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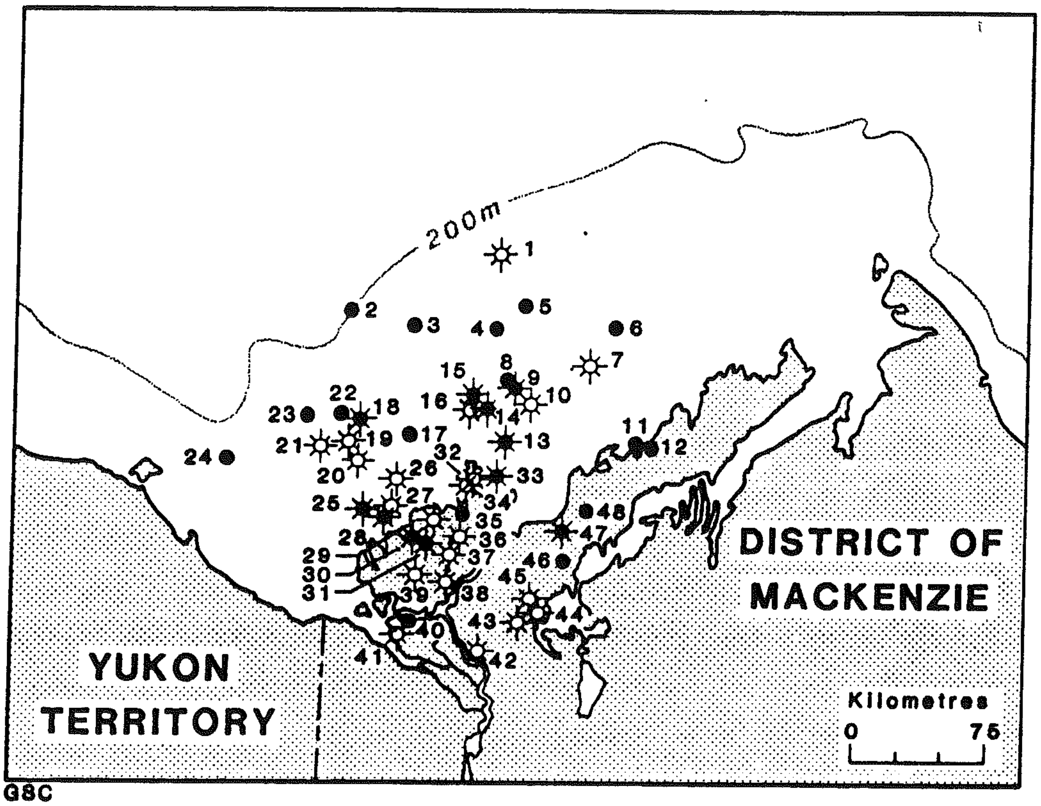

Figure 1 Map of significant discoveries

Exploration in the Mackenzie Delta - Beaufort Sea region has resulted in 49 significant oil and gas discoveries (Fig. 1). The total quantities of gas and oil discovered to date, plus the estimated remaining potential, make this region one of the most attractive petroleum provinces in North America today. The revised estimates presented in the following report are based on a thorough basin analysis by GSC and COGLA scientists, examining available geology, geophysics, geochemistry and petroleum geology.

From this analysis 20 exploration plays were identified and quantified, using advanced probability methods developed by the Geological Survey of Canada. The 20 exploration plays occur in 4 groups, distinguished by geographic, geologic and developmental criteria. The **Onshore and Shallow Offshore** group comprises 8 plays that exist in the Richards Island, South Delta and Tuk Peninsula areas, plus their extensions into adjacent shallow water. The plays include Paleozoic, Mesozoic and Tertiary targets. The **Offshore Delta** group of 4 plays forms a narrow fairway in which several major oil and gas discoveries have been made extending from the Tarsiut to the Amauligak fields. This group occurs in about 25 metres of water, and exists in rocks of similar Tertiary age and with similar structural style. The **West Beaufort** group of 3 plays differ significantly from the main delta plays in the structural style and grain of the area, the age of reservoirs and a different oil generation regime. The **Deep Water and Other** group consists of 5 plays, dominated by two plays that occur in deep water beyond the Offshore Delta and West Beaufort groups. These two Tertiary plays rely on deep-water sedimentation for reservoir opportunities. The other three plays are combined with this group because they are truly conceptual and will probably not attract serious exploration for some time.

The quantities of gas and oil discovered and the remaining potential are tabulated in Figure 2. Both categories

MACKENZIE DELTA-BEAUFORT SEA RESOURCES				
PLAY GROUP	OIL $\bar{X}$ (10^9 BBLS)		GAS $\bar{X}$ (TCF)	
	RESERVES	POTENTIAL	RESERVES	POTENTIAL
ONSHORE-SHALLOW OFFSHORE	0.251	1.05	7.48	14.46
OFFSHORE DELTA	0.910	1.2	3.29	11.4
WEST BEAUFORT	0.226	1.9	0	12.5
DEEP AND OTHER	0.357	1.1	0.88	17.7

GSC

Figure 2 Tabulation of mean values of reserves (discovered resources) and potential for groups of plays

of resource are estimated in a probability context and expressed as cumulative frequency distributions. The values shown in Figure 2 represent the arithmetic means ($\bar{X}$) of the distributions (illustrated in detail in the body of the report). Highlights from the analysis of discovery and potential include:

Onshore-Shallow Offshore: About 20 percent of the oil resources estimated for this group has already been discovered. The 251 million barrels discovered exists in 14 fields the largest being Adgo, Kumak, Ivik North and Atkinson. About 1 billion barrels remains undiscovered, dispersed in about 150 pools. For gas almost one third of the total 22 TCF has been discovered in 14 fields. These include the near-giant Taglu field plus Parsons and Niglintgak, each of which contain more than 500 Bcf gas. More than 14 TCF of gas remains undiscovered distributed in more than 170 pools. This group of plays has abundant geological diversity, is structurally complex and is a challenge for modern seismic methods. Resources are expected to be dispersed in a large number of traps, compared to other play groups, but still constitute very attractive on-land exploration prospects relative to remaining conventional western Canada basin targets provided a production infrastructure is developed in the area.

Offshore Delta: The giant Amauligak oil discovery dominates this group of plays. More than 40 percent of the 2.1 billion barrels of oil estimated to exist in this play group has been discovered in 7 fields. Most of the oil discoveries have associated gas which along with about 120 predicted but undiscovered pools, amount to substantial gas resources of almost 15 TCF. The success rate in this group of plays is about 50 percent, making this trend an outstanding area of opportunity by any standards. Remaining targets in this play are expected to include thick and highly productive pay zones in relatively simply but faulted structures.

West Beaufort: This is the least explored of the play groups but is estimated to contain about the same total oil resource as the Offshore Delta group. The discovery of a major oil field at Adlartok has identified a whole new family of potential opportunities including at least one giant-sized accumulation. This series of plays will be the "new frontier" within the region, containing numerous structures in somewhat deeper water (50-100 m) than those of the main Offshore Delta plays. All three plays extend into Alaska where one is being tested just west of 141° W longitude.

Deep Water and Other: Only one of the five plays in this group have been tested, resulting in several oil and gas discoveries. The Kopanoar oil and Kenalooak gas discoveries stand out as large but probably beyond economic development for the foreseeable future. The problem is one of thin discontinuous pay zones in broad structures located in water depths greater than 100 metres. The two deep-water plays are expected to contain large resources estimated at mean expectations of 1.5 billion barrels of oil and almost 20 TCF of gas.

Given the uncertainties associated with the plays in this group, and lack of comprehensive testing of structures, it is probably appropriate to look at speculative levels of potential for this group such as 2 billion barrels of oil and 30+ TCF of gas.

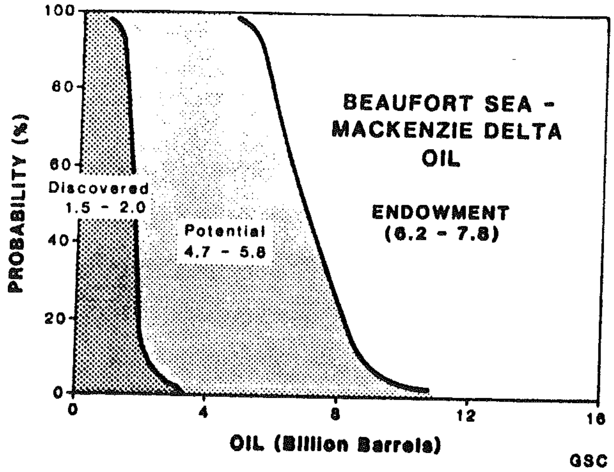

Figure 3 Distribution of estimates of oil endowment for the Mackenzie Delta-Beaufort Sea region. Values given are for the 75 and 25 percent probability levels

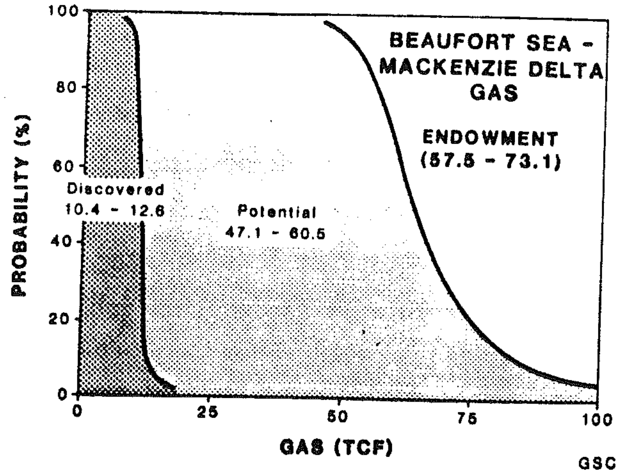

Figure 4 Distribution of estimates of gas endowment for the Mackenzie Delta-Beaufort Sea region. Values given are for the 75 and 25 percent probability levels

Total Regional Endowment

Figures 3 and 4 show the total quantities of oil and gas estimated to exist in the 20 exploration plays of the Beaufort Sea -Mackenzie Delta region. For oil (Fig. 3) it is estimated that between 6.2 and 7.8 billion barrels (75 to 25 percent probability range) may exist in the region. The mean expectation is 7.1 billion barrels. From 1.5 to 2.0 billion barrels, or about 24 percent, of this endowment are shown as discovered resources. The Figure also indicates a substantial undiscovered potential of between 4.7 and 5.8 billion barrels. For gas, it is estimated that between 57.5 and 73.1 TCF of gas may exist in the region (75 to 25 percent probability range). The mean expectation is 68 TCF. Approximately 17 percent of this endowment is in the already discovered category, leaving a very large undiscovered potential of from 47.1 to 60.5 TCF. Much larger values of undiscovered gas are shown at low probability levels.

The values quoted are those of the regional resource endowment based on our current geoscience knowledge. Although useful as a comparative measure of the total quantities that are estimated to exist in a basin, the values are not discounted for future economic viability, likelihood of discovery or difficulty of exploitation. They assume only current levels of technology in terms of recovery of resources. This lack of "discounting" may render the regional endowment values misleading for planners and economists who have to be concerned about sizes of individual fields and the likelihood of their discovery and development within some limited time-frame. The manner in which the endowment estimates have been prepared facilitates this requirement while still retaining the scientific and statistical integrity of the process. As an attempt to cast the results of the estimation process into a more useable product an attempt has been made to show how the endowment is dispersed in terms of size, and to identify the elements of the endowment most likely to be of "current" interest.

Resources of Current Interest

Although it would be inappropriate here to pre-judge the future economics of this region one could recognise that some elements of the total resource will be the focus of exploration for the next 20 years, assuming some current level of exploratory activity. Accordingly plays of the Onshore-Shallow Offshore, Offshore Delta and the oil plays of the West Beaufort play groups were identified as those most likely to receive attention in the near future (unshaded elements of Figure 2). For each of these elements the distributions of estimates have been examined in terms of how much of the resources exists within arbitrarily-selected size ranges. The results, described in Figures 5 to 9, are an attempt to identify the component of the restricted endowment that might be of "current" interest from a planner's viewpoint.

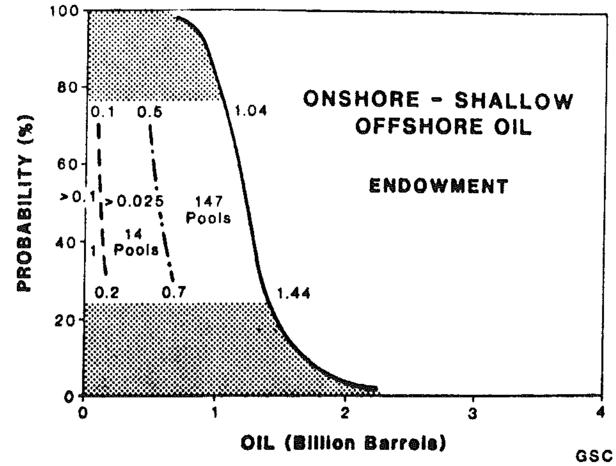

Figure 5 Distribution of oil endowment for the Onshore-Shallow Offshore group of plays, showing impact of predicted pool sizes

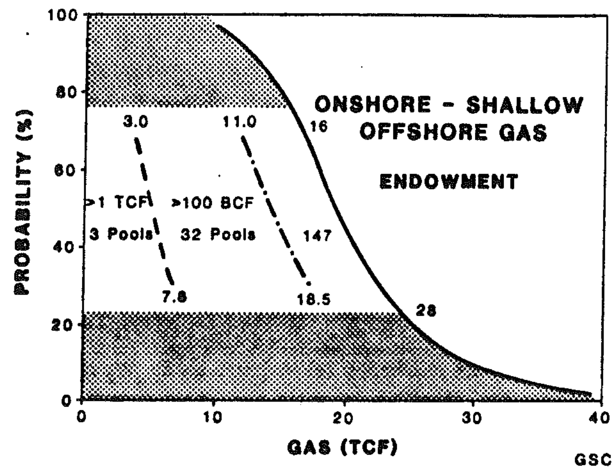

Figure 6 Distribution of gas endowment for the Onshore-Shallow Offshore group of plays, showing impact of predicted pool sizes

Onshore-Shallow Offshore: The portion of the total oil endowment for this group of plays that occurs in sizes greater than 100 million barrels, between 25 and 100 million barrels and in pools smaller than 25 million barrels is shown in Figure 5. Only one pool greater than 100 million barrels is indicated, and 14 pools greater than 25 million barrels. Together these

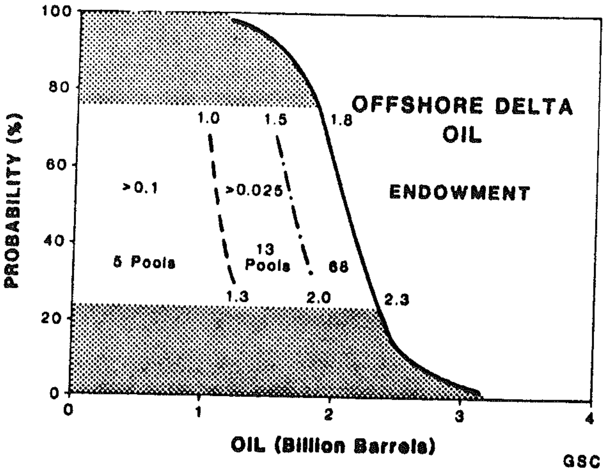

Figure 7 Distribution of oil endowment for the Offshore Delta group of plays, showing impact of predicted pool sizes

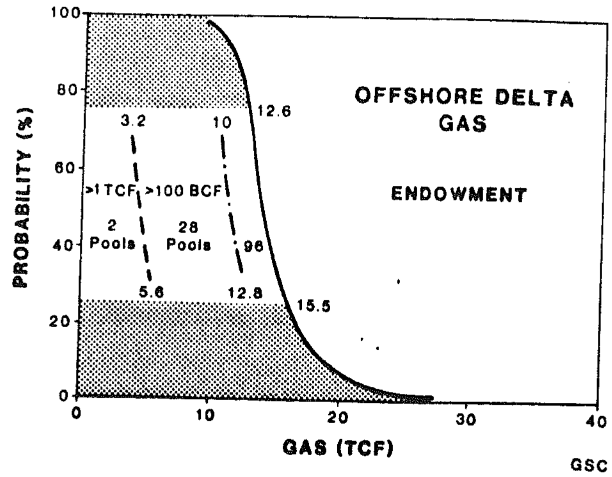

Figure 8 Distribution of gas endowment for the Offshore Delta group of plays, showing impact of predicted pool sizes

15 pools would contain about one half of the total, reducing the mean endowment from 1.3 billion barrels to just 738 million barrels if those two size ranges were the only ones of current interest. Figure 6 shows how much of the total gas endowment of 16 to 28 TCF occurs in pools greater than 1 TCF, in pools from 100 Bcf to 1TCF in size, and how much in pools smaller than 100 Bcf. Also shown are the expected number of pools in each size category. The analysis indicates only three pools larger than 1 TCF, two of which (Taglu and Parsons) are already discovered. The second size range consists of 32 pools that in total contain from 8 to 10.7 TCF suggesting that there are many potentially attractive targets for exploration in the onshore area. As seen in Figure 6, the remaining large number of small pools do not add significant resources. If one were to consider only the pools in the larger two size ranges to be of short term interest then the mean gas endowment for onshore-shallow offshore group of plays would reduce from 22 to 15.7 TCF.

Offshore Delta: Using the same criteria as described above, the gas and oil resources of the Offshore Delta play group are shown in Figures 7 and 8. Figure 7 shows how the oil endowment is distributed by size. Five major pools are anticipated in the larger than 100 million barrel range, one of which (Amauligak) is already discovered. This size range constitutes almost one half of the endowment. A combination of the larger two size classes would include 18 pools containing from 1.5 to 2.0 billion barrels. Thus the overall mean endowment would reduce from 2.1 to 1.8 billion barrels in the current interest category. For gas, 2 pools greater than 1 TCF are indicated,

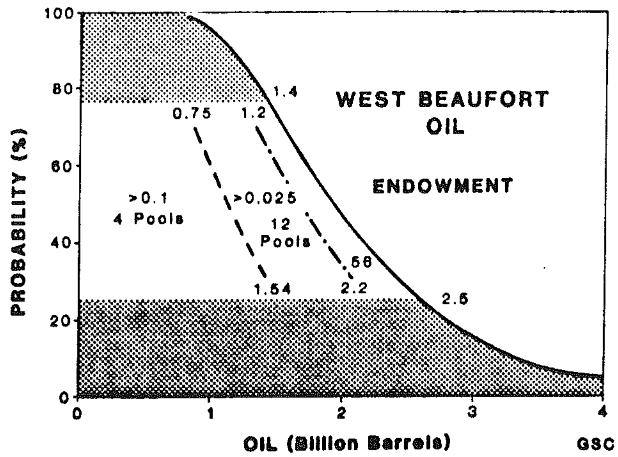

Figure 9 Distribution of oil endowment for the West Beaufort group of plays, showing the impact of predicted pool sizes

including the one associated with the Amauligak oil discovery. The second size range includes 28 pools that contain almost twice as much gas as the first. If only these two size groups were of current interest, then the mean endowment would reduce from 14.7 to 12.0 TCF.

West Beaufort: Only the oil resources of this group of plays was considered for size analysis. Figure 9 shows that four pools larger than 100 million barrels are estimated to exist, including the Adlartok discovery. Along with the 12 pools in the 25 to 100 million barrel size range, 16 pools would contain between 1.2 and 2.2 billion barrels. This would reduce the mean regional oil endowment from 2.2 to 1.8 billion barrels in the current interest category.

In summary, the resource endowment of the total Mackenzie Dela - Beaufort Sea region when viewed in terms of "current" interest, reduces from 7.1 billion barrels of oil and 68 TCF of gas (mean values) to 5.6 billion and 36.7 TCF respectively of oil and gas. Of this restricted endowment, if one chose only to consider the amounts contained in oil pools larger than 25 million barrels and in gas pools larger than 100 Bcf., then the resources would reduce to 4.4 billion barrels of oil distributed in about 50 pools; and 28 TCF of gas distributed in about 65 pools. Of this, 3.0 billion barrels of oil and 17.2 TCF of gas remain to be discovered. As the pool-size limits used in this scenario are probably somewhat larger than those that might support development if oil and gas production - transportation facilities existed in the region, there is encouragement that abundant opportunity exists for future exploration and investment in the region. One should expect fairly intensive exploration for both oil and gas in the onshore areas as well as continued search for major oil in the offshore Amauligak to Tarsiut trend. The West Beaufort oil opportunities are also bound to be the focus of exploration. Initially one would expect this future exploration to be tightly focussed on existing plays, while continuing the task of trying to understand the more complex conceptual plays. The Mackenzie Delta -Beaufort Sea region is already recognised internationally as one of the best petroleum provinces in which to explore. If circumstances permit continued exploration, that view will become even stronger.

INTRODUCTION

Foreword

Estimates of the oil and gas resources of various regions of Canada are prepared periodically by the Petroleum Resource Appraisal Secretariat of the Geological Survey of Canada, with the assistance of geologists and geophysicists of the Canada Oil and Gas Lands Administration (COGLA). The estimates are prepared using a probability methodology in which each of the individual exploration plays of a region are examined as to the opportunities for the existence of gas and oil resources. The method incorporates both objective data derived from exploration drilling, geophysics, and various forms of mapping with subjective opinion of informed experts. This systematic approach to the evaluation of Canada's resources has been conducted since 1973 and the last series of estimates for the Mackenzie Delta - Beaufort Sea region were prepared in 1983.

The present report on resources of the Mackenzie Delta - Beaufort Sea marks a new departure in the evaluation process. In the early years of the activity the primary focus was on the preparation of a gross estimate of the total resources of the region and a small number of people (six to nine) were able to effectively extract an appropriate level of data, information and opinion from a variety of sources for the evaluation. Over the years the evaluation process has matured, the methodology has evolved, and the focus has expanded from the simple estimation of resource abundance to one of producing the input data for economic analysis and supply projection. The number of plays also increased as the date base grew, and the need for an improved method of developing the geological foundation upon which the estimates are based was recognized. Because the quality and validity of the estimates is ultimately dependent on a correct perception of the geological opportunities for oil and gas accumulation that exist in any given area or basin, the decision was taken to restructure components of the Geological Survey of Canada into Basin Study Groups. In practice, the basin study group is asked to integrate all of the various types of geological, geophysical, geochemical, sedimentological etc. information for a basin, and to analyze and synthesize the historic development of the basin when dealing with frontier basins, the study group is commonly augmented with scientists from COGLA who have additional expertise in petroleum geology. By this process the sedimentological, structural, and stratigraphic models, which are the basis of exploration plays, become apparent. With the assistance of the Petroleum Resource Appraisal Secretariat, play definitions are developed and members of the basin study team are requested to compile data on a variety of reservoir characteristics appropriate for each play.

For each major resource evaluation exercise a Petroleum Resource Evaluation Committee is nominated by the Secretariat. This committee is responsible for approving the original play definitions and for reaching consensus on the various input data before final estimates are prepared. In practice, the Basin Studies Team provides a review of all relevant geology, exploration history, geochemistry etc. to the evaluation committee. In this exercise the lead role passes to the petroleum geologists in charge of play definition or play quantification who recommends preliminary values for each variable to the committee and becomes the focus of questions aimed at testing the degree to which the estimates reflect the fundamental geology presented, as well as the determination of the appropriate level of confidence attached to the values of each variable. Eventually consensus is reached by the committee which takes responsibility for the final estimates such as those contained in the present report.

Basin Study Group

The basin study group for the Mackenzie Delta - Beaufort Sea project consisted of J. Dixon, J.R. Dietrich, D.H. McNeil, and L.R. Snowdon of ISPG and G. Morrell, M. Fortier, U. Schmidt of COGLA. In addition a number of other scientists at ISPG and COGLA, either directly or indirectly contributed information based on years of experience in a variety of disciplines relevant to our understanding of the geology of the region. Particularly to be acknowledged is the technical support of N. Spooner, D. Duggan and A. Larabie to the COGLA effort.

Reserves Committees

An often unrecognized contribution to the total effort of any particular assessment is the contribution made by the Reserves Committee chaired by A. Hiles. An understanding of the nature of the discovered resources is the base from which assessments are produced. The work of K. Goble, C. Gemeroy of NEB and D. Smith, W. Ward and L. Richards of COGLA on the geology and of S.B. Young, T. Baker, and S. MacMullin (all COGLA) on the engineering aspects is gratefully acknowledged.

Petroleum Resource Evaluation Committee

The committee struck for this evaluation of the Beaufort Sea - Mackenzie Delta region consisted of G.C. Taylor (chairman), G.R. Campbell (COGLA), J.P. Hea (EMR), P.J. Lee, J.A. Podruski and R.M. Procter (all of GSC). Able assistance to the committee was rendered by P.R. Price (GSC) who operated most of the computer assessment programs.

Scope of Evaluation

In this report the focus is on a re-evaluation of the oil and gas resources of the Beaufort Sea region (Fig. 10). Reservoirs in these units are the primary target for the bulk of exploratory drilling in the Beaufort Sea and currently contain many of the important discoveries. In 1983 all plays in the Mackenzie Delta - Beaufort Sea were reviewed and estimates were updated. Since that time, significant additional data resulting from exploratory drilling, seismic exploration and geochemistry have been added to the data base. In addition the development of totally new concept of the depositional model and the application of the sequence concept in the stratigraphic analysis has permitted a better definition of the petroleum opportunities. In view of the important Tertiary units in terms of discovered resources and particularly the

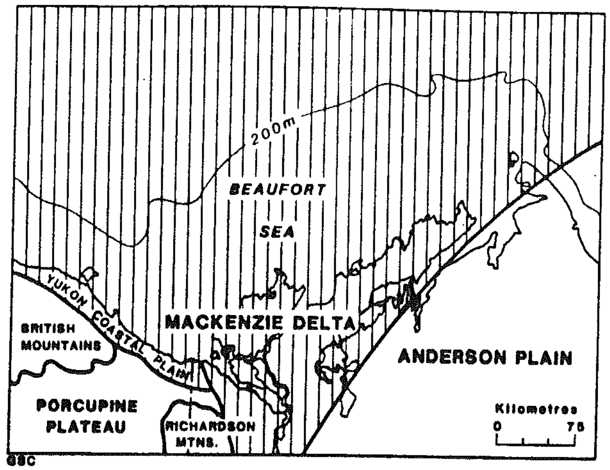

Figure 10 Map showing the area evaluated

need to provide better definition of pool sizes and reservoir characteristics for cost and supply analysis, the Mackenzie Delta - Beaufort Sea Basin Study group was requested to undertake the detailed studies that are summarized in this report.

In the report that follows, the regional geology of the Beaufort Basin is described with emphasis on the sedimentation of the Tertiary sequences as they relate particularly to petroleum geology. This is followed by a discussion of the definition of the plays used in the current assessment, the two parts representing the basin analysis contribution to the report. The final chapter deals with the total resource estimates for the Mackenzie Delta - Beaufort Sea incorporating the newly updated plays, and is the work of the assessment committee. Implications of the new estimates in terms of discovery rate and future supply conclude the report.

The area of the petroleum evaluation extends from the head of the Mackenzie Delta to the southern limit of the permanent ice pack in the Beaufort Sea, and from 127 to 141 degrees west. The onshore areas include Mackenzie Delta, Tuktoyaktuk Peninsula and the coastal plain of northern Yukon. The bulk of the evaluation area lies under the Beaufort Sea. Within this area over 189 exploration wells have been drilled (see Fig. 54) and many tens of thousands of kilometres of reflection seismic data are available. These data, plus studies of exposed strata on land, are the basis for the geological interpretations and the exploration play-concepts summarized in this report.

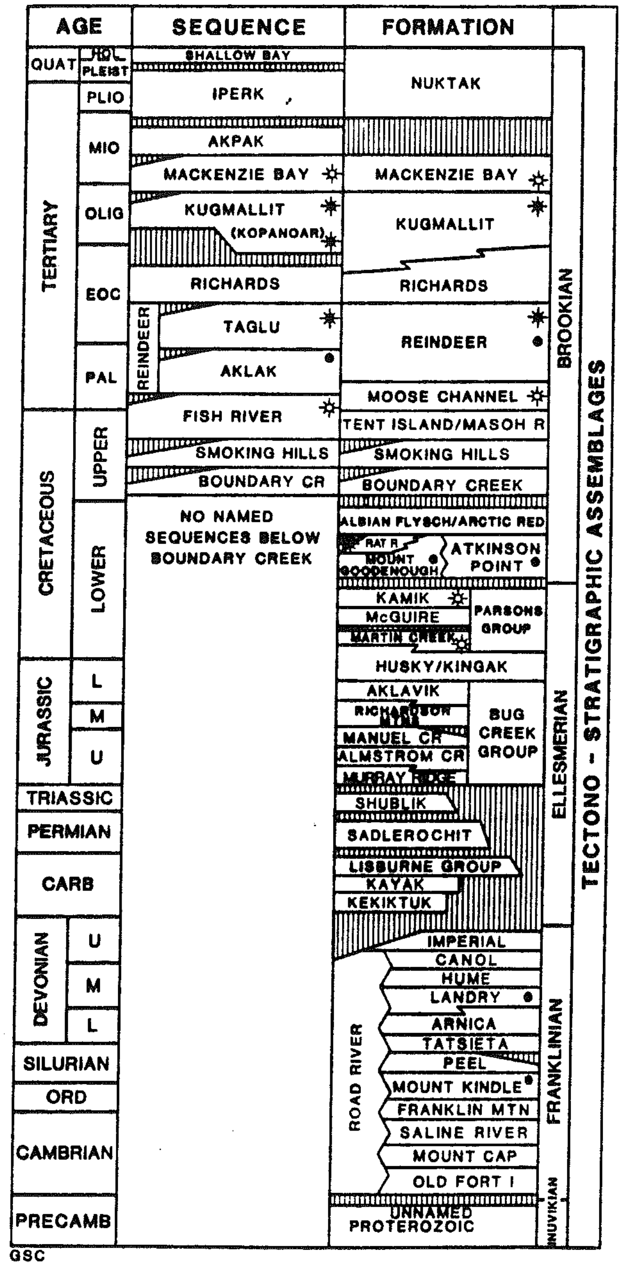

Figure 11 Stratigraphic column, Mackenzie Delta-Beaufort Sea

STRATIGRAPHY

The known strata in the Beaufort-Mackenzie area can be divided (Fig. 11) into several large-scale tectono-stratigraphic assemblages (Lerand, 1973; Norris and Yorath. 1981), these are:

1. Inuvikian: Proterozoic strata
2. Franklinian: Cambrian to Devonian strata
3. Ellesmerian: Mississippian to upper Hauterivian strata
4. Brookian: upper Hauterivian to modern strata.

These assemblages are separated from each other by major regional unconformities. The unconformities generally reflect significant changes in the tectonic regime. The Brookian sequence can be subdivided into lower and upper Brookian sequences based on the presence of a significant unconformity between Upper Cretaceous and underlying strata. The bulk of the discovered oil and gas in the Beaufort-Mackenzie area is present in upper Brookian strata, although discoveries in lower Brookian, Ellesmerian and Franklinian strata are known, but are generally of lesser volumes.

Inuvikian strata

Unknown thicknesses of Proterozoic strata crop out in the British Mountains and near Inuvik, in the Campbell Lake Uplift. Recent studies of deep-reflection seismic in the vicinity of Inuvik (Cook et al., 1987) clearly show that the area is underlain by a succession of thrust faulted Proterozoic strata that is in the order of 13-15 km thick. A belt of presumed Proterozoic strata can be traced in the subsurface from Campbell Lake northeastward along the length of Tuktoyaktuk Peninsula (Wielans, 1988). Proterozoic strata apparently thin dramatically towards the Beaufort Sea (Cook et al., 1987).

In the British Mountains the Proterozoic strata consist of highly deformed argillites, sandstones and argillaceous limestones and are all assigned to the Neruokpuk Formation (Norris, 1985). Sandstone, shale and carbonates are present in the Campbell Lake Uplift. In the subsurface occurrences along Tuktoyakyuk Peninsula quartzite is the most common lithology penetrated, commonly interbedded with shale. Locally present in the subsurface are volcanic rocks.

Detailed information concerning the internal stratigraphy and distribution of Proterozoic strata in the Beaufort-Mackenzie area is lacking due to limited exposures and few borehole penetrations. However, the petroleum potential, in terms of both source rocks and reservoirs is considered to be very minor in these strata, based on our knowledge of the high levels of organic maturity, poor source rock quality and the poor reservoir characteristics of known Proterozoic strata in this area.

Franklinian strata

Franklinian rocks are Cambrian to Devonian in age, are known from the onshore and nearshore areas, and are present in both outcrop and subsurface. In the eastern areas Cambrian to Middle Devonian strata crop out in the Anderson Plains and extend into the subsurface under Tuktoyaktuk Penisula. They are predominantly carbonates, although significant successions of Lower to

Upper Cambrian clastics, associated with salt and anhydrite, are present in the subsurface of the Anderson River area (Pugh, 1983). In ascending order these basal clastics and evaporites consist of the Old Fort Island, Mount Cap and Saline River formations. These Cambrian clastics appear to pinch-out towards the Eskimo Lakes area and they have not been identified with any degree of confidence in the subsurface of the Beaufort-Mackenzie area. However, late Cambian to Middle Devonian carbonates occur extensively under Tuktoyaktuk Peninsula, although stratigraphic subdivisions in these thick carbonates are not always readily identified. In the outcrop belts the stratigraphic divisions are, in ascending order, Franklin Mountain, Mount Kindle, Peel, Tatsieta, Arnica, Landry and Hume formations (Pugh, 1983). Dolostone is the dominant lithology in most formations except the Landry and Hume which are limestone units. In Campbell Lakes Uplift there is a limestone succession that has been correlated with the Cambrian-Silurian Vunta Formation and a dolostone succession originally identified as Gossage Formation, that is approximately equivalent to the Arnica and Landry formations (Norris, 1981). The carbonates underlying the eastern part of the evaluation area are mostly shallow water, shelf sediments.

Westward the carbonates are laterally replaced by shale, chert and sediment gravity-flow deposits of the Road River Formation. Outcrops of these lithotypes are present in the Richardson and Barn Mountains, and are known in the subsurface from wells on the east flank of the Richardson Mountains (Pugh, 1983). Within the British Mountains Cambrian volcanic rocks have been identified.

Upper Devonian strata form a thick wedge of clastic sediments that rest abruptly on the underlying carbonates. Generally a distinct black, radioactive shale, the Canol Formation, rests on the carbonates, in turn overlain by the much thicker Imperial Formation. The latter consists of interbedded conglomerate, sandstone and shale, deposited principally as sediment gravity-flow beds. Canol and Imperial clastics are present east of the Richardson Mountains and underlie considerable areas of Tuktoyaktuk Peninsula.

Franklinian rocks underlying Anderson Basin dip gently to the west and northwest, becoming more folded and faulted to the west and northwest. Under Tuktoyaktuk Peninsula the subcrop pattern of the Paleozoic carbonates suggest that they are either folded or that thrust faults repeat the section (Wielans, 1987). In the Barn Mountains Lower Paleozoic strata are isoclinally folded.

Ellesmerian strata

Ellesmerian strata are Carboniferous to middle Hauterivian in age. Carboniferous strata are exensively exposed around the perimeter of the British Mountains (Bamber and Waterhouse, 1971) and are known to have been locally penetrated under the southwestern part of Mackenzie Delta. On the east flank of Richardson Mountains, south of Fort McPherson, and extending eastward into the subsurface, is the clastic Tuttle Formation.

In northwestern Yukon the lowest Carboniferous units are clastics of the Kekiktuk and Kayak formations. The Kekiktuk unconformably overlies older strata and consists of interbedded conglomerate and sandstone. The overlying Kayak Formation consists of interbedded shale, coal and limestone. Both formations are predominantly non-marine in origin, although the Kayak contains a significant proportion of marine beds. Gradationally overlying the Kayak Formation are carbonates of the Lisburne Group. The Lisburne Group contains the Alapah and Wahoo formations; the former containing interbedded limestone and dolostone and the latter mostly limestone.

Disconformably overlying Carboniferous strata are shale, sandstone and minor amounts of limestone of the Permian Sadlerochit Group. Sadlerochit strata crop out in the British Mountains and eastward, in the Cache Creek Uplift, correlative, and considerably thicker, Permian strata are present and extend under the southwestern part of the Mackenzie Delta. These eastern Permian strata are predominantly marine sandstone and shale, although on the east flank of the Richardson Mountains non-marine Permian strata are present.

Only local occurrences of Triassic strata are known on the northern flank of the British Mountains. There, the Triassic strata consist of interbedded limestone, sandstone and shale and are correlated with the Shublik Formation of adjacent Alaska. Only about 150 m of strata are preserved.

Beginning with Jurassic sedimentation the depositional style and paleogeography changed dramatically from Permo-Triassic time. A series of northwestward prograding wedges of clastic sediment characterizes Jurassic to Hauterivian deposition. The bulk of the coarser materials (sands and gravels) form a southwest to northeast trending arenaceous belt extending along the Tuktoyaktuk Peninsula, through the northern Richardson Mountains, and along the Keele Range. At the north end of the Ogilvie Mountain this trend shifts to a north-south orientation. Within the arenaceous belt the vertical succession consists of alternating shale-and sandstone-dominant formations. The sandstone units grade laterally into shale-dominant strata towards the northwest and west.

In ascending order the formations within the arenaceous belt are: Bug Creek Group (mostly sandstone) Husky Formation (shale-dominant), Martin Creek Formation (sandstone-dominant), McGuire Formation (shale) and Kamik Formation (mostly sandstone). In northwestern Yukon the Bug Creek to McGuire interval is represented by a single shale succession, the Kingak Formation. Some local variations in the stratigraphy are present, for example, the Porcupine River and North Branch Formation are sandstone facies equivalents of the lower Husky Formation.

The bulk of the preserved record of Jurassic to Hauterivian strata consists of shoreline to shelf sediments, with a significant non-marine component in the lower part of the Kamik Formation (Poulton, 1982; Dixon, 1986). In the latter instance the non-marine beds are present principally under the Tuktoyaktuk Peninsula and south Mackenzie Delta. The source of the clastics during Jurassic to Hauterivian time was from the stable craton to the east and southeast.

Brookian strata

Brookian strata consist of Barremian to Holocene sediments and are separated from underlying strata by a major regional unconformity at the base of the Mount Goodenough Formation. Within the Brookian assemblage a major regional unconformity below Upper Cretaceous strata divides the succession into a lower and upper sequence.

Barremian strata are represented by the shale-dominant Mount Goodenough Formation. This unit is present throughout the northern Yukon, northern Richardson Mountains and in the subsurface of Mackenzie Delta and Beaufort Sea. A basal sandstone is locally developed, especially adjacent to, or on, tectonic uplifts such as the Cache Creek and Romanzoff uplifts. Gradationally overlying the Mount Goodenough are interbedded sandstones and shales of the Rat River Formation. Rat River strata crop out in the northern Richardson Mountains but have been eroded west of Rapid Creek. In the subsurface they occur in the southeast part of the Mackenzie Delta. Most of the preserved Rat River interval consists of marine strata, commonly arranged in a series of shale-to-sandstone, coarsening-upward cycles.

Under the central part of Tuktoyaktuk Peninsula there is a relatively thin succession of sandstone and conglomerate that is equivalent to both the Mount Goodenough and Rat River formations, these are strata of the Atkinson Point Formation. Atkinson Point strata have a limited distribution adjacent to the northwest flank of the Eskimo Lakes Arch and rapidly change facies into siltstone and shale (Dixon, 1979). The localized distibution and rapid lateral facies changes suggest that the Atkinson Point Formation was deposited as a small fan-delta on the northwest flank of the active Eskimo Lakes Arch.

Late Aptian and Albian strata are mostly shales and consist of the Martin House and Arctic Red formations east of the Richardson Mountains, and the informally designated Albian flysch west of the mountains. Local, thin, basal sandstone beds are present along the Eskimo Lakes Arch, especially where Arctic Red strata rests unconformably on older rocks. In the Albian flysch, shale is the dominant lithology but there are also significant intervals of sandstone and conglomerate, especially in the basal part of the succession (Young. 1977). A local ironstone unit, the Rapid Creek Formation (Young and Robertson, 1982), occurs on the northeast flank of the northern Richardson Mountains. Albian flysch beds underlie much of the Yukon coastal plain but plunge rapidly under a thick Tertiary cover in the nearshore areas. The flysch beds are at least 4000 m thick within the Rapid Depression and may be considerably thicker. Martin House strata consist of interbedded shale, siltstone and sandstone, with local coquinas and are identified only on the east flank of the Richardson Mountains. They represent deposition during a late Aptian/early Albian transagression on to the cratonic areas of northern Canada. Arctic Red strata are shale with thin interbeds of sitlstone and very minor amounts of sandstone, which were deposited as shelf sediments south and southeastward of the Eskimo Lakes Fault Zone. Northwestward of the Eskimo Lakes Fault Zone, within the Kugmallit Trough, Arctic Red strata were depsoited as slope and basinal deposits. The flysch beds west of the Richardson Mountains were deposited in the Blow Trough as sediment gravity-flow deposits in slope, submarine fan and basinal environments.

The unconformity between Albian and younger strata is especially prominent west of the Richardson Mountains, where weakly consolidated, low-density shales and thin interbeds of bentonite of the Boundary Creek Formation abruptly overlie dense, brittle Albian shales. East of the Richardson Mountains the contrast is not as marked but the Cenomanian-Turonian Boundary Creek strata are generally absent and

Campanian-Santonian shales of the Smoking Hills Formation rest disconformably on Albian shales. Both the Boundary Creek and Smoking Hills shales are rich in organic matter, averaging 3 to 5%, and locally as high as 12% in the Smoking Hills succession. Smoking Hills strata are eroded west of the Richardson Mountains, where Maastrichtian rocks of the Tent Island Formation rest erosionally on Boundary Creek shales. Boundary Creek and Smoking Hills strata were deposited on outer shelf to slope environments.

Late Maastrichtian to Holocene strata consist of a series of basinward prograding deltaic complexes which, cumulatively, consist of up to 12 km of strata under the central Beaufort Sea. Under Mackenzie Delta, and in outcrops, the succession consists of alternating shale- and sandstone-rich intervals which have been divided into conventional lithostratigraphic units (Fig. 10); Young, 1975; Young and McNeil, 1984). Basinward the sandstone-dominant units begin to be replaced by shale, consequently in some parts of the offshore areas many thousands of metres of section are shale-dominant and correspond to several units in the nearshore areas. This creates a major problem for realistic correlations and paleogeographic reconstructions. Consequently Dietrich et al. (1985) advocated the use of the depositional sequence concept (Mitchum et al., 1977) to identifiy basin-wide, genetically related, packages of sediment within the basin. This concept does not rely solely upon lithology to identify the stratigraphic units, instead, basin-wide stratigraphically significant surfaces are identified. The surfaces are unconformities or their basinward correlative conformities, and are identified principally from reflection seismic as well as from geophysical logs in exploration holes. The unconformities/conformities form the bounding surfaces of depositional sequences. Most of the Tertiary sequences can be up to 4000 m thick at its depocentre.

The sequences identified to date are (from oldest to youngest):

Boundary Creek - Cenomanian-Turonian
Smoking Hills - Santonian-Campanian
Fish River - late Maastrichtian-Paleocene (contains the Tent Island Formation and sandstone member of the Moose Channel Formation)
Reindeer super-sequence - this can be divided two sequences; **Aklak** -late Paleocene-early Eocene and **Taglu** - early-?middle Eocene
Richards - middle-late Eocene
Kugmallit - Oligocene (this sequence now contains the previously separated **Kopanoar** sequence and the latter is designated a subsequence)
Mackenzie Bay - Oligocene-Miocene

Akpak - Miocene
Iperk - Plio-Pleistocene
Shallow Bay - late Pleistocene-Holocene.

Each of the major Tertiary sequences consists of a thick succession of interbedded sandstone and shale at the basin margins, deposited in delta-plain and delta-front enviroments. In the distal delta-front environment the amount of shale increases and sandstone decreases. In the prodelta and shelf enviroments shale is the dominant lithology, although isolated sand-rich intervals may be present where delta-lobes prograded onto the shelf. Slope and basinal deposits tend to be mud-dominant but when deltaic deposits built out to the shelf edge, or when there was a relative sea-level drop, coarser material could be deposited in the deep-water enviroments.

The deltaic facies of the Fish River and Aklak sequences are centred over the western part of the Beaufort Sea and both form an areally extensive belt of sandstone-rich strata. In early Eocene time the delta depocentres switched to the east, and Taglu and Kugmallit deltaic strata are centred under Richards Island and the central Beaufort shelf respectively. To date we have not been able to identifiy the Mackenzie Bay and Akpak deltaic facies, either because they have been eroded at the basin margins or they are present to the west or north of the study area. The Iperk depocentre is located under the modern shelf edge in the eastern Beaufort Sea. Holocene deltaic deposition has shifted back to the central Beaufort Sea.

During the late Eocene there was a major drop in relative sea-level and the previously formed shelf was subaerially exposed. During this period of exposure submarine canyons formed on the slope and shelf, feeding sediment to large submarine fans. These low-stand submarine fan deposits form the distinct Kopanoar subsequence. During deposition of the succeeding Kugmallit delta significant quantities of sediment were shed directly from the delta-front into deep-water. The vertical stacking of these two successions has resulted in a thick, if muddy, interval of Oligocene sediment gravity-flow deposits within the central offshore area of the Beaufort shelf.

STRUCTURAL SETTING

The area can be divided into four large-scale structural terrains:

1. Stable Craton: East of Peel River and south of Tuktoyaktuk Peninsula, Paleozoic and Mesozoic strata are only moderately deformed. However, these stata are underlain by a thick, highly deformed succession of Proterozoic strata that would appear to have been part of a Precambrian

foldbelt. Paleozoic strata are part of a westerly thickening, homoclinal wedge which becomes more deformed towards the Richardson Mountains and on the north side of the Eskimo Lakes Fault Zone. The thin Mesozoic cover tends to be flat lying to gently warped into broad synclines and anticlines.

2. Faulted southeast margin of the Canada Basin: Under Tuktoyaktuk Peninsula and extending northeastward into the offshore there is a zone of large-scale, listric normal faults that extend through Lower Cretaceous and older strata (Cook et al., 1987), and which have had minimal offset in Upper Cretaceous and Tertiary strata. The bulk of the stratigraphic displacement is within Jurassic and Lower Cretaceous units, attesting to the early Mesozoic age for the main fault activity. These faults are interpreted to be the result of rifting and opening of Canada Basin during the Mesozic.

3. Cordilleran Foldbelt: The area west of the Richardson Mountains and extending into the western Beaufort Sea is underlain by highly deformed strata. Compressional and strike-slip structures formed during late Cretaceous and early Tertiary deformation. Within this terrain there are features of older origin,

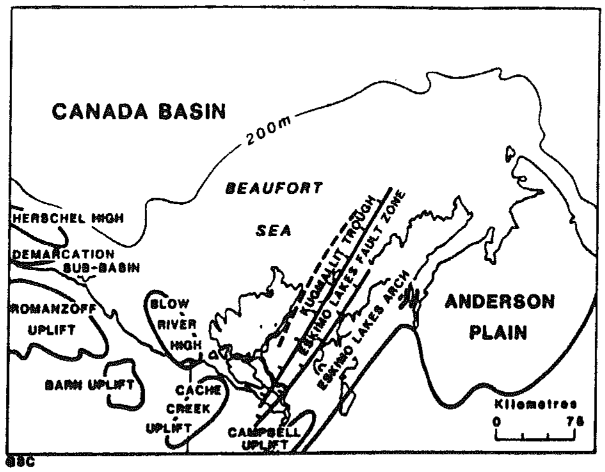

Figure 12 Map showing major structural elements in the region

such as the Cache Creek Uplift, Rapid Depression, Dave Lord Uplift and Eagle Arch (Fig. 12), all of which probably originated as Mesozoic fault-bounded structures. Undoubtedly some features have even older origins, such as the White Uplift, which was an isolated carbonate bank during early Paleozoic time.

4. Canada Basin: Oceanic crust underlies Canada Basin which resulted from continental rifting and sea-floor spreading during the Cretaceous. A thick cover of Tertiary sediment overlies the oceanic crust. The transition from continental to oceanic crust has not been identified with certainty but initial studies of refraction and gravity data suggest that the transition is very close inshore, perhaps even under the outer Mackenzie Delta. If correct then

oceanic, or transitional crust probably underlies most of the Beaufort shelf.

Under the Beaufort Sea, Tertiary strata have been deformed by compression and gravity-induced faulting. Most of the lower Tertiary strata have been folded into an arcuate foldbelt that dies out oceanward and to the northeast. The intensity of folding varies geographically; in the western Beaufort the anticlines tend to be asymmetric, verging oceanward, and are commonly cut by high-angle reverse faults on the oceanward limb. Basinward the folds tend to become more symmetric and less faulted. The folds show repeated thining of strata onto the structures, indicating intermittent growth, possibly resulting from some shale diapirism associated with episodic compression. In the central Beaufort, under Richards Island and the nearshore areas the folds are cross-cut by younger, gravity-induced listric faults. These listric faults usually face oceanward, although in the Tarsiut area there are large landward-facing listric faults. Extending from Tarsiut, northeastward through the Ukalerk area is a zone of very prominent listric faults, oceanward of which the section is essentially unfaulted. The thick Plio-Pleistocene Iperk sequence unconformably overlies older Tertiary strata and truncates underlying structures. Deformation within the Iperk sequence is minor, although equivalent strata in the northeastern part of Alaska are involved in folding.

West of the Mackenzie Delta there are several prominent large-scale structural features (Fig. 12). The Blow River and Herschel Highs are areas of closely spaced anticlines that have been uplifted relative to the adjacent sediment. Flanking the southern margin of Herschel High is Demarcation sub-basin that is a large synclinal structure filled with middle Eocene and younger strata.

Hydrocarbons have been recovered from Paleozoic carbonates, Lower Cretaceous sandstones and Tertiary sandstones. The Paleozoic and Lower Cretaceous reservoirs are all located in the south delta and along the Tuktoyaktuk Peninsula. Discoveries in Tertiary reservoirs are concentrated in the central area of the Beaufort-Mackenzie Basin, reflecting the focus of drilling activity. Recent drilling in the relatively unexplored western Beaufort Sea indicates that hydrocarbons are present (e.g. Adlartok P-09 oil discovery).

Only three accumulations in carbonates have been discovered, one at at Mayogiak J-17, the second at West Atkinson L-17, and the third at Unak L-28. In the Mayogiak and West Atkinson wells oil was recovered and the geochemical properties of the oil indicates that it was derived from the Upper Cretaceous Smoking Hills Formation. In both localities the reservoirs are on small fault blocks and the porosity is enhanced by fractures. Presumably oil generation occured within the adjacent Kugmallit Trough and the oils migrated up-dip along fault planes into the carbonate reservoirs. Overlying Jurassic and Cretaceous shale would provide the seal to the carbonates. In Unak L-28 the reservoir is in Carboniferous carbonates and gas was recovered. The source for the gas in Unak L-28 is not known but it could be from Jurassic-Cretaceous shales. The Unak trap appears to be related to closure against a thrust fault.

Both oil and gas have been trapped in Lower Cretaceous sandstones throughout the Tuktoyaktuk Peninsula and south Mackenzie Delta. Oil has been recovered from Parsons Group sandstones at Kugpik O-13 and Kamik D-48, from the Barremian-Aptian Atkinson Point Formation, and a minor recovery from a sandstone low in the Mount Goodenough Formation at Imnak J-29. With the exception of the Kamik discovery the oil appears to have been generated from Smoking Hills shale (Snowdon and Powell, 1979; Brooks, 1986). The origin of the Kamik oil remains unresolved. Trapping is in fault blocks adjacent to the Kugmallit Trough, in which it is presumed the oil was generated and migrated up-dip along fault planes.

Gas is present in large volumes in the Parson Group at the north and south Parsons gas field. The source of the gas has not been positively identified although the associated liquids are not correlatable with oil from the Smoking Hills Formation. Langhus (1980) suggested that the gas was derived from the Jurassic-Cretaceous Husky Formation. The terrestrially dominant organic matter in the Husky shale would be consistent with a gas-prone source rock for the Parsons gas. At the Unak L-28 well gas was recovered for the first time from the Lower Cretaceous Rat River strata. The source of the Unak gas is not known but could be from the thick Jurassic-Cretaceous shales in the area of Unak L-28.

Most of the hydrocarbon discoveries in the Beaufort-Mackenzie area are in Tertiary strata. Oil and gas have been recovered from the Fish River, Aklak, Taglu, Kugmallit and Mackenzie Bay sequences. Taglu and Kugmallit deltaic strata account for the bulk of the discoveries, with lesser volumes in deep-water sediments of the Kopanoar subsequence and the remainder of the Kugmalit sequence. While there is a general trend for the trapped hydrocarbons to be more oil-prone in a basinward direction, there is no identifiable pattern to the type of hydrocarbons discovered. Oil-to-source rock correlations indicate that the liquid hydrocarbons are derived from two possible Tertiary sources. Oils from the central Beaufort area contain a biomarker compound that has only been found in the basal part of the Richards shale (Brooks, 1986), suggesting that the Richards shale is the source rock. In the recent oil discovery at Adlartok P-09, in the west Beaufort, the Richards-type biomarker is not present and the geochemistry of the oil appears to indicate a possible source rock in Paleocene shales (L. R. Snowdon, pers. comm., 1987).

Even though drilling has reached depths of 4000 to 4500 m the Tertiary section in the central Beaufort area generally is thermally immature. Vitrinite reflectance values rarely reach 0.7% Ro. In the west Beaufort, where the Natsek and Edlok wells have been drilled, higher levels of thermal alteration are attained and values of 0.8% Ro have been measured in Paleocene strata. In the Blow River E-47 well, located on the Yukon coastal plain, very high levels of thermal alteration have been noted in the Tertiary strata, with values up to 2.0% Ro, well beyond the oil window.

The Tertiary succession is dominated by type III (terrestrial) organic matter. Using a conventional hydrocarbon generation model this type of organic matter would tend to produce mostly gas. While the Beaufort-Mackenzie succession does contain large volumes of gas there is an unusually large volume of liquids that could not be accounted for by the terrestrial dominance of the organic matter. Normally such volumes of oil are generated from organic matter that is more marine in character. As a possible explanation for this anomalous situation Snowdon and Powell (1979) postulated that the oils were generated from resin-rich terrestrial sediments. Resin is a common component of the Beaufort-Mackenzie deltaic sediments and it is not uncommon to find small globules in the cuttings samples from exploration wells. This type of organic matter has the added advantage of generating hydrocarbons at lower levels of thermal alteration, which would be consistent with the Beaufort-Mackenzie thermal regime.

Exploration Play Groups

The revised estimates presented in the following report are based on a thorough basin analysis by GSC and COGLA scientists, examining available geology, geophysics, geochemistry and petroleum geology. From this analysis 20 exploration plays were identified and quantified, using advanced probability methods developed by the Geological Survey of Canada. The 20 exploration plays occur in 4 groups, distinguished by geographic, geologic and developmental criteria (Fig. 13). The **Onshore and Shallow Offshore** group comprises 8 plays that exist in the Richards Island, South Delta and Tuk Peninsula areas, plus their extensions into adjacent

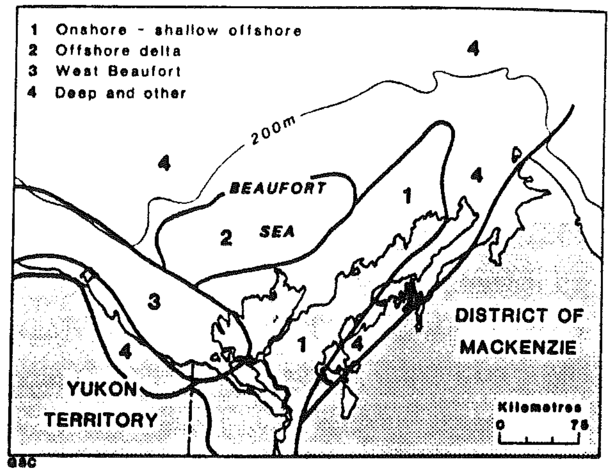

Figure 13 Map showing areal extent of play groups

shallow water. The plays include Paleozoic, Mesozoic and Tertiary targets. The **Offshore Delta** group of 4 plays forms a narrow fairway in which several major oil and gas discoveries have been made extending from the Tarsiut to the Amauligak fields. This group occurs in about 25 metres of water, and exists in rocks of similar Tertiary age and with similar structural style. The **West Beaufort group** of 3 plays differ significantly from the main delta plays in the structural style and grain of the area, the age of reservoirs and a different oil generaltion regime. The **Deep Water and Other** group consists of 5 plays, dominated by two plays that occur in deep water beyond the Offshore Delta and West Beaufort groups. These two Tertiary plays rely on deep-water sedimentation for reservoir opportunities. The other three plays are combined with this group because they are truly conceptual and will probably not attract serious exploration for some time.

PARSONS PLAY

Play Definition: **This play was defined to include all pools and prospects in the Lower Cretaceous Parsons Group along the southern Tuktoyaktuk Peninsula (Fig. 14).** Gas is the principle hydrocarbon in this play but significant amounts of oil may be present. The play area extends from the Caribou Hills, northeastward to the area of Tuktoyaktuk (Fig. 15). Southeast and east of the Eskimo Lakes Fault Zone Parsons strata are eroded.

Geology: Where fully developed, the Parsons Group consists of the sandstone-dominant Martin Creek Formation, abruptly overlain by shale of the McGuire Formation, in turn gradationally overlain by the Kamik Foramtion. The Kamik Formation has a distinctive twofold division; a lower sandstone-rich interval that contains fluvial and marginal marine beds, and an upper interval consisiting of a series of coarsening-upward cycles of barrier bar origin (Dixon, 1982).

The Parsons Group is up to several hundred metres thick in the Kugmallit Trough, thinning depositionally and erosionally to the east, northeast and southeast, on to the Eskimo Lakes Arch.

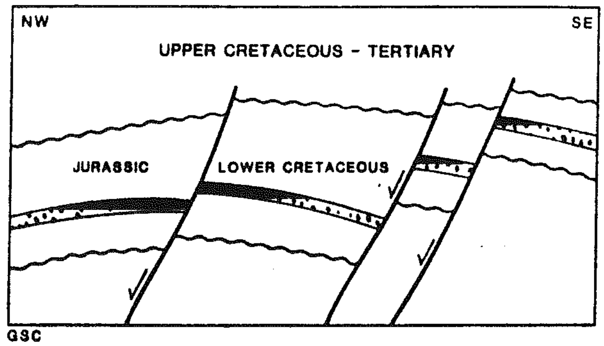

Figure 14 Schematic sketch of trap types - Parsons Play

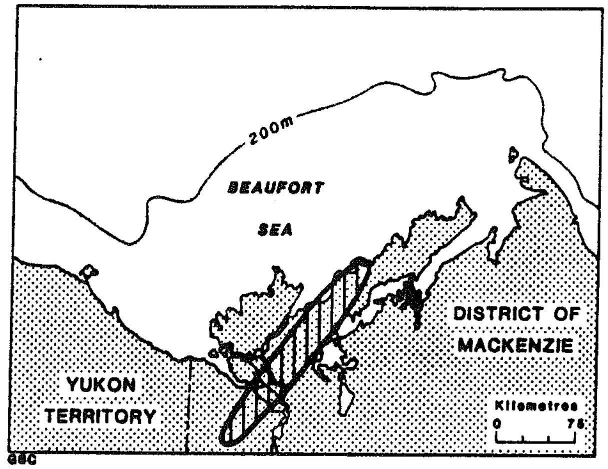

Figure 15 Sketch map locating Parsons Play area

Southwest of the Caribou Hills pre-Mount Goodenough erosion has removed considerable amounts of Parsons strata.

Porosity values are variable but generally in the 15 to 20% range for the quartz arenites and less for more argillaceous sandstones.

Included in this play is a sandstone unit that occurs within the Mount Goodenough Formation, immediately above the Siku shale. The sandstone unit can be correlated throughout the subsurface but it is of highly variable quality and thickness. Generally it is only a few metres to a few tens of metres thick and can range from a very argillaceous, silty sandstone to a fine grained, relatively clean, quartz arenite. Porosity values in this sandstone are usually less than 15%.

Structures associated with this play are closures against normal faults of the Eskimo Lakes Fault Zone and have a wide range of sizes, from the large anticline at Parsons gas field to the small fault blocks of the Tuk area. The thick overlying succession of Lower Cretaceous and Upper Cretaceous shales provide an efficient seal.

Source rocks for this play may include the Husky Formation which has a terrestrially derived organic content and would be gas-prone (Langhus, 1980). Other Lower Cretaceous shales, such as in the Mount Goodenough and Arctic Red formations could be potential source rocks, the former gas-prone and the latter with more oil-prone intervals. The Upper Cretaceous Smoking Hills Formation is a rich, oil-prone source rock that appears to have been the source for the oil in the Parsons Group.

Exploration History: The Parsons gas field was first drilled in 1972, and subsequent step-out drilling has indicated that there is 1.4 TCF of recoverable gas in two main pools. Subsequent exploration has resulted in a gas condensate discovery in Tuk L-09 and a small oil discovery in Kamik D-48, both in the Kamik Formation, and a minor oil discovery at Imnak J-29 in Mount Goodenough Sandstone. About 13 separate prospects have been drilled into Parsons Group strata.

ATKINSON PLAY

Play Definition: The Atkinson Point Play was defined to include all pools and prospects in the Hauterivian to Aptian Atkinson Point Formation along the northwest margin of Tuktoyaktuk Peninsula (Fig. 16). Oil is the principal hydrocarbon.

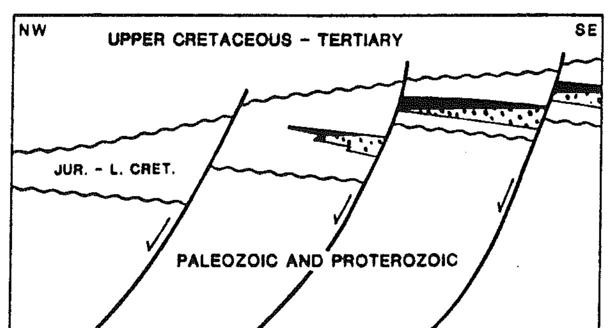

Figure 16 Schematic sketch of trap types - Atkinson Play

The play area extends from about the central part of Tuktoyaktuk Peninsula to its northernmost point, but the Atkinson Point Formation is limited to the western side of the peninsula. Some nearshore areas on the Beaufort Sea side of the peninsula are included in the play area (Fig. 17).

Geology: Aktinson Point strata consist of interbedded conglomerate and sandstone at its eastern limits, grading laterally into sandstone and siltstone; finally grading into marine shale and siltstone of the Mount Goodenough Formation (Dixon, 1979; Dixon et al., in press). Dixon (1979) interpetred the Atkinson Point Formation as a local, small, fan-delta deposit grading laterally into marine strata.

The type area is in the vicinity of the original discovery, Atkinson H-25, where the thickest and best reservoir facies are developed. A few kilometres to the west, at West Atkinson L-17, equivalent strata consist of silty and argillaceous sandstone of poor reservoir quality. Thin successions of Atkinson Point strata to the northeast and south of the type area may well represent deposits of the transgressive phase that terminated Atkinson Point deposition. As well as facies changes limiting the area of distribution, a mid-Cretaceous unconformity truncates Atkinson Point and equivalent strata south of the

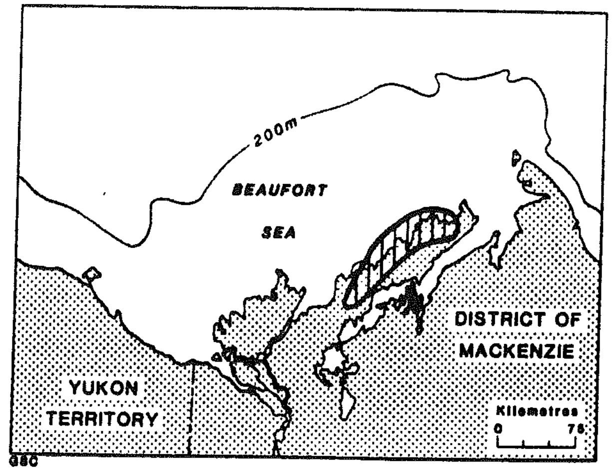

Figure 17 Sketch map

Eskimo J-07 well, on the Eskimo Lakes Arch. Within the Kugmallit Trough, from the Mayogiak area southwestward, equivalent strata are shale-dominant.

Porosity and permeability is highly variable, and generally facies-dependent. The best porosity/permeability values at present occur in clean sandstones and conglomerates in the vicinity of Atkinson H-25 (15-20%) well.

Thick, overlying Albian and Upper Cretaceous shales provide adequate top-seal. Lateral seals could be fault planes or by facies change to finer grained or argillaceous strata.

There is a strong correlation between the distribution of the Atkinson Point Formation and Jurassic-Cretaceous faults bounding the western margin of the Eskimo Lakes Arch. The Atkinson

H-25 discovery is in a small, tilted fault block on the margin of the Eskimo Lakes Arch and remaining prospects are anticipated to be a similar trap type.

Oil in the Atkinson H-25 apparently was derived from the organic-rich Upper Cretaceous Smoking Hills Formation. Maturity levels of Smoking Hills strata on the Eskimo Lakes Arch is low, consequently the oil must have migrated from deeper levels in the adjacent Kugmallit Trough to the west, probably facilitated by the numerous faults.

Exploration History: The Atkinson H-25 oil discovery was drilled in 1970. Subsequent drilling in the immediate area failed to find another discovery. Not until 1982, when West Atkinson L-17 was drilled, were hydrocarbons again tested in the Atkinson Point Formation. However, in L-17 the reservoir was so poor that the test was not recognized as an Atkinson Point discovery, rather the underlying fractured Paleozoic carbonates were the principal producing interval. Altogether 21 wells have penetrated Atkinson Point strata.

TUK PLAY

Play Definition: This play was defined to include all pools and prospects within the Paleocene–Eocene succession along the southern Tuktoyaktuk Peninsula (Fig. 18). It is an oil and gas play.

The play area (Fig. 19) is limited to the southeast by truncation of the potential reservoir, to the northeast by shale-out of the delta-front reservoir facies and to the southwest by the overwhelmingly sandy character of the deltaic sequence. The northwestern boundary with the Taglu Play is arbitrary and reflects the limits of the structural influence of the Eskimo Lakes Arch and the likelihood of effective Upper Cretaceous oil source rocks.

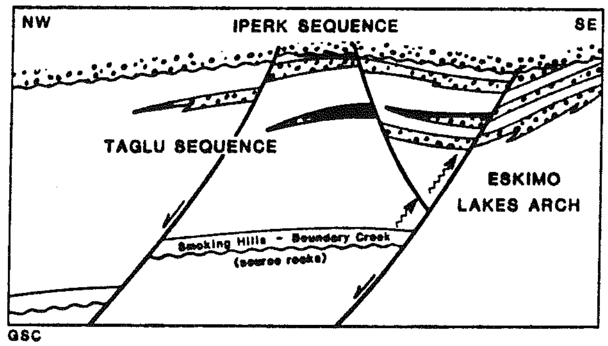

Figure 18 Schematic sketch of trap types - Tuk Play

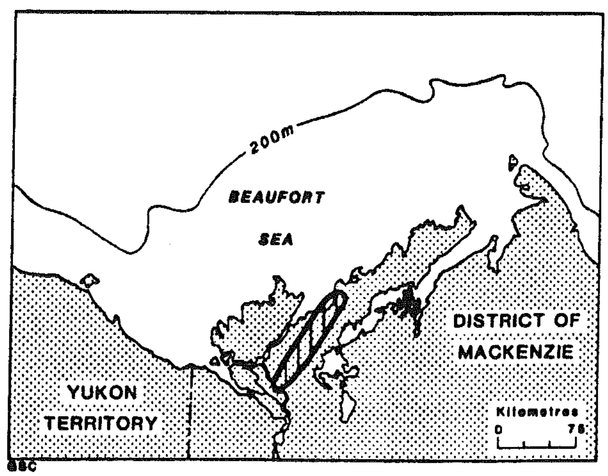

Figure 19 Sketch map locating Tuk Play area

Geology: The Eskimo Lakes Arch is a positive structural element which confines the Beaufort-Mackenzie Basin on the southeastern flank. Delta-front sandstones of the uppermost Aklak and lower Taglu sequences onlap the arch along much of its length. These sandstones succeed a thick succession of shale and siltstone of the Aklak and Fish River sequences which in turn overlie the pre-Tertiary core of the arch. The Taglu Sequence is overlain in this area by thick sandstones of the Iperk Sequence and are progressively truncated onto the arch by the strongly erosive basal Iperk unconformity with consequent increased risk to trap integrity.

Taglu delta front sandstones occur in upwards-coarsening cycles 15 to 45 m in thickness commonly capped by several metres of massive sandstone. Where the massive sandstone is absent, the delta front packages are thinly-bedded at a decimetre scale with individual sandstones unresolved on most conventional logs. Porosity is typically in excess of 27% in these relatively shallow sandstones. Delineation of the Tuk J-29 discovery has indicated that individual delta front sandstones are not areally extensive and pinchout between closely spaced delineation wells.

The flank of the Eskimo Lakes Arch is formed by major down-to-basin listric faults of the Eskimo Lakes Fault Zone. Many of these faults have a long history of reactivation extending into the Neogene. Fault displacements in the Tertiary are, however, much less than in older rocks and are in the order of tens of metres. Shorter faults cross-cut the major lineaments producing a large number of small, compact, fault-bounded prospects. Pool sizes are further reduced by stratigraphic pinchout that does, however, benefit up-dip seal in this play, where cross-fault leakage is a problem.

Oils in this play probably are derived from organic-rich shales of the Upper Cretaceous Smoking Hills and Boundary Creek Formations. Considerable vertical migration up fault planes and minimal lateral migration is required to place hydrocarbons in the shallow Tertiary reservoirs.

Pervasive flushing of thicker sandstone units by meteoric waters has resulted in degradation of oils. Wide variation in oil gravity is observed between zones. As a general rule, the shallower and thicker sandstones host heavy oil of less than 20^{o} API: oils of higher gravity are preserved in thinner, deeper zones. A risk factor for heavy oil has been included in the prospect risk.

Deep burial of the Upper Cretaceous source rocks may have resulted in gas generation on the down thrown side of the Eskimo Lakes Fault Zone. An older (Jurassic?) source for gas is, however, the more likely explanation for gas occurring as gas pools and associated with oil in this play. Reservoirs in this play are normally pressured.

Exploration History: Esso PCI Home <u>et al</u>. Tuk J-29, drilled in 1985, was drilled as a delineation to the Lower Cretaceous gas/condensate discovery at Tuk L-09. The primary objective proved wet but several up-hole zones in the Tertiary section tested substantial rates of both oil and gas. A flurry of drilling followed, directed exclusively to testing the Tertiary. Most wells in the vicinity of the original discovery tested hydrocarbons although from different zones and with minimal recoveries of low-gravity oil from the shallower zones. The wells of this follow-up program indicate a complex faulted structure and rapid lateral changes in many lithological units.

The play has been tested along the strike of the Eskimo Lakes Arch both to the northeast and southwest. A total of 14 wells have been drilled to test the play since the Tuk J-29 discovery. These wells have tested 9 separate prospects resulting in two discoveries; oil and gas at Tuk and gas in Ikhil K-35. Delineation drilling around Tuk has indicated the existence of several pools in the Tuk field which are separated both stratigraphically and geographically.
Wells drilled to test Lower Cretaceous targets may have failed to evaluate the shallower Tertiary sandstones which, in many cases, were cased without logging.

TAGLU PLAY

Play Definition: This play was defined to include all pools and prospects within the Taglu sequence occurring under the outer Mackenzie Delta and nearshore areas (Fig. 20). It is principally a gas play although a small proportion of pools contain significant quantities of oil.

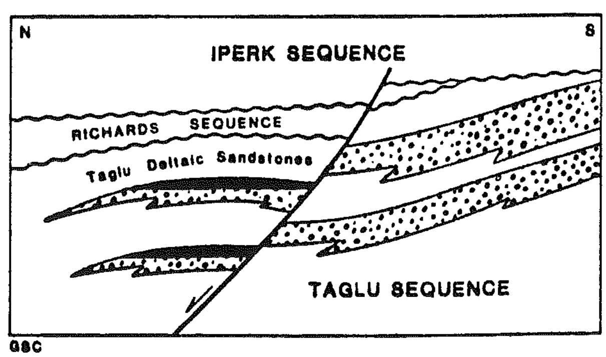

Figure 20 Schematic sketch of trap types - Taglu Play

The play area is confined by erosion beneath the basal Kugmallit and Iperk unconformities to the southwest, shale-out of deltaic facies to the north and northeast and a change in structural style along the flank of the Eskimo Lakes Arch to the southeast (Fig. 21).

Geology: The deltaic sandstones of the Taglu Sequence were deposited in a spectrum of delta-front and delta-plain depositional sub-environments. A proximal delta front assemblage of upwards-coarsening delta-front sandstones overlain by distributary mouth bar and distributary channel deposits characterizes the central area of this play. Sandstone packages occur up to 50 m in gross thickness with most falling in the range 15 to 30 m. Sandstones in the upwards-coarsening delta-front strata occur in beds 1-3 m thick, interbedded with mudstones. Overlying sandstones related to more proximal depositional environments are generally massive and form the prominent Taglu reservoir. Porosity and permeability are good. Lateral continuity of sandstones varies in this play, with thin sandstones likely to be of restricted areal extent. Thicker series of stacked channel sandstones extend laterally over considerable distances (in excess of 5 km at Taglu Field).

Top seal to the Taglu Sequence is provided by shales of the Richards

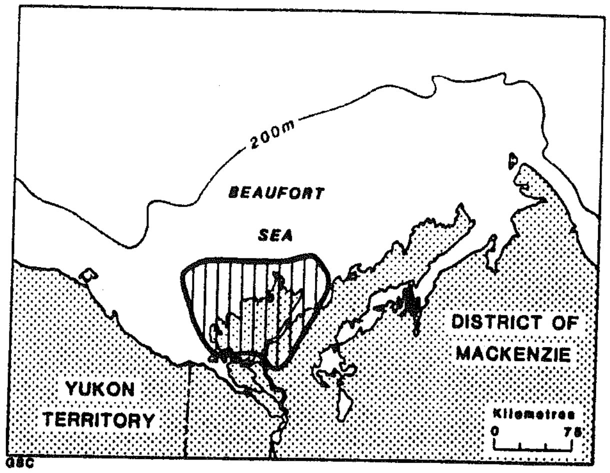

Figure 21 Sketch map locating Taglu Play area

Sequence. Unconformities at the base of the Kugmallit and Iperk Sequences truncate both Richards and Taglu sequences across some of the higher structures. The Kugmallit and Iperk sequences are sandy and no top seal can be expected where erosion to the level of the Taglu reservoirs occurred.

Traps in this play are mainly structural and involve northward plunging anticlines segmented by numerous east-west trending down-to-basin listric faults. Some of these faults exhibit large throws sufficient to completely offset the Taglu Sequence (e.g. at Taglu Field) and hence delineate separate prospects. More commonly, faults are of lesser throw and the entire anticline has been regarded as a single prospect. Faulting significantly increases the number of pools per field, hence the number of wells required to drain a prospect.

Many prospects in this play are truncated by an unconformity near the base of the Richards Sequence, lending a stratigraphic component to trapping. Poor seal over this unconformity is a possibility and is expressed by increasing prospect risk.

The source of the abundant gas in this play is unknown. The oils are believed to be derived from shales of the lower Richards Sequence. The relative quantity of oil and gas for this play was expressed as net gas pay and net oil pay probability curves based on the ratios in the significant number of discovered pools in the play.

The Taglu Sequence is not overpressured where drilled. However, it overlies a transition zone into overpressured strata. In prospects deeper than 3,500 m, overpressuring may be expected within the Taglu Sequence. This is a situation that may prove particularly common in the northeastern area of the play.

The majority of undrilled prospects in this play lie in shallow water around the fringes of the subaerial Mackenzie Delta. Water depths for the play do not exceed 15 m.

Exploration History: Taglu Field, discovered in 1971, is the largest gas field in this play. Median value for gas reserves is estimated to be 3 TCF. Subsequent to the discovery of Taglu, 10 additional but smaller discoveries were made in a further 27 exploration wells, for a discovery ratio of 0.370. With the exception of the 1986 gas test at Minuk, discoveries in this play have been onshore in the Mackenzie delta, or in extremely shallow waters of the delta fringe. Three discoveries contain significant oil reserves associated with gas.

IVIK PLAY

Play Definition: The Ivik play was defined to include all pools and prospects in delta-front sandstones of the Upper Richards and lower Kugmallit sequences present under the outer Mackenzie Delta and nearshore areas (Fig. 22). It is an oil and gas play.

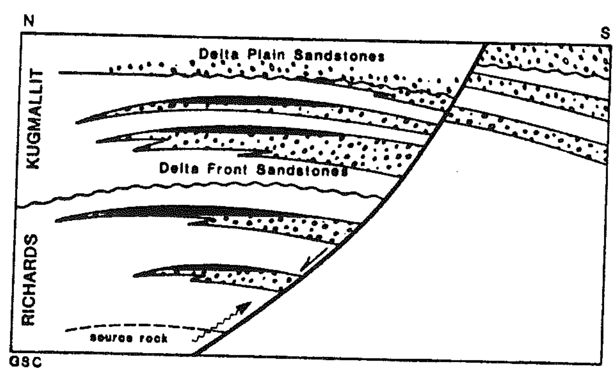

Figure 22 Schematic sketch of trap types - Ivik Play

The play area is limited to the south and west by erosion beneath the Kugmallit sequence and to the northeast by pinch out of potential reservoir sandstones (Fig. 23). The northern boundary is with the Amauligak Play. Different structural type, higher risk of top seal, thinner potential reservoir and lower sandstone continuity serve to distinguish between the Ivik and Amauligak plays.

Geology: Within the area of this play delta-front sandstones are present beneath the thick succession of Kugmallit delta-plain sediments. The delta-front deposits are characterized by upwards-coarsening packages of siltstone and sandstones, separated by shales. Similar sandstones occur both above and below the sequence boundary between Richards and Kugmallit sequences and are grouped together in this play.

Upwards-coarsening packages are typically 30 m thick with 40% net sandstone. Most wells encounter a series of these packages separated by shales that are effective seals. Lateral pinch-out of delta front sandstones is expected.

Traps in this play are structural and are created by rollover into northeasterly-trending listric faults. Syn-depositional growth on these faults is likely. Faults

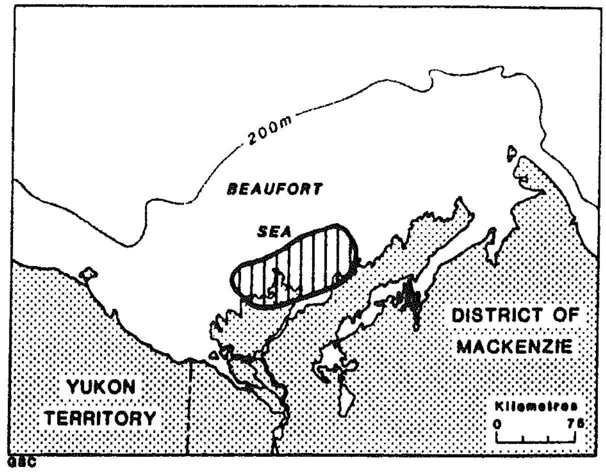

Figure 23 Sketch map locating Ivik Play area

commonly juxtapose the upper Kugmallit delta plain sandstones against potential reservoir units with an attendant high risk of cross-fault leakage.

The source of gas in this play is unknown. Oils are from a Tertiary source, probably in the lower Richards Sequence. The proximity, in a stratigraphic sense, of potential reservoir rocks in the upper Richards and basal Kugmallit sequences to a possible oil source in the lower Richards, enhances the prospects for oil migration.

Reservoirs in this play are expected to be normally pressured.

Pools and prospects are compact in area and underlie the northeastern Mackenzie delta and in shallow waters immediately offshore. Water depths do not exceed 12 m.

Exploration History: Six significant discoveries have resulted from 12 prospects tested, for a discovery ratio of 0.5. The first well to test this play was IOE Taglu G-33, which drilled deeper to prove hydrocarbons in the Taglu Sequence. No hydrocarbons were observed in the thin sandstones of the basal Kugmallit in this well. Imperial Mallik L-38 was the first discovery (gas) in the play, closely followed by an oil discovery at Imperial Ivik J-26, 12 km to the northeast. Recent discoveries are oil with associated gas at Arnak K-06 and gas with minor oil and condensate at Hansen G-07.

SOUTH DELTA - MESOZOIC PLAY

Play Definition: This play was defined to include all pools and prospects in Jurassic and Lower Cretaceous sandstones underlying the southern part of Mackenzie Delta (Fig. 24). It is a gas and oil play.

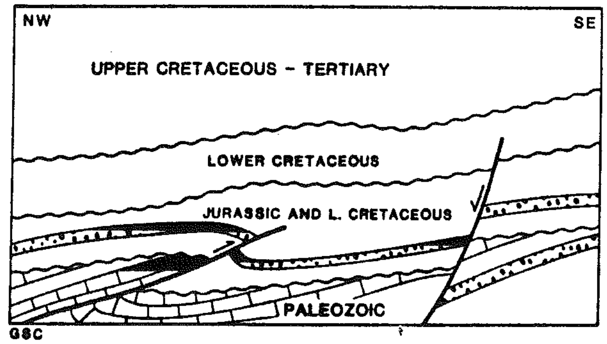

Figure 24 Schematic sketch of trap types - South Delta - Mesozoic Play

The play area is between the Caribou Hills in the east to the northern Richardson Mountains in the west, and the Eskimo Lakes Fault Zone in the south to about the Kugpik area on the Mackenzie Delta, in the north (Fig. 25).

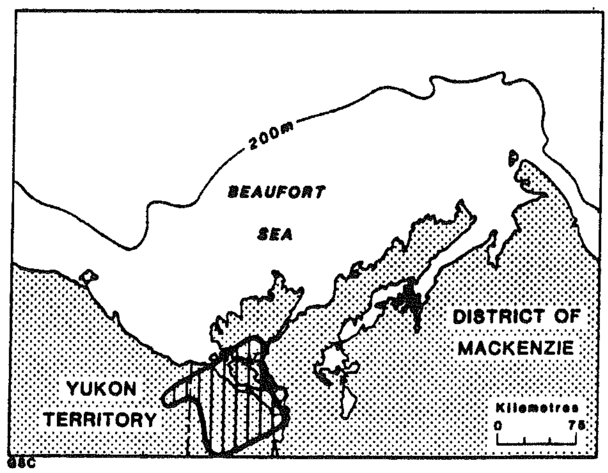

Figure 25 Sketch map locating South Delta - Mesozoic Play area

Geology: Within the play area there is a thick succession of Jurassic and Lower Cretaceous strata, consisting of alternating shale- and sandstone-dominant formations. The principle potential reservoirs are the Bug Creek Group, Parsons Group, basal sandstone of the Mount Goodenough Formation and the Rat River Formation.

Two major unconformities truncate some of the reservoir horizons. An unconformity at the base of the Mount Goodenough Formation has eroded significant amounts of Lower Cretaceous and Jurassic strata. The most pronounced effect has been the truncation of the Parsons Group in the southern half of the play area, especially adjacent to and across the Eskimo Lakes Fault Zone, and on, and adjacent to, the Cache Creek High. On the upthrown side of the Eskimo Lakes Fault Zone the Parsons Group is commonly absent. Adjacent to the Cache Creek Uplift the Martin Creek and part of the Kamik formations are commonly preserved below the unconformity. In the latter situation the basal Mount Goodenough sandstone cannot be differentiated from the Kamik sandstones.

The second unconformity separates Lower and Upper Cretaceous strata and is well illustrated in the Kugpik area. There, Upper Cretaceous shale rests erosionally on a truncated Kamik Formation at Kugpik O-13, whereas about 2 km to the west, at Kupik L-24, Upper Cretaceous strata rest erosionally on Permian rocks.

The Lower to Middle Jurassic Bug Creek Group (Poulton et al., 1982; Dixon, 1982) is present throughout the area but its distribution is also affected by the above two unconformities, as well as an apparent depositional pinch-out to the east. The Bug Creek Group consists of alternating sandstone and shale units.

The Berriasian to Hauterivian Parsons Group, which consists of the Martin Creek, McGuire and Kamik Formations, is the most widespread and thickest of the potential reservoir intervals. It originally underlay the play area but subsequent erosion (explained above) has modified thickness trends.

Rat River strata are late Barremian to early Aptian in age and consist of a series of coarsening-upward units deposited as marine bars/shoals. Its distribution is limited to the northwestern part of the play area, due to three factors: late Aptian/early Albian erosion in parts of the Kugmallit Trough, facies change to a more argillaceous succession to the north and northeast, and truncation by Late Cretaceous and Tertiary events.

The potential reservoirs in the Jurassic - Lower Cretaceous succession are mostly quartz arenites with variable degrees of cementation, although in most places porosity seems to be generally low because of widespread silica cementation. The bulk of the strata are marine in origin, with some local lagoonal and delta-plain deposits in the basal part of the Kamik Formation.

Adequate seals are present in the thick shale succession separating the sandy formations.

Trap types are dominantly structural, consisting of closure against faults. Normal faults are the most common type but the Unak L-28 well, in the northern part of the area, penetrated a repeated Mesozoic section, indicating the presence of thrust faults. The thrust faults are believed to be present only in the northwestern part of the play area. Generally poor quality reflection seismic in parts of the play area make it difficult to map thrust faults and related closure.

Potential source rocks are present in the extensive Jurassic and Lower Cretaceous shale successions, although terrestrially derived organic matter is dominant, indicating a gas-prone source. Some parts of the Albian Arctic Red Formation contain good marine source rocks, although levels of maturity of this shallowly buried interval are not generally high. The Upper Cretaceous Boundary Creek and Smoking Hills formations are the richest, oil-prone source rocks in the play area but due to Tertiary and Quaternary erosion they are limited to the northern part of the play area.

Exploration History: Approximately 14 wells in the play area penetrated Jurassic and Cretaceous strata, of which two were discoveries. Kugpik O-13 was drilled in 1973 and recovered oil from a truncated Parsons Group. The source rock is believed to be the Smoking Hills Formation, which directly overlies the Parsons Group at Kupik O-13. The second discovery was Unak L-28, drilled in 1986, in which gas was recovered from the Rat River Formation.

SOUTH DELTA - PALEOZOIC PLAY

Play Definition: This play was defined to include the pools and all the prospects in Upper Paleozoic strata underlying the southern part of Mackenzie Delta (Fig. 26). The play area is between the Caribou Hills in the east to the northern Richardson Mountains in the west, and the Eskimo Lakes Fault Zone in the

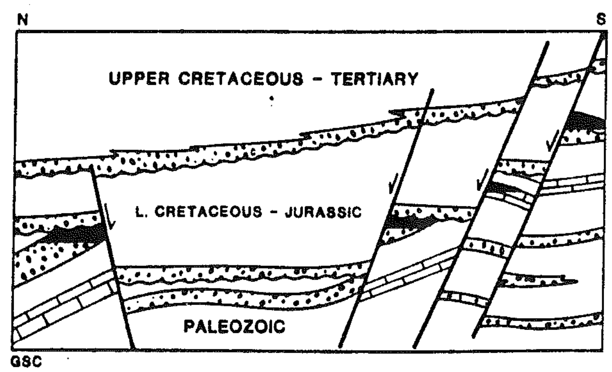

Figure 26 Schematic sketch of trap types - South Delta - Paleozoic Play

south to about the Kugpik area on the Mackenzie Delta in the north (Fig. 27). Gas may be the principal hydrocarbon.

Geology: Our understanding of Upper Paleozoic stratigraphy in this part of Mackenzie Delta is poor. Only 11 wells have penetrated Upper Paleozoic strata, most of which have only minimal penetration. Permian strata are mostly clastics, predominantly interbedded shale and sandstone, with some local coarser strata. The Permian strata presumably correlate with the Sadlerochit Formation in the British Mountains to the west. Presumed Carboniferous strata contain a mixture of clastics and carbonates and probably correlate with the Lisburne Group of the British Mountains and northeast Alaska.

Porosity and permeability in the penetrated Upper Paleozoic section is generally poor, and poor reservoir quality may be widespread. Fracturing in the carbonates could enhance porosity and permeability.

Structural traps consisting of closure against faults are readily recognized. Normal faulting is present throughout

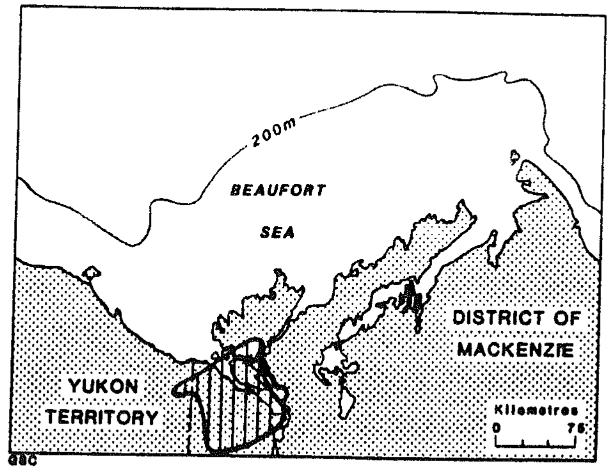

Figure 27 Sketch map locating South Delta - Paleozoic Play area

the play area but thrust faults also are present, at least in the northwestern part of the play area. The thrust faults are difficult to identify with presently available seismic data.

Potential Upper Paleozoic source rocks have not been identified but juxtaposition of Paleozoic reservoirs against Mesozoic source rocks could provide good trapping situations.

Exploration History: No significant discoveries or shows were recorded from Upper Paleozoic strata until Unak L-28 was drilled in 1987. Gas was recovered from Upper Paleozoic limestones in this well.

MAYOGIAK PLAY

Play Definition: This play was defined to include all pools and prospects in Paleozoic carbonates underlying Tuktoyaktuk Peninsula and South Mackenzie Delta (Fig. 28).

The play area extends from the southern part of the Mackenzie Delta along the northwest side of Tuktoyaktuk Peninsula into the shallow water areas of the Beaufort Sea (Fig. 29).

Geology: Fine to coarsely crystalline dolostone, bioclastic limestone and pelloidal limestone are present in the poorly understood carbonates that subcrop under Tuktoyaktuk Peninsula. Wielans (1987, 1988) compared them to the Lower Paleozoic succession in the Interior Plains to the south, based on lithological similarity and a limited amount of paleontological data. The north to north-northeast striking subcrop pattern of these carbonates indicate that the strata were faulted or folded prior to Mesozoic deposition (Wielans, op. cit.).

The limited lithological data indicates that the penetrated successions are mostly platform carbonates with generally poor porosity. Fractures enhance the porosity, and are present in the Mayogiak J-17 and West Atkinson L-17 reservoir strata.

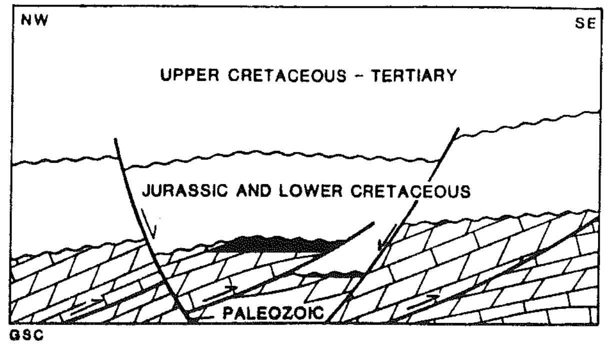

Figure 28 Schematic sketch of trap types - Mayogiak Play

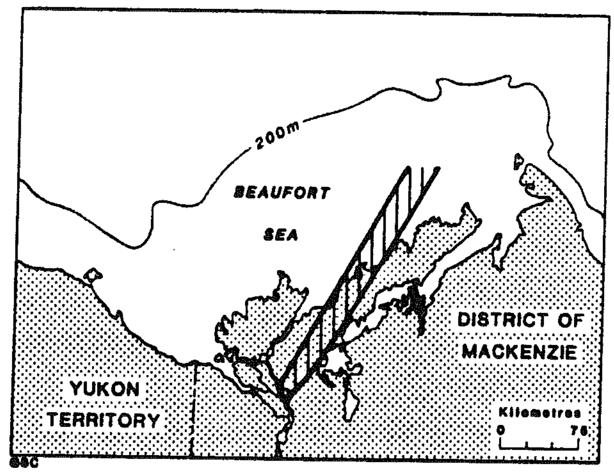

Figure 29 Sketch map locating Mayogiak Play area

Overlying Jurassic-Cretaceous strata contain thick shale units that provide adequate seal.

Traps are anticipated to be tilted fault blocks along the northwestern flank of the Eskimo Lakes Arch.

The two discoveries to-date have been oil, apparently derived from the Upper Cretaceous Smoking Hills Formation. The two discoveries are located on the flank of the Eskimo Lakes Arch, in a good position to trap migrating hydrocarbons from the deeply buried section in the Kugmallit Trough. No indigenous potential source rocks are known within the Paleozoic carbonates, although throughout the area the carbonates are capped by the Canol shale, an organic-rich unit. However, the Canol shale is usually thermally overmature in the play area and may be expected to be a gas source.

Exploration History: Eighteen separate tests have penetrated Lower Paleozoic carbonates, although there are as many more pentrations on the Parsons structure. Only two discoveries have been made, at Mayogiak J-17 and West Atkinson L-17, both oil in fractured carbonates. At J-17 the reservoir is in dolostone, presumed to be equivalent to the Ronning Group, and at L-17 the reservoir is in limestone of presumed Landry eqivalence.

Offshore Delta Play Group

NETSERK PLAY

Play Definition: The Netserk play was defined to include the pools and all the prospects in delta-plain facies of the Kugmallit Sequence and the transgressive sandstones at the base of the Mackenzie Bay Sequence that underlie the inner shelf areas offshore from Mackenzie Delta (Fig. 30). It is a gas play.

Water depths are less than 10 m across much of the play area, increasing to 18 m in the northeastern corner of the play. About half of the play area is in waters less than 5 m deep with prospects accessible from offshore islands.

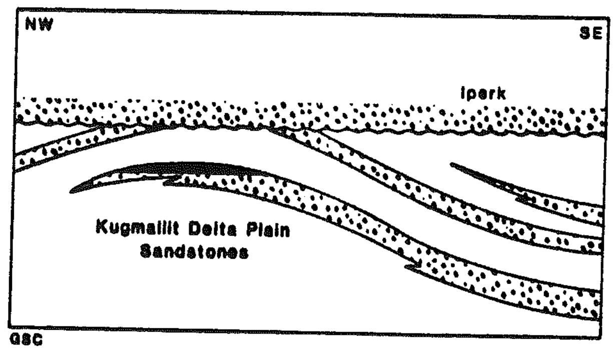

Figure 30 Schematic sketch of trap types - Netserk Play

The play is bounded on the northern side by a facies transition to delta-front (Amauligak Play) and to east and west by limits of sand deposition (Fig. 31). The southern limit is controlled by sub-Iperk Group erosion of Mackenzie Bay shales. The play is underlain by the Ivik Play over most of its extent.

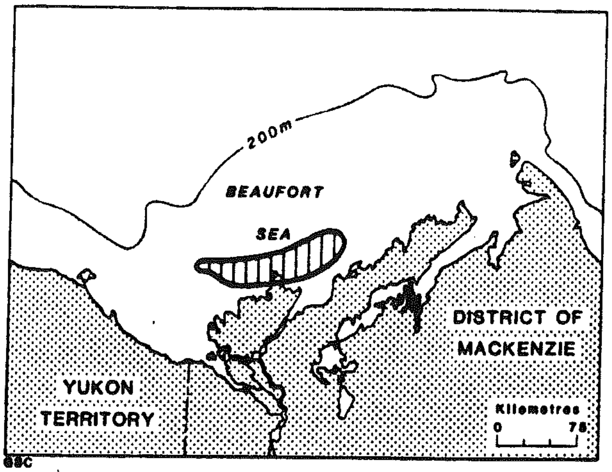

Figure 31 Sketch map locating Netserk Play area

Geology: This play is characterized by thick potential reservoir sections of high porosity and permeability. Net sand thickness varies from 200 m in areas of the delta plain which were remote from preferred river tracts, to more than 1000 m along an axial thick running south to north through the central area of the play. The sand-to-shale ratio commonly is between 0.5 and 0.7, declining towards the eastern and western limits of the play. Sandstones are blocky in log profile, and occur in units 50-200 m in thickness. The sandstones are fine to medium grained with coarse to conglomeratic channel lags common. Few shales are present within the sandstone units. In general, the sandy nature of the section increases the risk of absence of seal for this play.

Deposition of sandstones occurred in stacked channel tracts on the delta plain. Orientation of the axes of these tracts varied between northwesterly and northeasterly. Pinchout of sandstone units characterizes the flanks of the channel tracts. The orientation of channel tracts coincides with the orientation of anticlinal axes in this area of the basin. The up-dip pinchout of a channel tract on the flanks of these anticlines is a potentially effective trap and constitutes the principal trapping mechanism in this play.

Channel sandstones which extend across the crest of anticlines create purely structural traps. Crestal erosion of anticlines has resulted in prospects of this type being few in number and they have been included in this play as having a high risk equivalent to the flanking stratigraphic trap.

The potential hydrocarbon in this play is expected to be gas, possibly sourced from within the Kugmallit Sequence or migrating vertically from deeper units. Oil sourced from the underlying Richards Sequence and present in pools in the basal Kugmallit and Upper Richards sequences, is unlikely to have migrated in sufficient volume through the thick delta-plain sequence to form significant accumulations. Prospects in this play are elongate in a north-south direction. Drainage characteristics of pools are likely to be excellent. Normally pressured reservoirs are anticipated.

Exploration History: Ten wells have been drilled in the area of this play, generally on the crests of anticlines. Imperial Netserk F-40 is a gas discovery in delta plain sandstones near the top of the Kugmallit. This well does not test the stratigraphic potential of this play and is on the western fringe of the play area but does afford positive confirmation of reservoir quality and hydrocarbon type.

AMAULIGAK PLAY

Play Definition: The Amauligak play was defined to include all pools and prospects within proximal delta-front sandstones of the Kugmallit Sequence that underlie the mid-shelf area of the Beaufort Sea immediately north of Mackenzie Delta (Fig. 32). It is an oil and gas play.

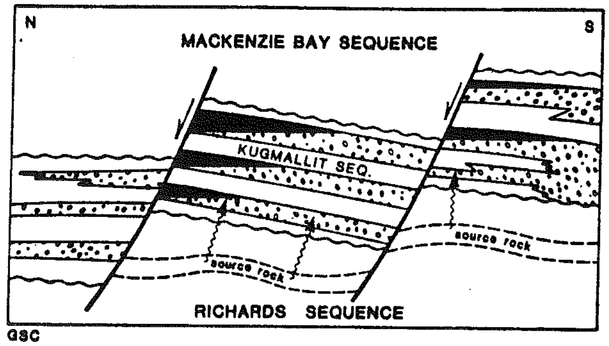

Figure 32 Schematic sketch of trap types - Amauligak Play

Vertical stacking of depositional environments during Kugmallit deposition enables facies boundaries to be used to delineate play area (Fig. 33). To the south the play is bounded by the facies boundary with the delta plain facies of the Kugmallit Sequence (Netserk) and to the north by the facies boundary with the distal delta front and shelf facies (Tarsiut and Akpak). The play area is entirely offshore in water depths between 15 and 35 m.

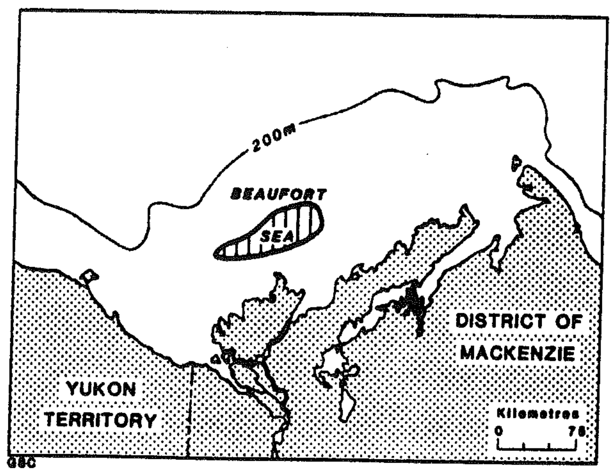

Figure 33 Sketch map locating Amauligak Play area

Geology: The proximal deltal front facies of the Kugmallit Sequence is characterized by upwards-coarsening sandstone units, generally capped by a thick sandstone, indicative of high-energy processes operating in the shallow marine environment. Wells drilled within the area of this play encountered numerous sandstones of this type, separated by shales and siltstones.

The overall net sand varies between 20% and 30% of the Kugmallit Sequence.

Evidence for the dissolution and removal of clay minerals and the development of secondary porosity has been noted in Kugmallit sandstones from several wells and is expected to characterize this play (Schmidt, 1987).

Pools in this play are characterized by reservoir sandstones between 5 and 15 m thick, average porosity of 21%, but with porosities up to 30% common, and recovery factors estimated (in the absence of sustained production statistics) of 30%. The larger fields contain numerous stacked pools with different water lines. Reservoir sands are expected to have good continuity across most prospects.

Thick interbedded shales and the overlying Mackenzie Bay shale succession provide good seals. Cross-fault seal can be a problem where throws are insufficient to completely juxtapose the Kugmallit Sequence against the Mackenzie Bay shales.

Major post-depositional movements on faults of the Tarsiut-Amauligak Fault System have resulted in the development of large rotated fault blocks, which comprise the class of structural trap envisaged in this play. Throw on these faults can be very large (in the order of thousands of metres) and sufficient to juxtapose reservoir sandstones with older source rocks of the lower Richards Sequence.

Source rocks for this play have produced both oil and gas in large quantities with oil and gas being typical of the large discoveries and gas typical of the smaller discoveries. A general increase in the relative quantity of oil occurs with depth below the top of the Kugmallit Sequence: the highest zone tend to be gas filled and the lower zones with much less gas and more oil. This phenomenon can be rationalized in terms of differential segregation of the lighter and heavier hydrocarbons during migration.

Reservoirs in the Kugmallit Sequence are generally normally pressured although increasing formation pressures occur towards the base of the Kugmallit Sequence in some wells. Overpressured reservoirs in the deeper prospects are a possibility.

Discovered pools and prospects are elongate along the strike of the controlling fault but not excessively so: length to breadth ratios of 1:3 are typical.

Exploration History: Of a total of nine prospects tested in this play, six are regarded as significant discoveries resulting in an excellent discovery ratio of 0.71. However, of these discoveries five are oil and gas discoveries, (Nipterk, Issungnak, Itiyok, Amauligak and West Amauligak): the remaining two, Amerk and Isserk, are small gas discoveries. Failures have occurred at North Issungnak and Kaubvik (suspect closures), and Kogyuk (failure of updip migration?).

The low trap fill typical of the small gas discoveries is probably the result of inadequate vertical migration.

The first well drilled in this play was Imperial Isserk E-27. A series of exploration wells followed through the early eighties, all drilled from artificial islands, which culminated in the 1984 discovery of the Amauligak field by Gulf Canada Ltd. and partners.

TARSIUT PLAY

Play Definition: The Tarsiut play was defined to include all pools and prospects within distal delta-front strata of the Kugmallit Sequence located in the mid-shelf areas offshore from the Mackenzie Delta (Fig. 34). The play includes both gas and oil.

The play area (Fig. 35) is bounded to the south by a facies change to proximal delta front (Amauligak Play), to the north by the Kugmallit Shelf edge, and to east and west by the disappearance of potential reservoir at the fringes of deltaic influence. The play is entirely offshore in water depths varying from 15 to 35 m.

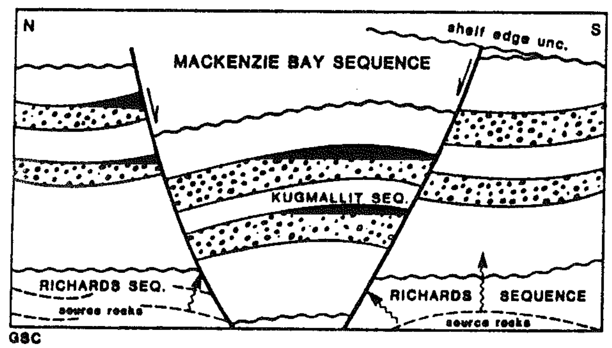

Figure 34 Schematic sketch of trap types - Tarsiut Play

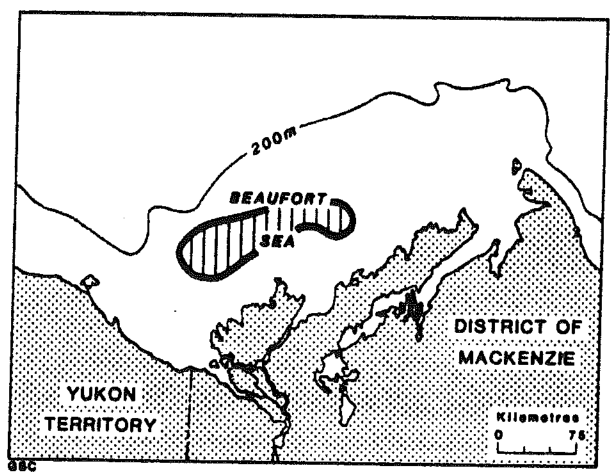

Figure 35 Sketch map locating Tarsiut Play area

Geology: The distal delta front facies of the Kugmallit Sequence is characterized by packages of interbedded sandstone and siltstone separated by thick shales. The sandstone/siltstone packages generally exceed 50 m in thickness and reach 200 m in some of the more proximal wells. Although most wells have encountered several stacked sandstone/siltstone packages, there is increasing risk of absence of reservoir towards the northern (distal) limits of the play.

The incidence of sandstone beds increases upwards through these packages giving an overall appearance on logs of upwards-coarsening. Bed thicknesses seldom exceed 2 m and are more commonly 1 m or less. Net clean sandstone percentage within the sandstone/siltstone packages averages 20%. Individual sandstone beds commonly have an abrupt base and exhibit some upwards-fining with increasing lamination and silt content. Excellent porosity occurs in the coarse and medium-grained sandstones and may be partially due to secondary dissolution. The thin-bedded nature of the reservoir is recognized as adversely affecting recovery factor.

The thick interbedded shales and overlying shale succession of the Mackenzie Bay Sequence provide good seals.

The majority of traps in this play are structural and were created by major post-depositional movement on faults of the Tarsiut-Amauligak Fault System. These faults are long, sinuous, and trend east-northeast. Throws are commonly large and variable along the fault and may be down-to-basin or antithetic. Resulting pools and prospects tend to be elongate along the strike of the fault with length-to-breadth ratios commonly exceeding 4:1.

Pinch-out of the sandstone/siltstone packages adds a stratigraphic component to trapping. These pinch-outs are visible seismically and have influenced the location of some wells. For this reason, the stratigraphic component is not considered to increase risk of reservoir absence across prospects, rather to lead to an increased number of smaller prospects.

A relatively small number of prospects in this play require sub-unconformity seal as a trapping component. The unconformity in question occurs near the edge of the Kugmallit palaeo-shelf and progressively truncates the Kugmallit Sequence to the north. This truncation affects the northern limit of the play where reservoirs are anticipated to be poor or absent. These prospects are not, therefore, considered to be important components of the play.

Hydrocarbon source rocks for this play occur in the lower Richards Sequence. Discoveries to date have been either gas or oil. The gas discoveries may reflect high source rock maturity and gas generation in the southwest and vertical migration of gaseous hydrocarbons only in discoveries with very low trap fill. Oil discoveries require long vertical migration routes, probably up fault planes from lower Richards source rocks within the oil window. With no adequate model available for predicting type of hydrocarbon generated and migration routes, a simple split of predicted pools into oil or gas was made on the basis of the current ratio of oil to gas discoveries.

Reservoirs in this play are expected to be normally pressured.

Exploration History: The first well drilled in this play was Dome et al. Tingmiark K-91, which was abandoned prematurely after encountering a gas kick at the top of the Kugmallit Sequence and failed to fully evaluate the prospect. The Ukalerk gas discovery followed. The first oil in the play was discovered in Dome et al. Tarsiut A-25. A total of seven prospects have been adequately tested resulting in six significant hydrocarbon discoveries for an extremely high discovery ratio of 0.857. Of these, two are oil discoveries and four are gas.

AKPAK PLAY

Play Definition: The Akpak play was defined to include all prospects in distal delta-front strata of the Kugmallit Sequence that underlies a shelf-edge unconformity under the mid-to outer-shelf of the Beaufort Sea (Fig. 36). It is an oil and gas play. The play area (Fig. 37) parallels the Kugmallit paleo-shelf edge distal to the Tarsiut play. Prospects lie in water depths between 35 and 55 m.

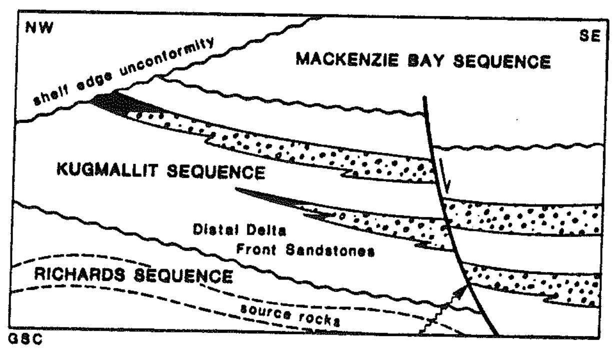

Figure 36 Schematic sketch of trap types - Akpak Play

Geology: The distal delta front facies of the Kugmallit Sequence has been described for the Tarsiut Play.

Sandstones are generally thin-bedded and thick vertical sequences of potential reservoir are not expected in this distal area of the delta front.

A reversal of regional dip towards the shelf edge, combined with a downcutting unconformity present at the self edge have created a unique trapping configuration which characterizes this play. Up-dip migration sites for hydrocarbons terminate beneath this unconformity and also at delta front sand pinch-outs.

The play is characterized by a relatively small number of prospects although some are of large size. High risks are assigned to the presence of sandstones of reservoir quality and to hydrocarbon migrations.

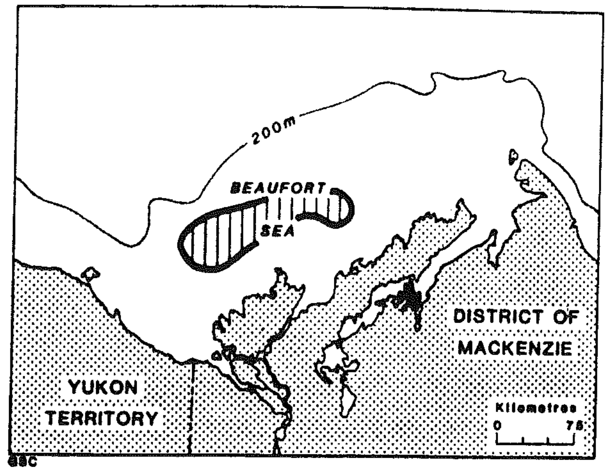

Figure 37 Sketch map locating Akpak Play area

Exploration History: Gulf et al Akpak 2P-35 is the only well to have been drilled into this play. The well was dry and abandoned. A high recovery of formation fluids from a 7 m sandstone within the Kugmallit Sequence, indicates good permeability. In general, however, the Kugmallit was sand-poor in the well.

West Beaufort Play Group

ADLARTOK PLAY

Play Definition: This play is defined to include all prospects and the one pool in large anticlinal structures that involve Paleocene and Eocene deltaic sandstones in the West Beaufort Sea region. Secondary targets include unconformity related stratigraphic traps in sandstones on the flanks of the folds (Fig. 38). The

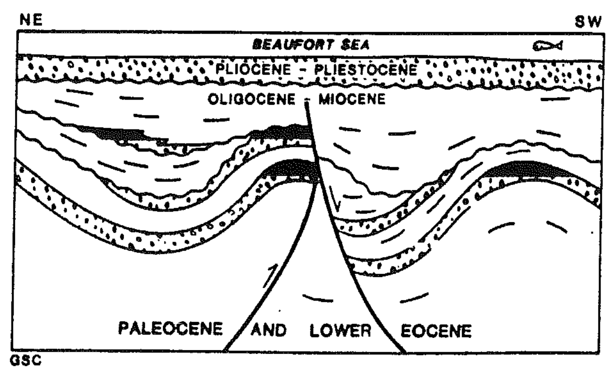

Figure 38 Schematic sketch of trap types - Adlartok Play

play area extends from the Yukon coastline north and northeastward to the (interpreted) depositional limits of the lower Tertiary deltaic facies (approximately 80 to 100 km offshore). The eastern boundary of the play area extends onto western Richards Island (Fig. 39). Water depths over the offshore prospects vary from a few metres nearshore up to 300 m at the north end of the Mackenzie Trough.

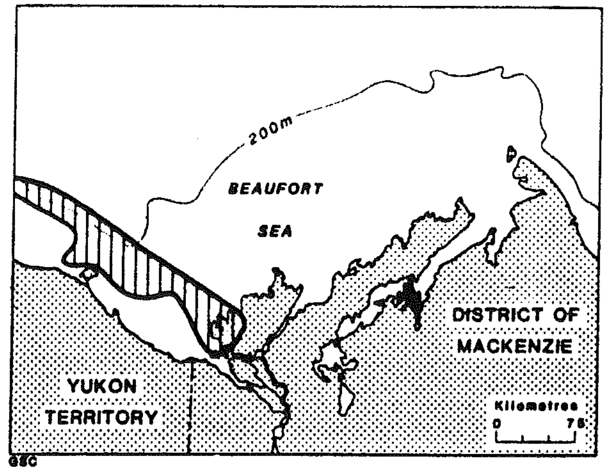

Figure 39 Sketch map locating Adlartok Play area

Geology: The Paleocene to Early Eocene Fish River and Aklak (lower Reindeer) sequences have a combined thickness of 5000 to 7000 metres in the West Beaufort area and both sequences contain thick and areally extensive successions of delta plain and delta front strata. The delta plain deposits consist of 10 to 40 m thick fining-upward, massive and coarsening-upward sandstone and conglomerate sections interbedded with thin shale and coal beds. The delta front deposits consist of 50 to 100 m thick coarsening-upward sandstone sections separated by thick shale beds. Sandstone porosity in these successions varies from averages of 10% to 20%. The lower porosity values result from carbonate and silica cementation within the sandstones. Other potential hydrocarbon reservoirs in the play area include shallow marine transgressive sandstones. The transgressive deposits occur above major erosional unconformities of Early and Middle Eocene age, which locally truncate substantial sections of sub-unconformity strata.

Oligocene and Miocene sediments throughout most of the West Beaufort area are mudstone-dominant and should provide adequate seals for many of the structural prospects.

Structural traps in the play area exist on large, asymmetric anticlines oriented in an arcuate array extending from Mackenzie Bay around to the Canada - U.S. border. The anticlines are compressional structures and are locally cored by thrust or high angle reverse faults. In addition to the anticlinal structures, the play area also contains numerous normal listric faults, most of which are oriented in a northeast direction. The normal faults modify or form part of many of the structural closures.

Potential hydrocarbon source rocks include the Tertiary shales of the lower Richards and lower Fish River sequences and the oil-prone shales of the Boundary Creek Formation/sequence. The distribution of Boundary Creek strata beneath the western Beaufort Sea is not known and its potential as a major oil source remains in question. Coal beds within the Tertiary deltaic sections may have some gas source potential. The lower Tertiary sequences in the West Beaufort area are at higher levels of thermal maturation than seen elsewhere in the basin. The maturation conditions appear to be very good for significant hydrocarbon generation in at least parts of the play area.

Exploration History: The 1985 oil discovery at Adlartok P-09 is the only discovery in the West Beaufort fold belt.

The uppermost portion of the prospective Aklak-Fish River deltaic section has been unsuccessfully tested in 2 offshore wells and 5 onshore wells. Most of these partially tested prospects still have hydrocarbon potential in deeper reservoir sections (typically below 3500 m) which were not penetrated by the individual wells. The stratigraphic targets have been unsuccessfully tested by one well (Natsek E-56). At least 60 large structural prospects remain completely untested along with a number of stratigraphic targets in the play area.

HERSCHEL PLAY

Play Definition: This play is defined to include all prospects in the complexly deformed Paleocene - lower Eocene strata within the Herschel and Blow River highs (Fig. 40). The two structural complexes occur beneath shallow waters of the southwestern Beaufort shelf (Fig. 41). The Blow River high extends onshore beneath the coastal plain near the Yukon-NWT border.

Geology: The Paleocene to Early Eocene Fish River and Reindeer sequences are

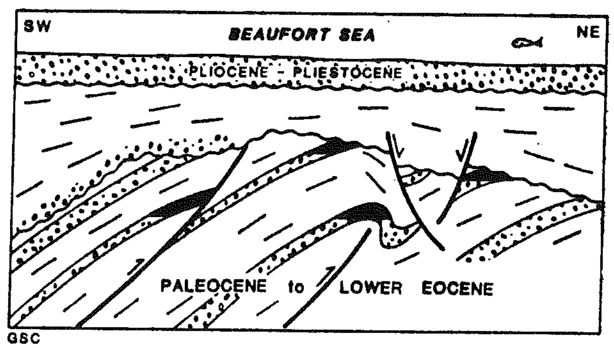

Figure 40 Schematic sketch of trap types - Herschel Play

intensely folded and faulted within the cores of two structurally elevated complexes that form components of the West Beaufort Tertiary fold belt. Potential reservoirs within the deformed lower Tertiary sequences include delta plain and delta front sandstones, similar to those in the Adlartok play. The Hershel and Blow River highs are cored by high amplitude, closely spaced folds and reverse faults (Fig. 40). Significant erosion of sub-middle Eocene strata occurs over the crests of the two highs. Steep (internal) structural dips and crest erosion limits the prospectivity of both complexes. Potential traps will be relatively small areally, confined to the crests of the folds and may include sandstones that subcrop the unconformity. Potential hydrocarbon sources include Paleocene and Upper Cretaceous shales, similar to those of the West Beaufort play.

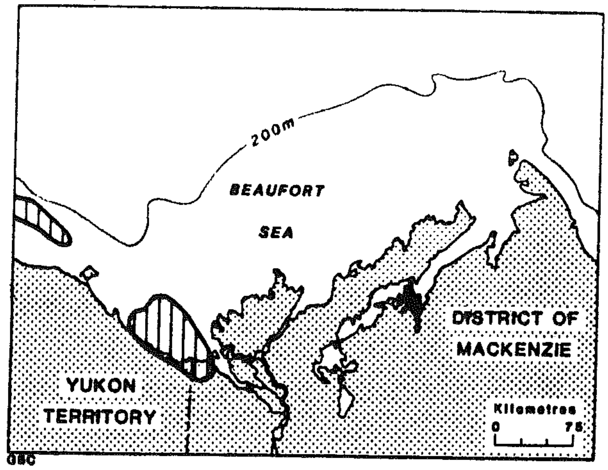

Figure 41 Sketch map locating Herschel Play area

Exploration History: No wells have tested either the Herschel or Blow River highs. Stratigraphic control in the area is provided by two nearby wells (Natsek E-56 and Adlartok P-09).

DEMARCATION PLAY

Play Definition: This play is defined to include all prospects within the upper Tertiary depocentre occurring in the Demarcation sub-basin. This is an offshore play in relatively shallow waters of the Beaufort Shelf (Fig. 43).

Geology: The Demarcation sub-basin is an east-west trending, asymmetric syncline containing up to 7 km of post-middle Eocene sediments within the Richards, Kugmallit and Mackenzie Bay sequences. Potential reservoirs within the sub-basin fill include transgressive sandstones above the base-Richards unconformity at the sub-basin floor and turbidite and shelf sandstones within and along the sub-basin margins (Fig. 42).

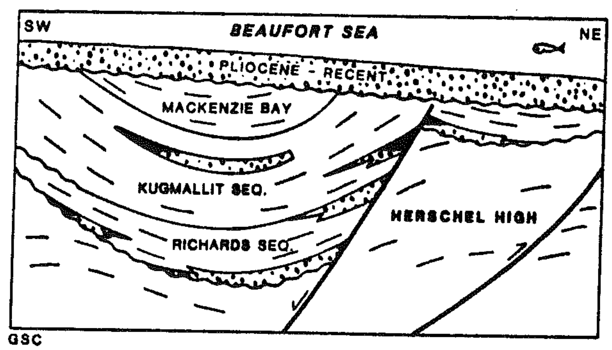

Figure 42 Schematic sketch of trap types - Demarcation Play

Porosity in the sandstones of the upper Tertiary sequences averages 25 to 30% indicating low levels of compaction.

The structure of Demarcation sub-basin is relatively simple with little internal deformation. A normal fault along the north margin of the sub-basin may contribute a structural component to the (otherwise) stratigraphic sub-basin traps. Hydrocarbon sources may occur in the deeper portions of the sub-basin or in adjacent lower Tertiary strata of the Herschel High complex.

Exploration History: The Demarcation sub-basin has been partially penetrated by one well (Edlok M-56) along the eastern basin flank. This well was dry and abandoned, but did encounter reservoir quality sandstones. Analysis of reflection seismic data indicates that the most prospective portion of the sub-basin occurs northwest of the Edlok location.

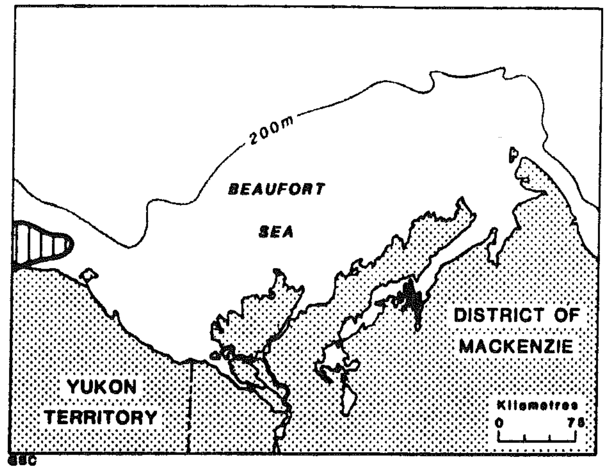

Figure 43 Sketch map locating Demarcation Play area

Deep Water and Other Play Group

KOPANOAR PLAY

Play Definition: This play was defined to include all pools and prospects involving deep water sandstones deposited on the continental slope, rise and basin plain as components of submarine fans. The principal trap type is structural drape over diapiric shale swells with a strong component of stratigraphic pinch out (Fig. 44). The play contains pools with a varied mixture of oil and gas.

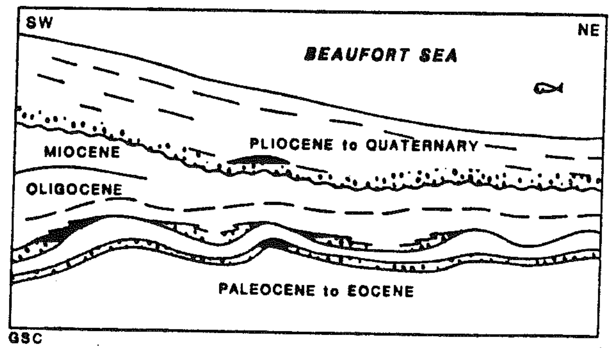

Figure 44 Schematic sketch of trap types - Kopanoar Play

The southern margin of the Kopanoar Play is defined on the Oligocene shelf to slope transition. The play extends

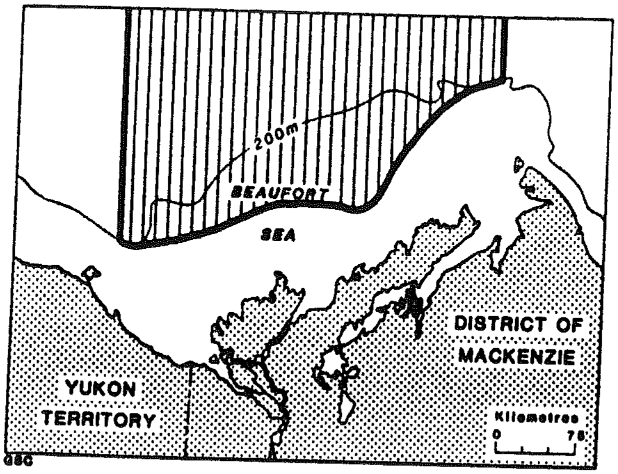

Figure 45 Sketch map locating Kopanoar Play area

northward beneath the outer portions of the modern shelf (Fig. 45). The northern limit is arbitrary and is drawn at approximately 75 km from the shelf/slope break, coinciding with the northern limit of seismic coverage. The western boundary of the play is arbritarily placed along the 137th meridian. Reservoir targets are Oligocene and older and are restricted to the eastern Beaufort-Mackenzie Basin.

Most prospects in this play lie in water depths between 60 and 100 m. However, the northwestern corner of the play falls beneath deeper waters beyond the modern shelf/slope break.

Geology: Reservoirs assigned to this play have been encountered in the Mackenzie Bay/Akpak, Kugmallit, Kopanoar and possibly older sequences. The Kugmallit and Kopanoar Sequences, in particular, contain strata equivalent in age to sand-rich deltaic deposits on the adjacent shelf. Potential reservoir sections in this play comprise packages of thinly-bedded sandstone up to several hundred metres in overall thickness. Individual sandstone beds are less than 1 m in thickness and interbedded with siltstone and shale. The sandstones have a higher clay and silt content than those on the shelf with correspondingly reduced porosity and permeability.

Sandstone units between 5 and 30 m thick are rarer than the thinly-bedded sandstone packages. These have an upwards-fining log profile, are fine to medium grained with average porosities of 15% and more homogeneous permeability. These sandstones can be attributed to deposition by channel processes on the submarine fan whereas the finer grained, thinly-bedded units would represent the product of inter-channel processes.

Wide variation in thickness is evident within seismic sequences beneath the area of this play. The mounded appearance on seismic sections suggests rapid change in the thickness of lithological units. Delineation drilling at Kopanoar has revealed a complex situation of pinch-out and/or local erosion, and partial drape of reservoir units across a large shale-cored structure. Thus reservoir continuity both on a large scale across structures and on the smaller scale of individual sandstone beds must be risked highly.

Most remaining mapped prospects are distal to existing discoveries. However, a diversity of stratigraphic traps are undoubtedly present within the proximal area of the play and may become viable drilling targets.

Oils and condensates in this play are sourced from the Richards Formation and are characterized by a very low level of maturity. Gas may well have originated from several unidentified source rocks within the play area. The absence of oil in the most distal discovery at Kenalooak may be an indication that the Richards oil source is ineffective in this portion of the area.

Exploration History: Thirteen wells have been drilled in this play with most tests in the proximal area of the play. With six significant discoveries, the success ratio is high. However, the characteristics of very thin sandstone beds, broad structures and inconsistent pay distribution within the reservoirs reduces the volume of entrapped hydrocarbons that could be considered recoverable from most of these discoveries. There does however exist the possibility that local conditions could have created above average reservoir characteristics which coupled with the large size of the prospects would result in very large accumulations.

DEEP MARINE WEST PLAY

Play Definition: This conceptual play was defined to include all hydrocarbon prospects with traps in turbidite sandstones of Tertiary age. The play is similar in nature to the turbidite play to the southeast, but includes older (Paleocene-Eocene) potential reservoirs and is located in an area of deeper water. Water depths over the slope and rise increase from 200 m at the shelf edge to 2700 m at the northern limit of the play area. The traps occur along the flanks of, or draped over areally large low relief folds (Fig. 46).

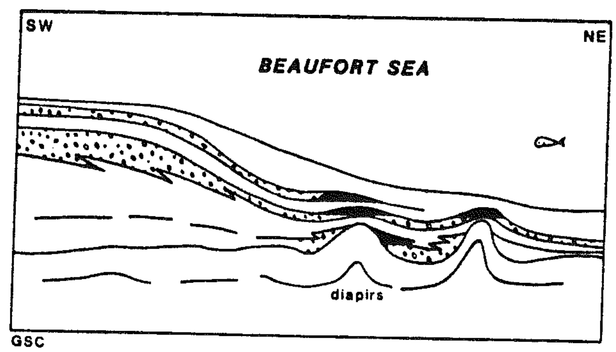

Figure 46 Schematic sketch of trap types - Deep Marine West Play

The play area is bounded on the west by the 141 st meridian west longitude, to the east by the 137th meridian of west longitude, and underlies the present day continental slope and rise of the western and central Beaufort Sea (Fig. 47).

Geology: Potential reservoirs in the northern areas include turbidite sandstones within the Aklak and Fish River sequences and, to a lesser extent, younger Tertiary sequences of Oligocene to Pliocene age. Most of the Tertiary section in this northern play area is expected to be mudstone-dominant basinal (or slope) facies.

The anticlines within the Deep Marine West play area form the northern extension of the West Beaufort fold belt. Structures within the fold belt become more symmetrical, less faulted and more diapiric (in appearance) in a northward direction.

The nature and thermal maturation conditions of potential hydrocarbon source rocks are unknown but it does appear that at least some gas has been generated and trapped in the play area. Reflection seismic profiles across several of the anticlinal structures display direct seismic hydrocarbon indicators, indicating local gas accumulations.

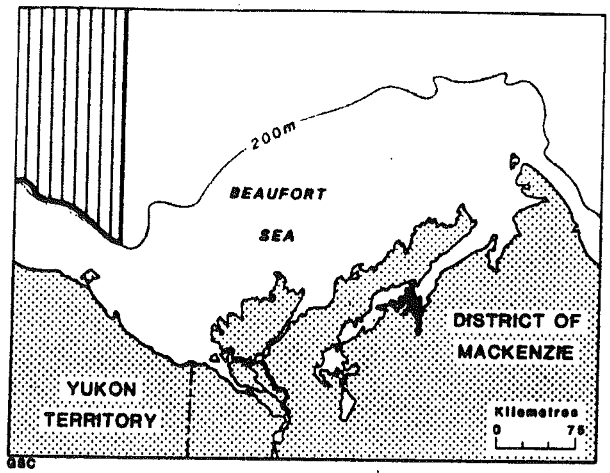

Figure 47 Sketch map locating Deep Marine West Play area

Exploration History: No wells have tested the play area. The deep water over most of the structures may slow the pace of exploration in this region.

HINGE PLAY

Play Definition: This conceptual play was defined to include any pooled hydrocarbons associated with two onlapping seismic sequences that overlie two distinct flexures or hinge lines in underlying bedded sequences (Fig. 48).

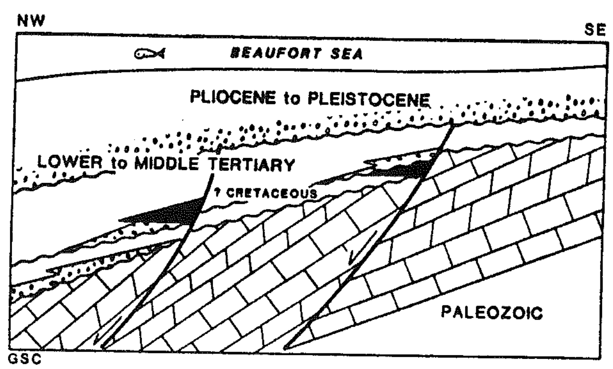

Figure 48 Schematic sketch of trap types - Hinge Play

The potential reservoir sequences are believed to represent lower Tertiary and Lower Cretaceous sandstones. The play occurs (Fig. 49) beneath the eastern Beaufort Sea shelf north of the Tuktoyaktuk Peninsula, in water depths from 20 to 60 m. The play probably extends to the northeast, to offshore Banks Island (and beyond).

Geology: The offshore (northeast) extension of the Eskimo Lakes fault zone is represented by two major tectonic hinge lines (and associated faults) beneath the eastern Beaufort Sea. The basinward (northwest) dip of the sub-Mesozoic unconformity increases abruptly across the hinge lines or fault zones. Reservoirs may occur within Cretaceous or lower Tertiary clastics which onlap the sub-Mesozoic strata, basinward of the hinge lines. In addition to the thick onlap wedge, small normal fault-bounded half grabens occur in some areas along the hinge zone. The grabens may locally contain Mesozoic strata up to several hundred metres thick. Potential reservoirs within the graben fill or onlap wedge include rift-related Lower Cretaceous sandstones and post rift lower Tertiary sandstones.

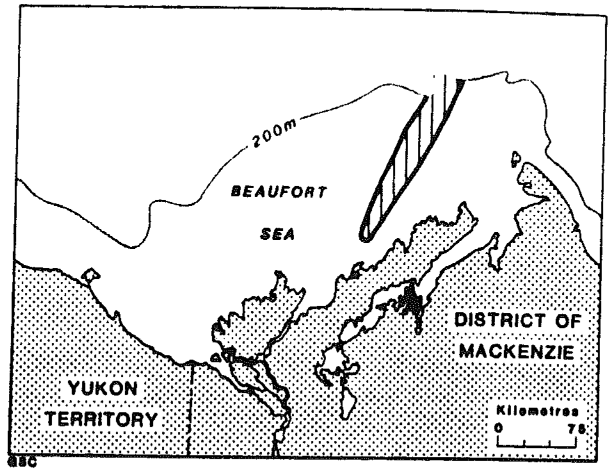

Figure 49 Sketch map locating Hinge Play area

Limited seismic coverage has been inadequate to define individual prospects and the stratigraphic nature of the play can allow for areally very large hydrocarbon accumulations.

Trap seals would be provided by Albian to lower Tertiary basinal shales. Potential hydrocarbon source rocks would be similar to those for the Parsons or Atkinson Point plays.

Exploration History: No wells have tested this play and it remains conceptual in nature. A portion of the onlap wedge section occurs below conventional drilling depths of 5 or 6 km.

IMPERIAL CLASTICS PLAY

Play Definiton: This conceptual play was defined to include all prospects within Imperial Formation clastic reservoirs in structures associated with the Eskimo Lakes Fault Zone (Fig. 50). The play area extends from hte northern end of Tuktoyaktuk Peninsula into the shallow waters of the Beaufort Sea, to the northeast (Fig. 51). Closures against normal faults are the main trap types and natural gas is expected to be the principle hydrocarbon.

Geology: The Upper Devonian Imperial Formation consists of interbedded shale and sandstone of sediment-gravity flow origin, with many of the sandstone beds deposited as turbidites. Some conglomerate beds are present under the northern part of Tuktoyaktuk Peninsula and there is a general tendency to become more argillaceous with thinner sandstone beds to the southwest. Complete sections of Imperial Formation are several hundred metres thick, but is locally only known on the east flank of the Eskimo Lakes Arch where the formation is erosionally truncated.

The cherty sandstone and conglomerate beds are extensively cemented with silica, consequently porosity is very low, usually less than 10%.

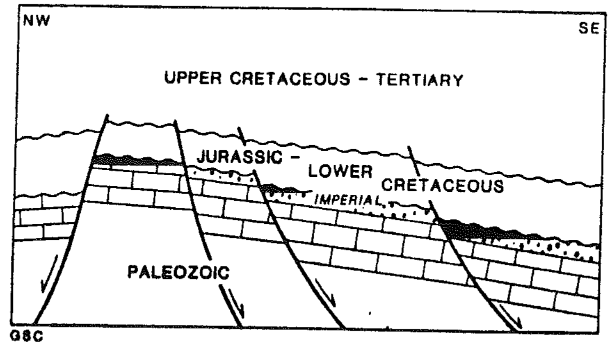

Figure 50 Schematic sketch of trap types -Imperial Clastics Play

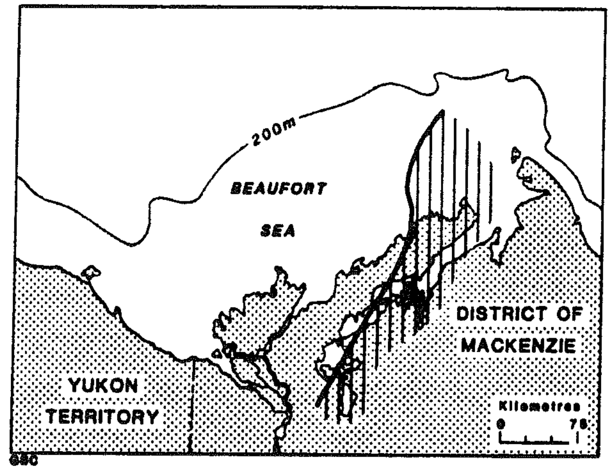

Figure 51 Sketch map locating Imperial Clastics Play area

The Imperial Formation occurs over the highly faulted Eskimo Lakes Arch and potential traps probably will be associated with the normal faults. Overlying Cretaceous shales would provide a seal.

Terrestrially derived organic matter is common within the formation and high levels of organic maturity have been attained. The underlying Canol shale, which tends to be more marine in its organic matter content, also is at high levels of maturity. The thermal maturity would suggest gas as the product of the source rocks. Migration of hydrocarbons from younger source rocks could be invoked but the wide separation of the Imperial subcrop from the Kugmallit Trough, where Cretaceous strata could be expected to be thermally mature, would tend to reduce this possibility.

Exploration History: Only nine wells have penetrated Imperial strata, of which the Kapik K-94 tested gas-cut mud.

YUKON COASTAL PLAIN PLAY

Play Definition: This conceptual play was defined to include all prospects in which hydrocarbons are trapped in pre-Cenomanian rocks. The play extends from the northern end of the Richardson Mountains, westward along the Yukon coastal plain to the British Mountains and includes a narrow strip of the inshore waters of Beaufort Sea (Fig.52). The play area extends southward to the Barn Mountains and the upper reaches of Blow River. All pre-Cenomanian strata are included in the play. Gas would be the principle hydrocarbon in structural traps (Fig. 53).

Geology: A thick Mesozoic succession fills the Rapid Depression and Paleozoic to Proterozoic strata are exposed within the surrounding mountains. Lower Paleozoic strata are exposed in the Barn Mountains where they consist of basinal shale, some sandstone, thin beded carbonates, and chert. Carboniferous strata are represented by the clastics of the Kayak and Kekiktuk formations and

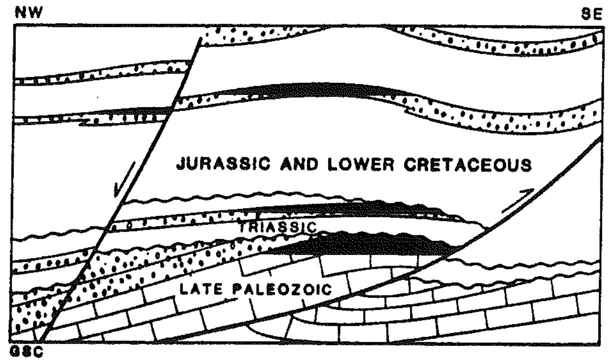

Figure 52 Schematic sketch of trap types - Yukon Coastal Plain Play

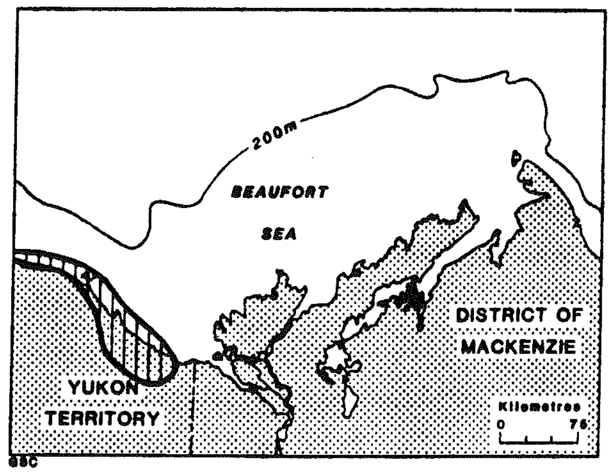

Figure 53 Sketch map locating Yukon Coastal Plain Play area

the carbonate and clastic Lisburne Group. Permian strata are mostly clastics, with some carbonates, in the Sadlerochit Group. A thin succession of Triassic strata, consisting of interbedded sandstone, shale and carbonate (Shublik

Formation) crops out on the flanks of the British Mountains.

Jurassic to Albian strata consist of shale- and sandstone-dominant formations that are probably between 5000 and 10 000 m thick in the Rapid Depression. Jurassic through Valanginian strata are mostly shale of the Kingak Formation; the sandstones of the Bug Creek Group, Porcupine River and Martin Creek formations shale-out west of Rapid Depression. Kamik Formation sandstones are present but they also contain more shale towards the British Mountains. As well the Kamik Formation is truncated under Mount Goodenough strata along the northeastern flank of the British Mountains. The latter formation is shale-dominant, although a local basal sandstone is present adjacent to the British Mountains. Late Barremian-Aptian Rat River strata are present only on the eastern side of the Rapid Depression, to the west it has been eroded. Albian strata form a thick (up to 5000 m in the Rapid Depression) succession of sediment-gravity flow deposits, consisting of interbedded conglomerate, sandstone and shale, with local ironstone beds. A local coarser facies is present on the western flank of the Rapid Depression that loses its identify to the north and east.

Although potential reservoir intervals should be numerous, the clastics are generally well cemented with silica, resulting in poor quality low-porosity reservoirs. Carbonates also tend to have low porosity characteristics, although fracturing is extensive.

The play area is structurally complex with thrust faults, normal faults and some strike-slip faults, and associated folds. Late Cretaceous and early Tertiary deformation created the bulk of the present structural configuration, although older events have influenced present trends.

Throughout the thick Mesozoic shale successions the thermal alteration of the rocks is very high, therefore any potential source rock, regardless of its organic type, would probably produce only dry gas.

Exploration History: Only three wells have been drilled in the play area, Blow River E-47, Roland Bay L-41 and Spring River N-58, all drilled in the early 1970's. None of the wells encountered hydrocarbons. Since these wells were drilled there has been a moratorium on drilling in this area, and since 1987 there has been a National Park from the Babbage River westward to the US border.

Drilling History: In general, onshore drilling has been restricted to periods when the ground surface is frozen; offshore drilling in water depths from 0 - 25 m was done from artificial islands, and drilling in water depths greater than 25 m has been accomplished from ice reinforced drillships and floating platforms. To date, including those wells that have been spudded this year (1988), a total of 237 wells have been drilled; 30 exploratory and 29 delineation wells have been drilled onland; and 59 exploratory and 19 delineation wells offshore (see Fig. 74).

Exploration activity was initiated in 1962 by the drilling of the Texcan Nicholson G-56 and N-45 tests on the coast of the Beaufort Sea east of the Tuk Peninsula. Drilling in the Mackenzie Delta proper commenced with the spudding of BA et al Reindeer D-27 in 1965, undoubtedly encouraged by the discovery that year of the giant Prudoe Bay oil field in Alaska. Three more dry holes were drilled in the winter of 1968-69 and five in 1969-70 drilling season prior to the initial oil discovery at Imperial Atkinson H-25, which was spudded in December of 1969 and completed in February 1970. The Taglu gas field was discovered in June 1971. The discovery well, 10E Taglu G-33, flowed gas at 28 MMCFD from Eocene sands at approximately 2 480 m. The Gulf-Mobil Parsons F-09 well, discovery well in the Parsons gas field, spudded in December of 1971, penetrated Lower Cretaceous gas bearing sandstones at 2 682 m.

Drilling onshore continued at an accelerated pace with 10 wells spudded in 1970, 11 in 1971, and 16 in 1972, all of which resulted in several small oil and gas discoveries; including Reindeer, Kugpik, Kumak, Mayogiak, Mallik, Ivik, Niglintgak and Ya Ya (see Table II). Onshore drilling activity peaked in 1973. Delineation drilling at previously indicated discoveries came into effect at that time in response to the continued rise in world oil prices. Twenty-four tests were spudded in 1973, eighteen in 1974, eighteen in 1975 and fourteen in 1976. Onshore drilling during this period resulted in only minor additions to reserves. Since 1978, one or two wells have been drilled each winter; these have been concentrated on Esso acreage on the Tuk Peninsula in search of "Atkinson Point type" oil plays.

Exploration moved offshore in 1973 with the drilling of Imperial Immerk B-48, and Imperial Adgo F-08 on gravel islands built in 2 - 3 metres of water. The Adgo F-28 test resulted in the discovery of the Adgo field (Figures 54, 55).

Esso pioneered drilling offshore wells from islands in water shallower than 20 metres. Two types of island designs have been used in waters up to 20 metres deep. These are sandbag retained, and sacrificial beach types. Secondary slope protection is provided in both types by sandbags and filter cloth. The largest - Issungnak, started in 1978 and having required two seasons to build, was built in 20 metres of water and required over four million cubic metres of sand fill.

As water depths increased and exploration moved towards the western Beaufort, where the seabed is silt and clay, a different island design was needed that would require reduced volumes of sand and prevent erosion of the islands in heavy open sea conditions. The caisson retained island (CRI) was introduced to serve the need. Tarsiut was the first caisson retained island; it was built in 1980-81 in 21 metres of water by placing four interlocked steel reinforced concrete blocks on an underwater berm to provide a stable drilling platform to allow delineation of the Tarsiut accumulation. Later types had the added advantage of being portable and reusable. Tarsiut A-25,

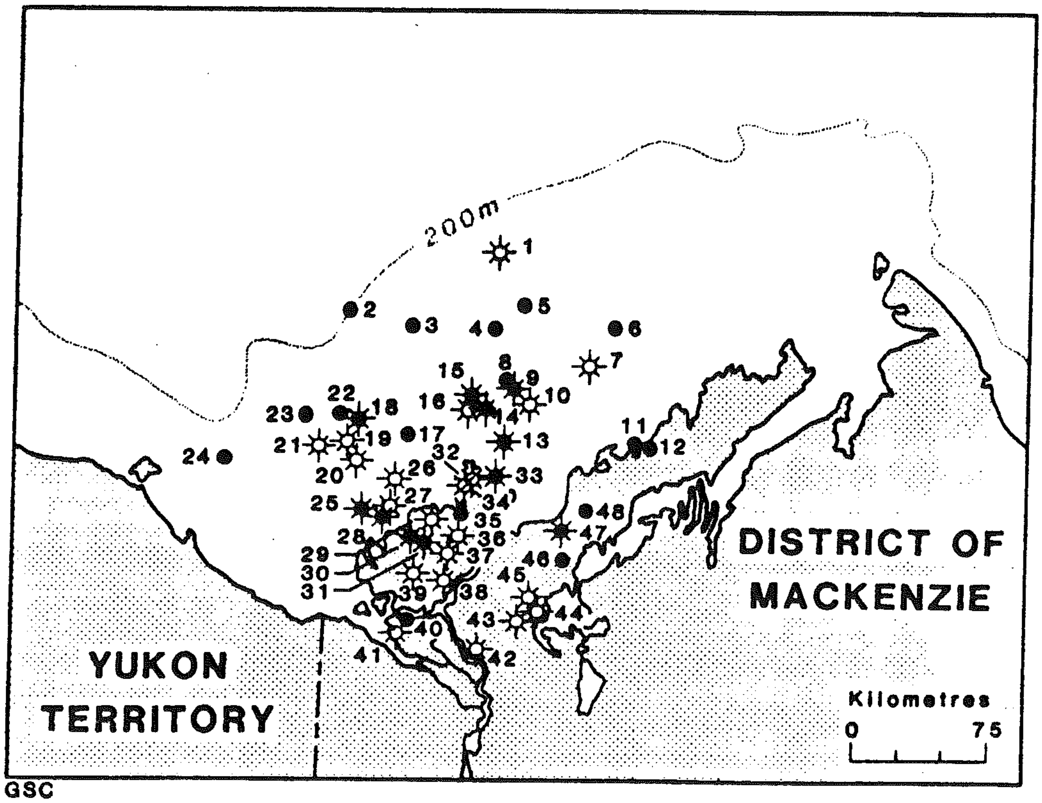

Figure 54 Map of significant discoveries

GAS (billion cubic feet)

	>2000	1000-2000	500-1000	100-500	10-100	<10
ONSHORE	29 TAGLU	43 PARSONS 45	30 NIGLINTGAK	25 ADGO 27 GARRY N. 28 GARRY S. 33 HANSEN 47 TUK M-09 37 YAYA S.	42 IKHIL 35 MALIK 21 MINUK 26 PELLY 38 REINDEER 39 TITALUK 36 YAYA N.	
OFFSHORE		9 AMAULIGAK 15 ISSUNGNAK	1 KENALOOAK	21 MINUK 20 NETSERK 7 UKALERK	10 AMERK 13 ARNAK 16 ISSERK 14 ITIYOK 19 KADLUK 18 KIGGAVIK 2 NEKTORALIK	5 NERLERK

OIL (million barrels)

	>500	500-100	100-25	25-10	<10
ONSHORE			25 ADGO 12 ATKINSON 32 IVIK N. 31 KUMAK	28 GARRY S. 34 IVIK S. 46 IMNAK 40 KUGPIK 30 NIGLINTGAK 47 TUK TERTIARY 11 W. ATKINSON	44 KAMIK 48 MAYOGIAK
OFFSHORE	9 AMAULIGAK	24 ADLARTOK 3 KOPANOAR	6 HAVIK 15 ISSUNGNAK 4 KOOKOAK 17 NIPTERK 23 PITSIULIK 22 TARSIUT	2 NEKTORALIK	13 ARNAK 14 ITIYOK 5 NERLERK

Figure 55 Discovered resources by rank of pool size

bored from a drillship between 1978 and 1980, was the discovery well.

The successful use of the Tarsiut island as a drilling platform led to the development of three new types of artificial islands. The Dome SSDC is a converted ice strengthened supertanker which rests on an underwater sand berm. It is movable and has relief well capability. The SSDC was used during the 1982-83 winter season to drill the Uviluk P-66 dry hole. The Esso "steel doughnut" caison retained island (CRI) featured eight separate 43 metre long steel segments fitted with ballast tanks. The vessel was towed to the Kadluk location and ballasted onto a 4 metre high subsea berm.

The construction of artificial islands has been the key element allowing exploration in the Beaufort Sea in water shallower than 25 metres, however, in deeper waters ice strengthened drillships have a technological and economic advantage. Ice breaking vessels are required to extend the limited open water season in which drillships can operate.

In 1976, drilling operations during the summer months from drillships was permitted. Explorer I, II and III were used to spud four wells in 1976 at Kopanoar, Tingmiark, and Nektoralik. Major oil accumulations were discovered at Kopanoar in 1978, and Tarsiut in 1979. Explorer IV joined the drillship fleet in August of 1979. A new generation of floating exploration drilling equipment was introduced by Gulf in the summer of 1983 when the Kulluk spudded the Pitsiulak A-05 discovery. The Kulluk, a floating conical shaped unit, was moored by twelve anchor cables and designed to better withstand the extreme environmental forces in the Beaufort Sea thereby extending the drilling season.

Oil and Gas Discoveries

The drilling of 130 exploratory wells onshore and 59 offshore has resulted in 49 significant discoveries. The discoveries are listed in Figure 55 arranged by size class and onshore versus offshore location. The size of individual discoveries at the present level of pre-production delineation is highly subjective. The values given were derived from frequency distribution curves for each discovery reflecting different confidence levels provided by the Reserves Committee, augmented in some cases by industry estimates from trade journals. Many discoveries have significant "top-side" potential, that is there are a small possibility of much

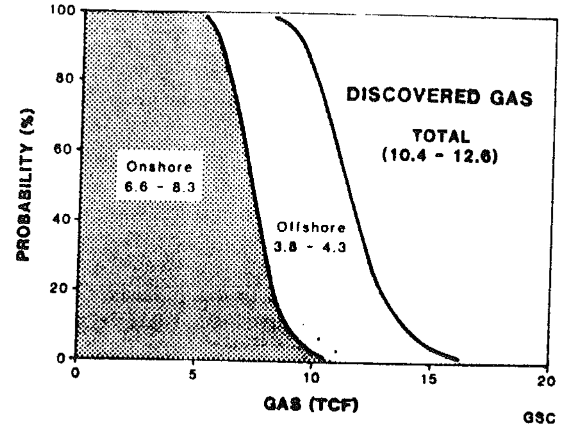

Figure 56 Distribution of estimates of discovered gas resources, * (numerical values are for the 25-75% confidence limits)

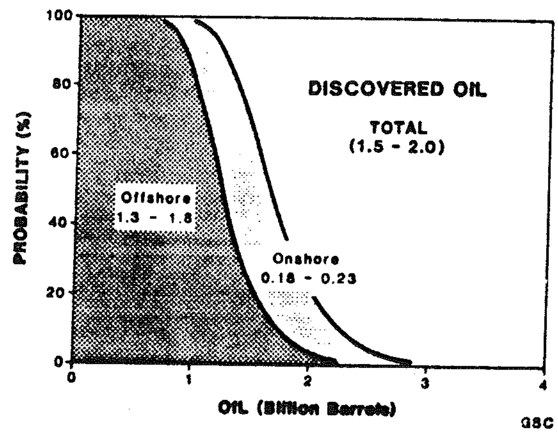

Figure 57 Distribution of estimates of discovered oil resources, * (numerical values are for the 25-75% confidence limits)

higher values than the average if net pay turns out to be thicker or more extensive areally than current drilling or geophysics can confirm with confidence. These "top-side" values tend to produce mean values that are larger than those commonly used, but they more acurately reflect the consensus regarding the size of discoveries.

Figures 56 and 57 illustrate the total quantities of discovered gas and oil. For gas it is estimated that between 10.4 and 12.6 TCF (75 to 25 percent probability range) have been discovered. About two thirds of this quantity exists in the Onshore and Shallow Offshore group of plays (6.6 to 8.3 TCF), whereas Offshore Delta discoveries total from 3.8 to 4.3 TCF. The total quantity of oil discovered (Fig. 57) is estimated to be between 1.5 and 2.0 billion barrels (75 to 25 percent probability range). In contrast to the location of gas discovery, the offshore plays dominate the discovery record with 1.3 to 1.8 billion barrels. This is the result of much larger individual discoveries in the offshore, dominated by the giant Amauligak Field.

It should be noted that the term reserves, although used in some figures in this report, is inappropriate. The expression reserves has specific requirements of current or foreseeable economic viability and a high degree of confidence in terms of quantity. The usage in this report is only in the sense of the technically recoverable portion of the discovered oil in place by means of primary and normal enhanced (i.e. gas re-injection, water flood) recovery techniques. Properly the quantities of discovered oil and gas for this region should be regarded only as "discovered resources".

Resource Endowment

Each of the twenty exploration plays identified within the Mackenzie Delta - Beaufort Sea region were evaluated using methods developed by Geological Survey of Canada (Podruski et al, 1988 p. 8-13). Only a few plays had numerically enough discoveries to make effective use of the discovery process method; the remainder were analyzed using the subjective probability play approach. For each play the procedure resulted in a pool size distribution, a number of pools distribution, a distribution of the total gas and oil endowment for the play, and size ranges for the predicted oil and gas pools that would be statistically appropriate for the analysis. The results were aggregated by play groups and are illustrated by a series of cumulative frequency curves.

Onshore - Shallow Offshore: The eight exploration plays in this group were estimated to contain 16 to 28 TCF of gas and 1.04 to 1.44 billion barrels of recoverable oil. The range reported represents the 75 and 25 percent probability ranges respectively, from the distributions shown as Figures 58 and 59. Figure 58 also shows much larger possible values of gas endowment at speculative levels. The estimates

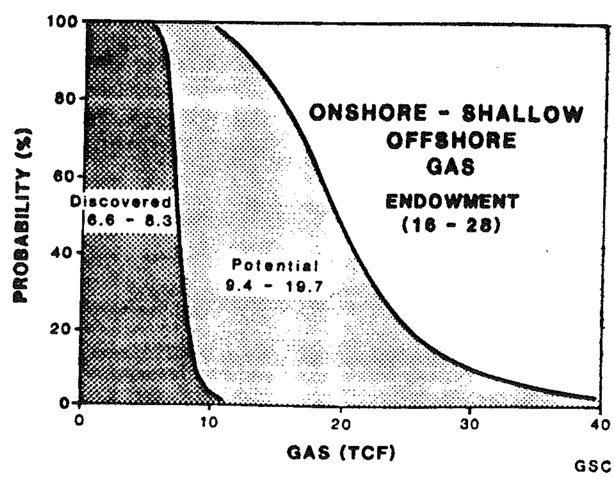

Figure 58 Distribution of estimates of gas endowment for the Onshore-Shallow Offshore play group

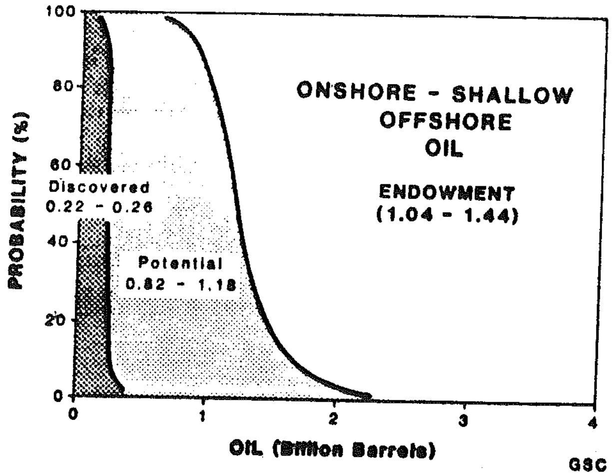

Figure 59 Distribution of estimates of oil endowment for the Onshore-Shallow Offshore play group

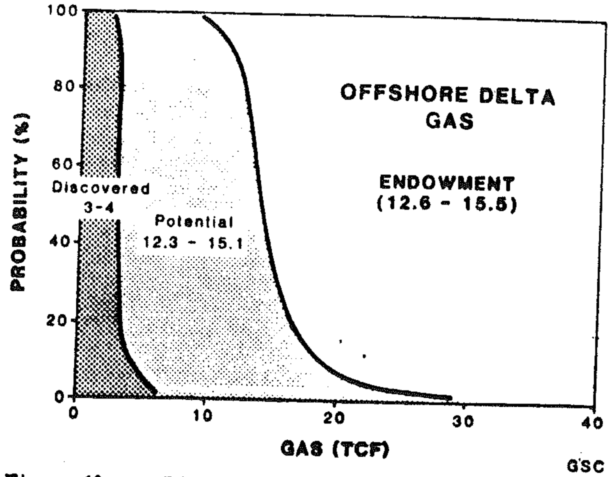

Figure 60 Distribution of estimates of the gas endowment of the Offshore Delta Play group

indicate that about one third of the gas but only one fifth of the oil has already been discovered. Remaining gas potential is concentrated in the Taglu, Parsons and Ivik plays. Although oil potential is more dispersed, the Taglu and Ivik are the more important. This group of plays has the highest ratio of gas-to-oil, about 16,900 cubic feet/barrel, (compared to 9700 for the region as a whole) reflecting the relatively shallow burial of source rocks.

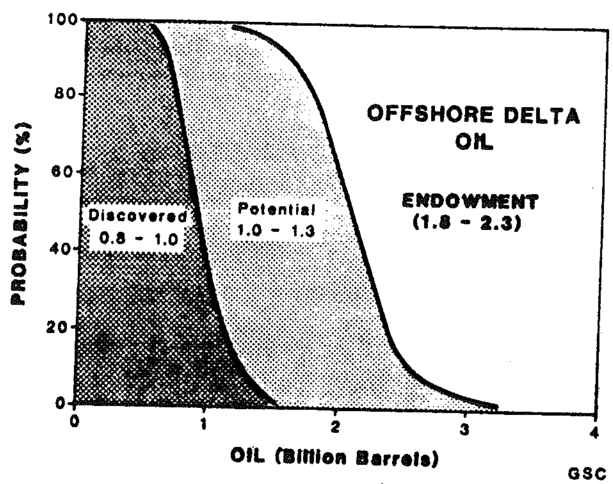

Figure 61 Distribution of estimates of the oil endowment of the Offshore Delta Play group

Offshore Delta: This group of four exploration plays, dominated by the Amauligak play, was estimated to contain between 12.6 and 15.5 TCF of gas and 1.8 to 2.3 billion barrels of technically recoverable oil. Both sets of estimates (Figures 60 & 61) have speculative values that are almost double those at the median. Although only a small portion of the total gas endowment has been discovered, more than 40 percent of the oil is shown as discovered. This relatively high percentage of discovered oil reflects the major accumulation at Amauligak and a trend of associated fields extending to Tarsiut, as well as a fairly mature level of exploration. The Offshore Delta group of plays has a low gas-to-oil ratio (7000 cubic feet/barrel) consistent with the Committee's opinion that this relatively small part of the basin is in an oil-preferred part of the hydrocarbon generation system.

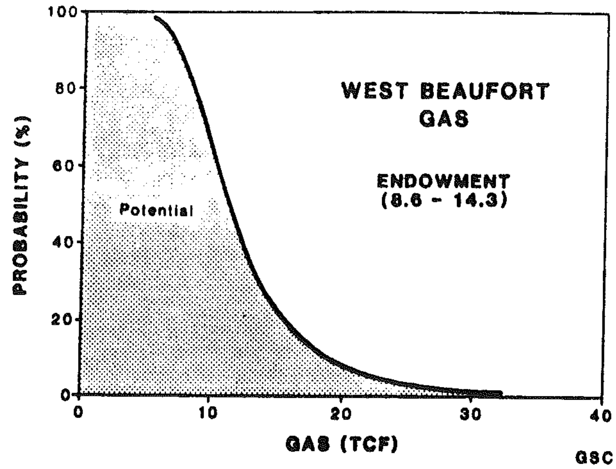

Figure 62 Distribution of estimates of the gas endowment of the West Beaufort Play group

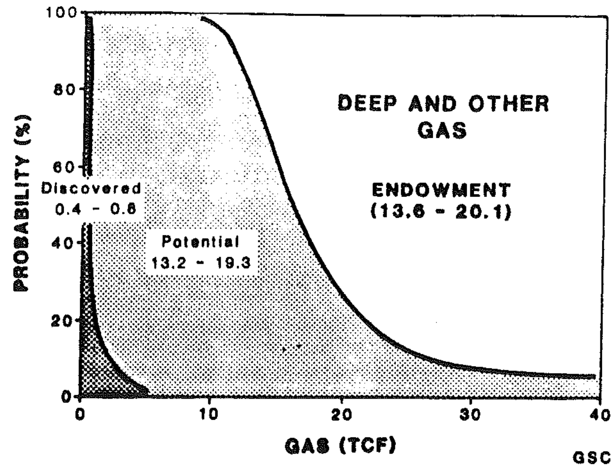

Figure 64 Distribution of estimates of the gas endowment of the Deep Water and Other Play group

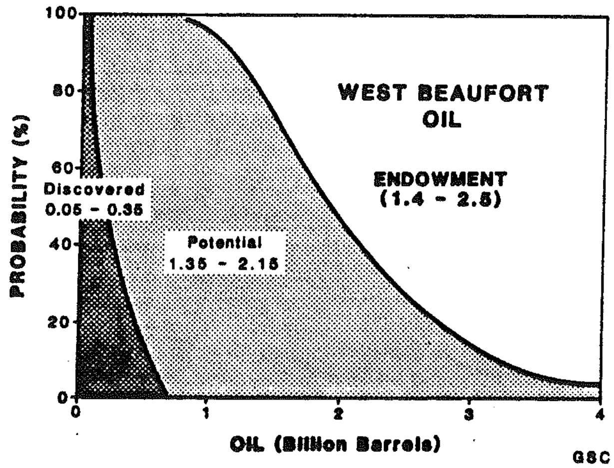

Figure 63 Distribution of estimates of the oil endowment of the West Beaufort Play group

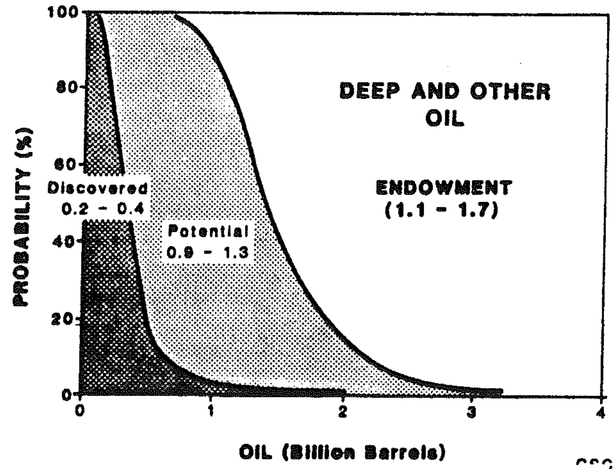

Figure 65 Distribution of estimates of the oil endowment of the Deep Water and Other Play group

West Beaufort: The three exploration plays in this group are estimated to contain between 8.6 and 14.3 TCF of gas and from 1.1 to 1.65 billion barrels of oil. The distributions of estimates of endowment (figures 62 and 63) are highly skewed, with long tails in the low probability or speculative ranges. These curve shapes are consistent with the uncertainty of estimates in a largely unexplored area. The only discovery in the area is the oil at Adlartok. The size of this discovery is expressed with a relatively wide range, but is most certainly of major significance. The West Beaufort group of plays is regarded as having high oil potential because of the number of large untested structures and geochemical indications of better thermal maturity than other play groups.

Deep Water and Other Plays: This group of five exploration plays is estimated to contain between 13.6 and 20.1 TCF of gas and from 1.1 to 1.7 billion barrels of oil. Figures 64 and 65 indicate very high values of resource endowment at the speculative or low probability levels, particularily for gas. The discoveries and potential are dominated by the Kopanoar and Deep Marine West plays, that also have the largest areal extent of all the plays in the Mackenzie-Beaufort region. Although there have been more oil than gas discoveries to date, the analysis suggests that the play group will have a high gas-to-oil ratio (13,300 cubic feet/barrel) compared the region as a whole. These are large numbers of untested structures in the plays of this group - many of them in deep water and in areas of permanent ice cover. The smaller plays in the group do not have well-defined targets at this time because of poor geophysical definition.

Total Regional Endowment

Figures 66 and 67 show the total quantities of gas and oil estimate to exist in the 20 exploration plays of the Beaufort Sea - Mackenzie Delta region. The distributions are obtained by statistically summing the estimate curves for each play by play groupings. For gas, it is estimated that between 57.5 and 73.1 TCF of gas may exist in the region (75 to 25 percent probability range). The mean expectation is 68 TCF. Approximately 17 percent of this endowment is in the already discovered category, leaving a very large undiscovered potential of from 47.1 to 60.5 TCF. Much larger values of

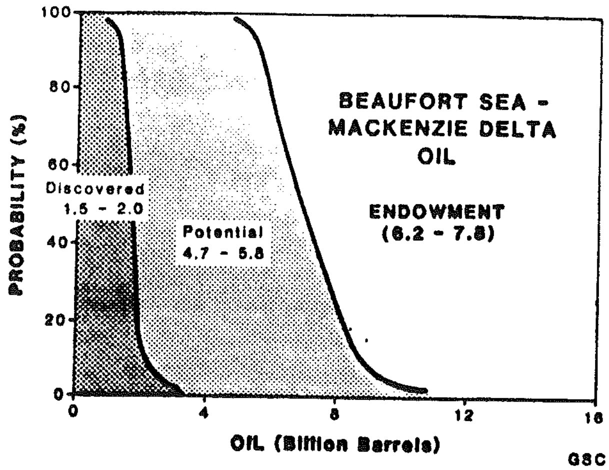

Figure 66 Distribution of estimates of gas endowment for the Mackenzie Delta-Beaufort Sea region. Values given are for the 75 and 25 percent probability levels

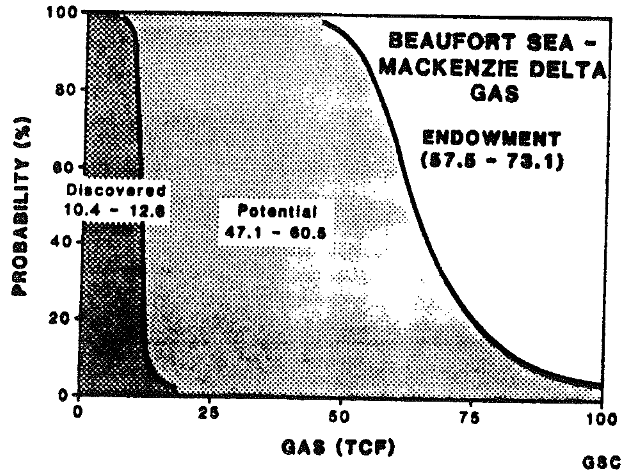

Figure 67 Distribution of estimates of oil endowment for the Mackenzie Delta-Beaufort Sea region. Values given are for the 75 and 25 percent probability levels

undiscovered gas are shown at low probability levels. For oil (Fig. 67) it is estimated that between 6.2 and 7.8 billion barrels (75 to 25 percent probability range) may exist in the region. The mean expectation is 7.1 billion barrels. From 1.5 to 2.0 billion barrels, or about 24 percent, of this endowment are shown as discovered resources. The figure also indicates a substantial undiscovered potential of between 4.7 and 5.8 billion barrels.

MACKENZIE DELTA-BEAUFORT SEA RESOURCES				
PLAY GROUP	OIL x̄ (10^9 BBLS)		GAS x̄ (TCF)	
	RESERVES	POTENTIAL	RESERVES	POTENTIAL
ONSHORE-SHALLOW OFFSHORE	0.251	1.05	7.48	14.46
OFFSHORE DELTA	0.910	1.2	3.29	11.4
WEST BEAUFORT	0.226	1.9	0	12.5
DEEP AND OTHER	0.357	1.1	0.88	17.7

GSC

Figure 68 Tabulation of mean values of reserves (discovered resources) and potential for groups of plays

Resources of Current Interest

Expressions of total regional endowment of oil and gas resources are useful in the sense of identifying the total inventory range that may exist for the region. These values are not discounted for current or future economic viability, technical exploitability or likelihood of discovery. As such they may be misleading for planners and for those who prepare forecasts of supply. For these purposes one needs information on where the resources are concentrated, the sizes of future discoveries and some limited reference time frame. In Figure 68 the resource endowment of the Beaufort Sea -Mackenzie Delta are summarized by play groups. If one were to consider which groups would be the focus of exploration for the next 20 years, one might conclude that the Deep and other oil and gas plays and the West Beaufort gas plays could be classed as "beyond current interest" because of their remoteness and probably difficulty in exploitation. In order to provide some discounting of the regional resource endowment values for the current study, those assumptions were used. As a result the total mean oil expectation for the region would be reduced from 7.1 to 5.6 billion barrels, and the mean gas expectation from 68 to 50 TCF. Each of the play groups included in the discounted endowment was then examined in terms of how much of the resource existed in given size ranges. The results of this analysis are shown in Figures 69 - 73.

Onshore-Shallow Offshore: Figure 69 shows how much of the total gas endowment of 16 to 28 TCF occurs in pools greater than 1 TCF, in pools from 100 Bcf to 1 TCF in size, and how much in pools smaller than 100 Bcf. Also shown are the expected number of pools in each size category. The analysis indicates only three pools larger than 1 TCF, two of which (Taglu and Parsons)

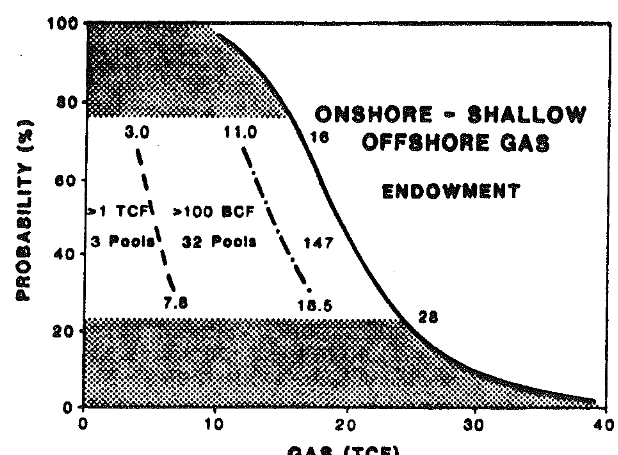

Figure 69 Distribution of gas endowment for the Onshore-Shallow Offshore group of plays, showing impact of predicted pool sizes

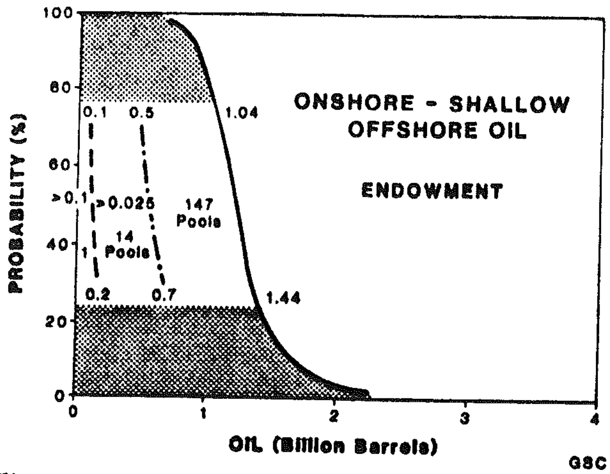

Figure 70 Distribution of oil endowment for the Onshore-Shallow Offshore group of plays, showing impact of predicted pool sizes

are already discovered. The second size range consists of 32 pools that in total contain from 8 to 10.7 TCF suggesting that there are many potentially attractive targets for exploration in the onshore area. As seen in Figure 69, the remaining large number of small pools do not add significant resources. If one were to consider only the pools in the larger two size ranges to be of short term interest then the mean gas endowment for onshore-shallow offshore group of plays would reduce from 22 to 15.7 TCF.

The portion of the total oil endowment for this group of plays that occurs in sizes greater than 100 million barrels, between 25 and 100 million barrels and in pools smaller than 25 million barrels is shown in Figure 70. Only one pool greater than 100 million barrels is indicated, and 14 pools greater than 25 million barrels. Together these 15 pools would contain about one half of the total, reducing the mean endowment from 1.3 billion barrels to just 738 million barrels if those two size ranges were the only ones of current interest.

Offshore Delta: Using the same criteria as described above, the gas and oil resources of the Offshore Delta play group are shown in Figures 71 and 72. For gas, 2 pools greater than 1 TCF are indicated, including the one associated with the Amauligak oil discovery. The second size range includes 28 pools that

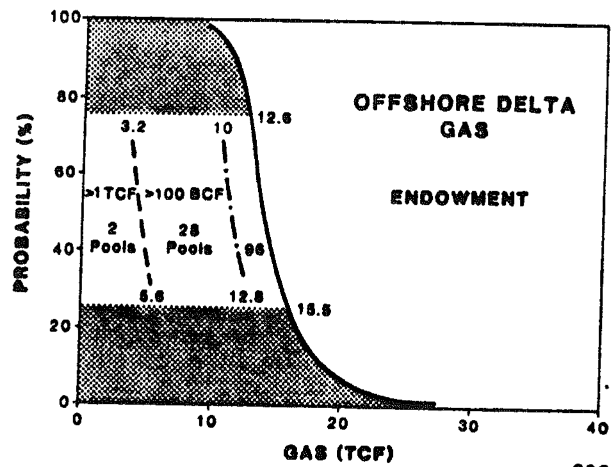

Figure 71 Distribution of gas endowment for the Offshore Delta group of plays, showing impact of predicted pool sizes

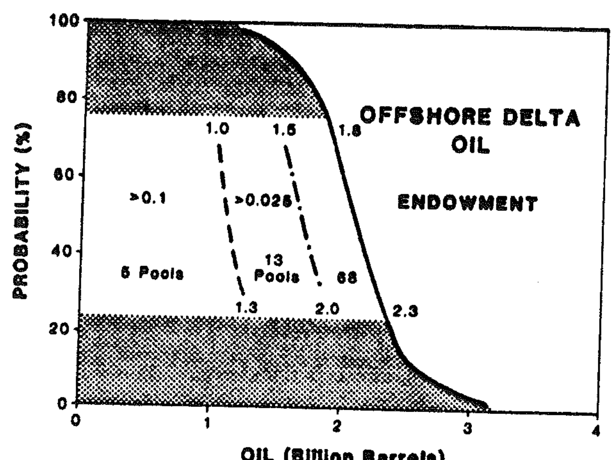

Figure 72 Distribution of oil endowment for the Offshore Delta group of plays, showing impact of predicted pool sizes

contain almost twice as much gas as the first. If only these two size groups were of current interest, then the mean endowment would reduce from 14.7 to 12.0 TCF.

Figure 72 shows how the oil endowment is distributed by size. Five major pools are anticipated in the larger than 100 million barrel range, one of which (Amauligak) is already discovered. This size range constitutes almost one half of the endowment. A combination of the larger two size classes would include 18 pools containing from 1.5 to 2.0 billion barrels. Thus the overall mean endowment would reduce from 2.1 to 1.8 billion barrels in the current interest category.

West Beaufort: Only the oil resources of this group of plays was considered for size analysis. Figure 73 shows that four

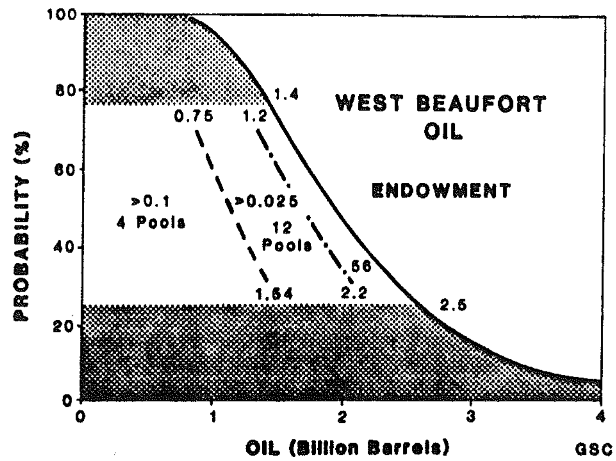

Figure 73 Distribution of oil endowment for the West Beaufort group of plays, showing the impact of predicted pool sizes

pools larger than 100 million barrels are estimated to exist, including the Adlartok discovery. Along with the 12 pools in the 25 to 100 million barrel size range, 16 pools would contain between 1.2 and 2.2 billion barrels. This would reduce the mean regional oil endowment from 2.2 to 1.8 billion barrels in the current interest category.

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12. IOE Atkinson H-25
13. IOE Nuvorak 0-09
14. IOE Natagnak K-23
15. Gulf Sholokpaoqak P-60
16. IOE Natagnak H-50
17. IOE Atkinson M-33
18. Gulf Onigat C-38
19. IOE Blow River Yt. E-47
20. Shell Aklavik A-37
21. Shell Beaverhouse Creek H-13
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28. IOE Mayogiak J-17
29. Gulf et al Ikhil A-01
30. IOE Pikiolik E-54
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40. IOE Taglu C-42
41. Imp. Atertak E-41
42. Gulf et al Siku C-55
43. Shell Unipkat I-22
44. Gulf et al Titalik K-26
45. Shell Niglintgak H-30
46. Gulf et al YaYa P-53
47. Imp. et al Akku F-14
48. Imp. Nuktak C-22
49. Imp. Umiak J-37
50. Imp. Ivik C-52
51. Pacific et al Roland Bay Yt. L-41
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53. Union Aklavik F-17
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58. Imp. et al Natagnak K-53
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67. Imp. Wagnark G-12
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78. Imp. Adgo F-28
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83. Gulf et al Parsons 0-27
84. Imp. Mayogiak L-39
85. Imp. et al Amarok N-44
86. Shell Napoiak F-31
87. Gulf et al Toapolok H-24
88. Imp. Pullen E-17
89. Shell Niglintgak M-19
90. Shell Kipnik 0-20
*91. Arco Smoking Hills A-23
92. Sun et al Unark L-24
93. Sun et al Pelly B-35
94. Gulf et al YaYa M-33
95. Gulf et al YaYa I-17
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97. Gulf et al Kikoralok N-46
98. Dome et al Imnak J-29
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100. Imp. Adgo P-25
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102. Shell Kugpik L-24
103. Chevron et al Upluk M-38
104. Imp. et al Louth K-45
105. Gulf et al Ogeoquoq J-06
106. Gulf et al Red Fox P-21
107. Shell Kumak K-16
108. Gulf et al Kilagmiotak M-16
109. Gulf et al Kamik L-60
110. Gulf et al Parsons A-44
111. Imp. Adgo C-15
112. Shell et al Titalik 0-15
113. Imp. et al Ikattok J-17
114. Sun et al Garry P-04
115. Shell Niglintgak B-19
116. Sobc N. Ellice J-23
117. Imp. Netserk F-40
118. Gulf et al Parsons L-43
119. Gulf et al Parsons N-17
120. Gulf et al Kamik D-48
121. Gulf et al Siku C-11
122. Shell Ulu A-35
123. Imp. Sarpik B-35
124. Gulf et al Tununuk F-30
125. Imp. et al Wagnark C-23
126. Gulf et al Siku A-12
127. Gulf et al Parsons D-20
128. Hunt et al Kopanoar D-14
129. Dome et al Tingmiark K-91
130. Dome et al Nektoralik K-59
131. Hunt et al Kopanoar M-13
132. Imp. Kugmallit H-59
133. Imp. Arnak L-30
134. Shell Tulugak K-31
135. Sun et al Unark L-24A
136. Imp. Taglu H-54
137. Gulf et al Kamik F-38
138. Imp. et al Kurk M-39
139. Gulf et al Parsons L-37
140. Gulf et al Parsons P-41
141. Chevron et al Upluk A-42
142. Shell Kumak F-58
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144. Imp. Kannerk G-42
145. Imp. Umiak N-10
146. Gulf et al Siku E-21
147. Gulf et al Ogruknang M-31
148. Chevron et al Fish River B-60
149. Dome et al Ukalerk C-50
150. Dome Kaglulik A-75
151. Dome Nerlerk M-98
152. Imp. Isserk E-27
153. Imp. Mallik J-37
154. Sun et al Garry G-07
155. Dome Natsek E-56
156. Dome et al Tarsiut A-25
157. Dome et al Ukalerk 2C-50
158. Dome Kaglulik M-64
159. Esso et al Napartok M-01
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161. Dome Kenalooak J-94
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165. Esso Mayogiak M-16
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195. Gulf et al Tarsiut P-45
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197. Dome et al Nerlerk J-67
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199. Gulf et al Akpak P-35
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201. Gulf et al Onigat D-52
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203. Esso et al Itkrilek B-52
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205. Esso et al Taglu West H-06
206. Esso et al Tuk H-30
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209. Dome et al Adlartok P-09
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226. Esso et al Mayogiak N-34
227. Esso et al Mayogiak G-12
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233. Esso et al Arnak K-06
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* Wells outside of map sheet