Energy in Newfoundland

Steven M. Millan
Government of Newfoundland, Department of Mines and Energy St. John's, Newfoundland

Summary:
Energy requirements of the Province of Newfoundland are met almost entirely by hydroelectricity and petroleum fuels in the ratio of 1:4. Hydroelectric resources, both developed and potential, are very large in relation to the Province's requirements.

The petroleum potential of the Province is also substantial and undergoing extensive exploration in the offshore Atlantic area. Two wells drilled in 1973, on the northern Grand Banks and on the Labrador shelf, seem particularly significant.

Introduction
At present, the only developed indigenous source of energy in the Province is hydroelectricity. Other energy resources such as petroleum, uranium, coal, oil shales, peat and wind, are in the potential phase. Of these, the potential petroleum resources of the continental margin are under active exploration while the quest for uranium is again gaining momentum. In this account, only the electrical and petroleum energy sectors are considered.

The energy requirements of the Province are almost entirely covered by electricity and petroleum fuels. In 1972, the total amount of electricity generated in the Province was 11,225 Gigawatt hours (1 Gigawatt hour = 10^6 Kilowatt hours). Of this, 6,400 Gwh were exported and 4,825 Gwh were used within the Province. More than 90 per cent of this energy was generated by hydroelectric plants.

The electrical energy consumed by the Province in 1972 has a calorific equivalence of 16 x 10^{12} British thermal units (BTU) or 4 x 10^{12} Kilocalories (Kcal).

In contrast, just over 13 million barrels of hydrocarbon products were used as fuels in the Province during 1972. All hydrocarbons used, were imported from outside of the Province either in the form of crude oil or refined products. The approximate calorific value of these hydrocarbon fuels is 65 x 10^{12} BTU's or 16 x 10^{12} Kcal.

The energy requirements of the Province are thus provided for through electricity and the burning of hydrocarbon fuels in the approximate proportions of 1 : 4 respectively.

Electric Power Resources
Introduction. In considering the electric resources of the Province, it is important that the geographic separation of mainland Labrador from the island of Newfoundland be borne in mind. By far the greater hydroelectric potential of the Province is located in Labrador. It has not been possible thus far to transmit this power across the separating Strait of Belle Isle onto the island part of the Province. This problem of crossing the Strait of Belle Isle with transmission cables is at present the subject of intensive geological and engineering investigation.

In contrast to the distribution of hydroelectric potential, the Provincial population of approximately 500,000 is predominantly located on the Island of Newfoundland.

Electric Power On The Island Of Newfoundland. Installed generating capacity on the integrated island system amounts to approximately 1,066 Megawatts, having an average annual energy capability of some 6,353 Gwh. Approximately 90 per cent of the electrical energy used annually is hydro-generated. The non-hydro units, such as thermal generators, gas turbines and diesel plants, are used mainly to meet the requirements of peak loads, isolated communities and emergency stand-by.

The major existing hydro developments on the island are listed in Table I and are located on the map, Figure 1.

The significant remaining sites of potential hydropower are presented in Table II and are located on Figure 1.

Table I. Installed hydroelectric capacity—island of Newfoundland.

Map Key	Development	Operator	Installed capacity (Mw)	Average Annual Energy Capacity (Gwh)
(1)	Bay D'Espoir	Nfld. & Lab. Power Com.	450	2,300
(2)	Deer Lake and Watson's Brook	Bowater Power Company Ltd.	129	816
(3)	Grand Falls Bishop's Falls	Price (Nfld.) Ltd.	39	290
	21 small hydro plants	Nfld. Light and Power Ltd.	77	375
Totals			695	3,781

Table II. Potential hydroelectric developments—island of Newfoundland.

Map Key	River	Potential of most economic development
4	Terra Nova	144
5	Pipers Hole	124
6	Cat Arm	115
7	Upper Salmon	80
8	Main River	110
9	Bay du Nord	62
10	Upper Humber	47
11	Hind's Brook	50
	Total	722

Electric Power In Labrador. Existing power developments in Labrador, excepting small diesel installations on the coast, all have a hydro base. These developments are listed in Table III and are located on Figure 1.

Table III Hydroelectric developments in Labrador.

Map Key	Development	Operator	Installed capacity (Mw)	Average Annual Energy Capacity (Gwh)
12	Twin Falls		225	1,600
13	Menihek Lake	Iron Ore Co. of Can.	18	104
14	Churchill Falls	Churchill Falls (Lab.) Corporation	5,225	34,500 (by 1975)

The Twin Falls plant was built to serve the mining load in Western Labrador. It will be shut down when the Churchill Falls plant is complete, its waters being diverted to Churchill Falls. Its output will be replaced by Churchill Falls power.

The plant at Menihek Lake serves the mining load at the Schefferville, Quebec operation of the Iron Ore Company of Canada.

The Churchill Falls plant, when completed in 1975, will have an installed capacity of 5,225 Mw with an annual energy capacity of 34,500 Gwh. The major portion of this power will be sold to Hydro Quebec under a long term contract. Up to 300 Mw may be recalled by Newfoundland, while some 225 Mw is reserved for replacement of Twin Falls power.

Remaining potential hydroelectric developments in Labrador are listed in Table IV and located on Figure 1.

Table IV. Potential hydroelectric developments in Labrador.

Map Key	River	Indicated available potential
15	Lr. Churchill	2,400
16	Naskaupi	1,933
17	Eagle	983
18	Canairiktok	817
19	Kenamu	313
20	Paradise	292
21	Red Vine	255
22	Goose	246
23	Fig	233
24	Big	230
25	Minip	216
26	St. Lewis	200
27	Metchin	180
28	North	160
29	Crooked	153
30	Alexis	143
31	Beaver	126
32	Pinware	120
33	Hawke Brook	45
	Total	9,045

Conclusions. The Province is well endowed with hydroelectric resources. The total energy potential of significant undeveloped sites is estimated at seven times the Provincial energy demand in 1972. Unless development of the Labrador rivers can be accomplished at low site costs, however, heavy transmission costs for bringing the power to market will adversely affect the overall economics. There is, of course, the possibility of developing the Labrador resources for use in Labrador but the local load demand would have to develop.

The problem of crossing the Strait of Belle Isle with transmission cables is under review. Alternative methods being investigated include laying the cables on the seafloor or placing them within a tunnel approximately 13 miles long running from L'Anse Amour in Labrador to Savage Point in Newfoundland. Geophysical profiling, detailed bathymetry and core hole drilling have recently been conducted and preliminary results indicate that

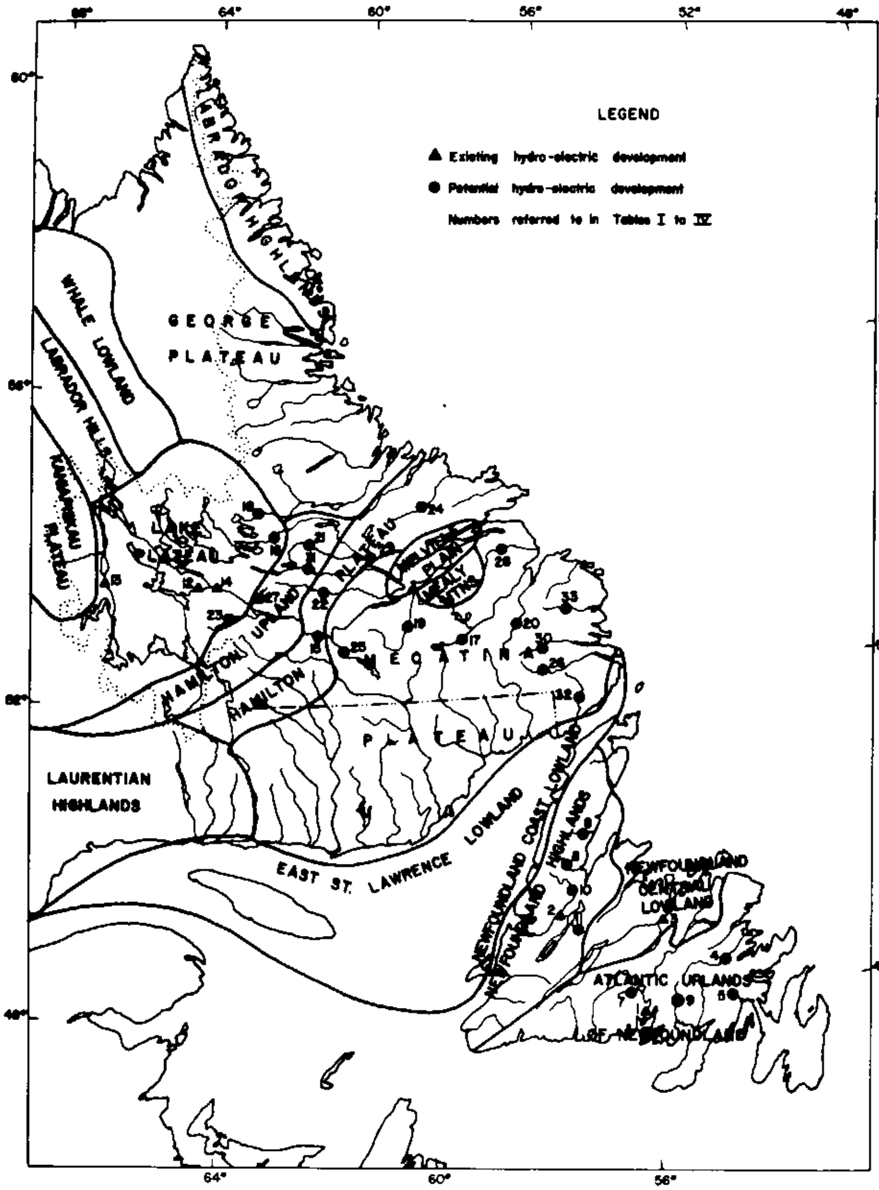

Figure 1
Major hydro-electric sites and physiographic regions—Province of Newfoundland.

either of the two methods of crossing the Strait is technically feasible.

The inherent difficulty of any large power development in the Province stems from the enormous costs involved and the relatively modest Provincial energy requirement, while the availability of this hydro potential suggests an opportunity for the development of energy-intensive industries.

The bulk of the power from any such large scale development may have to be exported from the Province in the initial phases. This would be facilitated by the existence of a national power grid into which power could be fed with the Province having the right to recall energy as the need develops.

Petroleum Resources

Introduction. Petroleum resources of the Province are still in the potential phase, there being no production at the present time. Considerable petroleum potential exists, however, in the post-Mesozoic sediments in the offshore basins of the Atlantic continental margin (Fig. 2). In addition, some petroleum potential is also recognized in the Lower Paleozoic cratonic cover rocks of the St. Lawrence platform and in the Upper Paleozoic, graben-fill basins of Western Newfoundland (Fig. 2). These potential resources are at present undergoing very active and expensive exploration by the oil industry.

Recent Activity. During the present year, four different semi-submersible drilling vessels and one ship-shaped rig were operational on the Province's Atlantic continental shelf. By the year's end, total drilling activity for 1973 will be 28 wells during 30 rig-months, for a total drilled footage of approximately 145,000.

In addition to drilling in the offshore area, one well was drilled on land in the Anguille Mountains of south-western Newfoundland (Fig. 2). This well, Union Brinex Anguille H-98, reached a total depth to 7,581 ft. and took two months to drill.

Some 22 marine geophysical programmes involved 13 companies or consortia and the use of 10 different geophysical vessels.

To date operations have been concluded on 29 exploration wells in the Grand Banks area and three wells are being drilled at present. In addition, three exploration attempts have been made on the Labrador shelf. Of these Labrador holes, one was junked short of its objective; one well was abandoned at target depth and the third well is temporarily suspended pending further evaluation in the 1974 season.

Although results of most of these wells are still confidential, non-commercial hydrocarbon shows have been reported from four wells on the Grand Banks. On the Labrador shelf one well encountered possible indications of hydrocarbons but has not been fully evaluated.

Of these wells with indications of hydrocarbons, perhaps the two most significant were drilled in 1973. On the northern Grand Banks approximately 200 miles east of St. John's, Mobil Gulf Adolphus 2K-41 (Fig. 2) recovered good quality 32° API crude at 268 barrels per day on drillstem test.

The second significant well drilled in 1972, Eastcan *et al.* Bjarni H-81, is situated approximately 50 miles seaward of Makkovik in central

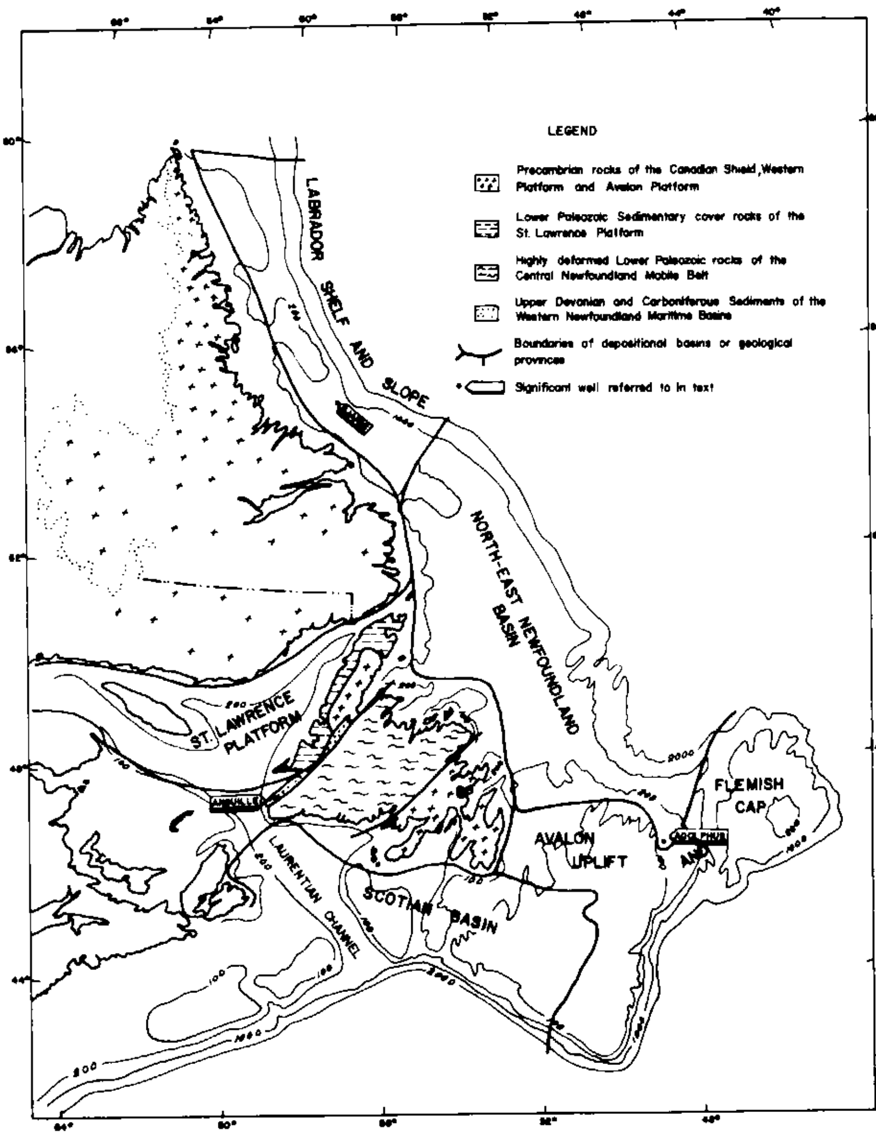

Figure 2
Generalized geological map—Province of Newfoundland.

Labrador (Fig. 2). This well is reported to have encountered a considerable thickness of possibly hydrocarbon-bearing sediments. The evidence of hydrocarbons is based on electric log interpretation only and the well remains to be tested.

Geological setting. First order geological provinces in Labrador and the island of Newfoundland are the Precambrian Shield complex and the northern extremity of the Appalachian chain respectively (Fig. 2).

The Precambrian Shield has been affected by four major orogenies dated at approximately 2480, 1735, 1370 and 955 m.y.b.p. The Precambrian bedrock exposed along the coast of Labrador is predominantly composed of granitic and gneissic rocks. Grant (1972) using seismic profiler surveys, has mapped the contact of the shield rocks with the overlapping coastal plain sediments off the coast of Labrador. This contact is approximately coincident with the pronounced bathymetric feature running parallel to the Labrador coast, the so-called "marginal channel".

The Appalachian system has been affected by the Taconic (Ordovician) and Acadian (Devonian) orogenies as well as by the Maritime disturbance in Carboniferous times. The Appalachian rocks of the island of Newfoundland may be separated into three main tectono-stratigraphic subdivisions (Williams, 1964). These divisions are the Western or St. Lawrence Platform, the Central Mobile Belt and the Avalon or Eastern Platform.

The Western Platform area includes basement complex of Precambrian rocks overlain by an autochthonous platformal sequence of 'Eocambrian', Cambrian and Ordovician rocks. This sequence is in turn structurally overlain by an allochthonous sequence of plutonic, volcanic and sedimentary rocks of similar age. Later rocks include neo-autochthonous upper Middle Ordovician marine strata, Silurian-Devonian marine and transitional facies and dominantly terrestrial Carboniferous red beds and evaporites.

Rocks of the Western or St. Lawrence Platform have some petroleum potential. Fleming (1970) has described the petroleum geology of the Western Platform in some detail. The Carboniferous sequence was in part recently tested by the Union-Brinex Anguille H-98 well (Fig. 2).

The Central Mobile Belt is distinguished on the basis of structural style and the lithofacies of its Cambrian and early Ordovician rocks. Rocks of this belt are not considered to have any petroleum potential.

The Avalon Platform consists chiefly of thick late Precambrian marine and terrestrial sediments and volcanic rocks which are locally overlain by remnants of a Cambro-Ordovician sedimentary cover. As in the case of the central belt, the Avalon Platform is not considered to have any significant petroleum potential.

The seaward extension of the Appalachian system has been traced geophysically by Sheridan and Drake (1968). The system extends north-eastward from Newfoundland to the vicinity of the continental shelf edge where it is replaced by oceanic crust. Grant (1972) has traced the contact between the Appalachian rocks and the younger sediments of the offshore basins off eastern Newfoundland. This contact is marked by a landward-facing escarpment.

History of offshore exploration. The exploration quest for hydrocarbons in the Atlantic offshore basins is remarkable in that the strata which present the primary prospects are entirely unrepresented onshore.

Earliest evidence of the presence of younger sedimentary rocks offshore was provided by the fishing industry. In 1878, the U.S. Fish Commission established a one year program to identify rock samples brought up by trawls from the fishing banks. Microfossils in rocks collected in this program enabled the identification of Tertiary strata in the Grand Banks area. The fishing industry continues to this day to provide much useful lithological and physiographic evidence—especially the Russians (Avilov, 1964). From this early start an increasing amount of evidence began to be collected, pointing to the presence of a sedimentary wedge of considerable thickness on the continental margin. This sedimentary sequence, of probably Cenozoic age, was remarkably similar to the onshore sediments of the U.S. Atlantic Coastal Plain. From the point of view of hydrocarbon exploration, the demonstration of a sedimentary wedge of similar thickness and character to the U.S. Gulf Coast was extremely significant.

In the initial stages of offshore east coast exploration, much of the data was provided by oceanographic institutes, government geological surveys and universities. Industry first entered the field in 1959 when Mobil Oil undertook an aeromagnetic survey of the Sable Island area. The years 1963 and 1964 saw a tremendous upsurge of industry interest in the offshore area and from that time a continuing series of geophysical investigations have been undertaken. Shallow core drilling was carried out in 1965 and exploratory drilling on the Grand Banks commenced in 1966 with two wells by Pan American (now Amoco).

Extensive drilling programs were commenced in 1968 by Shell on the Scotian Shelf and in 1971 by Amoco on the Grand Banks. An excellent summary of the stratigraphic sequence on the Scotian shelf has been published by N. L. McIvor (1972).

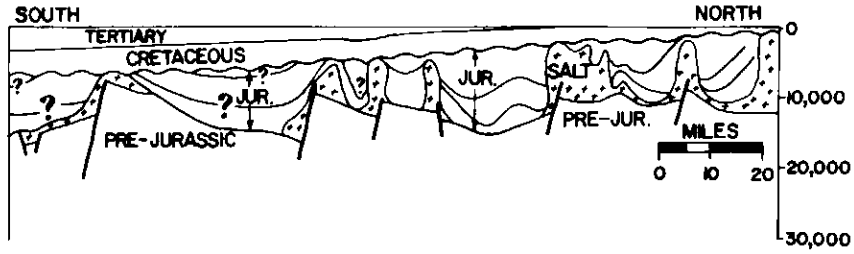

Figure 3
Generalized N-S geological cross-section —Grand Banks (after Ayrton et al, 1973).

A general description of the geology of the Grand Banks has been presented by W. G. Ayrton *et al.* (1973). A thick section of Tertiary, Mesozoic and Paleozoic sediments occurs in two distinct geological sequences separated by an angular unconformity at the base of the Cretaceous (Fig. 3).

The upper sequence of Tertiary and Cretaceous strata is comprised of nearshore marine clastics and thin carbonate horizons. Structure is relatively simple with a regional gentle seaward dip, disturbed locally by salt dome structures. Thickness varies from zero at the depositional edge to a maximum of 15,000 feet.

Beneath the unconformity, the structure is markedly different. Jurassic and older formations are preserved in structural basins bounded by faulted basement blocks. Structural types within the basins include salt domes, salt ridges, faults, drape folds over basement blocks and major truncations at the unconformity. Lithologies within the sub-basins include Carboniferous terrestrial clastics and shallow Jurassic evaporites; a Triassic or early Jurassic red shale unit, followed by Jurassic evaporites, carbonates and clastics. Total thickness of the Jurassic sequence may be in excess of 20,000 feet.

There is a general geological similarity between the Grand Banks and the Scotian Shelf suggesting that these areas are one depositional province, here termed the Scotian Basin (Fig. 2). The intervening bathymetric feature between the two geographic areas—the Laurentian Channel—appears to be an erosional feature of no major tectonic significance.

The basic stratigraphic sequence of the Scotian Basin is consistent with the progressive marine transgression of a trailing continental edge. Response of the basement to initial rift movements of the Atlantic floor in Triassic-Jurassic time, resulted in brittle fracture and the creation of depositional sub-basins. These sub-basins were either new grabens or reactivated late Devonian-Carboniferous basins. Some coast-paralleling basaltic intrusions are associated with this initial phase of rifting.

North of the Scotian Basin, a basement high with thin sedimentary cover separates the Scotian Basin from the East Newfoundland Basin. This basement high, termed the Avalon Uplift and Flemish Cap (Fig. 2), has some surface expression where outcrops occur at the Virgin Rocks and Eastern Shoals.

No geological information has yet been made public from exploration in the East Newfoundland Basin and the Labrador Basin. Separation of these basins, one from the other, is done on basis of the change in basement from Appalachian to Canadian Shield rocks from south to north respectively. Structural style of the basement would be expected to differ between these basins. Expected stratigraphic sequences would again involve the gradual transition from terrestrial to open marine rocks as in the Scotian Basin. The age of the sequence in the Labrador basin may well be relatively young compared with that of the Scotian basin, due to the later opening of the Labrador Sea compared with the main North Atlantic Ocean.

A recent compilation on the petroleum resources of Canada was made by the Geological Survey of

Canada and published in "An Energy Policy for Canada—Phase I" by the Department of Energy, Mines and Resources in Ottawa. Based on this compilation, an estimate of Newfoundland's potential recoverable petroleum resources has been made totalling some 58.41 billion barrels oil equivalent (Table V). The modest potential of the St. Lawrence Platform and Maritime Basins of western Newfoundland has not been included in this total.

Table V. Recoverable Petroleum Potential—Atlantic Basins of Newfoundland and Labrador.

Basin	**Ultimate Recoverable Oil** (billions of barrels)	**Ultimate Recoverable Gas** (trillions of cubic ft.)	**Ultimate Recoverable Oil Equivalent** (billions of barrels)
1) Scotian Basin			
Shelf	1.8	14.0	4.20
Slope	2.7	21.0	6.31
2) Avalon Uplift—Flemish Cap			
Shelf	0.3	1.9	0.66
Slope	2.3	12.9	4.41
3) E. Nfld. Basin			
Shelf	10.2	60.9	20.37
Slope	5.3	31.3	10.50
4) Labrador			
Shelf & Slope	5.5	38.7	11.96

Conclusions. The sedimentary basins of Newfoundland, especially the offshore Atlantic basins, contain an enormous petroleum potential. Exploration to convert this potential into producable reserves is being actively pursued with some indications of ultimate success. The likelihood of a major find being made in the area within the next 10 years has been estimated at over 90 per cent.

The Atlantic marine area is one of extreme and expensive operating conditions. Environmental difficulties include deep water, hostile sea-state, sea-ice and icebergs. In order to overcome these natural obstacles, considerable research and development of technological advances has been, and continues to be, vital.

Due to the high operating costs in the area, any discoveries will have to be large to be economically viable. Projected production rates of such a discovery will be much larger than the Province's petroleum requirements, putting Newfoundland into an exporting role. With the existing energy deficiency of Eastern Canada, in particular, and Eastern North America, in general, any production surplus to Newfoundland's needs will find a ready market. Any projects to extend the Western crude pipeline system into Eastern Canada should recognize this possibility and the system should be designed to allow a westward oil flow when necessary.

References

Avilov, I.K., 1964, Bottom contours and the nature of grounds and their significance for trawl fishing: ICNAF Environmental Symposium, Rome 1964. (*in:* ICNAF, Spec. Publ. no. 6, 1965, p. 81-789).

Ayrton, W.G., *et al.*, 1973, Regional geology of the Grand Banks: paper presented to the CSPG and CSEG in Calgary, April 18, 1973. Reported in Oilweek magazine, April 23, 1973 and the Daily Oil Bulletin, April 23, 1973.

Fleming, J.M., 1970, Petroleum exploration in Newfoundland and Labrador: Mineral Resources Rept. no. 3: Dept. Mines, Agriculture and Resources, Province of Newfoundland and Labrador, 118 p.

Grant, A.C., 1972, The continental margin off Labrador and Eastern Newfoundland—morphology and geology: Can. Jour. Earth Sci., v. 5, no. 11, p. 1394-1430.

McIver, N.L., 1972, Cenozoic and Mesozoic stratigraphy of the Nova Scotia Shelf: Can. Jour. Earth Sci., v. 9, no. 1, p. 54-70.

Sheridan, R.E., and C.L. Drake, 1968, Seaward estension of the Canadian Appalachians: Can. Jour. Earth Sci., v. 5, p. 337-373.

Williams, H., 1964, The Appalachians in northeastern Newfoundland—a two sided symmetrical system: Am. Jour. Sci., v. 262, p. 1137-1158.

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