GSC OPEN FILE No. 2055

STRUCTURAL CROSS-SECTIONS AND STRATIGRAPHY OF DEVONIAN ROCKS IN THE GREAT SLAVE AND GREAT BEAR PLAINS, DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES, CANADA.

Geological compilation by N.C.Meijer Drees;
drafting by Paul Wozniak.

INTRODUCTION

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 of Proterozoic, Paleozoic and Mesozoic ages. (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 terrain which is the extension of the Canadian Shield.

The general wedge shape of the Interior Platform is evident on cross-section (see sections A-A', B-B', C-C' and D-D'). The general homoclinal dip to the west and southwest is shown on a structural map (see Fig. 2). 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.

TECTONIC UPLIFTS AND FAULTS

The major tectonic structures are indicated on the structural contour map of the pre-Devonian surface (Fig. 2). 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. The configuration of the contour lines 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' 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. 1). 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. 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 before the Cretaceous rocks were deposited.

Liard High (law, 1971), a north trending structural and pre-Devonian paleotopographic high located just southwest of Martin Hills, forms the crestal part of La Martre Arch on Figure 2. On the pre-Devonian surface it is about 750 m high. On cross-section C this 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 2 outlines three closures north of Tathlina Lake and east of Kakisa Lake that represent local pre- Devonian high areas or uplifts. The interpretation of Sikabonyi and Rodgers (1959), Belyea (1971) and Wiliams (1977b) is that they are tectonic uplifts controlled by northeasterly trending, subvertical faults. The shape of the closures 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 on cross section B and appears to represent a pre-Devonian structure. The high structures penetrated by the Redknife River No. 2, E-33 well on cross section B and the Foetus Lake No 1, D-06 well on cross section A may represent fault controlled uplifts.

South of Smith Arm, on 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 (see Cook and Aitken, 1971) and may extend southward into the structure that is present in the subsurface between two wells in the Whitefish River area.

In the area south of Fort Norman the Devonian succession was removed by pre-Cretaceous erosion along the crest of Keele Arch, a north-south trending 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 in this well 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 the Early Devonian period.

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 Figure 2.

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 2.

Although cross-section E-E' does not suggest the presence of faults in the area west of the Keith Arm of Great Bear Lake, seismic information, submitted by BP Exploration Canada Ltd to the Government (file no. 039-06-05-033), in the form of a time structure map of the interval " Base Cambrian salt to top Cambrian", indicates the contrary. On this map the White M-04 well is located near the high edge of a northeasterly trending fault that has a downward displacement to the southeast of about 145 milli-seconds (corresponding to 300 to 400 m). The fault extends into the region just northwest of the Lost Hill Lake F-62 well, which is located in the down faulted block.

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. 3). 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.

A summary of the sedimentary and facies pattern in the central part of the Great Slave Plain, given in Figure 3, 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. The information from 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

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 in the late Middle Devonian (see Meijer Drees, 1988). The amount of section that was locally removed probably varies between 0 and 25 m.

STRATIGRAPHIC SEQUENCES

The stratigraphic information compiled in Figure 3 suggests that the Devonian in the District of Mackenzie includes seven sequences separated by minor unconformities.

Stratigraphic sequence number 1 onlaps a pre-Devonian upland and includes the Tsetso and the Camsell formations. Stratigraphic sequence number 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 number 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 reef mounds of the Pine Point dolostone. Sequence number 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 number 6 onlaps and erosionally overlies sequence 5. It includes the Watt Mountain, Fort Vermilion and Slave Point formations. Stratigraphic sequence number 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 Beaverhill Lake and Grumbler groups.

It is evident from the information summarized on 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 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.

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 sedimentary sequences in the study area are dominated by undathem deposits composed of carbonates and evaporites.

NON-TECTONIC STRUCTURES

There is evidence that in the past the processes of differential compaction and collapse due to dissolution of mineral deposits in the subsurface were active in the subsurface. The first process is active during periods of sedimentary deposition. The second process operates during periods of uplift and emergence.

During burial and associated compaction the reef mounds and the Presqu'ile Barrier acted as relative rigid structures. In the vicinity of these structures the overlying shale beds are draped around the mounds or dip away from the barrier edge. Vopni and Lerbekmo (1972) recorded dips of 15 degrees in the vicinity of the Fawn Lake reef mound. Norris (1965, p. 43) reported gently folded limestone beds along Clive River southwest of Clive Lake. These folds may indicate the presence of a reef mound in the subsurface. The southward dipping beds in the subsurface west of Windy Point on the northwest side of Great Slave Lake, shown in cross-section by Norris (1965, Fig. 8), probably are the result of draping over the Presqu'ile Barrier edge. Structural cross-sections A-A'and B-B' across Presque'ile Barrier indicate that draping along the reef flank is only of a local nature.

The outcrop region of the Devonian succession southwest of the Canadian Shield is characterized by the occurence of nummerous, small collapse stuctures that are the result of underground dissolution. Norris (1965) mentioned the presence of sinkholes and ephemeral lakes in the areas south and northwest of Great Slave Lake. In the Northwestern part of the Great Bear Plain, van Everdingen (1981) described similar karst features and showed that some lakes and rivers are being drained by a system of underground cavities.

Surface water disappears underground and appears elsewhere in springs. Some of the spring water in the region south of Great Slave Lake is saline.. The spring water in the region north of Great Slave Lake and west of Great Bear Lake is relatively rich in calcium sulfate. There is thus reason to believe that at present dissolution of evaporites in the subsurface by groundwater is an active process that leads to brecciation and local collapse of bedrock carbonates.

It is reasonable to assume that the process of leaching was also active in the geological past. The presence of the erosional unconformity between the Devonian to Mississippian strata and the Cretaceous beds suggest that leaching may have occurred during the pre-Cretaceous period of uplift and erosion. The presence of a structural depression northeast of the salt deposits of the Cold Lake Member on cross-sections A-A',B-B',C-C' and D-D'indicates that the situation in the Great Slave Plain is similar to that in northeastern Alberta and central Saskatchewan, where the leaching of salt was dated as pre-Cretaceous and post-Cretaceous (see Holter, 1969 and Meijer Drees, 1985).

On cross-section E-E' the suggestion is made that the salt deposits of the Cambrian Saline River Formation thin to zero in an updip direction because of the above described dissolution process. The presence of a regional collapse structure is indicated.

REFERENCES

Balkwill, H.R.
1971: Reconnaissance geology, southern Great Bear Plain, District of Mackenzie; Geological Survey of Canada, Paper 71-11.

Belyea, H.R.
1971: Middle Devonian tectonic history of the Tathlina Uplift, southern District of Mackenzie and northern Alberta; Geological Survey of Canada, Paper 70-14.

Cook, D.G.
1975: The Keele-Arch - A pre-Devonian and pre-Lake Cretaceous paleo-upland in the northern Franklin Mountains and Colville Hills; **in** Report of Activities; Geological Survey of Canada, Paper 75-1C, p. 243-246.

Douglas, R.J.W.
1959: Great Slave Lake and Trout River map areas, Northwest Territories; Geological Survey of Canada, Paper 58-11.

1974: Geology Trout River, District of Mackenzie; Geological Survey of Canada, Map 1371A.

Douglas, R.J.W., Gabrielse, H., Wheeler, J.O., Stott, D.F., and Belyea, H.R.
1970: Geology of Western Canada; **in** Geology and Economic Minerals of Canada, R.J.W. Douglas (ed.); Geological Survey of Canada, Economic Geology Report No. 1, p. 366-488.

Douglas, R.J.W., Norris, A.W., and Norris, D.K.
1974: Geology Horn River, District of Mackenzie; Geological Survey of Canada, Map 1372A.

Douglas, R.J.W. and Norris, D.K.
1960a: Horn River map-area, Northwest Territories; Geological Survey of Canada, Paper 59-11.

1960: Virginia Falls and Sibbeston Lake map areas, Northwest Territories; Geological Survey of Canada, Paper 59-6.

1961: Camsell Bend and Root River map areas; District of Mackenzie, Northwest Territories; Geological Survey of Canada, Paper 61-13.

1963: Dahadinni and Wrigley map areas, District of Mackenzie, Northwest Territories; Geological Survey of Canada, Paper 62-33.

1973: Geology Wrigley, District of Mackenzie; Geological Survey of Canda, Map 1373A.

1974a: Geology Sibbeston Lake, District of Mackenzie; Geological Survey of Canada, Map 1377A.

1974b: Geology Camsell Bend, District of Mackenzie; Geological Survey of Canada, Map 1375A.

1976: Geology Fort Liard, District of Mackenzie; Geological Survey of Canada, Map 1379A.

Law, J.

1955: Geology of northwestern Alberta and adjacent areas; American Association of Petroleum Geologists, Bulletin, v. 39, p. 1927-1975.

1971: Regional Devonian geology and oil and gas possibilities, Upper Mackenzie River area; Bulletin of Canadian Petroleum Geology, v. 19, no. 2, p. 437-486.

Holter, M.E.

1969: The Middle Devonian Prairie Evaporite of Saskatchewan; Department of Mineral Resources, Saskatchewan, Report No. 123, 134 p.

Meijer Drees, N.C.

1986: Evaporite deposits of Western Canada; Geological Survey of Canada, Paper 81-18.

1988: The Middle Devonian sub-Watt Mountain unconformity across the Tathlina Uplift; District of Mackenzie and northern Alberta, Canada; **in** Devonian of the world, N.J. McMillan, A.F. Embry and D.J. Glass (eds.), Proceedings of the Second International Symposium on the Devonian System, Canadian Society of Petroleum Geologists, Calgary, Alberta; v. II, p. 477-494.

Norris, A.W.

1965: Stratigraphy of Middle Devonian and older Paleozoic rocks of the Great Slave Lake region, Northwest Territories; Geological Survey of Canada, Memoir 322.

Sikabonyi, L.A. and Rodgers, W.J.

1959: Paleozoic tectonics and sedimentation in the northern half of the Western Canada basin; Journal of Alberta Society of Petroleum Geologists, v. 7, p. 193-216.

van Everdingen, R.O.

1981: Morphology, hydrology and hydrochemistry of

karst in permafrost terrain near Great Bear Lake, Northwest Territories; National Hydrology Research Institute, Paper 11.

Vopni, L.K. and Lerbekmo, J.F.
1972: The Horn Plateau Formation: A Middle Devonian coral reef, Northwest Territories, Canada; Bulletin of Canadian Petroleum Geology, v. 20, p. 498-548.

Williams, G.K.
1975: "Arnica platform dolomite", District of Mackenzie; Geological Survey of Canada; in Report of Activities, Part C; Geological Survey of Canada, Paper 75-1C, p. 31-35.

1977: The Celibeta structure compared with other basement structures on the flanks of the Tathlina High, District of Mackenzie; in Report of Activities, Part B; Geological Survey of Canada, Paper 77-1B, p. 301-310.

Yorath, C.J. and Cook, D.G.
1981: Cretaceous and Tertiary stratigraphy and paleogeography, northern Interior Plains, District of Mackenzie; Geological Survey of Canada, Memoir 398.

Government of Canada / Gouvernement du Canada

MEMORANDUM NOTE DE SERVICE

TO / A: Dr. R.P. Riddihough
Acting Director General
Programs, Planning and Central Services

FROM / DE: Scientific Editior, I.S.P.G.

SECURITY - CLASSIFICATION - DE SÉCURITÉ	
OUR FILE – N / RÉFÉRENCE	GS9680-6-1
YOUR FILE – V / RÉFÉRENCE	
DATE	May 2, 1989

SUBJECT / OBJET: **O.F. 2055**

Permission is requested to release the following open file material:

O.F. 2055: STRUCTURAL CROSS-SECTIONS AND STRATIGRAPHY OF DEVONIAN ROCKS IN THE GREAT SLAVE AND GREAT BEAR PLAINS, DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES, CANADA
by N.C. Meijer Drees

This unedited open file comprises a bedrock geology map at a scale of 1:1 000 000 accompanied by cross-sections, a table of formations and a contour map. A short report also accompanies the open file which is available at a cost of $18.00 from Riley's Datashare International of Calgary. Copies may also be viewed at all Geological Survey of Canada libraries.

Lynn Madden-Bourke (per)

N.C. Ollerenshaw
Geoscience Publications Subdivision, ISPG

C. L. [illegible]