The Catoche Dolomite Project, Anticosti Basin, Eastern Canada:

Final Report

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THE CATOCHE DOLOMITE PROJECT, ANTICOSTI BASIN, EASTERN CANADA FINAL REPORT

INTRODUCTION

This study presents a synopsis of the geological history of the Catoche Formation based upon the integration of measured sections, stratigraphic and sedimentological relationships, petrography, petrophysics, and earlier studies of the formation throughout western Newfoundland. Particular emphasis is placed upon the dolomitized parts of the formation and its potential as a hydrocarbon reservoir.

The Catoche Formation was studied in three areas of western Newfoundland (Figure 1), the northern part of the Great Northern Peninsula (Plate 1), the area of Port au Choix to Daniel's Harbour (Plate 2) and Port au Port Peninsula (Plate 3). Twenty-three drill hole and coastal sections were logged through the Catoche Formation. This includes 2 sections at the north of the Great Northern Peninsula, 7 sections at Port au Choix, 7 sections in the area between River of Ponds and Daniel's Harbour, and 7 sections in the Port au Port area. Outcrops were visited to confirm the sedimentological and petroleum characteristics of the rocks observed in the drill cores. Samples were obtained for further study. In the Port au Choix area, the section was examined up into the overlying Aguathuna Formation and the base of the Table Point Formation to resolve stratigraphic problems encountered during drilling of dolomitized sections in 1991. Also included in the study are observations of the sections preserved in deep drill cores that penetrated the Romaines Formation beneath Anticosti Island (Figures 1 and 7).

The Catoche Formation is a succession of subtidal shelf limestone and dolostone that outcrops discontinuously within folded and faulted Lower Paleozoic sedimentary rocks of the Humber Tectono-stratigraphic zone in western Newfoundland (Knight and James, 1987). The Catoche Formation which occurs in the upper part of the St. George Group correlates with the Ste-Genevieve Member, Romaines Formation and Beauhamois Formation, Beekmantown Group in Quebec (Desrochers, 1985; Bernstein, 1991) to form the Canadian part of the southern continental margin of Laurentia, bordering the Iapetus Ocean. These late Canadian carbonates are the deposits of an Arenigian (late Early Ordovician) transgression that inundated continental margins and cratonic interiors worldwide (Fortey, 1984). The margin at this time is generally considered a passive trailing type (James et al., 1989). However, analysis of the sediments of the Catoche Formation and overlying formations (Knight et al., 1991) and the presence of co-eval island arc sequences within the Iapetus ocean (Knight and Cawood, 1991; Dunning and Krogh, 1985, 1991) suggests that this tectono-geographic setting was or was soon to be terminated as the margin was increasingly influenced by accretion and overthrusting of oceanic sediments and island arcs along the leading edge of the Laurentian plate during the Taconian Orogeny. This is reflected in the rather abrupt shift to very shallow shelf settings as the deposition of the formation came to a close (Knight et al., 1991).

Prolonged restricted peritidal sedimentation followed this shallowing and culminated in the exposure of the Lower Ordovician shelf as Taconian peripheral bulge uplift migrated across the shelf. Tectonically-controlled karsting of the St. George platform reached the buried sediments of the Catoche Formation. Open spaces and possibly early dolomitization modified the formation throughout this period (Lane, 1990). Foreshortening of the ancient margin during the development of the Acadian fold and thrust belt telescoped the carbonate platform, carrying more outboard facies of the Catoche Formation westwards and juxtaposing them upon the inner shelf facies.

STRATIGRAPHY OF THE CATOCHE FORMATION

The Catoche Formation comprises a 140 to 185 m thick succession of grey bioturbated, fossiliferous and thrombolitic limestone and pale grey to off white peloidal and fenestral limestone. Throughout much of western Newfoundland, the peloidal limestones, which are referred to the Costa Bay Member by Knight and James (1987), mark the top of the formation. However, in outcrops along the northwestern edge of the carbonate belt (Portland Creek Pond to Port au Choix), rocks equivalent of the member are extensively dolomitized (Lane, 1990). Dolomitization, however, affects the formation below the Costa Bay Member elsewhere in western Newfoundland. Only in thrust slices near Hare Bay and near Goose Arm does the complete Catoche section appear to escape significant dolomitization.

The Catoche Formation lies between two units of cyclic carbonates of the St. George Group. It rests conformably upon interbedded limestone and dolostone of the Barbace Cove Formation of the Boat Harbour Formation and below dolostones, limestones and shales of the Aguathuna Formation (Knight and James, 1987). The basal contact is placed at the top of the last bed of laminated limestone and/or dolostone of the Barbace Cove Member and beneath the first thick bed of bioturbated, fossiliferous limestone of the Catoche Formation. The top is placed at the contact of the off-white peloidal and fenestral limestones of the Costa Bay member with the first bed of buff weathering, light grey mottled and laminated microcrystalline dolostones of the overlying Aguathuna Formation. In the Port au Choix to Portland Creek Pond area, the contact lies at the base of a unit of dark grey to buff grey, burrow-mottled dolostones that are referred to informally as the "dark grey dolomites" by Lane (1990). These rocks are placed in the Aguathuna Formation by Knight and James (1987) although in the aforementioned area they appear to overlie the dolomitized Costa Bay equivalents with which they appear to have colour and lithological affinities. However, at Port au Port, partially dolomitized limestones and dark grey dolomites resembling the "dark grey dolomite" unit occur several metres above the contact of the Costa Bay white peloidal limestone with overlying dololarninite of the Aguathuna Formation (section RND-2, Figures 2.1, and 5.1).

The Catoche Formation can be subdivided into a number of informal and formal members that occur locally or regionally in western Newfoundland. Near Port au Choix (Figures 1, and 2.1), the type area of the formation, it comprises a lower unit of well bedded, bioturbated fossiliferous, grey limestone containing beds of thrombolite mounds, skeletal-intraclastic rudstone and grainstone, and minor beds of thinly bedded, parted dolomitic lime mudstone. This is overlain by an informal unit of grey peloidal limestone called the Laignet Point member by Knight (1977). It is capped by an upper dolomite unit that originally comprised cycles of mudstone/wackestone, skeletal and peloidal wackestone and packstone and peloidal packstone and grainstone.

Near Daniel's Harbour (Figures 1 and 2.2), the lower limestone comprises four units consisting of lower and upper peloidal limestone intercalated with lower and upper nodular limestone (Lane, 1990). Lane (1990) interprets the the upper dolomite member to be dolomitized peloidal grainstones and packstones. In the northeast near Cape Norman (Figures 1 and 2.4) and eastward into the Hare Bay and Canada Bay thrust belt, the section consists of a lower bioturbated limestone, a middle thrombolitic limestone and an upper bioturbated but grainy limestone (Knight, 1986, 1987). These three members are capped by white limestones of the Costa Bay Member which locally includes some thrombolite mounds. In a belt that extends south from Cape Norman, the mound member thickens to the exclusion of the upper bioturbated and grainy member and is completely dolomitized.

At Port au Port Peninsula (Figures 1 and 2.3), the section comprises lower and upper grey bioturbated limestone separated by nodular grey limestone. These are overlain by a mound member that is capped by the Costa Bay Member. The mound member and the upper part of the upper bioturbated grey limestone are pervasively dolomitized. Such dolomitization appears to be less pervasive when traced to the northeast onto nearby Table Mountain. Instead, several beds within the upper part of the Catoche Formation equivalent of the Costa Bay Member and within the mound member are dolomitized (section 12B/10-036, Figure 5.3; Haywick, 1984). The Costa Bay Member at Table Mountain appears to contain cyclic peloidal grainstones and thrombolite mounds, but this interpretation which is based upon section 12B/10-036 requires further confirmation.

REMARKS CONCERNING THE STRATIGRAPHY IN THE PORT AU CHOIX AREA

Knight et al. (1991) indicated that the lower member of the Aguathuna Formation was eroded beneath the St. George Unconformity. This study indicates that the dark grey dolomite and a few meters of burrow mottled dolostone and dololaminite characteristic of the lowest part of the Aguathuna Formation intervene between the Catoche Formation and the Unconformity. The Unconformity is overlain locally by a succession of dolostones that probably belong to the upper Aguathuna Formation and by interbedded limestones and dolostones of the Spring Inlet Member of the Table Point Formation. These limestones, characterized by shallowing upward burrowed to fenestral to laminated intervals, are replaced extensively by dolomites in which abundant porosity is plugged by black hydrocarbon residues. The stratigraphic relationships however continue to support the proposition that the Port au Choix area was extensively eroded during Middle Ordovician uplift and was probably an arch during subsequent Table Point deposition.

FACIES OF THE CATOCHE FORMATION

For the sake of simplicity , the facies of the Catoche Formation are divided into four main types including:

A) Interbedded bioturbated lime wackestone and mudstone intercalated with grainstone and packstone,
B) Nodular bedded lime mudstone,
C) Thrombolite boundstone and grainstone, and
D) Peloidal grainstone to wackestone.

A) Bioturbated lime wackestone-mudstone with intercalated grainstone -these grey limestones (Plates 4A, B and C) are the commonest lithofacies in the formation dominating the lower limestone sections at Port au Choix, Daniel's Harbour, lower and upper bioturbated members in the north and the lower and upper part of the limestone section at Port au Port. The wackestones include skeletal wackestones and peloidal types with varying quantities of large to comminuted skeletal allochems. Fossil fragments are trilobites, ostracods, gastropods, crinoids, microbial grains eg. Girvanella and brachiopods. In the lower part of some beds, coated grains up to 0.5 cm in size occur. They are probably microbial rhodoliths. The mudstone and wackestone are bioturbated by sub horizontal to vertical burrows such as Chondrites, Planolites and Paleophycus. Compound burrows are common, with the cores of burrows occupied by later finer burrows. The burrows are mostly dolomitized.

Grainstone occurs as single thin beds, as several, closely-spaced, centimetre-thick beds interbedded in the wackestone, and as grainstone units up to 0.75 m thick. Most beds appear to be structureless but crossbeds and lamination do occur. Allochems comprise mudstone and peloidal intraclasts, peloids, and skeletal grains. No organization of wackestone and grainstone in cycles could be discerned but no systematic measurement of the limestone section was attempted.

Facies A is typical of the deposits of open marine shelf sedimentation during the Early Ordovician (Pratt, 1979; Pratt and James, 1982; Knight and James, 1987; Desrochers, 1985). Mixed grain size suggests a shelf dominantly below wave base accumulating peloidal muds and hosting an open marine fauna including a burrowing infauna. Storms reworked the seafloor eroding cemented layers of mudstone and wackestone, and sorting peloidal grains and skeletal remains.

B) Nodular mudstone lithofacies -The nodular mudstones are micritic, stylo-bedded grey limestones. Dolomitic seams outline the stylo-bedding. Fossil fragments are mostly unbroken and large and seem to be dominated by trilobites. Burrowing is sparse by comparison to the wackestone facies.

The finer grained nature of these sediments, combined with the more restricted, trilobite dominated fauna and sparce burrowing suggest they were deposited in deeper water below wave and storm base.

C) Thrombolite boundstone and grainstone -Thrombolite mounds occur as isolated beds up to 2 metres thick within the wackestone facies and as thick complexes of tens of metres thickness. The former occur in the westerly sections of the Portland Creek to Port au Choix area where they form unoriented to north-south elongated buildups. The mound complexes occur in the sections at Cape Norman, in the thrust belt of Hare Bay and Canada Bay, and in the Port au Port Peninsula. The mound complexes at Port au Port and Cape Norman are dolomitized (Plates 1 and 3). They remain limestone in the easterly thrust belt.

The boundstones consist of clotted and digitate structure which is mostly delineated in outcrop by partial do1omitization of the interclot or digitate parts of the boundstone (Plate 6A, B). According to Pratt and James (1982) and Kennard (1988), the boundstones consist of micritic and peloidal thromboids, microbial organisms such as *Renalcis* and *Girvanella*, the coral *Lichenaria* and the problematic organism *Pulchrilaminar*. Large sponges, Archeoscyphia, and large cephalopods, gastropods and trilobites are associated with the mounds and cavities in the mounds are occluded by fibrous marine cements (Knight, 1986, 1987).

The dolomitized mounds are easily identified in outcrop by the outline of the mounds ornamented by an invaginated cerebral fabric at the mound edge (Plate 6C) .Internally, clotted and digitate mesofabrics are defined by colour mottling and by variation in the grain size of the dolomite (Plate 6B). A common feature of the mounds at Port au Port is the presence of burrows reworking interthromboid carbonate (Plates 6B, C). The centres of the mounds are commonly brecciated in the Lower Cove section on the Port au Port Peninsula (Plate 6D).

Crossbedded grainstones occur in channels crossing the mound complexes (Knight, 1986, 1987). In several sections however, grainstones formed the substrate on which the mounds colonized. This is illustrated by grainstone-boundstone and wackestone-grainstone-boundstone cycles seen at Port au Port and Table Mountain (sections LC-90-11,12B/10-036, Figures 5.4 and 5.7). Grainstones, however, dominate 95% of a 40 metres thick section south of Aguathuna Quarry (section l2B/10-0001, Figure 5.5). The incomplete logs of several wells drilled throughout the Aguathuna area suggest that the grainstone may dominate the mound member in a wide belt in this area (Degrace, 1972). In spite of dolomitization, the grainy framework of the Catoche dolomites at Port au Port is clearly visible in core.

Grainstones fringe the margins of the isolated mounds of the Port au Choix area and pass laterally into burrowed wackestones (Pratt and James, 1982; Knight, 1991).

The boundstones are sub tidal rigid organic buildups consisting of calcified microbial organisms and a meagre assortment of skeletal mound dwelling organism lead by sponges (Pratt and James, 1982). The mounds inhabited two dominant niches. The first consisted of isolated bioherms within generally inner shelf settings that were dominated by peloidal and muddy sediment deposition (i.e., Port au Choix area). Orientation of mounds suggests that they were influenced by prevailing wind or tide driven currents. Mounds however dominated more outboard, high energy, nutrient-rich shelf positions. The boundstones must have formed a rigid wave and storm resistant belt and the importance of crossbedded grainstone channels suggests that the mounds frequently grew up into the surf zone. Domination of the section by grainstones at Aguathuna may indicate the location of a long lived channel between mound complexes (sections 12B/10-000I and 12B/10-0002, Figures 5.5 and 5.6). Alternatively, the widespread distribution of the grainstone throughout the Aguathuna area suggests that the mound complexes so extensive over much of the Peninsula are fringed by grainstone fore and back reef tracts.

D) Peloidal grainstone to wackestone -This facies is divided into two subtypes. The first and most common consists of well sorted, cemented peloidal grainstones and fenestral Peloidal packstone. The grainstones are commonly off-white to pale grey in colour, very stylolitic and display good sparry cements. Fossils and intraclasts of peloidal and coated grains occur in the grainstones. Thrombolite mounds are interspersed in the facies in the Hare Bay area. Fenestral and laminated peloidal packstones and wackestones are interbedded with the grainstones at Port au Port and in the Hare Bay thrust belt. They are believed to indicate the presence of some shoaling upward cyclicity in the grainstones.

The second association occurs in the Port au Choix to Daniel's Harbour area and in spite of the pervasive dolomitization, it is clearly cyclic in nature (Plates 7 A and B). At Port au Choix, the metre-scale cycles consist of buff-grey very fine grained dolostone overlain gradationally by dark to tan-grey fine grained dolostone and in turn gradationally by cream-grey, stylolitic sucrosic dolostone (Plate 7C). These are locally overlain by an upper dark or tan grey dolostone and in rare instances, the cycles are capped by dololaminite (e.g. , section WN-91-CH-3, Figure 3.5). Cycle thickness varies when traced laterally in drill core and outcrop.

Fabrics and original textures are generally obscure in the basal buff grey dolostones. However, faint burrows and possible gastropod and/or intraclasts appear to float in some beds. Originally these dolostones were mudstone (see Lane, 1990). The dark grey dolostone is commonly bioturbated and in some cycles hosts white chalcedonic and megaquartz cauliflower nodules. Similiar shaped dolospar filled nodules and less commonly vugs also occur in some cycles. Where this subfacies is partially dolomitized or undolomitized, it is a grainy wackestone to packstone. In the coastal sections at Port au Choix and Back Arm these fine grained dolostones are recessively weathering.

The overlying sucrosic dolostones are characterized by stylolites and cream-grey colour. The dolostones were originally peloidal grainstones and packstones. Remnants of lime grainstone occur in both core and outcrop (Plate 7D). The dolo stones are consistently very porous and are extensively replaced by coarse sparry dolomite (Plate 7E) to give the texture known locally as "pseudobreccia"(Lane, 1990; see dolomite discussion below). Dark grey irregular seams of fine crystalline dolostone outlining an uneven fabric that probably mimics bedding occur in many beds. Dark grey burrows mark the lower and upper part of the grainstone. Large gastropods and straight and coiled cephalopods occur as ghosts in the coastal sections. Lane (1990) describes calcified sponges and microbial organism as well as a variety of skeletal remains including molluscs, trilobites, brachiopods, sponges, ostracods and pelmatozoans in the grainstones. Burrows at the top of the beds are commonly zoned with a light coloured core surrounded by a dark envelope. Wide burrows that branch are internally burrowed by smaller tubes (Plate 7F). Other sedimentary structures are rare but planar thin stratification and lamination overlying crossbeds occur in one bed at Back Arm (Plate 7G). Cauliflower quartz is common in beds near the top of the formation at Back Arm and Pointe Blanche, Port au Choix.

The upper burrowed dark grey dol stone which is generally thin and often rust stained, probably was similar to the lower dark grey dolostone in the cycles. However, they are generally more bioturbated and in some beds are characterized by light coloured wormy tubular burrows that allow good correlation between sections at Port au Choix (see Plate 7C). Burrows can be seen to penetrate down into the underlying cream-grey dolostone. The upper burrowed dolostone does not always occur but the presence of the distinct burrows in the top of the cream-grey dolostone suggests that it was present at one time but probably eroded before the deposition of the next cycle. This is supported by the top of some cycles in the sections at Back Arm and Pointe Blanche where the top of the cycle is eroded by shallow scalloped scours that partially erode the burrowed dark grey dolomite down to the top of the cream-grey dolomite (Plate 7B; see units 10 to 13, Pointe Blanche section, Figure 3.2). Beneath the top of many cycles vugs and open spaces parallel to stylofabric are occluded by spar.

The contacts between the cycles appear to be sharp (Plate 7A, B). Tops are both planar and irregular and are commonly marked by a stylolite band. However, infill of deep irregularities by the overlying buff-grey dolostone occurs. Similar relationships occur when a dololaminite caps the cream grey dolo stone as in unit 7, section WN-91-CH-3, (Figure 3.5). This sculptured surface is connected to small cavities scattered through the cream-grey dolostone. The dololaminites are mudcracked and have a brecciated top. Spaces between breccia fragments are infilled by the buff-grey dolostones of the overlying cycle.

The clean well sorted peloidal grainstones associated with fenestral laminites of the first of the facies associations probably formed in a high energy shoal complex that fringed the shelf in a broad belt from the Great Northern Peninsula to the Port au Port Peninsula (Figures 16.1 to 16.3). A dominantly shallow sub tidal barrier, it was well oxygenated with constantly shifting ripples and dunes. Fenestrallaminites suggest it accreted locally into the intertidal zone where peloids were trapped in microbial mats.

In contrast, the cyclic association of the Port au Choix area suggests the repeated accretion of sediments from quiet shallow subtidal into higher energy intertidal zone. This is supported by the presence of a few dololaminite beds indicating the local development of carbonate flats. The cycles are essentially A (buff colored tight very fine dolostone after sparcely skeletal and burrowed mudstone), B (dark grey tan-grey fine dolostone after burrowed skeletal and peloidal wackestone and packstone), C (creamy grey stylolitic dolostone and pseudobreccia after crosslaminated and laminated peloidal grainstone and packstone) and B (wackestone with distinct, often abundant burrows). At Port au Choix, a few dololaminites overlie interval C sharply.

Intervals A and B mark the shallow subtidal parts of the cycles in which the fine grained nature of A reflects slow muddy deposition at the deepest part of the cycle following transgression. As the shelf gradually shallowed skeletal and peloidal wackestones (lower B) were widely deposited. Inrerval C marks deposition of a shallow subtidal to intertidal carbonate sand shoal. Lane (1990) interpreted the upper B interval to indicate gradual deepening preceeding maximum drowning by the next cycle (cycle interval A). The intense burrowing so commonly associated with this interval suggests that deposition was slow and lead to bioturbation of the top of interval C. However, the absence of upper B in many of the cycles suggests that there was frequently erosion prior to the deposition of the next cycle. The presence of dololaminites, some of which have a broken possibly karsted top, resting abruptly upon the erosion surfaces indicates that this erosion was related to shallowing. The presence of many occluded spaces in the cream-grey dolostones suggests the carbonate sands were karsted during exposure of these cycles. This is supported by the occluded cavities connected to the sculptured erosion surface at the top of the cream-grey dolostone of unit 7, WN-91-CH-3. The sculpture suggests solution weathering. This is supported by the scalloped surfaces illustrated in Plate 7B. It is interpreted as possible solution karren indicating subaerial exposure of the top of the cycle.

As a result, the grainstones are interpreted as a complex of local peloidal carbonate sand bodies that lay along or off shore of a shifting shoreline or formed discrete shoals scattered across a largely sheltered shallow inner shelf. Upper B intervals were deposited in back barrier lagoons rather than as a prelude to the deep phase of the next cycle. The combined implication of these features suggests that the cycles accreted to sea level but frequently were exposed and eroded as sea level fell. The next cycle occurred when sea level rose and drowned the erosion surface or karsted carbonate. Scattered, and in some cycles concentrated, cauliflower chert nodules in the lower dark to tan-grey dolostones (B interval) and at the base of the cream-grey stylolitic dolostone (C interval) indicates post-depositional precipitation of displacive evaporite. This supports increased salinities during the late stages of the cycles possibly reflecting a hypersaline lagoon during the deposition of the upper dark dolostones and evaporitic pumping of increasingly saline fluids through the lower part of the cycles during subaerial exposure of the carbonate cycles.

Because the cycles are so consistently developed (see Lane, 1990), the prograding shallowing upward cycles may have formed in the lee of and attached to the outer peloidal grainstone barrier complex. Areas such as Port au Choix were structurally influenced highs (see Knight et al., 1991) and likely nucleated the peloidal grainstone shoals.

REGIONAL DISTRIBUTION OF FACIES BELTS DURING DEPOSITION OF THE CATOCHE FORMATION

It is clear from the internal stratigraphy of the Catoche Formation from area to area that its stratigraphic architecture is a product of at least two long term cycles (probably 4th order) of sea level rise and fall. This supported by the two sequences of nodular to burrowed members capped by the peloidal member outlined by Lane (1990) in the Daniel' s Harbour area and by the four member architecture seen in some sections of Pistolet and Hare Bays and on the Port au Port Peninsula (Knight, 1986, 1987; Knight and Cawood, 1991; this study). The prolific development of thrombolite mounds dominated the shelf in some areas and expanded into other areas periodically. Because the Catoche Formation is dominated by subtidal deposition, it is only towards the top of the unit that small scale, 5th order cyclicity is demonstrably a factor during deposition. The influence of Taconian convergence on the Ordovician platform was also a key factor during the deposition of the Costa Bay Member (Knight et al., 1991).

The paleogeography of the Catoche shelf during its early, middle and Costa Bay stages is illustrated in Figures 16.1 to 16.3. The palinspastic maps are based upon known outcrop and drill hole stratigraphy and sedimentology. Only a conservative estimate of about 60 to 100 km of foreshortening is assumed in the construction of these maps. As will be noted this gives a generally smooth curve to the facies belts from west to northeast particularly in the middle and Costa Bay stages of the Catoche Formation. However, if foreshortening is increased to more than 200 km, the facies belts would assume a much more angular elbow shape reflecting the apex of the St. Lawrence Promontory. In the northeast the facies belts would then trend north-northwest and facies in the Port au Port to Comer Brook area would likely trend east-west for a greater distance than is shown.

1) Early stage - this followed Arenigian transgression of the Boat Harbour Disconformity. Widespread fine grained sub tidal deposition characterized by burrowed mudstone to peloidal wackestones dominated the shelf. Thrombolite mounds were scattered on the shallow shelf particularly in the Port au Choix area where other facies such as crossbedded rudstones indicate a near shore setting (Knight,1991). There appears to be no marked facies belts developed on the shelf although mounds are not found in outboard sections.

2) Middle stage - this stage marked the differentiation of the shelf into one dominated by an outer belt of thrombolite mounds and an inner peloidal and muddy belt. The mound belt was particularly long lived and dominant in the northeast (Knight, 1986, 1987; Knight and Cawood, 1991) but probably also occurred outboard of the Port au Port sections. This is based on the invasion of the Port au Port area prior to deposition of the Costa Bay Member by widespread mounds and the presence of mound-dominated sections seen near Comer Brook. The latter possess the stratigraphic architecture documented at Schooner Island, Pistolet Bay (Knight, 1986). The mound belt was a high energy rigid barrier complex flanked by a narrow zone of fore and back barrier sands.

The inner belt was essentially similar lithologically to the early stage so that there is no change other than long term relative deepening and shallowing of the shelf in the sections from Port au Choix to Daniel's Harbour. The consistent north-south orientation of elongate mounds suggests the width of the inner shelf was sufficient to allow wind-driven currents to shape these structures. Grainstones are interbedded in the muddy carbonates in more outboard sections such as Schooner Island and probably reflect the proximity to the barrier belt.

3) Costa Bay stage - This stage is differentiated into an outer belt of peloidal barrier sands protecting an inner shallow shelf characterized by cyclic sedimentation ranging from carbonate muds to peloidal sands. The outer barrier is represented by the Costa Bay Member proper, the inner belt occurs in the Daniel's Harbour to Port au Choix area, the peloidal member of Lane (1990). Thrombolite mounds locally occurred in this outer barrier complex (see Knight, 1986; section 12B/10-036, Figure 5.7, this report).

The sections logged in the Daniel's Harbour-Port au Choix area suggest that the development of the peloidal grainstones at the top of the cycles was concentrated in three seperate areas. The best development occurs near Port au Choix where the tops of the cycles are commonlyeroded, locally overlain by tidal flat laminites and locally karsted. The Port au Choix shoal probably extended from northwest and west of the Peninsula south towards River of Ponds. Grainstones are less well developed when traced southeastward between drill holes 12I/11-009 and 12I/11-002 (Figure 3.7 and 3.10) and the drill hole 12I/06-68-935 (Figure 4.1) east of River of Ponds Lake. Grainstone caps to cycles are poorly developed in the section observed at Bateau Barrens suggesting the shoal lies to the north of this section.

The second shoal area is suggested by abundant grainstones at the tops of cycles in the area southwest of the Daniel's Harbour mine as seen in the 12I/4 drill holes of US Borax (Figures 4.6 and 4.7). A third area apparently occurs to the east and northeast of Daniel's Harbour but here the eastern continuation of the Catoche outcrop belt is eroded. However, grainstone appears to more important in the top of cycles compared to sections measured to the north and in the vicinity of the Daniel's Harbour area itself (sections 12I/06-76-1549, 12I/06-77- 1550, Figures 4.2 and 4.3). The cycles in the intervening areas have sporadic development of grainstone and cycles are dominated by the buff colored and dark to tan-grey dolostones (intervals A and B of the cycles). This suggests an inner shelf consisting of several shoal complexes surrounded by shelf where sedimentation remained predominantly subtidal.

POST-DEPOSITIONAL STRUCTURES DEVELOPED IN THE CATOCHE DOLOMITES

Post-depositional structures in the Catoche Formation discussed here are those related to regional subaerial exposure during the formation of the St. George Unconformity and not to later tectonism. The structures include caves and small voids, matrix breccias, a network of small hairline fractures and stylo-fractures. They all appear to predate true stylolitization, later irregular and tectonic veining and pervasive late stage dolomitizations. In the Port au Port area they also predate Carboniferous flowstone and calcite lined fissures developed generally along earlier faults and fractures.

Caves and small centimetre sized voids are common throughout the Catoche dolomites and the dark grey dolomite of the Port au Choix area (Plates 8A and 8B). They have been observed in both outcrop and in drill hole. They also occur in the dolomitized mound member and the Costa Bay Member on the Port au Port Peninsula where they are filled by green dolomitic shales and marls.

In the Port au Choix area, the best developed caves are bedding parallel, tens of centimetres long, 10 to 25 cm high and are generally occluded by green colored dolomitic shales. They are irregular in shape, commonly with solution sculpted walls. The smaller voids are likewise irregular but are commonly occluded by laminated to massive, buff colored geopetal dolosiltite and by sparry dolomite. Laminae of pyrite dust the top of some geopetal dolomite. Cave stratigraphy from small caves in drill holes 12I/11-008 and 12I/11-010 indicate that multiple collapse breccia and geopetal dolomite silt sedimentation and the pyrite occurred prior to the precipitation of a millimetre-thick drusy cement. This cement coats clasts, geopetal sediment and cavity walls before the precipitation of coarse sparry dolomite in the remaining cave open space. Any remaining void space either remained open or was closed by white sparry calcite. The druse cement is white to bluish-grey and translucent. It also occludes most hairline fractures that form an irregular ramifying network cutting mostly the fine grained dolostones of the lower part of the cycles. Small millimetre-sized voids lined by the druse commonly occur at the intersection of the fractures. This druse is correlated with the druse lining open vug and fracture porosity in the pseudobreccias of the Port au Choix area (Plate 7 E) and the irregular spar veinlets in the peloidal lime grainstone vestige at Back Arm (Plate 7 D).

Matrix breccias effect the Catoche dolomites and the dark grey dolomite at Port au Choix and in some drill cores in the Daniel's Harbour area (see also Lane, 1990; Knight et al., 1991). The breccias are mostly oligomictic comprising sand-to chip-sized fragments of grey dolomite and locally chert in a dark grey vitreous dolomite matrix. When no fine vitreous matrix is present the breccias are cemented by white dolomite spar (Plate 8B). The breccias can effect single beds or transgress tens of meters of stratigraphy as in drill hole l2I/06-68-935. Matrix breccias and caves occur extensively in the dark grey dolomite at the top of the Pointe Blanche section at Port au Choix.

Collapse of beds was observed at two localities in the Back Arm and Pointe Blanche sections of the Port au Choix area. They occur in the cyclic dolomites 10 to 25 m below the base of the dark grey dolomites. Bedding is warped and chaotic in the zone at Back Arm over a width of 100+ metres (Plate 9A). Spar lined to open fractures trending north east cut the basal parts of the cycles (plate 9B). At Pointe Blanche, the collapse is marked by a 20 m wide zone where beds on both sides dip into a narrow zone of fractures and breccia with no apparent displacement of beds across the zone. Dark grey, vitreous, icing-sugar tine dolomite infills the fractures (see also Knight, 1991). The collapse zone trends northeast at 215° parallel to fractures that dip at 80 to 85° to the west. The collapse zone and fracture system trends directly towards narrow dolostone-filled fractures and a dolomitized joint system that cuts the lower Catoche limestone at Laignet Point, Port au Choix Peninsula (Knight, 1991) and has been linked to a deep subterranean fracture system beneath the St. George Unconformity (Knight et al., 1991).

Stylo-fractures are observed cutting the lower parts of cycles, oligomictic matrix breccias and dark grey dolomite in the Port au Choix to Daniel's Harbour area. They are large structures that meander across tens of centimetres of stratigraphy. The fractures are 0.5 to 4.0 cm wide, smoothly sinuous where cutting across beds but frequently bedding parallel at either end. They are commonly occluded by dark grey to black pyritiferous argillaceous detritus or by the dolomite druse and sparry dolomite seen in the caves and fractures of the Port au Choix area. Similar structures are less common at Port au Port Peninsula where they are sealed by green marl.

The features described above are believed to be early structures related to karsting during the St. George Unconformity or soon after. The shape of caves and small cavites with their sculptured walls and no compaction indicate the dissolution of lithitied carbonate. The green shaly dolostone and marl that occludes the caves together with cave detritus and geopetal dolomite silt is consistent with sedimentation in a subterranean karst system. The irregular hairline fractures that crosscut the fine grained tight dolostones of the lower parts of cycles probably date from the same time as they cut oligomictic breccias but are truncated by true stylolites and by dolomite veins. The vitreous dolomite and the dolomite druse lining the fine fractures are cements and sediments that date from this event. The oligomicitc breccias are interpreted as early subsurface solution collapse structures that occurred as the Aguathuna Formation was being deposited (Lane, 1990; Knight et al., 1991).

The origin and timing of the stylo-fractures is less clear. However, the association with the dolomite druse and the green marls at Port au Port Peninsula suggest they formed early in the subsurface and were open as they were folded during early compaction and lithification. They were subsequently cemented or filled by cave mud.

DOLOMITIZATION: ITS STRATIGRAPHIC POSITION AND DISTRIBUTION

This study shows that the stratigraphic position of the Catoche Dolomite is not the same in the different areas studied.

<u>Cape Norman area</u>

In the north of the Great Northern Peninsula, most of the Catoche is dolomitized in the section west of the trace of the Ten Mile Lake Fault. Only the basal part of the lower bioturbated member and the thin Costa Bay member escapes this event (Knight, 1986). Dolomitization is however, less extensive east of the Ten Mile Lake Fault zone. Here, it locally replaces parts of the mound member (see 1:50,000) N.G.S. map, l2P/6 and 8, Knight et al., 198?; Stouge, 1982). The drill hole 12P/01-018 was dolomitized near the base of the formation and towards the top of the incomplete 120? m thick Catoche section logged.

<u>Port au Choix to Daniel's Harbour area</u>

In the Port au Choix to Daniel's Harbour area, dolomitization affects rocks equivalent of the Costa Bay Member. Locally near faults such as the Bateau Barrens fault that strikes northwards just off the coastal cliffs north of Table Point, the Catoche Formation is completely dolomitized. However, this zone is narrow and does not exceed more than a kilo metre in width. Within the zone, rocks of the cyclic member are discernable, including the porous caps to cycles (Plates 10 A, B and C).

Rapid transitions from dolomite to limestone however, appear to mark the cyclic sequence equivalent of the Costa Bay Member south of the Daniel's Harbour mine area. The dolomite front appears to wander and this possible reflects the nature of the front (Figure 17). It is however possible that these are but small enclaves of undolomitized section surrounded by the Catoche cyclic dolomites because such an enclave is present northeast of River of Ponds Lake (Knight and Boyce, 1984) well within the dolomite region. However, this dolomite front must exist somewhere between Daniel's Harbour and Port au Port Peninsula because the Costa Bay Member is not dolomitized on the Peninsula although it is partly dolomitized at Table Mountain. All other Catoche sections between Daniel's Harbour and Port au Port have been thrust westward making resolution of this question impossible based on present geological knowledge.

<u>Port au Port Peninsula</u>

The dolomites replacing the Catoche Formation at Port au Port Peninsula occur in the 50 m of section immediately below the Costa Bay Member. Drill hole and outcrop indicate that this is consistent throughout the Peninsula as far west as Round Head. Southwest of this there is no published information available but a traverse of the section near Big Cove suggests that the equivalent section that is dominated by mounds is largely limestone (Knight, unpublished data). Traced northeastward onto Table Mountain, the Catoche section is partially dolomitized in the mound section and in cyclic burrowed, grainstone and thrombolite sequences believed to be possibly equivalent of the Costa Bay Member (section 12B/10-036, Figure 5.7).

Plates of

Catoche Outcrops and Cores,

Western Newfoundland

Plate 1
The barren rocks of Cape Norman, Great Northern Peninsula. The modern karsted landscape comprises sucrosic dolostones of the Catoche Formation that replaced thrombolitic mounds (foreground) and stratified grainstones (arrow).

Plate 2
Well bedded Catoche dolostones hugging the southeast shore of Back Arm, Port au Choix area. Arrow points to zone of collapse deformation.

Plate 3
Sucrosic and bituminous Catoche dolostones in the Lower Cove area of southern Port au Port Peninsula. The westerly dipping strata consists of thrombolite mounds that give the outcrop a hummocky, disjointed aspect.

Plate 4
A: Intercalated bioturbated dolomitic skeletal lime wackestones and skeletal-intraclastic lime grainstones. Lower Catoche Formation, Cape Norman area.

Plate 4
B: Bioturbated dolomitic lime wackestone and mudstone, lower Catoche Formation, Cape Norman area.

Plate 4
C: Dolomitized burrowed wackestones, and graded, cross laminated and planar laminated grainstones, Port au Port Peninsula.

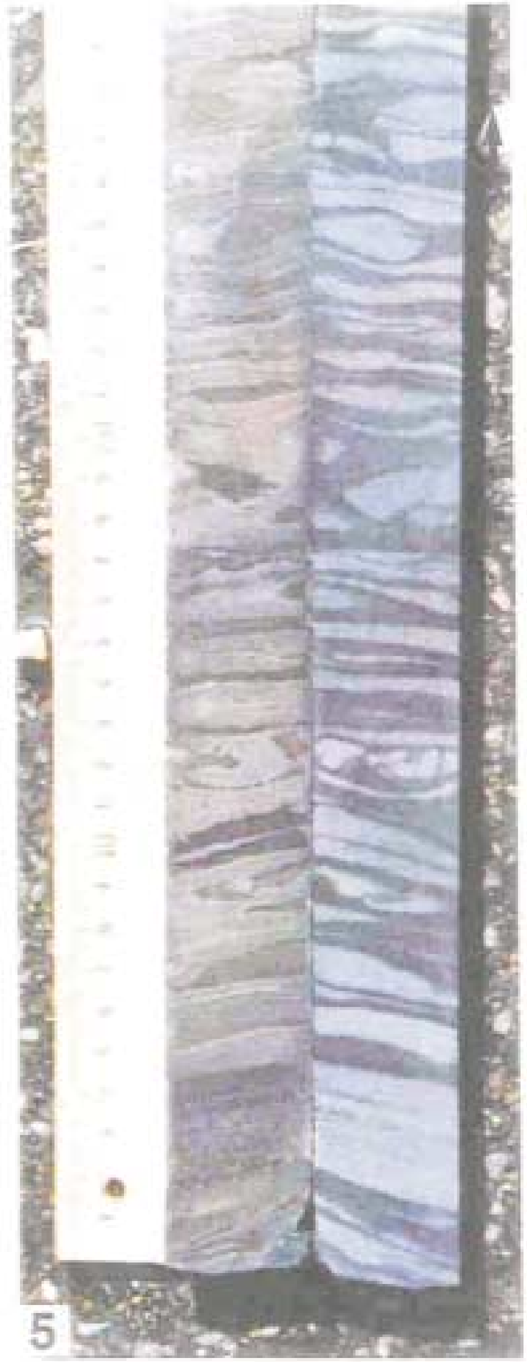

Plate 5
Thinly stratified dolomitic lime mudstone, Catoche Formation, Cape Norman area. A laminated and graded grainstone bed occurs at the bottom of the core.

Plate 6
A: Digitate structure in a thrombolitic mound bed at Aguathuna quarry, Port au Port Peninsula.

Plate 6
B: Cores of thrombolitic dolostone, RND-2 drill hole western end of Port au Port Peninsula. The core to the left is a dolomitized grainstone, clotted and digitate fabric is seen in the other three cores. Note the fine tubular burrows in the dark interthromboid areas in both the digitate fabric (centre right) and the clotted buff thromboids of the core at the right.

Plate 6
C: Cerebral weathering pattern common to the thrombolite mounds. Note the burrows in interthromboid areas. Lower Cove, Port au Port Peninsula

Plate 6
D: The brecciated core of a thrombolite mound, Lower Cove, Port au Port Peninsula.

Plate 7
A: A typical metre-scale dolostone cycle at Back Arm section, Port au Choix. The lower recessively weathering dolostone comprises buff to tan-grey, fine grained, non-porous, burrow-mottled dolostone. The upper part of the cycle comprises cream-grey, stylolitic, porous dolostones dappled by dark grey burrows and seams near the base. An oval mass of porous dolostone occurs to the left.

Plate 7
B: A dolostone cycle in the Pointe Riche section. The cycle rests on a scalloped surface at the top of the underlying cycle. The scallops can be traced beneath the recessive unit indicating they are exhumed ancient structures. Note the patches of porosity in the upper cream-grey dolostone of the cycle.

7C

Plate 7
C: A cycle traced through three drill holes, 12I/11 008 (left), 12I/l1 009 (centre) and 12I/11 010 (right). The holes young from left to right in the four views. Note the buff to tan-grey burrow mottled dolostone for the lower 40 cm (left view) overlain gradationally by the cream-grey stylolitic dolostone (centre left). Dark grey burrow mottles characterize the lower part of the latter overlain by a stylolitic sparcely burrowed interval (centre right view). Wormy tubular burrows mark the top of the crearn-grey dolostone (right view). Arrow indicates top.

Plate 7
D: A vestige of pale grey peloidal grainstone and packstone from near the top of the Catoche Formation section, Back Arm. Note the dolomitized burrows and the irregular network of dolomite-spar-lined fractures (foreground).

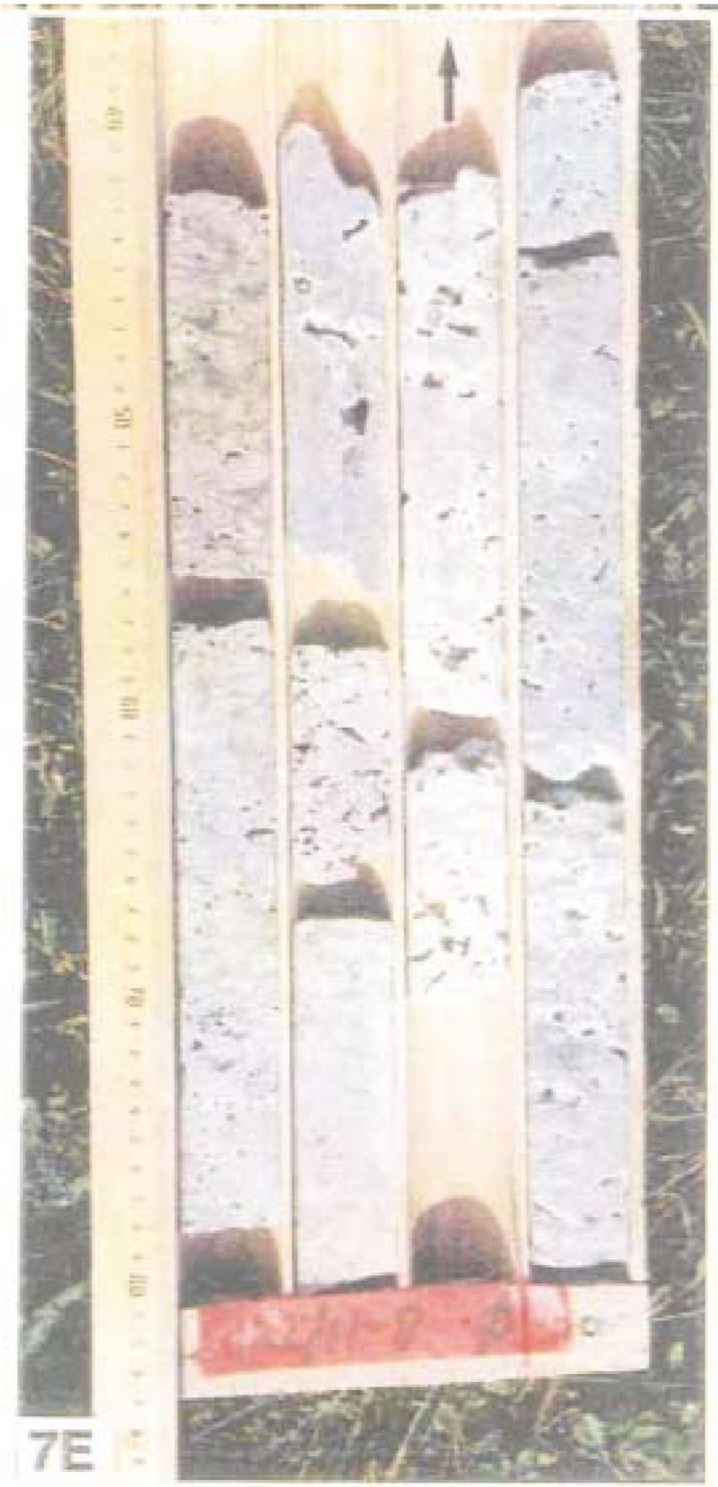

Plate 7
E: Porosity and late stage dolomitization in the cream grey dolostone intervals of several cycles in drill hole 12I/ll-008. Intercrystalline porosity marks the first three core pieces at the left. Enlarged fracture and vug porosity locally lined by a dolomite druse occur in the remaining core pieces. The two pieces in the centre right tube have poorly developed pseudobreccia. Arrow indicates top.

Plate 7
F: Burrows in the top of a cycle at Pointe Riche section, Port au Choix. Note the dark burrow fill in the larger burrows is inturn bioturbated by fine tubular burrows.

Plate 7
G: Ghosts of sedimentary structures in a cream-grey dolostone at the top of a cycle in the Back Arm section, Port au Choix. Cross lamination (upper far left) and very faint cross beds (above the hammer handle) are overlain by planar lamination.

Plate 8
A: An oligomictic matrix breccia in the dark grey dolomite of the Pointe Blanche section, Port au Choix. Dark burrow mottles and fine dolomite fragments are enclosed by anochre colored fine dolostone matrix.

Plate 8
B: An oligomictic breccia and crackle breccia cemented by white dolomite. Note the fine spar vein network above the breccia suggesting incipient roof stopping and the local collapse near the top of the breccia (centre and right of ruler). Some greenish grey fine dolostone occludes small cavities near the top of the breccia either side of the ruler. Dark grey dolomite, above Plate 8A, Pointe Blanche Section.

Plate 9
A: Gently warped Catoche dolostones at Back Arm. The cyclic beds are warped about a series of northeast-trending axes interpreted to be related to subsurface dissolution.

Plate 9
B: A dark grey dolostone bed sharply overlying a very porous cream-grey dolostone that is rich in black hydrocarbon residues. An angular network of fine dolostone fractures, locally with open spaces, cut the dark grey dolostone. They mostly trend northeast and are related to incipient collapse associated with underlying dissolution. White spar lines the porosity in the underlying dolostone (see Plates 11A for closeups). Back Arm section.

Plate 10
A: Complete dolomitization of well bedded Catoche limestones that underlie the upper cyclic member. Deer Cove, Bateau Barrens.

Plate 10
B: Bedded dolostones at Bateau Barrens still showing the cyclicity typical of the upper part of the Catoche Formation in this area. Note the porosity locally in the top at the cycle. Note also the general lack of cream-grey dolostone at the top of the cycles (see Plate 10C).

Plate 10
C: Burrow-mottled dark grey dolostone capped by vuggy, fabric-controlled, spar-veined dolostone at Bateau Barrens.

Plate 11
A: Black hydrocarbon residues clogging porosity in the upper cream-grey dolostone of a cycle within the Catoche dolomite at Back Arm. Same locality as Plate 9A.

Plate 11
B: Fine spar lined irregular fractures in tan-grey clotted dolostones of the thrombolite mound interval of the Catoche Formation, Cape Norman area. Note the local intercrystalline and fracture porosity in the middle core.

Plate 11
C: Black bitumen clogging intercrystalline porosity in three dolornitized thrornbolite mound beds (each tube represents a different bed) in the Catoche section at Table Mountain. Drill hole 12B/l0-036.

PETROGRAPHIC OBSERVATIONS AND DOLOMITIZATION

A total of 53 thin sections of dolostones were selected for petrographic examination (Table 1).The samples from field sections at Back Arm and Pointe Blanche were prepared from circular cut-offs following porosity and permeability determinations by Core Lab in Calgary. All other specimens were selected from slabbed cores.

The thin sections have been vacuum impregnated with dyed epoxy, enabling porosity to be observed under plane-polarized light. Diamond-studded laps were used to grind the sections to the correct thickness - thus porosity is very clear and there are no inclusions of carborundum in the epoxy. Prior to the application of cover slides, all sections were stained with Alizarin Red-S and potassium ferricyanide.

All sections have been examined, described and photographed. Representative, generally low magnification photomicrographs are presented as Plates 12 to 18. Abbreviated descriptions and sample locations are provided on the columnar stratigraphic logs; detailed descriptions are located in Appendix A.

The samples for thin sectioning were selected to provide a representative suite of dolostones that contain porosity. The detailed analysis of dolomite paragenesis is perhaps beyond the scope of this study especially considering time constraints and the fact that the only analytical tool used was a polarizing microscope (i.e. , no geochemistry or cathodoluminescence). Lane (1990) has given a very detailed account of the geology of the Catoche Formation in the vicinity of Daniel's Harbour, and Haywick (1984) presents a regional assessment of dolomitization in the rocks of the St. George Group. The nomenclature of Amthor and Friedman (1991) for the carbonates of the Ellenburger Group is employed in the descriptions in this study.

The earlier stage of dolomites that characterize the Catoche Formation range from very fine-to medium-crystalline planar mosaic dolomites that are sucrosic and preserve many sedimentary structures. These dolomites are overprinted in beds of crearny-gray dolomite by coarse sparry dolomites that essentially obliterate original structures although they mimic the earlier fabrics. Such dolomites include white, coarse-crystalline to megacrystalline, massive phases that suggest neomorphic replacement and cementation, and the characteristic white, pink to yellowish saddle dolomites that occlude cavities and veins throughout the dolomite complexes (Plates 12G,H, and 15D, E). These mixed dolomites occur in the Port au Choix to Daniel's Harbour area but not in the Port au Port area and are discussed extensively by Haywick (1984) and Lane (1990).

The fine-to medium-crystalline, sucrosic dolomites are interpreted by both Haywick and Lane to include an early shallow burial phase overprinted by a later progressively deeper burial phase. The observed dolomites contain dusky or turbid cores which is thought to represent early crystallization. Lane (1990) suggests that widely variant oxygen isotope signatures probably relates to long term crystallization from fluids of different oxygen isotope composition and equilibration of original sea water pore fluids with the rock. Because of the lack of detailed study, it is not the purpose of this report to dispute these conclusions however, some geological relationships bear on this discussion. Firstly, the sucrosic dolomites are unconformably overlain by Aguathuna dolostones near River of Ponds (Knight, 1991; Knight et al., 1991) and dolomites of this type are included in the oligomictic and polymictic breccias of the Daniel's Harbour area. This suggests that they were not buried deeply before they were partially exhumed. Maximum burial was of the order of 100 metres.

This suggestion is further supported by the presence of burrow-mottled sucrosic dolomite blocks comparable to the Catoche dolomites in the Cape Cormorant Formation at the west end of Port au Port Peninsula. This formation consists of conglomerates containing carbonate detritus derived by erosion of Late Cambrian to Middle Ordovician carbonates during tectonic uplift of the ancient shelf sequences during the early stages of the foreland basin (Stenzel, 1992; Stenzel et al., 1990; James et al., 1989). These relationships indicate that the sucrosic dolostones that retain sedimentary fabrics formed during burial that spanned the late Arenig to early Llanvirn (essentially during the early Whiterock stage).

Dolostones containing sucrosic, sparry and saddle dolomites that pervade the Port au Choix to Daniel's

Table 1
List of Thin Sections

1. Port au Choix Area
   - Back Arm (BA) Field Section
     - BA-1,2,3,4,5,6,7,8,9,10A,10B,11,12,13,14
   - Pointe Blanche (PB) Field Section
     - PB-l,2,3,4,5,6,7
   - drill hole 12I/11-008 (core samples)
     - 12I/11-008-16,17,18,19,21,23,24,25

2. Daniel's Harbour Area
   - drill hole 12I/06-78-1549
     - 12I/06-76-1549-2,3,4,5,6,7,8

3. Port au Port Area
   - drill hole 12B/10-0001
     - 12B/10-0001-1,2,3,4,5,6,7,8

4. Great Northern Peninsula/Cape Norman Area
   - drill hole 12P/1-018
     - 12P/1-018-7,8,9,10,11,12
   - drill hole 2M/12-002
     - 2M/12-002-1,2

Harbour area (Plates 12G, H, L, and 15D, E) are interpreted to have been developed in an epigenetic, deep burial setting associated with the passage of hydrothermal fluids. Lane (1990) has suggested that this dolomitizing fluid migration was coincident with Acadian thrusting and faulting of the Ordovician carbonate platform. The hydrothermal sparry dolomites are very common as cements in late stage fractures and faults cutting both the fine tight dolostones of intervals A and B of the cycles and also interval C of the cycles. Zones of dolomite also occur at the tops of beds signifying that bedding planes also allowed the horizontal passage of dolomitizing fluids.

However, the importance of sparry dolomite within the dolomitized grainy carbonates of the C interval of the metre-scale cycles of this area suggests a predisposition of this facies to facilitate the crystallization of this type of dolomite. This in turn suggests that the dolomitized grainstones at the C interval had retained porosity and permeability to this diagenetic stage. This porosity and permeability is believed to have resulted from vadose dissolution of the grainstones during sub aerial exposure that marked the top of many of the cycles at least at Port au Choix (see Figures 3.1 to 3.12 and Plates 7A, 7E, 12 to 14). Spar-cemented spaces in many of the cream-grey dolostones in places connected to karsted tops, supports this contention. The Costa Bay peloidal and fenestral grainstones and packstonest although probably deposited in a shallow sub tidal to intertidal setting, were never karsted and were lithified early by calcite cement. Consequently they largely escaped dolomitization.

Port au Choix

At Port au Choix, the dolostones in cycle interval C are reasonably similar to one another. Petrographically t they generally contain bimodal crystallinity. Crystallinity ranges from very fine-to medium-crystallinet with the other predominant mode coarse-to very coarse-crystalline. As has been mentioned the finer-crystalline dolomites are dusky , and possibly crystallized early. Commonly mottling is observed which is either a stylo-mottle and is related to primary fabric (burrowing). Often these mottle/intermottle areas are distinguishable on the basis of their contrasting concentration of intercrystalline porosity and higher concentration of small vugs compared to relatively tight areas. Boundaries between the finer and coarser modes are gradational over small distances and are often denoted by stylolites (Plates 12E, 120), variations in intercrystalline organic content (Plate 12/I), or merely by evidence of the development of larger, subhedral to euhedral crystals that appear to partly fill voids (Plates 12, 12K). These coarse-crystalline dolomites are frequently zoned with thin bands of ferroan dolomite near crystal margins (Plate 14E). The dolomites include sparry dolomite and saddle or baroque dolomite. There is possibly an early generation of sparry dolomite that was partly dissolved (ragged crystal margins) and later crystallized on by a second generation of dolomite. This latest phase of dolomite itself contains some evidence of zonal leaching. Low ferroan calcite is present but rare (Plate 13D). The smoothed crystal margins of the late calcite suggests some dissolution (possibly resulting from the same solutions that caused the small amounts of dolomite leaching).

Stylolites are common and occur mainly in two forms. Firstly, they are present as the typical dark organic/argillaceous insoluble form (e.g., Plates 12E, G and 14E), and secondly, they are observed as indistinct fracture/microbrecciated zones that could be termed stylobreccias (Plates 12D, J and 14D). Open pore space is frequent along some stylolites; microporosity is ubiquitous in most microbreccias. In places, the distinction between fracture-induced brecciation and stylolite-related brecciation could not be deciphered.

Very rare crystals of quartz are present. The brief hand specimen descriptions given by Core Laboratories (Appendix C) indicate the presence of anhydrite at both Back Arm and Pointe Blanche: anhydrite was not found in thin sections of the same analysed samples.

The apparent final diagenetic event was the migration of hydrocarbon. Black shards and "blebs" of bitumen are common in pore spaces including vugs, intercrystalline pores and fracture-related porosity .

Daniel' s Harbour

The dolomitization of the Catoche Formation in the vicinity of Daniel's Harbour has been very well documented by Lane (1990). Lane recognizes seven dolomite crystal types that developed in four major settings as follows:

1.	Syngenetic dolomite	(I)	
2.	Diagenetic dolomite	(II):	diagenetic crystals with turbid, replacive cores and clear rims
		(III):	pore-filling, clear zoned dolomite cements
3.	Epigenetic dolomite	(IV):	coarse dolostone/sphalerite complexes that overprint earlier dolomites
		(V, VI):	post-ore hydrothermal dolomites turbid
4.	Late fault-related	(VII):	dolomites which replaced limestones

These various types of dolomite were defined on the combined evidence of geology and sophisticated analytical techniques. In the present study, a series of thin sections from drill core at well 12I/06-76-1549 were examined petrographically (see also Figure 4.3). Samples were selected from this core primarily because the entire Catoche dolomite section was amenable to the point counting of porosity and thin sections would provide some control to the point-counted porosity determinations plotted on (Figure 4.3).

Generally, as at Port au Choix, shoaling upward cyclicity is represented in the Daniel's Harbour stratigraphic section although it is not as well developed. Sample 2 (Plate 15A) is located near the base of a cycle, in cycle interval A or B. As such, it is a sucrosic mosaic that probably developed relatively early. The dolomitization was pervasive leaving very low permeability and porosity. Rarely, minor porosity has been preserved (Plate 15B) and most porosity and permeability would be situated along intercrystalline sheet pores: this is clearly non-reservoir material. Although the sample 2 (Plate 15A and 15B) retains a planar-s fabric in its dolomite, other samples clearly contain complex, composite, non-planar , anhedral crystals (Plate l5D and l5E). This type of crystallinity may suggest higher temperatures of crystallization and could be due to deeper burial, or upwelling hydrothermal activity associated with the Daniel's Harbour mineralization.

Samples from this well are mineralogically more complex than those from Port au Choix to the north, which is understandable considering the proximity of base metal mineralization at Daniel's Harbour. Late quartz crystals (Plate l5C) and earlier silica nodules are evident. In samples 3 and 7 (Plate 15F), late, zoned ferroan-to non-ferroan calcite is present. Microporous aggregates of clay, possibly illite or illite/smectite are observed. Aggregates of replacive pyrite (cubes and framboids) are noted in places.

As at Port au Choix, stylolites, stylobreccias, and fractures are observed. Some dissolution is evident within stylolites (Plate 15G). Sparry dolomite adjacent to pore space contains evidence of partial dissolution.

Port au Port

Most of the core from 12B/I0-000l (Figure 5.5) on the Port au Port Peninsula is interpreted as dolomitized grainstone. Overall, the sequence of lithologies is far more uniform than the cyclic units at Port au Choix and Daniel's Harbour.

Core examination and thin sections reveal a variety of dolo stones which almost invariably contain dolomite with turbid, inclusion-rich cores that grade rapidly to inclusion-poor, clearer rims. Where interlocking mosaics are present (Plate 16A), crystals tend to be subhedral; elsewhere, and in the highly porous lithologies, dolomite crystals are strongly euhedral (Plate l6B and l6C). It is thought that many of the dolomite crystals nucleated on primary peloid grains, and did so fairly early in the diagenetic history of the rocks.

Most often the rocks are unimodal in terms of crystallinity, however in some samples there is a less abundant very fine-crystalline mode (Plate l6B). Well distributed dolomite crystals as in Plate 16C suggest the presence of many nucleation sites in a well sorted primary sediment. Hand specimens of this lithology contain sucrosic dolomite in a brittle mosaic (i.e., it is a competent rock and not friable) and very abundant intercrystalline porosity. Samples are usually tan-brown due to oil staining.

Minor stylolitization is observed locally, and in places there is a crumbly brecciation probably resulting from stylolitization or as an absorption of fracture energy in the more porous samples. In some of the more porous dolostones, hairline fractures have been cemented by clear dolomite; it is difficult to envisage fractures transecting such a porous lithology -possibly pore spaces were once cemented enabling continuous fractures to occur(?).

Judging from the nature of dolomite-to-dolomite crystal boundaries, it is suggested that two stages of dolomite crystal growth have occurred with an intervening corrosion of the early dolomite and with the partial dissolution of the most recent dolomite crystals (Plate 16D). Relatively late stage, zoned calcite/ferroan calcite is observed cementing dissolution voids in the second generation of dolomite and it is possible that the calcite is also partially dissolved.

Two other constituents are an indeterminate, microporous mineral (clay?) (Plate 16B) and silica nodules that form tight, 2-3 cm layers across the small diameter core. The final diagenetic episode has been the impregnation of the rocks by oil.

It is noted that the Catoche dolomite from well 12B/10-0002 is less porous, and contains more calcite cementation compared to 12B/10-0001 (compare Figures 5.5 and 5.6).

Great Northern Peninsula/Cape Norman Area

For comparative purposes with areas to the south, a number of thin sections were prepared from two wells on the Great Northern Peninsula of Newfoundland. The wells are 12P/1-018 (Plate 17) and 2M/12-002 (Plate 8), see also Figures 6.1 and 6.2. The lithologies tend to contain bimodal crystallinity varying from medium-to coarse-crystalline planar and non-planar fabrics, and coarse-to very coarse-crystalline dolomite spar and saddle dolomite on approaching pore spaces (the latter dolomite types are likely cement phases). Mottle fabrics, where observed in thin section (Plate 17B), are often encased by stylolites which separate zones of distinctive crystallinity. Possibly such mottles mimic a primary feature such as burrowing. At least some of the thin sectioned rock was selected from thrombolitic mounds - thus accounting for varying stylolite orientation and apparent haphazard orientation of linear vugs in some samples.

Dedolomitization is fairly common and accounts for nearly all the porosity in sample 10 from 12P/1-018 well (Plate 17D). Within sample 10 there is a bifurcating vertical veinlet, now filled with coarse calcite. In a halo zone surrounding the fracture, considerable dedolomitization has occurred. Presumably, the solutions from which calcite crystallized partly dissolved dolomite at crystal margins and along cleavage planes. Locally, and post-dedolomitization, authigenic chlorite (?) crystallized in some vugs and along partly dissolved cleavage planes in the dolomite.

Pyrite, fracture-filling quartz, and quartz nodules are accessory components in the rocks.

Plates of

Thin Section Photomicrographs,

Port au Choix Area

Plate 12: BACK ARM FIELD SECTION, PORT AU CHOIX
A: BA-2 -Sty1olitic dolostone containing common medium-to coarse-crystalline planar-s (subhedral) dolomite. Vuggy porosity is apparent (blue area), as is some microporosity along stylolites (black arrows). Petrophysically, this specimen contains 51.8 md horizontal permeability and 7. 0% porosity. Plane-polarized light, scale bar = 0.5 mm.

Plate 12
B: BA-3-Overview of dolostone that consists of fine-to medium-crystalline planar-s (subhedral) mosaic dolomite. Most porosity is present as sheet pores and small, angular , intercrystalline pores. The area in the micrograph contains relatively high porosity compared to elsewhere in the specimen. The sample contains 0.05 mD horizontal permeability and 1.0% porosity. Plane-polarized light, scale bar = 0.5 mm.

Plate 12
C: BA-4 -This hydrocarbon-bearing dolostone contains common intercrystalline porosity as well as vuggy pores up to 1 centimeter in thin section. It is possible that the porosity is related to interburrow areas. Sparry dolomite and saddle dolomite frequently line vuggy pores. The sample contains 4.26 mD horizontal permeability and 8.1% porosity .Plane-polarized light, scale bar = 0.5 mm.

Plate 12
D: BA-4 -In addition to containing intercrystalline and vuggy porosity, microbrecciation along fractures and stylolites is noted (arrow). This style of microbrecciation is common throughout the Catoche dolomite section and it occurred before the emplacement of hydrocarbon. Black bitumen is noted in some pores. Plane-polarized light, scale bar = 0.5 mm.

Plate 12
E: BA-7 -Low magnification overview of porous, vuggy, stylolitic dolostone. Porosity is evident in vugs up to 8 mm in thin section; these vugs tend to be elongated parallel to the general stratification. Often these vugs are lined by saddle dolomite and sparry dolomite. Porosity is present also as smaller, more equant and angular intercrystalline pores (not evident in this micrograph), and as microporosity associated with common stylolites. Splinters of bitumen are located in many pores. The sample contains 1.30 mD horizontal permeability and 11.5% porosity. Plane-polarized light, scale bar = 1.0 mm.

Plate 12
F: BA-9 -This is an overview of an apparent microbrecciated dolostone that contains significant amounts of vuggy and intercrystalline porosity (blue areas). It seems as though deformation was absorbed as a "crumbling" or brecciation rather than in the form of discrete fractures. In hand specimen the sample is very bitumen-rich and dark gray to black. The sample contains 317 mD horizontal permeabilityand 14.4% porosity. Plane-polarized light, scale bar = 1.0 mm.

Plate 12
G & H: BA-11 -These photomicrographs are of the same field of view. Spectacular saddle dolomite (arrows) displays typical curved crystal terminations and uneven extinction. This probable late-stage dolomite phase appears to be encroaching upon a rather large vug and appears to have nucleated on a dark stylolite. Plane- and crossed-polarized light (G and H, respectively), scale bar = 1.0 mm.

Plate 12
I: BA-12 -This specimen contains a considerable range of crystallinity ranging from fine-crystalline to very coarse-crystalline (vug-lining sparry dolomite and saddle dolomite to 2 mm). Within the finer crystalline dolomite there is extensive intercrystalline pseudo-amorphous debris (darker areas -related to original burrows?). Although intercrystalline porosity is present, most porosity is present in both elongate and equant vugs that are lined by void-filling saddle dolomite. 3,680 mD horizontal permeability (anomalous), 17.8% porosity. Plane-polarized light, scale bar = 1 mm.

Plate 12
J: BA-12 -Thin microbrecciated zones (arrow) are apparent throughout this specimen (which may partly account for the anomalously high permeability). Within these zones some dissolution is apparent and certainly microporosity is present. Plane-polarized light, scale bar = 0.5 mm.

Plate 12
K: BA-13 -This porous dolostone consists of a polymoda1 texture in terms of dolomite crystallinity. Note the very fme-crystalline mode in the lower part of the micrograph and the transition upward to clearer, medium-to coarse-crystalline dolomite that lines the sub horizontal vug. Porosity is present in equant and elongate vugs (both to 5 mm in thin section), in intercrystalline locations and within microbreccia zones. The sample contains 0.96 mD horizontal permeability and 13.8% porosity. Plane-polarized light, scale bar = 1.0 mm.

Plate 12
L: BA-14 -This image shows coarse-to very coarse-crystalline dolomite spar and saddle dolomite crystallizing in vuggy pore space. Black areas are bitumen; there is some slight dedolomitization of the coarse void-filling dolomite. The specimen contains 24.7 mD horizontal permeability and 10.5% porosity. Plane-polarized light, scale bar = 0.5 mm.

Plate 13: POINTE BLANCHE FIELD SECTION, PORT AU CHOIX
A: PB-2 -View of dolostone showing the contact between relatively tight planar-s mosaic dolomite in the lower part of the image, and a highly porous bitumen-bearing zone. The specimen contains 1.74 mD horizontal permeability and 7.2 % porosity. Plane-polarized light, scale bar = 1.0 mm.

Plate 13
B: PB-4 -Subvertical fracture pores may have occurred late; that is they may truncate the stylolite in the upper part of the image. Small crystals of relatively inclusion-free dolomite are seen lining the fractures (arrows). Note also the "dusky" cores of many of the dolomite crystals that form the planar-s mosaic. Plane-polarized light, scale bar = 1.0 mm.

Plate 13
C: PB-4 -This is another view of the (compare with Plate 2B) that illustrates the presence of good intercrystal1ine porosity (blue areas), plus pore linings of bitumen. This sample contains 224 mD horizontal permeability and 9.6% porosity -potentially and excellent reservoir rock for a dolomite. Plane-polarized light, scale bar = 0.5 mm.

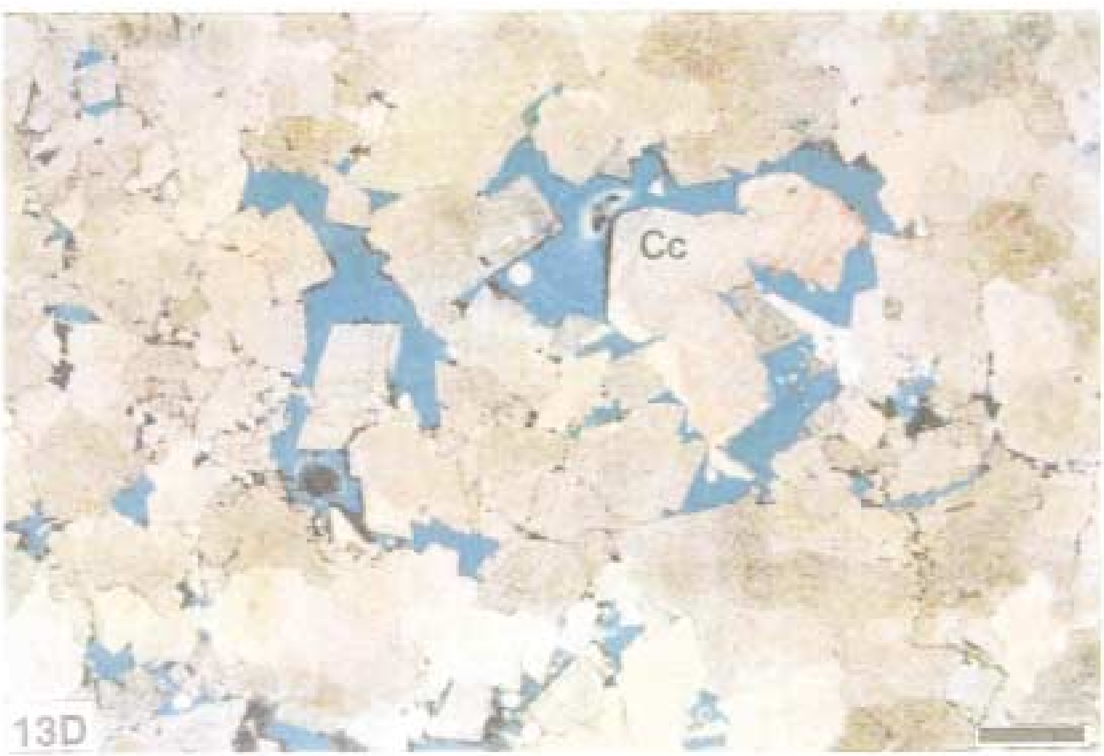

Plate 13
D: PB-6 -In contrast to the previous sample, PB-4, this specimen contains similar porosity at 7.6 % , but permeability is very low at 0.19 mD .This specimen contains vuggy porosity that is not well interconnected even though 6 mm vugs are noted in thin section. Late low ferroan calcite (Cc) appears to contain smooth margins and may be partly dissolved. Plane-polarized light, scale bar = 0.5 mm.

Plate 13
E: PB-7 -Dusky, inclusion-rich cores to dolomite crystals are evident (arrow), possibly suggesting the replacement of primary grains (1) - peloids?. Plane-polarized light, scale bar = 0.5 mm.

Plate 14: DRILL CORE 12I/11-008, PORT AU CHOIX

A: 12I/11-008-18 -Within this specimen. two distinctive zones are evident; the upper zone is tight. the lower zone contains good intercrysta11ine porosity. Porous zones may be connected by fractures (arrow), and this porous/non-porous fabric may be related to primary depositional texture such as burrowing. There is an estimated 7% porosity. probably poor permeability. Plane-polarized light. Scale bar = 1.0 mm.

Plate 14

B: 12I/11-008-21 - The variably oriented. elongate vugs in this specimen are related to both stylo1ites (arrows) and fracturing (and possible solution enlargement of fractures). Relatively large linear vugs are evident in thin section. ranging to 11 mm in length. There is an estimated 9% porosity. Plane-polarized light. Scale bar = 1.0 mm.

Plate 14
C: 12I/11-008-25 -The purpose of this micrograph is to show the variability in crystallinity , the presence of void-filling sparry dolomite, stylolitization, linear and equant vugs, and the presence of black splintery bitumen particularly in the linear vug in the upper right of the photo. Plane-polarized light, scale bar = 1.0 mm.

Plate 14
D: 12I/11-008-25 -This image is an overview of a microbreccia associated with fracturing and/or stylolitization. These microbreccia zones may either cross-cut the trace of stratification or they may conform with the stratification. In places, the microbreccia can contain much microporosity .P1ane-polarized light, scale bar = 0.5 mm.

Plate 14
E: 12I/ 11-008-25 -The central portion of the micrograph contains a small vug that is lined by euhedral zoned dolomite (contains slight iron enrichment near the crystal margin). Note also the strongly serrated stylolite at the upper part of the micrograph. The white arrow points to shards of bitumen. Small black arrows point to angular intercrystalline pores. Plane-polarized light, scale bar = 1.0 mm.

Plates of

Thin Section Photomicrographs,

Daniel's Harbour Area

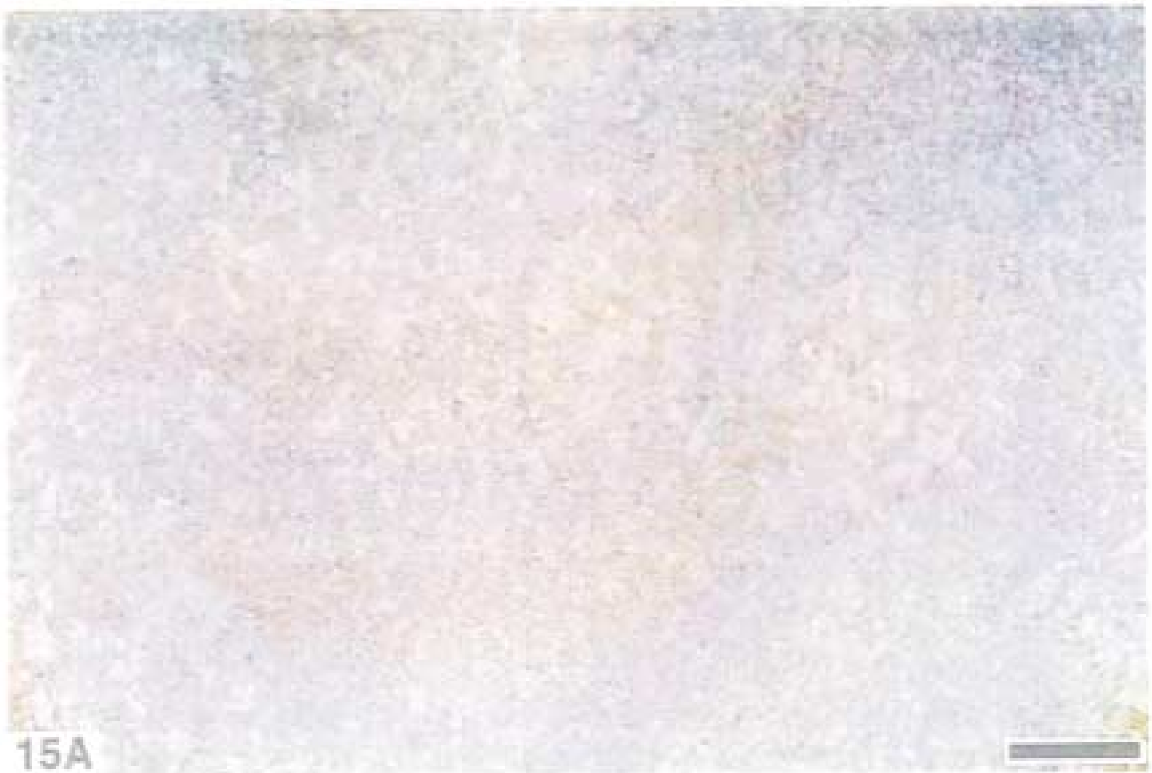

Plate 15: DRILL CORE 12I/06-76-1549, DANIEL'S HARBOUR
A: 1549-2 -Low magnification view of very fine-to medium-crystalline planar-s (subhedral) mosaic dolomite comprising a dolostone that is massive, non-stylolitic, and of low porosity. Plane-polarized light, scale bar = 1.0 mm.

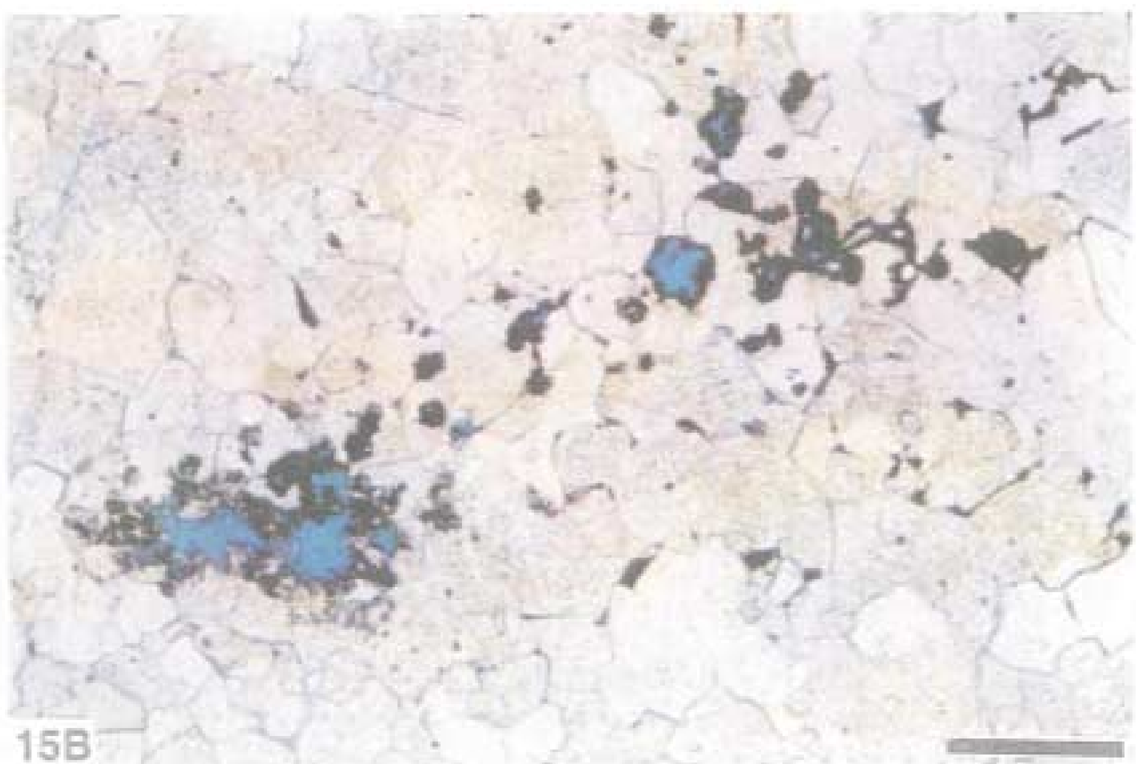

Plate 15
B: 1549-2 -Under higher magnification, and only locally within this specimen, minor amounts of dissolution porosity is observed. The dark material may be iron oxide (where thin, the material is reddish). Plane-polarized light, scale bar = 0.2 mm.

Plate 15
C: 1549-4- In addition to discrete euhedral and subhedral crystals of quartz (arrow), the sample also contains silica nodules up to 2 mm. The specimen contains good porosity (estimated at 8%), and possibly good permeability. Plane-polarized light, scale bar = 0.5 mm.

Plate 15
D & E: 1549-5 -The micrographs depict a low porosity zone that consists of coarse, non-planar a (anhedral) dolomite. With the presence of wavy extinction (micrograph E), it is very difficult in places to discern dolomite crystal boundaries. Textures such as this suggest dolomite crystallization at somewhat elevated temperatures. Plane-and crossed-polarized light (micrographs D and E, respectively), scale bar = 0.5 mm.

Plate 15
F: 1549-7 -Overview of the contact between tight and porous dolostone. Crystallinity in the tight zone is difficult to discern due the anhedral nature of the crystals and their wavy extinction under crossed-polarized light. Crystallinity significantly improves where dolomite is void-filling. The specimen is locally fractured and contains microbreccia; nevertheless, porosity is quite reasonable at about 7%. Plane-polarized light, scale bar = 1.0 mm.

Plate 15
G: 1549-7 -Dissolution porosity is noted within the relatively high amplitude stylolite. Plane-polarized light, scale bar = 0.5 mm.

<u>**Plate 15**</u>
H: 1549-8 - The white arrow points to a zone of microbreccia that may represent fracturing. Fracture porosity is clearly evident in the specimen (black arrows). Plane-polarized light, scale bar = 0.5 mm.

Plates of

Thin Section Photomicrographs,

Port au Port Peninsula

Plate 16: DRILL CORE 12B/10-0001, PORT AU PORT PENINSULA
A: 12B/10-0001-1 -This dolostone is relatively tight (estimated 1% porosity) and consists of subhedral dolomite that is strongly zoned (dusky , inclusion-rich cores and relatively clear rims). Minor porosity is evident (blue). Plane-polarized light, scale bar = 0.5 mm.

Plate 16
B: 12B/10-000l-3-In terms of crystallinity, this dolostone is bimodal as it contains a microcrystalline to fine-crystalline dolomite (white arrow), and common fine-to coarse-crystalline planar-e (euhedral) dolomite that contains dusky , inclusion-rich cores. Clear , open porosity is evident (black arrows), but most of the small vugs and intercrystalline pores contain a highly microporous clay aggregate (inspect porous areas closely). Total porosity is estimated at 22% , but effective porosity may be significantly lower. The specimen is hydrocarbon-bearing. Plane-polarized light, scale bar = 0.5 mm.

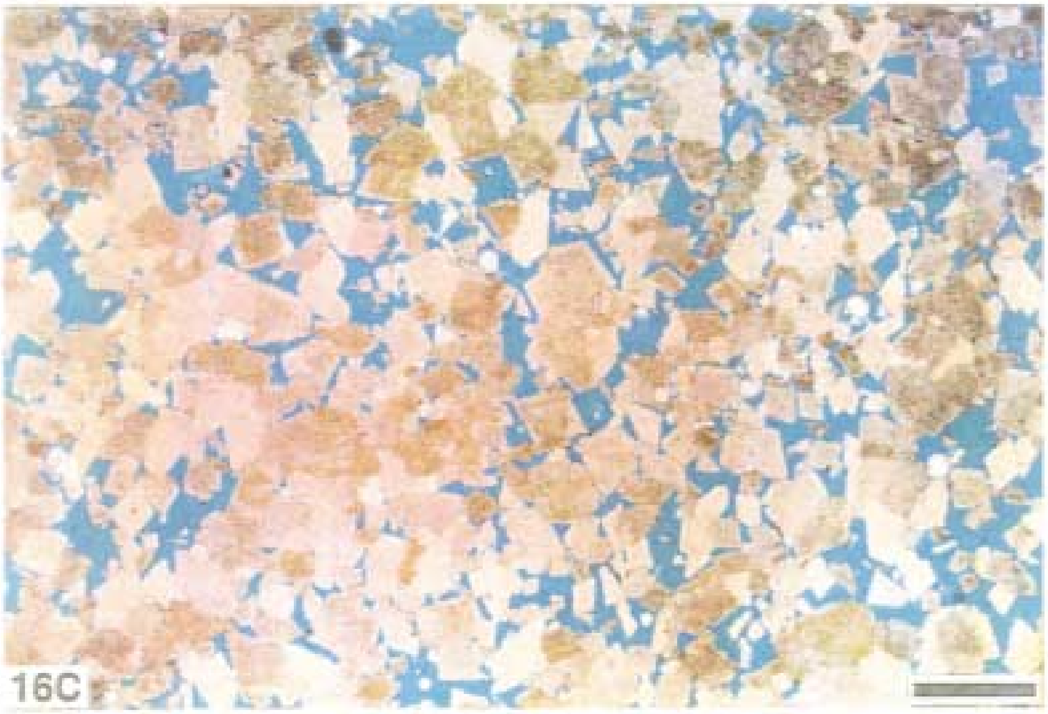

Plate 16
C: 12B/10-0001-5 -This dolostone constitutes a superb potential reservoir lithology. The primary lithology is inferred to have been a grainstone. All porosity is clear and open (i.e., effective), and is estimated to be about 22% by volume. In hand specimen, the sarnp1e is a light to medium brown due to uniform oil staining. There is no doubt that the rock is highly permeable. Plane-polarized light, scale bar = 1.0 mm.

Plate 16
D: 12B/10-0001-8 -Partial dissolution of dolomite (dedo1omitization) is apparent in this specimen (white arrows); the small black arrow points to a thin strip of dolomite that was not dissolved (thus, presumably, much porosity in the field of view is secondary in origin). Ferroan calcite {FeCc), which forms a minor cementing agent, also appears to be partly dissolved in places. Plane-polarized light, scale bar = 0.2 mm.

Plates of

Thin Section Photomicrographs,

Great Northern Peninsula/

Cape Norman Area

Plate 17: DRILL CORE 12P/1-018, GREAT NORTHERN PENINSULA
A: 12P/1-018-7-Brittle fracturing in saddle dolomite is depicted by the separation of dolomite chips (arrows) from the parent crystal. Plane-polarized light, scale bar = 0.5 mm.

Plate 17
B: 12P/1-018-7 -In this field of view, various crystal sizes in dolomite are delineated by stylolites. Possibly this fabric mimics primary burrowing(?). The specimen contains poor porosity (estimated 3%) with isolated vugs to 7 mm that parallel the stratification. Plane-polarized light, scale bar = 0.5 mm.

Plate 17
C: 12P/1-018-9 -This specimen contains common subhorizontal vugs that may be vertically and laterally connected by fractures. In fact the vug in the micrograph may have formed through the enlargement of a fracture. Locally, angular intercrystalline porosity is evident. Plane-polarized light, scale bar = 0.5 mm.

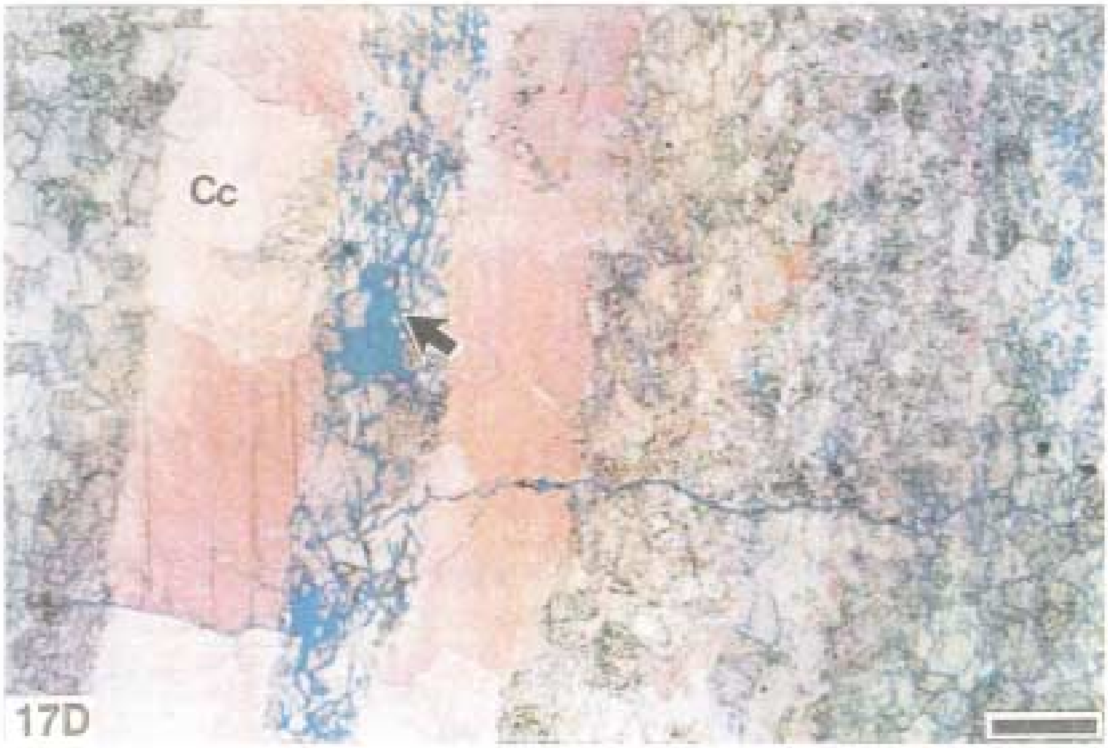

Plate 17
D: 12P/1-018-10 -A bifurcated vertical fracture within the specimen consists of very coarse-crystalline, low ferroan calcite (Cc). Interestingly, in the vicinity of the calite veinlet there is extensive dedolomitization and porosity development (arrow). To the right of the main veinlet there appears to be a vertical trending zone of replacive calcite. Plane-polarized light, scale bar = 0.5 mm.

Plate 17
E: 12P/1-018-10-The black arrows point to clots of microcrystalline clay (chlorite?) that partly fills some pore spaces. Another feature of note is the early stage of dedolomitization. Observe the light blue (porosity) along many cleavage traces of dolomite. Plane-polarized light, scale bar = 0.5 mm.

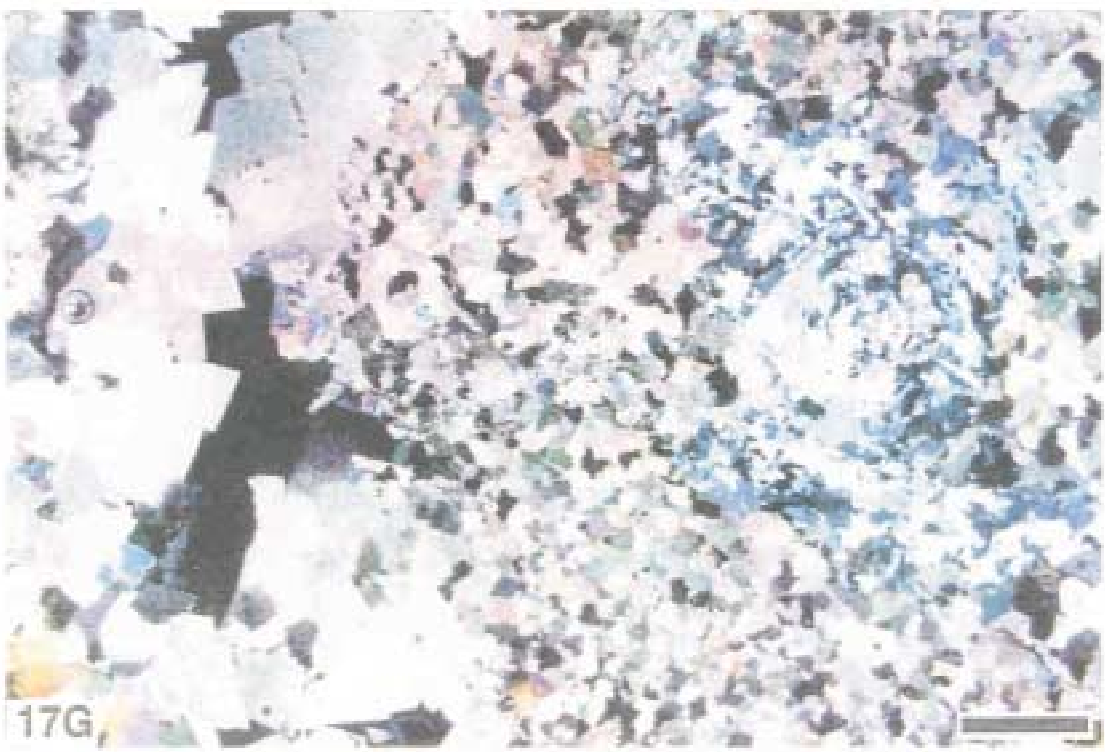

Plate 17

F & G: 12P/1-018-11 -Silica nodule development is evident in this specimen (arrow in micrograph F) .It is possible that the silica migrated in solution along the stylolite at the base of the nodule. The specimen contains stylolites of variable orientation. The stylolites Demark zones of distinctive dolomite crystallinity. Dolomite spar and saddle dolomite have encroached on a pore space at the left. Plane-and crossed-polarized light (F and G, respectively), scale bar = 1.0 mm.

Plate 17
H: 12P/l-018-12 -Late stage quartz (arrow) is observed to partly fill vugs and fractures. Quartz post-dates very coarse-crystalline dolomite spar and saddle dolomite. Plane-polarized light, scale bar = 0.5 mm.

Plate 18: DRILL CORE 2M/12-002, GREAT NORTHERN PENINSULA, C. NORMAN
A: 2M/12-OO2-1 -This is a view of dolomite breccia that may represent fractured and brecciated thrombolite mounds. Vugs are frequently linear and connected to other vugs by microbreccia zones. The arrow points to late quartz which is a void-filling mineral. Plane-polarized light, scale bar = 1.0 mm.

Plate 18
B: 2M/12-002-2 -Irregularly oriented vugs are largely fracture-induced and they separate breccia fragments. Locally, one may observe a breccia fragment that has been re-cemented (arrow, seen as later, clearer, coarser dolomite). Plane-polarized light, scale bar = 1.0 mm.

COMMENTS ON POROSITY, PERMEABILITY, HYDROCARBONS AND RESERVOIR QUALITY

Porosity and permeability are both essential petrophysical factors that respectively permit rocks to hold and transmit hydrocarbons. As part of the deliverables of this project porosity and permeability information is transmitted to the client by the following methods:

1. Field photographs, including photographs at the outcrop and at the core storage facilities in Newfoundland and Quebec, contain documentation regarding porosity.

2. Black bands along the right side of the lithology logs (Figures 3, 4, 5 and 6) show the stratigraphic location of porous Catoche dolostone, the general type of porosity, and often a qualitative estimate of porosity. This information was acquired while logging core or examining field sections.

3. It was proposed that contoured isopach maps of qualitative porosity in 2, above, be presented. The porosity thickness data were compiled and it was determined that due to the prevalence of partial sections, the paucity of data in some areas, and the high concentration of data in other areas that the porous rock isopachs would be of 1ittle value. In view of this, porosity thickness values are presented in Figures 9.7, 10.7 and 11.7 and on Table 2.

4. In order obtain some semi-quantitative porosity information in the field for the proposed net porosity / gross dolomite contour maps, porosity was assessed on slabbed cores from 13 wells (Figures 3.6, 3.7, 3.8, 3.10, 4.2 to 4.5, 5.3, 5.5, 5.6, 6.1 and 6.2). The porosity data were acquired by the point-counting of porosity utilizing a clear plastic transparency with a square grid scored upon it. Unfortunately, and as for item 3, above, only three cored and analysed Catoche dolomite sections at Port au Choix are complete; at Daniel's Harbour two complete dolostone sequences are available; at Port au Port, two dolostone sections may be considered to be complete, although one of these is a projected section and at the Northern Peninsula, neither section is complete. Thus only seven complete sections of dolomite are available for the computation of net porosity / gross dolomite and this is deemed an insufficient number for contouring. Quantitative histograms of raw point-counted porosity are presented as graphs plotted parallel to the stratigraphic lithology logs outlined above as Figures. A crossplot of porosity from point-counting versus Core Lab porosity is presented as Appendix B.

Nevertheless, values of net porosity / gross dolomite, expressed as percentages and at 5 % and 10% porosity cut-offs are presented as Figures 9.6, 10.6 and 11.6.

5. A total of 38 analyses of porosity and permeability were done by Core Laboratories of Calgary (Table 3 summarizes porosity and permeability of small diameter horizontal plugs, and porosity and maximum permeability of larger-diameter vertical cores; Appendix C provides the copies of the petrophysical information from Core Lab) .

A combined total of 22 outcrop samples at the Back Arm and Pointe Blanche sections were taken by sledge hammer. These fine specimens were then returned to Memorial University where horizontal plugs were cut parallel to the depositional stratification. The plugs were solvent-extracted and then analysed for porosity and permeability by Core Lab. The unextracted "but t-ends" were thin sectioned, thus allowing the observation of bitumen in epoxy-impregnated pore spaces.

Sixteen full diameter (about 2-3/4") core segments from RND-l and RND-2 wells (Port au Port Peninsula, see Figures 5.1 and 5.2) were analysed for porosity and permeability. The analyses are presented in Table 3 and Appendix C.

In addition, porosities and permeabilities are summarized graphically and numerically on the Back Arm, Pointe Blanche, RND-l and RND-2 lithology logs (respectively, Figures 3.2, 3.3, 5.1 and 5.2).

Table 2
Thickness and Porosity Data for Contour Maps

Area/Well	Catoche Formation	Catoche Dolomite						
	Thickness (m)	Thickness (m)	% of Total Catoche Fm.	Thickness of Porous Rock (m)	Thickness of Net Porosity... (m) >5%	>10%	% Net Porosity/Gross Dol. for Net Porosity... >5%	>10%
Port au Choix								
Pointe Blanche	161	34.1	27	10	nd		nd	
Back Arm	160	25.2	15.7	10	nd		nd	
WN-91-CH-3	160.1	33.2	20.7	11	nd		nd	
12I/11-001	149.1	22.2	14.9	0	nd		nd	
12I/11-002	168.3	41.4	24.6	7	nd		nd	
12I/11-004	141.6	14.7	10.4	1	nd		nd	
12I/11-008	168.7	41.9(c)	24.8	12	12.1	7.5	28.8	18.0
12I/11-009	167.1	40.2(c)	24.1	14	12.7	6.6	31.9	16.5
12I/11-010	169.5	42.6(c)	25.1	9	7.8	2.7	18.2	6.4
Daniel's Harbour								
12I/06-935	159.4	25.4(c)	15.9	3	nd		nd	
12I/06-1528*	134	8.9	*	0	nd		nd	
12I/06-1532	193.5	59.5	30.7	16	6.01	1.1	10.1	1.8
12I/06-1549	174.5	40.5(c)	23.2	15	10.9	3.8	26.8	9.3
12I/06-1550	162.0	28.0(c)	17.3	4	0.3	0.3	1.1	1.1
12I/06-001	142.3	8.3	5.8	0	nd		nd	
12I/06-002	162.5	28.5	17.5	2	nd		nd	
Composite[1]	175.0	42.0(c)	24.0	nd	nd		nd	

Table 2 (continued)
Thickness and Porosity Data for Contour Maps

Area/Well	Catoche Formation Thickness (m)	Catoche Dolomite Thickness (m)	% of Total Catoche Fm.	Thickness of Porous Rock (m)	Thickness of Net Porosity... (m) >5%	>10%	% Net Porosity/Gross Dol. for Net Porosity... >5%	>10%
Port au Port								
RND-1	157.5	53.5(c)	33.9	9	nd		nd	
RND-2	156.6	52.6(c)	33.6	18	nd		nd	
LC-90-11	162.8	58.8(c)	36.1	3	nd		nd	
12B/10-0001	161.24	57.2(c)	35.5	18	11.6	6.6	20.2	11.6
12B/10-0002	140.8	36.8	24.1	6	1.5	0.4	0.04	0.01
12B/10-036*		31.4						
12B/10-042	157.3	53.3	33.9	10	3.2	0.1	5.9	0.2
Isthmus Bay[2]	165.5	nd	nd	nd	nd		nd	
Smelt Canyon[3]	145	54	37.2	nd	nd		nd	
GNP/C.Norman								
12P/1-018	145.6	31.2	21.4	15	10.2	2.6	32.6	8.4
2M/12-002	91.5	31.0	33.9	4	2.6	0.1	8.4	0.2

nd not determined
* hybrid limestone/dolostone sections
1 Lane (1990)
2 Pratt (1979)
3 Haywick (1984)
(c) complete Catoche dolostone sections (or projections)

Table 3*

Petrophysically Analysed Porosity and Permeability on Horizontal Plugs from Back Arm (BA) and Pointe Blanche (PB)

Sample Number	Permeability K_{max} (air) (mD)	% Porosity (helium)
BA-1	0.04	3.3
BA-2	51.8	7.0
BA-3	0.05	1.0
BA-4	4.26	8.1
BA-5	0.02	3.3
BA-6	0.30	5.6
BA-7	1.30	11.5
BA-8	5.13	9.5
BA-9	317	14.4
BA-10A	17.7	11.7
BA-10B	0.15	6.8
BA-11	0.05	4.3
BA-12	3680.	17.8
BA-13	0.96	13.8
BA-14	24.7	10.5
PB-1	33.7	8.6
PB-2	1.74	7.2
PB-3	5.37	7.9
PB-4	224.	9.6
PB-5	134.	8.5
PB-6	0.19	7.6
PB-7	26.8	6.8

Table 3* (continued)

Petrophysically Analysed Porosity and Permeability on Vertical Cores from Round Head (RND), Port au Port Peninsula

Well and Sample Number	Sample Depth (m)	Permeability K_{max} (air) (mD)	% Porosity (helium)
RND-1-1	224.27	#	2.7
RND-1-2	230.48	26.3	4.6
RND-1-3	232.75	17.9	6.5
RND-1-4	235.01	11.7	4.9
RND-1-5	236.11	7.35	4.1
RND-1-6	244.40	9.62	4.6
RND-1-7	245.45	10.1	4.2
RND-2-1	230.26	305.	7.1
RND-2-2	230.84	342.	7.1
RND-2-3	231.51	0.10	0.6
RND-2-4	235.20	0.16	2.8
RND-2-5	242.95	147.	4.3
RND-2-6	259.78	2.46	4.5
RND-2-7	260.27	125.	3.3
RND-2-8	261.05	2.67	2.5
RND-2-9	267.63	158.	12.8

* see Appendix C for detailed petrophysical data
\# fractured

6. The plates of thin section photomicrographs contain blue areas under plane-polarized light (plates 12 through 18). This has resulted from the vacuum impregnation of blue-dyed epoxy into pore spaces before the thin sections were produced. It will be observed that porosity is widespread in the selected samples. Additionally, in specimens that were neither petrophysically analysed nor point-counted, qualitative estimates of porosity are presented (Appendix A).

7. Figure 17 is a map of western Newfoundland that shows present porosity zones in a schematic fashion.

Port au Choix

Porosity in the Catoche dolomite includes vug and intercrystalline, fracture, breccia, and stylolite-related types in approximate order of importance. The abundant porosity evident in Plates 12 through 14 include the aforementioned types of porosity and litho1ogically, all specimens represent the do1omitized stylolitic grainstones of interval C of the cyclic sequence.

The correspondence between dolomitized interval C rocks and peak porosity content is clearly depicted in Figures 3.6, 3.7 and 3.8. Petrophysically-determined porosities for the Back Arm section range from 1.0% - 17.8%; ignoring the anomalous 3680 mD (millidarcy) horizontal permeability value, more typical permeabilities range from 0.02 mD -317 rnD. Similarly, for the Pointe Blanche field section porosities range from 6.8% -9.6%, with a range in horizontal permeabilities from 0.19 mD -224 mD. This considerable range of porosity and permeability attests to the variability of vug and intercrystalline porosity concentration within the bounds of a small diameter plug. Additionally permeability and reservoir quality , especially in relation to vuggy porosity , are strongly influenced by the presence of fracturing and brecciation (e.g., Plates 12D, and at Pointe Blanche Plate 13A). A high density fracturing and/or brecciation in interval C of the cyclic sequence would increase the interconnectedness of vuggy porosity (see Plate 7E, the upper core piece in the second core slot to the right of the ruler in Plate 7E shows druse-lined tectonic fractures connecting large vugs). Two samples, BA-10A and BA-10B (Table 3) are from the same porous dolomite bed at Back Arm within 10 metres of one another. Note that BA-10A contains 11.7% porosity and 17.7 mD horizontal permeability and BA-10B has 6.8% porosity and only 0.15 mD permeability. This feature demonstrates the inhomogeneity of petrophysical parameters within a short lateral distance within a single porous horizon.

Porosity is diffused within meter-scale spherical zones within the beds of the interval C dolomites. These spherical zones frequently coalesce. Fracture porosity occurs associated with hairline fractures that cut the fine-crystalline dolostones at the base of cycles (Plate l0C). Fractures such as those observed in Plate 10C may supply additional conduits facilitating the migration of fluids through successions of porous, interval C dolostones. Some minor dedolomitization occurs at the margin of sparry dolomite and saddle dolomite that lines vuggy pores.

Within cored sequences, for example at 12I/11-008 well (Figure 3.6, Plate 14, Plate 7E) vugs attain dimensions of up to 2 cm. Locally within the porous zones of core, intermottles contain porosity (intercrystalline); this porosity increases in concentration up-section to such an extent that the intercrystalline pore system seems to coalesce to form what in effect are vugs.

The stratigraphic sections at Port au Choix containing the best overall porosity in the Catoche dolomite are wells 12I/11-008 and 121/11-009 (Figures 3.3 and 3.7).

Reservoir quality at Port au Choix is considered to be moderate. On the positive side, there is common cyclicity and therefore many porous interval C dolostones, and the lateral continuity of these porous beds is considerable. From the somewhat pessimistic view, porosity is predominantly vuggular and the prospect of extensive horizontal permeability would seem poor .

Black bituminous residues clog the porosity throughout the outcrop belt and it is also present in some of the cores. The most massive concentration of bitumen is within the Catoche dolomite at Back Arm (Plates 9A and 11A -Plate 11A is a close-up of bituminous sample in Plate 9A), and this corresponds to sample BA-9 which was thin sectioned and petrophysically analysed. Black shards and "blebs" of bitumen can also be observed in the thin section photomicrographs (Plates 12 through 14). Since these bituminous residues are ubiquitous in the region, it is fairly clear that many of the rocks have in the past been permeable to hydrocarbons.

Daniel' s Harbour Area

Porosity in the Catoche dolomite in the Daniel's Harbour area consists of vug and intercrystalline, fracture, breccia and stylolite-related types in their approximate order of importance. These types of porosity are identical to those at Port au Choix to the north, yet porosity is less common than at Port au Choix because much of it has been occluded by sparry dolomite. Porosity remains concentrated in dolostones of cycle interval C (Figures 4.3 and 4.4). In addition to more common sparry cements, low porosities are related to the poor development of the peloidal grainstones in the Daniel's Harbour area in general and also to the poor development of the dolomite locally southeast of Daniel's Harbour mine (Figures 9.4 and 9.5). Although erosion of the Catoche outcrop belt east of the mine does not permit conclusive evaluation, it appears that a second zone of good porosity associated with well developed grainstone caps may have occurred several kilometres east of the mine.

Point-counting of porosity in the field was performed on four wells in the Daniel's Harbour area: these are well numbers 1550, 1549, 1532, and 1528 (Figures 4.2 to 4.5). Only wells 1549 and 1532 contain considerable porosity in the Catoche dolomite. For example in the 1549 well, of the 40.52 m of Catoche dolomite (complete section), there is a net porosity greater than 5% of about 10.9 m, and a net porosity / gross dolomite of about 27%. Again, as at Port au Choix, the location of high porosity point-counts corresponds to the dolostones of cycle interval C.

In cores, intercrsyalline porosity and vuggy porosity are both observed; the increasing concentration of intercrystalline porosity up section within a given cycle ultimately causes a coalescence of pores to form vuggy porosity. Vugs are locally linear and subvertical, strongly suggesting the presence of fracturing and possibly the solution enlargement of fractures (note the fractures and brecciation in Plate 15H). Dissolution along stylolites is evident (Plate 15G).

Reservoir quality of the Daniel's Harbour area ranges from poor to moderate -the main purpose of its inclusion in this study is to provide additional stratigraphic control. Minor amounts of bitumen were noted in vuggy porosity within cores. Lane (1990) has suggested that thermal upwelling that caused the hydrothermal crystallization of dolomite also caused the thermal cracking and migration of hydrocarbons in the vicinity of Daniel's Harbour.

Port au Port Peninsula

Porosity present in the Catoche dolomites of the Port au Port Peninsula and nearby Table Mountain include intercrystalline, vuggular , breccia and fracture types. All four kinds of porosity occur in the mound dominated sections logged near Lower Cove (in the general vicinity of well LC-90-11, see Figure 9, Plate 3) and in the drill core 12B-11-042 (Figure 5.3) where porosity averages about 3% and is probably similar to the porosity observed in Plate 6D. Breccia porosity is associated with the centres of the mounds. Partial dissolution of the internal mound structure creates small pockets of collapse breccia, vuggy porosity and fracture porosity.

In the Aguathuna area, abundant intercrystalline porosity occurs over much of a 40 metre-thick interval of dolomitized grainstone (12B/10-0001, Figure 5.5). In terms of reservoir quality, this dolostone constitutes an excellent potential reservoir rock (Plate l6C) -certainly it contains the best reservoir quality of any dolostone examined in this study. In core, much of the section is a uniform light brown, and sucrosic in texture. The brown colour is the result of extensive oil impregnation and the samples yield oil cuts under UV light. Most of the porosity is uniformly distributed and of the intercrystalline type. Small vugs are in evidence. Locally there are tighter bands where silica nodules have formed. Permeability of the sucrosic dolostones is probably excellent and the more porous thin sections (Plate 6C,D) contain an estimated 22% porosity. It is thought that the precursor grainstones were likely highly sorted, permeable, and permitted evenly distributed nucleation sites for the crystallization of the euhdral dolomite. Locally, intercrystalline clay(?) is present, thus substantially reducing effective porosity (plate 16B).

This intercrystalline porosity appears to be facies-specific because said porosity is more restricted and poorly developed in the nearby stratigraphically equivalent mound dominated sections. The distribution of the good quality grainstone facies should be further investigated because just a short distance away at 12B/10-0002 well (Figure 5.6) porosity is poorer due to the presence of calcite cements. Pinpoint, or intercrystalline porosity occurs both in thrombolite mounds and grainstones in section 12B/Io-036 (Figure 5.7). The porosity is estimated to range from 5% to 25% , it is both patchy to pervasive, and contains black bitumen residues. Fractures that cut a few beds also contain bitumen.

Fracturing results in the predominant fracture porosity in the dolomitized mounds at Round Head and in the general vicinity of Round Head (see Figures 5.1 to 5.3 and Figure 9.1 -"RND" is the abbreviation for Round Head). Petrophysical analyses of porosity and permeability for full diameter core segments from RND-l and RND-2 wells are given in Table 3, Appendix C, and in Figures 5.1 and 5.2. Analysed core samples from RND-l contain a range of porosity from 2.7% -6.5% and permeability ranging from 7.35 mD -26.3 mD (k max). This porosity is associated with dilated fracture cleavage probably related to the emplacement of the Port au Port thrust sheet and backthrusting near Round Head (Waldron and Stockrnal, 1991).

Great Northern Peninsula / Cape Norman Area

During the field season the area at Cape Norman/Cape Norman Barrens was visited. The area consists of widespread outcrops of Catoche dolomite that are composed of thrombolite mounds (Figure 1). The porosity of the area is generally low, however there is some improvement in porosity in well 12P/I-018 (Figure 6.2). The histogram of porosity in Figure 6.2 shows the inhomogeneity in porosity distribution and apparent lack of facies cyclicit -no doubt the result of thrombolite mounds. Porosity , however, ranges up to 24% in vuggy areas and it is estimated that there is an average of about 3% porosity over the entire point-counted section. In the vicinity of well 12P/I-018 it is possible that poor to moderate reservoir quality exists, however considering the possible elevated temperatures the area has undergone, the lithologies of the mound complexes and inter-mound grainstones must be considered non-prospective. Core from well 2M/12-002 (Figure 6.1) contains very poor porosity, and seems akin to the lithologies evident at Cape Norman.

The fracture porosity which occurs along irregular, spar-lined fractures is not related to tectonism but is an effect of early unconformity events. Dedolomitization locally occurs in halos that surround fracture-filling calcite (Plate 17E).

POROSITY PREDICTION AND EXPLORATION

The present study is possibly the first to have examined a section of the Lower Ordovician platform carbonates of western Newfoundland with emphasis on carbonate sedimentology, petrography, and porosity and permeability development.

As a means to briefly discuss some relevant characteristics of the rocks as they pertain to petroleum exploration in the Catoche Formation, the following list of observations and recommendations is presented (see also Paleogeography Maps, Figure 16.1 to 16.3, and the Map of Present Porosity Zones, Figure 17):

1. Porosity in the dolostones of the Catoche is best preserved in the vicinity of Port au Choix (e.g., 12I/11-008, Figure 3.6), Daniel's Harbour (12I/06-76-1549, Figure 4.3), and Port au Port (12B/10-000I, Figure 5.5).

2. Carbonate facies analysis in the Port au Choix / Daniel's Harbour area indicates distictive shallowing upward cyclicity. Porosity, in the form of common vugs, and intercrystalline pores occurs

predominantly within a dolomitized grainstone unit in the upper part of each cycle (cycle unit C).

3. Petrophysical analysis of dolostones from the Back Arm and Pointe Riche field sections at Port au Choix indicate significant amounts of porosity and permeability. Vuggy porosity may be connected by means of fracturing, and stylolite-related brecciation.

4. In the vicinity of Port au Choix, the viability of a seismic program to evaluate the presence of fault-bounded structural highs should be evaluated. As it is known that hydrocarbon has migrated through the dolostone section, it is logical to presume that liquid hydrocarbons might be in the area if suitable trapping mechanisms are at play. In this instance, a structural/stratigraphic exploration play is envisaged.

5. Excellent porosity and permeability is evident in dolomitized grainstones on the Port au Port Peninsula (12B/10-0001, Figure 5.5). The rocks are sucrosic, with a well distributed intercrystalline pore system. The grainstones may be located in inter-mound channels. It is recommended that further studies be undertaken to examine the abundant core and refine the sedimentology and petrology of these rocks.

6. Lastly, at Port au Port, tectonic fracturing in the mound complexes around Round Head (RND-l, RND-2 wells) may have created sufficient porosity and permeability to enable reasonable reservoir properties to occur. Petrophysical analysis suggests fair permeability and moderate to low porosity in the dolostones of the mound complexes. Additionally, the structuring at Round Head on the Port au Port Peninsula might hold potential as a trapping mechanism.

THE ROMAINES FORMATION

INTRODUCTION

The Romaines Formation which outcrops along the north shore of the Gulf of St. Lawrence at Mingan Island and occurs in the subsurface beneath Anticosti Island (Figures 12.1 to 12.5) is equivalent of the upper part of the St. George Group. The formation is known to span the Arenigian containing conodonts and skeletal faunas similiar to those of the upper megacycle in Newfoundland represented by the Barbace Cove Member, Boat Harbour Formation, the Catoche Formation and the Aguathuna Formation. The Romaines Formation was named by Twenhofel (1926) but received little further study until a number of deep exploration wells were drilled on Anticosti Island between 1962 and 1974 and the cores which span the Lower Ordovician to Silurian section were logged and subdivided (Roliff, 1968). The most exhaustive work is that of Desrochers (1985; 1988) who studied the formation along with the Mingan Formation at Mingan Islands. It is his stratigraphic subdivisions that form the framework for the discussion below. The wells are stored at the Quebec Department of Naturelles Resources warehouse in Quebec City. Although 8 wells have been drilled only a few cores are still available. In addition, only the briefest outline of their stratigraphy is given in a Soquip report (1987) and in Ministere des Richesses Naturelles du Quebec well data file. In this study, the Romaines Formation was logged from the Lowlands Gamache Carleton Point (Figure 7.3) and the Lowlands Gamache Princeton No.1 (Figure 7.1) wells although the lower part of the latter is very broken and yields 1ittle detailed infomation for a hundred feet or more. Only the upper part of the Romaines Formation is present in the New Associated Consolidated Paper Anticosti No.1 well (Figure 7.2). There is some short footage from the Arco Anticosti No.1 and Lowlands Gamache Highcliffe No.1. Throughout the following discussion, the reader is referred to Figures 7 and 12.

STRATIGRAPHY

Desrochers (1985; 1988) subdivided the Romaine into three members. Overlying unconformably Precambrian granitic basement, the basal Sauvage Member is a crossbedded, arkosic sandstone, 2-3 m thick. It is overlain by a burrowed, fossiliferous and thrombolitic, sucrosic dolostone, 50 m thick, called the Ste. Genevieve Member. The formation is completed by the Grande-lle Member, a succession of mottled and laminated microcrystalline dolostones, that is only 22 m thick at Mingan Islands. The latter member is truncated by the Romaines Unconformity following gentle tilting of the formation (Desrochers and James, 1988). The overlying Mingan Formation is a Chazyan succession of grey bioturbated and fossiliferous Limestone.

The Romaines stratigraphy in the wells appears at first glance to follow this three fold division as in the Carleton Point well (Plates 19, 20,21 and 22, Figure 7.3). However, in the Princeton Lake well (Figure 7.1), a very thick upper dolostone sequence comprises dolostones of the Grand-Ile Member overlain by a succession of lithologically different dolostone and some limestone (Plate 23). This unit is also present above an incomplete section of the Grand-Ile Member in the New Consolidated Paper well (Figure 7.2) and will be referred to as the upper unnamed dolostone. It is however not placed within the Romaines Formation.

The Grand-Ile Member in the Carleton Point well is overlain unconformably by a unit of peloidal and fenestral white to light grey limestone (Plate 24) that bears a striking resemblance to the Springs Inlet Member of the Middle Ordovician Table Point Formation in Newfoundland. Although there are some short missing intervals at this point in the core, the last dolostone beds of the Grand-Ile Member are extensively brecciated and the limestones are completely pristine suggesting a major break between these two units. Comparison with the sections in the Princeton Lake and New Consolidated Paper wells (Figures 7.1 and 7.2) indicates that this disconformity coincides with the contact of the Grand-lle member and the upper unnnamed dolostone sequence. Again the Grand-Ile dolostones at this interval are brecciated though not as extensively as in the Carleton Point well.

Additional observations can be made. Firstly, the peloidal and fenestral white limestone of the Carleton Point well is not present in the other two wells and the Carleton Point well does not contain the upper dolostone unit (T .H. Clark, Ministere des Richesses Naturelles du Quebec, 19). The upper dolostone is overlain apparently conformably but sharply by a succession of dark grey, unevenly thinly stratified, bioturbated and fossiliferous limestone (Plate 25) and locally siltstone which probably belongs to the Mingan, Blackriver and lor Trenton formations. No biostratigraphic information is available to date these various limestones. However, the dark grey limestones are common in the Mingan, Blackriver and Trenton formations (Desrochers, 1985, 1988; Harland and Pickerill, 1982; Knight, unpublished data). White peloidal limestone occurs in the Mingan Formation (N.P. James, pers comm. 1992).

LITHOSTRATIGRAPHY OF THE ROMAINES FORMATION, ANTICOSTI ISLAND

Sauvage Member

The succeeding description is based on the section in the Carleton Point well and a short section in the Highcliffe No.1 well. The section in the Princeton Lake well is too broken to be successfully interpreted other than in the most general terms. The member comprises dolostones, sandstones, shales and chert. The member has a two part architecture. A lower interval of approximately 12-18 m (40 to 60') includes sandstones interbedded with dolostones. Local disconformitites are present towards the top of this interval. The upper part consists of meter-scale cycles of thin inntraclastic and glauconitic dolarenite overlain by burrowed and laminated dolostones.

The dolostones are generally finely crystalline, buff to grey and non porous (Plate 20A to 20C). They display burrow mottled, soupy, laminated and grainy fabrics. The burrowed dolostones are characterized by large to small burrows including Planolites, and Chrondrites . The soupy dolostones show a turbated bedding fabric that suggests they were soft, water saturated carbonate muds that were deformed. Dololaminites are well developed and exhibit planar to uneven lamination and thin stratification, disrupted bedding and brecciation, desiccation cracks and tepee structures. Intraformational dolorudstone is interbedded in some of the dololaminites. The dolarenites are oolitic grainstones which are glauconitic and sandy in some beds. They commonly display crossbedding. Locally the oolitic dolarenite is intercalated in thinly stratified dolostone.

Very fine to medium grained sandstones that are locally green spotted suggesting glauconite are interspersed throughout the member but dominate in the lower half of the member. The sandstones are mostly feldspathic and micaceous and locally contain granules and small pebbles of quartz and feldspar. They are crossbedded, cross laminated, laminated, thinly stratified and bioturbated. Shale drapes, flaser and thin beds occur in the bioturbated sandstones which are generally thinly stratified. The sandstones occur intercalated with oolitic dolarenite at the base of some cycles, and overlying burrowed dolostones at the top of other cycles in the lower half of the member. In the Highcliffe well they form the base of the member unconformably overlying Precambrian basement. A pebbly very coarse to medium grained sandstone forms the basal bed. The broken core of the Princeton Lake well suggests there is a basal siltsone unit overlain by shaly dolostone in this lower part of the member. This in turn is overlain by a glauconitic interval.

Metre-scale shallowing-upward cycles typify the uppper part of the member. They consist of burrowed dolostone and dololaminite, and dolarenite plus or minus glauconitic sandstone overlain by dololaminite or burrowed dolostone and dololaminite. Scours mark the base of the grainstones.

Towards the top of lower part of the member, there is evidence of subaerial exposure and karsting at the top of cycles. Irregular cavities and sheet cracks occluded by geopetal dolostone and dolomite spar occur below sharp truncation surfaces separating dolostone beds. Pyrite fringes the walls of the sheet cracks overlain by the internal cave sediment and cement.

Ste. Genevieve Member

The Ste. Genevieve Member comprises bioturbated, fossiliferous and thrombolitic grey limestones, dolostones and minor dark grey shale (Plates 21A to 21D). The succession is dolomitized at the base for 4.5 to 6 m. The upper 36 to 46 m (120 to 155') of the member is dolomitized in the Carleton Point and Princeton Lake wells. The limestones span a wide range of grainsizes. The main lithology is bioturbated, skeletal and peloidal wackestone which dominates intervals for several metres; thin packstones and grainstones are interbedded. Grainstones, packstones and rudstones, however also dominate intervals up to a metre or more in thickness. They are intraclastic, skeletal, and crossbedded. Intraclasts are mostly lime mudstone. Skeletal remains include trilobites and gastropods. Desrochers (1985) also reports sponges, graptolites, brachiopods and pelmatozoans. However, one bed of quartz arenite occurs in the lower part of the member in the Carleton Point well associated with grainy dolostone beds that are also oolitic, glauconitic and sandy.

Nodular dolomitic parted lime mudstones and burrowed mudstones are also interspersed through the lower part of the section but become more common upwards. They are bituminous when broken. Stylo-nodular skeletal wackestone and mudstones dominate the upper part of the member where the limestones are shalier. A few beds of silty pyritiferous shale up to 40 to 60 cm thick also occur. This lithofacies is also found in a short interval of core preserved from the Arco No 1 well (interval 10962 to 11021). The limestone however is shalier and consists of stylo-nodular and smooth planar thin-bedded lime mudstones and shale. Ostracods and articulated brachiopods occur in these fine carbonates. Lens and laminae of skeletal packstone also contain trilobites, crinoids as well as the ostracods and brachiopods. In its lithological character however, it is very similiar to Middle to late Ordovician limestones of the Table Point, Mingan, Blackriver and Trenton Formations. No fossils are available to distinguish the age.

Thrombolitic boundstones associated with intraclastic and skeletal grainstones and rudstones mark the upper 15 m of the member in the Princeton Lake well. They do not occur in the Carleton Point well. The mound intervals attain 0.20 to 1.9 m thickness and comprise clotted, lumpy and digitate fabrics. Burrows occur in inter-thromboid sediment. The grainstones consist of mound detritus and shell fragments.

Grand-Ile Member

The Grand-Ile Member consists of repetitive metre-scale sequences of mottled, soupyand laminated microcrystaline dolostones, argillaceous dolostones and dolomitic shales (Plates 22A to 22C). Dolostones vary in colour from dark grey, to pink, buff, cream, off-white and green. In the lower part of the member, the sequences comprise dark grey burrow-mottled dolostones overlain by pink and green burrow-mottled dolostones. Burrows fabrics in the latter appear deformed as though the burrows occurred in soft viscous sediments. Dololaminites are at first subordinate but occur in abrupt contact with the mottled dolostones. The dark burrowed dolostones decline upwards and the soupy burrowed dolostones are associated with thinly stratified, soupy and patterned pink, green, cream and buff dolo stones and dololaminites. The latter dominate thick sections of the member. Mudcracks, tepees, white cauliflower chert and fenestrae occur in the dololaminites. Collapse breccias cutting both mottled and laminite beds occur through the member in the Carleton Lake Well. Cross-laminated dolostone fills cavities within the collapse zones.

Cycles in the member include both burrow-mottled dolostone overlain by do1olaminite and vice-versa. In both cases the tops of the cycles may be brecciated and abruptly overlain by the next cycle. In some cases the cycles reach 2 to 3 m in thickness. However, the burrow-laminite cycles decrease to less than 100 cm in thickness near the top of the member. It is noted however that there is no apparent correlation in thickness variations from well to well. Several cycles are brecciated at the top of the member in the Carleton Point and New Consolidated Paper wells. In the Princeton Lake well, dololaminites in the last two cycles are both brecciated.

The Upper Unnamed Dolostone

This stratigraphic unit which sits abruptly upon the brecciated dolostones of the Grand-lle Member is marked by a cyclic sequence of mottled, thinly stratified and laminated microcrystalline to very fine dolostone, shale and minor limestone (Plate 23A to 23E). The cycles unlike those of the Grand-lle Member are consistently shallowing upward. However, comparison of the overall sequence in the Princeton lake and New Consolidated Paper wells suggest that although the main lithological character of the sections is the same there are some differences. For instance, cyclicity is largely absent in the lower 45 m of the New Consolidated well. Dolomitizied bioturbated wackestones are continous in this well whereas the same lithologies are intercalated with dololaminites in the Princeton well. Larninites dominate the middle of the New Consolidated Paper well but not the Princeton well where burrowed-laminite cycles continue.

The limestone of skeletal dolomitic wackestone and mudstone are dark grey with ostracods brachiopods, gastropods and trilobites. Some wackestone beds have comminuted ostracod debris. The limestones occur in the lower 10 m of the unit. Above this the limestones are all dolomitized. The burrowed beds are overlain in the cycles by cream coloured burrow-mottled soupy dolostones and in some instances capped by dololaminites. Very fine to fine grained, massive, crossbedded, laminated dolostone up to 3 to 6 m thick occur lower bioturbated interval in the member. They are characterized by intercrystalline porosity .

At 60 m the cycles consist of thinly stratified dolostone and shaly dolostone, minor patterned dolostone and capped by dololaminite. Thin skeletal and intraclastic grainstones mark the base of some cycles. Soft sediment deformation is common in the stratified dolostones. Cycles vary in thickness from 2 to 5 m. Dololaminites dominate cycles in the upper 60 m of the unit in the Princeton Lake well and are commonly intercalated with green-grey and dark grey shales up to 10 cm thick In the New Consolidated Paper well, the top of the larninites are extensively brecciated.

THICKNESS OF THE ROMAINS FORMATION AND THE UPPER UNNAMED DOLOSTONE

At Mingan Island, the Romaines attains no more than 75 metres in thickness (Desrochers, 1985, 1988); an unknown thickness of Grand-lle dolostone has been eroded. This relatively thin section is not just the product of post-Romaines erosion because all the Romaines members are significantly thinner than their counterparts beneath Anticosti Island. The formation attains a thickness of 206 m (685') in the Carleton Point well. This thickness comprises 29 m (97') for the Sauvage Member, 116 m (388') for the Ste. Genevieve Member and 60 m (200') for the Grand-lle Member. The formation barely thickens to 212 m (708') in the New Consolidated Paper well, consisting of 33 m (112') of Sauvage Member, 120 m (400') of Ste Genevieve Member and 54 m (180') of Grand-lle Member. Only the top few meters of the Grand-lle Member occurs at the base of the New Consolidated Paper well.

The upper unnamed dolostone attains 156 m and 159 m (520' and 529') in the Princeton Lake and New Consolidated Paper wells respectively suggesting an uniformly thick unit from well to well. This suggests that some conclusions are pertinent to further discussion of the Romaines Formation. The presence of this unit explains why the Romaines appears to thicken considerably between the wells in the northeast of Anticosti Island and those at the western end of the island and along the south coast ie. the Arco No.1 well (see Roliff, 1968; well logs, Ministere Richesses Naturelles du Quebec SOQUIP , 1981). Based on the measured sections in this study, variations in the thickness of Romaines' members is virtual negligal between the two wells. The thickness of the Grand-lle Member also remains essentially constant. Based on this restricted data base the thickness of the Romaines Formation in the other wells is reduced by 159 m (520') as illustrated on the isopach map of the Anticosti area (Figure 12.3).

In the interpretation of the Anticosti wells shown in Enclosure 4.2.2, Soquip report (1987), the Romaines is based upon gamma and sonic logs coupled where possible to lithology. The Romaines was interpreted to consist of five units, Rl to R5 , a lower dolostone-argillaceous unit, Rl, a limestone unit, R2, two dolostone un its, R3 and 4, and an upper limestone unit, R5. These five units were traced through the four wells at the western end of the island but were not easily defined in the Arco No l, Carleton Point and Scurry Rainbow Sandtop wells.

Based on the examination of the three wells in this study, the following interpretation of the five units in the western wells is presented. Unit Rl basically coincides with the dolostone-sandstone of the Sauvage Member. Some of the dolostones at the top of the unit will be dolomitized carbonates at the base of the Ste. Genevieve Member. The limestones of the Ste. Genevieve Member coincides with R2. R3 however probably consists of dolostones replacing the upper part of the Ste. Genevieve Member as well as dolostones of the Grand-lle and lower part of the upper unnamed dolostone. R4 is most likely the upper part of the upper unnamed dolostone since this part of the sequence is argillaceous as interpreted in the Soquip Report. R 5 is probably limestones of the Mingan/Blackriver Formations.

Interpretation of the Arco No 1 well is however less certain. A very thick (750') basal dolostone unit may combine a lower unnamed dolo stone unit with the Sauvage Member and dolomitized Ste. Genevieve Member. Alternatively, it may represent a very thick Sauvage Member. If the former is correct however, the lower unnamed dolostone section may be of late Cambrian to Tremadocian in age and be disconformably overlain by the Sauvage Member. The disconformity may occur at approximately 435' above the basal unconformity where argillaceous-arenaceous rocks are present in the dolostones. The remaining part of the dolostone is therefore interpreted to consist of at least 200' of Sauvage Member and possibly as much as 75' of dolomitized Ste. Genevieve Member. Overlying is approximately 300' of Ste. Genevieve limestone. Allowing for at least 520' of upper unnamed dolostone in the overlying dolostone unit, the Grand-lle Member will be 200' suggesting that only some 20' of the top of the Ste. Genevieve Member is likely to be dolomitized.

Based on the examination of the core from the Carleton Point well, and the electric logs of the Scurry Rainbow Sandtop well, the following geology is suggested. The Romaines in the Carleton Point well is unconformably overlain by limestones of Middle Ordovician age. No Romaines is likely in the Scurry Rainbow Sandtop well. A succession of basal sandstones, interbedded limestone and dolostone overlain by limestones compares closely to the Middle to Late Ordovician carbonate sequences of the foreland basin in Quebec (Desrochers, 1985; Harland and Pickerill, 1982). This suggests that a Precambrian basement high controlled the configuration of the Anticosti Basin. The high occurs beneath the east end of the island. It was a topographic arch or island during the deposition of the Romaines Formation and was only onlapped by carbonates during Middle to Late Ordovician deposition in the foreland basin. In addition it suggests a basin that trended northwestward.

DOLOMITES, POROSITY AND HYDROCARBONS IN THE ROMAINES FORMATION AND UPPER UNNAMED DOLOSTONE

Dolostones of the Romaine Formation and the upper unnamed dolostone are ubiquitously very fine to fine grained and for the most part non-porous. The peritidal dolostones in the Sauvage and Grand-ne members and the upper unnamed unit are characterized by well preserved sedimentary structures and compare well to those of other peritidal sequences in the Appalachians. They probably are essentially early shallow burial dolomites. The dolomites replacing the base and upper parts of the subtidal Ste. Genevieve Member are also fine grained and preserve sedimentary and grain fabrics well. This dolomitization however appears to inconsistently developed from section to section. It replaces 52% of the member in the Carleton Point well, largely the upper 155 m, but only 34% of the member in the Princeton Lake well (compare this to the proposed interpretation of the Arco No 1 well which has a lower percentage of dolomite, 24%). They are probably early burial dolomites related to the same conditions that prevailed during the dolomitization of the bounding peritidal members. Truncation of the Romaines dolomite by the Romaine Unconformity at Mingan Islands confirms that they formed early (Desrochers, 1985).

Porosity is very poor in the Romaines Formation in the the wells studied. Dolomite replacing the upper part of the Ste. Genevieve Member in the Car1eton Point well has some thin zones of intercrystalline pin point porousity at 2837' , 2822' and 2667' .The zones range from 25 to 50 cm in thickness and the porosity is estimated to vary between 2 and 15% .The dolostones at 2822 zone are slightly bitumienous.

Porosity in the upper unnamed dolo stone occurs in the first 15 and 50 m respectively of the Princeton Lake and New Consolidated Paper wells. The dolomites are fine grained, sucrosic and replace dark grey burrowed skeletal wackestones and mudstones and laminated and cross bedded grain1y lithologies. Some of the dolomite is massive. The dolomites may have replaced a grainstone interval representative of a shoreline barrier. Note that the upper unit in the New Consolidated Paper well occurs between the bioturbated interval and an interval dominated by dololaminite. Porosity is always fine pin point type; cores were previously sampled in some of the intervals in the New Consolidated Paper well. The dolomites in some instances have a khaki-brown colour suggestive of liquid hydrocarbon and a number of previously sampled intervals in the New Consolidated Paper well are marked as zones of oil bleeding.

The zones in the wells vary from 10 cm to 3.0 m in thickness. Two zones 0.25 m and 2.65 m respectively occur at 5005' and 4995' in the Princeton Lake well. Porosity is estimated to be up to 15% locally. The zones in the New Consolidated Paper well occur at 5685', 5672', 5631', 5601', 5586' and 5583'. In most cases the zones are 10-50 cm thick. The thickest zones occur at 5672 and 5583 where the porosity extends over 0.9 and 3.15 m respectively. This indicates no more than 6 m of porosity within this 50 m section.

The absence of fracture porosity is believed to reflect the largely untectonized nature of the Ordovician succession at Anticosti Island. A few narrow fault zones cut the cores.

CORRELATION OF THE ROMAINES FORMATION WITH THE ST. GEORGE GROUP

It is appropriate to emphasize that the Romaines Formation correlates with the upper megacycle of the St. George Group (see Knight and James, 1987, 1988). Only the Ste. Genevieve Member correlates with the Catoche Formation with which it is lithologically very similar. No peloidal grainstone occurs however at the transition from subtidal open shelf sediments of the Ste. Genevieve Member into the peritidal dolostones of the Grand-lle Member as they do in the case of the Catoche to Aguathuna Formations in Newfoundland ie. the equivalent of the Costa Bay Member is not present at Anticosti Island. The Grand-lle Member compares well with the stratigraphically and lithologically similar Aguathuna Formation of Newfoundland. The Sauvage Member is probably correlative of the Barbace Cove Member of the Boat Harbour Formation in Newfoundland. Lithologically however, it is characterized by do1omitized peritidal cycles and by the presence of both oolitic grainstones and sandstones reflecting the presence of a shoreline adjacent to a Precambrian craton.

<u>Correlation of the upper unnamed dolostone</u>

The upper unnamed dolostone is most probably Middle Ordovician or younger in age. This is suggested by the abundance of ostracods and trilobites and the character of the limestones at the base of the formation. Since the limestones that overlie the dolostone are likely to be Mingan-Blackriver equivalents, it is not unreasonable to speculate that the upper unnamed dolostone is time equivalent of the Table Head Group. A unit of this age is locally present between the Romaines and the Mingan according to Desrochers (pers. comm. 1992).

THE ANTICOSI BASIN: COMPARISON OF THE ROMAINES FORMATION AND UPPER ST. GEORGE GROUP

The comparison of the late Early Ordovician platform sequences of Anticosti Basin shows that there is a very similiar lithostratigraphy between the section in western Newfoundland and that of Anticosti and Mingan Islands in eastern Quebec. Each sequence shows the three fold division into a lower cyclic peritidal sequence, a middle subtidal sequence and an upper peritidal sequence. These are the product of a common megacycle of transgression and regression that occurred throughout the Arenigian. Both areas responded to early Arenigian transgression as worldwide sea level flooded a karsted Tremadocian carbonate platform in Newfoundland and onlapped for the most part Precambrian cratonic rocks in eastern Quebec.

Close scrutiny of the different parts of this megacycle however, suggests that there are differences between the two sequences. Firstly, coarse siliciclastics are an important part of the lower peritidal sequence in Quebec (Sauvage Member). This reflects the proximity to the cratonic hinterland. The cross bedded sands, oolitic grainstones and fine grained burow-mottled to laminated dolostones were deposits of offshore sand and oolite shoals as well as shallow lagoons and tidal flats. In Newfoundland, the terrigenous sands are absent in favor of a mixed tidal carbonate sand and mud flat (Barbace Cove Member) reflecting the mid-shelf setting of these rocks (James et al., 1989).

The middle subtidal sequence although fairly similar in both areas (Ste. Genevieve Member and Catoche Formation) is markedly different once the platform matured. In both areas, drowning of the shelf allowed the deposition of widespread muddy and peloidal sediments that hosted an extensive burrowing and skeletal fauna. In Quebec however, thrombolite mound proliferated over the inner part of the shelf near Mingan Islands (Desrochers, 1985) whilst muddy sediments continued to dominate more outboard areas of the Quebec shelf. Shaly thin bedded carbonates suggestive of deeper water settings occur in the most outboard sections found in the Princeton Lake and Arco No 1 wells. Only as the shelf shallowed near the end of this middle stage did mounds prograde into the western part of Anticosti Island. This appears to be in marked contrast to the differentiation of outer barrier mound and peloidal sand complexes protecting a mud-dominated inner shallow shelf in Newfoundland (Catoche Formation). A significant difference is the lack of peloidal grainstones and cyclic peloidal sediments in the Quebec succession at the top of this middle stage.

The upper peritidal stages of the megacycle appears to be quite similar in both areas since both are dominated by fine grained dolostones arranged in small scale cycles. There appears to be both shallowing and coarsening upward cycles in both areas and the presence of evaporitic chert, desiccation and tepee structures in both sequences supports a restricted, hypersaline setting for these shallow lagoon to mud flat sediments (Grand-lle Member and Aguathuna Formation).

The top of both sequences is capped by a disconformity. In the Anticosti area, this lead to extensive brecciation of the top of the Romaines. At Mingan Islands, the Romaines was tilted, extensively eroded and karsted (Desrochers, and James, 1987). In Newfoundland, there is evidence of faulting prior to and during the development of the St. George Unconformity. This lead to the development of an extensive surface and subsurface karst system that effected the upper St. George up to 120 m below the unconformity.

The similarity of these two sequences reflects the response to common long term events of transgression and regression along a common continental margin. The regression culminating in common disconformity reflects the effects of Taconian orogenesis ie. peripheral forebulge uplift. The significant differences are believed to reflect the geographic location of the Romaines at the eastern edge of the Quebec Reentrant whereas the St. George Group accumulated at the apex of the St. Lawrence Promontory.

Located within the Reentrant, the Romaines was positioned more inboard causing the later onlap of the Quebec craton compared to oceanward projecting Newfoundland. The succession preserved in Newfoundland was according to James et al. (1989) just inboard of the hinge zone of the platform and hence has a relatively thin platform sequence. Subsidence of the Anticosti Basin in eastern Quebec was however significant and was matched by sedimentation rates. An important structural arch during the late Early Ordovician is postulated to underlie the east end of Anticosti Island suggesting that much of this subsidence was focused along a northwest-trending fault between the Carleton Point and the Scurry Rainbow Sandtop No.1 wells. Basically undisturbed Romaines strata in the Carleton Point well suggests that the fault was not significantly reactivated during the Taconian uplift. The Inild effects of the Taconian forebulge in the eastern Quebec area is probably the combination of its inboard position that muted the crustal response to plate loading far outboard of the Reentrant and perhaps that it was sheltered from Taconian stress by the lateral flanking position of the area at the eastern edge of the reentrant.

In contrast, Newfoundland's platform was radically influenced by the encroachment of the Taconian forebulge across the shelf edge. It not only controlled uppermost St. George sedimentation but also lead to significant faulting and uplift of the platform sequence. The blockfaulted platform was open to shallow to deep stratal diagenesis during the late Early to early Middle Ordovician but also during later Devonian orogenesis. In addition, the block faulted platform controlled subsequent sedimentation in the Middle Ordovician.

Highs such as the Port au Choix arch were probably controlled by the dominant northeast-trending faults that transect this part of the Newfoundland shelf. Not only, did these faults control the location and development of subsurface oligomictic breccias while the lower Aguathuna Formation was being deposited, but thickness variations in the Catoche and the Aguathuna formations indicate that the faults were also actively but gently deforming the surface of the platform (Lane, 1990; Knight et al., 1991). This suggests that the Port au Choix arch could have influenced the location of the deposition of the Catoche cyclic carbonates including the development of erosion and karsting at the top of many of the cycles. This lead to later control of dolomitization and porosity in this area. Consequently, the dolomites over this arch were a significant hydrocarbon reservoir.

It is perhaps pertinent to consider if the pervasive multigeneration dolomitiziation that effected the top of the Catoche in different areas is also related in part to the structural control the Taconian events had on the platform. Knight et al. (1991) suggest that restricted shelf conditions prevailed in Newfoundland during the deposition of the Aguathuna Formation because the forebulge uplifted the edge of the ancient platform. Evidence presented previously suggests that initially, dolomitization of the upper Catoche occurred at burial depths of no more than 100m. This suggests that this may have been ongoing as the Aguathuna Formation was being deposited. Hypersaline brines generated in the Aguathuna lagoons and tidal flats possibly seeped down through the unconsolidated muddy and the karsted grainy sediments of the top of the Catoche in the inner cyclic facies belt. Pervasive dolomitization occurred. In addition, uplift of the platform and arches such as the Port au Choix arch would afford the creation of a freshwater hydrostatic head that could have lead to subsurface mixing zone dolomitization.

These fluids were prevented from effecting the outer peloidal-fenestral grainstone belt because this was essentially lithified by early cementation. Instead however, the inner edge of the underlying mound complexes were dolomitized. In Anticosti Island, the thickest dolomitization of the top of the Ste-Genevieve Member occurs close to the eastern arc and is ubiquitous in the section at Mingan Islands. Is this again indicating the importance of the arches and the proximity to the shoreline of the Anticosti Basin to allow the mixing of saline brines derived by downward seepage from the Grand-lle lagoons and tidal flats with freshwater from the Precambrian uplands? Desrochers (1985) suggested that the sucrosic dolomites of the Romaines at Mingan Islands was the result of mixing zone dolomitization. Traced into more distal sections such as the Princeton Lake well, dolomitization is very minor. Low conodont CAI values in surface rocks of at Anticosti Island suggest that the area was not deeply buried and that CAI values of 2 to 3 could expected in the subsurface Romaines Formation (Nowlan and Barnes, 1987).

Plates of

Core Photographs,

Anticosti Island Wells, Quebec

Plate 19
The basal unconformity of the Romaines Formation with Precambrian granite. No regoltith occurs. The basal bed of the Sauvage Member consists of unevenly stratified microcrystalline dolostones. Car1eton Point well. Arrow indicates top in every plate.

Plate 20: LITHOFACIES OF THE SAUVAGE MEMBER

A: Mottled pink to green grey colored microcrystalline dolostones (left and right cores) and a grey sparcely mottled dolostone showing sheet crack or stromactoid cavities (centre). The mottles are burrows in a soft soupy sediment, probably the deposits of a shallow lagoonal setting. No fossils occur in these dolostones. The cavities are floored by geopetal dolomite silt and occluded by spar (upper part of the cavity). These structures suggest subaerial exposure and vadose dissolution of the carbonate muds. Carleton Point well.

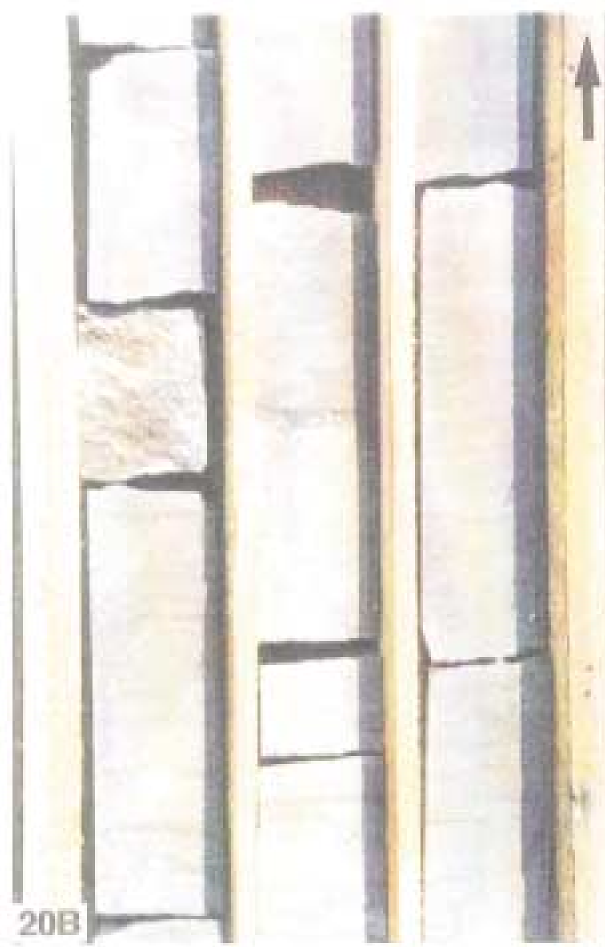

Plate 20

B: Grey very fine dolostones displaying thin stratification and generally sparse subhorizontal bioturbation. Some of the thin stratum appear grainy (bottom of the right core). A thin grey sandstone occurs at the upper left core. The setting is probably a muddy tidal flat with terrigenous sand at the edge of the flats or in channels. Carleton Point well.

Plate 20
C: Brecciated dolostone (left core), dololarninite (centre) and burrowed calcareous sandstone (right). The brecciated and laminated dolostone mark the supratidal and karsted top of a shallowing upward cycle. This is overlain by the burrowed sandstone that is green speckled probably reflecting glauconite. Carleton Point Well.

Plate 21: LITHOFACIES OF THE STE. GENEVIEVE MEMBER
A: Bioturbated, stylolitic, peloidal packstone and grainstone. Carleton Point well.

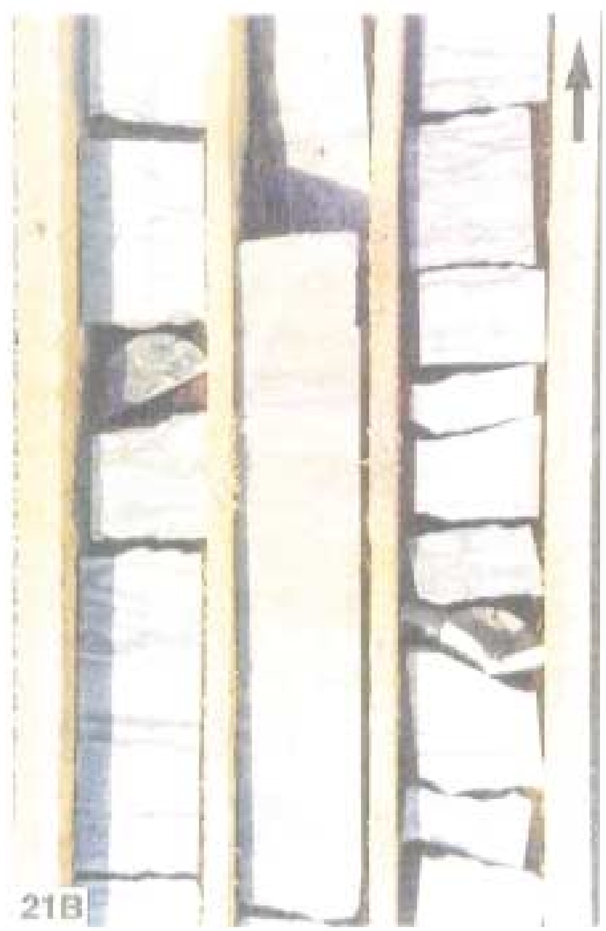

Plate 21
B: Stratified, bioturbated mudstone with interbeds of lime grainstone (Lower left core). The middle core is dolomitized equivalent. Carleton Point well.

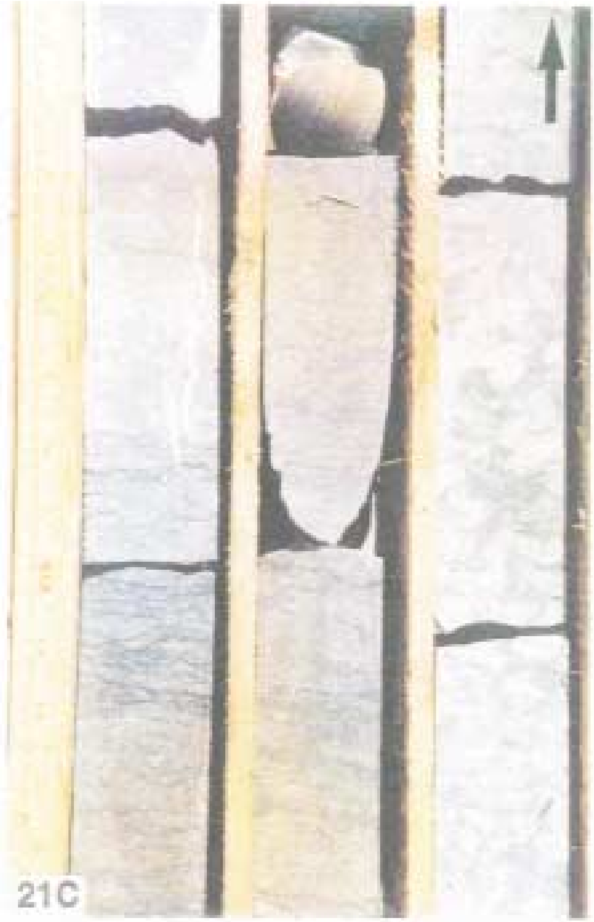

Plate 21
C: Bioturbated packstones (left), wackestones (centre) and mudstones (right core). The microload structure along the edges of the burrows suggests that the mudstone was soft and water laiden when bioturbated. Carleton Point well.

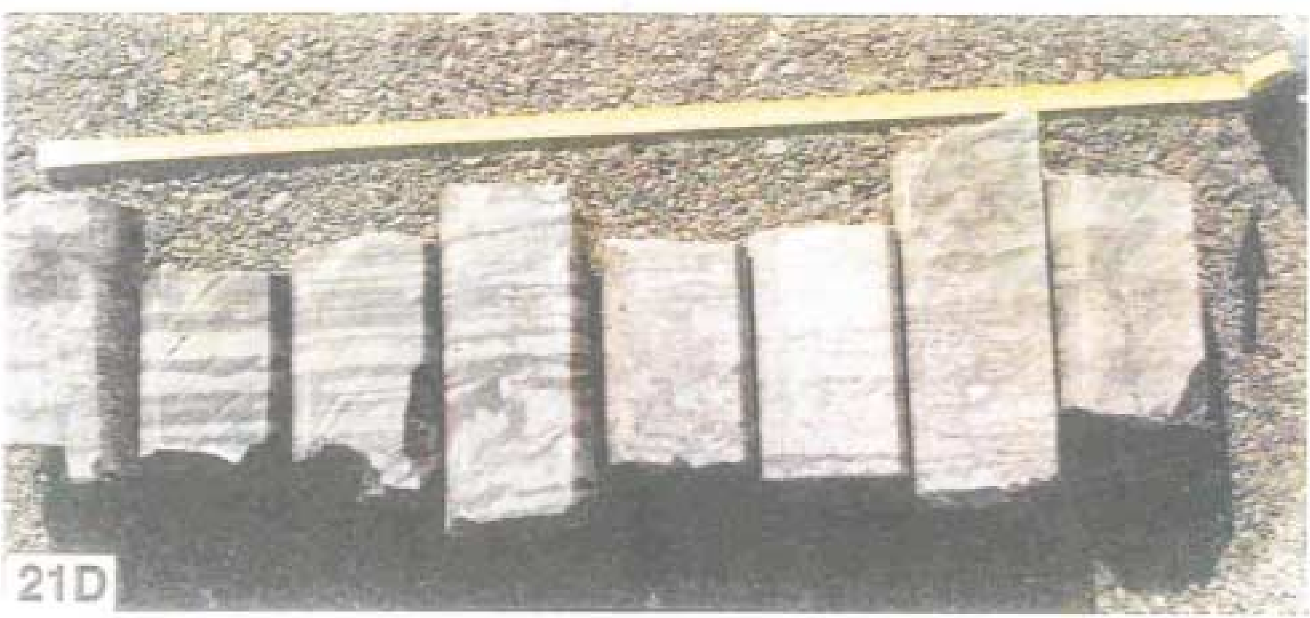

Plate 21
D: Bioturbated and planar thin bedded dolomitic lime mudstones and wackestones. Arco No.1 well, interval 10962 -11021. This facies is probably indicative of a deeper water shelf setting .

Plate 22: LITHOFACIES OF THE GRAND-ILE MEMBER
A: Burrow-mottled microcrystalline dolostone typical of the lower parts of shallowing upward cycles in the lower part of the member. These units are very similar to dolostones in the Aguathuna Formation in western Newfoundland. Carleton Point well.

Plate 22
B: Burrow-mottled dolostone (left core) and dololaminite (right core) in the middle part of the Grand-Ile Member. Note the local brecciation in the mottled core. Sparse pin point porosity occurs in the middle core. Carleton Point well. Plate 22 Continued

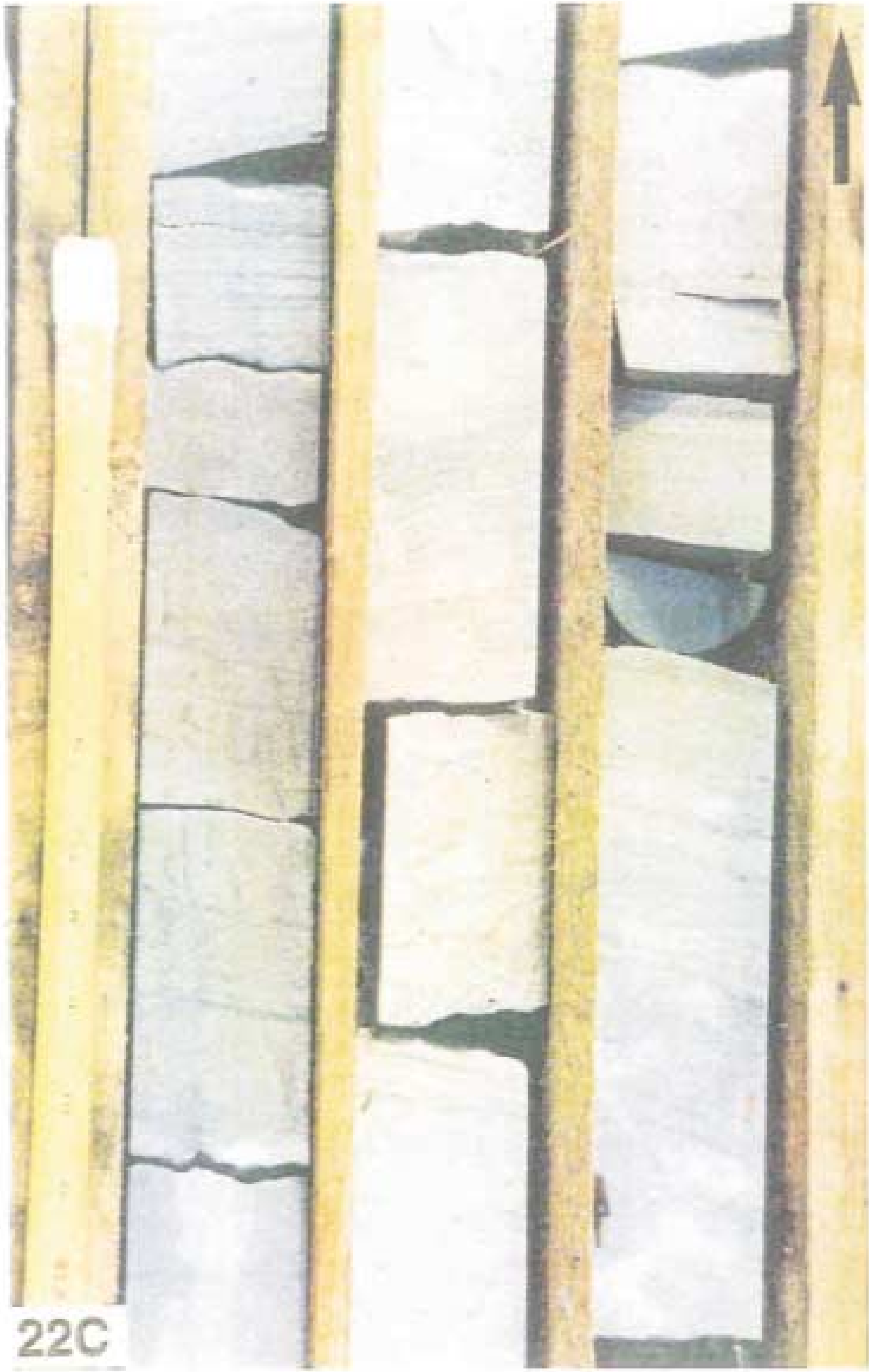

Plate 22
C: Sparsely bioturbated, thinly stratified dolostone and dolominite characteristic of the upper part of the Grand-Ile Member. Note the small carbonate nodules, probably after gypsum, in the dololaminite (bottom right core). Carleton Point well.

Plate 23: LITHOFACIES OF THE UPPER UNNAMED DOLOSTONE, PRINCETON LAKE WELL
A: Partly dolomitized bioturbated skeletal wackestones (left core) and bioturbated dolostones of the basal part of the upper unnamed dolostone.

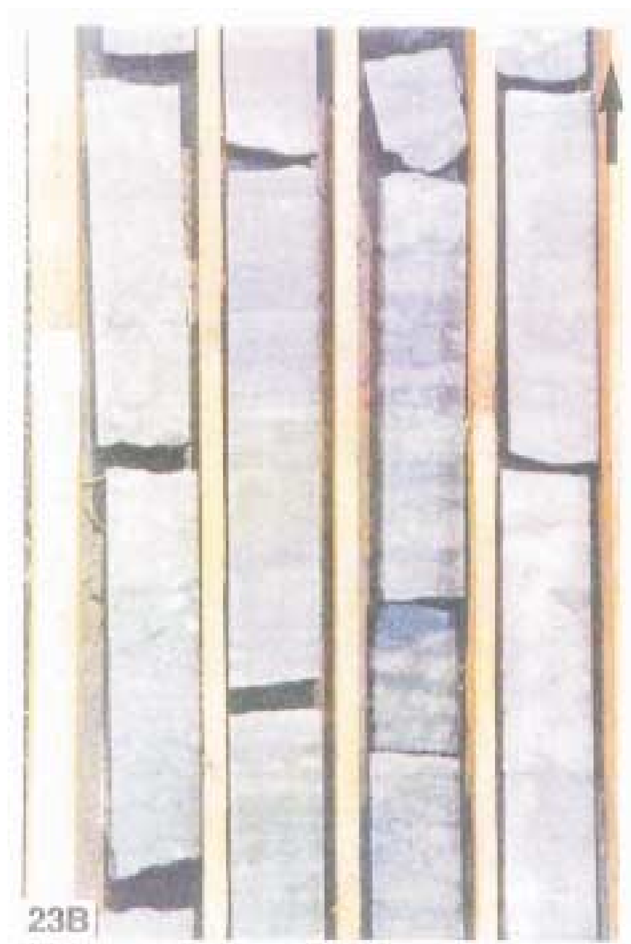

Plate 23
B: Bioturbated dolostones showing burrow fabrics characteristic of open shelf subtidal carbonates. Lower part of the upper unnamed dolostone.

Plate 23
C: Mottled (left core), grainy (middle cores) and thinly stratified (right core) dolostones from the middle of the upper unnamed dolostone.

Plate 23
D: Mottled and shaly dololaminite, upper part of the upper unnamed dolostone.

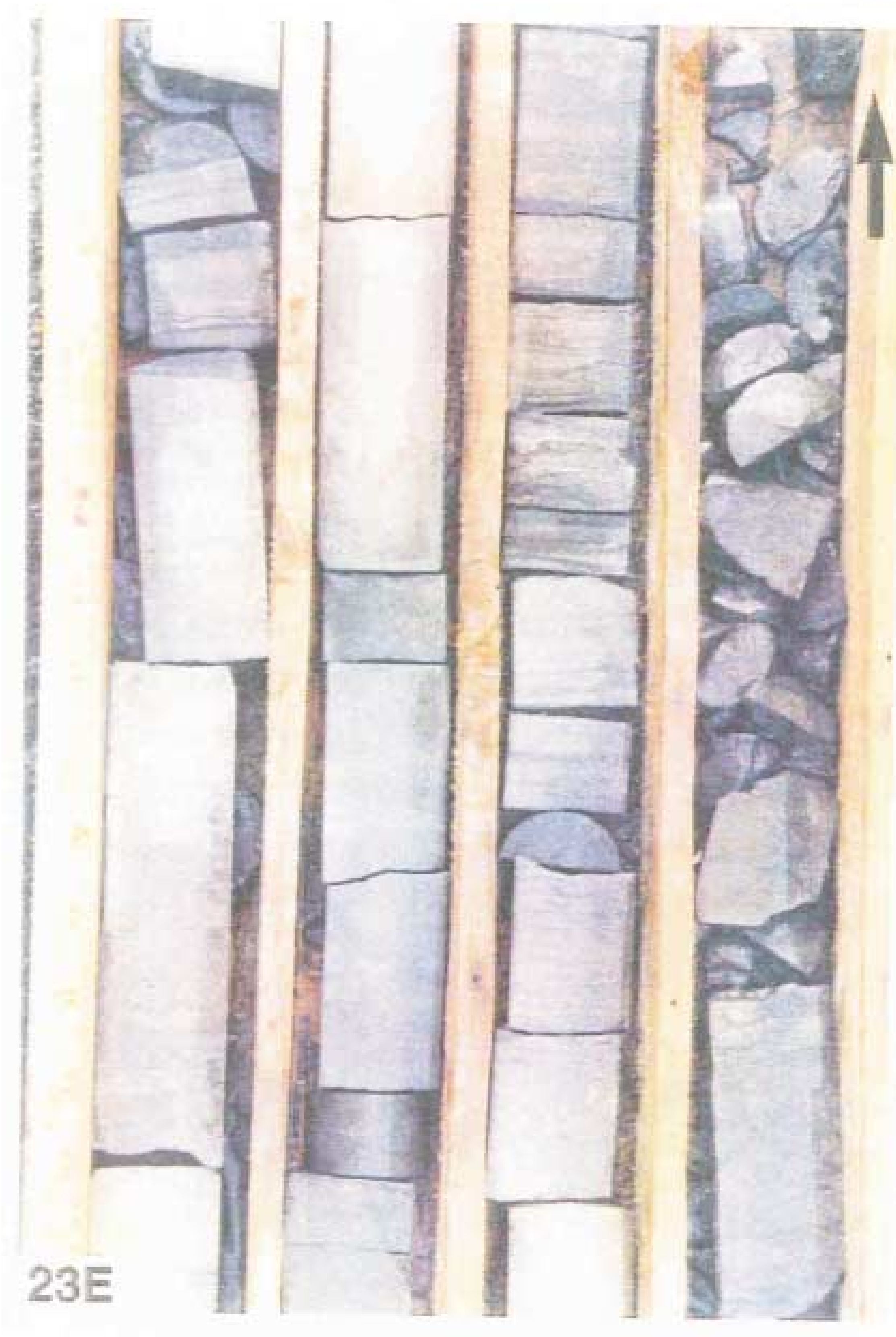

Plate 23
E: Mottled and shaly dololaminite, upper part of the upper unnamed dolostone.

Plate 24
Mingan Formation limestone, Carleton Point well. The off white, peloidal limestones (left and right cores) are characterized by fine tubular and irregular laminar fenestrae and fractures occluded by calcite spar .The presence of large curved to fine irregular spar cemented fractures in the indistinctly burrow? Mottled lime mudstone (middle core) is suggestive of early shrinkage of these probable shallow subaqueous sediments. The facies resembles limestones of the Middle Ordovician Springs Inlet Member in western Newfoundland.

Plate 25
Intensely bioturbated limestones equivalent of the Mingan or Blackriver Formations that overlie the upper unnamed dolostone. Princeton Lake well.

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APPENDIX A:

DETAILED THIN SECTION

DESCRIPTIONS

APPEND IX A

BA-l: Dolostone, medium-to coarse-crystalline, planar-s (subhedral) dolomite, containing two zones discemable based upon crystallinity as follows: 1) a generally medium-crystalline (0.3 mm) non-planar-a (anhedral) zone, locally containing thin, early fractures that are now dolomitized, and 2) an abrupt transition into a zone of porosity and coarse-crystalline planar-s dolomite. The specimen is slightly stylolitic; primary textures are not evident. Vuggy porosity ranges up to 1 mm, there is minor solution porosity I and most porosity is angular intercrystalline. (Core Lab: porosity 3.3%, horiz. penn. 0.04 mD, point-counted porosity: 3.6%)

BA-2: Dolostone, hydrocarbon (HC)-bearing, medium-to coarse-crystalline, planar-s mosaic dolomite. The bulk of the lithology consists of subhedral, dusky crystals of dolomite; the exception to this is in areas of good intercrystalline and vuggy porosity where euhedral crystal terminations are observed. Strongly anhedral dolomite is evident near stylolites and is probably the result of chemical compaction. Vugs (to 13 mm) and intercrystalline porosity are common. Vugs tend to be elongated parallel or sub-parallel to stratification and are frequently lined by sparry dolomite, and less commonly by saddle dolomite. Locally there is a strongly irregular distribution of microporosity that may have resulted from stylolite dissolution. There appears to be some dolomite dissolution along cleavage traces and some crystal margins are ragged. There may be two phases of dolomite crystal growth and possibly two phases of dissolution. (Core Lab: porosity 7.0% , horiz.perm. 51.8 mD, point-counted porosity: 8.6%, visual estimate of porosity in thin section: 15%)

BA-3: Dolostone, bimodal, fine-to medium-crystalline, rarely very coarse-crystalline (2 mm), planar-s mosaic dolomite. The specimen is fairly evenly crystalline, but contains several larger crystals of dolomite and thus the bimodal assignment. Planar crystal faces are common within the mosaic, indeterminate microgranular brown minerals are commonly located at intercrystalline apexes and replacive pyrite and framboidal pyrite are present. Dolomite crystals contain dusky cores and relatively clear rims. Nowhere are definitive primary grains observed. Porosity is poor and is limited to sheet pores and small vugs (about 0.02 -0.1 mm). Most pores are highly angular and are unequally distributed. Interconnectedness of pores is poor. (Core Lab: porosity 1.0%, horiz. perm. 0.05 mD, point-counted porosity on the slabbed horizontal plug: 1.3%, visual estimate of porosity in thin section: 1 %)

BA-4: Dolostone, HC-bearing, fine-to very coarse-crystalline, planar-s (to locally non-planar) mosaic dolomite. The rock appears locally to be fractured and microbrecciated. Non-porous areas contain the most regular fabric and crystallinity .These tight areas contain late fractures that are annealed by dolomite, but they do contain good porosity in places. Fracturing and fracture-induced porosity is pre-hydrocarbon migration. Porous areas are large (1 cm in thin section), clear and widespread. The most porous area contains common euhedral dolomite, large saddle dolomite (very coarse), with hydrocarbon splinters and vug linings. Intercrystalline porosity is very abundant, fracture porosity and porosity along microbreccia zones is apparent. Porosity distribution may have been controled in part by bioturbation. (Core Lab: porosity 8.1 %, horiz. perm. 4.26 mD, point-counted porosity on the slabbed horizontal plug: 9.3%)

BA-5: Dolostone, medium-to coarse-crystalline, non-planar mosaic dolomite. The dolomite within this sample is very similar to that observed above, except that there is more intercrystalline boundary irregularity here. The crystals seem tightly packed for the most part and permeability is unsurprisingly low. Planar crystal boundaries are noted around pore spaces. The specimen contains abundant, thin, and continuous stylolites signifying chemical compaction. Measured pores range from 0.05 -2.5 mm and the pores are generally small, clear (i.e. , devoid of pore filling minerals), and largely ineffective. (Core Lab: porosity 3.3%, permeability 0.02 mD, point-counted porosity on the slabbed horizontal plug: 4.5%)

BA-6: Dolostone, HC-bearing, very fine-to coarse-crystalline, non-planar-a and non-planar-c (cement) dolomite. The lithology is stylolitic, contains irregular zones of microbreccia. Porosity is evident as follows:

1) in large vugs (I cm), lined by saddle dolomite and of splinters of hydrocarbon
2) in linear vugs (presumably fracture-induced)
3) in pores and micropores associated with microbrecciation
4) in intercrystalline areas
5) associated with stylolites

Overall, a mediocre reservoir rock due to the isolation of vugs. (Core Lab: porosity 5.6%, horiz. perm. 0.3 mD, point-counted porosity on the slabbed horizontal plug: 6.4%)

BA-7: Dolostone, HC-bearing, fine-to coarse-crystalline, planar-s mosaic dolomite. Where dolomite encroaches upon pore spaces, the dolomite tends to be increasingly euhedral and it is generally coarser crystalline. There is evidence of initial dolomitization, followed by dedolomitization and again by late dolomite crystallization. Porosity is evident as follows:

1) elongate pores (to 8 mm in thin section) bounded by sparry dolomite and saddle dolomite
2) smaller, more equant, intercrystalline porosity
3) intercrystalline sheet pores
4) microporosity associated with stylolites

Splinters of hydrocarbon are noted in many pores. (Core Lab: porosity 11.5% , horiz. perm. 1.3 mD, point-counted porosity on the slabbed horizontal plug: 15.4%)

BA-8: Dolostone, HC-bearing, fine-to coarse-crystalline planar-s mosaic dolomite (although as with BA-6 and BA-7, this is borderline non-planar). The specimen contains two zones that are distinctive for their low porosity; these two zones are separated by a high porosity zone that contains more euhedral dolomite. All dolomite is dusky-brown with inclusion-rich cores and clear rims. Stylolites are evident, although not prevalent. Both open fractures and dolomite-annealed fractures are observed. Porosity is good and it takes the form of clear vugs (to 4 mm) and very common intercrystalline porosity. Hydrocarbon blebs and shards are evident in all varieties of pore space, attesting to the moderate permeability. (Core Lab: porosity 9.5%, horiz. pernl. 5.13 mD, point-counted porosity on the slabbed horizontal plug: 11.9%)

BA-9: Microbrecciated dolostone, HC-bearing, very fine-to coarse-crystalline, planar-s dolomite. Deformation that led to fracturing was taken up as grain movement and brecciation rather than brittle fracturing. Presently the lithology is very peculiar -almost like a 'crystal slush'. Dolomite tends to be dusky and devoid of primary features. Incipient stylolitization is observed locally. Vugs are anastamosing in thin section (creating good interconnectedness) and are approximately upwards of 5 mm. Intercrystalline porosity is common and seems to grade into vugs. Fracturing in the specimen is relatively late and has led to textural chaos. Hydrocarbon (bitumen) blebs and shards are common. Hydrocarbon was introduced post-fracturing and brecciation. (Core Lab: porosity 14.4%, horizontal perm. 317 mD, point-counted porosity on the slabbed horizontal plug: 17.9%)

BA-10A: Dolostone, HC-bearing, fine-to very coarse-crystalline, planar-s dolomite. In relatively tight areas the texture verges on being non-planar: intercrystalline clay/organic debris is present and where concentrations of this debris are present, stylolites have formed. Fracturing is relatively common and appears to be taken up in the form of open pore spaces (linear) and as breccia or microbreccia zones. Intersecting fractures occur, but it is difficult to decipher relative age on the basis of cross-cutting relationships. Vugs tend to be rather linear (some certainly are fracture-related) and up to 1.3 cm in length. Intercrystalline porosity is frequently filled by hydrocarbon pluslminus indistinct org./clay(?) debris. Along the margins of large vugs curved terminations of saddle dolomite are commonly observed. (Core Lab: porosity 11.7%, horiz. perm. 17.7 mD, point-counted porosity on the slabbed horizontal plug: 13.2%)

BA-10B: Dolostone, HC-bearing, fine-to very coarse-crystalline planar-s mosaic dolomite. The specimen has been strongly fractured. This early fracturing created porosity and these pores were subsequently enlarged. Subsequently, saddle dolomite crystallized, sealing fractures and isolating vuggy pore spaces. Megacrystalline dolomite spar and saddle dolomite form the void-fi11ing crystals which contain fewer inclusions compared to the bulk of the mosaic. In hand specimen the mottled appearance is the result of this fracture-fi11ing dolomite which contrasts with the bulk of the mosaic dolomite. Stylolites are observed and locally, near stylolites, porosity has been created. Porosity is for the most part vuggy (8 mm in thin section). Porosity is also evident in small fractures and as intercrystalline pores (i.e. , this is mainly the few remaining pores in the final stages of void-fi11ing). Hydrocarbon is observed in many pores. (Core Lab: porosity 6.8%, horiz. perm. 0.15 mD, point-counted porosity on the slabbed horizontal plug: 8.6%)

BA-11:Dolostone, HC-bearing, fine-to very coarse-crystalline, non-planar dolomite. This This dolostone consists of a large range of crystal sizes, with an estimated 20% saddle dolomite which becomes increasingly coarse as pores are encroached upon. The remaining 80% of the dolostone is composed of subhedral to anhedral dolomite. These zones tend to be tight, stylolitic and contain common intercrystalline organic/argillaceous debris. Fracturing and solution-enlarged fractures are common and are frequently lined by hydrocarbon. Local vugs are present in thin section and are about 5 mm across. Porosity is also evident in fractures and as intercrystalline JX}re spaces. (Core Lab: porosity 4.3%, horiz. perm. 0.05 mD, point-counted porosity on the slabbed horizontal plug: 10.0% -note the large discrepancy in porosiry volumes)

BA-12: Dolostone, HC-bearing, fine-to very coarse-(mega-) crystalline, non-planar-a (anhedral) and -c (cement). Within the finer-crystalline dolomite zones there is extensive intercrystalline pseudo-amorphous debris. Whispy pods and bands of this material occur throughout the sample (related to burrows?). Directly within these areas, porosity is negligible. Gradationally, but within small distances, coarser dolomite and coarse saddle dolomite have crystallized. Usually this form of dolomite contains few inclusions and org./arg. debris is not present. Saddle dolomite commonly rims vuggular pore space. In places, fractures are represented by thin, microbreccia zones that do contain some porosity. Elongate and equant vugs are evident (to 5 mm in thin section). Angular, intercrystalline porosity is observed but the larger vugs comprise the bulk of the porosity . Hydrocarbon is located in both vugs and intercrystalline pores. Although not evident in thin section, examination of the plug reveals silicification. (Core Lab: porosity 17.8 % , horizontal perm. 3,680 mD -the plug is not fractured, point-counted porosity on the slabbed horizontal plug: 18.8 %)

BA-13: Dolostone, HC-bearing, with a complex polymoda1 texture as follows:

lA) very fme-crystalline non-planar-a mosaic dolomite
lB) medium-crystalline gnerally non-planar-a mosaic dolomite
lC) coarse-crystalline planar-s dolomite (to planar-e at vugs)
2) coarse-crystalline planar-s to planar-e

The type lA/B crystallinities, although abrupt in transition, may mimic a primary texture. Porosity ranges from equant vugs (5 mm), to elongate vugs (5 mm). In addition to vugs, porosity is located in an intercrystalline setting and within microbrecciated fracture zones. Hydrocarbon is observed in all these types of porosity . (Core Lab: porosity 13.8%, horiz. perm. 0.96 mD, point-counted porosity on the slabbed horizontal plug: 17.4 %)

BA-14: Dolostone, HC-bearing, complex polymoda1 mosaic dolomite consisting of the following:

1) very fine-to fine-crystalline non-planar-a mosaic dolomite situated in pods and along org./arg. filaments, stylolites and fractures
2) medium-crystalline non-planar-a mosaic dolomite which locally contains crystal terminations and intercrystalline porosity
3) very coarse (to more than 3 mm) sparry dolomite and saddle dolomite located mainly at vug margins; locally these dolomite crystals contain evidence of partial leaching

There does not apppear to be a systematic trend to the fabric or normal or explainable pattern to the distribution of textures. Porosity occurs as large equant vugs, angular intercrystalline pores and within small fractures or breccia zones (plus in slightly leached dolomite crystals). (Core Lab: porosity 10.5% , horiz. perm. 24.7 mD, point-counted porosity on the slabbed horizontal plug: 10.5%)

PB-l: Dolostone, HC-bearing, generally medium-to coarse-crystalline, non-planar-a mosaic dolomite. Areas with common intercrystalline pores contain coarse-to very coarse-crystalline, planar-s to planar-e dolomite. Stylolitization and incipient stylolitization is evident. Fracture porosity and fracture microbrecciation is present in places. Vugs to 4 mm are evident in thin section and are bounded by relatively coarse dolomite as is mentioned above. Intercrystalline porosity is distributed adjacent to vugs, and locally within the relatively tight dolomite mosaic. (Core Lab: porosity 8.6% , horiz. perm. 33.7 mD)

PB-2: Dolostone, HC-bearing, fine-to coarse-crystalline, planar-s mosaic dolomite. This lithology in thin section appears to be a superior potential reservoir rock compared to PB-l. Here, pores are vuggy and intercrystalline, but are more uniformly distributed compared to PB-l. Overall, dolomite is dusky (inclusion-rich) and contains diffuse yellow/brown cores locally. In the vicinity of pore space dolomite spar and saddle dolomite become increasingly euhedral. Zoned dolomite is observed adjacent to some pore spaces. Organic/argillaceous and organic/pyritic stylolites are evident. Porosity is located as follows:

1) elongate vugs to 4 mm, and within equant vugs (2 mm)
2) as open fractures that have been encroached upon by dolomite
3) small vugs that have been encroached upon by several dolomite crystals
4) angular, intercrystalline pores (Core Lab: porosity 7.2%, horiz. perm. 1.74 mD)

PB-3: Dolostone, HC-bearing, with two major crystallinity types: I) fine-to coarse-crystalline planar-s mosaic dolomite, and 2) fine-to coarse-crystalline planar-e mosaic dolomite. Most dolomite crystals are strongly zoned with inclusion-rich cores and relatively inclusion-free rims. Pods or zones where the type 2 dolomite occurs tend to contain the best porosity of the sample (consists of vuggy, but predominantly intercrystalline pores). Stylolitization is evident locally. (Core Lab: porosity 7.9%, horiz. perm. 5.37 mD)

PB-4: Dolostone, HC-bearing, fine-to coarse-crystalline planar-s mosaic dolomite and fine-to coarse-crystalline planar-e mosaic dolomite. Overall, this lithology bears close similarity to PB-3 except it is vuggier and contains more extensive areas of planar-e mosaic dolomite. Common linear vugs attest to the presence of fracture porosity .Stylolites locally delineate the boundaries between porous euhedral mosaic and intercrystalline porosity, and tight subhedral/anhedral mosaic. (Core Lab: porosity 9.6%, horiz. perm. 224. MD)

PB-5: Dolostone, HC-bearing, consisting of 1) firie-to coarse-crystalline planar-s mosaic dolomite, and 2) medium-to coarse-crystalline planar-e mosaic dolomite. Type 1 dolomite is zoned, dusky , and ranges from anhedral to subhedral (it is termed planar-s (subhedral7. Generally, it is very rapidly distinguished from type 2 by its rmer crystallinity and its paucity of porosity .Fractures and minor fracture porosity are evident in areas containing type 1 dolomite. Areas of type 2 dolomite are concentrated and evident in several sweeping zones that parallel stratigraphy. They are highly porous zones estimated to contain about 20% porosity .The specimen is not highly vuggy, .but it contains a fairly continuous, coalesced, intercrystalline porosity that turns out to be quite permeable. Local clots of bitumen are observed. (Core Lab: porosity 8.5% , horiz. perm. 134. mD)

PB-6: Dolostone, HC-bearing, consisting of 1) fine-to coarse-crystalline non-planar-a mosaic dolomite. This dolomite is frequently zoned (dusky cores, often yellow/brown), and 2) fine-to coarse-crystalline planar-s to planar-e mosaic dolomite. Type 2 dolomite consists of dolomite spar that is zoned and contains a fairly ferroan band near crystal margins. Minor saddle dolomite is included in this category of crystallinity. Porosity is present in vugs to 6 mm and in intercrystalline pores (porosity is mainly vuggy). Minor porosity is observed in fractures that are now partly sealed. (Core Lab: porosity 7.6 horiz. perm. 0.19 mD)

PB-7: Dolostone, HC-bearing, containing two major dolomite types as folows: 1) fme-to coarse-crystalline planar-s mosaic dolomite (although many crystals are anhedral), and 2) firie-to coarse-crystalline planar-e (these dolomites line pore spaces). Type 1 dolomite is strongly zoned, in a clear/rusty brown/clear progression from crystal core to rim. Pores are mainly vugs up to 6 mm in thin section and nearly 2 cm in slabbed and analysed core pieces. These vugs are lined by the type 2 dolomite. Intercrystalline porosity is dispersed throughout the sample, primarily between type 1 dolomite crystals. Incipient dolomitization is present, fractures are not observed. (Core Lab: porosity 6.8%, horiz. perm. 26.8 mD)

12I/11 008-16: Dolostone, fine-to coarse-crystalline non-planar-a (anhedral) dolomite, and fine-to coarse-crystalline -planar-s (subhedral) to planar-e (euhedral) dolomite near porous areas. Dusky to very dusky (inclusion-rich) dolomite crystals are located in zones or pods consisting of fine-to medium-crystalline dolomite. These zones grade into areas with dusky dolomite containing fair, angular, intercrystalline porosity. Quartz crystals are evident locally and contain inclusions of dolomite. Locally, stylolites are observed. Vuggy porosity is equant and up to 4 mm in thin section, intercrystalline porosity is present. Estimated 5% porosity , probably poor permeability.

12I/11 -008-17: Dolostone, dusky , inclusion-rich, fine-to coarse-crystalline non-planar-a dolomite, and medium-to very coarse-(2 mm) crystalline planar-s mosaic dolomite, frequently strongly zoned. Areas of the first dolomite type are tightly packed, locally stylolitic and contain predominantly curved to somewhat serrated crystal boundaries, together with some intercrystalline porosity .The second type of dolomite tends to be subhedral to euhedral, zoned, and associated with free crystallization of dolomite around pore spaces. Vugs trend parallel to stratification and are about 5 mm in length, porosity is also observed in occasional fractures. Estimated 9% porosity, probably fair to good permeability.

12I/11 -008-18: Dolostone, containing two types of dolomite as follows: 1) fine-to coarse-crystalline,non-planar-a mosaic dolomite, and 2) fine-to medium-crystalline, planar-e mosaic dolomite. Type 1 dolomite is close-packed, contains irregular grain boundaries and bounds small intercrystalline pores. The dolomite is zoned, containing inclusion-rich cores and clearer rims. Stylolites are evident, but they are not widespread. Fractures locally connect areas of intercrystalline porosity .Porosity is predominantly intercrystalline and forms in depositionally-related (?) pods or zones. Visually estimated porosity in thin section is 7% .

12I/11 008 19: Dolostone, porous (estimated 18% vuggy and intercrystalline porosity), fine-to coase-crystalline, non--planar-a moasaic dolomite. This dolostone consists of dolomite crystals that form a relatively tight, anhedral to subhedral mosaic. Packing is commonly close, grain boundaries are frequently curved or irregular .In proximity to vugs dolomite is better-crystal1ized (i.e. , subhedral to euhedral) with local saddle dolomite. Some dolomite spar attain dimensions on the order of 1 mm. Authigenic minerals that occur in vuggy pores include smectite or mixed-layer clay and possible zeolite? (indetern1inate, low birefringence, low relief mineral with blocky crystal habit that occurs in aggregates - not kaolinite). Porosity, which is quite high (est. 18%), occurs mainly as vugs to 1 cm, as well as at intercrystalline locations.

12I/11 -008-21: Dolostone, porous (estimated 12% vuggy porosity), containing two types of dolomite as 21: follows: 1) fine-to coarse-crystalline, non-planar-a mosaic dolomite, and 2) medium-to very coarse-crystalline (to 3 mm) saddle dolomite adjacent to vugs. Thin zones of iron enrichment are noted near the edge of type 2 dolomite. This specimen contains excellent examples of saddle dolomite. Fractures are observed, and there is minor stylolitization. 90% of the porosity in the sample occurs in large (11 mm) vugs that seem to be of either random orientation or are elongate due to the influence of fracturing on their genesis. Films of greenish-brown clay (smectite? illite/smectite?) line portions of some pores. The sample probably has poor permeability.

12I/11-008-21: Dolostone, vuggy, stylolitic dolostone with two types of dolomite as in sample 21: fine-to medium crystalline planar-s mosaic dolomite, and medium-to coarse-crystalline sparry dolomite and saddle dolomite. The first type of dolomite appears inclusion-rich and is often separated from the sparrylsaddle dolomite by stylolites, or incipient stylolites (organiclargillaceous-rich bands). PIanar-s, or the first type of dolomite is located in areas that are tight, with only minor intercrystalline porosity .Pores are mainly vugs up to 8-9 mm in thin section. Porosity is fair (about 6%), but permeability is, in all likelihood, poor due to the apparent isolation of pores.

12I/11-008-24: Dolostone, HC-bearing, containing polymodal crystallinity, the two major types of which are as follows: 1) very fine-to coarse-crystalline, planar-s mosaic dolomite, and 2) medium-to very coarse-crystalline dolomite spar/saddle dolomite. In the first type of dolomite, each 'pod' or zone has a distinctive range of crystallinities, separated from adjacent zones by organic debris and stylolites. Stylolites and incipient stylolites are well represented in the first type of dolomite and they probably contribute to the low porosity nature of the areas. Type 2 dolomite crystals are spectacular , especially with the wavy/undulose extinction and curved crystal form of dolomites abutting pore spaces. Minor "blebs" of bitumen are evident in vuggy porosity. Vugs range in size from 0.5 mm to more than I cm. Locally, thin, linear fracture systems have remained open.

12I/11-008-25: Dolostone, HC-bearing, containing two major types of dolomite (as in sample 24) as 25: follows: I) fine-to medium-crystalline planar-s mosaic dolomite that is locally very strongly brecciated with breccia fragments that range from microcrystalline to medium-crystalline, and 2) medium-to very coarse-crystalline (2 mm) dolomite spar and saddle dolomite. The specimen is strongly stylolitic and the microbrecciation seems to disrupt the continuity of the stylolites thus suggesting a late stage tectonic origin for the brecciation. Various crystal size zones are segregated by stylolites. Locally, partially-cemented fractures are evident; they are ususally lined by the type 2 dolomite. Porosity is present in 5-6 mm dolomite-lined vugs, there is rare intercrystalline porosity. Microporosity may be concentrated in the microbrecciated zones; linear pores are inferred to have developed from the solution enlargement of fractures. Hydrocarbon is present as splinters and "blebs" in some pores.

1549-2: Dolostone, very fine-to medium-crystalline, planar-s (subhedral) mosaic dolomite. This is perhaps the finest crystalline dolomite examined during this study. Abundant, intercrystalline and locally replacive Fe-oxide(?) is observed in this specimen. Where this mineral is concentrated, dissolution porosity has developed. Clots and bands of medium-crystalline dolomite is observed in places, possibly mimicing the primary fabric. Intercrystalline porsity is estimated at only 1% of the lithology.

1549-3: Dolostone breccia, now largely annealed, remains chaoitic in terms of crystallinity variations. Microbrecciated zones and thin fractures occur throughout the sample. Fine-to very coarse-crystalline , planar-s mosaic dolomite contains fratures, and microbreccia, together with common vugs and intercrystalline porosity (these porosity types grade into one-another). Saddle dolomite is observed, as is late, euhedral quartz and zoned ferroan to low ferroan calcite. Microporous aggregates of clay (illite or illite/smectite) are widespread. Mosaic and saddle dolomite both contain abundant inclusions. Iron oxides and pyrite are observed. Porosity is estimated at 5% , Possibly with fair permeability.

1549-4: Dolostone breccia (similar to 1549-3), stylo1itic, fine-to very coarse-crystalline, planar-s dolomite, with tighter zones composed of very fine-to coarse-crystalline dolomite. Silica nodules as well as discrete crystals of quartz are observed. The silica nodules attain dimensions of about 2 mm in thin section. Stylolitization is apparent in places, and tend to be associated with tighter dolostone. Tighter zones parallel stratigraphy. Overall, vuggy porosity is prevalent, but vugs become increasingly constricted by dolomite and silica until the vugs are reduced to intercrystalline pores. Porosity is estimated at 8% , permeability is potentially good.

1549-5: Dolostone, fine-to very coarse-crystalline, non-planar-a dolomite. Most dolomite crystals, except those abutting porosity , contain strong undulose extinction. Many of these crystals are saddle dolomite, with typically curved crystal facets. Quartz euhedrons are often observed in vuggy pores. Fractures are observed and fracture porosity is common. Intercrystalline porosity , small vugs and vugs to 7 mm in diameter exhibit a weak trend parallel to stratigraphy. Porosity is estimated at 5 % , with potentially fair permeability.

1549-6: Dolostone, bimodal, fine-to medium-crystalline, planar-s mosaic dolomite and fine-to coarse-crystalline, planar-s to non-planar dolomite. The lithology may be distinguished on the basis of bimodal crystallinity .The boundary between the two types of crystallinity is fairly sharp, although there is a tendency of coarsening crystallinity close to the edge of the finer crystalline pods or lenses. Frequently the boundary is delineated by stylolites and/or thin fractures. Some of these boundary stylolites contain minor porosity .Locally there has been minor dedolomitization. Dolomite of the first type is dusky and contains fairly abundant inclulsions. Locally, at crystal edges, dark org./arg. debris is evident. Low ferroan calcite forms a late-stage minor void-filling phase. Minor pyrite is present. Porosity, through present in intercrystalline-fracture-and solution-settings, forms only 1% of the dolostone.

1549-7: Dolostone, medium-to coarse-crystalline, non-planar mosaic consisting of large, possibly composite dolomite crystals with wavy extinction (it is difficult in places to discern crystal margins; this includes saddle dolomite). High amplitude stylolites are common and frequently show signs of leaching (minor porosity development). Adjacent to pore spaces, crystal habit becomes subhedral to euhedral indicating free crystal growth into pore space. In areas of low porosity , crystal boundaries tend to be highly irregular -wavey and serrated. Porosity occurs as vugs, intercrystalline pores, fracture pores, and within J8rtial1y leached stylolites. Estimated 7% porosity , pernteability could be fair .

1549-8: Dolostone, two zones, possibly mimicing some aspect of the primary fabric are outlined as follows: 1) very fine-to fine-crystalline, planar-s mosaic dolomite contained in rather tight lenses or pods that may be related to burrows. These regions are largely parallel to stratigraphy, although they are seen to cross-cut stratigraphy in places. Often this zone of dolomite is stylolitic, or contains intercrystalline organic/argillaceous debris. Locally, fractures have cross-cut the zone; these fractures may be completely open, or partly filled with dolomite, chlorite(?), quartz, or local pyrite. 2) medium-to very coarse-crystalline, planar-s dolomite. These dolomite crystals are loosely aggregated, locally microbrecciated, and reside in regions of good intercrystalline porosity . Dedolomitization is apparent. Porosity occurs as vugs to 2 mm, in intercrysta11ine settings, as fracture-induced pores, and as a function of dedolomitization. Estimated 7 % porosity , potentially fair permeability .

l2B/10-0001-1: Dolostone, unimodal, fine-to medium-crystalline, planar-s mosaic dolomite. The specimen is basically unimodal (in terms of crystallinity), consisting of subhedral dolomite that is typically zoned by variations in concentration of inclusions. Most crystals have inc1usion-rich croes, imparting an extreme dusky appearance to the lithology. Partial to total void-filling minerals include ferroan calcite and low-ferroan calcite. In one small vug there appears to be a radiating clot of microporous chlorite(?) . Porosity in this sample forms mainly as intercrystalline pores, and comprises only about 1 % of the lithology. Permeability is likewise poor .

12B/10-0001-2: Dolostone, HC-bearing, fine-to coarse-crystalline, planar-e dolomite. This lithology constitutes an excellent potential reservoir rock. It consists largely of aggregates of euhedral, inclusion-rich dolomite and well distributed intercrystalline pore space. Porosity is poor only where subhedral aggregates of dolomite have crystallized (and this feature is not widespread). Locally there is a breccia collapse (fracturing was absorbed in this manner in this porous lithology). Chlorite may be present in minor quantities. Estimated 22% porosity , excellent permeability, light brown, pervasive oil stain in hand specimen.

12B/10-0001-3: Dolostone, HC-bearing, bimodal crystallinity as follows: I) microcrystalline to fme-crystalline, planar-e dolomite, and 2) fine-to coarse-crystalline, planar-e mosaic dolomite. Type I dolomite is concentrated almost as a stratum in the basal 2 mm of the thin section. It is composed of finely crystallized dolomite with abundant intercrystalline microporosity (ineffective?) and normal intercrystalline porosity Elsewhere in the specimen, type I dolomite, the finer mode, occurs in an intercrystalline location to the type 2 dolomite -the coarser mode. Additionally, the fine dolomite occurs in association with quite extensive and microporous clay" mats " .These clay-rich regions form as clay sheaves and may represent late-stage chlorite or possibly extensively leached lithic fragments. Type 2 dolomite, the coarser component, is inclusion-rich and similar to that observed in sample 2. Estimated 22% porosity (about 10% effective), and poorer permeability than in sample 2. Macroscopically, the specimen is light brown due to oil staining .

12B/10-0001-4: Dolostone, and microcrystalline quartz nodule (a 2 cm wide band in core and thin 4: section, presumably a nodule). The dolostone is composed of fine-to coarse-crystalline, planar-e mosaic dolomite; these dolomite zones, situated above and below the quartz nodule are similiar to sample 2 with respect to texture and in abundance of intercrystalline porosity (estimated 18% porosity). The quartz nodule contains an estimated 35-40% replacive dolomite crystals that are of similar dimension to those dolomite crystals adjacent to the nodule. Certainly there could be more complex scenerios, but certainly the band of quartz developed, was later fractured and there was later-stage quartz crystallization. There may have been two stages of dolomite crystallization and at least one, and possibly two stages of dolomite partial dissolution. The non-silica zones are light brown (oil stain), and contain excellent porosity (estimated 18% porosity).

12B/10-0001-5: Dolostone, HC-bearing, fine-to coarse-crystalline, planar-e mosaic dolomite. This sample constitutes another excellent potential reservoir lithology. It is composed predominantly of euhedral to subhedral dolomite, possibly with two stages of dolomite crystallization with an intervening stage of partial dolomite dissolution. There is some minor chemical compaction at crystal contacts. Most porosity is intercrystalline, although there are some 2 mm vugs present. Locally there are "clots", probably composed of organics or poorly-crystallized, finely comminuted minerals. The specimen is light brown, yields a hydrocarbon cut, contains about 22% well distributed porosity, and likely excellent permeability .

12B/10-0001-6: Silicified dolostone, the following sequence is proposed:

1)crystallization of fine-to coarse-crystalline dolomite
2) extensive crystallization of microcrystalline quartz (and corrosion of dolomite?)
3) extensive crystallization of very fine-to medium crystalline quartz (druse) with substrates of dolomite and microcrystalline quartz
4) crystallization of microcrystalline quartz on quartz druse
5) crystallization of microcrystalline to fine crystalline dolomite
6) final crystallization of drusy quartz
7) crystallization of a trace of calcite

Most dolomite rhombs are poikilotopic (they contain abundant inclusions of microcrystalline dolomite). The specimen is of low porosity and permeability and is considered to be non-reservoir .

12B/10-0001-7: Dolostone, HC-bearing, fine-to very coarse-crystalline, planar-s mosaic dolomite. Many dolomite crystals are poikilotopic (with dolomite) and euhedral, although most are subhedral. This lithology is similar to sample 5, but with dolomitization taken a step further. Partial dedolomitization has occurred and this was followed by the crystallization of zoned ferroan and low ferroan calcite. There may be some partial dissolution of calcite. Dolomite crystals contain inclusion-rich cores and clearer rims.
It is possible that much intercrystalline porosity was occluded by calcite and Fe-calcite that is now largely dissolved. Thin fractures have been cemented by light-coloured inclusion-free dolomite (syntaxial). Light brown oil stain is evident, but porosity is estimated at only 6%; permeability is poor to moderate.

12B/10-0001-8: Dolostone, bimodal, microcrystalline to fine-crystalline, planar-e mosaic dolomite, and fine-to coarse crystalline, planar-e mosaic dolomite. In stratigraphic terms, near the top of the thin section much of the finer mode of dolomite is located in an intercrystalline position to the coarser mode. The central part of the thin section consists mainly of the coarser dolomite mode, the basal part of the section contains the coarser dolomite mode with extensive cementation by calcite and ferroan calcite. The following paragenetic sequence is proposed:

1) dolomite crystallization
2) dolomite partial dissolution
3) calcite and ferroan calcite crystallization
4) fracturing
5) partial dissolution of calcite and ferroan calcite
6) crystallization of microcrystalline/fme-crystalline dolomite
7) late fracturing and brecciation

12P/1-018-7: Dolostone, low porosity, fine-to coarse-crystalline, planar-s mosaic dolomite, and medium-to very coarse-crystalline sparry dolomite and saddle dolomite that lines vugs. The first mode of dolomite crystallization is licated in stylolite-segregated "pods" or " lenses " where tight packing prevails and there is little intercrystalline porosity. In terms of porosity, vugs (7 mm x 1 mm) are elongated parallel to stratigraphy. Intercrystalline porosity is observed locally. Estimated 3% porosity, poor permeability .

12P/1-018-8: Dolostone, very fine-to medium crystalline, planar-s mosaic dolomite. The various crystallinities are fairly consistent within a given" region" or" zone" .Progressing away from one zone to another, there is a rapid gradation to another zone in which there is considerable consistency in crystallinity .Most dolomites contain zoning -usually dusky, inclusion-rich cores and clearer rims. Stylolites are present but they have not detrimentally affected reservoir properties. Intercrystalline porosity is fair and may be of equal volume compared to vuggy porosity .Narrow vugs to 5 mm are observed, and appear to "grade" outward to intercrystalline pores. pyrite cubes and framboids form disseminated opaque minerals. Estimated 3% porosity , possibly fair permeability.

12P/1-018-9: Dolostone, consisting predominantly of fine-to coarse-crystalline, non-planar-a dolomite, and fine-to crystalline sparry dolomite and saddle dolomite adjacent to pore spaces. Stylolitization is evident especially in the upper part of the thin section. It is in the stylolitic zones that there is some crystallization of microcrystalline dolomite that may have replaced parts of organic/argillaceous stylolites. Quartz crystals are present locally; pyrite cubes and frarnboids have replaced stylolites in places, and may be related to fractures. Dolomite adjacent to pyrite can be slightly ferroan and partly dissolved. Dedolomite porosity is present, and intercrystalline porosity is widespread. Vugs tend to be elongated parallel to the stratification.

12P/1-018-10: Dolostone (dedolomite), composed of fine-to coarse-crystalline, planar-s mosaic dolomite. The lithology is transected by bifurcating, vertical, megacrystalline calcite veinlet (1.4 mm in width), and there is also void-filling coarse-to very coarse-crystalline calcite. Some anastamosing replacive calcite forms a halo adjacent to the large veinlet. Additionally, there is much partial dissolution of dolomite in a halo surrounding the large calcite vein. Immediately adjacent to the veinlet partially dissolved dolomite is filled by authigenic chlorite(?). Elsewhere in the specimen, authigenic chlorite largely fills vugs and is highly microporous. Although there has been dedolomitization in the vicinity of the calcite vein, the lithology remains a poor reservoir lithology (unless there is massive dedolomitization elsewhere).

12P/I-018-11: Dolostone, fine-to coarse-crystalline, planar-s mosaic dolomite, and medium-to very coarse-(1.8 mm) crystalline pore lining dolomite spar and saddle dolomite. Locally there is extensive silicification of dolomite and the incipient development of nodules. The specimen contains stylolites of variable orientation, and they Demark zones of distinctive dolomite crystallinity . The finer mosaic dolomites are dusky .Areas of partly-filled vuggy porosity (or those areas that were once porous but are now completely occluded) consist of porosity and clearer, larger dolomites that are readily distinguished from the surrounding inclusion-rich dolomite mosaic. One sub-horizontal vug is about 15 mm in length. In that vug, and in others, the laterAl continuity of the vug is extended by post-void-filling fracturing. Locally there is dedolomitization of the specimen. pyritization is evident in places. Estimated 3% porosity and poor permeability.

12P/l -018-12: Dolostone, fine-to medium-crystalline, planar-s mosaic dolomite, and medium-to very coarse-crystalline sparry dolomite that is situated in vugs and along fractures. Both sparry dolomite and typical saddle dolomite are present. Along several fractures, late-stage, coarse-crystalline quartz is observed. Porosity is present only within fractures. Estimated 3% fracture porosity, possibly fair permeability.

M/12 -002-1: Dolostone breccia: in general, this is a largely annealed dolomite breccia that contains fair porosity, is fractured, contains dolomite and quartz fracture-fi1ling minerals, and is locally stylolitized. The dolostone consists of fine-to medium-crystalline, planar-s mosaic dolomite, and fine-to very coarse-crystalline dolomite spar and saddle dolomite. Most of the mosaic dolomite is non-porous (local intercrystalline pores), and contains intercrystalline organic(?)/argillaceous debris, and possible iron oxides. Leached lithics(?) now form illitic and siliceous microporous aggregates. Yellowish, granular , microcrystalline aggregates are commonly situated along dolomite cleavages. Vugs are preserved in fractures and fracture zones. Microbrecciated fracture zones are observed to interconnect vuggy porosity .Intercrystalline porosity is present. Estimated 5 % porosity , probably poor permeability .

M/12 -002-2: Dolostone breccia (similar to sample 1): breccia fragments are quite distinctive in their varying dolomite crystallinity and intercrystalline organic(? dark amorphous debris) content. Individual breccia clasts range from less than a centimetre to 2-3 cm as observed in thin section and on the hand specimen. The specimen is composed of fine-to coarse-crystalline dolomite that if variably non-planar to planar-s mosaic (non-planar where much intercrystalline organic debris is present), and medium-to very coarse-crystalline along breccia-clast margins. Composite quartz aggregates and discrete quartz crystals are observed in some pores. Most porosity is present as vugs of irregular shape and orientation: they range to about 1 cm in diameter in thin section. There is an estimated 5% porosity , and probably poor permeability .

APPENDIX B:

CALIBRATION OF POROSITY:

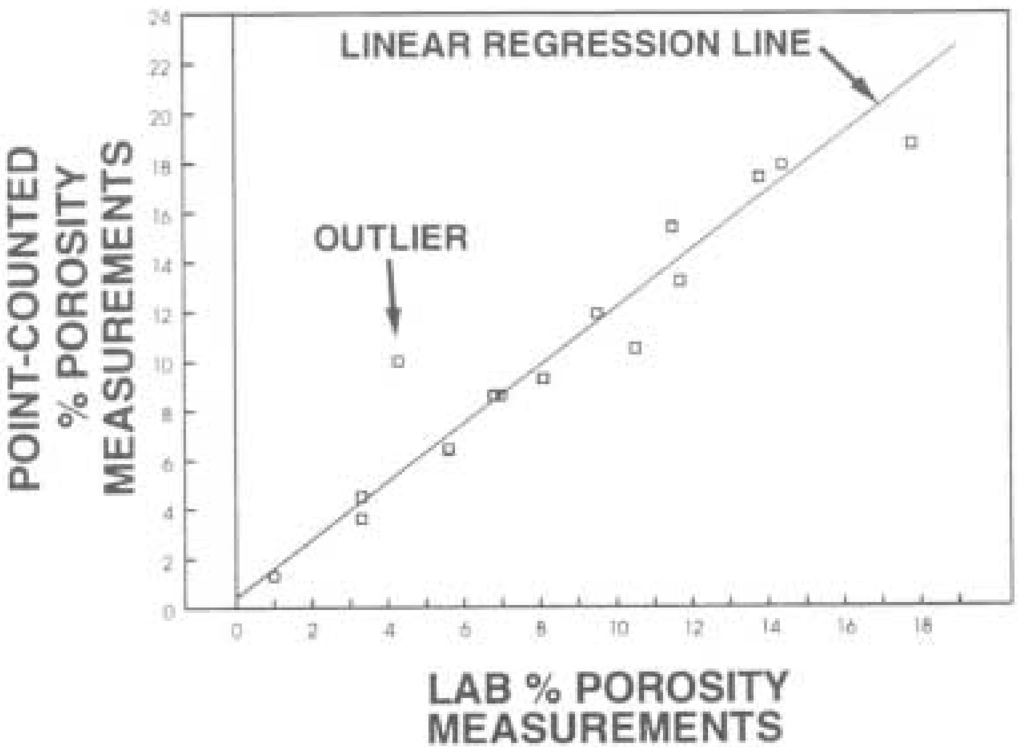
POINT COUNTING VERSUS

CORE LAB DATA

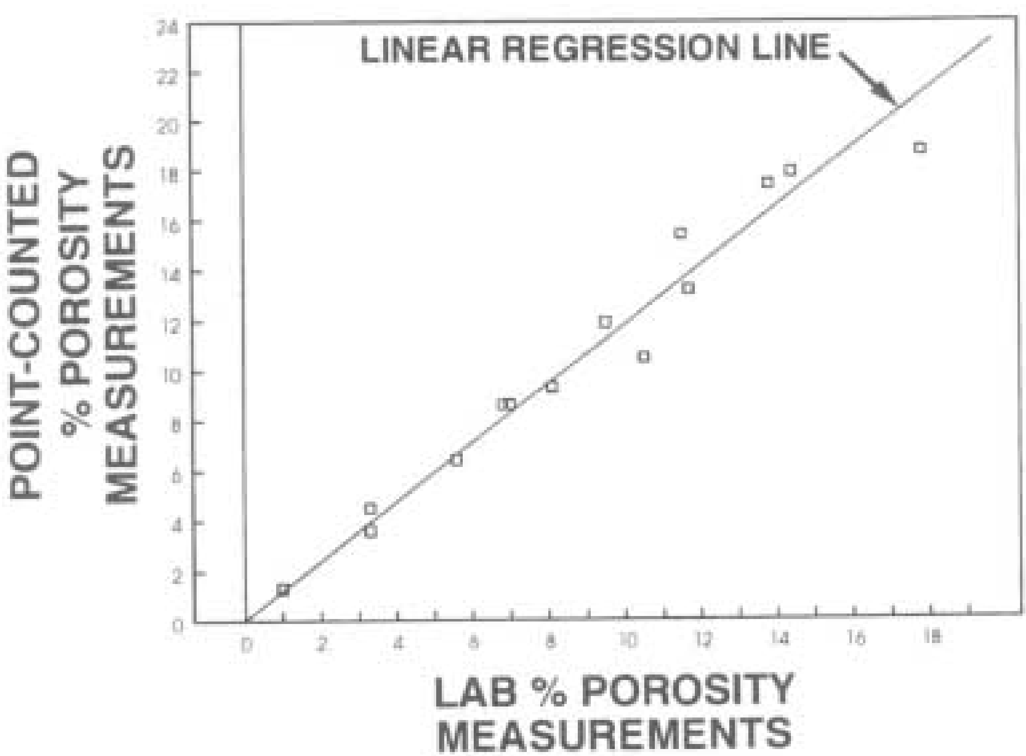
X	Y		X_1	Y_1				
3.60	3.30		3.60	3.30				
8.60	7.00		8.60	7.00				
1.30	1.00		1.30	1.00				
9.30	8.10		9.30	8.10				
4.50	3.30		4.50	3.30				
6.40	5.60		6.40	5.60				
15.40	11.50		15.40	11.50				
11.90	9.50		11.90	9.50				
17.90	14.40		17.90	14.40				
13.20	11.70		13.20	11.70				
8.57	6.80		8.57	6.80				
10.00	4.30		18.75	17.80				
18.75	17.80		17.40	13.80				
17.40	13.80		10.48	10.50				
10.48	10.50							
	X*Y Regression Output:					X_1*Y_1 Regression Output:		
Constant			-0.34671		Constant			-0.01778
Std Err of Y Est			1.452467		Std Err of Y_1 Est			0.977102
R Squared			0.912998		R Squared			0.961251
No. of Observations			15		No. of Observations			14
Degrees of Freedom			13		Degrees of Freedom			12
X Coefficient(s)		0.850608			X_1 Coefficient(s)		0.845546	
Std Err of Coef.		0.072826			Std Err of Coef.		0.049007	
Y=0.85X-0.35					Y_1=0.85X_1-0.02			

Comparison of point-counted % porosity values (X field) from slabbed core plugs versus values from % porosity values on the same plugs from petrophysical determinations (Y field). Number of point counts n = 5,691. X_1 and Y_1 columns have the outlier value removed before calculation of regression line.

$Y = 0.85X - 0.35$
REGRESSION LINE



$Y_1 = 0.85X_1 - 0.02$
REGRESSION WITH OUTLIER REMOVED



APPENDIX C:

PETROPHYSICAL DETERMINATIONS BY CORE LABORATORIES

CORE ANALYSIS REPORT

FOR

MEMORIAL UNIVERSITY OF NEWFOUNDLAND

MEMORIAL UNIVERSITY SELECTED SAMPLES

NEWFOUNDLAND

CORE LABORATORIES

Company : MEMORIAL UNIVERSITY OF NEWFOUNDLAND
Well : MEMORIAL UNIVERSITY SELECTED SAMPLES
Location :
Province : NEWFOUNDLAND

Field :
Formation : CATOCHE
Coring Equip.:
Coring Fluid :

File No.: 52131-92-0299
Date : 92-09-23
Analysts: LGM
Core Dia:

CORE ANALYSIS RESULTS

SAMPLE NUMBER		PERMEABILITY (MAXIMUM) Kair mD	POROSITY (HELIUM) fraction	GRAIN DENSITY kg/m3	DESCRIPTION
BA	1	0.04	0.033	2840.	dol i ppv sv
BA	2	51.8	0.070	2840.	dol i ppv mv anhy
BA	3	0.05	0.010	2850.	dol i anhy
BA	4	4.26	0.081	2830.	dol i ppv sv
BA	5	0.02	0.033	2840.	dol i ppv anhy
BA	6	0.30	0.056	2840.	dol i ppv sv anhy
BA	7	1.30	0.115	2830.	dol i ppv sv mv anhy pyrbit
BA	8	5.13	0.095	2830.	dol i ppv sv anhy pyrbit
BA	9	317.	0.144	2830.	dol i ppv sv anhy pyrbit
BA	10A	17.7	0.117	2830.	dol i ppv sv mv
BA	10B	0.15	0.068	2840.	dol i ppv sv anhy
BA	11	0.05	0.043	2840.	dol i ppv sv anhy pyrbit
BA	12	3680.	0.178	2830.	dol i sv mv anhy pyrbit
BA	13	0.96	0.138	2830.	dol i ppv sv mv anhy pyrbit
BA	14	24.7	0.105	2840.	dol i ppv sv anhy pyrbit
PB	1	33.7	0.086	2830.	dol i ppv sv
PB	2	1.74	0.072	2840.	dol i ppv sv anhy
PB	3	5.37	0.079	2840.	dol i ppv sv anhy
PB	4	224.	0.096	2840.	dol i ppv sv
PB	5	134.	0.085	2840.	dol i ppv sv
PB	6	0.19	0.076	2840.	dol i ppv sv mv anhy
PB	7	26.8	0.068	2840.	dol i ppv mv anhy

1 - 1

CORE LABORATORIES

Company : MEMORIAL UNIVERSITY OF NEWFOUNDLAND
Well : MEMORIAL UNIVERSITY SELECTED SAMPLES

Field :
Formation : CATOCHE

File No.: 52131-92-0299
Date : 92-09-23

ANALYTICAL PROCEDURES AND QUALITY ASSURANCE

HANDLING & CLEANING

Core Transportation	:
Solvent	: TOLUENE
Extraction Equipment	: VAPOUR PHASE EXTRACTOR
Extraction Time	: 48 HOURS
Drying Equipment	: GRAVITY OVEN
Drying Time	: 48 HOURS
Drying Temperature	: 115 DEGREES C

ANALYSIS

Grain volume measured by Boyle's law in a matrix cup using He
Bulk volume measured by calipering
Permeabilities measured on 38.1 mm diameter drilled plugs

CORE ANALYSIS REPORT

FOR

MEMORIAL UNIVERSITY OF NEWFOUNDLAND

RND-1

NEWFOUNDLAND

CORE LABORATORIES

Company : MEMORIAL UNIVERSITY OF NEWFOUNDLAND
Well : RND-1
Location :
Province : NEWFOUNDLAND

Field :
Formation : CATOCHE
Coring Equip.: DIAMOND
Coring Fluid : WATER BASE MUD

File No.: 52131-92-0343
Date : 92-11-05
Analysts: LGM
Core Dia:

CORE ANALYSIS RESULTS

SAMPLE NUMBER	DEPTH	SAMPLE LENGTH	PERMEABILITY			POROSITY (HELIUM)	BULK DENSITY	GRAIN DENSITY	DESCRIPTION
			(MAXIMUM) Kair	(90 DEG) Kair	(VERTICAL) Kair				
	m	m	mD	mD	mD	fraction	kg/m3	kg/m3	
1	224.27	0.10	*	29.8	*	0.027	2750.	2830.	dol i ppv sv mv calc frac
2	230.48	0.13	26.3	0.19	0.76	0.046	2680.	2810.	dol i ppv sv mv calc frac
3	232.75	0.12	17.9	15.7	37.9	0.065	2630.	2810.	dol i ppv sv mv calc pyr vfrac
4	235.01	0.13	11.7	10.6	55.8	0.049	2680.	2810.	dol i ppv sv mv calc pyr vfrac
5	236.11	0.11	7.35	0.08	<.01	0.041	2680.	2800.	dol i ppv sv mv calc pyr
6	244.40	0.10	9.62	3.63	0.42	0.046	2670.	2800.	dol i ppv sv calc
7	245.45	0.14	10.1	4.07	0.07	0.042	2700.	2820.	dol i ppv sv mv calc pyr frac

1 - 1

CORE LABORATORIES

Company : MEMORIAL UNIVERSITY OF NEWFOUNDLAND
Well : RND-1

Field :
Formation : CATOCHE

File No.: 52131-92-0343
Date : 92-11-05

ANALYTICAL PROCEDURES AND QUALITY ASSURANCE

HANDLING & CLEANING

Core Transportation	:
Solvent	:
Extraction Equipment	:
Extraction Time	:
Drying Equipment	: FRICTIONAIRE OVEN
Drying Time	: 3 DAYS
Drying Temperature	: 60 DEGREES C

ANALYSIS

Grain volume measured by Boyle's Law in a modified U.S.B.M. porosimeter using He
Bulk volume measured by calipering

CORE LABORATORIES

CODE KEY - DESCRIPTIONS

A	(Prefix A) Plug taken from full diameter sample due to fracture or mud invasion to measure horizontal matrix permeability
ACA	Removed for advanced core analysis
anhy	Anhydrite
AST	Appears similar to
bit	Bitumen
bk	Break
bldr	Boulder
c	Coarse
calc	Calcite (calcareous)
carb	Carbonaceous
cbl	Cobble
CEC	Cation exchange capacity
cem	Cemented
cgl	Conglomerate
cht	Chert
coal	Coal/coal inclusion
dol	Dolomite
f	Fine
FD	Full diameter analysis including three directional permeabilities, porosity and densities
foss	Fossil (fossiliferous)
frac	Fracture (undifferentiated)
fri	Friable
glauc	Glauconite (glauconitic)
grnl	Granule
gyp	Gypsum
HSP	Humidity analysis of small plug sample at 60 degrees Celsius and 50 percent relative humidity
hfrac	Horizontal fracture
hal	Halite (salt)
i	Intercrystalline
incl	Inclusions
lam	Laminae (laminated)
lmy	Limy
ls	Limestone
lv	Large vug
m	Medium
mi	Mud invaded
mic	Micaceous
ML	Mineralog™
mv	Medium vug
NA	Not analyzed by request
NP	No permeability measurement possible due to poor sample quality
NR	Not received
ool	Oolitic
OB	Overburden sample (permeability and porosity measured at net overburden stress)
P	Preserved for future studies
pbl	Pebble
PET	Removed for petrographic analysis
ppv	Pinpoint vug
PSA	Particle size analysis
pyr	Pyrite (pyritic)
pyrbit	Pyrobitumen
RU	Rubble
SA	Sieve analysis
sdy	Sandy
SEM	Scanning electron microscope analysis
sh	Shale
shy	Moderately shaly (20% - 40%)
sid	Siderite
sltst	Siltstone
slty	Silty
SP	Small plug (sample drilled from core in maximum horizontal direction and parallel to bedding plane where possible) permeability, porosity and grain density are measured
ss	Sandstone
sshy	Slightly shaly (<20%)
sty	Stylolite (ic)
sulf	Sulphur
sv	Small vug
TEC	Thermal Extraction Chromatography to determine oil richness
TS	Thin section
uncons	Unconsolidated
vc	Very coarse
vfrac	Vertical fracture
vf	very fine
VIS	Viscosity of oil measured
VOB	Vertical overburden sample (vertical permeability measured at net overburden stress)
vshy	Very shaly (>40%)
VSP	Vertical small plug drilled from whole core to measure vertical permeability and occasionally porosity
vug	Vuggy (vuggular)
ws	Water sand
XRD	X-ray diffraction
*	Perm unavailable due to broken core

CORE ANALYSIS REPORT

FOR

MEMORIAL UNIVERSITY OF NEWFOUNDLAND

RND-2

NEWFOUNDLAND

CORE LABORATORIES

Company : MEMORIAL UNIVERSITY OF NEWFOUNDLAND
Well : RND-2
Location :
Province : NEWFOUNDLAND

Field :
Formation : CATOCHE
Coring Equip.: DIAMOND
Coring Fluid : WATER BASE MUD

File No.: 52131-92-0344
Date : 92-11-05
Analysts: LGM
Core Dia:

CORE ANALYSIS RESULTS

SAMPLE NUMBER	DEPTH	SAMPLE LENGTH	PERMEABILITY			POROSITY (HELIUM)	BULK DENSITY	GRAIN DENSITY	DESCRIPTION
	m	m	(MAXIMUM) Kair mD	(90 DEG) Kair mD	(VERTICAL) Kair mD	fraction	kg/m3	kg/m3	
1	230.26	0.12	305.	233.	0.37	0.071	2620.	2820.	dol f ppv sv mv calc frac
2	230.84	0.08	342.	47.3	1.32	0.071	2620.	2820.	dol f ppv sv mv calc
3	231.51	0.16	0.10	0.02	<.01	0.006	2800.	2820.	dol f ppv sv calc frac
4	235.20	0.13	0.16	0.03	0.32	0.028	2750.	2830.	dol f ppv sv mv calc vfrac
5	242.95	0.11	147.	0.09	0.06	0.043	2690.	2810.	dol f ppv sv mv calc
6	259.78	0.22	2.46	0.93	0.11	0.045	2690.	2820.	dol f ppv sv mv calc
7	260.27	0.17	125.	14.7	0.18	0.033	2720.	2810.	dol f ppv sv calc frac
8	261.05	0.13	2.67	0.13	<.01	0.025	2750.	2820.	dol f ppv sv mv calc frac
9	267.63	0.24	158.	140.	81.1	0.128	2440.	2810.	dol f ppv sv mv calc

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ANALYTICAL PROCEDURES AND QUALITY ASSURANCE

HANDLING & CLEANING

Core Transportation :
Solvent :
Extraction Equipment :
Extraction Time :
Drying Equipment : FRICTIONAIRE OVEN
Drying Time : 3 DAYS
Drying Temperature : 60 DEGREES C

ANALYSIS

Grain volume measured by Boyle's Law in a modified U.S.B.M. porosimeter using He
Bulk volume measured by calipering

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CODE KEY - DESCRIPTIONS

A	(Prefix A) Plug taken from full diameter sample due to fracture or mud invasion to measure horizontal matrix permeability
ACA	Removed for advanced core analysis
anhy	Anhydrite
AST	Appears similar to
bit	Bitumen
bk	Break
bldr	Boulder
c	Coarse
calc	Calcite (calcareous)
carb	Carbonaceous
cbl	Cobble
CEC	Cation exchange capacity
cem	Cemented
cgl	Conglomerate
cht	Chert
coal	Coal/coal inclusion
dol	Dolomite
f	Fine
FD	Full diameter analysis including three directional permeabilities, porosity and densities
foss	Fossil (fossiliferous)
frac	Fracture (undifferentiated)
fri	Friable
glauc	Glauconite (glauconitic)
grnl	Granule
gyp	Gypsum
HSP	Humidity analysis of small plug sample at 60 degrees Celsius and 50 percent relative humidity
hfrac	Horizontal fracture
hal	Halite (salt)
I	Intercrystalline
incl	Inclusions
lam	Laminae (laminated)
lmy	Limy
ls	Limestone
lv	Large vug
m	Medium
mi	Mud invaded
mic	Micaceous
ML	Mineralog™
mv	Medium vug
NA	Not analyzed by request
NP	No permeability measurement possible due to poor sample quality
NR	Not received
ool	Oolitic
OB	Overburden sample (permeability and porosity measured at net overburden stress)
P	Preserved for future studies
pbl	Pebble
PET	Removed for petrographic analysis
ppv	Pinpoint vug
PSA	Particle size analysis
pyr	Pyrite (pyritic)
pyrbit	Pyrobitumen
RU	Rubble
SA	Sieve analysis
sdy	Sandy
SEM	Scanning electron microscope analysis
sh	Shale
shy	Moderately shaly (20% - 40%)
sid	Siderite
sltst	Siltstone
slty	Silty
SP	Small plug (sample drilled from core in maximum horizontal direction and parallel to bedding plane where possible) permeability, porosity and grain density are measured
ss	Sandstone
sshy	Slightly shaly (<20%)
sty	Stylolite (ic)
sulf	Sulphur
sv	Small vug
TEC	Thermal Extraction Chromatography to determine oil richness
TS	Thin section
uncons	Unconsolidated
vc	Very coarse
vfrac	Vertical fracture
vf	very fine
VIS	Viscosity of oil measured
VOB	Vertical overburden sample (vertical permeability measured at net overburden stress)
vshy	Very shaly (>40%)
VSP	Vertical small plug drilled from whole core to measure vertical permeability and occasionally porosity
vug	Vuggy (vuggular)
ws	Water sand
XRD	X-ray diffraction
*	Perm unavailable due to broken core