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GEOLOGY AND PETROLEUM POTENTIALITIES OF NORTHERN CANADA

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INTRODUCTION

In northern Canada, north of latitude 60° (Fig. 1) a total of 465,000 square miles is underlain by sedimentary rocks ranging in age from Cambrian to Tertiary that may be considered to be potentially productive of oil and gas. Of this vast region, which constitutes one of the largest remaining, relatively little explored petroleum provinces of the world, some 240,000 square miles are mainland, and 225,000 square miles comprise the Arctic Islands. Oil and gas seeps and bitumen residues are known; oil is produced at Norman Wells field; gas has been encountered in four wells in potentially commercial quantities. With so few known occurrences and so little knowledge of the habitat of hydrocarbons in this vast area, assessment of the potential of northern Canada depends largely on geological considerations. This paper accordingly sets forth a summary of the geological features of the sedimentary rocks that bear on their evaluation as a potential source of oil and gas and calls attention to the various factors of terrain, climate, and transportation that affect the development and marketing of these natural resources.

Some aspects of the regional stratigraphy are shown in a series of generalized isopach and facies maps complementary to the geologic and tectonic maps and by a series of restored stratigraphic cross-sections. From these the reader may appraise the possibilities of petroleum occurrence and ascertain the nature, sequence and structure of the rocks present in the potential areas and their general relationships to each other. Estimates of the volumes of sediment and gross facies have been made and tabulated. These maps and estimates are based on rather meagre and preliminary data in some areas.

Acknowledgments

In addition to the geological data obtained from sources listed in the bibliography much unpublished information has been contributed by several officers of the Geological Survey of Canada. . These contributions are gratefully acknowledged. Where specific unpublished data have been used in the preparation of the correlation tables and figures, the contributor's name is shown on appropriate columns of the tables.

PETROLEUM PROVINCES

Regional Relationships

The principal structural provinces of northern Canada (Fig. 1) are the Precambrian Shield, Interior Plains, Arctic Lowlands, Cordillera, Franklinian Geosyncline, Sverdrup Basin and Arctic Coastal Plain. Some provinces, and parts of others, include regions presently and potentially productive of oil and gas and will be described below. The Precambrian Shield, the western Cordillera and northern Franklinian Geosyncline embrace deformed sedimentary, volcanic, metamorphic and igneous rocks unsuitable for the retention of hydrocarbons.

The Precambrian Shield of northern Canada is flanked by cratonic cover beneath Interior Plains and Arctic Lowlands, beyond which lie the Franklinian and Cordilleran geosynclines. In the north are Sverdrup Basin and Arctic Coastal Plain.

Sedimentation during the Palaeozoic was dominated by carbonates and evaporites on the cratonic shelf and in the miogeosynclines; carbonates grade into clastics northward and westward towards the eugeosynclines. Franklinian geosyncline was affected by Caledonian and Variscan deformation, the latter concluding its depositional history. Cordilleran geosyncline in northern Yukon suffered local Variscan deformation but not until the Laramide was it regionally deformed. The Franklinian and Cordilleran geosynclines may have been linked through the Arctic Ocean in Palaeozoic time. This is suggested from the occurrence on both the northern mainland and the Arctic Islands of thick non-marine Upper Devonian clastics that had a common source to the north.

Mesozoic sedimentation was dominated by terrigenous clastics, mainly sandstone and shale. Triassic carbonates occur in southern Yukon but are absent in eastern Cordilleran geosyncline and Sverdrup Basin. Although carbonates are well represented throughout the Palaeozoic, their absence in the Mesozoic probably indicates cooling of marine environments, possibly due to restriction of oceanic currents by uplifts within the western Cordilleran geosyncline. Sedimentation was heavy and continuous in Sverdrup Basin throughout Mesozoic time but was confined mainly to the Cretaceous on the mainland. Most Mesozoic sediment in Arctic Islands was derived from the south and east; that on the mainland came from uplifts within Cordilleran geosyncline to the west.

Tertiary, probably Laramide, compressive deformation affected the Cordillera, Central and Northern Ellesmere Fold Belts and Sverdrup Basin. Late Palaeozoic evaporites in Sverdrup Basin were mobilized to form intrusive domes and diapirs. Post-Laramide Tertiary and Quaternary rocks of Arctic Coastal Plain are non-marine and extend seaward onto the continental shelf.

Acidic intrusions occur in Old Crow Range, British Mountains, Arctic Plateau, Liard Plateau, and Northern Ellesmere Fold Belt. Diorite plugs intrude rocks as young as Lower Cretaceous in western Liard Plateau. Pennsylvanian, Permian and Cretaceous extrusive basalts occur in the northern part of Sverdrup Basin. Gabbro dykes and sills intrude all formations below the Upper Cretaceous in the basin and the Palaeozoic of southeast Bathurst Island.

Interior Plains

The Interior Plains comprise several diverse elements (Figs. 1, 2). They are underlain mainly by horizontal or gently dipping Lower Palaeozoic, Devonian, Carboniferous and Cretaceous sediments (Tables 1, 4, 5) that thicken southward into northern Alberta and westward into the Cordilleran geosyncline. Regional unconformities lie at the base of the Palaeozoic, Middle Devonian and late Lower Cretaceous.

Beneath Great Slave Plain, Precambrian basement highs were relatively positive during the Middle Devonian and possibly also during the Lower Palaeozoic (Figs. 4, 10, 23). Strong topographic relief characterizes the portion underlain by Precambrian crystalline rocks (Fig. 20a) producing compaction folds in finely porous dolomites of the late Ordovician and Middle Devonian carbonates. Small faults related to the basement also occur. Rabbitt Lake gas (Fig. 3, Table 7) is trapped by such structures. Basal sandstones of the Cambro-Ordovician are porous but erratic in thickness, partly filling irregularities on the basement surface. Late Middle Devonian carbonates are thickest and largely biogenic on the flanks of Liard and Tathlina Highs (Figs. 11, 23). Netla and Celibeta gas discoveries (Fig. 3, Table 7) in these rocks are a northern extension of the gas belt of northern British Columbia. Coarse, porous dolomites of the Presqu'ile and fine, porous dolomites of the Pine Point occur marginal to evaporites. The Presqu'ile seeps oil on outcrop but several wells drilled on the trend have been unsuccessful. The Upper Devonian is mainly cover (Fig. 12), but where overlain by younger strata the limestones may be considered prospective. There is a regional gradation from green shales, siltstones, and carbonates, of the Great Slave Lake region to dark grey shales of Liard Plateau (Fig. 23). The carbonates are mainly dense and silty limestone but are partly biogenic to reefoid, porous and dolomitized. Southwestern Great Slave Plain is underlain by late Palaeozoic rocks (Figs. 14, 25), representing the northern limits of extensive deposits south of the area. They outcrop along Petitot River but adjacent to the mountains constitute potential reservoirs beneath thick Cretaceous cover.

Although Great Bear Plain is little known, available data suggest a west-dipping homocline of Ordovician and Middle Devonian carbonate, extensively exposed or overlain by a thin veneer of Cretaceous shale. The potential of this region is low as a result of the lengthy intervals of erosion represented by unconformities at the base of the Middle Devonian and Lower Cretaceous. North-trending

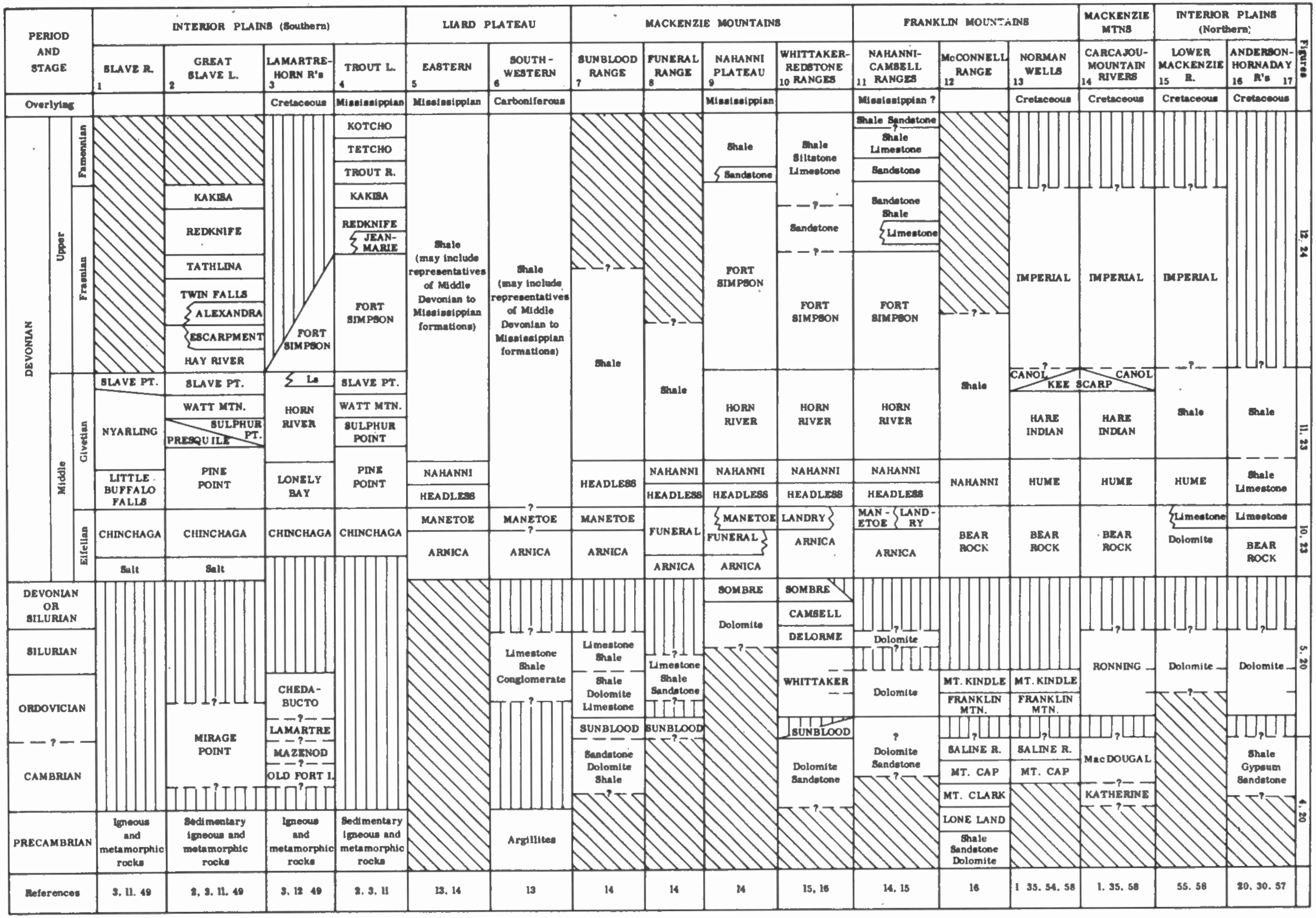


TABLE 1. CORRELATION OF DEVONIAN AND OLDER PALAEOZOIC ROCKS OF DISTRICT OF MACKENZIE

structures of the Colville Uplift bring Ordovician, Silurian and Middle Devonian rocks to the surface, these structures merging with the northwesterly trending Franklin Mountains. They may be pre-Laramide.

Anderson Plain is underlain by a west-dipping homocline of Devonian rocks that extends into the basin beneath Peel Plain and Plateau (Fig. 2). Gentle folds occur in Peel Plateau. Oil and gas seeps have been reported (Fig. 3). The early Middle Devonian (Figs. 10, 23) is mainly carbonate. It is overlain by a capping of late Middle Devonian shale (Figs. 11, 23) and underlain by Ordovician and Silurian dolomite (Figs. 5, 20). The latter sequence is thick and partly porous but lacks major shale intercalations, although eastward extensions of Road River shale may occur. The Cambro-Ordovician has not been drilled. In adjacent regions (Fig. 4) it consists of platy siltstone, carbonate or red beds with gypsum and salt. The northerly striking Palaeozoic is truncated by an east-trending homocline of Cretaceous rocks adjacent to Arctic Ocean that is overlain by Tertiary and Quaternary deposits of Arctic Coastal Plain and Mackenzie Delta. East-trending folds and faults in Campbell Uplift elevate the Palaeozoic differentially. These structures may continue along the coast disrupting the Cretaceous and Palaeozoic homoclines.

Mackenzie Mountain Area

Mackenzie Mountain Area embraces Mackenzie and Franklin Mountains, the intervening Mackenzie Plain and Liard Plateau (Fig. 1). Palaeozoic and Proterozoic rocks are widely exposed in the mountains. Mackenzie Plain and Liard Plateau are potential petroleum provinces; they are underlain by cover rocks of Upper Devonian, Carboniferous and Cretaceous and by thick Ordovician, Silurian and Middle Devonian rocks that contain several potential reservoir beds, including the producing horizon at Norman Wells (Tables 1, 4, 5). As Tertiary sediments of Mackenzie Plain have been folded, the deformation is considered Laramide.

In Liard Plateau the mountain ranges are anticlinal, slightly faulted, with several doubly plunging linked culminations (Fig. 2). Intervening valleys are synclinal. Gas has been discovered a few miles south in British Columbia in the Middle Devonian on the continuation of one of the folds. Much of Mackenzie Plain is characterized by extensive linear synclines and broad gentle brachy-anticlines, commonly linked en échelon and broken by faults of small displacement which cross on north, northeast and northwest lines.

Middle Devonian carbonates occur along the hinge line bounding Cordilleran geosyncline (Figs. 10, 11, 23) interfingering westward with shale and thinning markedly or grading to evaporites on the shelf to the east. The thick Arnica dolomites include several finely porous and vuggy intervals and together with coarse, very porous

Manetoe dolomite underlie many of the folds of southern Mackenzie Plain and may also be present beneath much of Liard Plateau. The complex of facies variations presents possibilities of stratigraphic traps on the flanks of the folds. Best porosity is present in the Manetoe adjacent to the facies change to shale and limestone of the Funeral. The Manetoe facies occurs as the uppermost beds of the Bear Rock and locally at lower stratigraphic levels separating the Arnica and Funeral facies. The Bear Rock breccias are porous, vuggy and cavernous on outcrop, but in the subsurface contain much anhydrite. Biogenic thickening of the Nahanni occurs near the facies change to Headless shale and also appears to be associated with margins of areas where the formations are abnormally thin transverse to the regional isopach trends. The Kee Scarp limestone and reefs underlies northern Mackenzie Plain and forms the reservoir for Norman Wells oil field (Fig. 23e). The oil is trapped in an isolated reef on the homoclinal flank of Franklin Mountains and was discovered in 1920 at the site of a seep. The reefs occur at the top of an extensive platform of bedded limestone and reach several hundred feet in thickness. They may be localized in the vicinity of an arch that extends across northern Mackenzie Plain and Franklin Mountains (Figs. 5, 10, 11). The shales of the probably equivalent Canol Formation are strongly bituminous and thinnest where overlying the reefs. An isolated reef occurs near Horn River (Fig. 11) and may constitute a trend. Several anticlines in the vicinity of Norman Wells have been drilled unsuccessfully.

Thick Ordovician and Silurian rocks (Figs. 5, 20) as developed in Mackenzie Mountains are progressively truncated across Mackenzie Plain and Liard Plateau beneath the unconformity at the base of the Middle Devonian, offering possibilities for stratigraphic traps, although the rocks above the unconformity are not particularly suitable as permeability barriers (Fig. 23). Late Ordovician porous reefoid dolomites of the Mt. Kindle and Whittaker Formations constitute potential reservoirs. The latter is conformably capped by argillaceous limestones and shales of Silurian age (Fig. 5) that become sandy to the east. The Silurian also changes facies northward to porous dolomites that underlie northern Mackenzie Plain.

Strong differential westward tilting as a result of Devonian and Cretaceous sedimentation (Figs. 23, 28) enhances the petroleum possibilities of Mackenzie Plain. The tilting probably continued into the Tertiary, as beds at the mouth of Great Bear River (Fig. 1) lie unconformably on Cretaceous to Middle Devonian rocks; that area apparently constituting an arch separating north and south Mackenzie Plain. Pre-Middle Devonian fault movements are indicated in the southern Mackenzie Mountains (Fig. 20a) and pre-Lower Cretaceous in southern Mackenzie Plain (Fig. 24b).

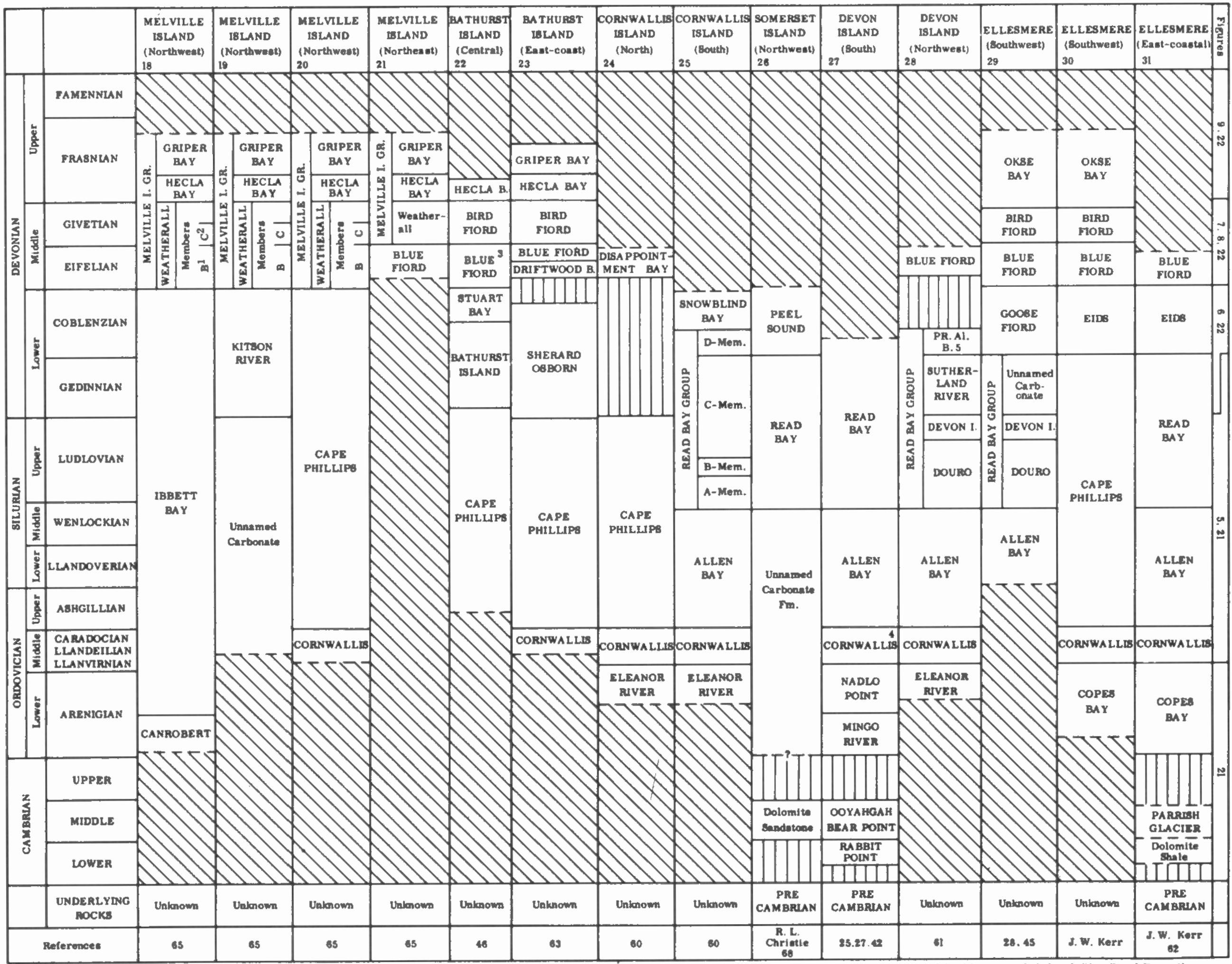
Northern Yukon Area

Northern Yukon Area includes a mountain complex of varied structural trends surrounding Old Crow and Eagle Plains and Arctic Plateau (Figs. 1, 2). The region is underlain by a thick sequence of rocks in which most systems are represented (Tables 3, 4, 5). The mountains comprise the west-trending, northern termination of Mackenzie Mountains and their structural continuation through Wernecke and southern Ogilvie Mountains into north-trending northern Ogilvie Mountains. These structures involve Upper Cretaceous rocks and are presumed to have been produced in the Laramide orogeny. Tilted Early Tertiary, non-marine sediments of Bonnet Plume Basin lie with strong angular unconformity on the Palaeozoic. Structural elements of British Mountains, and Old Crow and Keele Ranges, Barn Mountains of Arctic Plateau and Richardson Mountains trend southeast, northeast or north and involve Precambrian to Devonian rocks. These strata are overlain unconformably by Mississippian or Permian rocks and were deformed in the Palaeozoic, probably in phases of the Variscan orogeny. Further deformation involving strata as young as the Upper Cretaceous took place in the Laramide.

The intermontane basin beneath Eagle Plain and Arctic Plateau which extends northward beneath Arctic Coastal Plain and Mackenzie Delta are potential petroleum provinces. They are underlain by a cover of Jurassic and Cretaceous clastic rocks. Broad, open, north-trending flexures extend for tens of miles across Eagle Plain paralleling trends in Richardson and northern Ogilvie Mountains. West-trending folds flank southern Ogilvie Mountains. Lying unconformably beneath the cover are Devonian to Permian strata comprising a sequence of intertonguing limestone, shale and sandstone (Figs. 10, 11, 12, 14). Oil and gas were encountered in the Chance well in Pennsylvanian? sandstone and limestone (Fig. 3, Table 7). Beneath, and in part equivalent to, impermeable shale, chert and limestone turbidite of the Road River Formation is a thick succession of fine crystalline dolomite ranging in age from Cambrian to Silurian (Figs. 4, 5, 20) which may be within reach of deep tests in southwestern Eagle Plain or lie at higher levels beneath folds, exposing the Late Palaeozoic in southern Ogilvie Mountains and northeastern Keele Range.

Most of Arctic Plateau beneath the Jurassic and Cretaceous cover is probably floored by low grade metamorphic rocks of the Precambrian Neruokpuk Formation. Mississippian limestones and Triassic sandstones intervene in the southwest (Figs. 14, 25b) and Permian, Pennsylvanian? and possibly Devonian strata occur in the northeast (Figs. 10, 11, 14). Regional unconformities separate the rocks of each system. Early Lower Cretaceous sandstones are intercalated with thick, dark shale. They underlie a cover of younger Cretaceous shale in northeastern Arctic Plateau (Figs. 19, 28b) and are involved in complexly trending folds.

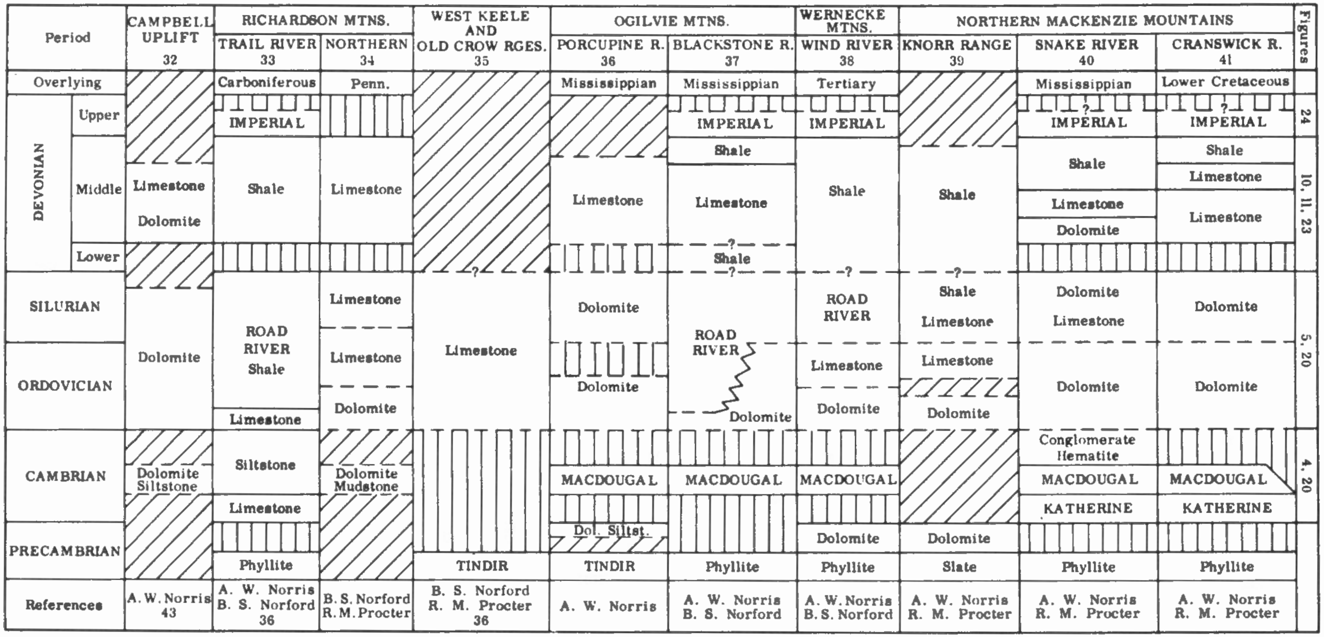
Little is known of the bedrock beneath the Tertiary and Quaternary cover of Old Crow Plain. The area is flanked on the south by Precambrian Tindir metasediments or granite and on other sides by Devonian and Mississippian carbonate and by Jurassic and Lower Cretaceous clastics. Oil and gas possibilities are accordingly slight.



1. B = Blackley member of Weatherall Formation 2. C = Cape de Bray member of Weatherall Formation 3. Rocks Formerly mapped as Eids on Bathurst Island herein included with Blue Fiord Formation

4 Upper part of Croker Bay Formation herein included in Cornwallis Formation; basal 290 feet of Croker Bay Formation is included in Nadlo Point Formation 5. PR. Al. B = Prince Alfred Bay Formation

TABLE 2. CORRELATION OF DEVONIAN AND OLDER PALAEOZOIC ROCKS OF ARCTIC ISLANDS



Period		CAMPBELL UPLIFT	RICHARDSON MTNS.		WEST KEELE AND OLD CROW RGES.	OGILVIE MTNS.		WERNECKE MTNS.	NORTHERN MACKENZIE MOUNTAINS			Figures
		32	TRAIL RIVER 33	NORTHERN 34	35	PORCUPINE R. 36	BLACKSTONE R. 37	WIND RIVER 38	KNORR RANGE 39	SNAKE RIVER 40	CRANSWICK R. 41	
Overlying			Carboniferous	Penn.		Mississippian	Mississippian	Tertiary		Mississippian	Lower Cretaceous	
DEVONIAN	Upper		IMPERIAL				IMPERIAL	IMPERIAL		? IMPERIAL	? IMPERIAL	24
	Middle	Limestone Dolomite	Shale	Limestone		Limestone	Shale Limestone ?	Shale	Shale	Shale Limestone Dolomite	Shale Limestone Limestone	10, 11, 23
	Lower				?		Shale ?	?	?			
SILURIAN		Dolomite	ROAD RIVER Shale	Limestone	Limestone	Dolomite	ROAD RIVER	ROAD RIVER	Shale Limestone	Dolomite Limestone	Dolomite	5, 20
ORDOVICIAN			Limestone	Limestone Dolomite		Dolomite	Dolomite	Limestone Dolomite	Limestone Dolomite	Dolomite	Dolomite	
CAMBRIAN		Dolomite Siltstone	Siltstone Limestone	Dolomite Mudstone		MACDOUGAL	MACDOUGAL	MACDOUGAL		Conglomerate Hematite MACDOUGAL KATHERINE	MACDOUGAL KATHERINE	4, 20
PRECAMBRIAN			Phyllite		TINDIR	Dol. Siltst. TINDIR	Phyllite	Dolomite Phyllite	Dolomite Slate	Phyllite	Phyllite	
References		A. W. Norris 43	A. W. Norris B. S. Norford 36	B. S. Norford R. M. Procter	B. S. Norford R. M. Procter 36	A. W. Norris	A. W. Norris B. S. Norford	A. W. Norris B. S. Norford	A. W. Norris R. M. Procter	A. W. Norris R. M. Procter	A. W. Norris R. M. Procter	

TABLE 3. CORRELATION OF DEVONIAN AND OLDER PALAEOZOIC ROCKS OF NORTHERN YUKON

Arctic Lowlands

The Arctic Lowlands are divided by salients and inliers of Precambrian rocks into a number of basins (Figs. 1, 2). It is not known whether the basins are crustal depressions with differentially thickened sedimentary sections, or are the result of crustal movements that postdate the principal periods of Lowlands sedimentation. Boothia Arch is flanked by Lower Devonian red sandstone and conglomerate (Fig. 6). The red beds are evidently syntectonic and date the principal movement of the Boothia Arch as Caledonian. Movement of Minto Arch occurred between the Upper Devonian (Frasnian) and the Lower Cretaceous (Albian).

The principal rocks of the Lowlands are limestones and dolomites that range in age from Middle Ordovician to Lower Devonian (Table 2). Of these the Cornwallis and Allen Bay dolomites are characterized by reefoid developments, vuggy porosity and bituminous residues. They are widely exposed in southerly regions of the Lowlands, but are covered by Silurian to Lower Devonian Read Bay limestones in Victoria Straits, Jones-Lancaster and Melville Basins (Figs. 1, 5). These basins are considered to offer the best petroleum possibilities in contrast with Wollaston and Foxe Basins where the succession is thin. Cambrian to Lower Ordovician rocks are represented by thin sequences of clastics and dolomites; they are largely covered and their petroleum potential is therefore poorly understood. The best developments of these rocks occur on Devon Island (Fig. 21) and the east coast of Ellesmere Island. The Read Bay is not generally porous. In Melville Basin it is overlain by limestone, partly crinoidal, and bituminous shale of the Middle Devonian Blue Fiord Formation (Fig. 7). Thick Middle to Upper Devonian shales and sandstone constitute a cover. Isolated Frasnian limestone reefs occur and may extend westward beneath the Cretaceous.

The Cretaceous and Tertiary rocks of Banks Basin (Table 5) contain basal porous sands of the Isachsen Formation overlain by marine shales and non-marine beds (Figs. 18, 19). They overlie with profound unconformity the Palaeozoics of the Prince Albert Homocline and at the south end of the island rest on an inlier of Proterozoic (Figs. 1, 2). Tertiary normal faults transect the Proterozoic there and involve Devonian at the north cape. These inliers suggest northern extension of Coppermine Arch to connect with Prince Patrick Uplift, an inlier of Devonian rocks showing gentle north-trending Variscan folds and Tertiary normal faults. These regions have undergone repeated uplift and offer good possibilities of several types of structural and stratigraphic traps.

Franklinian Geosyncline

The Franklinian Geosyncline (Fig. 1) embraces miogeosynclinal rocks included in the Parry Islands, Cornwallis and Central Ellesmere Fold Belts, and rocks of eugeosynclinal character included in Northern Ellesmere Fold Belt.

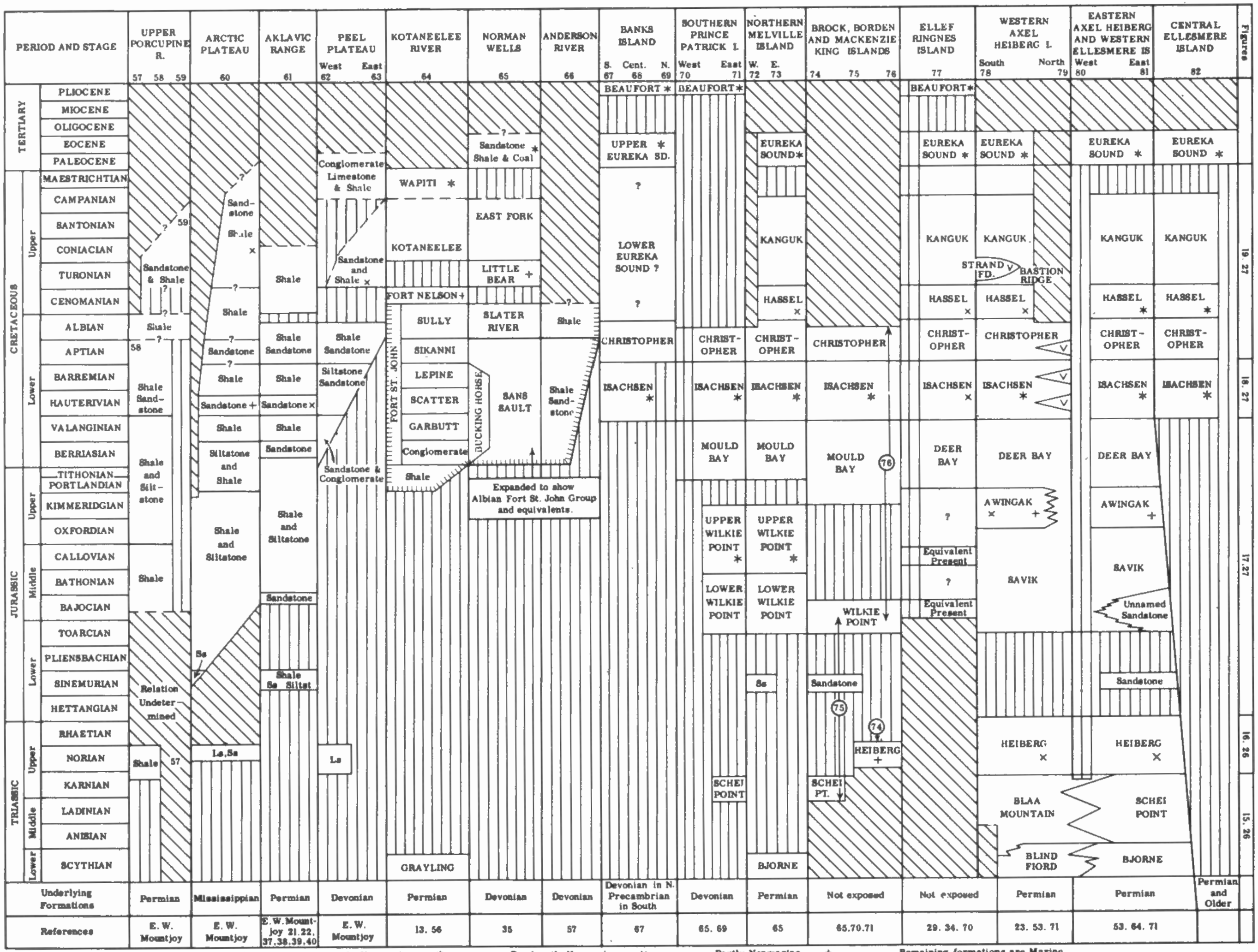
The Cornwallis Fold Belt (Fig. 2) is characterized by north trending folds and faults and broad, shallow synclines separating closely folded anticlines. This fold belt constitutes the northern extension of Boothia Arch and was affected by Caledonian tectonism. Structures of the Parry Islands Fold Belt include long, sublinear, symmetric, gently plunging, east-trending folds. They gradually decrease in amplitude towards the south. A well was recently drilled unsuccessfully on one of these anticlines at Winter Harbour (Fig. 3, Table 7). The principal deformation was early Variscan. To the west the fold belt is terminated by Eglinton graben and Prince Patrick Uplift. To the east, on Bathurst Island, the Variscan structures abut against Caledonian folds. Central Ellesmere Fold Belt embraces a region of northeasterly trending folds and thrusts produced by Variscan and Laramide orogenies. In southerly regions Variscan structures are broad open folds and Laramide tectonism appears to have been moderate. Both Variscan and Laramide structures are more intense in the north. Northern Ellesmere Fold Belt includes metamorphosed eugeosynclinal rocks as well as acidic and basic intrusions. These rocks extend southwesterly beneath the unconformable cover of Sverdrup Basin, and probably underlie the greater part (Fig. 1). Upper Devonian rocks cover much of Parry Islands Fold Belt. Older rocks containing the potential reservoirs outcrop extensively in Cornwallis and Central Ellesmere Fold Belts thereby limiting their petroleum potentialities.

Within Franklinian geosyncline thick carbonate, shale and sandstone sequences ranging in age from Ordovician to Devonian are known (Table 2). The Cambrian is probably present but is exposed only in eastern Ellesmere Island. The Ordovician, Silurian and Lower Devonian carbonates that underlie the Arctic Lowlands thicken northward into the geosyncline and grade into graptolitic shale (Figs. 5, 21). The Allen Bay includes several zones of coarsely crystalline porous dolomite. The Silurian part of the Read Bay is mainly dense, but the upper part includes biogenic, reefoid and porous limestones. The facies change between these formations and the Cape Phillips is generally abrupt, several thousand feet of carbonate passing into shale within a few miles, but on Cornwallis Island tongues of porous dolomite up to 100 feet thick extend 30 to 40 miles beyond the front. Porous zones and basal shales of the Cape Phillips contain much residual bitumen on Cornwallis Island. On Ellesmere Island a carbonate bank occurs beyond the main development entirely surrounded by clastics. Similar banks are also known at two localities on Melville Island. They are probably also detached, the area of their inferred occurrence being delineated by the facies boundary on Figure 5.

The upper part of the Cornwallis Formation contains reefoid dolomites on Cornwallis and Bathurst Islands but is dense on Melville Island where it grades into Ibbett Bay shale (Figs. 5, 21). The Cornwallis is very thick and extensive on Ellesmere Island and the isolated outcrops within Parry Island Fold Belt suggest that it is present in regions where the Allen Bay and Read Bay are replaced by Cape Phillips shale. The shale undoubtedly forms an effective capping on the Cornwallis Formation.

PERIOD									NORTHEAST MELVILLE ISLAND			ELLESMERE I.	AXEL HEIBERG I.	ELLESMERE ISLAND			
		PETITOT RIVER 42	LIARD PLATEAU 43	PEEL CANYON 44	OGILVIE MTNS. 45	NORTHERN RICHARDSON MTNS. 46	BRITISH MTNS. 47	48	49	GRINNELL PENINSULA 50	BLIND FIORD 51	WHITSUNDAY BAY 52	NORTH OF CANYON FIORD 53	NORTH OF CANYON FIORD 54	BLAA MTN. 55	NORTHERN AXEL HEIBERG I. 56
Overlying		L. Cretaceous	L. Cretaceous	L. Cretaceous	Triassic	Jurassic	Pre-Jurassic Sandstone	Triassic	Triassic		Triassic	Triassic	Triassic	Triassic	Triassic	Triassic
PERMIAN	Upper	▥ FANTASQUE	▥ FANTASQUE	▥	▥ TAHKANDIT ▥	▥ ?	▥	▥ ASSISTANCE	▥ ASSISTANCE SABINE BAY	▨ ASSISTANCE ▥	▥ Chert Shale Siltstone	← ? →	▥ ASSISTANCE SABINE BAY	▥ ASSIS-TANCE SABINE BAY	▥ Siltstone Shale	Red sandstone Chert Basalt
	Lower	▥	▥ MATTSON Upper	Sandstone	Calcarenite Shale	Siltstone Sandstone Limestone	▥ ?	▥	BELCHER CHANNEL ▥	BELCHER CHANNEL	BELCHER CHANNEL	Siltstone Shale Sandstone	Siltstone Sandstone Anhydrite	BELCHER CHANNEL	Siltstone Shale Limestone	Limestone
PENNSYLVANIAN	Upper	▥	MATTSON Middle	Calcarenite	Calcarenite	▥	Shale	▥	▥	▥	Limestone Siltstone		Limestone	Limestone CANYON FIORD		
	Middle	▥			? Limestone Shale	▥		CANYON FIORD	CANYON FIORD	▥	▨		▨		Reef Limestone	
	Lower	▥		▥ ?	? Shale	▥		▥	▥	▥	▨	Anhydrite Gypsum	▨	▥	Anhydrite Gypsum	Anhydrite Gypsum
MISSISSIPPIAN	Upper	MATTSON	MATTSON Lower	Limestone Shale	Limestone Shale	▥		▥	▥	▥	▨	▨	▨	▥	▨	▥ Sandstone Coal
	Middle	FLETT	FLETT	▥	▥	▥	? Lisburne limestone	▥	▥	▥	▨	▨	▨	▥	▨	▥
	Lower	'BANFF' EXSHAW	CLAUSEN YOHIN	▥	▥	▥	? Kyak shale	▥	▥	▥	▨	▨	▨	▥	▨	▥
Underlying		KOTCHO	? Upper Devonian	IMPERIAL	IMPERIAL ?	IMPERIAL	Precambrian NERUOKPUK	L. and M. Palaeozoic	L. and M. Palaeozoic	CORNWALLIS	▨	▨	▨	Lower Palaeozoic	▨	▥
References		13, 31	13, 31	E. W. Bamber	E. W. Bamber 48	E. W. Bamber	A. W. Norris E. W. Bamber	65	65	32	73	← R. Thorsteinsson →				R. Thorsteinsson 41
Figures																13, 14, 25

TABLE 4. CORRELATION OF CARBONIFEROUS AND PERMIAN ROCKS OF NORTHERN CANADA



Basalt . . . V Entirely Nonmarine . . . * Dominantly Nonmarine . . . × Partly Nonmarine . . . + Remaining formations are Marine

TABLE 5. CORRELATION OF MESOZOIC ROCKS OF NORTHERN CANADA.

Potential reservoirs of Lower Devonian age are limestones and small bioherms of the upper Read Bay and Sherard Osborn. On central Bathurst Island they grade into shale (Figs. 6, 22). The extensive Middle Devonian Blue Fiord is mainly bedded limestone with local biogenic and reefoid beds (Figs. 7, 22). Porous dolomite occurs in the lower part on Grinnell Peninsula. The Blue Fiord grades northward and westward into silty and calcareous shale, and is capped by late Middle Devonian shale and dense siltstone (Figs. 8, 22) succeeded by thick Upper Devonian sandstones and shale, mainly non-marine (Figs. 9, 22).

Sverdrup Basin

Sverdrup Basin contains a thick sequence of late Palaeozoic to early Tertiary strata (Tables 4, 5) that lies with profound unconformity on deformed older Palaeozoic beds (Fig. 1). Greatest subsidence occurred in the eastern part where the composite thickness of sediment is about 60,000 feet. This amount probably did not accumulate in any one place, as isopach maps (Figs. 13, 15-19) suggest a progressive westward movement of the axes of maximum sedimentation between the Pennsylvanian and Upper Cretaceous. In the axial region of the Basin the sequence appears concordant. Along the south and east margins stratigraphic units are thinned greatly by convergence or are absent through unconformities and overlap. The sequence thins northwest suggesting the presence of a marginal sill connecting Prince Patrick Uplift and northern Axel Heiberg Island, and separating the Sverdrup Basin from the Arctic Continental Shelf.

Laramide folding and thrusting affected much of the Sverdrup Basin, being most intense in the northeast part (Fig. 2). Generally, early Tertiary rocks are folded concordantly with the underlying sequence. On eastern Axel Heiberg Island, however, deformation extended through a longer interval than in areas to the east and west. There, early Tertiary coal measures and syntectonic conglomerates overlie deformed rocks ranging in age from Triassic to Albian. These Tertiary beds are also folded.

The Laramide strike is closely related to that of the older Palaeozoic deformations (Fig. 2). On western Ellesmere Island, from Baumann Fiord to Lake Hazen, Laramide structures parallel the Variscan trend. The folds on much of Axel Heiberg Island are aligned with those of Caledonian and Variscan age trending north at the north end of the Island. These older belts appear to have produced differential rates of subsidence during the Mesozoic (Figs. 26, 27). North to northwesterly trending folds on Cornwall and the Ringnes Islands suggest extension of Boothia Arch beneath the Basin. West of the Ringnes Islands deformation is less intense, dips are generally less than 5°, and the structure is a northeast plunging synclinorium with gentle folds radiating from the axis.

In the axial part of the basin there are at least two units of anhydrite, one of Mississippian or Pennsylvanian age, the other Permian. The evaporites intrude the overlying Mesozoic and Tertiary beds as domes, in diapiric folds, and along faults. Available evidence suggests that the lower evaporite is the principal source. No halite has been found, either in the intrusives or where the evaporites are known in situ.

In eastern Sverdrup Basin, where the Triassic forms the exposed core of many folds, Pennsylvanian and Permian rocks (Table 4) constitute the potential reservoirs. The thick succession on Ellesmere Island includes limestone banks, locally reefoid, and isolated reef masses capped by black shale (Figs. 13, 25). The limestones grade into a thin shale and siltstone sequence constituting the axial part of the basin and to marginal facies of sandstone and conglomerate to the east. Sandstone also occurs along the southern margin of the basin and by analogy with the facies relationships described above, a belt of carbonate and reefs may be inferred beneath Mesozoic cover of the southern part of the basin. This is also suggested by presence of blocks of vuggy Pennsylvanian limestone in the piercement domes of Sabine **Peninsula**. On Melville Island Pennsylvanian sandstones and conglomerates were folded during a local late Variscan disturbance and are unconformably overlain by Permian glauconitic sands; a contemporary disturbance is also indicated at Trold Fiord, Ellesmere Island (Fig. 25). On Prince Patrick Uplift, the late Palaeozoic rocks are overlapped by Triassic and Jurassic formations which lie on the Upper Devonian. Pennsylvanian and Permian rocks are not exposed on the northwest margin of the basin except on northwestern Axel Heiberg Island where a thin carbonate and chert sequence is present.

Mesozoic sedimentation is characterized by basinal marine shales and siltstones with marine sandstones intertonguing from the east and south margins and at some horizons also from the northwest. Triassic sands on the northwest edge of the basin may reflect uplift of the marginal sill. Non-marine deposits, mainly sandstone, are intercalated and are essentially uniform in lithology throughout the basin area. The Triassic Bjorne Formation includes much porous sandstone. It is reported to be oil-bearing on Melville Island (Fig. 3). On Ellesmere Island this formation does not extend far into the basin but it may be more widespread in the southwest (Figs. 15, 26). Sandstone and siltstone of the Schei Point and tongues of similar rocks that interfinger with the Blaa Mountain shales are commonly cemented by carbonate but are porous where exposed on Borden Island. The Upper Triassic Heiberg Formation is mainly non-marine but includes porous sands; it probably extends across the entire basin with marine shales above and below. Jurassic and Lower Cretaceous sands are found in the Wilkie Point, Mould Bay and Awingak Formations. On Mackenzie King Island the Wilkie Point and Mould Bay beds are partially replaced by shale; on northwestern Axel Heiberg Island this replacement is complete (Fig. 17). Jurassic and earliest Cretaceous formations show progressive overlap to the southwest, adjacent to Prince Patrick Uplift

(Fig. 27). The Lower Cretaceous Isachsen Formation is transgressive on the south and east sides of the basin. Cretaceous sands include the Isachsen and Hassel, both porous but mainly non-marine. Marine shales of the Deer Bay, Christopher and Kanguk are intercalated. Some sandstone occurs within the Christopher, but it is commonly cemented with carbonate.

In eastern Sverdrup Basin gabbro sills and dykes intrude formations as young as the Upper Cretaceous (Figs. 26, 27). Individual sills attain a thickness of 300 feet and are most abundant in the Triassic and Jurassic shale formations. Adjacent strata may be metamorphosed to a distance of about 80 feet. The dykes appear to be post-Laramide from their linearity and relationship to the folds but paradoxically none are known to cut strata younger than the Hassel and one is overlain non-conformably by Tertiary beds. The presence of numerous basic intrusives is not entirely an adverse feature as they could produce effective traps on the flanks of the folds.

In most folds of northeast Sverdrup Basin the Triassic and Jurassic are exposed but the succession is thick and part may be considered potential. The beds beneath the Heiberg Formation are concealed throughout much of western Axel Heiberg Island and the whole of the Triassic sequence is concealed in the Ringnes Islands. Most of Sabine Peninsula is underlain by Cretaceous and Tertiary beds and there is presumably a substantial subsurface Mesozoic section probably with intertonguing shale and sandstone. The Mesozoic rocks adjacent to the piercement domes of Axel Heiberg and Ringnes Islands are steeply upturned but warping is barely perceptible on Sabine Peninsula, where Tertiary strata are intruded.

Arctic Coastal Plain

Arctic Coastal Plain transects many of the petroleum provinces previously described. On the Islands and east of Mackenzie Delta, late Tertiary or Pleistocene non-marine sands and gravels of the Beaufort Formation, at least 250 feet thick, dip oceanwards, and may represent the edge of marine sediments constituting the Arctic Continental Shelf. It is cut by normal faults of small displacement on Prince Patrick Island. As the Beaufort effectively blankets older rocks indications of the nature of the underlying geology and petroleum potential of the plain must be gained from consideration of adjacent provinces. West of Mackenzie Delta, the gravels are only a veneer covering dissected pediment surfaces that extend deep into British Mountains and Arctic Plateau.

Tertiary non-marine beds form part of Mackenzie Delta but the early history of the delta is unknown. Fluviatile silts were encountered to a depth of 1, 100 feet in a well that lies at an elevation of 577 feet above sea-level near Mackenzie River at Fort Simpson. These silts presumably fill a former valley of Mackenzie River and, granting comparable grades to the river systems, it would appear that some 1, 100 feet of Pleistocene or pre-Pleistocene sediments could underlie Mackenzie Delta.

TABLE 6

VOLUME OF SEDIMENT (Hundreds of Cubic Miles), PETROLEUM PROVINCES OF NORTHERN CANADA

System	Formation Lithology	Interior Plains		Liard Plateau	Mackenzie Plain		Eagle Plain	Arctic Plateau	Arctic Lowlands[1]	Franklinian Geosyncline[2]	Sverdrup Basin	Sverdrup Basin (restored)
		Great Slave	North		South	North						
Albian and younger Cretaceous	Shale	17	) 100	7	—	) 6	) 31	) 4	) 20	—	*	300
	Sandstone and conglomerate	3		1	—							
Jurassic and pre-Albian Cretaceous	Shale, siltstone, sandstone and conglomerate	—	—	*	—	—	*	20	3	—	20	450
Triassic	Non-marine sandstone	—	—	—	—	—	—	—	—	—	20	200
	Shale, siltstone	—	—	*	—	—	—	*	—	—	150	550
Permian and Pennsylvanian Mississippian	Sandstone, shale and limestone	1	*	24	—	—	10	6	—	—	20	200
	Limestone	1	) *	3	—	—	) 15	) 6	—	—		
	Shale	5		7	—	—						
Devonian Upper	Shale	90	—	27	30	—	—	—				
	Sandstone, shale	—	150	—	20	12	25	—	) *	) *		
	Limestone	36	—	—	*	—	—	—				
Devonian Late Middle	Shale	12	8	8	8	10	10	—	—	150		
	Carbonate	38	14	2	9	5	*	—	*	35		
	Anhydrite, dolomite	4	—	—	—	—	—	—	—	—		
Devonian Early Middle	Shale, sandstone	1	—	*	7	—	—	—		*		
	Carbonate	8	60	15	10	—	29	1		40		
	Anhydrite, salt	30	—	—	—	—	—	—	) *	—		
	Breccia	10	20	—	6	8	—	—		—		
Devonian Lower	Shale	—	—	—	—	—	2	—	—			
	Carbonate	—	—	—	—	—	—	—	35	) *		
	Sandstone, conglomerate	—	—	—	—	—	—	—	8			
Silurian or Devonian	Dolomite and breccia	—	—	*	7	—	—	—	—	—		
Ordovician and Silurian	Shale	—	—	*	10	—	) 70	—		100		
	Carbonate	20	500	*	60	30		15	) 650	370[3]		
	Anhydrite	—	—	—	—	—	—	—	—	40		
Cambrian		*	*	*	*	*	23	—	*	*		

— Absent.
* Not estimated.
) Undivided.
[1] South of Lancaster and Viscount Melville Sounds.
[2] Includes Devon and southwestern Ellesmere Islands.
[3] Includes some Lower Devonian

TABLE 7

WELLS DRILLED, YUKON AND NORTHWEST TERRITORIES

Year and Classification	Mackenzie District			Yukon Territory		
	Great Slave Plain	Anderson and Peel Plains	Mackenzie Plain	Liard Plateau	Eagle Plain	Arctic Islands
1920–1939						
Wildcat wells						
Number....................	2		6*			
Footage....................	2,518		10,061			
Development wells						
Number....................			2			
Footage....................			3,439			
1940–1949						
Wildcat wells						
Number....................	6		20			
Footage....................	4,107		66,299			
Development wells						
Number....................			65			
Footage....................			113,380			
1950–1959						
Wildcat wells						
Number....................	64**		1		1	
Footage....................	140,164		2,778		9,589	
Development wells						
Number....................	2		4			
Footage....................	5,584		6,508			
Structure tests						
Number....................	257					
Footage....................	76,582					
1960–Nov. 1962						
Wildcat wells						
Number....................	46***	15		1	2****	1
Footage....................	160,946	33,104		10,890	16,652	12,543
Structure tests						
Number....................	257	12				
Footage....................	76,582	2,753				
Wells, location or drilling, Nov. 1962		1	1	2	1	

* Norman wells oil field; discovered in 1920; Middle Devonian, Kee Scarp reef; 556,747 bbls. produced in 1961 from 60 wells; reserves estimated at 30 to 50 million bbls.

** Includes Briggs Rabbit Lake No. 1 well drilled in 1955; gas at 17 MMcf per day from Middle Devonian Sulphur Point Formation at 2,690 foot depth.

*** Includes Home Signal CSP Celibeta No. 2 drilled in 1960; gas at 7.8 MMcf per day from Middle Devonian Slave Point Formation at 3,750 foot depth and Imperial Sun Netla F7 drilled in 1961; gas at 24 MMcf per day from Middle Devonian Slave Point Formation at 6,340 foot depth.

**** Includes Western Minerals Chance No. 1 well drilled in 1960; gas at 10 MMcf per day and some light gravity oil from the Pennsylvanian (?) at about 4,250 foot depth.

Volume of Sediment

Volumes of sedimentary rocks in the potential areas of northern Canada are shown in Table 6. These estimates are orders of magnitude only. Subsurface information is sparse as drilling (Table 7) has been largely concentrated in Great Slave and Mackenzie Plains and most wells do not reach the basement.

On the mainland, much of the Mesozoic and Upper Devonian is exposed, these rocks constituting the cover on older systems. Volume calculations include both the erosional remnants and that underlying younger strata. For the late Palaeozoic, Middle Devonian and older rocks only that portion within the structural provinces (Fig. 1) designated as petroleum provinces has been computed. About half the region embraced by Arctic Islands is land. Although isopachs, facies lines and limits of outcrop are generally extrapolated across water, volumes of sediment computed are those underlying the principal islands of the potential areas; in addition, restored volumes have been estimated for the Sverdrup Basin.

The volumes of sediment of various facies are presented as a descriptive adjunct for comparative purposes and are not intended to be directly indicative of the ultimate petroleum potential of individual provinces by applying arbitrary ratios of oil and gas per cubic mile of sediment. Some provinces may not attain such a potential whereas others may well exceed it. The petroleum potential of each province should be judged on the geological features evident that are favourable or unfavourable to the entrapment of hydrocarbons. Furthermore, the amount of drilling necessary to approach full development of the ultimate potential cannot be envisaged at this time in the remote reaches of northern Canada.

The volume of sediment originally deposited in Sverdrup Basin is estimated at more than 20,000 cubic miles for the Pennsylvanian and Permian and 150,000 cubic miles for the Mesozoic. The total approaches that of the Central Gulf Coastal Plain of the United States (50). The sedimentary facies in these two areas have many similarities: Upper Palaeozoic red beds, evaporites and carbonates in Sverdrup Basin invite comparison with those of Jurassic and Cretaceous age of the Gulf Coast and Mesozoic clastics of the Basin are analogous to Tertiary beds of the Gulf Coast. Both areas thus seem to have had comparable sedimentary histories and both have been subjected to evaporitic intrusions. Important differences must also be considered. Sverdrup Basin is an older feature and marine sedimentation was terminated by the Laramide orogeny whereas sedimentation in the Gulf Coast is continuing.

Northern Canada is not readily comparable with more southerly regions of Canada where the bulk of production is from Upper Devonian and younger strata. Apart from Sverdrup Basin and limited areas on the mainland, potential reservoirs are in Middle Devonian and older rocks, the equivalents of which in the south generally have not been found productive. In much of northern Canada the sediments are structurally disturbed and folds, faults, domes and diapirs are readily manifest from surface mapping. These features facilitate the early stages of exploration for petroleum.

ECONOMIC CONSIDERATIONS

Even though many geological factors in northern Canada favour the occurrence of oil and gas, other factors, such as geography, climate and government regulations largely determine the economic conditions for recovery and the rate at which these resources will be developed.

All of northern Canada falls under the Federal Territorial Lands Act (67) administered by the Department of Northern Affairs and National Resources. These regulations provide for large groupings of permit areas, and generally larger leases, lower work requirements and lower royalties than provincial regulations governing exploration in the more accessible southern regions. They eliminate the system of cash-bonus bids on Crown reserves and tend to reduce number of development wells.

Conditions of climate and terrain are severe. They do not, however, prevent exploitation but rather present obstacles that lead to greater costs, development of new techniques, and design of equipment to overcome them. On the mainland there are few roads and large areas are muskeg, impassable except in winter by tractor trains and more rarely trucks. Major supplies are moved by barge on Mackenzie River system during the summer. Accessibility has generally influenced drilling locations to date (Table 7). The table also shows the general pattern of exploration and present activity. The problem of muskeg is absent in the Arctic Islands. Bedrock lies at or near the surface, commonly covered by felsenmeer. Much of this terrain provides a reasonable surface for travel throughout the year but in the western Islands extensive areas underlain by Cretaceous shales may be impassable to tractors during the summer thaw. Only part of the Arctic Islands has been reached by ship during the short summer season. None has reached the islands that lie between the Arctic ice-pack and the limit of more than 90% summer ice cover (Fig. 3).

Aircraft have overcome the physical difficulties of the north for communications, movement of people, supplementary supply and the geological phases of exploration for petroleum. Transportation of heavy equipment for the geophysical and drilling phases of exploration is generally limited to the winter months on the mainland because of muskeg conditions. March to June, when the sun is up but the ground still frozen, are probably the most favourable months for tractor travel in the Arctic Islands.

Remoteness and accessibility are also major factors in considering the means whereby petroleum from northern Canada may be brought to market. Oil from the Norman Wells field is refined there and more than adequately serves the local market. The landlocked southern Mackenzie Territory is closely linked geographically and economically to northern Alberta and northeastern British Columbia. Developments will no doubt be integrated with those to the south resulting in still greater northward extension of existing pipelines as markets are extended or as requirements of present markets increase. With the greater distance to market the size of discoveries that are economically producible must be proportionately larger. Those that are marginal in the south would be submarginal and unproducible in the north.

Much of the northern mainland, even the Arctic Coast, lies within 500 to 600 miles of tide-water at Skagway, Alaska, which terminus offers minimum pipeline distances and most competitive position for marine tanker shipments to markets in Japan and California compared with, for example, the Middle East (57). The marine tanker advantage also applies to marketing of liquified gas in Japan (57). Construction of pipelines from Porcupine Plain, Peel Plateau and Mackenzie Plain through the mountains to the Pacific would encounter less rugged terrain than that on the route of the Trans-Mountain Pipe Line from Central Alberta to Vancouver. Oil discovered adjacent to the Arctic Coast could be shipped intermittently.

The tremendous petroleum requirements of the eastern seaboard of the United States, of Europe, and also of Eastern Canada which imports crude, suggests the obvious advantage to be gained were Arctic Islands oil to be made available on the Atlantic side. The transportation problems to be overcome are formidable. It has been suggested (8) that oil could be transported from the Parry Islands and the Eureka Sound area in the summer by strengthened tanker to interim open storage at the year-round port of Godthaab, Greenland, and thence to market by conventional tanker. At present it is difficult to visualize economic means of transporting oil from the most northwesterly and perennially ice-bound islands that have never been reached by ships. However, with further advances in the fields of design of nuclear powered submarine tankers and icebreakers, and underwater pipelines, this should eventually be possible.

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Illustrations

FIGURES 1 - 28

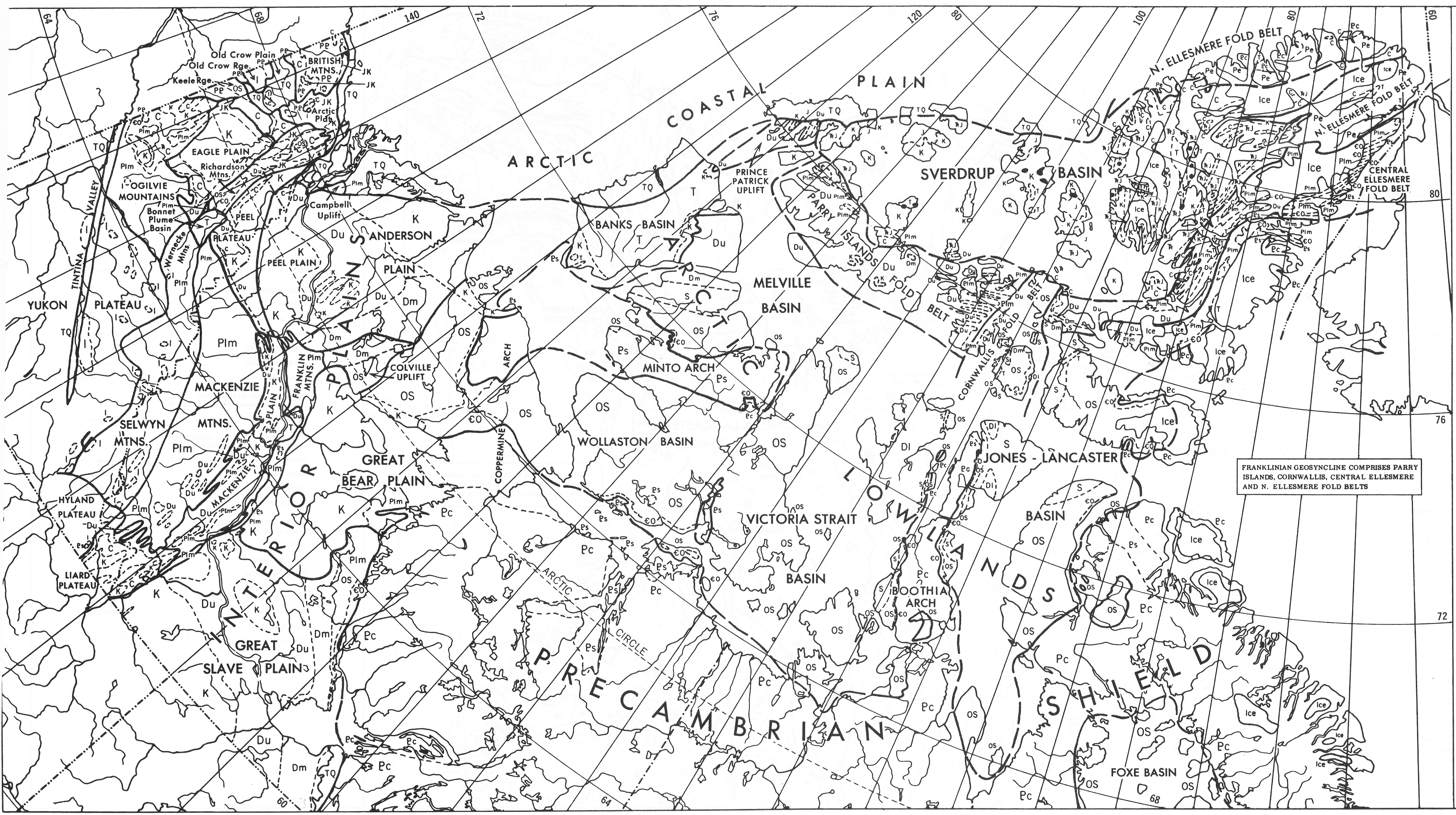


FIGURE 1

GEOLOGIC MAP OF NORTHERN CANADA SHOWING PRINCIPAL STRUCTURAL PROVINCES

Geology from published and unpublished maps of the Geological Survey of Canada, Department of Mines and Technical Surveys and, reports on open file, Department of Northern Affairs and National Resources

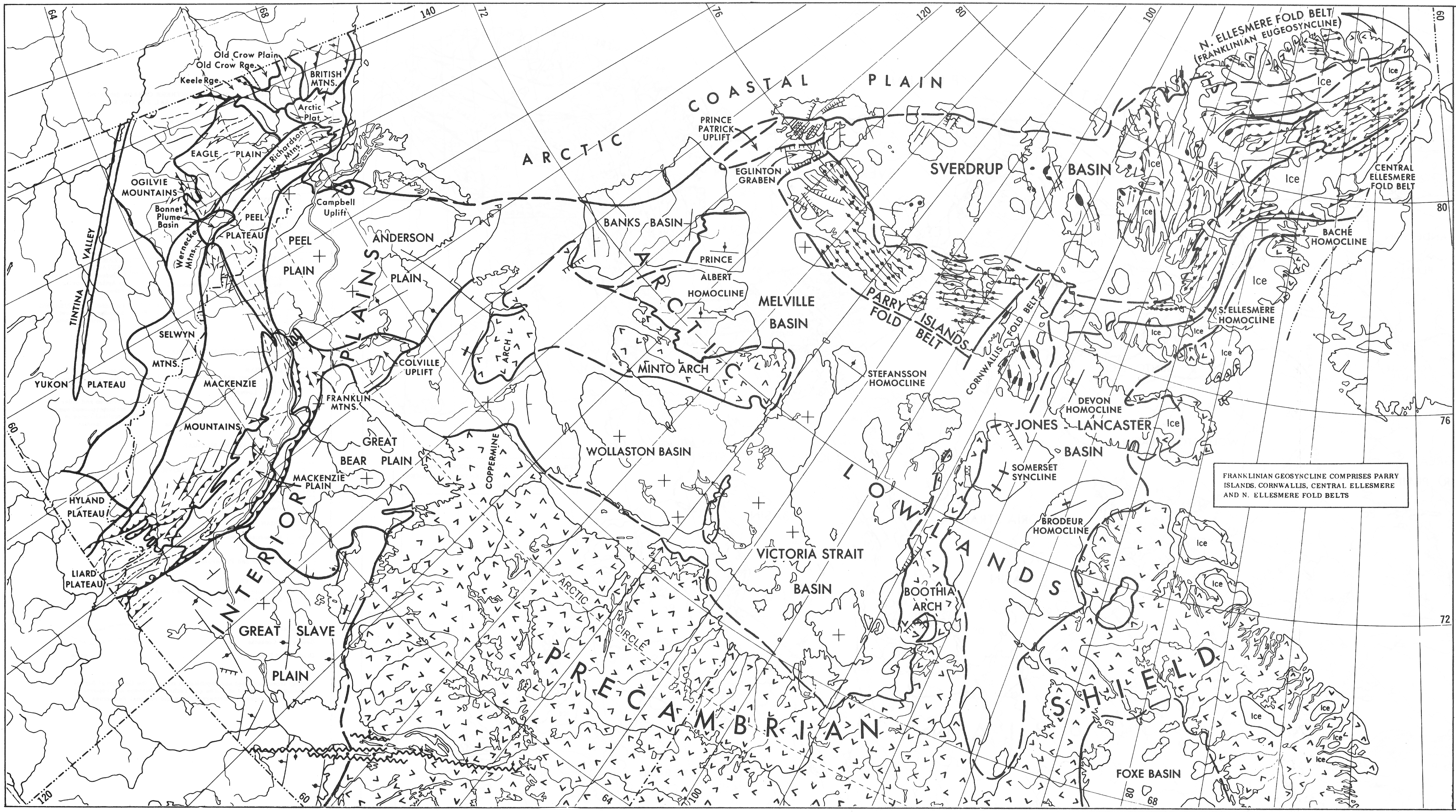


FIGURE 2

TECTONIC MAP OF NORTHERN CANADA

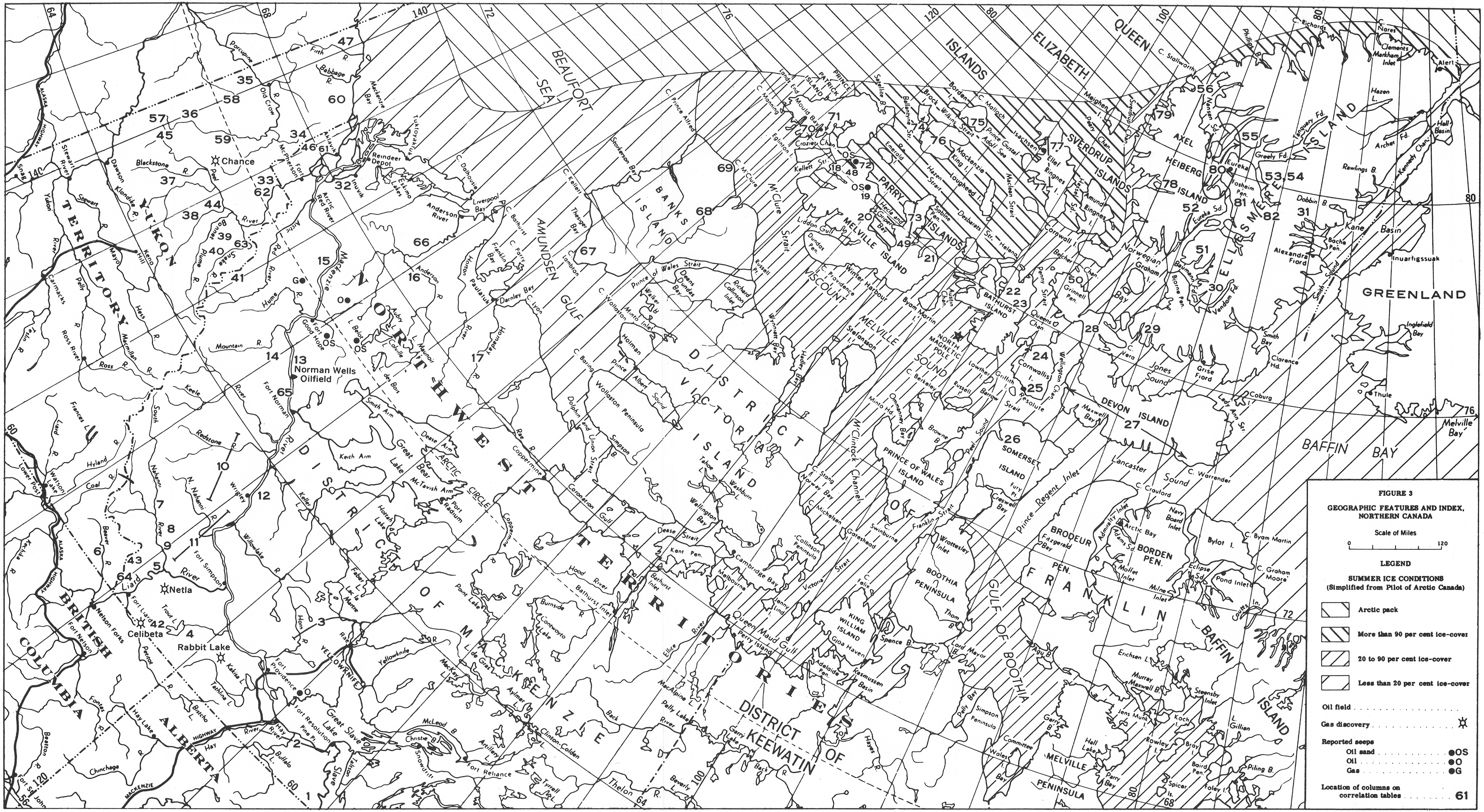


FIGURE 3

GEOGRAPHIC FEATURES AND INDEX, NORTHERN CANADA

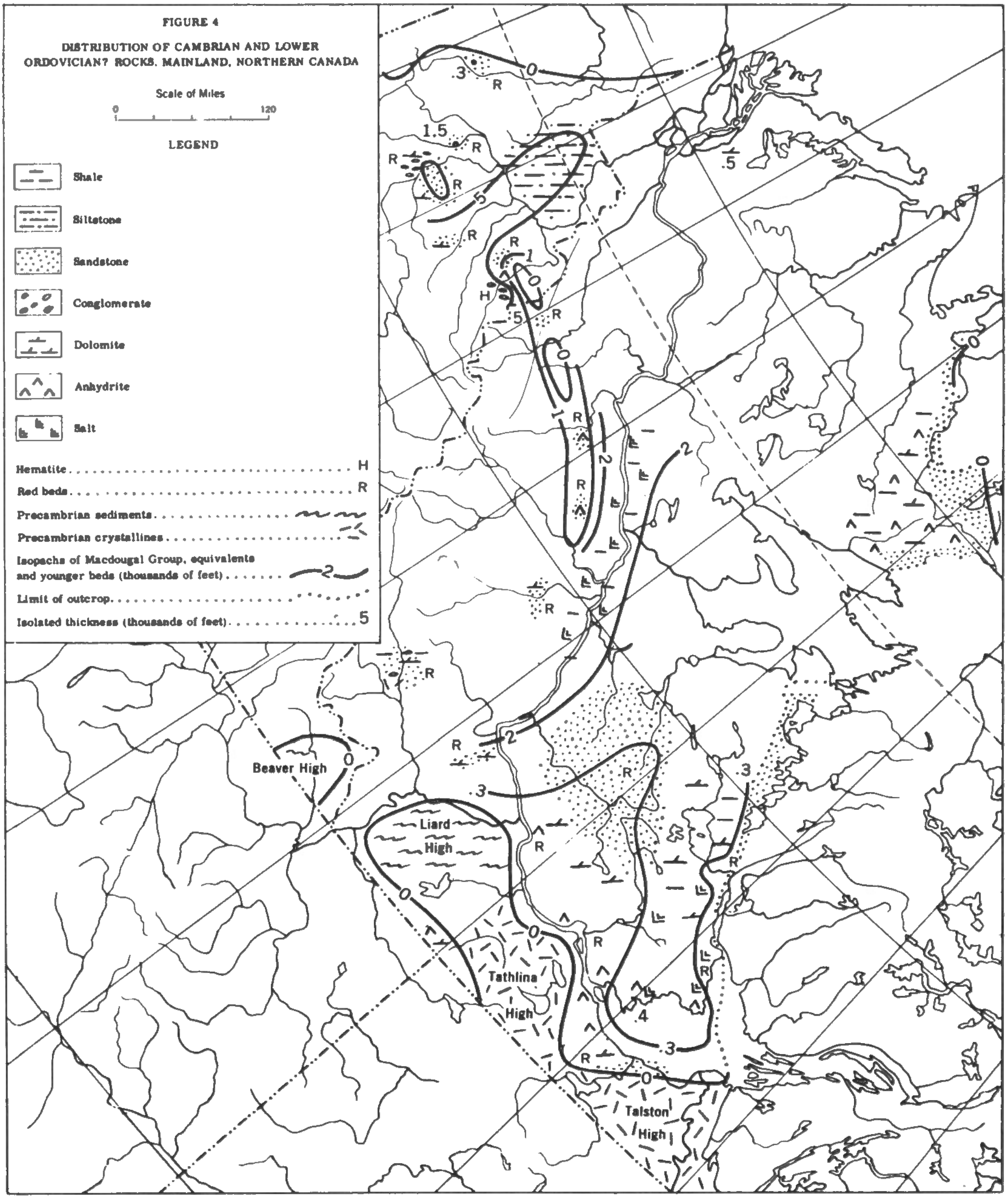


FIGURE 4

DISTRIBUTION OF CAMBRIAN AND LOWER ORDOVICIAN? ROCKS, MAINLAND, NORTHERN CANADA

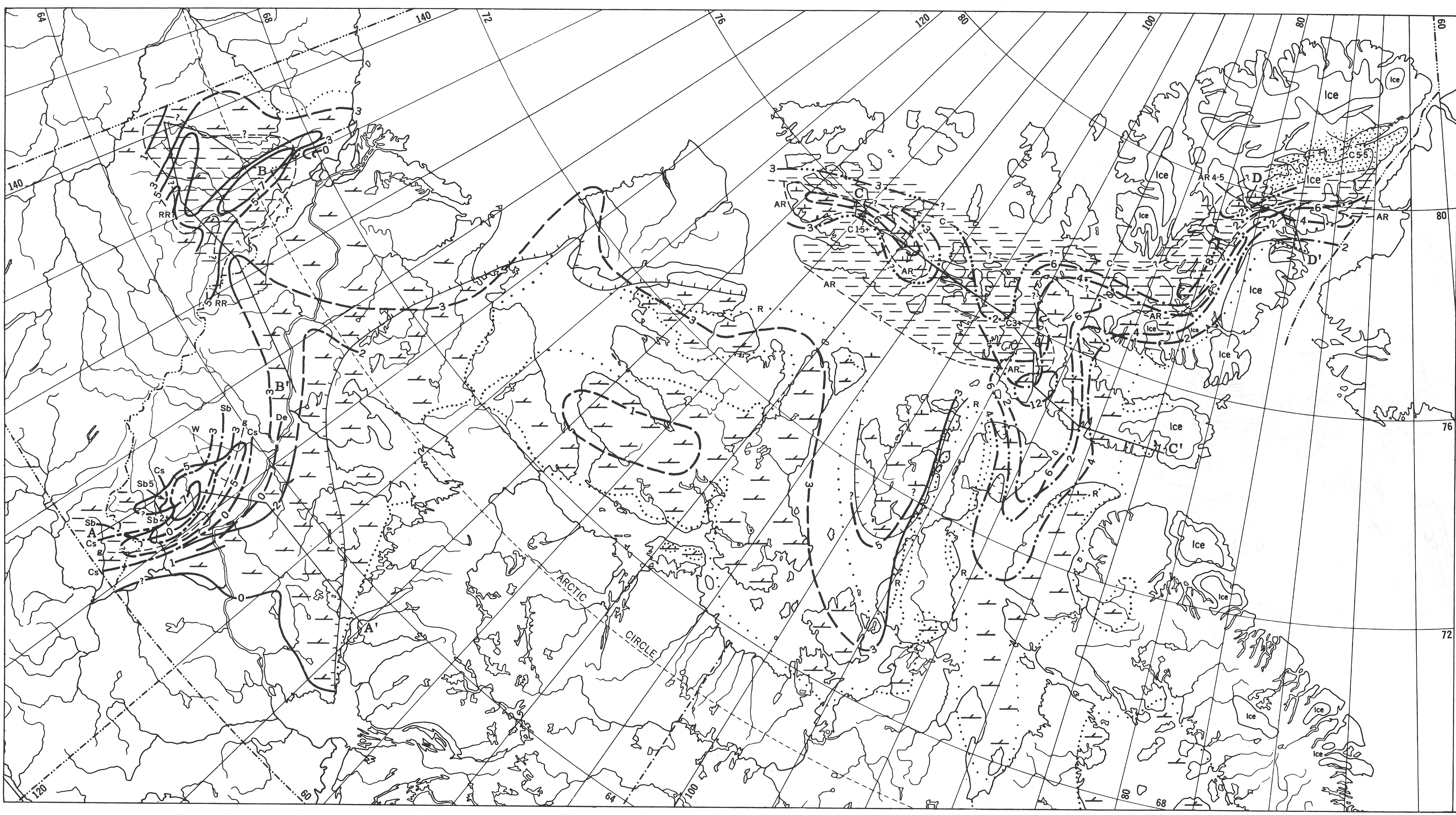


FIGURE 5
DISTRIBUTION OF ORDOVICIAN AND SILURIAN ROCKS, NORTHERN CANADA

Scale of Miles

0 120

Patterns in northern Arctic Islands refer to post-Cornwallis beds and Ibbett Bay equivalents

LEGEND

Shale and siltstone

Sandstone

Limestone

Dolomite

Limit of outcrop

Limit of cover Plains and Lowlands

Isopach (thousands of feet)

Whittaker, Delorme, Cornwallis, Allen Bay, Read Bay, Road River and equivalents

Isopach conjectural

Cornwallis (Arctic Islands)

Sunblood (mainland)

Allen Bay, Read Bay

Cape Phillips, Ibbett Bay

Silurian or Devonian, Camsell Sombre (mainland only)

Isolated thickness (with formation designation) C5

Isolated thickness in excess of . . . . +

Facies boundary

FORMATION DESIGNATIONS

A	Allen Bay
C	Cornwallis
Cb	Camsell breccia
Cs	Camsell and Sombre (southwest limit may be facies change to shale)
De	Delorme
g	Graptolitic shale facies of upper Whittaker and lower Delorme
R	Read Bay
RR	Road River
Sb	Sunblood
W	Upper Whittaker reefoid dolomites

For sections along lines A-A', and B-B', see Figure 20

For sections along lines C-C', and D-D' see Figure 21

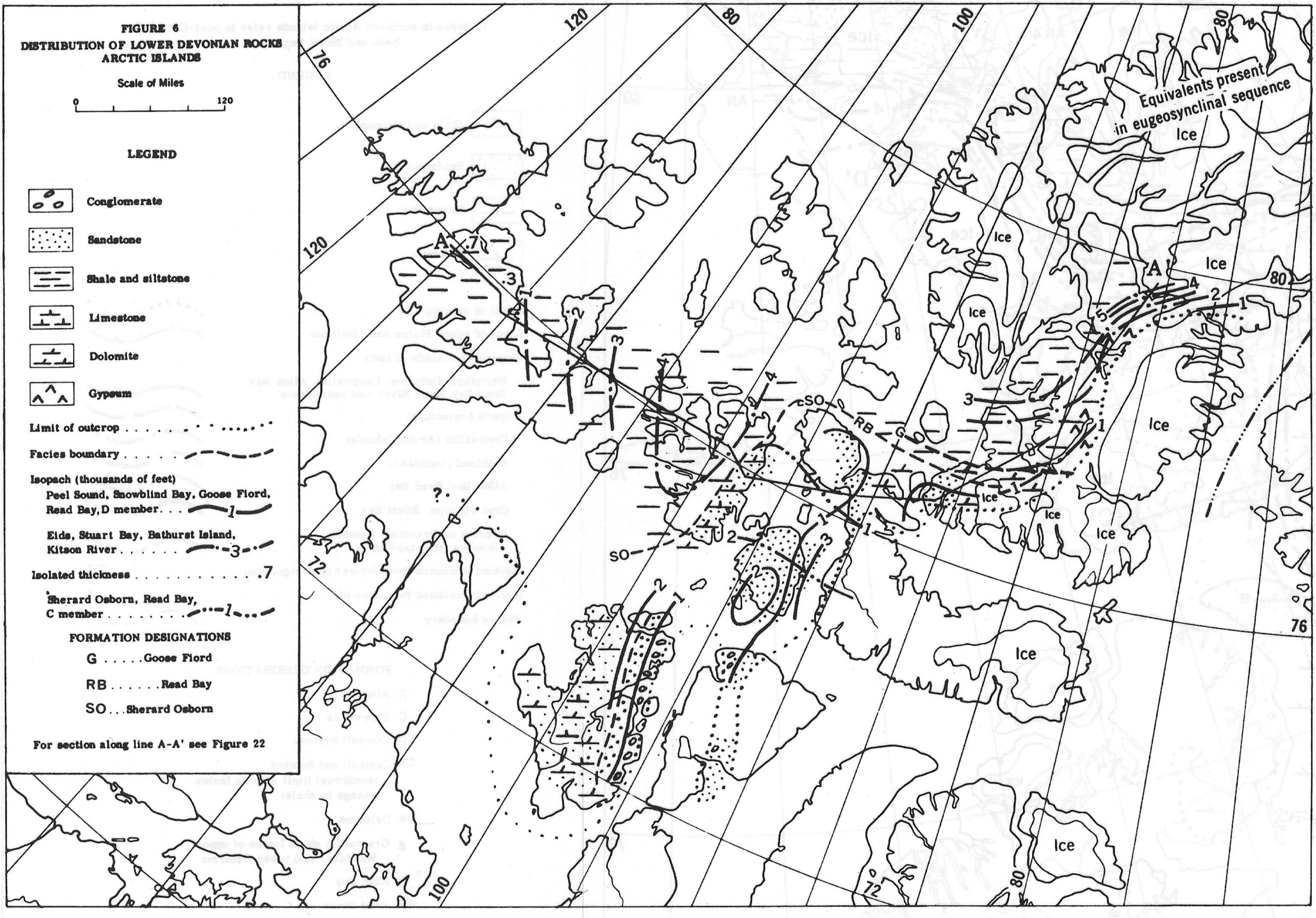


FIGURE 6
DISTRIBUTION OF LOWER DEVONIAN ROCKS
ARCTIC ISLANDS

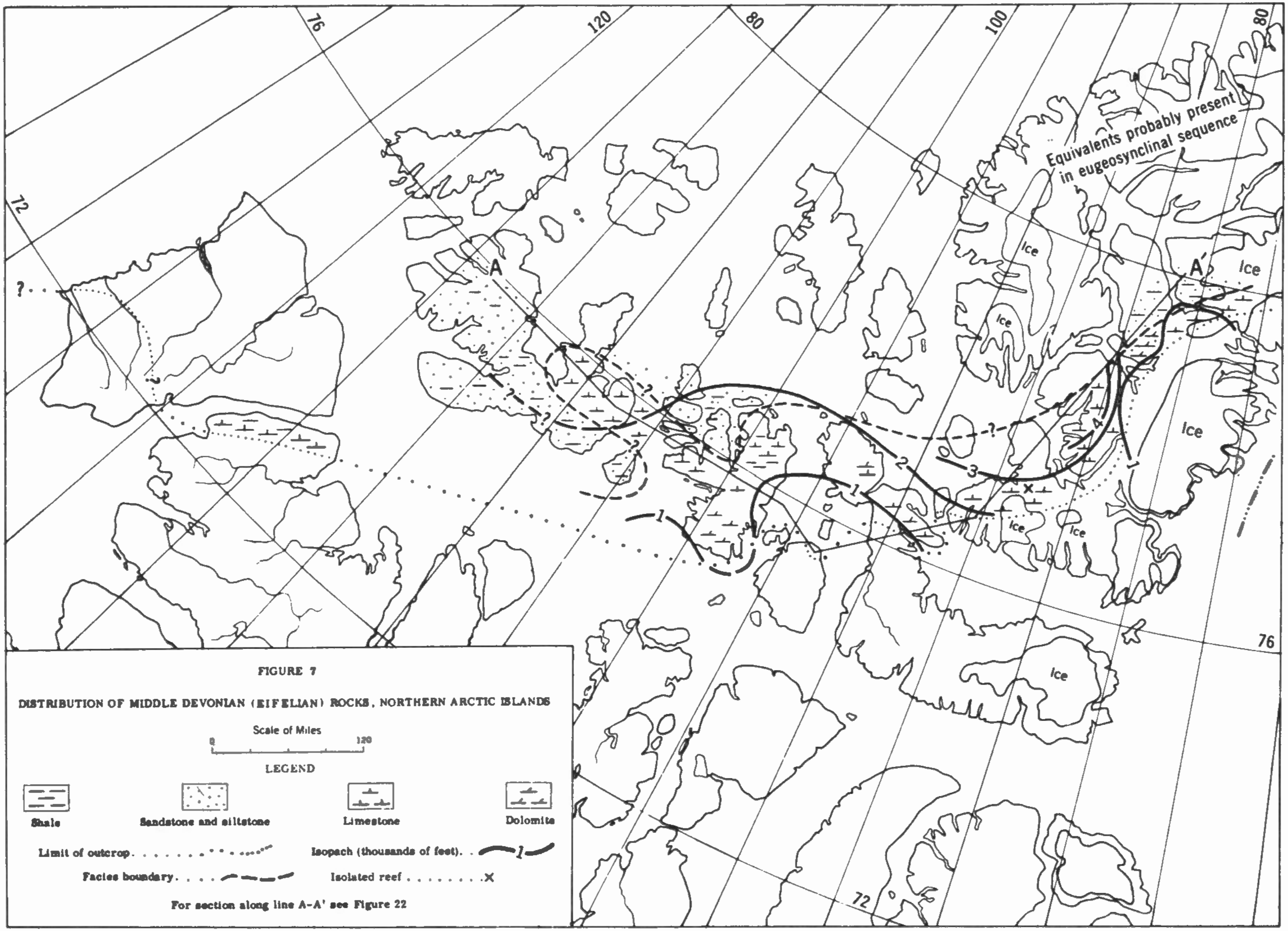


FIGURE 7

DISTRIBUTION OF MIDDLE DEVONIAN (EIFELIAN) ROCKS, NORTHERN ARCTIC ISLANDS

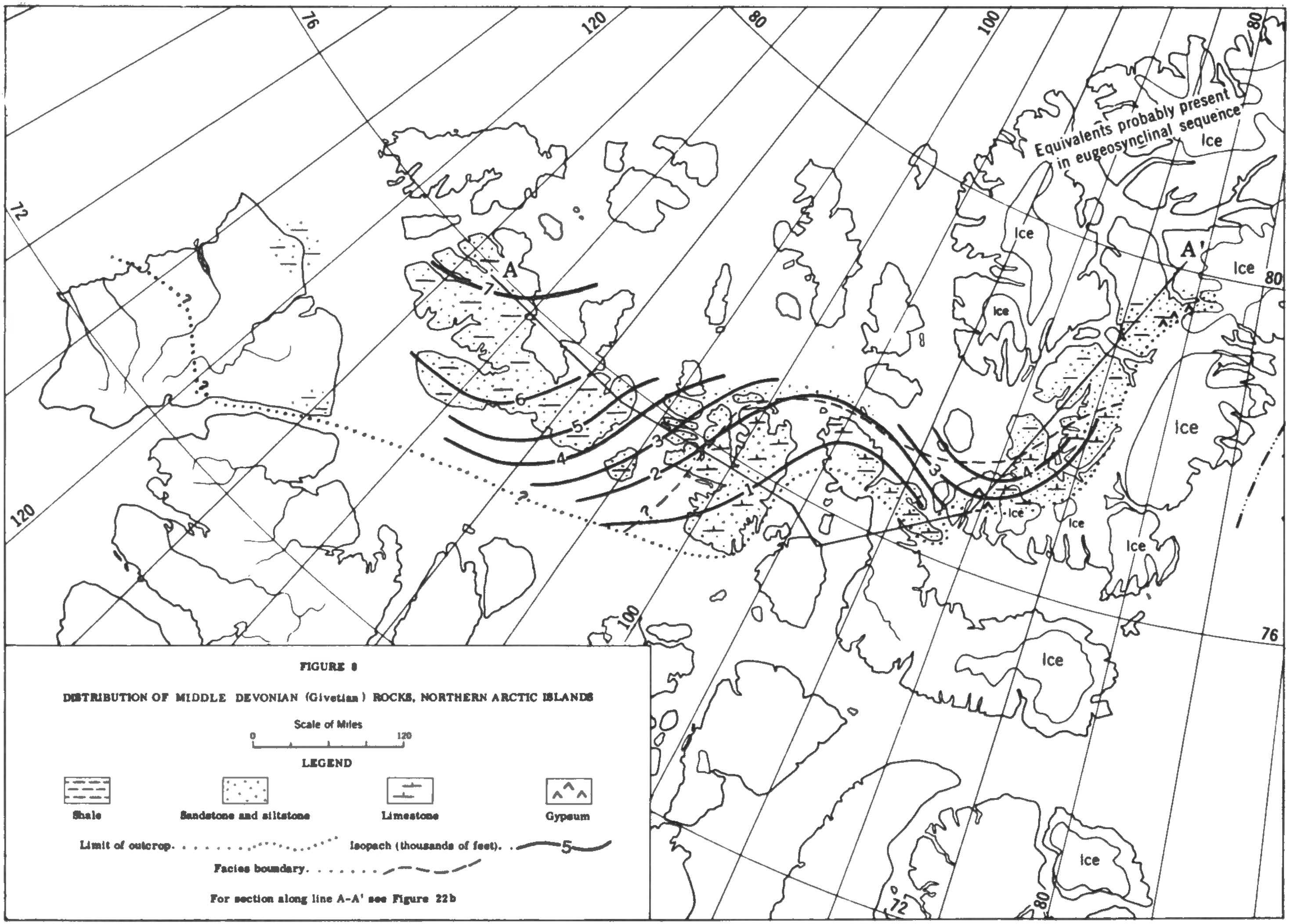


FIGURE 8

DISTRIBUTION OF MIDDLE DEVONIAN (Givetian) ROCKS, NORTHERN ARCTIC ISLANDS

For section along line A-A' see Figure 22b

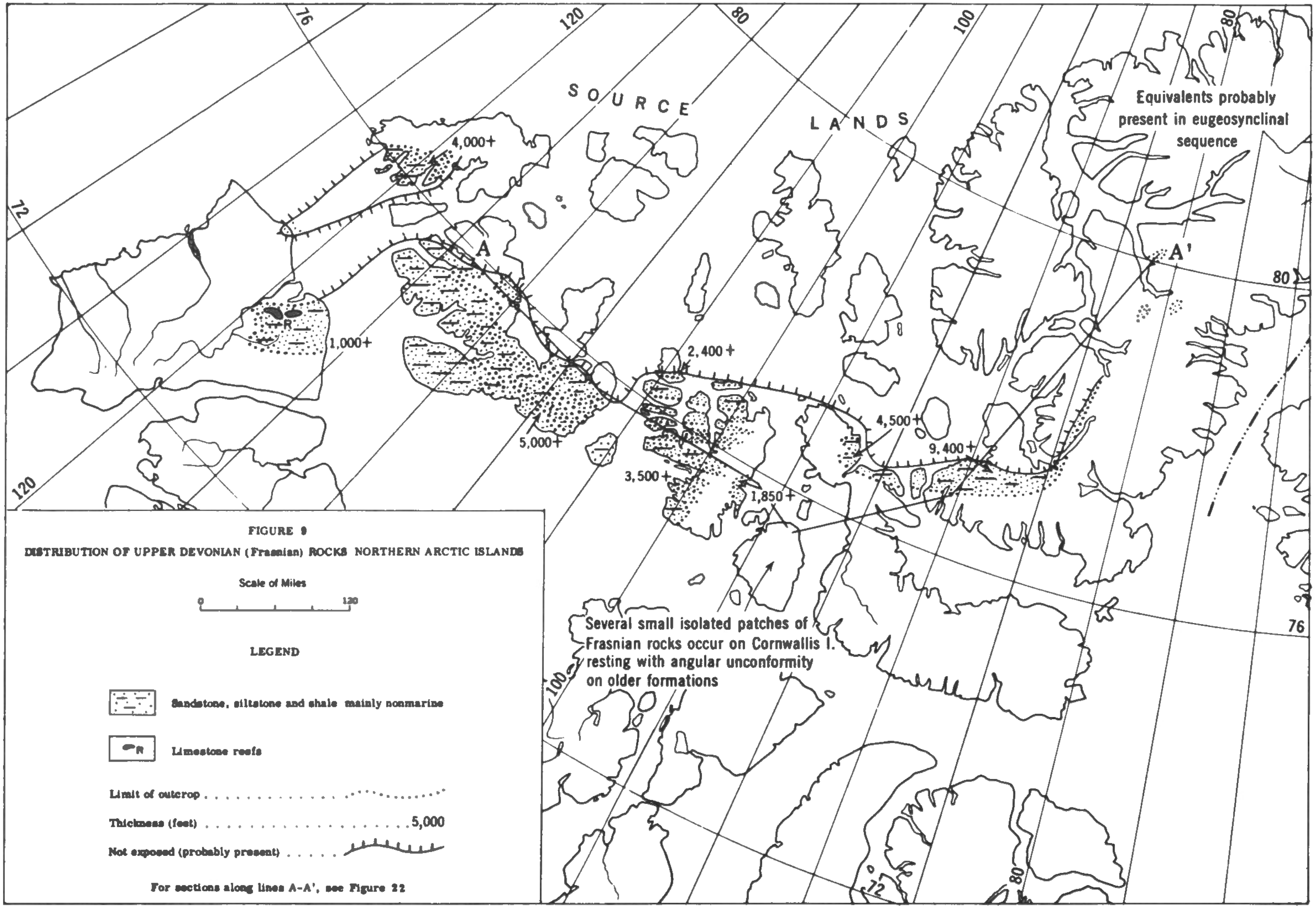


FIGURE 9

DISTRIBUTION OF UPPER DEVONIAN (Frasnian) ROCKS NORTHERN ARCTIC ISLANDS

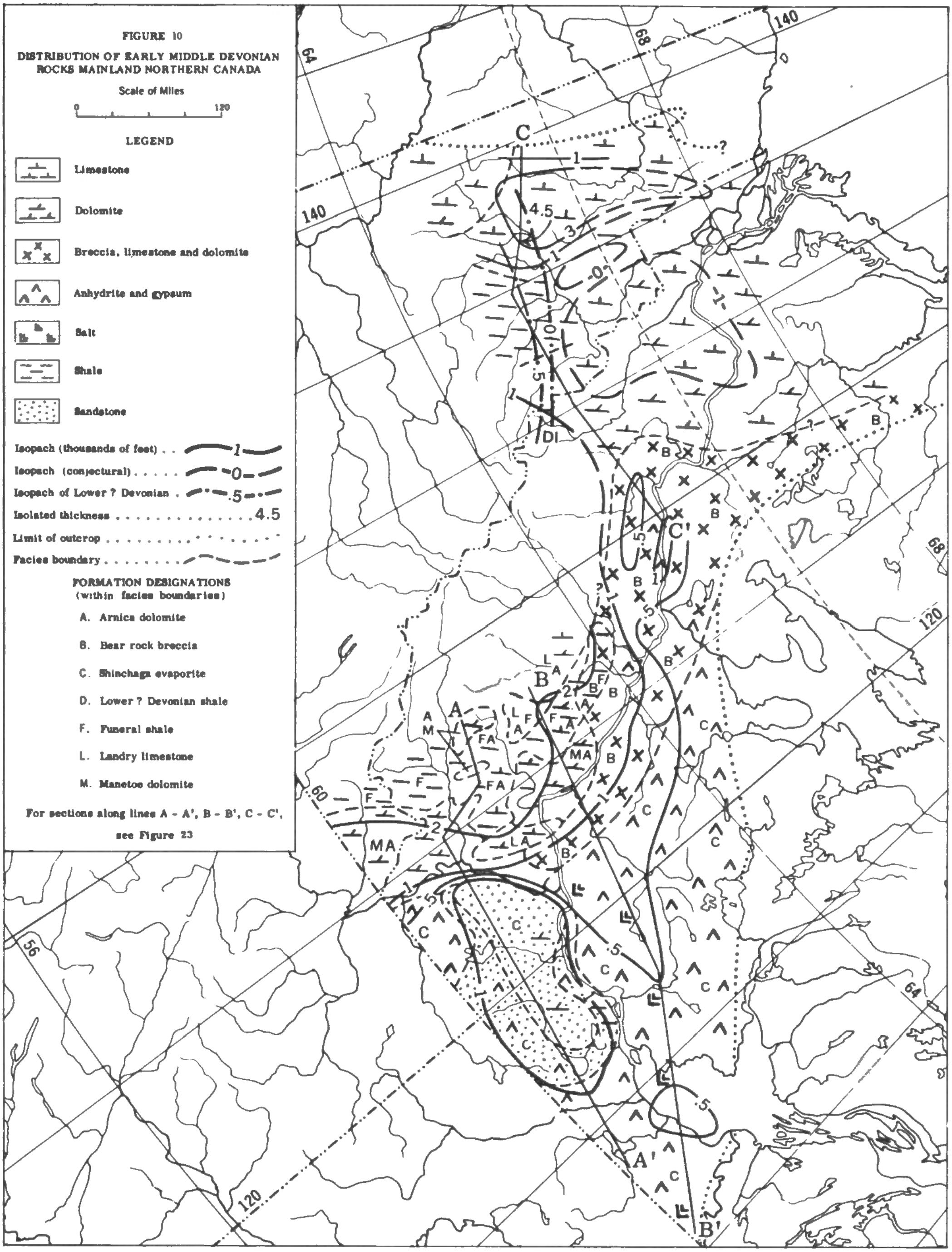


FIGURE 10

DISTRIBUTION OF EARLY MIDDLE DEVONIAN ROCKS MAINLAND NORTHERN CANADA

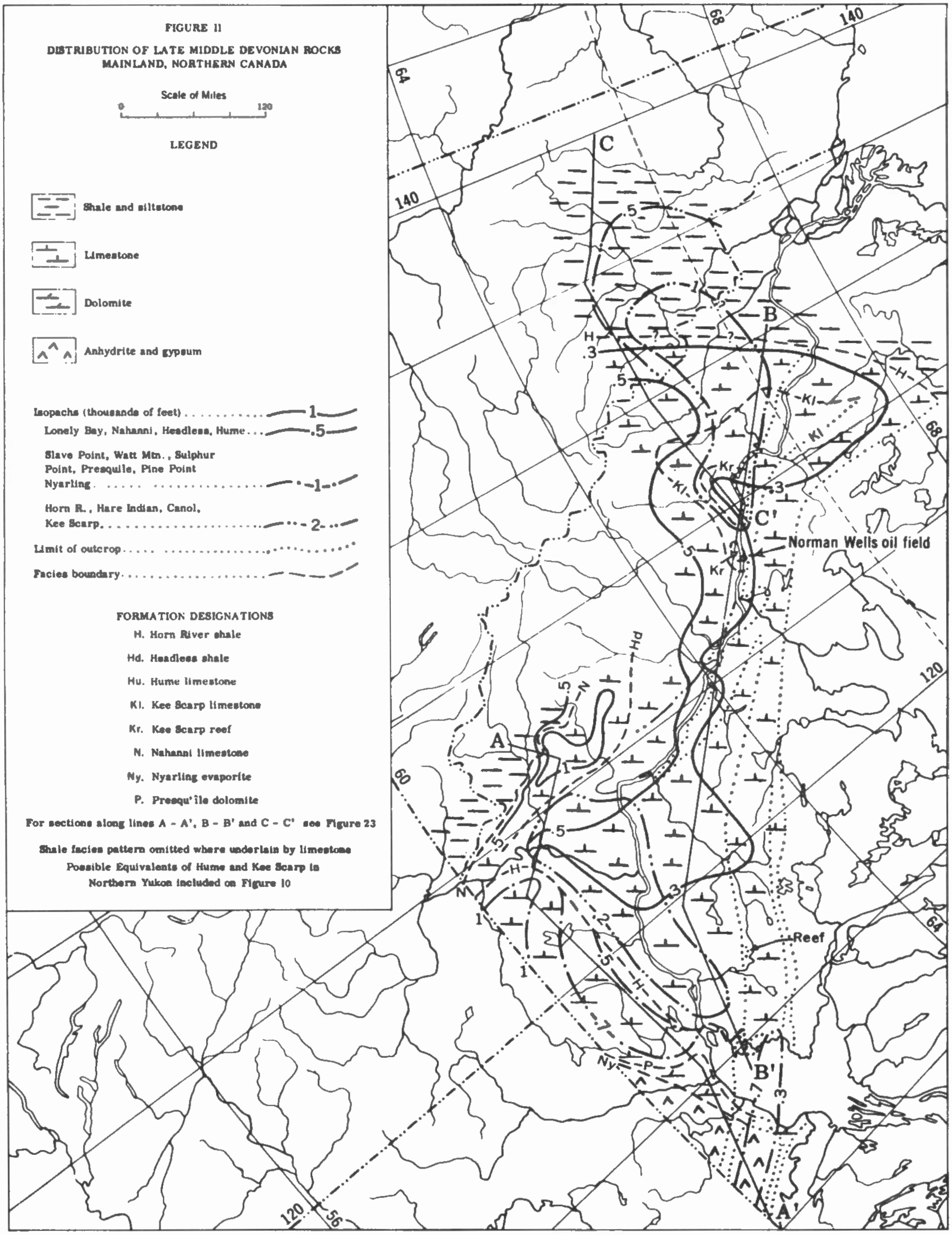


FIGURE 11

DISTRIBUTION OF LATE MIDDLE DEVONIAN ROCKS MAINLAND, NORTHERN CANADA

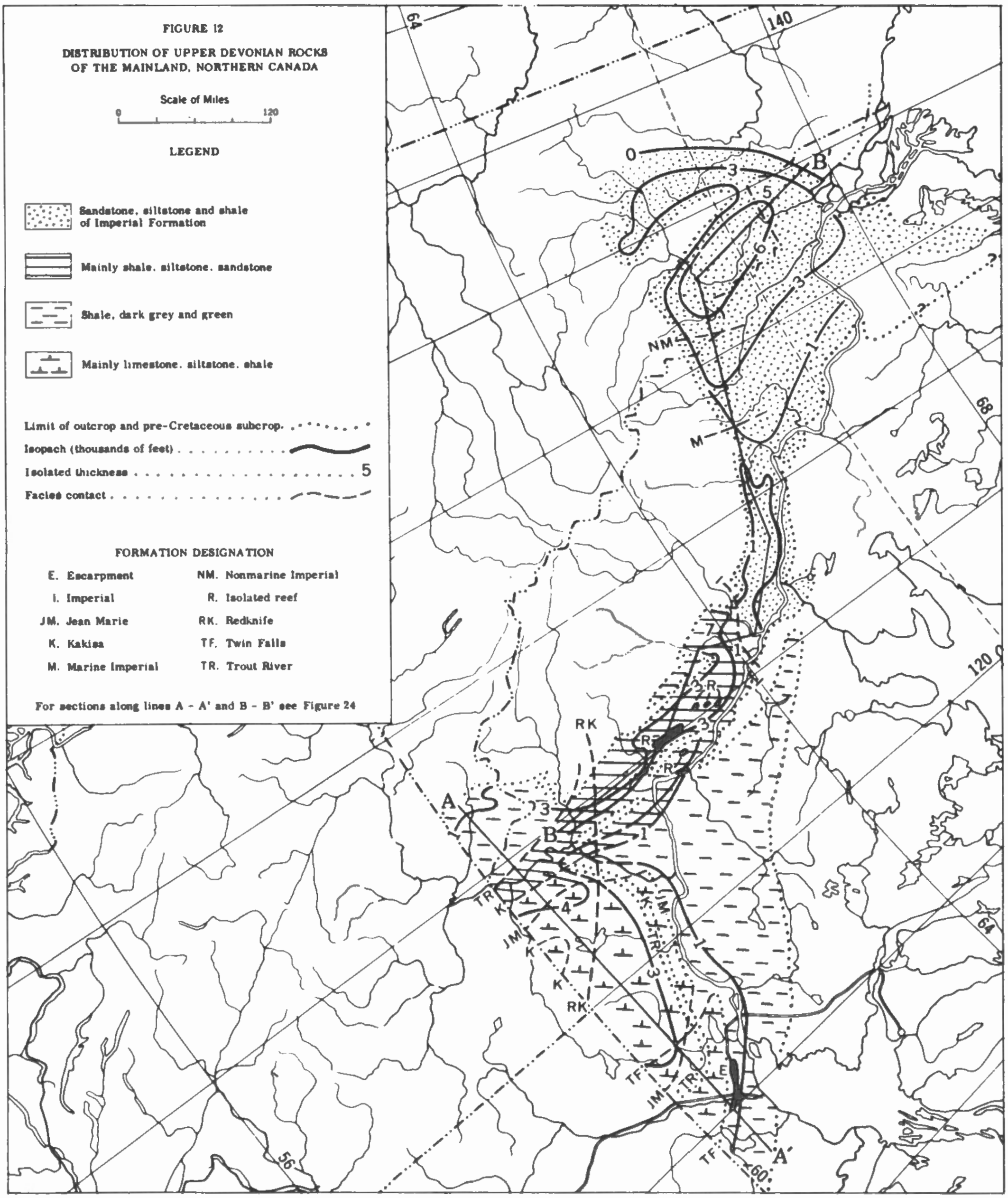


FIGURE 12

DISTRIBUTION OF UPPER DEVONIAN ROCKS OF THE MAINLAND, NORTHERN CANADA

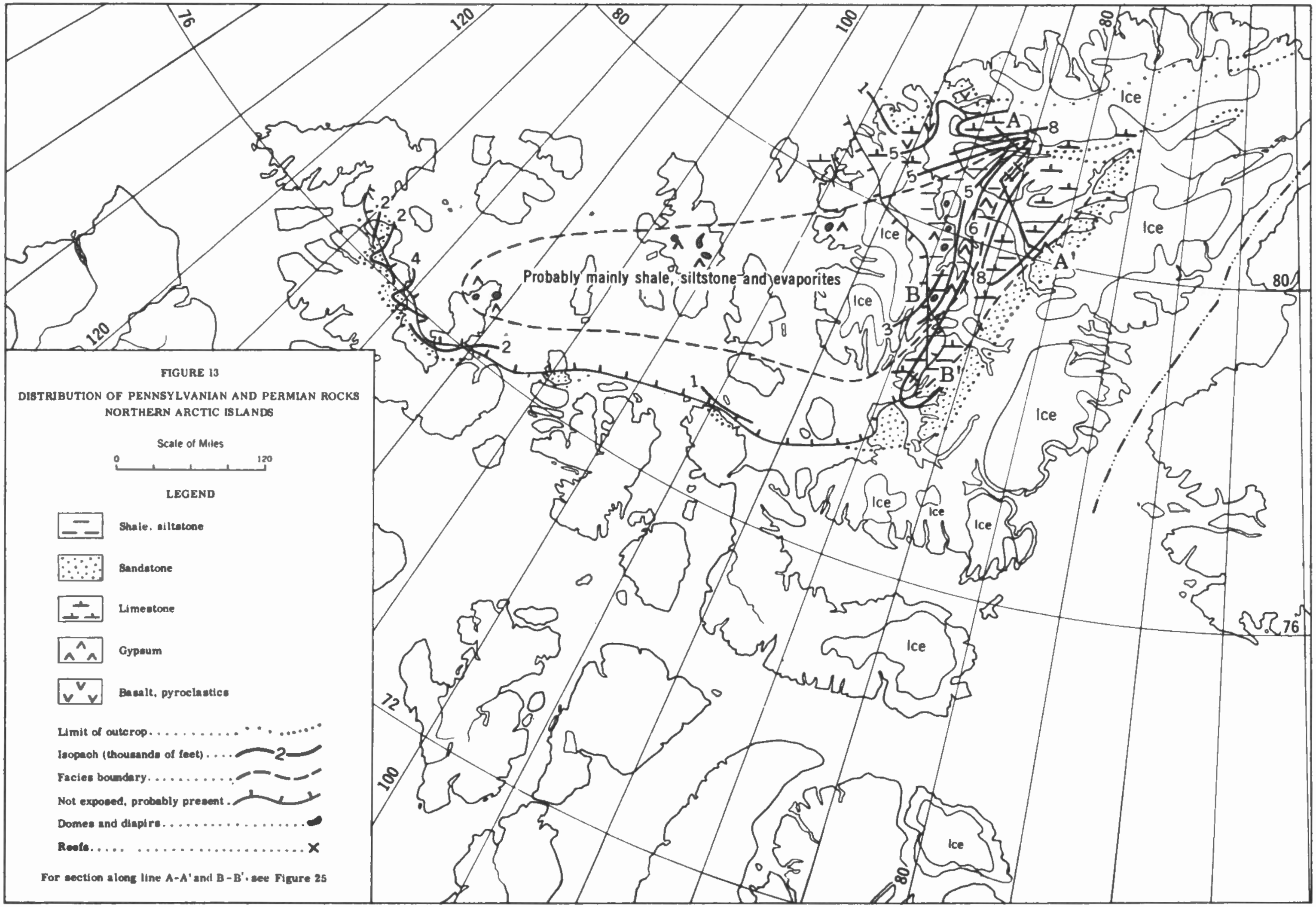


FIGURE 13

DISTRIBUTION OF PENNSYLVANIAN AND PERMIAN ROCKS NORTHERN ARCTIC ISLANDS

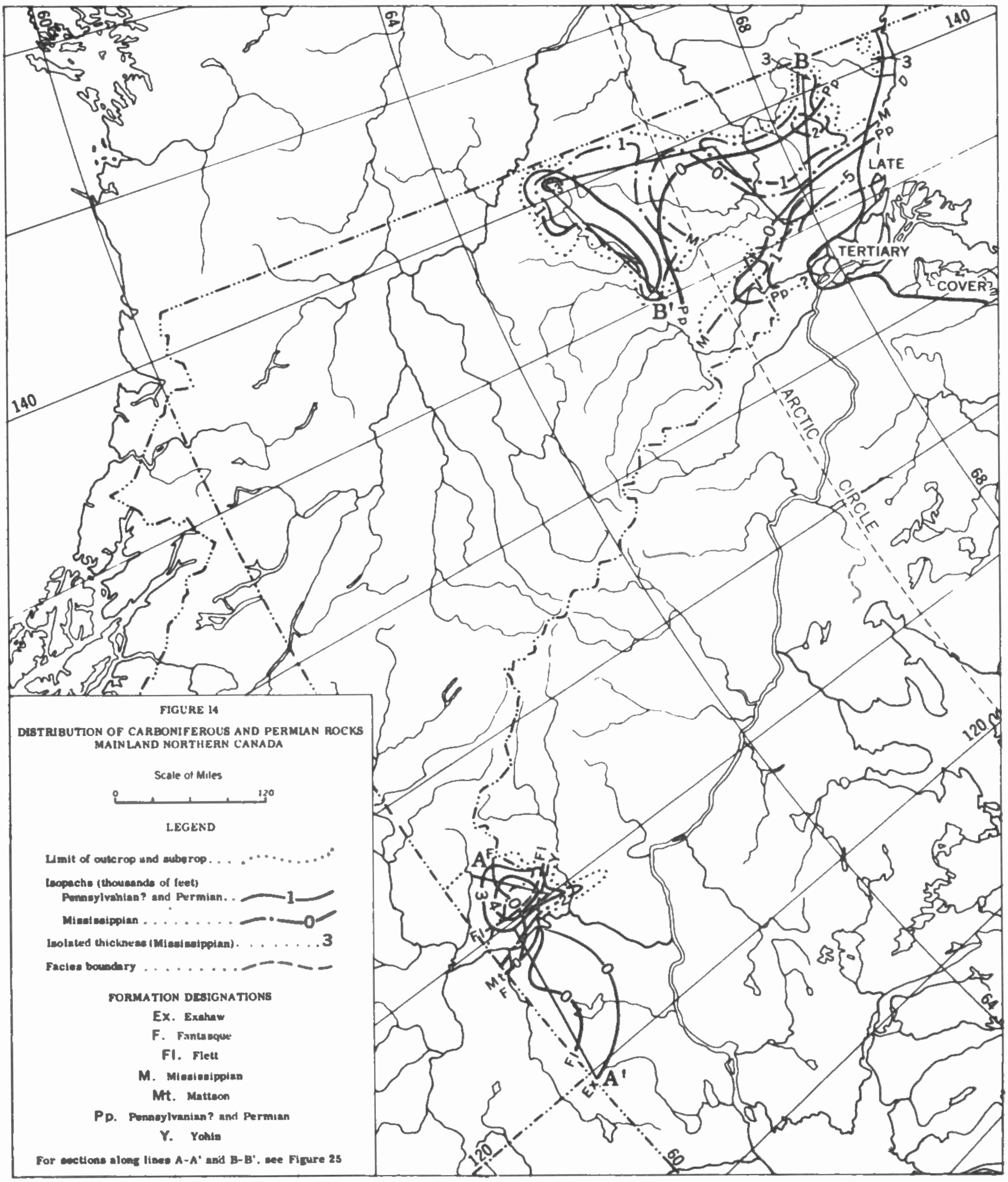


FIGURE 14

DISTRIBUTION OF CARBONIFEROUS AND PERMIAN ROCKS MAINLAND NORTHERN CANADA

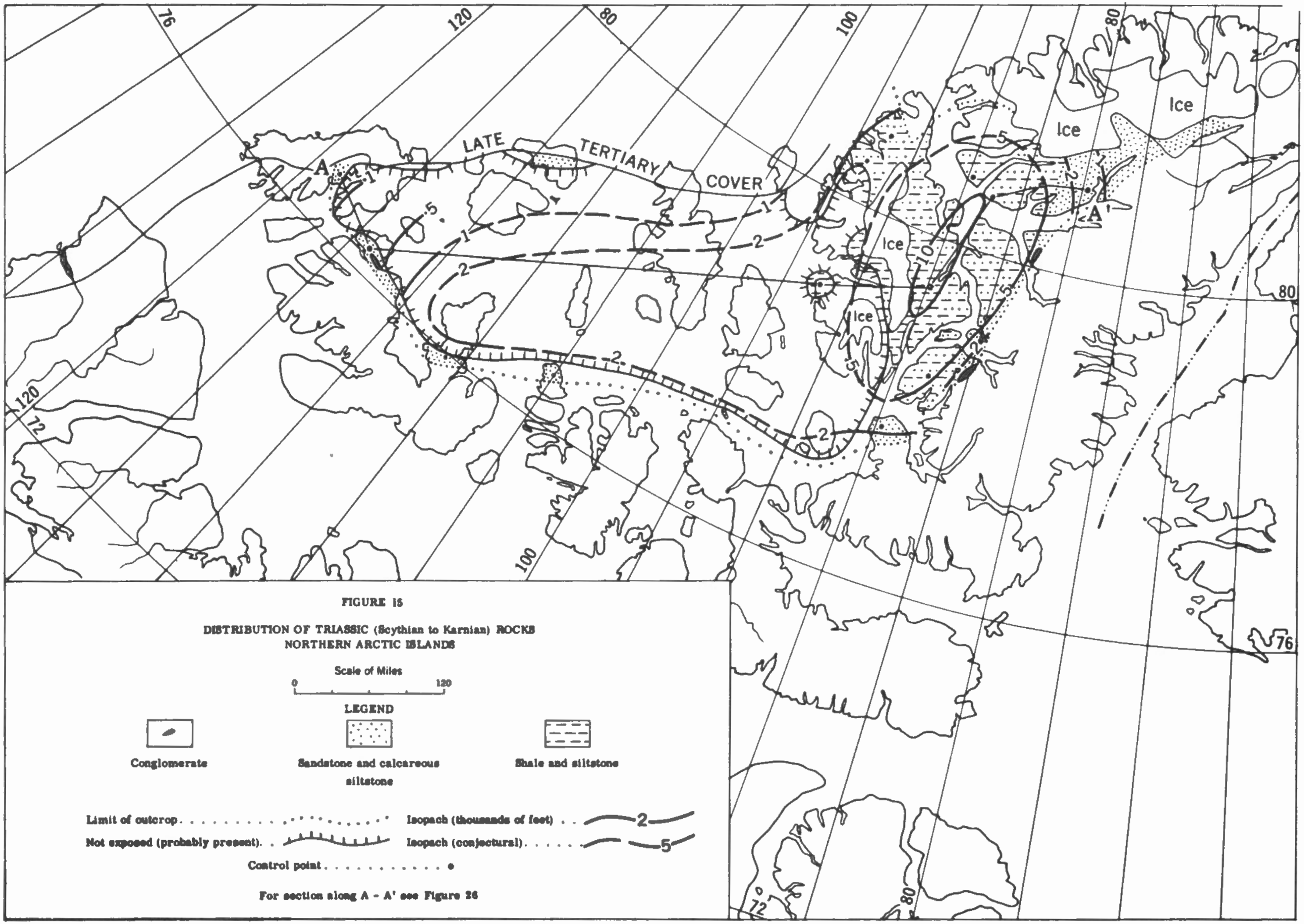


FIGURE 15

DISTRIBUTION OF TRIASSIC (Scythian to Karnian) ROCKS
NORTHERN ARCTIC ISLANDS

For section along A - A' see Figure 26

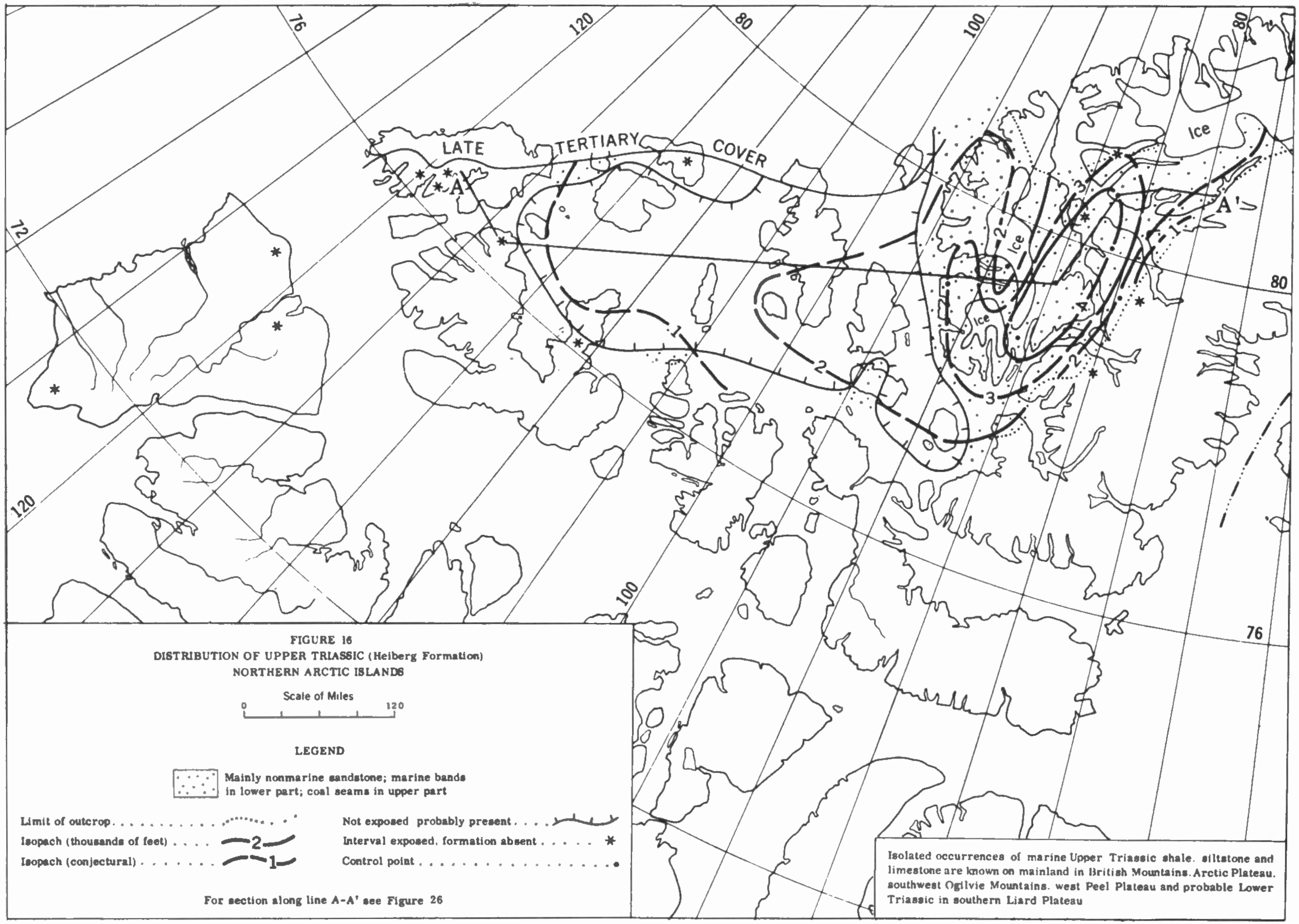


FIGURE 16
DISTRIBUTION OF UPPER TRIASSIC (Heiberg Formation)
NORTHERN ARCTIC ISLANDS

For section along line A-A' see Figure 26

Isolated occurrences of marine Upper Triassic shale, siltstone and limestone are known on mainland in British Mountains, Arctic Plateau, southwest Ogilvie Mountains, west Peel Plateau and probable Lower Triassic in southern Liard Plateau

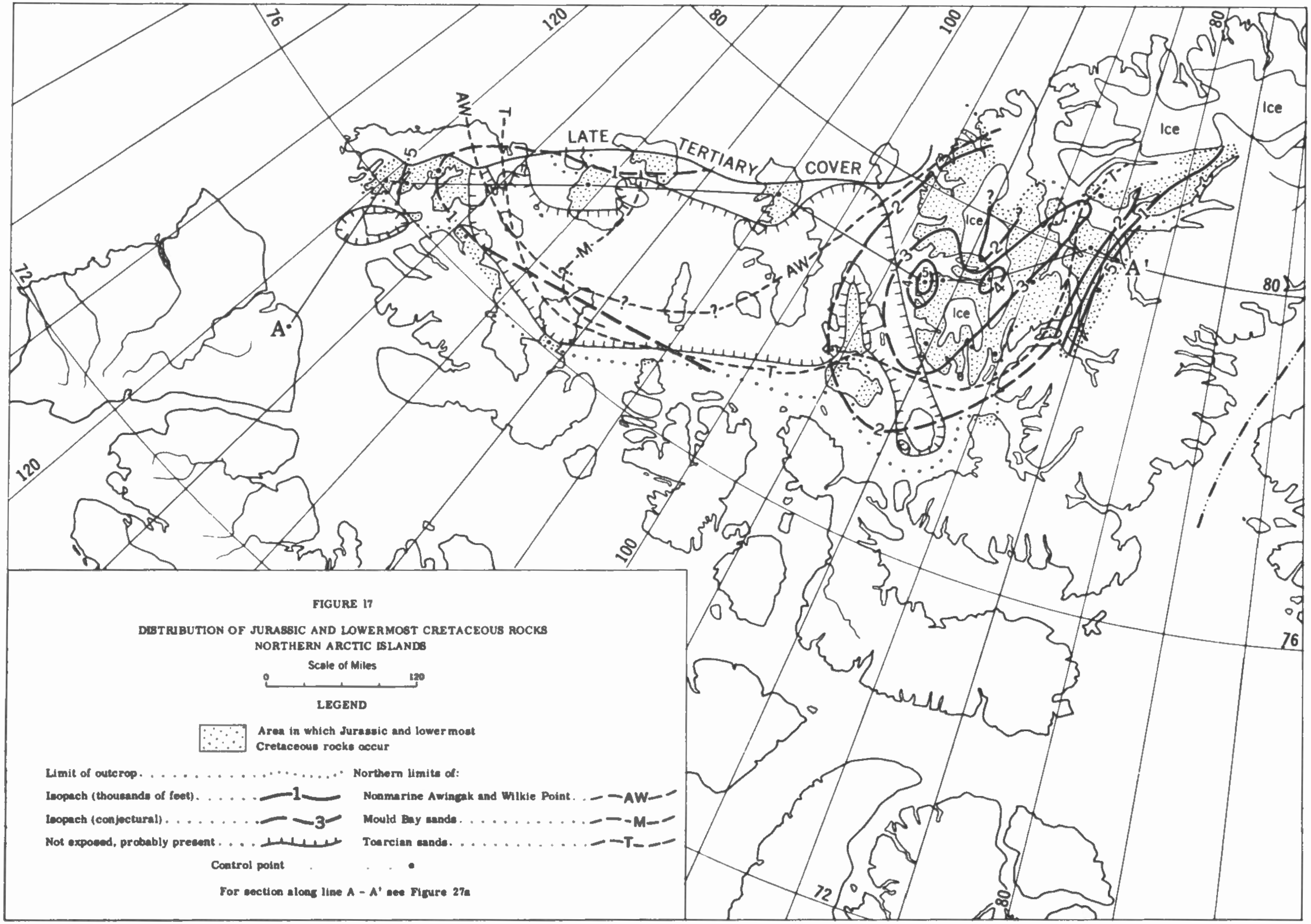


FIGURE 17

DISTRIBUTION OF JURASSIC AND LOWERMOST CRETACEOUS ROCKS
NORTHERN ARCTIC ISLANDS

For section along line A - A' see Figure 27a

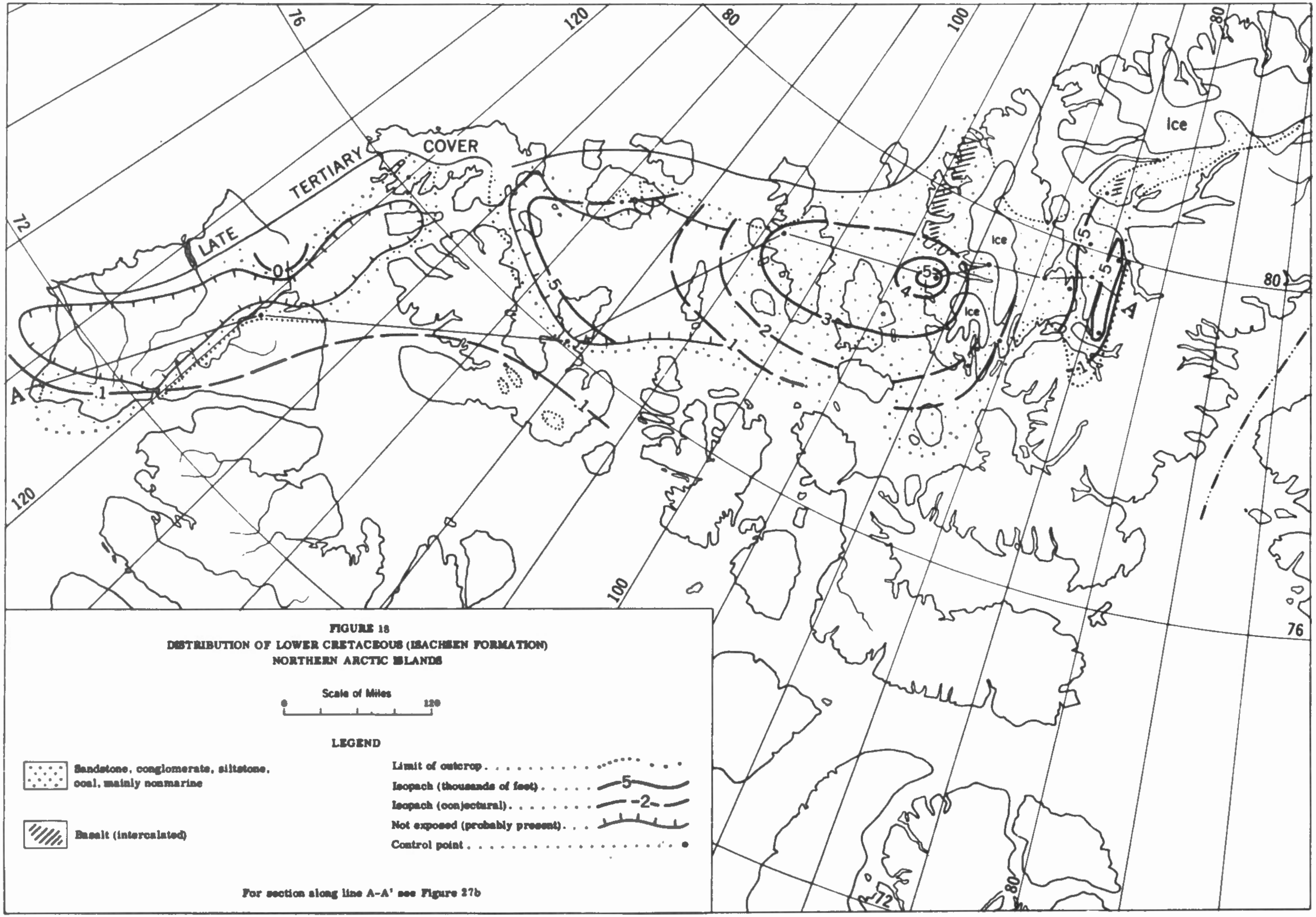


FIGURE 18
DISTRIBUTION OF LOWER CRETACEOUS (ISACHSEN FORMATION)
NORTHERN ARCTIC ISLANDS

Scale of Miles
0 120

LEGEND

▨ Sandstone, conglomerate, siltstone, coal, mainly nonmarine

▨ Basalt (intercalated)

Limit of outcrop
Isopach (thousands of feet) 5
Isopach (conjectural) 2
Not exposed (probably present)
Control point ●

For section along line A-A' see Figure 27b

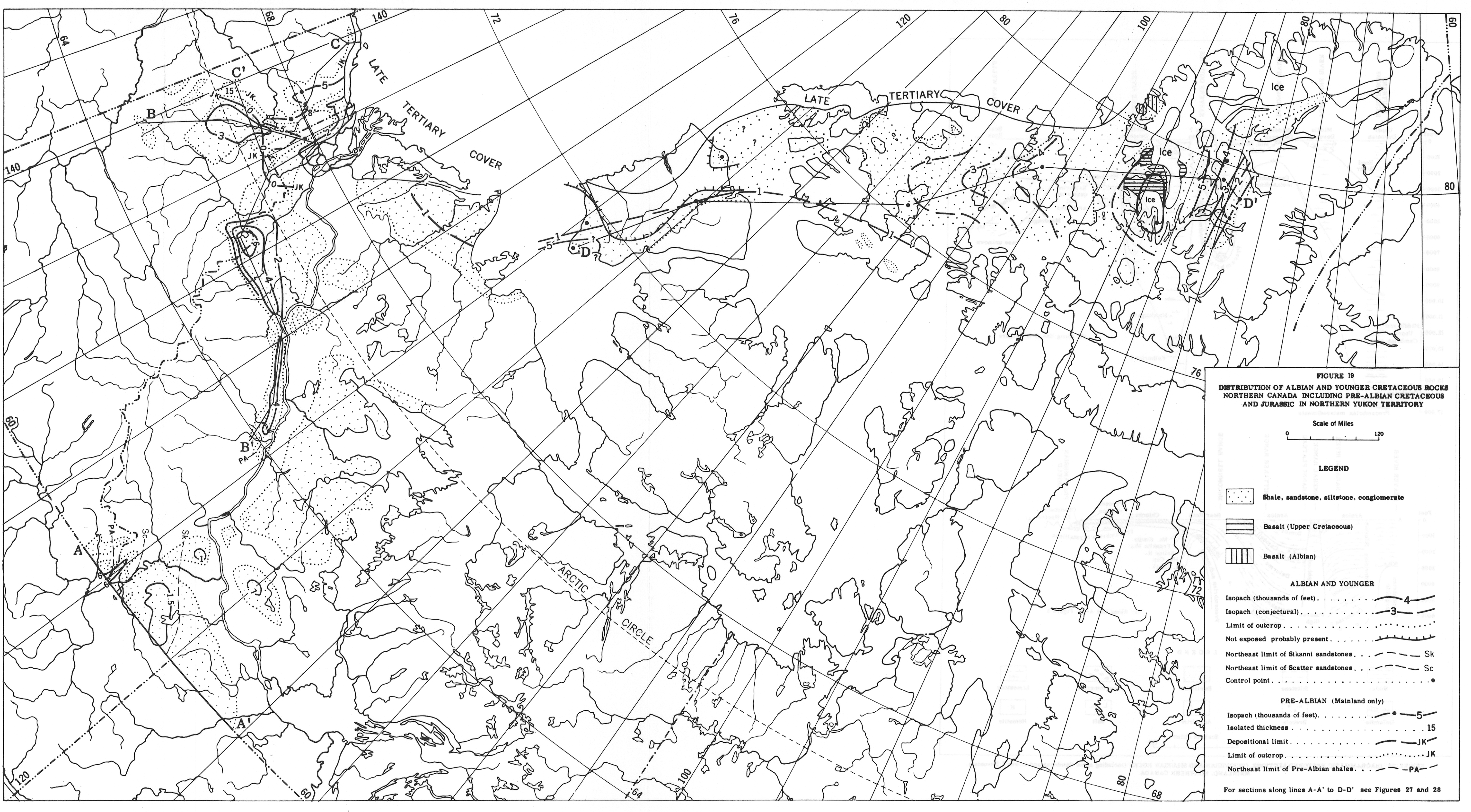
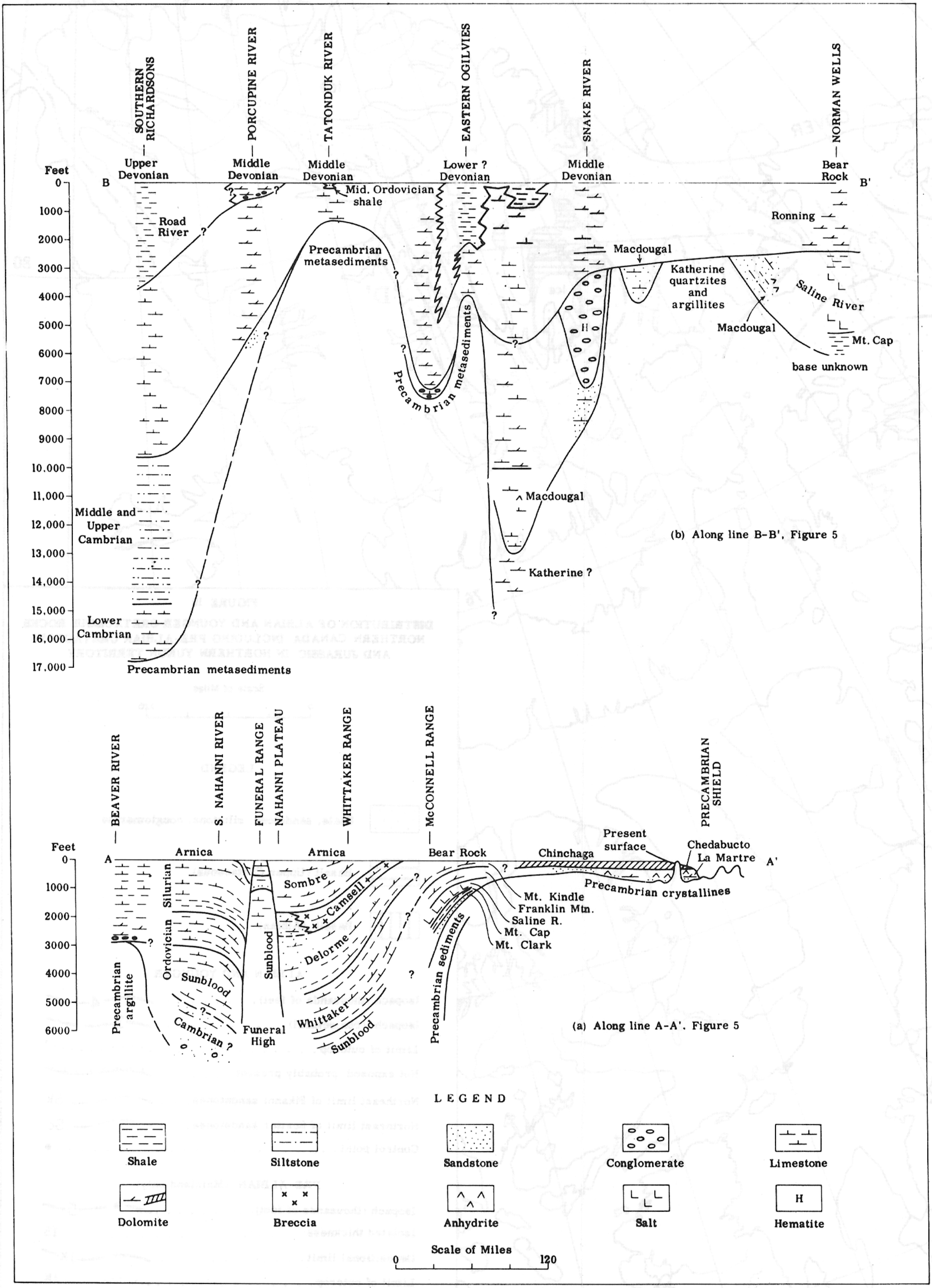


FIGURE 19

DISTRIBUTION OF ALBIAN AND YOUNGER CRETACEOUS ROCKS NORTHERN CANADA INCLUDING PRE-ALBIAN CRETACEOUS AND JURASSIC IN NORTHERN YUKON TERRITORY

For sections along lines A-A' to D-D' see Figures 27 and 28



(b) Along line B-B', Figure 5

(a) Along line A-A', Figure 5

FIGURE 20. DIAGRAMMATIC RESTORED SECTIONS, ORDOVICIAN AND SILURIAN ROCKS (including some Cambrian and Lower ? Devonian). MAINLAND, NORTHERN CANADA

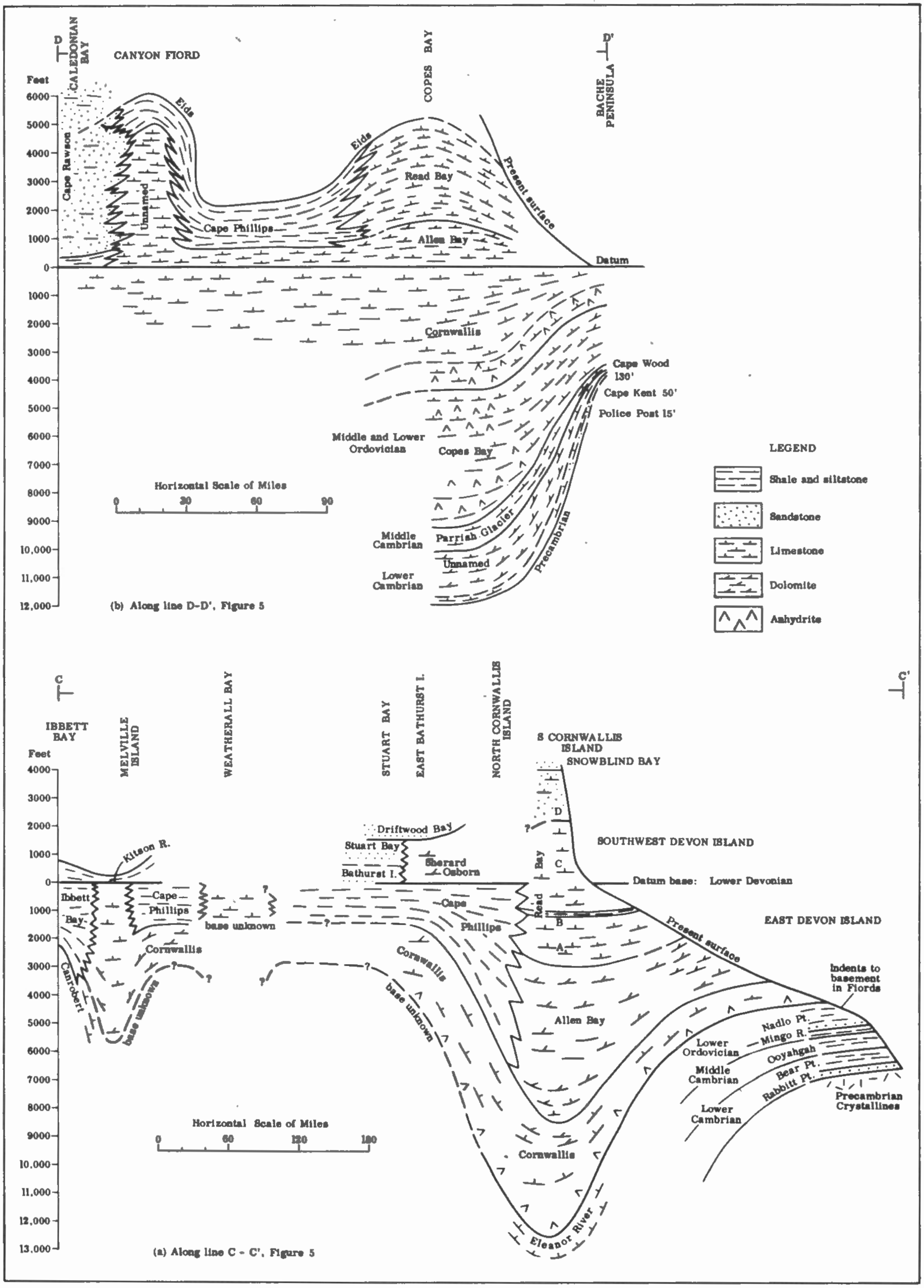
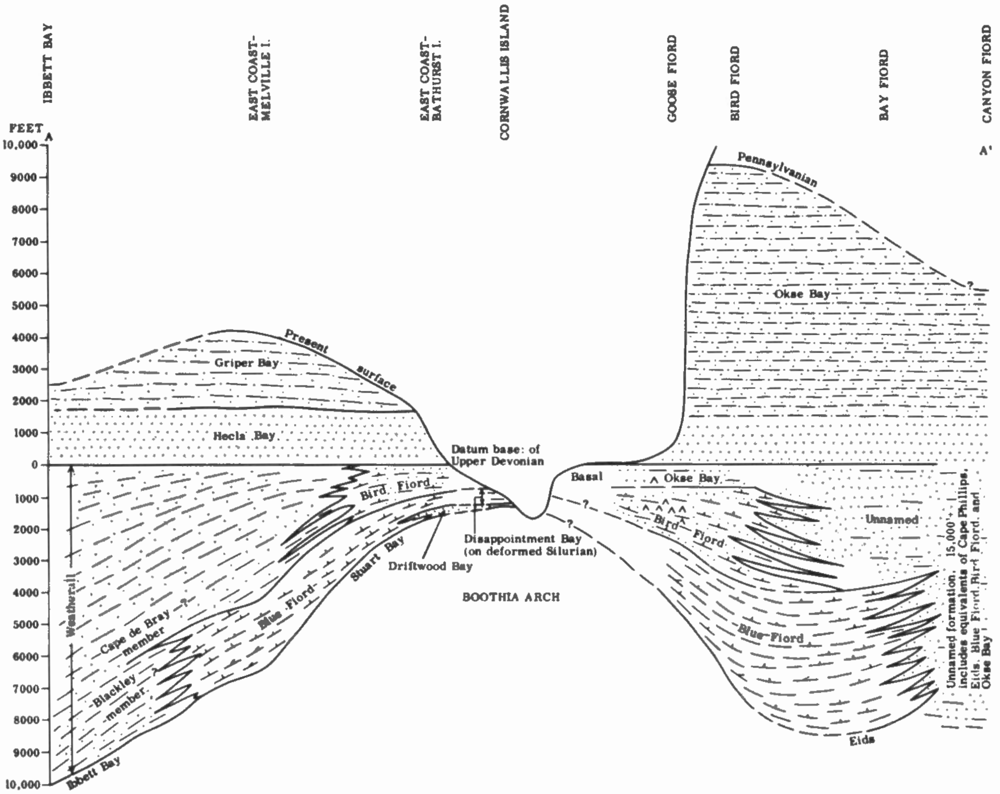
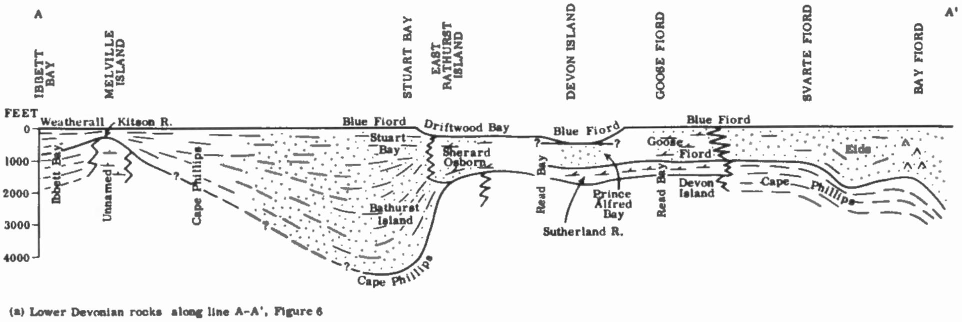


FIGURE 21. DIAGRAMMATIC RESTORED SECTIONS ORDOVICIAN AND SILURIAN, ARCTIC ISLANDS, (INCLUDING SOME CAMBRIAN AND LOWER DEVONIAN).



(b) Middle and Upper Devonian rocks, along line A-A', Figures 7 and 8



(a) Lower Devonian rocks along line A-A', Figure 6

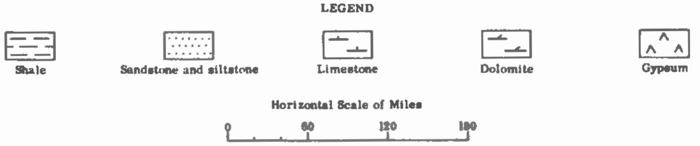
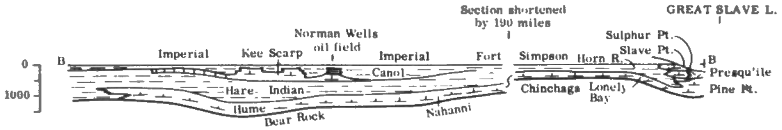
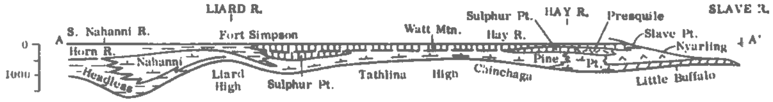


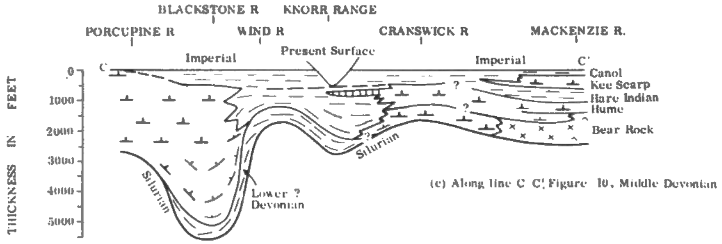
FIGURE 22 DIAGRAMMATIC RESTORED SECTIONS DEVONIAN ROCKS, NORTHERN ARCTIC ISLANDS



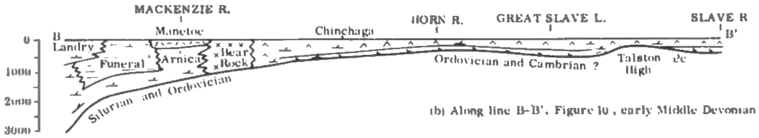
(e) Along line B-B', Figure 11, late Middle Devonian



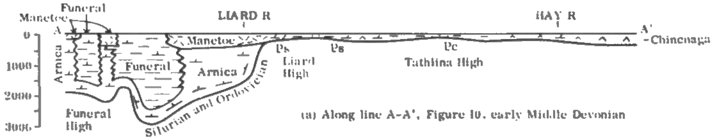
(d) Along line A-A', Figure 11, late Middle Devonian



(c) Along line C C', Figure 10, Middle Devonian



(b) Along line B-B', Figure 10, early Middle Devonian



(a) Along line A-A', Figure 10, early Middle Devonian

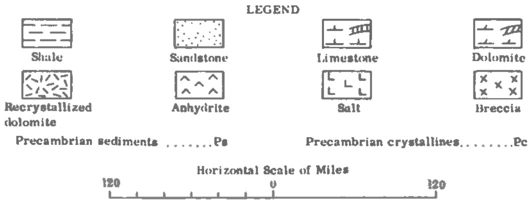
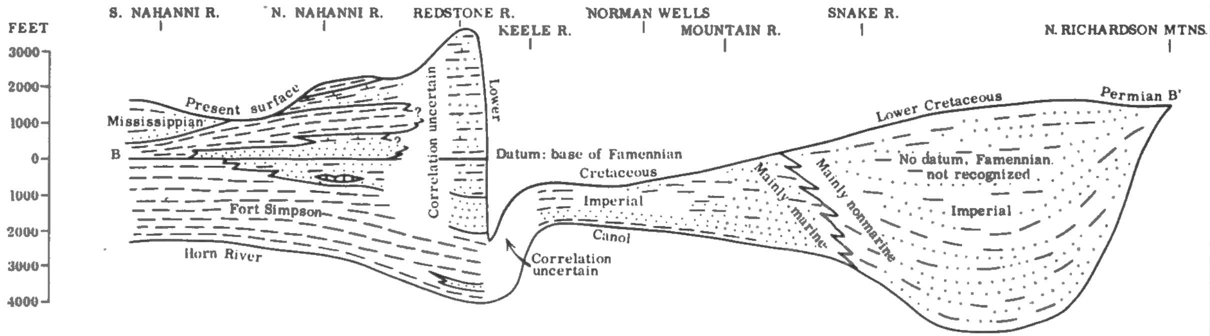
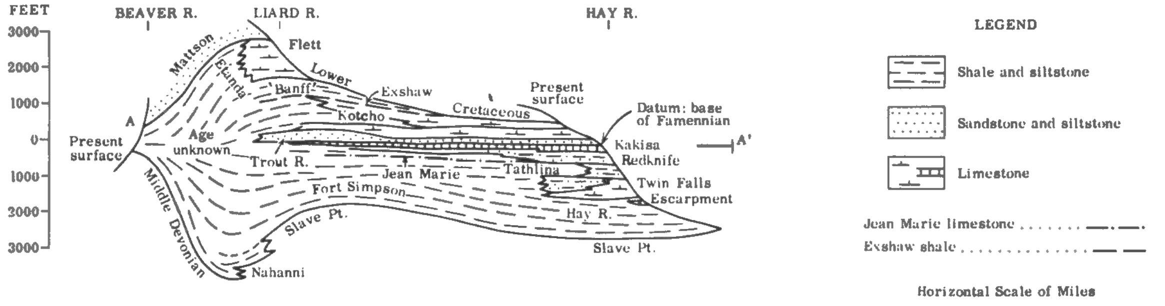


FIGURE 23: DIAGRAMMATIC RESTORED SECTIONS MIDDLE DEVONIAN ROCKS, MAINLAND NORTHERN CANADA



(b) Along line B - B' Figure 12



(a) Along line A - A', Figure 12

FIGURE 24. DIAGRAMMATIC RESTORED SECTIONS UPPER DEVONIAN ROCKS, MAINLAND NORTHERN CANADA

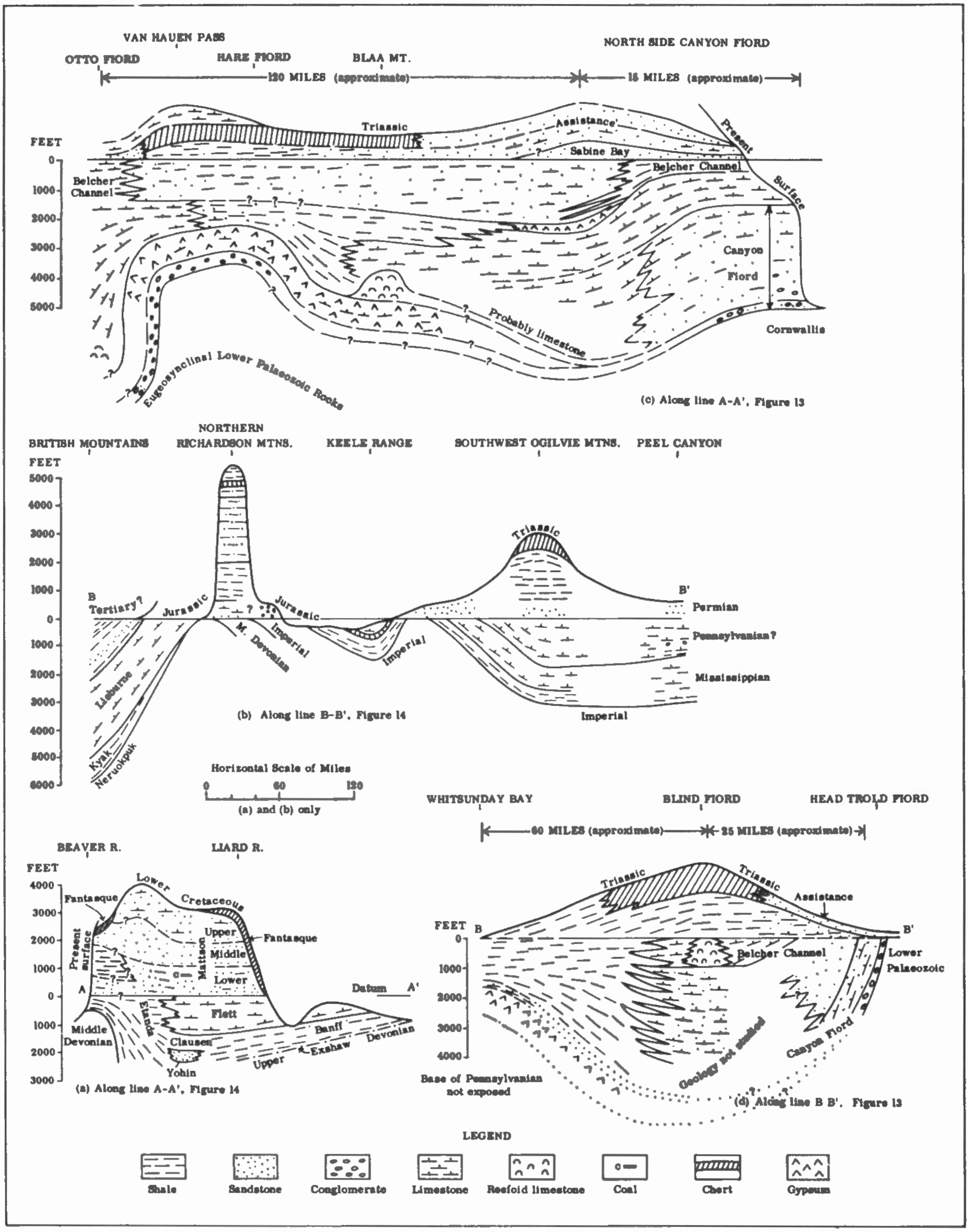


FIGURE 25. DIAGRAMMATIC RESTORED SECTIONS OF CARBONIFEROUS AND PERMIAN ROCKS

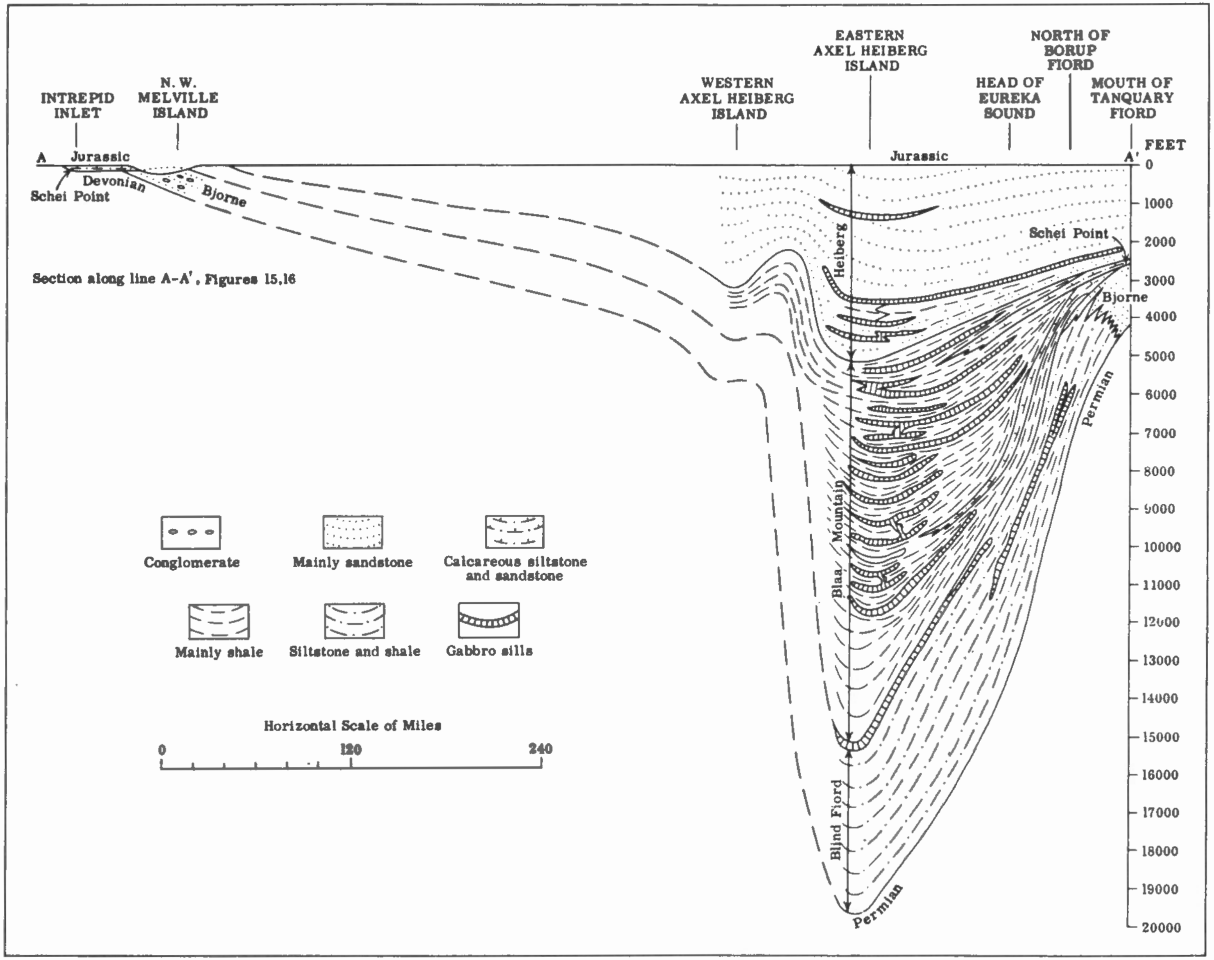
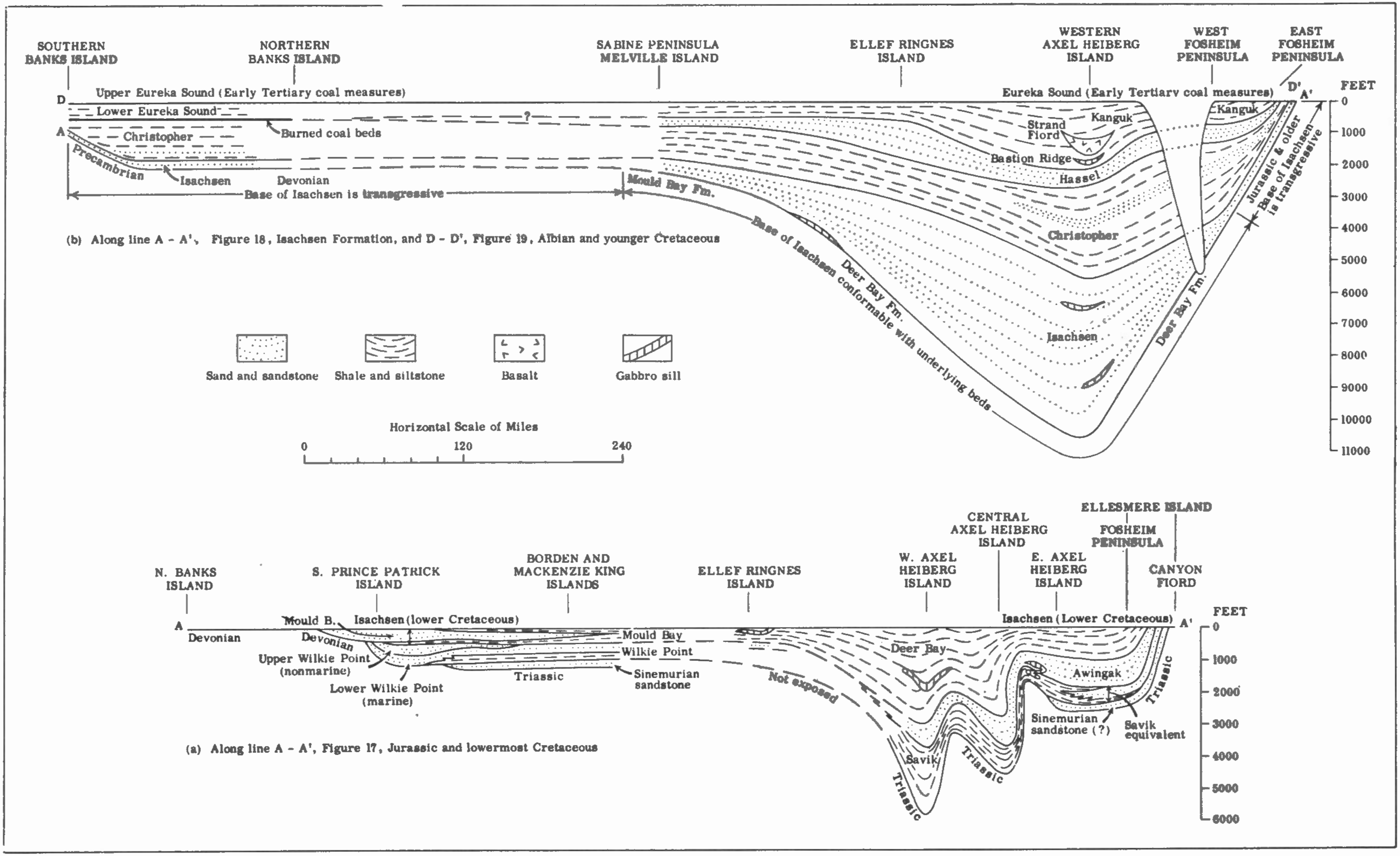


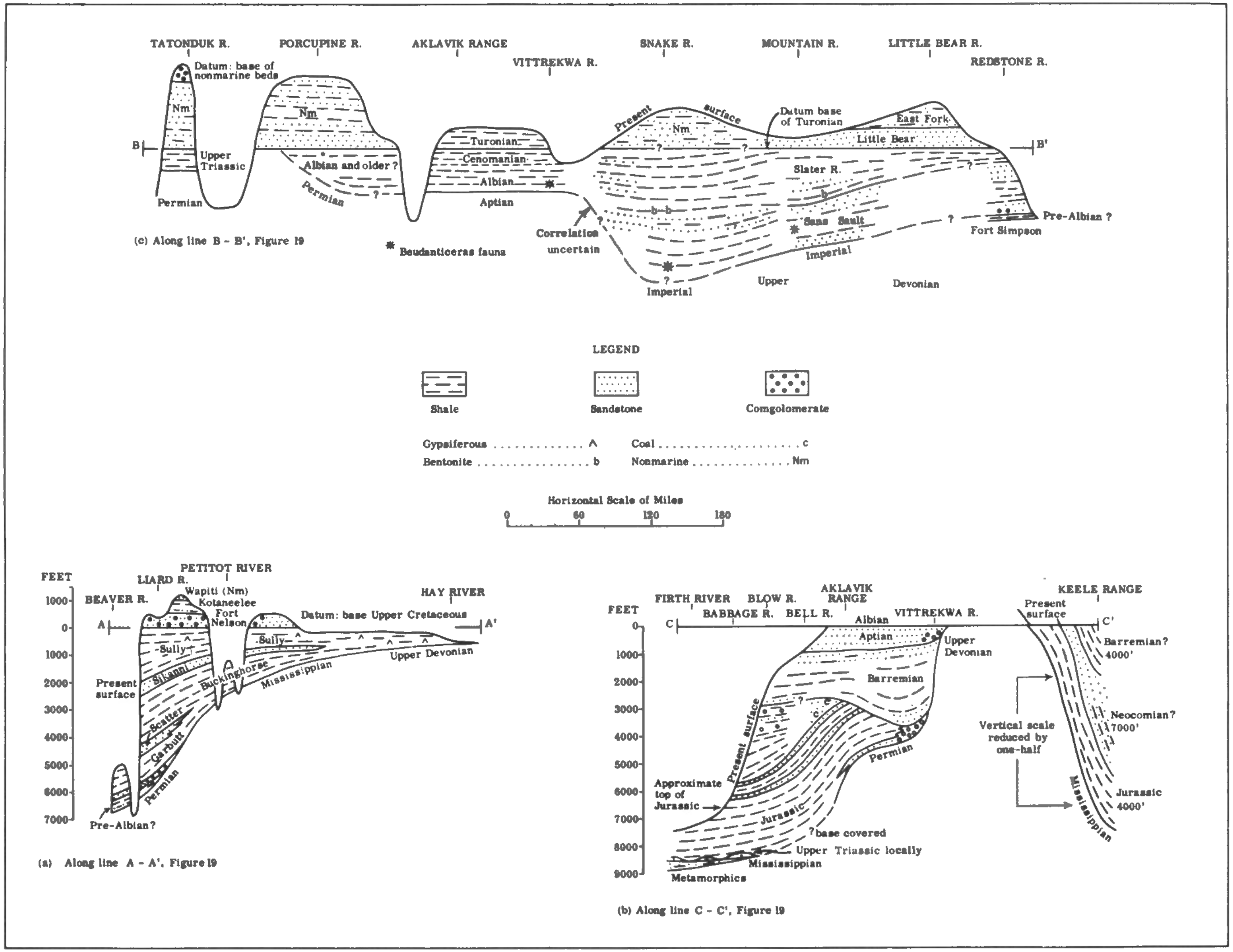
FIGURE 26 DIAGRAMMATIC RESTORED SECTION OF TRIASSIC ROCKS, NORTHERN ARCTIC ISLANDS



(b) Along line A - A', Figure 18, Isachsen Formation, and D - D', Figure 19, Albian and younger Cretaceous

(a) Along line A - A', Figure 17, Jurassic and lowermost Cretaceous

FIGURE 27. DIAGRAMMATIC RESTORED SECTIONS OF JURASSIC AND CRETACEOUS ROCKS, NORTHERN ARCTIC ISLANDS



(c) Along line B - B', Figure 19

(a) Along line A - A', Figure 19

(b) Along line C - C', Figure 19

FIGURE 28 DIAGRAMMATIC RESTORED SECTIONS JURASSIC AND CRETACEOUS ROCKS, MAINLAND, NORTHERN CANADA