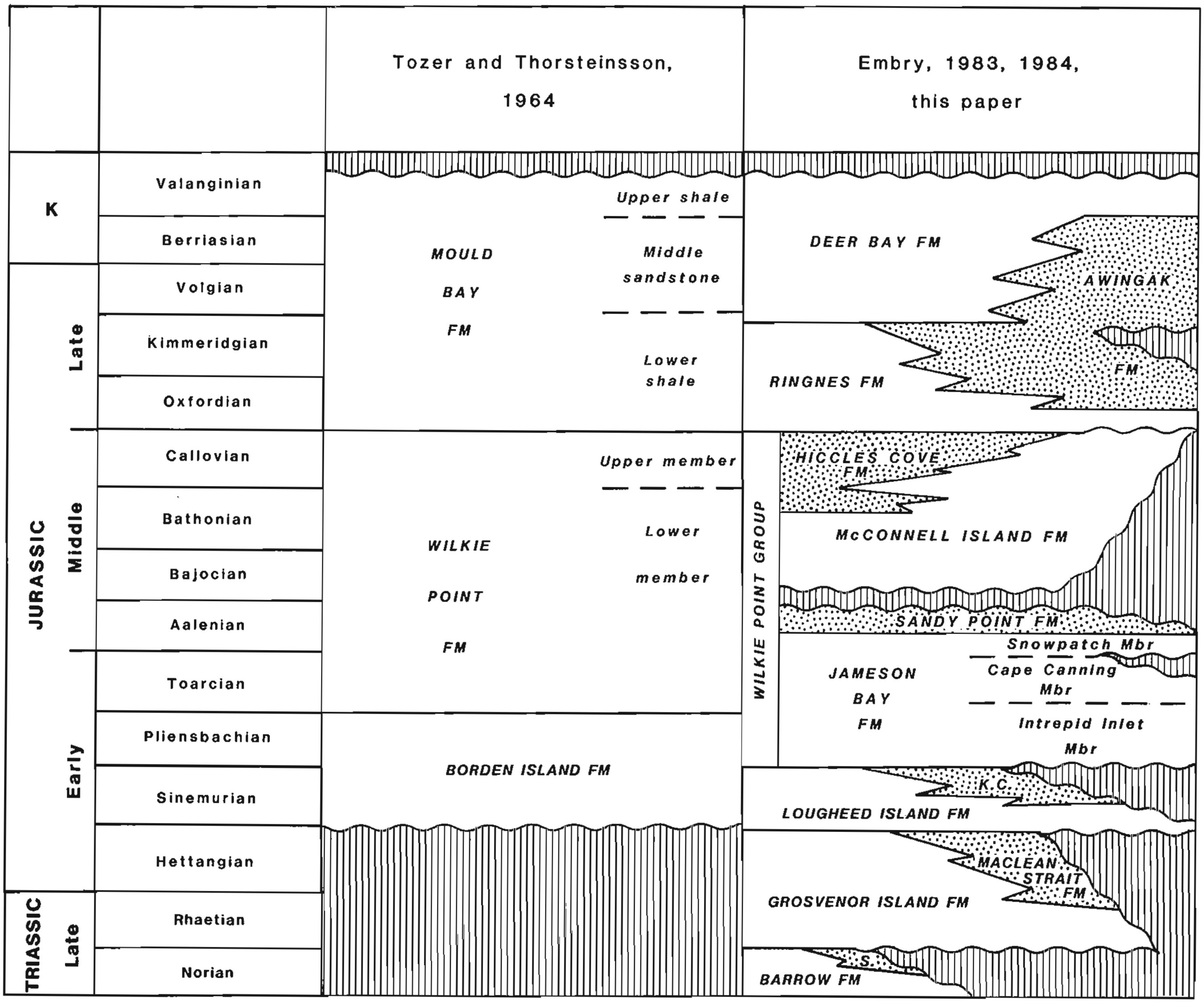

Figure 3. Uppermost Triassic–lowermost Cretaceous stratigraphic nomenclature of Tozer and Thorsteinsson (1964) compared with that used in this report.

beach origin. Embry and Johannessen (1992) agree with this interpretation. However, Embry and Johannessen noted a complete lack of burrowing in the Maclean Strait sandstones in the Sabine Peninsula area, and interpreted these sandy beds as having been deposited along the fringe of a restricted body of water. To the west, on Sproule Peninsula, sandstones of the Maclean Strait Formation have not been penetrated by the drill. In the three wells in the area, the Grosvenor Island Formation is unconformably overlain by the Lougheed Island Formation.

The upper part of sequence 1 consists of a second transgressive-regressive cycle that is bounded by unconformities along the basin margin. The Lougheed Island Formation forms the lower portion of the cycle and consists of burrowed shale and siltstone with minor very fine grained sandstone. The formation is up to 50 m thick and, where it overlies an unconformity, pebbly oolitic ironstone beds occur at the base. The strata are interpreted as open marine shelf deposits.

The King Christian Formation overlies the Lougheed Island Formation and consists of very fine to fine grained, burrowed sandstone. The formation is up to 12 m thick and is commonly unconformably overlain by the Jameson Bay Formation. The strata are interpreted as lower shoreface to inner shelf deposits.

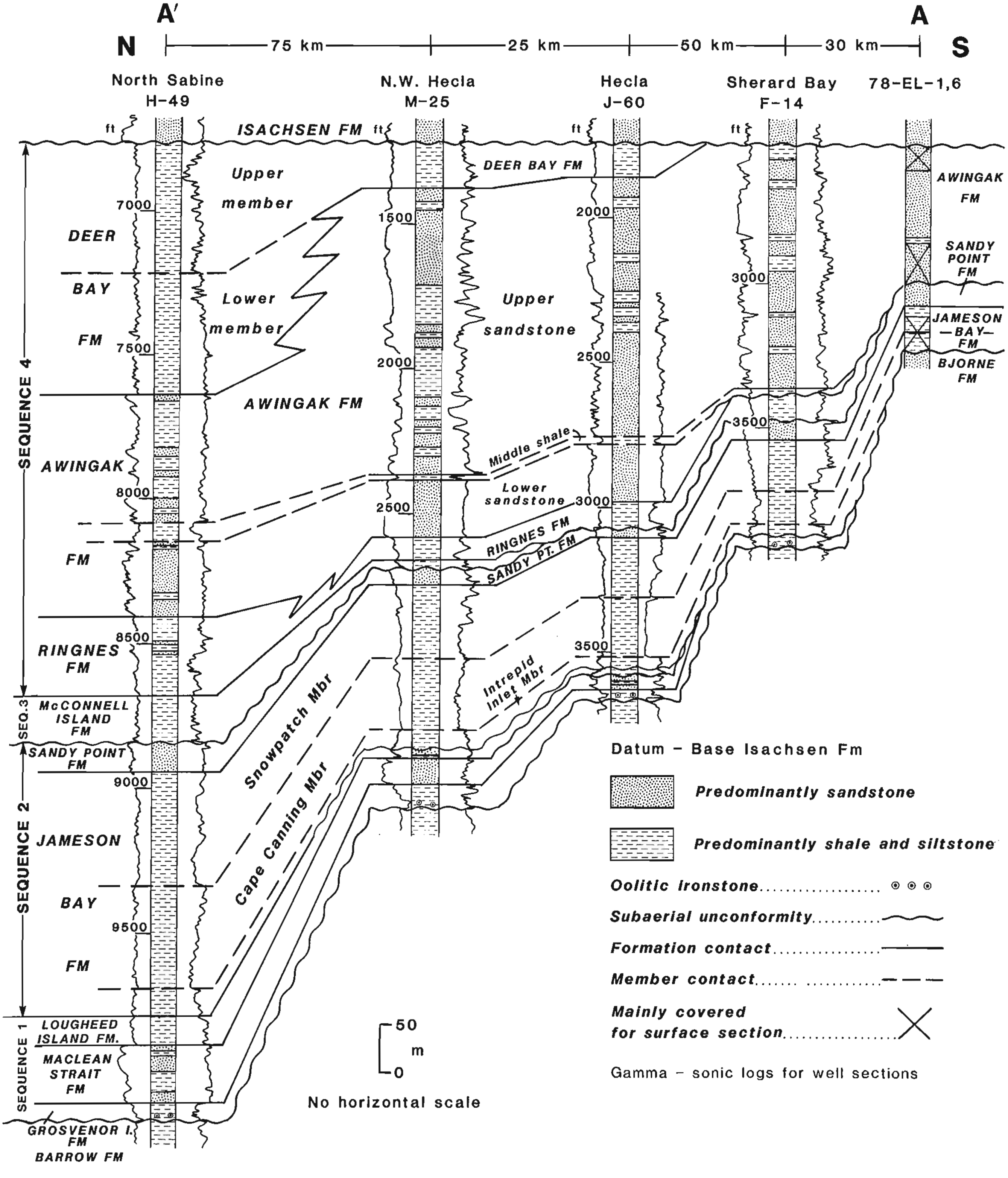

Figure 4. North-south stratigraphic cross-section, uppermost Triassic-lowermost Cretaceous succession, Sabine Peninsula, Melville Island. See Figure 1 for location of cross-section.

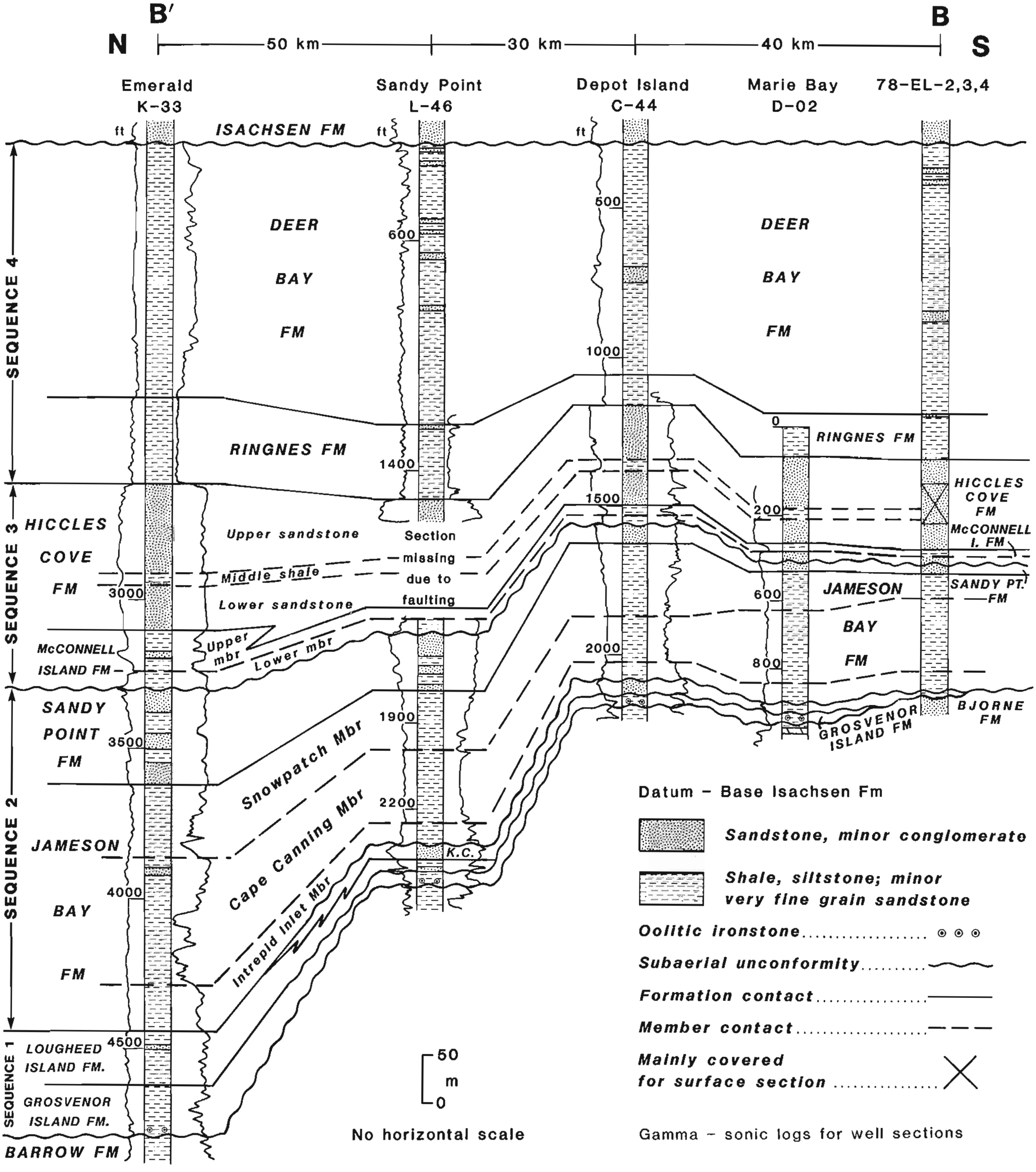

Figure 5. North-south stratigraphic cross-section, uppermost Triassic-lowermost Cretaceous succession, Sproule Peninsula-Emerald Island. See Figure 1 for location of cross-section.

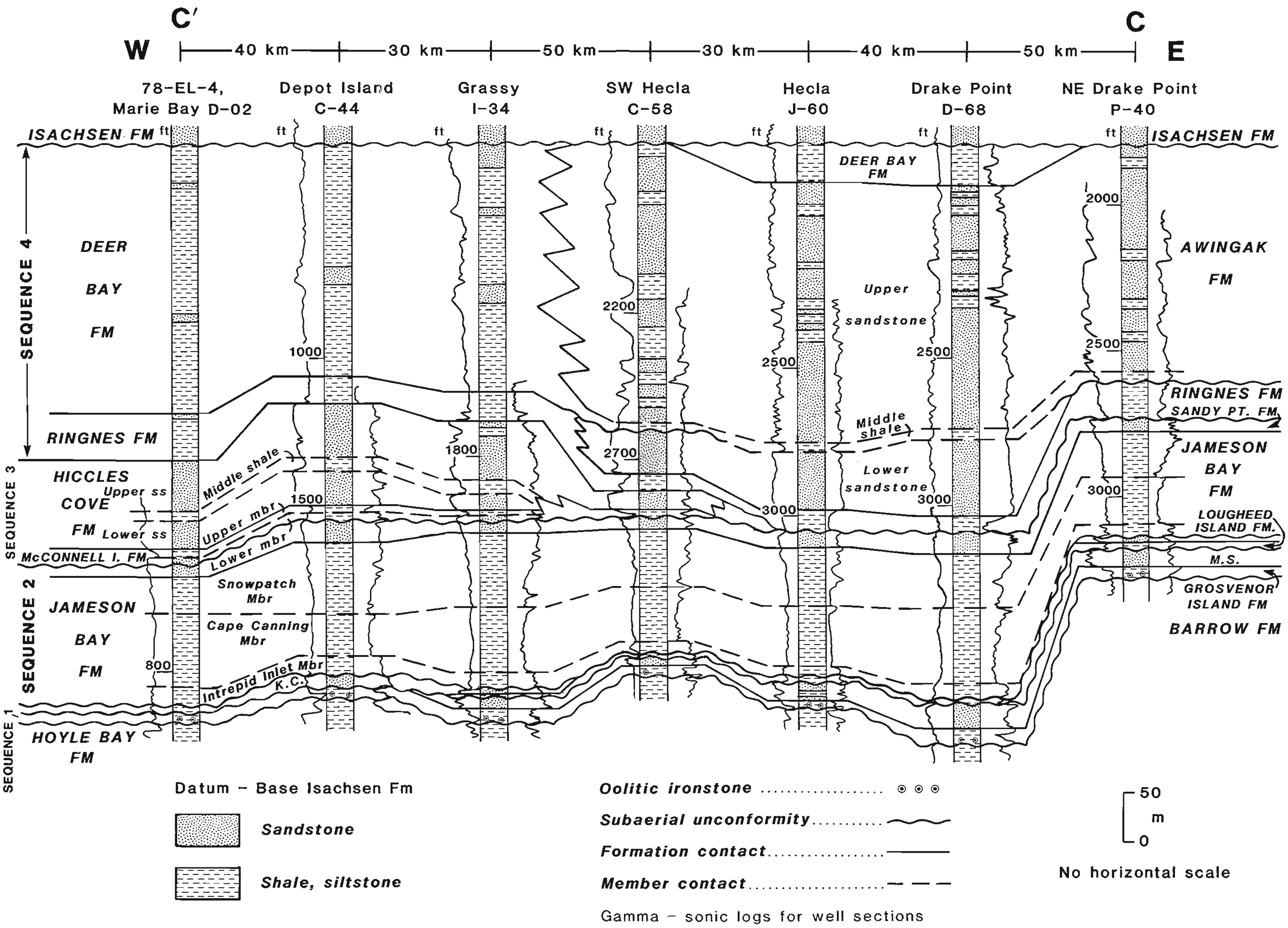

Figure 6. *East–west stratigraphic cross-section, uppermost Triassic–lowermost Cretaceous succession, Sabine Peninsula–Sproule Peninsula, Melville Island. See Figure 1 for location of cross-section.*

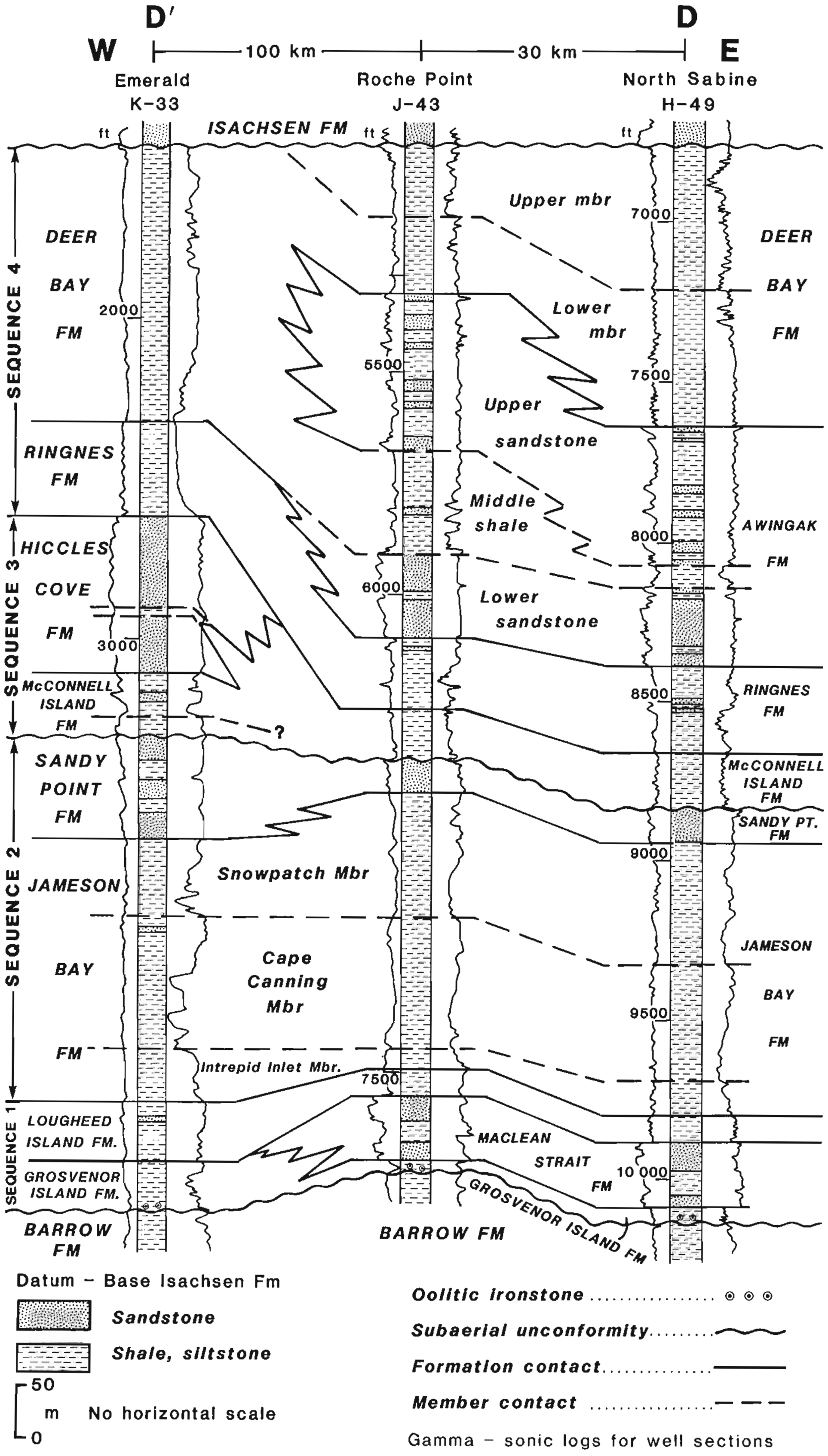

Figure 7. East-west stratigraphic cross-section, uppermost Triassic-lowermost Cretaceous succession, northern Sabine Peninsula-Emerald Island. See Figure 1 for location of cross-section.

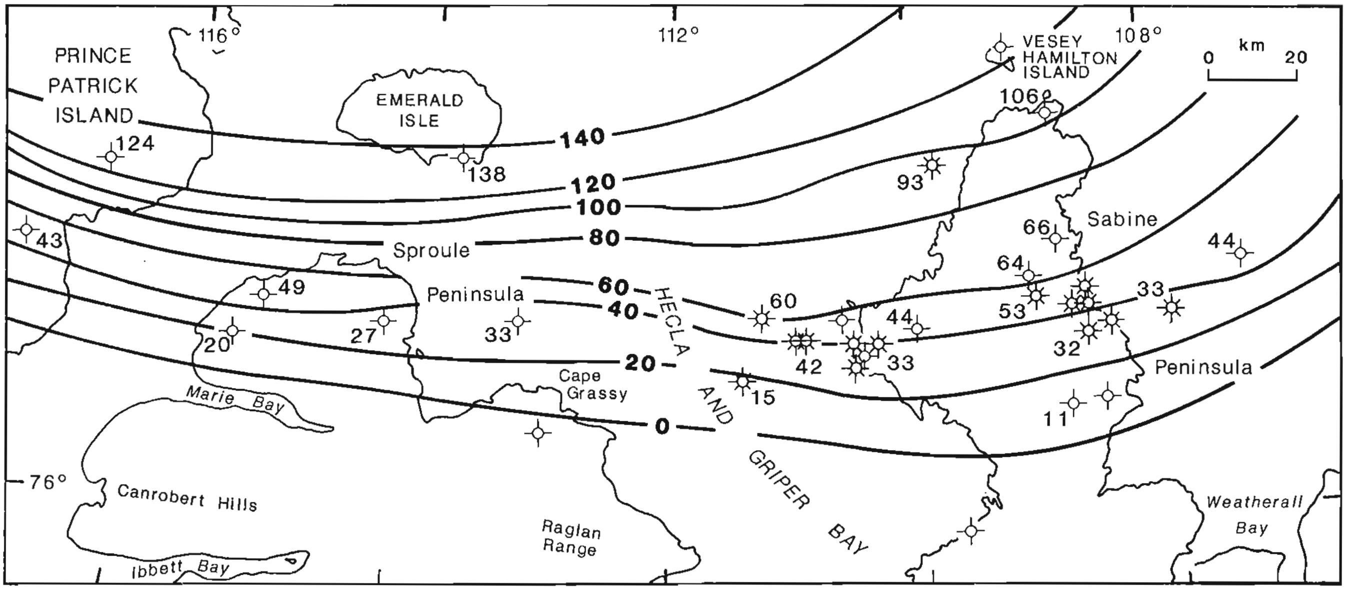

Figure 8. Isopach map, sequence 1, Rhaetian–Sinemurian. Contour interval 20 m.

The main stratigraphic relationships of sequence 1 are illustrated in Figures 4–7. In the subsurface of southern Sabine Peninsula, Maclean Strait strata are capped by a subaerial unconformity and are truncated before reaching the outcrop belt (Figs. 4, 5). The subaerial unconformity appears to be restricted to the south, and the formation thickens to the north to a maximum of 60 m in the North Sabine H-49 well. A similar stratigraphic pattern may well occur on Sproule Peninsula. The sandstones of the Maclean Strait Formation are not present on southern Sproule Peninsula owing to erosional truncation, and are completely absent in the north (Emerald K-33) because of a facies change to shale and siltstone of the Grosvenor Island Formation (Fig. 5). It is quite possible that a band of Maclean Strait sandstone occurs in the subsurface of northern Sproule Peninsula and/or the offshore area between Melville and Emerald islands.

The Lougheed Island Formation truncates the Maclean Strait and Grosvenor Island formations on the basin margin and completely oversteps these formations on Sproule Peninsula (Fig. 5). Basinward, the basal contact of the Lougheed Island Formation is conformable (Figs. 4, 5).

The King Christian Formation in the study area appears to be restricted to a relatively narrow band that trends east-west. The formation is truncated along the basin margin and is thus absent in many of the wells on Sabine Peninsula (Fig. 4). Basinward, the King Christian sandstones are replaced by shale and siltstone of the Lougheed Island Formation. The King Christian is absent in the northernmost wells in the study area (Emerald K-33, Roche Point J-43, North Sabine H-49) (Figs. 4, 5, 7).

The age of the sequence is interpreted as being Rhaetian–Sinemurian on the basis of:

1. Its stratigraphic position between well dated Norian strata below and Pliensbachian strata above.

2. The occurrence of early and late Sinemurian ammonites in the mid-upper portion of the sequence (Lougheed Island Formation) on Sproule Peninsula, Prince Patrick Island, and Borden Island (Poulton, *this volume*).

3. The occurrence of Rhaetian–Hettangian spores in the lower portion of the sequence (Grosvenor Island Formation) (L. Suneby, pers. comm., 1987).

Sequence 2. Pliensbachian–Aalenian

This sequence consists of a lower shale-siltstone unit, the Jameson Bay Formation, and an upper, arenaceous unit, the Sandy Point Formation. These formations, defined by Embry (1984), are mainly equivalent to the lower portion of the Wilkie Point Formation of Tozer and Thorsteinsson (1964). The basal strata of the Jameson Bay Formation are equivalent to the upper portion of the Borden Island Formation of Tozer and

Thorsteinsson (1964) and Reinson (1975) and to the "lower Wilkie Point" of Meneley (1977) and Henao-Londoño (1977).

The strata of this sequence outcrop across northern Melville Island but good exposures are rare (Fig. 9). Thicknesses along the outcrop belt vary from 80 m on southern Sabine Peninsula to 130 m on southern Sproule Peninsula. The sequence gradually thickens north-northwestward to reach a maximum of 344 m in the Emerald K-33 well (Fig. 10).

The argillaceous Jameson Bay Formation was divided into three formal members by Embry (1984): the Intrepid Inlet, Cape Canning, and Snowpatch members. Each member can be recognized throughout the study area. The basal member, the Intrepid Inlet, ranges in thickness from 12 to 35 m and outcrops only on Sproule Peninsula. It consists mainly of interbedded, medium grey shale, siltstone, and very fine grained, argillaceous sandstone. Thin units of oolitic ironstone are also present in some sections, mainly at or near the base or top of the member. Abundant burrowing and glauconite pellets indicate an offshore marine shelf origin for the member.

The overlying Cape Canning Member, up to 130 m thick, occurs along the entire outcrop belt. The Cape Canning consists of medium grey, clay shale in the lowermost portion and the strata gradually become coarser upward with argillaceous, very fine grained sandstone in the uppermost portions. In many sections an ironstone bed occurs at the top of the member. These strata are of offshore marine shelf origin and display an overall shallowing-upward trend.

The uppermost member, the Snowpatch, is up to 117 m thick and also occurs along the entire outcrop belt. This unit displays an overall coarsening-upward trend from clay shale, through silty shale and siltstone, finally grading into very fine grained sandstone of the basal Sandy Point Formation. The strata are of offshore marine shelf origin.

Figure 9. *Recessive, dark-weathering Jameson Bay shale overlain by resistant Sandy Point sandstone, Sproule Peninsula. (GSC photo no. 2870-7.)*

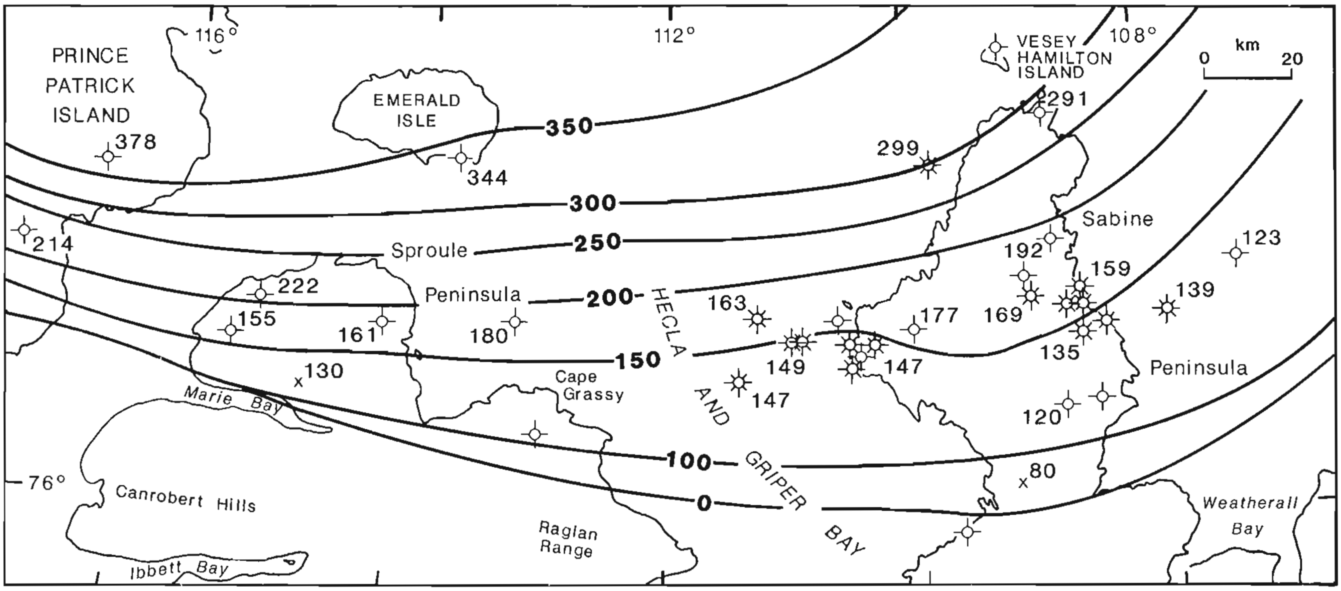

Figure 10. Isopach map, sequence 2, Pliensbachian-Aalenian. Contour interval 50 m.

The Sandy Point Formation conformably overlies the Jameson Bay Formation and thickens from a few tens of metres in the outcrop belt to 88 m in the Emerald K-33 well. In outcrop, the formation consists mainly of very fine to medium grained, burrowed, glauconitic and sideritic sandstone. In the northwest portion of the study area, the unit is characterized by coarsening-upward cycles of grey, silty shale, siltstone, and very fine grained to fine grained sandstone. The strata are interpreted as shallow marine shelf sediments that were deposited below wave base.

Figures 4-7 illustrate the main stratigraphic relationships of sequence 2. The Intrepid Inlet Member rests on an unconformity and onlaps southward, toward the Sverdrup Basin margin (Fig. 4). The abrupt upper contact of this member is interpreted as a submarine unconformity. The Cape Canning Member is capped by a subaerial unconformity along the basin margin. The unconformity disappears basinward and very fine grained sandstones appear at the top of the member in downdip localities (Fig. 4). Substantial sandstone also occurs in the member in an outcrop along East Kitson River (Poulton, *this volume*). The Snowpatch Member coarsens upward and its upper contact with the Sandy Point Formation is a gradational facies boundary. The Sandy Point Formation is truncated by a major unconformity and only the basal portion of the formation remains in the outcrop belt (Figs. 4, 5). Deeper erosion of the unit to the east is illustrated in east-west sections approximately parallel to the depositional strike (Figs. 6, 7).

The stratigraphic units of sequence 2 are reasonably well dated by data from ammonites (Poulton, *this volume*), foraminfers (J.H. Wall, pers. comm., 1985), and dinoflagellates (Tan, 1979; Davies, 1983). The Intrepid Inlet Member contains late Pliensbachian ammonites in outcrop (Poulton, *this volume*) and, considering the ages of the bounding strata, the member may include lower Pliensbachian and lowermost Toarcian strata. The Cape Canning Member is Toarcian and the Snowpatch Member is mainly Aalenian with the possibility of Toarcian strata in the basal portion. Within the study area, the Sandy Point Formation has yielded Aalenian ammonites (Poulton, *this volume*). In summary, the sequence appears to range in age from early Pliensbachian to Aalenian.

Sequence 3. Bajocian-Callovian

The third sequence is composed of the argillaceous McConnell Island Formation and the arenaceous Hiccles Cove Formation (Fig. 2). These formations were defined by Embry (1984). Embry (1986) interpreted the upper part of the Hiccles Cove Formation as equivalent to the Ringnes and Awingak formations and consequently modified the definition of the Hiccles Cove Formation. Recently obtained lithostratigraphic and biostratigraphic data have shown that the interpretation of Embry (1986) is erroneous. Thus the original definition of the Hiccles Cove Formation is used herein. The McConnell Island and Hiccles Cove strata are part of the Wilkie Point Formation of Tozer and Thorsteinsson (1964); they are equivalent to the upper portion of the Wilkie Point lower member and the Wilkie Point upper member. The strata reach the surface on north-central and northwestern Melville Island but do not outcrop on Sabine Peninsula (Fig. 11). The distribution and thickness of this sequence is illustrated in Figure 12. The maximum recorded thickness — 208 m — is found in the Emerald K-33 well.

The McConnell Island Formation consists of brown-grey to medium grey, soft shale and siltstone, commonly with thin ironstone beds. Two informal members are recognized in the formation (Figs. 4–7). The lower member is commonly arenaceous or silty, and fines upward. Glauconite and siderite are common, with burrows being the main sedimentary structures. The upper member displays a coarsening-upward trend from soft shale to siltstone and passes gradually into sandstone of the overlying Hiccles Cove Formation. The strata are interpreted as offshore marine shelf in origin.

In outcrop the Hiccles Cove Formation consists almost entirely of sandstone and consists of three informal members: lower sandstone; middle shale; and upper sandstone (Figs. 5, 6). The lower sandstone is characterized by rusty weathering, light brown, very fine to medium grained sandstone that commonly displays an overall coarsening-upward trend. Ironstone beds and nodules occur within the sandstone, and burrows and planar laminate are the main sedimentary structures. The member is interpreted as a shallow water marine to strandline deposit.

The middle (shale) member is thin and has been identified only in the subsurface in the western portion of the study area (Figs. 5, 6). It consists of medium grey, silty shale of offshore shelf origin. In the southwest, it is absent due to a facies change to sandstone. Eastward it becomes part of the McConnell Island Formation with the shale-out of the lower (sandstone) member (Fig. 6).

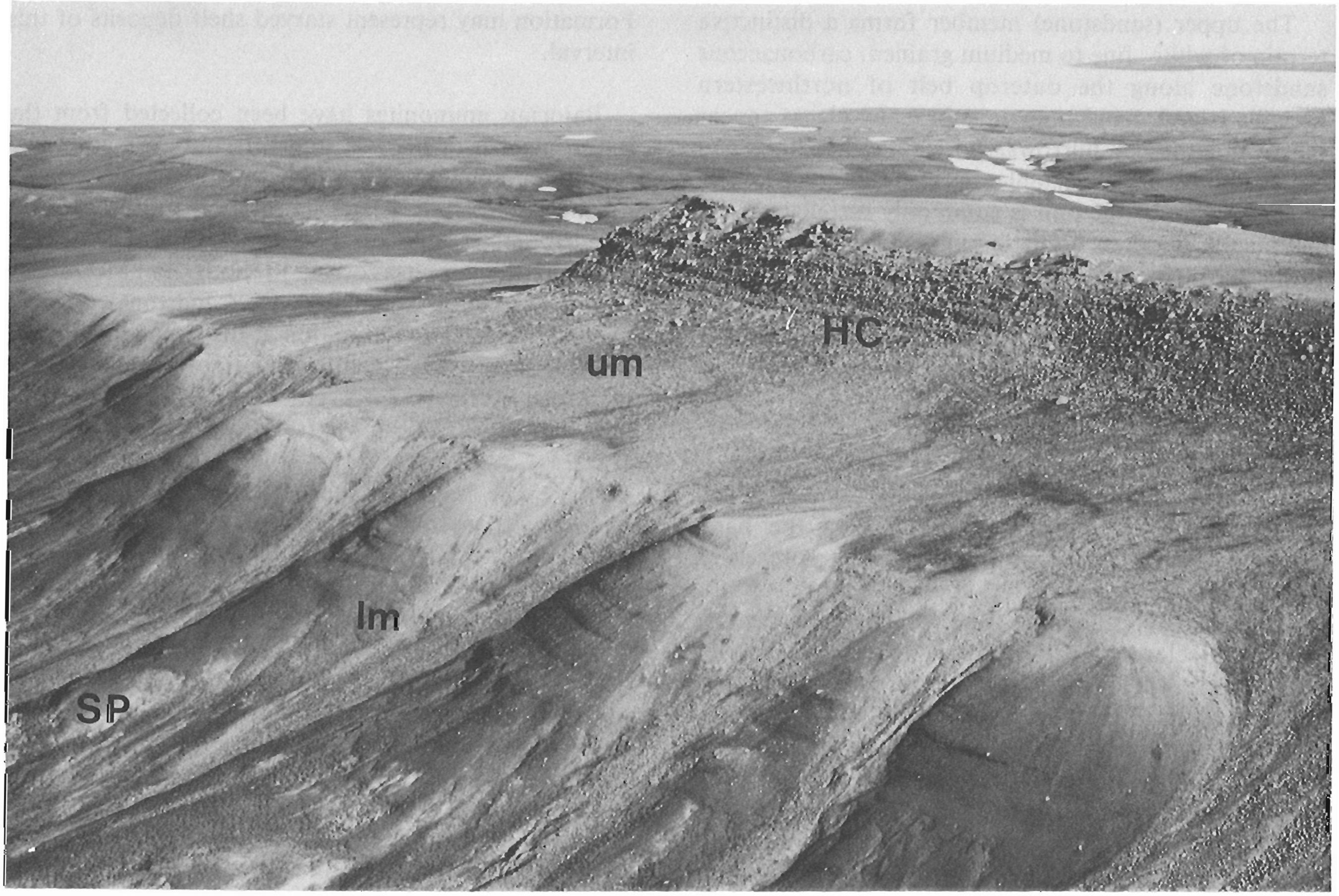

*Figure 11. McConnell Island Formation (**lm** = lower member, **um** = upper member) unconformably overlying Sandy Point Formation (**SP**) and conformably overlain by Hiccles Cove Formation (**HC**), Marie Heights, western Sproule Peninsula. (GSC photo no. 2870-4.)*

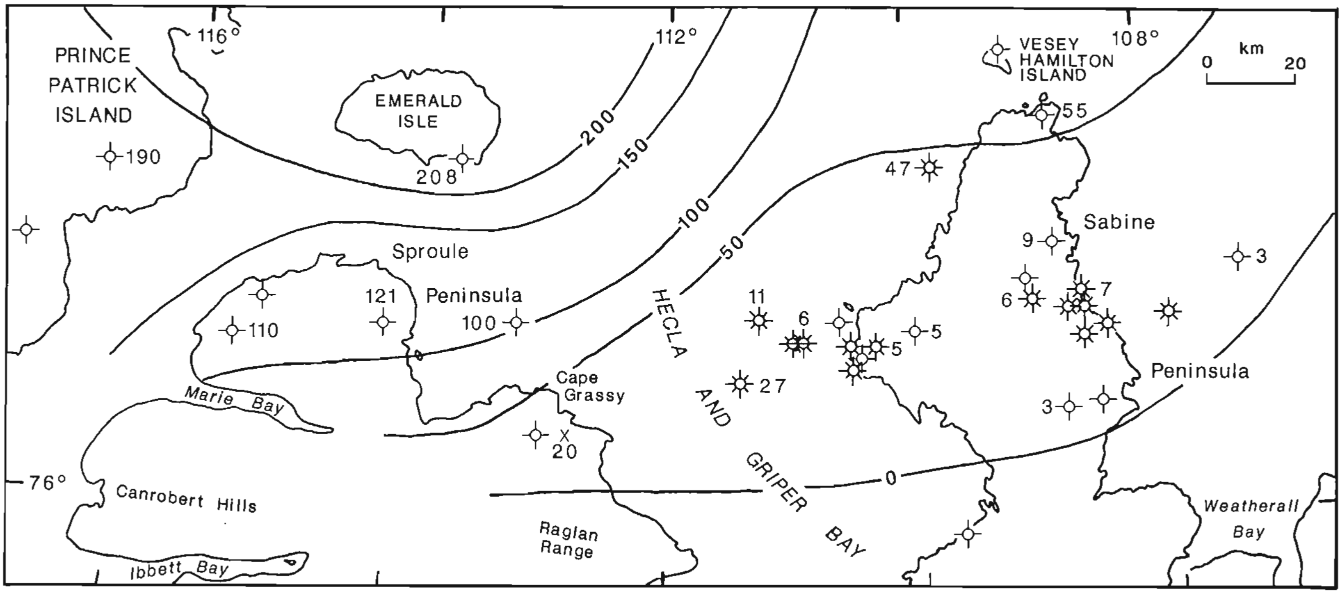

Figure 12. Isopach map, sequence 3, Bajocian-Callovian. Contour interval 50 m.

The upper (sandstone) member forms a distinctive terrain of white, fine to medium grained, carbonaceous sandstone along the outcrop belt of northwestern Melville Island. Sandstone units in many places appear massive, although burrows, horizontal bedding, and crossbedding are detectable in some outcrops. The upper portion of the unit is commonly castellated with spectacular hoodoos occurring in some areas (Fig. 13). In the subsurface, brown-grey shale and siltstone units occur within the member and well developed coarsening-upward cycles are present. The member is interpreted as consisting of shoreline and nearshore marine deposits.

The regional stratigraphy of this sequence is illustrated in Figures 4 to 7. The McConnell Island strata overlie a major unconformity and the basal sandy and silty strata (lower member) represent a transgressive episode. The upper member of the McConnell Island and the lower (sandstone) member of the Hiccles Cove Formation form a regressive succession, which thins to a "starved" shale and ironstone unit to the east. Sand supply was apparently from the southwest. The middle (shale) member and upper (sandstone) member of the Hiccles Cove Formation also represent a regressive succession with sediment supply from the southwest. Argillaceous units become more common to the northeast and the upper sandstone is absent on northern Sabine Peninsula owing to a facies change to shale and siltstone. On central and southern Sabine Peninsula, a thin interval of ironstone and glauconite at the base of the Ringnes Formation may represent starved shelf deposits of this interval.

Bajocian ammonites have been collected from the lower member of the McConnell Island Formation and Bathonian ammonites are found in the upper member of the McConnell Island Formation and the lower (sandstone) member of the Hiccles Cove Formation. Callovian ammonites occur in both the McConnell Island Formation and the upper (sandstone) member of the Hiccles Cove Formation at the East Kitson River locality (Fig. 14). Callovian dinoflagellates were identified by Davies (pers. comm., 1987) from near the base and top of the upper (sandstone) member of the Hiccles Cove Formation at a locality south of Cape Grassy. The sequence thus appears to range in age from Bajocian to Callovian.

Sequence 4. Oxfordian-Valanginian

The fourth sequence is thicker and stratigraphically more complex than any of the underlying three sequences just described. Sequence 4 is composed of three formations: the argillaceous Ringnes, the sandstone-dominated Awingak, and the shaly Deer Bay. The strata of this sequence are equivalent to the Mould Bay Formation of Tozer and Thorsteinsson (1964), a name that has been abandoned by Embry (1985). The strata occur along the entire Mesozoic outcrop belt of Melville Island, except on southeastern Sabine Peninsula, where the overlying Isachsen

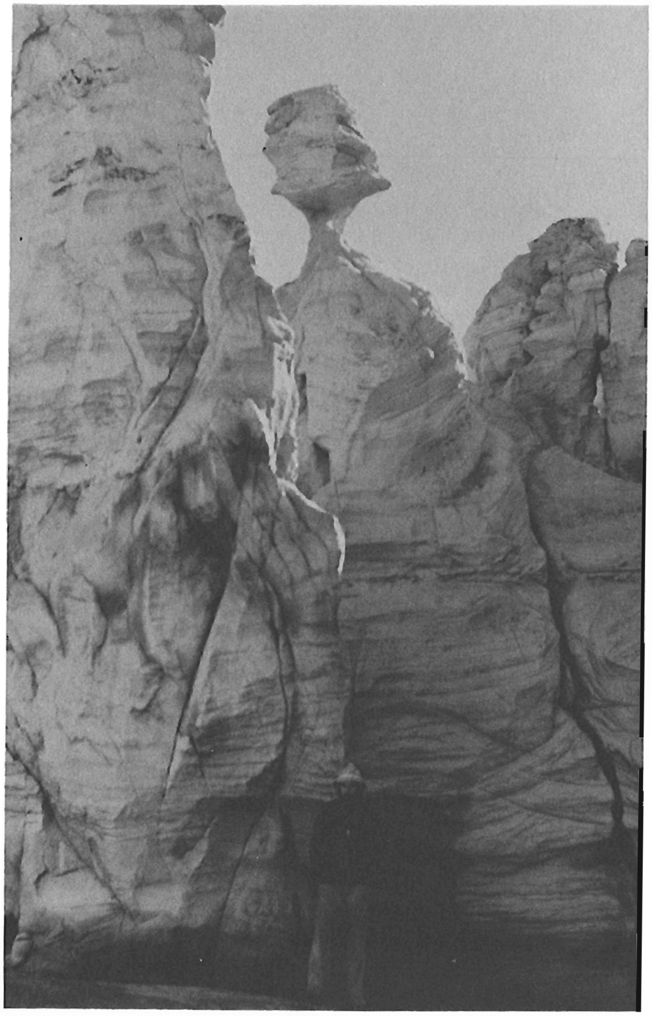

Figure 13. Hoodoo of white, fine grained, massive to horizontally bedded sandstone, upper sandstone, Hiccles Cove Formation, western Sproule Peninsula. (GSC photo no. 2870-8.)

Formation rests unconformably on the Sandy Point Formation. The sequence gradually thickens northward to a maximum of 556 m in the North Sabine H-49 well (Fig. 15).

The basal formation of the sequence, the Ringnes, consists of dark grey to black shale and siltstone with minor very fine grained, silty sandstone (Fig. 16). The formation thickens from 30 m in the southeast to 60 m in the north. In outcrop on Sproule Peninsula, the Ringnes contains large, buff weathering, dolomitic concretions, a feature characteristic of the type section on Amund Ringnes Island. Coarsening-upward trends are apparent in both the western and eastern parts of the island, and interbeds of sandstone occur in the uppermost part of the unit.

On Sabine Peninsula, the Awingak Formation conformably overlies the Ringnes Formation with the contact placed at the horizon where sandstone becomes the predominant lithology. However, in the west (Cape Grassy, Sproule Peninsula) the formation is conformably overlain by soft, clay shales of the Deer Bay Formation. Embry (1986) previously correlated strata now placed in the Ringnes Formation of this area with the Hot Weather Member of the Awingak Formation, but recent paleontological data (E.H. Davies, pers. comm., 1986) indicate that this correlation is likely incorrect.

The lithotypes, sedimentary structures, and occurrence of pelecypods in the Ringnes Formation suggest an offshore marine shelf environment of deposition.

The Awingak Formation, recognized only in the eastern portion of the study area, is up to 340 m thick. The Awingak can be subdivided into a lower sandstone, a middle shale, and an upper sandstone unit (Fig. 4). These units were earlier correlated with the Cape Lockwood, Hot Weather, and Slidre members of the Awingak Formation, units that were defined on Ellesmere Island (Embry, 1986). However, confirmation of this long-range correlation awaits further data and the three subdivisions on Melville Island are here treated informally.

The lower sandstone consists mainly of light brown-grey, very fine to medium grained sandstone with interbeds of shale and siltstone increasing northward. Coarsening-upward cycles occur throughout the unit in the north and the strata are interpreted as nearshore marine shelf deposits.

The middle shale is usually less than 10 m thick and consists of medium grey, silty shale and siltstone of offshore marine shelf origin. It is absent in a few wells in the southeastern corner of the study area.

The upper sandstone is thickest in the south, where it is up to 275 m thick. The unit is mainly sandstone, with interbedded shale, and siltstone. The fine to coarse grained, pebbly sandstones are usually arranged in coarsening-upward units of shallow water marine origin. A few thin coal beds within the succession indicate that lagoonal conditions occurred along the basin margin. Northward, the proportion of shale and siltstone increases, and coarsening-upward cycles are readily recognizable. The sandstone units become much finer grained (very fine to fine) and many grade laterally into shale and siltstone facies (Fig. 4).

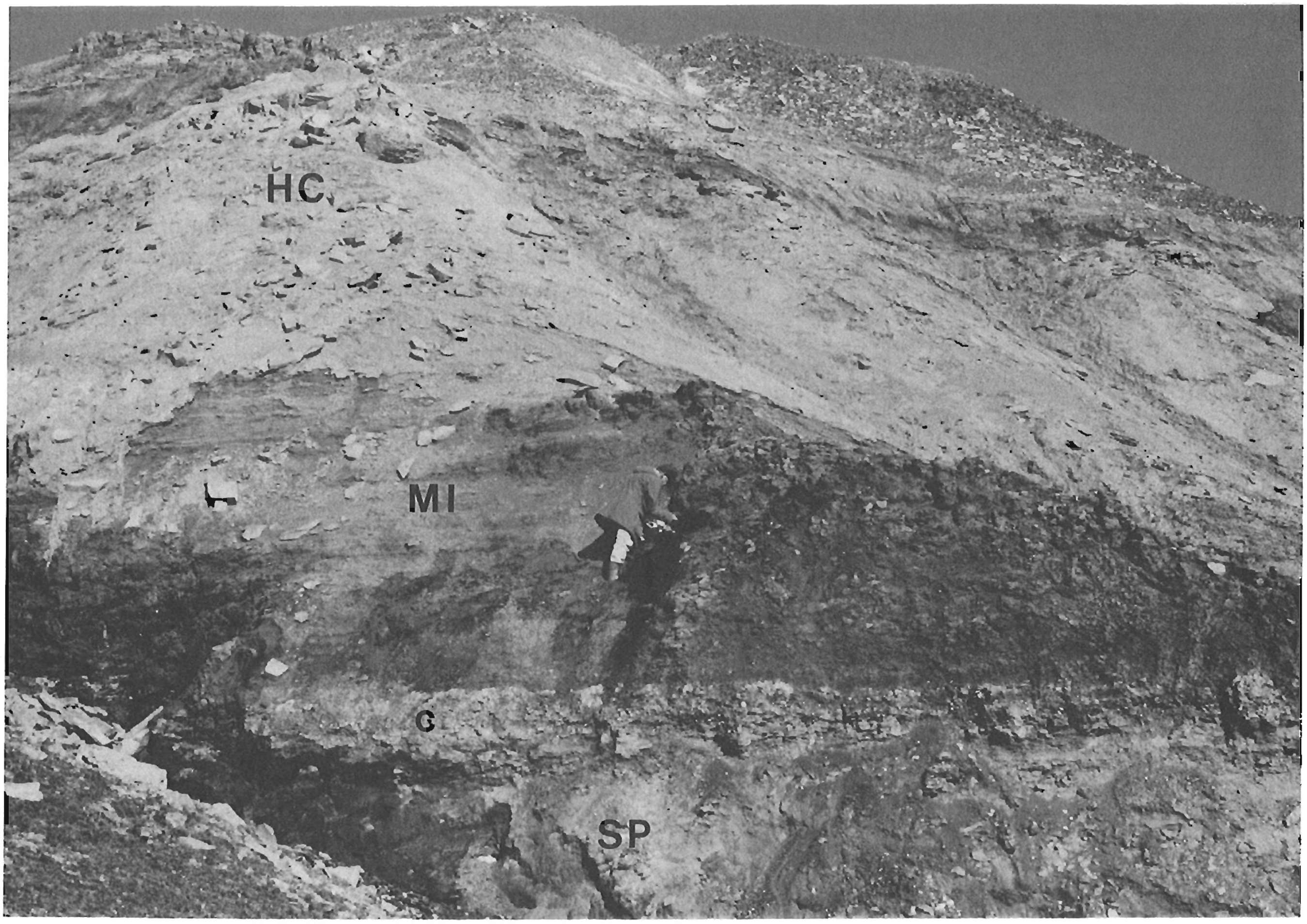

Figure 14. McConnell Island Formation (MI) with basal conglomerate (c) resting unconformably on Sandy Point Formation (SP), and conformably overlain by Hiccles Cove Formation (HC), East Kitson River, eastern Sproule Peninsula. (GSC photo no. 2870-6.)

The Deer Bay Formation consists mainly of medium grey, silty shale and siltstone with lesser amounts of very fine to fine grained sandstone. The formation in part overlies the Awingak Formation to the north; to the west it is laterally equivalent to the middle shale and upper sandstone units of the Awingak (Fig. 6).

The Deer Bay on Sabine Peninsula thins southward from a maximum thickness of 323 m in North Sabine H-49 well to a zero edge, still in the subsurface. The thinning is due to both lateral facies change to sandstone of the Awingak Formation and to regional truncation beneath the Isachsen Formation (Fig. 4). The Deer Bay does not reach the outcrop belt on southern Sabine Peninsula, where the Isachsen rests unconformably on the upper sandstone unit of the Awingak Formation.

In the Sabine Peninsula area, the Deer Bay is divided into two informal members; the contact between the two is placed at the base of a widespread clay shale unit (Fig. 4). The lower member consists of interbedded medium grey shale, siltstone, and very fine to fine grained sandstone of offshore marine shelf origin. The lower strata intertongue with the upper sandstone of the Awingak Formation. In general the contact between the two formations rises stratigraphically to the south (Fig. 4) and the strata represent an overall transgressive succession.

The upper member of the Deer Bay Formation rests abruptly on the lower member and consists of clay shale in the lower parts with silty shale and siltstone becoming common in the upper portion of the member. These strata are of offshore marine origin and form a regressive, shallowing-upward succession. The Isachsen Formation unconformably overlies the upper member of the Deer Bay Formation and progressively truncates it southward (Fig. 4).

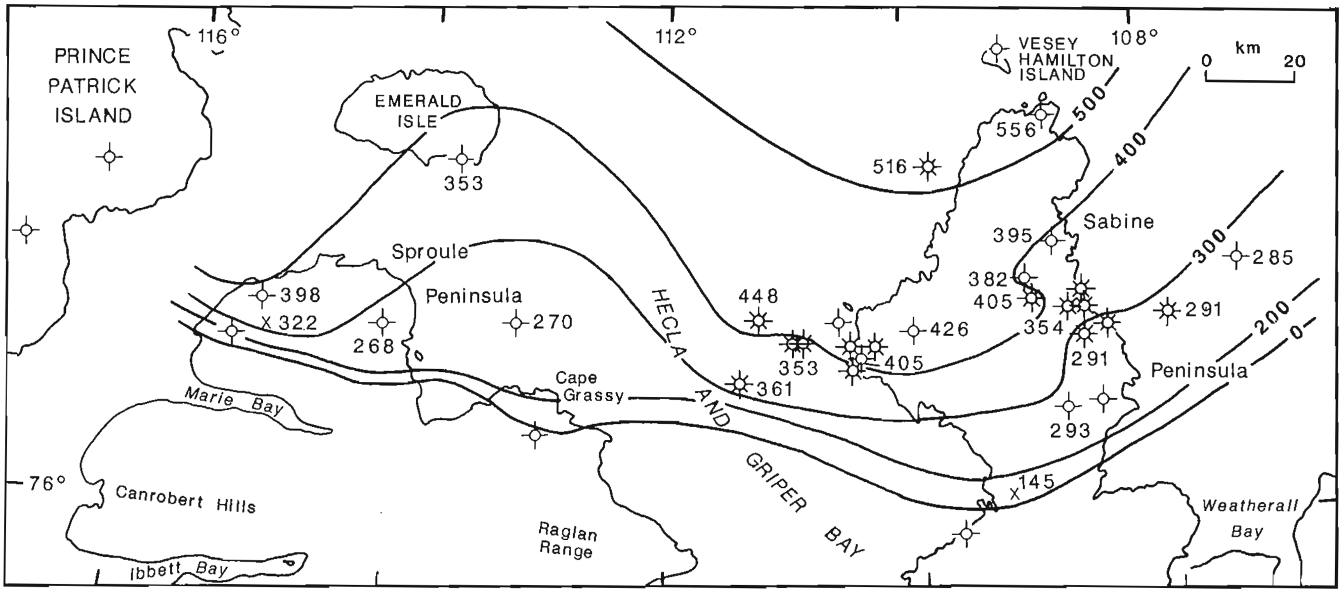

Figure 15. Isopach map, sequence 4, Oxfordian-Valanginian. Contour interval 100 m.

The Awingak Formation is not recognized in western Melville Island, where the Deer Bay Formation overlies the Ringnes Formation. The Deer Bay in this area consists mainly of medium grey shale and siltstone with interbeds of very fine to fine grained, burrowed sandstone. The basal beds consist mainly of clay-rich shale with siltstone and sandstone interbeds occurring higher in the formation. These strata are equivalent to the lower member of the Deer Bay of Sabine Peninsula, with the upper member being absent in the west due to truncation beneath the Isachsen Formation. A few, medium to coarse grained sandstone units occur in the Deer Bay Formation in sections east of Sproule Peninsula and these represent tongues of the upper sandstone unit of the Awingak Formation (Fig. 6).

The main stratigraphic relationships of the sequence on Melville Island are illustrated in Figures 4 to 7. These include:

1. The Ringnes Formation overlies a major unconformity in the southeast; the lower contact becomes conformable to the north and northwest.

2. The lower sandstone of the Awingak Formation occurs only in the east (see Figures 6, 7) and is truncated by an unconformity beneath the middle shale on the southeastern basin margin (Fig. 4).

3. The middle shale and upper sandstone of the Awingak Formation and Deer Bay Formation of Sabine Peninsula are laterally equivalent to the Deer Bay Formation to the west.

4. The Isachsen Formation unconformably overlies the Deer Bay Formation over the entire study area; sub-Isachsen erosion is least in the northeast, where the upper member of the Deer Bay Formation is preserved.

The Ringnes Formation has been dated as Oxfordian to early Kimmeridgian on the basis of pelecypods and dinoflagellates (Tan, 1979). The middle shale and upper sandstone of the Awingak Formation, as well as the overlying and laterally equivalent lower member of the Deer Bay Formation, are Volgian to Berriasian (Poulton, *this volume*). The upper member is Valanginian (J.H. Wall, pers. comm., 1985). The sequence thus ranges from Oxfordian to Valanginian and records major transgressions during the early Oxfordian, early Volgian, and early Valanginian.

GEOLOGICAL HISTORY

The uppermost Triassic to lowermost Cretaceous succession of Melville Island records numerous transgressive-regressive cycles that resulted from a complex interplay of rates of sedimentation, subsidence, and eustatic sea-level changes. The cycles reflect constantly changing paleogeography, with the main locus of sedimentation moving either landward or seaward in response to changes in the three variables

Figure 16. Dark-weathering Ringnes Formation (R) conformably overlying Hiccles Cove Formation (HC), south of Cape Grassy. (GSC photo no. 2870-2.)

just noted. The main transgressive and regressive episodes are outlined here, but their causes are not considered.

A major regression culminated in Late Triassic time (Norian) and much, if not all, of the Melville Island area was exposed to erosion. Latest Triassic (Rhaetian) time saw the initiation of a new transgression, with the sea gradually advancing during the early Rhaetian. The initial deposits of the transgressing sea were oolitic ironstones; these were followed by deeper water deposits of mud and silt (lower Grosvenor Island Formation). No signs of animal activity are evident in these initial deposits, which suggests a restricted latest Triassic sea. The transgression reached its maximum in the late Rhaetian. Regression occurred during the Hettangian, and sandy, shoreline and shallow shelf deposits (Maclean Strait Formation) prograded seaward over offshore muds and silts (upper Grosvenor Island Formation). The basin margin was progressively exposed as the shoreline advanced basinward. The regression culminated in late Hettangian when most of the study area was either undergoing erosion or receiving sandy sediment (Fig. 17). A similar cycle of transgression and regression occurred during the Sinemurian (Lougheed Island and King Christian formations). Sediment sources at this time were mainly deltaic centres to the east, beyond the present study area (Embry, 1982), and the supply of sand decreased westward across the study area.

Transgression was re-initiated in the Pliensbachian and, from Pliensbachian to earliest Toarcian times, the region received silty mud with minor sand input in the east (Intrepid Inlet Member, Jameson Bay Formation). Maximum transgression occurred in early Toarcian time, when the entire study area was an offshore shelf and only mud was deposited. Two transgressive–regressive cycles then followed in Toarcian and Aalenian times, when sandy, shallow water, shelf

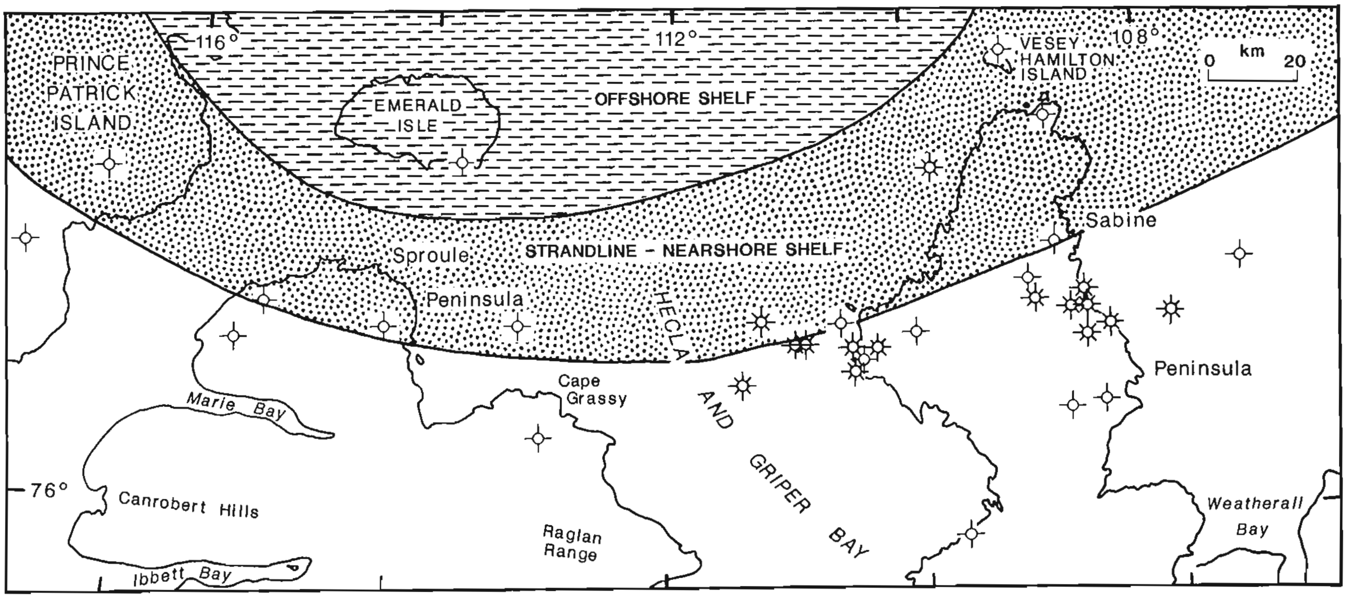

Figure 17. Late Hettangian paleogeography.

environments alternated with muddy, offshore shelf environments over most of northern Melville Island (Jameson Bay and Sandy Point formations). Sandy, shallow-water shelf sediments were deposited at times of maximum regression, when the basin margin was exposed nearby; at the heights of marine transgression, shorelines lay well to the south of the area, which was then an offshore shelf receiving mainly mud. Sediment supply was generally low during these cycles, and the marine sands are glauconitic and highly burrowed.

Uplift and widespread erosion occurred in latest Aalenian time. Uplift and depth of erosion were significantly greater in the eastern portion of the area.

A major transgression occurred in Bajocian-early Bathonian time and the area was again submerged to become an offshore shelf (lower member, McConnell Island Formation). A regressive phase took place in late Bathonian time, when shoreline to shallow shelf sands [lower (sandstone) member, Hiccles Cove Formation] prograded over the offshore mud and silt (upper member, McConnell Island Formation). Sediment was supplied from the southwest and the thickest and most extensive sand deposits occur in the western portion of the area. In the early Callovian, the area was again transgressed and the shoreline lay near the basin edge. Sediment supply was mainly from the southwest and arenaceous nearshore shelf deposits [upper (sandstone) member, Hiccles Cove Formation] prograded northeastward over offshore shelf muds [middle (shale) member, Hiccles Cove Formation] during the Callovian. The southeastern portion of the shelf was starved for most of the Bajocian-Callovian interval and underwent submarine, and possibly subaerial, erosion at various times (Fig. 18).

The area was again submerged during a major transgression in the early Oxfordian. During the subsequent regression, in the Oxfordian and early Kimmeridgian, shallow water shelf sands [lower (sandstone) member, Awingak Formation] prograded over offshore mud and silt (Ringnes Formation) in eastern parts of the area. Western parts remained an offshore shelf environment throughout this time (Ringnes Formation). The shelf margin, uplifted and exposed in the mid to late Kimmeridgian, was subsequently drowned in the early Volgian by a renewed transgression. During the Volgian and Berriasian, shallow water shelf sands (upper sandstone, Awingak Formation) again prograded over offshore mud and silt (middle shale, Awingak Formation) but much of the northern and western portions of the area remained as an offshore shelf environment (lower member, Deer Bay Formation) (Fig. 19).

Transgression again occurred in the early Valanginian, and the entire area was an offshore shelf during the early to middle Valanginian (upper member, Deer Bay Formation). A major regression and widespread uplift throughout the study area occurred in the late Valanginian to Hauterivian, with uplift most pronounced in the south and west.

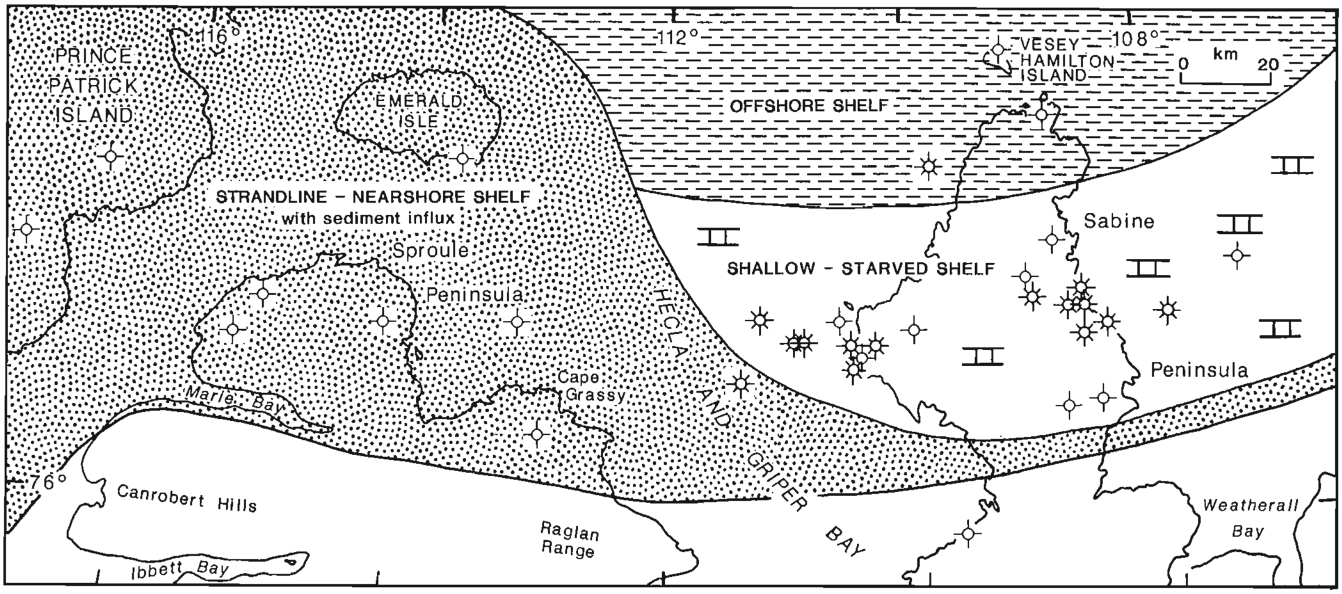

Figure 18. Late Callovian paleogeography.

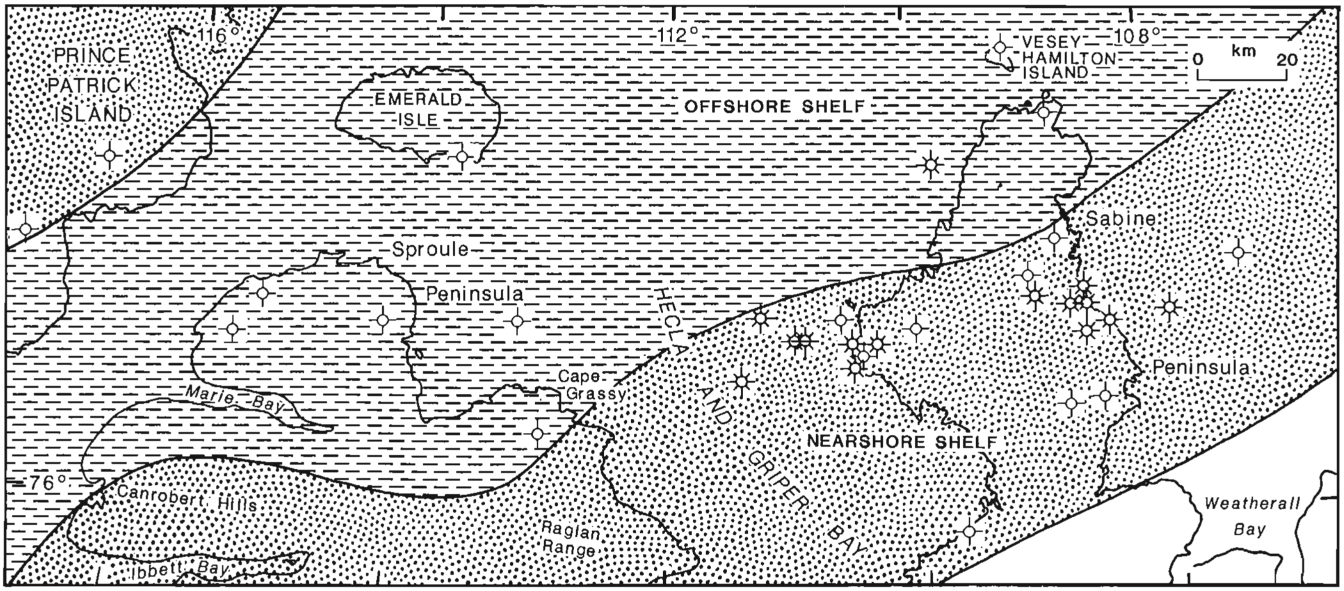

Figure 19. Late Volgian paleogeograhy.

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JURASSIC STRATIGRAPHY AND FOSSIL OCCURRENCES — MELVILLE, PRINCE PATRICK, AND BORDEN ISLANDS

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Poulton, T.P., 1993. Jurassic stratigraphy and fossil occurrences — Melville, Prince Patrick, and Borden Islands; in The Geology of Melville Island, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 161-193.

Abstract

The Jurassic rocks of Melville, Prince Patrick, and Borden islands are a condensed succession of shallow water marine sandstones and shales deposited around the western margin of Sverdrup Basin. Every stage of the Jurassic, except the Hettangian, is indicated by marine ammonites or bivalves. The succession is divisible into unconformity-bounded sequences, which are thin and sporadically preserved remnants of thicker basinal deposits to the east.

Résumé

Les roches jurassiques des îles Melville, Prince Patrick et Borden constituent une série condensée de grès et de shales marins épicontinentaux déposés en bordure de la marge ouest du bassin de Sverdrup. On y trouve des ammonites ou des bivalves marins de chaque étage du Jurassique, sauf l'Hettangien. La série peut se diviser en séquences que limitent des discordances; ces séquences sont des restes peu épais et sporadiquement conservés des dépôts de bassin plus épais à l'est.

INTRODUCTION

In 1984, I studied the Lower and Middle Jurassic rocks of northwestern Melville Island in three areas — Marie Heights near the mouth of Marie Bay on its north side, the north side of Marie Bay near its head, and East Kitson River (locs. 3, 4, 5 in Fig. 1). Descriptions of these successions form the main part of this report. In addition, the Jurassic strata on nearby Prince Patrick Island and Borden Island, studied by me in 1977, together with H.R. Balkwill, R. Rahmani, and J.T. Tan (Balkwill et al., 1978), are discussed for comparison with the Melville Island successions. Extensive new stratigraphic data and fossils were collected by A.F. Embry, J.C. Harrison, and me in 1987 (Harrison et al., 1988), primarily from Prince Patrick Island, with additional material from Melville Island. All the fossil material from the area that is available in the Geological Survey of Canada and University of Alberta collections was restudied by me, and results of this restudy have been incorporated in this report. Collections made by Petropar Canada (Elf Oil) company geologists, together with stratigraphic sections measured in 1965 and 1966, are of particular significance. The stratigraphic sections described here are composite, based on data from scattered small sections.

Acknowledgments

G. Hobson and others of the Polar Continental Shelf Project, H.R. Balkwill, and R.L. Christie provided logistical facilities and other help in performing fieldwork in 1977 and 1984. Karl Zberg (Bradley Air Service) provided exceptional air support on Prince Patrick and Borden islands, landing on difficult terrain close to stratigraphic sections. Dennis Braman assisted with the measurement of sections on Prince Patrick Island in 1977. Ray Rahmani, Tony Tan, and Hugh Balkwill did most of the lithostratigraphic study on Borden Island. Although the published and unpublished data of J.T. Tan were available for the present report, the descriptions presented here are entirely from my own notebooks. I am particularly appreciative of the opportunity to revisit Prince Patrick and Melville islands in 1987 with A.F. Embry and J.C. Harrison, and for the excellent support

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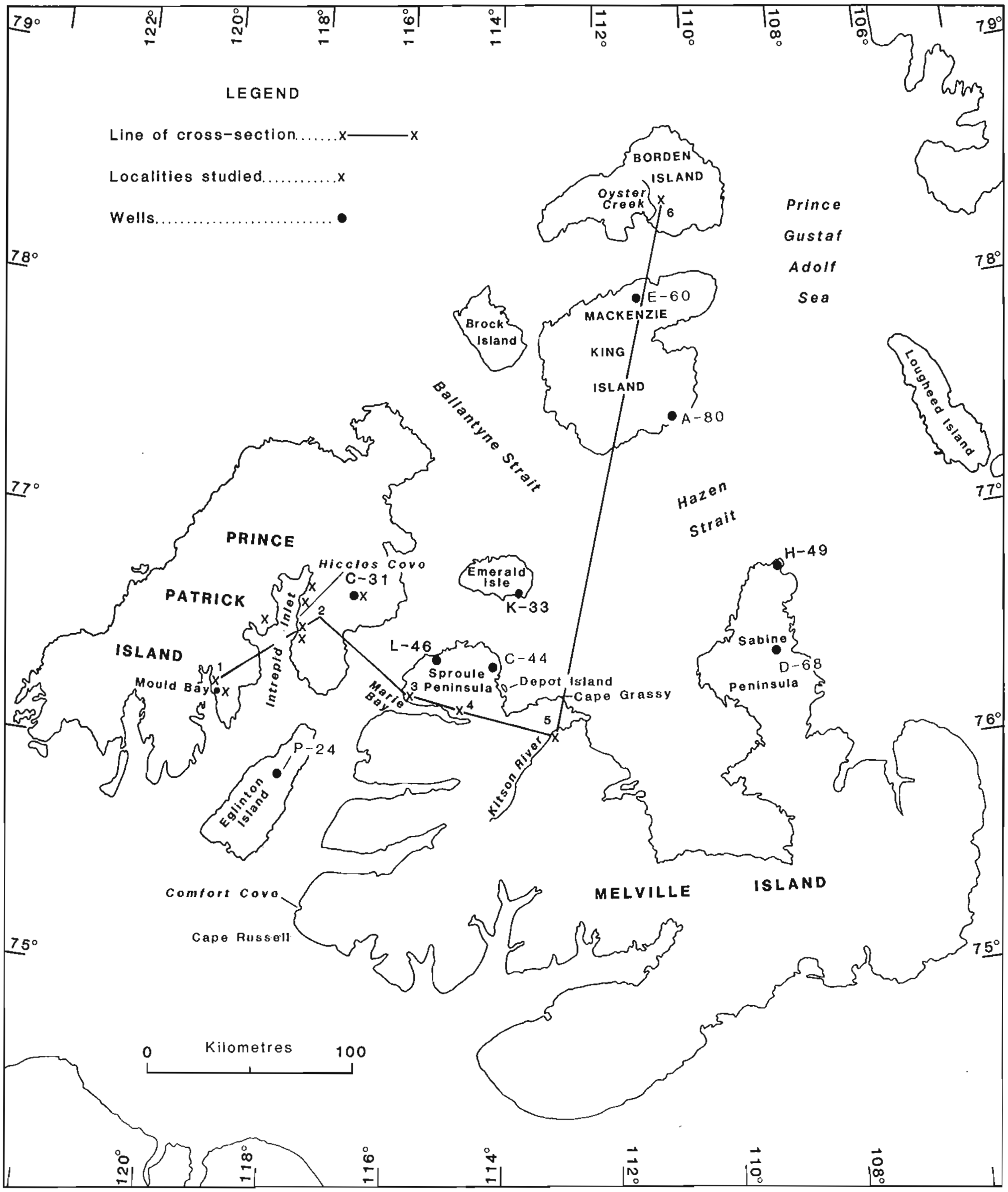


Figure 1. Index map, showing locations of stratigraphic sections (×), wells (●), and the cross-section 1-6 of Figure 2.

services supplied by pilot S. Kobayashi and the crew of the Mould Bay Weather Station.

A.F. Embry has discussed many aspects of Arctic Mesozoic geology with me, and in particular has provided valuable insight into the subsurface successions and his new formation nomenclature. Prior to 1980, the ammonites were identified by H. Frebold; *Buchia* specimens were identified by J.A. Jeletzky. Since then, however, they have all been re-examined by me and the conclusions presented here are mine. The University of Alberta paleontological collections were examined and some material borrowed for study, courtesy of Brian Jones. The manuscript has been critically read by R.L. Christie, A.F. Embry, and J.H. Wall.

REGIONAL GEOLOGY

The geology of the western Queen Elizabeth Islands was first described comprehensively by Tozer and Thorsteinsson (1964), following the publication of several preliminary reports by them. These authors recognized three Triassic formations — the Bjorne, Schei Point, and Heiberg, which had been described previously in the eastern Arctic Islands. They pointed out that, according to W. Fry (*in* Fortier et al., 1963, p. 81), the upper beds of the Heiberg contain "Rhaeto-Liassic" fossil plants of latest Triassic or earliest Jurassic age. The Jurassic rocks were assigned to a new formation — the Borden Island — and to two previously described ones, Wilkie Point and Mould Bay (Table 1). Correlation with the Savik, Awingak, and Deer Bay formations, previously described from the eastern Arctic, was proposed. The Mould Bay and Deer Bay formations also contain Cretaceous rocks.

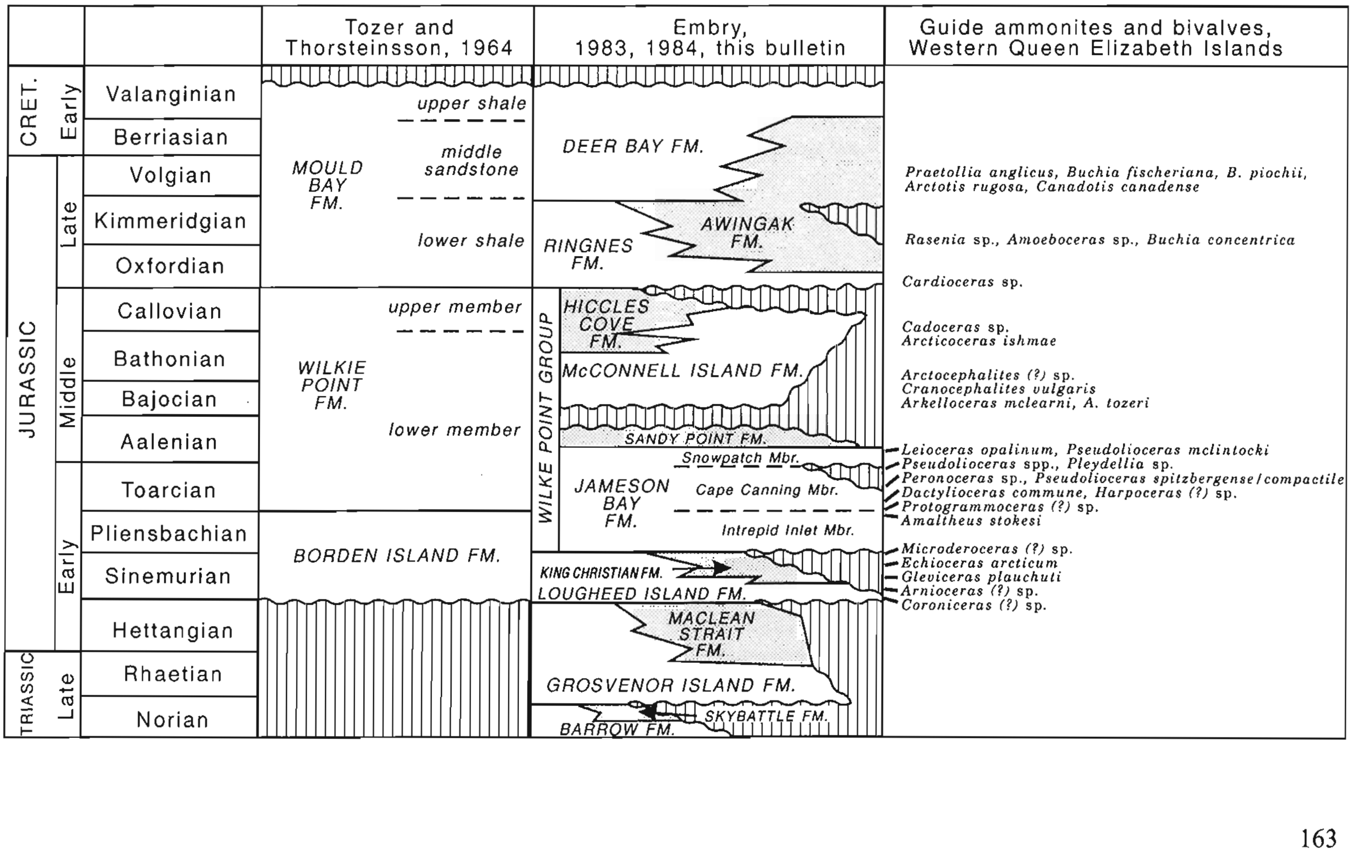
The Mesozoic strata of the Arctic islands have been the subject of recent regional stratigraphic analyses, which have been published in a series of reports by A.F. Embry (1982-86; *this volume*). Of particular note in Embry's papers, in addition to the new stratigraphic nomenclature, is the subsurface information for units described here from their surface exposures, and references to several palynological and micropaleontological studies.

The Jurassic rocks of Melville, Prince Patrick, and Borden islands lie along the southwestern, western, and northwestern margins of the Sverdrup Basin. They are predominantly a succession of thin, basin-margin sandstones that contrast with thicker, more argillaceous units farther east and north in the basin. Condensed beds and disconformities are common, so that the basin-margin succession is relatively incomplete (Fig. 2). In particular, the Sinemurian, Pliensbachian, Toarcian, Aalenian, Bajocian, younger Middle Jurassic, and lower Upper Jurassic beds represent the thin edges of formations that are more completely preserved basinward. This thinning was due to truncation of units below disconformities within the Jurassic and to lesser subsidence of the basin margin areas.

Each of the stratigraphic sequences described in this report represents deposition associated with a regressive event that follows a transgression. The last stage of each event is characterized by erosion in some cases, or by a period of stillstand and nondeposition in

TABLE 1

Table of Formations



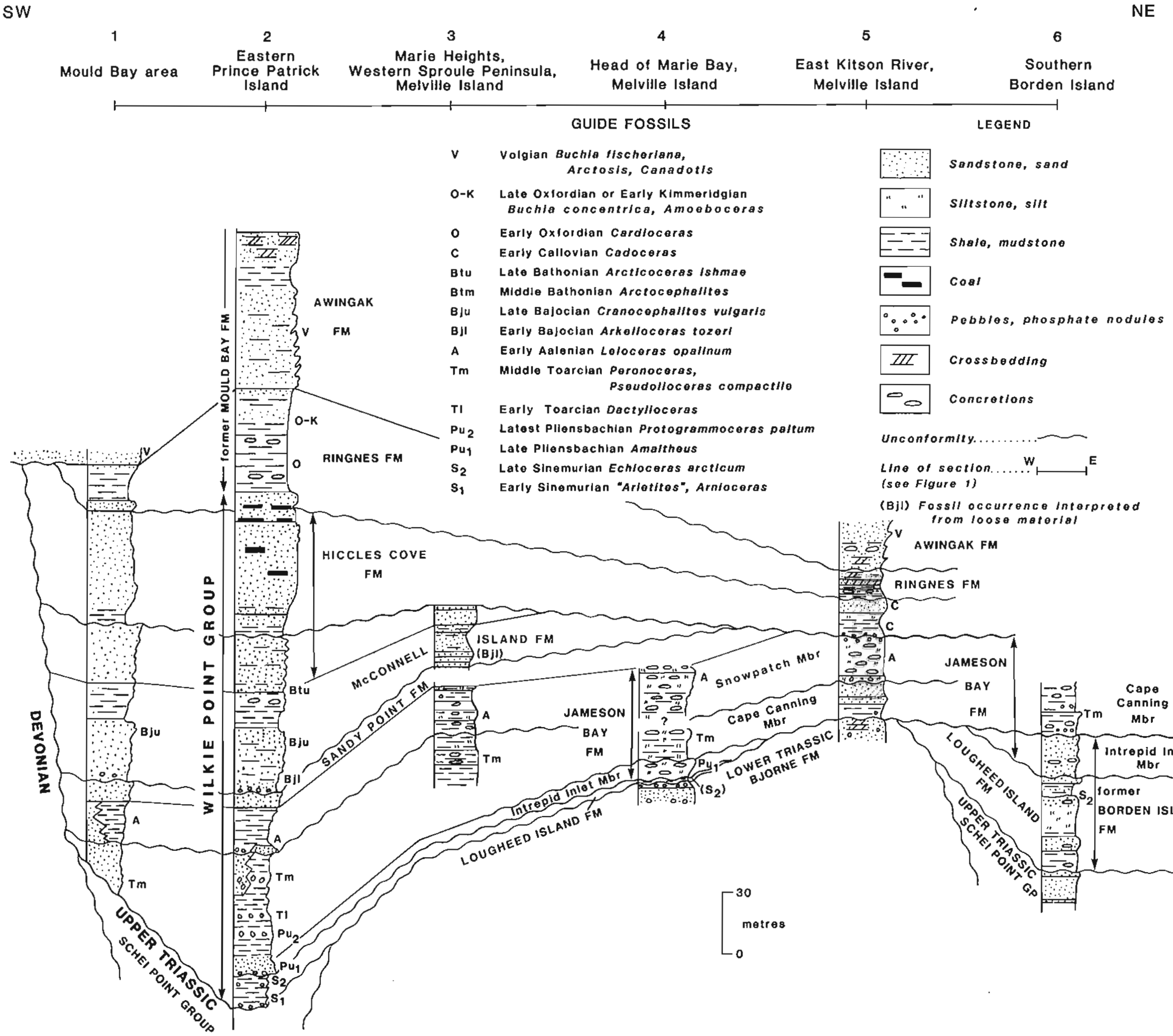


Figure 2. Stratigraphic cross-section 1-6; location shown in Figure 1. Fieldwork in 1987 indicated significant facies changes in the Jurassic formations on Prince Patrick Island toward the shorelines in the west and southwest, and a small syndepositional uplift north of Green Bay (Harrison et al., 1988).

others. The greatest transgressions, in the Early Toarcian and Late Oxfordian or Kimmeridgian, coincide with those observed elsewhere in Western Canada, and worldwide.

Jurassic fossils were first found in the Arctic islands by Leopold M'Clintock in 1853, and these collections from Wilkie Point on southern Prince Patrick Island, described by Reverend Samuel Haughton (1857), remained the only unequivocal evidence of the presence of Jurassic rocks, until 1954. E.T. Tozer revisited the locality in that year (Tozer and Thorsteinsson, 1964). Jeletzky (*in* MacDonald, 1954) had thought some of the *Buchia* and *Inoceramus* specimens collected by S.D. MacDonald in 1952 at Mould Bay were of Jurassic age, but pointed out that they could possibly be of Cretaceous age. Lower and Middle Jurassic ammonites, collected mainly by E.T. Tozer and R. Thorsteinsson and forming the basis for their stratigraphic correlations, were described and discussed by Frebold (1957, 1958, 1960, 1961). A few Toarcian ammonite species were illustrated by Imlay (1955, Pl. 11). Jeletzky (*in* MacDonald, 1954) gave preliminary identifications of the latest Jurassic and earliest Cretaceous macroinvertebrates. Later collections were described by Frebold (1975) and Jeletzky (1966).

The Sinemurian rocks described here are the oldest firmly dated Jurassic rocks of Arctic Canada, with the exception of those of Early Hettangian age near Bonnet Lake, northern Yukon Territory, described by Frebold and Poulton (1977). However, Embry (1982) considered that the poorly dated interval between the Norian (including Rhaetian) and Sinemurian in the Arctic islands may contain Hettangian rocks, because of the apparent stratigraphic continuity with Sinemurian strata, and the presence of "Rhaeto-Liassic" palynomorph assemblages.

Sinemurian

The western Queen Elizabeth Islands have produced several collections of Sinemurian fossils. Only one of the previously described specimens is now thought to be Early Sinemurian. It is *Arietites* sensu lato, collected loose from southern Borden Island (Frebold, 1960, p. 13, 26, Pl. 1, figs. 3a, b; GSC loc. 35322; loc. 84 of Tozer and Thorsteinsson, 1964). Newly discovered Early(?) and Late Sinemurian ammonites from Borden and Prince Patrick islands are discussed in the following section of this report.

Diagnostic Late Sinemurian fossils that have been described include *Gleviceras plauchuti* Frebold from the east side of Intrepid Inlet, Prince Patrick Island (Frebold, 1975, Pl. 2, figs. la-d; GSC loc. 70402). *Echioceras arcticum* Frebold has been described from Oyster Creek, Borden Island (Frebold, 1975, Pl. 3, figs. 1-6; GSC loc. 72608); *Echioceras* sp. (Frebold, 1960, Pl. 1, fig. 2) and *E. aklavikense* Frebold from Melville Island (Frebold, 1975, Pl. 2, figs. 5-9; GSC loc. 60220). Good exposures of unequivocal Sinemurian beds have not been seen by me on Melville Island.

In contrast to the absence or extreme thinness of Sinemurian sequences on northwestern Melville Island is their persistence in the subsurface just to the east (Borden Island-Mackenzie King Island-Sabine Peninsula). As on northwestern Melville and Prince Patrick islands, the Sinemurian beds thin southward, away from the basin axis, eventually disappearing below the Jameson Bay Formation (Embry, 1982). Embry (1983b) indicated the presence of a thick Sinemurian section below Jameson Bay shale near the head of Intrepid Inlet, eastern Prince Patrick Island (Jameson Bay C-31 well). This contrasts with an apparently thin development farther south, perhaps due in part to erosion below Pliensbachian and Toarcian units.

The Sinemurian beds in the western Queen Elizabeth Islands were included in the Borden Island Formation by Tozer and Thorsteinsson (1964) (see Table 1). Embry (1982, 1983b) correlated this interval with the Lougheed Island Formation, a subsurface unit defined in the Skybattle Bay C-15 well on Lougheed Island. Embry (1983b) abandoned the name Borden Island Formation, partly because a significant unconformity was thought to occur in Borden Island strata in the type area, and partly because the name had come to be used in different ways by different authors.

Oyster Creek, Borden Island (Loc. 6, fig. 1)

The uppermost beds of the Triassic Schei Point Group (Pat Bay Formation) form a broad terrace along the banks of Oyster Creek (Fig. 3). Erosional relief on a small scale marks the contact with overlying basal Jurassic strata so that they lie either on a thin fossiliferous limestone bed, on a fossiliferous sandstone that overlies the limestone, or on a mud-forming shale. Also, it appears that the lithology at the base varies from place to place, some beds perhaps filling erosional depressions in the top of the Triassic terrane.

The Sinemurian beds are poorly exposed, mainly forming sand- and silt-covered mud terraces that are covered with rusty rubble. Published descriptions of

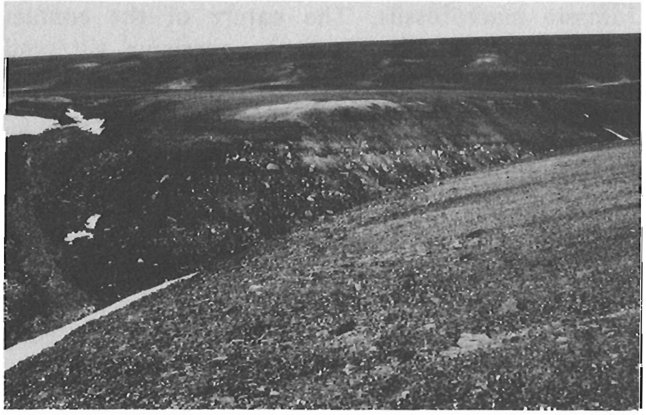


Figure 3. *Triassic Pat Bay (Schei Point Group) sandstone, limestone, and shale forming broad, gullied terraces in foreground and middle-ground, overlain by Sinemurian Lougheed Island (part of former Borden Island) sand, silt and mud, forming hillside in background; Oyster Creek, southern Borden Island (ISPG photo no. 2578-15).*

exposed sections invariably indicate a dominance of sand or sandstone, but Embry (1982) suggested, from subsurface data, that in fact shale and siltstone predominate. The shale is undoubtedly obscured at the surface by weathering and solifluction. The following stratigraphic description augments that of Rahmani and Tan (1978).

A locally developed redbed, which reaches 0.3 m in thickness and which appears to be the basal unit of the Jurassic, is composed of siltstone and fine to medium grained sandstone. The bed is strongly burrowed, and contains red siltstone rip-up clasts. The lowest 2 to 5 cm contain chert grit and pebbles, and remains of the Triassic bivalve *Minetrigonia* sp. The shells are abundant in the immediately underlying sandstone and those in the redbed may well have been reworked into it. On the other hand, strongly burrowed, rusty red laminae and rip-up clasts also occur in the grey sandstone below the redbed in the Borden Island exposures, so that the latter bed may be a Triassic unit, with its upper contact (with unexposed shale) representing the sub-Jurassic unconformity.

Overlying the redbed is a poorly exposed unit of light greenish grey, glauconitic[1] silty claystone that Rahmani and Tan (1978) considered to be the basal bed of the Borden Island Formation and to contain a basal lag of ironstone and burrows. This unit contains hard ferruginous red siltstone layers as thick as 2 to 3 cm and is 11 to 12 m thick. An overlying unit, about 15 m thick, of buff-grey and greenish, glauconitic unconsolidated sand and silt contains the lowest Jurassic macrofossils. The nature of the contact between the claystone and the overlying silt/sand subunits is not known in detail.

Rahmani and Tan (1978) thought that the "Borden Island" interval consists of a series of coarsening-upward cycles. Hard siliceous and phosphatic concretions in it are light brown-grey, subspherical, as large as 10 cm across, and contain wood fragments and decapod crustacean fragments. It is from this area that Copeland (1960) described *Erymastacus bordenensis* Copeland, now assigned to *Eryma bordenensis* by Feldmann and McPherson (1980). Feldmann and McPherson (1980) also described another crustacean, *Glyphaea robusta* from these beds. These concretions are particularly numerous near the exposed top of the subunit and the upper beds may be the source of loose concretions found at lower levels on the slope. Similarly, it is not clear whether specimens of the ammonite *Echioceras arcticum,* found loose in the rubble, come from the top of the unit, or from a lower level, below the main crustacean-bearing beds. The only diagnostic specimens found in situ are from isolated outcrops that are not easily correlated precisely with particular beds of the Oyster Creek sections. Perhaps more importantly, other unidentified ammonite fragments resembling *Charmasseiceras* (except for a bisulcate, keeled venter) and a specimen resembling *Coroniceras* or *Paracoroniceras* [which I found with loose specimens of *E. arcticum* in creek beds below this unit (GSC locs. C-76361, C-76362)] may be of Early, rather than Late Sinemurian age.

The highest bed of the probably Sinemurian beds is a conspicuous, continuous band, varying in thickness up to 3 m, of variably red- and white-weathering, partly concretionary siltstone or fine grained sandstone, in which phosphatic nodules also occur. This band (Marker 1 of Rahmani and Tan, 1978), is profusely burrowed (with *Ophiomorpha* and *Teichichnus,* according to Rahmani and Tan, 1978), thinly and irregularly bedded, and contains small chert pebbles and rare unidentified bivalves.

Overlying beds, tentatively assigned to the base of the Jameson Bay Formation (Embry, 1984) are described below under "Pliensbachian — Oyster Creek".

Rahmani and Tan (1978) interpreted the Sinemurian and Pliensbachian beds of Borden Island as a series of shallow water marine, migrating sand bars on the northwest margin of Sverdrup Basin. From regional relationships, Embry (1983b) ascribed the Sinemurian sediments to deltaic, prodeltaic, and offshore shelf depositional environments. The occurrences of Sinemurian fossils on Prince Patrick Island and northwestern Melville Island document the presence of thin, erosional remnants of Sinemurian units close to the basin margin.

East side of Intrepid Inlet, Prince Patrick Island (Loc. 2, Fig. 1)

Sinemurian fossils were found for the first time in 1987 by A.F. Embry and me along the east side of Intrepid Inlet in the few kilometres northward from Cape Canning. The upward succession of three faunas contains *Arnioceras*(?) together with a still unidentified ammonite resembling the Hettangian genus *Caloceras, Echioceras arcticum,* and finally a deroceratid species. This sequence is underlain by thin, unfossiliferous, basal Jurassic(?) red siltstone and mudstone that

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[1] The term glauconite or glauconitic is used throughout this report to indicate a green, pelletal mineral that has not been analyzed in detail.

overlies similar redbeds containing *Minetrigonia* and *Gryphaea* in the Triassic Schei Point Formation. These units appear to be absent south of Cape Canning.

Pliensbachian

Pliensbachian beds were first found in the Canadian Arctic by me in 1969. The *Amaltheus* specimens from redbeds at the top of the Heiberg sandstone at Depot Point, eastern Axel Heiberg Island were described by Frebold (1975, Pl. 4, fig. 3; GSC loc. C-4728). These redbeds were assigned to the Borden Island Formation (Thorsteinsson and Tozer, 1971), and are now included in the Remus Member, the uppermost unit of the Heiberg Formation (Embry, 1983a). In the western Queen Elizabeth Islands, Upper Pliensbachian units described in this report have been referred to the Intrepid Inlet Member, basal to the Jameson Bay Formation (Embry, 1984) (see Table 1).

The Pliensbachian has been documented in western Queen Elizabeth Islands by the presence of Late Pliensbachian *Amaltheus stokesi* (J. Sowerby) at Intrepid Inlet near Wilkie Point, Prince Patrick Island (Frebold, 1975, Pl. 4, fig. 4; GSC loc. C-12544), and near the head of Marie Bay, northwestern Melville Island (recent collections by the writer are described below).

Marie Heights, Melville Island (Loc. 3, Fig. 1)

No pre-Toarcian beds were identified at locality 3, and the interval from the top of the Triassic Bjorne Formation to the Middle Toarcian is mainly poorly exposed shale. The thickness of this interval appears to be highly variable in the Marie Heights area; it is not known whether this is due to relief on an erosional surface of the older Jurassic rocks at a pre-middle Toarcian erosional unconformity, to deposition on an irregular sub-Jurassic surface, or to subsequent, unrecognized faulting.

Head of Marie Bay, Melville Island (Loc. 4, Fig. 1)

The following description is based on sections at several localities from 1 to 3 km east of those studied by Tozer and Thorsteinsson (1964, locs. 88, 89) who, however, found Sinemurian rather than Pliensbachian fossils in the Lower Jurassic beds. The Sinemurian beds must be very thin, if present, in the sections seen by me and must occur in the lowest metre or so of the poorly exposed argillaceous unit above the Bjorne Formation. Intermittent preservation of thin units below the Toarcian from one locality to another near the head of Marie Bay is indicated.

One metre of white-weathering conglomerate occurs at the top of the Lower Triassic Bjorne Formation, which consists mainly of orange- and buff-weathering, cliff-forming sandstone and conglomerate (Fig. 4). Both the lower and upper contacts of the white conglomerate are sharp, and it is not known which contact represents the base of the Jurassic.

Immediately above the white conglomerate is a 7.5 cm-thick layer of hard, strongly indurated, dusky ironstone — clearly a hiatal or stillstand hardground.

A light grey-green, poorly consolidated siltstone unit 9 m thick forms a recessive bench at the tops of the cliffs formed by the Bjorne Formation. Subspherical, ferruginous, and phosphatic concretions up to 10 cm in diameter and containing decapod crustacean fragments are thought to occur in this unit, although they may be debris from the more resistant fossiliferous unit

Figure 4. *Upper Pliensbachian beds of Lower Jameson Bay Formation (part of former Borden Island) siltstone, sandstone, and mudstone forming slopes and upper part of terrace in background, underlain by Triassic Bjorne conglomerate forming bluffs at top of steep slope in foreground; north side of Marie Bay near its head. The muddy terrace may contain undiscovered Sinemurian beds. The precise location of the base of the Jurassic with respect to the 1 m thick white conglomerate in the foreground is not certain (ISPG photo no. 2578-8).*

immediately above. Trace fossils are abundant and varied. *Diplocraterion* and *Chondrites* are particularly conspicuous.

The higher fossiliferous unit, dark red from a distance because of its high content of ferruginous concretions and concretionary bands, also consists of poorly consolidated silt but contains some chert pebbles, fossil wood fragments and other fossils. The fossils occur both in the concretions and in the unconsolidated silt, and contain a variety of bivalves and the ammonite *Amaltheus* (GSC locs. C-107897, C-107898). Some *Amaltheus* specimens were collected in place, but others were collected from loose debris on the upper surface of the Bjorne and may have rolled down from the recessive siltstone interval just above the Bjorne. The top of the concretionary red silty unit forms the tops of bluffs along the north side of Marie Bay, near its head.

East Kitson River, Melville Island (Loc. 5, Fig. 1)

The contact between the Jurassic beds and the bluff-forming, crossbedded sandstone of the Lower Triassic Bjorne Formation is not well exposed at East Kitson River. The lowest exposed shales above the Bjorne contain bright rusty orange and red-weathering concretions, supporting the suggestion of Tozer and Thorsteinsson (1964) that Toarcian (Cape Canning Member of Jameson Bay Formation), rather than older Jurassic, strata overlie the Bjorne here.

Oyster Creek, Borden Island (Loc. 6, Fig. 1)

Higher beds of the former Borden Island Formation (see Table 1) were not studied in detail by me at locality 6 (Fig. 1). These beds are poorly consolidated, glauconitic silt and sand with hard, ferruginous, concretionary layers, subspherical phosphate concretions that contain decapod crustaceans, and wood fragments. They are similar to the Sinemurian beds in the same area, described above and by Rahmani and Tan (1978). Approximately 40 m of section is involved. The beds on Borden Island appear to be equivalent to the upper glauconitic unit of the "Borden Island Formation" as interpreted by Reinson (1975). Reinson's upper glauconitic unit was removed from the "Borden Island Formation" by Meneley (1977), who instead assigned the unit to the "Lower Wilkie Point Formation". Meneley (1977) demonstrated that it overlies a regional unconformity (see also Embry, 1983b). No age-diagnostic fossils are known from this part of the succession on Borden Island, but A.F. Embry (pers. comm.) suggests that it may be equivalent to the Upper Pliensbachian beds of Melville Island. The glauconitic silt and sand unit was assigned to the Jameson Bay Formation (basal Intrepid Inlet sandstone member) by Embry (1983b, Fig. 13).

Eastern Prince Patrick Island (Loc. 2, Fig. 1)

More specimens of *Amaltheus stokesi* were collected from the locality north of Wilkie Point originally described by Frebold (1975). New *Amaltheus*-bearing occurrences of the Intrepid Inlet Member were found by J.C. Harrison in 1987 north of Salmon Point on the west side of Intrepid Inlet. The Pliensbachian beds appear to be the basal Jurassic unit at all these localities.

Toarcian

The Toarcian stage is widely represented throughout the Arctic Islands, mainly by a soft, dark grey, mud-forming shale, formerly assigned to the lower part of the Wilkie Point Formation (Tozer, 1956; Tozer and Thorsteinsson, 1964) and now included in the Cape Canning Member of the Jameson Bay Formation (Wilkie Point Group) (Embry, 1984) in the western Queen Elizabeth Islands. Dark shale is characteristic of Toarcian beds throughout the northern hemisphere. Diagnostic Lower Toarcian fossils described and/or figured to date include "*Harpoceras* sp. cf. *H. exaratum* (Young and Bird)" from Borden Island (Frebold, 1960, p. 19, Pl. V, fig. 9) and Prince Patrick Island (Imlay, 1955, p. 88, Pl. 11, figs. 12, 13, 15); *Dactylioceras commune* (Sowerby) from near Mould Bay, Prince Patrick Island (Frebold, 1957, Pl. 1, figs. 2-7) and Borden Island (Frebold, 1960, Pl. V, figs. 4, 5), *D.* sp. cf. *D. commune*, *D.* sp. cf. *D. crassiusculosum* (Simpson) and *D.* sp. cf. *D. directum* (Buckman), from Prince Patrick Island (Imlay, 1955, Pl. 11, figs. 4-11, 14, 16-18).

Middle, or possibly early Late Toarcian fossils include *Peronoceras polare* (Frebold) from near Mould Bay, Prince Patrick Island (Frebold, 1975, Pl. 5, figs. 2a-d, GSC loc. 70390; Frebold, 1957, Pl. II, fig. 5, Pl. III, figs. 1, 2); *P. spinatum* (Frebold) from near Mould Bay (Frebold, 1957, Pl. II, figs. 1-4); *Pseudolioceras spitsbergense* Frebold from Intrepid Inlet, Prince Patrick Island (Frebold, 1975, Pl. 4, figs. 7-9, GSC loc. C-12546), and *P.* spp. cf. and aff. *P. compactile* (Simpson) from Intrepid Inlet (Frebold, 1957, Pl. III, figs. 3-5; Frebold, 1975, Pl. 4, fig. 5, GSC loc. 70390). The record of a keeled fragment, "probably *Hildoceras*" (Imlay, 1955, p. 73, 88), from Prince Patrick Island has not been confirmed.

Diagnostic Toarcian fossils have not been reported previously from Melville Island. In addition to the fossil occurrences found by the writer and discussed below, probable Toarcian *Pseudolioceras* occurs at the south end of Sabine Peninsula, northeastern Melville Island (GSC loc. 72578).

The Cape Canning shale seems to overstep underlying units on the southern Sverdrup Basin margin, apparently resting directly on the Triassic at East Kitson River, as suggested by Tozer and Thorsteinsson (1964). The probable Toarcian shales are thicker (70–120 m) in the subsurface north of the outcrop belt on Melville and Prince Patrick islands, toward the basin centre, than they are in their surface exposures (20–25 m). The basal Intrepid Inlet Member of the Jameson Bay Formation is also present in the subsurface (Depot Island C-44, Drake Point D-68, North Sabine H-49, Jameson Bay C-31 wells; Embry, 1984, 1985, *this volume*).

Marie Heights, Melville Island

The lowest Jurassic rocks exposed in this area are 15 to 18 m of soft grey shale; these beds form extensive mudflats that lack significant concretions, interbeds of coarser clastic rocks, or fossils. The shales are thought to be Toarcian because of their lithology and stratigraphic position below fossiliferous Aalenian beds. Just to the north, in the Sandy Point L-46 well, Sinemurian and Pliensbachian beds are thought to be present below Toarcian shales (Embry, 1983b, *this volume*).

Above the lower grey shale is an interval of about 7 m of shale that weathers with abundant rusty-red ferruginous siltstone rubble, but which otherwise is similar to the grey shale. The ammonites *Pseudolioceras compactile* or *P. spitsbergense,* and *Peronoceras,* and rare bivalves (GSC loc. C-127417) can be found in the rubble, but belemnites are apparently absent. Approximately 9 m of overlying mudstone with concretionary siltstone layers are unfossiliferous.

Head of Marie Bay, Melville Island

A 20 to 25 m thick, poorly exposed, argillaceous interval overlies the Pliensbachian *Amaltheus*-bearing concretionary unit at the head of Marie Bay, which was described earlier. There is little outcrop, and the unit is characterized by extensive fields of soft, grey mud or silt with rubble from occasional very thin bands of buff-weathering, platy, fine grained sandstone and rusty-red concretionary siltstone. Clay ironstone concretions, 2.5 cm thick, irregularly pancake shaped and weathering bright orange-red, occur in the lower part, and are characteristic of Toarcian beds regionally.

Small mounds, as large as 2 m high and 3 m across and comprising dark red chert-pebble conglomerate, with pebbles as large as 1 cm across, occur rarely on the muddy surface formed by this unit, and may represent scattered submarine channel deposits on the Toarcian shelf.

The lowest belemnites (GSC loc. C-107899) and a few bivalves occur high in the shale unit at an uncertain, probably small distance below its top. The top is designated here at a fossiliferous, buff and rusty siltstone and fine grained sandstone bed or thin series of beds which, although also soft and rubble-forming, appear as light coloured, low, round-topped knobs on aerial photographs. The fossils in these beds include a rich variety of belemnites, bivalves — notably *Oxytoma,* "*Propeamussium*", and oysters — the ammonites *Pseudolioceras spitsbergense* and *P.* sp. cf. *P. compactile,* decapod crustacean fragments, and plesiosaur or ichthyosaur vertebrae (GSC locs. C-107900, C-127401, C-127403). A varied and abundant trace fossil fauna is characterized by abundant *Rhizocorallium* and a few *Diplocraterion.*

East Kitson River, Melville Island (Loc. 5, Fig. 1)

Toarcian shales of the Cape Canning Member (Jameson Bay Formation; formerly Lower Wilkie Point Formation) are thought to lie directly on Bjorne sandstone at East Kitson River (Fig. 5). The lowest 6 m of the Jurassic consists of light grey, mud-forming shale with the characteristic pancake-like, 2.5 to 3 m thick, bright rusty orange-red-weathering concretions. Above the lowest shale are 2 m of dark chocolate brown, poorly sorted, gritty, crossbedded sandstone that form dark brown mounds on the land surface.

Overlying the shale–sandstone unit is light grey, mainly unconsolidated fine grained sand, 9 m thick, with large-scale crossbedding. Locally cemented pockets lead to an irregular, mainly recessive-weathering surface. A 1.5 m thick silt or mud unit (described below under "Aalenian") appears to lie upon the underlying sand with a marked angular discordance.

Figure 5. Bluff-forming Triassic Bjorne sandstone in foreground, overlain by probable Toarcian Jameson Bay Formation (Lower Wilkie Point Group) shale, forming muddy slope in mid-ground. Upper slopes in background are mainly Aalenian sandstone and siltstone (Sandy Point Formation). East Kitson River, Melville Island (ISPG photo no. 2578-6).

Sabine Peninsula, Melville Island

Recessive, poorly exposed shaly sandstone-siltstone occurs between the thin basal Jurassic conglomerate below, and sandstone with Aalenian *Pseudolioceras mclintocki* above in this area, and probably contains Toarcian strata at the base (see Embry, *this volume*).

Prince Patrick Island

The Toarcian rocks of Prince Patrick Island were described by Tozer and Thorsteinsson (1964). They noted a basal conglomerate and overlying poorly exposed sand and sandstone with Lower Toarcian *Dactylioceras commune,* which was illustrated by Frebold (1957, Pl. I, GSC locs. 24644, C-130993). Other Toarcian fossils, occurring in phosphatic nodules less than 30 m above the base of the Jurassic, were mentioned. These beds were included in the Wilkie Point Formation by Tozer and Thorsteinsson (1964). Additional collections of *Dactylioceras* are from the area immediately surrounding Mould Bay weather station (GSC locs. 23008, 23368, 24643, 24650, 24651, 24652). Middle, or possibly Upper, Toarcian beds, indicated by the presence of *Peronoceras* and *Pseudolioceras*, occur at several localities on Prince Patrick Island (GSC locs. 23002, 24641, 24642, 24645, 24649, 70390, 72596, C-63258). Many new occurrences were studied in 1987 by A.F. Embry, J.C. Harrison, and me, including one southeast of Manson Point where lowermost Toarcian, or uppermost Pliensbachian(?) beds with *Protogrammoceras*(?) gradationally underlie those with *Dactylioceras* at what must be very close to the base of the Jurassic section in that area.

Borden and Mackenzie King islands

The Toarcian and Middle Jurassic beds of Borden and Mackenzie King islands have not been studied by me. These beds form a poorly exposed succession of shale and siltstone, exceeding 400 m in thickness, that contains Toarcian, Aalenian, and possibly younger ammonites. The lower contact, with what may be Upper Pliensbachian sandstone, is apparently conformable on Borden Island (Rahmani and Tan, 1978). Frebold (*in* Tozer and Thorsteinsson, 1964, p. 134) identified *Harpoceras* sp. cf. *H. exaratum* and *Dactylioceras commune* from near the base of the argillaceous strata on southern Borden Island (GSC loc. 35342) and other occurrences of *Dactylioceras* are known from the same area (e.g., GSC loc. 72647). These fossils indicate an Early Toarcian age. Middle, or possibly Upper, Toarcian ammonites from southern Borden Island include the widespread Arctic *Pseudolioceras-Peronoceras* association (GSC loc. 72648). In one section studied by Petropar (Elf) geologists in 1966, these ammonites were confirmed to occur about 20 m stratigraphically above *Dactylioceras,* and about 30 m above the base of the shale unit. The shale and siltstone are now assigned to the Jameson Bay Formation of the Wilkie Point Group (Embry, 1984), and they appear to exceed 45 m in thickness at some places in southern Borden Island. Toward the east in southern Borden Island, Early and even Middle Toarcian beds may be absent, so that shale with *Pseudolioceras* apparently rests directly on what may be Pliensbachian sandstone (GSC locs. 72640, 72645).

On Mackenzie King Island, at least 50 m of shale of probable Toarcian age are exposed below sandstone (Sandy Point Formation) with probable Aalenian *Pseudolioceras* species. Toarcian ammonites from Mackenzie King Island include probable Middle (or possibly Upper) Toarcian *Pseudolioceras* and *Peronoceras* (GSC loc. C-57501).

Aalenian

Aalenian beds are widespread and well known throughout the Canadian Arctic. They are mainly siltstone in the lower part (upper Jameson Bay Formation) and sandstone with shale and siltstone interbeds in the upper part (lower beds of the Sandy Point Formation) (Embry, 1984). They appear to rest abruptly and perhaps even disconformably on Toarcian strata throughout the western Queen Elizabeth Islands. The Sandy Point Formation oversteps underlying beds and lies directly on Devonian strata in the subsurface of Eglinton Island (Embry, 1984; Eglinton P-24 well), south of the margin of the Sverdrup Basin. Upper parts of the Sandy Point Formation, which are more thickly developed in the subsurface to the north, are absent in the outcrops described in this report, below the sub-Bajocian unconformity.

The Aalenian beds in the outcrop belt of Melville Island are usually about 25 to 40 m thick. *Leioceras opalinum* (Reinecke) and *Pseudolioceras mclintocki* (Haughton) are the most commonly identified ammonites at many localities throughout the western Sverdrup Basin. Previously described specimens include Early Aalenian *L. opalinum* from near Wilkie Point, Prince Patrick Island (Frebold, 1957, p. 6, Pl. IV, figs. 1-6, Pl. V, figs. 1, 2) and northwestern Melville Island (Frebold, 1960, Pl. VI, figs. 1-4, Pl. VII, fig. 1). Many of the localities at which *L. opalinum* has been described contain very large specimens, approaching 25 cm in diameter, unlike *L. opalinum* of Europe and not necessarily indicating the *L. opalinum* zone. *Pseudolioceras mclintocki* characterizes equivalent and younger beds, and has been reported from Prince Patrick Island (Frebold, 1957, Pl. V, figs. 3, 4), Mackenzie King Island (Frebold, 1960, Pl. VIII, figs. 1-9; Pl. IX, figs. 2-4); and *P.* sp. cf. *P. mclintocki* from Mackenzie Island (Frebold, 1960, Pl. IX, fig. 1, Pl. X, fig. 1, Pl. XI, fig. 3, Pl. XII, fig. 1) and northwestern Melville Island (Frebold, 1960, Pl. XI, figs. 1, 2). *Leioceras opalinum* and *P. mclintocki* were found in the Mould Bay area of Prince Patrick Island (Tozer and Thorsteinsson, 1964, p. 129). In northern Yukon, *P. mclintocki* is associated with *Erycitoides howelli* (White), indicating its range into the *E. howelli* zone of the Upper Aalenian (Poulton, 1991). The fragment from Prince Patrick Island figured by Imlay (1955, p. 75, Pl. 11, figs. 1-3) as *Ludwigella*(?) sp. cf. *L. rudis* (Buckman) remains undetermined specifically and generically, but resembles some Toarcian *Pseudolioceras* species. The decapod crustacean *Glyphaea robusta* Feldmann and McPherson (1980) has been described from Aalenian beds from Intrepid Inlet (GSC locs. C-76307, C-76329).

Head of Marie Bay, Melville Island (Loc. 4, Fig. 1)

Lower Aalenian fossils occur in a unit of poorly consolidated silt and sand 6 to 6.5 m thick that is bluff-forming because of abundant, hard concretionary bands in its upper part (Fig. 6). The lower 3 m, with thin, irregular, dark rusty red-weathering concretionary bands is unconsolidated and soft, and contains well preserved bivalves *Oxytoma* and *Inoceramus* (part of GSC loc. C-127407). In the upper 3 to 3.5 m the concretionary bands are harder, dusky red and blocky and contain abundant fossils in some places, including the ammonites *Leioceras opalinum* and *Pseudolioceras*(?) among others (GSC loc. C-127408), and a rich variety of trace fossils, notably *Rhizocorallium* and a few *Diplocraterion*. Fossils collected below the bluffs are largely the same as those collected in place, which suggests that most have rolled down from above. However, oysters and belemnites (representing at least three genera) are more abundant in the rubble than in the bluffs, so that the vague banding in the rubble and the differences in ammonites from one locality to another may indicate that fossiliferous beds underlie the rubble below the bluffs and contribute some fossils to it.

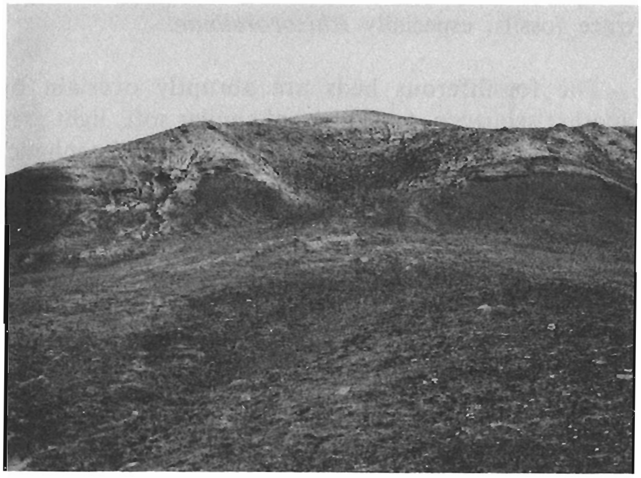

Figure 6. *Aalenian mudstone and siltstone (upper Jameson Bay Formation) in foreground, and siltstone and sandstone (lower Sandy Point Formation) forming bluffy slopes in background; north side of Marie Bay near its head, Melville Island (ISPG photo no. 2578-9).*

Above this bluff-forming concretionary unit lies 3 to 5 m of poorly exposed, soft, unconsolidated, slightly fossiliferous silt or mud, capped by a 0.3 to 0.6 m-thick, dark, rusty red, concretionary band with a few poorly preserved belemnites. This unit forms the top of a small hill.

The precise stratigraphic relationships of the Toarcian shales described previously and the Lower Aalenian rocks described here are not clear. There may be 10 to 15 m of unexposed shale between the two, not taken into account in the present description.

Marie Heights, Melville Island (Loc. 3, Fig. 1)

Abruptly overlying the Toarcian beds, perhaps disconformably, is a 6.5 m thick unit of soft grey shale, in the upper two thirds of which are abundant subspherical, rod- or irregularly shaped phosphatic and siliceous(?) concretions as large as 5 cm in diameter and containing vertebrae and other bone fragments.

Similar beds overlie the vertebrae-bearing shale but are red-weathering due to the presence of ferruginous concretions. The upper shales form a unit about 6 m thick and contain some dark red-weathering to dark grey siltstone, fine grained sandstone, and chert grit interbeds, as well as richly fossiliferous concretions reaching 15 cm in diameter. The fossils are dominated by *Leioceras opalinum* and *Pseudolioceras,* bivalves, decapod crustaceans, "*Pentacrinus*", belemnites, and trace fossils, especially *Rhizocorallium.*

The fossiliferous beds are abruptly overlain by another sequence, 6 m thick, of similar soft, light grey shale in which the concretions are grey and phosphatic. Only a few ammonites, possibly *Leioceras,* occur (GSC loc. C-127421) as does some fossil wood. The next overlying 4.5 m of similar shale is without concretions and contains only a reduced quantity of rusty siltstone interbeds. This shale is capped by an additional 1.5 m of concretionary shale and siltstone that forms a rusty red-brown-weathering layer, apparently unfossiliferous.

The succeeding concretionary shale, 10 m thick, is unexposed; "*Pentacrinus*" was seen in the rubble.

Tozer and Thorsteinsson (1964) also listed *Leioceras opalinum* and *Pseudolioceras mclintocki* from this area (GSC locs. 37018, 35314, 35348).

Strata that weather to unconsolidated mud or silt in the 9 to 12 m above the Lower Aalenian concretionary beds are entirely unexposed.

East Kitson River, Melville Island (Loc. 5, Fig. 1; Figs. 7, 8)

At the East Kitson River locality (loc. 5, fig. 1) the base of the Aalenian is placed somewhat arbitrarily at an apparent angular discordance in a poorly exposed silt interval. One metre of unconsolidated siltstone or mudstone with two thin (2.5 to 5 cm) rusty red-brown-weathering concretionary siltstone layers 8 cm

***Figure** 7. Aalenian mudstone and siltstone in foreground, grading up to sandstone and siltstone at the prominent marker just below the skyline; small hill on skyline is Lower Callovian sandstone; East Kitson River, Melville Island (ISPG photo no. 2578-3).*

***Figure** 8. Same sequence and location as in Figure 7, 0.5 km downstream and across East Kitson River. Left arrow indicates locality shown in detail in Figures 13, 14; right arrow shows base of shale-siltstone-sandstone sequence of Early Callovian age (ISPG photo no. 2578-13).*

apart and some broken-up phosphate nodules 2.5 cm across appears to rest discordantly on 9 m of unconsolidated sand with very large-scale crossbedding (as described above under "Toarcian"). Similar poorly exposed mud or silt occupies the next 17 m of the succession, and thin, rusty red-brown concretionary layers increase in abundance upward within it, but are absent in the highest 15 m of exposed beds. Lower Aalenian ammonites *Leioceras opalinum* and *Pseudolioceras* occur in the upper part of the unit (GSC loc. C-127425), as do a variety of bivalves, some belemnites, and fossil wood.

Lower Aalenian beds with abundant *Leioceras opalinum* occur at other localities, where, however, their contact with underlying strata is not exposed. The Lower Aalenian beds form a succession of light grey, becoming green-grey upward, variably consolidated silt or siltstone. Their thickness is uncertain, but it is at least 25 m. The siltstones are strongly burrowed, with indistinct, thin relict bedding. Abundant scattered small pyrite or marcasite nodules and variably continuous concretionary ironstone layers as thick as 0.25 m are present. Scattered throughout the siltstones are large *Leioceras opalinum,* other ammonites and some bivalves and fossil wood (GSC locs. C-127429, C-127430, C-127432). The siltstones are capped by bluff-forming sandstone that varies from 1 to 3 m in thickness. The sandstone is fine to medium grained, strongly burrowed and weathers dusky red and brown. It contains small pyrite nodules and subspherical pebbles or concretions, reaching 2.5 cm in diameter, that are oolitic or pelletal in general aspect; the weathered state of these forms precludes firm identification or any interpretation of their origin. A rich fossil assemblage contains *L. opalinum* and other ammonites, as well as *Inoceramus*(?), oysters, various trace fossils, including *Rhizocorallium,* and decapod crustacean fragments in small concretions (GSC locs. C-127421, C-127426, C-127427, C-127428).

Tozer and Thorsteinsson (1964) also reported *Leioceras opalinum* from this area (GSC loc. 37019).

Depot Island-Cape Grassy area, Melville Island

Tozer and Thorsteinsson (1964) reported the presence of *Pseudolioceras* sp. cf. *P. mclintocki* in the Wilkie Point Group at a locality on Melville Island 16 km south of Depot Island (T & T loc. 103; GSC loc. 35344), and recent collections from the Depot Island area made by J.C. Harrison contain *P. mclintocki* (GSC locs. C-128844, C-128845, C-128846).

Sabine Peninsula, Melville Island

Tozer and Thorsteinsson (1964) reported a 15 cm thick, undated basal Jurassic conglomerate resting directly on light grey Bjorne Formation sandstone at the south end of Sabine Peninsula. There are two thin conglomeratic beds in the 7 to 8 m immediately above the Bjorne, and the lowest of these may indicate the presence of a thin remnant of Schei Point strata. Overlying poorly exposed rubble with ironstone and glauconitic phosphatic nodules has yielded *Pseudolioceras,* crinoids, and belemnites (Frebold, 1960, p. 8; Tozer and Thorsteinsson, 1964, p. 133, 134). Petropar (Elf) geologists, in 1966, found *Pseudolioceras mclintocki* in concretionary beds about 25 and 70 m above the top of the basal Jurassic conglomeratic unit, in a poorly exposed, partly shaly sandstone and siltstone unit (GSC locs. 72571, 72572, 72573); and A.F. Embry, in 1978, found the same species from 61 to 87 m above the base of the Jurassic beds (GSC locs. C-80372, C-80380, C-80383).

Southeastern Prince Patrick Island

Aalenian beds at many localities along strike from the type section of the Wilkie Point Group on the east side of Intrepid Inlet yield a rich fauna of ammonites, including *Leioceras opalinum* and *Pseudolioceras mclintocki,* bivalves, and belemnites.

The following description supplements that of Tozer and Thorsteinsson (1964, p. 131-132), who reported *L. opalinum* in sandstone some 30 m above a sandstone bed containing *P. mclintocki.* The lowest outcrop in the section is a bed of Toarcian ferruginous, fine grained sandstone, up to 0.6 m in thickness, that forms a small bench on the slopes. The 0.15 m of soft rubble above it comprises a condensed basal transgressive deposit of strongly and finely burrowed "glauconitic" pelletal strata; this bed is characterized by phosphate nodules as large as 2.5 cm across, and abundant and varied fossils including *Pseudolioceras,* belemnites, fossil wood, and bone fragments (GSC loc. C-76304) and *Leioceras*(?).

Soft and recessive shale and argillaceous silt or fine grained sand form an overlying, poorly exposed unit, 31 m thick.

Light grey, fine grained sandstone, 2.5 m thick, lies gradationally above the recessive unit. The sandstone is partly "glauconitic", and is bioturbated with only indistinct relict fine bedding remaining. *Rhizocorallium* is conspicuous locally, and limonitic concretions reaching 2.5 cm by 7.5 cm are characteristic. Fossils include *Leioceras, Pseudolioceras, Oxytoma, Inoceramus, Camptonectes*, and decapod crustaceans (GSC loc. C-76307). This unit forms the most prominent bluffs in the area, the lowest of the bluffs near the tops of the hills, and is abruptly overlain by *Arkelloceras*-bearing Bajocian strata (Fig. 9). Other localities were studied in 1987. In particular, *Pseudolioceras mclintocki*(?) occurs above beds with Toarcian ammonites in sandstones capping the hills west of Disappointment Point.

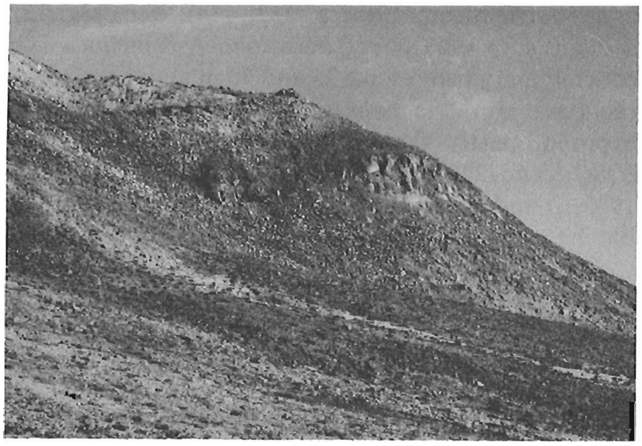

Figure 9. Aalenian upper Jameson Bay silt and mud (lower slopes, right) and lower Sandy Point sandstone bluffs (middle of photo), overlain by Lower Bajocian "Arkelloceras beds" (upper left); east side of Intrepid Inlet, Prince Patrick Island (ISPG photo no. 2578-25).

Mackenzie King Island

Aalenian beds are documented on Mackenzie King Island by the presence of *Pseudolioceras mclintocki, P.*(?) sp. indet., bivalves, and brachiopods (Frebold, 1960, p. 8; Tozer and Thorsteinsson, 1964, p. 135; GSC locs. 35312, 35313, 35315). *Leioceras opalinum* may be present in some of these collections as well. *Pseudolioceras mclintocki,* or a similar species, was found throughout a sandstone unit (Sandy Point Formation) about 125 m thick, between shales in a section studied in 1966 by Petropar (Elf) geologists (GSC locs. 70377, 70379, 70380), and many other occurrences are known.

Early Bajocian

The Early Bajocian beds are mainly glauconitic sandstone, siltstone, and shale that are thought to represent basal transgressive deposits of the McConnell Island Formation (Embry, *this volume*). *Arkelloceras mclearni* Frebold and *A. tozeri* Frebold are treated here as Early Bajocian in age, following Westermann (1964) and Poulton (1978), although their correlation with the European Bajocian ammonite zones is still not completely clear. *Arkelloceras mclearni, A. tozeri, Zetoceras thorsteinssoni* Frebold, and *Inoceramus lucifer* Eichwald have been described from Prince Patrick Island (Frebold, 1957, 1961; Tozer and Thorsteinsson, 1964; GSC locs. 24661, 35324), as has the decapod crustacean *Glyphaea robusta* Feldmann and McPherson (1980) (GSC loc. C-11494). Collections of *Arkelloceras* from the east side of Intrepid Inlet, Prince Patrick Island, are very numerous and come from north and south of the type section of the Wilkie Point Formation from about 18 to 19 km north of Cape Canning.

Marie Heights, Melville Island (Loc. 3, Fig. 1)

A prominent, banded sandstone about 8 m thick overlies the Aalenian beds. The sandstone is dark grey, fine to medium grained, argillaceous, and strongly bioturbated on a small scale. It weathers dark dusky red-brown; 0.6 m thick, harder, blocky fracturing bands at the top, middle, and base give it a dark, banded appearance when viewed from a distance (Fig. 10). The base appears to be sharp. The sandstone contains abundant fossil wood and bone fragments, and at its base a few bivalves such as *Oxytoma, Pleuromya,* and *Inoceramus*(?). Subspherical and oblong, grey weathering, phosphatic nodules 2.5 to 5 cm in diameter are also present.

About 10 m of similar argillaceous, fine grained sandstone and siltstone occur above the banded sandstone unit, but they are monotonous and lack both hard bands and fossils. The unfossiliferous unit forms smooth slopes below a more competent, cuesta-forming upper bed (Figs. 10, 11). This unit is partly pelletal, the pellets consisting of "glauconite". The uppermost 1 m weathers with a whitish powdery coating.

A specimen of *Arkelloceras* found loose below outcrops of the two sandstone units at Marie Heights is assumed to have rolled down from the sandstone beds (GSC loc. C-127422), and together they are probably equivalent to the *Arkelloceras*-bearing sandstones on Prince Patrick Island. Tozer and Thorsteinsson (1964) also reported *Arkelloceras mclearni* in talus from this area (GSC loc. 37020).

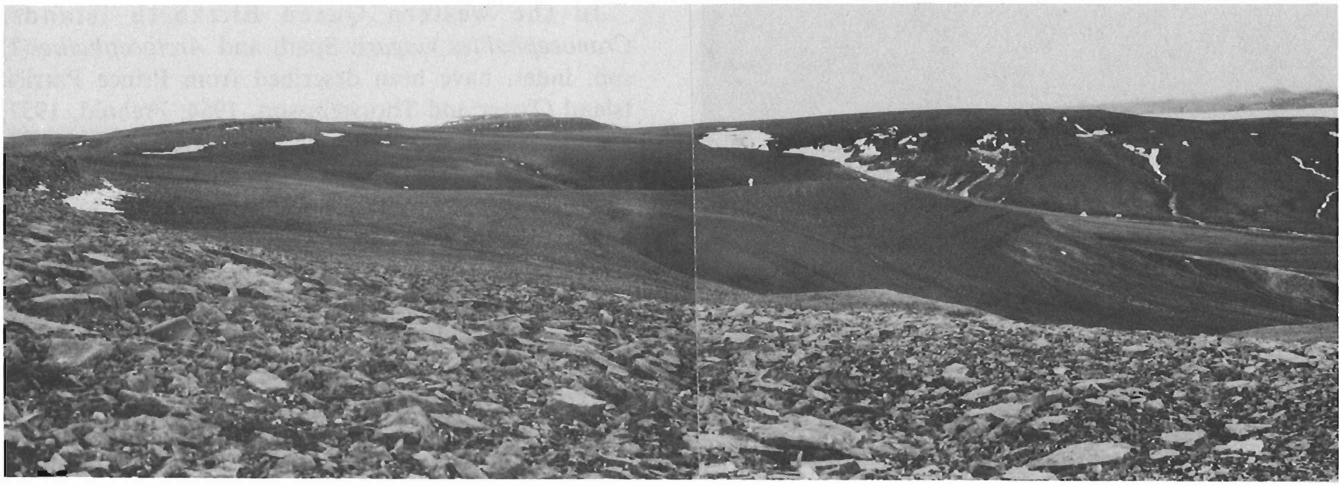

Figure 10. *Aalenian upper Jameson Bay mud and silt (lower slopes, right) to (?)Upper Bathonian sandstone (bluffs just below skyline at left, and rubble in foreground) sequence; Marie Heights, northwestern Melville Island. The banded wood- and bone-bearing dark sandstone is seen in the middle part of the slope right of centre and the "glauconitic", presumed "**Arkelloceras bed**" equivalent forms the broad terrace across the centre of the photograph, in the middle ground (ISPG photo nos. 2578-5, 2578-7).*

Figure 11. *Same sequence and locality as Figure 10, from below (ISPG photo no. 2578-4).*

West side of Intrepid Inlet, Prince Patrick Island

Rarely exposed *Arkelloceras* beds north of Salmon Point on the west side of Intrepid Inlet are thinner than those on the east side. They appear to directly overlie Triassic Schei Point strata at some places, but there are 10 to 13 m of Aalenian beds at other localities. Only about 6 m of sandstone are exposed, but at least two metres of the overlying, poorly consolidated, fine clastics are assumed to be of the same unit. The outcropping sandstone beds are resistant, ferruginous, very fine to fine grained, red-weathering, and contain abundant *Inoceramus*. Loose specimens of *Inoceramus, Arkelloceras*, and belemnites in the rubble below the exposed sandstone outcrop are assumed to come from poorly exposed beds below the outcrop.

East side of Intrepid Inlet, Prince Patrick Island (Loc. 2, Fig. 1)

The following description supplements the brief one given by Tozer and Thorsteinsson (1964).

The bluff-forming Aalenian sandstone containing *Leioceras* is overlain by 18.5 m of soft, recessive, unconsolidated, "glauconitic" silt or fine grained sand in which harder, rusty concretionary beds and subspherical phosphatic nodules are distributed (Fig. 12). Two metres above the base of the silty unit is a 0.6 m thick bed of harder, ferruginous fine grained sandstone. Abundant bivalves — *Inoceramus, Camptonectes,* the ammonite *Arkelloceras,* and belemnites (GSC loc. C-76308) — as well as round phosphatic nodules loose on the upper surface of this ferruginous bed probably come from the upper part of the unit. Eight and half metres above the base of this unit, 1 to 1.2 m of harder, resistant, fine grained sandstone, profusely bioturbated — particularly at the top — suggest a period of stillstand. The sandstone bed contains *Inoceramus,* pectinids, *Arkelloceras* (GSC locs. C-76309, C-76325) and, characteristically, *Rhizocorallium.*

Figure 12. Lower Bajocian lower McConnell Island sandstone, sand, and silt (left) overlying Aalenian bluff-forming lower Sandy Point sandstone (right); east side of Intrepid Inlet, Prince Patrick Island (ISPG photo no. 2578-14).

The succession in this area is capped by a unit, varying up to 2 m in thickness, of hard, resistant, dark red, fine grained glauconitic sandstone and siltstone that contains many phosphate nodules up to 5 cm across. *Inoceramus* and *Arkelloceras* are abundant within and just above this sandstone, and other fossils include decapod crustacean fragments, *Belemnoteuthis* phragmocones, and ichthyosaur bone fragments. Broad benches in this region are formed in unconsolidated silt or fine sand at a level about 3 m above the hard red sandstone. Subspherical concretions as large as 15 cm across contain *Inoceramus,* decapod crustaceans, bone and wood fragments, and belemnites (GSC loc. C-76329) in the upper part of the section. Here, as at Marie Bay on Melville Island, the brittle, hard red beds of the "*Arkelloceras* beds" weather with characteristic, white powdery fracture surfaces.

Late Bajocian and Early or Middle Bathonian

Post-Early Bajocian, Middle Jurassic time in the Canadian Arctic is well documented regionally by the presence of a sequence of ammonites of the family Cardioceratidae — namely species of *Cranocephalites* in the Late Bajocian or Early Bathonian, *Arctocephalites* in the Early and/or Middle Bathonian, *Arcticoceras* and early forms of *Cadoceras* in the Late Bathonian, and *Cadoceras* in the Callovian.

In the western Queen Elizabeth Islands, *Cranocephalites vulgaris* Spath and *Arctocephalites*(?) spp. indet. have been described from Prince Patrick Island (Tozer and Thorsteinsson, 1964; Frebold, 1957, Pl. VII, fig. 3, Pl. VIII, figs. 2, 3, GSC locs. 24664, 24665, 24667). They are perhaps all the same species, although some specimens are indeterminable, and they indicate a Late Bajocian or Early Bathonian age. These fossils came from 4.8 km south of Mould Bay weather station, from a thin sandstone unit with dusky red patches at the top of a succession that Tozer and Thorsteinsson (1964) correlated with a similar, *Arkelloceras*-bearing sequence on the east side of Intrepid Inlet. Collections made in 1987 confirm the variability of the cardioceratids from this locality.

The section just south of Hiccles Cove in the type area of the Wilkie Point Formation on the east side of Intrepid Inlet was restudied with A.F. Embry in 1987. A hard, ledge-forming ironstone band occurs 31 m above the base of the *Arkelloceras* beds, at the top of a variably lithified, concretionary sand sequence. It is overlain apparently disconformably by shale, and contains *Cranocephalites,* large *Inoceramus*, and belemnites.

All the Bajocian through Lower Bathonian rocks are included in the middle part of the McConnell Island Formation.

Mackenzie King Island

Tozer and Thorsteinsson (1964) suggested that, on Mackenzie King Island, Upper Bajocian through Callovian beds are missing below an unconformity that underlies Oxfordian-Kimmeridgian shales, and indeed diagnostic fossils of these ages are not present in the collections available from that island. However, Embry (1985) has identified McConnell Island strata in the Cape Norem A-80 well on Mackenzie King Island, as well as in outcrop and in the Wilkens E-60 well.

Late Bathonian

Tozer and Thorsteinsson (1964, p. 130) noted the differentiation of their "upper Wilkie Point beds" near Salmon Point into a lower unit of yellow sand with red hard bands and fossil wood, and an overlying unit of castellated soft, white, fine grained sand. They mentioned a 1 m thick coal seam near the top of the yellow unit. In their section (ibid., p. 131) about 8 km southeast of Hiccles Cove on the east side of Intrepid Inlet they recognized the same two units, 7 and 8 respectively, the former with *Arcticoceras ishmae* (Keyserling), a Late Bathonian ammonite (Poulton, 1987).

Embry (1984) erected the Hiccles Cove Formation for these units and also considered it to include basin margin sandstones as old as Bajocian, equivalent to his McConnell Island shale and siltstone formation (op. cit.). The type section of the Hiccles Cove Formation, designated in the Elf Jameson Bay C-31 well, also included probably younger strata in its upper part (e.g., Embry, 1986).

These widespread beds, together with the gradationally underlying shale (McConnell Island Formation) that overlies the *Cranocephalites*-bearing sandstone near Hiccles Cove, contain *Arcticoceras ishmae* at several localities.

Sproule Peninsula, Melville Island

Sandstone with ironstone concretions, which is distinguished from overlying sandstone by its rusty yellow appearance from a distance, outcrops at many localities throughout northern Sproule Peninsula. These strata have not been dated on Melville Island, but are homotaxial with *Arcticoceras*-bearing strata on Prince Patrick Island. They appear to be absent below the sub-Callovian unconformity at East Kitson River and may be represented in the uppermost sandstones capping the hills at Marie Heights.

Overlying the probable Lower Bajocian sandstone at Marie Heights abruptly, and presumably disconformably, is about 0.5 m of light grey, soft mud containing rare belemnites, and rubble indicating interbedded sandstone and siltstone. The sandstone-siltstone beds are light brown, buff-weathering, partly bioturbated, and partly finely laminated. The next 1.5 to 2 m is an unexposed, recessive shale or silt unit.

A resistant sandstone unit 10 m thick forms bluffs at the tops of hills in this area (Figs. 10, 11). The sandstone is fine grained, very light grey, variably finely laminated, thick bedded (1-1.5 m) or massive and has a few ripples, poorly defined crossbeds, trails, and rare belemnites, scaphopods(?) and *Inoceramus* shells. This "*Inoceramus* sandstone" weathers buff and either blocky or spheroidal. A black, shaly layer 15 cm thick separates the sandstone into upper and lower halves; there are thinner shaly seams in the upper half. This resistant unit was early recognized as a useful marker by Tozer and Thorsteinsson (1964). The shale and sandstone succession here may represent either the Upper Bathonian or Lower Callovian sequence, but since the former outcrop downdip just to the north, they are tentatively identified with it and assumed to be part of the Upper Bathonian sequence.

The "*Inoceramus* sandstone" is capped by 0.6 m of rubble-producing dusky red weathering concretionary siltstone that presumably signifies transgression and deposition of the overlying sequence.

Arcticoceras ishmae was collected from Melville Island by D.G. Wilson (GSC loc. C-63346), but stratigraphic details are unknown.

Southeastern Prince Patrick Island

Arcticoceras ishmae (Keyerling) from Prince Patrick Island (Frebold, 1961), and other species identified but not described by Frebold, were listed by Tozer and Thorsteinsson (1964). *Arcticoceras ishmae* was reported from about 30 m above Lower Bajocian *Arkelloceras*-bearing beds on the east side of Intrepid Inlet. The strata consist of medium grained, orange-weathering sandstone now assigned to the Hiccles Cove Formation.

In the type area of the Wilkie Point Formation south of Hiccles Cove on the east side of Intrepid Inlet, *A. ishmae* was found in a concretionary ironstone band 28 m above the ironstone containing *Cranocephalites,* immediately below the unconformable contact with the Tertiary Beaufort Formation. The sequence above the *Cranocephalites*-bearing ironstone consists of 18.75 m of shale with an abrupt base, containing many large belemnites, and overlain by 9 m of fine to medium grained, rusty white sandstone with large-scale, low angle crossbedding. At the top of this sandstone, the *Arcticoceras*-bearing bed occurs. Similar beds with *Arcticoceras, Inoceramus*, and belemnites are widespread in southeastern Prince Patrick Island.

Early Callovian

The distinctive upper, castellated white sandstone of the original upper Wilkie Point beds (Tozer and Thorsteinsson, 1964, p. 130, 131, Unit 8) was included in the Hiccles Formation (Embry, 1984). It has been traced over much of southeastern Prince Patrick Island, northern Sproule Peninsula, and the Depot Island vicinity of Melville Island (Embry, *this volume*). The unit was thought to be nonmarine originally, but *Cadoceras*, of probable Early Callovian age, and

Inoceramus occur in lower sandstone of this unit. The presence of Callovian dinoflagellates within the unit, and the assortment of burrows and crossbedding, further suggest shallow marine or shoreline depositional environments (Embry, *this volume*). An underlying thin shale and basal transgressive oolite at East Kitson River, where the Lower Callovian has overstepped Bathonian and Bajocian beds to lie on the Aalenian, belong to the same package. The shale in the lower part of the Callovian sequence is irregular in its distribution.

East Kitson River, Melville Island (Loc. 5, Fig. 1)

The Aalenian beds are overlain by deeply weathered, oolitic or pelletal, possibly glauconitic sandstone and siltstone about 50 cm thick (Figs. 13, 14). Variation in thickness of the unit and the discontinuity of an upper bed within it suggest that some erosion may have been associated with, or immediately followed, deposition of these beds. As a whole, the unit suggests a transgressive, condensed deposit or one associated with an ancient stillstand or hiatal surface. This undated unit may be the basal transgressive unit of the Lower Callovian sequence directly above it.

The 50 cm thick pelletal sandstone and siltstone unit consists of four parts. The basal 2.5 cm is a rusty, rubbly ironstone. This is overlain by a phosphate-nodule conglomerate, 22 cm thick. The nodules are up to 5 cm across, are irregularly shaped, and contain fragments of ammonites and bivalves, generally not similar to those of the underlying bed. The nodules probably are remnants of a unit otherwise not preserved at this locality (GSC loc. C-127431). The reworked phosphate nodules lie in a matrix of poorly preserved oolitic or pelletal, "glauconitic" ironstone. An irregular laminated unit follows, varying from 10 to 20 cm in thickness, and consisting of dark rusty red, concretionary siltstone interbedded on a scale of 2.5 to 5 cm with white silt arranged in small domes

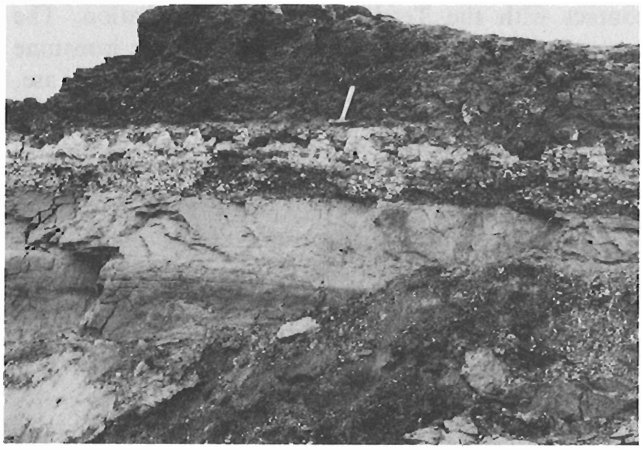

Figure 13. *Top of Aalenian lower Sandy Point sandstone (lower half of picture), overlain by 50 cm thick four-fold condensed unit, probably basal to Lower Callovian sequence (detail shown in Fig. 14), and by lower Callovian shale and siltstone (upper third of picture); East Kitson River, Melville Island (ISPG photo no. 2578-10).*

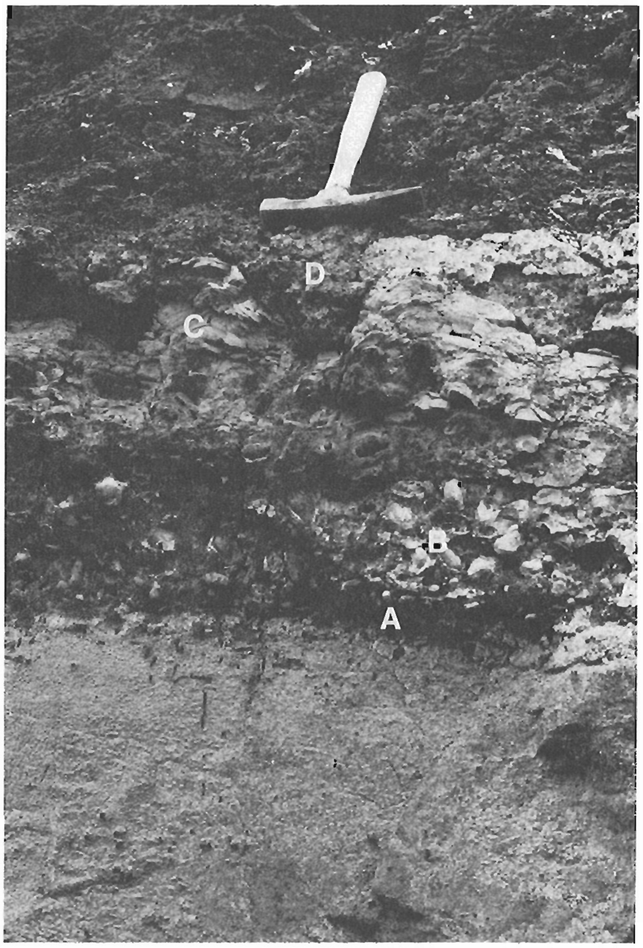

Figure 14. *Detail of the condensed beds that may be basal to the Lower Callovian sequence shown in Figure 13. Note upward sequence:* ***A.*** *basal rubbly ironstone lying on Aalenian sandstone unit;* ***B.*** *22 cm thick phosphate-nodule conglomerate;* ***C.*** *irregular stromatolitic unit, infilled finally by* ***D.*** *"glauconitic" pelletal or oolitic ironstone (ISPG photo no. 2578-2).*

characteristic of algal stromatolites. The maximum relief of the domes is 15 cm and their width and spacing vary from 10 to 25 cm. The highest 8 to 20 cm of this four-fold complex, condensed unit consists of poorly preserved glauconitic(?) pellets or oolites in a matrix of rusty red ironstone. Some poorly preserved and broken belemnites occur within it.

Rusty yellowish-brown-weathering siltstone, 5 to 10 cm thick, occurs in the lower part of what is generally a coarsening-upward sequence overlying the probable basal transgressive beds of the Callovian sequence. The siltstone is succeeded by 4.5 m of soft, recessive, dark grey-black shale and siltstone with scattered small marcasite nodules, containing *Cadoceras,* scattered medium to large belemnites [*Pachyteuthis*(?)], fragments of the bivalves *Meleagrinella, Oxytoma,* and *Inoceramus,* and fossil wood (Figs. 13, 14). The shale and siltstone is overlain, with an abrupt contact, by 9 m of similar but lighter coloured unconsolidated silt (Fig. 8), also containing scattered belemnites, and with some well sorted, fine grained sand or silt layers, rusty yellow-weathering and reaching 10 cm in thickness.

The silt unit grades over a short interval into an overlying resistant sandstone (Hiccles Cove Formation), which varies from about 3.5 to 6 m in thickness. The sandstone is fine grained, light to medium grey, indistinctly bedded, and finely and strongly burrowed, with conspicuous *Rhizocorallium.* The sandstone beds form bluffs that cap the top of the east bank of Kitson River and the surrounding hills. Within the sandstone are large *Inoceramus* shells, *Pinna,* and other bivalves. One juvenile specimen of the ammonite *Cadoceras* was found (GSC loc. C-127434). Tozer and Thorsteinsson (1964) correlated this distinctive bed with the one at the top of the Marie Heights succession that is tentatively assigned to the underlying sequence in this report. In some places, the upper 1 to 1.5 m of this "*Inoceramus* sandstone" is exceptionally strongly burrowed, rusty, rubbly, and deeply weathered (Fig. 15), which, combined with the abrupt contact above it and lateral impersistence of the upper beds, suggests an erosion surface beneath a disconformity at the base of the overlying sequence.

Abruptly overlying the Middle Jurassic *Cadoceras*-bearing sandstone (Hiccles Cove Formation) (Fig. 15) is a silty unit about 10 m thick, which is divisible into three parts of about equal thickness. The top and bottom subunits, distinctly darker, are soft, argillaceous, poorly consolidated silt and mud, dark grey-black in colour and recessive-weathering. The lower subunit contains 0.6 m of light grey, finely laminated silt 1.5 m above its base, and the upper unit contains similar clean, silty laminae throughout. The middle interval is composed entirely of finely laminated, light grey silt. The contacts between the three subunits are sharp, and the basal contact of the upper subunit is marked by a rusty, crumbly layer of ironstone breccia 20 to 30 cm thick that contains minor amounts of fossil wood.

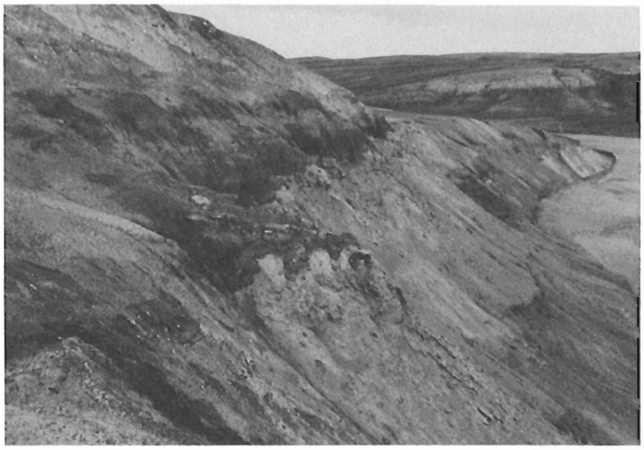

Figure 15. *Lower Callovian sandstone with rusty, rubbly upper surface (lower slopes, right), overlain by argillaceous silt and mud probably equivalent to the Ringnes Formation, then clean silt unit of Awingak Formation (upper slopes, left); East Kitson River, Melville Island (ISPG photo no. 2578-12).*

The silty unit is overlain, with an abrupt contact, by somewhat more consolidated siltstone or fine grained sandstone with large-scale, low-angle crossbed sets of beach or subaerial aspect. The siltstone–sandstone, 2.5 m thick, is truncated at its top by a reactivation surface (Fig. 16) with relief of 0.3 m, and is abruptly overlain by 20 cm of very soft carbonaceous black shale that grades up into 0.6 m of low-angle crossbedded, finely laminated silt with thin black shale partings. The strata above the *Cadoceras*-bearing sandstone are correlated with the Ringnes Formation. They yield Oxfordian to Berriasian dinoflagellates according to E.H. Davies (pers. comm.).

North of the East Kitson River section, halfway to Cape Grassy, only the upper castellated sands appear to be present, disconformably overlying yellow sands that may represent the Bathonian sequence. They contain reworked phosphate nodules at the base; in the lower 2 m abundant carbonaceous laminae contain Callovian dinoflagellates (Embry, *this volume*) and a plesiosaur skeleton (Russell, *this volume*).

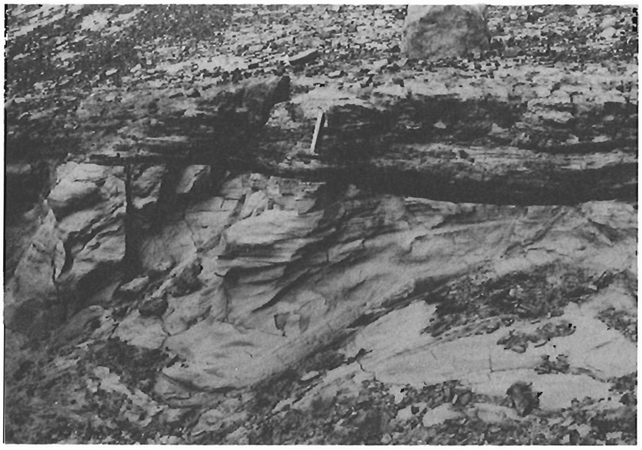

Figure 16. Reactivation surface in crossbedded uppermost Ringnes sandstone; East Kitson River, Melville Island (ISPG photo no. 2578-11).

Southeastern Prince Patrick Island (Loc. 1, Fig. 1)

The Upper Wilkie Point sandstone typically forms broad sand flats but is also well exposed in bluffs and hoodoos over broad areas of southeastern Prince Patrick Island. About 50 m of white sand are present west of Intrepid Inlet lying above similar sands that contain abundant ironstone layers and *Arcticoceras*, which are described in the previous section. The contact is apparently gradational in some places, sharp and perhaps disconformable in others. The sandstone is white or very light grey, fine grained, indistinctly bedded, and contains small pockets of coal. About an additional 20 m of somewhat darker, light grey sandstone overlie the white sand on the west side of Intrepid Inlet, but this darker sandstone is reduced to only about 5 m near Mould Bay weather station, farther west. The uppermost sandstone is banded, contains pockets and thin seams of coal, and some red ferruginous sandstone bands with occasional marine fossils, such as *Camptonectes* (GSC loc. C-76315).

Cadoceras and *Costacadoceras* of probable Early Callovian age have been found by Petropar (Elf) geologists at several horizons from about 100 to 150 m above the *Arkelloceras* beds on the east side of Intrepid Inlet (GSC locs. 70405, 70406, 70407, 70408, 72603). Some of the lower beds on Prince Patrick Island also contain large *Inoceramus*, and are distinguishable from similar, gradationally underlying Bathonian sandstones only on the basis of their stratigraphic position, and weathering colour as seen from a distance.

Where the Bathonian and Callovian sequences are apparently gradational, as over much of southeastern Prince Patrick Island, a particularly hard, ledge-forming ironstone with abundant *Inoceramus* may be the top of the Bathonian sequence and the unexposed, thin, recessive interval above it may be the basal Callovian shale.

Oxfordian to Volgian

Distinctive dark shales with rusty laminae and large concretions in western Sverdrup Basin contain *Amoeboceras* (described by Frebold, 1961 from Mackenzie King Island; GSC loc. 35346), *Cardioceras, Rasenia* (Frebold *in* Tan and Hills, 1978), and *Buchia concentrica* (Sowerby) in some localities. These shales were called the lower shale member of the Mould Bay Formation by Tozer and Thorsteinsson (1964), and the Ringnes Formation by Balkwill et al. (1977). Embry (1986) correlated the shales with the Hot Weather Member of the Awingak Formation, but now (Embry, *this volume*) also assigns them to the Ringnes. In the basinal parts of Sverdrup Basin, where they constitute the middle part of a continuous shale sequence, they are included in the Ringnes Member of the Mackenzie King Formation (Embry, 1985). The upper contact is gradational with the overlying marine sandstone (lower Mould Bay sand; Slidre Member of the Awingak Formation of Embry, 1986; Awingak Formation undiff., Embry, *this volume*).

Although the Ringnes shale (former "lower Mould Bay shale"), about 30 m thick, is exposed north of Marie Heights on northwestern Melville Island (Tozer and Thorsteinsson, 1964), it was not studied there by me. It was also reported (Tozer and Thorsteinsson, 1964, loc. 115; GSC loc. 37198), 20 m thick, south of Cape Grassy just north of the East Kitson River section studied by me, where the shale is apparently absent. Tozer and Thorsteinsson (1964) also described similar shale in a 30 m thick, more basinward development on Mackenzie King Island, where the presence of *Buchia* sp. cf. *B. fischeri* [i.e., *fischeriana* (d'Orbigny)] shows that it extends into the uppermost Jurassic.

The shale marks a regional transgressive event, in which shales overstep older units on the western basin margin. An equivalent thin sandstone west of Mould Bay included in the upper part of the upper Wilkie Point sandstone by Tan and Hills (1978) may be a basin-margin facies of the sequence. This event is about equivalent to that at the base of the regionally transgressive Husky Formation of Brooks-Mackenzie Basin and of the Upper Fernie Shale in western interior

Canada (Dixon, 1982; Poulton, 1984). The basal disconformity may also represent a considerable erosional event because diagnostic Middle and Upper Callovian fossils have not been found in western Sverdrup Basin. Younger (Volgian) sandstones in turn overstep the Upper Jurassic shales on Melville Island, a further example of the progressive character of the transgression throughout Late Jurassic time.

Intrepid Inlet, Prince Patrick Island

The lower contact of the Ringnes Shale is sharp with a 2 cm thick carbonaceous layer and is presumably disconformable, although A.F. Embry (pers. comm.) points out that the base of the sequence may actually be slightly lower, in the uppermost upper Wilkie Point white sand at some localities. The Ringnes is a soft, dark grey-black, partly silty shale/mudstone unit with characteristic buff-weathering concretions that are commonly as large as 1.5 m high and 3 m across, and at some localities much larger. Some smaller, grey, siliceous concretions and rusty siltstone laminae are also present. Fossils scattered within the shale unit include ammonites such as *Amoeboceras,* gastropods, belemnites, undetermined vertebrate bones, and bivalves, such as *Camptonectes*, *C.* (*Mclearnia*), and *Thracia*(?) or "*Arctica*"(?) (GSC locs. C-76330 to C-76338). The shales are about 50 m thick at Intrepid Inlet (Fig. 17), and about the same thickness on eastern Prince Patrick Island, according to Tozer and Thorsteinsson (1964).

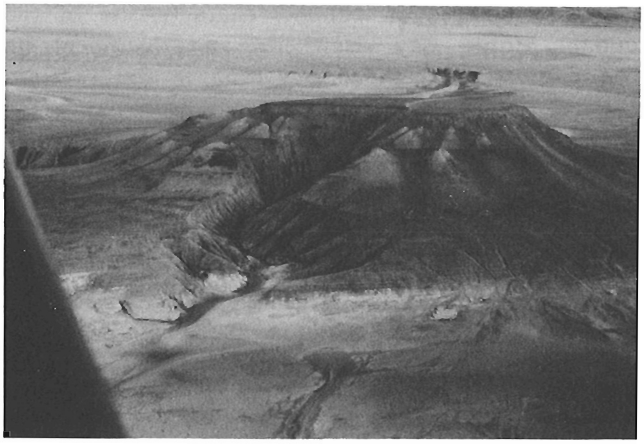

Figure 17. *Upper Oxfordian-Volgian Ringnes (lower Mould Bay) shale in butte overlying uppermost Wilkie Point sandstone at base of slopes; east side of Intrepid Inlet, Prince Patrick Island (ISPG photo no. 2578-24).*

Mould Bay, Prince Patrick Island (Loc. 1, Fig. 1)

At Mould Bay, the Ringnes is unusually thin (about 20 m) and lacks its characteristic concretions. It is also atypical in containing upwardly increasing amounts of silt, and rusty, thin bedded, fossiliferous, fine grained sandstone lenses and interbeds, gradational with the overlying Mould Bay Sandstone (Figs. 18, 19). The shale here may be only the upper part of what is a more completely preserved succession east of Intrepid Inlet. The Ringnes in the Mould Bay area does not contain the older, Oxfordian and Kimmeridgian faunas, to the best of my knowledge.

Volgian

Sandstones containing *Buchia piochii* (Gabb) and *Buchia fischeriana,* as well as many other fossils, gradationally overlie the lower Mould Bay shale (Ringnes) on Prince Patrick Island. The latter species was described from Prince Patrick Island by Jeletzky (1966). The most widely occurring and conspicuous of the rich and varied assemblages of other fossils include scaphopods, "*Ditrupa*", *Arctotis* (*Canadarctotis*) *rugosa* and *Canadotis canadensis* (both described by Jeletzky and Poulton, 1987), *Camptonectes*

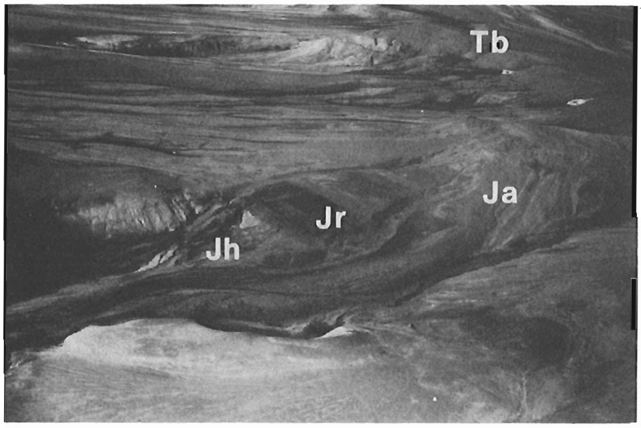

Figure 18. *Uppermost Wilkie Point sandstone (Jh; lower slopes, left), overlain by Ringnes Shale (Jr; lower Mould Bay) (centre), which grades up into lower part of the Awingak (Ja; middle Mould Bay) sandstone (right). The rounded noses of the dissected terrace in the upper right portion of the figure are formed by unconsolidated Tertiary (Tb; Beaufort Formation) gravels; ridge north-northeast of Mould Bay weather station, Prince Patrick Island (ISPG photo no. 2578-16).*

Figure 19. Fossil debris littering surfaces on slopes of Volgian upper beds of the Ringnes (lower Mould Bay) shales; northeast of Mould Bay weather station, Prince Patrick Island. The largest fragments are dominated by the bivalves ***Arctotis (Canadarctotis)*** *and* ***Camptonectes (Mclearnia)*** *(ISPG photo no. 2578-18).*

(*Mclearnia*), *Oxytoma aucta* Zakharov, and ophiuroids. Tozer and Thorsteinsson (1964) also pointed out the presence of crinoid columnals and marine reptile bones (see also D. Russell, *in* Harrison et al., 1985). In addition, the ammonite *Craspedites* (*Subcraspedites*) sp. cf. *C.* (*S.*) *suprasubditus* Bogoslowsky of earliest Cretaceous age was reported by Jeletzky (*in* Tozer and Thorsteinsson, 1964) from Mackenzie King Island, where a more basinal facies of the Upper Jurassic is present.

The Volgian sandstones are the middle sandstone member of the Mould Bay Formation of Tozer and Thorsteinsson (1964) or the Awingak Formation of Embry (*this volume*). On southwestern Melville Island and west of Mould Bay on Prince Patrick Island (Tozer and Thorsteinsson, 1964), Volgian strata appear to have overstepped underlying Jurassic rocks to lie directly on Devonian strata. The upper, Cretaceous, parts of the unit, not studied in detail by me, are thought to be absent on northwestern Melville Island (Tozer and Thorsteinsson, 1964).

East Kitson River, Melville Island (Loc. 5, Fig. 1)

A marine sandstone unit, of which about 20 m are exposed, caps the banks along the west side of East Kitson River near its confluence with Kitson River. The sandstone overlies about one metre of interbedded soft, carbonaceous black shale and crossbedded silt with thin shale partings of the Ringnes Formation. The marine sandstone is fine grained, varying to siltstone, with large-scale, low-angle crossbedding. It weathers light grey and is only moderately consolidated. At about 6 m above its base are layers of planar-bedded, slabby, more consolidated, light greenish grey, micaceous sandstone. The lowest of these layers contains siliceous concretions as thick as 0.5 m, some of which are ferruginous and weather very dark rusty red-maroon. Some of the slabs are covered with *Dentalium* and an assemblage of nondescript bivalves. Certain higher layers also contain *Buchia fischeriana* (GSC loc. C-127435), but it is not certain whether lower layers also contain this species, because it was found only in loose slabs on the lower parts of the slopes. The highest bed exposed in this unit is a concretionary layer, 0.6 m thick, of hard, dark red, fine grained platy sandstone that forms the tops of hills. Vaguely developed coarsening-upward cycles within the unit are comparable with those in the Awingak Formation.

Southwestern Melville Island

In 1984, Q. H. Goodbody, and in 1985, R.L. Christie, collected a rich and varied assemblage of marine bivalves from an isolated outlier of the middle Mould Bay sandstone at Comfort Cove (GSC loc. C-137941). In 1985, J.C. Harrison collected similar bivalves at Cape Russell. The collections include *Camptonectes* (*Mclearnia*) and several Lower Volgian *Buchia* species such as *B. russiensis, B.* sp. aff. *B. fischeriana, B.* sp. aff. *B. mosquensis,* and *B.* sp. aff. *B. terebratuloides* (J.A. Jeletzky, pers. comm.) characteristic of the middle Mould Bay elsewhere, and document its transgression onto Paleozoic strata in southwestern Melville Island.

East of Intrepid Inlet, Prince Patrick Island (Loc. 2, Fig. 1)

The base of the Volgian sandstone, studied briefly by me, appears to be gradational, the upper part of a coarsening-upward cycle initiated in the underlying Ringnes Shale. Eighty-two metres of the sandstone were noted at Intrepid Inlet, where buff-weathering, variably consolidated, and partly argillaceous silt, sand, and sandstone are exposed. The sandstone is fine grained, with low-angle crossbedding, and weathers to blocks or plates (Figs. 20, 21). The plates are commonly covered with invertebrate trails, scaphopods, and an assortment of bivalves, including *Buchia*

Figure 20. *Resistant beds of Volgian (Awingak; middle Mould Bay) sandstone; east side of Intrepid Inlet, Prince Patrick Island. The upper parts of the slope are covered by unconsolidated Tertiary (Beaufort Formation) gravel (ISPG photo no. 2578-22).*

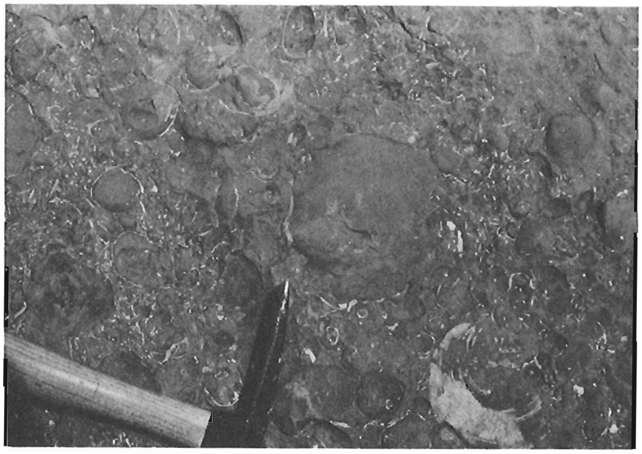

Figure 21. *Bivalve shell hash [**Camptonectes (Mclearnia)** centre and lower right] littering bedding surface, Volgian (Awingak; middle Mould Bay) sand. Same outcrop as Figure 20 (ISPG photo no. 2578-21).*

fischeriana, Canadarctotis rugosa, Canadotis canadensis, Camptonectes (*Mclearnia*), *Oxytoma aucta,* in part forming a comminuted shell hash, and some ophiuroid echinoderms (GSC locs. C-76339 to C-76341). The shell beds also contain a few pebbles. An interval about 20 m thick some 45 m above the exposed base contains shale in which there are a few small stellate nodules, small pyrite nodules, and pyrite-rich laminae.

The upper 20 m or so seen by me contains particularly abundant rusty, resistant crossbedded sandstone beds, some rusty ferruginous mudstone laminae, and rare subspherical fossiliferous concretions up to 10 cm across. Ripples, trails, and horizontal burrows on bedding surfaces become increasingly conspicuous upward through the unit.

Mould Bay area, Prince Patrick Island (Loc. 1, Fig. 1)

The base of the Volgian sandstone here is gradational and arbitrarily located where sandstone becomes the dominant lithology, about 20 m above the base of the underlying Ringnes (lower Mould Bay) shale. The sandstones (Figs. 22, 23) are the upper part of a coarsening-upward cycle that began in the shale. The sandstones are fine grained and variably ferruginous. The sandstone beds reach 1 m in thickness, and their bedding surfaces are marked by many ripples and trails. Rounded, elongate pebbles as large as 5 cm long of hard quartzite and softer siltstone and argillite occur on the bedding surfaces, and larger clasts loose on the ground surface may be weathered out of this unit. Fossils, particularly rich in the sandstone here, include the bivalves *Buchia fischeriana, Canadotis canadensis, Canadarctotis rugosa* (GSC locs. C-76348, C-76349, C-76350), scaphopods, belemnites, and ophiuroid echinoderms (Fig. 24). Some of the fossils occur in subspherical concretions 5 cm across.

Figure 22. *Upper part of the section shown in Figure 18. The broad flats over the top part of the landscape are within the Tertiary Beaufort gravels. The bluff-forming sandstone in the foreground is Volgian middle Mould Bay sandstone; it grades downward into the Upper Oxfordian-Volgian Ringnes (lower Mould Bay) shale (lower slopes, right) (ISPG photo no. 2578-77).*

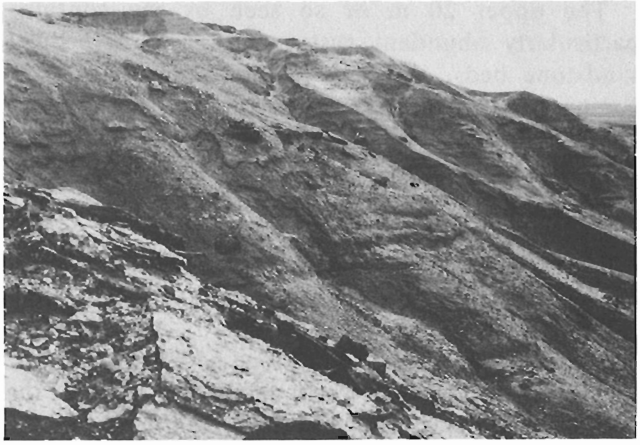

Figure 23. Upper part of the sequence shown in Figure 18. Middle Mould Bay (Awingak) sandstone northeast of Mould Bay weather station, Prince Patrick Island (ISPG photo no. 2578-19).

Figure 24. Shell hash beds in the section shown in Figure 23 (ISPG photo no. 2578-20).

Buchia sp. cf. *B. fischeri* (i.e., *fischeriana*) was reported [Tozer and Thorsteinsson, 1964; GSC locs. 24820, 24823 (corrected from original misprint "28423")] from the west side of Mould Bay, where the sandstone, about 60 m thick, directly overlies Devonian strata.

PALEOGEOGRAPHIC CONSIDERATIONS

The Jurassic sediments of western Queen Elizabeth Islands described here, and those of eastern parts of the Brooks-Mackenzie Basin of northwestern mainland Canada (see Fig. 25; Poulton et al., 1982; Poulton, 1984; Dixon, 1982), were deposited on either side of what appears to have been a broad promontory of the northwestern cratonic margin. This promontory was centred on what is now Banks Island. [The post-Paleozoic, pre-Cretaceous stratigraphic record of Banks Island is as yet somewhat unclear. The strata that Chamney (*in* Miall, 1979) identified as Middle Jurassic in the subsurface there have since been re-assigned to the Upper Jurassic Deer Bay Formation (Balkwill et al., 1983)]. It is inviting to compare the Jurassic strata of the Sverdrup and the Brooks-Mackenzie basins because of their bearing on questions of the eustatic component of relative sea-level fluctuations, and on the opening of the Canada Basin.

The Lower Jurassic records of eastern Brooks-Mackenzie and western Sverdrup basins are most similar in the general, commonly glauconitic lithologies, the transgressive character of the Toarcian shale, and in the removal by erosion of older Jurassic beds toward the basin margins. The great Pliensbachian shelf sandstone wedge of eastern Brooks-Mackenzie Basin (Almstrom Creek Formation; Poulton et al., 1982) has its equivalents in the King Christian Formation (upper Heiberg Group) in Sverdrup Basin, which, however, is thin and sporadic in the southwestern parts of the basin described in this report. The coarsening-upward character of the Toarcian shale through Aalenian sandstone of western Sverdrup Basin is analogous to that of the Manuel Creek Formation of eastern Brooks-Mackenzie Basin (Poulton et al., 1982), although the abundance of *Leioceras* in western Sverdrup Basin suggests that there, the coarse upper parts of the cycle were developed earlier. The *Arkelloceras* beds are similar in certain respects in both basins: condensed, phosphate- and limonite-rich units in each case are perhaps basal transgressive facies. The *Inoceramus*-rich sandstones (Hiccles Cove and overlying Early Callovian formations) of western Sverdrup Basin may have their counterpart in the Waters River Member of the Richardson Mountains Formation (Poulton et al., 1982) of eastern Brooks-Mackenzie Basin, and the upper Wilkie Point sandstone may correspond to the Lower Callovian Waters River Member or with lower parts of the mainly Lower Oxfordian Aklavik Formation. The Ringnes Shale and middle Mould Bay sandstone correspond to the Husky and Porcupine River formations, respectively. Overall, the similarities of the strata in western Sverdrup and eastern Brooks-Mackenzie basins are striking, and indicate common, passive responses to widespread episodes of uplift of the cratonic source areas, and subsidence of the Arctic cratonic margin.

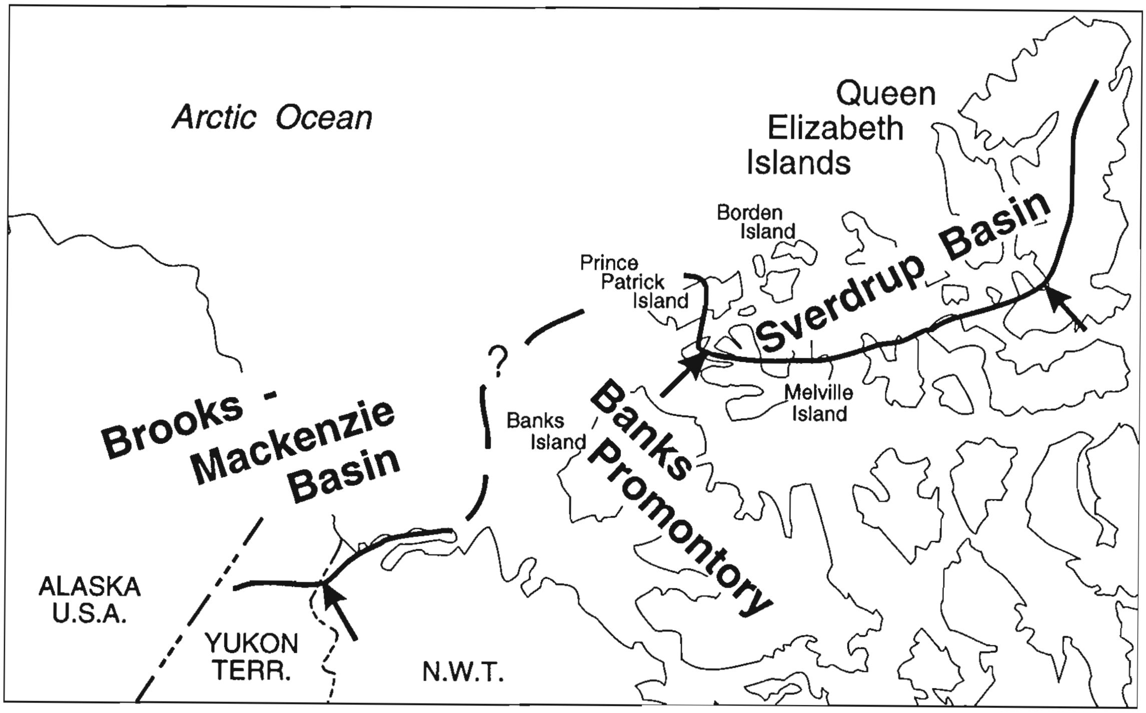

Figure 25. Configuration of eastern Brooks-Mackenzie and western Sverdrup Basin, Canadian Arctic. Arrows indicate direction of major sediment supply.

Correspondence with some of the "eustatic" events of Hallam (1981) and Vail and Todd (1981) is also striking (see Poulton, 1984, Fig. 23; 1988).

Certain models for the origin of the Canada Basin portion of the Arctic Ocean require Early Cretaceous rifting of northern Alaska away from Arctic Canada, and counterclockwise rotation and/or strike-slip movement to place it in its present position (e.g., Grantz et al., 1979). The Jurassic succession in the northern Alaska part of Brooks-Mackenzie Basin is mainly shale (the Kingak Formation), with northerly derived, thin sandstones in the lower part (Detterman, 1970). Clockwise rotation with little strike-slip movement would restore Arctic Alaska to a position off Banks Island. The Jurassic succession of northern Alaska would then fill the gap between the Sverdrup and eastern parts of Brooks-Mackenzie Basin, with a mainly shale facies, indicating an absence of nearby major river systems. The hypothesis of post-Jurassic counterclockwise rotation of northern Alaska is one of several models available for the origin of the Canada Basin. None of them is completely satisfactory in explaining the known geology of Arctic areas (see Balkwill et al., 1983). In particular, there are no volcanic rocks in the area supposedly pivotal to rotation (Poulton, 1982).

The Middle Jurassic ammonite faunas of northern Alaska are mainly Boreal, but nevertheless have some components indicative of Pacific influences in contrast with the strictly boreal faunas of Sverdrup Basin. The ammonite *Tmetoceras* for example, which occurs in northern Alaska (Imlay, 1955), is found abundantly in circum-Pacific parts of Canada, and worldwide, but never in Arctic Canada. The faunal difference between northern Alaska and Arctic Canada can perhaps be explained by the hypothesis of the proximity of the two areas in Middle Jurassic time if a landmass had separated them. In the rotation model, this landmass would be the fragmented upland that now lies northwest of the Sverdrup Basin, and underlies the present Coastal Plain north of Alaska (Balkwill et al., 1983). It may be indicated in the Canadian Arctic by thinning and shallowing depositional features in the Jurassic strata (Meneley et al., 1975).

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APPENDIX

List of GSC fossil localities

(The extensive collections made on Prince Patrick Island in 1987 will be described in a later report and are not listed here)

23002. S.D. MacDonald, 1952. On top of hills overlooking bay 3 miles (4.8 km) north of station, Mould Bay, Prince Patrick Island, Northwest Territories. Middle or Late Toarcian.

23008. S.D. MacDonald, 1952. Picked up in stream beds, Mould Bay, Prince Patrick Island, Northwest Territories. Early Toarcian.

23368. A. Sawchenko, 1952. Approximately 3/4 mile (1.2 km) northwest of station, on a hill, 2 to 5 feet (sic) above sea level. Mould Bay, Prince Patrick Island, Northwest Territories. Early Toarcian.

24641. E.T. Tozer, 1954. 3 3/4 miles (6 km) northeast of Mould Bay Weather Station, phosphatic nodules collected on the surface of disintegrated outcrops representing beds not more than 100 feet (30 m) above the base of the (Wilkie Point) formation; Prince Patrick Island, Northwest Territories; lat. 76°14′30″, long. 119°12′. Middle or Late Toarcian. (Tozer and Thorsteinsson, 1964, p. 127; Frebold, 1957).

24642. E.T. Tozer, 1954. East of Landing Lake, small down-faulted outcrops, Prince Patrick Island, Northwest Territories. Middle or Late Toarcian. Nodules from small down-faulted outcrop. (Tozer and Thorsteinsson, 1964, p. 127; Frebold, 1957).

24643. E.T. Tozer, 1954. East side of Mould Bay, Prince Patrick Island, Northwest Territories. Early Toarcian. (Frebold, 1957).

24644. E.T. Tozer, 1954. Prince Patrick Island, Northwest Territories. Early Toarcian. (Frebold, 1957).

24645. E.T. Tozer, 1954. East side of Intrepid Inlet, Prince Patrick Island, Northwest Territories. Middle or Late Toarcian. (Frebold, 1957).

24649. E.T. Tozer, 1954. East side of Intrepid Inlet, 12 miles (19 km) north of Cape Canning, Prince Patrick Island, Northwest Territories. Middle or Late Toarcian. (Tozer and Thorsteinsson, 1964; Frebold, 1957).

24650. E.T. Tozer, 1954. On ridge 3 miles (4.8 km) southeast of Mould Bay Weather Station, Prince Patrick Island, Northwest Territories. Early Toarcian. (Tozer and Thorsteinsson, 1964, p. 127; Frebold, 1957).

24651. E.T. Tozer, 1954. Hill 1 mile (1.6 km) north of Mould Bay Weather Station, Prince Patrick Island, Northwest Territories. Early Toarcian. (Tozer and Thorsteinsson, 1964; Frebold, 1957).

24652. E.T. Tozer, 1954. Hill 1 mile (1.6 km) north of Mould Bay Weather Station, Prince Patrick Island, Northwest Territories. 10 feet (3 m) of dusky red sandstone and conglomerate. Early Toarcian. (Tozer and Thorsteinsson, 1964, p. 126; Frebold, 1958, p. 18).

24661. E.T. Tozer, 1954. 10 miles (16 km) north of Cape Canning, east side of Intrepid Inlet, Prince Patrick Island, Northwest Territories. Lower Bajocian. (Frebold, 1957; Tozer and Thorsteinsson, 1964, p. 132).

24664. E.T. Tozer, 1954. 3 miles (4.8 km) S 30° E of Mould Bay Weather Station, Prince Patrick Island, Northwest Territories. Late Bajocian-Early Bathonian. (Frebold, 1957, 1961).

24665. E.T. Tozer, 1954. Prince Patrick Island, Northwest Territories. Late Bajocian-Early Bathonian. (Frebold, 1957).

24667. E.T. Tozer, 1954. 10 miles (16 km) north of Cape Canning, Prince Patrick Island, Northwest Territories. Late Bajocian-Early Bathonian.

24820. E.T. Tozer, 1954. 7.5 miles (12 km) northeast of Mould Bay Weather Station, Prince Patrick Island, Northwest Territories. Volgian, near top of lower member of Mould Bay Formation. (Tozer and Thorsteinsson, 1964, p. 137).

24823. E.T. Tozer, 1954. 7.5 miles (12 km) northeast of Mould Bay Weather Station, Prince Patrick Island, Northwest Territories. Volgian, near top of lower member of Mould Bay Formation. (Tozer and Thorsteinsson, 1964, p. 137).

35312. R. Thorsteinsson and E.T. Tozer, 1958. 9 miles (14.5 km) east of the west coast, Mackenzie King Island, Northwest Territories. Early Aalenian. (Frebold, 1960).

35313. R. Thorsteinsson and E.T. Tozer, 1958. 9 miles (14.5 km) east of the west coast, Mackenzie King Island, Northwest Territories. Early Aalenian. (Frebold, 1960, p. 8).

35314. R. Thorsteinsson, 1958. North side of Marie Bay, Melville Island, Northwest Territories. Early Aalenian. Collected 60 feet (18 m) above base of Wilkie Point exposures. (Tozer and Thorsteinsson, 1964, p. 135).

35315. R. Thorsteinsson, 1958. North side of Marie Bay, Melville Island, Northwest Territories. Early Aalenian. (Tozer and Thorsteinsson, 1964, p. 135).

35322. R. Thorsteinsson, 1958. South-central Borden Island, in bed of small tributary on the east side of Oyster Creek, Northwest Territories. Early Sinemurian (Frebold, 1960, p. 13; Tozer and Thorsteinsson, 1964).

35324. R. Thorsteinsson, 1958. East side of Intrepid Inlet, between 11 and 12 miles (17.7-19.3 km) north of Cape Canning, Prince Patrick Island, Northwest Territories. Early Bajocian (Tozer and Thorsteinsson, 1964, p. 132).

35342. R. Thorsteinsson, 1958. Southern Peninsula, on southern coast, Borden Island, Northwest Territories. Early Toarcian. About 100 feet (30 m) stratigraphically above base of Wilkie Point Formation. (Frebold, 1960).

35344. R. Thorsteinsson, 1958. 10 miles (16 km) south of Depot Island, on north coast of Melville Island, Northwest Territories. Aalenian. (Tozer and Thorsteinsson, 1964, p. 133).

35346. R. Thorsteinsson, 1958. West of Leffingwell Crags, Mackenzie King Island, Northwest Territories. Late Oxfordian-Early Kimmeridgian, Mould Bay Formation. (Frebold, 1961).

35348. R. Thorsteinsson and E.T. Tozer, 1958. North side of Marie Bay, collected 120 feet (36.5 m) above base of Wilkie Point formation exposures, Melville Island, Northwest Territories. Early Aalenian.

37018. E.T. Tozer, 1958. Marie Heights, northwestern butte, Melville Island, Northwest Territories. Early Aalenian.

37019. E.T. Tozer, 1958. East Kitson River, 12.5 miles south of Cape Grassy, Melville Island, Northwest Territories. Early Aalenian. About 100 feet (30 m) above base, lower part of marine unit.

37020. E.T. Tozer, 1958. Marie Heights, Melville Island, Northwest Territories. Early Bajocian. (Frebold, 1961).

37198. E.T. Tozer, 1958. About 6 miles (9.6 km) southwest of Cape Grassy, Melville Island, Northwest Territories. Latest Jurassic.

60220. J.C. Sproule and Associates, 1963. Melville Island, Northwest Territories. Late Sinemurian. (Frebold, 1975).

70377. Petropar Canada Ltd., 1965. Section 16 miles (25.7 km) north of McConnell Island, Mackenzie King Island, Northwest Territories. Early Aalenian.

70379. Petropar Canada Ltd., 1965. Section 12 miles (19.3 km) northeast of McConnell Island, Mackenzie King Island, Northwest Territories. Early Aalenian.

70380. Petropar Canada Ltd., 1965. Section 12 miles (19.3 km) northeast of McConnell Island, Mackenzie King Island, Northwest Territories. Early Aalenian.

70390. Petropar Canada Ltd., 1965. 4 to 6 miles (6.4 to 9.6 km) northeast of Mould Bay weather station, Prince Patrick Island, Northwest Territories. Middle or Late Toarcian. (Frebold, 1975, p. 4).

70402. Elf Oil, 1965. East side of Intrepid Inlet, 7 miles (11.2 km) south of Hiccles Cove, Jameson Bay, Prince Patrick Island, Northwest Territories. Late Sinemurian. (Frebold, 1975, p. 3).

70405. Petropar Canada Ltd., 1965. North of Mould Bay, 1/2 mile (0.8 km) southeast of Hiccles Cove, Prince Patrick Island, Northwest Territories. Early Callovian.

70406. Petropar Canada Ltd., 1965. Jameson Bay, 1.5 miles (2.4 km) east of Hiccles Cove, Prince Patrick Island, Northwest Territories. Early Callovian.

70407. Petropar Canada Ltd., 1965. Jameson Bay, 1.5 miles (2.4 km) east of Hiccles Cove, Prince Patrick Island, Northwest Territories. Early Callovian.

70408. Petropar Canada Ltd., 1965. Jameson Bay, 1.5 miles (2.4 km) east of Hiccles Cove, Prince Patrick Island, Northwest Territories. Early Callovian.

72571. Petropar Canada Ltd., 1965. Sabine Peninsula, Melville Island, Northwest Territories. Early Aalenian.

72572. Petropar Canada Ltd., 1965. Sabine Peninsula, Melville Island, Northwest Territories. Early Aalenian.

72573. Petropar Canada Ltd., 1965. Sabine Peninsula, Melville Island, Northwest Territories. Early Aalenian.

72578. Petropar Canada Ltd., 1965. Sabine Peninsula, Melville Island, Northwest Territories. Toarcian.

72596. Petropar Canada Ltd., 1965. Landing Lake, Prince Patrick Island, Northwest Territories. Middle or Late Toarcian.

72603. Petropar Canada Ltd., 1965. North Green Bay, Prince Patrick Island, Northwest Territories. Early Callovian.

72608. Petropar Canada Ltd., 1965. Oyster Creek, Borden Island, Northwest Territories. Sinemurian. (Frebold, 1975, p. 3).

72640. Petropar Canada Ltd., 1965. Oyster Creek, Borden Island, Northwest Territories. Toarcian.

72645. Petropar Canada Ltd., 1965. Section south of Oyster Creek, Borden Island, Northwest Territories. Toarcian.

72647. Petropar Canada Ltd., 1965. Section south of Oyster Creek, Borden Island, Northwest Territories. Toarcian.

72648. Petropar Canada Ltd., 1965. Section south of Oyster Creek, Borden Island, Northwest Territories. Middle or Late Toarcian.

C-4728. Panarctic Oil, 1970. Depot Point, Axel Heiberg Island, Northwest Territories, lat. 79°36′30″N, long. 85°46′W. Late Pliensbachian. (Frebold, 1975, p. 4).

C-11494. Atlantic Richfield, 1971. Head of Jameson Bay, Prince Patrick Island, Northwest Territories. Early Bajocian.

C-12544. Elf Oil Canada, 1971. North of Wilkie Point, Prince Patrick Island, Northwest Territories; lat. 76°21′, long. 117°30′. Late Pliensbachian. (Frebold, 1975).

C-12546. Elf Oil, 1971. West of Intrepid Inlet, Prince Patrick Island, lat. 76°41′, long. 118°43′. Middle or Late Toarcian. (Frebold, 1975, p. 4).

C-57501. H.R. Balkwill, 1976. Mackenzie King Island, Northwest Territories; lat. 77°49′, long. 113°16′. NTS 89 O. Middle Toarcian, Wilkie Point Group. 15 m above top of lower Savik member.

C-63258. D.G. Wilson, 1976. Northwest Territories. Middle or Late Toarcian. 30 m from base of Wilkie Point.

C-63346. D.G. Wilson, 1976. Melville Island, Northwest Territories. Late Bathonian. 136 m from base of Wilkie Point.

C-76304. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°33′, long. 117°55′. Aalenian.

C-76307. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°33′, long. 117°55′. Early Aalenian.

C-76308. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories. Early Bajocian.

C-76309. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°33′, long. 117°55′. Early Bajocian.

C-76315. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°35′, long. 118°30′. Callovian or Oxfordian.

C-76325. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°30′30″, long. 117°51′. Early Bajocian.

C-76329. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°30′30″, long. 117°51′. Early Bajocian.

C-76330. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°40′, long. 117°42′. Oxfordian, Ringnes Formation.

C-76331. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°40′, long. 117°42′. Oxfordian or Kimmeridgian, Ringnes Formation.

C-76332. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°47′, long. 117°42′. Late Oxfordian or Kimmeridgian, Ringnes Formation.

C-76333. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°42′, long. 117°42′. Late Oxfordian to Kimmeridgian, Ringnes Formation.

C-76334. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°42′, long. 17°42′. Late Oxfordian or Kimmeridgian, Ringnes Formation.

C-76335. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°42′, long. 117°42′. Late Oxfordian or Kimmeridgian, Ringnes Formation.

C-76336. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°42′, long. 117°42′. Late Oxfordian or Kimmeridgian, Ringnes Formation.

C-76337. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°42′, long. 17°42′. Late Oxfordian or Kimmeridgian, Ringnes Formation.

C-76338. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°39′, long. 117′47′. Early Kimmeridgian, Ringnes Formation.

C-76339. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, lat. 76°42′, long. 117°37′. Volgian, Mould Bay Formation.

C-76340. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°42′, long. 117°42′. Volgian, Mould Bay Formation.

C-76341. T.P. Poulton, 1977. Intrepid Inlet, Prince Patrick Island, Northwest Territories; lat. 76°42′, long. 117°42′. Volgian, Ringnes Formation.

C-76348. T.P. Poulton, 1977. 5.5 km north of Mould Bay Station, Prince Patrick Island, Northwest Territories; lat. 76°17′30″, long. 119°20′. Volgian, Mould Bay Formation. From 60–71 m level of argillaceous unit.

C-76349. T.P. Poulton, 1977. Prince Patrick Island, Northwest Territories. Volgian, Mould Bay Formation.

C-76350. T.P. Poulton, 1977. Mould Bay, Prince Patrick Island, Northwest Territories; lat. 76°17′30″, long. 19°20′. Volgian, Mould Bay Formation.

C-76361. T.P. Poulton, 1977. Oyster Creek, Borden Island, Northwest Territories; lat. 75°23′, long. 110°47′. Early(?) Sinemurian, Borden Island Formation.

C-76362. T.P. Poulton, 1977. Oyster Creek, Borden Island, Northwest Territories; lat. 78°23′, long. 110°47′. Early Sinemurian, Borden Island Formation.

C-80372. A.F. Embry, 1978. South Sabine Peninsula, Melville Island, Northwest Territories; lat. 76°07′, long. 109°. Aalenian, Wilkie Point Formation, 61 m above base.

C-80380. A.F. Embry, 1978. South Sabine Peninsula, Melville Island, Northwest Territories; lat. 76°08′, long. 109°. Aalenian, Wilkie Point Formation, 81 m above base.

C-80383. A.F. Embry, 1978. South Sabine Peninsula, Melville Island, Northwest Territories; lat. 76°09′, long. 109°. Aalenian, 87 m above base of Wilkie Point Formation.

C-107897. T.P. Poulton, 1984. North side of Marie Bay, 4.5 miles (7.24 km) west of head, Melville Island, Northwest Territories; lat. 76°11′, long. 114°52.5′. NTS 89 A. Late Pliensbachian.

C-107898. T.P. Poulton, 1984. North side of Marie Bay, 4 miles (6.4 km) west of head, Melville Island, Northwest Territories; lat. 76°11′, long. 114°51.5′. NTS 89 A. Late Pliensbachian.

C-107899. T.P. Poulton, 1984. North side of Marie Bay, west end of small ridge, 3.5 miles (5.6 km) west of head of bay, Melville Island, Northwest Territories; lat. 76°11′20″, long. 114°50′. NTS 89 A. Toarcian.

C-107900. T.P. Poulton, 1984. North side of Marie Bay, east end of small ridge 3.5 miles (5.6 km) west of head of bay, Melville Island, Northwest Territories; lat. 76°11′20″, long. 114°48′. NTS 89 A. Toarcian.

C-127401. T.P. Poulton, 1984. North side of Marie Bay, 3 miles (4.8 km) northwest of head, Melville Island, Northwest Territories; lat. 76°11′45″, long. 114°45.5′. NTS 89 A. Toarcian.

C-127403. T.P. Poulton, 1984. North side of Marie Bay, 3.5 miles (5.6 km) northwest of head, Melville

Island, Northwest Territories; lat. 76°12′10″, long. 114°44.5′. NTS 89 A. Toarcian.

C-127407. T.P. Poulton, 1984. 5.5 miles (8.35 km) northwest of head of Marie Bay, Melville Island, Northwest Territories; lat. 76°13′15″, long. 114°53.5′. NTS 89 A. Early Aalenian.

C-127408. T.P. Poulton, 1984. 5 miles (8 km) west of head of Marie Bay, north side, Melville Island, Northwest Territories; lat. 76°13′20″, long. 114°53.5′. NTS 89 A. Early Aalenian.

C-127417. T.P. Poulton, 1984. Marie Heights, Melville Island, Northwest Territories; lat. 76°16′46″, long. 115°42′. NTS 89 A. Toarcian.

C-127421. T.P. Poulton, 1984. Marie Heights, Melville Island, Northwest Territories; lat. 76°16′46″, long. 115°42′. NTS 89 A. Early Aalenian.

C-127422. T.P. Poulton, 1984. Marie Heights, Melville Island, Northwest Territories; lat. 76°17′, long. 115°41′. NTS 89 A. Early Bajocian.

C-127425. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°05′05″, long. 113°2.5′. NTS 89 A. Early Aalenian.

C-127426. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°05′50″, long. 113°. NTS 89 A. Early Aalenian.

C-127427. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°05′50″, long. 113°. NTS 89 A. Early Aalenian.

C-127428. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°06′10″, long. 113°. NTS 89 A. Early Aalenian.

C-127429. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°06′, long. 112°58′. NTS 89 A. Early Aalenian.

C-127430. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°06′, long. 112°58′. NTS 89 A. Early Aalenian.

C-127431. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°06′, long. 112°58′. NTS 89 A. Early Bajocian. Phosphatic pebble bed.

C-127432. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°06′, long. 112°58′. NTS 89 A. Early Aalenian. Green sandstone.

C-127434. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°05′50″, long. 112°58′. NTS 89 A. Early Callovian–latest Bathonian.

C-127435. T.P. Poulton, 1984. East Kitson River, Melville Island, Northwest Territories; lat. 76°06′30″, long. 112°57.5′. NTS 89 A. Volgian. Talus.

C-128844. J.C. Harrison, 1984. Depot Island, Northwest Territories; NTS 89 A. Aalenian. 40.5 m above base, Wilkie Point Group. UTM NQ5793/84559.

C-128845. J.C. Harrison, 1984. Depot Island, Northwest Territories; NTS 89 A. Aalenian, Wilkie Point Group. UTM NQ5793/84559.

C-128846. J.C. Harrison, 1984. Depot Island, Northwest Territories; NTS 89 A. Aalenian, Wilkie Point Group. UTM NQ5793/84559.

C-130993. R. Thorsteinsson, 1958. 1 mile (1.6 km) north of Mould Bay Weather Station, Prince Patrick Island, Northwest Territories. Early Toarcian. Same locality as specimens collected by Tozer and described by Frebold (1957).

C-137941. R.L. Christie, 1985. Isolated outlier, Comfort Cove, western Melville Island, Northwest Territories; lat. 75°21′20″, long. 117°28′30″. Early Volgian.

JURASSIC MARINE REPTILES FROM CAPE GRASSY, MELVILLE ISLAND, ARCTIC CANADA

D.A. Russell[1]

Russell, D.A., 1993. Jurassic marine reptiles from Cape Grassy, Melville Island, Arctic Canada; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 195-201.

Abstract

The occurrence of two taxa of marine reptiles is documented in the Upper Jurassic Awingak Formation on Melville Island, Arctic Canada. A plesiosaur (cf. *Cryptoclidus richardsoni*) and an ichthyosaur (*Ophthalmosaurus chrisorum* n. sp.) are closely related to taxa in the United Kingdom and United States from strata of similar age.

Résumé

Deux taxons de reptiles marins se rencontrent dans la Formation d'Awingak du Jurassique supérieur, dans l'île Melville, Arctique canadien. Un plésiosaure (cf. *Cryptoclidus richardsoni)* et un ichthyosaure (*Ophthalmosaurus chrisorum* n. sp.) sont étroitement apparentés à des taxons provenant de strates d'âge comparable au Royaume-Uni et aux États-Unis.

INTRODUCTION

Although remains of continental vertebrates have rarely been reported in Mesozoic strata in the Canadian Arctic Archipelago, those of marine reptiles are sporadically encountered by earth scientists. During the summer of 1984, a concentration of bone fragments discovered by J.C. Harrison south of Cape Grassy on northwestern Melville Island was immediately recognized as potentially significant (Fig. 1 for location). Sylvia A. Edlund made field photographs available to the author for a preliminary identification.

Acknowledgments

I am extremely grateful to George D. Hobson, of the Polar Continental Shelf Project, for logistical support, and to Robert L. Christie for extending the hospitality of the Geological Survey of Canada camp on Melville Island during the summer of 1985.

The specimens described below were collected from July 21 to 27, 1985 with the able assistance of Clayton C. Kennedy, of the Canadian Museum of Nature. Richard G. Day, also a museum staff member, provided archival data and prepared photographs of the major ichthyosaur specimen. The photographs were examined by Christopher McGowan of the Royal Ontario Museum, who recognized the generic affinities of the specimen. Ashton F. Embry, of the Institute of Sedimentary and Petroleum Geology, Calgary, provided valuable counsel on the biostratigraphic position of the vertebrate occurrences. It is a pleasure to acknowledge my indebtedness to these generous and supportive colleagues.

SYSTEMATIC PALEONTOLOGY

Order PLESIOSAURIA

Superfamily Plesiosauroidea

Family Cryptoclididae

cf. *Cryptoclidus richardsoni* (Lydekker, 1889)

Referred specimen. NMC 40729, anterior portion of a skeleton from which the skull, seven cervical centra, and a right forepaddle were collected (specimen cited in Christie, 1986, p. 798).

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[1] Canadian Museum of Nature, Ottawa, Ontario K1P 6P4.

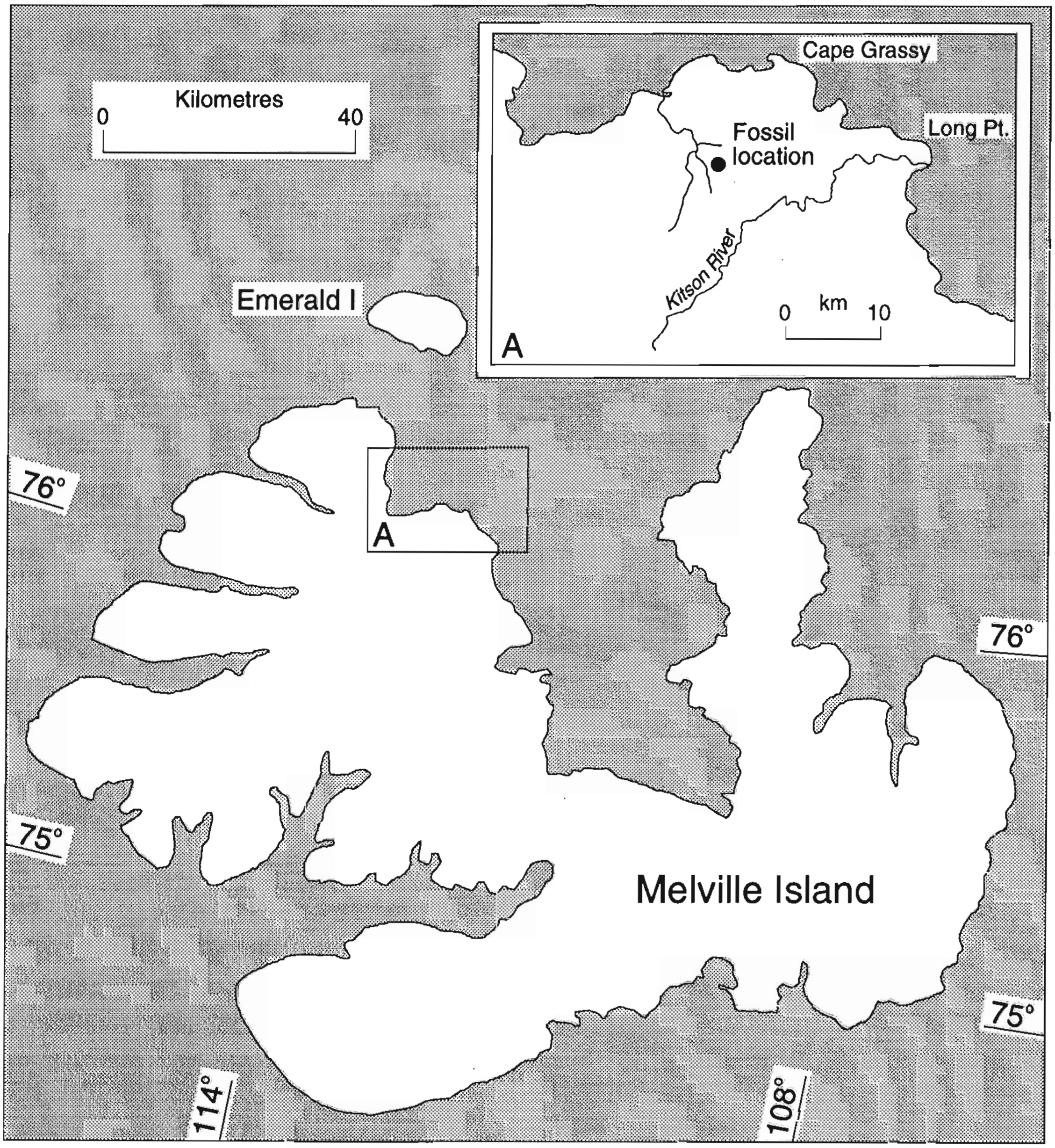

Figure 1. Location of the plesiosaur and ichthyosaur discovery.

Locality. 76°9′4″N, 113°30′W, "upper member of Hiccles Cove Formation", Callovian, Middle Jurassic (A.F. Embry, pers. comm., 1987), Cape Grassy, Melville Island.

Occurrence. The specimen was located at the base of a white, crossbedded and poorly consolidated sandstone. The surrounding sandstone contains small fragments of coal and streaks of carbonaceous material. A brownish siltstone unit 2.58 m thick separates the sandstone from a yellow limonitic concretionary sandstone below, which is capped by an indurated purplish layer. The skeleton was oriented in a plane dipping 15° to the east. The posterior (western) regions of the trunk and tail had been scattered through erosion, although many bone fragments had fallen into open erosional fissures and were still preserved at the level of the anterior (eastern) portion of the skeleton. The entire skeleton had been badly disrupted by small faults with offsets on the order of a few centimetres. No gastroliths were observed in the abdominal region (Fig. 2).

Measurements. The skeleton was probably about 3 m long when complete. The skull measured 38 cm in length along the midline, 47 cm from the tip of the

Figure 2. *The cf.* ***Cryptoclidus richardsoni*** *skeleton in situ. The skull (foreground) measures 38 cm along the midline.*

snout to the end of the left quadratic suspensorium, and 33.5 cm in maximum width across the quadratic suspensoria. An articulated series of 26 vertebrae extended behind the axis for a distance of 92 cm, terminating in the region of the shoulder girdle. Fragments of ten long ribs lying approximately in situ indicate a body width of about 120 cm. The thoracic region of the body was probably more than one metre long; the broken spines of seven dorsal vertebrae were spaced over an interval of 31 cm and ended within a broken mass of gastralia. As preserved, the length of the right paddle is 70 cm. The humerus is 33 cm long, 9.0 cm wide proximally and 17.8 cm wide distally. For other measurements see Table 1.

TABLE 1

Measurements for specimen NMC 40729, cf. *Cryptoclidus richardsoni*

Bone measured	Length (mm)
Radius	82
Ulna	73
Metacarpal I	33
Metacarpal II	37
Metacarpal III	39
Metacarpal IV	37

Centrum[1]	Length (mm)	Width (mm)	Height (mm)
A	26	44	36
B	25	44	36
C	26	47	40
D	26	47	41
E	28	50	41
F	27	49	41
G	29	52	44

[1] Seven centra (A, anterior, to G, posterior) were removed from the middle of the cervical series.

Discussion. The skull is badly fractured and at the time of writing had not been prepared, so that the above identification must be considered preliminary. In accordance with the diagnoses of Brown (1981), the relatively small size of the skull indicates plesiosauroid affinities, cervical centra of moderate length bearing single rib facets are characteristic of cryptoclidids, the presence of a saggital crest on the skull is typical of *Cryptoclidus*, and a relatively unexpanded distal end of the humerus is suggestive of *Cryptoclidus richardsoni*. A degree of immaturity in NMC 40729 is indicated by the imperfect closure of the sutures between the neural arches and vertebral centra. In size, the Melville specimen appears to be approximately three quarters that of the "old adult" type specimen (cf. Brown, 1981, p. 282; Lydekker, 1889, p. 241). The type is from the Oxford Clay of England, in strata of Callovian or Oxfordian age (Brown, 1981, p. 280). The skull of the Melville specimen is larger relative to the neck and foreflipper than in *C. eurymerus* (Phillips, 1871) (cf. Brown, 1981, Fig. 10); it is not preserved in the type specimen of *C. richardsoni*.

The posterior half of what was originally a six metre long plesiosaur skeleton was collected from strata of possibly Oxfordian age on Spitsbergen, and described as the type of *Tricleidus svalbardensis* (Persson, 1962). Because only the anterior half of the skeleton is preserved in NMC 40729, it is not possible to make direct comparisons between the two specimens. It would appear that the paddles are relatively larger in the Canadian specimen.

Order ICHTHYOSAURIA

"Suborder Latipinnati" (cf. McGowan, 1976, 1983, p. 154)

Family Ichthyosauridae

Ophthalmosaurus chrisorum n. sp.

Etymology. Name derived from an arbitrary combination of letters to recognize the contributions of Christopher McGowan, an eminent modern student of ichthyosaurs, "Chris" Harrison, the discoverer of the fossiliferous site, and R.L. Christie, the director of G.S.C. operations on Melville Island during 1984 and 1985.

Type. NMC 40608 associated skeleton lacking most of the skull, from which the basisphenoid, basioccipital, appendicular elements, and centra from representative portions of the vertebral column were collected.

Referred specimen (on basis of proximity to type locality). NMC 40609 fragmentary skeleton (ribs and vertebrae were identified), from which a scapula was collected (both specimens are cited in Christie, 1986, p. 797).

Locality. For NMC 40608, 100 m east of, and stratigraphically above, locality for NMC 40729 (see above), Ringnes Formation, Oxfordian-Kimmeridgian (A.F. Embry, pers. comm., 1987), Cape Grassy, Melville Island. The specimen was found 51 m above the base of the formation, 3.4 m above a sandstone ledge, and 14.7 m above a lower sandstone ledge, which in turn occurs 36.5 m above the base of the formation. For NMC 40609, Ringnes Formation, at approximate level of lower sandstone ledge and 1.5 km to the south of locality for NMC 40608.

Occurrence. NMC 40608 was weathered out on the surface of the outcrop and slightly scattered. Although none of the bones were found in situ and most had been broken, they were otherwise in an excellent state of preservation. NMC 40609 was similarly, although much less completely, preserved.

Species diagnosis. Proximal width of humerus approximately equal to 80 per cent of humeral length; distal width of humerus approximately equal to 90 per cent of humeral length.

Discussion. McGowan (1983, p. 163) has suggested that the described Upper Jurassic species of *Ophthalmosaurus* may be grouped under *O. icenicus* (Seeley, 1874) in Europe and *O. discus* (Marsh, 1880) in North America. Humeri from specimens referred to these species can be arranged in a morphological series from the relatively slender humerus in *O. discus* (Gilmore, 1905, Fig. 24) through "*O. reedi*" (Gilmore, 1907, Fig. 1, from a horizon above the *O. discus* specimens described by him previously) and *O. icenicus* (Andrews, 1910, Fig. 36), to culminate in the relatively robust humeri in the type of *O. chrisorum*. Although the latter is a large specimen (if the ratio of the lengths of the humerus and skeleton was as in "*O. reedi*", the animal would have been nearly 6.5 m long), there is no evidence from English specimens of *O. icenicus* that humeral proportions change ontogenetically (cf. data in Andrews, 1910). The vertebral centra of *O. chrisorum* appear to be higher and wider with respect to their lengths than in *O. discus* (cf. Gilmore, 1905, Figs. 13-18) and *O. icenicus* (cf. data in Andrews, 1910). For measurements of the type specimen see Table 2 and Figure 3.

The remains of NMC 40609 represent a small individual (the minimum width of the distal end of the scapula is 65 mm). Other specimens have been referred to *Ophthalmosaurus* by Wann Langston, Jr. from either the Ringnes Formation or the Awingak Formation 148 km to the west, on Prince Patrick Island (NMC 21861, a left humerus taken from the "Mould Bay Formation", see Tozer and Thorsteinsson, 1964, p. 139; McGowan, 1978, Pl. 2, fig. 1), and from the Ringnes Member of the Mackenzie King Formation on Mackenzie King Island 170 km to the north (NMC 21860, a basioccipital and three anterior dorsal vertebrae collected in the "lower shale member, Mould Bay Formation", Tozer and

TABLE 2

Measurements for specimen NMC 40608, Ophthalmosaurus chrisorum n. sp.

Bone measured	Length (mm)	Width (mm)	Height (mm)
Basisphenoid	78+	98	
Basioccipital	73	87	
Occipital condyle		74	
Occipital condyle			67
Vertebral			
Atlas-axis	60	83	99
Mid-cervical	35	crushed	92
Anterior dorsal	40	100	94
Anterior caudal	30	131	125
Mid-caudal	27	103	89
Posterior caudal	20	25	27
Scapula			
Left		95 (di.)	
		79 (min. di.)	
Right		85 (di.)	
		78 (min. di.)	
Coracoid			
Right		233	
Humerus			
Left	220	172 (pr.)	
		195 (di.)	
Right	213	171	
		196 (est.)	
Radius			
Left	82	76	
Right	80	78	
Ulna			
Left	67	78	
Right	74	77	
Femur			
Left	141	76 (pr.)	
		83 (di.)	
Right	148	75 (pr.)	
		86 (di. est.)	

min. di. = minimum width distal end; pr. = proximal; di. = distal; est. = estimated.

Thorsteinsson, 1964, p. 145). This material is indistinguishable from comparable elements in the type of *O. chrisorum*. As noted by Langston (*in* Tozer and Thorsteinsson, 1964), one of the vertebrae in NMC 21860 is from a large animal that may even have slightly exceeded the type in size.

Ophthalmosaurus has been recorded in sediments of Callovian through Albian age in England, and elsewhere from Upper Jurassic strata in Argentina, France, and the western United States (McGowan, 1978, 1983, p. 165). The robust nature of the humerus in *O. chrisorum* relative to its more slender form in other Jurassic representatives of the genus is in keeping with its occurrence in younger (Kimmeridgian) strata. In the Albian species, *O. cantabrigiensis* (Lydekker, 1888, p. 8), the humerus is small and the width of the proximal end exceeds that of the distal end.

Other ichthyosaur occurrences of approximately similar age in the Sverdrup Basin include isolated vertebrae from the "Wilkie Point Formation" on northwestern Melville Island (NMC 30597, GSC loc. C-63341), and the Savik Group on Axel Heiberg Island (Fricker, 1963, p. 35; of Callovian to Oxfordian age, pers. comm., A.F. Embry, 1987). J.C. Sproule and Associates have also collected vertebral impressions and ribs from an articulated skeleton of a small ichthyosaur in the lower part of the Deer Bay Formation on Ellef Ringnes Island (NMC 40754); the formation is of Volgian-Valanginian age (Balkwill, 1983). What appears to be the femur (length approximately 63 mm) is shorter relative to the vertebrae (length of 12 articulated thoracic centra is 357 mm) than in *O. chrisorum*. A similarly preserved specimen was collected by E.T. Tozer from the "Wilkie Point Formation" on Prince Patrick (NMC 21862), from strata of early Bajocian age (Tozer, 1955, p. 19; Tozer and Thorsteinsson, 1964, p. 131-132).

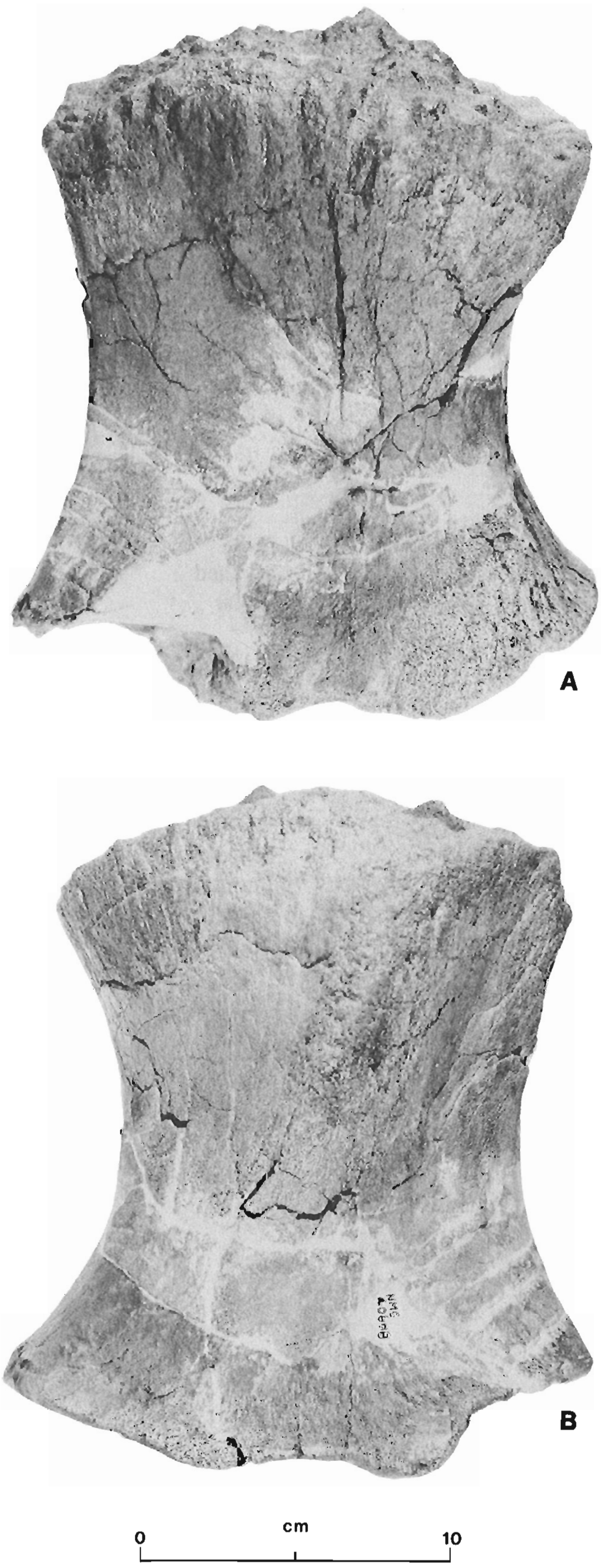

Figure 3. Ophthalmosaurus chrisorum (NMC 40608), left humerus in dorsal (A) and ventral (B) aspect. Scale in centimetres.

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PETROLOGY AND DEPOSITIONAL ENVIRONMENT OF UPPER DEVONIAN COALS FROM EASTERN MELVILLE ISLAND, ARCTIC CANADA

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Goodarzi, F., Gentzis, T., and Harrison, J.C., 1993. Petrology and depositional environment of Upper Devonian coals from eastern Melville Island, Arctic Canada; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 203-213.

Abstract

The petrology of Upper Devonian coals from the Beverley Inlet and Parry Islands formations of eastern Melville Island is described. The coals are rich in huminite and extremely poor in inertinite macerals. Sporinite is the most dominant liptinite maceral, followed by cutinite, resinite and amorphous fluorescing material. The well preserved, structured huminite is indicative of a low degree of microbial degradation, whereas the lack of inertinite indicates that the peat surface was not exposed to the atmosphere or to fire.

The coals were deposited in interdistributary bays of a floodplain area of a delta and experienced only minor fluvial influence. They are sub-bituminous A in rank and have experienced shallower depth of burial than other Upper Devonian coals in western Melville Island.

Résumé

Les auteurs décrivent la pétrologie des charbons du Dévonien supérieur qui proviennent des formations de Beverley Inlet et de Parry Islands, dans l'est de l'île Melville. Ces charbons sont riches en huminite et très pauvres en macéraux de l'inertite. Le macéral prédominant de la liptinite est la sporinite; viennent ensuite la cutinite, la résinite et les matières fluorescentes amorphes. La présence d'huminite structurée bien conservée témoigne d'une faible dégradation microbienne, tandis que l'absence d'inertite indique que la surface de la tourbe a été exposée ni à l'atmosphère ni au feu.

Les charbons se sont accumulés dans des baies entre des défluents de la plaine d'inondation d'un delta; l'influence fluviale a été faible. Ce sont des charbons subbitumineux A dont la profondeur d'enfouissement est inférieure à celle d'autres charbons du Dévonien supérieur dans l'ouest de l'île Melville.

INTRODUCTION

Coal occurs in the Canadian Arctic islands in strata ranging in age from Middle Devonian to Early Tertiary. The oldest economic coal seams in the world are of Middle to Upper Devonian age and are found in the Kuzuetsk Basin and in Kazakhstan (Teichmüller and Teichmüller, 1982). Devonian coal-bearing strata are part of an extensive clastic wedge representing the final phase of deposition in the Franklinian Geosyncline (Ricketts and Embry, 1984).

Devonian coal seams were observed in the Hecla Bay (Givetian) and Beverley Inlet (Frasnian) formations on southwestern Melville Island and were described petrologically by Goodarzi and Goodbody (1990), Gentzis and Goodarzi (1991), and Gentzis (1991). The seams are thin (0.2–0.3 m), liptinite-rich,

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and were deposited in a lower delta plain environment. Coal seams in the younger Parry Islands Formation (Famennian), on the other hand, attain thicknesses of up to 2 m and are more abundant than in other formations (Ricketts and Embry, 1984). The samples used in this study are from the Parry Islands Formation of eastern Melville Island, with the exception of one from the Beverley Inlet Formation.

The coal samples were studied for a variety of reasons: 1) coals in the Canadian Arctic may have some economic potential in the future; information about the rank, composition, distribution, and abundance of the coal seams could be useful; 2) the rank of coal reveals information about the thermal maturation history of the coals and interbedded sediments; and 3) an estimation of the maximum depth of burial for the coals can be made using reflectance values. The amount of eroded section may also be determined.

GEOLOGY

Stratigraphy

The samples studied originate from some of the youngest Devonian beds known to exist anywhere in the Canadian Arctic. On eastern Melville Island (Fig. 1), the Beverley Inlet Formation (Fig. 2) is poorly exposed and consists of two informal members that together range between 280 and 570 m in thickness. Member 1 is made up of thinly interbedded siltstone, shale, mudstone, and minor amounts of sandstone. Member 2 consists of interbedded shale, siltstone and sandstone with minor coal, plant remains and fish parts. Lithotypes and depositional sequence suggest a fluvial, lower delta plain depositional environment for member 1 and interdigitating delta-marginal (lower delta plain, distributary channel) and delta-proximal shelf environment for member 2.

The Parry Islands Formation is divided into three members: the Burnett Point, the Cape Fortune and the Consett Head (Fig. 2). The Burnett Point Member (200–310 m) consists of quartz sandstones of fluvio-deltaic origin, with minor coal. The Cape Fortune Member (50–420 m) is composed of marine siltstone in the lower part, containing brachiopods, crinoids, nautiloids and bivalves. The upper part is an interbedded sequence of siltstone, quartz sandstone, and minor coal. The Consett Head Member consists of a nonmarine quartz sandstone at the base (195–250 m), overlain by a possibly marine or lacustrine shale (65 m) with siderite nodules, and a nonmarine quartz sandstone with coal near the top (>65 m).

Regional tectonic history

The Parry Islands Formation, in the upper part of the Devonian foredeep clastic wedge, represents the youngest known strata involved in the post-Middle Famennian, pre-Viséan Ellesmerian orogeny, the tectonic event that was widespread in the Arctic Islands. The strata sampled were eroded to a peneplain during the Early Carboniferous, and, from the Carboniferous to the Cretaceous, occupied a cratonic region that was generally stable. There was probably no significant sedimentation in the area until the Aptian (Early Cretaceous), when a marine transgression occurred. It is suggested, therefore, that the contrast in thermal maturity between the Upper Devonian strata and the overlying Lower Cretaceous Isachsen Formation in eastern Melville Island (Goodarzi et al., 1992) is an indication of the thickness of Upper Famennian (and possibly Lower Carboniferous?) clastic sediments that were originally deposited in the Ellesmerian foredeep prior to the Carboniferous erosional event.

Sample locations

Sample 1109 (Table 1) was taken from a frost-heaved coal seam, apparently up to 5 m thick, that is extensively exposed along the axis of a broad syncline lying 39.7 km west of Robertson Point (Fig. 1). The seam lies within 20–30 m of the top of the preserved Consett Head Member of the Parry Islands Formation (Fig. 2). The coal seam, relatively free of clay or sand interbeds, is underlain by 10–20 m of grey shale containing siderite nodules and an abundance of plant fragments and is overlain by quartz sandstone. The shale is interpreted as representing a marginal marine to deltaic or interdistributary lacustrine deposit, and the sandstone, a fluvial deposit.

Sample 1108 (Table 1) came from a thin (10–30 cm) coal seam, exposed 23.7 km west of Richardson Point (Fig. 1). The seam is intercalated with quartz sandstone at 250 m above the base of the Consett Head Member of the Parry Islands Formation (Fig. 2).

Samples 1115, 1116, and 1117 (Table 1) were collected from a riverbank exposure at 47.5, 73.5 and 79.5 m, respectively, above the base of the Cape Fortune Member (Fig. 2). The section is located 30.4 km west of Richardson Point on the Baldwin

TABLE 1

Maceral analysis of samples from eastern Melville Island (% volume)

Sample No.	1	2	3	4	5	6	7	R_O, random (EB)
1108/84	41	27	15.3	3.6	5.0	6.3	1.6	0.57
(MMF)*	(41.8)	(27.5)	(15.3)	(3.8)	(5.2)	(6.4)		
1109/84	35.3	6.6	12.3	0.3	37.8	5.0	3.0	0.61
(MMF)	(36.4)	(6.8)	(12.7)		(39.0)	(5.1)		
1112/84	2.3	92.6	0.0	0.3	0.0	0.0	4.6	0.57
(MMF)	(2.4)	(97.3)						
1115/84	41.3	0.3	2.0	0.0	7.2	1.0	47.6	0.60
(MMF)	(79.7)	0.6	(3.8)		(14.0)	(1.9)		
1116/84	6.0	68.3	11.3	2.0	3.0	6.0	3.0	0.59
(MMF)	(6.2)	(70.6)	(11.6)	(2.1)	(3.3)	(6.2)		
1117/84	6.3	46.0	22.0	1.3	14.3	5.6	4.3	0.55
(MMF)	(6.6)	(48.2)	(24.3)	1.4	(15.0)	(5.8)		
1118/84	49.3	15.0	12.3	0.3	8.0	3.0	12.0	0.58
(MMF)	(56.0)	(17.0)	(14.0)	0.5	(9.1)	(3.4)		

LEGEND
*(MMF) Mineral matter free values; 1. Eu-uliminite B; 2. Eu-uliminite A; 3. Phlobaphinite; 4. Porigelinite; 5. Sporinite; 6. Humodetrinite; 7. Mineral matter.

River (Fig. 1). The seams are thin (<10 cm) and discontinuous. The enclosing beds are mainly grey-green siltstone and silty shale of deltaic association, with ripple crosslamination, bioturbation and plant fragments present throughout the section.

Sample 1118 (Table 1) was collected from the same section as the previous three samples, 60 m below the top of the Burnett Point Member (Fig. 2). The coal seam is 30 cm thick and is interbedded with green siltstone of fluvial/deltaic association.

Sample 1112 (Table 1) was collected from the Beverley Inlet Formation on the south facing limb of the Beverley Inlet Anticline, 25.5 km west of Nelson Griffiths Point (Fig. 1). The coal seam, about 10 cm thick, is interbedded with fine grained quartz sandstone and siltstone displaying ripple cross-lamination and an abundance of well preserved plant fragments of possibly fluvial/deltaic origin. The sample was collected about 100 m above the base of the Beverley Inlet Formation (Fig. 2).

EXPERIMENTAL METHODS

Coal samples were crushed to -20 mesh (<850 microns), mounted in resin epoxy, ground, and then polished. Reflectance in oil (n_O = 1.518 at 546 nm) was measured using a Zeiss MPM II microscope equipped with white (halogen) and ultra-violet (HBO) light sources, based on the procedure outlined in the International Handbook of Coal Petrology (I.C.C.P., 1971, 1975). Fifty reflectance measurements (%R_O, random) were made on each sample, and maceral composition was determined on 500 points using a Swift (Model F) automatic point counter attached to a mechanical stage (Table 1). Photomicrographs were taken under white and fluorescent light.

RESULTS

Microscopic characteristics

The coals are sub-bituminous A (%R_O, random = 0.55-0.61) in rank, and their petrological characteristics are described using the terminology of sub-bituminous coals.

Eu-ulminite showing cellular structure is the most abundant maceral of the huminite group. Samples 1108, 1109, 1115, and 1118 are rich in eu-ulminite B (35-49%); by contrast, samples 1112, 1116, and 1117 are rich in eu-ulminite A (15-93%). Neither textinite

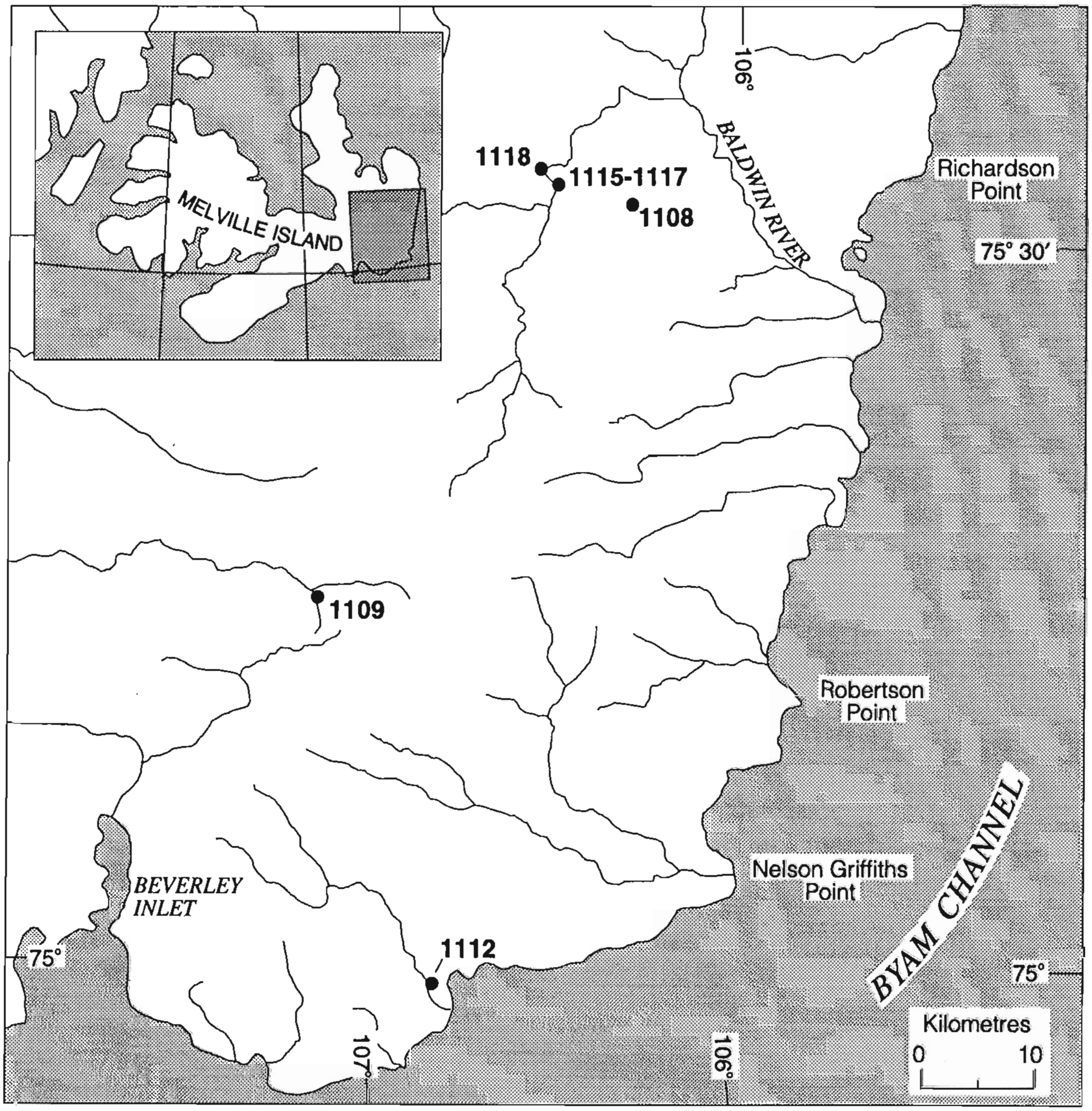

Figure 1. Map of eastern Melville Island showing sample localities.

nor texto-ulminite was observed in the samples. Humodetrinite, in the form of densinite (Fig. 3a), never exceeds 7 per cent and forms the groundmass for other macerals such as sporinite, corpohuminite and inertodetrinite. Corpohuminite (phlobaphinite) is relatively abundant, ranging from 2 to 22 per cent. These cell excretions appear as angular, subangular, spherical or elliptical bodies hosted in humodetrinite (Fig. 3a).

Almost the entire liptinite content is made up of sporinite with a minor cutinite input. Sporinite occurs in modest amounts (up to 15%) (Fig. 3b), mostly in densinite or associated with ulminite (Fig. 3a). Only sample 1109 is rich in spores (38%). Sporinite occurs as either megasporinite showing a fine granularity (Pl. 1, fig. 1) or as microsporinite (Pl. 1, figs. 2, 3). Degraded sporinite (Pl. 1, fig. 3) and amorphous fluorescing material (Pl. 1, fig. 4) are also present in the coals. Cutinite is commonly present as are very thin, elongated masses of untoothed tenuicutinite (Pl. 1, figs. 5, 6). Resinite occurs only rarely as globular bodies fluorescing dark brown. The Devonian coals are very poor in inertinite and only micrinite is present in minute amounts in sample 1108.

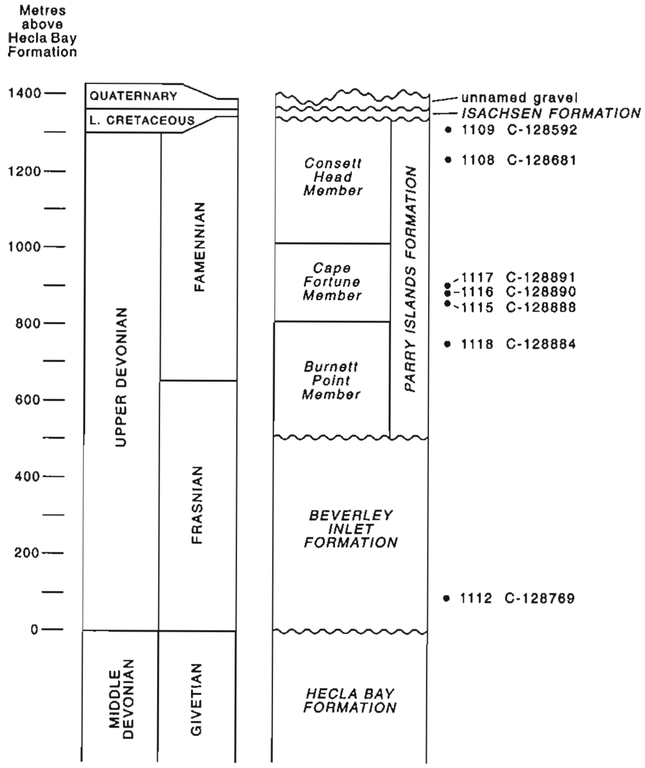

Figure 2. *Age and stratigraphic position of the samples within the Upper Devonian sequence.*

DISCUSSION

Organic petrology and depositional environment

The suite of samples here described from eastern Melville Island differs significantly from a suite of Middle to Upper Devonian coals taken from numerous sections of central-western Melville Island, earlier described by Goodarzi and Goodbody (1990). The latter coals, also taken from the Hecla Bay and Beverley Inlet formations, have a reflectance range from 0.77–0.90 per cent R_o, random (high-volatile bituminous A). They are extremely rich in mega- and microspores and contain small amounts of other liptinite macerals. Inertinite is virtually absent and these cannel coals were deposited underwater.

Structured huminite is the dominant coal maceral in the coals from the Beverley Inlet and Parry Islands formations of eastern Melville Island; such a composition indicates deposition in situ, from woody plants. The well preserved cell structures are indicative of relatively low acidity in a swamp, and thus low degree of microbial degradation of vegetal matter. Styan and Bustin (1983), and Groeneveld and Stasiuk (1984) noted that restricted bacterial and fungal activity result in a higher ratio of huminitic framework (eu-ulminite) to matrix (densinite), a characteristic feature of the eastern Melville Island Devonian coals. The precursor of the eu-ulminite was probably the woody tissues of plants present in the Late Devonian. The association of humodetrinite enclosing spores is typical of coals formed in forested swamps (Teichmüller, 1982).

In addition, the absence of framboidal pyrite and the occurrence of only finely disseminated pyrite suggests that there was little marine influence in the area. This implies a fluvial, lower delta plain depositional environment, as indicated by the sedimentology of the enclosing strata. The low mineral matter content of the coals, with the exception of sample 1115, is an indication that there was little influx of sediment. The absence of massive gelinite is evidence that no decomposition of humic substances took place and that ulminite tissues were not

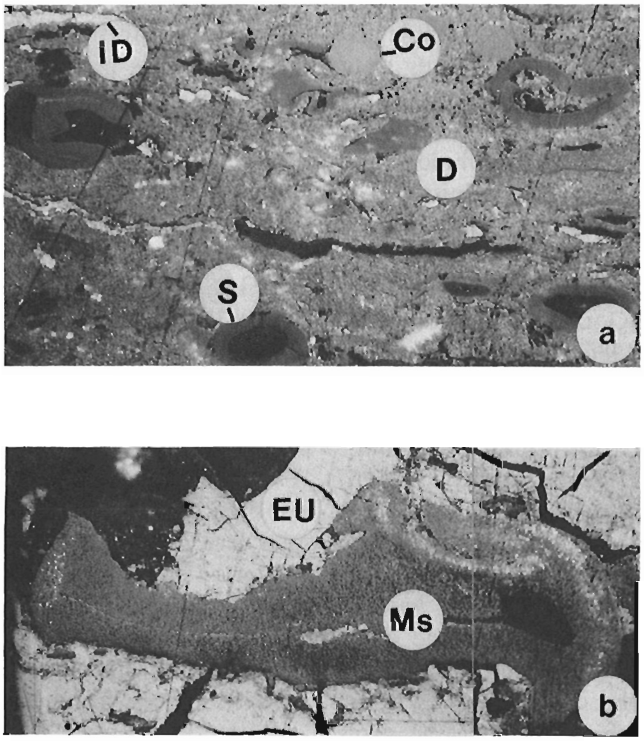

Figure 3. *Photomicrographs of Upper Devonian coals from eastern Melville Island. All photomicrographs taken in reflected light, oil immersion. The long axis of each photograph is 240 microns.* ***a.*** *Densinite (D) containing corpohuminite (Co), inertodetrinite (ID) and sporinite (S), sample no. 1109.* ***b.*** *Megasporinite (Ms) showing pitted surface in eu-ulminite (EU), sample no. 1112.*

transformed pseudomorphologically into humic gels (Teichmüller, 1982). The lack of inertinite in the coals indicates that the peat surface was not exposed to the influence of atmospheric oxygen or to fire. A fluctuating water table following deposition of the original peat would have caused extensive oxidation and degradation, and an increase in the amount of inertinite. However, this is not seen in the coals studied. Humic coals, such as the ones in this study, can be deposited under partly anaerobic conditions; this contrasts with sapropelic coals, which require subaquatic deposition under fully anaerobic conditions (Teichmüller, 1982). A necessary condition for the preservation of structured huminite is protection from the atmosphere, which is effectively achieved by a high groundwater level (Teichmüller, 1982). The petrographic nature of the coals studied (low humic detritus, absence of inertinite) indicates almost no exposure of the peat surface to the atmosphere.

The Devonian coals from eastern Melville Island can be classified as liptinite-poor clarites, with the exception of sample 1109, which is a liptinite-rich clarite. Amorphous fluorescing material is present in the liptinite-rich clarite (sample 1109, Table 1). This fluorescing material shows a homogeneous and granular morphology and is associated with individual bodies of sporinite (Pl. 1, figs. 2, 4). Because sporinite forms the bulk of liptinite in this coal, it is possible that the amorphous fluorescing material formed from sporinite. In this case the material is bituminite type II (Gormly and Mukhopadhyay, 1983; Snowdon et al., 1986).

In eastern Melville Island, Devonian coals represent depositional sites that were swamp environments (Hacquebard et al., 1967). The liptinite-poor clarites are thought to have been deposited in a forest moor that had a relatively high water level, the spores and cuticles representing forest litter. The liptinite-rich clarite sample was most likely deposited in a limnotelmatic zone (reed marsh) under deeper water (Teichmüller, 1982). The low mineral matter content of the coals indicates a calm depositional environment, which allowed the growth of vegetation over time under uniform conditions.

Fluviodeltaic sandstone, siltstone and shale occur as intercalations in the thin coal seams. The coals therefore probably represent interdistributary bay fills of a delta floodplain with minor fluvial influence (Fig. 4). Where thick coal seams lie stratigraphically between shale and sandstone, as in the case of sample 1109, the coal may represent the end product of eutrophication of shallow interdistributary bays and lakes by the prolonged growth and accumulation of limnic vegetation. The petrographic characteristics of the coals thus appear to be in accordance with the sedimentological interpretation. The depositional site must have been near a forested area to account for the high huminite content. However, limited marine or lacustrine influence during deposition of the Consett Head shale should be considered to account for the siderite nodules.

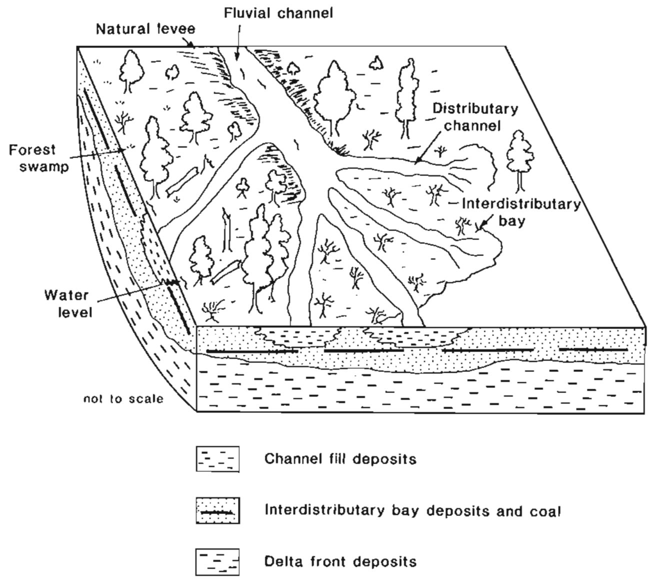

Figure 4. Model of fluviodeltaic environment of deposition, similar to that responsible for the formation of the coals examined in this study.

A ternary composition diagram (Fig. 5) shows the predominance of structured huminite macerals and almost total absence of inertinite. Huminite was formed by humification of the lignin and cellulose in plant tissue (Teichmüller, 1982). Therefore, a relatively high degree of peat preservation, and conditions favouring humification rather than oxidation of the peat are suggested. The petrological and reflectance differences between the Upper Devonian coals from eastern Melville Island (Fig. 5) are a result of differences in original material in the peat swamp, depositional environment, and burial history. The samples from eastern Melville Island were buried at shallower depths than the samples from western Melville Island (Goodarzi and Goodbody, 1990).

Vitrinite reflectance near the contact between the Lower to Middle Devonian Blue Fiord Formation and the Lower Carboniferous Canyon Fiord Formation in the Sherard Bay F-34 drillhole, situated approximately 100 km to the northwest of the present study area is

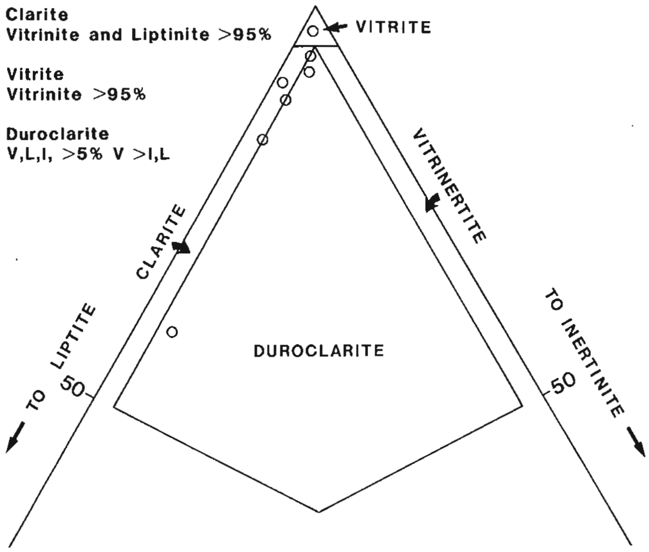

Figure 5. Ternary composition diagram for coal samples from eastern Melville Island.

approximately 1.0% at a depth of 5.3 km (Gentzis, 1991). Under a "normal" geothermal gradient of 25°C/km, the reflectance values of the Upper Devonian coals could be attained following a burial depth of approximately 2.0 to 2.5 km. Since the thermal maturity of disconformable Cretaceous cover is much lower (R_O = 0.37; Goodarzi et al., 1992, *this volume*) the 2.0 to 2.5 km of eroded strata are assumed to have been deposited in post-mid Famennian through Early Carboniferous time prior to the Ellesmerian Orogeny and subsequent post-tectonic peneplanation.

The suite of samples used in the present study may be compared to the Eocene Hat Creek deposits of British Columbia. The latter are lower in rank (lignite - 0.35% R_O, random to sub-bituminous C - 0.50% R_O, random) but are also very low in inertinite and contain some liptinite-rich intervals (Goodarzi, 1985; Goodarzi and Gentzis, 1987). The low inertinite content indicates low levels of peat fire or oxidation, and deposition in a relatively wet environment under humid climatic conditions (Goodarzi, 1985).

CONCLUSIONS

The petrographic composition of the coals suggests that the main peat-forming communities were of the forest swamp type with only minor influence from the reed moor type, and the groundwater table covered the peat surface. The coals were deposited in an interdistributary bay and floodplain area of a delta with minor fluvial influence. The lack of inertinite indicates that the oxygen supply remained relatively low at all times during deposition of the original peat.

Reflectance data indicate that the Upper Devonian coals of eastern Melville Island were buried at shallower depths compared to the Devonian coals of western Melville Island.

ACKNOWLEDGMENTS

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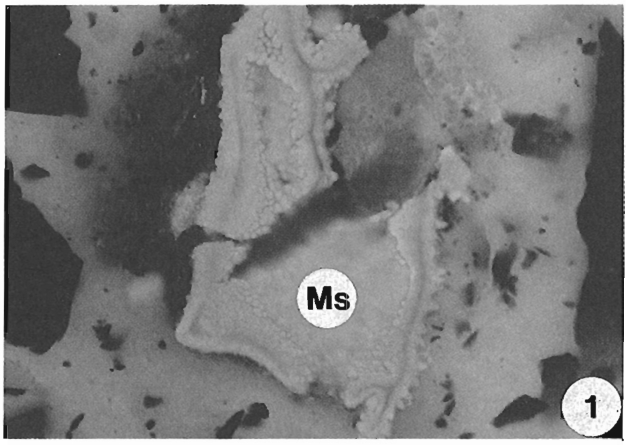
PLATE 1

All photomicrographs were taken in fluorescent light (blue-violet, excitation filter 450 nm, barrier filter 520 nm), and water immersion. Long axis of each photograph is 240 microns.

Figure 1.	Megasporinite (Ms) sectioned parallel to bedding, showing ornamentation; sample no. 1112.
Figure 2.	Concentration of strongly (SS) and weakly (SW) fluorescing spores, cutinite (CU) and amorphous fluorescing material (B) in huminite (H); sample no. 1117.
Figure 3.	Sporinite (S) showing tetrad morphology and stronger fluorescence intensity. The degraded sporinite (DS) has weaker fluorescence intensity; sample no. 1109.
Figure 4.	Amorphous fluorescing material (B) showing granularity, and sporinite (S) in huminite (H); sample no. 1119.
Figure 5.	Concentration of cutinite (CU) in huminite (H); sample no. 1109.
Figure 6.	Cutinite (CU) and sporinite (S) in huminite (H); sample no. 1115.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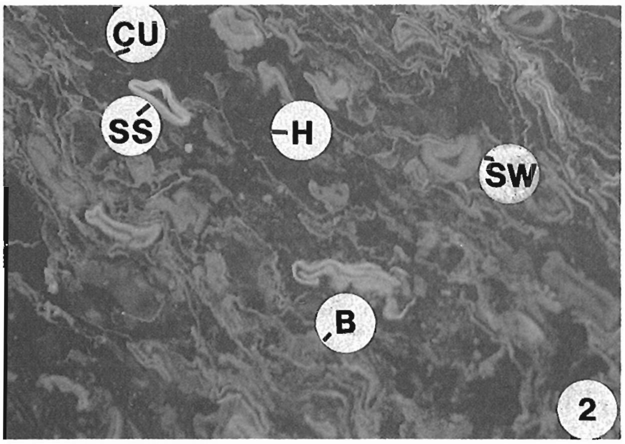
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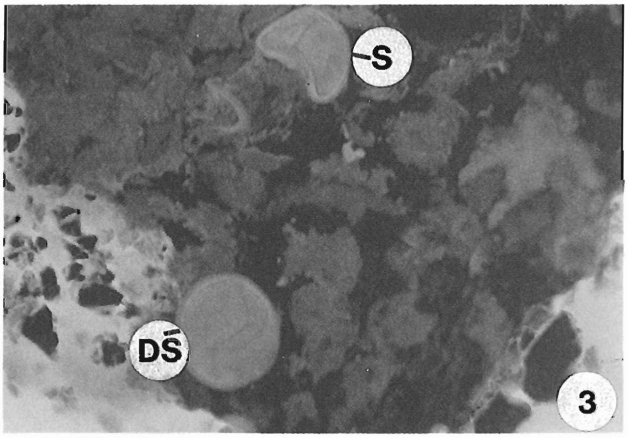
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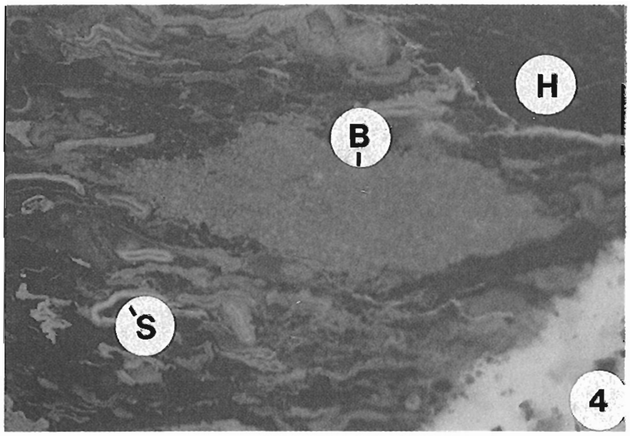
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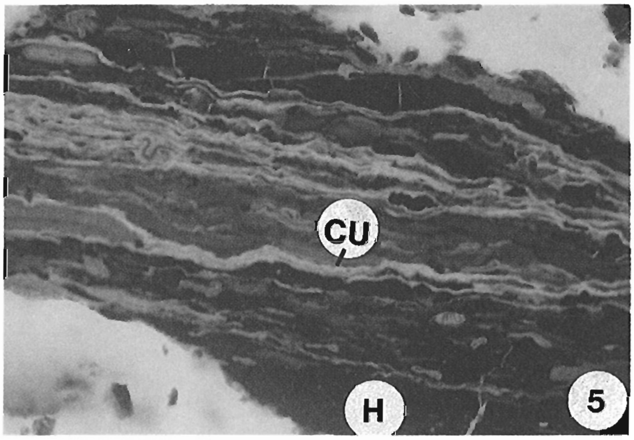
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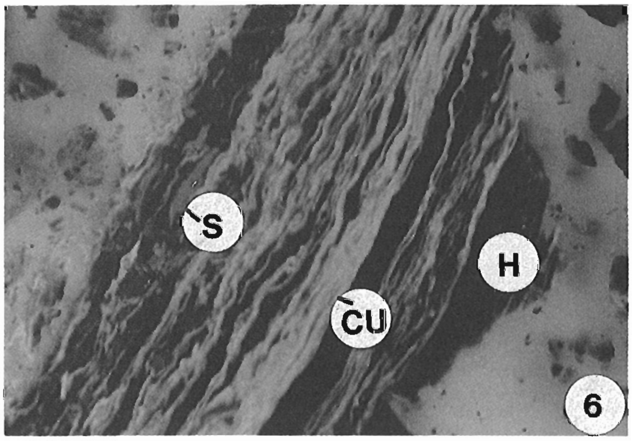
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A BRIEF STUDY OF THE ORGANIC MATTER IN PALEOZOIC AND MESOZOIC STRATA IN THE PANARCTIC DUNDAS C-80 AND CHADS CREEK B-64 WELLS, MELVILLE ISLAND, ARCTIC CANADA

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Goodarzi, F. and Gentzis, T., 1993. A brief study of the organic matter in Paleozoic and Mesozoic strata in the Panarctic Dundas C-80 and Chads Creek B-64 wells, Melville Island, Arctic Canada; in *The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 215-227.*

Abstract

Core and cutting samples from Paleozoic and Mesozoic strata from the Panarctic Dundas C-80 and Chads Creek B-64 drillholes in Melville Island, Arctic Canada contain various types of organic matter, such as vitrinite, bitumen, thermally altered bitumen, and algal material (*Tasmanales* and *Botryococcus*). Bitumen from both drillholes has a wide range in reflectance indicating numerous possible stages of oil generation and/or migration through the sediments.

The reflectance of vitrinite and/or bitumen indicates that the organic matter in both drillholes is in the marginally mature to overmature stage of hydrocarbon generation. Dispersed organic matter within the mature stage consists mainly of vitrinite with a minor amount of liptinite and is considered to be gas prone. The only exception is the Triassic Schei Point Group sediments, which contain marine algae and should be examined closely for hydrocarbon potential.

Résumé

Des carottes et des déblais de forage provenant de strates paléozoïques et mésozoïques dans les puits Panarctic Dundas C-80 et Chads Creek B-64, dans l'île Melville, Arctique canadien, contiennent divers types de matière organique, notamment de la vitrinite, du bitume, du bitume altéré thermiquement et des algues (*Tasmanales* et *Botryococcus*). Le bitume provenant des deux puits donne des chiffres de réflectance très variés, ce qui indique qu'il pourrait exister de nombreux stades de génération ou de migration du pétrole dans les sédiments.

La réflectance de la vitrinite ou du bitume indique que dans les deux puits, la matière organique est au stade de maturité marginale ou de maturité avancée de la génération d'hydrocarbures. La matière organique dispersée qui en est au stade de maturité se compose principalement de vitrinite, avec des quantités mineures de liptinite; elle pourrait donner du gaz. La seule exception se trouve dans les sédiments triasiques du Groupe de Schei Point, qui contiennent des algues marines; il faudrait étudier ces sédiments en détail afin de déterminer leur potentiel en hydrocarbures.

INTRODUCTION

Maturity determination is normally carried out on sediments containing phytoclasts, as well as on coal. Melville Island sediments of this description are mainly Upper Paleozoic (Permian) or younger, and are commonly rich in higher plant remains (Van Gijzel, 1981).

In Lower Paleozoic (Ordovician to Devonian) sediments, higher plant organic matter is normally absent and maturity must be determined on alternative

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available and reliable organic matter. Dispersed organic matter identifiable in Lower Paleozoic sediments may consist of: a) bitumen (Goodarzi et al., 1985); b) graptolites (Goodarzi, 1984a); c) chitinozoans (Goodarzi, 1985) and scolecodonts (Goodarzi and Higgins, 1987; Goodarzi et al., 1992); and d) acritarchs and *Tasmanales* algae.

Organic matter in Mesozoic sediments includes: a) amorphous algal organic matter (Type I kerogen); b) herbaceous or liptinitic organic matter (Type II kerogen); c) woody or vitrinitic organic matter (Type III kerogen); and d) coaly or inertinitic organic matter (Type IV kerogen) (Brooks, 1981).

The purpose of this study was to identify and characterize the organic material present in two drillholes on Melville Island, Arctic Canada: Panarctic Dundas C-80 in the Franklinian Geosyncline, and Panarctic Chads Creek B-64 in the Sverdrup Basin (Fig. 1).

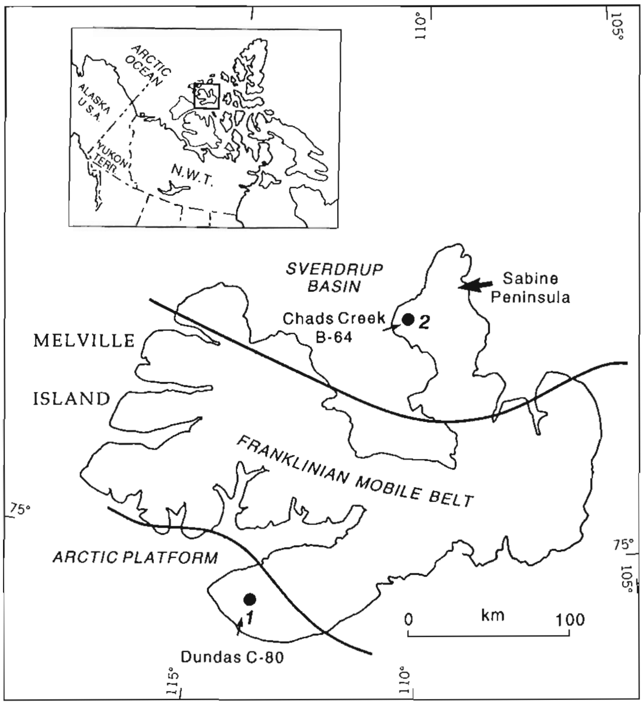

Figure 1. Map of Melville Island showing the locations of the two drillholes studied.

EXPERIMENTAL METHODS

Polished sections of cuttings and core from a total of 120 samples were made and examined using a Zeiss MPM II reflected light microscope fitted with both white (halogen) and ultraviolet (HBO) light sources. Reflectance in oil (n_O = 1.518) at 546 nm of dispersed organic matter was determined in the following manner: a) maximum and minimum for most bitumens and b) random for vitrinite.

RESULTS

Organic petrology

Panarctic Dundas C-80

A succession approximately 3940 m thick and Middle–Late Ordovician to Devonian in age was penetrated in Panarctic Dundas C-80. The Ordovician and Lower Devonian formations are mainly creamy grey dolomites, whereas Middle to Upper Devonian formations consist of alternating shale, siltstone and sandstone. The sandstone is slightly calcareous, with carbonaceous streaks. The reflectance versus depth profile is shown in Figure 2. Organic matter is moderately abundant throughout the succession, but is more abundant in the Devonian Hecla Bay and Griper Bay formations.

Liptinite is mainly composed of micro- and megasporinite, amorphous fluorescing material, cutinite and resinite (Fig. 3a–d). This type of organic matter is common in the Hecla Bay and upper part of the Weatherall formations, where it occurs in association with a considerable amount of coal fragments. Vitrinitized *Tasmanales* algae was observed at 803 m (Fig. 4a).

Vitrinite (Fig. 4b) was identified in the Griper Bay, Hecla Bay and upper part of the Weatherall formations. It consists of both the higher reflecting, oxygen-rich, and the lower reflecting, hydrogen-rich vitrinite types (Goodarzi et al., 1987a). Vitrinite reflectance at the top of the drillhole averages about 0.80% R_O. Reflectance gradually increases with depth until it reaches the upper limit of the "oil window" (1.25% R_O) at 1800 m.

The interval between 1300 m and total depth is rich in three types of bitumen, all of which are anisotropic. The interval between 1300 m to 2400 m contains two types of bitumen, but only sparse vitrinite. The low-reflecting bitumen has an elongated morphology (Fig. 4c) and a reflectance range from 1.5 to 3.0% R_O (max) (epi- to meso-impsonite maturity stage), whereas the high-reflecting bitumen (Fig. 4d) has a reflectance ranging from 2.5 to 4.1% R_O (max) with increasing depth. The latter is highly angular, granular under

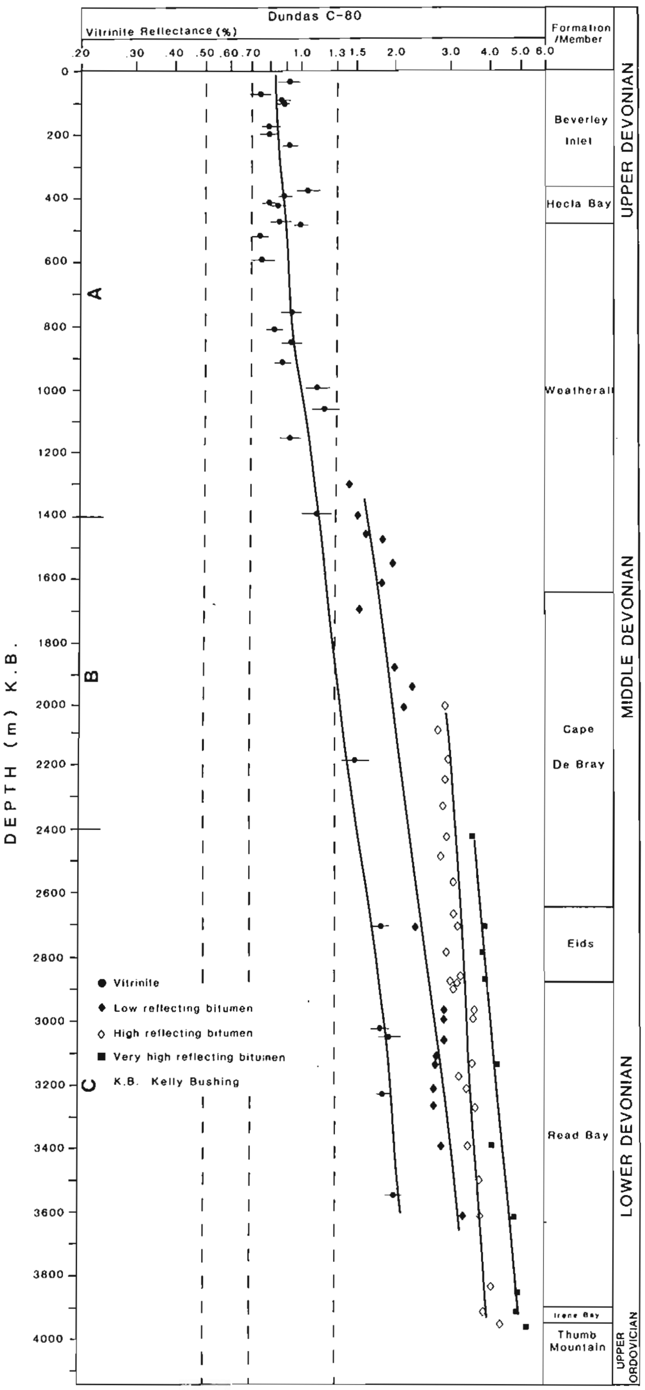

Figure 2. Reflectance depth profile for drillhole Panarctic Dundas C-80.

crossed polars, and is associated with carbonate grains. It closely resembles metabituminite of Teichmüller (1982).

The interval between 2400 m and total depth contains a third type of bitumen. This strongly reflecting bitumen shows granularity and its reflectance increases from 3.5 to 5.0% R_0 (max) (cata-impsonite) with increasing depth. This material occurs as massive, subangular fragments having a bireflectance of almost 2%. Finally, it should be noted that reflectance of low-, high- and strongly reflecting bitumen, as well as of vitrinite, increases with depth and follows subparallel trends (Fig. 2).

Panarctic Chads Creek B-64

Panarctic Chads Creek B-64 penetrated a succession almost 5200 m thick ranging in age from Permian to Cretaceous. The top 3000 m consist mainly of alternating shale, siltstone and calcareous sandstone with carbonaceous streaks. The interval from 3000 m to 3700 m is dominated by dark grey to black chert, which is very argillaceous and slightly calcareous. Below this depth, a medium to dark grey siliceous, slightly glauconitic shale dominates, containing black carbonaceous inclusions.

Organic matter in the Permian sediments is mainly composed of inertinite, "vitrinitized" *Tasmanales*, and bitumen. Generally, the Triassic section contains phytoclasts along with reworked material of higher reflectance. The Triassic Schei Point Group contains marine liptinite, amorphous fluorescing material, dinoflagellates, and *Tasmanales*, whereas the Bjorne Formation sandstones are very poor in organic matter. The Jurassic and Cretaceous formations contain low to moderate amounts of organic matter. Visible organic matter consists of bitumen, vitrinite, inertinite and palynomorphs such as dinoflagellates, *Tasmanales* and *Botryococcus* algae.

The reflectance versus depth profile is shown in Figure 5. Phytoclast content is generally low to moderate, except for the interval between 3900 m and total depth, where it is moderate to high. Very low-reflecting (0.15% R_0), yellow fluorescing material was observed filling cracks among huminite macerals at depths of 257 m and 972 m (Pl. 1, fig. 1). It is most likely exsudatinite. *Botryococcus* colonial algae, fluorescing with an intense yellow colour (Pl. 1, fig. 2) is present at 850 m, along with other small algal bodies. *Tasmanales* algae with a high intensity yellow colour (Pl. 1, fig. 3) was observed at 1666 m, and amorphous material of possibly algal origin is present at 1070 m (Pl. 1, fig. 4) and at 1557 m (Pl. 1, fig. 5). Cutinite was also identified at 518 m (Pl. 1, fig. 6). Dinoflagellate cysts were identified at depths of 1818 m, 2133 m and 2636 m; they have characteristic spines and fluoresce with a lime-yellow colour (Pl. 1, fig. 7). They are, however, invisible in white light, making reflectance measurements impossible.

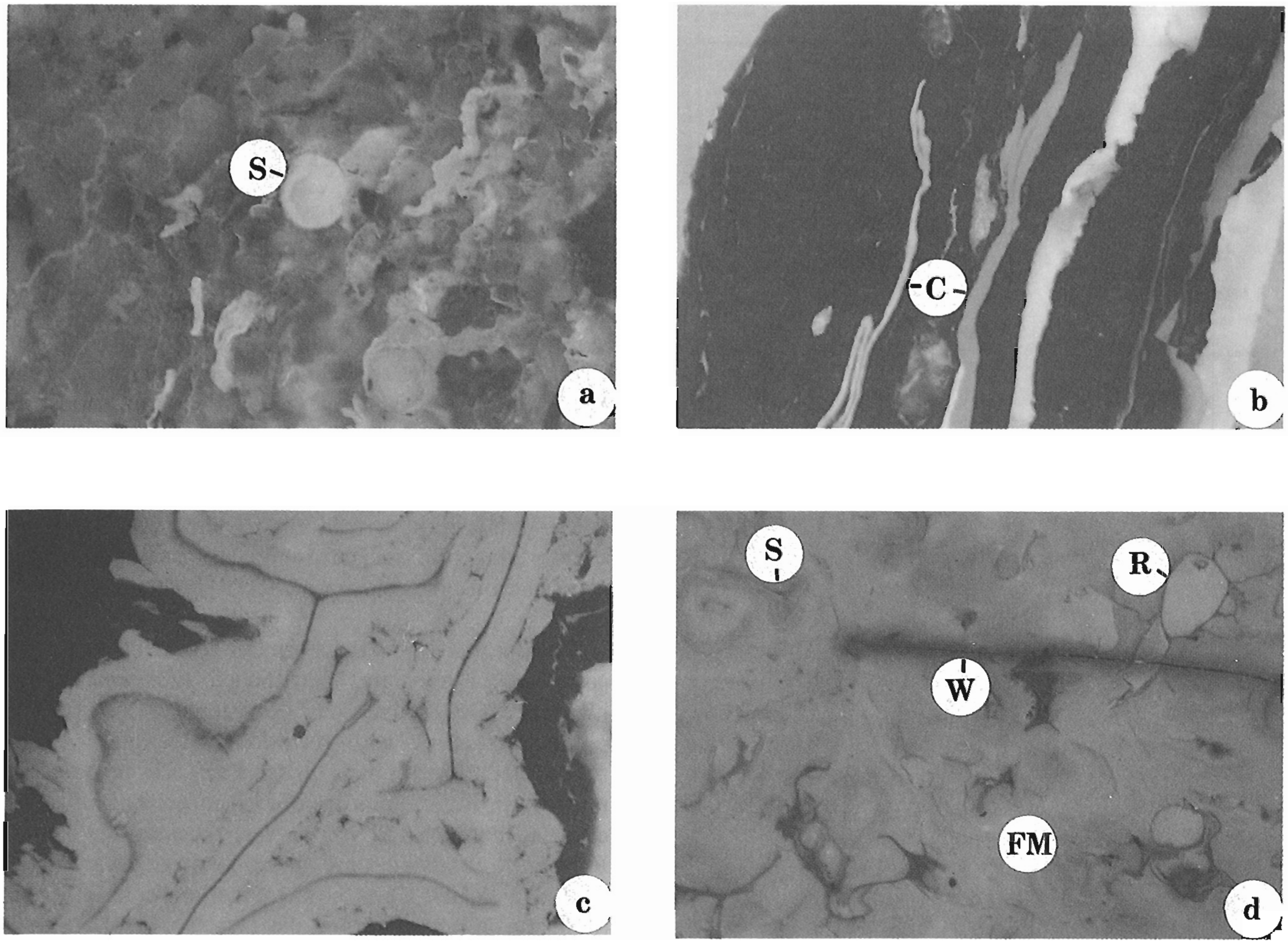

Figure 3. Dispersed organic matter in Dundas C-80. Photographs taken in UV light (excitation filter and barrier filter at 510 µm). Long axis 260 µm. ***a.*** *Spores (S), depth = 518 m showing characteristic trilete mark;* ***b.*** *Folded cutinite (C), depth = 518 m;* ***c.*** *A megaspore showing ornamentation of the exine, depth = 518 m;* ***d.*** *Amorphous fluorescing matrix (FM) containing resinite globules (R), degraded sporinite (S), and showing the influence of weathering (W), depth = 476 m.*

Low-reflecting bitumen of epi-impsonite maturity (1.4–3.0% R_O) was observed only sporadically and its trend is more clear below the igneous intrusion occurring at a depth of >3400 m. High-reflecting bitumen is present throughout the succession except in the Triassic Blind Fiord, Bjorne and Schei Point Group formations. It has a reflectance range between 1.6 and 4.0% R_O (max) is slightly granular, associated with carbonates and, at least in the Jurassic–Cretaceous part of the section, appears to be metabituminite (Teichmüller, 1982). The bitumen is highly reflective [up to 6.0% R_O (max)] and shows signs of thermal alteration such as development of granular texture and high anisotropy (Fig. 6) at a depth of approximately 3800 m. This sudden increase in reflectance is the result of an igneous intrusion, described as a diabase sill (Balkwill and Haimila, 1978).

DISCUSSION

Panarctic Dundas C-80

The organic matter found in Lower Paleozoic sediments in Panarctic Dundas C-80 located on Dundas Peninsula is identified as exinite (sporinite, resinite, amorphous fluorescing material), vitrinite and bitumen. Based on the type of organic matter and its optical properties, three different sections can be distinguished in the Lower Paleozoic of Dundas C-80.

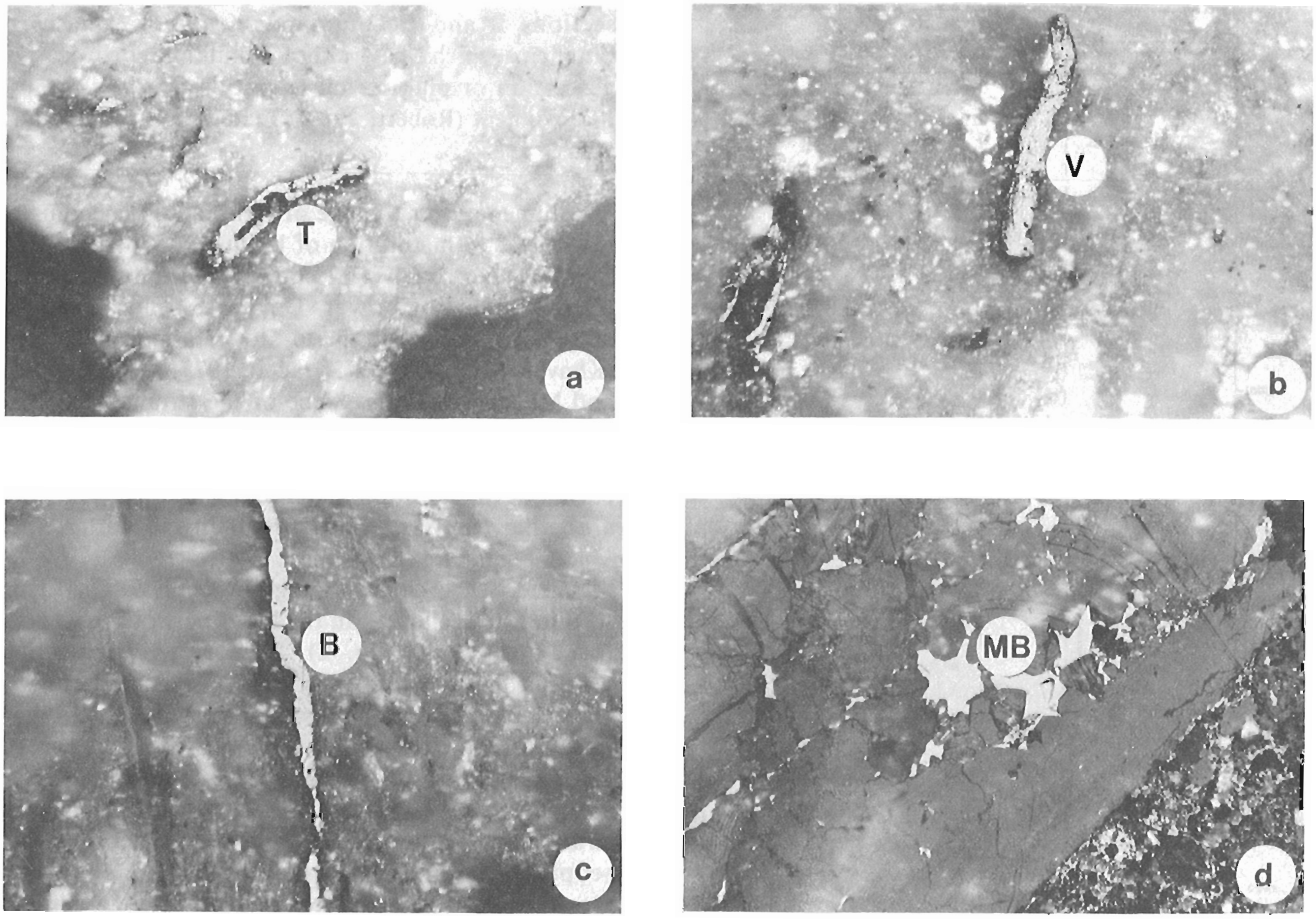

Figure 4. *Photographs taken in incident white light, (partially crossed polar). Long axis 240 μm.* ***a.*** *Vitrinitized algae, most likely* ***Tasmanales,*** *showing characteristic suture (T), depth = 1878 m;* ***b.*** *Phytoclast (vitrinite) (V), depth = 1697 m;* ***c.*** *Low-reflecting elongated bitumen (B), depth = 1880 m;* ***d.*** *High-reflecting bitumen, possibly metabituminite (MB) in carbonate matrix, depth = 2712 m.*

Section A, the top section (Fig. 2), contains only phytoclasts and no bitumen. The organic-rich samples in the Hecla Bay Formation contain coal fragments rich in liptinite material. Reflectance of vitrinite in these sediments is suppressed because of the varying amounts of liptinite. Hutton and Cook (1980), Snowdon et al. (1986), and Goodarzi et al. (1987b), have demonstrated that reflectance of vitrinite associated with liptinitic materials is significantly lowered (up to 50%) as the amount of liptinitic materials increases.

Organic matter in this section is similar to that described by Goodarzi and Goodbody (1990) in a suite of Devonian coals from the Hecla Bay Formation in the western part of Melville Island. The coals contain large amounts of micro- and mega-sporinite with minor cutinite, fluorinite, exsudatinite, resinite, amorphous fluorescing material and fluorescing vitrinite. One sample consisting of what appears to be amorphous fluorescing material (bituminous) (Gormly and Mukhopadhyay, 1981; Snowdon et al., 1986) shows the effect of weathering and/or microbiological degradation. It consists of degraded sporinite and well defined resinite bodies in a fluorescing matrix. Weathering is represented by a dark fluorescing rim surrounding a crack (Fig. 3d) and microbiological degradation is evident on sporinite and resinite.

Section B (Fig. 2) includes the lower half of the Weatherall Formation and contains very little vitrinite suitable for determining thermal maturation. It commonly contains solid bituminous black material, which, downhole in section C, occurs as a coating or filling between carbonate grains. This material resembles bitumen, and microscopic examination shows that it is insoluble in oil immersion and shows no fluorescence under UV light. Numerous samples in

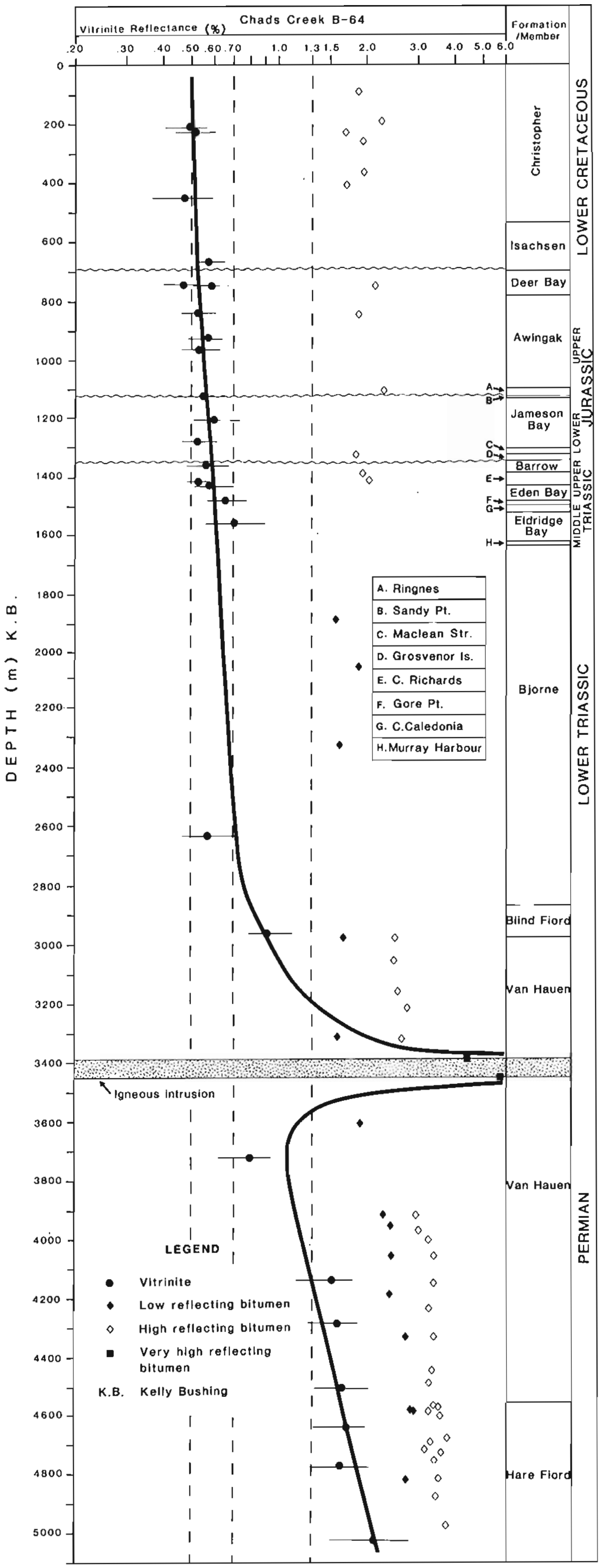

Figure 5. Reflectance depth profile for drillhole Panarctic Chads Creek B-64.

sections B and C contain one or more phases of bitumen, which may indicate multiple hydrocarbon generation or multiple oil migration episodes through the sediment (Robert, 1980; Goodarzi, 1982; Goodarzi et al., 1985).

Bitumen covers a range of reflectance depending on the degree of maturation of bitumen (Goodarzi et al., 1985). The strongly reflecting bitumen in section C (Ordovician to Lower Devonian) has granular anisotropy and is in meso- to cata-impsonite stage (Khavari-Khorasani 1975; Jacob, 1975, 1983; Goodarzi and Macqueen, 1990). Some of the strongly reflecting bitumen has developed pores and vesicles ranging in diameter from a few to 50 microns, which indicates partial devolatilization and strong maturity. The pores are either empty or filled with mineral matter.

There is a lithology change in drillhole C-80 from section B to section C, in the lower part of the Cape de Bray Formation (Fig. 2). The strongly reflecting, granular, and highly anisotropic bitumen occurs in Ordovician to Lower Devonian dolomite with vugs partly or completely filled with clear dolomite crystal growth, medium to coarse in size. Bitumen is present around the edges of the vugs or along carbonaceous stringers, a feature that can be seen after a macroscopic examination of samples from the cored intervals. The presence of highly reflecting bitumen may be related to the age, porosity and lithology. It may also represent a de-asphalted bitumen in a former reservoir.

Panarctic Chads Creek B-64

The Schei Point Group contains marine liptinite dinoflagellates and *Tasmanales*. The sediments of the Eden Bay Member are bitumen-stained. A suppression of vitrinite reflectance has been caused by the presence of hydrogen-rich organic matter.

The phytoclast content in the Bjorne Formation is very low. Dinoflagellates are present at depths of 1818 m, 2133 m and 2636 m, and possess characteristic spines. The presence of dinoflagellates indicates a marine environment for these sediments. Dinoflagellates generally have long processes, indicating a quiescent offshore environment, whereas in turbulent conditions naked or short-processed forms are prevalent (Sherwood and Cook, 1986). The Jurassic and Cretaceous sediments are rich in organic matter. Phytoclasts consist of vitrinite, inertinite dinoflagellates and algae such as *Tasmanales* and *Botryococcus*. The huminite fragments in the Lower

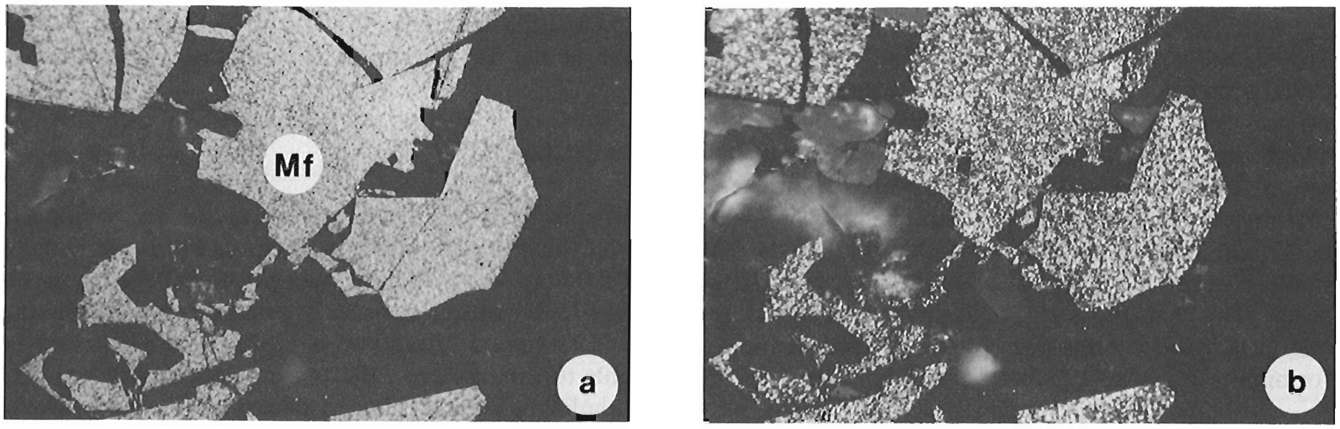

Figure 6. Heat affected bitumen showing fine grained mosaic texture and high anisotropy, Chads Creek B-64, 3390 m. Photographs taken in incident white light. Long axis 240 µm. ***a.*** *Partially crossed polars and* ***b.*** *microscope stage is rotated 90° to show the anisotropy. Mf = fine grained mosaic.*

Cretaceous Christopher Formation (257 m) and Upper Jurassic Awingak Formation (972 m) contain cracks filled with exsudatinite, indicating a mobilization of hydrogen-rich material, which occurs at the early catagenetic stage of hydrocarbon generation ($\%R_0>0.5$) (Murchison, 1987; Teichmüller, 1982; Goodarzi et al., 1987a). The occurrence of marine algae, such as *Nostocopsis* at depths of 850 m in the Deer Bay Formation indicates a marine environment of deposition (Moore, 1968; Goodarzi et al., 1987b) for these sediments, and a good potential for hydrocarbon generation.

The sediments at the top of this drillhole are marginally mature and become fully mature at a depth of 4800 m. The presence of laminae, coupled with fine grain size shows that the Schei Point Group formations were deposited in quiet, low-energy conditions at a slow rate of sedimentation. The preservation of the laminated texture indicates little bioturbation and biodegradation and, therefore, few burrowing benthonic organisms. This type of sediment should, particularly when rich in liptinite and exinite (e.g., 1070–1757 m), have an excellent source rock potential.

Drillhole Panarctic Chads Creek B-64 can be subdivided into two possible sections, based on type and degree of metamorphism of organic material (Fig. 5). The upper section contains vitrinite and bitumen at the top. The bitumen is metabituminite associated with dolomitic shale of the Christopher Formation. In lower section B, metabituminite is transformed into a thermally altered, highly reflecting product because of the effect of a diabasic sill, which caused a large increase in reflectance due to the high temperatures of the intrusion (Fig. 5). Reflectance increases suddenly from approximately 1.8% to 3.0% R_0 (max) near the contact. Reflectance values of 3.0% R_0 (max) are common in contact metamorphism and Dow (1977) states that the maturity of the intruded rock is affected to about twice the diameter of the intrusive body, often slightly more above the intrusion than below it. The actual distance depends on the temperature of the intrusion and the thermal conductivity of the intruded rocks (Hunt, 1979). At a depth of 3900 m and below, bitumen reflectance resumes the extrapolated trend above the intrusion.

All bitumens in drillhole Chads Creek B-64 are anisotropic, with the exception of a very low-reflecting and fluorescing type of organic matter present in section A. This material infills primary cavities in phytoclasts and, based on reflectance and fluorescence, is most likely exsudatinite. It is apparent from this relationship that exsudatinite has a secondary origin and is less abundant than bitumen in the samples studied.

The reflectance of both low- and high-reflecting bitumen in section B increases with depth, with the low-reflecting bitumen showing a trend subparallel to that of the high-reflecting population (Fig. 5). Bitumens in the Permian–Lower Triassic are most likely primary. They were generated from the primary phytoclasts in these sediments, and were therefore subjected to thermal stress similar to that of vitrinite. However, bitumens are more sensitive to thermal stress than vitrinite (Khavari-Khorasani and Murchison, 1976; Goodarzi and Macqueen, 1990) and can attain higher aromaticity, and higher reflectance than vitrinite, due to their structural mobility during heat treatment (Khavari-Khorasani and Murchison, 1976).

In contrast to the bitumen in the Permian–Lower Triassic section, bitumen in the Upper Triassic–Upper Cretaceous has a similar reflectance for about 1000 m, whereas reflectance of vitrinite increases above this depth (Fig. 5). This indicates that the bitumen is a residue from the migration of hydrocarbons into these sediments. The migrated bitumen has probably undergone thermal stress much higher than its thermal stability because of the continuous subsidence of the basin. This has resulted in thermal cracking of the migrated hydrocarbons trapped in this section and the formation of residual high-reflecting bitumen (Fig. 5).

The bitumens in the two drillholes studied have a wide range of optical properties, indicating that their source, origin and diagenetic history may be quite different. Based on morphology and optical properties, most appear to have matured (Jacob, 1985; Goodarzi and Macqueen, 1990). Most of the bitumens fall within the impsonite stage of maturity and may have been formed in two different ways: 1) they may represent the products of thermal alteration of heavy oils (Krebs and Macqueen, 1984); or 2) they may have formed by the alteration of earlier migrated heavy oil by de-asphalting (Rogers et al., 1974). In both drillholes, the lower reflecting bitumen that shows no increase in reflectance with depth may represent the most recent migration and the higher reflecting bitumen the oldest migration (Robert, 1980; Goodarzi et al., 1985).

SOURCE-ROCK POTENTIAL

The level of thermal maturation of the samples was determined petrographically using reflectance and qualitative fluorescence only. Organic material in the Upper Paleozoic and Mesozoic sediments in Chads Creek B-64, is derived mainly from terrestrial vascular plants, dinoflagellates, algae, and bitumen. The fluorescence intensity of dinoflagellates, *Tasmanales* and *Botryococcus* algae in Chads Creek B-64, along with reflectance values, indicates that the enclosing sediments are immature to marginally mature. Phytoclasts in the Triassic–Cretaceous strata of Chads Creek B-64 are marginally mature (0.5–0.6% R_O) and this, along with the moderate occurrence of marine liptinite in the Schei Point beds would make the organic matter capable of producing liquid hydrocarbon beyond an R_O value of 0.7%. The relative degree of maturation varies depending on the type of organic matter.

Taking into consideration the type of organic matter, its content and level of maturation, the phytoclasts in Dundas C-80 down to a depth of 1800 m are in the oil generation zone and are gas-prone.

CONCLUSIONS

On the basis of organic petrology studies, it appears that the Paleozoic strata of drillhole Panarctic Dundas C-80 may formerly have been petroleum source rocks. The highly reflecting material present in the Ordovician and Devonian formations is bitumen, and one may be able to use bitumen reflectance to differentiate among lithologies and possibly to determine the depositional environment.

In drillhole Panarctic Chads Creek B-64, a classic example of alteration of organic material can be seen due to heat produced by a sill. It is assumed that no liquid hydrocarbons were generated at depths greater than 4300 m (the oil window limit), although they could have migrated to shallower depths such as 200–1100 m. The Triassic Schei Point Group strata are the most promising for further source-rock potential studies.

ACKNOWLEDGMENTS

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PLATE 1

Photographs taken in UV light, excitation filter and barrier filter at 510 nm. Long axis 240 μm.

Figure 1. Fluorescing exsudatinite (Ex) in coaly particle, depth = 973 m.

Figure 2. Yellow-fluorescing colonial *Botryococcus* algae (B) in a fluorescing matrix, depth = 849 m.

Figure 3. Unicellular *Tasmanalas* algae (T) fluorescing with a very high intensity. Note the surrounding fluorescing amorphous matrix (FM), depth = 1849 m.

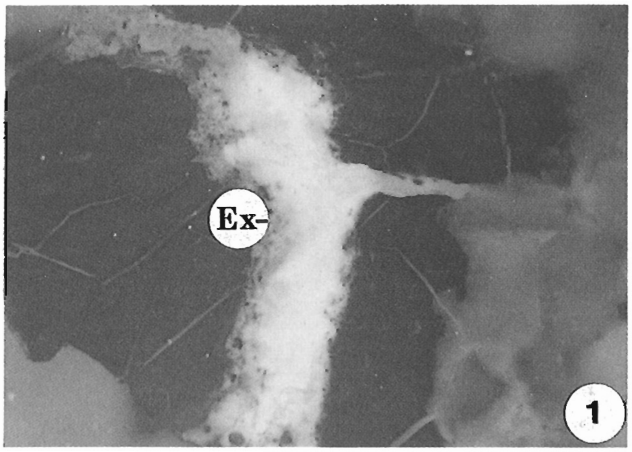
Figure 4. Orange-fluorescing filamentous algal material (A) trapped among carbonate grains, depth = 1070 m.

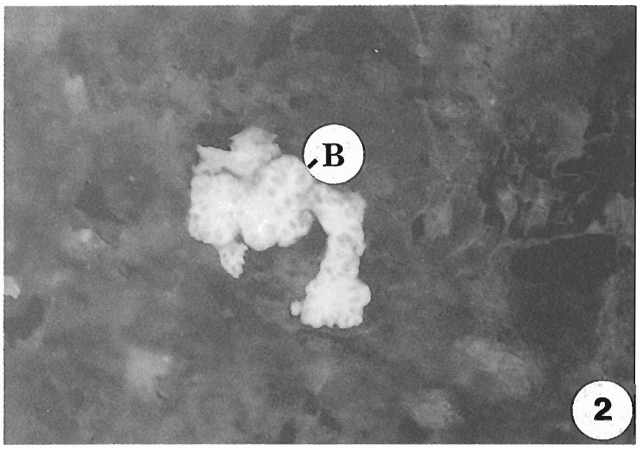
Figure 5. Broken *Tasmanales* (T) fluorescing lime-yellow in a fluorescing matrix, depth = 1757 m.

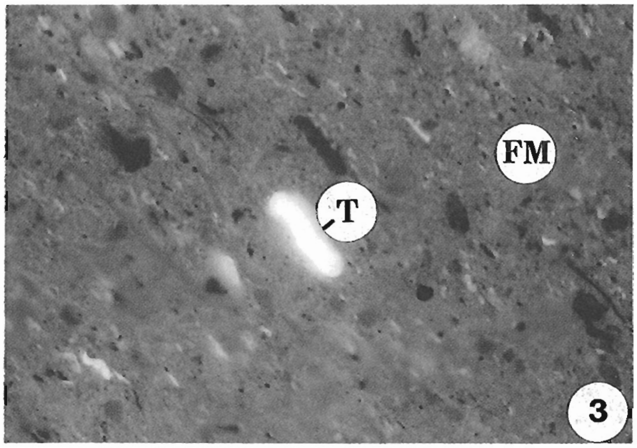
Figure 6. An oblique section through a cuticle (C) fluorescing bright yellow with a darker interior, depth = 518 m.

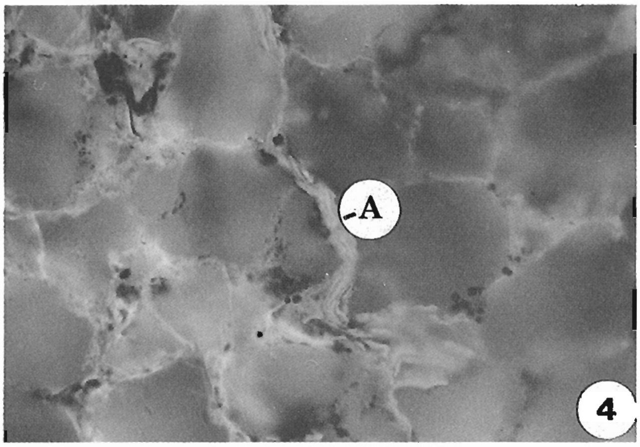
Figure 7. Lime-yellow fluorescing dinoflagellate (D) depth = 1818 m.

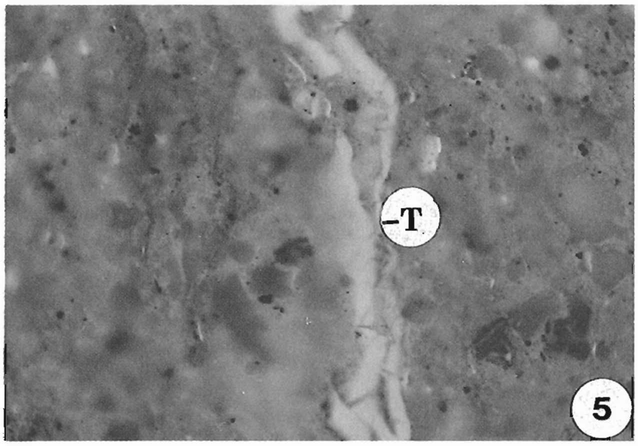
PLATE 1

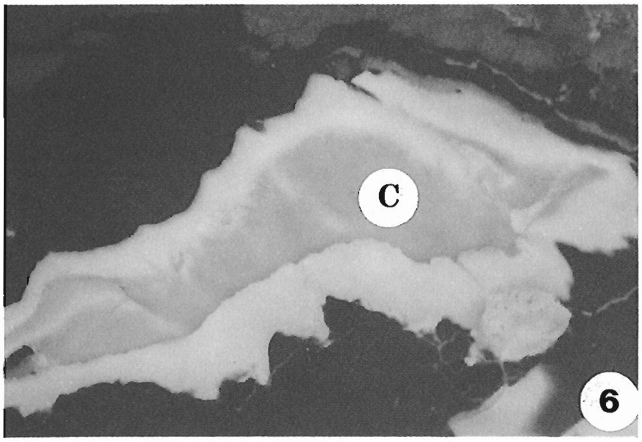


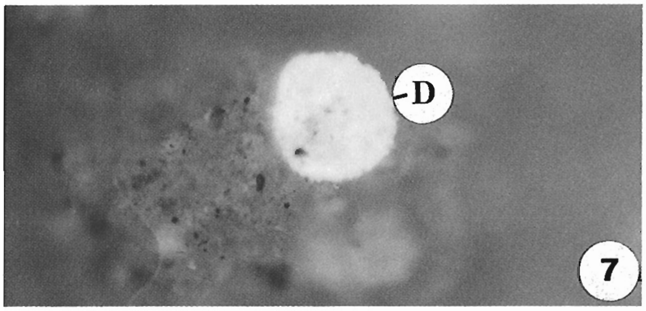












STRATIGRAPHY AND PETROLOGY OF LOWER CRETACEOUS COAL, SOUTHEASTERN MELVILLE ISLAND, DISTRICT OF FRANKLIN, ARCTIC CANADA

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Goodarzi, F., Harrison, J.C., and Wall, J.H., 1993. Stratigraphy and petrology of Lower Cretaceous coal, southeastern Melville Island, District of Franklin, Arctic Canada; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 229–245.

Abstract

The Lower Cretaceous strata of southeastern Melville Island are up to 100 m thick and, within three outlier areas, lie with pronounced angular unconformity, on folded and peneplained Devonian rocks. The vertical succession of lithofacies is fluviatile sandstones and conglomerates at the base in the lower Isachsen Formation, passing upward through reed marsh coal, lagoonal siltstone and barrier sheet sandstone of the upper Isachsen Formation and overlying shallow marine shales of the Christopher Formation at the top. This accumulation sequence is consistent with a regional marine transgression onto the craton observed in strata of late Aptian to early Albian age throughout the Arctic islands. General setting of coal formation was a humid, temperate coastal marsh bordering a brackish back-barrier lagoon on the southern ancestral periphery of the Sverdrup Basin.

Coal seams in the Isachsen Formation are laterally continuous and from 1 to 3 m thick within two of the three outlier areas. The coals at four localities range from lignite to high-volatile bituminous in rank and are petrologically classified as liptinite-rich duroclarites, vitrinertites and vitrinertoliptites. The liptinite-rich coals were formed in a limnotelmatic (reed) marsh setting. There are also indications of selective oxidation and weathering during formation. The vitrinertoliptite-rich coals are similar to "needle" coal reported by Gibson (1977) from the Lower Cretaceous Kootenay Group of southern British Columbia.

Résumé

Dans le sud-est de l'île Melville, les strates du Crétacé inférieur atteignent une épaisseur maximale de 100 m et, dans trois buttes-témoins, reposent en discordance angulaire prononcée sur des roches dévoniennes plissées et pénéplanées. La succession verticale de lithofaciès comporte des grès et des conglomérats fluviatiles de base dans la partie inférieure de la Formation d'Isachsen; ils se transforment vers le haut de la coupe en charbon de roseraie, en siltstone lagunaire, en couverture de grès de cordon dans la partie supérieure de la Formation d'Isachsen et enfin, au sommet, en schistes épicontinentaux sus-jacents de la Formation de Christopher. Cette séquence d'accumulation est compatible avec une transgression marine régionale sur le craton que l'on observe dans les strates de l'Aptien tardif-Albien précoce partout dans l'archipel arctique. En général, le charbon s'est accumulé dans un marais côtier tempéré et humide, en bordure d'une lagune saumâtre d'arrière cordon, sur la marge sud du proto-bassin de Sverdrup.

Les filons de charbon de la Formation d'Isachsen sont latéralement continus, et leur épaisseur varie de 1 à 3 m dans deux des trois buttes-témoins. À quatre endroits, les charbons varient d'une lignite à un charbon bitumineux à haute teneur en matières volatiles; ils sont classés pétrologiquement en duroclarites riches en liptinites, en vitrinertites et en vitrinertoliptites. Les charbons riches en liptinite se sont formés dans un marais limnotelmatique (à roseaux). Selon certains indices, il y a eu oxydation et altération sélectives au cours de leur formation. Les charbons riches en vitrinertoliptite ressemblent aux charbons en aiguille signalés par Gibson (1977) dans le Groupe de Kootenay du Crétacé inférieur, dans le sud de la Colombie-Britannique.

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INTRODUCTION

Coal occurs in the Canadian Arctic islands in rocks ranging from Middle Devonian to Eocene in age (Ricketts and Embry, 1984). Lower Cretaceous coals are found exclusively in the nonmarine sections of the Isachsen Formation, where most seams range from 0.10 up to 1 m thick. Roy (1973) has also suggested that most Isachsen "coals" in the Sverdrup Basin are actually carbonaceous shales, and that true coal seams are much thinner and have limited lateral persistence (less than 1 km).

Lignite and subbituminous coals have been found in the Lower Cretaceous strata of southeastern Melville Island. Coal beds are 1 to 3 m thick and laterally continuous over distances of 10 to 15 km. This paper reports on the geology and properties of the Lower Cretaceous coals, and on their enclosing strata.

REGIONAL GEOLOGY

The Isachsen Formation was named by Heywood (1955, 1957) for 900 m of quartz sandstone, siltstone, minor interbedded claystone, and coal exposed around Isachsen Dome on Ellef Ringnes Island. The unit was subsequently mapped throughout the Sverdrup Basin, from Prince Patrick Island to northern Ellesmere Island (Thorsteinsson and Tozer, 1962; Tozer and Thorsteinsson, 1964; and others, see recent review by Embry, 1985).

From a thorough examination of well and surface sections, Embry (1985) subdivided the Isachsen Formation into three members. These include a basal, fluviodeltaic sandstone-siltstone unit (Paterson Island Member), a thin transgressive marine shale marker (Rondon Member), and an upper, deltaic sandstone-siltstone unit (Walker Island Member).

In many areas, the basal contact of the Isachsen Formation is a regional unconformity, and the Isachsen Formation oversteps Jurassic, Triassic, upper Paleozoic and older rocks, proceeding outward from the Sverdrup Basin depocentre (Thorsteinsson and Tozer, 1960). Both Miall (1979) and Embry (1985) suggested that basal Isachsen beds become younger outward as a result of this shelf to basin-margin onlap.

The upper contact of the Isachsen Formation is gradational with marine shale and fine sandstone of the Invincible Point Member of the Christopher Formation (Embry, 1985), also of the Sverdrup Basin succession.

Beyond the Sverdrup Basin, the Isachsen Formation is preserved in erosional remnants and small fault-bounded basins on southern Prince Patrick Island, on Eglinton and Banks islands, on southeastern Melville Island and in the Lake Hazen area of northern Ellesmere Island. On Banks Island, the Isachsen ranges from 0 to 200 m in thickness, with considerable lateral variation in lithology, possibly reflecting local paleotopographic relief (Miall, 1979).

ISACHSEN FORMATION ON MELVILLE ISLAND

The Isachsen Formation is preserved in three northwest-trending erosional remnants on southeastern Melville Island (Fig. 1), where the unit unconformably overlies peneplained Middle to Upper Devonian clastic rocks of the Parry Islands Fold Belt (Fortier and Thorsteinsson, 1953). The three outcrop areas are here informally named the Mecham River, Bridport, and Skene Bay outliers.

Sverdrup Basin occurrences

The distribution of the Isachsen Formation in southeastern Melville Island is shown in Figure 1. Exposures along the northern edge of the island define the southern limit of preserved Isachsen Formation in the Sverdrup Basin. In these areas, the Isachsen ranges from 140 to 180 m thick. The three members recognized by Embry (1985) can be observed in outcrop on southern Sabine Peninsula. On Sproule Peninsula, the lower, or Paterson Island Member, is a mature, pebbly quartz sand containing allochthonous coal fragments and rare, lenticular patches of coalified plant debris. The thicker Walker Island Member consists of castellate-weathering, fine to medium grained, grey to white sand, silt, and lesser grey shale. Coal occurs as discontinuous seams, up to 20 cm thick, intercalated with carbonaceous shale and black carbonaceous silt.

On Sproule Peninsula and near Cape Grassy, the Isachsen Formation lies disconformably on the Deer Bay Formation and is conformably overlain by the basal Christopher Formation. On southern Sabine Peninsula, the Isachsen lies unconformably on the Awingak, Ringnes and Sandy Point formations and is conformably overlain by a notably sandy facies of the Invincible Point Member of the Christopher Formation.

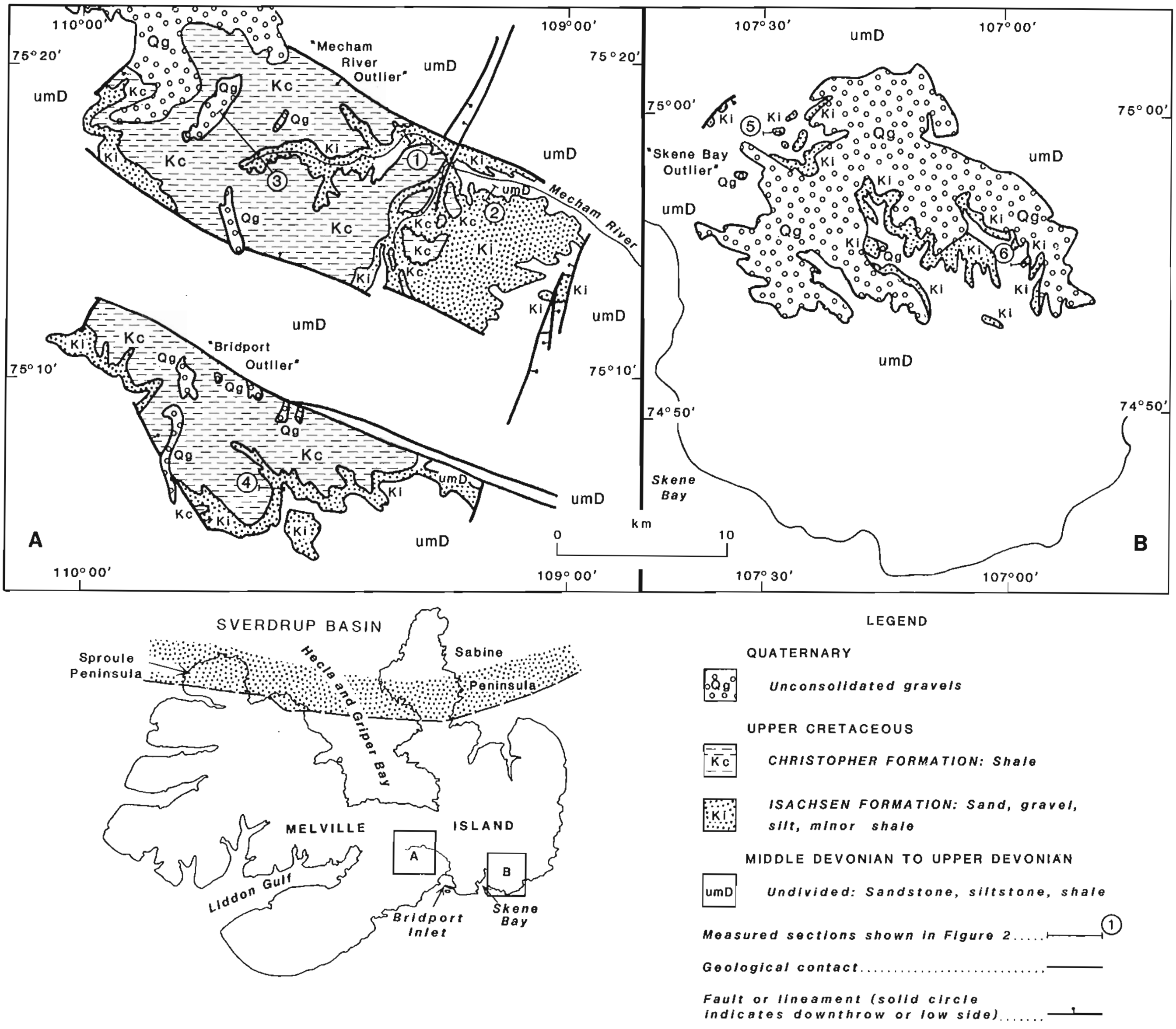

Figure 1. Areas of Lower Cretaceous rocks, southeastern Melville Island.

Mecham River outlier

The Mecham River outlier is the largest of three structural depressions. Nearly flat-lying (dip: less than 5 m/km to the north) Lower Cretaceous rocks are preserved throughout an area of 280 km^2. Steeply dipping boundary lineaments trend N 60°W to N 70°W and have erosional relief of at least 130 m. A separate set of post-Early Cretaceous faults strikes N 15°E to N 10°E. These faults, arranged in closely spaced pairs and en echelon sets, display limited displacement, and are probably associated with the emplacement of Jurassic to Late Cretaceous sills as described by Balkwill and Fox (1982). The Isachsen Formation in the Mecham River outlier is about 25 to 30 m thick, as shown in Figure 2. It unconformably overlies folded Frasnian sandstone of the Beverley Inlet Formation, an indication that approximately 500 m of Upper Devonian strata belonging to the Burnett Point, Cape Fortune, and Consett Head members have been eroded (Goodarzi et al., *this volume*). The Beverley Inlet Formation is abruptly, but conformably, overlain by at least 70 m of clay shale assigned to the Christopher Formation. The Cretaceous section is capped by a veneer of Quaternary diamictite and glaciofluvial gravels.

The Isachsen Formation in the Mecham River outlier is divided into two informal members. The lower member consists of three lithofacies which, in order of decreasing abundance, include:

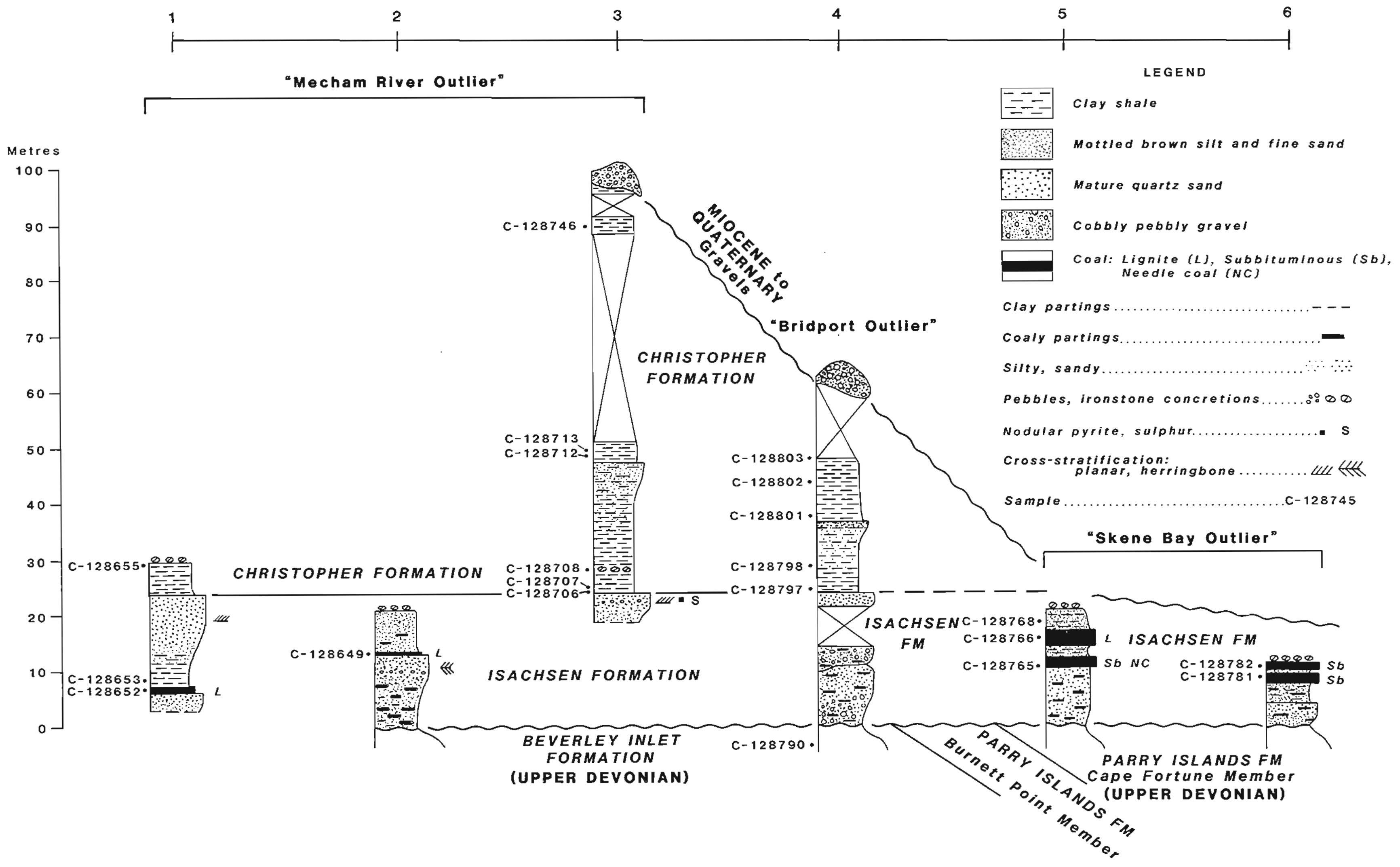

Figure 2. Lower Cretaceous stratigraphic sections, southeastern Melville Island.

1. Mottled light brown and dark brown silt, intercalated with light brown to yellow-brown, fine to very fine sand and minor medium grained quartz sand. These unconsolidated deposits contain lenticular and discontinuous partings of coalified plant debris and allochthonous coal fragments. Sedimentary structures include flat laminae, ripples, and both trough and planar crossbedding.

2. Lignite coal. At Section 1 (Fig. 2) a coal seam exposed in a cut bank on the Mecham River measures approximately one metre. Lignite is also believed to be exposed throughout the eastern end of the outlier, where the flat-lying beds occur on the plateau surface. Coal samples C-128649 and C-128652 were collected at two localities in the outlier and are discussed under organic petrology.

3. Papery to fissile, dark grey to black silty shale contains an abundance of arenaceous Foraminifera of limited faunal diversity.

The upper member of the Isachsen Formation consists of 3 to 8 m of mature quartz sand, and pebbly sand. Pebbles are moderately to well rounded. Clast composition includes grey sandstone, chert, white quartz, minor siltstone, and coal. Sedimentary structures include flat laminae, and planar and trough cross-stratification. The upper member displays remarkable lateral continuity and is present throughout the inlier.

Bridport outlier

The Isachsen and Christopher formations are also prominently exposed in a fault-bounded structure northwest of Bridport Inlet, here informally named the Bridport outlier. The Lower Cretaceous beds are preserved due to post-Early Cretaceous, pre-late Tertiary differential erosion. A prominent lineament strikes N 70°W and defines the northern limit of the outlier. At section 4 (Fig. 2), 25 m of Isachsen Formation, 37 m of overlying Christopher Formation, and at least 10 m of Quaternary gravels were measured.

The Isachsen Formation at Section 4 can again be subdivided into two members. The lower member is a sandy gravel containing subrounded pebbles and small cobbles (up to 5 cm) of Devonian sandstone, and angular to subangular, fine to coarse pebbles of micritic, oolitic and bioclastic limestone and grey-blue chalcedony. The gravels are clast-supported, with normal grading. The sparse sand matrix contains lenticular stringers of coalified plant debris. The upper member of the Isachsen Formation is represented by a laterally persistent, mature quartz sand bed, not unlike the upper member of the Isachsen in the Mecham River area. Coal seams of notable thickness have not yet been identified in the Bridport Inlet area.

Skene Bay outlier

A third outlier of flat lying Cretaceous strata lies some 15 km northeast of Skene Bay. Structural controls on the distribution of the Isachsen Formation in this area are obscured by a widespread blanket of Quaternary till and glaciofluvial deposits. Coal beds form a prominent part of two small sections measured in the Skene Bay outlier.

The eroded remnants of Isachsen strata in this outlier do not exceed 25 m. The dominant rock types in the section are similar to those encountered in the lower member of the formation in the Mecham River outlier. These types include mildly compacted, brown, dark brown and yellow-brown, fine to very fine sand, and silt with lesser, intercalated, medium grained, quartz sand and lenticular coal partings.

Two coal seams are exposed at the eastern edge of the outlier and were measured at Section 5 (Fig. 2). The lower seam is 1.5 m thick and includes what appears to be a fossilized needle layer (C-128765). The upper coal seam, separated from the lower seam by two metres of brown silt, is 3 m thick and consists of brown fissile lignite (C-128766). The section is capped by 3.7 m of brown silt containing a sparse foraminiferal assemblage.

At Section 6 (Fig. 2), near the eastern edge of the Skene Bay outlier, coal with minor brown silt is present throughout the top 4 m of the exposure (samples C-128781, C-128782).

AGE AND CORRELATION

The Isachsen Formation of Sverdrup Basin has an age range of late Valanginian to Aptian or early Albian. The basal Paterson Island Member in central Sverdrup Basin contains late Valanginian bivalves. Evidence from reflection seismic profiles suggests that the basal Isachsen is diachronous, being younger toward the basin margin. Foraminifera and palynomorphs from the Rondon Member indicate Barremian-Aptian (Wall, 1983, p. 263) and Barremian ages, respectively

(D. McIntyre, pers. comm., 1986). The age of the Walker Island Member of the Isachsen Formation is either Aptian or early Albian, based on paleontological collections from underlying and overlying marine beds (Embry, 1985).

Samples collected from the Isachsen Formation on southeastern Melville Island generally have not yielded a diagnostic marine faunal assemblage (Table 1). One sample collected from a silty shale interval in Section 1 of the Mecham River outlier contains a restricted assemblage of agglutinated Foraminifera similar to those in the Rondon Member (generally taken to be late Barremian to early Aptian in age although an Albian age cannot be entirely ruled out).

The shales of the overlying Christopher Formation in both the Mecham River and Bridport outliers contain a more diverse assemblage of agglutinated Foraminifera, with rare ostracodes and bivalve fragments. An age range of late Aptian to early Albian is indicated for the basal strata.

From the seismic and regional paleontological data, the Isachsen Formation is interpreted as being diachronous and, in general, younger in southeastern Melville Island than at the southern margin of the Sverdrup Basin. On paleontological grounds alone, the entire Isachsen section of southeastern Melville Island could be correlative with the upper part of the Walker Island Member of the Isachsen Formation of the

TABLE 1

Distribution of microfossils in the Lower Cretaceous of southeastern Melville Island

MICROFOSSILS **R - rare** **X - average** **C - common**	**Locality**	**Mecham River**			**Bridport Inlet**	**Skene Bay**
	Section No.	**1**		**3**	**4**	**5**
	Formation	**Ki**	**Kc**	**Kc**	**Kc**	**Ki**
Foraminifera						
Saccammina lathrami Tappan				X		
S. sp.-spp.				X		
Hippocrepina barksdalei (Tappan)				R		
Miliammina awunensis Tappan		X		X	R	
M. ischnia Tappan			C	C	X	R
M. manitobensis Wickenden		X	R	X	X	
M. sproulei Nauss			X	X	X	
Psamminopelta bowsheri Tappan		X	X	X	X	
P. subcircularis Tappan				X		
P.(?) sp. 1 of Wall 1983				X	X	
Haplophragmoides collyra Nauss				X		
H. sp. cf. *H. gigas minor* Nauss				C		
H. sp.-spp.			R	X	X	R
Siphotextularia(?) *rayi* Tappan				R		
Trochammina rainwateri Cushman & Applin				X	X	
T. sp.-spp.				X	R	R
Gaudryina sp.						X
Uvigerinammina(?) sp.						R
Verneullinoides neocomiensis (Myatliuk)		C	C	C	X	
V. sp. cf. *V. neocomiensis* (Myatliuk)				R		X
Astacolus sp.				R		
Ostracoda						
Haplocytheridea(?) sp.				R		
Bivalvia						
Fragments				X		

Ki = Isachsen Formation; Kc = Christopher Formation. Composite faunal assemblages from samples located in Figure 2: Section 1 (C-128653, 128655); Section 3 (C-128706–128708, C-128712, 128713, C-128746); Section 4 (C-128797, 128798, C-128801–128803); Section 5 (C-128768).

Sverdrup Basin. Similarly, but with less certainty, the Christopher Formation of the outliers can be correlated with the Invincible Point Member of the Christopher Formation on Sabine Peninsula.

The reservations noted above arise from the contrast in lithology between the strata of the Christopher Formation in the two regions correlated. Whereas the Christopher Formation in southeastern Melville Island is almost entirely dominated by shale with intercalated silt, the presumed correlative interval basinward, on Sabine Peninsula, contains substantial sand interbeds in units up to 4 m thick, with the most substantial sand development in the most southerly Christopher Formation exposures of the peninsula.

PETROGRAPHIC ANALYSIS

Coal samples were crushed to -20 mesh (850 μm), mounted in epoxy resin, then ground and polished.

Random reflectance in oil (n_O = 1.518) was determined using an MPM II Zeiss microscope connected to a Zonax microcomputer and printer following the procedure in the International Handbook of Coal Petrology (I.C.C.P., 1971). Fifty reflectance values were determined for each sample. Maceral composition and mineral matter were determined on 500 points in each sample using a Swift automatic point counter (Model F) and mechanical stage. Three main maceral groups (huminite/vitrinite, liptinite, and inertinite) were determined. Coal samples were photographed using both white and fluorescent blue light (400–440 nm excitation, 460 nm barrier filter).

RANK

As determined from the samples, coal rank evidently increases from west to east (Sections 1 to 6, Fig. 2) in southeastern Melville Island. Coal from the Isachsen Formation of Sections 1 and 2 is in the lignite stage ($\%R_{oil}$ = 0.37), whereas coals from Sections 5 and 6 are in the lignite to subbituminous stage ($\%R_{oil}$ = 0.37–0.49) (see Table 2).

ORGANIC PETROLOGY

The presence of a number of liptinite-rich coals and one "needle" coal (Table 2) in this suite indicates that these coals were mainly deposited in a wet environment, either in a reed marsh or subaquatically (Teichmüller, 1982).

Alginite, amorphous fluorescing material, cutinite, resinite and sporinite are the major components of liptinite-rich coals. The coals of southeastern Melville Island can be divided on the basis of microscopy into: duroclarite, vitrinertite, liptinite-rich clarite, and "needle", vitrinertoliptite coals (Tables 2, 3).

Liptinite-rich duroclarite and clarite

Duroclarite, deposited in the limnotelmatic marsh (reed marsh) section of coal-forming peat, represents a wet depositional environment (Teichmüller and Teichmüller, 1968; Teichmüller, 1982). Samples 1, 2, 4, and 7 fall within this group. Samples 1, 2, and 4 have a higher content of vitrinite than liptinite and inertinite. The liptinite consists of resinite, sporinite with minor amounts of alginite, and cutinite (Pl. 1, figs. 1–4; Pl. 2, figs. 1, 2). Sample 1 also contains amorphous, fluorescing material, a component that is usually thought to arise through selective decomposition of the liptinite of higher plants (Snowdon et al., 1986). Sample 6 has a high cutinite content (Plate 1b); cutinite occurs as both crassicutinite and tenuicutinite (thick- and thin-walled cutinite, respectively). Micrinite, also present in this coal (Pl. 2, fig. 2), indicates degradation of liptinite macerals (Stach, 1968; Snowdon et al., 1986). Samples 6 and 7 are subbituminous coal and contain high amounts of sporinite and cutinite (Table 2), which suggests deposition at a boundary between a reed (marsh) swamp and open water swamp; a feature that characterizes gyttja (organic mud) deposits (Teichmüller, 1982).

Vitrinertite-rich coal

Fusinite needles, which crumble easily between the fingers, are a notable component of sample 3. Vitrinertite-rich coal is a subbituminous coal and contains macrinite, inertodetrinite (Pl. 2, fig. 3), and other inertinites, some of which are weathered. The main liptinite macerals in this coal are cutinite and bituminite. The occurrence of granular bituminite, macrinite, weathered inertinite and inertodetrinite indicates extensive weathering of this coal during its formation (a feature that could result from a fluctuation in the water table after deposition of the original peat).

Vitrinertoliptite-rich coal

Sample 5 is macroscopically typical of "needle" coal; the needles have a characteristic elastic nature and can

TABLE 2

Petrographic characteristics of samples studied

Sample	Reflectance in oil (%)	Rank of coal	Microlithotypes[1]	Type of Liptinite	Maceral (%)		
					Vitrinite	Liptinite	Inertinite
1. C-128652 1107/84	0.37	Lignite	Duroclarite-rich coal	Bituminite III, cutinite, sporinite, alginite, resinite	60.8	9.6	24.8
2. C-128649 1106/84	0.37	Lignite	Duroclarite-rich coal	Cutinite, resinite, sporinite	71.6	9.2	19.4
3. C-128766 1111/84	0.38	Lignite	Vitrinertite-rich coal	Bituminite III, cutinite	61.2	3.4	35.4
4. C-128765 1110	0.41	Subbituminous	Duroclarite-rich coal	Cutinite, resinite and bituminite type II	69.5	11.5	19.0
5. C-128765a	0.22	Needle coal	Vitrinertoliptite	Mainly bituminite type II and III	36.2	61.4	2.4
6. C-128782 1114/84	0.49	Subbituminous Bituminous	Liptinite-rich clarite?	Cutinite and sporinite	39.4	35.6	25.0
7. C-128781 1113/84	0.47	Subbituminous	Duroclarite-rich coal	Cutinite and sporinite	61.0	12.2	26.8

[1] After Stach, 1982.

be bent to a very sharp angle before breaking. Microscopically, vitrinertoliptite-rich coal has identical morphology to the needle coals described by Snowdon et al. (1986). Needle coals are liptinite-rich coals that exhibit pine needle morphology on weathering. Gibson (1985) reported the occurrence of needle coals in several Jurassic to Lower Cretaceous coals from British Columbia. Snowdon et al. (1986) have made a detailed organic petrological and chemical study of needle coals reported previously by Gibson. Their study suggests that the needles are products of homogenization of a liptinite-rich precursor with minimal algal input. Petrologically, the main components of needle coals are the non-algal lipids, amorphous fluorescing material (bituminite II and III).

Petrological study indicates that sample 5 is composed mainly of amorphous fluorescing material and other liptinite macerals, for example resinite and sporinite (Pl. 3, fig. 1), and large masses of amorphous fluorescing components, which may show remnants of cell structure (Pl. 3, fig. 1). Weathering (oxidation) and biodegradation are evident in some fragments (Pl. 3, fig. 2). The altered material forms a darker fluorescing halo around a lighter fluorescing groundmass (Pl. 3, fig. 2). Experimental work by Goodarzi (1986) suggests that oxidized resinite forms a rim of darker fluorescence. Many of the fluorescing fragments in this needle coal were severely weathered before deposition. This is evident from the occurrence of fragments showing various fluorescence colours (Plate 2b) (the darker the fluorescence colour of amorphous fragments, the more severe was the weathering). Snowdon et al. (1986) referred to the amorphous fluorescing fragments as bituminite II and III.

The occurrence of needle coal in Section 6 indicates a similar environment of deposition to that of the needle coal in the Cretaceous coals of the Kootenay Group, British Columbia (Gibson, 1977). The needle coals of Melville Island of the Northwest Territories, and of the Kootenay and Minnes groups of British Columbia are the same general age, namely Early Cretaceous.

PALEOENVIRONMENTAL INTERPRETATION

Mottled fine to very fine sand and silt containing lenticular coal partings dominate the lower member of the Isachsen Formation in southeastern Melville Island. Until a more thorough study is completed, this lithofacies is ascribed to a variety of nonmarine, moderate energy environments including point bar, overbank, and delta plain settings. The normally graded, clast-supported conglomerates in the lower member of the Isachsen in the Bridport Outlier undoubtedly represent two or more successive fluvial channel deposits. The absence of Cretaceous conglomerate to the north and the distinctive clast compositions (possibly lower Paleozoic platform carbonate and replacement chert clasts derived from the Victoria Island and Viscount Melville Sound regions) indicate a general south to north transport of fluviatile debris.

TABLE 3

Simplified microlithotypes[1]

Maceral composition (mineral-free)	Microlithotype	Maceral-group composition (mineral-free)	Microlithotype group
Bimaceral			
V + S 95%	Sporoclarite		
V + Cu 95%	Cuticoclarite	V + L = 95%	Clarite
V + R 95%	(Resinoclarite)		V, L
I + S 95%	Sporodurite		
I + Cu 95%	(Cuticodurite)		
I + R 95%	(Resinodurite)	I + L = 95%	Durite
I + LD 95%			I, L
Trimaceral			
V, I, L >5%	Duroclarite	V > I, L	Trimacerite
	Vitrinertoliptite	L > I, V	V, I, L
	Clarodurite	I > V, L	

[1] After Stach, 1982; S = sporinite; Cu = cutinite; R = resinite; LD = liptodetrinite; V = vitrinite; I = inertinite; L = liptinite.

Marine beds are uncommon in the Isachsen Formation, but were noted at the top of the lower member in Section 1 of the Mecham River Outlier. These silty shales contain a low diversity assemblage of agglutinated Foraminifera typical of brackish marine settings. Deposition in a back barrier lagoon or estuary is suggested.

The well sorted, pebbly sand of the upper member of the Isachsen throughout the Bridport and Mecham River outliers is typical of transgressive sheet sands deposited in an upper shoreface environment.

Most of the Isachsen coal seams are liptinite-rich and are typical of coals associated with reed marsh and open swamp settings. The "needle" coals (liptobiolith of Potonié, 1920) encountered in the Skene Bay Outlier were probably formed by selective oxidation of coal macerals in flowing water (the water almost completely destroying the humic substances in the coal). This needle coal has similar petrological characteristics to those from Kootenay described by Snowdon et al. (1986).

In general, the Isachsen and overlying Christopher Formation represent a single conformable marine transgressive event that advanced from The Sverdrup Basin onto the adjacent continental platform during late Aptian or early Albian time. In Section 1 of the Mecham River outlier, various fluvial and delta plain deposits give way upward to liptinitic coals (representing the coastal swamp environment) which, in turn, are gradually replaced upward by brackish marine lagoonal muds, all of which are overlain by the transgressive sheet that caps the Isachsen Formation throughout the Mecham River and Bridport outliers. This onlap sequence is overlain by the shallow water marine shales of the Christopher Formation.

The lack of ferric iron oxidation colours and the abundance of both primary and detrital coal in the Isachsen Formation suggest an environmental setting in which precipitation habitually outstripped evaporation. Conifer-dominated flora in the coastal environment implies a temperate climate suitable for effective conversion to peat and preservation of coal.

The association of coal seams with coastal lagoonal deposits suggests that the distribution of this coal is strike-aligned or parallel to the original transgressive shoreline (which we assume trended westerly to northwesterly, subparallel to the margin of the Sverdrup Basin).

CONCLUSIONS

The Isachsen Formation of southeastern Melville Island is considered to have been deposited in a marginal marine environment. The basal strata probably represent several fluvial systems that drained highlands in the vicinity of what today is Victoria

Island and Viscount Melville Sound. A wide floodplain would have been conducive to the formation of laterally persistent lignite coal seams in a semibrackish to brackish water lagoonal setting. The marginal marine Isachsen strata were eventually overwhelmed by transgressive sheet sand and marine shale of the Christopher Formation.

The coals are liptinite-rich and range in rank from lignite to subbituminous to high-volatile bituminous. The high liptinite content of these coals indicates a wet to subaquatic depositional environment. The occurrence of "needle" coal at the top of the formation indicates a similar depositional environment to that of the "needle" coals of the Kootenay and Minnes groups of British Columbia, which are also of a similar general age (Gibson, 1985).

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PLATE 1

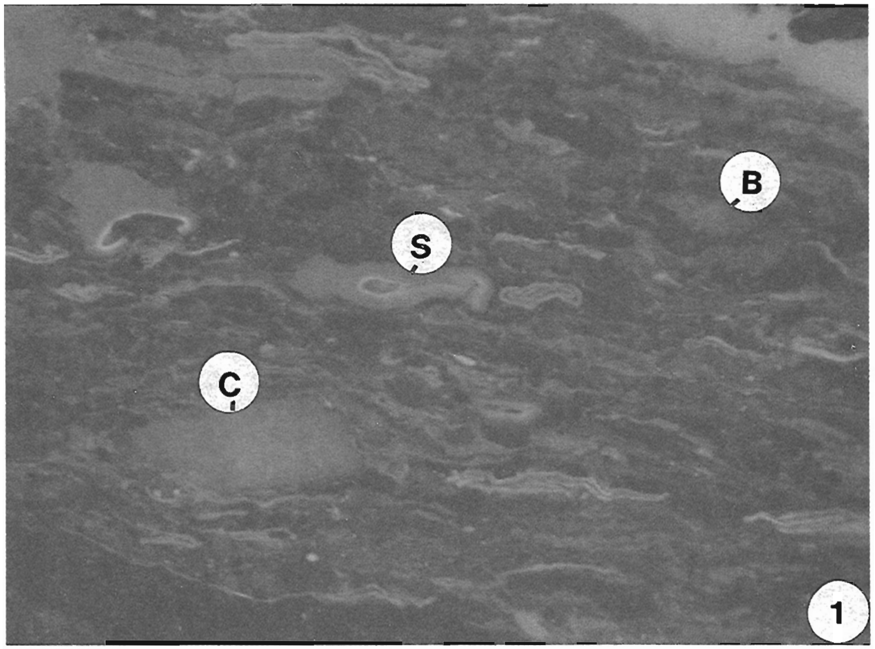
Morphology of liptinite-rich coals, blue fluoresent light excitation (400–440 nm barrier filter, 460 nm) and oil immersion. The long axis of each photograph is 230 μm.

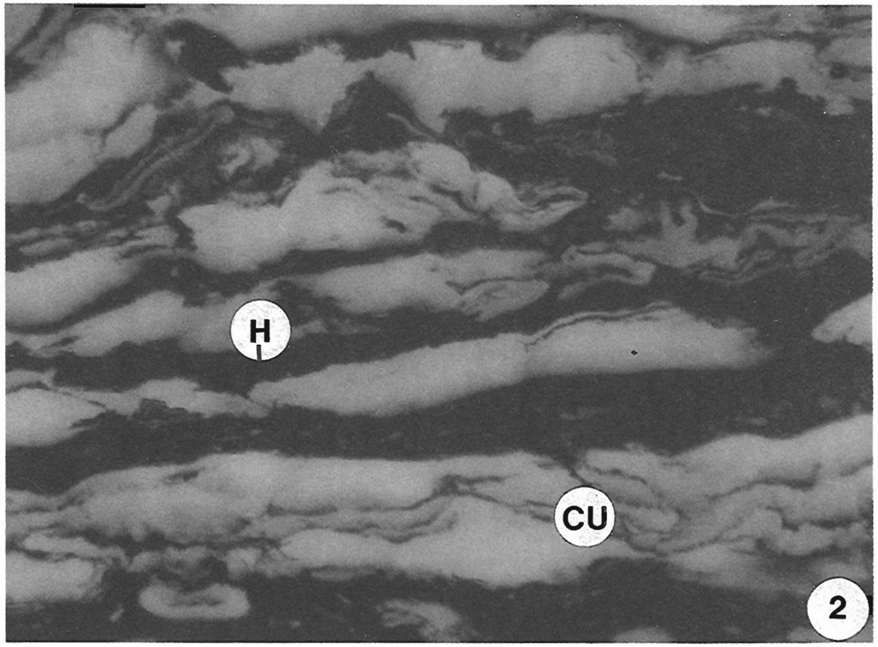
Figure 1. Sporinite (S), amorphous fluorescing material (B), carbonate (C); sample 5.

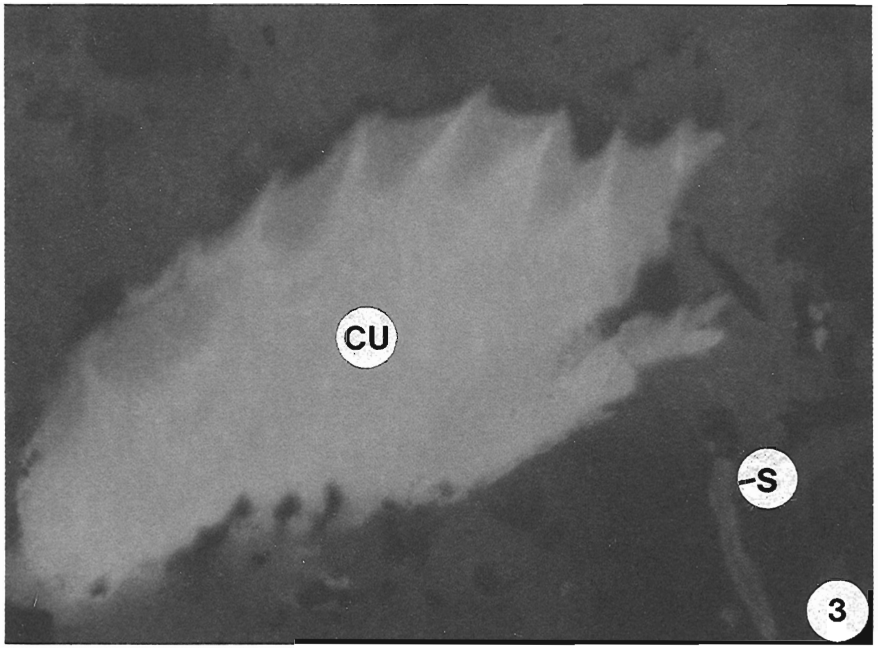
Figure 2. Thick-walled cutinite, crassicutinite (CU) in huminite (H); sample 3.

Figure 3. Crassicutinite (CU) horizontally cut and sporinite (S); sample 3.

Figure 4. A group of *Botryococcus* algae (A) in huminite (H); sample 1.


B
S
C
1


H
CU
2


CU
S
3

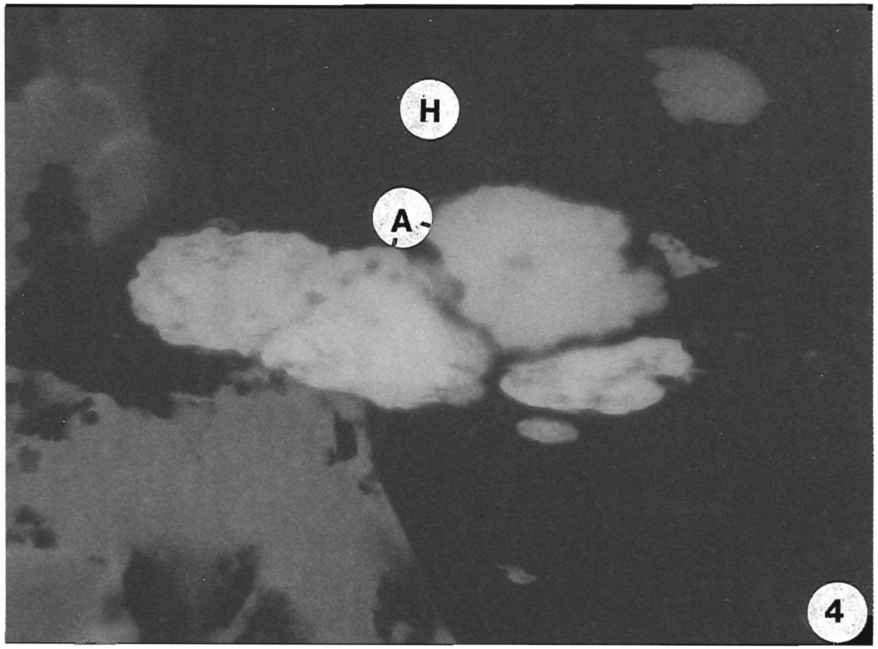

H
A
4

PLATE 2

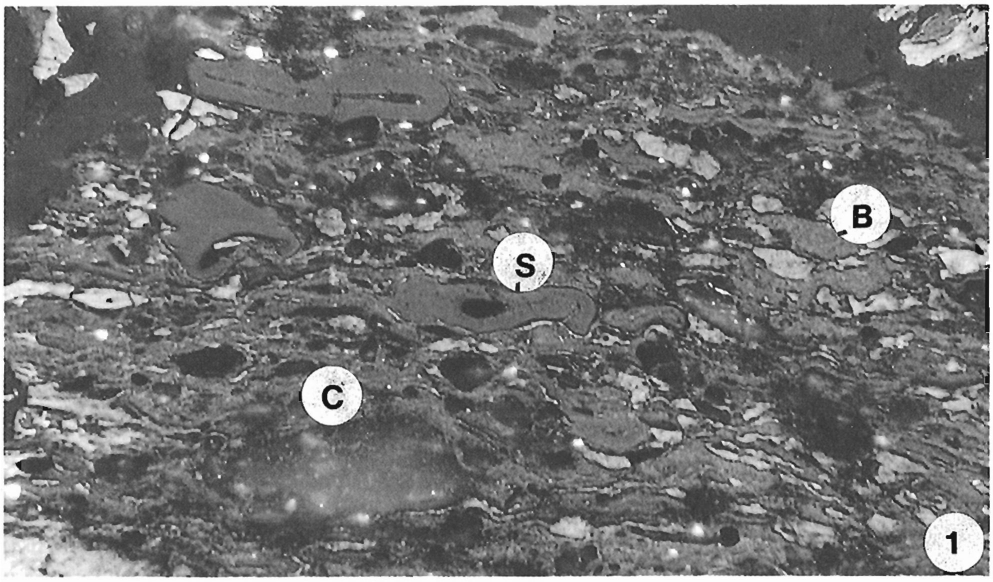
Morphology of liptinite-rich coal, white light, plane polarized, oil immersion. Magnification is same as for Plate 1; a and b are same field views as Plate 1, figs. 1 and 2.

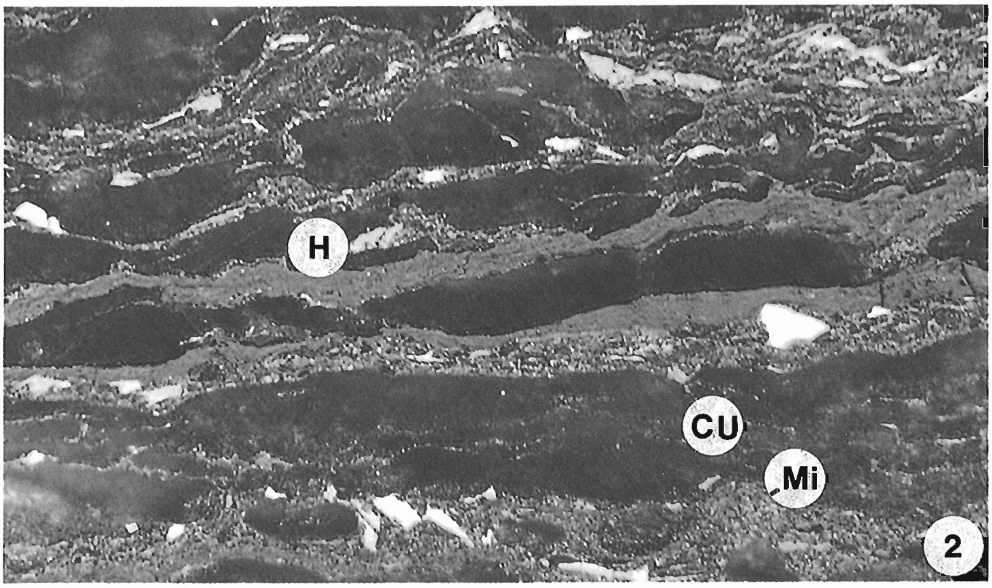
Figure 1. Sporinite (S), amorphous, fluoresing material (B), carbonate (C); sample 5.

Figure 2. Thick-walled cutinite, crassicutinite (CU) in huminite (H); micrinite (Mi) is present; sample 3.

Figure 3. Macrinite (Ma), inertodetrinite (I); sample 3.

PLATE 2





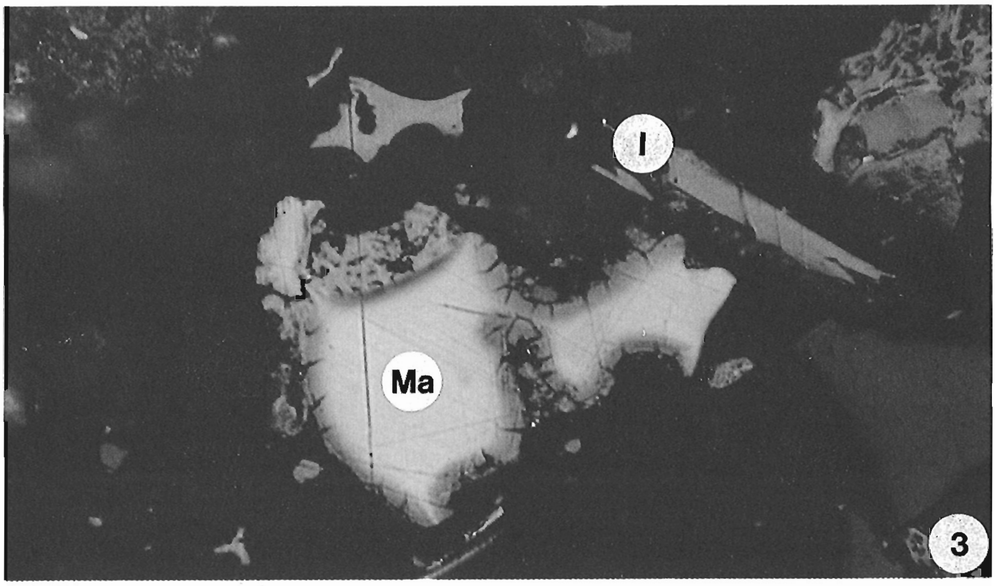
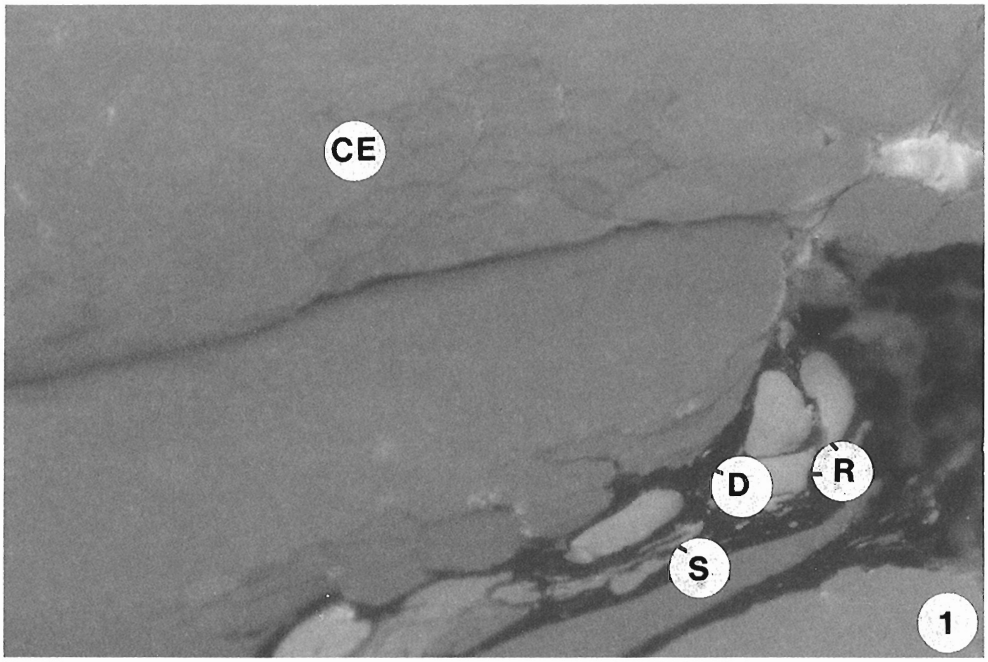


PLATE 3

Needle coal, sample 4

Figure 1. Amorphous fluorescing material containing cell structure (CE), resinite (R), sporinite (S), and desmocollinite (D).

Figure 2. Massive amorphous material II (B), relatively less oxidized amorphous material (B1) showing oxidation rim (O), strongly oxidized amorphous material (B2) and desmocollinite (D).


CE
D
R
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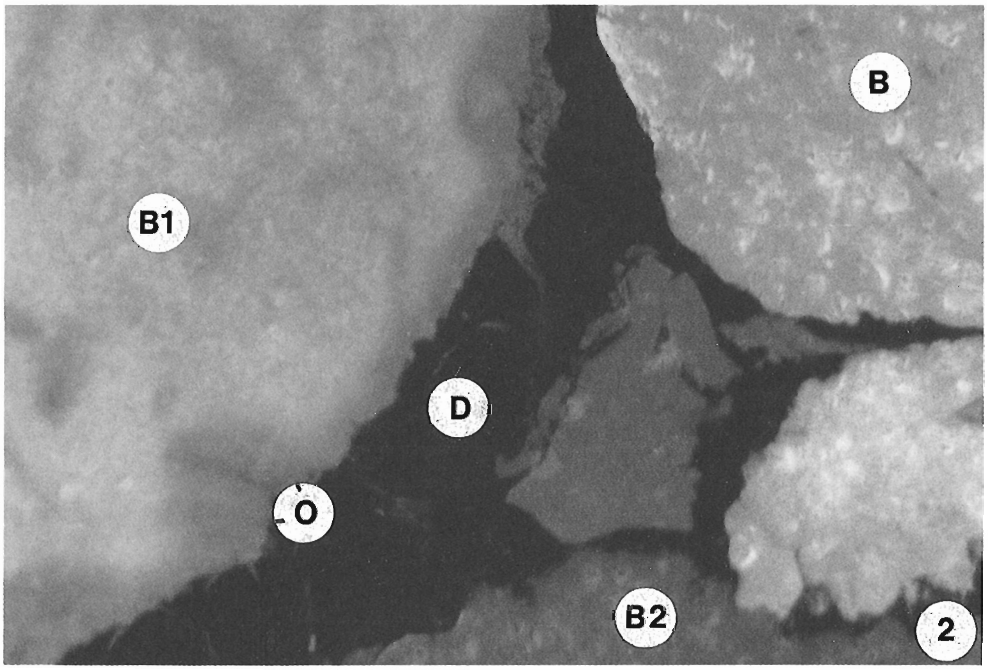
1


B
B1
D
O
B2
2

THE DISTRIBUTION OF PLANT COMMUNITIES ON MELVILLE ISLAND, ARCTIC CANADA

S.A. Edlund[1]

Edlund, S.A., 1993. The distribution of plant communities on Melville Island, Arctic Canada; in The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 247-255.

Abstract

Melville Island, within the High Arctic vegetation region, has areas of great vegetational diversity and abundance, and areas of great impoverishment of flora and plant assemblages. Two major factors control the distribution of vascular plants on Melville Island: surficial materials, particularly their chemistry, texture, and available moisture, and the summer climate as it influences the intensity and duration of the thaw period. Five bioclimatic zones that reflect the increasing impoverishment of vegetation with decreasing mean July temperatures are described. They are:

Zone 0: unvegetated, lichen free, no vascular plants; Zone 1: entirely herbaceous, sparse, lowest diversity; Zone 2: herbaceous species dominant, local woody plants and sedges; Zone 3: woody species and one species, or sedges, dominant, zone 2 herbs common; Zone 4: woody species and sedges dominant, greatest diversity, legumes, carices and compositae abundant.

Résumé

L'île Melville, qui se situe dans la phytorégion de l'Arctique, présente des zones à végétation très diverse et abondante et des zones très pauvres en flore et en associations végétales. Deux grands facteurs contrôlent la répartition des plantes vasculaires dans l'île : les matériaux de surface, notamment leur chimisme, leur texture et l'humidité disponible, et le climat estival, dans la mesure où il influe sur l'intensité et la durée de la période de dégel. L'auteur décrit les cinq zones bioclimatiques suivantes, qui reflètent l'appauvrissement croissant de la végétation avec la diminution de la température moyenne en juillet.

Zone 0 : non végétalisée, sans lichens, aucune plante vasculaire; Zone 1 : végétation entièrement herbacée, clairsemée, diversité minimale; Zone 2 : prédominance d'espèces herbacées, avec localement des espèces ligneuses et des carex; Zone 3 : espèces ligneuses et prédominance d'une espèce ou de carex, herbacées de la zone 2 fréquentes; Zone 4 : prédominance d'espèces ligneuses et de carex, diversité maximale, abondance de légumineuses, de carex et de Compositae.

INTRODUCTION

Melville Island lies within the High Arctic vegetation region (Polunin, 1951) — the most impoverished vegetation region in the northern hemisphere (Young, 1971). One hundred and thirty vascular plant species occur on the island. These are segregated into thirteen broad vegetation communities — monocotyleden (sedge and grass) dominated communities in the wetlands, nearly continuously vegetated prostrate shrub and herb tundra communities on sheltered moderately to imperfectly drained soils, and sparsely vegetated prostrate shrub and herb barrens communities on the better drained and more exposed soils (Fig. 1).

The area is not uniformly impoverished, however. There are regions of exceptional diversity and abundance, such as along the north and south coasts of Dundas Peninsula and along the margins of several

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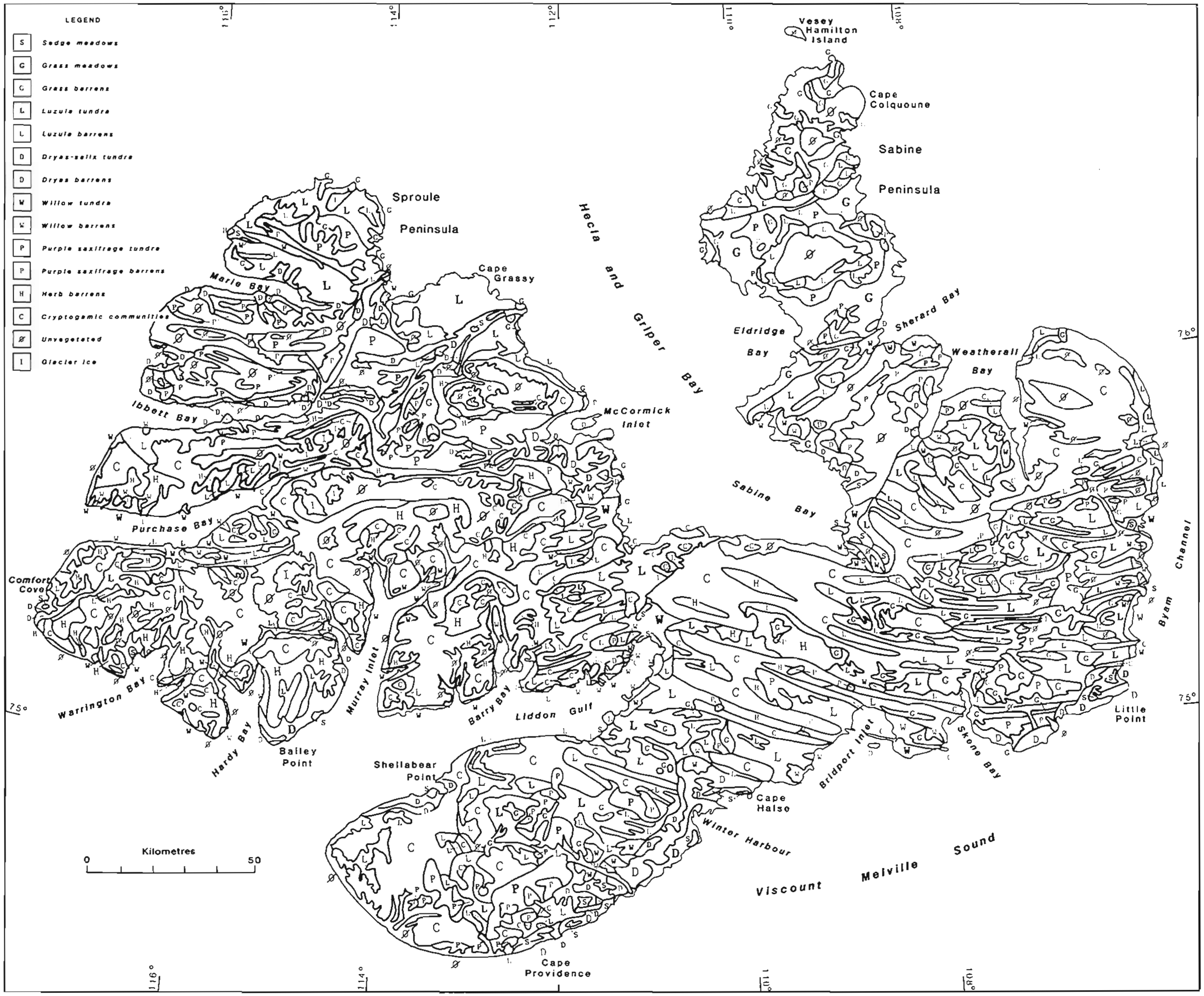

Figure 1. Vegetation types found on Melville Island.

bays and inlets in the western portion of the island. Other parts of the island are extremely impoverished. Some areas are unvegetated; some have only cryptogamic (moss- and lichen-based) communities; whereas others are sparsely vegetated, and have a total vascular flora of less than 10 species. Physical and chemical properties of the surficial materials and the regional summer climate are the two dominant factors influencing the distribution of vascular plant species and their segregation into plant communities.

SUBSTRATE CONTROL OF VEGETATION PATTERNS

The surficial geology of the region greatly influences the type and abundance of vascular plant species. Soil development in the region is primitive. Vascular plants generally root directly into weathered residual deposits or into reworked, weathered rock debris such as that on river terraces, deltas, beaches, colluvium, and glacial deposits. The local bedrock is the primary source of plant nutrients. Glacial tills originating other than on Melville Island are present, but represent only a small part of the total surficial deposits.

The most common surficial material on Melville Island is weathered bedrock, essentially in situ (Barnett et al., 1975; Hodgson et al., 1984; Fig. 2). This predominance can readily be seen on satellite imagery, where linear bands of Devonian formations of the Parry Islands Fold Belt and the less well lithified sediments of the Sverdrup Basin are clearly delineated (see Harrison et al., 1985, Fig. 74.1). Almost everywhere the bedrock has been shattered by weathering and frost action into fine sand to coarse rubble. Major disruption of bedrock-controlled surface patterns occurs only on Dundas Peninsula and nearby southern coastal areas and on the southern uplands and plateau. In these areas, glacial deposits in the form of thick till and numerous erratics, remnants of Laurentide ice incursions during the Quaternary, mask the bedrock geology. More than 25 types of weathered bedrock and Quaternary deposits have been identified (Tozer and Thorsteinsson, 1964; Barnett et al., 1975; Hodgson et al., 1984; Harrison et al., 1985; Edlund, 1986). Major changes in vegetation patterns commonly coincide with major lithological boundaries (Edlund, 1982, 1986a, 1987a).

Local glaciers in the western highlands have not produced major disruption of bedrock patterns, although glacial erratics from local sources have been found on adjacent bedrock formations. Lichen-free surfaces around small glaciers on the plateaus of western Melville Island suggest that the ice caps and snowfields expanded to more than six times their present size during the Little Ice Age (Edlund, 1985). No glacial features were found on the plateaus to indicate ice movement in the small icecaps during that period.

Unvegetated areas

The ability of the surficial materials (Fig. 2) to support plant growth varies; some materials are incapable of supporting any vegetation. The unvegetated materials include those that are highly acidic or basic, contain no available nutrients, or are physically unstable.

Soils derived from a facies of Kanguk Shale on Sabine Peninsula and adjacent Vesey Hamilton Island are highly acidic (pH 3) and do not support plant growth due to the lack of plant nutrients. At the other extreme are materials with pH greater than 8.4; these include nearly pure carbonates, such as those that outcrop between the arms of Weatherall Bay, on the west arm of Weatherall Bay, an inlier west of the Raglan Range, and facies of the Canrobert and Ibbett Bay formations in the Canrobert Hills, and materials derived from the gypsum domes of northern Sabine Peninsula. These are unvegetated due to the lack of plant nutrients, to the overwhelming toxicity of Ca and Mg ions, and to a lack of other buffering ions.

Hecla Bay sandstone produces weathered materials that are unvegetated. In eastern Melville Island this rapidly eroding, poorly lithified sandstone weathers into a white sand that contains few, if any, plant nutrients. Soils derived from such materials are generally unvegetated. This facies occurs in regularly repeated east-west-trending bands on the southeastern plateau and along the south coast of Sabine Bay. Some facies of the Isachsen and Eureka Sound formations produce similar white sands, and they too are unvegetated.

On a local scale, cryoturbation, mudboil activity, and wind deflation and deposition create local disruption of soils; the resulting lack of vegetation is due to the instability or immaturity of the soils.

Cryptogamic communities

The texture of rubble, one of the most common weathered surficial materials, is too coarse to support vascular plant communities (Fig. 2). Neutral to weakly acidic facies of the Hecla Bay, Griper Bay, Parry

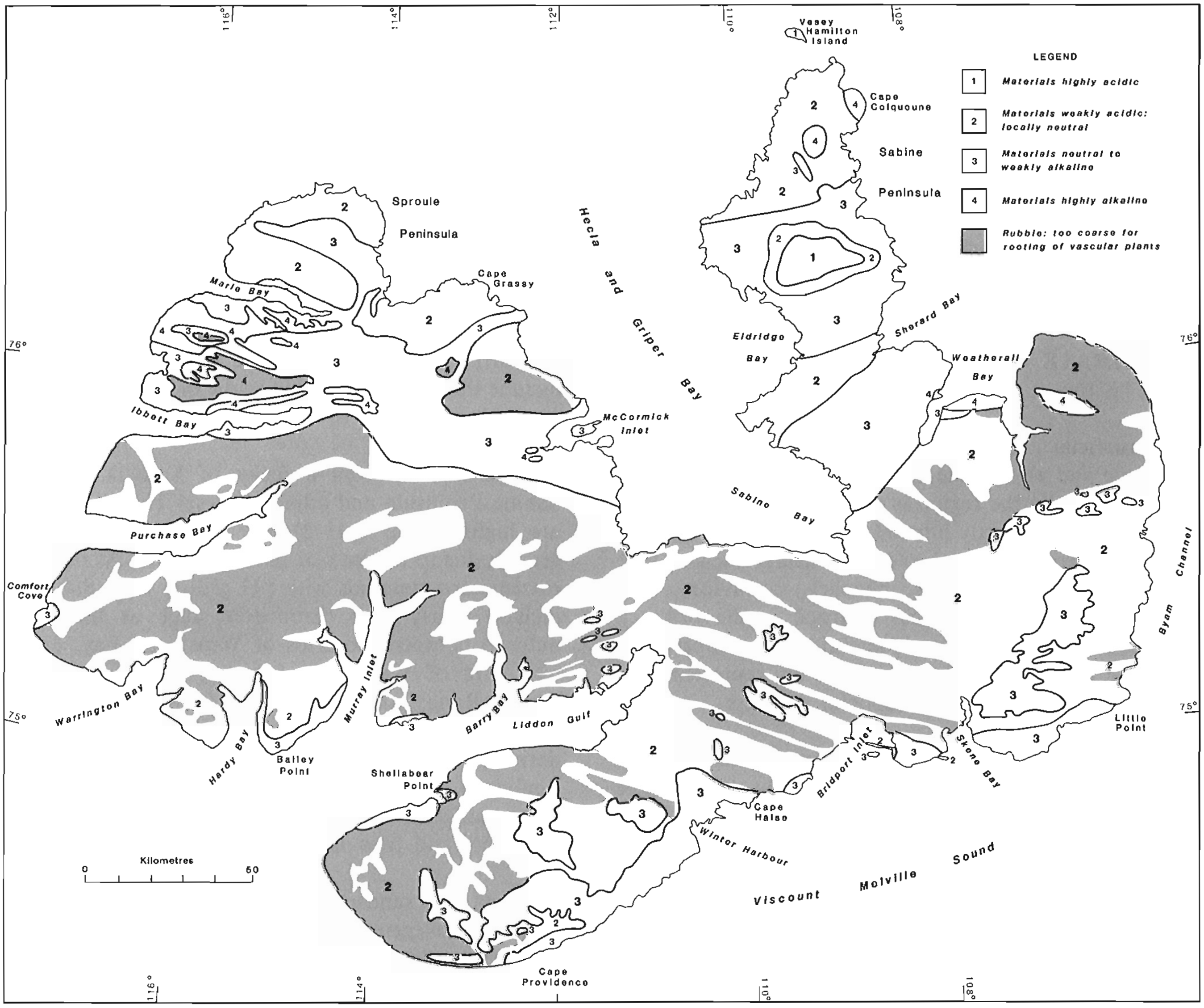

Figure 2. Generalized pH of surficial materials on Melville Island.

Island, and Beverley Inlet sandstones weather into slabs and boulder rubble; the fine grained materials needed for rooting plants are conspicuously absent. Only cryptogamic communities such as crustose and fruticose lichens and moss mats intertwined with foliose lichens grow on such materials.

Cryptogamic communities also occur on some alkaline felsenmeer. However, in many cases carbonate rocks weather too fast for the successful establishment of even crustose lichen communities. Only the more slowly weathering siliceous limestone facies of the Canrobert Formation, which is mantled by angular gravel- and cobble-size debris, supports a substantial crustose and foliose lichen community.

Vascular plant communities

The rest of the surficial materials of Melville Island are capable of supporting plant communities with a substantial vascular plant component. Even among these materials, however, the chemical composition influences the composition of the plant assemblages. Calciphilous (calcium-loving) species and communities abound on weakly to moderately akaline materials. A different suite of plants, either acetophilous (acid-tolerant or preferring) or pH indifferent species, grows on weakly to moderately acid materials.

The fertility of some surficial materials was affected by marine submergence in the Quaternary. During the late Quaternary, coastal areas of Melville Island were submerged to elevations of 40 m on the northwestern coast, 55 m along Hecla Bay and Griper Bay, and more than 90 m on the southern and eastern coasts (Prest et al., 1969; McLaren and Barnett, 1978; Hodgson et al., 1984). In some areas this caused a simple reworking of residual deposits. More common, however, is a discontinuous to continuous veneer of finer grained sediments with an additional complement of nutrients that have been mixed, by cryoturbation and solifluction, into the surficial materials. This addition of fine grained sediments and nutrients has resulted in an enhancement of the vegetation — so that the limit of the Quaternary marine inundation in some places, such as along the south shore of Sherard Bay and the corridor between western Hecla and Griper Bay and Liddon Gulf, closely coincides with the change from nearly continuous vegetation to sparse vegetation.

Thick, raised marine silt and clay deposits are locally unvegetated because of rapid erosion and high salt content. Only a few halophytic species initially colonize these materials.

Available moisture also influences the composition of plant assemblages. Continuous vegetation cover occurs primarily in lowlands below the marine limit and on seepage slopes where moisture is readily available throughout most or all of the annual thaw period. The pH of wetland soils does not closely follow that of the underlying bedrock because some soil development occurs due to accumulation of organic and mineral matter. The wet depressions act as catchment basins for fine grained water- and wind-carried mineral and organic detritus, and additional nutrients become available through decomposition of these "parent" materials.

Wetland communities

Wetland meadow communities, dominated by species such as grasses, cotton grasses, sedges, and woodrushes, are restricted in areal coverage. They are most common below the marine limit and are best developed on materials with a predominance of fine sand and silt. Sedge meadows (dominated by *Carex aquatilis* var. *stans* and to a lesser extend *Eriophorum triste* and *E. scheuchzeri*), the densest and most diverse type of wetland communities, occur exclusively below the marine limit. The largest group occurs in the southeast near Little Point, a corridor along the south coast of Dundas Peninsula between Cape Halse and Cape Providence, and on fluvial deltas and terraces at Shellabear Point, the head of Liddon Gulf, Murray Inlet, Bailey Point, Warrington Bay, central McCormick Inlet, head of Ibbett Bay, and eastern Sabine Bay, where the depressed centres of ice-wedge polygons contain numerous small ponds and lakes. These communities support an abundance of musk oxen and waterfowl.

Sparse grass meadows, dominated by *Alopecurus alpinus* or *Phippsia algida*, are common on wetlands above the marine limit on the southern and western plateaus, the headwaters of the Kitson River, and at or near sea level on northern Sabine Peninsula, Cape Grassy, and Sproule Peninsula. Grassy meadows, dominated by *Alopecurus alpinus* and *Dupontia fisheri*, are particularly common along the coasts of Hecla Bay and Griper Bay, and southern and central Sabine Peninsula.

Tundra communities

Tundra communities, nearly continuously vegetated terrain with an extensive cryptogamic ground cover, are generally confined to moderately to imperfectly drained soils on mid- to lower slopes where there has been a persistent snow cover in winter. The densest tundra vegetation, a *Dryas integrifolia* (Arctic avens) dominated tundra with nearly 100% cover, 25 to 50% of which is *Dryas* mats, occurs in the black shale slopes of the Ibbett Bay and Canrobert formations in the Canrobert Hills. These alkaline, black platy shale units have a high ice content (L. Dyke, pers. comm., 1986), and provide a continuous supply of moisture throughout the thaw period. In spite of the abundance of moisture, ready drainage through these weathered sediments produces very little ponding and no large sedge meadow complexes. Instead, *Dryas* tundra with common associates including *Salix arctica*, calciphilous species such as *Saxifraga oppositifolia, Poa abbreviata, Parrya arctica, Lesquerella arctica, Potentilla vahliana, Oxytropis arctica*, and *Astragalus alpinus* abound. At higher elevations, *Saxifraga oppositifolia* (purple saxifrage) becomes the most common associate of *Dryas* tundra communities and the legumes are absent.

Salix arctica (arctic willow) is the major prostrate shrub on acidic sediments. *Cassiope tetragona* (Arctic white heather) also occurs but very locally, generally on warm, sheltered south-facing sites with snow beds. Common associates include grasses such as *Alopecurus alpinus, Poa arctica, P. alpigena*, and *Puccinellia vaginata* particularly on silt and clay, and *Luzula confusa* and *Potentilla hyparctica* on sandier soils.

Prostrate shrub tundra communities (dominated by *Dryas*, or *Salix*) are also found primarily on the richest, moderately to imperfectly drained soils such as fluvial, marine, and glacial deposits, and are densest where the soils contain the most diverse plant nutrients. These shrub tundras, like sedge meadows, occur primarily below the marine limit in the southern and central part of the island. They occur at or near sea level on the coast of northern Sabine Peninsula and the north coast of Sproule Peninsula.

At higher elevations and latitudes, prostrate shrub tundra is replaced by herbaceous tundra. In most cases species that were the common associates of the prostrate shrub tundras become dominant. *Saxifraga oppositifolia* tundra is common on alkaline soils, and *Luzula* and grass tundras on weakly acidic soils. In some places, such as in the fine grained sediment bands at the high elevations of the western and southern plateaus, there is no clear dominance of vascular plants; instead, there is a variety of herbs in low abundance.

Barrens communities

Barrens communities (communities that form less than 20% cover) are common on well drained soils, such as those found on gravels and coarse sandy deposits, and on upper slopes and exposed knoll crests and ridges. These communities are the most common type of vascular plant-based communities on Melville Island. As with tundra communities, barrens communities can be divided into two major categories: those dominated by prostrate shrubs, and those dominated by herbaceous species.

Barrens dominated by *Dryas* and *Salix* are particularly abundant along the coast and lowlands of Dundas Peninsula and fluvial terraces near the coast. They show the same general geographic distribution as prostrate shrub tundra. The woody component of this community is generally confined to shallow depressions and runnels where snow accumulates and persists longer than on the adjacent more exposed soils.

Dryas-dominated communities with calciphilous associates are common on well drained, weakly to moderately alkaline soils below the marine limit. *Salix* barrens with grass and rush associates dominate more silty, though well drained, weakly alkaline to weakly acidic soils.

Herbaceous barrens are common in the same regions where herbaceous tundra communities occur: at or near sea level on the northern peninsula, and at elevations above 100 to 150 m in the southern half of the island. Herbaceous barrens also occur locally on knolls and ridges that blow free of snow in winter in regions where prostrate shrub barrens are more common.

The dominant herbs of herbaceous barrens communities are generally those species that are common associates of the prostrate shrub communities. *Saxifraga oppositifolia* forms the most common community on well drained, weakly to moderately alkaline soils. In some places purple saxifrage occurs locally as a monoculture. *Luzula* and grass barrens are common on well drained, weakly acidic to neutral, respectively sandy and silty soils. In some sparsely vegetated areas, vascular plant dominance is unclear. Such undifferentiated herbaceous barrens are common at the highest elevations, generally over 250 to 300 m on the plateaus and uplands, and locally where materials are at an early stage of colonization.

A striking illustration of the influence of materials on vegetation occurs on Dundas Peninsula. Several glacial episodes brought the northern margin of the Laurentide ice sheet into the southern part of the map area (Hodgson et al., 1984). Weakly alkaline silty till and ice-content sand and gravel deposits derived primarily from the carbonates of Victoria Island to the south were deposited on top of neutral to acidic bedrock formations on Dundas Peninsula, the coast west of Shellabear Point, and locally at Bailey Point and Comfort Cove, western Melville Island. These contrasting types of materials are highlighted by major changes in vegetation patterns. Calciphilous *Dryas* and *Saxifraga oppositifolia* based communities prevail on the alkaline glacial deposits, whereas *Salix, Luzula*, grass and cryptogamic communities occur on the materials derived from the local neutral to weakly acidic bedrocks.

CLIMATIC CONTROL OF VEGETATION PATTERNS

Climate plays an important role in the distribution of plants and plant communities. The Queen Elizabeth Islands have the harshest regional summer climate in North America (Maxwell, 1980). Mean July temperatures on Melville Island range from at least 5°C on the southernmost coast and in sheltered valleys and inlets, to about 1°C along the northern coastal areas, where multiyear ice impinges on the coast.

Similar low mean July temperatures also occur at high elevations, where snow persists throughout most of the summer.

The regional decrease in temperature does not follow a simple latitudinal progression toward the North Pole. Instead, a complex interaction among atmospheric circulation patterns, topography, inter-island channels, and radiation regime produces an intricate pattern (Edlund, 1986b, 1987b).

The response of vegetation to thermal gradients in the area differs from the response to lithological changes. Climate-induced changes are seen in variation in the growth form of dominant species, the floristic composition of wetlands, and changes in the diversity irrespective of lithology. Several major shifts in vegetation patterns are roughly coincident with summer temperature patterns, and have been used to construct five bioclimatic zones (Edlund, 1982, 1985, 1986a, b), all of which occur on Melville Island (Fig. 3).

Zone 4 encompasses the most diverse and abundant vegetation on the island and roughly corresponds to mean July temperatures near 5°C or above. Prostrate and matted shrubs (*Dryas integrifolia* and *Salix arctica*) provide at least 25% cover. Legumes such as *Oxytropis arctica, O. arctobia, O. maydelliana*, and *Astragalus alpinus* are common associates. Also present are *Rosaceae* including *Potentilla vahliana, P. pulchella, P. rubricautis*, and *Geum rossi*; Asteraceae including *Crepis nana, Antennaria compacta, Arnica alpina, Petasites frigidus*, and several *Taraxacum* species. Sedge meadows consist of several species of sedge, cotton grass, and a diverse assemblage of emergent species and aquatics, including *Caltha palustris, Ranunculus gmelini, Hierachloe pauciflora, Pleuropogon sabinii, Arctophila fulua*, and *Hippuris vulgaris*. Woody plants occur locally in these wetlands on raised mossy hummocks.

In Zone 3, which roughly corresponds to areas with mean July temperatures above 4°C, the same woody plants as in Zone 4 are dominant, but the density and diversity of the communities are lower. Fabaceae and most Asteraceae are absent; wetland sedges are generally restricted to *Carex aquatilis* var. *stans* and, to a lesser extent, to two *Eriophorum* species. *Pleuropogon sabinii* and *Ranunculus hyperboreus* are the most common emergent and aquatic species. This zone represents the most northwestern extent of woody plant and sedge dominance in Arctic Canada.

In Zone 2, where mean July temperatures are roughly 3 to 4°C, herbaceous species dominate all but the wettest terrain. Grasses dominate the wetlands. Woody species and sedges, although locally present, are never dominant. This zone represents the northwestern extent of woody plants and sedges in Arctic Canada.

In Zone 1, mean July temperatures are generally 3°C or below. Here, woody plants and sedges are absent, and vascular plant species diversity is low. A total of 35 vascular plant species is present in this zone, growing on all types of materials. A maximum of 10 to 15 species occurs on any one type of material. The vascular plant flora is extremely sparse (less than 5% cover) within this zone.

There are also areas where no lichens, mosses, or vascular plants occur, even on surficial materials capable of supporting vegetation. This zone has been designated Zone 0 (Edlund, 1985, 1986a). Zone 0 does not have an expression at sea level; it occurs at high elevations (>350–400 m) around small ice caps on the plateaus of western Melville Island, on the Raglan Range plateau north of McCormick Inlet, and on small areas of the plateau east of Weatherall Bay. Similar zones may be postulated for carbonate plateaus reaching similar elevations, but Zone 0 cannot be distinguished because these carbonates do not support vegetation at any elevation.

Zone 0 delineates surfaces that have recently emerged from under ice or snow beds, or at present have such a harsh climate, extremely low temperatures, and short snow-free periods that plants are not able to establish themselves.

Two major phytogeographic boundaries are found on Melville Island. The northern boundary between Zones 3 and 2 represents the northern limit of plant communities with woody species as the dominant vascular plants. This is analogous to the boundary represented by the northern limit of continuous forest in the boreal forest ecosystem. Similarly, the boundary between Zones 2 and 1 represents the northern limit of woody species, a "mini-treeline". The shift from sedge dominance, to sedge presence and to sedge absence follows the same progression as that of woody plants.

These boundaries are as readily identifiable phytogeographic markers as are the forest limit and treeline, and may ultimately also serve as paleoecological and paleoclimatic indicators.

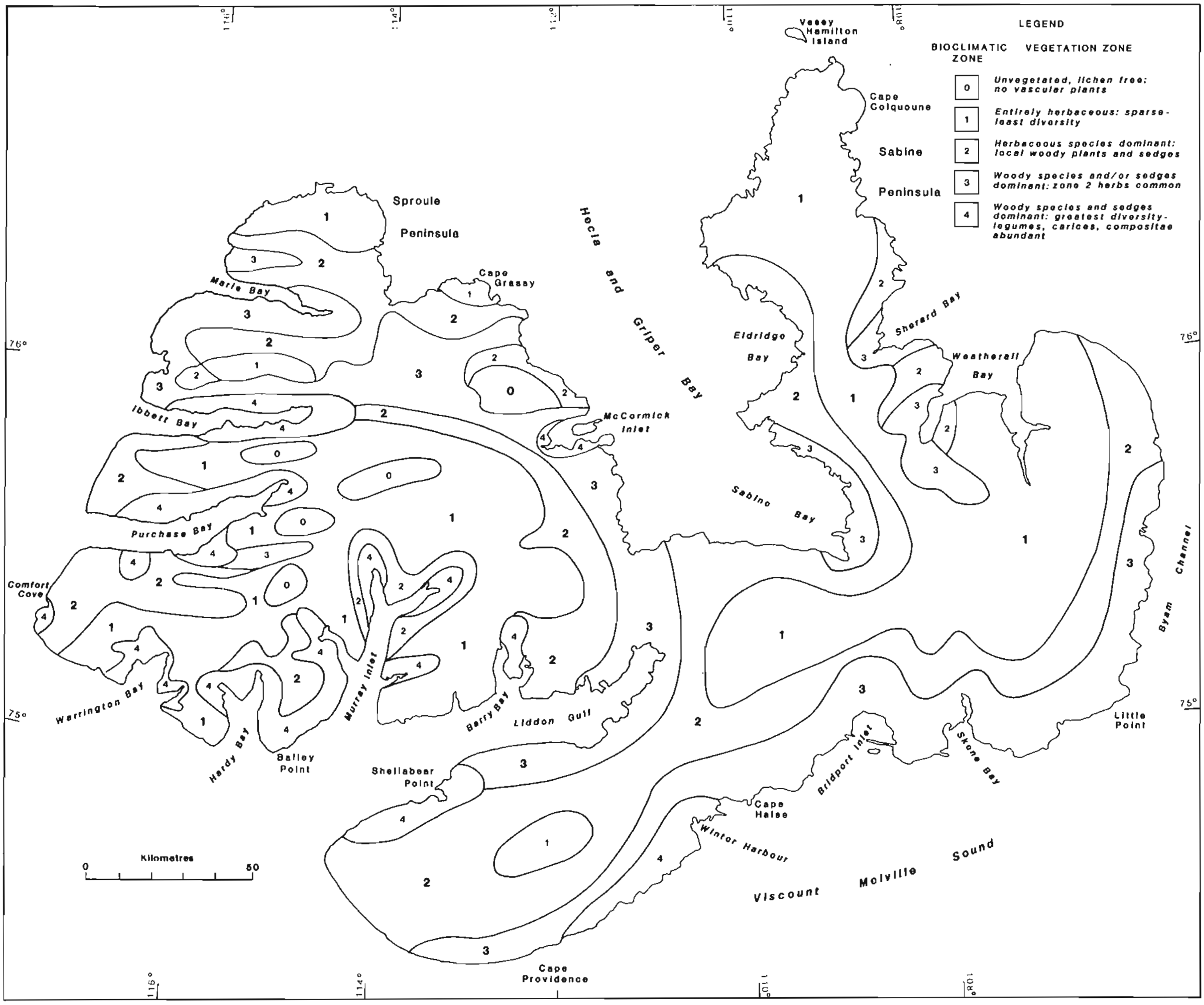

Figure 3. Bioclimatic zonation of Melville Island.

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A SUMMARY OF THE STRUCTURAL GEOLOGY OF MELVILLE ISLAND, CANADIAN ARCTIC ARCHIPELAGO

J.C. Harrison[1]

Harrison, J.C., 1993. A summary of the structural geology of Melville Island, Canadian Arctic Archipelago; <u>*in*</u> *The Geology of Melville Island, Arctic Canada, R.L. Christie and N.J. McMillan (eds.); Geological Survey of Canada, Bulletin 450, p. 257–283.*

Abstract

Ellesmerian (latest Devonian or Early Carboniferous) deformation produced the major compressive tectonic elements of the island, including a 180 km wide salt-based, thin-skinned fold belt that dominates surface structure. The fold belt conceals a seismically imaged panel of thrust faulted strata with up to 28 km (15%) horizontal shortening. This belt features a basal detachment at about 5 km depth and a complex array of forward- and backward-vergent thrusts, most of which do not reach the surface. Different styles of coeval deformation are found in the Canrobert Hills region and in the western part of the island.

Thrusts that ramp up to the sub-salt décollement through (?)Cambrian and Lower Ordovician strata have produced a series of large-scale anticlinoria near the present margin of the Sverdrup Basin. A complex array of faults associated with the margin of the post-Ellesmerian Sverdrup Basin has been active repeatedly since the Cambrian. Phases of deformation related to fault reactivation include (?)Cambrian and (?)Lower Ordovician growth faulting, and inversion of these growth faults during the Ellesmerian Orogeny. A rifting phase of the Sverdrup Basin occurred in late Paleozoic time, and mid-Permian inversion tectonics are associated with the Melvillian disturbance. Incipient rifting in the Jurassic and Cretaceous is linked to the opening of Canada Basin, and a third phase of inversion tectonics is coeval with the mid-Tertiary Eurekan Orogeny and the evolution of North Atlantic spreading centres.

Résumé

La déformation ellesmérienne (Dévonien terminal ou Carbonifère précoce) a produit les grands éléments tectoniques en régime compressif que l'on trouve dans l'île, y compris la zone de plissement de couverture à base de sel de 180 km de largeur qui domine la structure superficielle. La zone de plissement masque un panneau de strates chevauchées dont le raccourcissement horizontal maximal est de 28 km (15 pour 100); le panneau se reconnaît sur les images sismiques. Cette zone comporte un décollement basal à une profondeur d'environ 5 km et un faisceau complexe de chevauchements à vergence avant et à vergence arrière, la plupart desquels n'atteignent pas la surface. On reconnaît divers styles de déformation contemporaine dans la région des collines Canrobert et dans l'ouest de l'île.

Des chevauchements qui montent en pente jusqu'au décollement inférieur au sel en traversant les strates du (?)Cambrien et de l'Ordovicien inférieur ont produit une série de grands anticlinoriums près de la marge actuelle du bassin de Sverdrup. Un faisceau complexe de failles associées à la marge du bassin de Sverdrup post-ellesmérien a été actif à maintes reprises depuis le Cambrien. Les phases de déformation associées à la remobilisation des failles comprennent la formation de failles synsédimentaires au (?)Cambrien et à l'(?)Ordovicien inférieur et l'inversion de ces failles au cours de l'orogenèse ellesmérienne. Le bassin de Sverdrup a subi une phase de rifting au Paléozoïque tardif; l'inversion tectonique au Permien moyen est associée à l'accident du Melvillien. La phase initiale de rifting au Jurassique et au Crétacé est associée à l'ouverture du bassin Canada, et une troisième phase d'inversion tectonique est contemporaine de l'orogenèse eurékienne du Tertiaire moyen et de l'évolution des centres d'accrétion de l'Atlantique Nord.

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INTRODUCTION

Phanerozoic orogens rim the North American continent on all sides (Bally et al., 1989). The Innuitian Orogen of north Greenland and Arctic Canada is one of these. This orogen is distinctive in having undergone two cycles of orogenic activity: the widespread mid-Paleozoic Ellesmerian Orogeny of the Franklinian Mobile Belt, and the mid-Tertiary Eurekan Orogeny, which is most fully developed on Ellesmere and Axel Heiberg islands (Trettin, 1989).

The general surface structural features of the southern orogenic belts of North America have been known for over a century. However, the Ellesmerian deformation of the western Arctic islands (including Melville Island) was not discovered until 1950. The relatively late investigation of the structural geology of the western Arctic region is attributable to that area's remoteness, its subdued topographic character, and the superficially featureless aspect of the landscape when viewed at ground level. The discovery of the surface fold belt, which underlies Melville, Bathurst, and adjacent smaller islands, was a result of the first air photographic survey of the region (Fortier and Thorsteinsson, 1953). This prompted geological mapping and surface structural studies in the area by E.T. Tozer and R. Thorsteinsson beginning in 1955. Their observations revealed a depositional history for the area that spans most of Ordovician through Tertiary time and a tectonic history that includes the terminal Devonian Ellesmerian Orogeny, the construction of the post-Ellesmerian Sverdrup Basin margin, and the modification of the entire region by younger tectonic events (Tozer and Thorsteinsson, 1964). These results were later incorporated into the first significant syntheses of Arctic islands geology (Thorsteinsson and Tozer, 1960, 1970).

These and other reports by officers of the Geological Survey of Canada contributed directly to an interest in the area by the oil and gas industry, beginning in 1960. The earliest exploratory wells in the Arctic islands were drilled on Ellesmerian anticlines and, although economic results then and later have been somewhat disappointing, geophysical surveys conducted in the area by industry have permitted a greatly improved understanding of subsurface structure. Important contributions based on industry data include those by Drummond (1973), Meneley et al. (1975), Daae and Rutgers (1975), Balkwill and Fox (1982), Fox (1983, 1985), Dailly and Plauchut (1986), and Kanasewich and Berkes (1988, 1990).

The seismic profiles acquired during petroleum exploration have in recent years led to an improved understanding of the tectonic history of the Melville Island region. With these data it is possible to comment on aspects of the entire (?)Precambrian through Quaternary geological record both within and beyond the limits of surface outcrop and exploratory wells. The tectonic history now features a deep-seated (?)Proterozoic structure, the development of the lower Paleozoic miogeocline, details of the destruction of the miogeocline, the internal geometry of the fold belt and kinematics of deformation, the nature of the fold belt beneath Carboniferous and younger cover, and the styles of superimposed deformations (including two phases of incipient rifting and two additional phases of folding) that have also contributed to the origin and evolution of the Melville Island region, including the Sverdrup Basin (Harrison, 1991a).

The purpose of this paper is to present some of these new results. Supportive data released separately include 1:250 000 scale preliminary geological maps, structural cross-sections, and reprocessed industry seismic profiles (Harrison, 1991a, b).

GEOLOGICAL PROVINCES

Melville Island lies astride three geological provinces: the Arctic Platform, the Franklinian Mobile Belt, and the Sverdrup Basin (Fig. 1). The Arctic Platform, in the south and southeast, is part of an extensive region of the Arctic islands underlain by relatively undeformed Cambrian through Devonian strata that unconformably overlie variably metamorphosed sedimentary and volcanic successions of the Canadian Shield. On Melville Island and elsewhere, the Arctic Platform is transitional into the Franklinian Mobile Belt; a mid-Paleozoic orogen that contains shelf marginal and basinal sediments, and foreland-type siliciclastic rocks that are age equivalent to those of the Arctic Platform. The foreland deformed regions of the Franklinian Mobile Belt include the Central Ellesmere Fold Belt of the eastern Arctic and the Parry Islands Fold Belt of Melville and Bathurst islands. Boothia and Inglefield (Bache Peninsula) uplifts are two crystalline basement-involved arches with links to the foreland region of the Franklinian Mobile Belt. The internal zone of the Franklinian Mobile Belt includes deformed lower Paleozoic basinal shale, clastic, and carbonate facies in the Hazen Fold Belt of northern Ellesmere Island, and similar strata in the Canrobert Hills Fold Belt of western Melville Island. Volcanic and clastic terranes of the Franklinian Mobile Belt are prominently represented in the Clements Markham and

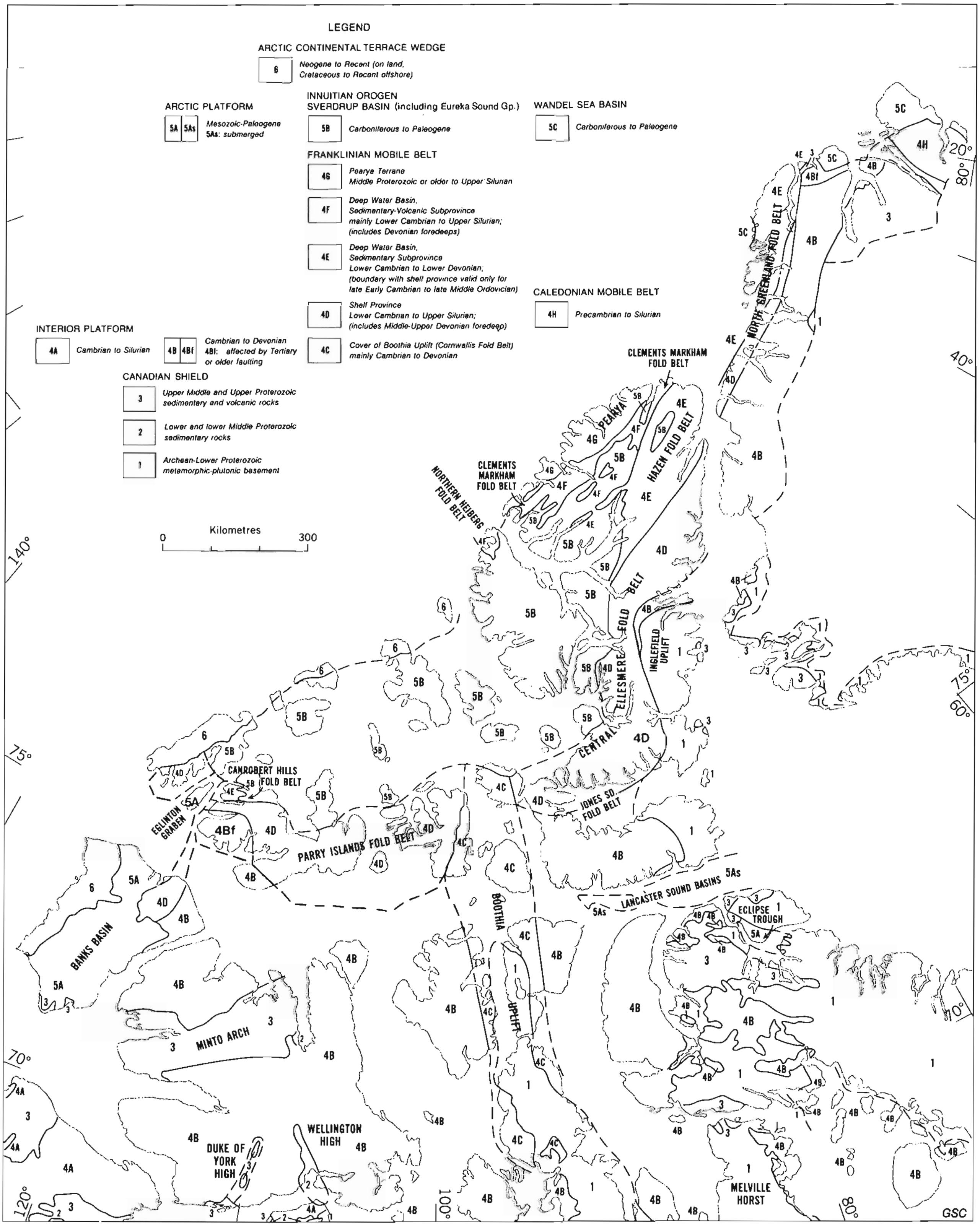


Figure 1. Geological framework of the Arctic islands (modified from Trettin, 1987 and Harrison, 1991a). The Canrobert Hills Fold Belt of northwestern Melville Island was named and first described by Harrison and Bally (1988). In the eastern Arctic, the term "Inglefield Uplift" was first applied by Smith and Okulitch (1987) to a tectonic feature discovered previously by Kerr (1976). Kerr, who called this the Bache Peninsula Arch, believed it was an easterly trending structure of more limited dimension.

Northern Heiberg fold belts of northern Ellesmere and Axel Heiberg islands, respectively (Trettin, 1987). The northern margin of the Franklinian Mobile Belt is defined by the faulted contact between Clements Markham Fold Belt and Pearya Terrane. The latter is interpreted by Trettin (1987) as an accreted terrane with Grenvillian and Caledonian affinities.

The bulk of the internal zone, and some parts of the foreland zone, of the Franklinian Mobile Belt are covered by Carboniferous through Paleocene strata of the Sverdrup Basin on, and north of, Melville Island. The foreland part of the mid-Paleozoic orogen continues northwestward onto Prince Patrick Island (Harrison et al., 1988; Harrison and Brent, 1991) and also southwestward onto Banks Island beneath Cretaceous and Tertiary cover of the Arctic Coastal Plain (Miall, 1979; Dailly and Plauchut, 1986).

STRATIGRAPHY

Introduction

Data from surface stratigraphic sections, exploratory wells, and seismic surveys have been used in the stratigraphic interpretation of Ordovician through Tertiary units. Deeply buried, older, acoustically stratified units of probable Precambrian and Cambrian age are known only from seismic reflection and refraction surveys. Depths and thicknesses quoted for these units are based on assumptions of sonic velocity and are prone to significant error. Unit interval velocities and methods of depth conversion are listed and described in Harrison (1991a).

In the present account, five major unconformity-bound packages are recognized (Fig. 2). These are:

1. Possible (?)Archean crystalline basement;
2. Locally stratified (?)Proterozoic units;
3. Cambrian(?) through latest Devonian sediments;
4. Carboniferous through Paleocene strata; and
5. Neogene and Quaternary deposits (not shown in Fig. 2).

Acoustic basement

A high amplitude semicontinuous reflector occurs at and below a depth of 6.4 seconds (20 km) on many seismic profiles of eastern Melville Island. This reflector was first identified by Kanasewich and Berkes (1990), who suggested that it may be the impedance contrast generated by the nonconformity above crystalline basement (unit sAP of Fig. 2). Possibly correlative crystalline basement rocks, exposed in small areas on Victoria Island, consist of granodiorite containing xenoliths of fine grained micaceous metasediments (Campbell, 1981). These rocks are exposed at two localities near Hadley Bay and at an outcrop of granite or granodiorite north of Washburn Lake near the north end of the Wellington High (Dixon, 1979). The oldest radiometric ages were obtained from the granodiorite at Hadley Bay for which Thorsteinsson and Tozer (1962) report a K-Ar age of 2405 Ma. These rocks are tentatively correlated with crystalline basement rocks of the Slave Craton, widely exposed on the mainland south of Coronation Gulf.

(?)Proterozoic succession

The (?)Proterozoic succession in the subsurface of Melville Island consists of three distinct seismic units (Harrison, 1991a, b; Kanasewich and Berkes, 1990): a lower unreflective unit (sP1) that is 2000 to 8000 m thick (interval velocity = 6200 m/s); a medial acoustically stratified unit (sP2) 4300 to 4400 m thick (v = 6200 m/s); and an upper reflection-poor unit (sP3) that ranges up to at least 3400 m in thickness (v = 5700 m/s). Seismically defined unconformable relationships between each of these units and between these units and overlying strata of (?)Cambrian (or [?]latest Proterozoic) age are observed. In other areas, however, the seismic contacts between the units are apparently conformable, apparently gradational, or inadequately imaged.

Four pre-Phanerozoic, very low grade [or (?)unmetamorphosed] sedimentary/volcanic successions are known from surface studies to overlie the presumed post-Archean nonconformity on Victoria Island. They range from Early Proterozoic through Late Proterozoic in age and have a combined total thickness of about 10 000 m (Thorsteinsson and Tozer, 1962; Christie, 1964; Young, 1981; Campbell, 1981).

The assumed correlation of (?)Proterozoic seismic units of subsurface Melville Island with known Proterozoic successions of Victoria Island is shown in Figure 2. A similar correlation is also favoured by Kanasewich and Berkes (1990).

(?)Cambrian to Devonian succession

Lower Paleozoic strata, including surface formations, drilled strata, and Cambrian and Lower Ordovician seismic units below drill depth have a total thickness ranging from 8500 m in the southeast (in Beverley Inlet area; see Figs. 3, 4, and 5 for place names), to over 14 000 m in the north (south of McCormick Inlet).

The entire lower Paleozoic succession is divisible into three units, each of which responded differently to episodes of deformation: 1) a (?)Cambrian and Lower Ordovician miogeoclinal wedge that ranges from 3200 m to over 8000 m thick (v = 5700 m/s); 2) a Middle Ordovician to lower Middle Devonian foundered shelf margin succession 1200 to 3500 m thick (velocity range = 4500-6400 m/s); and 3) a Middle and Upper Devonian clastic wedge of foreland association with a preserved thickness that ranges from 3300 to 4600 m (v = 3300-4300 m/s). The minimum thickness is that found in tectonically undisturbed parts of western Dundas Peninsula; the maximum thickness has been calculated to exist within Blue Hills Syncline.

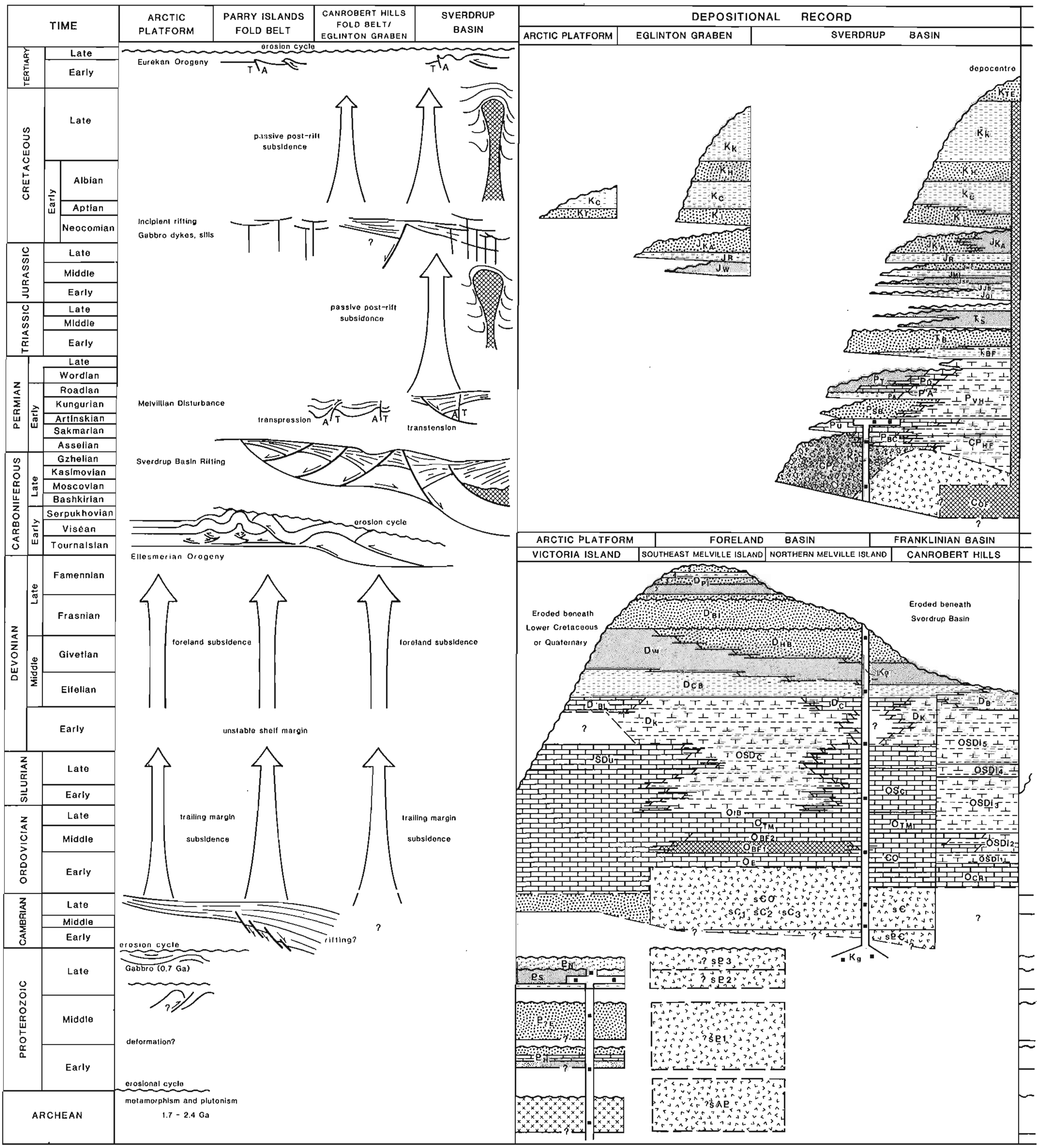
The position of the Cambrian–Precambrian boundary in the seismic section is unknown. It seems likely that the boundary lies beneath a widespread, seismically defined angular unconformity at variably 8 to 13 km below surface. In the central and northwestern parts of subsurface Melville Island, however, a reflection-poor unit (sP€) of possible Late Proterozoic age appears to be seismically conformable with reflection-dominated units assigned to the basal Cambrian.

The (?)Cambrian and Lower Ordovician miogeoclinal prism thickens progressively from the southeast toward the north and northwest. This lower Paleozoic wedge consists of at least six seismically defined, second order sequences, each marked by locally developed, basal onlapping reflection patterns. Each sequence has distinctive bounding reflections and distinctive internal reflection patterns that indicate lithological contrasts both between and within sequences. Aspects of (?)Cambrian and Ordovician seismic stratigraphy and correlation were treated in Harrison (1991a).

Middle Ordovician through early Middle Devonian time is represented in four areas of Melville Island by age-equivalent rocks that are of contrasting depositional environments. These are: 1) In the Canrobert Hills region, slope and basinal facies strata of the Ibbett Bay Formation consisting of about 1200 m of graptolitic shale, deep water carbonates, and chert. Deposition of these sediments was continuous from the Early Ordovician (Arenig) to the Early or Middle Devonian (late Emsian or early Eifelian). 2) Throughout central and southeastern Melville region, age-equivalent strata consisting of 200 to 800 m of halite-bearing evaporites of Middle Ordovician age (lower Bay Fiord Formation), 500 to 900 m of shallow marine carbonate of Middle and Late Ordovician age (upper Bay Fiord, Thumb Mountain, and Irene Bay formations), and 400 to 1000 m of deeper water shale and carbonate of Late Ordovician through early Middle Devonian age (Cape Phillips Formation). 3) In western Raglan Range and in the subsurface of western Dundas Peninsula, a third succession of Middle Ordovician to Upper Silurian rocks including at least 2000 m of shallow marine carbonates. This structurally competent interval is overlain by 60 to 130 m of Lower Devonian shale and thin-bedded black carbonates (Kitson Formation). 4) In the Weatherall Bay area, evaporites present in the lower part of the Bay Fiord Formation. The Upper Ordovician through lower Middle Devonian strata includes up to 2900 m of shallow water carbonate strata. The nature of the pre-Emsian Lower Devonian part of the rock record in this area is uncertain and may consist of either platformal carbonates or a condensed shale interval. [The various formations are described by Tozer and Thorsteinsson (1964), Fox and Densmore (1992) and Goodbody (*this volume*)].

Competency contrasts within the Bay Fiord through Cape Phillips succession of central and southeastern Melville Island have played a direct role in influencing regional variations in the structural style of Melville Island area. The bedded evaporite facies of the Bay Fiord Formation has distinctly ductile features. The subsurface geographic distribution of this facies also defines the areal extent and the lower stratigraphic limit of the thin-skinned portion of the Parry Islands Fold Belt (Balkwill and Fox, 1982; Harrison and Bally, 1988). The upper part of the Bay Fiord Formation, and the Thumb Mountain, Irene Bay, and Cape Phillips formations consist of competent strata. Style of deformation, reflecting this competence, includes thrust ramps and concentric style folds.

The Middle and Upper Devonian clastic wedge, which is everywhere conformable with underlying miogeoclinal strata, is composed of shale, siltstone, and sandstone with minor conglomerate and coal. Siliciclastic sediment gravity flows typical of the Blackley Formation (700 m) are restricted to ancient deep water realms of the Canrobert Hills region. The Cape De Bray Formation (100 to 1300 m) is a widespread basin rise and basin slope shale unit dominated in the upper half by clinoform strata. Like the lower part of the Bay Fiord Formation, the Cape De Bray is a highly ductile unit of fundamental importance to the development of structural style. The



TIME
TERTIARY
Late
Early
CRETACEOUS
Late
Early
Albian
Aptian
Neocomian
JURASSIC
Late
Middle
Early
TRIASSIC
Late
Middle
Early
PERMIAN
Late
Wordian
Roadian
Early
Kungurian
Artinskian
Sakmarian
Asselian
CARBONIFEROUS
Late
Gzhelian
Kasimovian
Moscovian
Bashkirian
Early
Serpukhovian
Viséan
Tournaisian
DEVONIAN
Late
Famennian
Frasnian
Middle
Givetian
Eifelian
Early
SILURIAN
Late
Early
ORDOVICIAN
Late
Middle
Early
CAMBRIAN
Late
Middle
Early
PROTEROZOIC
Late
Middle
Early
ARCHEAN
ARCTIC PLATFORM
PARRY ISLANDS FOLD BELT
CANROBERT HILLS FOLD BELT/ EGLINTON GRABEN
SVERDRUP BASIN
erosion cycle
Eurekan Orogeny
T A
T A
passive post-rift subsidence
Incipient rifting
Gabbro dykes, sills
?
passive post-rift subsidence
Melvillian Disturbance
transpression
A T
A T
transtension
A T
Sverdrup Basin Rifting
erosion cycle
Ellesmerian Orogeny
foreland subsidence
foreland subsidence
unstable shelf margin
trailing margin subsidence
trailing margin subsidence
?
rifting?
erosion cycle
Gabbro (0.7 Ga)
?
deformation?
erosional cycle
metamorphism and plutonism
1.7 - 2.4 Ga
DEPOSITIONAL RECORD
ARCTIC PLATFORM
EGLINTON GRABEN
SVERDRUP BASIN
depocentre
K_{TE}
K_K
K_H
K_C
K_I
K_C
K_I
K_K
K_H
K_C
K_I
J_{KA}
J_R
J_W
J_{KA}
J_{KA}
J_R
J_{MI}
J_{SF}
J_B
J_{OI}
$Ŧ_S$
$Ŧ_B$
$Ŧ_{BF}$
P_T
P_D
P_A
P_A
P_{VH}
P_{SB}
P_U
P_{BC}
CP_{HF}
K_g
CP_C
C_{OT}
?
ARCTIC PLATFORM
FORELAND BASIN
FRANKLINIAN BASIN
VICTORIA ISLAND
SOUTHEAST MELVILLE ISLAND
NORTHERN MELVILLE ISLAND
CANROBERT HILLS
D_{PI}
D_{BI}
D_W
D_{HB}
K_g
D_{CB}
D_{BL}
D_C
D_K
?
D_K
D_B
Eroded beneath Lower Cretaceous or Quaternary
Eroded beneath Sverdrup Basin
SD_U
OSD_C
?
$OSDI_5$
$OSDI_4$
OS_{CI}
$OSDI_3$
O_{IB}
O_{TM}
O_{BF2}
O_{BF1}
O_E
O_{TMI}
$OSDI_2$
$€O$
$OSDI_1$
O_{CR1}
$sۼO$
$s€_1$
$s€_2$
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K_g
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P_E
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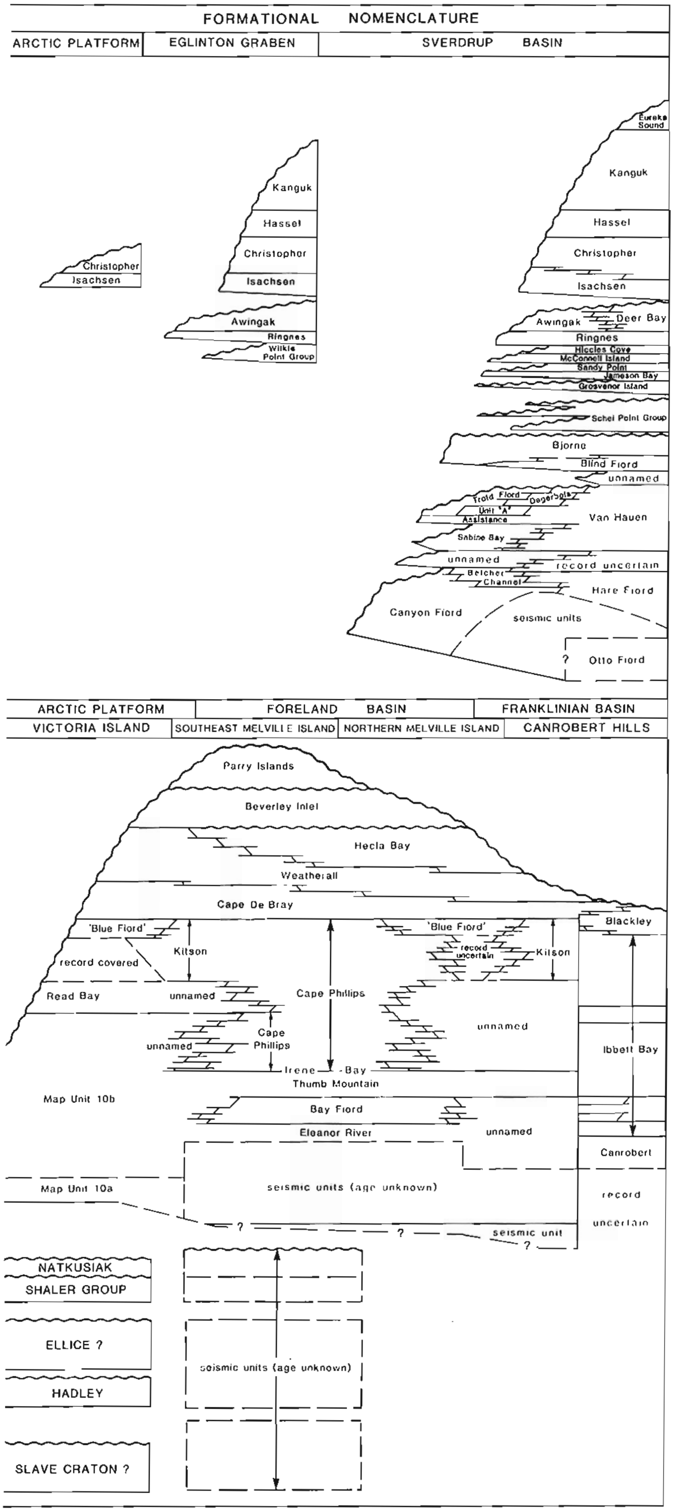


DEPOSITIONAL SETTING		ROCK TYPES
Alluvial fans	⁘	Redbed sandstone, conglomerate
Fluvial-deltaic	⁘	Sandstone, coal
Clastic/carbonate shelf	▒	Calcareous sandstone, limestone, siltstone
Pelitic shelf and slope	┄	Shale, siltstone
Carbonate shelf and slope	▦	Limestone, dolostone
Restricted shelf	░	Evaporites
Starved basin	┴	Black shale, chert, black carbonates
Submarine fans	┄	Sandstone, shale, 'turbidites'
Mafic volcanic flows	⁘	Basalt
Mafic intrusives	▫	Gabbro
Crystalline basement	×	Orthogneiss, felsic intrusives
Seismic stratigraphy	⌄	Unknown

Figure 2. *Correlation chart for the Franklinian Mobile Belt and Sverdrup Basin of Melville Island, Eglinton Graben of Eglinton Island, and the Arctic Platform of Melville and Victoria islands. The tectonic phases and events shown on the left side of the chart include stylized arrows that define times of basin subsidence. Width of the arrow is directly proportional to the rate of subsidence. The arrow points to the end of the passive subsidence phase.*

overlying Weatherall Formation (800 to 1500 m) is a mixed very fine and fine grained siliciclastic unit of shelf, prodeltaic, and delta front association. It is overlain by quartz sandstones of the Hecla Bay Formation (0 to 1300 m) that have a fluvial and delta plain association in the east and a delta front association in the west. The Beverley Inlet and Parry Islands formations (up to 1500 m total) represent fluvial, deltaic, and shallow marine clastic strata (Embry and Klovan, 1976; Goodbody, *this volume*).

Carboniferous through Paleocene

The base of the Carboniferous through Paleocene succession of the Sverdrup Basin is marked by a widespread angular unconformity. The upper Paleozoic and younger units rest on a post-Devonian peneplain surface that is underlain by folded and tilted rocks of Ordovician through Devonian age. In many northern outcrop areas (southern Sabine Peninsula, McCormick Inlet, and Canrobert Hills), basal strata of the younger succession include Upper Carboniferous and Lower Permian redbeds of the Canyon Fiord Formation. In the northwest, Carboniferous strata are overstepped by marine Upper Permian rocks assigned to the Trold Fiord Formation. Near Marie Bay, northwestern Melville Island, Lower Triassic beds rest on the unconformity, and near Comfort Cove, at the southwest corner of the island, Upper Jurassic beds of the Awingak Formation form the base of the succession. In the southeast, three outliers of Lower Cretaceous strata lie unconformably on folded Devonian beds.

Above the Carboniferous and Lower Permian horst and graben system, Upper Permian through Tertiary sediments form a continuous, homoclinal cover on older units of northern Melville Island. Exploratory wells and seismic profiles reveal a northward-thickening wedge of formations that, north of the central part of Sabine Peninsula, attains a maximum thickness in excess of 8000 m. The Carboniferous and Permian formations within the wedge display dramatic variations in both thickness and facies. Facies belts of the Carboniferous and Lower Permian include rift-related redbeds in the south (Canyon Fiord Formation), carbonate and marine coarse clastic formations beneath central Sabine Peninsula, and basin facies shale (Hare Fiord Formation) and diapiric evaporites (Otto Fiord Formation) in the north. The post-Canyon Fiord Permian succession includes marginal marine clastic formations (Assistance, Sabine Bay, and Trold Fiord formations), shallow water carbonates (Degerböls Formation) and a basinal chert and shale unit (Van Hauen Formation). The post-Wordian Upper Permian is believed to be marked by a disconformity in the marginal region of the basin and a highly condensed succession farther north in the subsurface (Beauchamp et al., 1989b). Lower Triassic through Paleocene strata are dominated by shales and siliciclastic sediments of basin marginal environments and temperate to boreal paleoclimatic associations. Thin limestone units are represented in part of the Middle and Upper Triassic section. Other, subordinate, rock types include phosphatic and ferruginous siltstone, conglomerate, and coal. Disconformities are numerous throughout the sub-Cretaceous section. [In contrast, the mid-Lower Cretaceous (Barremian) through Paleocene section is nearly devoid of depositional breaks]. The disconformities account in part for the southward thinning of the sedimentary prism and the progressive overstepping of progradational shale and shallow marine sandstone formations by overlying units.

Quaternary

Raised beaches and glaciomarine deposits fringe all low lying coastal areas of Melville Island and rest unconformably on upper Paleocene and all older strata. Diamictites of glacial origin form a thicker veneer on Devonian strata of Dundas Peninsula. A veneer of bouldery mud of glacial derivation but uncertain age is also present over a wide area of upland southeastern Melville Island. In some areas, this unit is associated with outliers of glaciofluvial gravels. All these glacially derived deposits are dissected by the Holocene drainage system.

The Beaufort Formation [(?)Pliocene], which is widely exposed on Prince Patrick and adjacent islands of the Arctic coastal plain, has also been reported by Tozer and Thorsteinsson (1964) and J.G. Fyles (pers. comm., 1992) to occur in one or more numerous erosional remnants on central and southeastern Melville Island. This correlation was not confirmed by our fieldwork.

STRUCTURAL GEOLOGY

Introduction

The structural geology of Melville Island is dominated by large surface folds that are evident on both satellite images and air photographs. Tozer and Thorsteinsson (1964) and Temple (1965) speculated that the folds were developed above the base of a widespread Middle

Ordovician evaporite: the Bay Fiord Formation. This hypothesis was later confirmed by industry seismic data collected across the fold belt (Fox, 1983, 1985). It was further discovered that the large surface folds masked a spatially and kinematically related fold and thrust belt that does not outcrop, but which is sandwiched between the Bay Fiord evaporites, below, and the Cape De Bray Formation (shale), above, at the base of the Devonian clastic wedge (Harrison and Bally, 1988). It was also discovered that forward- and backward-vergent thrusts were equally developed above the salt, and that horizontal shortening in the fold belt was almost exactly half the shortening in the buried thrust belt. The style of deformation is similar to the one predicted for thin-skinned deformed belts developed above a weak basal decoupling level (Davis and Engelder, 1985). Ductility contrasts between units have created vertical and lateral variations in structural properties that also allow for an unusual kinematic model for the deformed belt (Harrison and Bally, 1988). However, the discrepancies between measured surface and subsurface shortening are more difficult to reconcile. The shortening problem is introduced by Harrison and Bally (1988) and considered in detail by Harrison (1991a).

Surface features

Many of the structural features of Melville Island are visible in LANDSAT satellite images (Fig. 3). Some of these features are noted below, and are plotted, along with other surface structures, in Figures 4 and 5.

Areas of Dundas Peninsula that are monotone in the image (Fig. 3) are relatively undeformed. The Devonian Beverley Inlet Formation is exposed at the surface in this area and is known to be either flat-lying or very gently folded.

The pattern of light and dark banding, the most dramatic feature of the island, is due to folded rock layers of varying composition; this is the dominant Franklinian structural style at the surface on Melville Island. The regional grain of these folds on the southeastern parts of the island defines an arcuate westerly trending deformed belt that faces south on its convex side. The light-weathering bands include Silurian and Devonian carbonate units, Hecla Bay Formation, and three units of the Parry Islands Formation. The darker units include the uppermost Cape De Bray, Weatherall, and Beverley Inlet formations, and two units of the Parry Islands Formation. Together, these surface units represent about 3000 m of section. The carbonate rocks are quite rare and only exposed in three areas around Weatherall Bay: the outcrops of Tingmisut Inlier (TI of Figs. 3 and 5), Spencer Range Anticlinorium (SRA), and Towson Point Anticlinorium (TPA).

Fewer, but individually thicker, stratigraphic units appear at the surface on central Melville Island. There, the darker areas are underlain by the upper Cape De Bray, Weatherall, and Beverley Inlet formations. The Hecla Bay Formation is light-weathering. Lower Paleozoic rocks are also light-weathering but are limited in distribution to two small areas: one south, and the other west, of Raglan Range (McCormick Inlet Anticlinorium [MIA] and Kitson River Inlier [KRI], respectively). Topographic relief also plays a part in unit discrimination; uplands defined by dendritic drainage patterns are generated in part by resistance to erosion of the Hecla Bay Formation. The most obvious feature in this region is an area of northeasterly trending folds and tilted beds north of Liddon Gulf; this deformed region also defines the northwesterly limit of the conspicuous fold system in the eastern part of the island.

Folds are also obvious in the Canrobert Hills and throughout the peninsula between Ibbett and Marie bays. The separate light-weathering (partly ice-covered) uplands define axial culminations on doubly plunging anticlines of westerly and northwesterly trend. The units exposed in these culminations include some of the oldest known strata (Canrobert Formation and the lower two members of the Ibbett Bay Formation). The relatively thin black unit that outlines these plunging folds represents the upper three members of the Ibbett Bay Formation, and the grey areas between the anticlines are synclines and synclinoria with Cape De Bray and Blackley formations at the surface. The southern limit of these folds in the Canrobert Hills region is defined, between Ibbett and Purchase bays, by a system of westerly trending hogback ridges that represent the erosional response of a south-facing homocline underlain by the upper part of the Cape De Bray, Weatherall, Hecla Bay, and Beverley Inlet formations.

Folds are not apparent south of Purchase Bay and west of Murray Inlet. The only obvious structures are low sinuosity lineaments of variable trend that segment the area into separate regions of (locally ice-cap covered) plateaus, lower hills, and wide linear valleys. Most of these linear features are faults with recessive strata of the Beverley Inlet Formation on the downthrown sides, and Hecla Bay Formation supporting highlands on the upthrown sides.

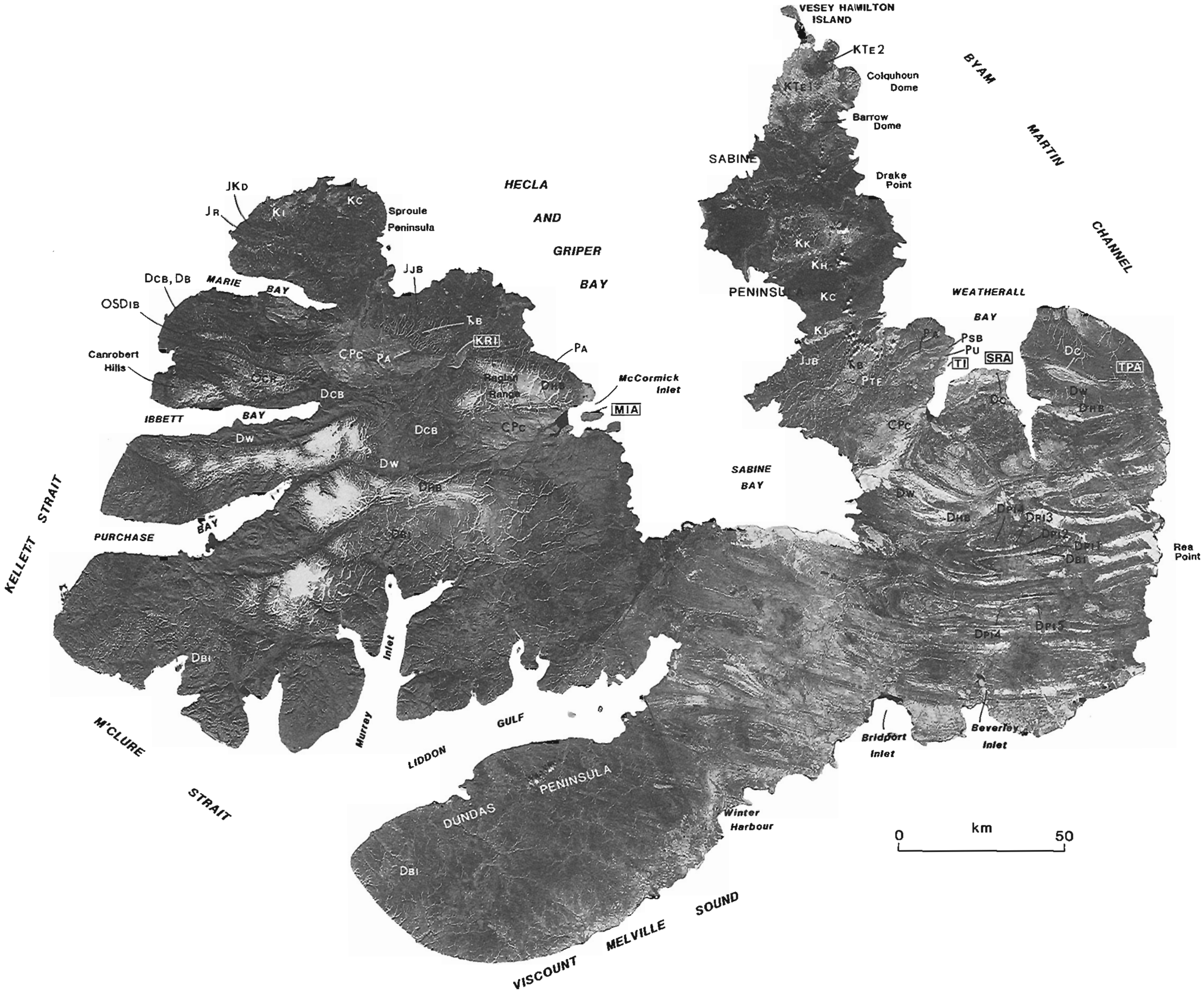


Figure 3. *Composite LANDSAT image of Melville and adjacent small islands. This image has been compiled from colour-enhanced satellite images acquired on July 18, 1974; July 29, 1976; July 23, 1977. Geological symbols and boxed abbreviations are explained in Figures 2 and 5, respectively.*

The Canyon Fiord Formation (labelled CPc in Figs. 3 and 4), the oldest exposed unit of the Sverdrup Basin succession on Melville Island, is represented by moderately reflective beds of patchy distribution across the northern part of the island. The sub-Canyon Fiord contact on southern Sabine Peninsula and between the arms of Weatherall Bay is marked by several visible faults of easterly and northeasterly strike. The Canyon Fiord Formation is known to be in fault contact with, and to rest with angular unconformity on, a variety of Ordovician through Devonian formations in the western part of the island, but the basal contact relations there are difficult to interpret in these satellite images.

The generally dark areas across the northern part of the island, including all of Sabine and Sproule peninsulas and the headland north of Raglan Range, represent a continuous cover of Permian through Tertiary strata of the Sverdrup Basin (Fig. 4). Differences in the reflective properties of the various surface formations contained within the Sverdrup Basin succession help to identify a structural grain that varies from northeasterly on Sabine Peninsula to northwesterly at the west end of the island. This grain is parallel to the edge of the Sverdrup Basin and also parallel to the depositional strike of some facies belts of the Sverdrup Basin. Also easily visible on Sabine Peninsula is a saucer-shaped syncline and, farther north, two evaporite diapirs: smaller circular features of rugged and dissected appearance.

These features as well as observations from air photos, fieldwork, and seismic reflection profiles are summarized on simplified geological and tectonic maps of Melville Island (Figs. 4 and 5). The features visible at the surface are classified in order of their approximate age. Structural characteristics of the three main geological regions of Melville Island can be readily identified in Figure 4: 1) the undeformed areas of western Dundas Peninsula are included in the Arctic Platform; 2) the folded areas of eastern, central, and northwestern Melville Island, and the faulted areas of the southwest are included in the Franklinian Mobile Belt; and 3) the mildly deformed strata of Carboniferous and younger age are included in the Sverdrup Basin.

The Franklinian Mobile Belt is further subdivided into two distinct regions or terrains: the Parry Islands Fold Belt (including faulted areas of southwestern Melville Island), and the Canrobert Hills Fold Belt. The Parry Islands Fold Belt is a foreland region in which lower Paleozoic miogeoclinal strata and Middle and Upper Devonian foredeep siliciclastic strata are deformed. In the southeastern parts of Parry Islands Fold Belt on Melville Island (which includes the region of surface folding as far west as Liddon Gulf), the typical structural style is that of thin-skinned deformation of Middle Ordovician through Upper Devonian strata. The "thin-skinned" character is indicated at the surface by fold repetition of the same 3000 m thick panel of strata across the entire width of the fold belt. In contrast, folds of the central and western parts of Parry Islands Fold Belt are deep-seated in character and affect all lower Paleozoic strata from the (?)Cambrian to the Devonian.

The Canrobert Hills Fold Belt of northwestern Melville Island is a region of close and tight folding of basinal and basin slope Lower Ordovician to Middle Devonian strata. The nature of the contact between Parry Islands Fold Belt and Canrobert Hills Fold Belt is somewhat uncertain; the contact may be a subsurface fault west of Raglan Range.

Two phases of folding in the Canrobert Hills region were noted by Tozer and Thorsteinsson (1964). An earlier phase of deformation resulted in an angular discordance of up to 90° between deformed Middle Devonian and older rocks, below, and Carboniferous and younger cover, above. A younger phase of deformation affected both the Carboniferous Canyon Fiord Formation and pre-Carboniferous strata and has produced, in some areas, an angular unconformity ranging up to 30° beneath the Upper Permian Trold Fiord Formation. The second phase of deformation is kinematically and spatially linked to the Canrobert Hills Fold Belt, but coincides in time with the early development of the Sverdrup Basin.

Subsurface structural features

The major subsurface structural features of Melville Island are shown in two simplified cross-sections in Figure 6. These cross-sections are derived in part from migrated and unmigrated reflection seismic profiles and include structural information to depths exceeding 20 km.

Section A^1A^5, 360 km long, begins in the Arctic Platform on western Dundas Peninsula, crosses Parry Islands Fold Belt to the Sverdrup Basin margin near Weatherall Bay and continues to the axial area of the basin beneath northern Sabine Peninsula. The section illustrates the major subsurface structural features of the area, although it should be noted that the section, in taking advantage of available seismic profiles, is oblique to the structural grain of eastern Dundas

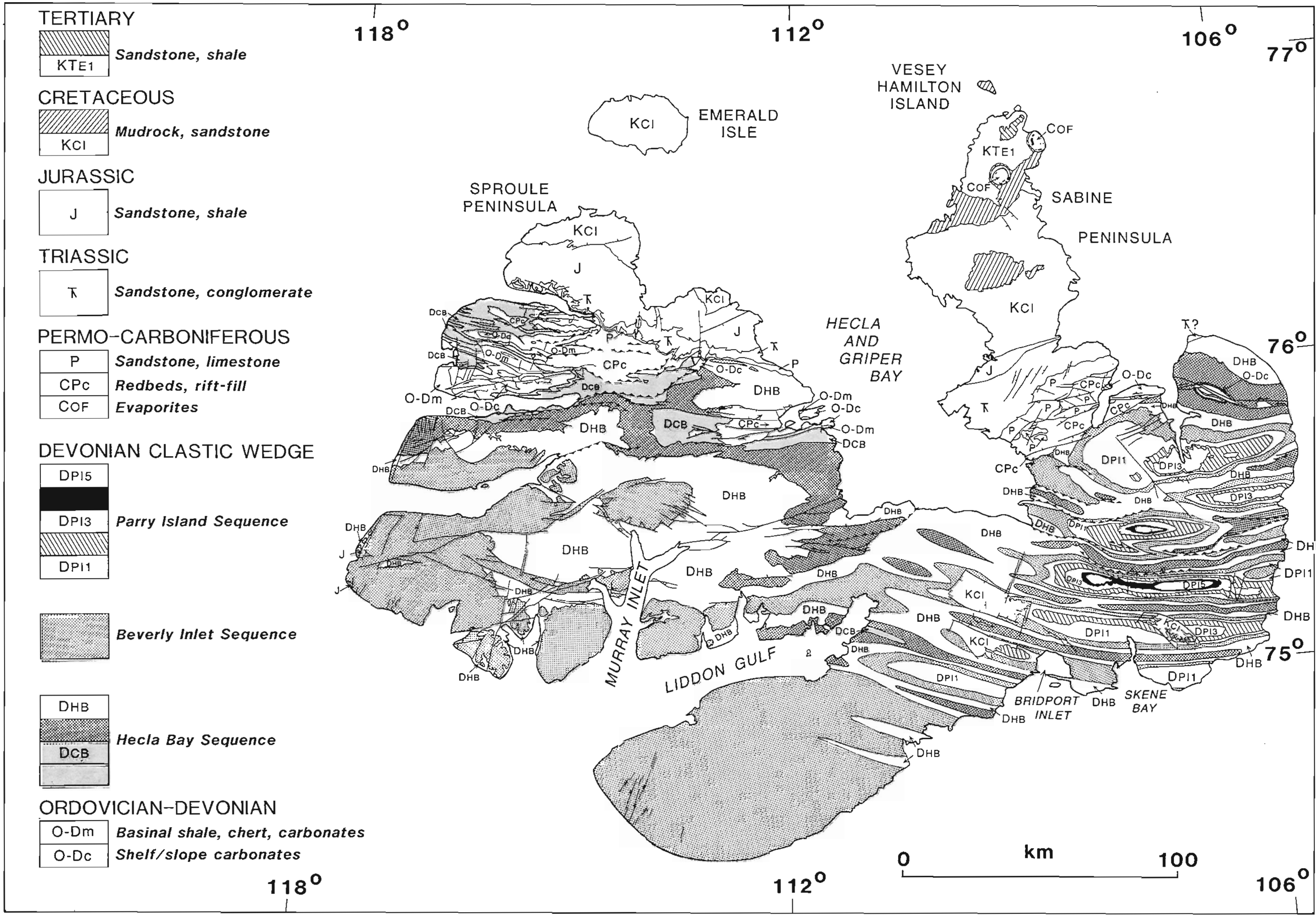


Figure 4. Simplified geological map of Melville Island (adapted from Harrison, 1991b). For the sake of clarity, most faults and all fold axes have been omitted.

Peninsula. Only the broadest stratigraphic subdivisions of the fold belt are shown; details are provided on smaller scale fold belt cross-sections in Harrison (1991b), and Harrison and Bally (1988).

Section B^1B^4, 295 km long, lies parallel to Dealy Island Anticline in the southeastern and central part of the island, then crosses the structural grain of central and northwestern Melville Island. The section includes parts of Parry Islands Fold Belt, Canrobert Hills Fold Belt, and the Sverdrup Basin margin on Sproule Peninsula.

Arctic Platform and pre-Phanerozoic structural features

The Arctic Platform of Melville Island is limited to southwestern parts of Dundas Peninsula. The lower Paleozoic units in this area, although thick (10 000 m), are essentially horizontal and apparently undeformed. Generally undeformed (?)Cambrian and Lower Ordovician strata also underlie large parts of the thin-skinned Parry Islands Fold Belt of southeastern Melville Island.

The base of the (?)Cambrian succession in the subsurface, southeastern part of the island is an irregular unconformable surface. Depressions in this surface have been filled in by a reflection-poor succession (unit sPЄ) of uncertain age. A correlative reflection-poor succession occurs in northern subsurface areas but there it is thicker and the structural relationship to underlying (?)Proterozoic units is not determinable.

Certain distinctive features of the seismic stratigraphy in the (?)Precambrian allow some observations on the structural characteristics of these units. A cautious approach in interpreting these features is adopted as a result of the highly variable quality of the supportive seismic data. It is clear, however, that several different and variably deformed units subcrop beneath an ancient erosional surface that underlies the (?)Cambrian succession, that folding and regional scale uplift can account for many of the larger features within the (?)Precambrian interval, and that most of this deformation does not affect (?)Cambrian and younger cover.

Unit sAP, which is presumed to be crystalline basement, has been identified seismically at depths ranging between 18 and 24 km. In the Beverley Inlet area (Fig. 6, B), unit sAP is apparently closer to the surface and may be located at a depth of less than 16 km. This structurally elevated region is also defined by several overlying (?)Proterozoic units that dip away from the high and that have been partially removed as a result of pre-Phanerozoic erosion of the high.

Other sub-(?)Cambrian features include a large saucer-shaped erosional remnant in the subsurface of Cape Clarendon area, in which up to 3400 m of unit sP3 is preserved. In most parts of the subsurface of southeastern Melville Island, unit sP2 lies beneath the sub-(?)Cambrian unconformity. Locally, unit sP2 is tectonically thickened, possibly as a result of pre-Phanerozoic thrust faulting.

Parry Islands Fold Belt

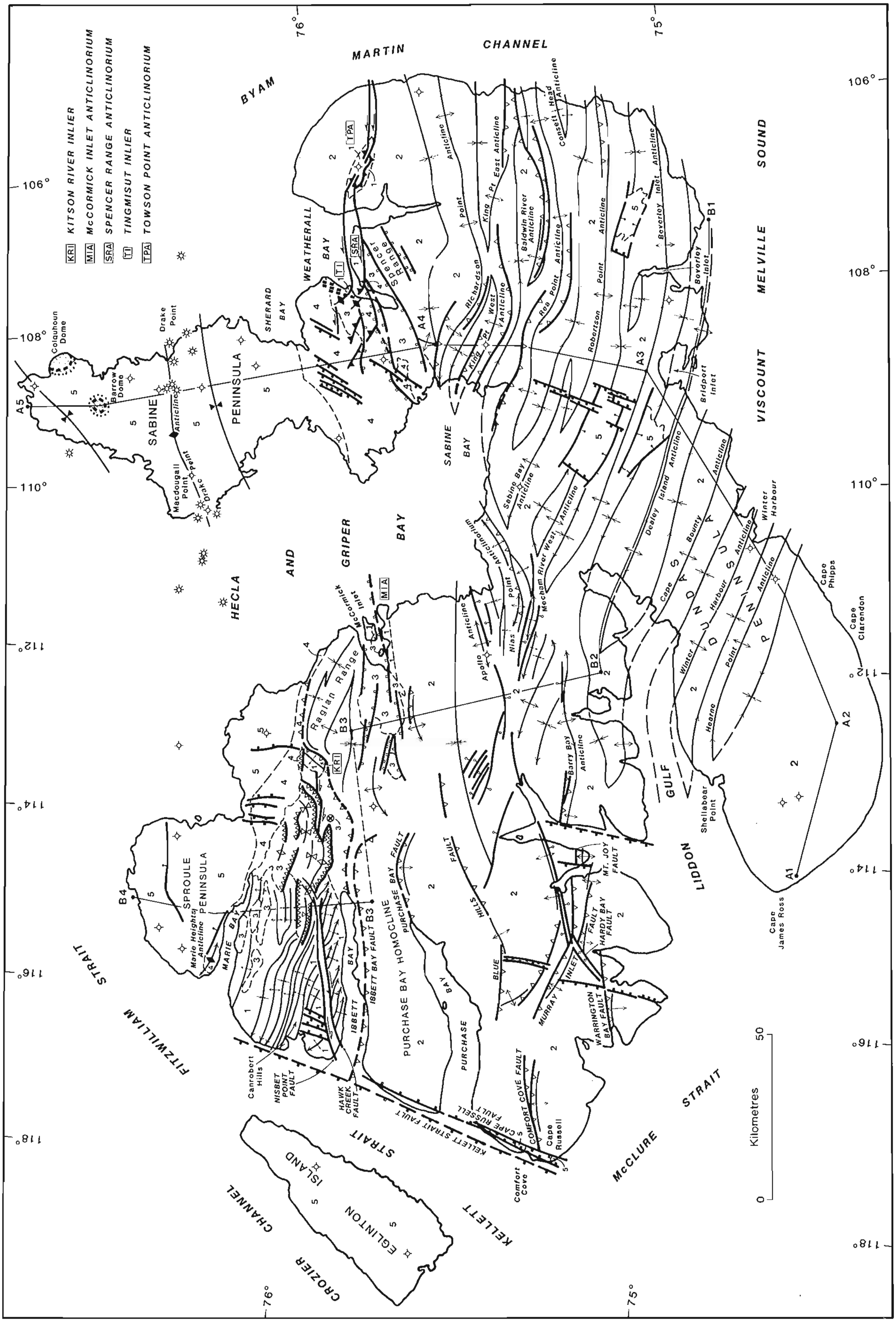
Southeastern region

The Parry Islands Fold Belt of southeastern Melville Island is continuous, across Byam Martin Channel, with similar structures on Bathurst Island (described by Temple, 1965; Kerr, 1974; Fox, 1985). The regional tectonic fabric of Melville Island is arcuate, convex toward the foreland, and varies systematically from N 90°E at the east end of the island, to N 75°W along a line joining Liddon Gulf and Hecla and Griper Bay.

The exposed anticlines in this region are narrow and up to 150 km long (Figs. 4, 5, 6, A). Axial zones, which commonly expose Middle Devonian beds of the lower Weatherall and even uppermost Cape De Bray formations, dip 50° to 90° north and south. Dips on the limbs range from 30° to 45°. The folds are regularly spaced, with average wavelengths of 13.5 km and amplitudes of less than 3.5 km. The folds are only slightly asymmetric, with an equal representation of northward and southward apparent vergence (Harrison and Bally, 1988). Synclines are also very long and are, on average, 2.4 times the width of the anticlines (measured between dip inflection points near the surface).

Faults exposed at the surface commonly lie parallel or subparallel to the axial traces of folds on eastern Melville Island. Faults can be followed 10 to 40 km along strike, and stratigraphic throws range from several hundred metres to nearly one kilometre. Seismic reflection profiles indicate a reverse sense of slip for some of these structures.

Hidden at depth is a widespread subsurface layer that is deformed by numerous large- and moderate-scale folds and thrusts with up to 3 km displacement; a detachment surface at the base of this


KRI KITSON RIVER INLIER
MIA McCORMICK INLET ANTICLINORIUM
SRA SPENCER RANGE ANTICLINORIUM
TI TINGMISUT INLIER
TPA TOWSON POINT ANTICLINORIUM
BYAM MARTIN CHANNEL
VISCOUNT MELVILLE SOUND
HECLA AND GRIPER BAY
WEATHERALL BAY
SHERARD BAY
SABINE BAY
SABINE PENINSULA
Colquhoun Dome
Drake Point
Barrow Dome
Macdougall Point
Drake Point Anticline
Spencer Range
Raglan Range
McCormick Inlet
King Pt West Anticline
King Pt East Anticline
Richardson Point Anticline
Baldwin River Anticline
Consett Head Anticline
Rea Point Anticline
Robertson Point Anticline
Beverley Inlet Anticline
Beverley Inlet
Bridport Inlet
Winter Harbour
Sabine Bay Anticline
Mecham River West Anticline
Nias Point Anticlinorium
Apollo Anticline
Dealey Island Anticline
Cape Bounty Anticline
Winter Harbour Anticline
Hearne Point Anticline
DUNDAS PENINSULA
Cape Phipps
Cape Clarendon
Cape James Ross
Shellabear Point
LIDDON GULF
Barry Bay Anticline
MT. JOY FAULT
HARDY BAY FAULT
WARRINGTON BAY FAULT
MURRAY INLET
BLUE HILLS FAULT
PURCHASE BAY FAULT
PURCHASE BAY HOMOCLINE
PURCHASE BAY
IBBETT BAY FAULT
IBBETT BAY
MARIE BAY
Marie Heights Anticline
SPROULE PENINSULA
FITZWILLIAM STRAIT
Canrobert Hills
NISBET POINT FAULT
HAWK CREEK FAULT
KELLETT STRAIT FAULT
CAPE RUSSELL FAULT
COMFORT COVE FAULT
Cape Russell
Comfort Cove
KELLETT STRAIT
EGLINTON ISLAND
CROZIER CHANNEL
McCLURE STRAIT
Kilometres
0
50
A1
A2
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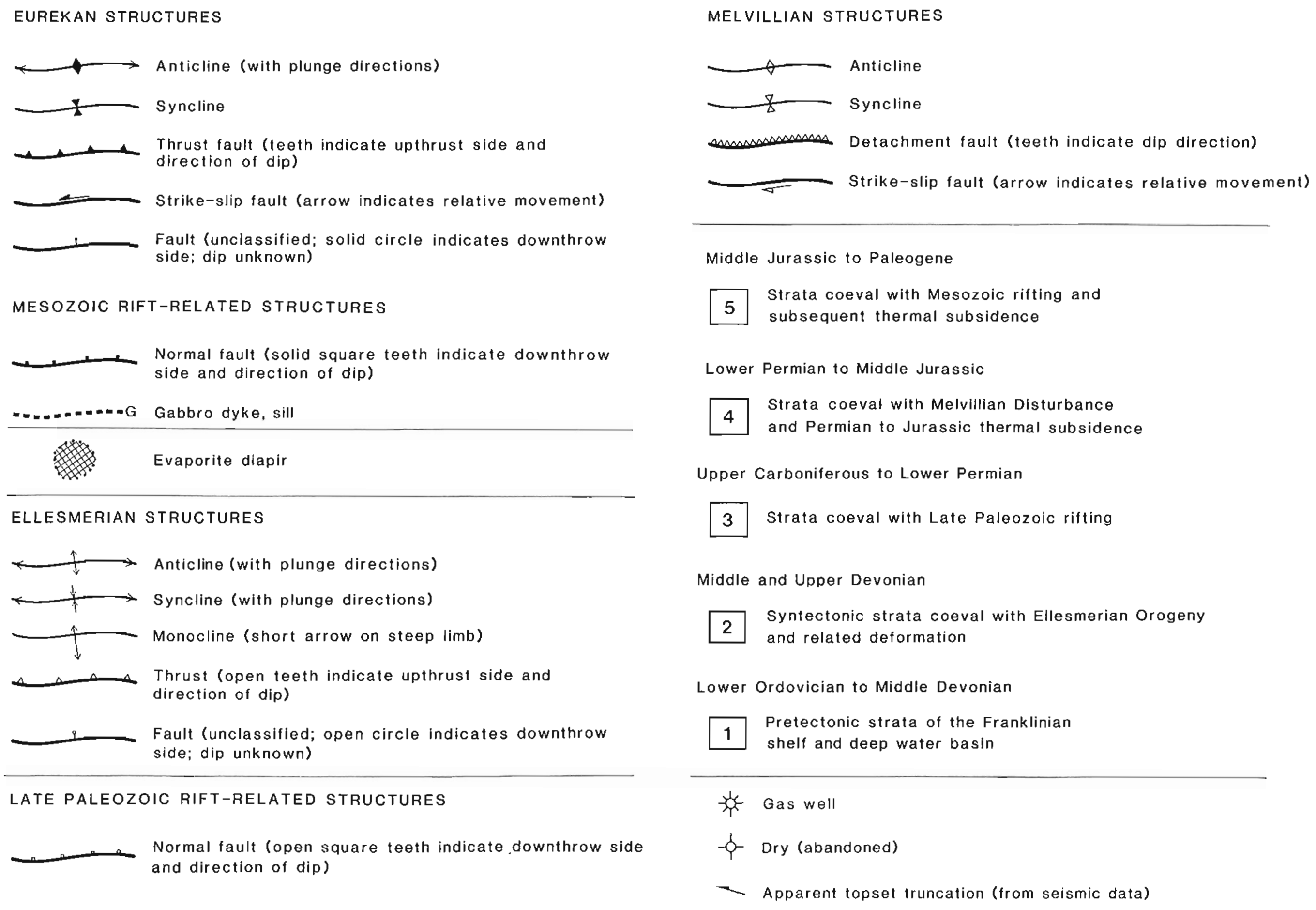

Figure 5. *Structural elements of Melville and adjacent small islands. An attempt has been made to classify the various structural elements by their timing of motion. Formations included in the numbered units are: Unit 1 — Bay Fiord, Thumb Mountain, Irene Bay, Cape Phillips, and Kitson formations, and undivided carbonates of Parry Islands Fold Belt; Ibbett Bay, Canrobert, and Blackley formations of Canrobert Hills Fold Belt; Cape De Bray Formation of all areas. Unit 2 — Weatherall, Hecla Bay, Beverley Inlet, and Parry Islands formations. Unit 3 — Canyon Fiord, Belcher Channel, and Hare Fiord formations, and unnamed Lower Permian formations. Unit 4 — Sabine Bay Formation and all overlying units as high as the Sandy Point Formation (Middle Jurassic), inclusive. Unit 5 — McConnell Island Formation and all overlying units as high as the Eureka Sound Formation, inclusive.*

deformed sheet lies 5.0 ± 0.6 km below mean sea level in many subsurface areas. The cratonward limit of slip on the lower detachment corresponds to the depositional limit of the evaporitic facies of the lower Bay Fiord Formation. The covered thrust faulted system is nearly everywhere sandwiched between two apparently ductile units. The evaporite-dominated lower member of the Bay Fiord Formation (Middle Ordovician) forms the ductile layer between the basal detachment and the base of the obvious thrusts, and the shale-dominated Cape De Bray Formation (Middle Devonian) is the ductile unit above the upper limit of the thrust system. The buried thrust sheet between the two ductile units incorporates a competent interval of strata 0.9 to 1.6 km thick that includes the upper Bay Fiord, Thumb Mountain, Irene Bay, and Cape Phillips formations. These units are not distinguished on the two cross-sections (Fig. 6). However, they do appear on the more detailed cross-sections published by Harrison and Bally (1988) and Harrison (1991b).

The surface folded succession overlies, and is structurally separated from, the buried system of thrusts and folds by the ductile Cape De Bray Formation. The fold belt includes all the siliciclastic formations of the Middle and Upper Devonian clastic wedge: the Weatherall, Hecla Bay, Beverley Inlet, and Parry Islands formations. These units form an upper

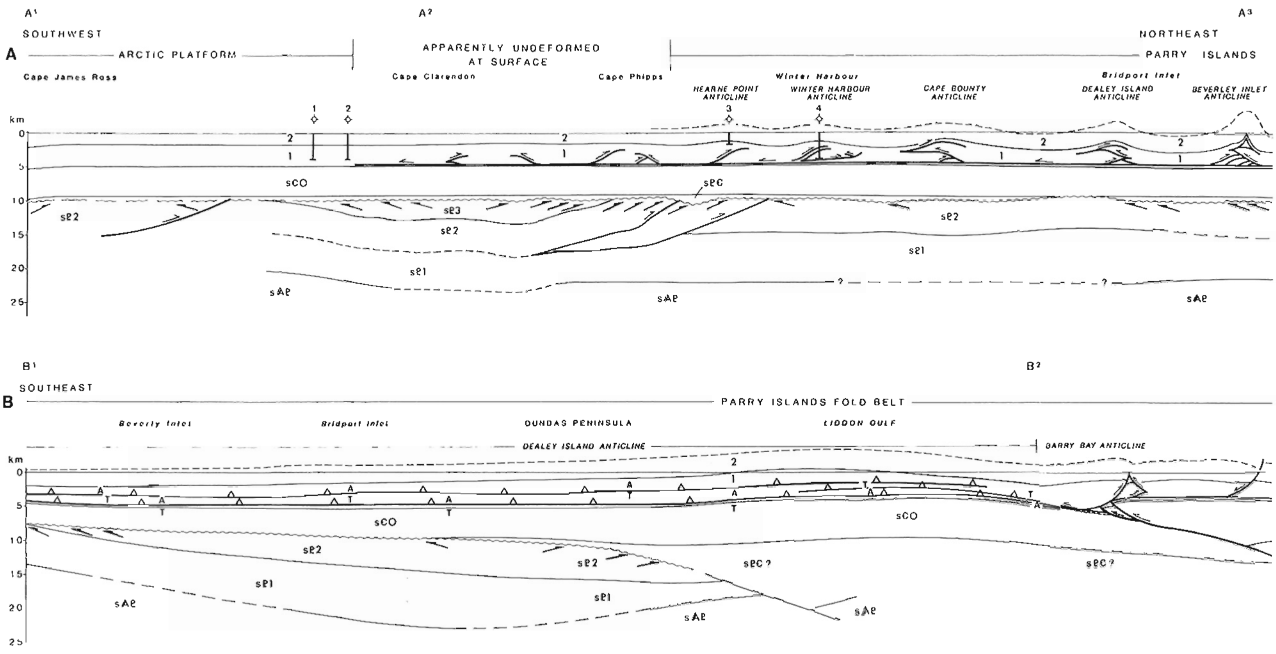

Figure 6. ***A.*** *Simplified structural cross-section from Cape James Ross on western Dundas Peninsula to north of Barrow Dome on northern Sabine Peninsula (see Fig. 5 for location of line of section). The cross-section has been drawn without vertical exaggeration. Thrusts and other subsurface features have been identified on reprocessed and time migrated seismic reflection data that exist along the line of section. Seismic units have been converted from time to depth using 1) sonic velocities for stratigraphic units penetrated by wells, 2) refraction velocities for units below well penetration (Overton, 1970), and 3) DIX interval velocities for some near-surface horizontal units exposed in synclines (see text for interval velocity ranges). Numbered units and other geological symbols are explained in the legend of Figure 5. Formations included in the numbered units are listed in the caption of Figure 5. Probable Precambrian and Cambrian seismic units are indicated by a small prefixed "s" (see also Fig. 2). Small arrows indicate the direction of slip on faults. Larger arrows define the location of real or apparent topset truncation of strata as observed on seismic data (see also legend of Fig. 5). The dashed line, drawn to define the shape of an upper surface of the fold train within unit 2, is close to the contact above the Hecla Bay Formation (Fig. 4) and does not appear in Figure 5.*

B. *Simplified structural cross-section from Beverley Inlet on southeastern Melville Island to the north coast of Sproule Peninsula. The section has been drawn with zero vertical exaggeration. Subsurface structure has been obtained from seismic reflection data. Sources of velocity data are the same as for those of Figure 5. Numbered units and other geological symbols are explained in the legend and caption of Figure 5. Seismic units indicated by a small prefixed "s" are the same as those shown in Figure 2.*

structurally competent succession that is 2600 to 3600 m thick (measured in synclines; upper contact not seen).

Fold amplitude and complexity of the subsurface thrust system are greatest near the Sverdrup Basin margin and tend to decrease progressively southward toward Dundas Peninsula. The foreland boundary between the Parry Islands Fold Belt and the Arctic Platform is gradational. Some subsurface folds and thrusts with limited displacement occur beneath apparently undeformed Devonian strata near the foreland (southwestern) limits of deformation (Fig. 6, A).

Thrust faults in the covered thrust system verge equally forward (to the south) and backward, tend to be localized beneath surface anticlines, and tend to be stacked vertically. The stacking arrangement of thrusts is due in part to the presence of intermediate

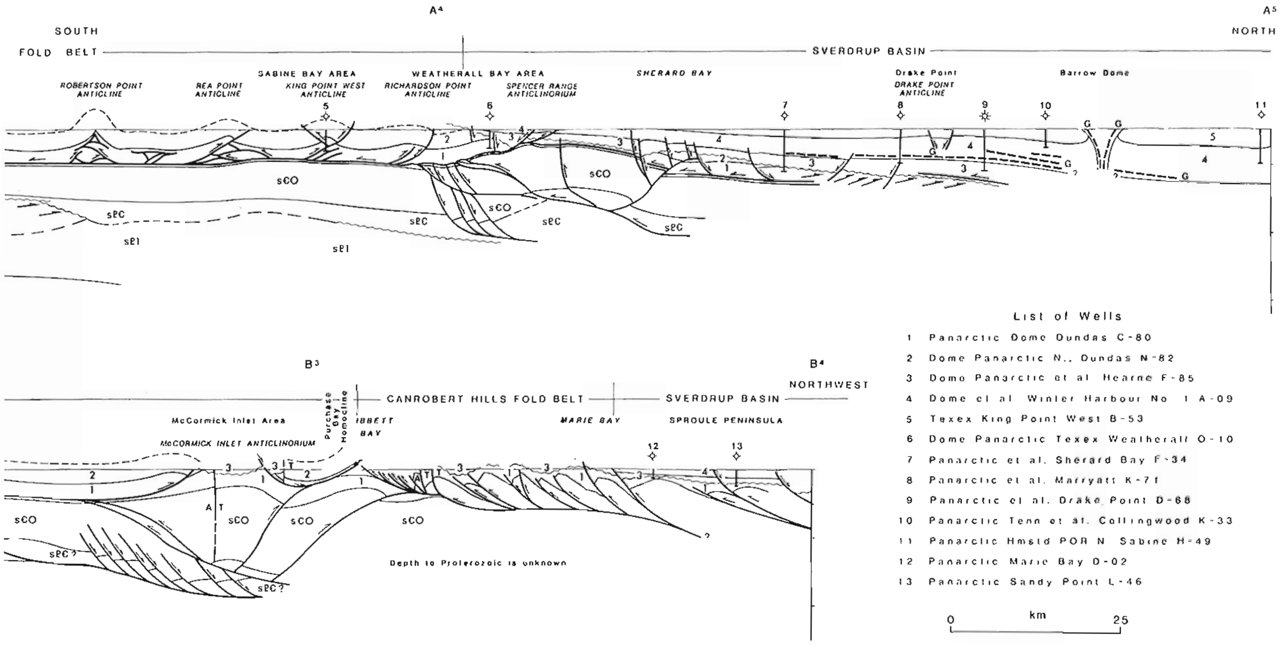

Figure 6. (cont'd)

detachment levels. This has created, in profile, a zigzag pattern of short displacement thrusts. Shortening across the buried thrust system ranges up to to 28 km (15%). In contrast, shortening in the overlying fold belt, measured by bed length of the sub-Beverley Inlet Formation contact is approximately 50 per cent of this amount. As noted earlier, these contrasting estimates of measured shortening create a serious problem in balancing structural cross-sections; details of this problem were presented in Harrison and Bally (1988) and Harrison (1991a).

Northwestern region

Folds of the southeastern part of Melville Island die out gradually west of a line connecting the south shore of Liddon Gulf and the southwest corner of Sabine Bay. The transitional boundary coincides with a westward lateral facies change of the lower evaporitic member of the Bay Fiord Formation, as indicated by exploratory wells that penetrate this interval: halite-dominated in the Panarctic et al. Sabine Bay A-07 well, to anhydrite-dominated in the Panarctic Apollo C-73 well, to carbonate-dominated in the Sun K.R. Panarctic Kitson River C-71 well (Fox and Densmore, 1992). The lower ductile layer, which facilitated the formation of buckle folds and thrusts in the upper Bay Fiord, Thumb Mountain, and Cape Phillips formations, thus disappears to the west and north. Shortening in the northwestern part of the Parry Islands Fold Belt, instead, has been accomplished by long-wavelength folding and by reverse faulting of much if not all of the (?)Lower Cambrian to Middle Devonian carbonate-dominated section.

A more complex, though generally compressional pattern of deformation occurs at the surface throughout the central part of Parry Islands Fold Belt between Liddon Gulf and Raglan Range, and across the northern part of Parry Islands Fold Belt (in the vicinity of Weatherall Bay). In these areas, there is a tendency toward increased fold wavelength and lower or more irregular fold amplitude. The level of erosion of both anticlines and synclines is also deeper than in the southeastern region.

The nature of the subsurface deformation in the northwestern part of Parry Islands Fold Belt is shown in Figure 6, A. The left side of the cross-section in Figure 6, B is drawn parallel to and along the axial trace of one of the thin-skinned surface anticlines of southeastern Melville Island (Dealy Island Anticline). The basal detachment beneath the Bay Fiord Formation is marked at about 5 km depth in the section. Toward the north shore of Dundas Peninsula, the shallow detachment thrusts and, beneath them, the (?)Cambrian and Lower Ordovician succession have been uplifted into a broad anticlinorium with an amplitude of 2.5 km and a wavelength of 70 to 80 km. These uplifted features are part of a common set of cross-folds that have an east-northeasterly orientation. The thin-skinned folds are also oblique to the longer wavelength deep-seated folds, with about 40° to 45° between them.

Two major anticlinoria, the McCormick Inlet and Spencer Range structures, intersect sections A and B (Fig. 6) north of the uplifts just described. Both anticlinoria are underlain by several long thrust ramps; the thrusts flatten upsection into the lower part of the Bay Fiord Formation and therefore are known only from interpreted seismic profiles.

Important deformational features in the northwestern part of the Parry Islands Fold Belt are down-to-the-north, extensional growth faults that were apparently active during the deposition of (?)mid-Cambrian and Lower Ordovician strata. In Figure 6, B, the growth faults are associated with a dramatic thickening of the (?)Cambrian and Lower Ordovician interval; the stratigraphic section increases from 7000 m to more than 9500 m in a distance of less than 20 km.

In McCormick Inlet and Weatherall Bay areas, structural style has been modified by deformation associated with late Paleozoic rifting, the Melvillian Disturbance, and subsequent phases of tectonism. These features are described below in the section dealing with the Sverdrup Basin.

Canrobert Hills Fold Belt

Regional-scale folds of Canrobert Hills Fold Belt trace out an arcuate tectonic fabric that is convex to the foreland and swings in trend from N 70°E north of the head of Ibbett Bay to N 90°E south of Marie Bay to N 65°W adjacent to Kellett Strait (Figs. 3, 5). A linear plunge culmination occurs along the line of the east-northeasterly-striking Nisbet Point and Hawk Creek faults (shown in Fig. 5). East of the culmination, folds developed in Blackley Formation and older strata plunge eastward to disappear within the apparently ductile Cape De Bray Formation. West of the linear culmination, most folds plunge westward to the limits of the exposed Canrobert Hills Fold Belt.

Folding is locally associated with the development of axial planar cleavage in fissile strata near the axial region of some larger folds. Other features typical of the fold belt include spectacular cross-fibre calcite veins up to 17 m thick, several reverse faults with limited displacement, northerly striking tear faults, various younger normal faults, and dextral strike-slip faults, some of which are shown in Figure 5.

The scale, and to some extent the style, of chevron folding in the Canrobert Hills varies vertically within the stratigraphic succession. The largest folds have wavelengths of about 3 km and are developed in the Canrobert and Ibbett Bay formations. These folds tend to be tight, asymmetric or marginally overturned (to about 110°). Overturning is especially prominent on the south-facing limbs of en echelon folds in the frontal range of structures north of Ibbett Bay.

The largest folds in the Blackley Formation are comparable to those in the older units. However, higher-order folds with wavelengths of 0.7 km or less are also present and can be parasitically distributed about larger underlying structures. Overturning in places is extreme (up to 145°, locally), and plunge variation along strike is common. Tight, plunging folds have produced an interleaving of Blackley and lower Cape De Bray strata in some areas.

Deformation in the Cape De Bray Formation is characterized by apparent ductile behaviour and outcrop-scale, tight to isoclinal folds and minor thrusts. These small structures, as with most of the contractional features of the Canrobert Hills Fold Belt, verge to the south. The Ibbett Bay Fault, an important south-dipping planar surface south of Ibbett Bay, transects the upper Cape De Bray and lower Weatherall formations. Above this fault, mesoscopic folds and thrusts display an opposite (that is, northerly) sense of apparent displacement. The Ibbett Bay Fault is interpreted as being the upper plane of detachment (roof thrust) of a triangle zone above which the upper Weatherall, Hecla Bay, and Beverley Inlet formations have been passively raised into a south-facing homoclinal flexure (Purchase Bay Homocline). Lying structurally below the roof thrust, the Canrobert Hills Fold Belt is interpreted as having been inserted to the south as a tectonic wedge. The preserved width of the hypothesized wedge is at least equal to the width of the Purchase Bay Homocline, or approximately 30 km.

No seismic surveys have been carried out in the Canrobert Hills. Aspects of subsurface structure are, however, obtainable from adjacent areas with reflection seismic coverage. In the Eglinton Island and Sproule Peninsula areas, the basinal facies rocks typical of the Canrobert Hills region are believed to exist unconformably beneath post-Devonian cover. In these two adjacent areas, thrust faulting, rather than than folding, is a more significant mechanism of horizontal shortening. Seismically defined thrusts below the top of the Canrobert Formation merge upsection into tightly folded synclinoria of the Ibbett Bay, Blackley, and Cape De Bray formations. This interpretation has been favoured in the cross-section of the fold belt in Figure 6, B.

The lower detachment level for the seismically defined thrusts of the Sproule Peninsula region is undetermined. This is due to uncertainties in the correlation of sub-Canrobert seismic reflectors with the better understood seismic stratigraphy of the Parry Islands Fold Belt. The generally short wavelength of the folds in the Canrobert Hills imply a shallow depth to detachment, probably not exceeding 2 to 3 km below the top of the Canrobert Formation. If the (?)Lower Cambrian through Lower Ordovician seismic intervals are as thick in the subsurface of Canrobert Hills as they are beneath McCormick Inlet area, then the basal detachment probably lies in strata of mid-Cambrian age.

Sverdrup Basin

Structural features that are spatially and or genetically associated with the southern margin of the Sverdrup Basin can be classified under five headings: 1) basin-parallel extensional structures, most of which are associated with the early development of the Sverdrup Basin; 2) compressive and wrench tectonic structures that have affected the Canyon Fiord Formation and all underlying strata, 3) evaporite diapirs; 4) northerly to northeasterly striking faults, dykes, linear elements of similar trend, and associated gabbro bodies; and 5) late-stage folds.

Basin parallel rift-related structures

Easterly to east-northeasterly striking normal faults located east and west of Hecla and Griper Bay are roughly parallel to the Sverdrup Basin margin; these have been documented at the surface and on seismic profiles. Many of these faults have also been mapped at the surface in the outcrop belt of upper Paleozoic formations (Fig. 4; unit 3 of Fig. 5). An important characteristic of this group of faults is a tendency to become less abundant upsection and to be generally absent above the base of the Bjorne Formation. (One exception is a fault of uncertain dip, exposed on Sproule Peninsula, that has displaced Lower Cretaceous strata at the surface.)

Basin-parallel faults of southern Sabine Peninsula can be readily identified on reflection seismic profiles; some of them are represented in cross-section A (Fig. 6). Related structures shown in the cross-section include listric growth faults that flatten downward to become parallel with sub-Carboniferous strata. Down-to-basin (north-dipping) and down-to-craton (south-dipping) faults are also represented. In the Weatherall Bay area it is apparent that the basal detachment level for several down-to-craton listric growth faults lies beneath the evaporitic member of the Bay Fiord Formation.

Syndepositional movement of some basin-parallel faults is evident in seismic intervals that are correlative with the Canyon Fiord, Belcher Channel, Sabine Bay, lowermost Van Hauen, and Trold Fiord formations. Both seismic and surface stratigraphic data reveal an important relationship between uplifts and depressions and rift-related deformation. Both the ancestral Spencer Range and Raglan Range were elevated features during periods of tectonic extension. Downwarp of at least two semi-isolated depressions (one in southern Sabine Peninsula region and the other west of McCormick Inlet) and infilling by terrigenous sediments are related to such deformation.

Structures related to the Melvillian disturbance

The Canyon Fiord Formation in the Canrobert Hills region and areas to the east (as far as Raglan Range) was open folded, uplifted, and eroded during the mid-Permian Melvillian disturbance (Thorsteinsson and Tozer, 1970). Subhorizontal detachment faults, out-of-basin reverse faults and easterly to east-northeasterly striking dextral wrench faults also affected the Canyon Fiord Formation and older units during this deformation. Some of these structures are shown in Figures 5 and 6, B.

The importance of short displacement strike-slip faults is perhaps not properly shown in the cross-section due to a lack of subsurface information and to the uncertainty of whether reflection seismic profiles can image vertical faults of this kind. Lateral displacement of up to 2.5 km can be documented from surface observation on each of two dextral strike-slip faults in the Canrobert Hills (Hawk Creek and Nisbet Point faults of Fig. 5).

The existence and full extent of compressive and strike-slip structures of Melvillian (Permian) age beyond northwestern Melville Island are uncertain. An angular unconformity above a tilted and buckled seismic unit correlated with the Canyon Fiord Formation has been identified on some offshore seismic profiles of western Hecla and Griper Bay area. Direct evidence of uplift and folding has not been discovered anywhere in the surface or subsurface area of Sabine Peninsula.

Melvillian deformation in the Canrobert Hills region can probably be accounted for by dextral transpression that was influenced by the anisotropy of pre-existing fold-parallel and basin-parallel faults. Inversion features are important elements in Melvillian deformation; that is, rift-related faults of Carboniferous age were later reactivated as thrust faults, and rift fill (Canyon Fiord Formation) was inverted and folded (Beauchamp et al., 1989a).

Diapirs

The widespread presence of evaporite diapirs in the central Sverdrup Basin was recognized by Heywood (1955, 1957). Two of these intrusions form prominent features on northern Sabine Peninsula (Figs. 4, 5; Tozer and Thorsteinsson, 1964). Anhydrite at the diapir surface is interleaved with carbonate rocks, sandstone, and minor shale. The carbonate lenses of Barrow Dome, thought to have been originally interbedded with the evaporites, were precisely dated on the basis of ammonoids as Chesterian to Bloydian (Serpukhovian to Bashkirian) by Nassichuk (1975), who correlated these rocks with the Otto Fiord Formation of northern Ellesmere Island.

Internal structure in the diapirs is complex due to ductile flow. Structural patterns tend to be diverse near the centre of the bodies and become contact-parallel toward the outer rims. The outer contact of both diapirs is marked by a locally inward-dipping reverse fault that is nearly circular in plan view. Intruded strata of the Kanguk Formation (Upper Cretaceous), outside the intrusive margin, are subhorizontal in attitude, but in the immediate vicinity of the contact are variably steep-dipping, vertical, and slightly overturned.

Other intrusive evaporite bodies have been identified in offshore areas between northern Sabine Peninsula and Mackenzie King Island through geophysical surveys; included among these are seven piercement diapirs and the Vesey Hamilton salt wall (Balkwill and Fox, 1982; Fox, 1983). Marine seismic reflection surveys conducted over the salt wall reveal dramatic thinning of seismic stratigraphic units in the vicinity of the intrusive evaporite contacts. The thinned units are correlated with Lower Triassic through Upper Cretaceous (Albian) strata intersected in local exploratory wells.

Northerly trending structures and related intrusions

Included under this heading are a variety of structural and igneous intrusive features (some only defined geophysically) that are believed to have been created during a phase of east-west extension that affected the greater part of the Sverdrup Basin region and adjacent parts of the Franklinian Mobile Belt. These features include: northerly striking faults, gabbro dykes exposed at the surface and related linear magnetic anomalies, gabbro sills (exposed and drilled), and seismically imaged intrusive sheets.

Three gabbro dykes are exposed near the Tingmisut inlier on the west side of Weatherall Bay (Fig. 5); these bodies intrude Permian and older strata. The outcrop pattern of the dykes is right hand en echelon. The magnetic response of both exposed and geophysically defined subsurface dykes in the western Arctic islands was documented by Balkwill and Fox (1982). The characteristic linear anomalies, trending north through N 40°E, are widespread in the Melville Island region.

Other gabbro bodies have intruded halokinetic evaporites of Barrow and Colquhoun domes on northern Sabine Peninsula. Subsurface gabbro sheets are evidently widespread, and several have been intersected during exploratory drilling in the Sabine Peninsula area. Many sheets are readily identified on certain seismic reflection profiles. These intrusive bodies have apparently been emplaced at several Permian stratigraphic levels and can be seen to cut upsection at low oblique angles.

Extension faults parallel to and in some cases coinciding with linear magnetic anomalies are equally widespread. Many such faults have been mapped on Sabine and Sproule peninsulas, where they cut Upper Jurassic and underlying strata (Fig. 5). Other parallel faults are recognized in the subsurface of Sabine Peninsula but are not shown in Figure 5; these subsurface faults die out as they pass up section into Lower Cretaceous strata.

Late-stage folds

Two regional-scale synclines and an intervening anticline (Drake Point Anticline) cross central and northern Sabine Peninsula (Figs. 3, 4, 5), and a relatively small doubly plunging anticline lies on the north side of Marie Bay (Marie Heights Anticline; see Fig. 5). These folds, and possibly also several faulted folds in Spencer Range and east and west of Weatherall Bay (Spencer Range Anticlinorium and Towson Point Anticlinorium) are here assigned to a late stage of folding.

Eureka Sound and Kanguk formations are preserved in the synclines of Sabine Peninsula, and the upper part of the Christopher Formation is exposed in the intervening Drake Point Anticline. Fold orientation is variably east-northeast through northeast (Fig. 5) and maximum amplitude along the line of section in Figure 6, A is about 1000 m. The three folds may be described simply as a major anticline superimposed on the regional northward dip of beds on the Sverdrup Basin margin. The northwestern limb of the northern syncline may be due to the doming effect of the Vesey Hamilton salt wall, which lies immediately offshore to the northwest. The anticline, which can be traced from Drake Point to MacDougall Point, may also be linked to the intrusion of the Otto Fiord evaporites. The anticline is interpreted as having originated by out-of-basin compressive slip along a detachment surface at the base of the Carboniferous evaporites (north of the Panarctic et al. Marryatt K-71 well in Fig. 6, A). This interpretation is indirectly supported by seismic profiles, from which it appears that mobile evaporites are absent south of the folded region, but are known from piercement diapirs to the north. The Drake Point Anticline forms a structural trap for hydrocarbons in Jurassic strata in the Hecla and Drake fields (Henao-Londoño, 1977).

Kinematic elements (including minor slip planes and related slip lineations, minor folds, mappable faults, and tensile carbonate veins) within several anticlines and spatially related faults located in and around Weatherall Bay (noted earlier) indicate a common origin by sinistral slip on west-striking wrench faults, and folding and thrusting along northwesterly striking segments of restraining bend faults. This pattern of deformation affects Lower Triassic and underlying strata at the surface. Minor slip planes related to a younger phase of fault movement have also displaced the gabbro dykes west of Weatherall Bay.

AGES OF DEFORMATION

The geological history of the Melville Island region, based on evidence from stratigraphy and subsurface structures, extends from probably Precambrian [(?)Archean] to Tertiary time (Fig. 2).

Precambrian structural history

The interpretation of the Precambrian structural history of the area presented here is based on sequence correlation of reflection seismic profiles. An Archean or Proterozoic crystalline basement may exist at depth throughout most of southern Melville Island and parts of the Lower, Middle, and Upper Proterozoic periods may be represented by stratified sequences. Units of possible Middle and Late Proterozoic age appear to have been involved in a phase of long-wavelength folding and regional uplift. Pre-(?)Early Cambrian erosion and peneplanation has locally removed up to at least 4000 m of Proterozoic section.

Cambrian to Devonian structural history

The (?)Cambrian through Middle Devonian history of the region is one of almost continuous basin margin subsidence and sedimentation (Fig. 2). The wedge-shaped geometry and exceptional thickness of this succession is consistent with the notion that the northern part of the Melville Island area may have been close to the northwestern shelf-slope break of the ancestral North American plate throughout that time. Trailing shelf margin instability is recorded by down-to-basin (basin to the north) growth faults that were active during deposition of stratigraphic units of probable mid-Cambrian age.

The Melville region continued to subside from the Early Ordovician to early Middle Devonian, with large local variations in rates of subsidence and organic productivity becoming evident in the stratigraphic record. A crystalline terrane of northern Ellesmere Island, Pearya, is believed to have been accreted to the North American craton by the Late Silurian (Ludlovian) (Trettin, 1987). The Boothia and Bache Peninsula (Inglefield) structures in central and eastern Arctic islands, respectively, are also known to have begun uplift in the Late Silurian and to have experienced phases of renewed uplift during the Early Devonian (Kerr, 1976; Thorsteinsson and Uyeno, 1981). Coeval depositional units in the Melville Island area include variably condensed intervals of deep water carbonate and shale (Kitson, upper Cape Phillips, and upper Ibbett Bay formations) or shallow marine carbonates that are generally devoid of terrigenous components.

The thin-skinned compressive features of southeastern Melville Island, some, if not all, of the thick-skinned compressive structures of central Melville Island, and the pre-Carboniferous close folds of Canrobert Hills Fold Belt formed primarily during the Ellesmerian Orogeny, which ended in latest Devonian or Early Carboniferous time. An earlier but related period of deformation is recorded in the Middle and Upper Devonian clastic wedge; this 2800 to >4500 m thick apron of siliciclastic strata was shed from orogenic highlands that once existed to the north and northeast. By the end of the Devonian, the wedge had become incorporated into the orogen.

The base of the clastic wedge in the foreland provides the earliest depositional record of orogenic activity in what were once (and are again) offshore areas. In most of the northern Melville Island region, siliciclastic strata derived from the ancestral Ellesmerian highlands overwhelmed the then-existing shelf margin in the early Eifelian (Fig. 2; *costatus* conodont zone; Goodbody, *this volume*). This event is marked by the sequence boundary beneath the Cape De Bray Formation. The progradational pattern of the Devonian clastic wedge and its generally coarsening-upward and shallowing-upward character reflects the expansion toward the foreland of the ancestral Ellesmerian Orogen. The common occurrence of sand-grade and angular pebble-grade chert fragments in the upper Hecla Bay Formation and overlying Upper Devonian formations indicates that older, chert-rich formations (such as the Ibbett Bay Formation) were undergoing active uplift and erosion by late Givetian to early Frasnian time.

A sequence of structural events in the Franklinian Mobile Belt of Melville Island is here proposed, modelled on the sequence deduced by Bally et al. (1966) for the Alberta Rocky Mountains. Compressive structures in the orogenic hinterland are considered to have formed before those in the foreland, and shallow detachment structures are cross-folded by younger structures that possess deeper levels of detachment. This model appears to account for the major features of the Parry Islands Fold Belt, although certain smaller features do not fit the scheme (Harrison and Bally, 1988).

From the hinterland position and the relatively shallow depth to detachment in the Canrobert Hills Fold Belt, it may be taken that deformation began there before the onset of deformation in the Parry Islands Fold Belt. The first appearance of chert pebbles in the clastic wedge dates the beginning of the erosion and uplift that presumably accompanied early deformation (late Givetian to early Frasnian) of a northern portion of the Canrobert Hills Fold Belt. A subsurface shale to carbonate facies change in Lower Ordovician to Upper Silurian strata is locally close to the southeastern limit of the Canrobert Hills Fold Belt (between eastern Canrobert Hills and the Kitson River Inlier). The platform carbonates, because of their greater competence, may have acted as a buttress to shallow detachment, southerly vergent thrusts beneath the Canrobert Hills Fold Belt, and may have caused the Canrobert Hills structures to be uplifted and inserted as a tectonic wedge into the Cape De Bray Formation. Thrust wedging permitted the creation of a triangle zone beneath the Purchase Bay Homocline.

Large anticlinoria of northern and central Melville Island have a deep, sub-Phanerozoic level of detachment; these structures, which lie close to the foreland, may be younger than the Canrobert Hills Fold Belt. The long wavelength folds probably originated through compressive reactivation of earlier shelf-marginal, normal growth faults. Some of these reactivated faults linked slip surfaces within and below (?)Cambrian strata with a newly formed slip plane at the base of the Bay Fiord Formation.

The thin-skinned folds and thrusts above the Bay Fiord evaporites formed simultaneously with the buckling and deformation of many internal (hinterland) and external (foreland) folds. However, embryonic external structures then coexisted with more complex and advanced folds in the inner part of the fold belt. Thus, it has been suggested by Harrison and Bally (1988) that the inner folds formed first and continued to evolve. In some parts of central and northern Melville Island, both the thin-skinned structures and the underlying (?)Cambrian and Ordovician units were subsequently cross-folded by slip on deep detachments (if such exist). Thus, the entire lower Paleozoic succession was, it is suggested, affected by this shortening.

Ellesmerian tectonic activity ended at a time between deposition of the youngest strata involved in folding, and the age of the oldest overlying strata that are not folded. In southeastern Melville Island, some of the youngest beds of the Parry Islands Formation contain palynomorphs assigned to the upper *torquata-gracilis* palynomorph zone of the middle or late (not latest) Famennian (Fig. 2; McGregor, *this volume*). A prolonged period of erosion and peneplanation post-dates the Ellesmerian Orogeny. In the north, much, if not all, of the clastic wedge was removed prior to the deposition of younger cover. The oldest post-Ellesmerian cover rocks known in the Arctic islands are those of the Emma Fiord Formation of northern Ellesmere Island, northern Axel Heiberg Island, and Grinnell Peninsula of western Devon Island. This unit has been dated, from palynomorphs, as late Viséan (Utting et al., 1989). In the Melville Island area, the Canyon Fiord Formation, which is Moscovian or Bashkirian at the base, represents the oldest unit known to lie unconformably on deformed and peneplaned rocks affected by Ellesmerian deformation. [Evaporites of the Barrow and Colquhoun domes contain Serpukhovian (Namurian) ammonoids and are also undoubtedly post-Ellesmerian (Nassichuk, 1975); however, the original structural relationship of these rocks to older strata in the Melville Island area is unknown].

Carboniferous to Cretaceous structural history

The Carboniferous and (pre-Roadian) Lower Permian formations in the Melville Island region were evidently deposited during a phase of rifting that represented an embryonic stage of the Sverdrup Basin (Fig. 2; Beauchamp et al., 1989a). Rift-related faulting can be dated through the detection of growth faults on reflection seismic records. From such data, it has been observed that faulting was either continuously or sporadically active between the Late Carboniferous (Moscovian and or Bashkirian) and the Early Permian (Artinskian). This is also the time when intrabasinal and basin marginal uplifts within the rift marginal zone were important sources of proximal coarse clastic debris.

Growth faulting in the southern Sabine Peninsula region was also active during deposition of the clastic wedge of the Sabine Bay Formation. This late Early Permian (Roadian) tectonism is considered to be coeval with dextral strike-slip faulting and inversion tectonics (Melvillian disturbance) of northwestern Melville Island region. The Sabine Bay Formation, which contains Roadian fauna, is believed to provide a depositional record of Melvillian uplifts near the Sverdrup Basin margin (Henderson *in* Beauchamp et al., 1989a).

Growth faulting occurred locally along the basin margin as late as the Late Permian (Wordian). However, most growth faults do not displace strata that are younger than Roadian. A pattern of thermal subsidence dominates the tectonic history of the Sverdrup Basin margin from the Permian to the Middle Jurassic (Fig. 2; Stephenson et al., 1987). Seismic stratigraphic units near the Vesey Hamilton salt wall have been thinned by the diapiric rise of Otto Fiord Formation evaporites during the Late Triassic, Early to Late Jurassic, and Early Cretaceous.

The direction of transport of sediments changed from southerly derived to at least partly westerly derived in the early Middle Jurassic. The McConnell Island and Hiccles Cove formations (Bajocian to Callovian) represent an important new influx of siliciclastic detritus derived from northerly trending uplifts to the west in the Prince Patrick Island area (Harrison et al., 1988; Embry, *this volume*). These uplifts are interpreted as having been created by block rotation on listric normal faults of similar orientation, and perhaps mark the beginning of an important phase of east-west extension that continued to be active up to the Early Cretaceous. The extensional deformation may be related to the opening of the Canada Basin (Balkwill and Fox, 1982).

Dykes and sills

Widepread dykes and sills, and spatially associated normal faults of northerly orientation, are related to this rifting phase (Fig. 2). Radiometric ages for gabbro bodies are quoted by Balkwill and Fox (1982). The exposed dykes west of Weatherall Bay possess an isotopic age of 123 ± 6 Ma. Sills that intrude Permian strata and that have been penetrated by exploratory wells have yielded isotopic ages of 131 ± 6 Ma and 152 ± 6 Ma. This evidence, combined with the observation that northerly striking extension faults are uncommon above the Deer Bay Formation (Upper Jurassic and pre-Valanginian Lower Cretaceous), indicates that most of the active east–west extension had ended by mid-Early Cretaceous time. A renewed phase of thermal subsidence continued from the late Early Cretaceous or early Late Cretaceous to the Paleocene (Stephenson et al., 1987).

Tertiary and Eurekan Orogeny

Peneplaned folds in late Paleocene and older strata of central and northern Sabine Peninsula are unconformably overlain by Pleistocene and Holocene glaciomarine deposits; a mid- to late Tertiary age for a late stage of deformation is indicated. This is roughly coeval with the Eurekan Orogeny of the eastern Arctic Islands and the later stages of spreading within Baffin Bay Basin (Thorsteinsson and Tozer, 1970; Srivastava et al., 1981; De Paor et al., 1989). Other late-stage structures of Sproule Peninsula and the Weatherall Bay area may also have formed during the Eurekan Orogeny.

Modern earthquake activity

A swarm of recent earthquakes in the offshore subsurface area east of Sabine Peninsula indicates ongoing intraplate deformation in the Melville Island region (Basham et al., 1977; Hasegawa, 1977).

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