GEOLOGICA ULTRAIECTINA

Mededelingen van het
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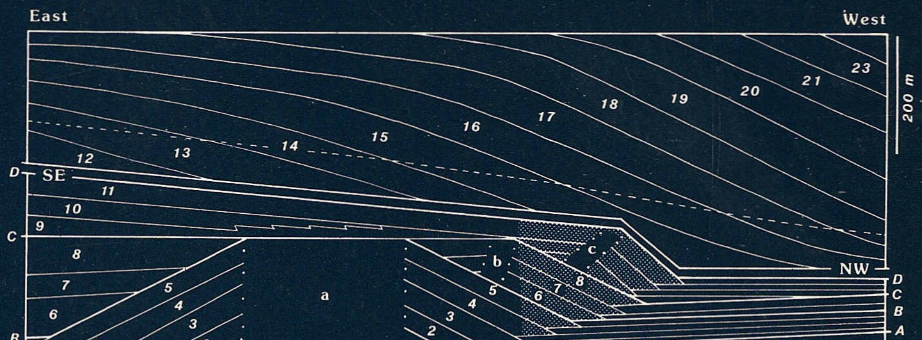
Rijksuniversiteit te Utrecht

No. 63

SEDIMENTOLOGY AND FACIES ANALYSIS OF DEVONIAN ROCKS, SOUTHERN DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES, CANADA



Nico C. Meijer Drees

ERRATUM:

Page 34, Figure 15, legend, evaporite facies: (Camsell **Fm and equivalents.**

Page 47, Ommit lines 1 to 7. At base of page add:

along the southwest flank of Tathlina Uplift.

The shaly and sandy beds which overlie the crest of Tathlina Uplift appear to be continuous with the Ebbutt Member of the Chinchaga Formation and are indicated as a separate unit on Figure 37.

Lithology

In drill cuttings the La Loche Formation southeast of Kakisa Lake includes friable, fine-to

Page 122, Figure 47, insert: **Steen Member.**

Page 126, Figure 48, insert: **Steen Member.**

Page 135, line 17 reads: ... onlap of beds 20 to 23 against surface B.

line 22 reads: The boundary between stratigraphic sequences 3 and 4......

Page 136, line 7 reads: The boundary between sequences 4 and 5 ......

Page 147, last line reads: ..(see Plate XV c,gand f) ..

Page 159, Plate III: Reverse photographs a and b.

Page 177, Plate XII, Photograph a: One arrow should point to mottled area 1 cm above a.

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SEDIMENTOLOGY AND FACIES ANALYSIS OF DEVONIAN ROCKS,

SOUTHERN DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES, CANADA

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Sedimentology and facies analysis of Devonian rocks, southern District of Mackenzie, Northwest Territories, Canada

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Sedimentologie en facies analyse van het Devoon, District van Mackenzie zuid, Northwest Territories, Canada

(met een samenvatting in het Nederlands)

PROEFSCHRIFT

Ter verkrijging van de graad van Doctor aan
de Rijksuniversiteit te Utrecht op gezag van
de Rector Magnificus Prof. Dr. J.A. van Ginkel
volgens besluit van het College van Dekanen
in het openbaar te verdedigen op
Vrijdag 8 December 1989,
des namiddags te 14.30 uur.

DOOR

Nico Cornelis Meijer Drees

geboren op 16 Maart 1937 te Bogor, Indonesia.

PROMOTORES: PROF. DR. S.D. NIO

PROF. DR. W. SCHLAGER

This paper will be published as volume 63 (1989) in Geologica Ultraiectina.

Ter herinnering aan mijn vaders

H.E. Steutel

A. van Royen

E. Meijer Drees

LIST OF CONTENTS

SUMMARY

The Devonian rock succession in the southern part of the District of Mackenzie consists of interbedded evaporites and carbonates, fossiliferous carbonates and shales.

In the study area the Devonian succession unconformably overlies Lower Paleozoic or Precambrian strata and thins in a northeastward direction because of truncation below the pre-Cretaceous unconformity. The Lower and lower Middle Devonian parts of the succession have a restricted distribution and onlap Tathlina Uplift, a pre-Devonian paleotopographic high area situated in the southern part of the Great Slave Plain. They include detrital, carbonate and evaporitic facies. The upper Middle and Upper Devonian parts of the succession are widely distributed. They consist of carbonates and shales.

The Devonian succession includes seven stratigraphic sequences separated by slight angular unconformities or depositional hiati. Sequence 1 includes Lower Devonian evaporites and carbonates of the Camsell and Tsetso formations and their equivalents. The sequence accumulated in Root Basin, a tectonic depression along a shelf edge that formed an embayment northwest of an ancient landmass situated in the Great Slave Plain.

The Middle Devonian succession can be subdivided into five stratigraphic sequences, each including fondo-, clino- and undathem deposits. The two older sequences of the Middle Devonian succession (including in sequence 2, the Sombre, Arnica, Fort Norman and Mirage Point formations and in sequence 3 the Funeral and Landry formations) accumulated during periods of relative sea level rise on the northern flank of Tathlina Uplift. The three younger sequences are part of the Elk Point Group of Alberta and accumulated in the northern part of the Elk Point Basin during subsequent relative rises in sea level. Sequence 4 includes the Headless, Nahanni, Hume and Lonely Bay formations and the Horn Plateau and Pine Point reef mounds. Sequence 5 consists of the Pine Point Assemblage, the lower part of the Undivided map unit and the Muskeg Formation of Alberta. Sequence 6 comprises the upper part of the Undivided map unit, and the Watt Mountain, Fort Vermilion and Slave Point formations.

Middle and Upper Devonian strata are included in sequence 7. Only the lower part is preserved in the District of Mackenzie. It includes the Spence River, Fort Simpson, Hay River formations and the formations of the Grumbler Group.

Information from regional and structural geology suggests that the Devonian sediments and evaporites accumulated in slowly subsiding embayments. A comparison between the textures and sedimentary structures of Recent sediments and Devonian rocks indicates that the Devonian rocks have undergone many diagenetic changes. It is speculated that these changes were brought about by burial during the Late Paleozoic Era; by the episodes of uplift, erosion, subsidence and renewed burial during the Mesozoic and Cenozoic Eras; and by the effects of the Laramide Orogeny.

SAMENVATTING

Het Devoon in het zuidelijke deel van het Mackenzie District bestaat uit een afwisseling van evaporieten en karbonaten, biogene karbonaten en schalies.

De Devonische opeenvolging in het studie gebied ligt diskordant op oudere gesteenten die toebehoren tot het Paleozoicum of het Precambrium en wordt dunner naar het oosten vanwege de diskordantie onder het Krijt. Het Onder Devoon en onderste deel van het Midden Devoon omringen Tathlina uplift, een massief dat zich bevindt in het zuidelijke deel van de Great Slave Plain. Deze lagen bestaan uit een zandige gesteenten, karbonaten en evaporieten. Het bovenste deel van het Midden Devoon en het Boven Devoon zijn wijd verbreid en overlappen het massief. Deze lagen bestaan uit karbonaten en schalies.

Het Devoon kan ook worden onderverdeeld in zeven stratigraphische eenheden (sequenties) die van elkaar zijn gescheiden door flauwe hoek diskordanties of sedimentaire hiati. Sequenti 1 omvat het Onder Devoon, inclusief de evaporieten en karbonaten van de Camsell en Tsetso formaties. Deze formaties vormden zich in Root Basin, een tektonische depressie gelegen aan de rand van het vroegere continentale plat, dat een sedimentair bekken vormde ten noordwesten van het voornoemde massief in the Great Slave Plain.

De sedimentaire gesteenten van het Midden Devoon kunnen worden onderverdeeld in vijf sequenties, welke, in het studie gebied, ieder fondo-, clino- en undathem afzettingen omvatten. De twee oudere sequenties van het Midden Devoon (sequentie 2 inclusief de Sombre, Arnica, Fort Norman en Mirage Point formaties en sequentie 3 met de Funeral en Landry formaties) werden afgezet gedurende perioden van relatieve zee spiegel stijgingen, langs de westelijke en noordelijke flank van Tathlina Arch, dat een eiland vormde in het zuidelijke deel van de Great Slave Plain. De drie jongere sequenties overlappen Tathlina Arch naar het zuiden en behoren tot de Elk Point Group van Alberta. Deze formaties werden afgezet in het noordelijke deel van het Elk Point Basin ten gevolge van verdere relatieve stijgingen van de zee spiegel. Sequentie 4 omvat de Headless, Nahanni, Hume en Lonely Bay formaties en de Horn Plateau en Pine Pont rif afzettingen. Sequentie 5 bestaat uit de Pine Point Assemblage, het onderste deel van de "Undivided map unit" en de Muskeg formatie van Alberta, Sequentie 6 omvat het bovenste deel van de "Undivided map unit" en de Watt Mountain, Fort Vermilion en Slave Point formaties.

De sedimentaire gesteenten van het Midden en Boven Devoon behoren tot sequentie 7. In het Mackenzie District is alleen het onderste deel van deze sequentie bewaard gebleven. Het omvat de Spence River, Fort Simpson, Hay River formaties en de formaties van de Grumbler Group.

Geologische informatie van regionale en structurele aard duidt erop dat de Devonische sedimenten en evaporieten werden afgezet in langzaam dalende epeirische bekkens. Een vergelijking tussen de texturen en sedimentaire strukturen van recente sedimenten en die van de Devonische gesteenten toont aan dat de Devonische gesteenten veranderingen hebben ondergaan van diagenetische aard. Deze veranderingen zijn waarschijnlijk het gevolg van de begraving onder jongere Paleozoische sedimenten, van de erop volgende perioden van tektonische opheffing en erosie, van de hernieuwde daling en begraving onder Mesozoische en Cenozoische sedimenten, en het gevolg van de Laramide gebergte vorming.

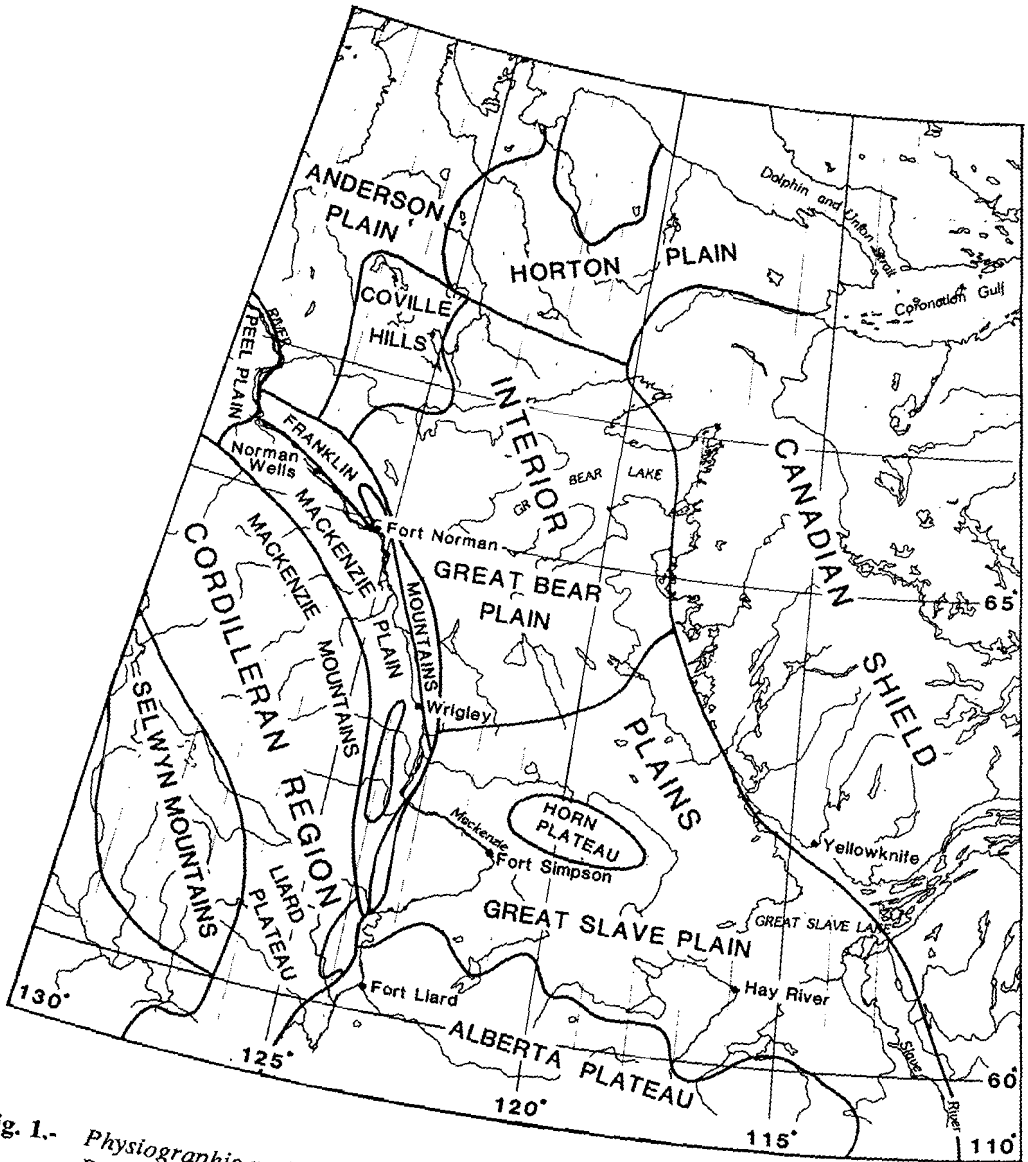


Fig. 1.- *Physiographic regions, District of Mackenzie, Northwest Territoritories (after Bostock, in Douglas et al., 1970).*

CHAPTER I: INTRODUCTION

Location

The report describes the subsurface geology of the Devonian succession in the southern part of District Mackenzie of the Northwest Territories, between the latitudes 60 and 66 degrees north. It includes the region situated between the Mackenzie Mountains in the west and the Canadian Shield in the east that is part of the Great Slave and Great Bear plains.

Previous work

The Geological Survey of Canada initiated a large scale mapping program in 1957 named Operation Mackenzie. During this program the Devonian rock succession in the Great Slave Plain was described, using surface and subsurface information. The results of this work were compiled by Douglas (1959) and Douglas and Norris (1960a). A.W. Norris (1965) described the stratigraphy of the Devonian and older Paleozoic rocks of the Great Slave Lake region and included in his discussion all work previously done in that area. The subsurface geology as known from available boreholes in the southern part of the Great Slave Plain were discussed in reports by Belyea and McLaren (1962) and Belyea and Norris (1962). The eastern part of the southern Mackenzie Mountains was also mapped during the operation and is described in four reports by Douglas and Norris (1960a, 1960b, 1961 and 1963).

The discovery of an isolated Middle Devonian reef mound near Fawn Lake resulted in a report by McLaren and Norris (1964). The reef mound was studied in detail with the aid of five core holes by Vopni and Lerbekmo (1972). It was quickly realized that reef mounds similar to the one at Fawn Lake existed elsewhere in the subsurface of the Great Slave Plain. A number of exploration wells were drilled to test these reef mounds and other prospective horizons for the presence of hydrocarbons. The geological knowledge obtained from these new boreholes was summarized and integrated with the regional geology of the area by Law (1971) and by de Wit et al. (1973). Belyea (1971) studied the Devonian succession in the subsurface of northern Alberta and in the southern District of Mackenzie, and described the geologic history of the Tathlina Uplift, a paleotopographic arch of pre-Devonian and Devonian age that is cut by steeply dipping, normal faults.

New faunal evidence related to the position of the boundary between the Middle and Upper Devonian in the subsurface of the Great Slave Plain was given by Pollock (in Fuller and Pollock, 1972). This evidence verified the observations made earlier by Braun (in Norford et al. 1970) that part of the Givetian Stage is is not represented in the subsurface.

In 1971 the Geological Survey started the Basin Analysis Program to evaluate the petroleum potential of the Northwest Territories. During the years 1971 to 1977 the Paleozoic rock units in the subsurface of the Great Slave Lake, Horn River, Fort Liard, Sibbeston Lake and Camsell Bend map areas were mapped and studied from borehole logs, samples and cores. This resulted in reports on the geology of the Lower Paleozoic strata (Meijer Drees, 1975), the Upper Devonian Hay River Formation (Williams, 1977a) and the Devonian succession in the Dahadinni M-43A well (Meijer Drees, 1980).

<table>
<tr><td colspan="6">Allochthonous sediments</td><td colspan="3">Autochthonous sediments</td></tr>
<tr><td colspan="4">containing less than 10 percent very coarse (larger than 1 mm) particles</td><td colspan="2">containing more than 10 percent very coarse particles</td><td rowspan="4">original components bound by organisms which acted as a baffle</td><td rowspan="4">original components bound by organisms which bind and encrust</td><td rowspan="4">original components bound by organisms which build a rigid frame work</td></tr>
<tr><td colspan="3">containing mud matrix composed of particles smaller than 0.03mm</td><td>no mud matrix</td><td colspan="2"></td></tr>
<tr><td colspan="2">coarse particles are supported by a mud matrix</td><td colspan="2" rowspan="2">the coarse particles are not supported by a mud matrix</td><td rowspan="2">the very coarse particles are supported by a matrix</td><td rowspan="2">the very coarse particles are not supported by a matrix</td></tr>
<tr><td>less than 10 percent particles larger than 0.1 mm</td><td>more than 10 percent particles larger than 0.1 mm</td></tr>
<tr><td>mud-stone</td><td>wacke-stone</td><td>pack-stone</td><td>grain-stone</td><td>float-stone</td><td>rud-stone</td><td>baffle-stone</td><td>bind-stone</td><td>frame-stone</td></tr>
</table>

Fig. 2.- *Classification of sedimentary rocks (modified from Embry and Klovan, 1971).*

<table>
<tr><td>Deposit consist of macroscopic anhydrite crystals or crystal aggregates in a non-anhydritic matrix</td><td colspan="3">Deposit consist of distinct nodules or nodular beds in a non anhydritic matrix</td><td colspan="3">Deposit is a relatively pure, laminated or bedded anhydrite without nodular or mosaic structures</td></tr>
<tr><td>CRYSTALLOTOPIC</td><td colspan="3">NODULAR</td><td colspan="3">BEDDED</td></tr>
<tr><td rowspan="2"></td><td>Nodules or beds are separated</td><td>Nodules or beds are partly separated</td><td>Matrix is almost absent</td><td>Micro to fine blocky crystals</td><td>Fine to coarse, elongate crystals are not aligned</td><td>Fine to coarse, elongate crystals are aligned</td></tr>
<tr><td>Nodular or bedded nodular-anhydrite</td><td>Nodular mosaic or bedded nodular-mosaic anhydrite</td><td>Massive mosaic or massive nodular-mosaic anhydrite</td><td>Subfelted anhydrite</td><td>Felted anhydrite</td><td>Aligned-felted anhydrite</td></tr>
</table>

Fig. 3.- *Classification of anhydritic rocks (modified from Maiklem et al., 1969).*

Present work

The maps, correlations and lithological descriptions in this report are based on the study of borehole logs, cores and samples of 290 non- confidential exploration wells stored at the Institute of Sedimentary and Petroleum Geology, Calgary. In the northern part of the study area, indicated on Figure 1 (the southern part of the Great Bear Plain), well control is very sparse and the Devonian succession thins northward because of erosion below the pre-Cretaceous unconformity. Correlations between the Devonian succession of the study area and the equivalents in the Norman Wells area described by Tassonyi (1969) is thus hampered by a lack of information. However, the Devonian succession in the study area is continuous with the Devonian strata in northern Alberta and many formations defined in Alberta extend northwards into the subsurface of the Great Slave Plain. Subsurface correlations indicate that the Devonian rock succession in the study area thickens in a westerly direction and that itincludes several major facies changes. The facies changes are schematically shown on several east-west and southeast-northwest oriented stratigraphical cross-sections. The cross-sections are also usefull to determine the relative stratigraphic positions of available borehole cores.

Lithological descriptions of the formations discussed in this report are based on information obtained from borehole cores. A total of 2450 m was described. Core samples were slabbed, polished and examined with a binocular microscope. A relatively small number of thin sections were made for detailed observations. Drill cuttings from 78 wells shown on cross- sections were examined to complete the study.

Because a regional stratigraphic framework relies on relative age determinations an effort was made to collect fossils wherever possible. Eighty five fossil samples were submitted to A.E.H. Pedder, A.W. Norris, and T.T. Uyeno for identification and 65 core samples were processed to obtain conodonts.

Classification of sedimentary rocks

The bulk of the Devonian rocks discussed in this report belong to the sedimentary and evaporitic rock groups. Sedimentary rocks are lithified accumulations of particles, such as rock and mineral fragments, which originated from weathering and erosion of older rocks and were transported over some distance in air or water. Evaporitic rocks are lithified mineral deposits which precipitated by evaporation from mineral rich water.

Sedimentary and evaporitic rocks are usually composed of two or more minerals bound together by cement. The cement is thought to have been precipitated from mineral rich pore-water. Some sedimentary rocks are thus cemented by evaporitic minerals, such as anhydrite, gypsum or halite. These evaporitic minerals commonly have replaced some of the original sedimentary minerals as well. Such rocks composed of a mixture of sedimentary and evaporitic minerals belong to a separate class of diagenetically altered rocks.

In this report the sedimentary, evaporitic and diagenetically altered rocks are not rigidly separated but a descriptive classification is used, based on the mineralogical composition of the main constituents.

Silicates: The Devonian rocks in the study area composed of silicates and clay minerals are classified and named according to grain size, using the scale of Wentworth (1922). The names claystone, shale, marl, siltstone, sandstone and conglomerate are used to describe these rocks.

Carbonates: Carbonates were previously classified according to grain size and for limestone names such as calcilutite, calcisiltite, calcarenite and calcirudite were introduced. During the past two decades it has become apparent that most calcareous grains originated locally from the disintegration of calcareous plant and animal skeletons. Some carbonates are almost entirely composed of the remains of colonial, reef building organisms. Other carbonates contain a lot of material in the form of cement that originated as a chemical precipitate. In modern classifications the subdivision according to grain or crystal size is relegated to a secondary level and emphasis is put on the sedimentary fabric (see Folk, 1959; Dunham, 1962).

The classification proposed by Embry and Klovan (1971) is used here. Carbonates are subdivided in allochthonous and autochthonous sediments and the allochthonous carbonates are further subdivided in mud supported and grain supported sediments (see Fig. 2). All Devonian carbonates present in the report area are more or less recrystallized and in some instances the grain size of the original sediment can only be inferred. The fine sedimentary structures are often obliterated by the process of recrystallization and dolomitization it is sometimes difficult or impossible to use a classification based on the original sedimentary textures. Such recrystallized rocks are thus described as being micro, very finely, finely, medium, coarsely or very coarsely crystalline.

Sulfates: Devonian rocks largely composed of anhydrite are divided into three groups according to the classification proposed in Figure 3. Crystallotopic anhydrite consists of macroscopic, blocky crystals or crystal like aggregates, which often resemble gypsum crystals. Nodular anhydrite consists of massive, nodular aggregates of fine, needle-like crystals. Bedded anhydrite resembles a laminated sedimentary rock and commonly includes remnants of carbonate particles. The first two groups have a diagenetic origin and these rocks are named according to the classification proposed by Maiklem et al. (1969). The third group has a sedimentary origin and can be classified using the subdivision of Embry and Klovan (1971).

Chlorides: The rocks composed of halite are thought to represent recrystallized deposits which accumulated at or near the original sediment-water interface by precipitation. Most Devonian salt beds are impure and are mixed with siliceous clay, dolomite and anhydrite. Some impure halites may be classified as sedimentary rocks if there is evidence that the halite originated as a secondary mineral or as a cement.

Terms used in this report: In order to avoid confusion, the use of the terms anhydrite and dolomite is restricted to designate the minerals. Rocks principally composed of calcite or aragonite are named limestone, those composed principally of dolomite are named dolostone. For gypsiferous rocks and rocks composed of halite the terms alabaster and rocksalt are usefull. Rocks principally composed of anhydrite do not have a common name.

The terms used to describe the sedimentary structures, bedforms and particles in carbonates and sulfates have been reviewed by Bathurst (1975). The description of the various types of stratification is based on the classification of C.V.Campbell (1967).

CHAPTER II: PHYSIOGRAPHY

General setting

The report area includes the eastern part of the Cordilleran and the western part of the Interior Plains regions of the District of Mackenzie, Canada. The Mackenzie and Franklin Mountains in the west are part of the Cordilleran region, the Great Slave and Great Bear Plains are part of the Interior Plains. The Interior Plains are bordered in the east by the Canadian Shield (see Fig. 1).

The entire area is drained by the Mackenzie River and its tributaries. The most important tributaries are the Slave, Liard, Willow Lake, North Nahanni, Root, Redstone, Keele, Blackwater and Great Bear rivers.

Interior Plains

The Interior Plains include flat lying lowlands and gently rolling plateaux or hills (see Plate Ia). Bostock (1970) subdivided the northern Interior Plains region into the Colville Hills and the Great Slave, Great Bear, Horton and Anderson plains. Important plateaux are Cameron Hills, Horn Plateau, Martin Hills, Ebbutt Hills and Cartridge Mountain.

The hills and plateaux are erosional remnants of flat lying rocks of Cretaceous age. In the plateaux and hills elevations range between 600 and 790 m above sea level. In the lowlands the Cretaceous cover has been eroded and here flat lying to gently dipping rocks of Paleozoic age occur below a relatively thin veneer of glacial or fluviatile deposits. Elevations in the lowlands range between 150 and 300 m above sea level. Local relief is generally due to glacial landforms.

Cordilleran region

The Cordilleran region in the west includes the Franklin and Mackenzie mountains. The Franklin Mountains consist of discontinuous north-south trending ranges and are separated from the Mackenzie Mountains by a low intermontane area, named the Mackenzie Plain (see Fig. 1). The Nahanni and Camsell Ranges are west- dipping homoclinal ridges underlain by thrust-folds. The McConnell Range is an asymmetrical, north tending anticline underlain by thrust faults, complicated by faults in the crestal region and broken along strike by transverse faults (Douglas and Norris, 1963).

Elevations in the eastern part of the cordilleran region range between 150 and 1500 m above sea level.

Surfacial geology

Great Slave and southern Great Bear Plain are covered by glacial deposits of Pleistocene age and fluviatile or lacustrine deposits of Holocene age. Much of the area that is not covered byHolocene deposits has the typical hummocky topography of a ground moraine (Craig, 1965). Relief is generally less than 3 m except in those areaswhere the ground moraine is interrupted by glacial ridges. TheDevonian outcrop area southwest of the Canadian Shield includes many features related to karst. These include sinkholes, sinking streams, intermittent sinkhole ponds or lakes and large depressions (see van Everdingen, 1981).

Bedrock geology

The Canadian Shield consists of Precambrian igneous and metamorphic rocks. In the subsurface of the Interior Plains its westward continuation is erosionally overlain by sedimentary rocks of Paleozoic age. The pre-Paleozoic, erosional surface has moderate paleotopographic relief and dips gently to the southwest. The overlying sedimentary rocks also dip to the southwest and gradually increase in thickness toward the mountain front from about 305 to 1219 m (see Figs. 4 and 5).

The Paleozoic succession outcrops sporadically in the eastern part of the Interior Plains, along the shores of GreatSlave Lake and Lac La Martre. In the central part of the Interior Plains scattered outcrops occur in the valleys of the smaller rivers. Well exposed sections of thePaleozoic succession are present in the Cordilleran region.

The Paleozoic rock succession consists of two parts. The lower part ranges in age from Early Cambrian to Silurian and includes sandstone, shale, anhydrite and dolostone. The Cambrian to Silurian strata are absent in the southern part of the Great Slave Plain. The upper part of the Paleozoic succession is of Devonian age and includes evaporites, carbonates and shales. The upper Paleozoic succession unconformably overlies the lower part and directly overlies Precambrian granite in the southern part of the Mackenzie District.

In the more elevated parts of the Great Slave Plain and in the southern part of the Great Bear Plain the upper Paleozoic succession is unconformably overlain by flat lying or gently dipping shale and sandstone of Cretaceous age (Stott, 1960). In the topographically low areas the Cretaceous rocks are missing and the upper Paleozoic strata are deeply eroded and overlain by Pleistocene deposits.

CHAPTER III: STRUCTURAL GEOLOGY

The Great Slave and Great Bear Plains are part of the Interior Platform, a westerly to southwesterly dipping, northeastward thinning wedge, composed of relatively undisturbed, sedimentary rocks (Douglas et al., 1970). The Interior Platform is flanked in the west by the Cordilleran Orogen and in the east by the Canadian Shield. It erosionally overlies a Precambrian igneous and metamorphic terain which is the extension of the Canadian Shield.

The general wedge shape of the Interior Platform is evident on cross-section (see Fig. 5, sections A, B, C, D). The general homoclinal dip to the west and southwest is shown on structural maps (Figs. 6 and 7). The cross-sections and maps indicate that the homocline is locally modified by the presence of tectonic uplifts, folds and faults, relief on regional erosional unconformities, collapse structures due to dissolution of salt and anomalies due to differential compaction over buried Precambrian hills.

The major tectonic structures are indicated on the structural contour maps of the pre-Devonian surface (Fig. 6) and the upper surface of the Middle Devonian carbonate succession (Fig. 7). The regional dip in the southern part of the Great Slave Plain is to the southwest. In the northwestern part of the Great Slave Plain and in the southern part of the Great Bear Plain the dip is to the west and increases dramatically just east of the Nahanni and McConnell Ranges.

Tectonic uplifts and faults

The configuration of the contour lines on Figure 6 suggests that there is a large southwestward trending arch between Lac La Martre and Martin Hills. It is proposed to name this arch La Martre Arch. On structural cross-section F-F' of Figure 5, the arch is visible on the pre-Devonian surface and on all the formational boundaries in the Devonian succession.

The presence of La Martre Arch can also be inferred from the outcrop and subcrop pattern of the Upper Devonian rocks in the Great Slave Plain (see Fig. 4). Mississippian rocks are present in the subsurface below the pre-Cretaceous unconformity in the Trout Lake region flanking the southwestern part of the arch. They are also present in a position on the northwestern flank of the arch in the Yohin Syncline just west of the Nahanni Range (see Fig. 4). Mississippian and younger Paleozoic rocks have been removed by pre-Cretaceous erosion from the crestal part of La Martre Arch. This situation suggests that the arch was formed and eroded after the Devonian and before the Cretaceous rocks were deposited.

Liard High (law, 1971), a north trending structural and pre-Devonian paleotopographic high located just southwest of Fort Simpson, forms the crestal part of La Martre Arch on Figure 6 and 7. On the pre-Devonian surface it is about 750 m high (see Fig. 6). On cross-section C-C' (Fig. 5) the pre-Devonian high is overlain by Devonian rocks which include a relatively thin section of pre-Headless strata. The configuration suggests that the basal Devonian beds abutt a pre-excisting paleotopographic high and that the overlying beds are truncated by an erosional unconformity below the Headless Formation.

The 600 m structural contourline on Figure 6 outlines three closures north of Tathlina Lake and east of Kakisa Lake that represent local pre- Devonian high areas or fault controlled uplifts. The interpretation of Sikabonyi and Rodgers (1959), Belyea (1971) and Williams (1977b) is that they are uplifts controlled by northeasterly trending, subvertical faults. The shape of the closures

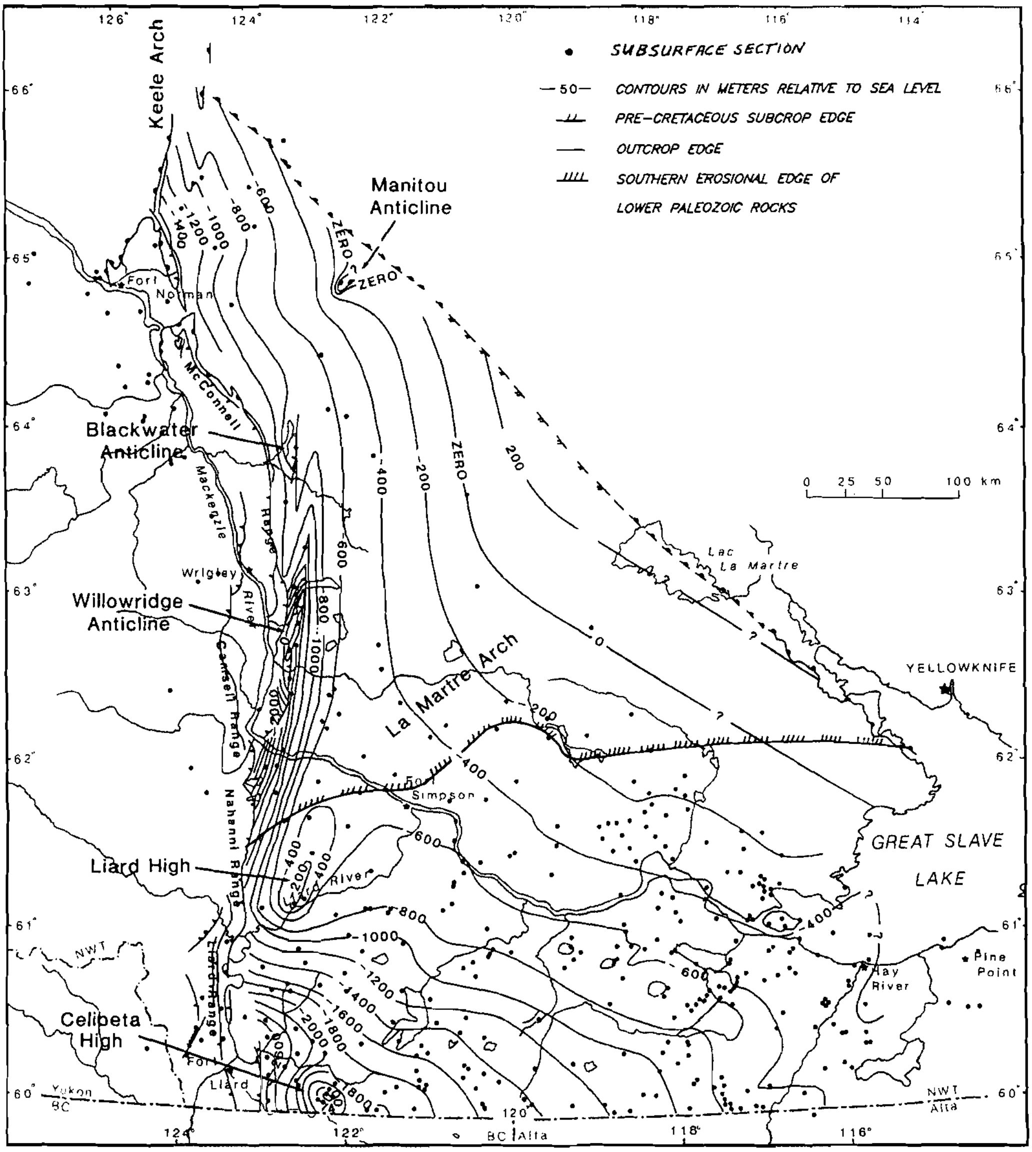


Fig. 6.- *Structural contour map of pre-Devonian surface.*

suggests that northwesterly trending faults are also present, but without additional information one is not sure. The most westerly high was tested by the Redknife J-21 well (see cross-section B-B', Fig. 5). It appears to be a pre-Devonian structure. The high structures penetrated by the Redknife River No. 2 E-33 well on the same cross section and the Foetus Lake No 1 D-06 well on cross-section A-A' of Figure 5 may also represent fault controlled uplifts.

In the area northeast of Fort Norman and south of Smith Arm (Great Bear Lake) Siluro-

Ordovician beds are folded into a north-south trending anticline. This anticline may be related to the Good Hope Ridge anticline farther north (see Cook and Aitken, 1971). It may extend southward into the high structure that is present in the subsurface between two wells in the Whitefish River area (see Fig. 6).

In the area south of Fort Norman the Devonian succession was removed by pre-Cretaceouserosion along the crest of Keele Arch, a north-south trending fault controlled uplift which partly coincides with the southeastern part of Norman Wells High (see Cook, 1975 and Williams, 1975). In the Shell Keele River L-04 well (lat. 64 23'37"N, long. 125 01'43"W) Cretaceous beds overlie Middle Cambrian strata and in the Aquitaine Old Fort Point E-30 well (lat. 64 49'26"N, long. 124 50'16"W) Cretaceous rocks overlie Cambrian rocks.

Information from the Aquitaine Brackett Lake C-21 well (lat. 65 10'02"N, long. 125 05'08"W) indicates that the Fort Norman Formation is absent at this location and that the Arnica Formation erosionally overlies equivalents of the Tsetso Formation. This suggests that parts of the Keele Arch may have been emergent at the end of early Devonian.

Celibeta High is a relatively small but prominent structural anomaly in which Cretaceous rocks are deformed (Williams, 1977b). This Laramide uplift is located in the Liard River area and stands about 1300 m above the regional trend as shown on Figures 6 and 7.

The Willow Ridge anticline (Douglas and Norris, 1961), a north-south trending Laramide structure east of the McConnell Range, coincides with a weak, pre-Devonian paleotopographic high. Subsurface information suggests that the anticline is underlain by a thrust fault. It is assumed that this thrust fault comes to the surface east of the anticline and that the paleotopographic high, being more rigid than the overlying sedimentary rocks during the eastward push of the Laramide Orogeny, was instrumental in the development of the thrust fault.

A thrust fault in the Blackwater Lake G-52 well (Law, 1971) suggests the presence of a faulted anticline in the Blackwater Lake area. Little is known about this structure because it is buried below Cretaceous strata.

Balkwill (1971) mapped a tight anticline in Siluro- Ordovician strata on Manitou Island, near the southern shore of Keith Arm, Great Bear Lake. This structure is schematically drawn on Figure 6.

Epeirogenic events

The analysis of the sedimentary and facies pattern in the central part of the Great Slave Plain, given in this report, indicates that there is a regional erosional unconformity below the early Middle Devonian Headless Formation. The central part of the Great Slave Plain region was emergent during a period of time in the early Middle Devonian. Figure 12 gives an inverted image of the sub-Headless topography in the Willow Lake Embayment. It clearly outlines the previously described paleotopographic highs and demonstrates that Tathlina Uplift (Belyea, 1971) is the most prominent pre-Devonian paleotopographic high in the Great Slave Plain. The information from this map and the structural cross-sections suggests that the amount of sub-Headless erosion was minor (in the order of 0 to 30 m).

Evidence of an minor erosional event below the Watt Mountain Formation in the area east of Kakisa Lake suggests that the crestal part of Tathlina Uplift was emergent during a period of time somewhere in the late Middle Devonian. The portion of section which was locally removed probably varies between 0 and 25 m.

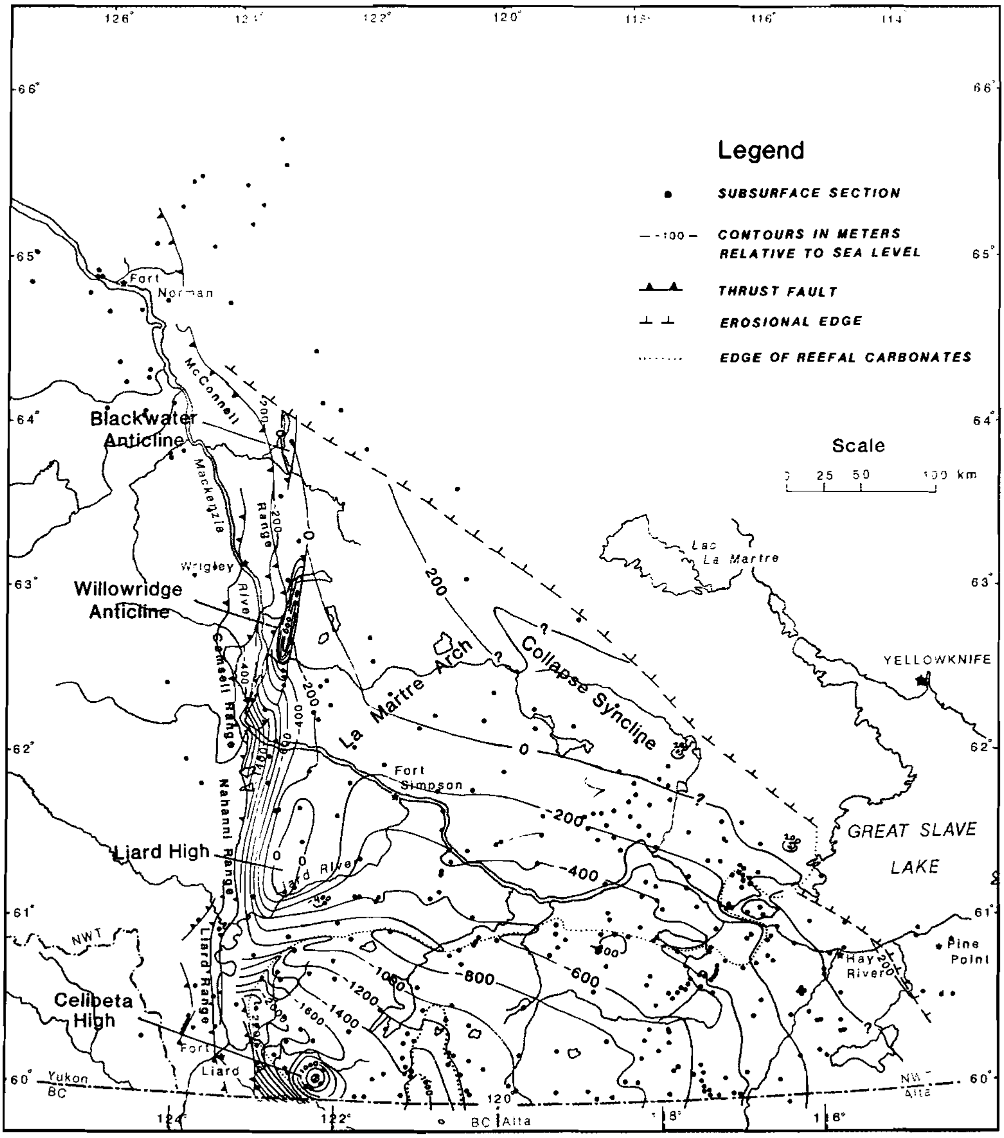


Fig. 7.- *Structural contour map of Middle Devonian carbonates.*

CHAPTER IV: STRATIGRAPHY

In the District of Mackenzie the upper Paleozoic succession (the Kaskaskia sequence of Sloss, 1963) consists of Devonian and Mississippian strata. It unconformably overlies either lower Paleozoic or Precambrian rocks. The unconformity is believed to be of pre-Devonian age. It is an irregular, paleotopographic surface and the more elevated parts of this surface remained emergent during the deposition of the lower Devonian rocks.

In the southern part of the study area Devonian beds overlie Precambrian igneous and metamorphic rocks or sedimentary rocks of Proterozoic age. Here the base of the Devonian is easily established. In the northern part of the Great Slave Plain Devonian beds overlie sedimentary rocks of Cambrian to Silurian age and here the base of the succession is not easily established. Some of the Pre-Devonian beds include lithologies that resemble the lithology of the Devonian beds and detailed geological work was needed to establish the depth of the pre-Devonian unconformity in the subsurface.

The Upper Paleozoic succession in the subsurface of the Interior Plains is overlain with an erosional contact by strata of Cretaceous or Pleistocene age. In the northern part of the Interior Plains the upper part of the succession is eroded and only strata of Devonian age are present. In the southwestern part strata of Mississippian age are preserved and here the Devonian succession is complete. Complete sections of the Devonian are also present in the Cordilleran region south and west of the Nahanni Range.

The Devonian succession is readily subdivided into two parts. The lower part includes carbonates and evaporites of Early and Middle Devonian age, the upper part consists of shale and locally includes carbonates at the top. It is of Late Devonian age. The boundary between the two parts is fairly sharp but occurs at different levels in the succession. Paleontological information suggests that this boundary more or less coincides with the recently proposed boundary between the Middle and Upper Devonian stages.

The succession of the Lower and Middle Devonian carbonates and evaporites in the study area is impossible to subdivide into laterally consistent regional map units because (1) the succession onlaps a paleotopographic surface of significant relief, (2) it includes several lateral facies changes and (3) the upper boundary of the succession occurs at different levels in the stratigraphic column (see Fig. 8). If one takes into consideration the facts that the evaporitic deposits have been leached or are diagenetically altered in the outcrop areas but are well preserved in the subsurface, that various strataform carbonate units are partly altered to a distinctive, very coarsely crystalline dolostone facies and that one Middle Devonian unit is lithologically similar to the basal part of the Upper Devonian succession, it becomes clear why the Middle Devonian formational nomenclature, summarized in Figure 8, is so complex.

Litho-stratigraphy

The previously used subdivisions of the Devonian succession in the District of Mackenzie are based on the concept that sedimentary rock formations are more or less tabular units of great lateral extent. It was assumed that formations were deposited in sedimentary basins as subhorizontal units and the differences in fossil content and lithology were explained by assuming that periodic changes occurred in the environment of deposition. According to this concept each formation represents a discrete episode in the geological history and a specific depositional environment.

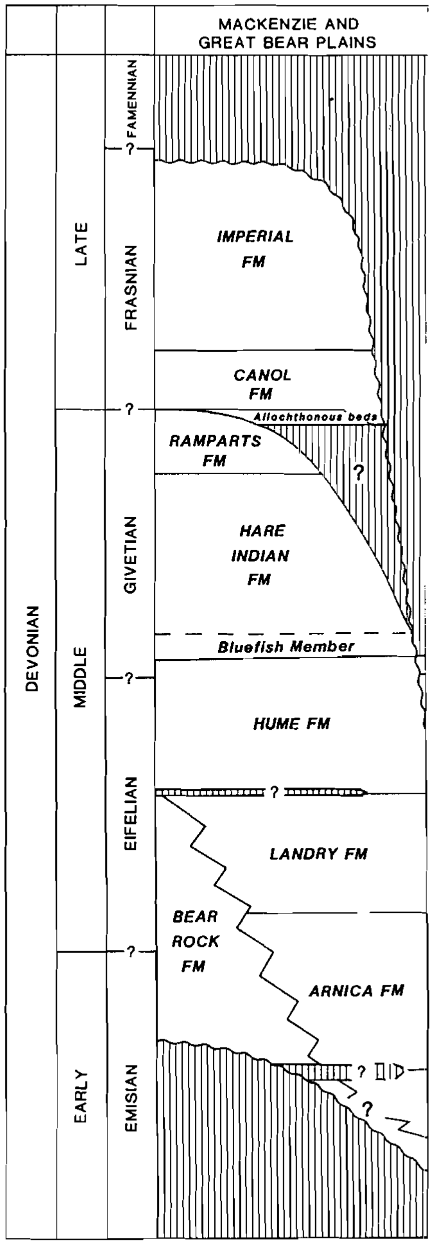
The difficulty of relating subsurface and surface geology and the application of the "layer cake" litho-stratigraphic model has lead to the introduction of many locally defined map units. Some of these map units were defined according to the rules set up by the American Commission on Stratigraphic Nomenclature, but many of the litho-stratigraphic map units were introduced before the Code of Nomenclature was enforced.

The subdivision and correlations discussed in this report are based on the subdivisions introduced by Law (1955), Belyea and Norris (1962), Belyea and McLaren (1962), Douglas and Norris (1960, 1961 and 1963) and Tassonyi (1969). It is apparent from Figure 8 that there is a large number of formations. Most of these were first defined in the outcrop areas along the southeastern margin of the Canadian Shield or in the Mackenzie Mountains. Other map unitswere introduced in the subsurface of northern Alberta. The Devonian stratigraphy in these three areas is rather different and each area was mapped and described using locally defined formations. Because the Great Slave Plain is situated in a central position relative to the three previously described regions, the geology of the study area ties together three different stratigraphic subdivisions.

General facies pattern related to paleotopography

The correlation pattern in Figure 8 indicates that the lateral facies changes are related to the presence of a paleotopographic upland in the southern part of the District of Mackenzie and the irregularities of the pre-Devonian surface. The facies pattern due to onlap is truncated by several disconformities which subdivide the Devonian succession into stratigraphic sequences. Regional information from areas northwest and southeast of the study area suggest that the stratigraphic sequences include four facies belts. These are 1) a "nearshore" detrital facies, 2) an evaporitic facies, 3) a fossiliferous carbonate facies and 4) an "offshore" shale facies.

The lithological, sedimentological and paleontological evidence presented later in this report indicates that the



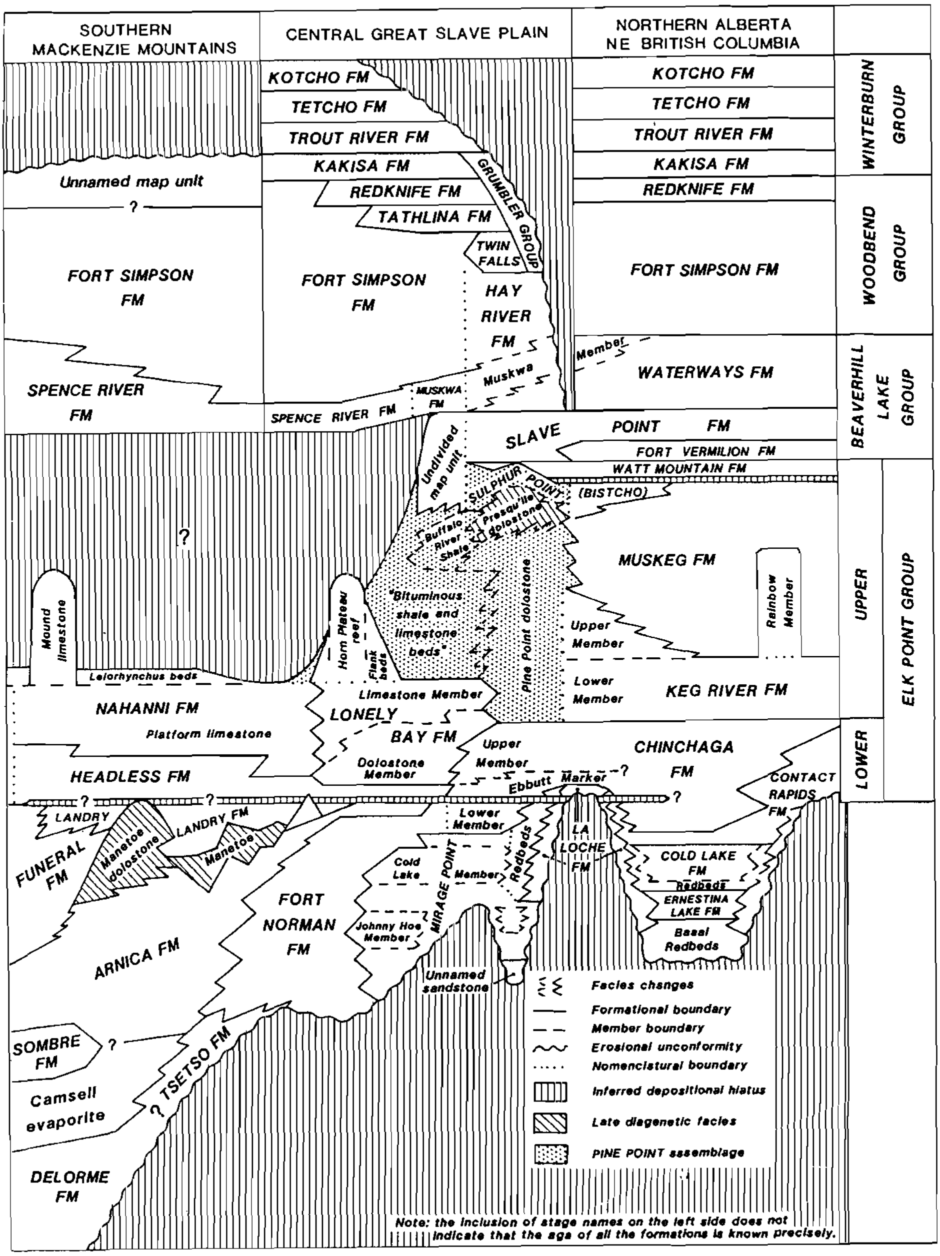


Fig. 8.- *Table of formations and other map-units*

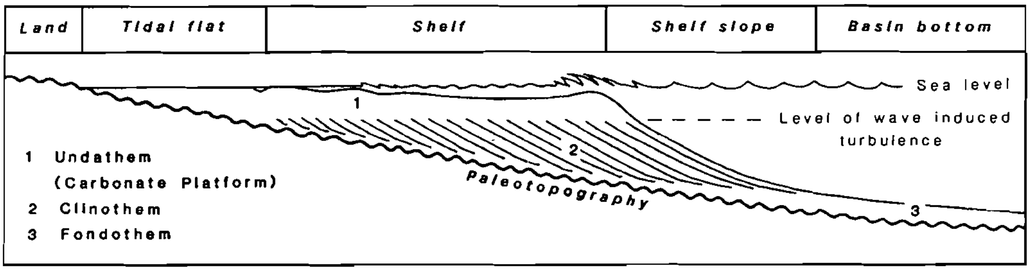


Fig. 9.- *Diagrammatic cross section of a wedge of carbonates prograding into a basin, including critical environments of deposition (adapted from Rich, 1951 and Meissner, 1972).*

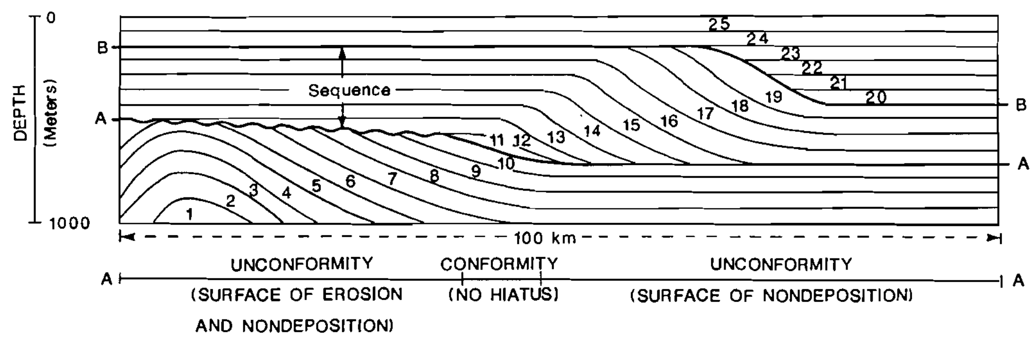


Fig. 10.- *Basic concepts of a stratigraphic sequence (from Mitchum, Vail and Thompson III, 1977).*

stratigraphic sequences form wedge like deposits and and include units similar to the Permian "carbonate platforms" in west Texas and New Mexico described by Meissner (1972). Meissner's concept of the "carbonate platform" in relation to the unda-, clino ,and fondoform environments of deposition as defined by Rich (1951) for a prograding sedimentary wedge is shown in Figure 9.

Wilson (1975) applied the platform concept to all the wellknown carbonate successions in the world and established a standard sequence of facies, including those with shale, anhydrite and halite interbeds. He described nine standard facies belts.

On cross-section the carbonate platforms have a general prismatic shape (see Fig. 9). On plan view they form irregularly shaped belts which more or less parallel the ancient coastline or outline the shape of ancient embayments. The carbonate platforms commonly include a reefal facies at the seaward edge of the undathem environment and an evaporitic or detrital facies in the nearshore undathem environment.

Regional unconformities

The Devonian rock succession is underlain and overlain by regional unconformities. The succession onlaps an erosional unconformity at the base and is truncated at the top by the pre-Cretaceous unnconformity. Minor regional unconformities occur within the succession. The most visible is the one at the base of the Headless Formation (see Fig. 8). Detailed correlations in the subsurface indicate that other, less obvious disconformities are present in the upper part of the Mirage Point Formation, within the Watt Mountain Formation and above the Middle Devonian carbonates.

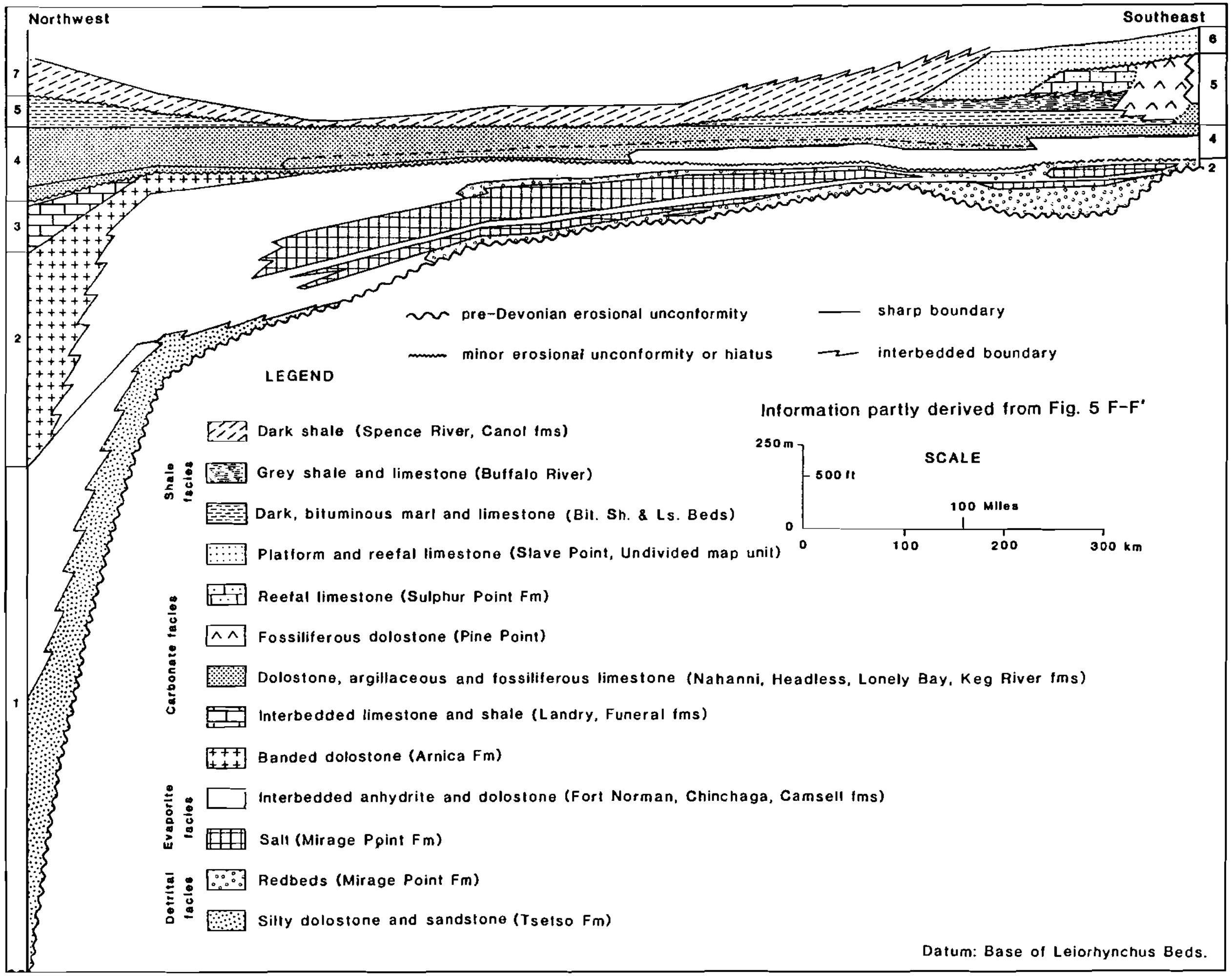
The amount of uplift and erosion that took place during the period of non-deposition at the unconformities varies from place to place. Regional geologic information clearly demonstates that epeiorogenetic periods of general uplift and severe erosion separate the Devonian rock succession from the rock successions above and below. This information also indicates that there was minor uplift and erosion prior to the deposition of the Headless and Watt Mountain formations and very little or no erosion prior to the deposition of the Upper Devonian Spence River, Canol and Muskwa formations.

Stratigraphic sequences

If the concept of the prograding sedimentary wedge of Rich (1951) is applied to the Devonian stratigraphy of the Northwest Territories one can group together several laterally equivalent formations into larger units. Ideally, such large stratigraphic units would be bound at the base and the top by a disconformity or a depositional hiatus, include representatives of the three critical environments of deposition of Rich (1951) and display an upward shoaling (regressive) sequence of sedimentation in the upper part of the succession.

Mitchum et al (1977) used this concept and defined the "depositional sequence". They used the term sequence, because in the Mesozoic and Cenozoic sedimentary wedges underlying the continental shelfs these units are bound by unconformities . They saw a resemblance with theunconformity-bound stratigraphic sequences in the Paleozoic rocks preserved on the North American continent described by Sloss (1963), although those sequences are of a larger magnitude

Fig.11.- *Early and Middle Devonian stratigraphic sequences 1 to 6, including principal lithologies.*



and may include more than one sedimentary wedge.

In order to outline stratigraphic map units on regional seismic profiles Mitchum et al (1977) defined the criteria that characterize a depositional sequence and described four basic patterns (see Fig. 10). The four types of sequences were named the onlapping sequence, the offlapping or prograding sequence, the conformable sequence and the erosionally truncated sequence. The first three sequences are intact and include the original depositional framework. In the last sequence the original depositional framework is often difficult to recognize and needs to be reconstructed before it can be classified as being onlapping, prograding or conformable.

Vail et al (1977) noted that the depositional sequences mapped by Mitchum et al with the aid of offshore seismic span a time interval of 1 to 10 million years and named them third-order sequences. Subsequent work by others in siliciclastic Cenozoic and Mesozoic strata has shown that many third-order depositional sequences include thin transgressive units not recognizable on seismic profiles (see Haq et al, 1987; Embry and Podruski, 1988). The presence of these thin transgressive units makes it often difficult to precisely define the sequence boundaries in the rock succession.

The stratigraphic relationships resulting from the analysis of the Devonian succession in the subsurface of the District of Mackenzie in the Northwest Territories are summarized in figures 8 and 11. The information suggests that the Devonian in the District of Mackenzie includes seven stratigraphic sequences locally separated by erosional unconformities that, in many respects, are similar to the progradational sedimentary wedge and the third order depositional sequence described above. Because figures 8 and 11 only show a small segment of the Devonian basin it is not evident that the older part of the Devonian succession eventually thins westward.

Stratigraphic sequence 1 onlaps a pre-Devonian upland and includes the Tsetso and the Camsell formations. Farther to the west it includes a number of other map units. Stratigraphic sequence 2 conformably overlies sequence 1 and onlaps the crestal part of the upland (Tathlina Uplift). It includes the the Sombre, Arnica, Fort Norman, Mirage Point and La Loche formations, the Unnamed sandstone unit and the lower member of the Chinchaga Formation. Stratigraphic sequence 3 onlaps sequence 2 and consists of the Funeral and Landry formations. Sequence 4 overlies an erosional unconformity which has truncated sequences 2 and 3. It includes the Headless, Nahanni, Hume, Keg River and Lonely Bay formations, the Horn Plateau reefs, the Upper member of the Chinchaga Formation and the autochthonous reefal part of the Pine Point dolostone. Sequence 5 conformably overlies sequence 4 and includes the Bituminous Shale and Limestone Beds, the Buffalo River Shale and the allochthonous deposits in the Pine Point Assemblage, situated between the Watt Mountain and the Keg River formations, the Muskeg Formation and, locally, the basal ,brecciated part of the Watt Mountain Formation. Sequence 6 onlaps and erosionally overlies sequence 5. It includes the Watt Mountain, Fort Vermilion and Slave Point formations. Stratigraphic sequence 7 is strongly progradational and overlies sequences 4, 5, 6 and 7. It consists of the Muskwa, Spence River, Fort Simpson and Hay River formationes and also includes the upper part of the Beaverhill Lake Group and the formations of the Grumbler Group.

It is evident from the information summarized in Figure 3 that the pre-Devonian paleotopography had a major influence on the facies distribution in sequences 1 to 4. Sequence 2 is truncated by the sub-Headless unconformity and the base of sequence 3 forms a relative flat surface and a prominent marker bed in the subsurface. The isopach map of the pre-Devonian beds below this surface show the paleotopography in reverse (see Fig. 12). The isopach map of the Middle Devonian beds above

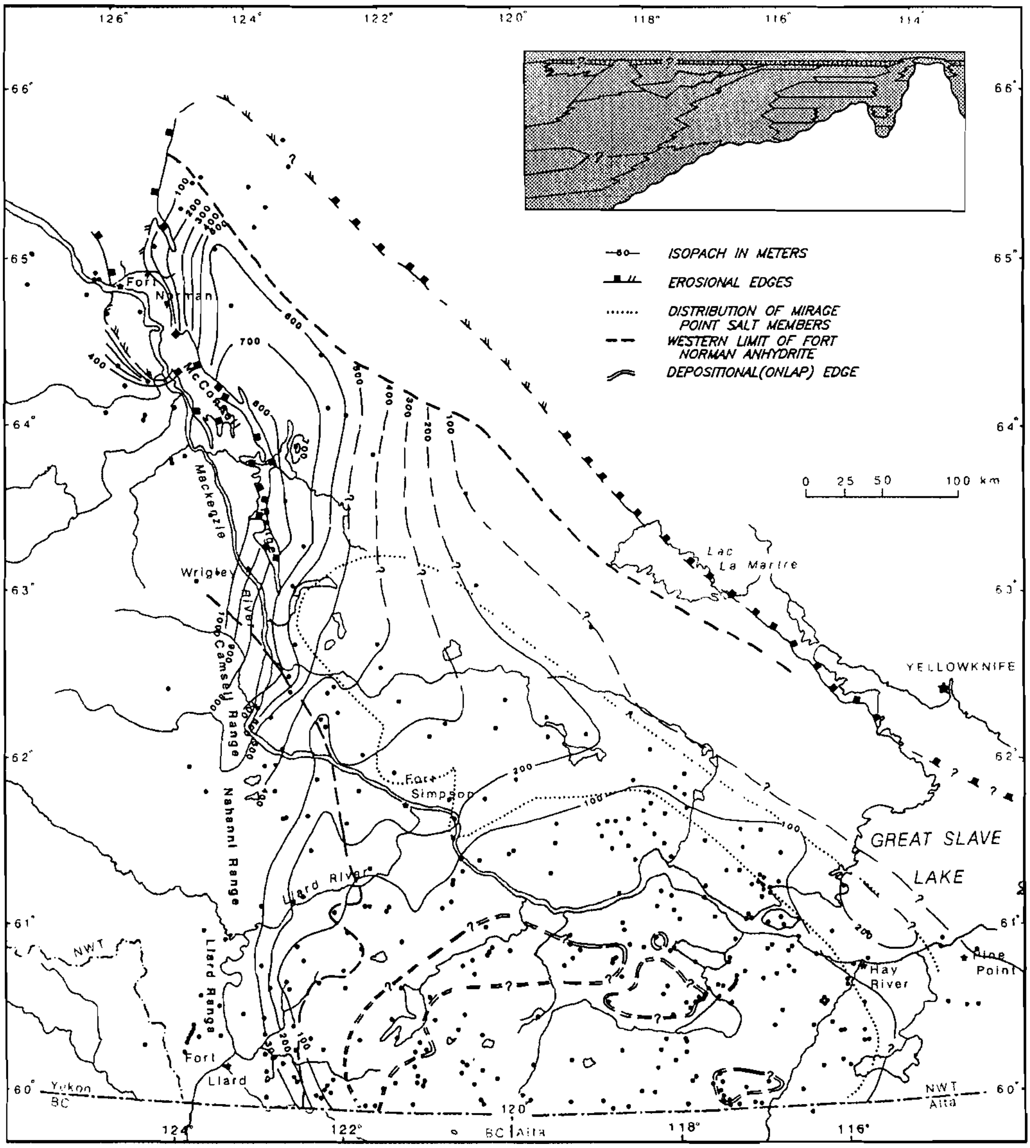


Fig. 12.- *Isopach map of sequences 1, 2 and 3 (interval between pre-Devonian and sub-Headless unconformities).*

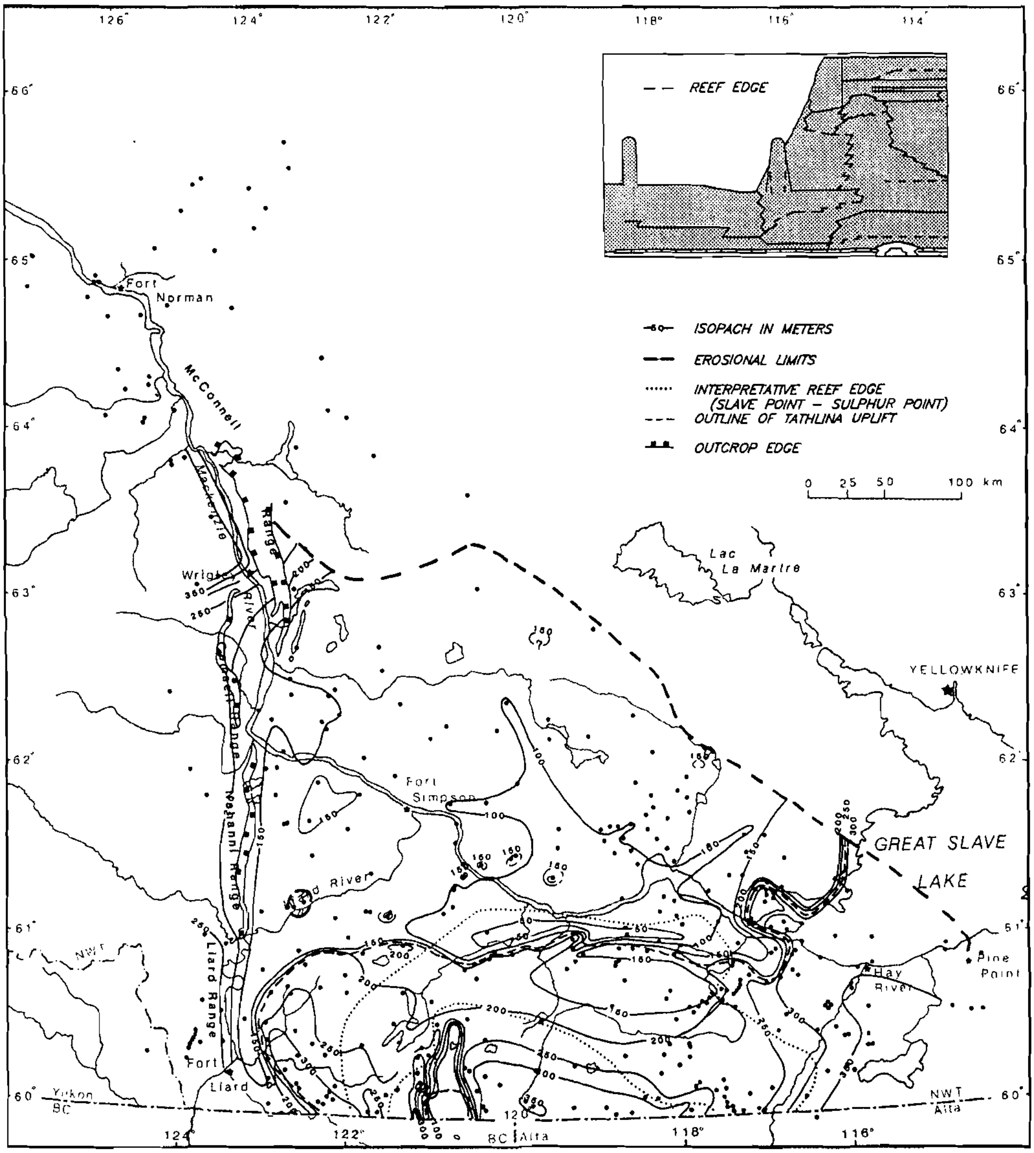


Fig. 13.- *Isopach map of sequences 4, 5 and 6 (interval between sub-Headless unconformity and top Middle Devonian carbonates).*

SERIES	STAGES		STANDARD CONODONT ZONE (Pelagic Biofacies)		
UPPER DEVONIAN	FAMENNIAN				
			?		
UPPER DEVONIAN	FRASNIAN		*Palmatolepis linguiformis*		
			Palmatolepis gigas		U.
					L.
			Ancyrognathus triangularis		
			asymmetricus		U.
					M.
					L.
MIDDLE DEVONIAN	GIVETIAN		Lowermost *asymmetricus*		
			disparilis		
			hermanni–cristatus		U.
					L.
			varcus		U.
					M.
					L.
	EIFELIAN	COUVINIAN	*ensensis*		
			kockelianus		
			australis		
			costatus		
			patulus		
LOWER DEVONIAN	EMSIAN	DALEJAN	*serotinus*		
			inversus	*laticostatus*	
		ZLICHOVIAN	*gronbergi*		
			dehiscens		
	?	PRAGIAN	*kindlei*		
			sulcatus		
		?			
		LOCHKOVIAN	*pesavis*		
			delta		
			eurekaensis		
			hesperius	*woschmidti*	
		PRIDOLIAN			

Fig. 14.- *Early and Middle Devonian stages and conodont zones.*

this surface shows the paleotopography at the end of the Middle Devonian (see Fig. 13).

The upper surface of stratigraphic sequence 5 more or less coincides with the base of the Watt Mountain Formation and forms another relatively flat surface. This surface is an important marker in the subsurface of the southern Interior Plains and an iopach map of the Devonian beds below it gives an inverse image of the Pre-Devonian paleotopography in the southern Interior Plains.

On Figure 8 only the third, fifth and seventh stratigraphic sequences include representatives of clino- and fondothem deposits. These are the Funeral Formation, the Bituminous Shale and Limestone Beds and the Spence River and Muskwa formations. The other sedimentarysequences in the study area are dominated by undathem deposits composed of carbonates and evaporites.

Biostratigraphy

The lower part of the Devonian succession, composed of evaporites and carbonates, is generally devoid of diagnostic fossils. It is not possible to establish a correlation with Devonian faunas from elswhere. The upper part of the Devonian succession is composed of carbonates and shales and includes a reasonable diverse, marine fauna that has been correlated with the faunas in Middle and Late Devonian rocks of Europe by Sartenaer (1969) and McLaren (1954). The fossil material collected from the subsurface cores is too meagre for a reliable zonation based on one or two fossil groups. However, some subsurface collections establish firm correlations with collections from outcrop sections and others include diagnostic fossils that tie in with the internationally accepted biostratigraphic zonation of the Devonian.

A zonation for the upper part of the Devonian succession in western Canada by means of megafossils was introduced by Warren and Stelck (1950 and 1956) and worked out in more detail by Pedder (1975). This zonation is based on a combination of brachiopods and corals. It includes eight sub-zones that do not overlap but are separated from each other by unfossiliferous beds. The presence of brachiopods belonging to the genus Stringocephalus establishes a correlation with the Givetian Stage.

Braun (1967) proposed a zonation for the Middle Devonian carbonates in the District of Mackenzie based on ostracodes. Copeland (1977) introduced an ostracode zonation for the Lower Devonian of western Canada.

The international zonation based on conodonts is shown on Figure 14. The age assignements made by T.T. Uyeno and presented in this report are based on this zonation. Good conodont collections were obtained from the dark, basinal shale facies that overlies several Middle Devonian carbonate formations. The conodonts in the dark shales are typical for the Frasnian Stage and their presence clarified the problem around the Middle- Upper Devonian boundary in the District of Mackenzie.

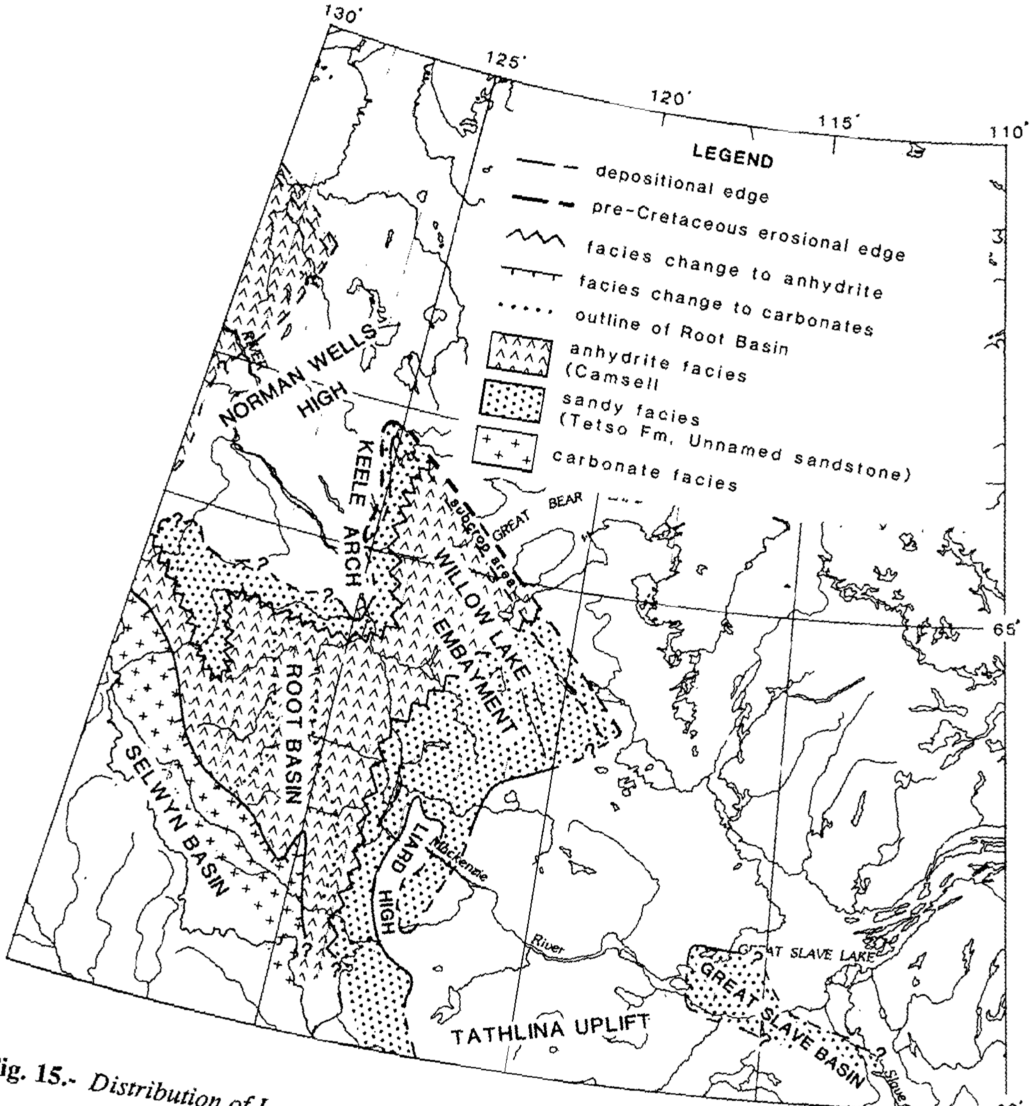


Fig. 15.- *Distribution of Lower Devonian rocks.*

CHAPTER V: STRATIGRAPHIC SEQUENCE 1

Interpretations based on a regional facies study of the Paleozoic rocks in the Cordilleran Orogen by Douglas et al. (1970) indicate that during the early Devonian period the area was part of an elongate, northwest trending, geosynclinal basin (the Cordilleran Geosyncline). Along the northeastern margin of the geosyncline the area now occupied by the southern Mackenzie Mountains included a slowly subsiding embayment (the Meilleur River Embayment) that was filled with Upper Ordovician, Silurian and Lower and Middle Devonian, basinal siltstones and shales (see Bassett and Stout, 1967). Regional geological information also suggests that the Canadian Craton was emergent and part of an ancient, Euramerican continent (see Heckel and Witzke, 1979).

During the early Devonian the area along the northern margin of the embayment became the centre of a slowly subsiding basin and was filled with a very thick succession of Lower Devonian carbonates and evaporites. The depositional centre of this basin lies in the southern Mackenzie Mountains between the South Nahanni and Root rivers and Gabrielse (1967) proposed the name Root Basin. The name Selwyn Basin refers to the northeastern part of the geosyncline which is filled with basinal shales and siltstones (see Fig. 15).

During the transgression that started in the early part of the Devonian period an increasingly larger part of the southwestern margin of the Candian Craton became submerged. First the paleotopographically low regions situated east of Root Basin were inundated and filled with sediments. Later the sea spread to the southeast and across the entire southwestern part of the craton. Some paleotopographic high areas remained emergent until the late Devonian and acted as barriers. During the Middle Devonian several isolated or landlocked sub-basins on the southwestern margin of the Canadian Craton, such as Great Slave Basin (see Fig. 15), were filled with clastics and evaporites.

Law (1971) named the relatively shallow extension of Root Basin into the southern Great Bear Plain the Willow Lake Basin. Here the term Willow Lake Embayment is used (see Fig.15). Willow Lake Embayment is separated from Great Slave Basin by an high area that remained emergent. This high underlies the southeastern part of La Martre Arch and its crestal part coincides with Tathlina Uplift. Willow Lake Embayment is flanked on the northwest by another paleotopographically high area for which Williams (1975) used the name Norman Wells High.

Morrow (1984) indicated that the seaward edge of the Lower Devonian stratigraphic sequence defines the southwestern limit of Root Basin. He described a silty and sandy, slope and basin-bottom facies (the pink shale member, Cadillac Formation), a silty, peritidal carbonate facies (the Corridor Member of the Camsell Formation) and a lagoonal and supratidal anhydritic facies that outcrops as a limestone breccia (the Camsell Formation). Along the margins of Root Basin and Willow Lake Embayment the anhydritic facies grades laterally into a nearshore, sandy facies for which the name Tsetso Formation is introduced. Because it is difficult to establish precise correlations between the anhydritic facies and the limestone breccia, the stratigraphic nomenclature in the subsurface is kept informal. Thus the terms "Tsetso equivalent" and "Camsell evaporite" are used.

Although paleontological information is limited, Morrow and Cook (1987) and Douglas and Norris (1963) indicated that in Root Basin the Devonian strata conformably overlie beds of Silurian age. In the Willow Lake Embayment the Devonian strata overlie older Paleozoic rocks with an

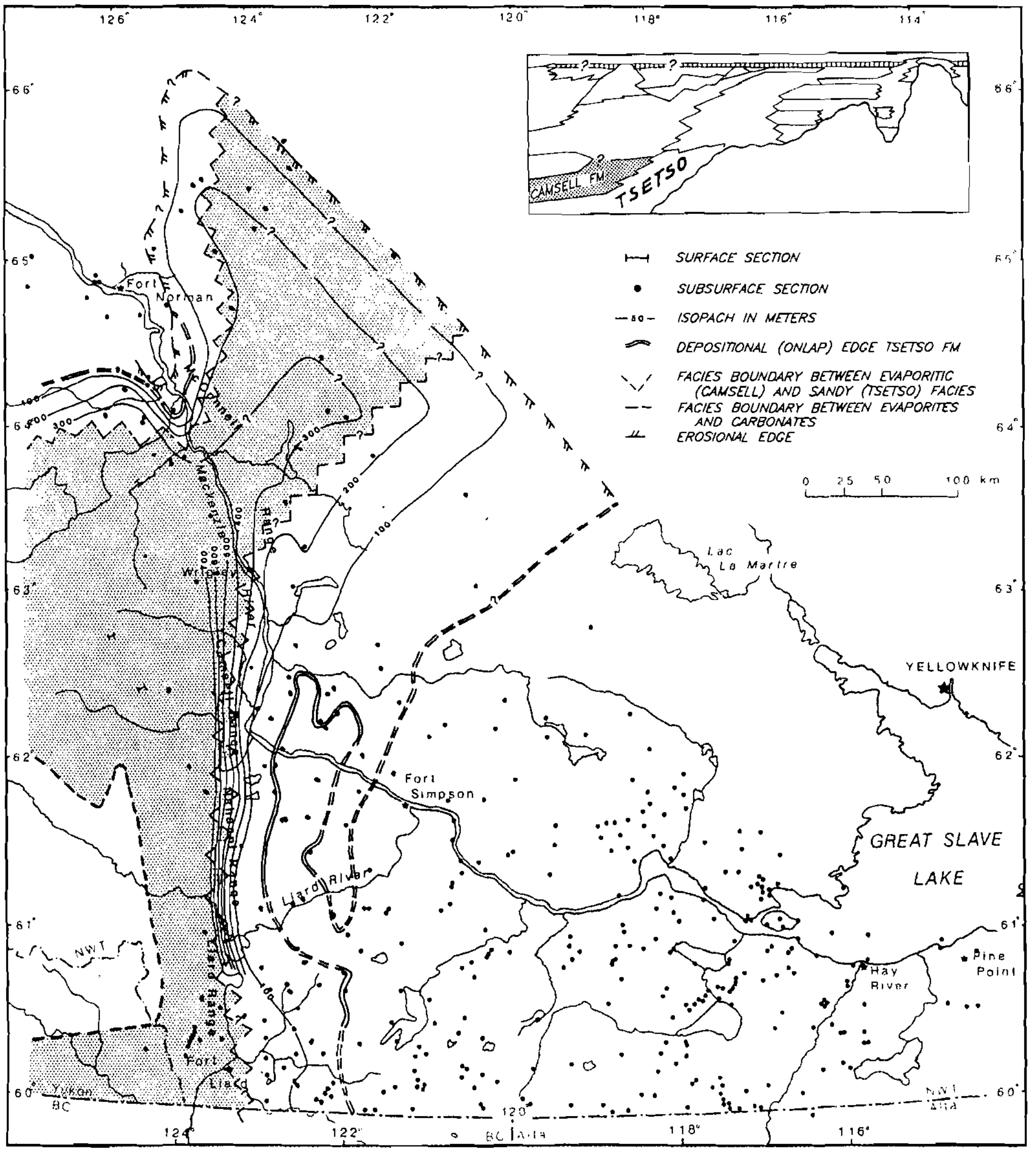


Fig. 16.- *Distribution of Lower Devonian detrital and evaporitic facies.*

erosional contact (see Meijer Drees,1975).

In the central part of Willow Lake Embayment the upper contact of sequence 1 constitutes a fairly sharp change in lithology. Pale coloured, sandy and anhydritic dolostone and greenish grey sandy beds are overlain by dark grey, peloidal dolostone of sequence 2. Along the margin of the embayment the sandy and anhydritic dolostone of sequence 1 grades, or is overlain, by nearshore, sandy and evaporitic deposits of sequence 2.

1. Detrital facies of sequence 1

In the northwestern part of the study area the detrital facies is represented by a single map unit for which the name Tsetso Formation is proposed. It is a laterally continuous unit of interbedded sandstone and dolostone which accumulated along the margins of Root Basin (see Fig. 15). The Tsetso Formation onlaps Norman Wells High in the north and the precursor ofTathlina Uplift in the southeast, two structures that were emergent during the early Devonian and presumably acted as sources for quartz sand.

Tsetso Formation

The Tsetso Formation (Meijer Drees, in press) is an interbedded succession of light grey dolostone, sandy dolostone, dolomitic sandstone, greenish grey argillaceous dolostone, reddish brown mottled shale and minor anhydrite which unconformably overlies rocks of Late Ordovician to Early Silurian age. The formation is unfossiliferous and its age can only be inferred. It unconformably overlies the Mount Kindle Formation of Silurian or Late Ordovician age and is locally overlain by the Arnica Formation of Early or early Middle Devonian age.

In the subsurface of the southern Great Bear Plain the Tsetso Formation is a fairly well defined unit and is easily mapped with the aid of borehole logs and sample descriptions. The regional distribution and thickness of the formation, and the location of the facies change between Tsetso Formation and its subsurface equivalents in the Camsell Formation, are shown on Figure 16.

In the subsurface of the Great Slave Plain the Tsetso Formation onlaps a paleotopographic high area and the depositional edge on Figure 16 is presumed to represent the approximate position of the highest level of the shoreline. The formation is up to 150 m thick. The thin, discontineous, silty beds which form the basal unit of the Devonian succession in the area south of the zero line on Figure 16 are mapped together with the evaporite facies of the overlying sedimentary sequence.

In the central part of the Great Bear Plain it is difficult to map the distribution of the Tsetso Formation because the Devonian succession is missing in the area south of Fort Norman as a result of pre-Cretaceous uplift and erosion along Keele Arch (see Cook, 1975). Present information suggests that the Tsetso Formation occurs in the area east of Fort Norman and the isopachs on Figure 16 suggest that there was a paleotopographic high area in the region of Fort Norman. This paleotopographic feature is named Norman Wells High (Williams, 1975, Fig. 7.1). The Tsetso Formation is present in the area east of the Norman Wells High and overlies Cambro-Silurian carbonates.

The formation extends eastward to the erosional edge of the Devonian. Here it subcrops against the overlying Cretaceous beds. On Figure 16 it is thus assumed that the eastern limit of the Tsetso Formation in the Great Bear Plain parallels the erosional edge of the Devonian succession.

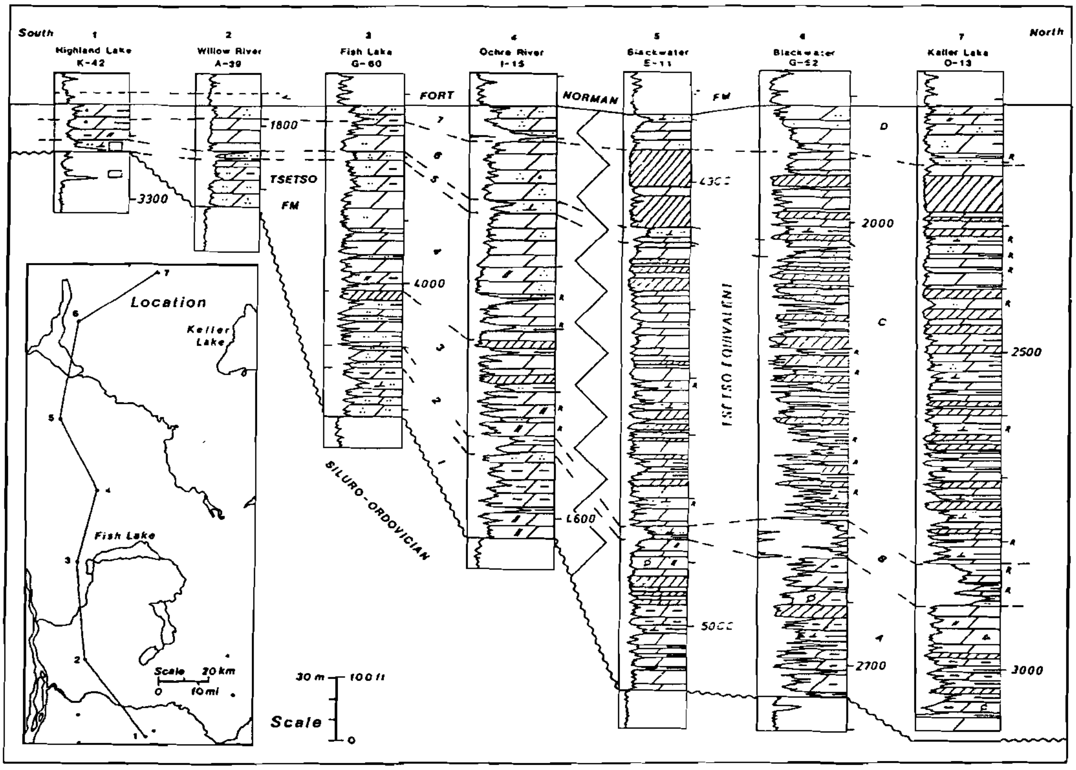


Fig. 17.- *Stratigraphic cross-section across the northeastern extension of Root Basin including the detrital and evaporitic facies of sequence 1. Legend on Fig. 24.*

It is possible that the Tsetso Formation is also present along the southern flank of the Norman Wells High (see Fig. 15). Probable equivalents of the Tsetso Formation occur in the Carcajou Canyon map area of the Mackenzie Mountains, where Aitken and Cook (1974) included, with reservation, beds stratigraphically equivalent to the Tsetso Formation in the Delorme Formation.

In the subsurface of the Great Slave Plain, just east of the Nahanni and Liard Ranges, the Devonian succession unconformably overlies Lower Paleozoic or Proterozoic rocks and the Tsetso Formation is a relatively thin unit. It ranges in thickness between 33.5 and 0 m and is overlain by, or grades laterally into thin sandy equivalents of the evaporite facies of sedimentary sequence 2. The Tsetso Formation onlaps the precursor of Tathlina Uplift and is overlain by the sandy facies of sequence 4 (the Ebbutt Member of the Chinchaga Formation), which forms a basal transgressive deposit and covers part of Tathlina Uplift.

In the subsurface the Tsetso Formation is characterized by the presence of light coloured dolomitic, quartzose sandstone and siltstone interbeds; greenish grey, thinly bedded and laminated, cryptocrystalline dolostone and greyish green or reddish brown dolomitic shale. These lithologies are prominently present in the central part of the Great Bear Plain, in the northwestern part of the Great Slave Plain, on Nahanni Range and in the southern part of the McConnell Range. The silty and sandy facies is well developed in the Shell Ochre River I-15 well (see Fig. 17,section 4) located east of the McConnell Range and thins gradually toward the southeast (see Fig.16). West of Nahanni and Camsell Ranges and northwest of the Ochre River I-15 well the silty and sandy beds are less prominent and equivalent strata consist largelyof pale coloured, dolomitic and anhydritic rocks. The anhydritic facies belongs to the Camsell Formation.

In the Ochre River I-15 well, the Tsetso Formation is 147.5m (484 ft) thick and includes seven members (see Fig. 17, section 4). The basal member (member 1) includes a lower sub-member of light greyish brown, anhydritic dolostone, a middle sub-member of interbedded, dark grey, argillaceous dolostone and silty, dolomitic shale and an upper sub-member composed of greyish green, silty and sandy dolostone. Member 2 is a widespread marker composed of greyish green, dolomitic, silty shale and argillaceous dolostone. Member 3 is an interbedded succession of reddish brown, anhydritic dolostone; grey, sandy and argillaceous dolostone; reddish brown and green, silty shale; very light coloured dolostone and minor light coloured anhydritic rocks. Member 4 consists of very light greyish brown, very finely to finely crystalline, succrosic dolostone. Member 5 is a very light greyish brown dolomitic sandstone which forms a local marker. Member 6 consists of a very light greyish brown, sandy dolostone and member 7 includes very light coloured sandstone and sandy dolostone beds. The correlations on Figure 10 suggest that members 1, 2, 3, 5 and 7 extend northward into the evaporitic equivalents of the Tsetso Formation, while the sandy members 4 and 6 grade into anhydritic or dolomitic beds. The upper units extend farther south than the lower members and onlap Tathlina Uplift.

2. Evaporite facies of sequence 1

The Lower Devonian evaporites and associated carbonates are present in the southern Mackenzie Mountains and in the southern part of the Great Bear Plain. In the southern part of the Mackenzie Mountains the evaporites are exposed in the form of limestone breccia. The limestone breccia has been mapped previously on the surface as the Camsell Formation. The equivalent strata in the deep subsurface consists of interbedded anhydrite and dolostone, for these the term "Camsell Evaporite"

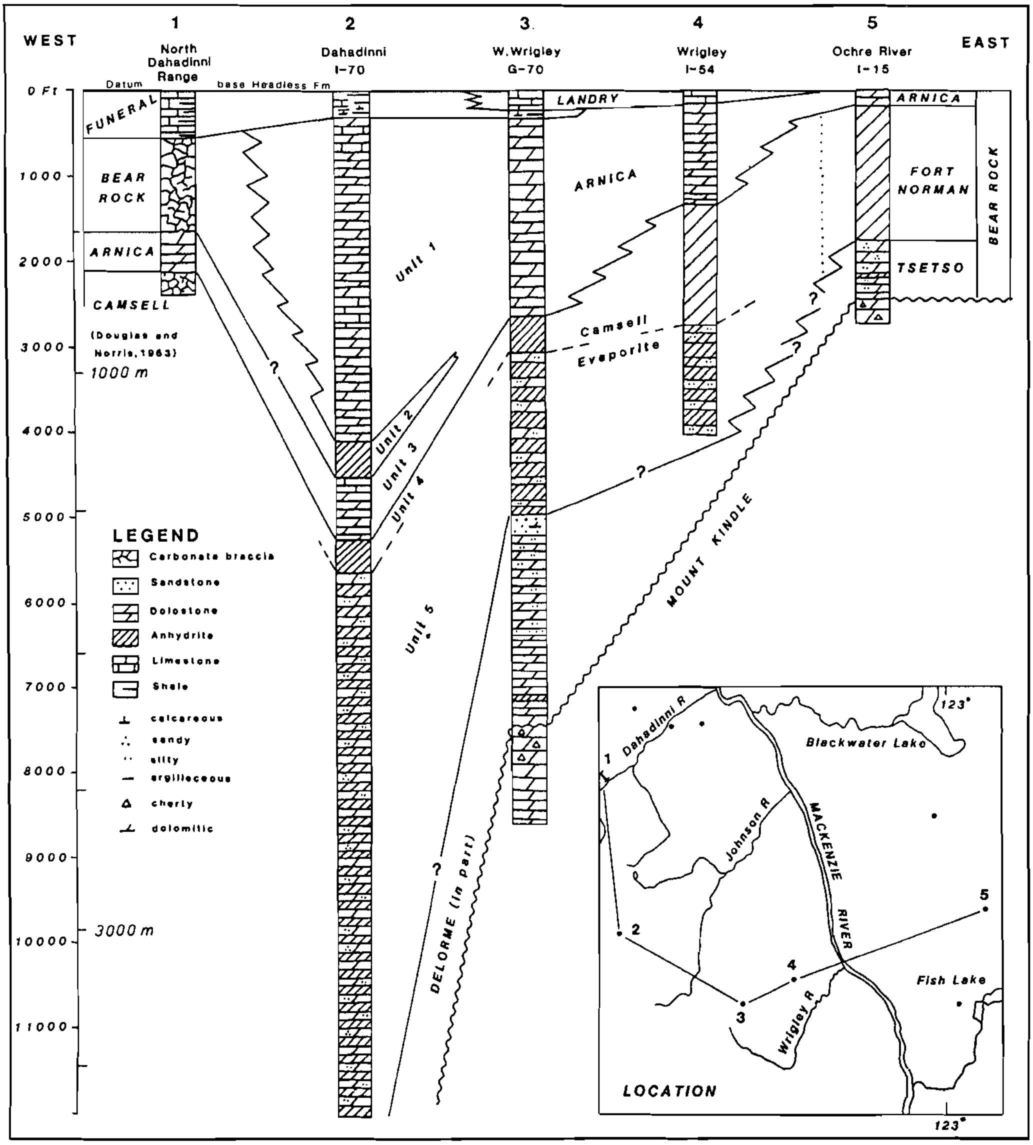


Fig. 18.- *Stratigraphic cross-section across the northern part of Root Basin including the Camsell Formation and its equivalents.*

is introduced.

In the Great Bear Plain the Lower Devonian carbonates and evaporites were previously mapped together with the overlying, early Middle Devonian Bear Rock Formation. However, it is possible by using new subsurface information to segregate the Bear Rock evaporites into two parts. Because the lower part grades into the Tsetso Formation it is described as the "Tsetso equivalent". Regional correlations indicate that the evaporites in the "Tsetso equivalent" and the "Camsell evaporite" are more or less equivalent and both evaporites are thus regarded as part of the Camsell Formation.

The "Camsell evaporite" occupies the central part of Root Basin (Gabrielse, 1967), the "Tsetso equivalent" is present in the Willow Lake Embayment, a north- easterly extension of Root Basin in the subsurface of the Great Bear Plain (see Fig. 15). The distribution of the different facies suggest that the evaporites accumulated in an elongate bay or in a seaway between two islands.

Camsell Formation

The resistant, ridge-forming breccia situated between the Delorme and Sombre Formations on Whittaker and Delorme Ranges in the northern part of the Root River map area of the southern Mackenzie Mountains was named by Douglas and Norris (1961) the Camsell Formation. No type section was designated. The Camsell Formation consists of grey, cryptograined, massive or brecciated limestone which weathers light- to medium-grey. The limestone breccia fragments are up to 3 m or more in diameter and occur in a matrix of coarse calcite, limonite or ochre which weathers brown, yellow, orange or red. Douglas and Norris (1961) reported the thickness as being between 426 and 533 m.

The stratigraphical equivalents of the limestone breccia in the southern part of the Root River map area consist of alternating, dark grey to nearly black, thick- bedded dolostone, light grey to white dolostone and yellow, silty dolostone; or are composed of interbedded, light grey and dark grey limestone, light grey dolostone and brownish orange weathering, laminated, fine grained sandstone. Douglas and Norris (1961) mapped all these beds together with the Camsell Formation. Morrow (1984) regards this banded facies as the Corridor Member of the Camsell Formation.

It is interesting to note that the limestone breccia facies is absent in the subsurface. It isassumed that in the shallow subsurface the sulfates were leached by circulating groundwater causing collapse and brecciation of the interbedded and overlying carbonates. The interbedded succession of anhydrite and dolostone is thus more or less equivalent to the Camsell breccia. However, it is obvious that the upper and lower boundaries of the evaporitic succession in the subsurface do not coincide with the lower and upper boundaries of the breccia. It is therefore proposed to regard the evaporites in the subsurface as a member of the Camsell Formation and in this report the informal term "Camsell evaporite" is used.

Morrow and Cook (1987) report the presence of early Devonian conodonts in beds overlying and underlying the Camseel Formation. On the basis of this information both the Camsell Formation and the "Camsell evaporite" are considered to be early Devonian.

"Camsell evaporite"

The Camsell Formation is widely distributed in the subsurface of the Mackenzie Mountains, but only a small number of wells have penetrated the evaporites. One of the wells which did penetrate

Camsell evaporites is the IOE Gobles Hersey Dahanni I-70 well. Since this well is located on Dahadinni Range in close proximity to the surface sections of the Camsell Formation described by Douglas and Norris (1961, 1963) it is logical to define the boundaries of the "Camsell evaporite" here first and then correlate the other known subsurface sections with the section in the Dahadinni I-70 well. Unfortunately the succession in the Dahadinni I-70 well is not suitable as a reference section because the borehole is located on a faulted anticline. The vertical thickness of the Devonian succession at this locality is so great that the well had to be abandoned at a total depth of 3663.7 m (12 020 ft) without reaching the base of the "Camsell evaporite".

It is assumed on Figure 18 that unit 2 of the Dahadinni I-70 well correlates with the "Bear Rock" breccia of Douglas and Norris (1963) and that unit 3 correlates with the Arnica Formation. Units 4 and 5 contrast sharply in colour with the overlying, dark coloured Arnica Formation and it is assumed that these two units are equivalent to the Camsell breccia. If the correlations shown on Figure 18 are correct one can define the upper contact of the "Camsell evaporite" in lithological terms as the boundary between a thickly interbedded succession composed of dark coloured dolostone and light coloured anhydrite and a thinly interbedded succession of silty and sandy, light coloured anhydrite and dolostone. Note that the top of the Camsell evaporite in the Dahadinni I-70 well does not coincide with the top of the silty interbeds.

If one defines the lower boundary of the "Camsell evaporite" at the base of the stratigraphically lowest occurrence of bedded anhydrite the member becomes a mappable unit.

Lithology

In the Decalta et al. Wrigley I-54 well and the Shell Wrigley G-70 well (see Fig. 18) the Camsell Evaporite consists of a thick succession of interbedded anhydrite and silty or sandy dolostone. In the Wrigley G-70 well, the silty and sandy evaporites overlie a thick unit including dolostone and silty dolostone with minor amounts of dolomitic sandstone, reddish brown, dolomitic shale and anhydrite. The silty and sandy evaporites are considered to be part of the Camsell evaporite; the underlying carbonates may be part of the Delorme Formation as defined by Douglas and Norris (1961) in the Root River map area.

"Tsetso equivalent"

Although the correlation between the Camsell Formation, the Camsell evaporite, the Delorme and the undivided equivalents of the Tsetso Formation is uncertain and largely depends on a clarification of the nomenclature introduced by Douglas and Norris (1961, 1963) it is proposed for the sake of convenience to group the evaporitic beds equivalent to the Tsetso Formation with the Camsell Formation.

Lithology

In the subsurface of the Mackenzie Plain and the southwestern Great Bear Plain the silty andsandy dolostone beds of the Tsetso Formation grade laterally into an, up to 300 m thick succession, of carbonates and evaporites (see Figs. 11 and 16). This succession is characterized by the presence of silty and sandy interbeds, but also includes anhydrite, light coloured dolostone, reddish brown and greenish grey shale and dark grey dolostone. On Figure 17 it is evident that the "Tsetso equivalent" can be subdivided in several mappable units, and it appears worthwhile to introduce and describe four "mappable units". Because of a limited amount of information it is not possible to map the areal distribution of the four map units.

The basal unit (map unit A) is characterized by the presence of pale greenish grey dolostone, associated with light greyish green, siliceous shale; dark greyish brown to greyish brown, microcrystalline, argillaceous dolostone; and in the upper part, light greyish brown to greyish brown, microcrystalline dolostone, in part fine peloidal and anhydritic. In the CDN Res. Signal Keller Lake O-13 well (see Fig.17, section 7) the light greyish brown dolostone contains light coloured chert and inclusions of pale green siliceous shale. In the Ochre River I- 15 and Fish Lake G-60 wells (see Fig.17, section 3) the equivalent of map unit A is interbedded with reddish brown mottled, silty and dolomitic shale.

Map unit A is overlain by a pale greyish green and reddish brown mottled, dolomitic and in part silty shale, which is interbedded with greenish grey, cryptocrystalline dolostone. This is map unit B. In most wells the contact between map unit A and B is sharp. In places the lower contact is overlain by a very pale green, dolomitic siltstone. In the Ochre River I-15 and Fish Lake G-60 wells the equivalent of unit B is thin and difficult to recognize.

Map unit B is transitionally overlain by map unit C, an interbedded succession of very light greenish grey or very light greyish brown coloured, micro to crypto- crystalline dolostone containing varying amounts of siliceous clay; very light coloured anhydrite and pale greenish grey and reddish brown mottled, dolomitic shale. In the Union Japex et al. Blackwater Lake E-11 well and in the Shell Blackwater Lake G-52 well map unit C includes several interbeds of dolomitic siltstone.

Map unit D forms the upper part of the succession equivalent to the Tsetso Formation. It includes very light coloured, anhydritic dolostone; pale greenish grey, silty and sandy dolostone; greenish grey dolomitic sandstone or siltstone and locally reddish brown, dolomitic siltstone.

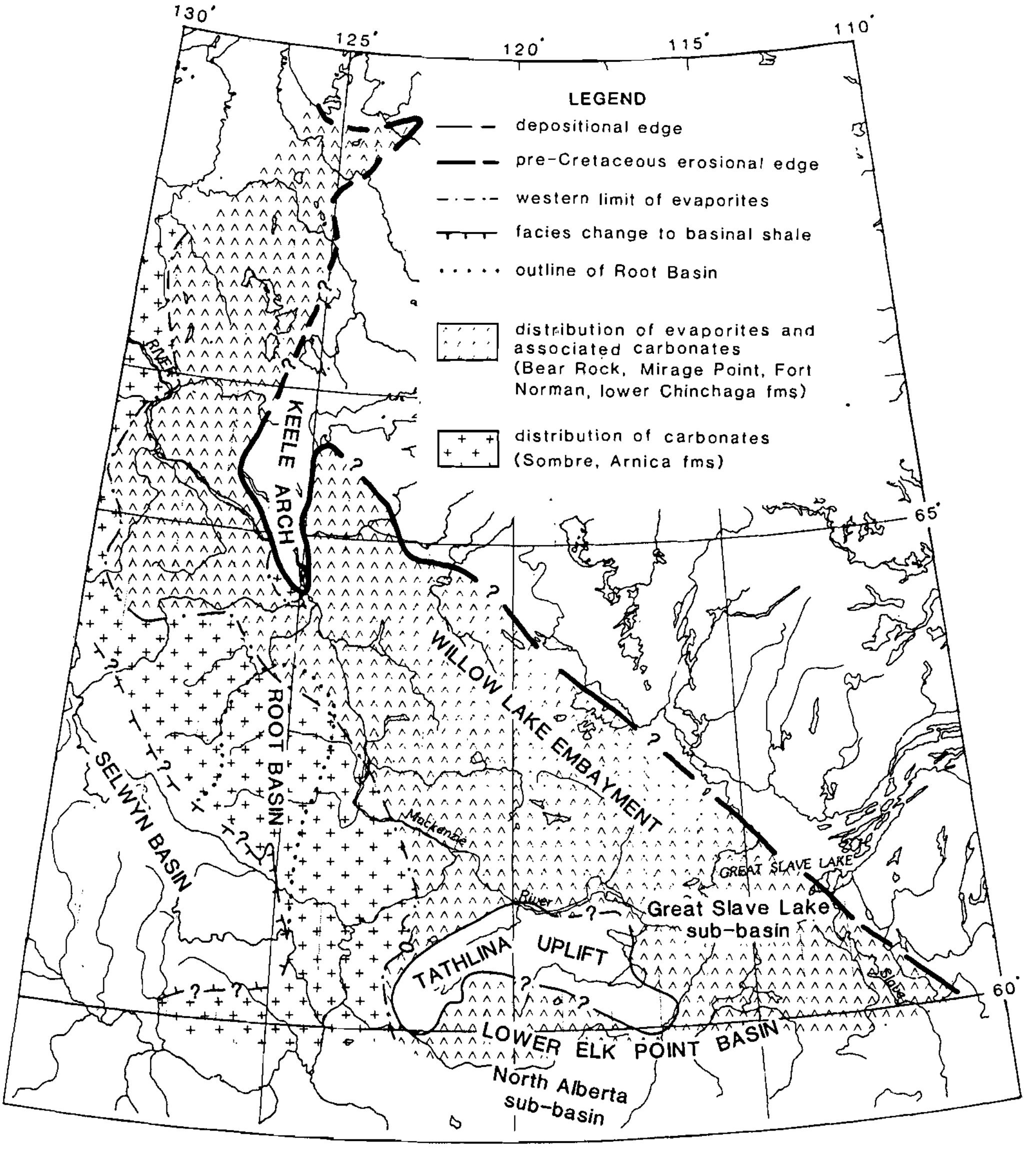


Fig. 19.- *Distribution of late Lower to early Middle Devonian rocks.*

CHAPTER VI: STRATIGRAPHIC SEQUENCE 2

During the deposition of the second stratigraphic sequence the sea expanded toward the southeast and Willow Lake Embayment was much enlarged. It is unknown how far the sea expanded to the east onto the Canadian Craton, because the eastern part of all the Devonian sequences was removed by pre-Cretaceous erosion. The depositional centre remained in Root Basin, where a thick succession of carbonates was deposited. Basinal shales accumulated east of the carbonates, in Selwyn Basin (see Fig.19). The edge of the carbonate succession coincides with the eastern limit of Selwyn Basin. It includes a small embayment at the southern limit of Root Basin. Deposition in the expanded Willow Lake Embayment and the Great Slave and Northern Alberta sub-basins of the Lower Elk Point Basin (see Fig 19) was dominated by evaporites.

In the District of Mackenzie the second Devonian stratigraphic sequence includes: 1) a detrital facies which accumulated in paleotopographic depressions in the central part or on the flanks of the basin (the "Unnamed Sandstone Unit" and the La Loche Formation), 2) an interbedded redbed and halite facies which accumulated in the Willow Lake Embayment and the Lower Elk Point Basin (the Mirage Point Formation), 3) an anhydritic facies (the Fort Norman Formation and the Lower Member of the Chinchaga Formation) which outcrops as a limestone breccia (the Bear Rock Formation) and 4) the carbonate facies (including the Sombre and Arnica formations).

The evaporites of sequence 2 generally are unfossiliferous, but a thin carbonate unit in the evaporitic facies includes early Middle Devonian ostracodes. The conodont fauna in the carbonate facies indicates an early to early Middle Devonian age.

In Root Basin and the northern part of the Willow Lake Embayment the lower boundary of sequence 2 is relatively sharp and conformable, in the southern part of the embayment and in the Elk Point Basin the lower boundary coincides with the pre-Devonian unconformity.

1. Detrital facies of sequence 2

In the central parts of the Elk Point Basin the pre-Devonian unconformity is overlain by reddish brown coloured, sandy and shaly deposits that were named the "Basal Red Beds" unit (Sherwin, 1962). The redbeds onlap paleotopographic high areas that remained emergent. In the central parts of the lower Elk Point sub-basins they are overlain by salt deposits of the Lotsberg Formation.

In the central part of Great Slave Basin Precambrian igneous and metamorphic rocks are overlain by the "Unnamed Sandstone Unit". In this report it is assumed that the "Unnamed Sandstone Unit" is equivalent to the "Basal Red Beds" unit (see Fig.8) and it is included with sequence 2.

In the northern part of the Willow Lake Embayment the detrital facies of sequence 2 does not make a distinctive map unit. In the southern part of the embayment the detrital facies overlies Precambrian rocks of Tathlina Uplift. It forms a discontinuous unit (the La Loche Formation) that fills local depressions situated on the flank of Tathlina Uplift and includes arkosic and dolomitic sandstones.

"Unnamed Sandstone unit"

The informal term "Unnamed Sandstone" is used in the subsurface of the Great Slave Lake region to describe the sandstone beds which overlie Precambrian igneous and metamorphic rocks and underlie redbeds of sedimentary sequence 2.

In the reference section, the Horn River et al. Hay River B-52 well the "Unnamed Sandstone" overlies Precambrian granite and is overlain by reddish brown dolomitic, silty and sandy shale of Unit 1 of the Mirage Point Formation (see Fig.20, section 5). The lower boundary is an erosional unconformity, the upper boundary is transitional. No fossils have been recovered from the sandstone but regional geological information suggests that the "Unnamed Sandstone" is of Lower or early Middle Devonian age.

The distribution of the "Unnamed Sandstone Unit" in the Great Slave Basin is shown on Figure 15. The unit was penetrated by five wells in the Great Slave Lake region, two of which are shown as sections 4 and 5 on Figure 20. In the Hay River B-52 well the unit isapproximately 13.7 m thick, in the Windy Point No. 1 well the unit is 33.5 m thick (Cameron, 1922).

Lithology

Norris (1965, p. 16) described the interval in the Cominco Test G-4 well as composed of light brown quartzose and feldspathic sandstone with greenish grey argillaceous laminae overlain by light buff, green and red quartzose siltstone. The upper siltstone beds include occasional layers of gritstone and interbeds of red and green coloured, argillaceous siltstone. In the Hay River B-25 well the unit includes light grey, light purplish red or green mottled, very fine- to fine-, in places coarse-

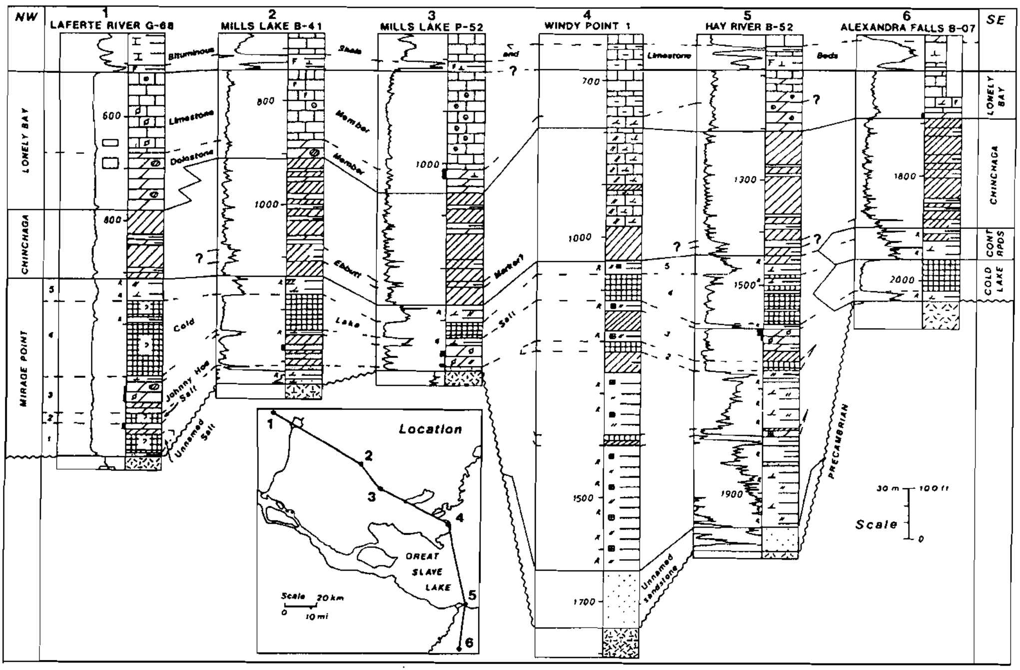


Fig. 20.- *Stratigraphic cross-section across Great Slave Lake Basin.*

Lithology

Norris (1965, p. 16) described the interval in the Cominco Test G-4 well as composed of light brown quartzose and feldspathic sandstone with greenish grey argillaceous laminae overlain by light buff, green and red quartzose siltstone. The upper siltstone beds include occasional layers of gritstone and interbeds of red and green coloured, argillaceous siltstone. In the Hay River B-25 well the unit includes light grey, light purplish red or green mottled, very fine- to fine-, in places coarse- to very coarsely grained, dolomitic sandstone and green shale.

Cameron (1922) described the unit in the Windy Point No. 1 well as composed of red and brownish red sandstone.

La Loche Formation

The name La Loche Formation is used in the subsurface of the Great Slave Plain for the discontinuous basal Devonian sandstone beds that overlie Precambrian igneous and metamorphic rocks and are equivalent to, or are overlain by, the upper part of the Mirage Point, the Chinchaga, the Keg River or the Lonely Bay formations. The formation is exposed in west central Saskatchewan along the Clearwater River at Contact Rapids, and in northeastern Alberta on the Stony Islands in Slave River south of Fitzgerald (see Norris, 1963).

These basal Devonian sandstone beds are discontinuously distributed and vary in thickness. They are overlain by argillaceous, dolomitic or anhydritic beds of the Keg River, the McLean River, the Chinchaga, the Cold Lake or the Ernestina Lake formations (see Belyea, 1971). Since the last three formations onlap but do not overlie the crestal part of Tathlina Uplift, and the underlying sandstones onlap and overlie the Uplift, it appears that the basal Devonian sandstone beds on the uplift are lateral equivalent to these formations. Thus the sandstone may be regarded as a basal transgressive unit that varies in age from place to place.

The lower boundary of the La Loche Formation, is an erosional unconformity, the upper boundary is transitional and drawn at the top of the highest sandstone bed.

The age of the La Loche Formation as defined above varies from place to place. At the type section on Clearwater River the formation underlies beds containing Middle Devonian fossils (Norris, 1963). Along the Slave River the overlying carbonates contain fossils of Lower Devonian or early Middle Devonian age (Norris, 1962; Craig et al., 1967; Pedder, pers. comm.). In the subsurface of the Northwest Territories between Tathlina and Trout lakes the La Loche Formation underlies the Lonely Bay and Keg River formations both considered to be Middle Devonian (Belyea, 1971).

The La Loche Formation is a relatively thin unit. At the type section the formation is about 1.5 m thick. On the Stony Islands the thickness ranges between 1.9 and 2.0 m. In the subsurface of the Great Slave Plain the basal Devonian sandstone beds do not form a continuous unit and in most sections the sandstone is less than 1.5 m thick. Such thin, discontinuous sandstones are considered to be part of the overlying Lower Elk Point formations. However, in the subsurface southeast of Kakisa Lake the La Loche Formation reaches a maximum thickness of 21 m and here the formation forms a mappable unit that flanks Tathlina Uplift and passes northeastward into redbeds (see Fig.29). Correlations indicate that here the La Loche Formation and the adjacent redbeds underlie the Ebbutt Member of the Chinchaga Formation. It is assumed that the same relationship exists coarsely grained quartzose sandstones, sandy dolostones and dolomitic arkoses. In the region between Kakisa and Trout Lakes the La Loche Formation consists of light or greenish grey, fine- to coarsely grained quartzose or dolomitic sandstone and pale green, silty or sandy,pyritic shale. The sandstone is described by Belyea and Norris (1962) from several wells as part of the Chinchaga Formation.

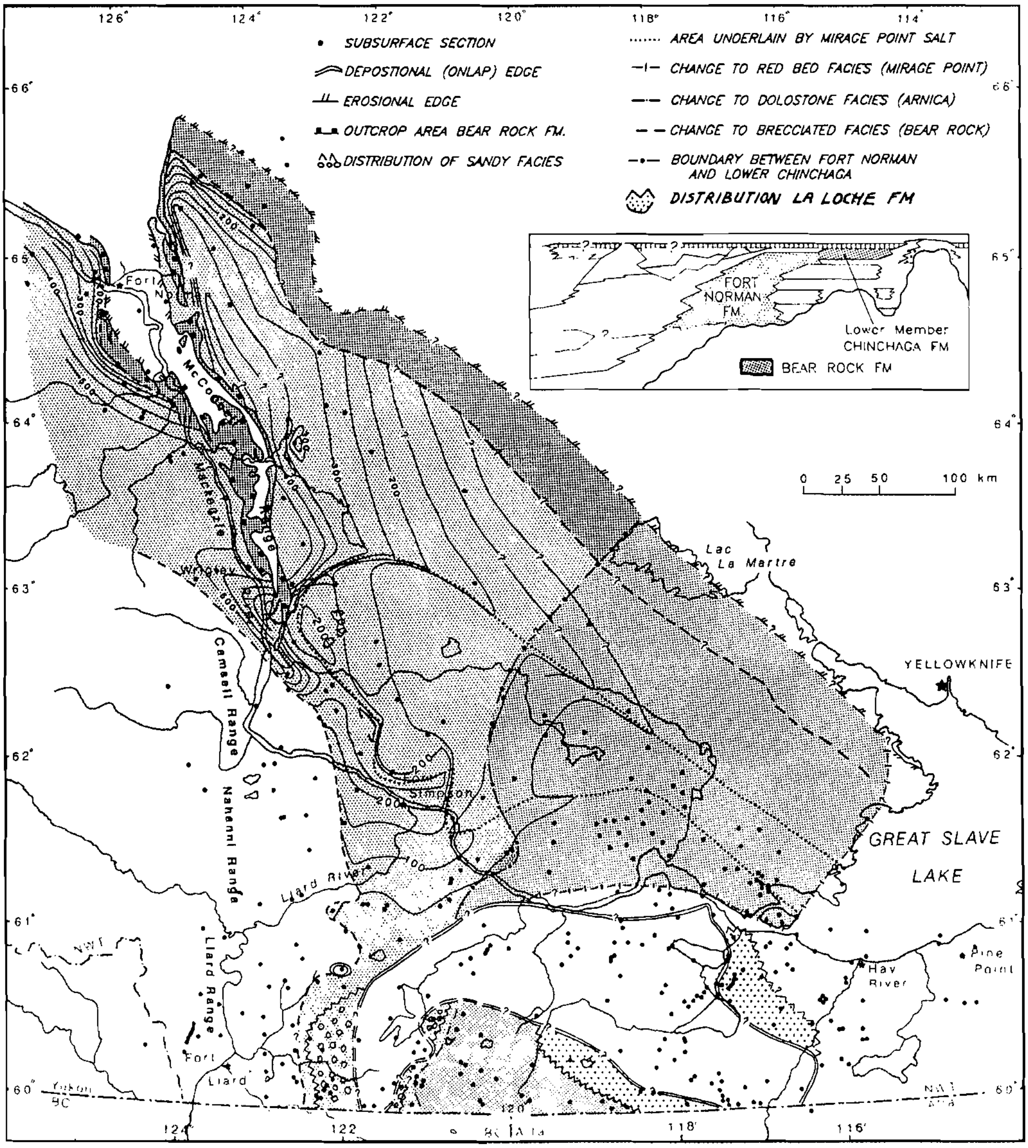


Fig. 21.- *Isopach map of the late Lower to early Middle Devonian evaporite facies.*

2. Evaporite facies of sequence 2

The evaporites and associated carbonates of the second sequence are widely distributed in the northern Interior Plains and the northern Mackenzie Mountains. In surface sections they are represented by the Bear Rock Formation: a massive limestone or dolostone breccia, in places gypsiferous. In the subsurface the approximate equivalent of the Bear Rock Formation is an interbedded succession of anhydrite and dolostone that grades southeastward into a unit including halite and redbeds.

Our knowledge of the subsurface equivalents of the Bear Rock Formation is good enough to introduce a formal subdivision. Thus the previously informally defined subsurface map units are revised to accommodate three units. They are the Fort Norman (new name), the Mirage Point (redefined) and the Chinchaga formations (see Meijer Drees, in press).

The Fort Norman and Mirage Point formations, and the Lower Member of the Chinchaga Formation formation form a diachronous succession of redbeds and evaporites which overlies the pre-Devonian unconformity on Norman Wells High, overlies older Devonian evaporites in Root Basin and the northern part of Willow Lake Embayment, overlies the "Unnamed Sandstone Unit" in Great Slave Basin and changes laterally into the a sandy facies on the flanks of Tathlina Uplift (see Fig. 21). The distribution suggests that the evaporites accumulated in the onshore and nearshore environments along a gently sloping flank of an ancient landmass, located somewhere on the Canadian Shield and in an embayment north of Tathlina Uplift.

On Figure 8 the diachronous succession of evaporites is truncated by the sub-Headless unconformity. This unconformity extends southeast- and southward below the Ebbutt Member and cuts the Chinchaga Formation in two parts. The Lower Member belongs to stratigraphic sequence 2. The Ebbutt and Upper members belong to sequence 3.

Bear Rock Formation

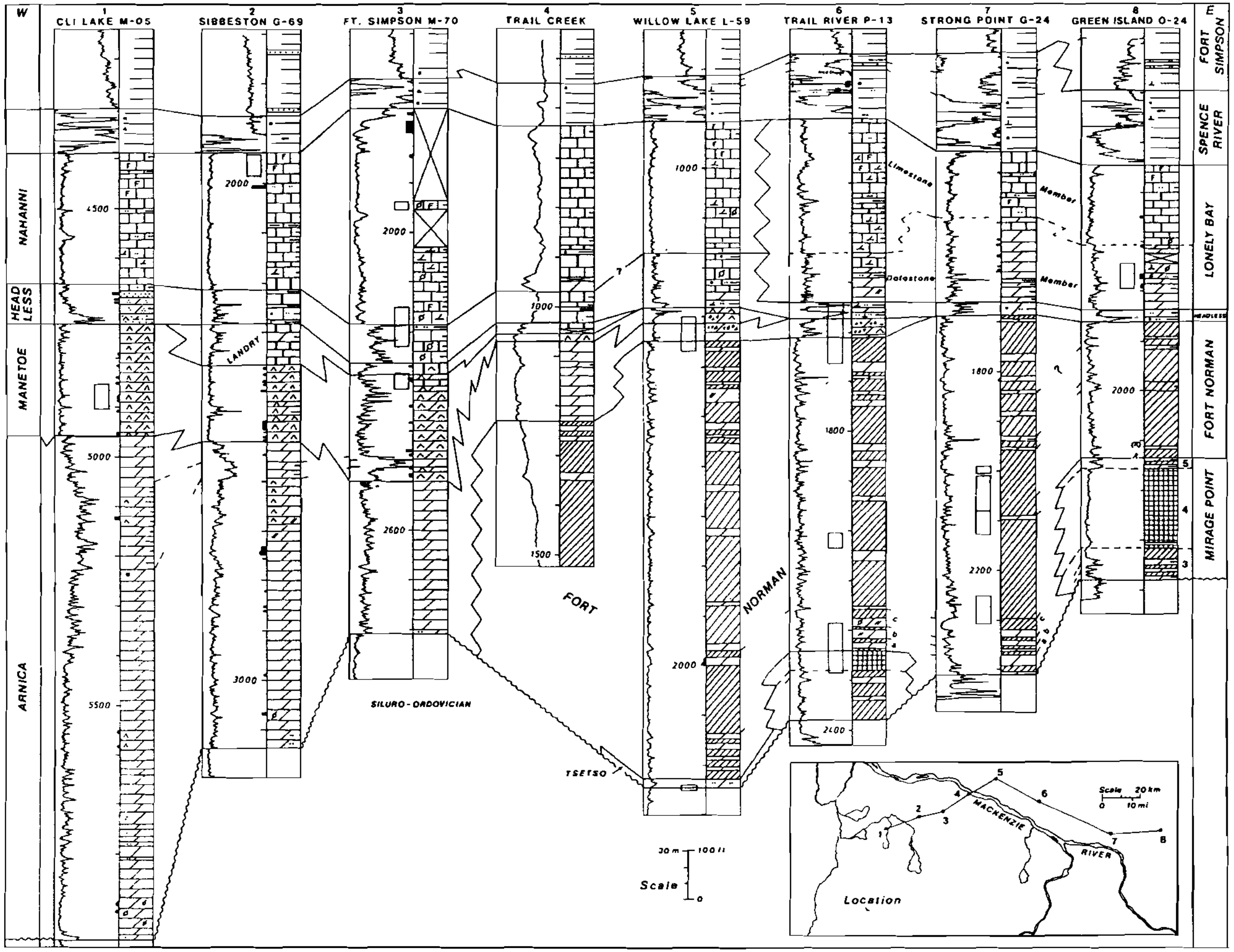
The term Bear Rock Formation (Hume and Link, 1945) is used in the Great Bear Plain to describe the succession of non-bedded, gypsiferous carbonates, gypsum and carbonate breccia present at the surface and in the shallow subsurface, "lying below Middle Devonian strata and above a sharp disconformity with well bedded Silurian limestones". At the type section on Bear Rock near Fort Norman the formation is 154 m thick (see Morrow and Meijer Drees, 1981) and overlies Late Cambrian to early Middle Ordovician rocks with an erosional unconformity (see Hume and Link, 1945, p.12; Aitken, Macqueen and Usher,1973, p.122).

The typical Bear Rock facies is only present at the surface and in the shallow subsurface; in the deep subsurface the limestone breccia is represented by an undisturbed interval including anhydrite (see Hume, 1954; Tassonyi, 1969). The upper boundary of the Bear Rock Formation in the subsurface, as defined by Tassonyi (1969), corresponds with the base of the Landry Formation. There is thus a discrepancy between surface and subsurface nomenclature and in this report the term Bear Rock only describes the carbonate breccia as seen in exposures and in the shallow subsurface.

The Bear Rock Formation rarely contains fossils. Cook and Aitken (1971) reported the presence of the giant ostracode Moelleritia canadensis from a section in the Colville Hills region. This fossil probably indicates a Middle Devonian (Eifelian) age.

The Bear Rock Formation is exposed in the McConnell and Norman Ranges, in the unnamed

Fig.22.- *Stratigraphic cross-section across Willow Lake Embayment (Fort Simpson area).*



mountain ranges north and south of Mount Charles and in the Colville Hills region (see Fig. 21). It is also present in the northern Mackenzie Mountains (see Aitken et al., 1982). The Bear Rock Formation outcrops sporadically in the northern part of the Great Bear and the western part of the Horton Plains. Douglas and Norris (1963) measured the formation on the south end of the McConnell Range and reported a thickness of 326.1 m.

Lithology

In most surface sections in the northern Franklin and northeastern Mackenzie Mountains the Bear Rock Formation is a chaotic, calcareous and gypsiferous breccia containing angular toslightly rounded dolostone or limestone fragments (see Plate Ib). The matrix of the breccia is calcareous and weathers more recessive than the fragments. Calcite is present in the form of scattered, fine to coarse, blocky inclusions and short veins, or as cement and vug filler. The blocky inclusions occur in the fragments as well as in the matrix and are reminiscent of anhydrite crystals. On weathered surfaces the breccia appears porous and cavernous because the calcite is locally leached. The Bear Rock Formation is in general poorly exposed and the upper and lower contacts are disturbed or concealed. Extensive gypsum outcrops are present about 8 km north of Mount St. Charles (lat. 65 07'30"N, long. 124 43'W).

In the shallow subsurface of the Mackenzie and Great Bear Plains the Bear Rock breccia commonly includes gypsum veins and secondary calcite deposits. In deep subsurface sections, the approximate stratigraphical equivalents of the Bear Rock Formation are undisturbed and consist of interbedded dolostone and anhydrite; breccias are notably absent (see Meijer Drees, 1980). In these equivalents some of the anhydrite is replaced by calcite. This information suggests that the brecciation is be a late diagenetic phenomenon, related to pre- Cretaceous dissolution and recent weathering.

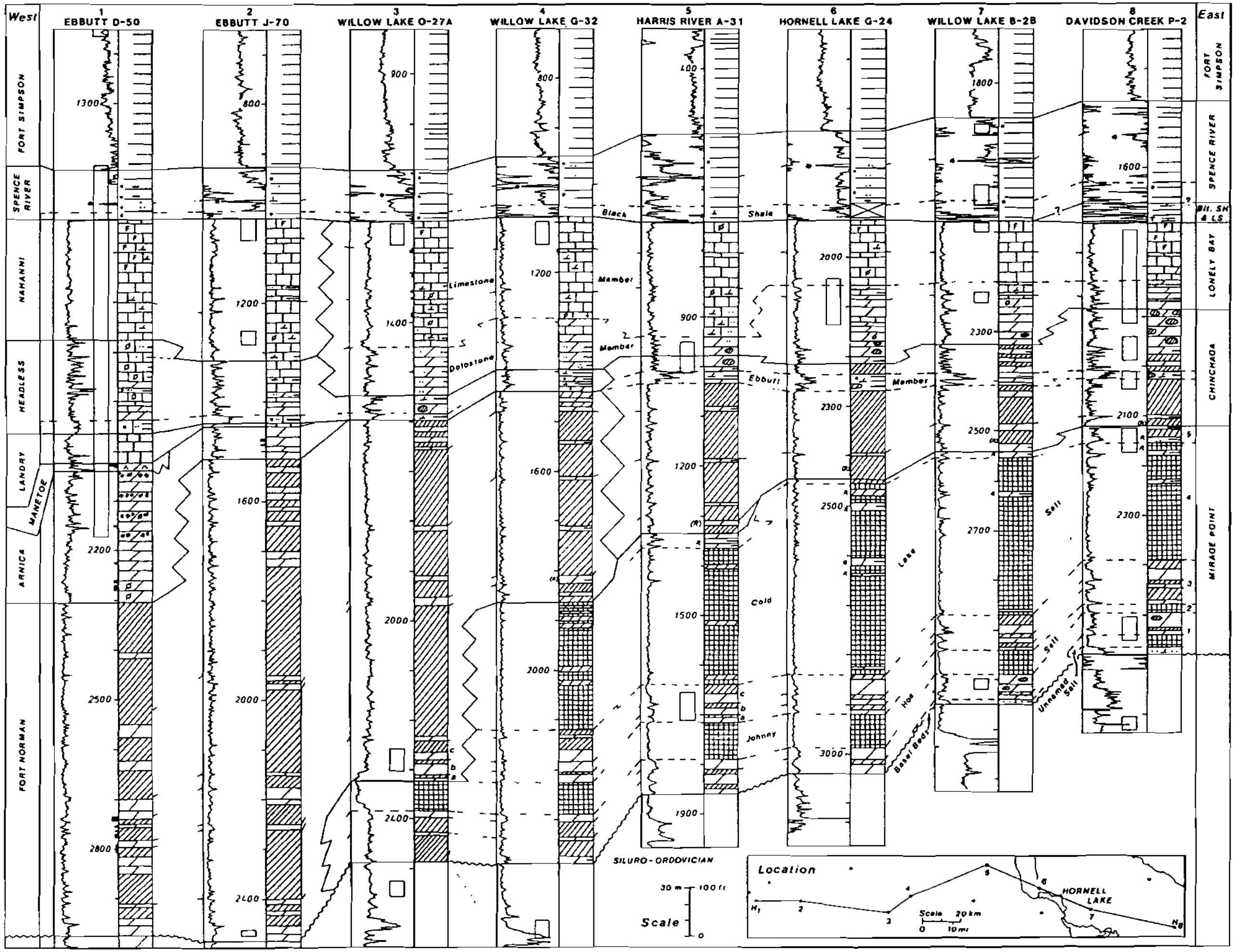
Fort Norman Formation

The name Fort Norman Formation (Meijer Drees, in press) is proposed for the interbedded succession of anhydritic and dolomitic rocks which underlies the Arnica Formation and overlies the Tsetso Formation or the Tsetso equivalents. In places where the Tsetso Formation is absent the Fort Norman Formation unconformably overlies Silurian or older rocks. The formation is widely distributed in the subsurface of the northern Interior Plains of the Mackenzie District. It consists of light brown or greyish brown coloured, cryptocrystalline to finely crystalline, in part anhydritic dolostone; light grey or greenish grey, mostly dolomitic, crypto- to microcrystalline anhydrite and white to translucent, nodular-bedded, finely to coarsely crystalline anhydrite.

The type section in the Fina et al. Willow Lake L-59 well between depths 411.4 and 679.7 m (1350 and 2230 ft) is shown on Figure 22, section 5. In the Willow Lake L-59 well the formation consists of interbedded nodular anhydrite, greenish grey anhydritic mudstone and light greyish brown or greyish brown, micro- to cryptocrystalline dolostone. It overlies a thin unit of silty and sandy dolostone, which is regarded as part of the Tsetso Formation, and is conformably overlain by dolomitic beds of the Arnica Formation.

Because the Fort Norman Formation does not contain diagnostic fossils the age of the formation is not precisely known. Stratigraphical equivalents of the Fort Norman Formation, the Mirage Point

Fig. 23.- *Stratigraphic cross-section across Willow Lake Embayment (Horn Plateau area).*



and Arnica formations, contain Amphipora sp. and Planetophyllum sp. Fossiliferous beds overlying the Fort Norman Formation are of early Middle Devonian age.

The Fort Norman Formation is widely distributed in the subsurface of the Great Slave, Great Bear and Mackenzie Plains. It reaches its maximum thickness in the southwestern part of the Great Bear Plain and in the southern part of the Mackenzie Plain, where it is more than 450 m thick (see Fig. 21). In the type section the formation is 268 m thick, overlies the Tsetso and underlies the Arnica Formation. Farther east, in the subsurface of Horn Plateau the formation overlies and is in lateral contact with the Mirage Point Formation (see Fig. 23).

The upper part of the Fort Norman Formation is in mappable continuity with the Lower Member of the Chinchaga Formation. The upper contact of the Fort Norman Formation moves upward in section, going from west to east, in the subsurface of Horn Plateau, because the Arnica Formation thins to zero (see Figs.22 and 23). The Fort Norman Formation is thus in places directly overlain by the Headless Formation.

The eastern limit of the Fort Norman Formation is defined by the last occurrence of anhydritic interbeds. This boundary is relatively sharp and has been mapped as a line on Figure 21. East of the line, dolomitic beds equivalent to the Fort Norman Formation are mapped together with the Arnica Formation although there is evidence, that some sections near the facies boundary are brecciated and originally included anhydrite interbeds.

In the southwestern part of the Great Slave Plain the Fort Norman Formation overlies the Mirage Point Formation and on Figure 24 the formation thins in a southerly direction. Here the lower part of the formation grades laterally into the Tsetso and Mirage Point formations along the northwestern flank of Tathlina Uplift while the upper part is in lateral contact with silty dolostone of the Arnica Formation.

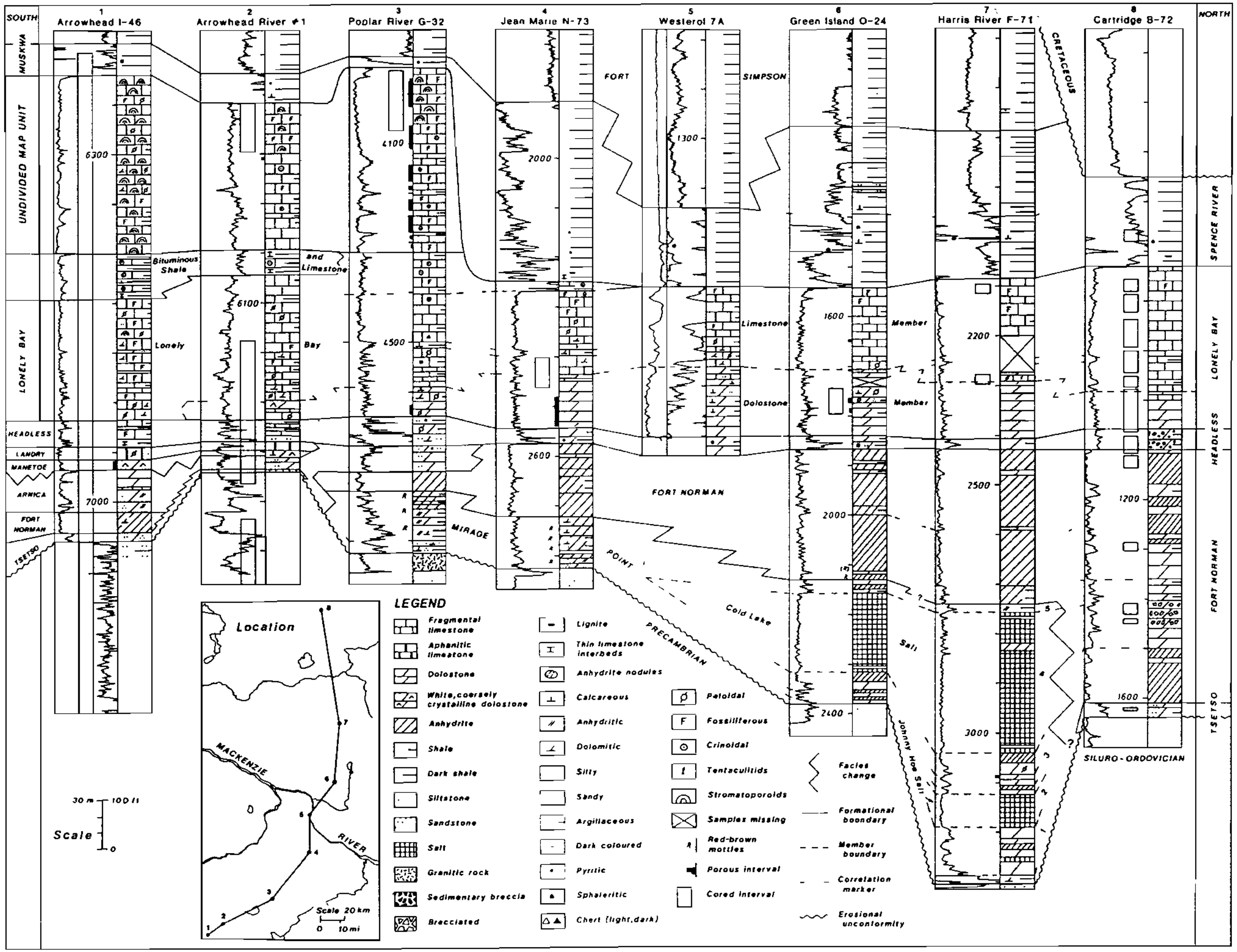
The cross section on Figure 24 also shows the northeastern limit of the salt beds of the Mirage Point Formation. In the Imperial Cartridge B-72 well (see Fig.24, section 8) the lower part of the Fort Norman Formation includes the equivalents of the salt beds but in this well the thickness of the Fort Norman Formation is less than the combined thickness of the Mirage Point and Fort Norman in the Harris River F-71 well. The structural cross sections on Figure 5 indicate that the thinning is related to the proximity of the outcrop area. A similar situation is present along the entire southern part of the Devonian outcrop belt in Alberta, Saskatchewan and Manitoba. Apparently salt was leached in the shallow subsurface causing the overlying beds to collapse (see Holter, 1969; Meijer Drees, 1986).

Lithology

In the deep subsurface the Fort Norman Formation consists of an inter- bedded succession of greenish grey, or grey anhydritic mudstones, light grey nodular or nodular bedded anhydrite and light brown to greyish brown dolostone, commonly anhydritic. The anhydritic lithologies are poorly represented in well cuttings and consequently no detailed information can be obtained from a study of samples. Fortunately a large part of the formation was cored in the Candex et al. Dahadinni M-43A well and a number of short cores were cut in several other wells. The following description of the lithology is thus primarily based on a study of cores.

The section in the Dahadinni M-43A well was described by Meijer Drees (1980) and correlated with the Evaporitic member of the Bear Rock Formation. It is an interbedded succession of

Fig.24.- *Stratigraphic cross-section across Willow Lake Embayment (Laird River area).*



dolomitic and anhdyritic rocks and locally includes regressive, sedimentary sequences (see Fig. 25).

In the southern part of the Mackenzie and Great Bear Plains the Fort Norman Formation includes in the lower part many dark grey, peloidal and in places porous dolostone beds. Some of these beds form mappable units on Figure 26. In most wells this dolostone facies overlies an anhydritic unit of variable thickness, but in the Sinclair Wolverine Creek D-61 well the pelodial dolostone directly overlies the Tsetso Formation. Several short cores were cut in the dark grey dolostone facies in the lower part of the Fort Norman Formation.

In the Fort Norman area the Fort Norman Formation consists mainly of anhydrite and the dark grey, porous dolostone interbeds are absent. Here the principal lithologies are nodular-bedded anhydrite, greenish grey subfelted, anhydritic mudstone and light greyish brown or light brown, dolomitic mudstone.

In the western part of the Great Slave Plain the Fort Norman Formation locally overlies the Mirage Point Formation (see Figs. 22 and 23). Here it is an interbedded succession comprising nodular and nodularly bedded anhydrite; greenish grey anhydritic, mudstones; light greyish brown, micro-crystalline, anhydritic and dolomitic mudstones ; grey peloidal, dolomitic wackestones and anhydrite breccia. This succession was partly cored in several wells. By using the correlations in figures 23 and 24 the cores can be placed in stratigraphic order so that a more or less continuous section is obtained.

In the northeastern part of the Great Slave Plain the Fort Norman Formation includes in the lower part beds equivalent of the Mirage Point Formation. Regional geologic evidence suggests that in the area just southwest of the Devonian outcrop belt salt was leached from the shallow subsurface, causing the overlying carbonates to collapse. (see Fig. 5, sections A-A', B-B', C-C' and D-D').

The correlations on Figure 24 thus suggest that the two short cores in the lower part of the Fort Norman Formation in the IOE Cartridge B-72 well should display some evidence of this dissolution process. They consist of light greyish brown to greyish brown, breccias composed of subangular, very finely crystalline dolostone fragments in an aphanitic limestone or porous dolostone matrix, and minor dark brown, nodular anhydrite. Some dolostone beds have a fine to medium peloidal fabric, others contain blocky, calcitized crystallotopic anhydrite. One breccia consists of a limestone matrix and includes fragments of porous dolostone and fragments of dolostone containing calcitized, crystallotopic anhydrite. The porous dolostone is similar to the halite-cemented dolostone in unit 3 of the Mirage Point Formation in the western part of the Great Slave Plain.

In the southwestern part of the Great Slave Plain the Fort Norman Formation is relatively thin (see Fig. 21). Here the formation was cored in Imperial Sun Arrowhead I-46 well (see Fig. 24, section 1). Interval 218.2 to 231.6 m (7016 to 7060 ft) consists of light grey and grey mottled, dolomitic and anhydritic mudstones. Some mudstone beds have a bioturbated appearance, others are laminated and include scoured surfaces and scattered mud clasts. Interbeds of light grey, anhydritic mudstone are present locally. In these beds the laminae are frequently distorted or broken up.

Mirage Point Formation

The Mirage Point Formation (as redefined by Meijer Drees, in press) is a map unit in the southeastern part of the Great Slave Plain which unconformably overlies older Paleozoic or

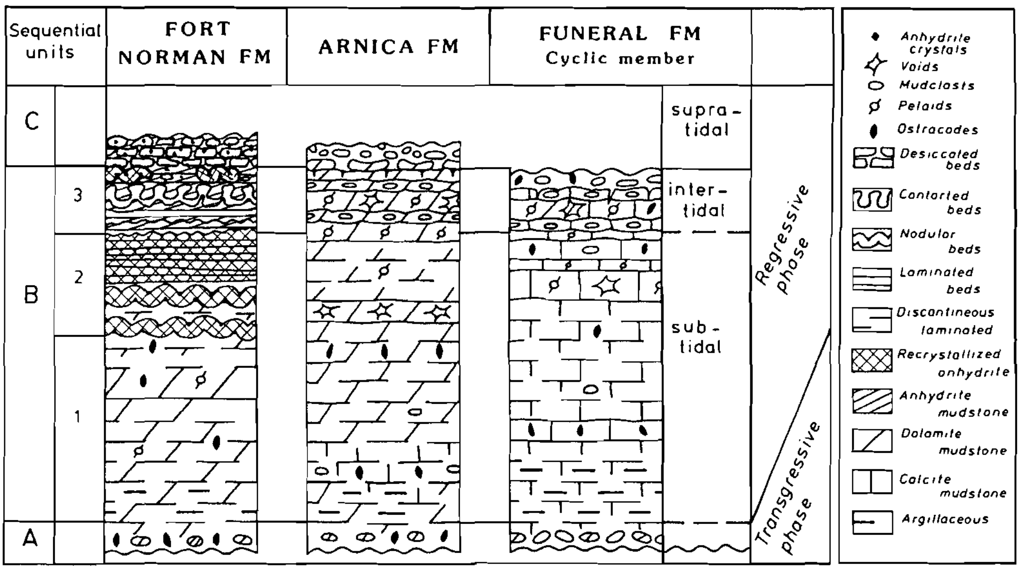


Fig. 25.- *Regressive sedimentary sequences in the Fort Norman, Arnica and Funeral formations of the Dahadinni M-43A well (modified from Meijer Drees, 1980).*

Precambrian rocks or transitionally overlies the "Unnamed Sandstone Unit" and is overlain by the Chinchaga Formation. It is an interbedded succession of anhydrite, dolostone, halite and redbeds. It onlaps Tathlina Uplift to the south and grades laterally into the Fort Norman Formation to the west and north. The Mirage Point Formation belongs to the Lower Elk Point Subgroup and includes the equivalents of the "Basal Red Beds", Lotsberg, Ernestina Lake, Cold Lake and Contact Rapids formations (see Law, 1971).

The type section is shown on Figure 20, section 5, and consists of two parts. The lower part (interval 500.7-598.9 m, 1643-1965 ft) includes reddish brown dolomitic shale, sandstone and sandy dolostone. The upper part is an interbedded succession of redbeds, halite, dolostone and anhydritic beds, which includes equivalents of the Ernestina Lake, Cold Lake and Contact Rapids formations. The top of the Mirage Point Formation is selected at the highest occurrence of reddish brown, dolomitic shale and coincides with the base of the Chinchaga Formation as proposed by Law (1955).

The lower part of the Mirage Point Formation is unfossiliferous and its age is unknown. The upper part of the Mirage Point Formation includes a fossiliferous dolostone member (the Fitzgerald member). The fossils from this member were dated by Norris (1965) and Rice (1967) as possibly Middle Devonian.

The distribution of the lower part of the Mirage Point Formation (unit 1 on Figs. 20, 27 and 28) is restricted to the Great Slave Lake and Horn Plateau regions and appears to have been deposited in paleotopographic depressions. The lower part of the formation ranges in thickness between 0 and 128 m (420 ft) and reaches its maximum thickness in the Windy Point no. 1 well (see Fig.20).

The upper part of the Mirage Point Formation, comprising the equivalents of the Ernestina Lake, Cold Lake and Contact Rapids formations, fringes the northeastern part of Tathlina Uplift. It can be traced in the subsurface on figures 20, 23 and 27 from the Great Slave Lake region to Horn Plateau, where it passes laterally into anhydritic rocks of the Fort Norman Formation. The reddish brown colour, which characterizes the argillaceous beds that make up the upper part of the Mirage Point Formation in the Great Slave Lake region, disappears westward and in the subsurface of Horn Plateau the top of the formation is picked at the highest occurrence of rock salt. Farther eastward salt beds are not present and the eastern edge of the lower salt bed is regarded as the eastern limit of the Mirage Point Formation. The upper part of the Mirage Point Formation attains its greatest thickness in the subsurface of Horn Plateau and is relatively thin in the subsurface of the Great Slave Lake region (see Fig. 29). It varies in thickness between 0 and 160.3 m (526 ft).

On the isopach map of the Mirage Point Formation (see Fig. 29) it is clear that the formation onlaps Tathlina Uplift in the southwest and accumulated in two, more or less separate basins in the Horn Plateau and Great Slave Lake regions. The facies change between the Fort Norman and the Mirage Point Formation in the west is due to the loss of redbeds and salt. The thinning towards the northeast is related to the absence of the salt beds in the shallow subsurface just southwest of the Devonian outcrop area. Since the salt edge coincides with a structural depression in the overlying beds (see Fig. 5, sections A-A', B-B',C-C'and D-D') it is assumed that the salt was removed by circulating groundwater at a relatively late stage in the geological history of the area.

Lithology

The Mirage Point includes several mappable units, each with a distinct lithology. In the following

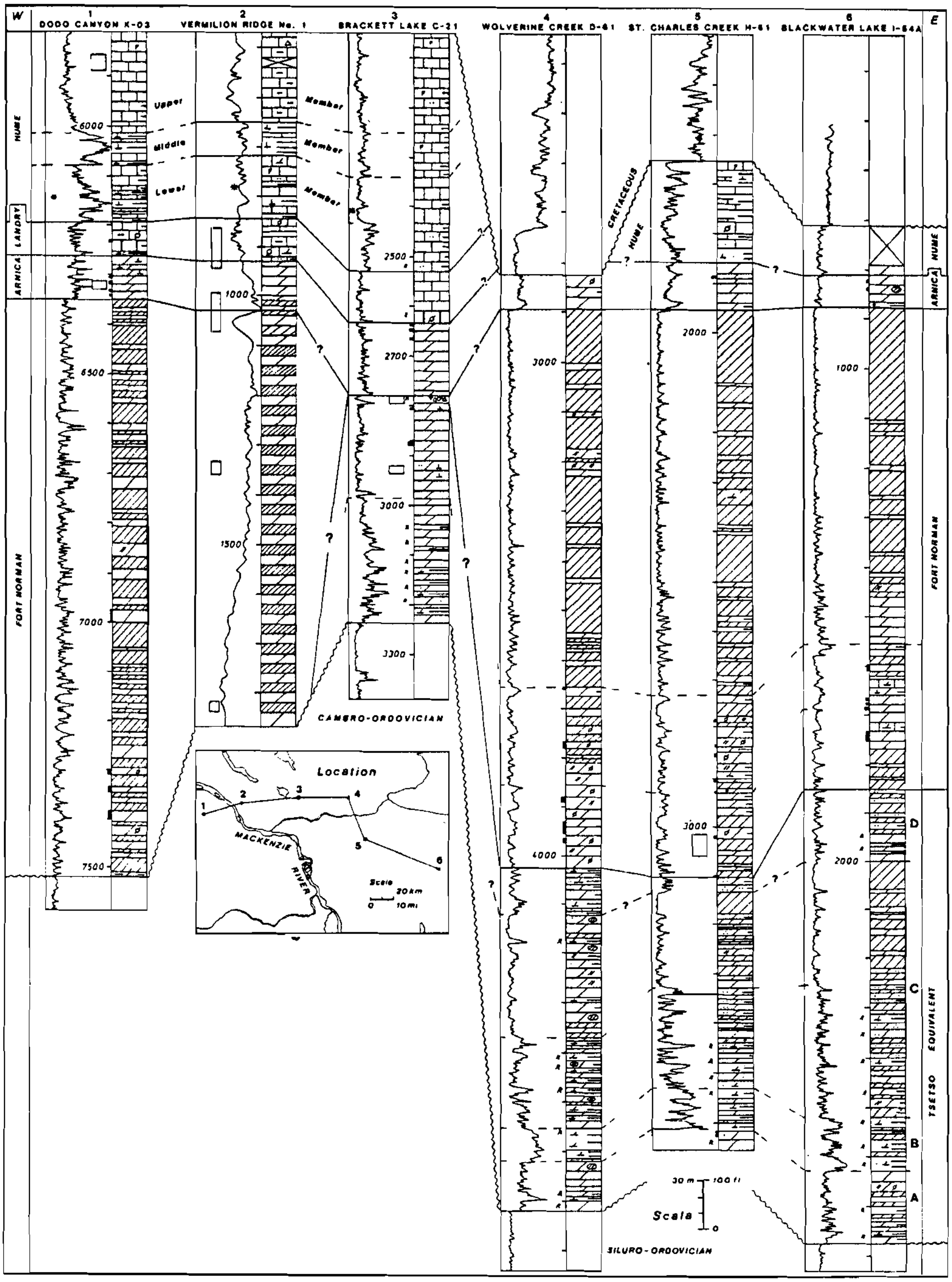


Fig. 26.- *Stratigraphic cross-section across Willow Lake Embayment (Fort Norman area).*

discussion an informal subdivision is used which includes five units. The lower part of the Mirage Point Formation in the Hay River B-52 well is regarded as unit 1 and it isassumed that this unit is of Early or early Middle Devonian age. The upper part of the formation includes four units of which two are composed of halite. The proposed informal subdivision does not apply in the areas where the halite interbeds are absent because the formation abutts Tathlina Uplift and in the region southwest of the Canadian Shield where salt is absent due to dissolution.

Unit 1: The lower part of the Mirage Point Formation in the Hay River B-52 well (unit 1 on Fig. 20, section 5) consists of reddish brown, dolomitic or anhydritic, silty and sandy shale with interbeds of dolomitic sandstone and sany dolostone. In this well and in the Windy Point no. 1 well the lower part includes in the middle a thin, prominent unit (between 3 and 6 m thick) consisting of pale coloured anhydrite, peloidal dolostone and halite. In these two wells and in the Horn River Big Island O-78 well (see Fig. 28, section 7) unit 1 underlies a thin bed of halite which belongs to the Johnny Hoe member (see Figs. 23 and 24).

Unit 2: (Johnny Hoe member): Unit 2 is present in the Hay River B-52 and the Davidson Creek P-2 wells and is composed of rocksalt. The salt and the underlying and overlying beds were cored in the IOE Trail River P-13 well (see Fig. 22, section 6) but very little halite was recovered. Salt is present as inclusions in the overlying and underlying anhydritic mudstone beds is colourless and semi-translucent.

Unit 3: In the Hay River B-52 well unit 3 includes three sub units (see Fig. 20, section 5). The lower two sub units correlate with the Fitzgerald Formation of Norris (1963), The upper sub unit is the basal member of the Cold Lake Formation.

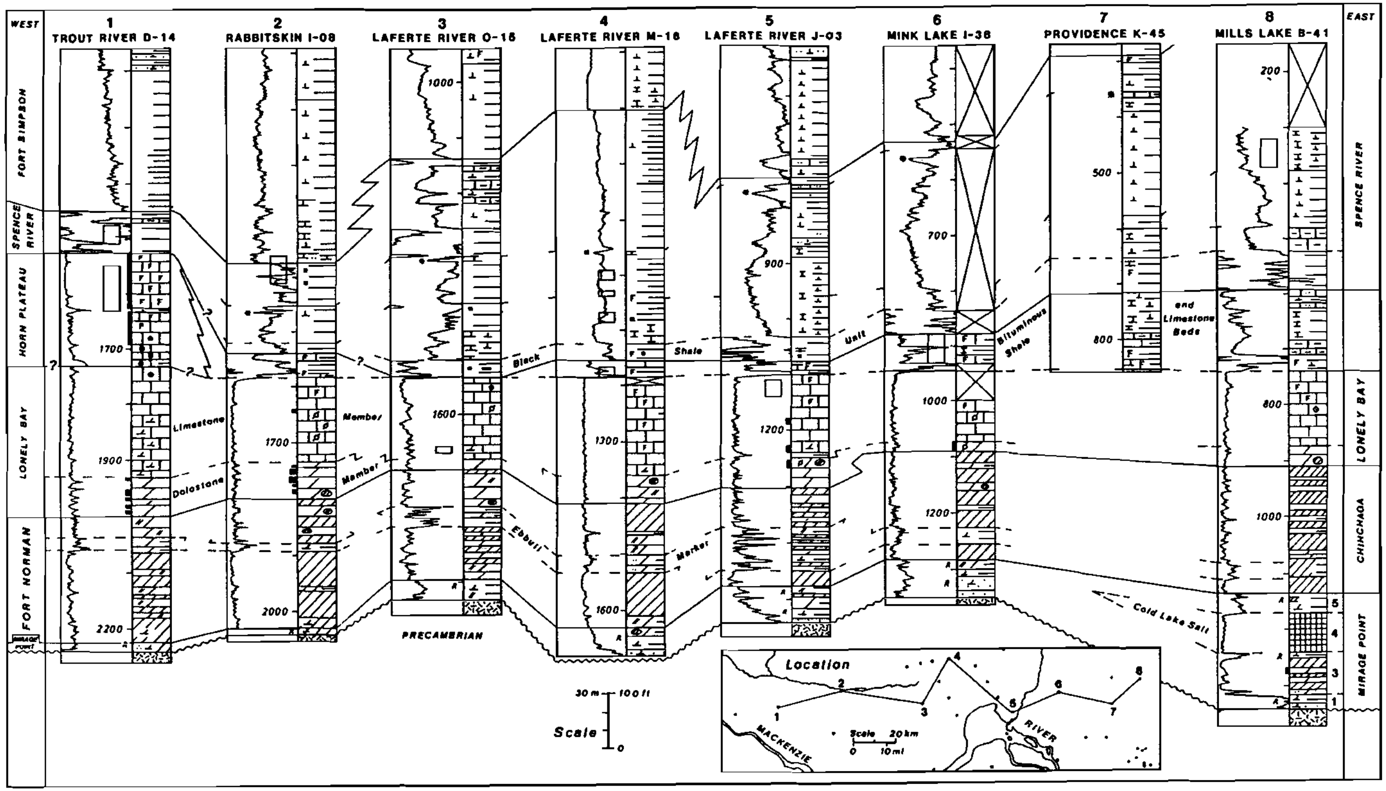
The lower sub unit consists of light grey anhydrite, greenish grey argillaceous dolostone and dark greyish brown anhydritic dolostone. The middle sub unit is a greyish brown, very fine to finely crystalline, peloidal dolostone with vuggy porosity. The upper sub-unit is a reddish brown, in part sandy, dolomitic shale.

In the Great Slave Lake region the middle sub unit is a widely distributed and is locally fossiliferous. Rice (1967) reported the presence of the ostracode Welleria meadowlakensis in the Pyramid 202A well and described the fauna from subsurface and surface sections in northern Alberta. He concluded that the ostracodes are of early Middle Devonian age.

Correlations on figures 27 and 28 indicate that going west and northwestward unit 3 onlaps paleotopographic high areas and ceases to be recognizable. In the Horn Plateau region the unit does not include an upper redbed sub unit. In the Davidson P-2 well unit 3 is an interbedded succession of dolostone and anhydrite which can be subdivided in three sedimentary sequences (see Fig. 23, section 8). Unit 3 was partly cored in the Chevron Harris River A-31 well (see Fig. 23, section 5) and includes the same three sedimentary sequences (a,b and c) present in the lower part of the Fort Norman Formation of the Willow Lake O-27A well. In the Harris River A-31 well the first two sequences and the lower part of the third sequence were cored. The dolostone is peloidal and fossiliferous. One coral was identified by A.E.H. Pedder (pers. comm.) as Planetophyllum sp.

Unit 4 (Cold Lake Member): It is demonstrated on Figure 20 that unit 4 in the Hay River B-52 well is in mappable continuity with the upper part of the Cold Lake Formation. In the Davidson

Fig. 27.- *Stratigraphic cross-section across Willow Lake Embayment (Laferte River area).*



Creek P-2 well only the uppermost part of the Cold Lake Member was cored. This core consists of a light reddish brown, semi-translucent, very coarsely crystalline (1.5-3 cm in diameter) halite. In the region northeast of the dissolution edge the interval equivalent to the Cold Lake salt consists of a breccia composed of angular fragments of white, green and red anhydrite and red dolomitic shale in a matrix of red dolomitic shale (Rice, 1967). The thickness of the breccia in the three wells is 15.5, 10.3 and 11.2 m.

Unit 5: In the Hay River B-52 and Windy Point no. 1 wells, unit 5 is the uppermost member of the Mirage Point Formation. In samples it is a reddish brown, dolomitic shale with minor amounts of anhydrite. Figure 20 indicates that unit 5 correlates with the Contact Rapids Formation.

In the subsurface of the Horn Plateau region unit 5 ceases to be a distinctive unit west of the Harris River A-31 well because of a facies change to light grey coloured anhydrite (see Fig. 23).

Unit 5 was cored in the Davidson Creek P-2 wells and includes reddish brown and greyish green, anhydritic, dolomitic and shaly beds. The basal part is a breccia composed of angular and angular pieces of reddish brown, anhydritic claystone (which represent salt crystal moulds as large as 1.5 x 2 cm) set in a matrix of reddish brown claystone. This pseudobreccia grades upward into a unsorted mixture of pale green and reddish brown, in part laminated fragments of anhydritic claystone, claystone, gypsum crystals (partly altered to white anhydrite) and a matrix of reddish brown anhydritic claystone.

Chinchaga Formation

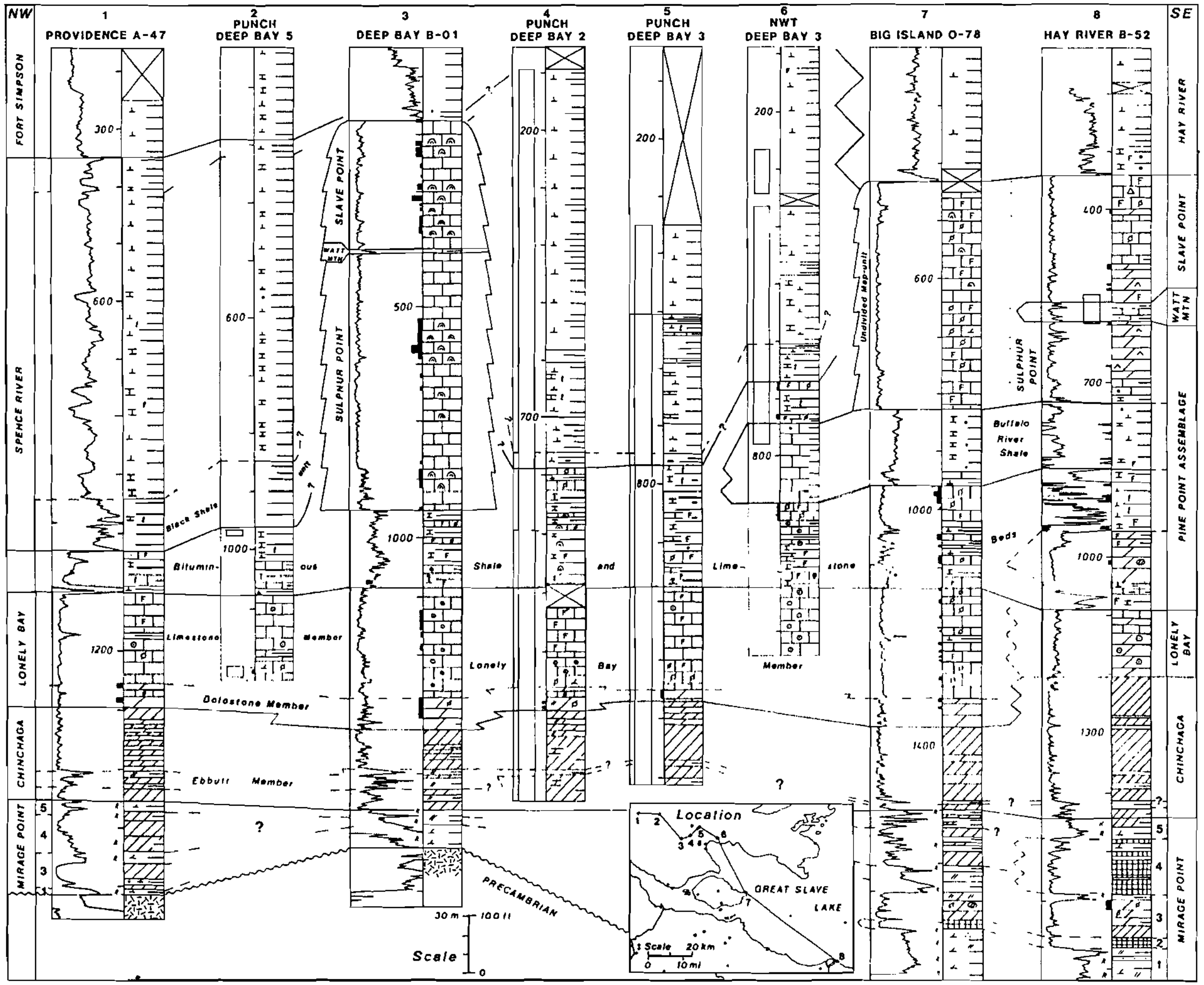
The Chinchaga Formation (Law, 1955) is a pale coloured unit of anhydrite and anhydritic dolostone which is widely distributed in northern Alberta, in northeastern British Columbia and in the southern part of the District of Mackenzie, Northwest Territories. The formation is part of the Elk Point Group and is the lateral equivalent of the upper part of the Contact Rapids Formation in east central Alberta (see Fig. 8). In northern Alberta it overlies redbeds which are in mappable continuity with the lower part of the Contact Rapids Formation and underlies carbonates of the Keg River Formation. In the District of Mackenzie the formation overlies redbeds of the Mirage Point Formation, sandy beds of the La Loche Formation or, locally, rocks of Precambrian age. In the District of Mackenzie it is overlain by the carbonates of the Lonely Bay Formation or lower part of the "Pine Point assemblage" (see Fig. 8).

In the type section, the California Standard Steen River no. 2-22 well (located in northern Alberta, see Fig. 30, section 1), the map-unit is present between depths 1668.78 m (5475 ft) and 1731.26 m (5680 ft) (see Law, 1955). The formation consists of light grey coloured anhydrite, dolostone and minor sandy interbeds.

In the Steen River no. 2-22 well the formation includes three members. The Lower Member is present between depths 1725.8 and 1731.2 m (5660 and 5680 ft), the Ebbutt Member lies between 1711.4 and 1725.8 m (5615 and 5660 ft) depth and the Upper Member occupies the interval between 1668.7 and 1711.4 m (5475 and 5615 ft) depth. Because this report describes the Chinchaga Formation in the Willow Lake Embayment, it is appropriate to use the section in the Imperial Triad Davidson Creek P-2 well (Fig. 23, section 8) as reference section.

The Lower Member of the Chinchaga Formation overlies the Mirage Point Formation with a gradational contact. The Member onlaps Tathlina Uplift and is absent in the crestal part of the Uplift

Fig.28.- *Stratigraphic cross-section across Willow Lake Embayment (Deep Bay area).*



(see Fig. 21). The Lower Member grades westward into the Fort Norman Formation and the boundary between the Fort Norman and Chinchaga formations has to be selected arbritrarily (see Fig. 8). The Ebbutt Member partly overlies Tathlina Uplift and grades westward in the basal part of the Headless Formation. The Upper Member extends up to the crestal part of Tathlina Uplift and is in facies contact with the Dolostone Member of the Lonely Bay Formation. It is proposed to use this facies boundary as the western limit of the Chinchaga Formation (see Fig. 8).

The Chinchaga Formation is sparsely fossiliferous. Norris (1962) reported the presence of fossils in the outcrop area which are of a possible early Middle Devonian age. The Chinchaga Formation is widely distributed in the southern eastern part of the District of Mackenzie, in northern Alberta and in northeastern British Columbia. The variation in thickness of the formation is related to pre-Devonian paleotopography and facies changes in the Devonian succession. In the northern Alberta the Chinchaga Formation grades southward into the Contact Rapids Formation (Sherwin, 1962). In northeastern British Columbia and in the Great Slave Plain of the District of Mackenize it grades westward into parts of the Fort Norman, Headless and Lonely Bay formations. This facies change is indicated as a north-south oriented line on Figure 31. The presence of a depositional edge in the southern part of the Great Slave Plain suggests that parts of Tathlina Uplift were emergent during the deposition of the Chinchaga Formation.

In the subsurface southwest of the outcrop area the uneroded thickness of the Chinchaga Formation ranges between 85.3 and 102.7 m and reaches a maximum thickness of 108.8 m in the subsurface of Horn Plateau. In the southern part of Great Slave Plain the formation ranges in thickness between zero and 50 m.

Only the Lower Member of the Chinchaga Formation belongs to stratigraphic sequence 2. The Ebbutt and Upper members are part of the third sequence and are described later.

Lower Member

The distribution and the variation in thickness of the Lower Member of the Chinchaga Formation is shown on Figure 21. The member reaches a maximum thickness in the subsurface of Horn Plateau near the facies boundary between the Fort Norman and the Chinchaga formations.

On the north flank of Tathlina Uplift the Lower Member passes laterally into redbeds of the Mirage Point Formation. This facies change is related to onlap. The Lower Member thins toward Tathlina Uplift and is gradually replaced from the base upward by reddish brown shale. It is truncated by the sub-Headless unconformity.

In the subsurface northwest of Great Slave Lake the Lower Member thins in a southeasterly direction and ceases to be a mappable unit (see Fig. 28). The gradual decrease in thickness of the Lower Member below the Ebbutt Member on Figure 28 can be partly explained by truncation below the sub-Headless unconformity and partly by the facies change from anhydrite to reddish brown shale.

Lithology: In the Davidson Creek P-2 well the Lower Member is present between depths 618.3 and 646.1 m (2028.7 and 2120 ft). The upper part of the Lower Member was cored and consists of irregularly interbedded, light greenish grey and greyish brown, anhydritic mudstone, locally containing pale coloured dolomitic mud clasts and dark coloured, deformed anhydrite inclusions; green shale and pale coloured dolomite- mudstone. The interval between 618.3 and 620.2 m

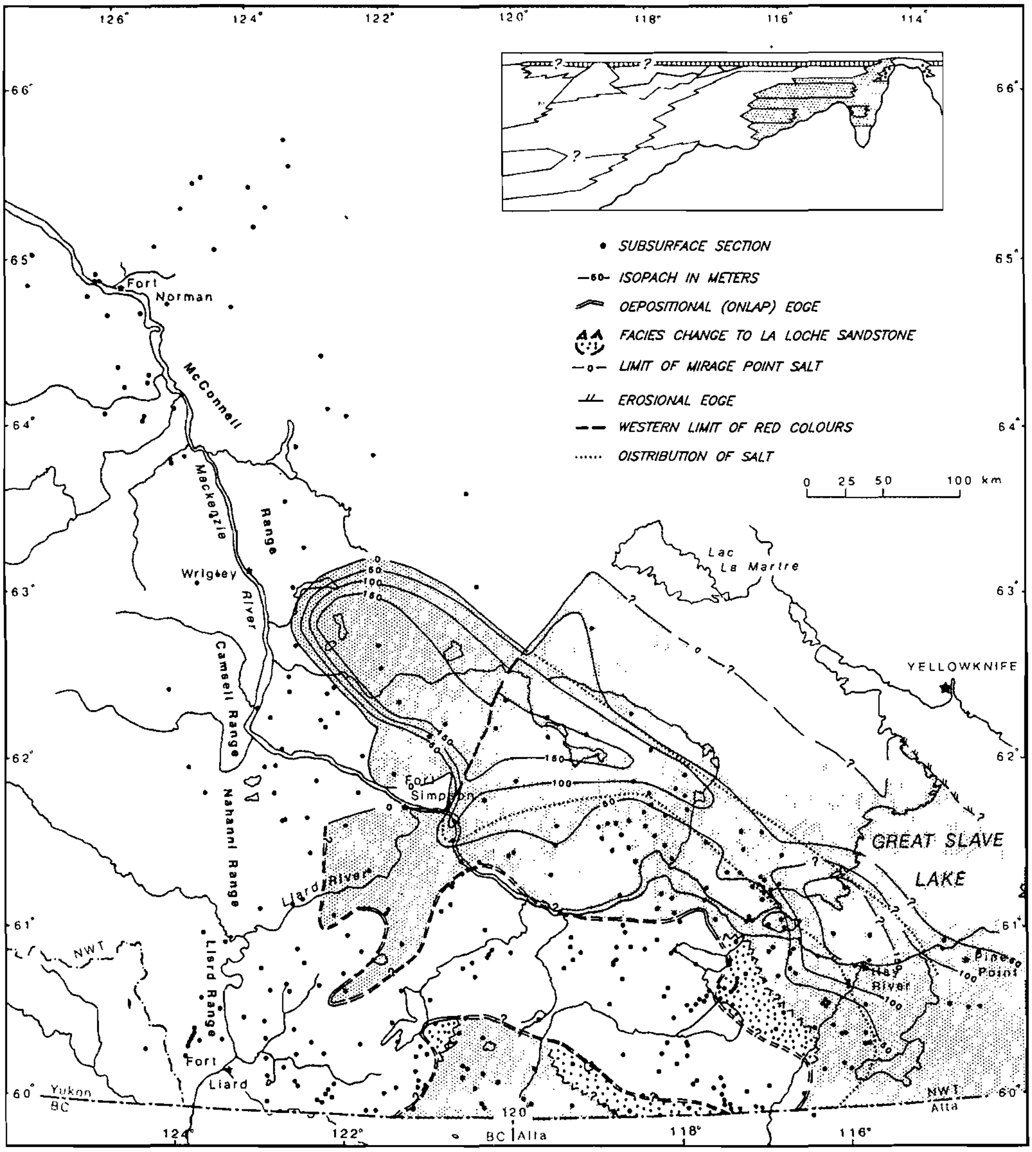


Fig. 29.- *Isopach map Mirage Point Formation*

(2028.8 and 2035 ft) depth includes several anhydritic breccias. The upper contact of the Lower Member lies at the base of an interval that includes green shale interbeds.

3. Carbonate facies of sequence 2

The late Lower to early Middle Devonian carbonate facies is widely distibuted in the Mackenzie Mountains and reaches its greatest thickness in Root Basin. The carbonates accumulated on a broad platform and change to shale along the northeastern margin of Selwyn Basin (see Fig.19).

The carbonate facies includes two map units. The distribution of the lower map unit (the Sombre Formation) is more or less confined to Root Basin. The Sombre Formation overlies the Camsell Formation and changes eastward into the lower part of the overlying Arnica Formation. The Arnica Formation is the upper map unit of the carbonate facies and extends farther eastward than the Sombre Formation. It is present in the subsurface in the western part of Great Slave Plain. Here it onlaps the western flank of the precursor of Tathlina Uplift and is in lateral facies contact with the evaporite facies of the second sequence (the Fort Norman Formation).

Sombre Formation

The name Sombre Formation was introduced by Douglas and Norris (1961) for a map-unit in the southern Mackenzie Mountains consisting of massive or thick-bedded dolostone. It overlies the Camsell Formation or its silty and sandy equivalents (the Tsetso Formation of this report) and is overlain by the Arnica Formation. Douglas and Norris (1961) stated that the formation is typically developed on Delorme Range and on Tundra Ridge of Nahanni Plateau and selected the type section on Tundra Ridge.

Work by Morrow (1984) indicates that the Sombre Formation is in lateral facies contact with the Arnica Formation. On Nahanni Range beds similar to the Sombre Formation underlie the Arnica Formation and it is thus possible that the Sombre Formation extends farther eastward than originally was indicated.

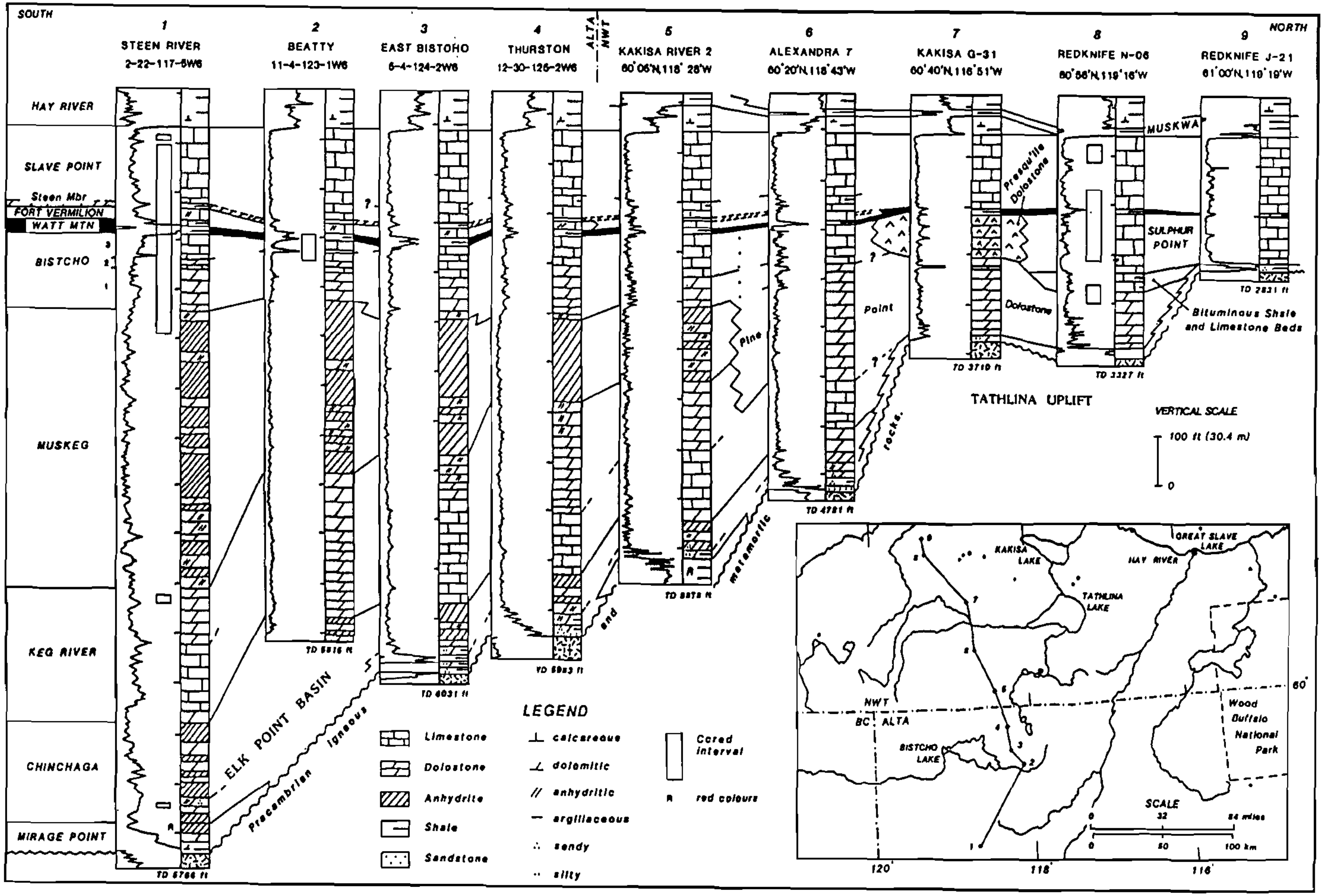
The Sombre Formation is generally unfossiliferous. However, Uyneo (in Morrow and Cook, 1987) reports the presence of Polygnathus dehiscens in a sample from the basal part of the formation. The dehiscens Zone is of Early Devonian age.

In the southern Mackenzie Mountains the Sombre Formation is 1249.6 m thick on Tundra Ridge (Douglas and Norris, 1961). Possible equivalents on Nahanni Range vary in thickness between 128.9 and 205.7 m. In the Pan Am A-1 Mattson Creek well (lat. 61 02'28"N, long.123 48'30"W) the possible equivalents are present between depth 1348.4 and 1586.7 m (4424 and 5026 ft). The thickness of this interval is 2383 m, but because the Mattson Creek well is located near the crest of a faulted anticline this value may not represent the true thickness.

Lithology

On Nahanni Range the possible equivalents of the Sombre Formation overlie the Tsetso Formation with a conformable contact. They consist of light and greyish brown to grey, poorly bedded or thick-bedded, microcrystalline, in places very finely crystalline dolostone, which has in places poor to fair microcrystalline and vuggy porosity. The beds weather grey and dark grey and

Fig. 30.- *Stratigraphic cross-section across Tathlina Uplift.*



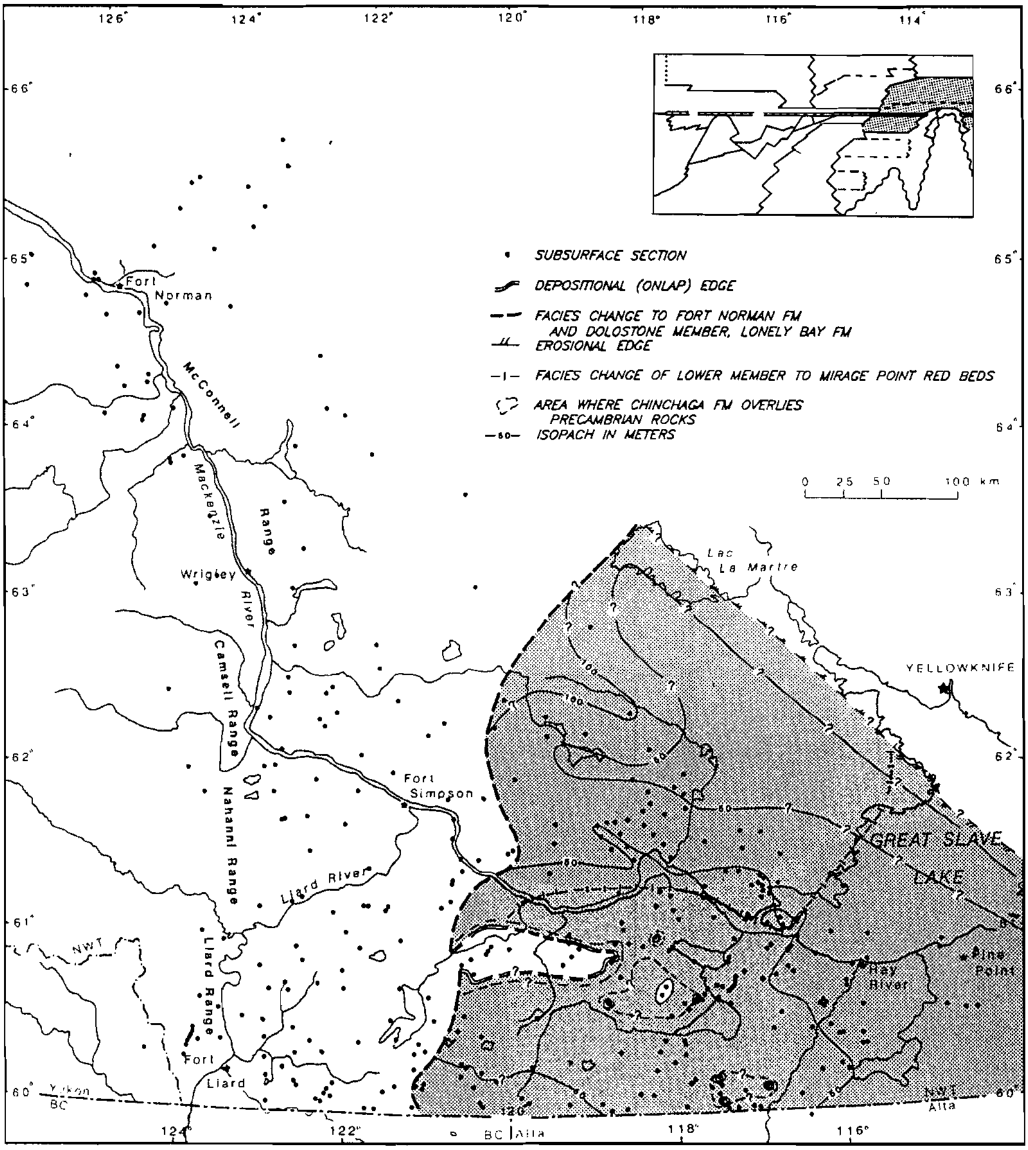


Fig. 31.- *Isopach map Chinchaga Formation.*

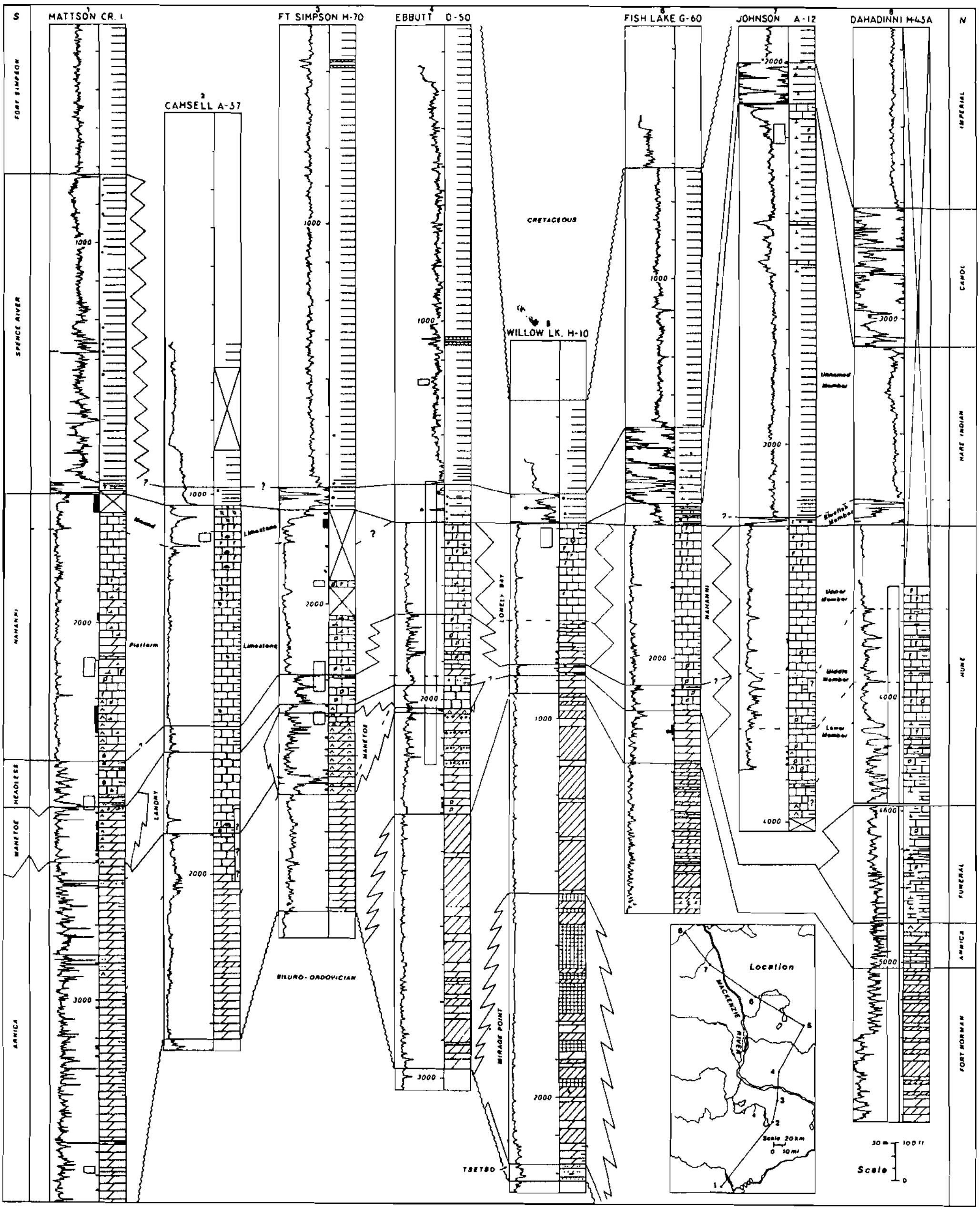


Fig. 32.- *Stratigraphic cross-section across Willow Lake Embayment (Mattson Creek to Dahadinni River).*

locally include poorly preserved Amphipora-like fossils.

Arnica Formation

The Arnica Formation (Douglas and Norris, 1961), describes a thick succession of distinctively banded, grey and dark grey dolostone in the southern Mackenzie and Franklin Mountains. The succession varies greatly in thickness and its stratigraphic positon changes from place to place. At the type section in the South Nahanni River area the formation gradationally overlies pale coloured, massive weathering dolostones of the Sombre Formation (Morrow, 1984), and is overlain by Manetoe dolostone. In the region northwest of the type area, (dissected by Prairie Creek and Root River) the upper part of the Arnica Formation grades laterally into argillaceous beds of the Funeral Formation (see Douglas and Norris, 1960 and 1961). Because of a facies change of the Manetoe Dolostone in this area the Arnica is in places overlain by the Landry Formation. These complex stratigraphic relationships are schematically shown in Figure 8.

At the type section in the First Canyon of South Nahanni River the Arnica Formation is 502.9 m thick (Douglas and Norris, 1960). A good subsurface reference section is present in the Pan Am Mattson Creek no. 1 well (see Fig. 32, section 1), between depths 801.6 and 1327.3 m (2630 and 4355 ft).

The Arnica Formation is sparsely fossiliferous and locally includes the upper Emsian conodont Polygnathus serotinus Telford (see Chatterton, 1978). The upper part of the Arnica grades laterally into, or is overlain by, the Funeral Formation, which includes fossils of early Eifelian or Eifelian age (Chatterton, 1978; Uyeno, in Meijer Drees, 1980). These facts suggest that the Arnica Formation ranges in age from late Early to early Middle Devonian.

The Arnica Formation is widely distributed in the Mackenzie Mountains (see Gabrielse et al., 1973; Aitken and Cook, 1974; Aitken, Cook and Yorath, 1982) and is a distinctive unit in the southern Franklin Mountains (Douglas and Norris, 1960, 1961, 1963). In the southern Mackenzie Mountains the formation ranges in thickness between 200 and 740.6 m (Douglas and Norris, 1960, 1961, 1963 and Morrow, 1984). On the Camsell and Nahanni Ranges the formation ranges in thickness between 360 and 618 m (see Figure 33).

The Arnica Formation extends eastward from the Cordillera into the subsurface of the Great Slave, Mackenzie and Great Bear Plains. It thins in an eastward direction from about 325 m in the area just east of the Nahanni Range to zero in the Keller Lake and Horn Plateau regions. In the southwestern part of the Great Slave Plain the formation fringes Tathlina Uplift, includes silty and sandy interbeds and either overlies the Tsetso, Fort Norman or Mirage Point formations (see Figs. 22 and 24).

In the subsurface east of Nahanni Range the Arnica Formation unconformably overlies Lower Paleozic rocks and is in lateral contact with the Fort Norman Formation. The formation thins rapidly eastward on Figure 33 because it onlaps and overlies a paleotopographic ridge (Liard High on Figs. 6 and 7). This situation and the complex stratigraphical relationships between the Arnica, the Manetoe and the Fort Norman are shown on cross-section in Figure 23. The Arnica Formation thins from west to east across Liard High and is transitionally overlain by Manetoe dolostone. On the east flank of Liard High the Arnica Formation overlies the Fort Norman Formation and thins eastward to zero below the Manetoe dolostone. Correlations on Figure 26 indicate that in the western part of Great Bear Plain the Fort Norman Formation is overlain by a relatively thin unit

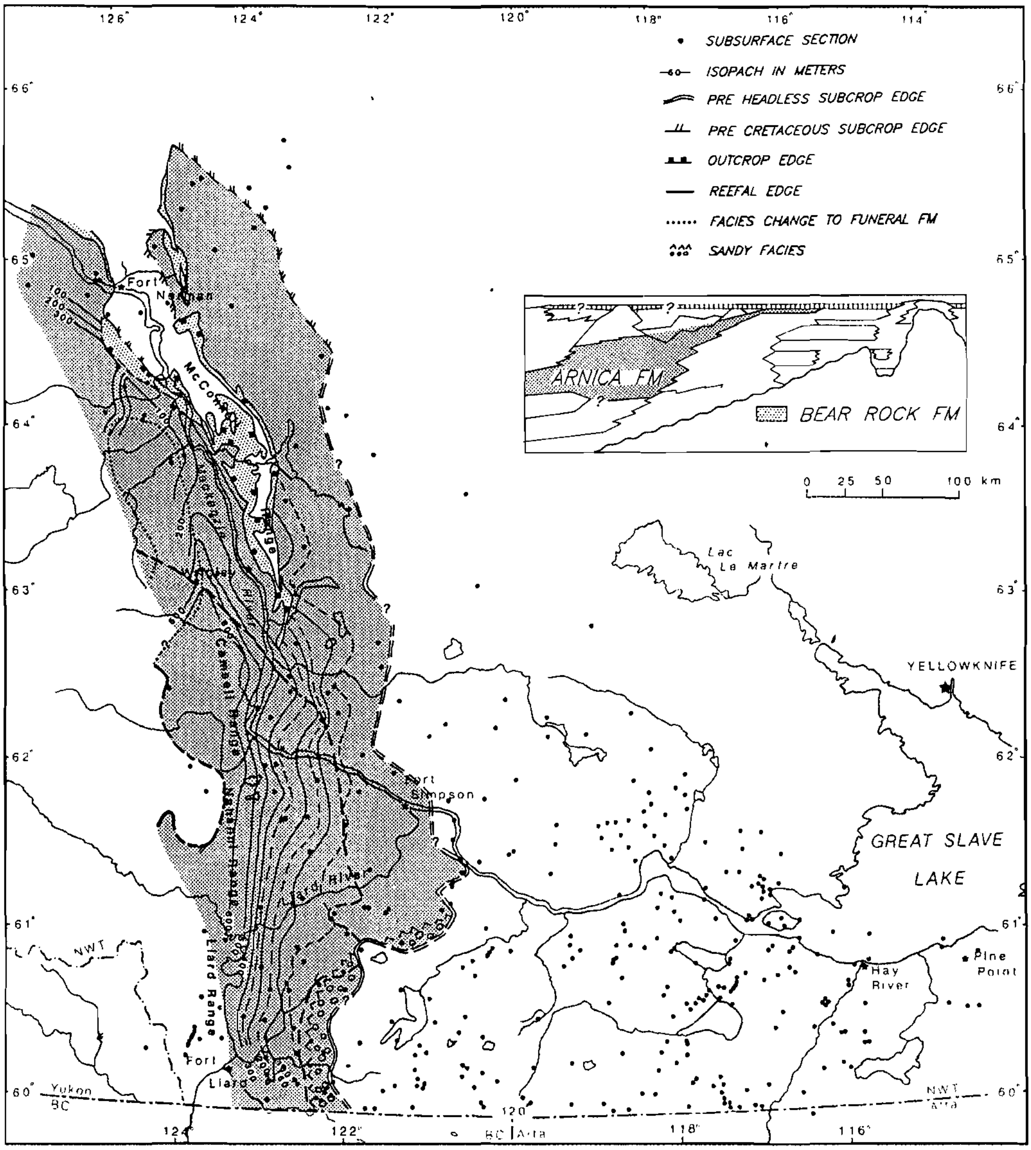


Fig. 33.- *Isopach map Arnica Formation.*

of Arnica dolostone. It is interesting to note that, although this dolostone unit is not brecciated in the Imperial Vermilion Ridge no. 1 well (Fig. 26, section 2), it includes collapse type breccia interbeds in the Great Slave Plain (see Fig. 22, section 5 and 6,Fig.24, section 1). The western limit of the Arnica Formation is mapped as a facies change between the Arnica and Funeral Formations. In the southern Mackenzie Mountains, the Arnica Formation becomes more argillaceous in a westward direction, and the upper part is replaced by a dark coloured interbedded succession composed of argillaceous limestone and calcareous shale (the Funeral Formation). The precise location of the facies change is poorly known and the line which represents the western limit of the Arnica Formation on Figure 33 is largely inferred. In the area west of this facies change to shale the Arnica Formation is less than 100 m thick.

Lithology

In the southern Mackenzie and Franklin Mountains the Arnica Formation is an interbedded succession of dark grey, somewhat argillaceous or bituminous dolostone and greyish brown non argillaceous dolostone. The dark grey beds commonly include fossils, mainly crinoidal debris, brachiopods or Amphipora. The greyish brown beds are locally laminated or contain scattered fenestral vugs filled with dolomite. White dolomite veins and patches are commonly present and so are dark grey, stylolitic shale partings.

In the wells located directly east of the Nahanni and Camsell Ranges the Arnica Formation was not cored, but in the drill cuttings collected at 3 m intervals both the greyish brown and the dark grey dolostone are commonly present in each sample. This indicates that the two types of dolostone are regularly interbedded. In the Ebbutt Hills and Fort Simpson areas the Arnica Formation is relatively thin and is underlain by the Fort Norman Formation. In this region the Arnica Formation consists of light greyish brown or greyish brown, micro- to finely crystalline dolostone and includes in the upper part brecciated intervals cemented by white, very coarsely crystalline dolomite. The Arnica Formation was cored in five wells of which four are shown on cross-sections (see Figs. 22 and 23).

In the subsurface of the Liard Range and in the Texaco Bovie J-72 well (lat. 60 11'39"N, long. 122 58'44"W) the Arnica Formation includes much coarse- to very coarsely crystalline dolomite, which has obliterated many of the original sedimentary structures. Subsurface correlations in this region suggest that the Arnica Formation is present as a thin unit in the Imperial Sun Arrowhead I-46 well and in the Murphy BOC Arrowhead River no. 1 well (see Fig. 24).

In the Arrowhead River no. 1 well (see Fig. 24, section 2) the Arnica Formation overlies a thin basal Devonian sandstone unit and the lower part (interval 1958.4 to 1961.6 m, 6425.5 to 6436 ft) is a pale yellowish grey and light grey mottled, microcrystalline dolostone containing scattered fine quartz grains and light coloured dolostone pebbles. The distribution of the sandy facies is restricted to a narrow zone west of Tathilina Uplift (see Fig. 33).

This sandy dolostone facies is overlain by a dolostone conglomerate which grades upwards into grey, micro to very finely crystalline, laminated dolostone.

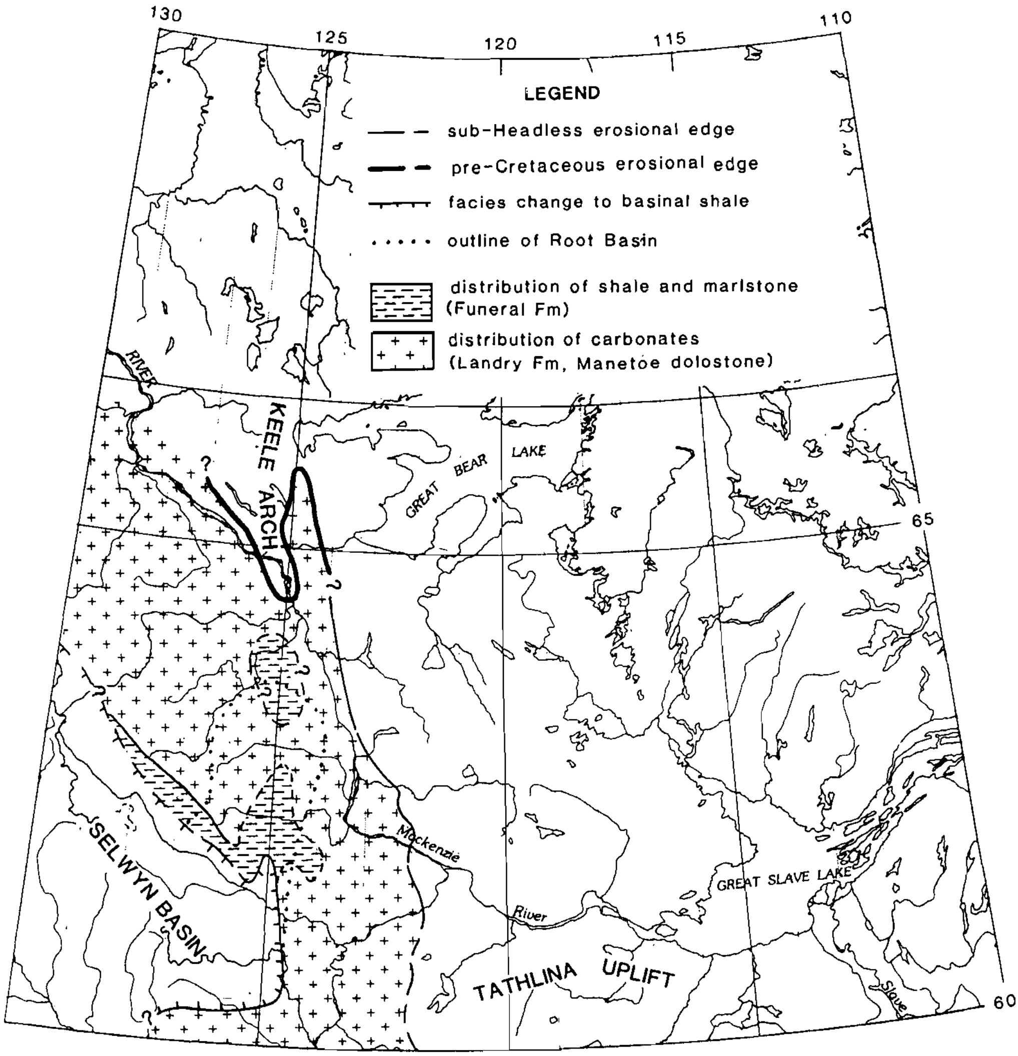


Fig. 34.- *Distribution of early Eifelian rocks.*

CHAPTER VII: STRATIGRAPHIC SEQUENCE 3

In the Interior Plains of the District of Mackenzie the third stratigraphic sequence is relatively thin and is truncated by a minor unconformity (see Fig. 8). The landward side of the sequence may have had a larger distribution in the Willow Lake Embayment than is indicated on Figure 34. In Root Basin the succession is relatively thick and includes 1) a calcareous shale facies (the Funeral Formation) and 2) a carbonate platform facies (including three map units).

The eastern shoreline deposits of the carbonate platform of stratigraphic sequence 3 are missing because of erosion. It is thus difficult to reconstruct its original shape. In many places the carbonates are partly replaced by white dolomite.

Because the recrystallization to white dolomite has destroyed the original sedimentary fabric and commonly extends far down into the underlying carbonates of stratigraphic sequence 2, it is not possible to elaborate on the original regional aspects of the lower boundary. Evidence in one subsurface section (the Dahadinni M-43A well) suggests that the boundary is transitional. The upper boundary is an erosional surface (the sub-Headless unconformity).

The carbonates of sequence 3 include a ostracode fauna without diagnostic species. The shale facies is fossiliferous and contains lower Eifelian fossils.

1. Carbonate facies of sequence 3

The carbonates of stratigraphic sequence 3 form a westward thickening wedge that changes laterally into, or is in sharp contact with, an argillaceous, shelf slope facies (the Funeral Formation). In the southern Mackenzie Mountains the carbonate platform includes a dolomitized, shelf-edge reef complex (the Ram River Reef). This reef fringes the western part of a north-south trending shale basin for which Morrow (1984) introduced the name Prairie Creek Embayment. Ellswhere the carbonate platform includes a semi-restricted limestone facies (the Landry Formation) and a late, diagenetic, white dolomite facies (the Manetoe dolostone).

In the Nahanni region of the southern Mackenzie Mountains the white dolomite facies extends deep down into the Arnica Formation and has cemented dissolution- or collapse-breccias. Morrow (1975, 1984a) reported the presence of large cavities filled with breccia and white dolomite. He suggested that the cavities were formed by a paleo-aquifer system. The proximity of the sub-Headless unconformity indicates that the dissolution process may have been initiated before the upper Eifelian to lower Givetian sediments of sequence 4 were deposited.

Landry Formation

The Landry Formation (Douglas and Norris, 1961) is a unit of grey weathering, thick-bedded to massive, dark grey limestone, which, in the northwestern part of the Root Basin overlies the Arnica Formation and in the southern part of the Root Basin overlies or grades laterally into the Funeral Formation.

Douglas and Norris (1961) did not designate a type section but stated that the section on "Delorme Range may be taken as typical". They also stated that the Landry Formation is everywhere overlain by the Headless Formation and that it is equivalent the Manetoe dolostone. On Nahanni Range the Landry Formation Formation is partly or completely replaced by Manetoe

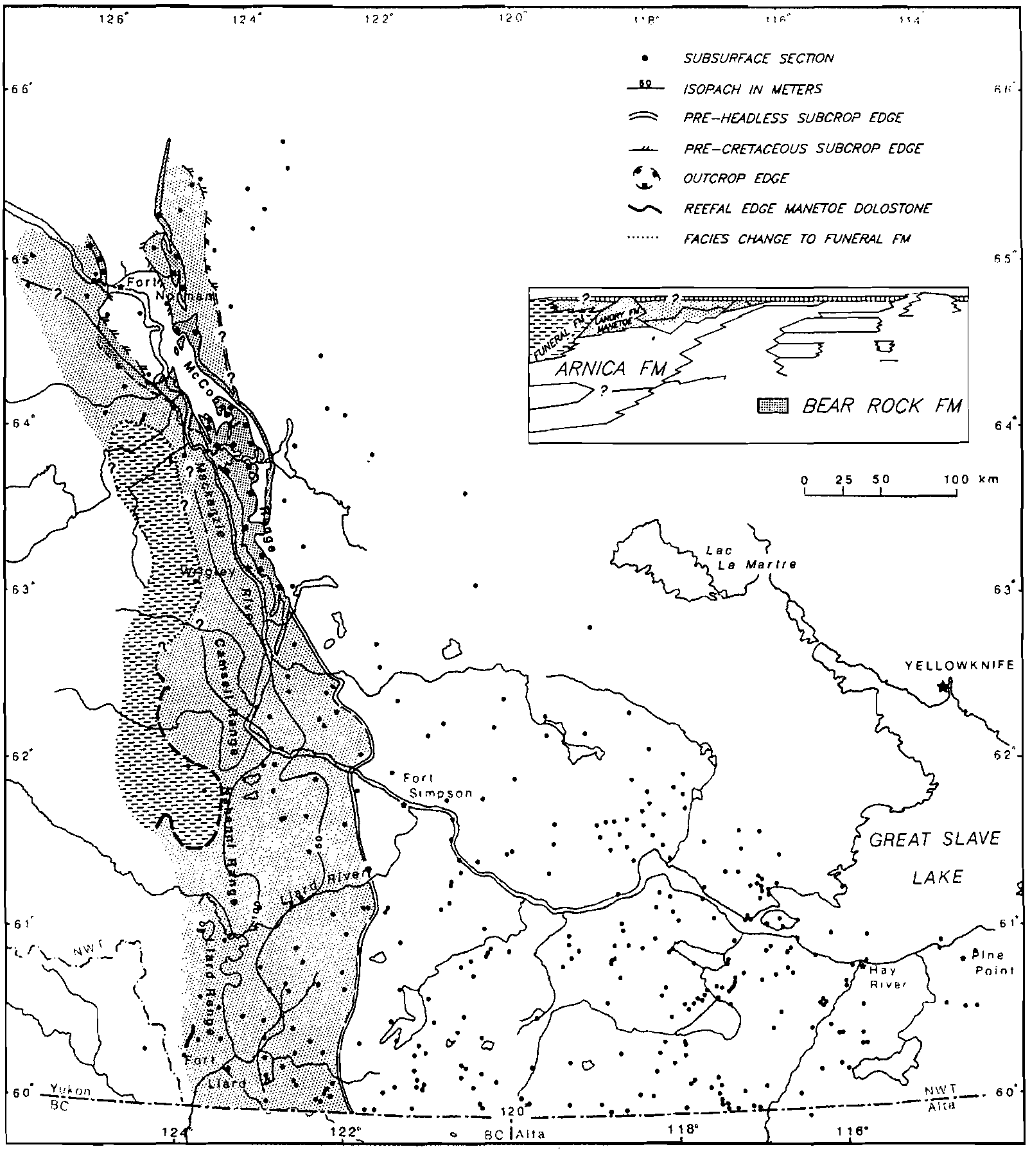


Fig. 35.- Isopach map of Landry Formation and equivalents.

dolostone and the lower contact with the Arnica Formation is obscured.

In many sections the Landry Formation contains a fauna characteristic of a semi-restricted environment which lacks diagnostic species, but on Whittaker Range Chatterton (1978) obtained samples that include conodonts. These conodonts may indicate an early to middle Eifelian age.

The Landry Formation was mapped as a distinct unit in the southern Mackenzie Mountains and ranges in thickness between 91.4 m on Delorme Range to 222.5 m on Rouge Range (Douglas and Norris, 1963 and 1964). On Nahanni Range the Landry Limestone is interbedded with Manetoe dolostone and varies in thickness between 12.8 and 69.1 m.

In the subsurface east of the Nahanni Range the Landry Formation and the Manetoe dolostone are interbedded and appear to be facies equivalents. In some sections the Manetoe facies is absent. The correlations shown on Figures 23 and 24 indicate that the combined interval occupied by the Landry limestone and Manetoe dolostone thins eastward to zero. The thinning appears to be related to a combination of the erosional truncation at the top below the sub-Headless unconformity and the facies change from bedded limestone to dolomite breccia. The zero edge of the Landry-Manetoe interval is mapped as a subcrop edge on Figure 35.

In the Fort Norman area the Landry Formation occurs between the Arnica and Hume formations (see Fig. 26).

Lithology

In the southern Mackenzie Mountains the Landry Formation is a resistant, medium- to thick-bedded unit of grey to dark grey, very fine grained, in places peloidal and fossiliferous limestone. The fossils are usually outlined by white calcite and include ostracodes, gastropods, brachiopods and amphipores.

In the subsurface east of the Nahanni and Camsell Ranges the Landry Formation is a light brown to greyish brown, aphanitic, in places peloidal limestone. It was entirely cored in the Ebbutt D-50 well (see Fig. 23, section 1). The core consists of nodularly bedded, greyish brown limestone and minor, dark greyish brown to dark grey limestone. The limestone commonly includes dark grey, stylolitic shale partings and in the upper part many, irregular interbeds of light greenish grey or pale green, silty and pyritic claystone are present. Some beds contain "calcispheres", charophyte oogonia and ostracodes. Just below the contact with the Headless Formation, the pale green claystone matrix increases to 10 or 20 per cent of the volume and the lithology resembles a shaly, limestone conglomerate. This rubble deposit may represent a paleo-regolith and is sharply overlain by the sub-Headless unconformity.

The limestone rubble deposit in IOE Trail River P-13 and Fina et al. Willow Lake L-59 wells is underlain by dolomite breccias which include much white, coarsely crystalline Manetoe type dolomite (see Fig.22, sections 5 and 6).

The Landry Formation is also present in the Imperial Sun Arrowhead I-46 and Murphy BOC Arrowhead River no. 1 wells (Fig. 24, sections 1 and 2). In the Arrowhead I-46 well the bulk of the limestone unit is a mudstone, but there are scattered interbeds of fine- to coarsely peloidal wackestone or packstone that contain fenestral vugs, small elongate mud pebbles, oolites and oncooids (see Plate XVd). Some beds are slightly silty, others include irregular lenses of pale green, pyritic shale. The contact between the Landry and the overlying Headless Formation is very irregular. The basal part of the Headless Formation is a rubble deposit composes of irregularly shaped limestone pebbles and a matrix of pale green pyritic claystone (see Plate V).

Manetoe dolostone

The informal term Manetoe dolostone is used in this report to designate the late diagenetic, white, very coarsely crystalline and porous dolostone which overlies, or occurs as thick interbeds in the upper part of the Arnica Formation or as a replacement of the Landry Formation.

The Manetoe dolostone was considered to be a tabular map unit of formational rank by Douglas and Norris (1961, 1963, 1973 and 1974). Evidence reported by Morrow (1984a), Morrow and Cook (1987) and observations in the field and in the subsurface by the author, indicate that the vuggy, white, very coarsely crystalline dolostone facies is locally present in the Arnica, Headless and Nahanni formations as a diagenetic deposit similar to the Presqu'ile type dolomite- breccia facies in the Stone and Pine Point formations of northeastern British Columbia (see Macqueen and Taylor, 1974; Taylor et al., 1975).

The Manetoe dolostone is widely distributed in the southern Mackenzie and Franklin Mountains. On Nahanni Range the dolostone is mappable as a continuous unit between the Arnica and Headless formations. Here it interfingers with the Landry Formation and varies in thickness between 6 and 115.3 m. In most sections the upper and lower boundaries of the Manetoe are difficult to select because of interbedding.

In the subsurface east of the Nahanni and Camsell Ranges the Manetoe dolostone probably forms a discontinuous unit. In some wells the same interbedded relationship exists between the Landry, the Manetoe and the Arnica Formation as in surface exposures (see Fig. 22, section 3). In the Fort Simpson area the Manetoe dolostone facies thins eastward to zero and the isopach map on Figure 35, which combines the Landry Formation andthe Manetoe dolostone indicates that the distribution of the white dolostone facies is limited to the western part of the Great Slave Plain and to the southern Mackenzie Plain. Subsurface information from the southern part of the Liard Range and the Netla River area indicates that in this area the white dolostone facies has ceased to be a distinctive map-unit. In this region the Arnica Formation contains much white dolomite in the form of veins and patches. The Landry, Headless and Nahanni formations are dolomitized and also include much very coarsely crystalline, white dolomite.

Lithology

On Nahanni Range the Manetoe dolostone is a recessive weathering unit consisting of white or very light grey, very coarsely crystalline, vuggy and cavernous dolostone with interbeds of grey and dark grey, fine to medium crystalline dolostone and dark grey, grey or light grey, fine grained or aphanitic, locally fossiliferous limestone. The intercrystalline porosity in the very coarsely crystalline beds is commonly filled with black bitumen; the open vugs are lined with white dolomite, quartz and locally sphalerite or pyrite.

The upper part of the Manetoe dolostone and the overlying beds were cored in the Mattson Creek no. 1 well (see Fig. 32, section 1). In this core the Manetoe is a mixture of very coarsely crystalline, white dolomite and fine crystalline, grey and dark grey dolomite. The Manetoe has a brecciated appearance and it is apparent that the white dolomite has partly replaced a grey and dark grey Arnica- like dolostone. In some beds sedimentary structures are preserved which are typical of the

Arnica Formation. The contact between the Headless Formation and the Manetoe dolostone is still recognizable as a sedimentary boundary (see Plate VIIa).

In the subsurface of the Great Slave Plain the Manetoe facies is restricted to the western part where it forms an extensive aquifer. The white dolomite is easy to recognize in the drill cuttings and the facies stand out as a clean porous unit on borehole logs (see Figs. 22 and 23).

Ram River reef complex

In the northern part of Ram Plateau the relationship of the Manetoe dolostone and the adjacent rock units suggests that the Manetoe dolostone is laterally equivalent to the Landry and Funeral formations and represents a shelf-edge reef complex (see Douglas and Norris, 1961; Brady and Wissner, 1961; Noble and Ferguson, 1971). Noble and Ferguson (1971) reported that at a number of localities, faint relics of stromatoporoids and corals or well-developed algal laminites can be seen in the Manetoe dolostone. They also described the abrupt transition between the vuggy dolostone and the Funeral shale. In some places the dolostone includes dome-like structures which protrude upward 3 to 4.5 m into the lower part of the overlying interbedded shale and argillaceous limestone succession of the Headless Formation.

Noble and Ferguson (1971) thus argued that the coarsely crystalline, vuggy dolostone in the Ram Plateau region represents a dolomitized reefal facies which occupied a position between an offshore shale facies (the Funeral Formation) and a nearshore limestone facies (the Landry Formation). In this region the diagenitc dolostone is clearly not a stratiform map-unit related to karst below the sub-Headless unconformity but has replaced a large, originally porous, shelf-edge reef complex.

2. Shale facies of sequence 3

The lower Eifelian interbedded shale and argillaceous carbonate succession accumulated in a north-south trending sedimentary basin for which Morrow (1984) proposed the name Prairie Creek Embayment. In this basin the shaly facies, known as the Funeral Formation, is in sharp lateral contact or grades into a dolomitized reef complex (the Ram River reef complex) which fringes the western part of Prairie Creek Embayment.

Morrow (1984) suggested that the Funeral Formation was deposited in a basinal- and shelf slope environment.

Funeral Formation

The Funeral Formation is a map-unit introduced by Douglas and Norris (1961) in the southernMackenzie Mountains and describes the buff, recessive weathering limestones and shales laterally equivalent to the dolomitized Ram River Reef complex and the Arnica Formation. The section on northern Nahanni Plateau (described in Douglas and Norris, 1960 as map-unit 17) is the type section of the Funeral Formation. In this section the Funeral Formation overlies the Arnica Formation.

The lower part of the type section consists of "dark grey to black, platy, calcareous shale and calcareous mudstone, interbedded with black, silty to argillaceous, pale-buff weathering, very recessive limestone". The lower part is 507.4 m thick and is overlain by a locally resistant weathering unit, 68.5 m thick, composed of black, silty and argillaceous, thin- bedded, bioclastic limestone with black shale partings.

The upper part of the Funeral Formation is 204.2 m thick and includes black calcareous shale and mudstone interbedded with thin lenticular beds of black bioclastic limestone and thick-bedded to massive, black, argillaceous limestone.

At the type locality the Funeral Formation is overlain by shale and shaly limestone of the Headless Formation, but in other places it is overlain by the Landry Formation.

The lateral contact between the Funeral Formation and the dolomitized Ram River reef complex and the Arnica Formation was described in some detail by Noble and Ferguson (1971). They showed that the contact is abrupt "over a few tens of feet" and they stated that there is little or no intertonguing with the reefal dolostone. They concluded that the lateral contact represents the edge of a reef which dips relatively steep into the shale basin.

Fossils collected from the Funeral Formation by Noble and Ferguson (1971) include brachiopods, crinoids, pelecypods, gastropods and a pelagic fauna including *Tentaculites*, *Styliolina*, *Novakia*, *Agoniatites*, *Anarcestes* and orthoconic nautiloids. The presence of the brachiopod *Warrenella praikirki* Johnson suggests that the Funeral Formation is lower Eifelian (Ludvigsen and Perry, 1975). Chatterton (1978) described the conodonts recovered from surface sections and concluded that the formation is "probably mainly early Eifelian".

The distribution of the Funeral Formation is limited to the Prairie Creek Embayment in the southern Mackenzie Mountains (see Fig. 34 and 35). At the type section, on northern Nahanni Plateau, the reported thickness of the Funeral Formation is 777.2 m. In the nearby subsurface the formation was penetrated by two wells. In the Texaco North Nahanni N-42 well (lat. 62°01'54"N, long. 124°08'36"W) and in the Texaco Ram Plateau N-44 well (lat. 61°53'47"N, long. 123°53'36"W) the apparent thickness is about 413.0 and 337.4 m. In these two wells the Funeral Formation underlies the Landry rather than the Headless Formation.

The most northerly occurrences are at the north end of Dahadinni Range (Douglas and Norris, 1963) and in the Candex et al. Dahadinni M-43A well. In the Dahadinni M-43A well the Funeral Formation was cored entirely and the thickness is about 93.5 m (see Meijer Drees, 1980).In this section the Fort Norman, the Arnica and the lower part of the Funeral include regressive, "shallowing upward", subtidal to supratidal sedimentary sequences (see Plate IV). The presence of similar sequences in the three formations suggests that they are part of the same depositional wedge.

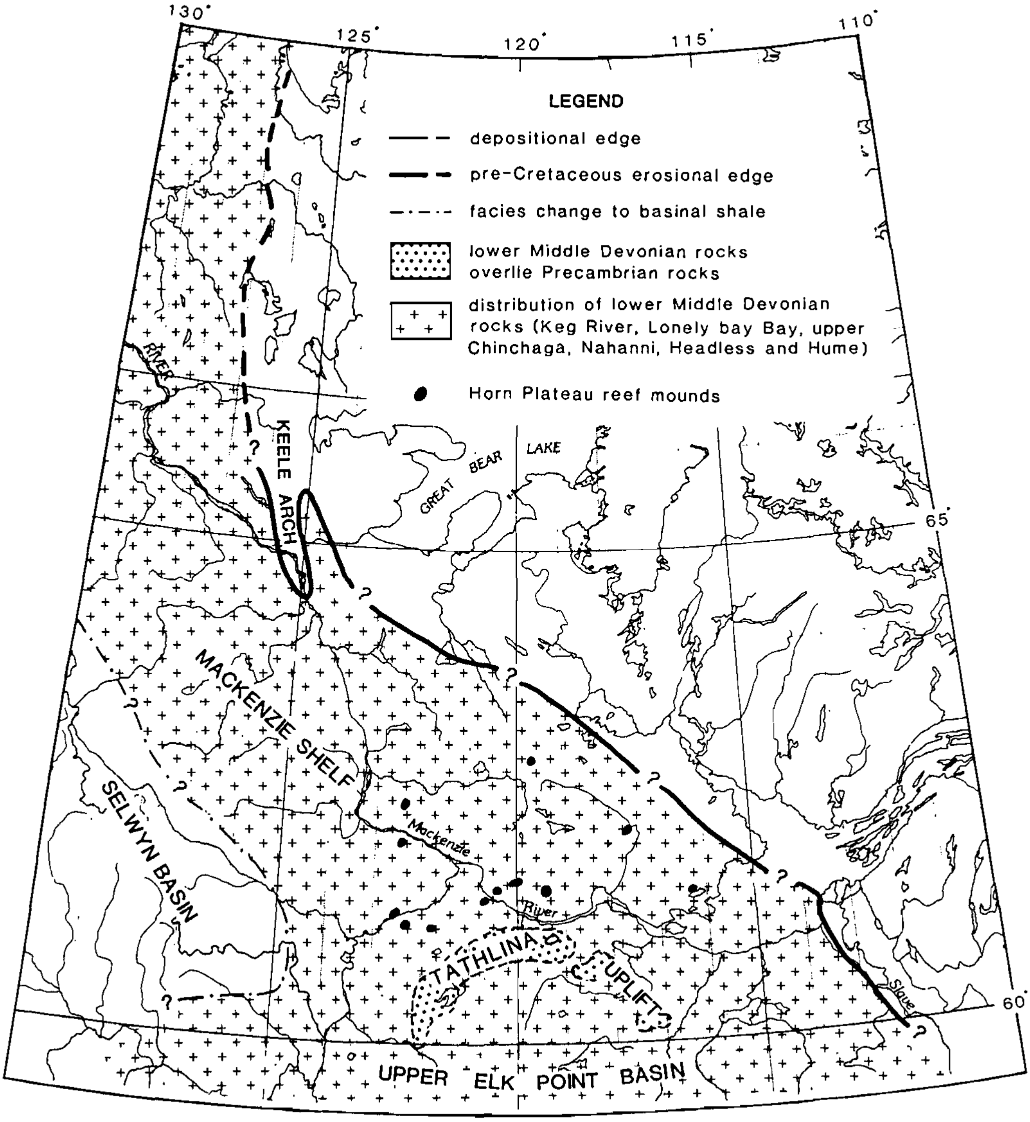


Fig. 36.- *Distribution of late Eifelian to early Givetian rocks.*

CHAPTER VIII: STRATIGRAPHIC SEQUENCE 4

The fourth stratigraphic sequence within the Devonian succession is widely distributed in the Interior Plains and northern Cordillera of western Canada (see Fig. 36). The sequence includes several facies which accumulated in the upper part of the Elk Point Basin, across Tathlina Uplift and on the Mackenzie Shelf (these paleogeographic elements were defined by, respectively, Grayston et al. 1964; Beleyea, 1971 and Morrow, 1984b). The western edge of the carbonate platform facies defines the boundary with Selwyn Basin. Clinothem deposits are present below the western margin of the platform in the Mackenzie Mountains. Fondothem deposits occur beyond the western edge of the carbonate platform and accumulated in Selwyn Basin. At the eastern edge the sequence is truncated by the pre-Cretaceous unconformity.

In the District of Mackenzie stratigraphic sequence 4 overlies the sub-Headless unconformity. It includes 1) a basal, nearshore detrital facies, 2) a peritidal, evaporitic facies and 3) a carbonate platform facies. An older detrital facies fringes Tathlina Uplift and has a shaly character. It grades upward and basinward into an interbedded sub- and intertidal facies. This interbedded facies grades southeastward into a peritidal, evaporitic facies that onlaps the crestal part of Tathlina Uplift and changes further southward, in the Elk Point Basin, into a younger, nearshore detrital facies. The younger detrital facies includes redbeds and occurs in the southern part of Elk Point Basin (the Central Alberta sub-basin). The lateral facies changes are schematically shown on Figures 8 and 11. They are related to onlap and suggest deposition during a transgression.

The nearhore and evaporitic facies are overlain with a transitional contact by a carbonate platform facies that prograded across the Elk Point Basin and the Mackenzie Shelf. The carbonate platform facies is locally overlain by a reefal mound facies (see Fig. 36).

The interbedded subtidal and intertidal rocks of the detrital facies is fossiliferous and includes an endemic fauna. The megafauna in the carbonate platform facies indicates an Eifelian to Givetian age.

On the Mackenzie Shelf stratigraphic sequence 4 overlies Lower to lower Middle Devonian rocks with an erosional unconformity. There is evidence that the eatern part of the study area was uplifted and eroded. In the Elk Point Basin the unconformity is not apparent and the lower boundary is transitional.

The upper boundary of sequence 4 lies at the top of the carbonate facies. The local presence of low and high reefmounds on the platform suggest that at the end of the depositional period the supply of carbonate sediment was only locally able to keep up with the relative rise in sealevel. This situation marks the beginning of a new transgression.

1. Nearshore, detrital facies of sequence 4

In the District of Mackenzie the nearshore detrital facies fringes Tathlina Uplift and is a relatively thin, shaly and locally sandy unit. In the western part of the Great Slave Plain the shaly beds form a distinct unit in the middle of the Chinchaga Formation (the Ebbutt Member) and the basal beds of the Headless Formation. They locally overlie a shaly rubble deposit that is interpreted to represent a paleo-regolith.

In the western part of the Great Slave Plain the shaly detrital facies grades upward into an interbedded succession of shale and limestone (the upper part of the Headless Formation).In the

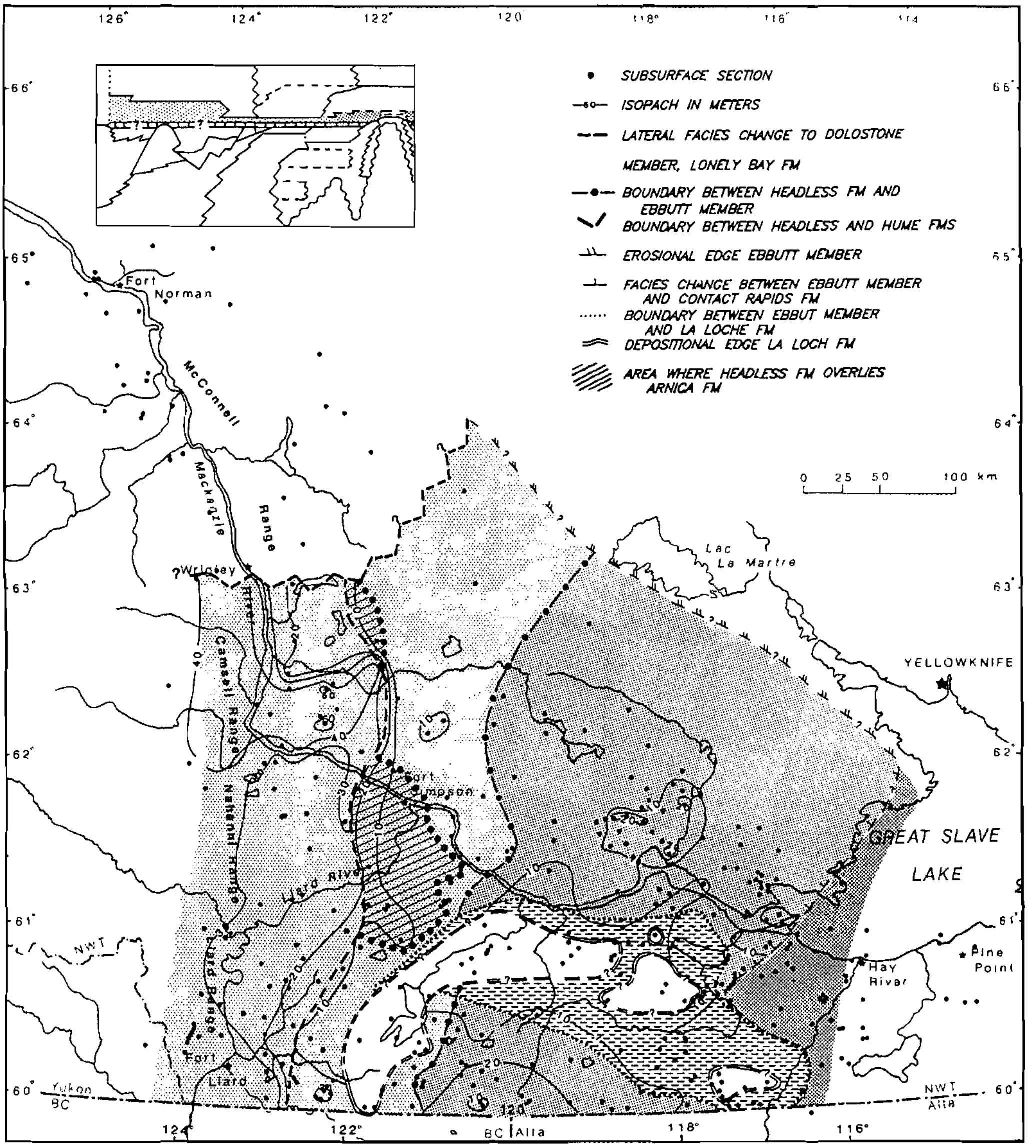


Fig. 37.- *Isopach map of Headless Formation and Ebbutt Member.*

crestal part of Tathlina Uplift the detrital facies (Ebbutt Member) includes interbeds of sandstone and overlies Precambrian igneous and metamorphic rocks. Here it grades into the upper part of the La Loche Formation

In the southern Interior Plains the detrital facies is represented by redbeds. It includes the Contact Rapids, Mclean River and Ashern formations. These shaly and sandy strata occur on the landward side of the Elk Point Basin and are lateral equivalents of the Chinchaga Formation (see Fig. 8).

Chinchaga Formation

Ebbutt Member

The distribution of this distinct unit is shown together with the Headless Formation on Figure37. It is a relatively thin unit. Only locally it is more than 20 m thick in the Laferte River and Trainor Lake areas. On Tathlina Uplift the unit grades laterally into the upper part of the La Loche Sandstone and onlaps the crestal parts of the Uplift.

The cross-sections presented by Belyea (1970, 1971) suggest that the Ebbutt Member overlies an erosional unconformity. This unconformity can be traced below the Headless Formation from west to east across the Great Save Plain. The Ebbutt Member gradually moves down section from west to east on Figures 27 and 28. It is suggested on Figures 27 and 28 that the Member extends into the Deep Bay area. East of the Deep Bay area and south of the Great Slave Lake well control is sparse and the Ebbutt Member is difficult to recognize. The correlations on Figure 20 suggest that the member is present in the basal part of the Chinchaga Formation and that it grades into equivalents of the Contact Rapids Formation.

Lithology: In the Davidson Creek P-2 well the Ebbutt Member is present between depth 613.4 and 618.3 m (2012.5 and 2028.7 ft) (see Fig.24, section 8). It consists of light greyish green and green dolomitic shale. In the lower part interbeds of pale greenish grey dolomitic and argillaceous siltstone are present. In the upper part of the shale is nodularly interbedded with pale coloured dolostone and anhydrite. The basal contact at depth 618.3 m (2028.7 ft) is sharp and conformable. The upper contact is gradational.

Headless Formation

The Headless Formation, introduced by Douglas and Norris (1961) describes a persistent, thinly bedded unit of shale and argillaceous limestone which underlies the Nahanni Formation in the southern Mackenzie Mountains, southern Franklin Mountains and western Great Slave Plain. The sections in the vicinity of Headless Range, on a tributary to Meilleur Creek, and at the First Canyon on the South Nahanni River were considered to be the type sections.

On Headless Range the Headless Formation grades laterally into the Nahanni Formation. In the vicinity of Virginia Falls and on Nahanni Plateau the Headless Formation either overlies the Funeral Formation or Manetoe dolostone. The Headless Formation is relatively thin (25.9 to 44.1 m) on Nahanni Range where it forms a recessive weathering, thinly bedded and fossiliferous unit between the Manetoe or Landry below and the Nahanni above.

According to Douglas and Norris (1963) the Headless Formation is absent in the McConnell

Range. In the Mackenzie Mountains north of latitude 64 degrees the term Headless was not used. Here the equivalents of the Headless and Nahanni formations were mapped as the Hume Formation (see Bassett, 1961; Tassonyi, 1969; Aitken and Cook,1974; Aitken et al., 1982).

In the western part of the Great Slave Plain the Headless is a fairly distinct unit below the Nahanni or Lonely Bay formations (see Figure 8). It overlies with a sharp and unconformable contact the Landry or Fort Norman formations or sharply overlies Manetoe dolostone.

The Headless Formation is fossiliferous and contains a fauna characterized by the brachiopod *"Schuchertella" adoceta* (Pedder, 1975), believed to belong to the Eifelian Stage. Chatterton (1978) reported the presence of two informal conodont zones characterized by *Pelekysgnathus pedderi* and *Polygnathus curtigladius.*

Subsurface and surface information suggest that the lateral boundary between the Headless and Hume formations lies in the southern part of the Mackenzie Plain (see Meijer Drees, 1980, Fig. 4). The Headless Formation passes northward into the Lower and Upper members of the Hume Formation somewhere north of the Shell West Wrigley G-70 well. This facies change is schematically indicated on Figure 32 between sections 3 and 4.

The isopach map of the Headless Formation and Ebbutt Member (Fig. 37), clearly shows the presence of Tathlina Uplift in the southeast. The Headless Formation varies in thickness between 4.8 and 60.9 m. In the Great Slave Plain it reaches its maximum thickness below Ebbutt Hills. The thinning south of Ebbutt Hills is due to a decrease of shaly interbeds in the upper part of the formation (compare sections 3 and 4 on Fig. 32). In the Fort Simpson M-70 well the Headless Formation is only 23.4 m and in the Mattson Creek no. 1 well it is 37.4 m thick. In the Mattson Creek no. 1 well (Fig. 32, section 1) part of the interval is dolomitized. Farther south, in the Pointed Mountain Gas Field and in the Texaco Bovie Lake J-72 well (lat. 60°11'39"N, long. 122°58'44"W) both the Nahanni and Headless Formations are partly or completely dolomitized.

The upper part of the Headless Formation passes laterally in an eastward direction into the Dolostone Member of the Chinchaga Formation, while the lower part of the formation becomes the Ebbutt Member of the Chinchaga Formation (see Fig. 8). This facies change is schematically indicated on figures 22 and 23 and mapped as a line on Figure 37.

Lithology

On Nahanni Range the Headless Formation is a very dark grey, finely grained, partly dolomitized, argillaceous limestone. It is 39.6 m thick at Nahanni Butte (Douglas and Norris, 1960, p. 15).

In the nearby subsurface the Headless Formation is present in the Pan Am Mattson Creek no. 1 well and was partly cored (see Fig. 32, section 1). Here it includes light brown, aphanitic limestone; dark grey argillaceous limestone and grey and dark grey, variably argillaceous, micro- to finely crystalline dolostone. The lower part of the Headless Formation is a very dark grey, pyritic and dolomitic shale bed. This shaly bed overlies a dolostone breccia (see Plate VIIa). The upper part is a dark grey coloured, very argillaceous dolostone including many, irregular shale laminae. In places the dolostone is medium to coarsely recrystallized and contains scattered fragments of poorly preserved ostracodes, gastropods, brachiopods, *Amphipora* and "calcispheres". Some dolostone beds include a laminar-peloidal fabric, others are disturbed or brecciated. The beds are commonly separated by scoured surfaces.

The Headless Formation was entirely cored in the IOE Triad Ebbutt D-50 well and includes at the base, between depths 591.00 and 600.15 m (1939 and 1969 ft), a prominent argillaceous interval that can be correlated with the Ebbutt Member (see Fig. 23).

It consists of greenish-grey, very argillaceous, pyritic limestone interbedded with green, pyritic and silty shale. The argillaceous limestone beds are mudstones and contain a fair amount of siliceous clay and minor amounts of illite. The limestone beds are massive and contain pale green, discontinuous shale laminae and clear calcite or dolomite filled fenestral vugs. Fossils are locally present and include calcispheres, ostracodes and charophyte oogonia. At depth 599.99 m (1968.5 ft) bone fragments of ostracoderm fish were found. The upper contact of the basal shale unit is fairly sharp and conformable.

The upper part of the Headless Formation in the Ebbutt D-50 well consists of a thinly interbedded and irregularly laminated succession of light greyish brown or grey, peloidal calcite-wackestones, peloidal packstones and argillaceous mudstones. The packstone beds locally include scattered, elongate mud pebbles. The mudstone beds are interlaminated with dark grey shale or include thin beds of greenish-grey, pyritic shale. The packstones are fine- to coarsely peloidal and contain calcispheres, ostracodes, gastopods and digital stromatoporoids. Between depths 581.40 and 591.00 m (1908.5 and 1939 ft) the succession is dolomitized. The boundary between the Nahanni and Headless formations is selected at depth 542.2 m (1779 ft) at the top of a 0.6 m thick, grey, very calcareous claystone bed.

The Headless Formation was also cored in the Mobil Fort Simpson M-70 and IOE Trail River P-13 wells (see Fig.22, sections 3 and 6). In the Trail River P-13 well the Headless is relatively thin and only includes the equivalents of the Ebbutt Member. The beds equivalent to the upper part of the Headless are included with the Dolostone member of the Lonely Bay Formation. The dolostone conglomerate of the Arnica Formation is overlain by a greenish grey, rubble deposit composed of deformed, light brown limestone pebbles and a matrix of pale greenish grey, calcareous and very argillaceous siltstone (see Plate XVa).

The Headless Formation was cored in three wells located on Figure 24. These are the Imperial Cartridge B-72, the Arrowhead No. 1 and the Arrowhead I-46 wells. On the cross-section the Headless Formation is relatively thin, only includes the interval equivalent to the Ebbutt Member and is overlain by the Lonely Bay Formation.

In the Cartridge B-72 well the Headless Formation overlies the Fort Norman Formation with a sharp contact at depth 334.6 m (1098 ft). It is a breccia like, conglomerate composed of light brown, greenish grey, brown and very dark grey, subangular dolostone pebbles; somewhat deformed, greyish brown, in places pyritic dolomite-mudstone pebbles and a matrix of greenish grey very dolomitic shale or argillaceous dolostone.

In the two Arrowhead wells the Headless Formation overlies possible equivalents of the Landry Formation (see Fig. 24). In both wells the basal part of the Headless is a rubble deposit or limestone breccia composed of light brown limestone fragments or pebbles in a matrix ofpale green, pyritic shale.

The rubble deposit is overlain by an interbedded interval of light brown to brown, in part argillaceous limestone and greenish grey, calcareous, pyritic and in places silty claystone. Some limestone beds are somewhat nodular, contain large (0.5-3 cm) unsorted and slightly compacted mudclasts and have irregular inclusions of pale greenish grey shale (see Plate V, box 196). Other limestone beds include dark grey shale laminae, are in places peloidal, fossiliferous (amphipores, ostracodes, calcispheres, charophyte oogonia) and contain scattered, calcite filled fenestral vugs.

The argillaceous limestone beds are aphanitic and commonly contain greenish grey, pyritic mottles. Several sharp contacts are present which may represent periods of non-deposition (such as the surface on Plate XIVf).

Equivalents of the Headless Formation are present in the wells of the Pointed Mountain Gas Field and in the Texaco Bovie Lake J-72 well (lat. 60°11'29"N, long. 122°58'44"W). Because the beds overlying and underlying the Headless are fine- to coarsely recrystallized into a Manetoe-type dolostone, it is difficult to define the formational boundaries in these sections. The sedimentary structures are partly obliterated and the white, coarsely crystalline dolomite comprises 20 to 50 per cent of the core.

2. Evaporite facies of sequence 4

In the District of Mackenzie the Upper Member of the Chinchaga Formation forms the evaporitic facies of the late Eifelian to early Givetian sedimentary sequence. On the crest of Tathlina Uplift the evaporite facies locally overlies Precambrian rocks. It grades northwestward into the intertidal facies (Headless Formation) and the lower part of the carbonate platform facies (Nahanni Formation). These facies changes are schematically shown on Figure 8.

Chinchaga Formation

Upper Member

The distribution of the Upper Member of the Chinchaga Formation coincides with the distribution shown on Figure 31. On Tathlina Uplift the Upper Member is relatively thin (0- 23 m) and and is not present in the crestal part of the Uplift.

The Upper Member attains a maximum thickness of 52.1 m in the Willow Lake Embayment north of Deep Bay. It thins westward and northwest of Hornell Lake it passes laterally into the Dolostone Member of the Lonely Bay Formation. The nature of this facies change is related to the gradual loss of anhydritic interbeds in the section (see Fig. 23 and 27). The top of the Chinchaga Formation occurs at a progressively lower level in the section, if one goes westward. The western limit of the Chinchaga Formation is defined by the last occurrence of anhydrite interbeds in the Upper Member. This limit is indicated on Figures 21, 31 and 37.

Lithology: In the Davidson Creek P-2 well the Upper Member is present between depths 575.1 and 613.4 m (1887 and 2012 ft) (see Fig. 23, section 8). The lower contact and the basal 67 cm of the Upper Member were cored. The basal beds are regularly and thinly interbedded and laminated light grey, anhydritic mudstones and light brown, anhydritic dolostones with scattered, deformed mudstone granules.

The basal beds are overlain by an interbedded succession of light brown, dolomitic mudstones, dark brown anhydritic mudstones, greenish grey, argillaceous floatstones including deformed mudstone pebbles, greenish grey, dolomitic shale beds including anhydrite nodules, and light grey, nodularly bedded or nodular-mosaic anhydrite. Some dolomitic beds include erosional surfaces, hardgrounds (Bathurst, 1976, p. 395) and firmgrounds (Dunn, 1975). Other dolomitic mudstone beds contain many dark brown, crystallotropic anhydrite inclusions. In the upper part of the succession interbeds of dolomitic wackestones, packstones and floatstones occur and the bedding is locally distorted by nodular anhydrite. The dolostone lithologies include up to 50 percent of fine to coarse mudstone grains, peloids and pebbles. The pebbles commonly overlie scoured surfaces. Some dolostone beds are cemented by anhydrite. An example of a lithology similar to that described above is shown in Plate XIVa.

4. Carbonate platform facies of sequence 4

The carbonate platform facies of sequence 4 is widely distributed in western Canada. It includes an upper Eifelian to lower Givetian fauna. In the District of Mackenzie it is represented by the upper part of the Hume Formation, the Nahanni and the Lonely Bay formations. In the Elk Point Basin it includes the Keg River and Winnipegosis formations.

Nahanni Formation

The Nahanni Formation consists of fossiliferous carbonates and is widely distributed in the southern Mackenzie Mountains, southern Franklin Mountains and western Great Slave Plain. It is underlain by the Headless Formation and overlain by shaly beds of sequence 5 or locally by Upper Devonian shale. The formation is in mappable continuity with the Dunedin Formation of northeastern British Columbia and grades into the upper part of the Hume and Lonely Bay formations (see Fig. 8).

The Nahanni Formation is resistant and forms prominent west dipping ridges in the southern Franklin Mountains and undulating plateaux in the southern Mackenzie Mountains. It is poorly bedded and commonly forms high cliffs. The contact with the overlying, recessive weathering shales is rarely seen in outcrop and complete surface sections of the formation are scarce. Because the lithology of the formation is fairly homogeneous and bedding poorly developed it is difficult to correlate incomplete sections with the type section. Thus relatively little is known about the variations in lithology and thickness of the formation in the outcrop area.

The upper contact of the Nahanni Formation is not well exposed at Nahanni Butte. Brady and Wissner (1961, Fig. 47) found a transitional boundary between the Nahanni Formation and the overlying dark shales on Ram River (lat. 61°54'45"N, long. 124°07'30"W) but they did not describe it.

Fossils collected from the Nahanni Formation near Meilleur Creek, 69 km east of the Nahanni Range suggest that the formation includes three faunal assemblages (Noble and Ferguson, 1971, Fig. 8). These are characterized by the brachiopods *Schuchertella adoceta*, *Billingsastrea verrilli* and *Leiorhynchus castanea*. According to Pedder (1975) the Verilli Zone of Crickmay (1960) includes the brachiopod *Carinatrypa dysmorphostrota* and both the *adoceta* and *verrilli* faunas are believed to belong to the Eifelian Stage.

Noble and Ferguson (1971) and Pedder (1975, p. 572) indicated that fossils collected from the uppermost beds of the Nahanni Formation in the southwestern part of the District of Mackenzie include *Leiorhynchus castanea*, believed to belong to the Givetian Stage. A partly exhumed reef mound exposed on Root River (located at lat. 62°56'N, long. 125°14') which direcly overlies the Nahanni Formation includes *Stringocephalus* sp. (Pedder, pers. comm.) and thus includes strata of Givetian age.

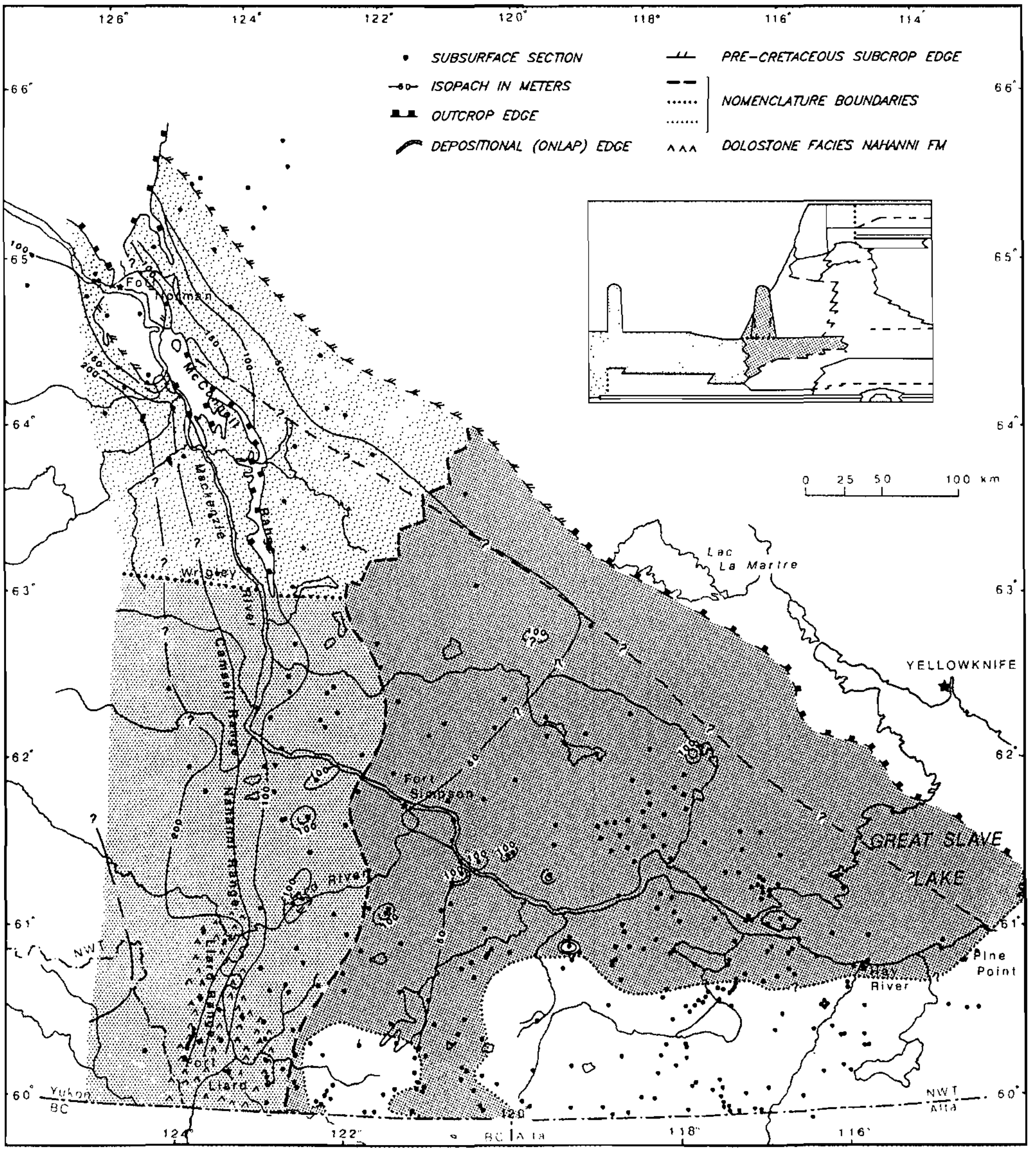


Fig. 38.- *Isopach map of Hume, Nahanni and Lonely Bay, Limestone Member.*

The Nahanni Formation reaches a maximum thickness in the southern part of the Mackenzie Mountains. It is 252.9 m thick on the west flank of Nahanni Plateau and 294.1 m in the southern part of the Iverson Range (Douglas and Norris, 1960, 1961). The approximate western limit of the formation was mapped by Gabrielse et al. (1973) and extends from the Liard River area in northeastern British Columbia northward to the South Nahanni River and then northwestward to Keele River (see Fig. 38). The western limit of the formation is marked by a lateral change to shale. The thinning of the formation in a westward direction is related to this facies change and to the thickening of the Headless Formation. The facies change to shale was studied in some detail in the Meilleur Creek area by Noble and Ferguson (1971). The same facies change occurs farther north in the Glacier Lake map-area east of Broken Skull River (see Gabrielse et al. 1973).

The thinning of the formation to the east and southeast on Figure 38 is a depositional feature and related to the presence of Tathlina Uplift. The isopach map of the Nahanni Formation and its equivalent suggests that the formation is in mappble continuity with the Dunedin Formation of northeastern British Columbia and the upper parts of the Hume and Lonely Bay formations (see Fig. 8).

Lithology

The Nahanni Formation cannot be subdivided into distinct members. However, in order to discuss the marked variation in thickness, the presence of three distinct faunal assemblages and the occurrence of a local reef mound facies above or in the upper part of the Nahanni Formation, it is necessary to introduce several informal units. They are the "Platform limestone", the "Mound limestone" and the "Leiorhynchus beds". Although these units are named, there is no intent to mold them into mappable units.

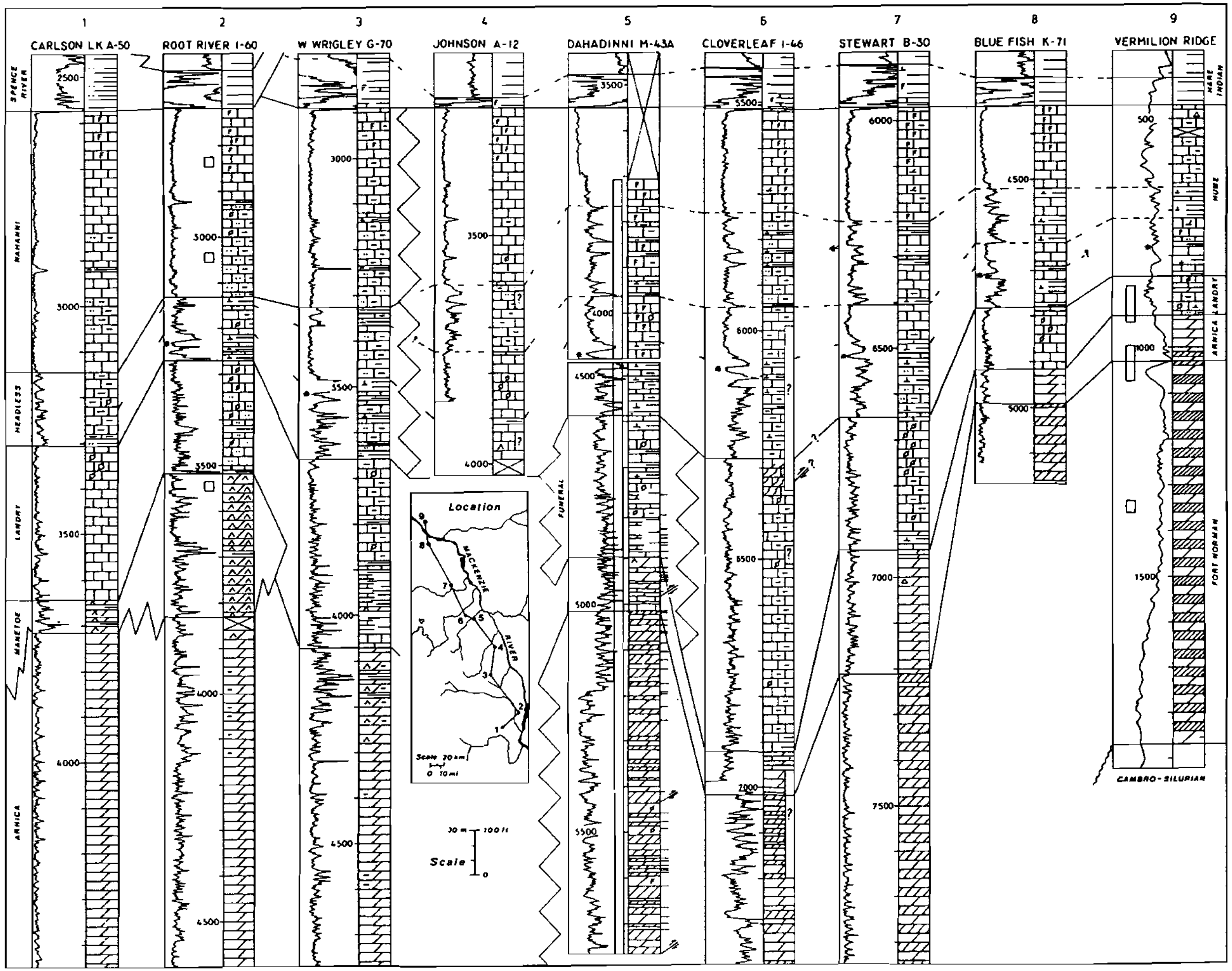
In the type section at the south end of Nahanni Range the dark, finely grained, massive to thickly bedded limestone is partly recrystallized to light and dark grey mottled, fine- to very coarsely crystalline dolostone, a facies similar to the Manetoe dolostone. In several wells south of Nahanni Butte and in the Pointed Mountain Gas Field, the Nahanni Formation is partly or entirely dolomitized and one may argue about the merits of applying here either the term Nahanni or Manetoe. In this report the term "Nahanni equivalent" is used.

Subsurface sections which resemble the facies at Nahanni Butte are present in the Pan Am Mattson Creek No. 1 well (see Fig. 32, section 1) and the Mesa Nahanni Butte L-20 well (lat. 60°59'42"N, Long. 123°33'30"W). In these two wells the Nahanni Formation is considerably thicker than at the type section, 214.5 and 232.5 m versus 195.9 m. Regional information indicates that the two wells include an additional limestone unit at the top, which is apparently missing in the type section (Morrow, pers. comm.).

In order to facilitate the following lithological description the Nahanni Formation in the subsurface is subdivided into two parts, a lower "Platform limestone" and an upper "Mound limestone" (see Fig.32, sections 1, 2 and 3). The distribution of the Mound limestone may not be continuous, even though the correlation lines on Figure 32 suggest that it is a continuous unit between the Mattson Creek No. 1, the Camsell A-37 and the Fort Simpson M-70 wells.

In the Mattson Creek No. 1 well the "Platform limestone" was partly cored. It consists of light and dark greyish brown mottled, poorly and nodularly bedded or massive, very finely fragmental and fossiliferous limestone, including irregular, dark and light grey, dolomitized patches. The dark

Fig. 39.- *Stratigraphic cross-section southern Mackenzie Plain*



grey patches are very fine crystalline, the light grey patches are coarse to very coarse crystalline. Dark grey, stylolitic shale partings and white calcite veins are commonly present. Fossils and fossil fragments occur scattered in the limestone and include a semi-restricted marine fauna, including brachiopods, corals, gastropods, bulbous stromatopores, *Amphipora*, ostracodes and crinoids.

Correlations on Figure 32 suggest that the "Mound limestone" is also present in the HB Amerada Camsell A-37 well. The short core cut in the lower part of the "Mound limestone" consists of a somewhat nodularly bedded, dark grey and greyish brown mottled, very fossiliferous, micro- to coarsely fragmental limestone. The fossils and fossil fragments occur in a matrix of a dark grey, bituminous, slightly pyritic calcite-mudstone which includes many very fine quartz crystals. The fossils are not sorted to size and include large corals and bulbous *Stromatopora*. According to Pedder (see Norford et al. 1971) and Uyeno (in Meijer Drees, in press) the fauna belongs to the late Eifelian or early Givetian Stages.

The Nahanni Formation was cored completely in the IOE Triad Ebbutt D-50 well. Correlations on Figure 32 indicate that the formation in this well is relatively thin because the underlying Headless Formation is relatively thick and the "Mound limestone" is absent. The Nahanni Formation consists of somewhat nodularly interbedded, greyish brown limestone; dark greyish brown to dark grey argillaceous limestone; brown and dark grey mottled, variably argillaceous and silty limestone and light brown to greyish brown, peloidal limestone. The dark coloured limestone beds are calcite-mudstones and include dark grey, wavy, and discontinuous shale laminae or dolomitic shale partings. The brown and greyish brown limestone beds are nodular and fossiliferous (including fragments of crinoids, ostracodes, brachiopods, gastropods, bulbous *Stromatopora*, *Amphipora*, corals and microforaminifera), locally peloidal and include scattered vugs filled with clear calcite.

The megafossils collected from the Ebbutt D-50 cores are not very diagnostic but the ostracodes collected and identified by Braun (in Norford et al., 1970, p. 13) between 472.4 and 533.4 m (1550 and 1750 ft) are similar to the Ostracode b-fauna of the lower part of the Hume Formation (see Braun, 1966), which was thought to belong to the Eifelian Stage (see Braun, 1966).

Correlations on Figure 22 and 23 indicate that the sections of the Nahanni Formation in the Husky et al. Sibbeston Lake G-69 well and the IOE Triad Ebbutt J-70 well are relatively thin and do not include the "Mound limestone". These sections are thus similar to the Ebbutt D-50 well. The core cut near the top of the formation consists of a nodular-bedded, dark greyish brown and light brown mottled, fossiliferous limestone, with irregular, dark grey shale partings. Fossils collected by G.O. Raasch were identified by A.E.H. Pedder (see Brideaux etal. 1976) and belong to the upper Eifelian or lower Givetian Stages. Fossils collected from the interval between 313.9 and 327.0 m (1030 and 1073 ft) were identified by A.W. Norris, A.E.H. Pedder and T.T. Uyeno. The presence of *Leiorhynchus awokanak* McLaren and the presence of ostracodes similar to the Ostracode-C fauna of the upper part of the Hume Formation (Braun, in Norford et al., 1970, p. 11) indicate that these beds are lower Givetian.

Hume Formation

The Hume Formation is a map unit in the northern part of the District of Mackenzie and describes the Middle Devonian carbonates equivalent to the Headless and Nahanni formations. Bassett (1961) selected the type locality on the east branch of the Hume River at lat. 65°20'30"N, long.

129°58'00"W. Tassonyi (1969) introduced the formation in the subsurface of the Norman Wells area and selected a subsurface reference section in the Imperial Loon Creek No. 2 well (lat. 65°07'20"N, long. 126°28'51"W). Here the Hume Formation is present between 546.5 and 662.9 m (1793 and 2175 ft) depth and includes three members. In the Loon Creek No. 2 well the Hume Formation overlies the Pellet Limestone member of the Gossage Formation (the Landry Formation of this report) and is overlain by the Hare Indian Formation.

Bassett (1961) published a list of fossils and established two Middle Devonian faunal assemblages. Later work by Lenz and Pedder (1972) indicated the presence of three formal zones characterized by the brachiopods *"Schuchertella" adoceta* Crickmay; *"Carinatina" dysmorphostrota* (Crickmay) and *Leiorhynchus castanea* (Meek). The *adoceta* and *dysmorphostrota* zones are representatives of the Eifelian Stage, the *castanea* zone belongs to the Givetian Stage.

The Hume Formation is widely distributed in the northern Interior Plains, northern Franklin Mountains and northern Mackenzie Mountains (see Aitken and Cook, 1974; Aitken et al., 1982). Tassonyi (1969) reported that the thickness in the subsurface of the Norman Wells area is about 114 m. The formation grades southward into the Nahanni and Headless formations. The boundary between the Hume Formation and the Nahanni and Headless formations lies somewhere south of the Decalta SOBC et al. Johnson A-12 well (see Fig. 32, section 7). South and east of this well the shaly beds in the upper part of the middle member of the Hume Formation are thin or absent (see Fig. 32) and the characteristic gamma ray log profile of the Hume is no longer present.

The lateral boundary between the Hume and Lonely Bay formations lies somewhere in the southern part of the Great Bear Plain and is selected at the northern limit of the Headless Formation (see Figs. 37 and 39).

In the southern part of the Mackenzie Plain the thickness of the Hume Formation ranges between 121.3 and 220.6 m. It is assumed that the variation is due to the fact that in many wells the borehole is at an oblique angle to the bedding.

Lithology

Tassonyi (1969) subdivided the Hume Formation in lower, middle and upper members. The lower and middle members appear to correlate with the Headless Formation, the upper member is the equivalent of the Nahanni Formation (see Fig. 39).

The lower and middle members and the lower part of the upper member were cored in the Candex et al. Dahadinni M-43A well (see Fig. 39, section 5). The lower member is a thinly and nodularly interbedded succession of dark grey marl and dark greyish brown, micro- to very finely fragmental, in places peloidal and very fossiliferous limestone. Some limestone beds are argillaceous and contain quartz sand and silt, other beds are fairly clean and contain up to twenty per cent fossil fragments, such as stromatoporoids, corals, gastropods, brachiopods, ostracodes, tentaculitids, foraminifera and calcispheres. The lower member includes one or two limestone beds which are prominent on borehole logs. The middle member is an interbedded succession of nodular, argillaceous limestone, marl and silty shale. The upper member is a nodularly bedded, bioturbated, greyish brown argillaceous and silty, very fossiliferous limestone.

Lonely Bay Formation (redefined)

The Lonely Bay Formation (see Meijer Drees, in press) is a map unit in the Great Slave and southern Great Bear Plains composed of dolostone and fossiliferous limestone. The carbonates conformably overlie anhydritic beds of the Chinchaga Formation or locally overlie argillaceous beds of the Headless Formation. They are conformably overlain by dark coloured Middle Givetian shale or marl (the Bituminous Shale and Limestone Beds), by light coloured late Eifelian to early Givetian carbonates (the Horn Plateau reefs) or are overlain with a depositional hiatus by Upper Devonian shale (the Spence River Formation).

In the Imperial Triad Davidson Creek P-2 section (see Fig. 23, section 8) the formation includes two formal members, a lower Dolostone and an upper Limestone Member. The Dolostone Member is approximately equivalent to the Upper Member of the Chinchaga Formation and the upper part of the Headless Formation. The Limestone Member is more or less equivalent to the Nahanni and Keg River formations and the upper part of the Hume Formation (see Fig. 8).

Diagnostic macrofossils are not present in the Dolostone Member, but the Limestone Member includes a relative abundance of early Middle Devonian fossils (see Norris, 1965, p. 41).

The Lonely Bay Formation is widely distributed in the Great Slave and southern Great Bear Plains. The lower part is discontinuously exposed in the area northwest of Great Slave Lake where the formation was mapped and described by Norris (1965) as the Lonely Bay Member of the Pine Point Formation. Norris (1965) estimated the thickness of the formation to be about 36.5 m.

In the subsurface the formation is relatively thin and locally absent in the southern part of the Great Slave Plain because it onlaps the crestal part of Tathlina Uplift. The formation is relatively thick in the northern part of Great Slave and southern Great Bear Plains and reaches a maximum thickness of 99 m (see Fig.38). It is 53.3 m thick in the Davidson Creek P-2 well.

The western and northwestern limits of the Lonely Bay Formation are generally drawn at the lateral facies change from dolostone of the Dolostone Member to limestone of the Headless Formation. The southern limit of the Lonely Bay Formation is the arbitrary boundary with the Keg River Formation. Only in places where the Bituminous Shale and Limestone Beds are present is it possible to segregate the Lonely Bay from the Keg River Formation or the Pine Point dolostone (see Fig. 8).

Dolostone Member

The Dolostone Member includes the lower part of the Lonely Bay Formation and forms a facies transitional between the Chinchaga Formation and the upper part of the Headless Formation (see Fig. 8).

The thickness and distribution of the Dolostone Member are indicated on the isopach map, Figure 40. In the southern part of Great Slave Plain the member onlaps the crestal part of Tathlina Uplift and grades into the lower part of the Pine Point dolostone. The southern limit is a nomenclatural boundary which coincides with the facies change between the Limestone Member and the Pine Point dolostone. In the western part of Great Slave Plain the Dolostone Member is in lateral contact with the upper part of the Headless Formation. This facies change is indicated on several cross-sections (see Figs. 22, 23 and 32).

In the southern part of Great Bear Plain the Headless Formation is difficult to recognize or absent (see Fig. 37) and here the Lonely Bay equivalent may either overlie the Arnica or the Fort Norman formations. The Dolostone Member is discontinuously exposed in the region between Lac La

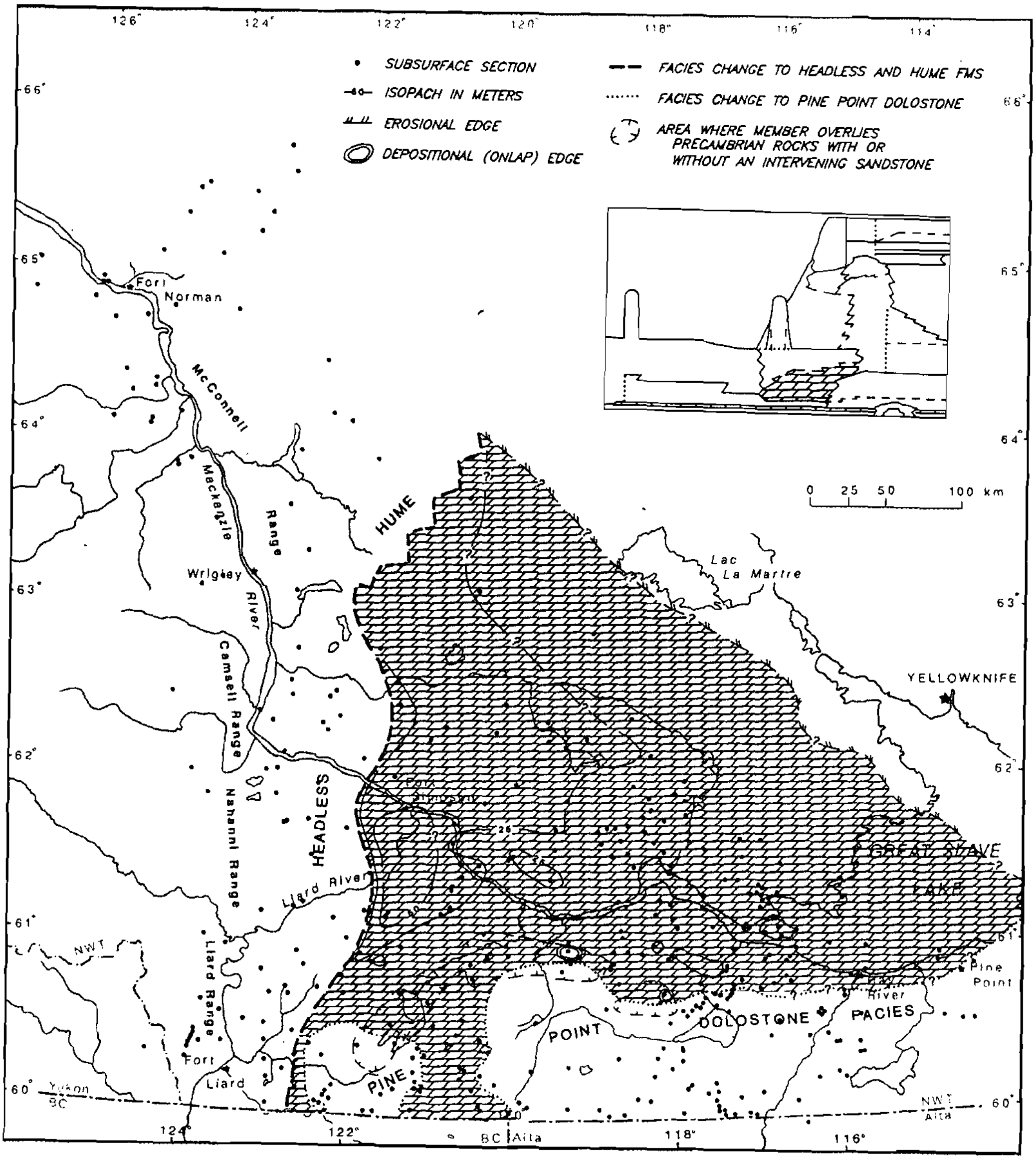


Fig. 40.- *Isopach map of Lonely Bay, Dolostone Member.*

Martre and Great Slave Lake (see Fig. 40). Northwest of Lac La Marte the Dolostone Member subcrops below Cretaceous strata (see Fig. 5, sections D-D' and E-E').

Lithology: In the Davidson Creek P-2 well the Dolostone Member is present between depths 557.3 and 575.1 m (1828.5 and 1887 ft). The boundary with the underlying Chinchaga Formation is transitional and selected at the highest occurrence of nodular anhydrite. The member was completely cored and consists of light coloured, thinly bedded and in part laminated, micro- to very finely crystalline, in places porous dolostone. Minor interbeds of limestone occur in the upper part.

Most dolostone beds can be classified as mudstones, wackestones, packstones or floatstones.The mudstones are discontinuously interlaminated with dark grey argillaceous material. The wackestones and packstones are peloidal, and are commonly laminated. They include scattered mud pebbles and granules; microfossils such as "calcispheres" and ostracodes; and contain scattered or layered fenestral vugs filled with either anhydrite, dolomite or calcite. They commonly include erosional surfaces and hardgrounds. The floatstones are thin, flat pebble or edge-wise conglomerates, and overlie scoured surfaces. They are similar to the one shown in Plate XIVa.

In the upper part of the Dolostone Member interbeds of limestone or partly dolomitized limestone are present. This suggests that at least part of the dolostone beds in the Dolostone Member were originally limestone. However, the fact that some limestone conglomerates include dolomite mud pebbles and overlie with erosional contact dolomite-mudstone beds suggests that some beds were dolomitized at an early stage.

Some dolostone beds are porous and it appears that they originally were partly dolomitized limestones from which the calcite is leached at a later stage. In the basal part of the Dolostone Member the porosity is partly filled with anhydrite.

Limestone Member

This member represents the upper part of the Lonely Bay Formation. It consists of greyish brown and pale brown, nodular limestone and includes characteristic early Middle Devonian fossils. The distribution and thickness of the member are mapped together with the Nahanni Formation on Figure 38. In the central part of the Great Slave Plain the Limestone Member overlies the Dolostone Member with a transitional contact. The upper boundary of the Limestone Member is selected at the highest occurrence of nodular-bedded, greyish brown, fossiliferous limestone below the dark coloured, highly radioactive beds of the Bituminous Limestone and Shale Beds or the very dark coloured shale beds of the Upper Devonian, Spence River Formation (see Figs. 22, 23 and 24). In places the Lonely Bay Formation is directly overlain by a reefal mound similar to the "Mound limestone" of the Nahanni Formation (see Fig. 27, section 1) or by reefal limestone of the "Undivided map unit" (see Fig. 24, section 3.

In the southern and southwestern part of Great Slave Plain the Dolostone Member is locally absent, either because of non-deposition over the central part of Tathlina Uplift (see Fig. 40) or because of the absence of dolostone interbeds in the lower part of the Lonely Bay Formation (see Fig. 24, section 1). In these places the Limestone Member either overlies a detrital facies similar to the Ebbutt Member or overlies the Headless Formation.

The southern limit of the Limestone Member lies in the southern part of Great Slave Plain and is drawn at the lateral facies change from limestone to dolostone. This facies change coincides with the nomenclatural boundary between the "Pine Point dolostone" and the Lonely Bay Formation (see Fig. 38). The western limit of the Limestone Member is a nomenclatural boundary and coincides with the facies change between the Dolostone Member and the Headless Formation on Figure 38.

In the southern part of the Great Bear Plain the Limestone Member grades into the upper part of the Hume Formation. The boundary between the Hume and Limestone Member coincides with the facies change between the Dolostone Member and the lower part of the Hume Formation.

The Limestone Member is locally exposed in the area northwest of Great Slave Lake. Well control in this region is too sparse to map the outcrop edge. In the Great Bear Plain the Limestone Member subcrops below Cretaceous strata (see Fig. 5, sections D-D' and E-E'). There is not enough information to accurately map the limits of the subcrop region on Figure 38.

Lithological, stratigraphical and paleotological information indicates that the Limestone Member includes three facies which are similar to the "Platform limestone", "Mound limestone" and "Leiorhynchus beds" of the Nahanni Formation. The Platform facies is widely distributed, the "Mound limestone" (or Horn Plateau reef) facies and the "Leiorhynchus beds" are only locally present. The "Leiorhynchus beds" may be regarded as thin equivalents of the Bituminous Shale and Limestone Beds. The cross-section in the Laferte River area (Fig. 27) explains the stratigraphical relationships between the Lonely Bay, Horn Plateau, Bituminous Shale and Limestone Beds and the overlying Upper Devonian shale beds of the Spence River Formation. The cross-section suggests that the early Givetian carbonates are in places overlain by Upper Devonian shale and that the upper contact of the Lonely Bay Formation may be erosional or may mark a period of non-deposition.

Lithology: In the Davidson Creek P-2 well (see Fig. 23, section 8) the lower part of the Limestone Member is a thinly bedded, light brown and greyish brown limestone. It includes fine- to medium peloidal packstones and grainstones, commonly with dark grey, stylolitic shale partings, scattered or layered interpeloidal or fenestral vugs, filled with calcite or pale green, quartz silt; indistinctly laminated mudstones and wackestones with scattered mudclasts and thin floatstone beds containing light coloured mud pebbles. These pebble beds commonly overlie a scoured surface. The thin dolostone interbeds near the base of the member are wackestones, including dolomitic or calcitic mud pebbles and anhydrite filled fenestral vugs. Fossils occur locally and include "calcispheres", gastropods and amphipores.

In the upper part of the Davidson Creek P-2 section the limestone beds are mudstones and peloidal or pisolitic wacke- or packstones cemented by calcite. Towards the top of the member the bedding becomes increasingly nodular and the mudstones are replaced by finely biofragmental wackestones, including scattered microfossils (such as "calcispheres", crinoid ossicles, ostracodes, microforaminifera, tentaculitids) and scattered brachiopods, gastropods and stromatoporoids. The nodular beds are separated by discontinuous, dark grey shale partings.

The conodonts found in the limestone were identified by Uyeno (in Norford et al., 1970). They include *Polygnathus liguiformis* (Hinde) which is probably a Middle Devonian species.

The "Leiorhynchus beds" and the upper part of the " Platform limestone" were cored in the Husky HB et al. Willow Lake H-10 well (see Fig. 32, section 5) and in the Imperial Cartridge B-72 well (Fig. 24, section 8). In these wells the "beds" sharply overlie peloidal limestone including desiccation fractures (see Plate VIId). The "Leiorhynchus beds" consists of thinly and nodularly interbedded, dark grey to dark greyish brown, argillaceous limestone and very dark grey marl or shale. The limestone beds are fossiliferous mudstones and contain crinoidal debris, tentaculitids, ostracodes and large, Leiorhynchus like brachiopods. The marl includes *Lingula* shells and scattered burrow-like structures. The shale interbeds in the upper part of the core contain coaly plant remains and scattered, compressed tentaculitids. Corals from the limestone below depth 159.4 m (523 ft) were identified by Pedder and belong to the Eifelian Stage.

It is worth noting that the "Leiorhynchus beds" are absent in the cores of the Imperial Triad Willow Lake B-28 well, the Husky HB et al. Willow lake G-32 well and the Husky HB et al. Willow Lake O-27A well (see Fig. 23, sections 3, 4 and 7). In these cores the Limestone Member is represented by a nodularly bedded, fossiliferous limestone facies which is characterized by the coral *Dendrostella trigemme* (Quenstedt), a representative of the *Carinatrypa dysmorphostrota* Zone of the upper Eifelian. Representatives of this Zone are also present in the limestone beds which underlie the "Leiorhynchus beds" in the Willow Lake H-10 core.

5. Reef mound facies of sequence 4

The carbonate platform facies is locally overlain by carbonate mounds or "build-ups" which include reefal deposits. In the District of Mackenzie these mounds are known as Horn Plateau reefs, in the Elk Point Basin they are known as the Rainbow Member of the Keg River Formation or as as the upper member of the Winnipegosis Formation.

In the southern part of the District of Mackenzie the carbonate platform facies is overlain by carbonates of the Pine Point assemblage (see Fig. 8). During the Givetian stage these carbonates developed into a barrier-reef by the amalgamation of the upper Eifelian to lower Givetian reef mounds (the Presqu'ile barrier). Because the Presqu'ile barrier is dolomitized and also includes late diagenetic deposits of white dolomite (Presqu'ile dolostone), it is difficult to segregate the older autochthonous from the younger allochthonous deposits.

Horn Plateau reefs

The isolated limestone mounds occurring north and northwest of the northern margin of the Pine Point dolostone or Presqu'ile barrier are known as Horn Plateau reefs. The mounds directly overlie the Lonely Bay limestone and are surrounded and overlain by shale.

Most reef mounds in the subsurface of the Great Slave Plain directly overlie the Lonely Bay Formation, but there are reef mounds in the Deep Bay area which overlie beds belonging to the the Bituminous Shale and Limestone Beds (see Fig. 28, sections 3 and 7).

The Horn Plateau reefs transitionally overlie the Lonely Bay Formation and it is difficult to select the boundary with the aid of well cuttings and borehole logs. Vuggy porosity is commonly associated with fossiliferous beds and one may segregate the reefal and non-reefal beds on the basis of porosity. One may also define the lower contact at the imaginary boundary between platform and mound facies by extrapolating the thickness of the Lonely Bay platform from nearby, non-reefal sections (see Fig.27, section 1).

The boundary between the Horn Plateau reefs and the overlying Upper Devonian shale is sharp and probably coincides with a hiatus (see Fuller and Pollock, 1972).

The Horn Plateau reef exposed near Fawn Lake includes reef core and reef flank deposits. Vopni and Lerbekmo (1972) considered the reef core to be of late Middle Devonian age. The reef core is surrounded by penecontemporaneous reef detritus and younger flank deposits which include a conodont fauna of the *Polygnathus varcus* Zone (see Fuller and Pollock, 1972).

The Horn Plateau reefs in the subsurface transitionally overlie the Lonely Bay Formation and in several mounds the assemblage of corals includes an upper Eifelian to lower Givetian fauna.

The locations of all the presently known Horn Plateau reefs are shown on Figure 38. It is difficult to report on the thickness of the Horn Plateau reefs because of the transitional lower boundary in the reef core. It is thus better to refer to the height as measured from the top of the Lonely Bay platform. The top of the exposed reef mound near Fawn Lake is presumed to have a height of 122.5 m and has a circular outline with a diameter of about 1.28 km (Vopni and Lerbekmo, 1972). If one assumes that the wells which penetrated the buried Horn Plateau reefs indicated on Figure 40 were drilled near the crest of the mound, the maximum height of the buried reefs ranges between 60 and 84 m.

Lithology

The Horn Plateau reef mound exposed west of Fawn Lake (see Figure 5, section B and Plate VIII) consists of light coloured, fossiliferous limestone and includes poorly cemented, porous beds. Vopni and Lerbekmo (1972) recognized 1. an organic reef, 2. a reef flat and 3. a reef flank facies.

1.The organic reef facies consists mainly of colonial corals and stromatoporoids, many in growth positions, scattered in a matrix of fossil fragments and cemented by sparry calcite. The main frame builders are massive and branching corals and massive and tabular stromatoporoids. The corals *Chaetetes* and *Thamnopora* are abundantly present. Most of the fossiliferous limestones are rudstones, but some may be classified as coralliferous or stromatoporoidal framestones (see Fig. 2).

2.The reef flat facies include crinoidal grainstones, *Stachyodus* rudstones and coralliferous, stromatoporoidal and crinoidal rudstones. These rocks are coarse to very coarse-grained and are often porous. The most common fossil fragments are derived from crinoids; tabulate and rugose, solitary corals; brachiopods and stromatoporoids. The reef flat facies is distributed asymmetrically around and over the organic reef facies, which forms the central core of the mound.

3. The reef flank facies occurs on the periphery of the reef mound and consists of crinoidal and coraliferous grainstones, crinoidal and *Thamnopora* rudstones or floatstones, brachiopodal rudstones and fossilferous mudstones. The brachiopodal rudstones contain *Ambocoelia* cf. *A. umbonata*, *Atrypa nasuta*, *Camarotoechia*, *Cranaena?* and *Spinatrypa hornensis*.

According to Vopni and Lerbekmo (1972, p. 511) the reef mound near Fawn Lake only suffered from relatively minor, post- depositional alterations. Cementation by calcite and subsequent neomorphism are the most visible diagenetic changes.

Little is known about the Horn Plateau reefs present in the subsurface of the Great Slave Plain. Most reefal mounds were penetrated by a single well and only four wells include cored sections.

The writer only examined two reef mound cores in detail. They are the Trout River D-14 and Jean Marie J-52 mounds. The reef mound of the Gulf et al. Trout River D-14 well represents a "low reef" and consists of fossiliferous limestone (see Fig. 27, section 1). The core consists of mottled, very light grey and light brown, massive, porous, very fossiliferous rudstone, with interbeds of framestone. Gravel sized fragments of coral (mainly *Thamnopora*), tabular and bulbous stromatoporoids and crinoids are supported by a matrix of coarse fossil fragments or occur in a light brown, slightly argillaceous and silty mudstone matrix. Good intrafossil and interfragmental porosity is present in some parts of the core, in other parts the porosity is filled or partly filled with light brown calcite-mudstone and lined with white and clear calcite crystals. The central part of most cavities consists of brown, subhorizontally laminated, porous, calcareous and argillaceous, very fine grained quartz sand or silt. Some cavities are open in the upper part.

Pedder (in Norford et al., 1973, p. 23-24) reported the presence of the following corals: *Psydracophyllum lonsdaleiaformis* Pedder, *Sociophyllum glomeratum* (Crickmay) small variant, *Pachyfavosites* sp. indet., *?Utaratuia* undescribed sp. and *Thamnopora* sp. indet. Fuller and Pollock (1972) reported the presence of the conodont *Polygnathus pseudofoliatus*. The fauna belongs to the Middle Devonian, upper Eifelian Stage.

The core in the Cdn Sup. KMG Jean Marie J-52 well consists of massive, light brown and greyish brown mottled, very fossiliferous, non-porous limestone. The dark parts are very coarse fragmental and conglomeratic packstones or crinoidal wackestones with scattered fragments of tabular Stromatopora, colonial corals and Thamnopora. The pale coloured parts are conglomeratic rudstones including large fragments of colonial corals. The fossil fragments are recrystallized and cemented by sparry calcite. Boundaries between dark and light coloured parts are frequently marked by stylolites.

A.E.H. Pedder identified some of the corals and suggested that they are indicative of a late Eifelian to early Givetian age.

The reef mound penetrated by the Gulf et al. Redknife H- 28 well is relatively high and consists of massive, well cemented limestone. The stromatoporoidal framestones and interbedded mud- or floatstones include several corals similar to those found in the Nahanni and upper Headless formations of the southern Mackenzie Mountains (see Pedder in Norford et al., 1973). The limestone is cut by several subvertical fissures filled with dark grey, noncalcareous shale.

Fuller and Pollock (1972) briefly described some of the other Horn Plateau reefs in the subsurface and sampled the sediments present in the fissures and cavities of some of the reefal mounds. Conodonts recovered from sediment in the fissures of a "low reef" core in the Cdn Sup. KMG Jean Marie B-48 well (lat. 61°27'10"N, long. 120°38'16"W) and from sediment in a cavity of a "high reef" core in the IOE Sun Blackstone E-72 well (lat. 61 11'27"N, long. 122 14'54"W) belong to the *Polygnathus asymmetricus* Zone.

They concluded from this information that the Horn Plateau reefs underwent a period of "subaerial decay" during which cavities and fractures were formed and partly filled with sediment. The reef flank facies was also deposited during this period. This period of decay may have been coincident with the hiatus below the Upper Devonian shale succession on Figure 8.

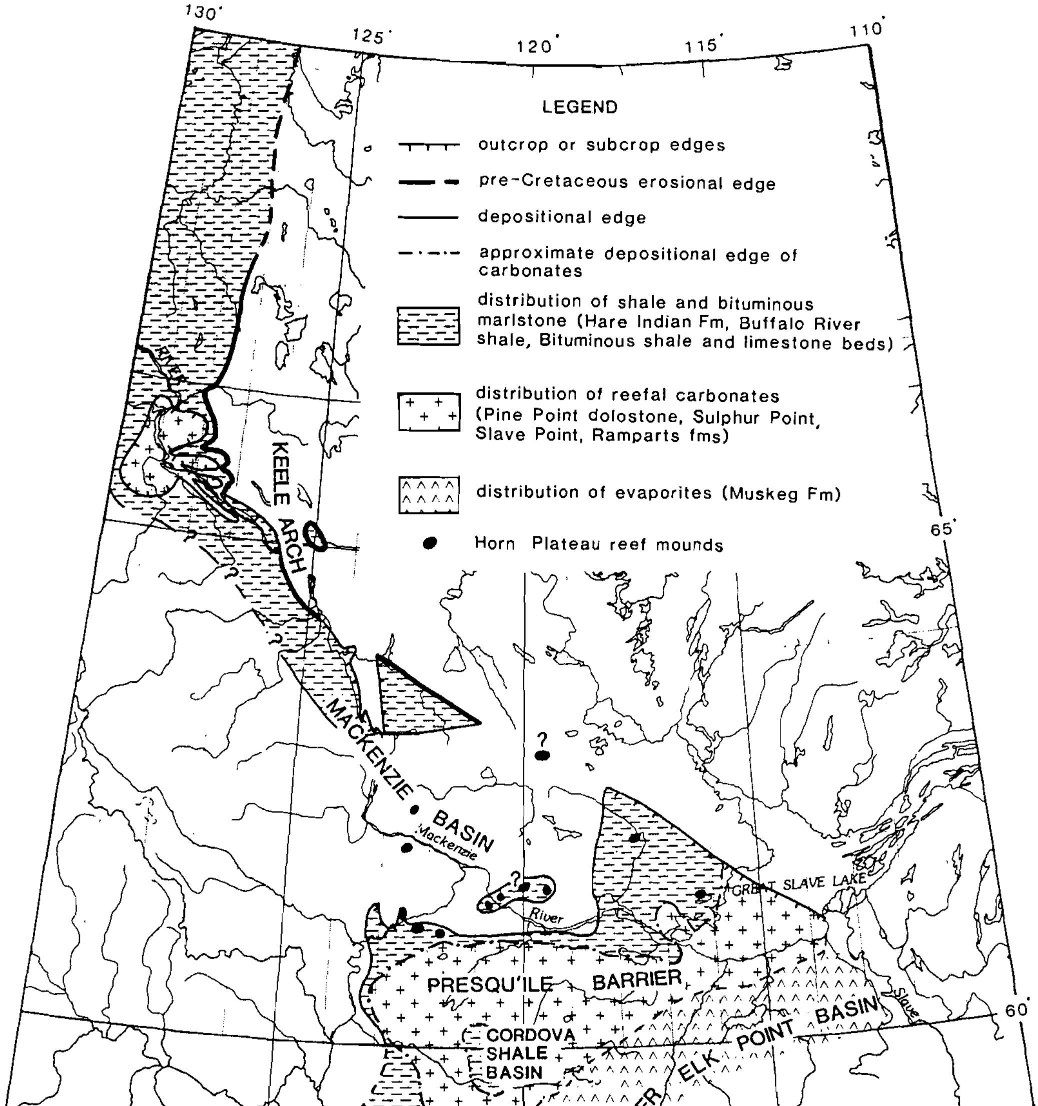


Fig. 41.- *Distribution of mid-Givetian rocks.*

CHAPTER IX. SEQUENCE 5

The fifth stratigraphic sequence accumulated in the upper part of the Elk Point Basin and on the southern and eastern part of the Mackenzie Basin (see Fig. 41). Only a small part of the sequence is present in the study area. The sequence overlies the southeastern part of stratigraphic sequence 4 with a fairly sharp, irregular contact which has paleo-depositional relief. The succession includes 1) a nearshore, shaly detrital facies, 2) an evaporite facies, including halite and anhydrite deposits, 3) a carbonate barrier facies (the Presqu'ile Barrier), 4) a clinoform reef flank facies and 5) a thin, shaly fondothem facies.

The nearshore detrital facies and the evaporites accumulated in the upper part of the Elk Point Basin, situated in the southern part of the Interior Plains. The detrital facies occurs along the eastern margin of the basin and onlaps a land mass situated in southwestern Alberta. The evaporites occupy the central part of the basin in northeastern Alberta and southern Saskatchewan. The carbonate barrier facies forms a wide belt which extends from Great Slave Lake westward and turns southward into northeastern British Coloumbia. The reef flank facies is relatively narrow and fringes the northern and northwestern edge of the barrier reef facies. It forms a seaward thinning wedge and grades laterally into the shaly fondothem deposits (see Fig. 41).

Although the carbonate barrier, reef flank and fondothem deposits include a Givetian mega-fauna, the general scarcity of conodonts in the carbonates does not allow the establishment of a detailed microfossil zonation.

The lower boundary of the fifth stratigraphic sequence onlaps the reef mound facies of sequence 4. The contact with the platform carbonate sequence of facies 4 is fairly sharp and drawn at the change from pale coloured carbonates to dark coloured marl. The contact with the reef mound facies varies from place to place. On the reef flank the boundary is transitional through slope deposits. On the crest of the reef mound the contact is sharp and marked by a hiatus.

1. Detrital facies of sequence 5

The detrital facies includes much shale and occurs along the southwestern margin of the Elk Point Basin in central Alberta. It onlaps Western Alberta Ridge and Peace River Arch, two emergent paleo-topographic highs in southwestern Alberta. In central Alberta the facies overlies strata of Cambrian age and grades eastward into the salt beds of the Prairie Evaporite Formation. In northern Alberta it overlies Precambrian rocks and grades northward into the anhydrite deposits of the Muskeg Formation.

The detrital facies is not represented in the District of Mackenzie.

2. Evaporite facies of sequence 5

The evaporites belonging to the fifth sequence accumulated in the central part of the Elk Point Basin. There is evidence that the bulk of the evaporites were deposited during periods of low water stand behind the Presq'ile Barrier. In the southern part of the basin it includes the salt beds of the Prairie Evaporite Formation. In the northwestern part of the basin the facies is represented by the

Muskeg Formation, an interbedded succession of dolostone, anhydrite and minor salt. The Muskeg Formation extends northward into the southeastern part of the District of Mackenzie and grade laterally into the Pine Point dolostone facies of the Presqu'ile Barrier (see Fig. 30).

Muskeg Formation

The anhydritic equivalents of the Prairie Evaporite and Dawson Bay formations in northern and central Alberta are known as the Muskeg Formation. This map-unit was introduced by Law (1955) in northern Alberta and later redefined by Belyea and Norris (1963) to exlude the upper unit, composed of carbonates (the Bistcho Formation). The Muskeg Formation as redefined by Meijer Drees (1986b and in press) is shown in the type section on Fig. 30, section 1. It is an interbedded succession of nodular, nodular-mosaic and nodular-bedded anhydrite, anhydritic dolostone, fossiliferous dolostone and minor halite. It overlies the carbonates of sedimentarysequence 4 (The Keg River Formation) and underlies a tongue of carbonates (the Bistcho Formation) which extends southeastward from the Presqu'ile Barrier into the Elk Point Basin. This situation is schematically drawn in Figure 8.

The evaporitic deposits of the Muskeg Formation are widely distributed in northern Alberta, northeastern British Columbia and extend into the southeastern part of the District of Mackenzie. The succession attains a maximum thickness of about 265 m in a relatively narrow zone just north of the Peace River valley in northern Alberta. Here the Muskeg Formation occupies the entire interval between the carbonates of sequence 4 (the Keg River Formation) and the sub-Watt Mountain unconformity.

Going westward from the area of maximum thickness the amount of dolostone interbeds increases and the upper boundary moves down in section. The lateral facies change between the Pine Point dolostone facies and the Muskeg anhydrite is transitional over a distance of about 25 km.

In the direction southeast and east from the area of maximum thickness the interbedded anhydrite and dolostone facies is gradually replaced by the interbedded anhydrite and halite facies of the Prairie Evaporite Formation. This lateral facies change is about 50 km wide (see Meijer Drees; 1986a, Fig. 52).

The Muskeg Formation thins toward the south and onlaps Peace River Arch, a paleotopographic high area in central Alberta that was emergent during the Early and Middle Devonian. In the depositional onlap area the evaporites are replaced by a nearshore, shaly facies which includes an abundance of charophyte oogonia (see Meijer Drees, in press).

McCamis and Griffith (1967), Bebout and Maiklem (1973) and Tranchant (1975) described the Muskeg Formation in some detail using borehole logs and cores. The formation can be subdivided with the aid of borehole log markers and locally includes a basal unit of halite. Hriskevich (1966), Tranchant (1975), Klose and Holland (1976) and Bebout and Maiklem (1973) discussed the relationships between the salt beds, the lower and upper parts of the Muskeg Formation and the Keg River reef mounds. They showed that the anhydrite beds, which directly overlie the salt beds, are absent around the base of the carbonate mounds and that the upper part of the Muskeg Formation is unusually thick in the area around the reefal mounds, where salt is absent. They suggested that some salt was leached around the reefal mounds during or just after the period in which the upper part of the Muskeg Formation accumulated.

Lithology

Relatively little is known about the salt deposits in the basal part of the Muskeg Formation. Fuller and Porter (1969, Fig.17) describe the salt as light grey, coarsely crystalline and locally including chevron halite or anhydrite stringers.

The salt beds are overlain by an interbedded succession of anhydrite and dolostone. The lower part of this succession onlaps or interfingers with the carbonate mounds (Tranchant,1975, Fig.1). It consists of dark grey, interlaminated, very fine to fine- grained limestone and anhydrite and grades upward to medium and dark grey, bedded anhydrite. The interbeds of dark coloured dolostone include calcispheres. Interbeds of dolomite breccia attest to the former presence of halite.

The upper part of the Muskeg Formation overlies the carbonate mounds and includes several widely distributed units of dolostone. In the area north of Zama Lake, the Zama Member of McCamis and Griffith (1967) directly overlies the carbonate mounds and consists of brown, laminated and discontinuously laminated, fine to medium recristallized dolostone with scattered brachiopods and *Amphipora*-like fossils. In the Rainbow Lake area, the "Rainbow Dolostone Member" of Bebout and Maiklem (1973) consists of medium to dark brown, laminated and burrowed dolostone, which includes a fossiliferous bed.

In both areas, the intervening evaporites include many dolostone to anhydrite cycles. Each cycle starts at the base with a medium to dark brown, laminated or burrowed dolostone, in places including calcispheres. The laminated dolostone grades upward into dolostone containing irregular, dark grey laminae of bituminous shale and angular anhydrite nodules. The irregularly laminated dolostone is overlain by dolostone with abundant nodular and nodular-mosaic anhydrite. This lithology grades upward into massive-mosaic anhydrite. The complete cycle contains, at the top, a dark unit of bedded, massive anhydrite. Many cycles are incomplete andunits are missing either because of erosion or nondeposition at the top (see Bebout and Maiklem, 1973, Fig. 25).

Little is known about the lithologies of the Muskeg Formation in the District of Mackenzie because the formation was not cored. Skall (1975) and Rhodes et al. (1984) described the anhydritic facies of the Muskeg Formation in the area south of Great Slave Lake but did not report the presence of the dolostone to anhydrite cycles.

3. Carbonate facies of sequence 5

In the northern Interior Plains these carbonates form a broad belt that extends westward from Great Slave Lake and swings southward into northeastern British Columbia. It is a succession of reefal and shallow marine deposits (the Presqu'ile Barrier) behind which accumulated the thick evaporitic deposits of the Upper Elk Point subgroup (see Fig. 41). The carbonate deposits have retained much of their original shape and are recognizable as shoals, reef mounds and amalgamated reef, reef flank and inter-reef deposits.

The carbonate succession is difficult to subdivide in litho-stratigraphic map units for the following reasons. ① In the southern part of Great Slave Plain, where the succession flanks and overlies Tathlina Uplift, correlations within the Middle Devonian succession are often ambiguous because the two distinct argillaceous units used for the subdivision (the Bituminous Shale and Limestone Beds and the Watt Mountain Formation) have a limited distribution and only partly overlap each other. ② There is a considerable amount of thinning across Tathlina Uplift. The

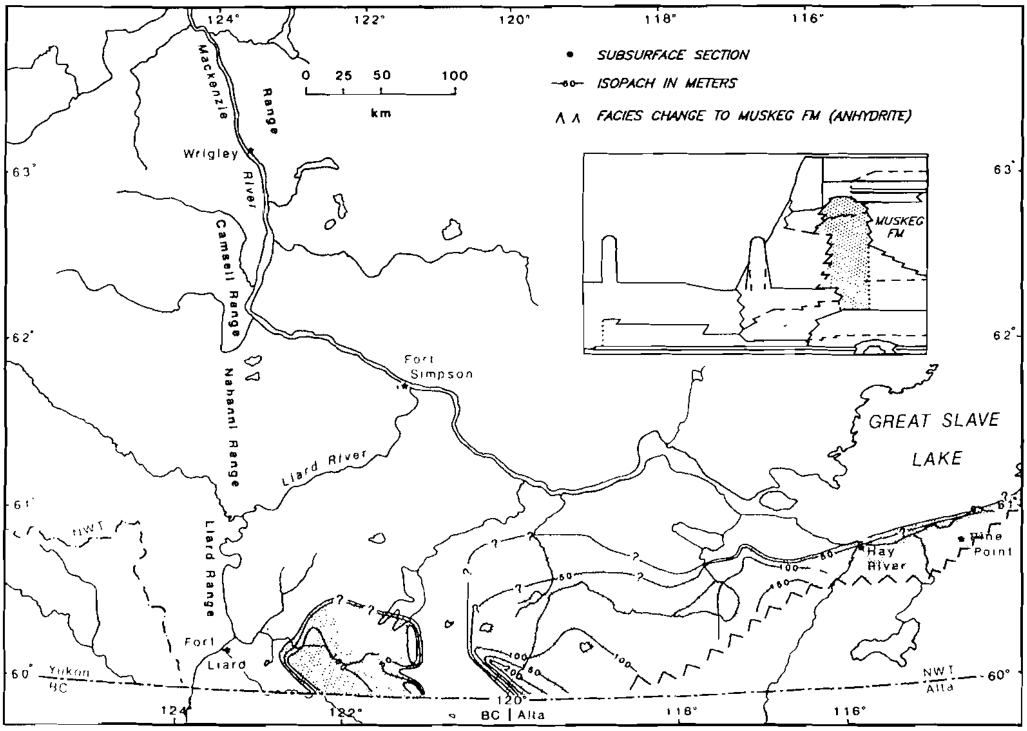


Fig. 42.- *Isopach map of Pine Point dolostone facies.*

thinning is partly due to erosion below the sub- Watt Mountain unconformity and partly due to onlap against Tathlina Uplift (see Fig. 30). ③ The Givetian carbonates are extensively dolomitized and it is often difficult or impossible to establish the boundary between the mid-Givetian and late Eifelian to early Givetian carbonate facies. ④ In places a late diagenetic, white dolostone facies similar to the Manetoe dolostone (known as the Presqu'ile dolostone) has destroyed much of the original sedimentary stuctures.

The Presqu'ile Barrier assemblage includes three principal lithological units. These are: ① a very fine- to finely crystalline dolostone (the Pine Point dolostone), ② a fossiliferous limestone (the Sulphur Point Formation), and ③ a white, very coarsely crystalline, late diagenetic dolostone (the Presqu'ile dolostone). In the northwestern part of Presq'ile Barrier the mid-Givetian carbonate facies is represented by the lower part of the "Undivided map unit". Another map unit of carbonates (the Bistcho Formation) extends southward from the Presq'ile Barrier across the evaporite facies. The stratigraphic relationships between these map-units is schematically shown on Figure 8.

The Presqu'ile Barrier was delineated by Grayston et al. (1964) and Basset and Stout (1967). It forms a 60 to 150 km wide belt which extends westward from Great Slave Lake to Trout Lake, then turns south into northeastern British Columbia towards Kotcho Lake. Within this belt the thickness varies because the assemblage overlies and flanks Tathlina Uplift and is truncated by the sub-Watt Mountain unconformity. In the region south of Great Slave Lake, the barrier assemblage has a maximum thickness of about 125 m (Skall, 1975). In the region between Great Slave Lake and Trout Lake the assemblage is between 12 and 213 m thick.

Pine Point dolostone

The Pine Point dolostone is a greyish brown and light brown, very fine- to finely crystalline dolostone facies which has replaced the platform and reefal limestones of the Upper Elk subgroup in the area north and northwest of the Muskeg evaporites (see Fig. 30). The lower and upper boundaries of this diagenetic facies vary from place to place and do not always have a stratigraphic significance. In 106 sections where the equivalents of the Lonely Bay and Keg River formations include limestone, the lower boundary of the Pine Point dolostone coincides with the transition from dolostone to limestone.

The Pine Point dolostone is in places fossiliferous but most fossils are poorly preserved. Norris (1965) collected fossils from the "Fine- grained Dolomite" member of the Pine Point Formation and reported the presence of *Stringocephalus*, a brachiopod typical of the Givetian Stage. Skall (1975) reported the presence of middle Givetian ostracodes in facies B. Senior (1977, p. 49) found late Eifelian conodonts in facies A and late Eifelian and mid Givetian conodonts in facies B.

The Pine Point dolostone is the most widely distributed lithology of the carbonate facies of sequence 5 and occupies the inner (southern and eastern) margin and the centre of the Presqu'ile Barrier. The thickness and distribution of the Pine Point dolostone in the southern part of Great Slave Plain is schematically indicated on Figure 42. The northern limit represents the lateral facies boundary with the Bituminous Shale and Limestone Beds, the Buffalo River shale and the Sulphur Point limestone (see Fig.43). The southern limit represents the change to the Muskeg Formation.

In the region south of Great Slave Lake the Pine Point dolostone attains a maximum thickness of about 100 m (Skall, 1975) and is overlain by Presqu'ile dolostone. In the region between Great Slave Lake and Trout Lake it overlies the southern flank and the crest of Tathlina Uplift. The

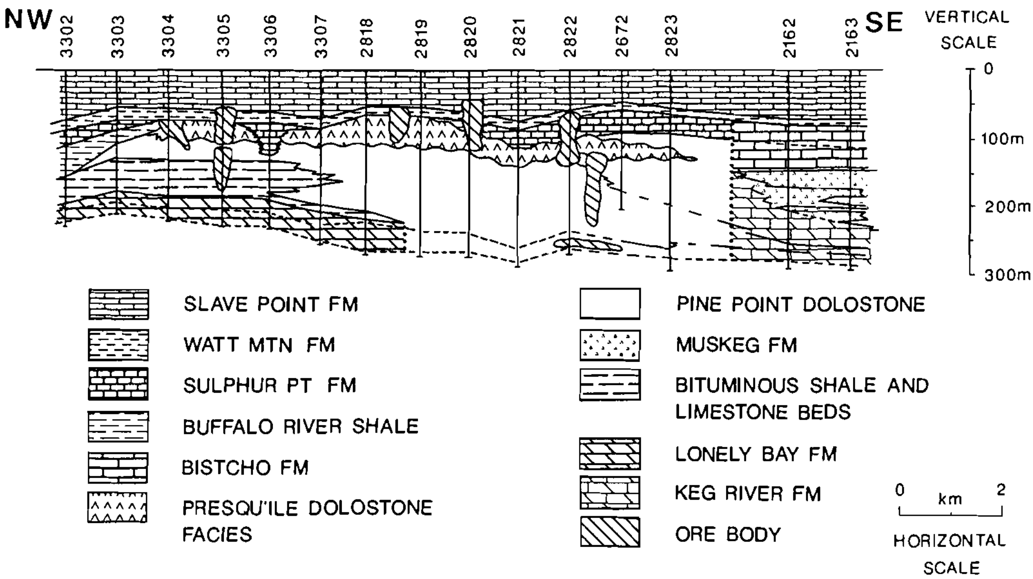


Fig. 43.- *Schematic cross-section across Presq'ile Barrier in the region south of Great Slave Lake (modified from Rhodes et al., 1984).*

thickness reaches a minimum value of 12 m in the Rabbit Lake area (see Fig. 42). Relative thick sections occur in the area west of the Cameron Hills. Here the dolostone facies reaches a maximum thickness of 213 m.

In certain areas over Tathlina Uplift the equivalent of the Lonely Bay Limestone Member is dolomitized (see Fig. 38). Here the Pine Point dolostone extends down to the detrital facies of stratigraphic sequence 4 or overlies Precambrian rocks. It includes all beds between the base of the Lonely Bay and Watt Mountain formations. This situation is schematically shown on Figure 8.

The Pine Point dolostone is relatively thin over the crestal part of Tathlina Uplift. The thinning is due partly to the depositional onlap of the dolomitized equivalent of the Lonely Bay Formation and partly to erosion below the Watt Mountain unconformity.

Section A-A' on Figure 5 indicates the structural situation at the lateral facies contact between the Pine Point dolostone, the Sulphur Point Formation, the Bituminous Shale and Limestone Beds and the Lonely Bay Formation.

Lithology

The variety of fine-crystalline dolostone types in the area south of Great Slave Lake was described by Skall (1975), Kyle (1981) and Rhodes et al. (1984). The dolostone is also described by Belyea and Norris (1962) from cores and samples in the region west of Great Slave Lake. Here the dolomitized equivalents of the Lonely Bay Formation consist of nodularly bedded and bioturbated wacke- and floatstones including crinoidal debris and brachiopods (see Kyle, 1981). This lithology is similar to that of the lower part of the Keg River Formation.

In the area south of Great Slave Lake the upper part of the Pine Point dolostone includes much coarse and very coarse crystalline, white dolomite and grades upward into Presqu'ile dolostone. In the area west of Great Slave Lake the white dolomite is present but it does not form a regional map unit.

Sulphur Point Formation

The pale coloured, fossiliferous carbonates which underlie the Watt Mountain Formation and either overlie the mid-Givetian shale facies or the Pine Point dolostone are considered to belong to the redefined Sulphur Point Formation (see Meijer Drees 1986b and in press).

In the Horn River et al. Hay River B-52 well the redefined Sulphur Point Formation occurs between 179.2 and 223.7 m (500 and 734 ft), see Figure 28, section 8. In this reference section the Sulphur Point Formation is partly dolomitized and overlies the shale facies of sequence 5 (the Buffalo River shale) with a fairly sharp contact. The upper contact below the sub-Watt Mountain unconformity is difficult to select on borehole logs. In the core it lies somewhere between the top of the dolostone (below) and a thin, pale green calcareous claystone bed (above).

The schematic cross-sections across the Presqu'ile Barrier by Kyle (1981) and Rhodes et al. (1984) in the Pine Point Mines property, south of Great Slave Lake suggest that the carbonates of the Bistcho Formation are not in mappable continuity with the carbonates of the Sulphur Point Formation north of the Presqu'ile Barrier, because the sub-Watt Mountain erosional unconformity cuts down section in a northerly direction (see Fig. 43). Lantos (1983) and Rhodes et al. (1984) suggested that the carbonates situated between the Watt Mountain Formation and the Buffalo River

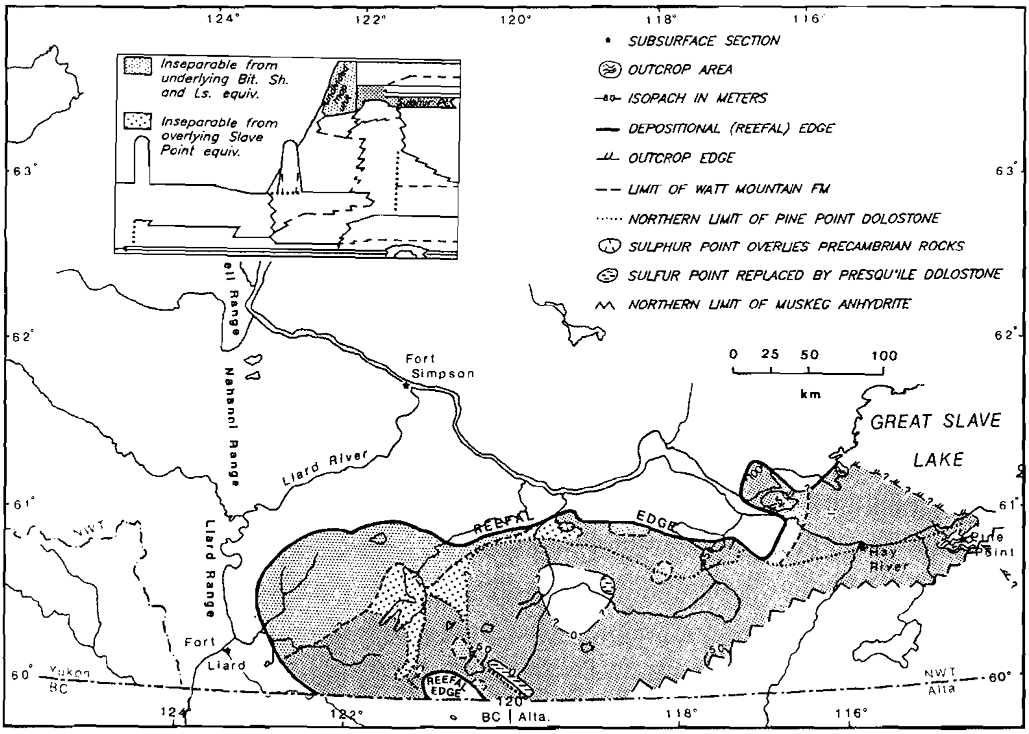


Fig. 44.- *Distribution of Sulphur Point Formation and equivalents.*

shale unit in the area north of the Presqu'ile Barrier are significantly younger. However, the regional information presented in this report suggests thatthe upper part of the Sulphur Point Formation (redefined) is in mappable continuity with the Bistcho Formation in of northern Alberta.

The lower part of the Sulphur Point Formation is very fossiliferous and includes stromatopores, corals, brachiopods, gastropods and crinoidal debris. The presence of the brachiopods *Stringocephalus burtini* Defrance and *Hypothyridina cameroni* Warren in the exposed sections along the south shore of Great Slave Lake (Norris, 1965) and the presence of the coral *Grypophyllum mackenziense* (Pedder) in the subsurface suggest that the lower part of the Sulphur Point Formation is of late Middle Devonian age.

The distribution of the Sulphur Point Formation in the District of Mackenzie is restricted to the southern part of Great Slave Plain. The depositional limit of the formation is drawn at the lateral transition from carbonate to shale indicated on Figure 44 as "reefal-edge". This transition probably represents the seaward edge of a barrier reef.

The Sulphur Point is locally exposed along the south shore of Great Slave Lake. Norris (1965) and Rhodes et al.(1984) traced the formation on bedrock geology maps between the Buffalo River shale and the Watt Mountain Formation. In the nearby subsurface it is respectively 17.9 and 45.7 m thick in the Cominco Sulphur Point G-4 corehole and the Horn River et al. Hay River B-52 well.

The rufal-edge southeast of Trout Lake represents the margin of the Cordova Shale Basin (see Fig. 41). Also indicated on the map as a line limiting the distribution of the Sulphur Point Formation is the depositional edge of the Watt Mountain Formation. North of this line the Sulphur Point Formation becomes the lower part of the "Undivided map unit". South of this line the Watt Mountain Formation is locally absent. Because the lower part of the Sulphur Point Formation changes to dolostone in the southern part of Figure 44 the limit of the Pine Point dolostone facies is also indicated.

In the region between Kakisa Lake and Redknife River the Sulphur Point Formation is thin or absent. It is assumed that the formation was removed by erosion from the crest of Tathlina Uplift prior to the deposition of sedimentary sequence 6.

The Sulphur Point Formation overlies the mid-Givetian shale facies in a number of wells drilled southeast of Trout Lake. The interpretation on Figure 44 suggests that it surrounds the Cordova Shale Basin. Because in this area the equivalents of the Bituminous Shale and Limestone Beds are rich in limestone and the Watt Mountain Formation is locally absent it is difficult to map the thickness in this area.

Lithology

In the type section (the Cominco G-4 borehole, lat. 61°54'N, long. 114°46'W) the redefined Sulphur Point Formation includes a lower, massive biostromal unit (the Windy Point member of Rhodes et al.,1984) and an upper, interbedded member. The lower member is 10.3 m thick and consists of a light brown, stromatoporoidal and coraliferous, partly dolomitized limestone. The upper member is a grey, very fine-textured limestone including scattered, green shale partings (Lantos, 1983).

In the Horn River et al.Hay River B-52 well (Fig. 28, section 8) the lower part of the Sulphur Point Formation consists of greyish brown to brown limestone, in part argillaceous, in part fossiliferous (crinoid ossicles, ostracodes, brachiopods). The upper part is a light greyish brown, very fine- to fine-, or fine- to coarsely crystalline, in part porous dolostone. It includes near the top, light brown, aphanitic limestone with fenestral vugs filled with clear calcite and white dolomite and minor white to semitranslucent nodular anhydrite. The upper boundary of the Sulphur Point lies at the base of a thin, pale green, pyritic claystone bed.

In other coreholes the lower or Biostromal member consists of very light brown coloured, fossiliferous floatstone and includes a fine- to coarsely grained matrix. The upper, interbedded member consists of very fine- to finely peloidal and fragmental wacke- and mudstones including many, discontineous shale partings and very fossiliferous wacke- and packstones. These limestones include calcite or dolomite filled, laminoid-fenestral voids, stomatolitic laminations, scattered mudstone pebbles, fragments of gastopods, stromatoporoids, brachiopods, ostacodes, calcispheres and charophyte oogonia. The larger fossil fragments are commonly encrusted with calcareous algae.

Dissolution vugs and fractures in the upper part are partly filled with green, pyritic shale, light brown claystone or quartz silt and partly filled with isopachous cement (see Meijer Drees,1986b).

Bistcho Formation

The wedge of carbonates that extends south and eastward from the upper part of the Presq'ile Barrier into the northern part of the Elk Point Basin and overlies the Muskeg Formation is named the Bistcho Formation (see Meijer Drees, 1986b and in press). The type section was selected by McCamis and Griffith (1967) in the BA-HB Zama North 16-19-116-4W6 well, located in northern Alberta. The contact with the underlying Muskeg Formation is transitional and was chosen at the top of the highest stratigraphic occurence of nodular-bedded anhydrite. The upper contact is placed at the sub-Watt Mountain unconformity.

The Bistcho Formation does not include diagnostic fossils and its age can only be inferred from its sratigraphic position.

The formation is widely distributed in northern Alberta. It extends southeastward from the Presqu'ile Barrier and thins to zero in a southeastward direction. The northern limit of the Bistcho Formation coincides with the northern limit of the Muskeg Formation.

In the type section the formation includes three members. These are in ascending order: ① a lower Dolostone member, ② a middle Interbedded Limestone and Dolostone member and ③ an upper Limestone member. The Dolostone member is light and dark greyish brown, very fine- to finely crystalline dolostone and consists of recrystallized, peloidal pack-, wacke- and mudstones. The Interbedded member includes similar dolostone lithologies and light to dark greyish limestone interbeds. The limestone beds are mudstones or finely peloidal wacke- and packstones locally including fragments of stromatoporoids, ostracodes and "calcispheres". The upper, thinly bedded Limestone member consists of similar limestone lithologies and includes in the upper part brecciated intervals wth sediment filled cavities and fractures. It grades upward into a shaly, limestone conglomorate which resembles a rubble deposit. The shaly rubble deposit is the basal part of the Watt Mountain Formation.

"Undivided map unit"

It is not possible, with the presently available information to accurately map the seaward edge of the Presqu'ile Barrier and distinguish between high Horn Plateau reefs and mid-Givetian reefal limestone sections belonging to the Presqu'ile Barrier assemblage. The litho-stratigraphic subdivision is based on the presence of the Mid-Givetian shale facies and the Watt Mountain Formation. In sections where these two markers are absent one cannot recognize the boundaries between the carbonates of depostional sequences 5 and 6 (see Fig. 8).

The "Undivided map unit" includes equivalents of the Sulphur Point, Watt Mountain and Slave Point formations. It overlies the shale facies of sequence 5 (the Bituminous Shale and Limestone Beds or the Buffalo River shale), is overlain by dark coloured Upper Devonian shale (the Muskwa Formation) and consists of fossiliferous, in part reefal limestone (see Meijer Drees 1986b and in press). It represents the undolomitized, seaward edge of the Presqu'ile Barrier, beyond the depositional edge of the Watt Mountain Shale. It and may include some high reef mounds of the Horn Plateau type. The stratigraphical relationships between the "Undivided map unit" and the other Givetian map units is indicated on Figure 8.

The "Undivided map unit" includes corals, ostracodes, brachiopods and conodonts of late Middle Devonian age. The ostracodes of both the lower and upper parts are similar to those of the Slave Point Formation. The lower part of the map unit includes the coral *Grypophyllum mackenziense*.

The thickness of the "Undivided map unit" ranges between 75.2 and 155.4 m. The distribution of the map unit is shown on Figure 44. The northwestern limit of the map unit on Figure 61 represents the seaward edge of the Presqu'ile Barrier and the broken line represents the depositional limit of the Watt Mountain Formation. Also indicated on the map are the localities where the "Undivided map-unit" occurs within the boundaries of the Sulphur Point Formation.

Lithology

The undivided Sulphur Point-Watt Mountain-Slave Point interval was cored in several wells in the Arrowhead River area, including the Imperial Sun Arrowhead I-46, the Murphy ArrowheadRiver No. 1 and the Amoco Decalta Poplar River G-32 wells, shown on Figure 24. In the Arrowhead I-46 well the undivided succession is present in the core between 1870.5 and 1979.9 m (6137 and 6496 ft), see Figure 24, section 1. The lower part of the succession (interval 1963.5 to 1979.9 m, 6442 to 6496 ft) consists of poorly bedded, light greyish brown to greyish brown and dark greyish brown, argillaceous limestone. The limestone is very fossiliferous, includes thick beds composed of tabular or digital Stromatopora in growth position and thinner beds, composed of pebble sized fragments of closely or loosely packed, tabular and digital *Stromatopora* and corals. Using the classification in Figure 2 the limestone beds can be named stromatopore framestones and stromatoporoidal or coralliferous rudstones or float-stones. The matrix of the floatstones is a fine peloidal, wacke-, pack- or grainstone, cemented by sparry calcite. Some float- and mudstones have a very dark grey argillaceous matrix. The rudstones appear to be welded together by encrusting *Stromatopora* or calcareous algae (see Plate XVf). Pedder (1972) reported the presence of the corals *Thamnopora* sp. and *Grypophyllum mackenziense* (Pedder) at a depth of 1973.4 m (6474.5 ft).

The middle part of the succession, interval 1954.3 to 1963.5 m (6412 to 6442 ft) consists of dark greyish brown to very dark grey, very argillaceouse and very fossiliferous limestone. Fragments of tabular or digital *Stromatopora* and corals, up to 1 cm in diameter, occur together with crinoid ossicles in a dark grey matrix of marl or very fine to coarse fragmental wackestone. This interval includes several coral species and *Stachyodes verticillata* (McCoy). The corals were identified by Pedder (in Norford et al., 1971) and include *Thamnopora* sp., *Temnophyllum* sp., *Cladochonus* sp., *Alveolites* sp. and *Grypophyllum mackenziense* (Pedder). The ostracodes collected from this interval and the underlying beds were identified by Braun (in Norford et al., 1970, p. 16) and are similar to the ostracode fauna of the Slave Point Formation.

The upper part of the succession is approximately equivalent to the carbonate platform facies of depositional sequence 6 (the Slave Point Formation). Interval 1870.5 to 1963.5 m (6137 to 6442 ft) consists of light greyish brown and greyish brown, very fossiliferous limestone with scattered dark grey, stylolitic shale partings. The interval is poorly bedded and includes finely to coarsely peloidal grainstones, packstones and wackestones with scattered fossil fragments; mudstones with scattered brachiopods, *Amphipora* and microfossils; and stromatoporoidal rudstones and floatstones composed of fragments of digital, tabular and bulbous stromatopores and rare corals.

Ostracodes collected between from this succession were identified by Braun (in Norford et al., 1970). The fauna is similar to that of the Slave Point Formation of north-central Alberta and was placed in the Givetian Stage. Raasch (1981) reported the brachiopod *Ladjia landesi* from depth 1876.6 m (6157 ft).

The contact between the Slave point equivalent of the "Undivided map unit" and the overlying Upper Devonian Muskwa Shale in the Arrowhead I-46 well is very sharp and dips about 60 degrees. The contact truncates a small bulbous stromatopore indicating that some limestone was dissolved. It is assumed that this sharp contact represents the hiatus between the depositional sequence 6 and the Upper Devonian shale succession (see Fig. 11).

The lithology of the Slave Point equivalent of the "Undivided map unit" in the Arrowhead No. 1 well (see Fig. 24, section 2) is similar to the upper part of the Arrowhead I-46 well. In this well Pedder (1972) identified the coral *Temnophyllum richardsoni* (Meek)? from depth 1765.0 m (5791 ft).

The core in the Poplar River G-32 well (see Fig. 24, section 3) only includes the equivalents of the Slave Point Formation. It may represent a "high reef" (see Fuller and Pollock, 1972). It is a brown to greyish brown, fossiliferous and in places peloidal wackestone. The limestone includes intervals with scattered fragments of bulbous and digital *Stromatopora*, brachiopods and gastropods. At two places Amphipora was found in a growth position. Fuller and Pollock (1972) reported the presence of the conodont *Spathognathodus brevis* from five levels in the core.

Raasch (1981) described the cores of the Arrowhead Aurora M-47, the Arrowhead N-2, Arrowhead B-76 and Netla Raven F-73 wells and reported the presence of *Grypophyllum mackenziense* from the lower part and *Ladjia landesi* from the upper part of the "Undivided map unit".

The Watt Mountain Formation is also absent in several wells south of Trout Lake. A core sample collected from the uppermost Slave Point equivalent in the Pan Am A-1 Island River D-29 well (lat. 60°08'07.74"N, long. 121°05'17.10"W) yielded conodonts equivalent to the Lowermost- and Lower Polygnathus asymmetricus Zones.

Presqu'ile dolostone

The Presqu'ile dolostone is a white, very coarsely crystalline, diagenetic facies that occurs in the

Middle Devonian carbonate succession around Great Slave Lake. Skall (1975) stated that in the Pine Point Mining District south of Great Slave Lake, the Presqu'ile facies (facies K) not only represents the reef core but is also developed in the fore-reef and back-reef facies of a barrier reef complex (the Presqu'ile Barrier) below the Watt Mountain disconformity. Kyle (1981) and Rhodes et al. (1984) described examples of Presqu'ile ore bodies which were initially formed as a result of collapse (presumably because of dissolution of evaporites in the deep subsurface) and which have expanded upward into the Slave Point Formation (see Fig. 43).

The Presqu'ile facies is the host rock in the Cominco Pine Point lead-zinc property. Krebs and Macqueen (1984) recognized eight major stages in the mineralization and dolomitization of the orebodies. It is thus not likely that the Presqu'ile facies was deposited during one specific time interval. The age of the facies differs from place to place and may be the result of several episodes of karst formation and dolomitization. The initial stages may be as old as the sub-Watt Mountain erosional event but the major part of the dissolution and dolomitization process probably occurred during latest Paleozoic and early Mesozoic time.

In the eastern portion of the Pine Point Mines property the Presqu'ile facies occurs mainly in strata equivalent to the Sulphur Point Formation and forms two elongate bodies on the bedrock surface (see Fig. 45). These northeast- southwest trending bodies are known as the North and Main Trends (Rhodes et al., 1984). The North and Main trends are separated by a zone in which the Sulphur Point Formation is unaffected by Presqu'ile type dolomitization.

In the western part of the Pine Point Mines property the Presqu'ile dolostone facies occurs as a stratiform deposit between the Sulphur Point Formation (below) and the sub-Watt Mountain unconformity (above).

The Presqu'ile dolostone extends westward from the Pine Point Mines property as far as Trout Lake but well control is so sparse that it is not possible to map the limits of the facies with any confidence. In the region between Great Slave and Trout lakes the Presqu'ile facies occurs in stratigraphical equivalents of the Sulphur Point and Slave Point formations and is underlain by Pine Point dolostone. Belyea and Norris (1962) reported its presence in several wells. The location of an additional number of Presqu'ile occurrences is indicated on Figure 45.

In northeastern British Columbia a dolostone facies similar to the Presqu'ile dolostone is the reservoir rock in the Clarke Lake, Yoyo, Sierra, Kotcho Lake, Louise, Cabin, Tsea, Dilly, Petitot and Helmet gas fields. Here the facies extends upward into the equivalents of the Watt Mountain and Slave Point formations. The western edge of the Presqu'ile Barrier more or less coincides with the western limit of the Slave Point Formation or "Undivided map unit". The Presqu'ile facies in northeastern British Columbia was described by Griffin (1965).

The Presqu'ile facies in the reefal beds of the Slave Point equivalent extends northward into the southwestern part of the District of Mackenzie along the eastern and western edges of the Cordova Shale Basin (see Fig. 45). The upper part is gas bearing in the H.B. Pan Am South Island River M-41 well (lat. 60°00'55"N, long. 121°09'00"W). The western edge of the Presqu'ile Barrier extends northward into the Celibeta area where it is gas bearing in the Home Signal CSP Celibeta No. 2 well (lat. 60°07'29.31"N, long. 122°13'35.25"W).

Lithology

The Presqu'ile facies is a light grey to white, massive, very coarse to coarsely crystalline

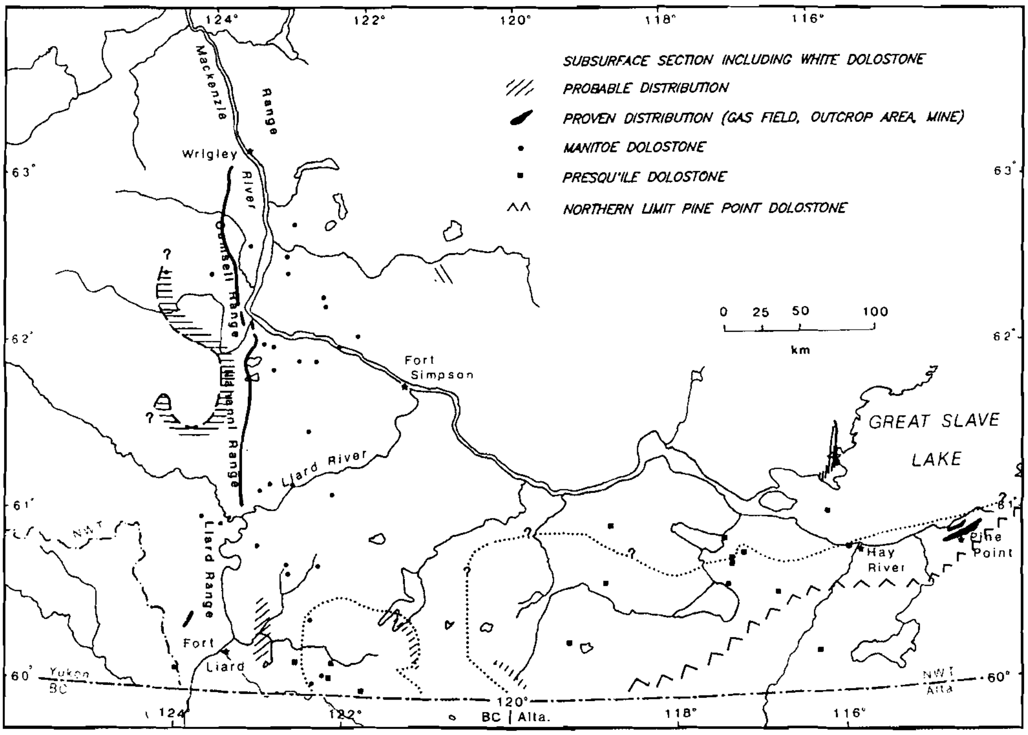


Fig. 45.- *Distribution of white, late dagenetic dolostone facies (Manetoe and Presqu'ile).*

dolostone with vuggy porosity. In places it includes remnants or interbeds of dark, fine crystalline dolostone. There is a great deal of variation in the amount of dark grey dolostone interbeds, porosity, shape of vugs and type of mineralization.

Rhodes et al. (1984, Fig. 17) show examples of white, coarsely crystalline dolostone with structures that resemble grains, fenestral vugs, fossils and stylolites. The recrystallization of a finely textured dolostone into a coarse textured one results in a very coarse, nodular fabric not unlike that of nodular or nodular bedded anhydrite. Rhodes et al. (1984) were able to trace some of the original lithologies as typical for the reefal facies or back reef (lagoonal) facies. Rhodes et al. (1984), and Kyle (1981) also described the presence of large, tabular, ore bearing dolomite bodies that resemble cavity fillings. Also present are smaller ore bodies that represent chimney like collapse structures.

4. Shale facies of sequence 5

The shale facies of the fifth sequence forms a northward thinning wedge of clinoform and fondoform deposits that fringes the seaward edge of the Presqu'ile Barrier. It consists of two parts. The lower part is a dark coloured, fossiliferous deposit, the upper part is greenish grey. Stratigraphic and facies relationships along the northern and northwestern edge of the Presqu'ile Barrier assemblage suggest that the dark coloured deposits are in lateral contact with the lower part of the carbonate facies and the greenish grey coloured beds are more or less equivalent to the upper part of the carbonate facies.

The lower, dark coloured part is prominently present in the region around Great Slave Lake, in the subsurface along the northern edge of the Presqu'ile Barrier assemblage and along the margin of the Cordova Shale Basin (see Fig. 41). It has been mapped previously as the Bituminous shale and Limestone Beds. In the northern Mackenzie Mountains the dark shales are relatively thin and form the basal part (the Bluefish Member) of the Hare Indian Formation.

The upper, greenish grey deposits in the Great Slave Lake region are known as the Buffalo River Formation. In the northern Mackenzie Mountains similar shales are included in the upper part of the Hare Indian Formation. They are absent in the Horn Plateau region, presumably because of non deposition.

Hare Indian Formation

The Hare Indian Formation (Bassett, 1961) is widely distributed in the northern Mackenzie Mountains. It includes the very thinly bedded, bluish grey, calcareous shale between the Hume Formation (below) and the Canol Formation or Ramparts Formation (above). Tassonyi (1969) designated as reference the section in the Imperial Range on Mountain River (lat. 65°25'30"N, long. 129°08'00"W) described by Parker (1944) and Hume and Link (1945, p. 20).

Tassonyi (1969) and Pugh (1986) recognized the presence of two members in the Mackenzie Mountains. The lower "spore bearing" or Bluefish Member consists of dark grey, bituminous shale and contains trilete spore cases. The upper member is not named. It is relatively thick and is an interbedded succession of grey to green, calcareous shale and minor, thin interbeds of limestone.

Equivalents of the Hare Indian Formations are present in the subsurface of the Great Slave Plain. The Bluefish Member more or less correlates with the Bituminous Shale and Limestone Beds of

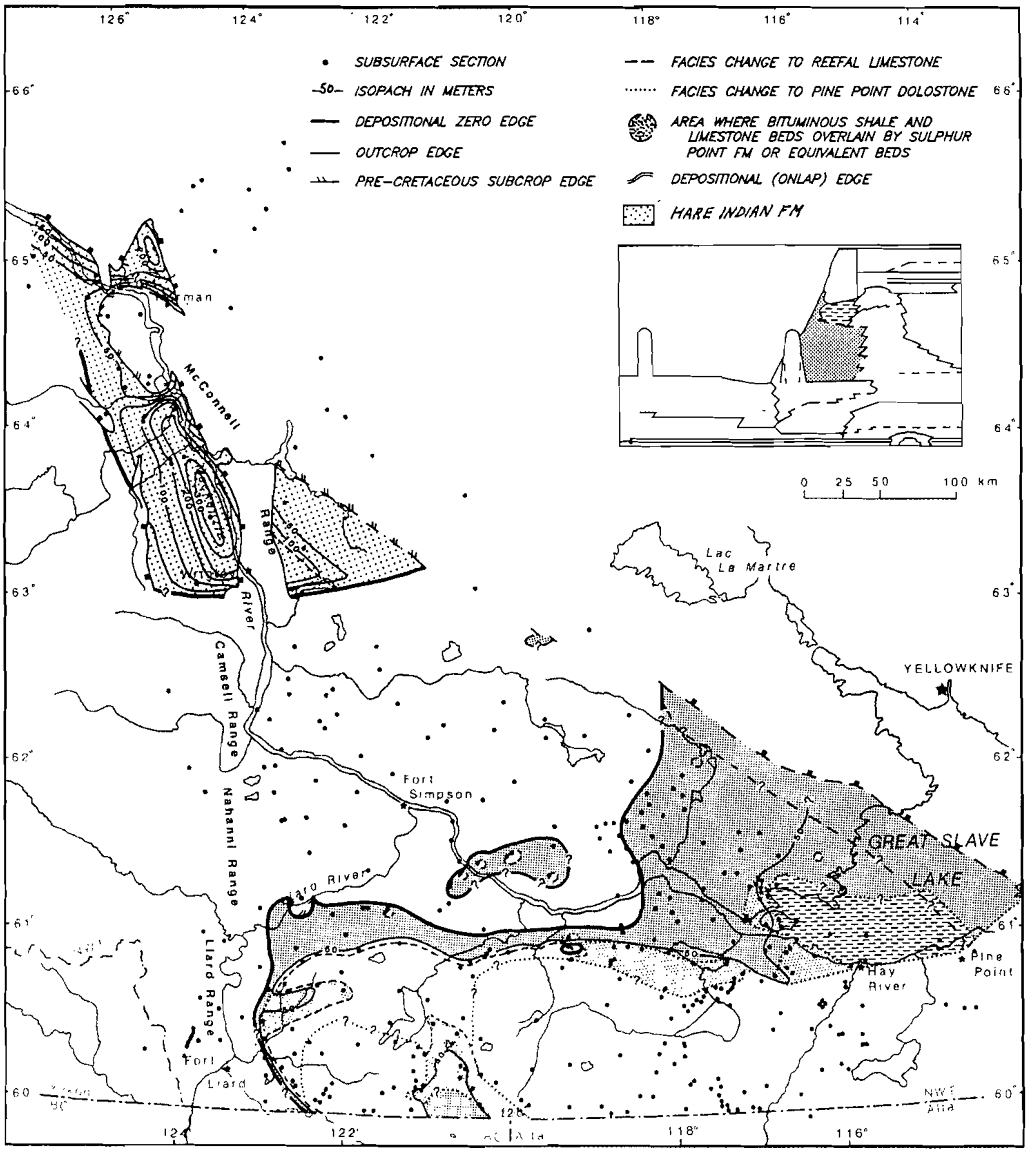


Fig. 46.- *Isopach map of Hare Indian Formation and equivalents.*

Norris (1962), the unnamed upper member is the equivalent of Campbell's (1957) Buffalo River Formation. All these map-units are thus considered to be part of the Hare Indian Formation.

The Hare Indian Formation is fossiliferous. The Bluefish Member includes Lingula- like brachiopods and tentaculitids. The upper member includes brachiopods and corals characteristic of the *Ectorensselandia laevis* Zone and conodonts of the *Polygnathus varcus* Zone (Pedder, 1975; Lenz and Pedder, 1972). Both zones belong to the Givetian Stage.

The Hare Indian Formation is widely distributed in the northern part of the Mackenzie Mountains. The reference section in the Imperial Range was measured by Parker (1944) for the Canol Project and is 213.3 m (700 ft) thick (see Tassonyi, 1969, p. 70). In a nearby section, at Powell Creek, the Hare Indian Formation is about 164.5 m thick (see Lenz and Pedder, 1972). In the subsurface of the Norman Wells area the formation varies in thickness between 140.2 and 30.4 m. In places where the Ramparts Formation is absent, the formation is overlain by the Canol Formation (see Tassonyi, 1969, Fig. 10). The distribution of the Hare Indian Formation north of Norman Wells was shown by Mackenzie (1974b).

The Hare Indian Formation is easily traced in the subsurface from the Norman Wells area into the area west of Wrigley (see Fig.39). It is present in the Decalta et al. Wrigley I-54 well and the Shell Wrigley G-70 well. The formation is absent in wells located farther south and is only a thin unit in the HB Gulf Fish Lake G-60 well, see Figure 32, section 6. The distribution of the formation is shown in the northwestern part of Figure 46.

Bluefish Member

The Bluefish Member is present in the southern part of the Mackenzie Plain. It is easily recognizable on gamma-ray logs because it highly radioactive (see Fig. 39). In the southern Mackenzie Plain the member ranges in thickness between 10 and 33.2 m. It is absent in the Fish Lake G-69, the Ochre River I-15 and the Blackwater Lake E-11 wells (see Fig. 32), presumably because of non-deposition.

Lithology

The lithology of the Bluefish Member is typically that of a fondothem deposit. It consists of very dark brownish grey or black, bituminous, calcareous and non-calcareous shale, containing trilete spore cases, tentaculitids, pyrite nodules and poorly preserved brachiopod(?) shells (Tassonyi, 1969, p. 72). The algal spore cases belong to the genus Leiecphaeridia (Sweet in Mackenzie, 1974b). According to Mackenzie (1974b) the algal spore cases are rarely present in the southern and eastern parts of the area in which the Hare Indian Formation is present.

Bituminous Shale and Limestone Beds

The Bituminous Shale and Limestone Beds is an informal map-unit in the Great Slave Plain. It overlies the Lonely Bay Formation and underlies the Buffalo River Shale or the carbonates of the Sulphur Point or "Undivided map-unit", see Figure 8.

The Bituminous Sale and Limestone Beds are disconitnuously exposed along the shores of Great Slave Lake and were mapped by Norris (1965, Fig. 7). The unit was penetrated by several boreholes in the region south of Great Slave Lake and was cored in the Cominco G-4 well. In this well the member is 34.8 m thick. The Bituminous Shale and Limestone Beds are present in the Hay River B-52 well between depths 260.2 and 291.3 m (854 and 956 ft). Here they are underlain by the Lonely Bay Formation and overlain by the Buffalo River Shale (see Fig. 28, section 8).

In the outcrop area of the Bituminous Shale and Limestone Beds, along the south shore of Great Slave Lake and along the shores of Green and McKay Islands, the map-unit includes two parts. One part, presumable the lower, is very fossiliferous and consists of dark coloured, bituminous marl interbedded with brown to dark brown, nodular limestone. The other part, presumably the upper, includes brown to dark brown, irregularly and thinly bedded, fossiliferous limestone. Along the shore west of Isle du Mort, the Biomituminous Shale and Limestone Beds appear in part to underlie and intertongue with the Buffalo River Shale (see Norris, 1965).

Fossils of the Bituminous Shale and Limestone Beds include brachiopods such as *Emannella meristoides* (Meek), *Warrenela* sp., *Hadrorchynichia* sandesoni (Warren) and *Leiorhychus castanea* (Meek). This fauna is thought to be Givetian (see Norris, 1965). The conodont fauna reported by Senior (1977) includes *Polygnathus varcus*, a speciies typical of the Givetian Stage.

The distribution of the Bituminous Shale and Limestone Beds and the Buffalo River Shale is mapped on Figure 46. In the area south and west of Great Slave Lake the Bituminous Shale and Limestone Beds are locally overlain by the Buffalo River Shale. The map suggests that the southern limit of both units lies at the lateral facies contact with the Pine Point dolostone.

Skall (1975) and Rasmussen (1981, Fig.4) indicated that the Bituminous Shale and Limestone Beds in the subsurface south of Great Slave Lake pass laterally into an argillaceous, dark brown to black, sucrosic, in part dense dolostone with chert nodules and is overlain by a similar dolostone which is in part medium to coarsely recrystallized.

This facies change is mapped on Figure 46 as the northern limit of the Poine Point dolostone and extends westward into the area north of Tathlina and Trout lakes.

It is possible to trace the Bituminous Shale and Limestone Beds on Figure 28 from the region south of Great Slave Lake into the area northwest of Great Slave Lake. The figure indicated that tin the Deep Bay area the Bituminous Shale and Limestone Beds range in thickness between 40.2 and 62.4 m and underlie different rock-units. In the Big Island 0-78 and MWT Deep Bay No. 3 wells (sections 6 and 7) they are overlain by the Buffalo River shale. In the Punch Deep Bay No. 2 and 3 wells (sections 4 and 5) they are overlain by Upper Devonian Hay River shale and in the Deep Bay B-01 well they are overlaind by reefal limestone of the"Undivided map unit".

In the northwestern part of Figure 27 (sections 1 and 2) and on Figure 27 the Bituminous Shale and Limestone Beds are relatively thin and are overlain by the Upper Devonian Spence River Formation. The stratigraphic relationships on Figure 33 suggest that the upper part of the Bituminous Shale and Limestone Beds are unconformably overlain by the Upper Devonian Spence River shale and locally may include nonreefal beds equivalent to the Horn Plateau reefs.

In the area south of Horn Plateau the Bituminous Shale and Limestone Beds are relatively thin and surround Horn Plateau Reefs. Here they are overlain by the Upper Devonian shale succession (see Fig. 5, sections A-A', B-B'). The zero edge mapped on Figure 46 represents the depositional limit of the Bituminous Shale and Limestone Beds.

In the area north and west of Trout Lake the Bituminous Shale and Limestone Beds include only minor amounts of dark shale and are difficult to recognize on borehole logs. Typical sections are shown on Figure 24, sections 1 and 2. Because the Watt Mountain Formation is absent in this region the "Beds" are overlain by the "Undivided map unit".

In the area southeast of Trout Lake dark coloured argillaceous limestone and shale beds more or less equivalent to the Bituminous Shale and Limestone Beds occur in and along the margins of the Cordova Shale Basin (see Fig.41). In this shale basin the overlying Givetian carbonates are missing because of nondeposition. In the central part of this shale basin equivalents of the Bituminous Shale and Limestone Beds are overlain by the Upper Devonian shale. Along the edge of the basin they are overlain by equivalents of the Sulphur Point or the "Undivided map unit" (see Fig. 5, section B-B'). The stratigraphy along the periphery of the shale basin resembles the situation along the edge of the Presqu'ile Barrier in northeastern British Columbia described by Griffin (1965).

It appears on Figure 46 that the Cordova Shale Basin does not extend northward across the barrier reef complex. The reason for this is that over the crestal part of Tathlina Uplift the bituminous shale interbeds are absent and it is thus impossible to segregate in this region the limestone unit between the Poine Point dolostone (below) and the Watt Mountain Formation (above) into the Lonely Bay Limestone, Bituminous Shale and Limestone Beds or Sulphur Point Formation.

Lithology

In the Hay River B-52 well (see Fig.28, section 8) the lower part of the Bituminous Shale and Limestone Beds consists of very dark grey to dark grey marl and includes many tentaculitids. The upper part is a dark grey limestone with light coloured fossil fragments, mainly brachiopod shells and tentaculitids.

In the Punch Deep Bay No. 2 and 3 wells (see Fig. 28, sections 4 and 5) the Bituminous Shale and Limestone Beds were cored. In these two wells the "Beds" are directly overlain by Upper Devonian shale (the Spence River Formation). They include the equivalents of the Buffalo River shale and consist of a dark coloured, thinly interbedded succession of bituminous marl, argillaceous limestone and peloidal, in part fossiliferous limestone. The marl contains many compressed Tentaculitids, crinoid ossicles, scattered *Amphipora*, bulbous Stromatopora and *Thamnopora* like corals. The boundary between the Bituminous Shale and Limestone Beds and the Upper Devonian shale succession is drawn at the base of a very dark grey, calcareous and pyritic shale unit which includes coaly plant imprints and scattered lingulas and tentaculitids. This contact is fairly sharp in the Punch Deep Bay No. 2 well (see Plate VII). It is transitional in the Punch Deep Bay No. 3 well and was selected at the top of tentaculitid-coquina interbeds, depth 237.7 m (780 ft).

In the Horn River et al. IOE Deep Bay B-01 well the Bituminous Shale and Limestone Beds are relatively thin and overlain by reefal limestone (see Fig. 28). In the Punch Deep Bay No. 5 and the IOE Providence A-47 wells the "Beds" are directly overlain by the Spence River Formation (see Fig. 28). In these three wells the Bituminous Shale and Limestone Beds are an interbedded succession of light greyish brown or light brown and dark brown mottled, in places peloidal or fossiliferous limestone and dark greyish brown to very dark grey, fossiliferous marl. The fossils include tentaculitids, *Lingula*, ostracodes and crinoid ossicles. In the Providence A-47 well the contact between the Bituminous Shale and Limestone Beds and the Spence River Formation is sharp and easy to recognize on borehole logs.

The Bituminous Shale and Limestone Beds and the underlying and overlying beds were cored in the IOE Providence K-45 well and CS Laferte River M-16 and Horn River et al. Mink Lake I-38 wells (see Fig.27, sections 7, 4 and 6). These cores consist of thinly and nodularly bedded, dark to very dark greyish brown, very argillaceous limestone and dark greyish brown, bituminous, marl or shale. The succession is in places fossiliferous and includes the brachiopod *Leiorhynchus castanea* (Meek) (see Norris in Brideaux et al., 1976), and conodonts of the *Polygnathus varcus* Stauffer Group (see Uyeno in Brideaux et al., 1976).

The interval between depths 955.2 and 969.2 m (3134 and 3180 ft) in the Imperial Redknife N-6 (No. 1) well (see Fig. 30, section 8) were partly cored. Norris (in Norford et al., 1970) reported *Leiorhynchus cf. L. castanea* (Meek) and *?Leiorhynchus awokanak* McLaren from the basal part of the interval.

In the southwestern part of the Great Slave Plain the equivalents of the Bituminous Shale and Limestone Beds are present in several wells northwest of Trout Lake. Here the "Beds" are not clearly visible on the gamma ray log, because they include only a minor amount of bituminous shale. However, it is possible to recognize the unit in samples and cores.

Buffalo River shale

The Buffalo River shale is a map unit in the Great Slave Lake region composed of bluish-grey to dark green, fissile, pyritic, limy shale (Campbell, 1957). it is underlain by the Bituminous Shale and Limestone Beds or its dolomitized equivalent in the Pine Point dolostone and is overlain by the Sulphur Point Formation or the "Undivided map unit" (see Fig. 8).

The nature of the lower boundary of the Buffalo River shale varies from section to section. In places where the shale overlies dark, bituminous shale, the boundary is transitional. In places where it overlies carbonates, the contact is fairly sharp The upper boundary of the Buffalo River shale is placed at the highest occurrence of grey, pyritic shale below bioclastic carbonates of the Sulphur Point Formation.

The Buffalo River shale is in lateral facies contact with the Pine Point dolostone (see Fig. 5, section F-F'). Rasmussen (1981, Fig. 6) suggested that the lower part of the shale unit is in contact with Facies B of Skall (1975) and that the upper part thins, changes into a dolomitized calcarenite and onlaps reefal carbonates of Facies D and E of Skall (1975). This situation is shown on Figure 43. Correlations on Figure 28 indicate that the Buffalo River shale extends northward below Great Slave Lake into the area northwest of Deep Bay, where it reaches its depositional limit.

The Buffalo River shale is sparsely fossiliferous and includes conodonts of the *Polygnathus varcus* Stauffer Group which indicates a late Middle to Upper Givetian age (Lantos, 1983). The shale also contains microscopic plant remains (see Audretsch, 1967).

The distribution of the Buffalo River shale is restricted to the region around Great Slave Lake (see Fig.46). It is present in the shallow subsurface in the area immediately west of the mouth of the Buffalo River and is presumed to be present near the surface east of Presqu'ile Point on the south side of Great Slave Lake (Norris, 1965). In the Cominco Sulphur Point G- 4 test corehole the shale unit is 56.5 m thick and in the Hay River B-52 well (see Figure 28, section 8) it is 36.5 m thick. Subsurface information indicates that the shale unit extends northwestward below the western part of Great Slave Lake into the Deep Bay region. Here it reaches a thickness of about 42.6 m in the NWT Deep Bay No. 3 well (see Fig.28, section 6).

Lithology

The dominant lithology of the Buffalo River is a greenish grey, fissile, pyritic and calcareous shale (Rasmussen, 1981). In the type section of the formation includes at the base a light to dark mottled, greyish brown, argillaceous and pyritic, bioturbated, micritic limestone, containing scattered crinoid ossicles and brachiopod shells. In the upper part the formation includes a 0.5 to 0.6 m thick dark brown argillaceous limestone bed, which is locally fossiliferous and in places dolomitized. South of the type section, near the dolomitized Presqu'ile Barrier, the basal micritic limestone unit overlies greyish brown to dark brown and black, slightly argillaceous to argillaceous, sucrosic dolostone of the Pine Point dolostone facies and the shale includes several thin, northward dipping beds of nodular, argillaceous limestone, containing thamnoporid corals, brachiopods and gastropods. Near the southern limitof the Buffalo River shale, the characteristic shale and argillaceous limestone facies is thin and the lateral equivalents in thePine Point dolostone facies include, according to Rasmussen (ibid.), a basal light brown, massive, dolomitized calcarenite facies composed of well sorted fine to coarse bioclastic grains, a laminated dolomitized calcarenite facies and a grey, argillaceous, dolomitic limestone facies. These three facies are relatively thin (0.1-1.8m) and Rasmussen regarded them as nearshore equivalents of the (offshore) Buffalo River shale facies.

The Buffalo River shale unit was entirely cored in the McDermott et al. Hay River No. 1, I-41 well (lat. 61°00'37"N, long. 115°37'58"W). In this section the unit is about 60m thick. It is a grey coloured, thinly and nodularly interbedded succession of sparsely fossiliferous, argillaceous limestone and calcareous shlae. The limestone beds are dark grey mottled mudstones including sediment filled burrows and scattered ostracodes, brachiopods and crinoid ossicles. Also present are several thin beds of finely peloidal and fossiliferous wackestone. These beds include in addition to the previously mentioned fossile also *Amphipora*, rare *Charophyta* oogonia and microscopic plant fragments. The boundary with the underlying very dark grey, laminated, calcareous shale of the Bituminous Shale and Limestone Beds appear to be gradational over a 12m thick interval. The upper boundary with the overlying Sulphur Point Limestone is sharp and marked by a thin, flat-pebble conglomerate.

In the NWT Deep Bay No. 3 well (Fig.28, section 6) the lower part of the Buffalo River shale is a grey to greenish grey, very argillaceous limestone in samples. The upper part of the map unit was cored and consists of greyish brown, argillaceous limestone including dark grey, pyritic mottles and minor, dark greenish grey shale partings. The limestone is aphanitic and includes scattered calcispheres and tentaculitids.

The lithologies of the Buffalo River and the upper member of the Hare Indian Formation are similar. In the Decalta et al. Johnson A-12 well (see Fig.32, section 7) it an unusually thick succession of greenish grey, micro-micaceous shale and dark grey, calcareous shale and includes in the upper part interbeds of fossiliferous limestone. The upper part was cored and yielded conodonts of the Upper *Polygnathus dengleri* subzone. The subzone is transitional between the Givetian and Frasnian stages.

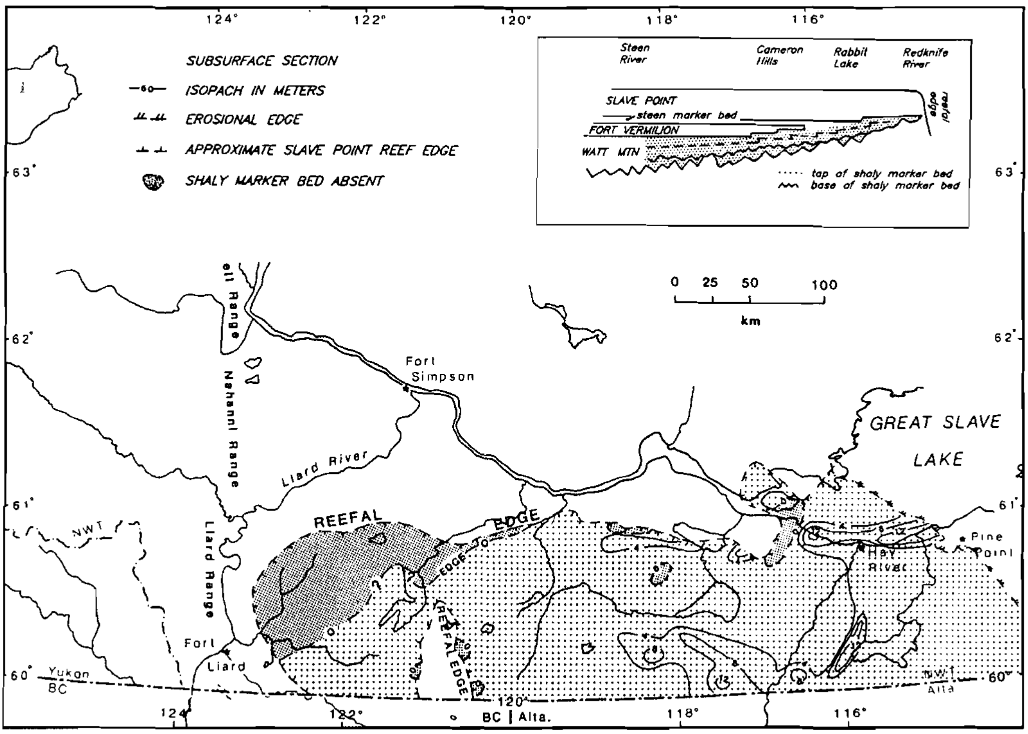


Fig. 47.- *Isopach map of Watt Mountain Formation.*

CHAPTER X: STRATIGRAPHIC SEQUENCE 6

Stratigraphic sequence 6 is a relatively thin, but widely distributed succession in the southern Interior Plains. It sharply overlies the evaporites of sequence 5 (the Prairie Evaporite and Muskeg formations) and thins toward the southeast. In central Alberta the sequence onlaps Peace River Arch and the upper part of the sequence extends across Western Alberta Ridge. In the region south of Peace River Arch the sequence is relatively thick and includes four facies. These are in ascending order: ① a basal detrital facies (the Watt Mountain Formation), ② an evaporitic facies (the Fort Vermilion Formation), ③ a carbonate platform including a semi-restricted fauna (the Slave Point Formation) and ④ a stromatoporoidal mound facies (the Swan Hills Formation).

The detrital, evaporitic and carbonate platform facies are present in northern Alberta, northeastern British Columbia and in the southern part of the District of Mackenzie but the mound facies is absent or poorly developed. The sequence onlaps the northern flank of Peace River Arch in the southwest and onlaps and overlies the successor of Tathlina Uplift (a paleotopographic high area that was emergent during the deposition of the detrital and evaporitic facies). In northeastern British Columbia and the District of Mackenzie the Late Givetian sequence overlies the reefal carbonates of sequence 5 (the Presqu'ile Barrier) and grades north- and westward into a succession of stromatoporoidal carbonates. The stromatoporoidal carbonatea are in sharp lateral contact with Upper Devonian shale and constitute the seaward edge of the carbonate platform.

The sequence includes a semi-restricted fauna which is difficult to correlate with the standard Middle Devonian fauna of Europe. The ostracodes in the carbonate platform facies suggest a late Givetian age.

In the Elk Point Basin the sixth statigraphic sequence overlies the sub-Watt Mountain unconformity. The contact is sharp or transitional in places where it overlies a paleo-regolith. Along the seaward edge of the platform the lower boundary is often difficult to establish because there is little contrast in lithology. Here it represents a hiatus or a change in the environment of deposition.

The character of the upper boundary changes from place to place. In the southeastern part of the Elk Point Basin the platform carbonates are overlain with a fairly sharp contact by argillaceous beds including marine, upper Givetian fossils. In the northwestern part of the Elk Point Basin the carbonate platform is sharply overlain by dark coloured shales including Upper Devonian fossils.

1. Detrital facies of sequence 6

During the hiatus in deposition that separates sequences 5 and 6 from each other the nearshore part of sequence 5 in northern Alberta and the part underlain by the crest of Tathlina Uplift were emergent and subjected to erosion. The detrital facies of sequence 6 onlaps and overlies these paleotopographic high areas and may be regarded as a basal transgressive deposit. In northern Alberta sandy deposits fringe and overlie Peace River Arch and grade northward into shales, locally interbedded with anhydrite. In the southern part of the District of Mackenzie the shaly part of the detrital facies onlaps and overlies, in the crestal part of Tathlina Uplift, a paleotopographic high composed of carbonates of sequence 5.

The detrital facies is relatively thin and is represented in the northern part of the Elk Point Basin by the Watt Mountain Formation. In the southeastern part of the Basin it is known as the "First Red Beds" member of the Souris River Formation.

Watt Mountain Formation

The Watt Mountain Formation was originally defined as a relatively thin, subsurface map unit including green, silty and pyritic shale; arkosic or quartzose sandstone; nodular and argillaceous limestone or dolostone; limestone breccia and minor amounts of anhydrite (see Law, 1955). The formation is the uppermost unit of the Elk Point Group and includes a useful regional log-marker in the subsurface of central and northern Alberta, northeastern British Columbia and the southern District of Mackenzie. In northern Alberta the formation overlies the Bistcho or Muskeg formations and is overlain by the Fort Vermilion or Slave Point formations(see Fig. 8). In the District of Mackenzie it overlies the Sulphur Point Formation and underlies the Slave Point.

The Watt Mountain Formation onlaps and partly overlies a paleotopographic high area in central Alberta similar to Tathlina Uplift. This high area, known as the Peace River Arch, is composed of Precambrian metamorphic and igneous rocks. The fact that the arkosic and quartzose sandstone beds in the Watt Mountain Formation increase in amount and thickness toward the crestal part of the arch suggest that the sands were derived from emergent areas on the arch.

At the type section in northern Alberta (the California Standard Steen River 2-22-117-5W6 well, Fig.30, section 1) the Watt Mountain Formation as redefined by Meijer Drees (1986b and in press) includes in ascending order: ① a lower, shaly Breccia Member, ② a middle Shale Member and ③ an upper Interbedded Shale and Limestone Member. The contact between the Breccia Member and the Shale Member is erosional. There is evidence that the limestone-breccia member represents a paleoreolith whichgrades upward into a rubble deposit. Although the limestone breccia is not a continuous unit it may locally reach a considerable thickness.

The relationship between the three members of the Watt Mountain Formation and the usefull log marker unit are schematically shown in the insert on Figure 47. Near the northern limit of the Watt Mountain Formation the Sulphur Point Formation or Breccia Member of the Watt Mountain Formation are overlain with an erosional contact by a succession of interbedded limestone and shale, which includes a "brackish water" fauna. This interbedded succession is the lateral equivalent of the Fort Vermilion Formation (see Belyea and Norris, 1962, Fig.2 and Meijer Drees, 1986b). It is thus indicated on the insert on Figure 47 that the upper, Interbedded Member of the Watt Mountain Formation forms a nearshore deposit which, in some areas on Tathlina Uplift, directly overlies the sub-Watt Mountain unconformity.

In the area south of Great Slave Lake the Watt Mountain Formation does not include a Breccia Member. Wiley (1970), Skall (1975), Lantos (1983) and Rhodes et al. (1984) described the succession in the Cominco Pine Point Mines District. Here it includes a lower unit of blueish green, calcareous and dolomitic shale and greenish grey marl, and an upper unit similar to the Interbedded Member at the type section. The Interbedded Member south of Great Slave Lake may be partly equivalent to the Fort Vermilion Formation.

In the Hay River area the Watt Mountain Formation is a thin, dolomitic shale unit which overlies Pine Point dolostone. Because dolomitization has obliterated the original sedimentary structures it is difficult to correlate these Watt Mountain sections with those in northern Alberta.

The Watt Mountain Formation is fossiliferous. Guthrie (1956) and Kramers and Lerbekmo (1967) found remains of fresh- and brackish water algae (*Cyzica sp.*), primitive fish (*Antiarchs*) and primitive plants (*Psilophytes*) in the area east of Lesser Slave Lake, central Alberta. Skall (1975) reported the presence of late Givetian ostracodes from the Cominco G-4 corehole, located south of Great Slave Lake. The shaly beds overlying the Breccia Member include ostracodes, stromatoporoids, brachiopods, gastropods and charophyte oogonia. The precise age of this "brackish water" fauna has yet to be established.

The thickness and distribution of the shaly beds in the Watt Mountain Formation is shown on Figure 47. The inset on Figure 47 explains the relationship between the shaly beds within the Watt Mountain and the underlying and overlying formations. Thus the zero edge of the shaly beds as defined by geophysical logs more or less coincides with the depositional limit of Watt Mountain Formation.

In the area southeast of the zero edge the shaly beds are absent in several wells. In these wells the upper member of the Slave Point Formation directly overlies the Sulphur Point equivalent in the "Undivided map unit".

Because the shaly log unit in the Watt Mountain Formation follows the unconformity, the zero edge of the shaly beds cannot be used for the reconstruction of onlap edges in the same way as the depositional edges of lithological map-units are. Without the depositional edge of the Fort Vermilion Formation one cannot draw the approximate outline of Tathlina Uplift on a paleogeographic map.

The shaly beds of the Watt Mountain Formation form a discontinuous map-unit which ranges in thickness between 0 and 16.4 m. Rhodes et al. (1984) reported a maximum thickness of 32.5 m in the area south of Great Slave Lake. In the Cominco G-4 corehole the Watt Mountain Shale member is present between 15.2 and 35 m (53 and 115 ft) and is 19.8 m thick (Lantos,1983, p. 127). Because these values are not based on the analysis of borehole logs they cannot be directly compared with those on Figure 47 and were therefore not used in the construction of the isopach map.

Lithology

In the type section in northern Alberta (Fig. 30, section 1) the redefined Watt Mountain Formation is 18.5 m thick and includes three members. The lower Breccia Member is 4.1 m thick and composed of very poorly sorted, angular to subrounded limestone fragments. The limestone breccia includes a greenish grey shale matrix and may represent a paleo-regolith. The middle member (the Shale Member) is a 1.7 m thick, greyish green to dark greyish green, in part calcareous and pyritic shale, including *Charophyta* oogonia. The upper member (the Interbedded Member) is 6.7 m thick and is an interbedded succession of greyish brown, light grey and greenish grey, micro fragmental and argillaceous limestone; and minor, greyish green shale. The limestone beds in the upper part include charophyte oogonia, fish teeth, fish scales and ostracodes (see Law, 1955).

The Shale Member and the underlying shaly part of the Breccia Member form a prominent marker unit on geophysical logs. In the District of Mackenzie the Watt Mountain Formation and parts of the underlying and overlying formations were cored in a relatively large number of wells. In many sections the shaly beds form a prominent marker, but in several sections the shaly interval is too thin to be recorded as a unit on geophysical logs. In those sections where the Watt Mountian Formation overlies Pine Point or Presqu'ile dolostone the beds are dolomitized and sedimentary structures obliterated.

The subsurface sections not affected by dolomitization are segregated into three groups. The sections in group 1 resemble the type section but the Shale Member is thin or poorly developed.

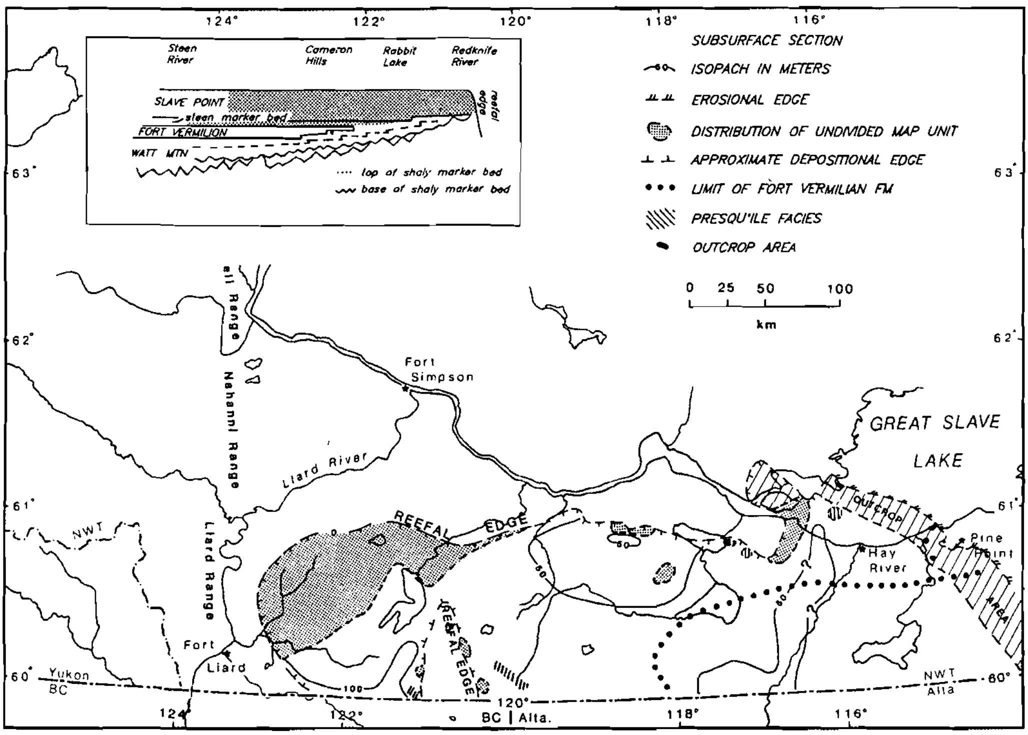


Fig. 48.- *Isopach map of Slave Point Formation.*

The sections in group 2 are relatively thin because the Shale Member and the underlying Breccia Member are absent. In group 3 the shaly interval is too thin to be recorded as a mappable unit on geophysical logs but is still recognizable in a core.

2. Evaporitic facies of sequence 6

The evaporitic facies is relatively thick in the eastern part of central Alberta and thins to zero in a northwesterly direction. The thinning represents a facies change to carbonates. The evaporitic facies does not extend across the paleotopographic high areas, but changes laterally into nearshore, shaly deposits of the detrital facies. The evaporites form a relatively thin unit and are represented by the Fort Vermilion Formation.

Fort Vermilion Formation

The anhydritic beds situated between the Watt Mountain Formation (below) and the Slave Point Formation, as restricted by Leavitt and Fischbuch, 1968, (above) are assigned to the Fort Vermilion Formation (see Meijer Drees, 1986b and in press). The type section is located in northern Alberta in the California Standard Steen River 2-22-117-5W6 well between depths 1349.8 and 1356.9 m (4428.7 and 4452 ft on Fig. 30, section 1). The Fort Vermilion Formation is only present in the southeastern part of the Great Slave Plain (see Fig 48).

The depositional limit in relation to the Slave Point isopachs and the fact that the anhydritic facies grades northward into an argillaceous limestone facies similar to the upper member of the Watt Mountain Formation suggest that the Fort Vermilion Formation flanks a paleotopographic high area located between the Kakisa and Mackenzie rivers. The depositional limit may be due to onlap.

In northern Alberta the amount of anhydrite and the number of anhydritic interbeds in the formation increases to the east and decrease to the west of the Steen River well. Thus the thickness of the formation increases to the east and decreases to the west. It is 7.1 m thick in the Steen River well and is 36.5 m thick in the Pan Am A-1 Club Lake 10-15-120-8W5 well described by Richmond (1965). It is more than 18 m thick in the District of Mackenzie southeast of Buffalo Lake (Richmond, 1965, Fig. 31A). In the CDR Woodbuffalo C-74 corehole (lat. 60°33'07.79"N, long. 114°44'05.02"W) and the CDR Woodbuffalo C-03A corehole (lat. 60°32'0.04"N, long. 114°30'59.91"W) located near the northern boundary of Wood Buffalo National Park at the Fort Vermilion Formation is respectively 25.9 and 17.9 m thick.

Lithology

In the California Standard Steen River 2-22-117-5W6 well the Fort Vermilion Formation consists of very light brownish grey, cryptocrystalline anhydrite, greyish brown aphanitic limestone, dark greenish grey, argillaceous and pyritic limestone and minor limestone breccia (Law, 1955). In the CDR Woodbuffalo C-74 and C-03A wells the formation is an interbedded succession of pale greyish brown dolostone, light brown limestone, semitranslucent gypsum and very light grey, nodular anhydrite.

3. Carbonate platform facies of sequence 6

The platform carbonates are widely distributed in the central and northwestern parts of the Elk Point Embayment. They include a typical, semi-restricted fauna of ostracodes, stromatoporoids and conodonts. The facies is relatively thick along the seaward edge of the platform, in northeastern British Columbia and in the southwestern part of the District of Mackenzie, and thins toward the southeast. The thinning is related to the regional facies change to evaporites. The platform also thins across paleotopographic high areas, such as Western Alberta Ridge and the successor of Tathlina Uplift, because of the change to a nearshore, detrital facies.

In central Alberta the platform facies locally grades upward into stromatoporoidal reef mounds of different heights (the Swan Hills Formation). In northern Alberta and the District of Mackenzie the mound facies is absent but the presence of high and low areas on the platform surface suggest that the platform locally grades upward into reefal shoals.

Slave Point Formation

In northern Alberta, northeastern British Columbia and southern Mackenzie District the platform facies is represented by the Slave Point Formation. The formation conformably overlies the Fort Vermilion Formation and is sharply overlain by shaly beds of the Beaverhil Lake Group.

The Slave Point Formation, as redefined by Meijer Drees in the type section (1986b and in press) occurs between depths 1301.4 and 1349.8 m (4270 and 4428.7 ft) in the Steen River 2-22-117-5W6 well. It includes a lower argillaceous member, named the Steen Member, and an upper Limestone Member (see Fig.30, section 1).

The Slave Point Formation includes stromatoporoids, brachiopods, ostracodes and locally conodonts. The ostracodes suggest a late Givetian age (McGill, 1966; Braun, 1978); the conodonts include a fauna of low diversity belonging to the *polygnathid-icriodid* biofacies which may be the same age as the newly named *Palmatolepis disparillis* Zone (Norris and Uyeno, 1983). This zone belongs in the upper part of the Givetian stage (see Fig. 14).

The Slave Point Formation is widely distributed in northern Alberta, northeastern British Columbia and in the southern part of the District of Mackenzie. The formation was mapped by Law (1955, Fig. 6) and by the Committee on Slave Point and Beaverhill Lake formations (1964, Fig. 6-5). Griffin (1965) mapped the Slave Point Formation in northeastern British Columbia. The formation is more than 120 m thick in the Sikanni Chief area of northeastern British Columbia and ranges in thickness between 60 and 90 m in northwestern Alberta. In northeastern British Columbia and the District of Mackenzie the formation changes abruptly to shale. This facies change is thought to represent the seaward edge of a barrier reef complex. It is assumed that in many areas the edge of the Slave Point reef facies more or less coincides with the edge of the Presqu'ile barrier.

In the District of Mackenzie the Slave Point is only mappable as a subsurface unit in the area southeast of the zero-edge of the shaly log marker. In sections where the Watt Mountain and Fort Vermilion formations are absent the Slave Point becomes the upper part of the "Undivided map unit". In sections where the Slave Point limestone is partly altered to white, coarsely crystalline dolostone the contact between the Slave Point and Presqu'ile dolostone is a diagenetic boundary. It is thus difficult to construct an isopach map of the Slave Point Formation without a knowledge of the distribution of the Watt Mountain shale and the Presqu'ile dolostone facies.

Figure 48 represents an isopach map of the interval between the top of the Watt Mountain shale marker and the top of the Middle Devonian carbonates. The interval mapped is relatively thin in the area between the Kakisa and Redknife rivers and is relatively thick in the area southwest of Trout Lake.

The Slave Point Formation reaches bedrock surface along the Buffalo River (see Fig. 48) and is exposed on the south shore of Great Slave Lake near the mouth of Buffalo River.

In the southern part of the District of Mackenzie the Slave Point Formation includes three informal units, a basal unit (the Steen Member) which, north of the depositional edge of the Fort Vermilion anhydrite, merges with the "Beds equivalent to the Steen and Fort Vermilion" and an upper fossiliferous limestone unit (the Limestone member) which locally directly overlies equivalents of the Sulphur Point Formation in the Undivided map unit (see insert Fig. 48).

Steen Member

In the Steen River 2-22-117-5W6 well the Fort Vermilion Formation is overlain by a 60 cm thick very argillaceous and pyritic limestone bed. This argillaceous bed and the somewhat argillaceous dolostone and aphanitic limestone beds overlying it, form a distinct basal member of about 1.5 m thick on the geophysical borehole logs between depths 1348.1 and 1349.6 m (4423 and 4428 ft).

Correlations suggest that the Steen Member grades northward into upper part of the non-anhydritic equivalents of the Fort Vermilion Formation north of the zero-edge on Figure 30. In northeastern Alberta the Member can be traced from the Steen River well northeastward into the area just west of Wood Buffalo National Park where it is present in the lower, argillaceous part of the Fort Vermilion Formation.

Beds equivalent to the Steen and Fort Vermilion

The subsurface correlations by Belyea and Norris (1962) and Belyea (1971) in northern Alberta and the southern District of Mackenzie suggest that in the region north of the zero edge of the Fort Vermilion anhydrite the Watt Mountain is overlain by an argillaceous limestone unit which includes the stratigraphic equivalents of the Fort Vermilion Formation and the Steen Member. This argillaceous limestone unit is not easily identifiable on borehole logs. The lower part of this unit appears to be continuous with the Watt Mountain shale , and the upper part with the Steen Member.

In the area north of Kakisa River the Watt Mountain breccia is erosionally overlain by an argillaceous limestone unit which is equivalent to the upper part of the Fort Vermilion Formation and the Steen Member (see insert on Fig. 48). This unit may represent a nearshore facies because it onlaps and overlies a sub-Watt Mountain paleotopographic high area. It was cored in a number of wells located on the crest of Tathlina Uplift.

Lithology: The argillaceous beds equivalent to the Steen Member and the Fort Vermilion Formation are between 4.6 and 9.8 m thick and consist of a thinly interbedded succession of nodular, greyish brown, argillaceous limestone; wavy laminated, greenish grey, very argillaceous limestone and minor greyish green, calcareous and pyritic shale. The interval includes burrowed firmgrounds, stromatolitic beds, fenestral vugs and sediment filled burrows. Many beds include scattered limestone pebbles or granules and are very fossiliferous, including stromatoporoids, gastropods, brachiopods, ostracodes and Charophyte oogonia. In the Steen River 2-22-117-5W6 well the lower contact with the Fort Vermilion Formation is erosional (see Meijer Drees, 1986b, Plate IIIb).

In area south of Great Slave Lake the Shale Member of the Watt Mountain Formation is overlain by an interbedded interval of dolostone, limestone and minor shale which was subdivided by Lantos (1983) into six informal members. Lantos (ibid.) and Rhodes et al. (1984) considered this 14.1 to 22.6 m thick interbedded interval to be the upper part of the Watt Mountain Formation. Campbell (1957) designated the upper part of this interval to the Slave Point Formation.

This interbedded limestone, dolostone and shale unit is overlain by the Amco shale unit which includes a 3.1 m thick, blueish grey, very argillaceous limestone or dolostone bed in the middle. Norris (1965) and Rhodes et al. (1984) selected the base of the Amco shale unit as the base of the Slave Point Formation. Because the lithology of the interbedded interval and the overlying Amco shale unit as described by Lantos (1983) and Rhodes et al. (1984) is similar to the lithology of the upper member of the Watt Mountain Formation, the equivalents of the Fort Vermilion Formation and the Steen Member it is suggested that the proposal by Campbell (1957) to select the boundary between the Slave Point and Watt Mountain formations in the area south of Great Slave Lake at the uppermost *Charophyta* zone (or Gritty member of Lantos, 1983) merits consideration. The charophyte bearing beds may be considered to represent a nearshore facies equivalent to the evaporitic facies of the Fort Vermilion Formation.

Limestone Member

The interval between 1301.4 and 1348.2 m (4270 and 4423.7 ft) in the Steen River 2-22-117-5W6 core consists of interbedded brownish grey, brown and olive grey aphanitic, micro fragmental and fossiliferous, in part dolomitic or anhydritic limestone, and includes scattered brachiopods, stromatoporoids, ostracodes and gastropods (Law, 1955). Because the limestone beds form a widely distributed map-unit above the Steen Member bed the name Limestone Member is proposed. In the Steen River 2-22-117-5W6 well the Limestone Member is 46.8 m thick.

In northern Alberta the lower part of the Limestone Member becomes anhydritic in the area east of Steen River and is in facies contact with the upper part of the Fort Vermilion Formation. Thus the thickness of the Limestone Member decreases toward the east and is only 18.1 m thick in the Pan Am A-1 Club Lake 10-15-120-8W5 well, located north of Margaret Lake and south of Wood Buffalo National Park.

Lithology

In the southern District of Mackenzie the Limestone Member overlies argillaceous equivalents of the Fort Vermilion Formation and Steen Member, mapped as part of the Watt Mountain Formation, with an erosional contact. In this area the Limestone Member is an interbedded succession of brown, greyish brown and dark greyish brown limestone. It consists of very fine- to finely peloidal and fragmental wacke- and packstones and includes scattered large fragments of stromatoporoids, gastopodes and brachiopods. The mudstones are dark coloured, nodularly bedded and argillaceous.

In the western part of Great Slave Lake the Slave Point Formation forms the upper part of the

"Undivided map unit" because the Watt Mountain Formation is absent or does not include the typical, greenish grey shale interbeds. The Slave Point Formation consists of interbedded light brown, greyish brown and dark greyish brown limestone or dolomitic limestone. It includes laminar fenestral wackestones; massive, sparsely fossiliferous, very fine- to fine peloidal and fragmental wacke- and packstones; massive, very fossiliferous floatstones; dark coloured, nodular argillaceous, fossiliferous float- and rudstones. Fossils include bulbous stromatoporoids, *Amphipora*, gastropods, brachiopods, ostracodes, "calcispheres" and, in the lower part of the section, charophyte oogonia.

The upper part of the Slave Point Formation and the overlying shales were cored in several wells. In the NWT Heart Lake No. 2 well (lat. 60°50'30"N, long. 116°37'30"W) the upper part of the Slave Point and the lower part of the Hay River formations were cored. The nodular, light greyish brown fossiliferous Slave Point limestone is truncated at depth 368.8 m (1210 ft) by an irregular surface which includes sediment filled borings (see Plate Xb). Similar surfaces are present in the basal beds of the Hay River Formation at depth 368.1 m (1208 ft), see Plate Xc.

The contact between the Slave Point and the Waterways formations was cored in two wells located just south of latitude 60° and between longitudes 116° and 117° in Alberta (see Fig. 48). In the Texan Whitesand 5-35-126-12W5 well the greyish brown, micritic, in part dolomitized limestone of the Slave Point grades upward into a 25 cm thick, very fossiliferous, nodular limestone bed. The nodular limestone bed is overlain by an interbedded succession of greenish grey, argillaceous limestone and calcareous shale of the Waterways. The Waterways Formation includes a marine fauna of brachiopods and conodonts of the Lowermost *Polygnathus asymmetricus* Zone.

CHAPTER XI: NATURE OF SEQUENCE BOUNDARIES

According to the concept proposed by Mitchum et al (1977), the nature of a sequence boundary changes from place to place. It may represent an erosional unconformity, a clinoform surface or a paraconformity marked by a depositional hiatus. Sequence boundaries A and B on Figure 10 are subhorizontal or dip gently to the right (presumably toward the basin centre). If the origin of the sedimentary basin is due to differential tectonic subsidence, the subhorizontal part of the two sequence boundaries will dip toward the basin centre and variations in thickness are more pronounced than shown in Figure 10.

It is evident that the landward thinning of the onlapping sequence in Figure 10 is related to the basinward dip of the erosional unconformity (surface A) and influenced by local paleotopographic irregularities. The basinward thinning of the prograding part of the sequence is related to the basinward dip of the clinoform (surface B, in part). The clinoform part of surface B coincides with a hiatus in deposition, during which the geometry and the original depositional slope of the basin margin was altered by submarine erosion. The paraconformable part of surface B thus coincides with a hiatus and a change in the environment of deposition. This surface is commonly marked by intense bioturbation and includes carbonate or ferromanganese oxide crusts, including phosphate or glauconite.The erosional unconformity at the base of the Devonian succession is comparable to surface A on Figure 10. The sequence boundaries within the Devonian succession are minor erosional unconformities or represent relatively sharp, regional changes in the environment of deposition, similar to surfaces A and B. The sequence boundaries below the Headless formation and at the base or in the basal part of the Watt Mountain formation (see Fig. 8) locally truncate the underlying beds and resemble surface A. The sequence boundary below the Sombre and Arnica formations is a facies change similar to the boundary between beds 23 and 24 on Figure 10. The sequence boundary below the Funeral and Landry formations resembles surface B; the sequence boundary below the Waterways, Muskwa and Spence River formations represents a complex situation not represented on Figure 10.

It may be noted here that reefal carbonates include sedimentation patterns different from those shown in Fig. 10. Firstly, during a relative rise in sea level the reefs grow up and leave a record of continuous shallow water deposition. Secondly, reefs form barriers that establish a favourable circulation pattern for continued reefgrowth. Thirdly, reefs act as local source for coarse sediment that accumulates as flank beds below the zone of reefgrowth. Fourthly, the slope of carbonate shelf deposits is generally steeper than the slope of siliciclastic shelf deposits (see Schlager and Camber,1986). Fifthly, the accumulation of fine clastics in the basinal areas is independent from the (often episodic) progradation of the coarse carbonates that accumulate downslope of reefmounds.

Figure 10 applies to sequences dominated by clastic sediments.The inclusion of reef mounds would necessitate the introduction of a more complex pattern. Examples of growth patterns in carbonate sediments at the shelf margin or in reef complexes are described by Mullins and Neumann (1979), Mullins et al (1984), Johnson and Searle (1984), Bosellini (1984) and Harris (1986).

Base of stratigraphic sequence 1

The erosional unconformity at the base of sequence 1 is generally known as the pre-Devonian unconformity. Regional geologic information in the Interior Plains of Western Canada (see Douglas et al, 1970) suggests that it truncates rocks ranging in age between Precambrian and Silurian and that it is overlain by Middle Devonian carbonates and older evaporites. Because the unconformity is in many places overlain by unfossiliferous redbeds and evaporites it is not possible to determine its precise age. Parts of this erosional surface were still emergent during the Late Devonian.

In the subsurface of the Great Slave and Great Bear plains the pre-Devonian unconformity is usually well defined on geophysical, borehole logs. Its depth was selected with the aid of gamma-ray and sonic curves. In places where it truncates Precambrian plutonic or metamorphic rocks, the erosional surface overlies a regolith and the earliest Devonian beds include feldspathic sandstone; clean and porous quartzose sandstone and redbeds (see Plate IIb). In places where it overlies Proterozoic or Lower Paleozoic sedimentary rocks, the underlyingbeds are commonly brecciated and include deposits of secondary anhydrite, while the beds overlying the unconformity include redbeds, anhydritic dolostone or dolomitic sandstone (see Plates IIa and III).

In the central part of Root Basin, in the southwestern part of the Mackenzie Mountains, the erosional unconformity at the base of sequence 1 is difficult to identify. The hiatus between the Silurian and Devonian succession is not pronounced and there is a facies change to more basinal sediments (see Morrow,1984b, Fig.11).

On the basis of the above information it is concluded that the base of sequence 1 is similar to surface A of Figure 10.

Base of stratigraphic sequence 2

Little is known about the nature of this contact. The basal part of the sequence is exposed on a mountain range south of Mount Charles (see Plate Ib), but it is not evident at this locality whether the base of sequence 2 lies below the collapse breccia or at the base of the dolomitic sandstone below the breccia. In the subsurface the contact between sequences 1 and 2 was not cored and it is thus impossible to detect the presence of an hiatus.

In the central part of Willow Lake Embayment (see cross section, Fig. 17) the upper contact of the Tsetso appears to represent a nearly flat surface, because of the nature of the underlying and overlying evaporitic and peritidal beds. Here the base of sequence 2 may be a paraconformity. Along the margin of the Embayment the sequence boundary may extend into the Tsetso Formation as an intra-formational unconformity that separates the erosional remnants of the sandy, nearshore facies of sequence 1 from the basal transgressive nearshore facies of sequence 2.

In Root Basin the base of sequence 2 is selected at the base of the Sombre Formation. The contact between the Camsell and Sombre formations was described by Morrow (1984b, Fig.5) as being fairly sharp in the central, and diachronous in the marginal part of Root Basin.

The information to date suggests that the base of sequence 2 represents a major shift in the depositional environment from restricted to semi-restricted and is associated with a major retreat of the shoreline. The situation resembles that shown on Figure 10, where the boundary between beds 23 and 24 marks the final stage of infill of a local depression in the sedimentary basin. Haq et al (1987) and Embry and Podruski (1988) have shown that the boundary between beds 23 and 24 is more complex than is indicated on Figure 10. They postulate the presence of an unconformity between older, regressive, nearshore deposits and younger, transgressive, nearshore deposits.

Base of stratigraphic sequence 3

The contact between stratigraphic sequences 2 and 3 is difficult to interpret because it is truncated by the sub-Headless unconformity. Beds underlying this unconformity are locally replaced by a white, diagenetic, very coarsely crystalline dolomite facies that has obliterated sedimentary structures.

The relationships shown in Figure 8 suggest that the base of sequence 3 is conformable and represents a change in the environment of deposition, associated with a rise in sea level, or an increase in the rate of subsidence. During the relative rise in sea level the shore line moved inland and the Ram River Reef complex was established. Because the reef complex acted as a barrier, the change in the depositional environment coincident with the base of sequence 3 in the area east of the reef complex is one from peritidal to lagoonal. In the area west of the reef complex the change in the environment of deposition is one of peritidal to open marine.

The first facies boundary is truncated by the base of sequence 4 and occurs somewhere within the Manetoe dolostone facies. The second boundary is visible in the core of the Dahadinni M-43A well at depth 4895 feet (1491.9 m) and coincides with the base of the Funeral Formation. In Plate IV it is overlain by a 4.5 m thick, dark greyish brown, argillaceous limestone.

The effect of a relative rise in sea level on the sedimentation pattern is schematically shown on Figure 10 by the onlap of beds 20 to 23 against surface A. It is evident that the pattern on Figure 10 applies to siliciclastic sediments. The effect of a relative rise in sea level on reefal carbonates is different. It leads to an increase of vertical reef growth and the establishment of a new sedimentation pattern.

Base of stratigraphic sequence 4

The boundary between stratigraphic sequences 4 and 5 in the Willow Lake Embayment coincides with the sub-Headless unconformity. The angular relationship at the unconformity is slight but clearly visible on regional cross sections in the subsurface of Horn Plateau (see Figs. 5 F-F', 23 and 24). This, and the curvature of the contours on the structural map of the pre-Devonian surface (Fig. 6) and the isopach map of interval between the pre-Devonian surface and the sub-Headless unconformity, suggest that the sub-Headless unconformity is related to local uplift in the area between Lac la Martre and Martin Hills.

The nature of the sub-Headless unconformity can be studied in detail in a number of cores. The unconformity is represented by a sharp contact on geophysical borehole logs and coincides with a change from clean carbonate to shale. In cores the interval below the contact includes limestone breccia and conglomerates with a silty claystone matrix (see Plates V and VI). This transitional interval is interpreted to represent a regolith or rubble deposit. The rubble deposit is sharply overlain by a unit of greenish grey, calcareous or silty shale including much pyrite, charophyte oogonia and locally remains of primitive fish. The green, pyritic shale forms a distinct marker-bed on the gamma-ray and sonic logs.

In the nearshore facies that surrounds Tathlina Uplift the sub-Headless unconformity lies at the base of the Ebbutt Member and merges landward with the pre-Devonian unconformity (see Figs. 8 and 11).

The erosional aspect of the sub-Headless unconformity becomes less pronounced toward the depositional centre of the basin, located in the southern part of the Mackenzie Mountains (see Plate VII a and b). Here the unconformity more or less coincides with the base of the Headless Formation, which locally truncates the Funeral Formation (see Morrow and Cook, 1987, Fig. 71).

The nature of the sub-Headless unconformity is similar to surface A in Figure 10, but the amount of tectonic deformation of the underlying strata is minimal.

Base of stratigraphic sequence 5

The boundary between sequences 5 and 6 represents a major transgression of the sea into the Elk Point Basin. The relative rise in sea level resulted in a change of the depositional environment that is recognizable in the rock succession as a facies change from shallow to deep water deposits (shallow shelf to below-wave-base basin-bottom). This suggests that the early Middle Devonian carbonate platform was "drowned" (see Schlager, 1981), because the accumulation of carbonate sediment did not keep up with the relative rise in sea level.

In the area north and west of the Presqu'ile Barrier the "drowning" event is represented by the facies change at the base of the Leiorhynchus beds in the Nahanni Formation, by the facies change at the base of the Bituminous Shale and Limestone Beds and by the facies change at the base of the Hare Indian Formation (see Plate VIId). In the area south and east of Presqu'ile Barrier the event is represented at, or near, the boundary between the Keg River and Muskeg formations as the facies change from platform carbonates to anhydritic or dolomitic "laminites" (see Bebout and Maiklem, 1973).

The relatve rise in sea level initiated a landward shift of the shoreline and probably altered the circulation pattern in the Elk Point Basin. Reefs started to grow on favourably located shoals on the platform surface. They grew upward in response to the rise in sea level and shed relatively steeply dipping flank deposits (see Plate VIIIa).

One may argue that the beginning of vertical reef growth marks the onset of the transgression and that, within the reefmounds, the boundary between sequences 3 and 4 lies at the base of the autochthonous reef core. Such a boundary cannot be mapped without detailed information from cores.

One may also argue that there is a depositional hiatus between the onset of the transgression and the accumulation of the relatively deep water "laminites". It is well known that the potential of reefs to grow upward exeeds the speed of sea level rise caused by long-term geologic processes (see Schlager, 1981). Thus it is logical to assume that the autochthonous cores of the Horn Plateau, Presqu'ile and upper Keg River reefs are older than the allochthonous flank deposits and the inter reef "laminites". The boundary between the reef core and reef flank deposits can be schematically mapped on a regional scale and this boundary is selected as the base of sequence 5 (surface A on Fig. 49).

Base of stratigraphic sequence 6

The boundary between sequences 6 and 7 is represented by a minor erosional unconformity for which the name sub-Watt Mountain unconformity is used (see Meijer Drees, 1986b). The sub-Watt Mountain unconformity is similar to the sub-Headless unconformity and both were formed during relatively low water stands (see Williams, 1984). Because the sub-Watt Mountain unconformity onlaps Peace River Arch and the successor of Tathlina Uplift, these two emergent regions may have acted as more rigid, relatively positive tectonic elements during the compaction of the Elk Point sediments that took place during the hiatus associated with the unconformity (see Meijer Drees, 1986b). In the northern part of the Elk Point Basin the unconformity locally overlies a regolith or dissolution breccia and is overlain by sandy and shaly beds including a "brackish water" fauna. Along the seaward edge of Presqu'ile Barrier the sub-Watt Mountain unconformity is reduced to a hiatal surface, persumably because reefgrowth continued on the seaward edge at a lower level. The reef prograded seaward during the drop in water level and grew upward again during the subsequent, gradual relative rise in sea level. The resultant sedimentation pattern is schematically shown in Figure 49.

The base of stratigraphic sequence 6 is usually well defined on geophysical borehole logs as a contact between a clean carbonate (below) and a shale (above). In some sections the boundary is difficult to select because the geophysical logs suggest that the clean carbonate includes shaly "interbeds". Information from cores indicate that these "interbeds" are shale filled cavities and fractures.

In the Elk Point Basin the sub-Watt Mountain unconformity overlies limestone, a rock type easily dissolved by meteoric water. This explains the presence of sediment or cement filled fractures and dissolution cavities in the Bistcho and Sulphur Point limestones and the interbeds of limestone breccia (see Plate IXc and d). In most of the cores examined the limestone is overlain by a regolith-breccia composed of unsorted, subangular limestone pebbles and cobbles in a very pale, greenish grey, silty claystone shale matrix, which includes scattered charophyte oogonia and an irregular network of dissolution fractures filled with pale green, siliceous shale (see Plate IXa).

In two cored sections near the reefal edge of the Sulphur Point Formation in the District of Mackenzie (McD. et al Hay River No.1 and Union Pan Am Trainor L-59) the Watt mountain Formation is an interbedded unit of fossiliferous limestone and shale similar to the upper, Interbedded Limestone and Shale Member of the Watt Mountain Formation in northern Alberta. The middle Shale and lower Breccia Members are not represented, suggesting onlap against a paleotopographic high area. The base of sequence 6 in the two cores coincides with the base of the lowermost prominent green shale or calcareous siltstone bed, which includes many charophyte oogonia (see Plate Xa). This contact is similar to the erosional contacts found in the overlying beds of the Watt Mountain and Fort Vermilion formations and represents either a minor erosional hiatus or a bioturbated surface.

In one core (McD. et al Desmarais Point E-72) the Watt Mountain Formation is absent and the equivalent interval is a fossiliferous limestone including dark grey, stylolitic shale partings (see Plate IXe). Here the base of sequence 6 is a bioturbated surface.

Thus the sub-Watt Mountain regression resulted in a northward progradation of reefal beds over the basinal Bituminous Shale and Limestone Beds (area C on Fig. 49), just like the previous regression resulted in the progradation of reefal beds (area B onFig. 49) during the accumulation of the evaporites in the Elk Point Embayment (beds 6, 7 and 8 on Fig. 49).

Differential compaction across Tathlina Uplift and La Martre Arch resulted in a slight regional dip to the south and created a local paleotopographic high near the reef edge (surface B on Fig. 49) that remained emergent during the onset of the subsequent (Slave Point) transgression. In the area north and west of Presqu'ile Barrier the sub-Watt Mountain regression may have left its mark as a hiatus or a slight unconformity in the reef flank deposits similar to the one shown on Figure 49 below surface B.

Base of stratigraphic sequence 7

In the southern District of Mackenzie the base of sequence 7 coincides with a "drowning" event. A major relative rise in sea level combined with an influx of fine siliciclastic sediment halted reefgrowth on the reefal edge of the Slave Point platform.

The clinoform pattern in the fine siliciclastics that overlie the Slave Point platform indicate that the clastic sediments prograded from east to west and that the ancient shoreline was located somewhere southeast of Great Slave Lake (Williams, 1977). Thus the western portions of the "drowened" platform and the Slave Point reef edge initially received little or no sediment. The same situation applies in the basinal shale basin north and west of the edge of the Slave Point platform. Here sediments of sedimentary sequence 5 (the Horn Plateau reefs ,the Bituminous Shale and Limestone Beds and the Leiorhynchus beds of the Nahanni Formation) are directly overlain by clastics of sequence 7.

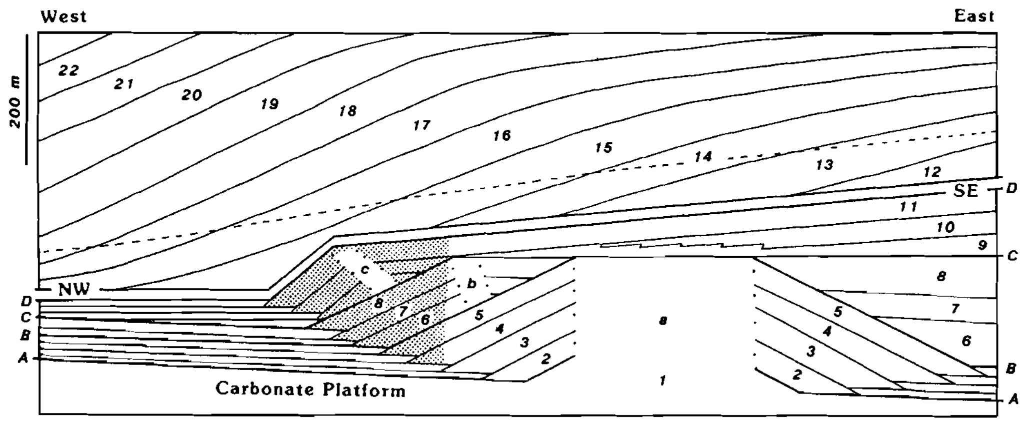


Fig. 49.- *Hypothetical sedimentation pattern across Presqu'ile Barrier. Note that this conception cross-section includes two parts. The lower part is oriented southeast to northwest. The upper part is east to west. White areas a, b and c represent the reefal facies of the Presqu'ile barrier, Sulphur Point and Slave Point. Beds 1-5 represent the Pine Point dolostone; beds 6 and 7 on the left represent the Muskeg Fm; bed 8 on the left the Bistcho Fm. The unshaded part of beds 6-8 on the right represent the Sulphur Point Fm; beds 9, 10 and 11 represent the Watt Mountain, Fort Vermilion and Slave Point fms. The shaded part of beds 6-11 is the "Undivided map unit" of Figure 8. The toe ends of beds 12 to 23, below the broken line represent the Muskwa, Spence River and Canol fms. Surfaces A, B, C and D are sequence boundaries. The amount of truncation at surface C increases toward the crest of Tathlina Uplift.*

The nature of the contact at the base of sequence 7 changes from place to place. On the Slave Point platform the contact more or less coincides with the formational boundary between the Slave Point limestone and the shaly beds of the Waterways Formation (see Fig. 8).

In the outcrop area of the Devonian rock succession in northeastern Alberta remains of the Waterways Formation are present in sinkholes, widened fissures and other irregular cavities within the upper part of the Slave Point Formation. Also present are collapse and dissolution breccia composed of Slave Point and Fort Vermilion lithologies. It is now realized that these features are related to the dissolution of the upper Elk Point salt beds in the subsurface and the collapse of the overlying strata (see Norris and Uyeno, 1981; Park and Jones, 1985). Conodonts collected from the Waterways and Slave Point formations do not suggest that there is a major hiatus between the Slave Point and Waterways formations (Norris and Uyeno, 1983).

In the subsurface west of the outcrop area the Fort Vermilion and the Elk Point evaporites are not so severely affected by circulating groundwater and the boundary between the Slave Point and Waterways is undisturbed. Griffin (1965) traced the boundary on geophysical borehole logs in the subsurface of northeastern British Columbia into northeastern Alberta and Williams (1977) analyzed the nature of the transition in closely spaced wells. Williams concluded that the boundary is either a transitional facies change or represents onlap of the Waterways shale against a pre-existing Slave Point surface. Information from the three cored intervals that include the boundary suggest that it changes character from place to place. In one section it is transitional over a distance of 30 cm, in the two other sections the boundary is sharp and is marked by a crust-like surface (see Plate X b and g).

The greenish grey, argillaceous beds of the Waterways Formation (or basal Hay River) overlying the Slave point platform in the area southwest of Great Slave Lake and in northern Alberta thin to zero in a westerly direction below the dark, radioactive shale of the Muskwa Formation (see Fig. 8). Griffin (1965, Figs. 6 and 7) indicated this on his cross sections in northern Albera and postulated the presence of an erosional unconformity that changes southeastward into a paraconformity. Williams (1977, p. 9) did not find evidence of erosion at the base of the Muskwa in northern Alberta and suggested that the thinning below the Muskwa is due to progradation and facies change. The fossiliferous Waterways and Hay River formations representing the relatively thick basin-margin deposits and the Muskwa Formation the relatively thin, condensed, euxinic deposits in the central part of the basin (see Fig. 8).

Along the the seaward margin of the Slave Point platform the Waterways Formation is absent and the Muskwa Formation overlies Slave Point carbonates (see Figs. 24 and 30; Griffin, 1965, Figs. 6 and 7). The contact between the Muskwa and the Slave Point formations is sharp on geophysical borehole logs. It was cored in several wells. Griffin (1965, p. 81) described the contact in the West Nat. Kotcho 94-P-3-F-9-a well located in northeastern British Columbia as interbedded.

In the Pan Am Island River D-29 well (lat. 60°08'08"N, long. 121°05'17"W) the Muskwa Formation includes a dark coloured, basal unit consisting of interbedded argillaceous limestone and marlstone that yielded conodonts of the *ensensis* to Lowermost *asymmetricus* Zones (see Uyeno, in Meijer Drees, in press). The cored interval that included the contact between the Slave Point and Muskwa formations is missing.

In the Arrowhead I-46 well (Fig. 24, section 1) the contact is very sharp and represents a dissolution surface (see Plate Xf). The beds just above and below the Slave Point - Muskwaboundary locally include conodonts of the Lowermost *asymmetricus* to Lower *asymmetricus* zones (Uyeno, in Meijer Drees, in press). In the Arrowhead I-46 core the Muskwa includes conodonts of the Upper *asymmetricus* to Lower *gigas* zones suggesting an equivalence with the middle part of the Waterways Formation. Thus it appears that there is no major hiatus across the Slave Point - Muskwa boundary but instead a considerable amount of condensation in the Muskwa Formation.

In the region north and west of the Slave Point platform the base of sequence 7 coincides with the boundary between the Spence River shale (above) and the Horn Plateau reefs or the Bituminous Shale and Limestone Beds (below), see Fig. 11. This boundary moves down section to the west on Figures 28, 27 and 23. The Spence River Formation thins westward because of a condensation of strata in the lower part (see also Gunther and Meijer Drees, 1977).

The dark, euxenic fondothem deposits of the Spence River Formation include thin calcareous siltstone beds that form markers on geophysical borehole logs. They can be traced from section to section over large distances. One marker bed is indicated with a star on Figures 28, 27 and 23 to show the presence of eastward thinning clinoform beds in the Spence River Formation.

The Basal Black Shale unit of the Spence River Formation, mapped on Figures 27 and 28, yielded Upper Devonian conodonts belonging to the Lower and Middle *asymmetricus* zones (see Uyeno, in Meijer Drees, in press). In the Providence K-45 well (Fig. 27, section 7) the Basal Black Shale unit overlies the Bituminous Shale and Limestone Beds with an erosional contact (see Plate Xe). Farther to the west, in the Ebbutt D-50 well (Fig. 23, section 1), the unit overlies the Platform Limestone of the Nahanni Formation with a thin, coarse, crinoidal lag deposit (see Plate Xd). The equivalents of the Bituminous Shale and Limestone Beds are not present in the Ebbutt D-50 well, presumably because of non-deposition.

Somewhere in area north and west of the Slave Point platform edge the base of sequence 7 may join the extension of the sub-Watt Mountain unconformity. This situation is schematically indicated on Figure 49. Surface C represents the base of sequence 7. Beds 12 to 17 "offlap" the "drowned" Slave Point platform, reef edge and reef flank deposits and progressively cut down section to the right until they almost overlie surface B. In the left part of the figure the sediments are thin and may not be everywhere represented. The period not represented by sediments in the area above surface C becomes longer toward the left side and eventually may include several microfossil zones.

CHAPTER XII: NATURE OF FACIES PATTERN

According to the concepts of Rich (1951) and Meissner (1972), summarized in Figure 9, the facies pattern along the margin of a sedimentary basin filled with water is related to the environment of deposition. The most important environmental factors being waterdepth, wave and current action and tidal range.

During the infill process of a sedimentary basin, sediments accumulate along the margin and in the central part of the basin. Siliciclastics are carried into the nearshore area by rivers and wind from the landmass that surrounds the sedimentary basin. Carbonate sediments are derived from the skeletons of animals and plants, which are found most abundantly in the relatively warm, shallow water environment of the basin margin. The finer particles are reworked by storm induced waves and are carried into the central, deeper parts of the basin by currents. The bulk of the coarser particles remains in the nearshore environment and forms a beach. If conditions are favourable and there is an abundance of sediment supply the beach moves seaward and forms a wave resistant structure.

In the concept on Figure 9 a wedge of sediments has prograded a certain distance toward the basin centre during a rise in sea level. An equilibrium exists between destructive and constructive forces and the supply of sediment was large enough for the formation of an extensive shelf. In the wedge of sediments underlying the shelf four depositional environments are recognizable. They are the basin bottom, the shelf slope, the shelf and the nearshore environments.

The correlation with the terminology proposed by Rich (1951) into fondothem, clinothem and undathem deposits is indicated on Figure 9. Meissner (1972) introduced the term "Carbonate Platform" and Wilson (1970) used the term platform in some of the names of his "Standard Carbonate Facies Belts". Wilson (ibid) recognized 1, a basin facies - starved or filled basin (fondothem); 2, a shelf facies (deep undathem); 3, a basin margin or deep shelf margin facies (clinothem); 4, a foreslope facies of carbonate platform (marine talus; clinothem); 5, an organic reef of platform margin; 6, a winnowed platform edge sand facies; 7, an open marine platform facies (shallow undathem); 8, a facies of restricted circulation on marine platform and 9, a platform evaporite facies.

Figure 9 indicates that the water depth across the undathem gradually increases seaward and decreases again near the shelf edge. The topography and water depth on the undathem are dependent on the energy of the wind driven waves and tidal currents and on the absence or presence of wave resistant barriers on the shelf.

On the clinothem the basinward slope is much steeper than on the undathem but seldom exceeds 30 degrees. The angle and the shape of the slope depend on the balance between accumulation and erosion at the boundary between sediment and water. The dominant lithology is an important factor. Schlager and Camber (1986) discovered that in the Atlantic and Pacific oceans the submarine slopes of the carbonate platforms are steeper than the slopes of the siliciclastic shelves. They also found that the upper part of high-rising platforms can be so steep that submarine erosion is active and the slope is being eroded by slumps and turbidity currents.

It should be realized that the dominant lithologies, the internal structure and the three dimensional shape of a sedimentary wedge are also dependent on circumstances and processes that operate outside the basin. Important are the initial geographic and climatic setting of the basin, its tectonic setting and the rate of subsidence of the basin relative to sea level. These, and possibly other factors, will more or less control the rate of sediment supply and define the balance between constructive and destructive forces operating in the basin.

For example, undathem deposits will dominate a sediment wedge which accumulates in a sheltered, slowly subsiding embayment. Clinothem deposits are dominant in a rapidly subsiding deep water embayment which receives an abundance of sediment. Fondothem deposits are dominant in the same setting if there is little supply of sediment or if sediment is trapped on shelf.

If one considers the possible interactions between rate of subsidence and amount of sediment supply in cratonic basins it is possble to recognize six combinations. The combinations give rise to the six types of basin fill shown in Figure 50. The six types of sediment wedges differ from each other in shape and in the distribution of the facies. In type 1 the facies boundaries between the unda-, clino- and fondothem deposits rise upward toward the centre of the basin.In type 2 the facies boundaries are sub-vertical and in type 3 the boundaries more or less parallel the underlying paleotopography. In the non subsiding basins (types 4, 5 and 6) the boundaries between the unda-, clino- and fondothem deposits are more or less horizontal.

The concept of progradation summarizes how a sedimentary basin is filled with sediments and how a wedge of sediments accumulates after or during a relative rise in sea level. The concept does not explain what happens during a period of destruction when sea level rises and the shoreline recedes.

It is evident that during a period of rising sea level the shoreline will be eroded and the shelf will be covered by sediments derived from the former shoreline system. The deposits behind the shoreline, largely composed of lagoonal and marsh-like sediments, are partly eroded and the

	Rate of subsidence	Amount of sediment	Shape of sediment wedge	Nature of shoreline	Facies distribution
1		ample supply	thick and extensive	regressive	
2	SUBSIDING	fair supply	thick but narrow	stable	
3		little supply	thin and extensive	transgressive	
4		ample supply	thick and extensive	strongly regressive	
5	NON SUBSIDING	fair supply	thin and narrow	regressive	
6		little supply	thin and narrow	stable	

Fig. 50.- *Diagram showing six possible patterns in the facies distribution of prograding shoreline deposits.*

coarser fraction of these sediments will form a new beach that is located at some distance inland from the old one. The new shoreline deposits presumably overlie the remnants of the old lagoonal and marsh-like deposits with a sharp contact. The basal deposit of the new wedge of sediments may include a winnowed deposit containing debris of the former nearshore and backshore sediments.

Figure 51 schematically shows the situation described above for siliciclastic sediments at the end of the rise in sea level. The old unda- and fondothem deposits are covered with a new layer of sediment. The clinothem has not prograded toward the basin centre because the supply of sediment was used to construct the new undathem. The boundary between the older and younger deposits is sharp and overlain by reworked material from the older deposits because space has been created for new sediment. The landward deposits of the new undathem overlie the older ones and the edge has moved inland.

During a drop in sea level the shoreline deposits fall dry and are reworked by rain and wind. If precipitation exeeds evaporation meteoric water enters the exposed sediments and reacts with the minerals and the original pore fluids. Some of the minerals dissolve near the surface and precipitate in the shallow subsurface as a cement. Other minerals recrystallize causing the boundaries between the original fragments and grains to change shape. If evaporation exeeds precipitation mineral deposits may form, either in the form of shallow subsurface deposits, or as surface deposits of ephemeral lakes.

After a fall in sea level a new shoreline is established at some distance seaward from the old one. The shallow parts of the shelf are eroded by wave and current action and the erosional products are transported to the edge of the shelf. Excess sediment moves down the shelf slope and accumulates at the base of the clinoform.

The scenario described above is schematically shown in Figure 52 and applies to siliciclastic sediments. The older clinoform deposits are truncated and sharply overlain by younger undathem deposits. The erosional products of the previous undathem have been transported to form the new shelf edge, which has moved some distance toward the centre of the basin.

Sedimentary wedges largely composed of carbonates will not be so easily reworked because the sediments become lithified. Thus many of the physical changes brought about by relative movements in sea level become a permanent part of the sedimentary succession and are visible as minor disconformities, erosional surfaces or "hardground" crusts. These surfaces dip toward the centre of the basin at a much smaller angle than the depositional slopes in the clinothem deposits. In Figures 51 and 52 the dip of the erosional surfaces is defined by the width of the undathem and the vertical distance between high and low water levels.

The periods of non-deposition associated with the surfaces described above are relatively minor in basins where an abundance of sediment accumulates, but the hiati become significant in basins that receive or generate little sediment. In this regard it is important to note that in a given basin the rate of sediment supply changes from place to place and may fluctuate trough time. If the centre of deposition shifts position, local supply of sediment may dwindle or halt and result in a period of non-deposition or erosion that has only local significance.

Not all the minor disconformities, erosional surfaces and crusts are related to relative changes in sea level. Changes in climate may result in a cessation of biogenic carbonate production, a reduction in the supply of siliciclastic sediments or lead to dessication, if a basin is not connected to the ocean.

The information compiled in Figure 11 indicates that the Devonian succession includes six stratigraphic sequences which on- and overlap a paleotopographic high area. Although the figure shows only a limited portion of each sequence (it only shows the lower three sequences as wedge like, nearshore deposits and only one complete transition from carbonates to shales),there is a resemblance between individual Devonian sequences and the sedimentary wedge of Figure 9.

The concept illustated in Figure 9 is based on sedimentological observations in Holocene and Pleistocene deposits. Figure 11 represents a summary of regional stratigraphic relationships in an ancient succession of sedimentary and evaporitic rocks. Thus it may be interesting to compare the lithologies and characteristic sedimentary structures of the different Devonian facies with those of Holocene and Pleistocene deposits and see if they share certain features that can be used to identify the environment of deposition.

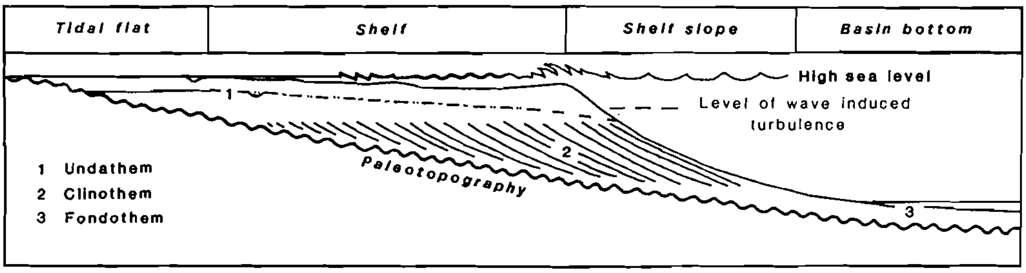


Fig. 51.- *Diagrammatic cross section of a prograding wedge of sediments showing the result of a rise in sea level.*

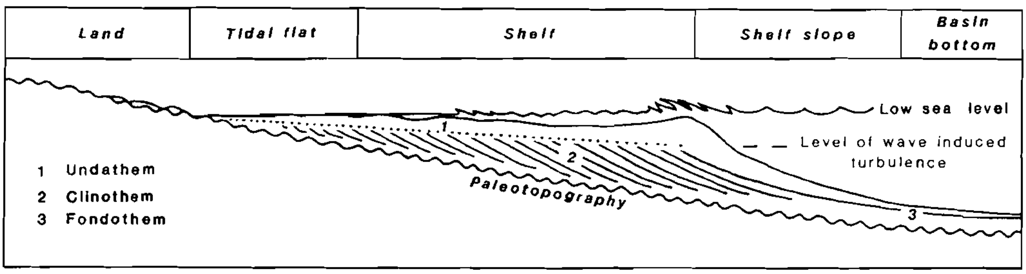


Fig. 52.- *Diagrammatic cross section of a prograding wedge of sediments after a fall in sea level.*

The Middle Devonian detrital facies

The detrital facies consists of feldspathic sandstones and conglomorates, sandy carbonates and quartzose sandstones. The facies overlies the pre-Devonian unconformity and commonly includes at the base a regolith-like rubble deposit.

The distribution of the feldspathic and quartzose subfacies is limited to the subcrop area of the Precambrian igneous and metamorphic rocks (see Fig. 6). The poorly sorted, conglomeratic and sub-angular nature of the particles (see Plates IIb and XIe) and the common presence of sericitic and kaolinitic clay minerals suggest that the feldspathic subfacies is a continental deposit.

The pale coloured, dolomitic sandstone and sandy carbonate subfacies is widely distributed in the lower part of the Middle Devonian succession. It sharply overlies either the feldspathic sandstone subfacies, Proterozoic sedimentary rocks or older Paleozoic carbonates. In the Proterozoic subcrop area (see Fig. 6) the basal beds include poorly sorted conglomorates composed of subangular particles derived from the underlying strata (see Plate IIa).

The quartzose sandstones are clean, well sorted, laminated or cross-bedded (see Plate IIb) and locally include burrow like structures (see Plate XIa). Some of the sandstones are similar to those found in large rivers, tidal channels and along the shore. The interbedded sandy carbonates commonly include fenestral and laminoid-fenestral structures, oncooids and nodular anhydrite (see Plate XI b and c). The oncooids and the fenestral stuctures are similar to the algal concretions and algal mats described from Holocene supratidal sediments in Shark Bay, Australia (see Davies, 1970) and the Persian Gulf (see Kendall and Skipwith, 1968). The nodular and nodularly bedded anhydrite resembles the nodular anhydrite deposits described by Shearman (1963 and 1966), Kinsman (1966) and Evans, Schmidt and Nelson (1969) from the Pleistocene and Holocene sediments along the Trucial Coast of the Persian Gulf.

The pale coloured, quartzose sandstone and sandy carbonate subfacies commonly grades into, or is gradationally overlain by greyish green or greenish grey and reddish brown mottled, dolomitic, silty, anhydritic or gypsiferous shale. If these shaly beds include remains of gypsum or halite crystals (see Plates XId and XIIc) or are cemented by halite, they are classified with the evaporites. If they include remains of charophytes, small crustaceans, primitive fish, gastropods or calcareous algae (see Plates IX b and d, XIf and XIVg) they are classified on the basis of the dominant lithology with either the carbonate or the detrital facies.

The Middle Devonian evaporite facies

The evaporite facies overlies and grades toward the margin of the basin into the detrital facies (see Fig. 6). In the Elk Point Embayment the evaporite facies includes two tongues of carbonates. The upper part of the evaporite facies grades northwestward into carbonates. In the Willow Lake Embayment only the lower part of the the evaporite facies is present. It includes one carbonate tongue and it also grades northwestward into carbonates.

The evaporite facies is an interbedded succession of redbeds, halite, laminated and nodular anhydrite and anhydritic dolostone. Deposits of sylvite and carnallite are present in the Elk Point Embayment but absent in the Willow Lake Embayment. Each of these lithologies is considered to represent a separate subfacies.

The redbed subfacies consists of reddish brown or reddish brown and greenish grey mottled, dolomitic, anhydritic, halitic or silty shale. It commonly includes nodular inclusions of gypsum, anhydrite, halite, halite crystals, gypsum crystals or remains of halite crystals (see Plates XId and XIIc). In places it is interbedded with laminated anhydrite. The subfacies is unfossiliferous. Only the nearshore, argillaceous equivalents of the Shell Lake Member (PrairieEvaporite Formation) locally include microscopic fragments of plants and Charophyte oogonia (Meijer Drees, 1986, p.63).

The halite subfacies includes greyish and reddish brown to orange, semitranslucent salt deposits. The greyish salt is interbedded with undulating beds and partings of dolomitic anhydrite and often contains relicts of the original halite ("Chevron halite") crystals (see Plate XII d and g). The reddish brown salt is massive, includes discontinuous and irregular partings or inclusions of reddish brown or greyish green, dolomitic shale (see Plate XII b and e).

It is assumed that the grey salt deposits accumulated in shallow water lacking in oxygen, because they contain pyrite and locally include oscillating or rippled surfaces (see Meijer Drees,1986, p.77). In the southern part of the Elk Point Embayment the greyish salt deposits include, in the upper part, interbeds of reddish brown shale and polygonal dessication cracks filled with grey and reddish brown potash salts. It is assumed that these salt beds were exposed for long periods of time and subjected to partial dissolution.

In the reddish brown salt deposits the sedimentary structures are largely destroyed by the growth of porphyroblastic halite crystals. These deposits may have been deposited as a result of the dessication of an ephemeral lake. The presence of hematite suggests an environment rich in oxigen and the porphyroblastic nature of the halite is indicative of growth in an unconsolidated sediment.

The laminated or bedded anhydrite subfacies is closely associated with the halite or the nodular anhydrite subfacies. It is composed of very fine dolomitic particles and anhydrite cement. The subfacies includes primary sedimentary structures such as stromatolitic laminations, laminoid-fenestral stuctures, cross-bedding and erosional or dessicated surfaces. Also present are subangular mudclasts, rounded mudstone granules, peloids, calcispheres and locally, anhydritized remains of hopper like halite crystals (see Plates XII a and f, XIII a, b, d and e). The sedimentary structures suggest deposition in very shallow, saline water. The bedded anhydrite deposits may have accumulated at the margin of playa lakes or lagoons.

The nodular and nodularly bedded anhydrites are widely distributed in the Middle Devonian evaporite facies and commonly include interbeds of fossiliferous carbonate and laminated anhydrite. The nodules have grown displacively in the host sediment and have partly destoyed the original sedimentary structures. It is thus considered to represent a diagenetic deposit similar to the nodular anhydrite present in the Holocene supratidal carbonates along the Trucial Coast of the Persian Gulf (see Shearman, 1963 and 1964). Whether or not the host sediment was deposited in an intertidal setting or along the margin of an ephemeral, saline lake is difficult to tell. Deposits closely associated with carbonates including digital stromatoporoids may have accumulated in a marine environment. Deposits closely associated with reddish brown or green sediments including remains of charophytes may be regarded as lacustrine deposits.

The Middle Devonian carbonate facies

The facies pattern in the lower part of the Middle Devonian succession of Figure 11 is related to onlap against a paleotopographic high. Within each sequence the carbonate facies occupies a more central position in the basin than either the evaporite or the detrital facies. The facies pattern in the upper part of Figure 11 indicates that the seaward edge of the Middle Devonian sedimentary wedge is dominated by carbonates and that the central part of the basin is occupied by a succession of dark, bituminous marl and limestone or dark shale.

The carbonate facies includes three environmental settings: 1 - a ramp, 2 - a platform and 3 - a mound subfacies. The boundaries between these subfacies are difficult to draw without a good knowledge of the regional geology.

The "Ramp" (Ahr, 1973) constitutes a wedge of carbonates that gradually thickens seaward and does not include a thick barrier deposit near the break in slope that marks the top of the shelf edge slope. The ramp carbonates are a thin- to medium bedded, light and dark grey banded succession including clean, very fine- to finely peloidal and fragmental carbonates; grey to dark grey, fossiliferous carbonates and dark grey, argillaceous carbonates (see Plates XIV a, b, c, d, e, f and g).

The ramp includes complete and incomplete regressive or "shallowing upward" sequences (Wilson, 1975 and James, 1977), separated from each other by erosional surfaces. The regressive sequences become thicker and include more argillaceous material toward the centreof the basin. Along the basin margin they are relatively thin and include interbeds of laminated and nodular anhydrite. The erosional surfaces commonly overlie thin, pale coloured beds that are dolomitized and include sediment filled burrows, stromatolitic structures, desiccated surfaces or flat-pebble conglomorates (see Plate VIIIa, d, e, f and g).

The carbonates of the ramp subfacies are locally fossiliferous. The Arnica Formation includes a poorly preserved fauna of crinoids, corals (such as *Alveolites*, *Syringopora* and *Thamnopora*), brachiopods, digital stromatoporoids (*Amphipora*) and conodonts. The Landry Formation of the Mackenzie Mountains is sparsely fossiliferous and locally includes ostracodes, gastropods, digital stomatoporoids, corals and calcispheres. The Dolostone Member of the Lonely Bay Formation only includes ostracodes and calcispheres.

The regressive sedimentary sequences include erosional and burrowed surfaces, flat-pebble conglomorates and desiccated surfaces characteristic of Pleistocene and Holocene tidal deposits (Ginsburg, 1975; Shinn, 1983; Shinn, Lloyd and Ginsburg,1969; Evans, Schmidt and Nelson, 1969). It is thus concluded that the carbonate ramp subfacies includes shallow marine and tidal flat deposits. The adjacent nodular and nodular-bedded anhydrite subfacies may represent a peritidal and supratidal environment of deposition.

The term "Platform" (Wilson, 1975, p. 21) describes a wedgelike deposit of carbonates with a more or less flat top that includes, at the shelf edge a relatively thick deposit of coarse grained sediments that act as a barrier. The platform carbonates are a massive or poorly and nodularly bedded succession of fossiliferous, very fine- to coarse fragmental and finely peloidal carbonates (see Plate XVe). The primary sedimentary structures are partially destroyed by the burrowing activity of animals that live in or feed on the sediments. In the lower part of the carbonate platforms the bedding is marked by shale partings or shale interbeds (see Plate XVa). The bedding in the upper part is due to the scattered presence of partly dolomitized crusts or marked by erosional surfaces (see Plate XVb). Biostromal and oncoidal interbeds (see Plate XVd) are commonly present.

The carbonate platform forms a wedge like deposit that thins gradually in a landward direction but ends rather abruptly toward the centre of the basin. Along this depositional edge the platform is relatively thick and locally includes very fossiliferous deposits (see Plate XV c, e and f) that are interpreted to represent the remains of a wave resistant barrier. These fossiliferous deposits include, at the platform edge, relatively steeply dipping flank beds that may represent debris deposits (see Plate XVIa).

The upper surfaces of the Middle Devonian platforms are relatively flat. Sedimentological information suggests that the uppermost beds were deposited in various environments. The top of the Nahanni-Lonely Bay platform locally includes a dessicated surface (see Plate VIId) suggestive of a supratidal environment of deposition. The uppermost beds of the Sulphur Point platform include fossil fragments and peloids encrusted by calcareous algae (see Plate IXe) characteristic of shallow water deposits. The Keg River and Winnipegosis platform in the Elk Point Embayment includes shoals and basins with a regional relief of up to 20 m (Bebout and Maiklem, 1973; Meijer Drees, 1986). On the shoals the uppermost carbonate beds are interbedded with nodular and nodular-bedded anhydrite similar to the sabkha anhydrite. In the basins the platform deposits include laminated carbonates and anhydrites that resemble the varved, deep water, lacustrine deposits described by Dean and Fouch (1983). These laminites are overlain by bedded halite. This scenario suggest that during progradation certain parts of the Elk Point Embayment did not receive much sediment and remained relatively deep water (between 20 and 30 m).

Fossils in the carbonate platforms indicate a normal marine environment of deposition. They include corals, brachiopods, bulbous stromatopores, digital stromatoporoids, gastropods, crinoids, bryozoans, ostracodes and cricoconarids. The most commonly found fragments are crinoidal ossicles, ostracode shells, brachiopod shell hash and branches of amphipores. In the Nahanni and Lonely Bay formations the fauna includes a fair number of corals of which the genera *Dendrostella*, *Favosites* and *Thamnopora* are common. The fact that corals are uncommon or rare in the other Middle Devonian platform formations suggests that they were deposited in a more restricted environment. Both the Keg River and Winnipegosis platforms characteristically include various forms of amphipores but no corals. The Sulphur Point Formation includes bulbous stromatopores, *Stachyodes* like stromatoporoids and *Thamnopora*. The Limestone Member of the Slave Point Formation contains a similar megafauna but *Amphipora* is commonly present and *Stachyodes* is not.

It is concluded that the platform carbonates accumulated in the middle part of the shelf in the sense of Wilson and Jordan (1983) and corresponds to Standard Facies Belt number 7 (Open marine platform facies or shallow undathem) of Wilson (1975). This assignement is mainly based on the presence of the diverse, normale marine to semi-restricted fauna, because the primary sedimentary structures are largely obliterated. The Nahanni-Lonely Bay platform grades landward into a tidal flat (the Dolostone member of the Lonely Bay Formation) and seaward into an interbedded succession of dark shale and argillaceous limestone of a basinal character (see Noble and Ferguson, 1971). The other platforms grade landward into nearshore detrital deposits and change seaward into reefal deposits (see Fig. 11).

Carbonate mounds consist of an organic framework and are flanked by coarse debris deposits. The Devonian mounds mainly include loosely or closely packed, poorly sorted, pebble or cobble sized fragments of bulbous and tabular stromatopores, digital stromatoporoids, colonial corals, brachiopods and a coarse- to fine- grained matrix composed of peloids and fragments of echinoderms, brachiopods and ostracodes (see Plate VIII a and c). Bedding is poorly developed in these coarse deposits, but in the lower part of the mounds fine- to coarse grained, crinoidal interbeds and dark coloured, argillaceous mudstones are locally present. In the upper and central parts of the mounds some intervals include fossils in growth position and in others the fossil fragments are bound together by laminar deposits (see Plate XV c and f). In places the space between the fossilfragments is occupied by laminated deposits of calcareous mudstone or greenish grey shale, which form geopetal structures (see Plate XVg).

The carbonate mounds include a variety of forms. Some mounds are relatively small bioherms (ranging in diameter beween 500 and 1500 m, with heights between 60 to 125 m), others are large, irregular,flat topped bodies (ranging in diameter between 38 to 72 km and heights between 120 and 210 m).

In the Ram River and the Presqu'ile barriers and along the seaward edge of the Slave Point and Sulphur Point platforms the original sedimentary fabric of the reefal facies is destoyed by recrystallization to dolomite. This makes it difficult to separate the reef core and reef flank deposits from each other. The outcrop information in the Ram River area suggests that the individual reef mounds have amalgamated to form a chain of reefs or a reef complex. Within the complex the authochtonous and allochthonous intervals appear to be interbedded. Thus the boundary between the mound and platform subfacies is difficult to establish. The boundary between the mound subfacies and the adjacent basinal shale facies coincides with the seaward limit of the reef flank. This boundary represents a depositional slope and the dip into the shale basin is generally not more than 30 degrees.

It is worth noting that the reef mounds in the Willow Lake Embayment are surrounded by dark shale and are not dolomitized. Fossils and sedimentary fabrics are well preserved. The reefal mounds in the Elk Point Basin are surrounded by evaporites. Many are dolomitized and include white, coarsely crystalline, porous intervals. In many mounds the allochtonous deposits are dominant and the flank beds are interbedded with nodular and nodular-bedded anhydrite. Some Winnipegosis mounds in Saskatchewan include interbeds composed of pisolites and contain dissolution cavities filled with isopachous cement (see Plate Xd). The pisolites were formed in very shallow water. The cement filled dissolution cavities suggest that the mounds were above water and underwent a period of decay before they were buried by evaporites (for a more complete discussion see Wardlaw and Reinson, 1971; Shearman and Fuller, 1969).

The principal frame builders of the reef mounds are bulbous and tabular stromatopores, digital stomatoporoids and corals. Most of the coarse sediment was supplied by digital stromatoporoids, crinoids and brachiopods. Modern reef building corals grow in relatively shallow, clear, warm water, rich in nutrients, that is turbulent or in constant motion. Modern brachiopods and crinoids live in relatively deep water. The stromatopores and stromatoporoids are extinct and their preferential life habitats can only be inferred. Two lines of evidence suggest that the stromatopores and stromatoporoids lived in shallow water. In some Middle Devonian reef mounds the autochthonous beds include both laminar stromatopores and corals in close proximity, in others the coarse, allochthonous beds include many fragments of digital stromatoporoids (*Amphipora* sp. and *Stachyodes* sp.) that are coated by calcareous algae. Algae are dependent on sunlight and live in shallow water. In order to be able to build the extensive reef complexes the Middle Devonian reef builders needed optimum growth conditions, similar to the conditions required by modern coral reef builders. It is thus inferred that the linear reef trends of the Ram River and Presqu'ile barriers indicate the former presenceof a longshore current. The wide spread distribution behind the Presqu'ile barrier of detritus derived from the reef complex suggests that tidal or wind induced currents were operative in a direction perpendicular to the reef trend. The Middle Devonian reefs also had room to expand. The Horn Plateau reefs and the Presqu'ile reef complex reach heights of 60 to 125 m and this required a relative rise of sea level of the same magnitude. The reefal deposits of the Sulphur Point Formation range in thickness between 30 and 100 m; they quickly grew seaward over a distance that ranges between 5 and 70 km.

The Middle Devonian shale facies

The shale facies occurs at three places in the Middle Devonian succession. Although on Figure 11 the shale facies is only shown twice as a wedge-like deposit that onlaps or abutts members of the carbonate facies, the uppermost Givetian shale unit is also in sharp lateral contact with carbonates. The lower shale unit is represented by the Funeral Formation. The middle shale unit includes two map unites; the Bituminous Shale and Limestone Beds and the Hare Indian Formation. The upper shale unit, represented by the Waterways Formation, includes the boundary between the Middle and Late Devonian.

The Middle Devonian shale facies is an interbedded succession of greenish grey or dark greyish brown, calcerous shale and nodular, geryish brown, argillaceous limestone, that includes units composed of dark gery, laminated, bituminous shale or fossiliferous marl. Typical lithologies are shown in Plate XVI.

According to Morrow and Cook (1987) the upper part of the Funeral Formation in the Prairie Creek Embayment includes many, up to 1 m thick, mudflow or turbidite deposits. In places where the Funeral Formation is particularly sandy, the lower part includes sand to silty shale laminae and the upper part includes bedding surfaces with faint groove marks. They considered these sedimentary structures as indicative of deposition on a submarine slope. The regional divergence in depositional dip between the Funeral and Headless formations was also explained by the presence of a depositional slope.

At the north end of the Funeral shale basin (see Fig. 34) the situation is different. Here the Funeral Formation is not in lateral contact with the Ram River barrier reef edge and is overlain by carbonates of the Landry Formation. The lower part of the Funeral Formation consists of an interbedded succession of dark grey, argillaceous limestone and marl, which includes "shallowing upward sequences" similar to those of the underlying Arnica Formation (see Plate IV).

On the isopach map of the Bituminous Shale and Limestone Beds (Fig. 46) the middle shale unit forms a wedge like deposit that thins toward the centre of the basin and thickens toward the reefal edge of Presqui'ile barrier. Cored sections in the Deep Bay area located at distances ranging between 2 and 4 km away from the reef edge include few if any coarsely grained beds. Sections located within 1 or 2 km distance from the reef edge do include,in the lower part, coarsely grained, poorly graded beds that may be classified as turbidites (see Plate XVIa).

This information and the detailed information obtained from coreholes drilled in and around the Horn Plateau reef mound near Fawn Lake (see Vopni and Lerbekmo, 1972) indicates that most of the reefal detritus accumulated at the base of the reefs in the form of reef flank deposits.

The Waterways Formation grades westward in the lower part of the Hay River Formation and includes in the upper part a dark grey, bituminous shale unit that continues into the Muskwa and Spence River formations. The greenish grey, lower part of the Waterways Formation thins westward to zero. The thinning is partly depositional and partly due to the facies change into the overlying dark shale. The depositional thinning and the presence of clinoform limestone markers in the Spence River Formation that dip gently to the west, indicate that the uppermost Middle and lowermost Upper Devonian shale units form a westward prograding clinothem deposit.

The Middle Devonian shale facies includes a variety of fossils of which the plagic tentaculitids are the most characteristic. The Funeral Formation contains in addition to the tentaculitids, ammonites and orthoconic nautiloids (Noble and Ferguson, 1971). Morrow and Cook (1987) reported the presence of pyritized fish fragments. The argillaceous limestone interbeds in the lower part of the Funeral include fragments of ostracodes, calcispheres, brachiopods and crinoids. The fauna of the Bituminous Shale and Limestone Beds is similar. Argillaceous limestone beds in the lower part are bioturbated and rich in brachiopods and crinoids (see PlateXVI b, f and g); the shaly beds, prominently present in the upper part, include *Tenticulatis*, *Styliolina*, *Lingula* and conodonts. The dark, highly radioactive shale of the Bluefish Member of the Hare Indian Formation contains radiolaria, trilete spore cases and tentaculitids. The greenish grey, calcareous shales and argillaceous limestones of the upper, unnamed member of the Hare Indian Formation and the Buffalo River Formation are sparsely fossiliferous and include, in addition to the above mentioned fossils, microscopic plant fragments and conodonts. The greenish grey, calcareous shale and argillaceous limestone beds of the Waterways Formation include a marine fauna of brachiopods, corals, stromatoporoids, ostracodes, conodonts and bryozoans. The dark, pyritic shales of the Upper Devonian Muskwa and Spence River formations are sparsely fossiliferous and include coaly plant remains, conodonts, tentaculitids and sponge spicules (see Plate XVIk).

It is evident from the above information that the greenish grey and limestone rich parts of the Middle Devonian shale facies accumulated in a marine environment. The bioturbated, poorly sorted wackestone beds, including well preserved brachiopods, are relatively shallow water (within the photic zone) deposits. The moderately well sorted and graded, crinoidal wacke- and packstone beds, including very sharp erosional contacts at the base and gradational upper boundaries, may represent debris flow deposits or turbidites in relatively deep water (below the photic zone).

The Late Devonian shale facies

The dark coloured, laminated, bituminous, calcareous and non-calcareous shales of the Bluefish Member and the Spence River and Muskwa formations probably accumulated in a marine, euxinic environment. The scarcity of sedimentary structures related to current and wave action (such as shown in Plate XVI h and i) and the local abundance of pelagic microfossils and sponge spicules suggest deposition in relatively deep (below average wave base) water.

CHAPTER XIII: CONCLUSIONS

The Devonian succession in the southern part of the District of Mackenzie thickens to the west and northwest. It onlaps a pre-existing paleotopographic high area in the southern part of the Great Slave Plain. The crestal part of this high area, named Tathlina Uplift, was emergent until the Middle Devonian.

The Lower and lower Middle Devonian rocks accumulated in a slowly subsiding basin, located in the southern part of the Mackenzie Mountains. The name of the basin is Root Basin. During the Middle Devonian rise in sea level, it expanded sideways to include an embayment on the north flank of Tathlina Uplift, named Willow Lake Embayment. The episodes of sedimentation in Root Basin and the subsequent progradational infill from the southeast of Willow Lake Embayment and Root Basin are recognizable as three discrete events in the Devonian rock succession. The location of the facies boundaries between the nearshore, evaporitic, peritidal, lagoonal and shallow marine deposits of the three individual basin-fill sequences shifts laterally across the basin over considerable distances.

The Lower and lower Middle Devonian rocks are separated from overlying Devonian strata by the sub-Headless unconformity. This unconformity truncates the eastern parts of sequences 2 and 3. It may have been the result of local uplift, a world wide fall in sea level or from a combination of these two events.

The upper part of the Middle Devonian succession onlaps the sub-Headless unconformity and extends southeastward across Tathlina Uplift into the Elk Point Basin. It includes a basal carbonate platform from which extends upward a large number of reef mounds and the Presqu'ile barrier reef complex. The reefs probably grew upward in response to a rise in sea level and deteriorated during early Givetian because of a subsequent fall in sea level. The salt and anhydrite deposits southeast of Presqu'ile Barrier that fill the Elk Point Basin were deposited during the rise in sea level that followed the early Givetian low stand by the process of "evaporite drawdown".

The Elk Point evaporites and the carbonates of Presqu'ile Barrier are overlain by the sub-Watt Mountain unconformity, which represents a basin-wide regression. Charophyte-rich shale overlies the unconformity and onlaps a part of Presqu'ile Barrier that overlies the crestal part of Tathlina Uplift. It is suggested that this part of Presqu'ile Barrier was a positive feature because of differential compaction.

The upper Givetian carbonates of the Slave Point Formation represent a platform that includes a reefal facies along its northwestern margin. This reefal facies overlies Presqu'ile Barrier and extends farther north, or coincides with the seaward edge of the barrier. Apparently reef growth at the barrier edge was not halted by the sub-Watt Mountain regression. It is shown that during the regression reef growth may have moved down the seaward slope of Presqu'ile Barrier and may have moved upward and outward during the Slave Point transgression.

Dark, bituminous marlstones, including Givetian fossils, occur between the reef mounds northwest of Presqu'ile Barrier. They are regarded as fondoform deposits equivalent to the reefal, and the clinoform deposits of both the Presqu'ile Barrier and the Slave Point Formation.

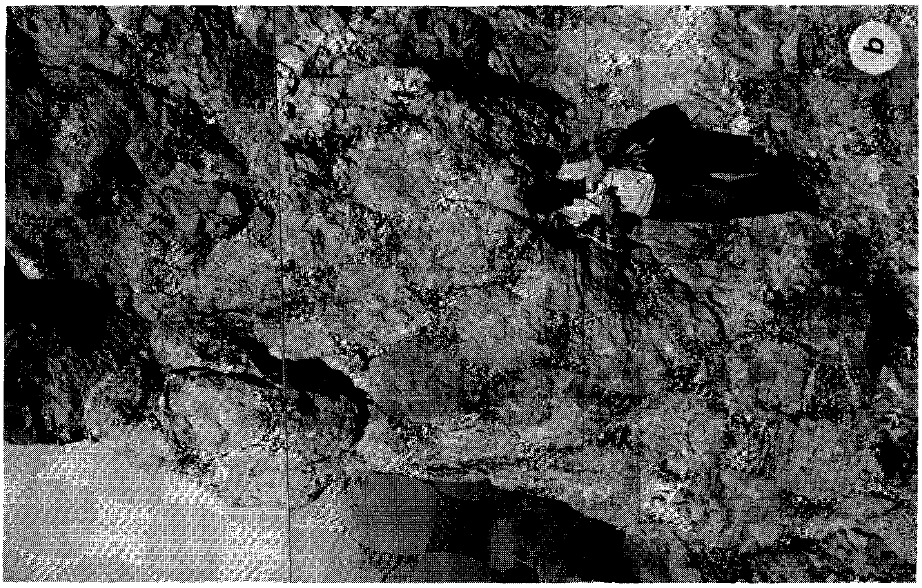
Upper Devonian shales and argillaceous limestones overlie the Slave Point platform and reefal carbonates, the Givetian fondothem deposits and the late Eifelian reefmounds north of Presqu'ile Barrier. They are clinoform deposits of stratigraphic sequence 7 and prograded westward across the basin after a major relative rise in sea level.

DESCRIPTION OF PLATES

PLATE I

a. Panoramic view from a point on Nahanni Range south of Little Doctor Lake (lat.61°42'22"N, long.123°18'15"W) across Great Slave Plain. Tsetso Lake is visible in the far distance.

b. The boundary between stratigraphic sequences 1 and 2 is exposed at the surface in a section south of Mount Charles (location: lat. 64°52'15" N, long. 124°38'30" W). It lies below a 7 m thick unit of limestone-breccia. The breccia is in many respects typical of the Bear Rock Formation, except for its fine-grained, calcareous, sandstone matrix. The boundary is an irregular, possibly erosional surface. Beds below this surface belong to the Tsetso Formation. They include, in the upper part, a 1 m thick unit of a thin-bedded, fine-grained, calcareous sandstone that is underlain by stromatolitic dolostone.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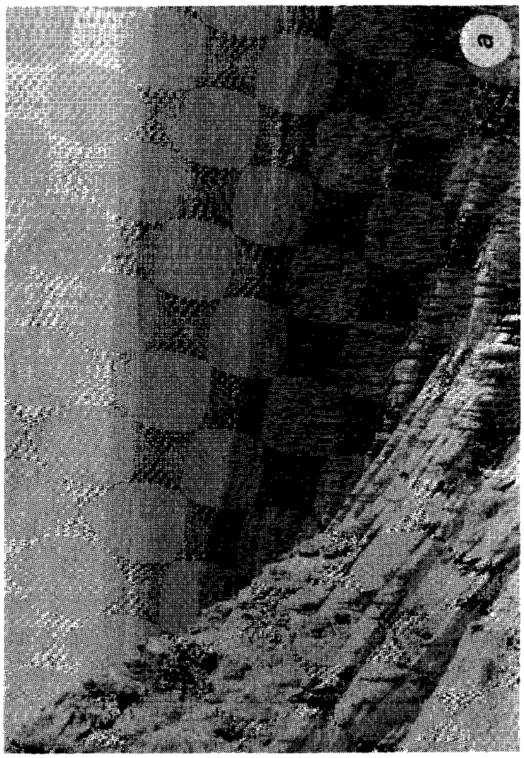
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PLATE II

The pre-Devonian, erosional unconformity in two borehole cores.

In the Arrowhead I-46 core (right) the unconformity lies at the base of the conglomerate in box 241 (depth 2159.5 m or 7085 ft) and overlies a thinly bedded and laminated succession of greenish grey shale and light grey, quartzitic siltstone. The conglomerate is composed of angular pieces of quartzitic siltstone and includes a, locally dolomitic, siltstone matrix. It grades upward into a dolomitic siltstone. The conglomerate and the siltstone are part of the Devonian Tsetso Formation. The underlying succession belongs to the Proterozoic.

In the Little Buffalo K-22 core (left) the unconformity lies at the base of a light brown, fine- to coarsely grained, cross-bedded, quartzose sandstone and is underlain by a partly decomposed, crystalline rock including quartz, feldspar, kaolinite, chlorite and reddish brown clay. The sandstone belongs to the La Loche Formation; the crystalline rock is part of the Precambrian igneous and metamorphic complex.


bottom
box 98
box 97
box 96
top

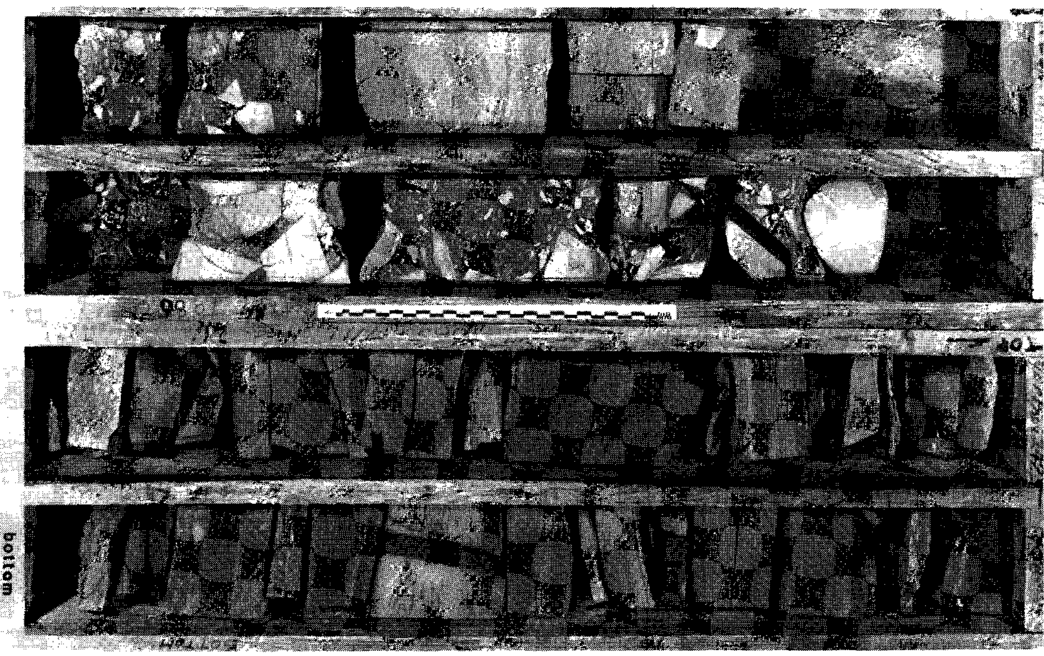
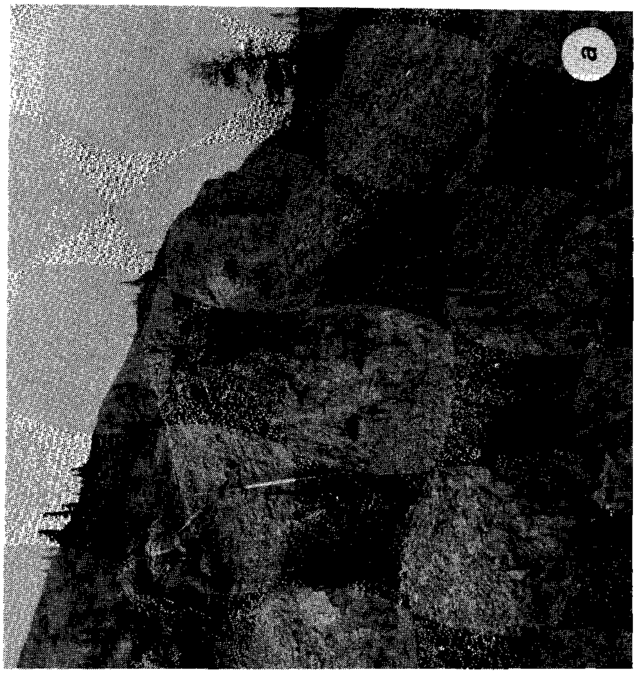

top
box 241
box 242
bottom

PLATE III

The pre-Devonian, erosional unconformity in a core sample and a surface section.

a. In the Willow Lake L-59 borehole, core 4, depth 684.8 m (2247 ft), of greyish brown dolostone of the Mount Kindle Formation (age: late Ordovician to early Silurian) is sharply overlain by pale coloured, anhydritic and reddish brown, silty dolostone of the Devonian Tsetso Formation.

b. At the southeast end of Bear Mountain, District of Mackenzie (lat. 64°54' N, long. 125°41' W), the unconformity lies between the Devonian Bear Rock Formation and the Cambro-Silurian Franklin Mountain Formation. It is located just below the geologists feet and abutts a subvertical dyke of limestone-breccia that is believed to represent a wedge-like dissolution cavity filled with Bear Rock breccia.


a


b

PLATE IV

The contact between sequences 2 and 3 in the core of the Dahadinni M-43A borehole (box 190, 4898 ft) is represented by an erosional surface at depth 1492.9 m. This surface overlies a pale coloured succession of microcrystalline dolostones (the Arnica Formation). It is overlain by a layer of dolomitic pebbles and a thick, interbedded succession of dark grey, locally very finely dolomitized, very argillaceous limestone, containing white, irregularly shaped, dolomite or calcite inclusions; light grey, coarsely crystalline dolostone; and greyish brown, peloidal, partly dolomitized limestone (the Funeral Formation). Note that both the Arnica and Funeral formations include a number of regressive sedimentary sequences that are capped by burrowed or erosional surfaces similar to those of Figure 25. These are marked by white flags.


bottom
box 191
box 190
box 189
box 188
box 187
top
4998

PLATE V

The sub-Headless unconformity in the Arrowhead I-46 core is present in box 196 at depth 6881 ft (2097.3 m). The unconformity overlies aphanitic, locally peloidal limestone (the Landry Formation) and is overlain by a thinly interbedded and interlaminated succession of medium to coarsely peloidal limestone and greyish green shale (the Headless Formation). The beds below the unconformity are brecciated and cavities are filled with green claystone. The beds above the unconformity are undisturbed and include stromatolitic structures, mudclasts and charophyte oogonia.

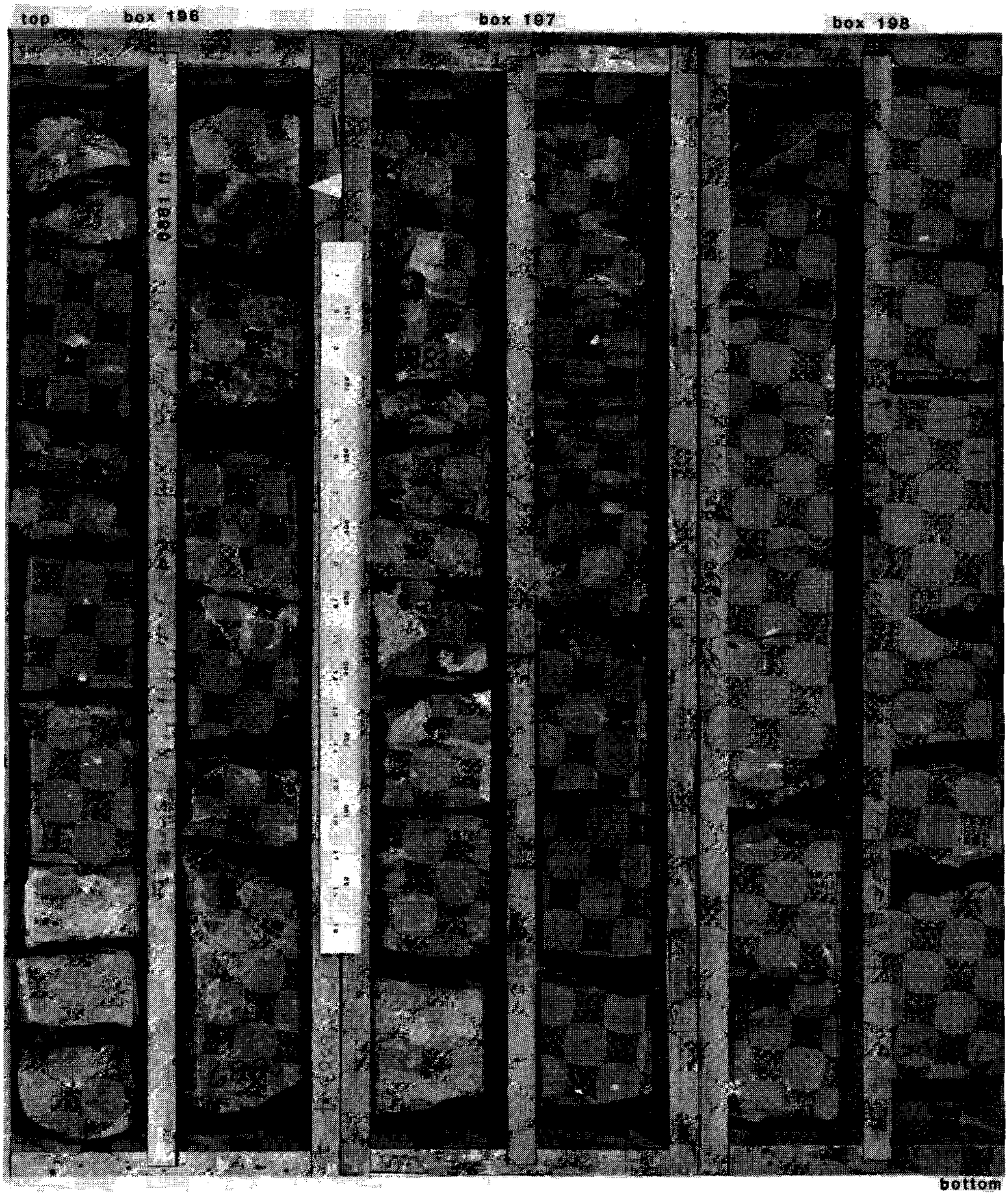

top
box 196
box 197
box 198
bottom

PLATE VI

The sub-Headless unconformity in the core of the Trail River P-13 well is present in box 6, at a depth of 1574 ft (479.7 m). The Headless Formation is a greenish grey, argillaceous and calcareous siltstone that includes many grains, granules and small pebbles of grey limestone.The interval below the unconformity (the Arnica Formation) is a rubble deposit or regolith composed of closely packed limestone and dolostone fragments. The space between the fragments is occupied by siltstone. In the lower part rubble deposit the cavities are partly filled with white dolomite.


top
bottom

PLATE VII

The boundaries between stratigraphic sequences 4 and 5 and sequences 5 and 7 in core samples (reduction 72 %, except a)

a. The sub-Headless unconformity in the Mattson Creek No.1 well. Dark grey, brecciated dolostone of the Manetoe Formation is overlain at depth 757.4 m (2485 ft) by dark, argillaceous dolostone of the Headless Formation.

b. The sub-Headless unconformity in the Dahadinni M-43A borehole. Light grey, microfragmental limestone of the Lower member of the Hume Formation is sharply overlain at depth 1256.2 m (4121.5 ft) by dark grey, pyritic marl including grains, granules and pebbles of the underlying limestone.

c. The contact between sequences 5 and 7 in the Punch Deep Bay No.2 well at depth 239.8 m (787 ft) coincides with the boundary between the Bituminous Shale and Limestone Beds (below) and the Spence River Formation (above). A dark, interbedded and bioturbated succession of marlstone and limestone is sharply overlain by dark shale at the top of the sample. The interbedded succession includes peloids, calcispheres, tentaculitids and fragments of crinoids. The dark shale includes a scattering of compressed tentaculitids.

d. Boundary between stratigraphic sequences 4 and 5 in the Willow Lake H-10 well. A thinly interbedded and interlaminated succession of peloidal wacke- and packstones is broken up and bound together by dark, stromatolitic mudstone layers. Is sharply overlain at depth 159.3 m (523.5 ft) by a very dark coloured, bituminous limestone including sediment-filled burrows. This contact more or less coincides with the base of the "Leiorhynchus beds" of the Lonely Bay Formation.

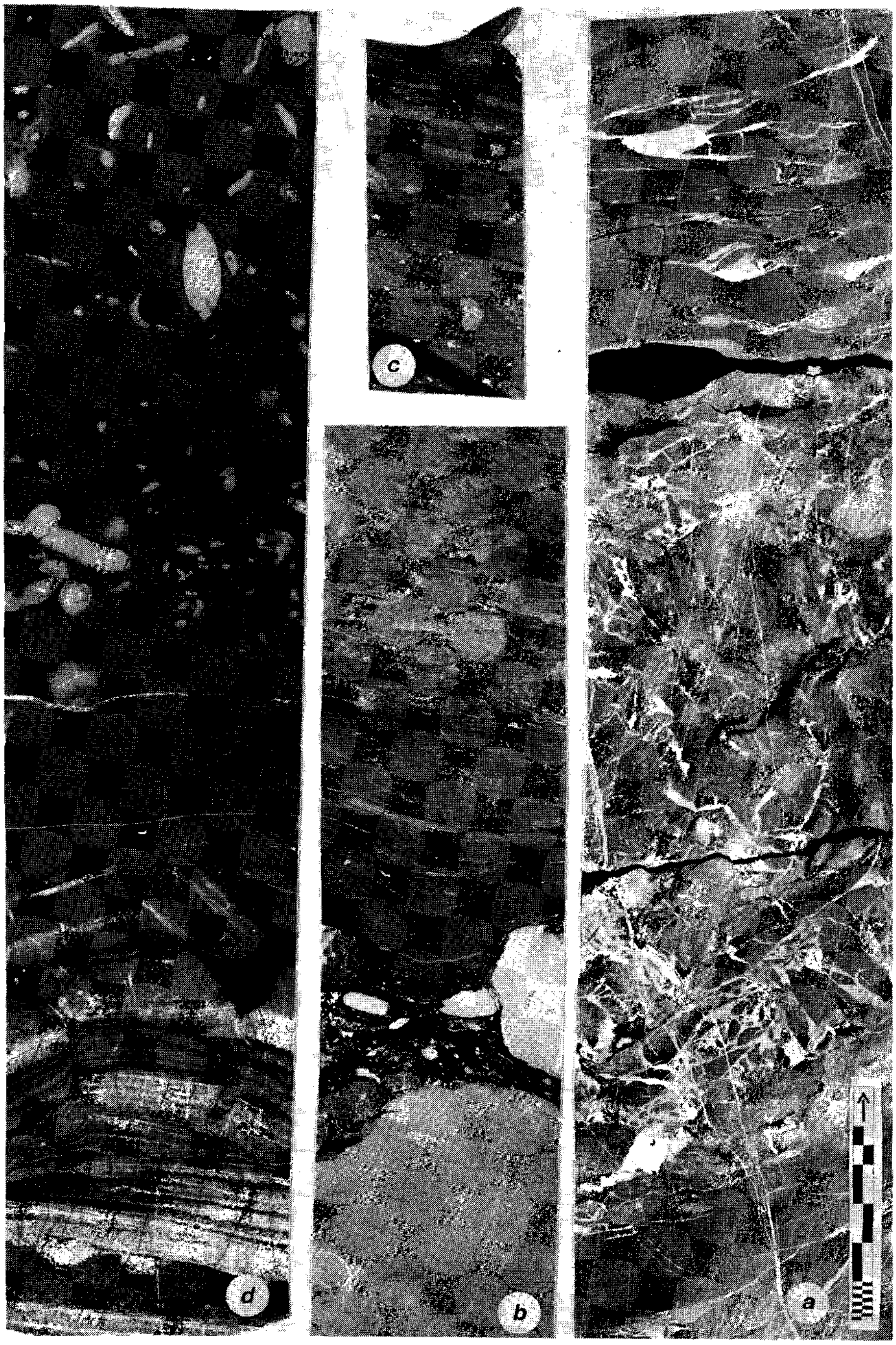

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PLATE VIII

Exposures of Horn Plateau reef near Fawn Lake,
District of Mackenzie (lat. 62°08.2' N, long. 117°39' W).

a. Flat topped, northward dipping knobs of reefal limestone in the northeastern part of the reefmound. The knob and gully topography may, in part, represent the exhumed paleotopographic surface below the Spence River Formation and is similar to the spur and groove topography of modern reefs.

b. Detail of an erosional remnant of a knob in which the depositional dip of about 30 degrees away from the centre of the reef is visible. The coral head above the hammer is overlain by a loosely cemented, coarse-grained, crinoidal grainstone.

c. Erosional edge of a knob composed of poorly cemented brachiopods, corals and bulbous stromatopores in near growth positions.

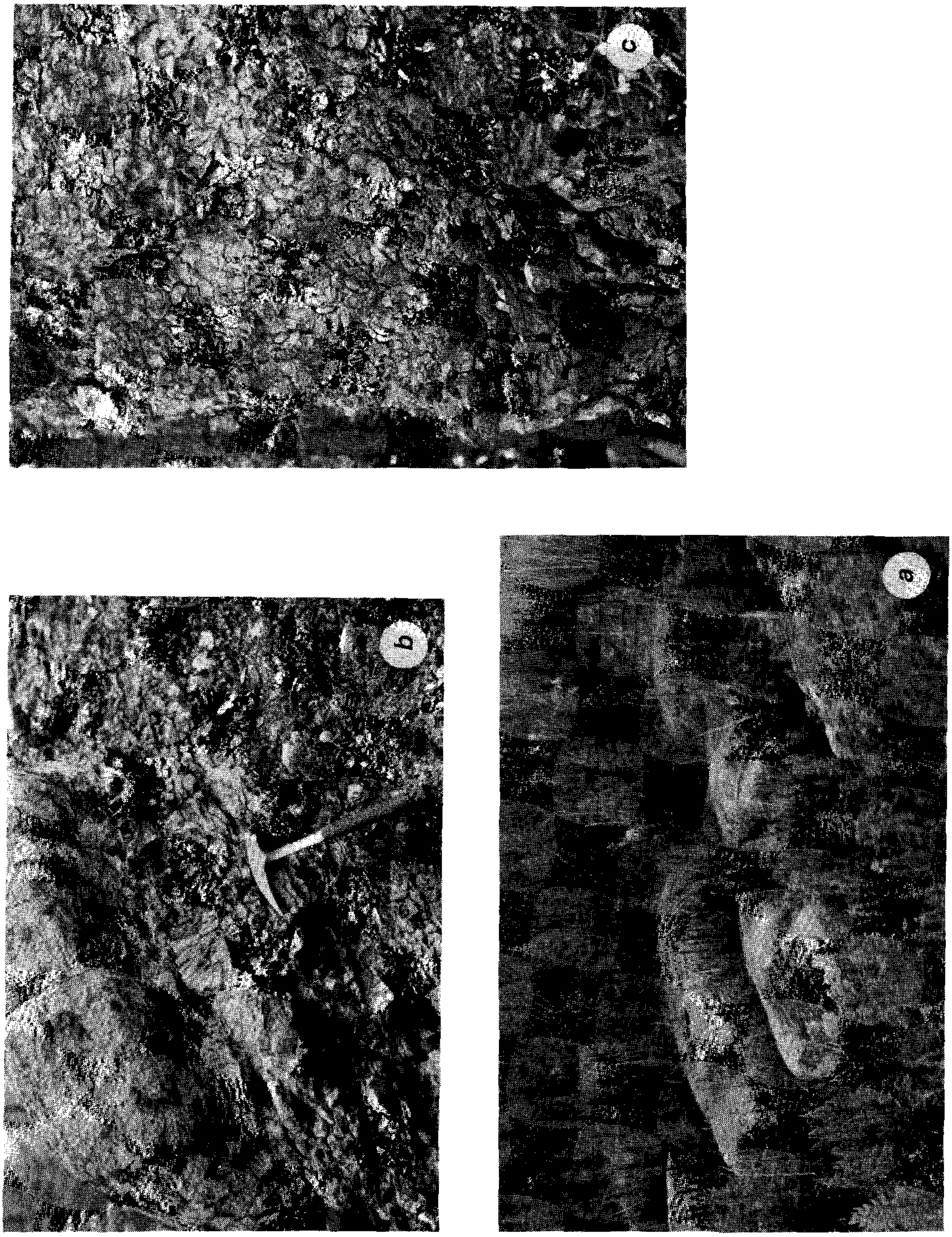
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PLATE IX

The sub-Watt Mountain unconformity in core samples.
(reduction 72 %)

a. Limestone breccia or regolith composed of dark fragments of crinoidal mudstone and a matrix of light brown, peloidal and crinoidal packstone. Matrix is cut by an irregular network of pale greenish grey, calcareous shale partings. The breccia is truncated by greyish brown, nodular limestone including irregular shaped, crinoidal limestone pebbles, fragments of ostracodes, brachiopods and charophyte oogonia. Rabbit Lake No. 2 well, depth 806.5 m (2646 ft); Watt Mountain Formation.

b. The unconformity truncates light brown Sulphur Point limestone and is overlain by dark greyish brown Watt Mountain limestone including nodular shale partings. The Sulphur Point limestone is a sparsely fossiliferous mudstone. Small, calcite filled fenestral vugs and burrow-like cavities are filled with dark brown mudstone or white calcite crystals. Watt Mountain limestone is a fossiliferous wackestone containing ostracode shells and charophyte oogonia. Redknife N-06 well, deth 917.1 m (3009 ft).

c. Brecciated limestone of the Sulphur Point Formation below the unconformity is composed of large stomatopores and a matrix of microfossiliferous wackestone. Sample is cut by an irregular, nodular network of pale greenish grey, calcareous shale partings Cavities are filled with laminated, calcareous silt and quartzose sand. Redknife N-06 well, depth 919.5 m (3017 ft).

d. Light brown, Sulphur Point limestone truncated by pale greyish green, Watt Mountain shale. Limestone is a fine to very coarsely grained rudstone composed of rounded fossil fragments and peloids cemented by calcite. Shale is a nodularly interlaminated succession of light brown calcitic mudstone (including ostracodes and charophyte oogonia) and green, pyritic and silty shale. Northeast Tathlina Lake No. 9 well, depth 728.4 m (2390 ft).

e. Burrowed surface in the lower part of the sample represents the sub-Watt Mountain unconformity in the core of the Desmarais Point E-72 well, at 243.8 m (800 ft). Basal part of sample represents the Sulphur Point Formation. It is a well cemented, very fine- to fine-peloidal packstone rich in calcispheres, includes scattered fragments of *Stachyodes* like stromatopores and deformed burrows filled with light brown, peloidal limestone. Middle and upper parts of the sample are composed of light brown, loosely cemented, peloidal packstone and include encrusted amphipores, fragments of brachiopods, ostracodes, charophyte oogonia and calcispheres. The dark grey, stylolitic shale partings in the middle part of the sample may represent the feather edge of the Watt Mountain Formation. The limestone in the upper part is the equivalent of the Slave Point Formation.

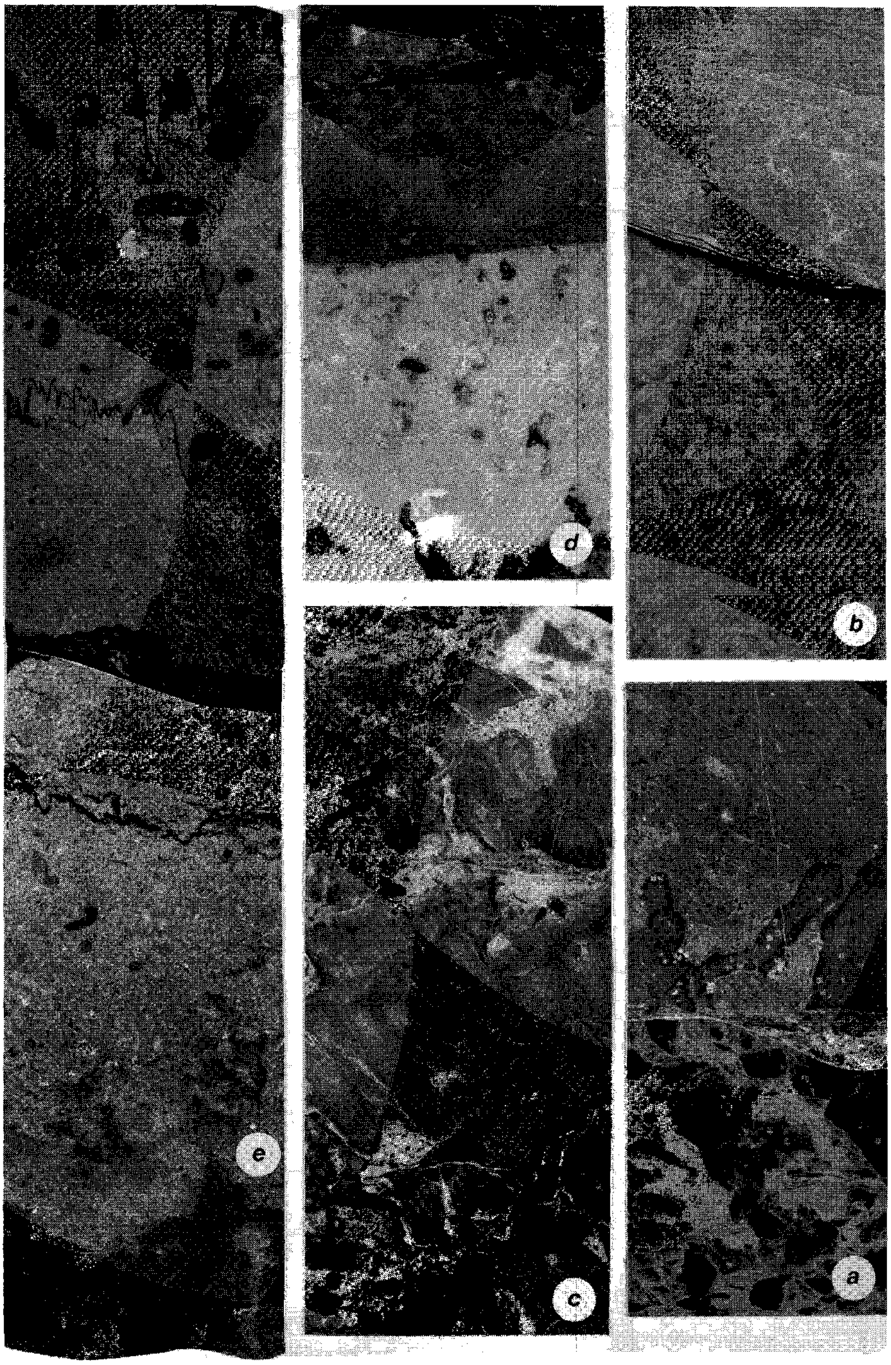
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PLATE X

The sub-Watt Mountain unconformity, the base of stratigraphic sequence 7 and an example of the carbonate mound subfacies in core samples (reduction 72 %).

a. The sub-Watt Mountain unconformity in the Trainor L-59 well at 1767.3 m (5798.5 ft). Fossiliferous limestone of the Sulphur Point is sharply overlain by shaly beds of the Watt Mountain. Limestone is a Stachyodes float- to rudstone, locally including a pale greenish grey, pyritic and calcareous shale matrix with charophyte oogonia. Shaly beds consist of interlaminated greenish grey shale and light brown calcite mudstone.

b. This hardground crust forms the contact between Slave Point (below) and Hay River (above) formations in the Heart Lake No. 2 well at 368.8 m (1210 ft) and represents the base of sequence 7. Slave Point limestone includes burrows filled with greenish grey, argillaceous and very fossiliferous limestone of the overlying formation. The walls of the burrows, the crust and the limestone pebbles in the overlying, argillaceous bed are pyritic.

c. A crust at depth 368.1 m (1208 ft) in the basal part of the Hay River Formation of the Heart Lake No.2 well is similar to sample a. Mudstone includes fragments of crinoids and brachiopods. Burrows are filled with fragments of brachiopods, crinoids and bryozoans.

d. Light brown dolostone of a Winnipegosis reef mound includes stromatopores, fragments of crinoids, brachiopods, corals, ostracodes and scattered dissolution vugs lined with a brown, laminated dolomite crust or filled with isopachous cement. Humbolt 12-19-36-23W2 well, Saskatchewan, depth 1068 m (3508 ft).

e. Boundary between sequences 4 and 7 in the Ebbutt D-50 well, at 466.6 m (1531 ft) coincides with the contact between the Nahanni (below) and Spence River (above) formations. Samples are continuous. Lower limestone sample includes a chert nodule. In the upper sample the limestone is overlain by an interlaminated unit of black, pyritic shale and fine- to coarsely crinoidal limestone that includes pebble-like chert nodules. This represents a coarse lag deposit at the base of sequence 7. It is overlain by dark shale including conodonts and rare tentaculitids.

f. Erosional contact between sequences 5 and 7 in the Providence K-45 corehole at 218.2 m (716 ft). Limestone of the Bituminous Shale and Limestone Beds, including deformed, sediment filled burrows, is sharply overlain by dark somewhat calcareous Spence River shale. Limestone is an argillaceous, pyritic mudstone and contains fine peloids and fragments of tentaculitids. The burrows are filled with pyritized crinoid ossicles, mudclasts and pyrite nodules. The thin lag deposit at the base of the Spence River shale includes granules and pebbles of limestone.

g. Dissolution surface in the limestone sample represents the contact between sequences 6 and 7 at 1870.5 m (6137 ft) in the Arrowhead I-46 well. It coincides with the boundary between the Slave Point (below) and Muskwa (above) formations. Small stromatopores in the finely peloidal and microfossiliferous limestone are truncated at the steeply dipping contact.

h. Boundary between sequences 6 and 7 in the Woodbuffalo C-74 well at 26.2 m (86 ft) lies at top of sample and coincides with the contact between the Slave Point (below) and Waterways (above) formations. The limestone includes two vertical, sediment filled borings. It is, a locally pyritic wackestone including ostracodes, gastropods, brachiopods, crinoids, tentaculitids and charophyte oogonia. The borings are filled with pale, calcareous claystone, fine to coarsely grained quartzose sand and fossil fragments. Upper surface of sample is very pyritic and overlain by a brachiopod coquina or by greenish grey shale.

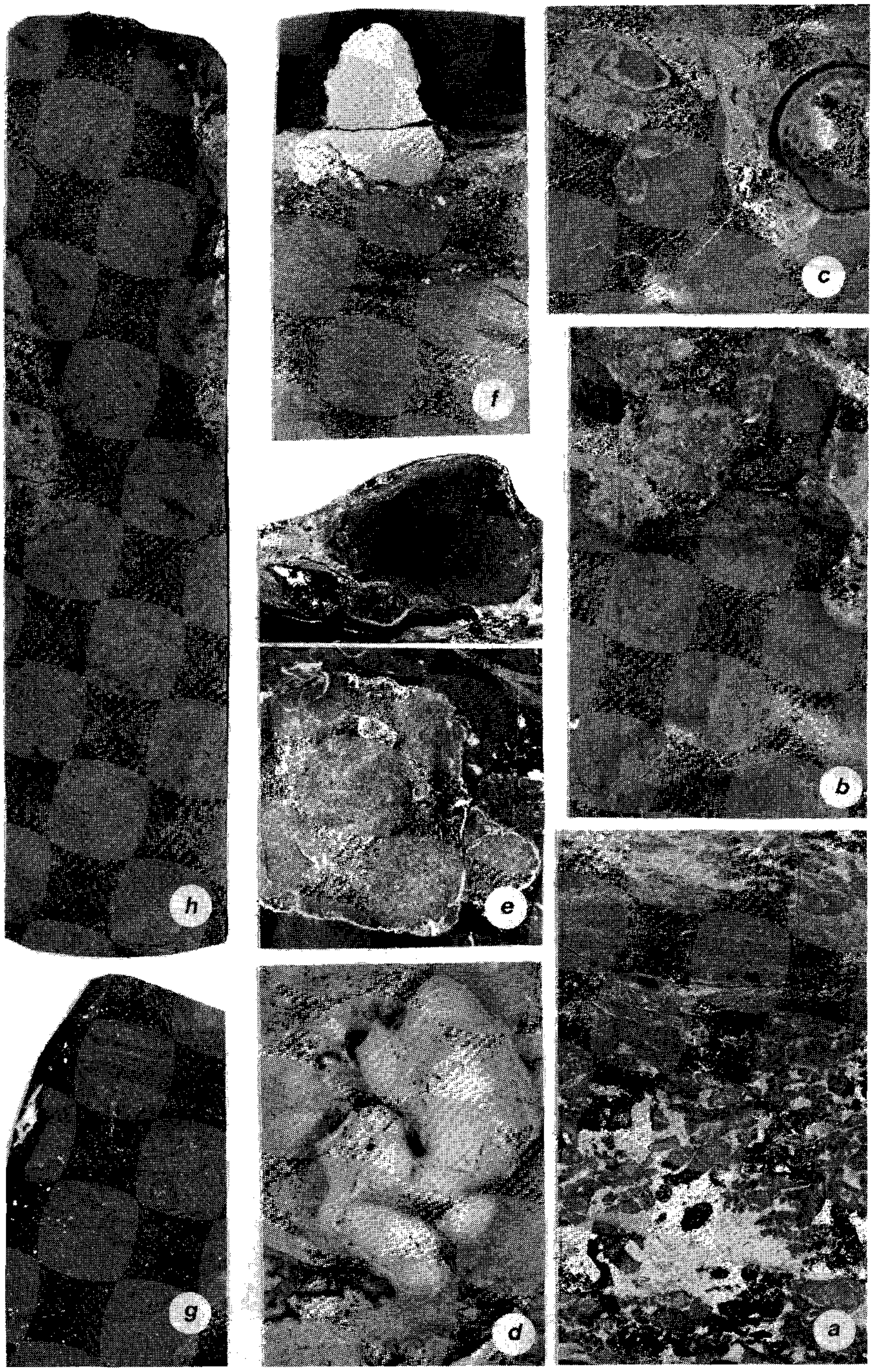
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PLATE XI

Core samples representative of the detrital facies.
(reduction 72 %)

a. Sandstone overlain by dolomitic shale. Sample includes four units, boundaries indicated by flags. Basal unit is a light and dark grey mottled, fine-grained, very sandy dolostone. It is overlain by a light grey mottled, slightly dolomitic, fine-grained sandstone. The third unit consists of very thinly interbedded sandstone and shale including sand-filled burrows. The upper unit is similar to the third unit, but the sandy beds are very dolomitic and it includeslaminated sandstone lenses. Mattson Creek No. 1 well, depth 2378.6 m (7804 ft); Tsetso Fm.

b. Grey, anhydritic dolostone composed of mudstone pebbles and oncoids in a microcrystalline, dolomitic matrix that includes dark coloured, anhydrite filled, fenestral vugs. White veins consist of coarsely crystalline calcite. Mattson Creek No. 1 well, depth 1919.8 m (6266 ft); Tsetso Fm.

c. Greyish brown, microcrystalline, anhydritic dolostone including scattered, fine quartz grains and white inclusions and veins of finely crystalline anhydrite. Sample consists of three parts. Basal part is a sandy dolostone. Middle part consists of thin, elongate (algal mat fragments?) and rounded mud clasts, ostracodes, quartz grains cemented by anhydrite. It includes a pale coloured, anhydritic dolostone pebble. Upper part is light grey and is an anhydritic dolomite-mudstone including layers and lenses rich in quartz sand. Mattson Creek No. 1 well, depth 2376.8 m (7798 ft).

d. Conglomerate composed of greenish grey and reddish brown, dolomitic claystone pebbles in a matrix of reddish brown shale. White anhydrite has filled voids and locally occurs as nodules. Part of the anhydrite is recrystallized to light grey gypsum. Davidson Creek P-2 well, depth 647.7 m (2125 ft); Upper Redbed member, Mirage Point Fm.

e. Reddish brown, nodular anhydrite (dark coloured) overlain by greyish brown, dolomitic sandstone. Sandstone is composed of a siltstone matrix and fine to very coarse fragments of igneous rocks, white chert, translucent quartz, pink feldspar and partly chloritized, dark minerals. Laferte River A-66 well, depth 551.3 m (1809 ft); La Loche Fm.

f. Greyish brown, locally peloidal and fossiliferous, very anhydritic and silty, microcrystalline dolostone, including scattered, coarse grains of quartz, green glauconite, white chert, pink feldspar and crystalline rock fragments (arrows). Anhydrite occurs as cement and as a void filler between particles or in some gastropods. Basal, dark coloured part is argillaceous. A fragment of a solenoporid alga is present in the upper part. Laferte River A-66 well, depth 550.4 m (1806 ft); La Loche Fm.

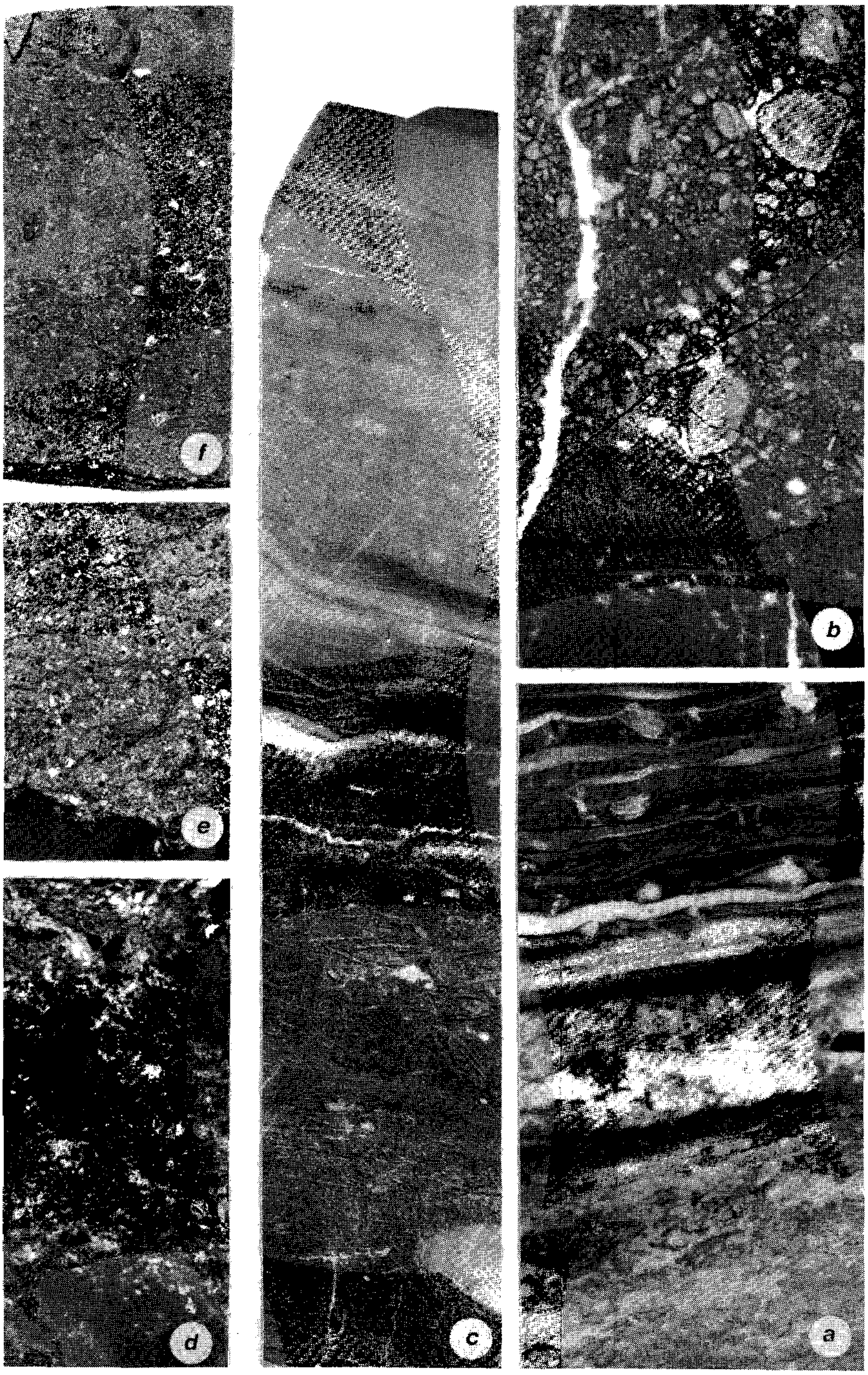
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PLATE XII

Core samples representative of the evaporite facies.
(reduction 72 %, except b and g)

a. Greyish brown, dolomitic and anhydritic wackestone including halite cement and scattered halite crystals. Light coloured beds are mainly dolomite, dark beds mainly anhydrite. The bedding is disrupted by porphyroblastic halite crystals (arrows). The halite crystals contain very fine pyrite crystals. Davidson Creek P-2 well, depth 770.7 m (2528.5 ft); Mirage Point Fm, Unnamed salt member.

b. Massive, yellowish brown salt composed of large, semitranslucent and yellowish brown halite crystals separated by light grey or reddish brown, anhydritic claystone. The bedding is destroyed by the growth of the porphyroblastic crystals. Davidson Creek P-2 well, core box 72, interval 658.9 to 660.5 m (2162 to 2167 ft); Mirage Point Fm, Cold Lake Member.

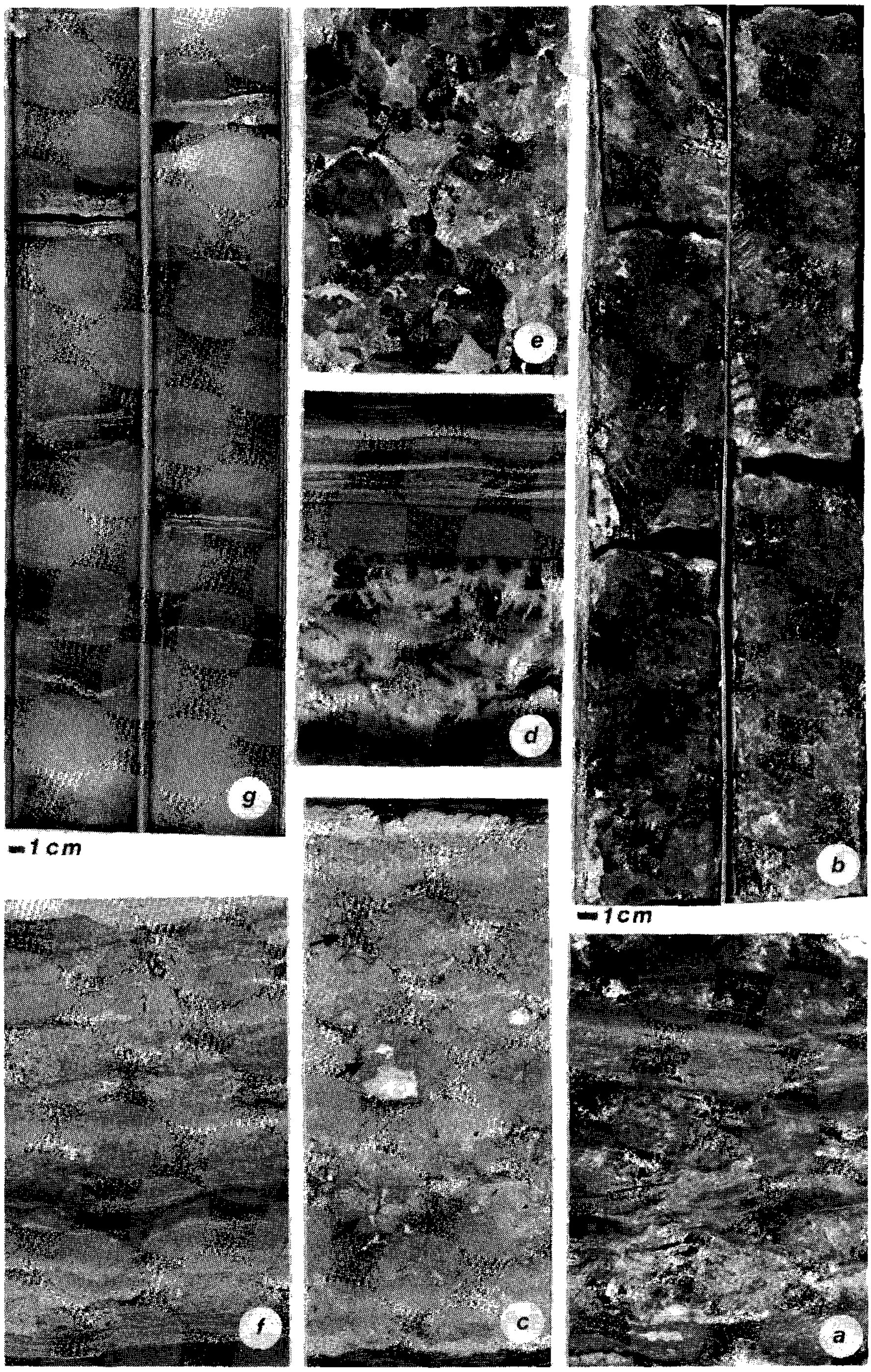
c. Greyish brown, microcrystalline dolostone is sharply overlain by very dark anhydritic shale. The dolostone is a peloidal wackestone that includes several scoured surfaces overlain by coarse grains. These surfaces are locally distorted by small collapse structures (see errows). In the centre of the sample are two quadrangular halite-crystal moulds filled with light grey anhydrite. One of the moulds is partly filled with sediment. It is assumed that the collapse stuctures formed after the dissolution of former halite crystals. Utikuma 4-2-83-9W5 well, Alberta, depth 1748.3 m (5736 ft); Muskeg Fm.

d. Laminated mudstone including an impure salt bed with a chevron growth pattern similar to those of sample g. The salt bed is gradationally underlain by an anhydritic mudstone cementedby halite. It is sharply overlain by greenish grey and dark grey dolomite-mudstones that include anhydrite cement. The upper boundary of the salt bed represents a dissolution surface. Bat Lake 6-31-84-7W4 well, Alberta, depth 1546.6 m (5074 ft); Prairie Evaporite Fm, Leofnard Member.

e. Detail of the salt in the core samples shown in b. Laminated inclusions of reddish brown, dolomitic claystone probably represent remnants of the original host sediment. Davidson Creek P-2 well, depth 658.7 m (2161 ft).

f. Irregularly interbedded and laminated succession of dolomitic mud- and wackestones including erosional and dessicated surfaces. The beds in the lower part of the sample contain mud pebbles and crust like fragments. The dark bed in the middle overlies a mud-cracked surface that includes a collapse structure. The wackestone beds in the upper part contain dark, halite filled, fenestal vugs and fractures. Davidson Creek P-2 well, depth 769.7 m (2525.5 ft); Mirage Point Fm.

g. Bedded, semitranslucent salt with thin, wavy interbeds of light grey dolomitic anhydrite. The salt beds include light grey inclusions that show a chevron pattern typical of competitive crystal growth. The sharp boundaries between the beds suggest that they are dissolution surfaces. Telegraph Creek 6-30-86-13W4 well, Alberta, core 3, box 5; Prairie Evaporite Fm, Whitkow Member.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1 cm
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PLATE XIII

Core samples representative of the carbonate-ramp and evaporite facies (reduction 72 %).

a. Very thinly and interlaminated succession of pale coloured, dolomitic and dark coloured, anhydritic mudstones is cut by mud-crack like fractures filled with microcrystalline anhydrite. In the upper part of the sample the bedding is distorted by nodular anhydrite. The interbedded interval is sharply overlain by a light and dark grey mottled, microcrystalline anhydrite in which no sedimentary structures are preserved. Trail River P-13 well, depth 492.2 m (1615 ft); Fort Norman Fm.

b. Interbedded and cross-laminated, halite impregnated, anhydritic and dolomitic mudstone. In the dark, circular patches the dolostone is replaced by halite. Davidson Creek P-2 well, depth 774.2 m (2540 ft); Mirage Point Fm.

c. Light coloured, microcrystalline dolostone erosionally overlain by dark grey limestone including, in the basal part, dolostone pebbles and a thin bed of pyritic shale. The dolostone consists of interbedded mud - and wackestones. In the lower part the bedding is discontinuous, in the upper part the dolostone resembles a sedimentary breccia and includes several dessicated and erosional surfaces. It is sharply overlain by a conglomerate composed of dolostone pebbles and granules set in a dark grey calcite-mudstone matrix. The upper part of the sample is a fossiliferous wacke- to floatstone including pale coloured patches of partly dolomitized limestone. Dahadinni M-43A well. depth 1502.6 m (4930 ft); Arnica Fm.

d. Upper part of a regressive sedimentary sequence in anhydritic rocks. Basal part is a light grey, laminated, microcrystalline, somewhat dolomitic anhydrite mudstone. The beds are locally broken up in a fashion reminescent of a mud-cracks. The laminated interval is overlain by a wackestone composed of unsorted, light grey, dolomitic particles, grey anhydrite nodules and a matrix of microcrystalline, anhydritic dolostone. The upper, dark coloured bed is a laminated, microcrystalline anhydrite-mudstone. The sharp contact below the dark bed marks the top of the regressive phase of deposition. Dahadinni M-43A well, depth 1703.4 m (5588.5 ft); Fort Norman Fm.

e. Light brown, stromatolitic dolostone overlain by greenish grey, stromatolitic anhydrite. The dolostone is microcrystalline, includes undulating and hemispherical, anhydritic laminae; darkbrown aggregates of crystallotopic anhydrite; discontinuous, anhydrite filled fractures and anhydrite veins; partly anhydritized styloliths; and an anhydrite nodule. The anhydrite bed is somewhat dolomitic. The stromatolitic laminae are locally broken up in fragments and are separated by anhydrite veins, light coloured anhydrite inclusions and styloliths. Willow Lake L-59 well, depth 411.1 m (1349 ft); Arnica Fm.

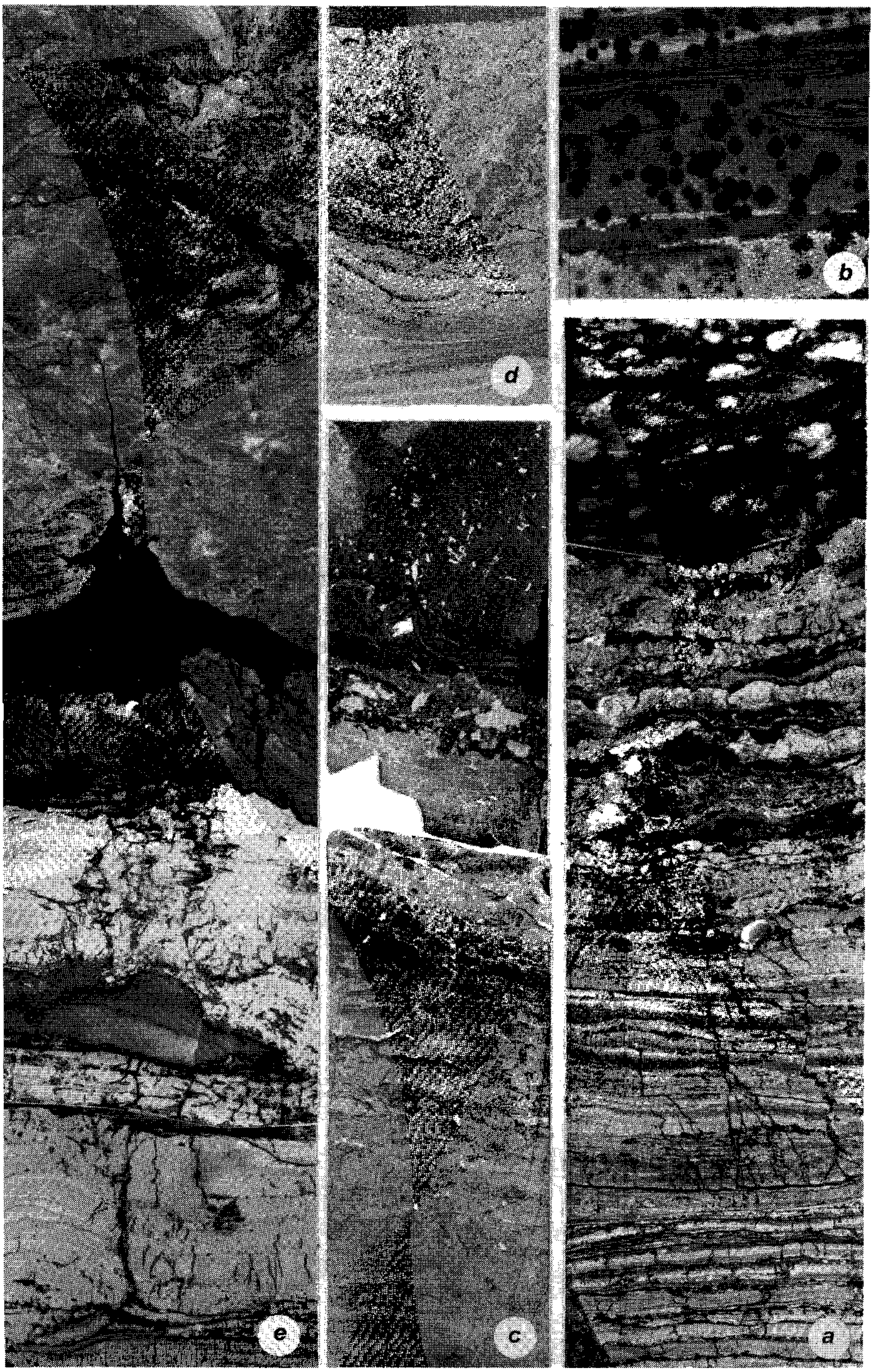

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PLATE XIV

Representative core samples of the evaporite and carbonate-ramp facies (reduction 72 %).

a. Nodular anhydrite overlain by anhydritic dolostone. Sample includes five units. Basal unit of nodular anhydrite includes shaly partings and undulating gypsum veins. Unit 2, a pale coloured microcrystalline, pyritic dolostone is a mudstone with relicts of calcite cement. It grades upward into unit 3, a dolostone that contains dark fractures and aggregates of crystallotopic anhydrite. This contact represents a dessicated, mud-cracked surface. It is overlain by unit 4, a flat pebble conglomerate, composed of pale coloured, crust-like fragments and an anhydritic matrix. This unit consists of two parts that are separated by mudstone. The upper part of unit 4 grades upward into unit 5, a dark, very argillaceous, finely crystalline anhydrite including grains and granules of mudstone. It is an anhydritized wackestone. Harris River A-31 well, depth 299.6 m (983 ft); Upper member, Chinchaga Fm.

b. Laminated, porous, micro-crystalline dolostone sharply overlain by dolostone breccia. Laminated dolostone is a finely peloidal wackestone including dark grey, argillaceous layers. Breccia includes subangular fragments of, laminated, greyish brown wackestone, dark grey pyritic shale and irregularly shaped, light and dark coloured mudstone. Willow Lake L-59 well. depth 404.9 m (1328.5 ft); Arnica Fm.

c. Micro- to very finely crystalline, slightly argillaceous dolostone containing fragments of amphipores, corals, crinoids, brachiopods and ?ostracodes. This lithology is common in the Arnica Formation. Dahadinni M-43A well, depth 3036.7 m (9963 ft); lower part Fort Norman Fm.

d. Greyish brown, micro-crystalline dolostone overlain by dark grey, somewhat argillaceous dolostone. The paler dolostone is finely peloidal and includes vugs filled with white calcite. The dark dolostone is indistinctly laminated. The contact between the two beds is irregular and may represent a hiatus. Highland Lake K-42 well, depth 641.6 m (2105 ft); Arnica Fm.

e. Laminated limestone sharply overlain by dark marl. Lower part of limestone includes scattered granules. In the upper part the laminae are distorted by fenestral voids filled with white dolomite and clear calcite. Near the top are charophyte oogonia. The contact between the limestone and the dark marl may represent a burrowed surface. The marl is laminated and includes light grey, peloidal lenses and charophyte oogonia. Hay River I-41 well, depth 92.9 m (305 ft); Sulphur Point Fm, upper member.

f. Nodular, pale green mottled limestone. Lower part includes many calcispheres and burrow like structures filled with mud clasts and pale green, pyritic, calcareous shale. This interval is overlain by a finely to coarsely peloidal grainstone with scattered ostacodes, calcispheres, charophyte oogonia and mud clasts. The grainstone is cemented by calcite, but locally reddish brown and pale green, calcareous clay is present. Arrowhead No. 1 well, depth1931.8 m (6638 ft); Headless Fm.

g. A pyritic (arrow) crust separates two limestone beds. Lower includes charophyte oogonia, fragments of crustaceans and calcite filled burrows. Upper is a laminated mudstone with fenestral vugs, small sediment filled burrows, stromatolitic layers and dessication cracks. Rabbit Lake No. 2 well, depth 804.3 m (2639 ft); Slave Point Fm, Fort Vermilion equivalent.

h. Cross-laminated mudstone underlies breccia like floatstone. Mudstone consists of very fine to fine dolomitic peloids, scattered anhydritic mudstone particles and an anhydrite matrix. Floatstone includes pale, dolomitic and dark, anhydritic fragments in a matrix of microcrystalline anhydrite. Strong Point G-24 well, depth 643.8 m (2112.5 ft); Fort Norman Fm.

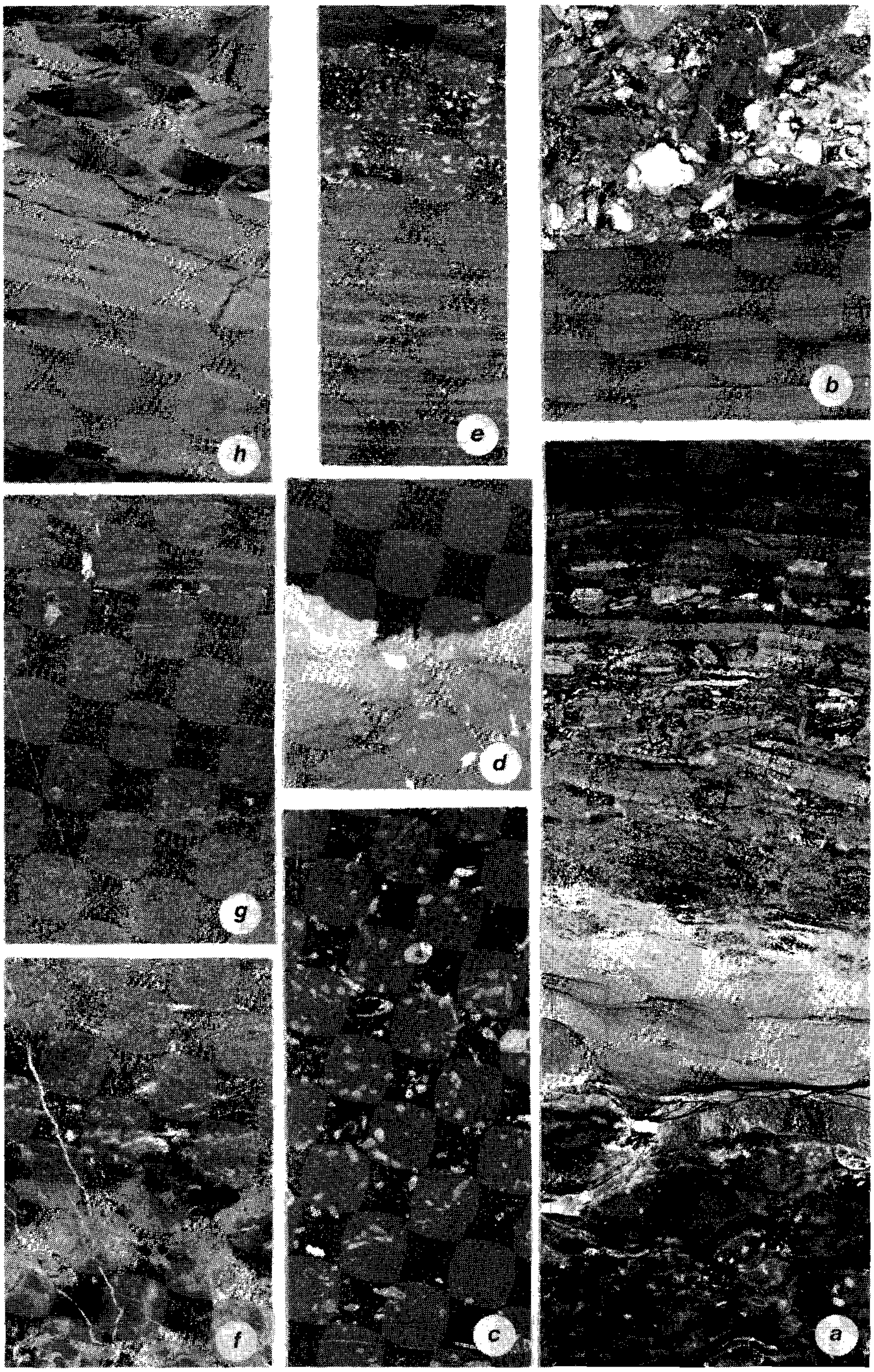
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PLATE XV

Representative core samples of the carbonate ramp and platform facies (reduction 72 %).

a. Contact between Headless (below) and Nahanni (above). Headless Formation is a pale greenish grey, argillaceous and silty limestone. Nahanni Formation is a greyish brown, aphanitic limestone, in places somewhat peloidal, including irregular, partly dolomitized mottles, gastropods and ostracodes. Fort Simpson M-70 well, depth 666.5 m (2187 ft).

b. Burrowed surface separates greyish brown, somewhat silty limestone (below) and dark grey, laminated limestone (above). The lower part is a finely peloidal mudstone including dark grey mottles and deformed burrows or vugs, partly filled with sediment and partly with white or clear calcite. One burrow and a depression in the burrowed surface (arrows) are partly filled with coarse particles and peloids. The upper limestone is a argillaceous mudstone with lighter coloured layers and lenses including particles and peloids. Jean Marie N-73 well, depth 742.6 m (2436.5 ft); Lonely Bay Fm, Dolostone Member.

c. Greyish brown, reefal limestone including autochthonous (framestone) and allochthonous (floatstone) beds. Basal framestone consists of a colony of digital stomatoporoids and original porosity is filled with very dark grey wackestone or white calcite. The upper floatstone is composed of fragments of digital stromatoporoids in a wackestone matrix. It includes dark shale partings. A tabular stromatopore, possibly in situ, is also present. Arrowhead I-46 well, depth 1966.1 m (6450.5 ft); Undivided map-unit, Sulphur Point equivalent.

d. Greyish brown, peloidal packstone partly cemented by clear or white calcite, partly pale green or red brown, silty clay. Limestone includes peloids, coated peloids, oncoids and pebble-like aggregates of coated peloids. Arrowhead I-46 well, depth 2089.2 m (6901 ft); Landry equivalent.

e. Light brown and brown, nodularly bedded limestone. Lower bed is a peloidal packstone with scattered, calcite filled vugs, dark grey stylolitic shale partings and fossil fragments, including a bulbous stromatopore. Upper bed is a peloidal wackestone with scattered fenestral and interpeloidal vugs filled with calcite. It includes corals and a brachiopod partly filled with sediment and partly with cement (a geopetal structure). Willow Lake G-32 well, deth 335.2 m (1100 ft); Lonely Bay Fm, Limestone Member.

f. Fossiliferous limestone including fragments of digital stromatoporoids (Stachyodes) encrusted by calcareous algae. Arrowhead I-46 well, depth 1939.8 m (6364.5 ft); Undivided map-unit.

g. Greyish brown, reefal limestone. A Stachyodes floatstone with a nodular wackestone matrix, including ostracodes and calcispheres. The interfossil cavities are filled with pale, laminated calcite-mudstone, claystone and clear calcite. The irregular, very dark grey shale inclusion in the upper part of the sample fills a dissolution cavity. Trainor L-59 well, 1794.5 m (5887.5 ft); Sulphur Point Fm, lower member.

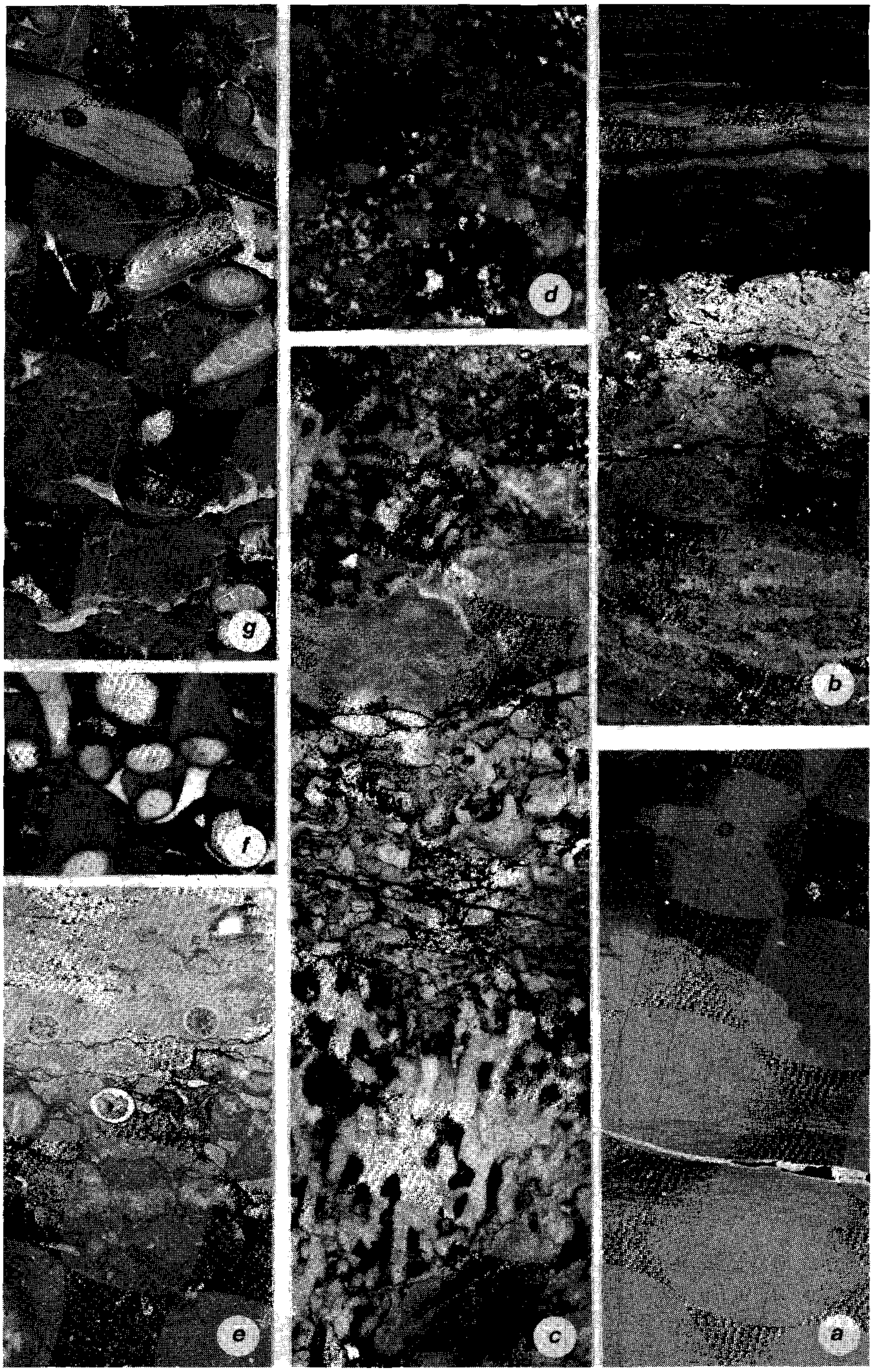
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PLATE XVI

Representative core samples of the shale facies
(reduction 72 %).

a. Two beds of greyish brown limestone separated by very dark grey, bituminous marl. Note scoured surfaces. The limestone is a finely peloidal grainstone cemented by calcite and includes fragments of digital stromatoporoids, crinoids, brachiopods, ostracodes, tentaculitids and gastropods. The marl contains many, compressed tentaculitids. NWT Deep Bay No. 3 well, 220.6 m (724 ft); Bituminous Shale and Limestone Beds.

b. Very dark greyish brown, argillaceous limestone. Lower part is a mudstone with scattered fragments of brachiopods, crinoids, tentaculitids and pale coloured nodular inclusions and burrow like structures. Upper part is a floatstone with many Leiorhynchus type brachiopod shells and tentaculitids. Limestone is overlain by dark shale. Willow Lake H-10 well, 153 m (502 ft); Lonely Bay Fm, Leiorhynchus Beds.

c. Greyish brown, nodular and argillaceous limestone bed including, in the upper part, a deposit of mudstone pebbles and microfossils (tentaculitids, ostracodes and charophyte oogonia). Punch Deep Bay No. 3 well, 164.1 m (538.5 ft); Spence River Fm, top of a clinoform marker.

d. Wavy interbedded and interlaminated greenish grey, calcareous shale and greyish brown, very argillaceous limestone. Mills Lake B-41 well, depth 100.8 m (331 ft); Hay River Fm.

e. Regularly interbedded and interlaminated greenish grey, calcareous shale and dark grey, bituminous shale. Providence K-45 well, deth 196.4 m (644.5 ft); Spence River Fm.

f. Dark greyish brown, argillaceous limestone (mudstone) with a sediment filled burrow. Ebbutt J-70 well, depth 326.7 m (1072 ft); Nahanni Fm, Leiorhynchus beds.

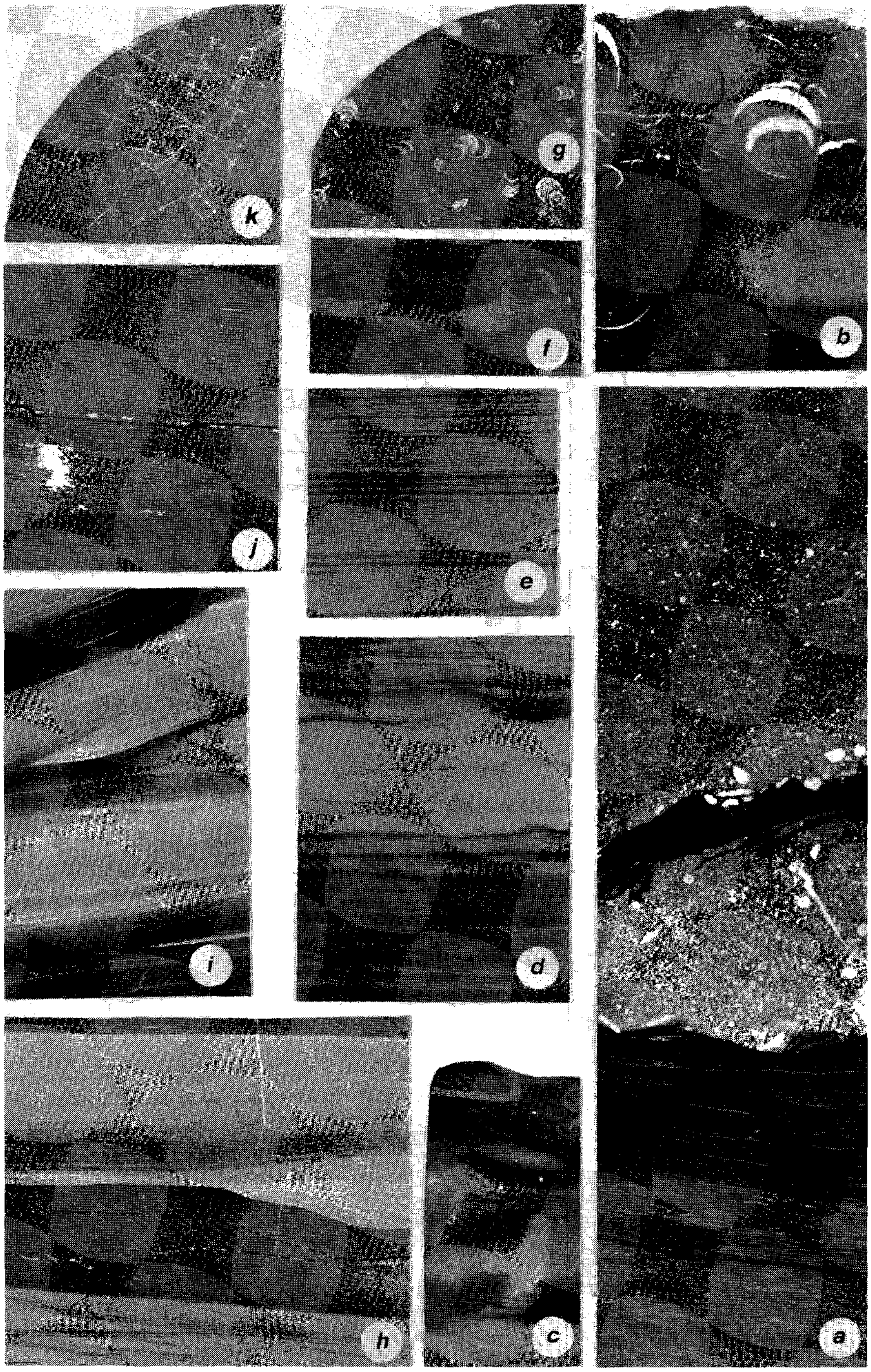
g. Bedding surface of very dark grey, calcareous shale with Lingula type brachiopod shells. Willow Lake H-10 well, depth 152.2 m (499.5 ft) Lonely Bay Fm, Leiorhynchus Beds.

h. Interbedded very dark grey, pyritic - and dark greenish grey, crosslaminated, silty shale. Sample includes a scoured surface and infill structure. Some beds are graded. Enlargement 1.5 x. Rabbitskin I-08 well, depth 417.7 m (1370.5 ft); Spence River Fm.

i. Parallel interlaminated and crosslaminated light grey marl and dark grey shale. Interval is somewhat pyritic includes scoured surfaces, infill stuctures and graded beds. Dahadinni M-43A well,depth 1405.4 m (4611 ft); Funeral Fm.

j. Very dark grey, evenly laminated shale with pyritic layers and an interval replaced by pyrite (white on photograph). Ebbutt D-50 well, depth 456.1 m (1496.5 ft); Spence River Fm.

k. Bedding surface of very dark grey shale with pyritic sponge spicules. Willow Lake B-28 well, 610.9 m(2004.5 ft); Spence River Fm.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CURRICULUM VITAE

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Nick is a devoted field geologist and print-maker artist.

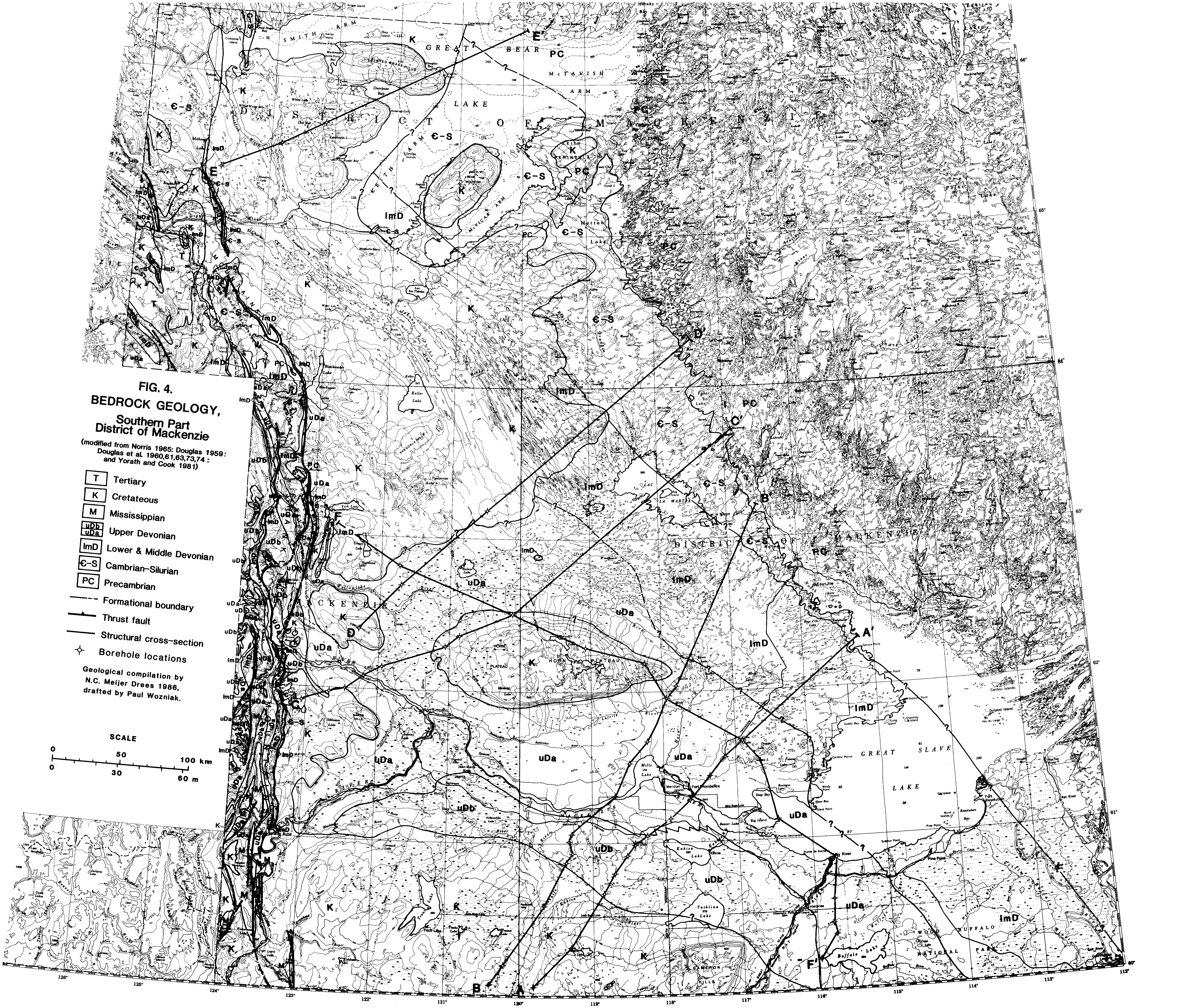
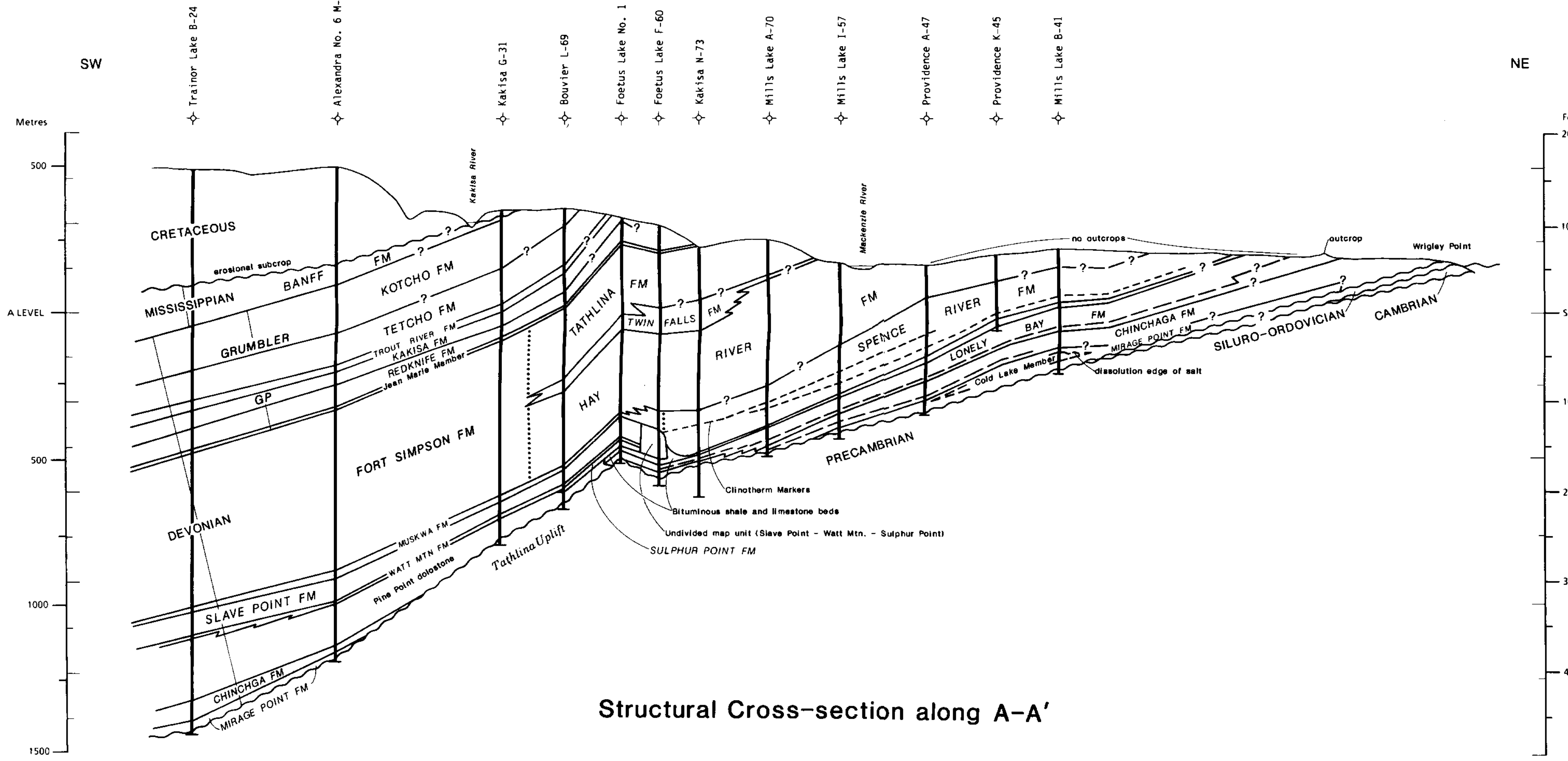


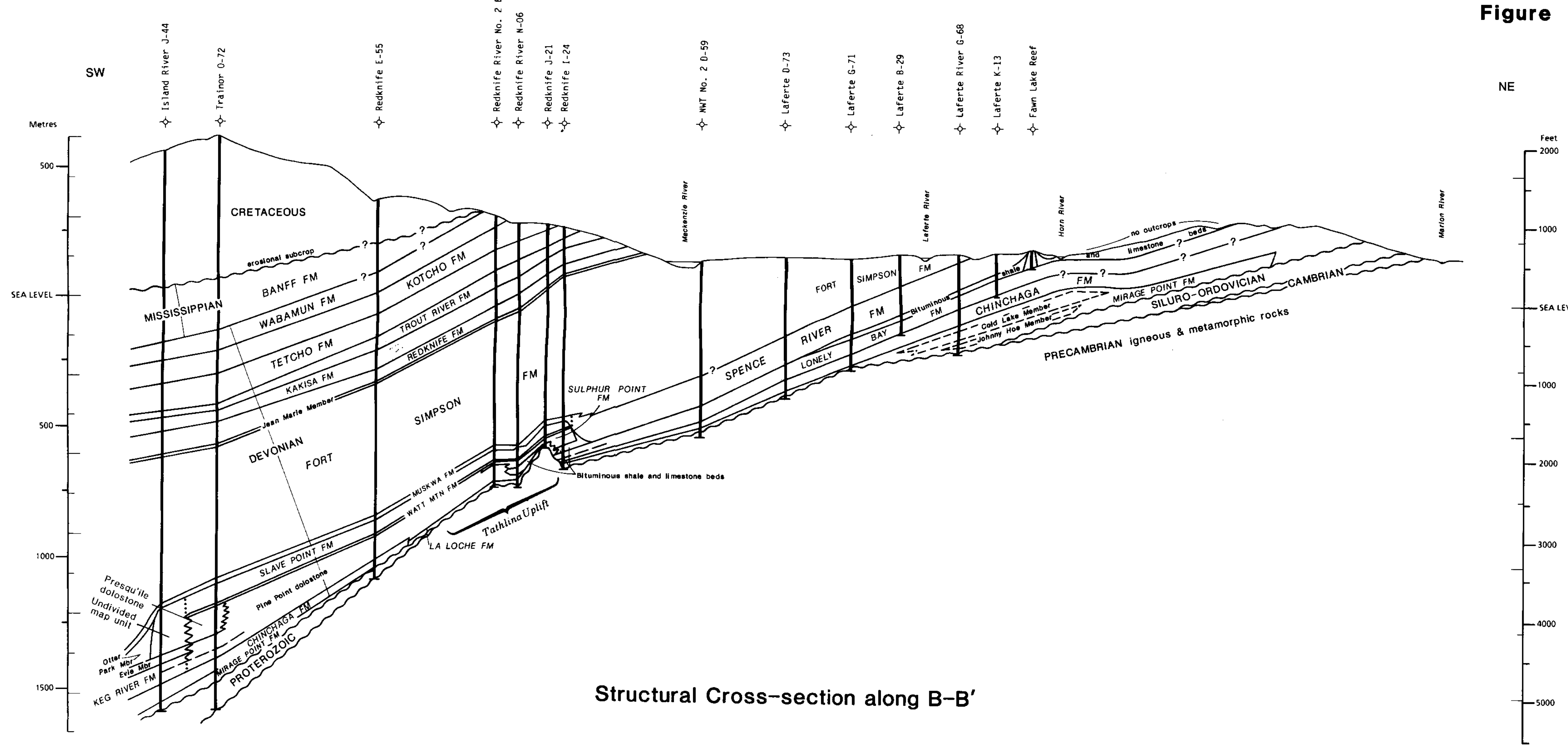
FIG. 4.
BEDROCK GEOLOGY,
Southern Part
District of Mackenzie
(modified from Norris 1965: Douglas 1959: Douglas et al. 1960,61,63,73,74: and Yorath and Cook 1981)
T Tertiary
K Cretateous
M Mississippian
uDb uDa Upper Devonian
lmD Lower & Middle Devonian
Є-S Cambrian-Silurian
PC Precambrian
Formational boundary
Thrust fault
Structural cross-section
Borehole locations
Geological compilation by N.C. Meijer Drees 1986, drafted by Paul Wozniak.
SCALE
0 50 100 km
0 30 60 m
GREAT BEAR LAKE
SMITH ARM
McTAVISH ARM
KEITH ARM
McVICAR ARM
DISTRICT OF MACKENZIE
HORN PLATEAU
GREAT SLAVE LAKE
WOOD BUFFALO NATIONAL PARK
CAMERON HILLS
Fort Simpson
Fort Providence
Fort Resolution
Mills Lake
Keller Lake
Kakisa Lake
Tathlina Lake
Buffalo Lake
Hay River
Yellowknife
A A' B B' C C' D D' E E' F F'
66° 65° 64° 63° 62° 61° 60°
126° 125° 124° 123° 122° 121° 120° 119° 118° 117° 116° 115° 114° 113° 112°

Figure 5



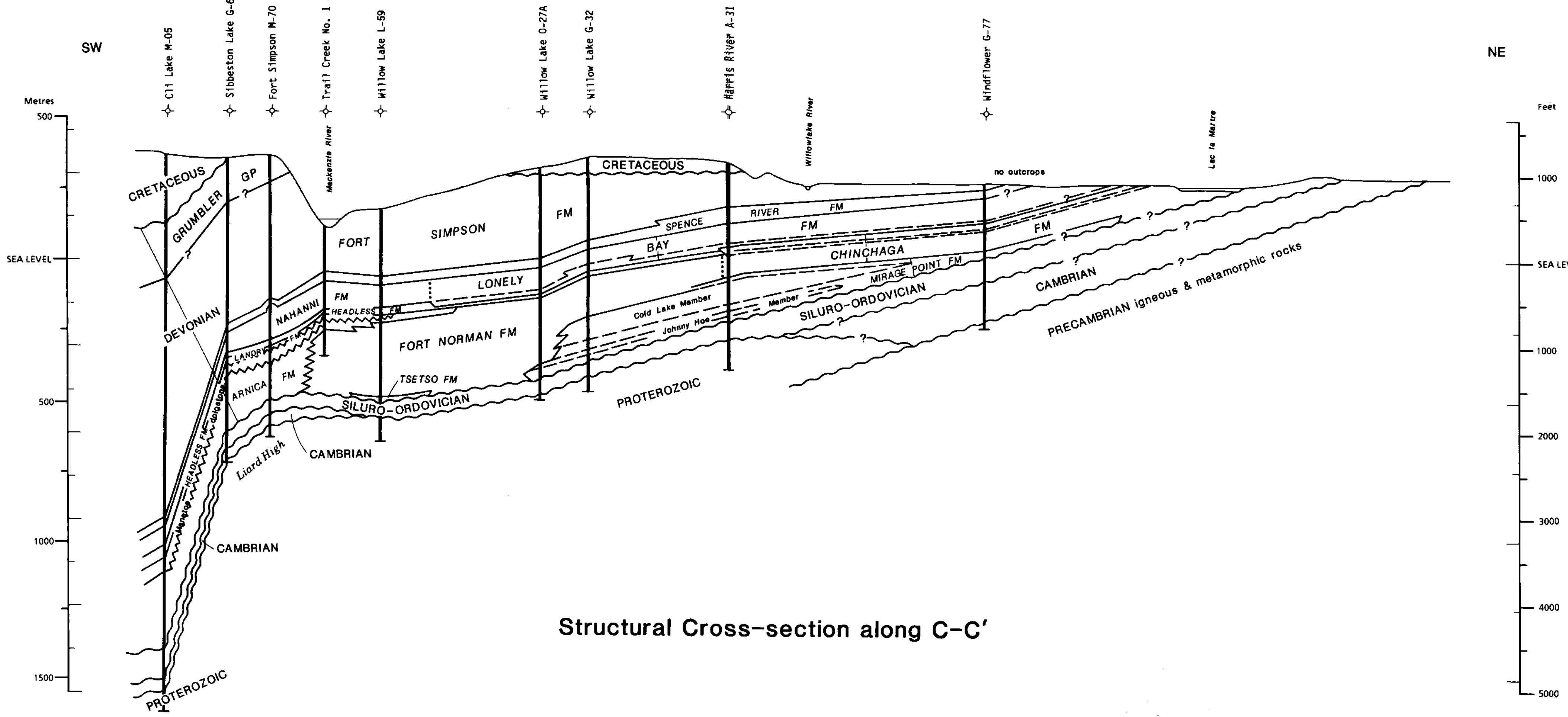
Structural Cross-section along A-A′

Figure 5



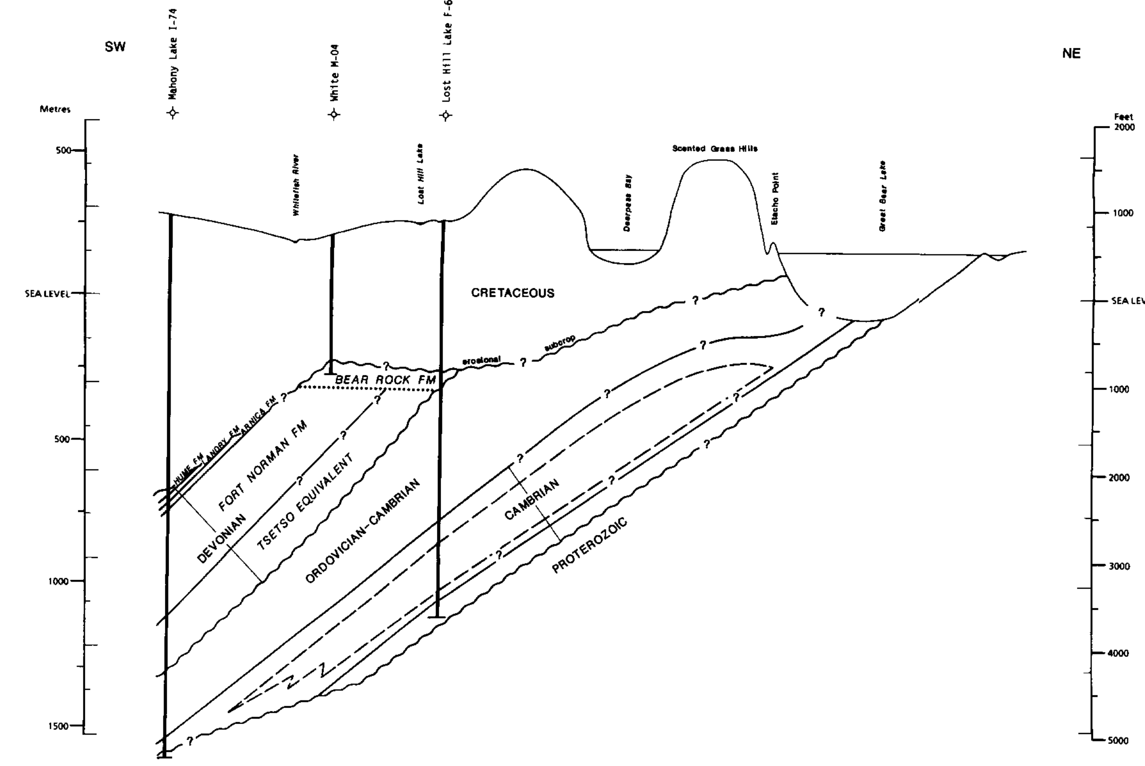
Structural Cross-section along B-B′

Figure 5



Structural Cross-section along C-C′

Figure 5



Structural Cross-section along E-E′

Figure 5

Legend

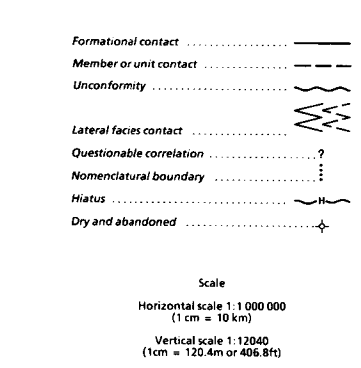
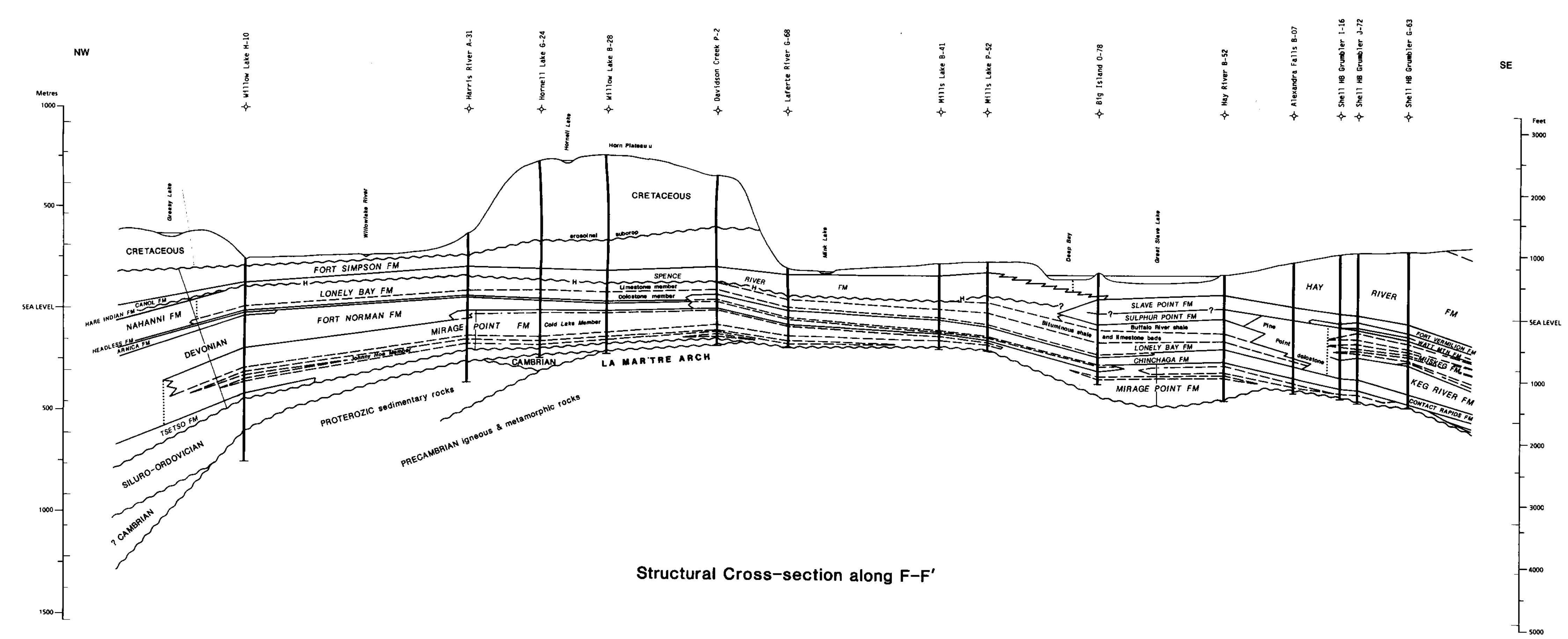
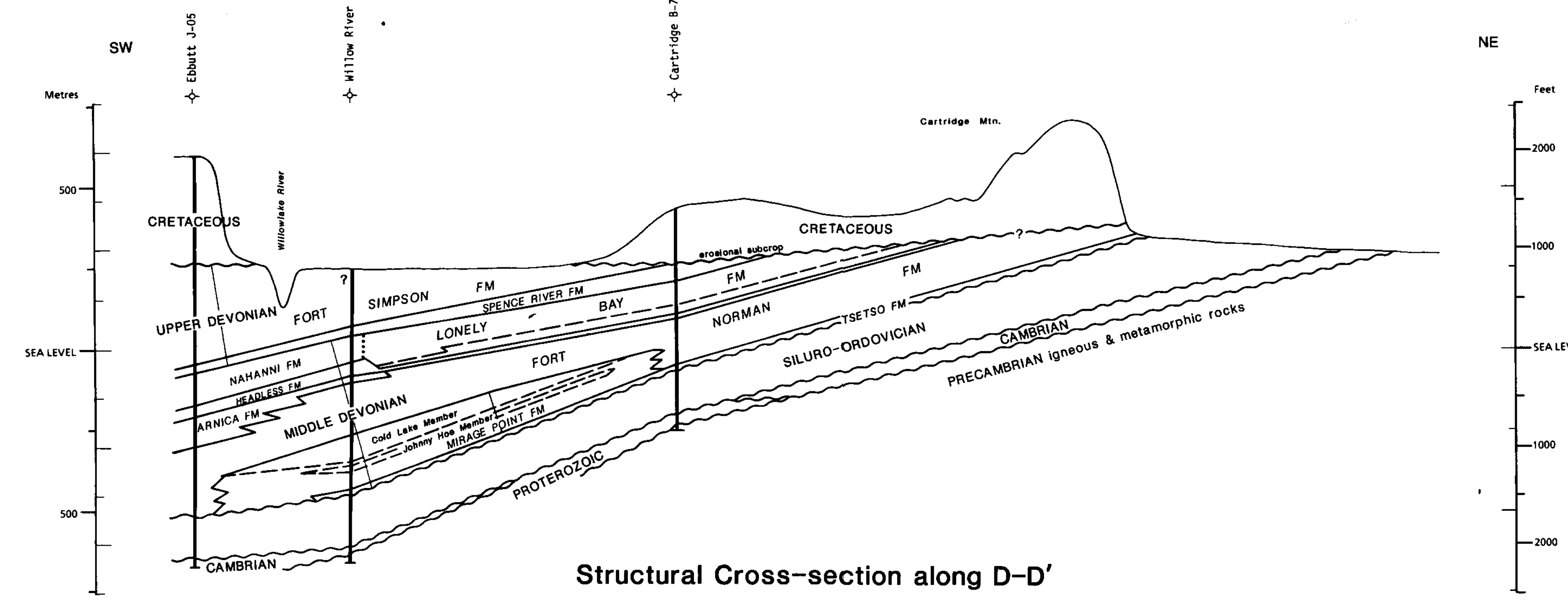


Figure 5



Structural Cross-section along F-F′

Figure 5



Structural Cross-section along D-D′