Exploration in the Parry Islands and Cornwallis Fold Belts: Canadian Arctic

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Abstract

Introduction

Huge, highly visible folds in the Arctic Fold Belt (Figure 1) attracted interest from explorerers from the earliest stages of Arctic oil exploration. The Parry Islands and Cornwallis fold belts on Melville and Bathurst Islands offer prospects for large hydrocarbon accumulations, but exploration to date has proven to be remarkably unsuccessful. What has gone wrong? Has the drilling all been in the wrong places or is there some overriding factor that has destroyed hydrocarbon accumulations. The oil discovery at Bent Horn is on a structure distinctly different from the structures in the fold belts.

Exploration History

Pioneering surface geological work by the geological survey of Canada (Fortier et al., 1963) set the stage for the great land rush that started in 1960 and ran through 1968 by which time almost every available acre of land, sea and ice cap in the Canadian Arctic was held under exploration permits. Onshore permits on Melville and Bathurst Islands were some of the earliest permits filed on. Onshore structures are readily mappable from the air and are well defined on seismic as well. Limited offshore seismic was less successful. Devonian clastics and some carbonates outcrop on Melville, Bathurst and adjacent islands. The fold belt is characterized by long, sinuous folds that are developed as decollements on the Ordovician Bay Fiord salt. Thrust faulting is a component of the deformation, but no far travelled thrusts are developed.

The first three exploratory wells in the arctic, Winter Harbour, Resolute Bay and Caledonian River were drilled between 1961 and 1963 on locations based only on surface geology on Melville Island, Cornwallis Island and Bathurst Island respectively (Figure 1). By 1967 Panarctic Oils Ltd. had negotiated a series of farmin agreements covering most of the onshore permits. These agreements had strict time limits on when the earning wells were required. In the heady days following the Prudhoe Bay oil discovery Panarctic was able to farm out some of their earning wells to meet the time constraints and budget limitations. Panarctic farmed out some of their earning wells on Melville and Bathurst Islands to King Resources and British Petroleum. Sun subsequently took over the King obligations. Early dry holes at Towson Point (POL), Hotspur (BP), Kitson River, Allison River and Young Inlet (Sun) were drilled with minimal or no seismic control. Of these wells Towson Point reported oil stained Blue Fiord carbonate, but the Blue Fiord outcrops on the structure. There is an anecdotal report (Kennedy, 1988) that Young Inlet well found soft bitumen.

With most of the obligatory drilling done, Panarctic turned their own exploration efforts to the western part of Melville Island and drilled seismically confirmed surface structures at Zeus and Apollo, both of which were dry. Seismic mapping of a large reef complex on Cameron Island in early 1973 changed the focus of exploration toward that area. Following the discovery of oil in the Devonian Blue Fiord carbonate in early 1974 attention was directed to oil prospects on Cameron

Island and this occupied an inordinate portion of Panarctic's attention and resources from 1974 through 1986. Attempts to extend the oil play from Cameron Island to nearby Parry Islands folds resulted in some small oil and gas shows from Upper Devonian clastics, but no significant flows were achieved. Subsequent structural tests, particularly the deep test at Sabine Bay that evaluated both the Thumb Mountain reservoir on a Parry Islands fold and the Eleanor River reservoir on a huge sub-salt structure below the Bay Fiord salt. No success was achieved in this deep drilling program that was targeted to find very large gas resources to support the proposed Polar Gas Pipeline.

The stratigraphy and structure of the Parry Islands, Cornwallis and Canrobert Hills fold belts has been discussed by many authors, the latest relevant publications include Fox, 1985, Harrison, 1995, Trettin, 1991 and Anglin and Harrison, 1999.

Results of Exploration

Potential reservoirs in the Parry Islands and Cornwallis fold belts are illustrated on the schematic cross section (Figure 2). They include Eifilean Blue Fiord carbonates, Ordovician Read Bay/Allen Bay carbonate buildups and the Irene Bay/Thumb Mountain carbonates in the off reef areas. Eleanor River carbonates are found below the Bay Fiord salt or its adjacent carbonate/evaporite equivalent. Upper Devonian sands tested gas at at low flow rates at Winter Harbour. Consistent, high-quality reservoirs have not been found. Source rocks are present, particlularly in the shale immediately above the carbonate section. Source rocks are generally gas-prone and the level of maturation increases toward the west (Harrison, 1995 and Anglin, 1999).

The Parry Islands fold belt occupies a large part of Melville and Bathurst Islands and the smaller adjacent islands (Figure 3). Parry Islands folds are confined to the area of the Bay Fiord salt basin and the axis of the major structures are shown in red. A large carbonate complex of Blue Fiord and Read Bay/Allen occupies northern Melivlle Island and extends to the northeast to Cameron Island. The Blue Fiord carbonates extend basinward from the underlying Read Bay/Allen Bay reef.

West of the Bay Fiord salt basin structures of the Canrobert Hills fold belt tested Read Bay/Allen Bay, Thumb Mountain and Eleanor River reservoirs at Kitson River, Zeus and Apollo, but only water was recovered.

On the southern margin of the Bay Fiord salt basin an arcuate trend of Read Bay/Allen Bay reefs extend across Melville Island and then under Viscount Melville Sound before connecting up with the outcrop of these units on Cornwallis Island east of the map (Figure 3). In this area the Blue Fiord carbonate complex lies shelfward from the Read Bay/Allen Bay reef edge. It is present on northeastern Banks Island where oil cut mud was tested in Chevron's Parker River well. It is expected to extend beneath Viscount Melville Sound to the outcrops on Cornwallis Island.

The structural style of the Parry Islands folds are illustrated by the cross section over the Stokes Range and Beverley Inlet structures (Figures 4 and 5). Each of these tests was well-located using seismic control and tested water from the prime Thumb Mountain reservoir.

In total there have been ten diagnostic tests of Thumb Mountain, Read Bay/Allen Bay and Blue Fiord reservoirs on Parry Islands and Cornwallis folds and in the Canrobert Hills. In addition, thirteen

non-diagnostic tests were drilled that were; not deep enough, found no top-seal or were drilled off-structure. Only marginal reservoir rocks were found and the dominant result has been minimal water recoveries or mud. Bitumen and oil staining have been reported, but only traces of hydrocarbons have been found. The common factor for these structures is the latest Devonian age of the folding and thrust faulting followed by uplift and deep truncation of the folds in the Upper Paleozoic. The shale seals on the structures may have been fractured and any trapped hydrocarbons lost.

Only one large structure, Sabine Bay, has tested the Eleanor River section on a 250 square mile closure beneath Bay Fiord salt. No effective reservoir was found in this test (Meneley, 1976), but this type of sub-salt structure offers the best chance for preservation of entrapped hydrocarbons. Tests of the Eleanor River at Kitson River, Apollo and Eldridge Bay lay outside of the Bay Fiord salt basin; where reservoir was developed, it was water bearing.

The north south striking Cornwallis folds are older than the Parry Islands folds. Figure 6 illustrates the complete discordance of structures between the Eleanor River and Thumb Mountain on the Caledonian River anticline on Bathurst Island. If reservoir is developed at the top of the Eleanor River section and source rocks are available, the deep Caledonian River structure could house a significant hydrocarbon accumulation; probably gas. The Caledonian River J-34, drilled in 1963, did not test the uppermost oil stained dolomite in the Thumb Mountain/Irene Bay and did not drill deep enough to evaluate the sub-salt Eleanor River section (Meneley, 1976). This is one of the non-diagnostic tests in the fold belts, but environmental constraints shut down exploration in this area.

The Bent Horn oil discovery in the Blue Fiord limestone on Cameron Island is outside of the Parry Islands fold belt and is on a distinctly different style of structure (Figure 7). Bent Horn was not uplifted by Parry Islands folding and the structure is not expressed at surface. At least two slices of Blue Fiord are thrust to the northeast. After thrusting the section was cut by a series of major normal faults that place Upper Devonian Parry Islands section in contact with the Blue Fiord with about 3000 m of vertical displacement. The trend of the normal faults is parallel to the older thrusts. The presence of low velocity Canyon Fiord and younger section combined with the transition from thick permafrost to no permafrost at the shoreline produced extreme velocity variations in the seismic data. This was problem was eventually solved, but was the cause of much frustration in the initial drilling.

Paleo-karst and fractured reservoirs were found in some of the wells drilled on southwest Cameron Island and this indicates subareal exposure of the Blue Fiord prior to deposition of the Cape de Bray shales. Reservoir development is not consistent and in the absence of caverns or fractures no flow of oil could be obtained in spite of oil saturation, bleeding and staining in the wells. The most northeasterly well on the Blue Fiord reef, Cape Fleetwood, reported bitumen plugged porosity similar to wells in the Parry Islands fold belt. It will be important to determine if the bitumen is from the same source as the Bent Horn oil or whether there are two petroleum source rocks involved. In total, 13 wells, including whipstocks, were drilled on Cameron Island, but only one well produced a sustained flow of oil.

The Bent Horn field produced about three million barrels of 43° API oil that had a very low gas/oil ratio from a single producing well Bent Horn A-02. The field was produced seasonally and the oil was used as fuel for some drilling operations and at mines in the area, but mainly exported to Montreal. The producing well was abandoned in the fall of 1996 due to falling reservoir pressure.

Now What?

Assessment of the undiscovered hydrocarbon potential in the Parry Islands and Cornwallis fold belts presents a daunting challenge. There are large well-mapped structures and no shortage of source rock at maturation levels that would likely produce gas. While quality reservoirs are lacking there have been enough to be important because of the large structures. A key cause of failure appears to be the lack of top-seal due to the uplift and erosion of the structures.

Where can go to get good top-seal? Play the sub-salt Eleanor River carbonate reservoir providing reservoir can be located. For example are there other large sub-salt structures that could be tested. Are there other locations available on the huge Sabine Bay structure? Did we give up too easily on that structure?

Is there a play for Upper Paleozoic reservoirs on and around Cameron Island on listric fault structures analogous to the Hibernia structure offshore Newfoundland? This would be particularly important if the oil source for Bent Horn was established to be Upper Paleozoic.

Conclusions

The land is available, access is relatively easy by Arctic standards and the potential prospects are large. The fold belts are strategically positioned along the market access route for gas from the Sverdrup Basin. What needs be done is to develop a new exploration model to address the remaining targets. Continuing the status quo is not good enough.

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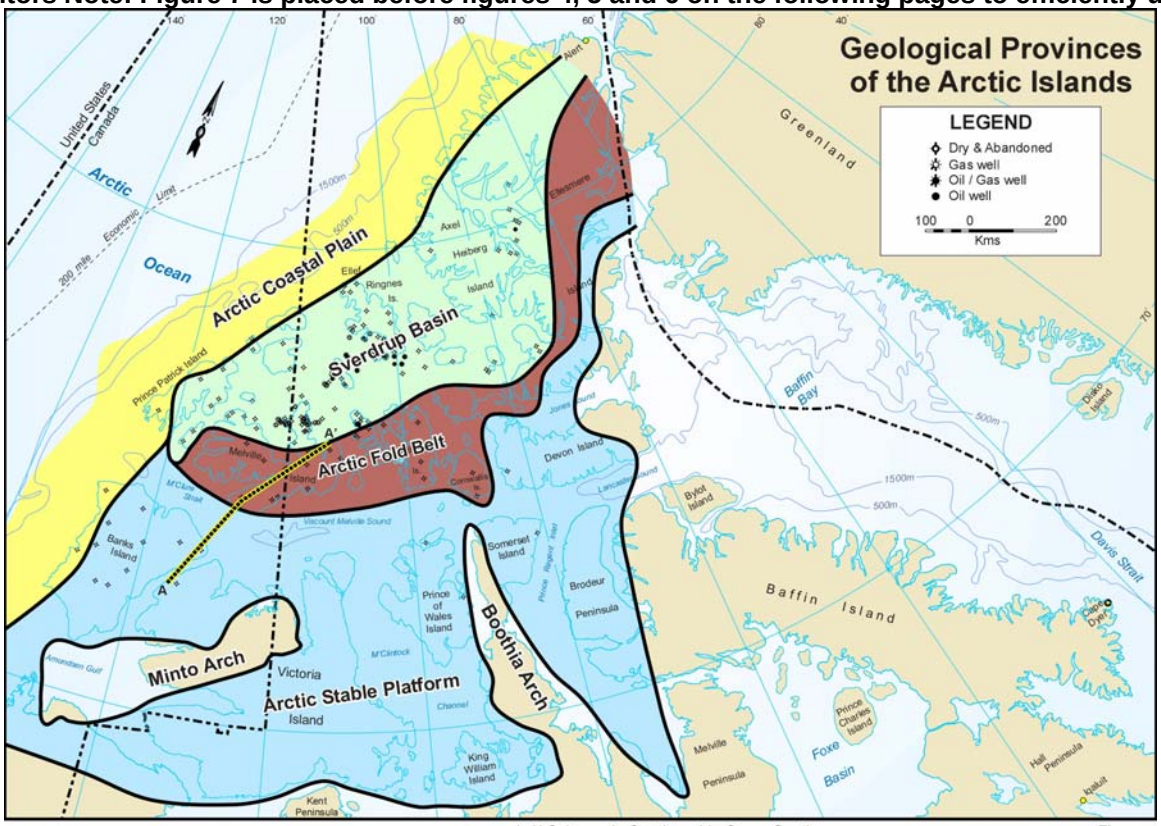
Editors Note: Figure 7 is placed before figures 4, 5 and 6 on the following pages to efficiently utilise space.



Modified from Trettin, 1991 Fig. 1 and CGPC, 2001 A-A' Schematic Stratigraphic Cross Section Figure 1

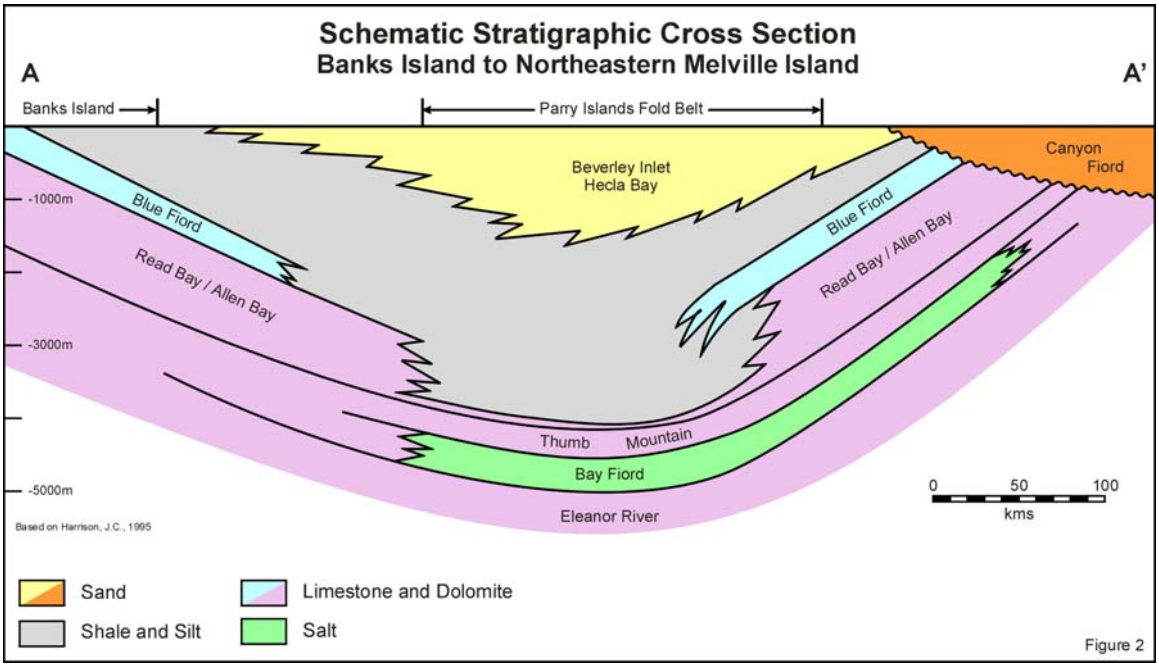


Figure 2

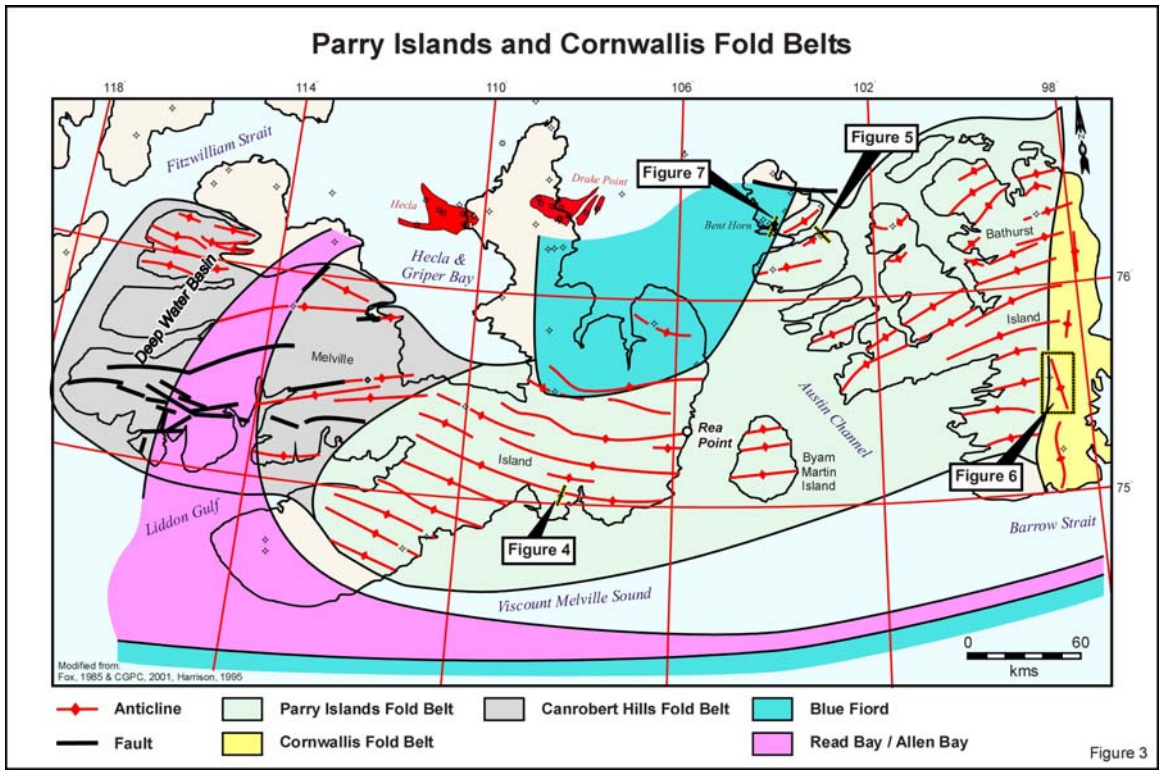


Figure 3

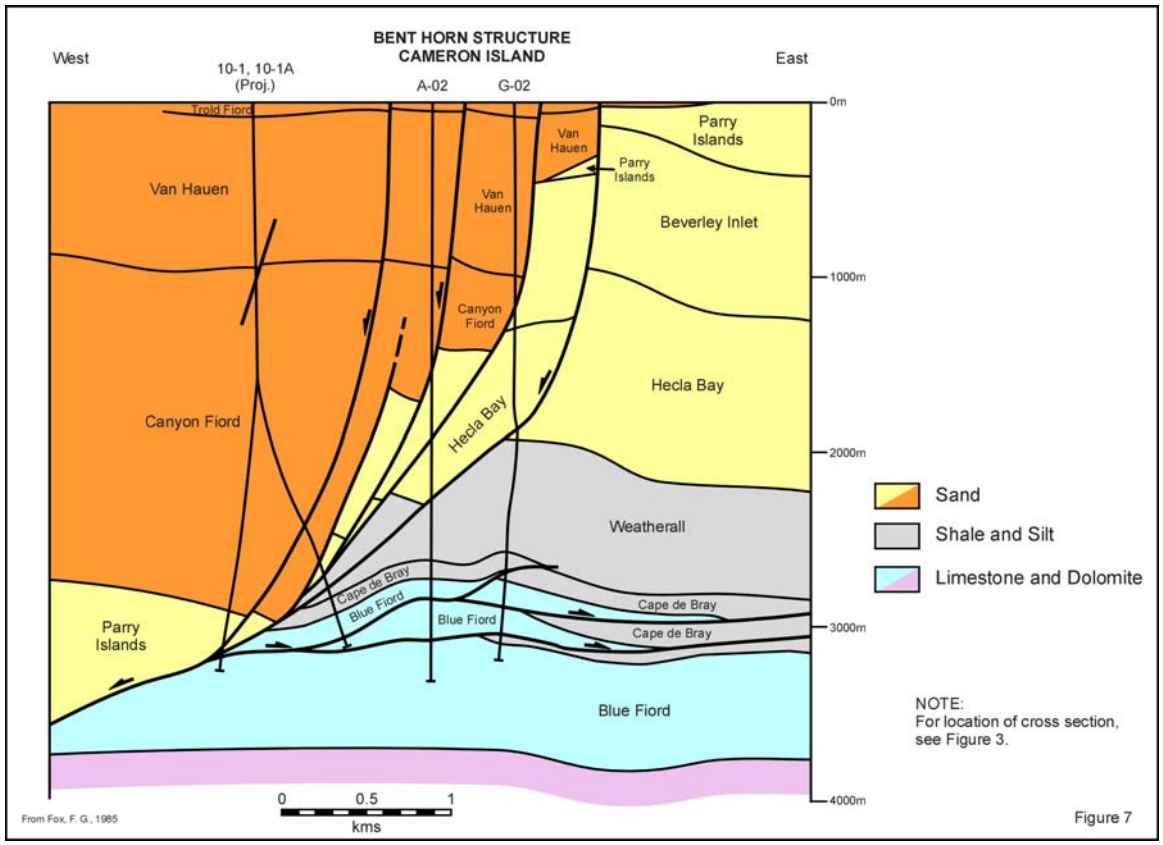


Figure 7

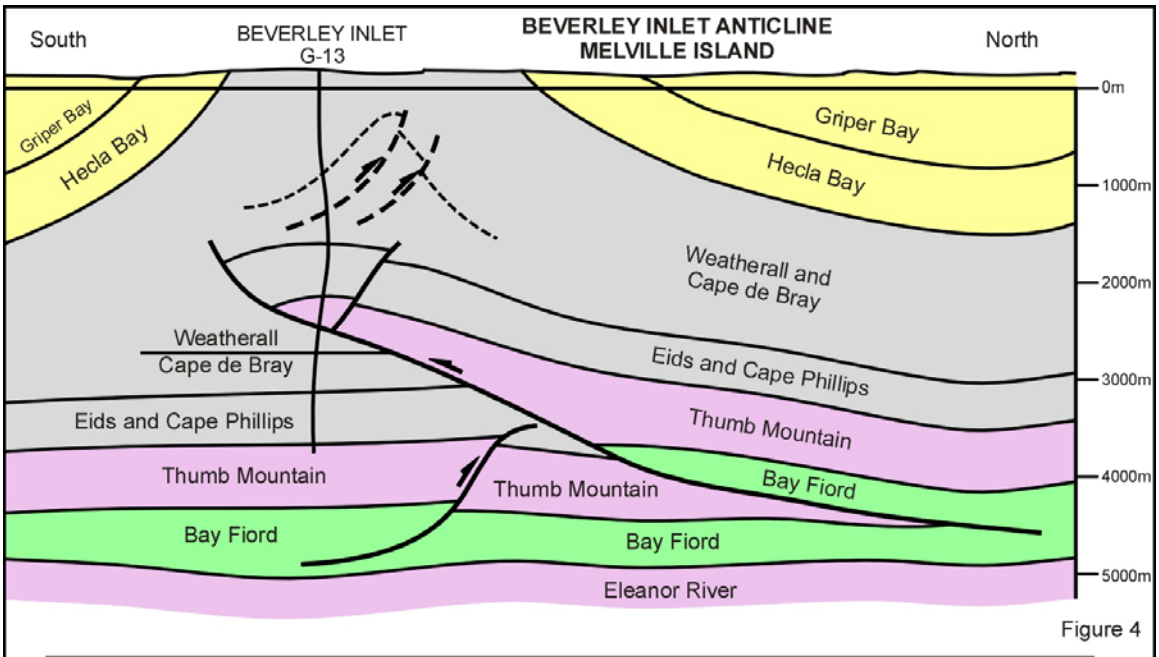


Figure 4

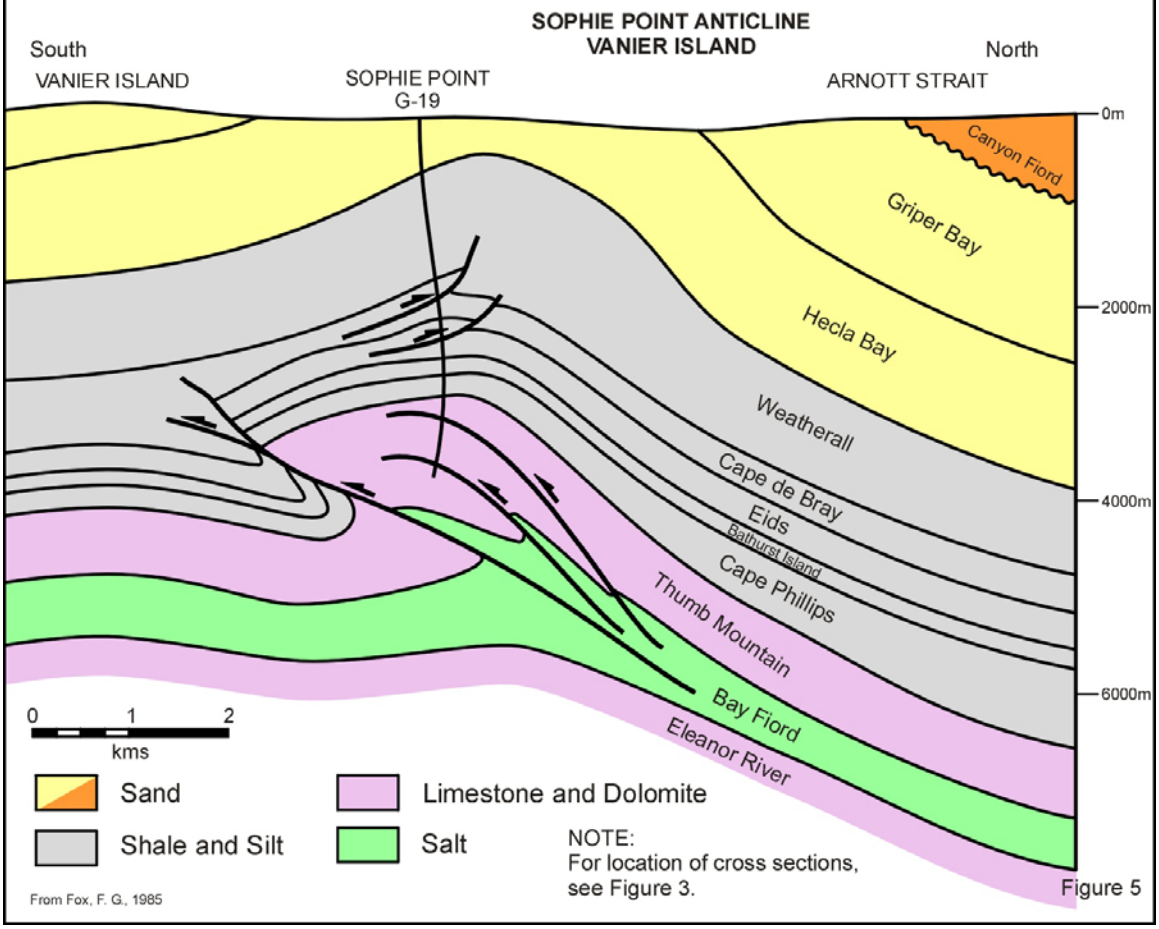
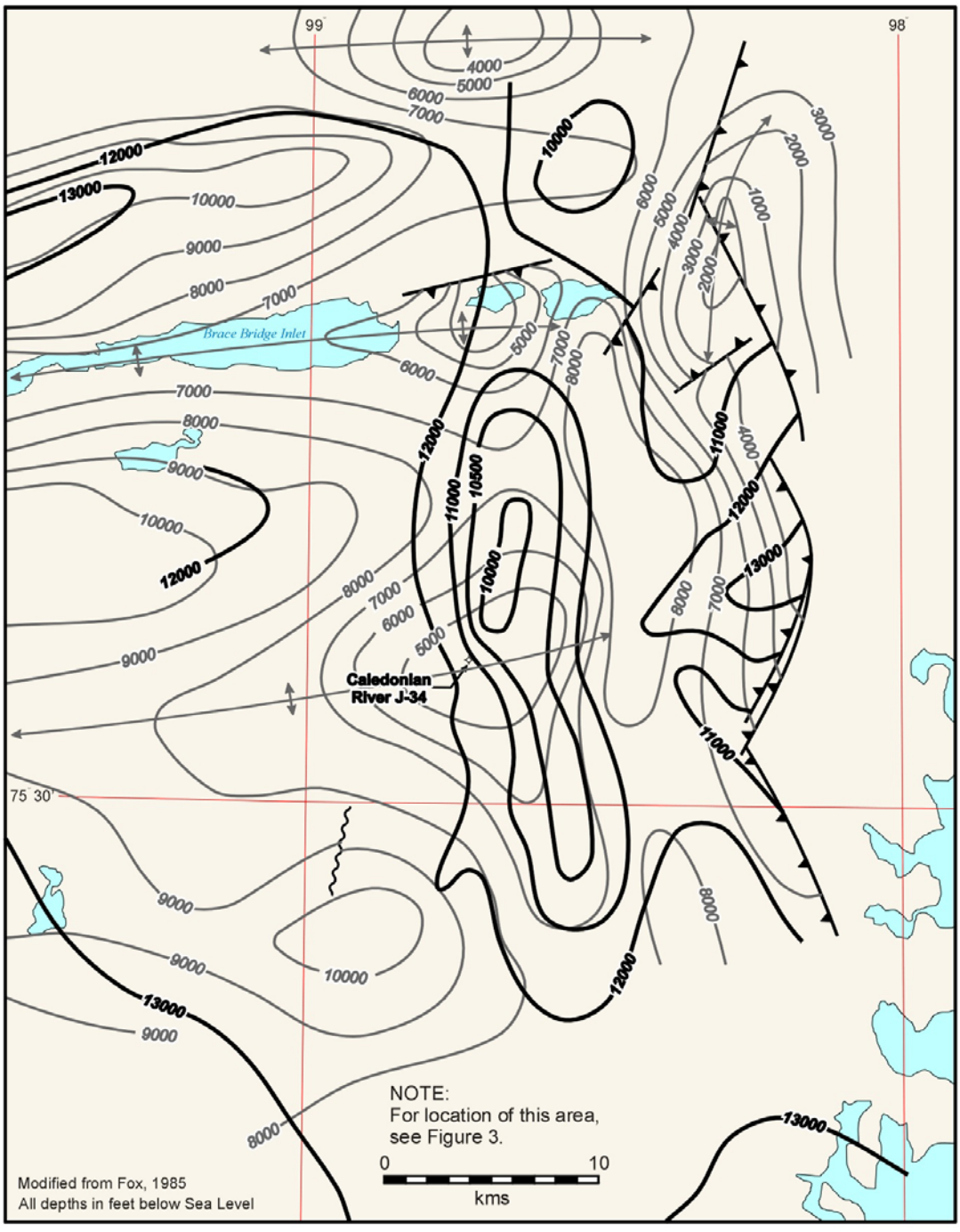


Figure 5



Seismic depth structure contours, Caledonian River Anticline.
Heavy contours on Eleanor River (base of salt), light contours on Thumb Mountain.

Figure 6