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Sub-Paleozoic Structure in Manitoba's Northern Interlake Along the Churchill Superior Boundary Zone: A Detailed Investigation of the Falconbridge William Lake Study Area

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Sub-Paleozoic Structure in Manitoba's Northern Interlake Along the Churchill Superior Boundary Zone: A Detailed Investigation of the Falconbridge William Lake Study Area

by R.K. Bezys
Winnipeg, 1996

This publication is available in large print, audiotape or braille on request

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INTRODUCTION

This report provides a preliminary interpretation of the sub-Paleozoic and Paleozoic structural and isopach variations in the William Lake area. The work is based on data compiled from drill core supplied by Falconbridge Limited from recent exploration along the southwestern extension of the Thompson nickel belt.

The drill core from 42 Paleozoic holes was logged in the summer of 1993. This report deals with 37 cores in the immediate vicinity of William Lake (NTS 63G/14). Interpretations, however, are based on all the available Falconbridge Limited cores, core from two Geological Services drillholes, and confidential Paleozoic core data from nearby properties. The names and locations of the latter are omitted.

Figures 7 to 16 in this report are reduced from 1:50 000 maps that accompany Manitoba Energy and Mines, Open File OF94-3 (Preliminary), which is available for viewing at the department library. Copies of the maps are available from Manitoba Energy and Mines at the cost of reproduction.

The drill logs for all drillholes and a detailed description of the geological units intersected in the Williams Lake core, and photographs of the drill core from two of the drillholes are contained in Appendix A and Appendix B in Manitoba Energy and Mines, Open File OF94-3 (Preliminary). The drill logs and photographs are available for reproduction at cost.

REGIONAL GEOGRAPHY AND GEOLOGICAL SETTING

William Lake is located 500 km north of Winnipeg, west of Provincial Highway 6 (Fig. 1). The area around William Lake is part of the Manitoba Lower Paleozoic outcrop belt. This outcrop belt is located on the northeast edge of the Williston Basin, which is part of the Western Canada Sedimentary Basin (Fig. 2). The Paleozoic stratigraphic succession presented in this report encompasses both clastic and carbonate sedimentary rocks deposited from Ordovician to Silurian time. This sedimentary succession is equivalent to the Tippecanoe sequence (Norford *et al.*, 1994) of Sloss (1963).

The Manitoba outcrop belt approximately parallels regional structural contours for the Precambrian surface (Fig. 2, 3). The Ordovician outcrop belt shows marked change in lithology and stratigraphic thickness that support north and south variations in a complex tectonic and depositional framework. The outcrop succession is not marginal to the depositional basin, but exposes a series of dip sections of the original basin that show the maximum possible isopach and lithofacies variation. Outcrops typical of the deeper basinal Ordovician occur at the southern end of the outcrop belt, whereas marginal facies occur in outcrops along the northern edge of the outcrop belt (*cf.* McCabe and Barchyn, 1982).

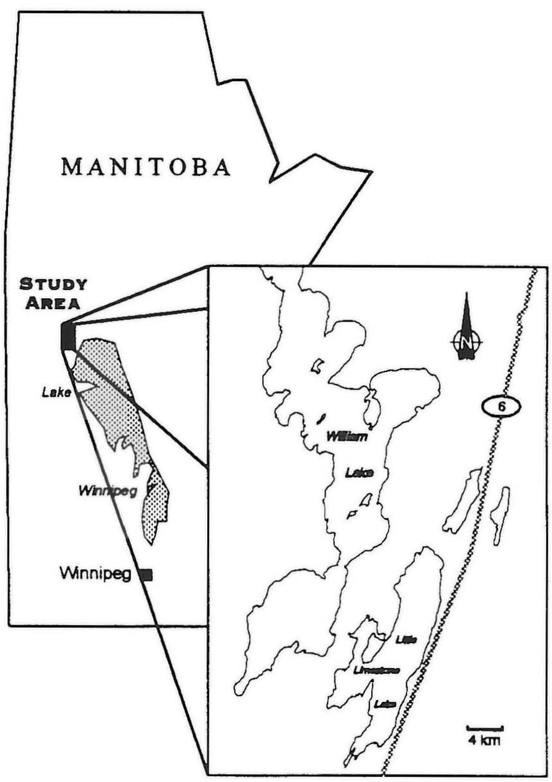


Figure 1: Location of the William Lake study area.

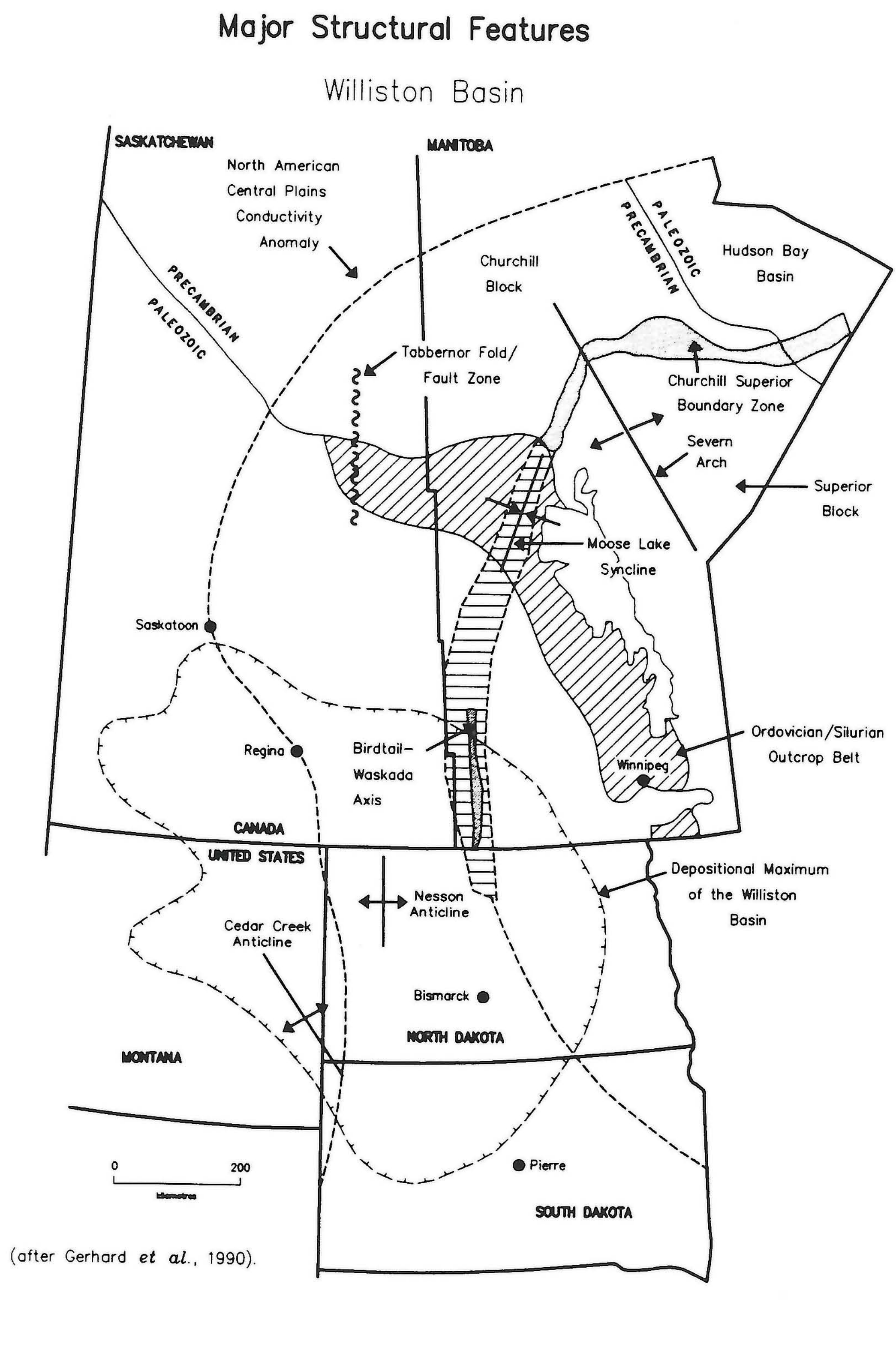


Figure 2: Major structural features in the Williston Basin (after Gerhard et al.*, 1990).*

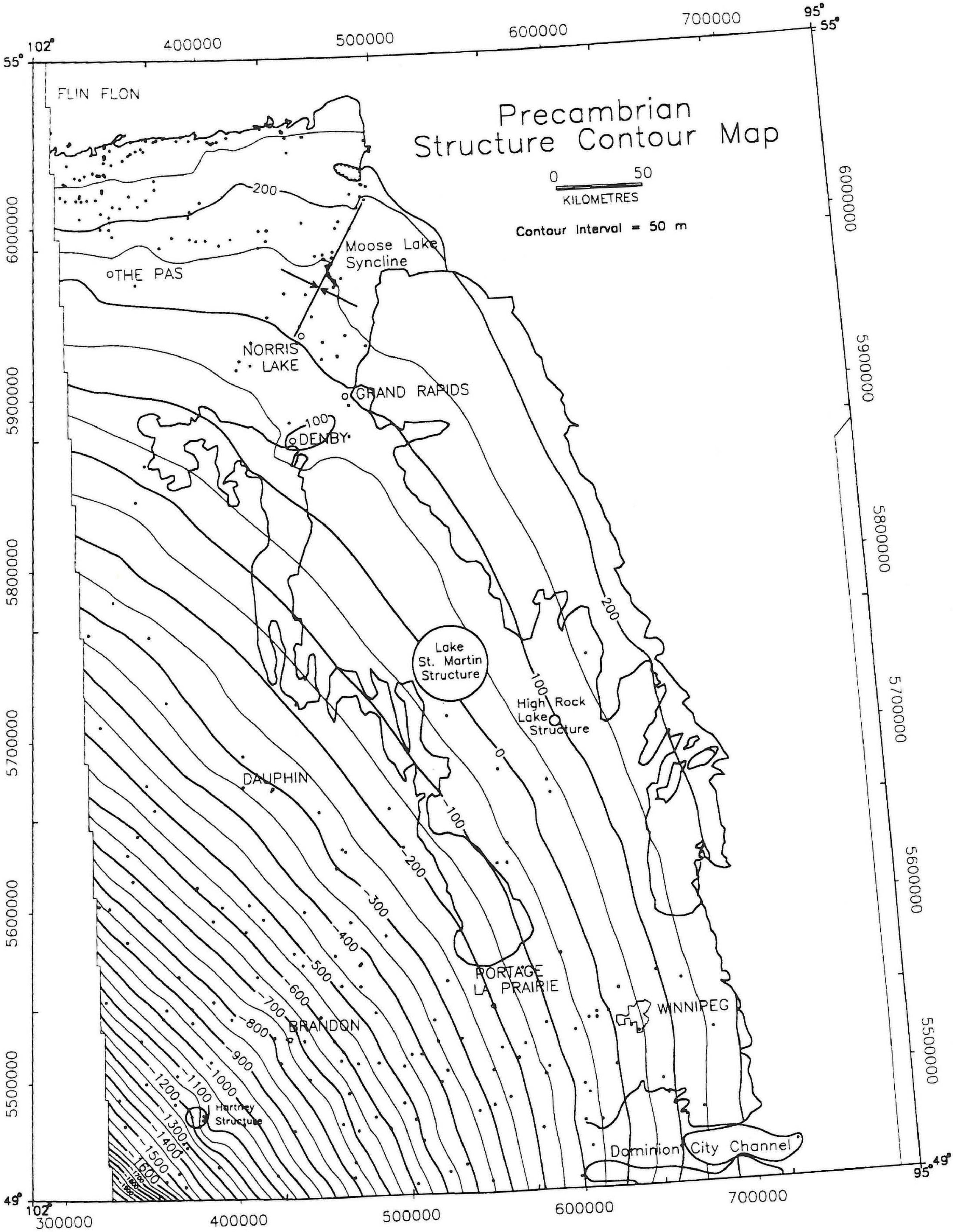


Figure 3: Precambrian structural map of Manitoba.

REGIONAL STRUCTURAL HISTORY

The Churchill Superior Boundary Zone (CSBZ), a prominent basement feature, influenced the Paleozoic tectonic framework in the William Lake area (Fig. 2) (*cf.* Bezys and McCabe, 1990; McGregor *et al.*, 1990; Macek and Nagerl, 1992; McGregor and Macek, 1992, 1993). This zone marks the collision zone of two major Precambrian terranes, the Archean Superior and Proterozoic/Archean Churchill provinces along the eastern margin of the Trans Hudson Orogen (not indicated on Fig. 2). The Precambrian blocks have distinctly different tectonic histories and lithostratigraphic features. The collision zone is defined geophysically by linear gravity lows and magnetic anomalies in the exposed shield area (Thompson belt) and along its southwest extension below the Paleozoic rocks (Green *et al.*, 1979).

McCabe (1967) suggested that these two blocks had different tectonic responses to basin subsidence and uplift during Paleozoic deposition; however, structure contour maps of Precambrian basement and of overlying Paleozoic strata show only minor deviation along the CSBZ, except in the area north of Grand Rapids and east of The Pas (Fig. 3). McCabe (1967) noted a prominent northeast-trending synclinal feature in this area and named it the Moose Lake Syncline (Figs. 2, 3).

The Moose Lake Syncline is inferred from the northeast-trending flexure of the structure contours in the area northwest of Lake Winnipeg. The axis of the syncline coincides with the CSBZ. The configuration of the Ordovician/Silurian outcrop belt in the Moose Lake area suggests the syncline is post-Silurian (McCabe, 1967; McCabe and Barchyn, 1982). Other structural anomalies are present along the southern extension of the CSBZ. The Denby structure and the Norris Lake anomaly are distinct Precambrian highs that were originally intersected by drilling (Cominco Denby #2 and Amax Norris Lake MXD-72-1) (Fig. 3). Recent drilling by Falconbridge in NTS 63G/12 has revealed a major Precambrian topographic low of approximately 85 m below regional trends. The interval between the base of the Winnipeg Formation and the top of the Precambrian consists of fine grained mudstone and siltstone that could represent the Cambrian Deadwood Formation.

In southwest Manitoba the CSBZ coincides with the Birdtail-Waskada Axis (see Fig. 2), which is the site of numerous, sharply defined structural and isopach anomalies generally related to post-Middle Devonian salt collapse (McCabe, 1971).

PALEOZOIC DEPOSITIONAL FRAMEWORK

The Ordovician Winnipeg Formation (Fig. 4) shows the greatest variation in isopach thickness and lithofacies differences of all Paleozoic formations in Manitoba. It irregularly thins from a maximum of 60 m near the U.S. border to zero metres at its northern limit, a thinning of approximately 17%/100 km (McCabe and Barchyn, 1982). The Winnipeg Formation consists of interbedded sandstone and shale; the abundance of these lithologies ranges from greater than 90% shale to greater than 90% sandstone (McCabe, 1978). In the William Lake area the formation ranges in thickness from 4.0 to 15.0 m and consists predominantly of sandstone lithofacies with minor mudstone and siltstone.

The contact between the Winnipeg Formation and the overlying Red River Formation is placed at the base of the first dolomite bed. The base of the transitional beds is termed the Hecla Beds in the southern portion of the Red River Formation outcrop belt (Fuller, 1961). In the William Lake area, the Hecla Beds have not been identified and contact to the Red River strata is conformable and transitional. In NTS 63K and 63J, the Winnipeg Formation is missing in places, and the Red River Formation rests unconformably on the Precambrian.

The Ordovician Red River Formation thins from about 175 m in the southern Manitoba outcrop belt to 40 m in the north, where at its erosional limit it thins at about 13%/100 km (McCabe and Barchyn, 1982). In southern Manitoba the lower Red River Formation can generally be divided into the Dog Head, Cat Head, and Selkirk members (Foerste, 1929); however, in the Grand Rapids - William Lake area these members are not developed and this division is not used. Formational thinning towards the north is accompanied by a lithologic change from dolomitic limestone in the south to dolomite in the William Lake area. The upper Red River Formation (Fort Garry Member) retains a relatively uniform dolomite lithology (mainly mudstone and minor breccia) throughout the outcrop belt. In the William Lake area, the Red River Formation ranges from 35.0 to 51.0 m thick.

The Ordovician Stony Mountain Formation thins from 50 m in the south to about 30 m to the north with a rate of thinning at 7%/100 km (McCabe and Barchyn, 1982). In the south, the formation can be divided into three members: the Gunn (lower Stony Mountain), an interbedded limestone and calcareous shale; the Penitentiary (lower Stony Mountain), slightly argillaceous dolomite; and the Gunton (upper Stony Mountain), a nodular dolomite. In the William Lake area the entire Stony Mountain Formation becomes Gunton-like, in place of the underlying members, and therefore is not divided. It ranges from 24.0 to 34.0 m thick.

The Stonewall Formation straddles both the Ordovician and Silurian periods and the boundary is placed just at or above the t-marker (Fig. 4) (Porter and Fuller, 1959; Brindle, 1960; McCabe, 1988). Recent biostratigraphic studies at Cormorant Hill confirm this placement (Bezys, 1991). Stearn's (1956) stratigraphic division has been modified and is used for the Silurian Interlake Group in Manitoba's outcrop belt (Fig. 4).

The Stonewall Formation and the Silurian Interlake Group consist almost entirely of dolomitic mudstone to grainstone with intraclastic breccia beds and stromatolites, which represent uniform, basin-wide deposition. These dolomite sequences are interrupted by a number of thin, sandy argillaceous marker beds believed to represent para-time-stratigraphic markers (Porter and Fuller, 1959) (t, u_1, u_2, and v-markers in Fig. 4). These marker beds may represent minor, but widespread, depositional hiatuses or erosional surfaces.

The stratigraphic units from the Fort Garry Member to the Interlake Group indicate cyclic sedimentation. Complete cycles consist of a thin, basal, argillaceous and commonly arenaceous dolomite, overlain by a fossiliferous wackestone (commonly burrowed), a laminated argillaceous dolomite and capped by an anhydrite bed (Kendall, 1976; Haidl, 1990; Norford *et al.*, 1994). Evaporites are present in the central parts of the Williston Basin (southwest Manitoba).

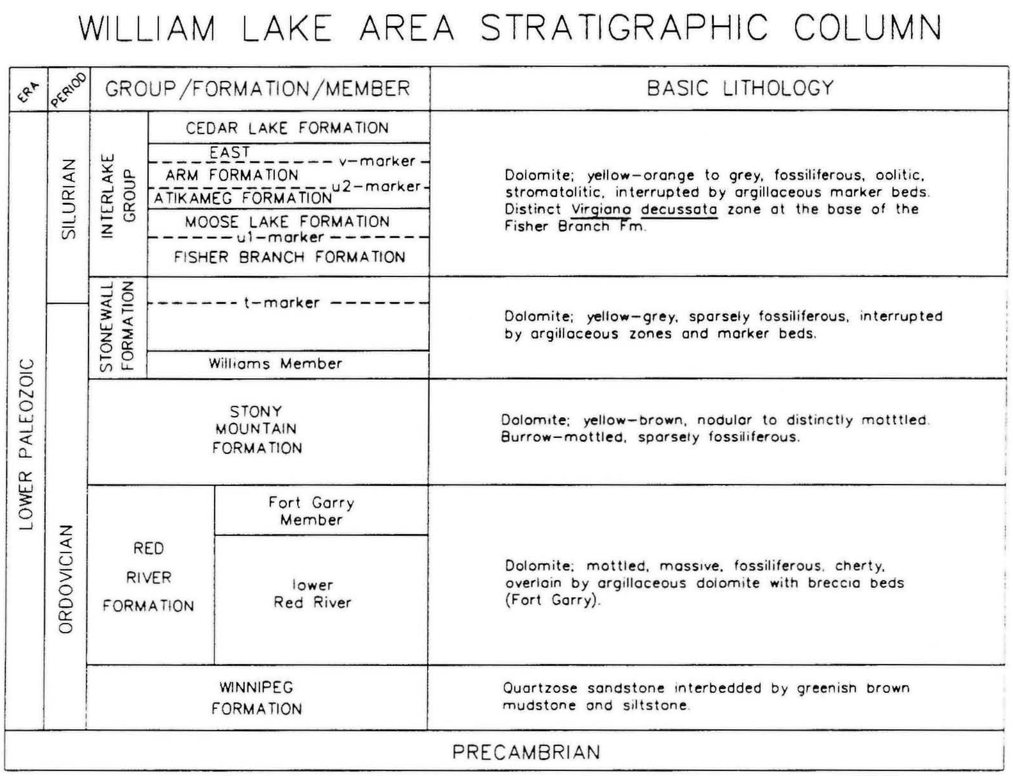


Figure 4: Stratigraphic nomenclature chart for the William Lake area.

GEOLOGIC SETTING OF THE WILLIAM LAKE AREA

The bedrock geology of the William Lake area, determined from core logging and outcrop field mapping, is shown in Figure 5. Some formations, such as the Cedar Lake Formations, have a limited areal extent due to erosion. In addition, Quaternary sediments, up to 26 m thick, and Cretaceous sedimentary rocks of Late Albian to Cenomanian age occur locally within William Lake (McIntyre, 1993).

Lower Paleozoic strata in the carbonate sequence at William Lake is exclusively dolomite (after limestone). Clastic sequences are dominant in the Winnipeg Formation, and minor sand, silt, and mud layers occur, in places, within the overlying carbonate sequence as distinct marker horizons. The detailed stratigraphy of the William Lake area is shown in Figure 4. The classification scheme used for the core descriptions is shown in Figure 6.

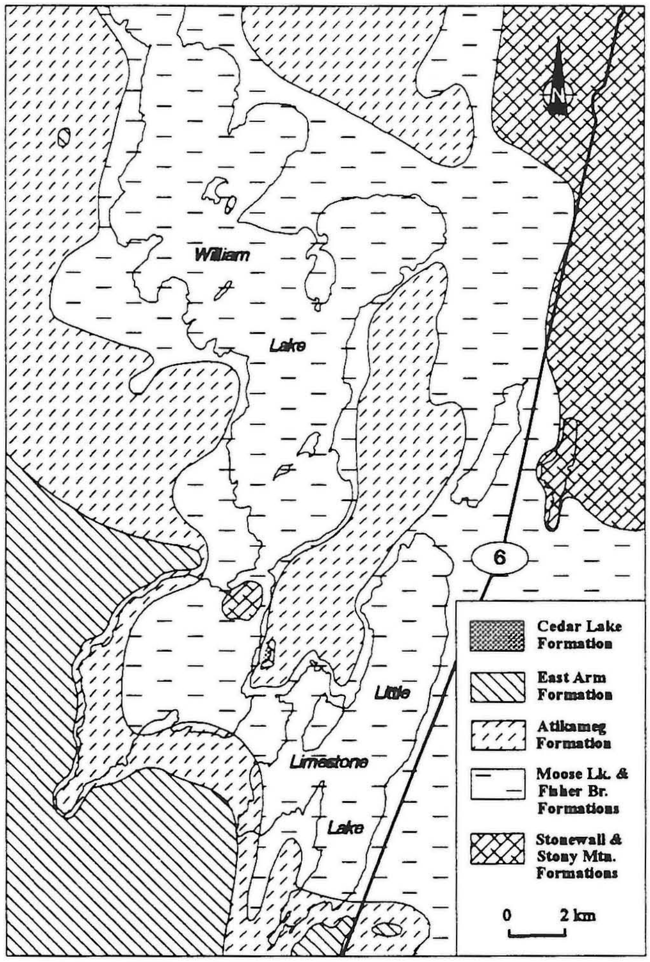


Figure 5: Schematic geology map of the William Lake area.

<table>
<tr><td colspan="6">Allochthonous Limestones
Original components not organically bound during deposition</td><td colspan="2">Autochthonous Limestones
original components organically bound during deposition</td></tr>
<tr><td colspan="4">Less than 10% >2mm components</td><td colspan="2">Greater than 10% >2mm components</td><td rowspan="4">By organisms which encrust and bind</td><td rowspan="4">By organisms which build a rigid framework</td></tr>
<tr><td colspan="3">Contains lime mud (<0.03mm)</td><td>No Lime Mud</td><td rowspan="3">Matrix supported</td><td rowspan="3"><2 mm component supported</td></tr>
<tr><td colspan="2">Mud Supported</td><td colspan="2" rowspan="2">Grain Supported</td></tr>
<tr><td>Less than 10% grains (>.03 <2mm)</td><td>Greater than 10% grains</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>Bind-stone</td><td>Frame-stone</td></tr>
</table>

Figure 6: Classification of carbonate rocks (after Dunham, 1962; Embry and Klovan 1971; Fig. 2).

ISOPACH AND STRUCTURAL VARIATIONS

Nine of the ten maps that accompany this report (simplified versions are also shown in Fig. 7-15) illustrate isopachs (formational thickness) and structure contours on top of the specific units. These maps are available upon request through the Energy and Mines Information Centre. The map units include: the Precambrian (structure only), the Winnipeg, Red River, Stony Mountain and Stonewall formations. The Silurian Interlake Group is not shown due to its erosional and unconformable top. Structural and isopach control follow areas of good drill core control; however, in areas where drill core control is poor, the contours were extrapolated. Map 10, 1:50 000 scale, shows the location of the stratigraphic and structural cross sections (see Fig. 16-20). The figures in this report do not show the drillhole locations: please refer to the maps.

Structural variations are observed on several surfaces. A 12.0 m elevation difference on top of the Precambrian is evident between holes 22 and 23 (0.3 km apart) (Map 1; Fig. 7). The structural variation in the Winnipeg Formation (11.0 m difference) results in an isopach thickness of 6.7 and 8.4 m in holes 22 and 23, respectively (Maps 2, 3; Fig. 8, 9). The structural change is less evident on top of the Red River Formation (1.8 m), with an isopach thickness of 37.7 and 46.8 m in holes 22 and 23, respectively (Map 4; Fig. 10, 11). On top of the Stony Mountain Formation, the structural difference is 5.4 m and the isopach values range from 25 m and 29 m (holes 22 and 23, respectively) (Maps 6, 7; Fig. 12, 13). The top of the Stonewall Formation is similar structurally in holes 22 and 23, 256.9 and 257.0 m, respectively, and isopach thicknesses range from 15.1 to 21 m (holes 22 and 23). Core data indicate that portions of the Stonewall Formation have been eroded (Maps 8, 9; Fig. 14, 15).

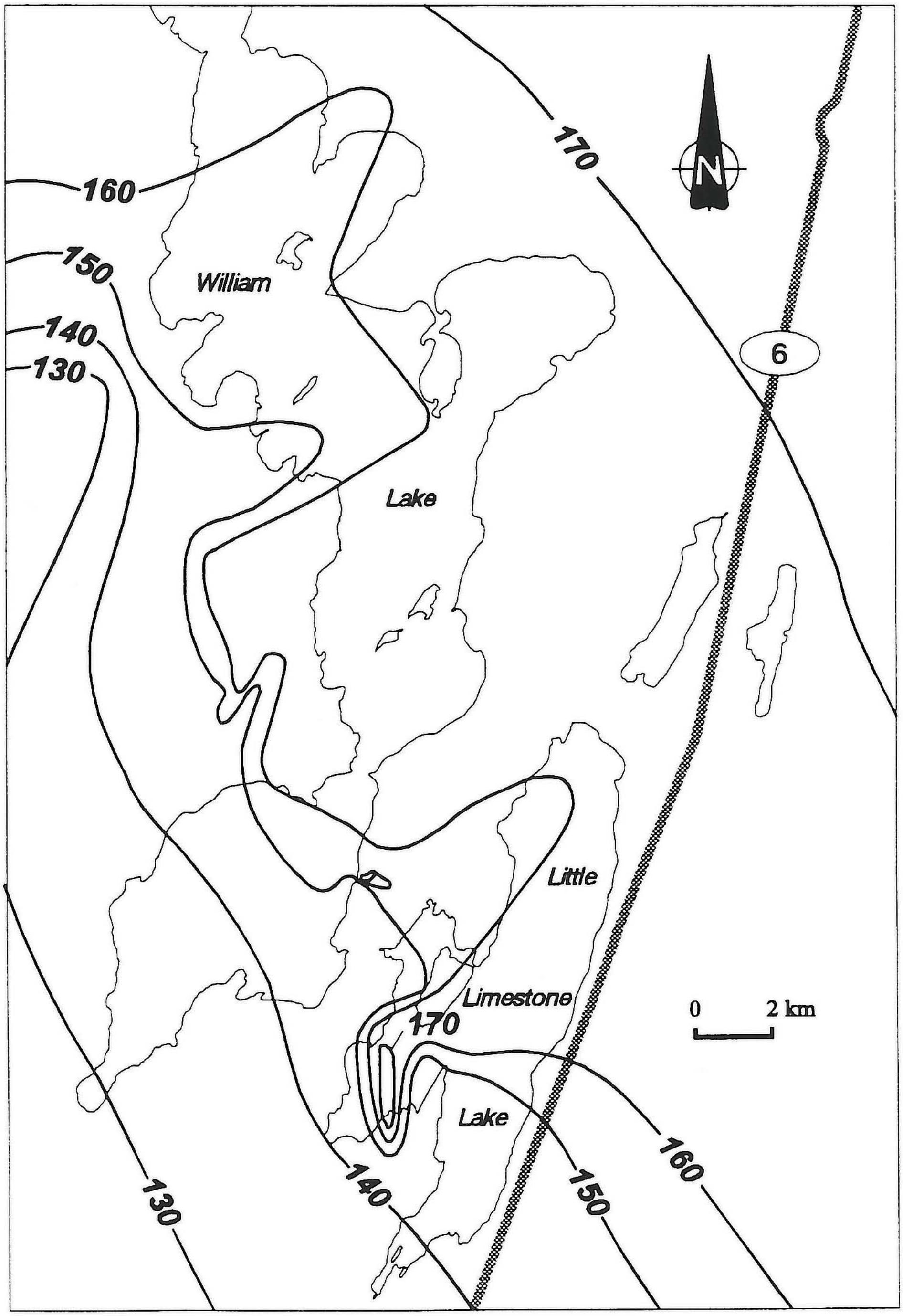
On the west shore of William Lake, holes 52 and 61 show a structural high on top of the Precambrian and on top of the Winnipeg Formation, with variable isopach values (8.6 to 14.0 m, respectively, for the Winnipeg Formation) (Maps 1-3; Fig. 7-9). In the Red River Formation, holes 52 and 61 also show a minor structural difference of 2.2 m, and have isopach values of 36.4 and 37.5 m (holes 52 and 61) (Maps 4, 5; Fig. 10, 11). The Stony Mountain Formation shows a structural low in hole 60 (227.0 m) compared to a high associated with hole 52 (241.5 m). The isopach values for holes 60 and 52 are 23.6 and 27.6 m, respectively, but an adjacent hole (53) has a thicker isopach at 29.4 m (Maps 6, 7; Fig. 12, 13). For the Stonewall Formation, the structural range varies from a low of 250.8 m for hole 60 to 260.1 m for hole 52. Isopach variations range from 18.6 m for holes 52 and 61 to 24.6 m for hole 57 (Maps 8, 9; Fig. 14, 15).

Southeast of these holes, along the east shore of William Lake, other drillholes exhibit structural complexity. On top of the Precambrian, holes 17 and 36, 0.5 km apart show a structural difference of 28.8 m (Map 1; Fig. 7). A Winnipeg Formation structural high is present in hole 17 (178.4 m), with a 24.4 m difference between holes 17 and 29, 1.3 km apart (Map 2; Fig. 8). Drillholes with structurally high Winnipeg Formation values, holes 17 and 20, have thinner isopach values of 5.0 m and 4.4 m, respectively, in comparison to other nearby holes (*i.e.* holes 32, 36, and 37 with isopach values of 11.3, 11.0, and 11.7 m, respectively). The Red River Formation displays structural variations of up to 28.0 m, between holes 17 and 36, and an isopach difference of 15.5 m between holes 36 and 41/43 (Maps 4, 5; Fig. 11, 12). The Stony Mountain Formation shows a difference in structural elevation of 17.3 m between holes 17 and 32, but exhibits deviations in isopach trends of 9.9 m (holes 25 and 41/43) (Maps 6, 7; Fig. 13, 14). The Stonewall Formation shows a structural variation of 9.7 m between, holes 25 and 27, and a slight isopach difference of 4.0 m between holes 25 and 51 (Maps 8, 9; Fig. 15, 16). Many of the drillholes in this area have been truncated into the Stonewall Formation level. In hole 37 erosion has occurred through to the Stony Mountain Formation level (see Fig. 4).

South of William Lake there are similar structural highs in the Precambrian, and in Winnipeg, Red River and Stony Mountain formations, within and around Little Limestone Lake (up to 32 m on top of the Precambrian). Isopach trends are extremely variable. The structural variation present at Little Limestone Lake (where no drillholes are indicated) is based on confidential drillhole information. Also, hole 10 is shown on Maps 1 and 2, but is absent in the others because of missing core.

Precambrian Formation

Structure Contour Map

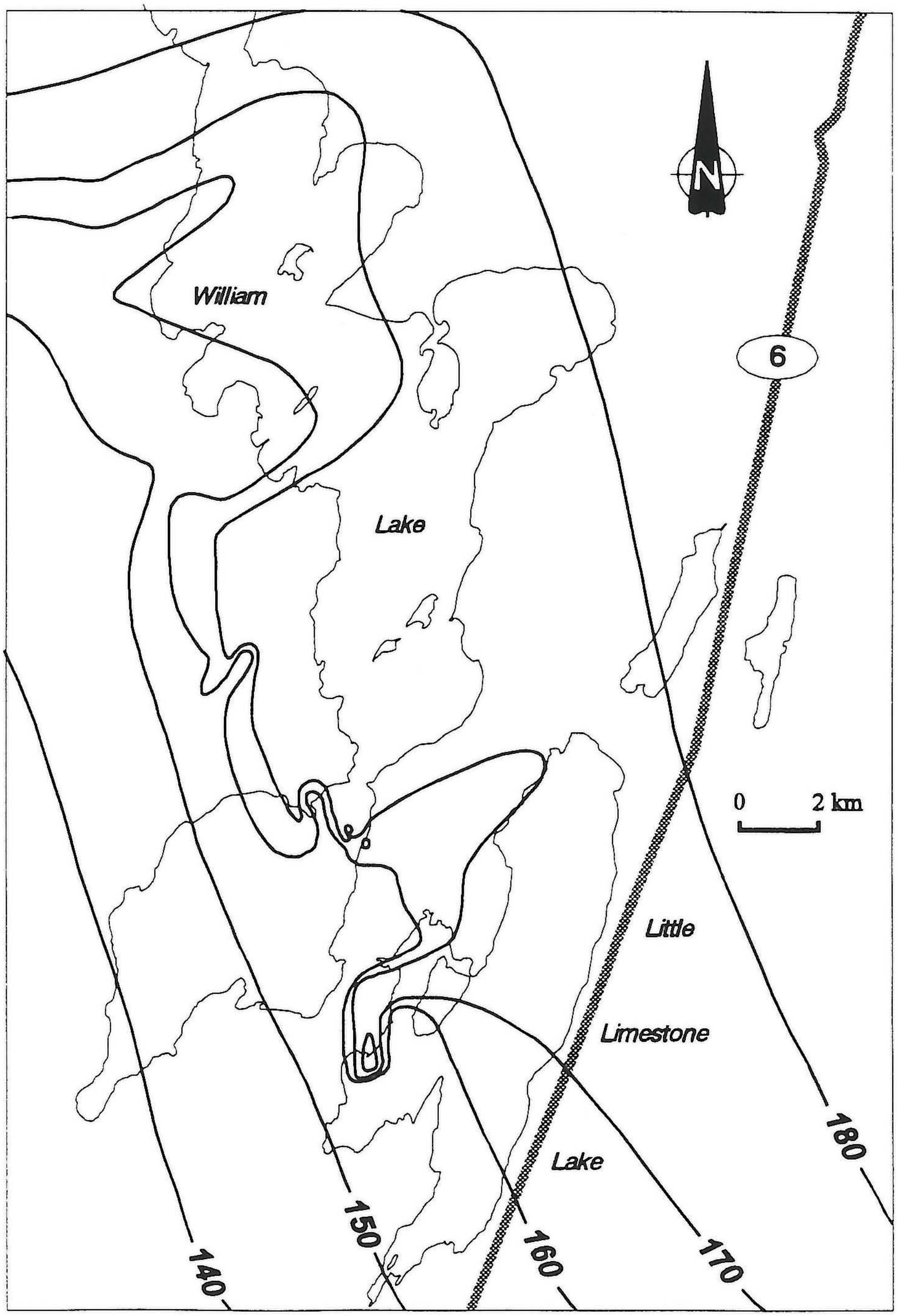


Contour Interval - 10m

Figure 7: Precambrian structure contour map of the William Lake area (meters above sea level).

Winnipeg Formation

Structure Contour Map



Contour Interval - 10m

Figure 8: Winnipeg Formation structure contour map of the William Lake area (meters above sea level).

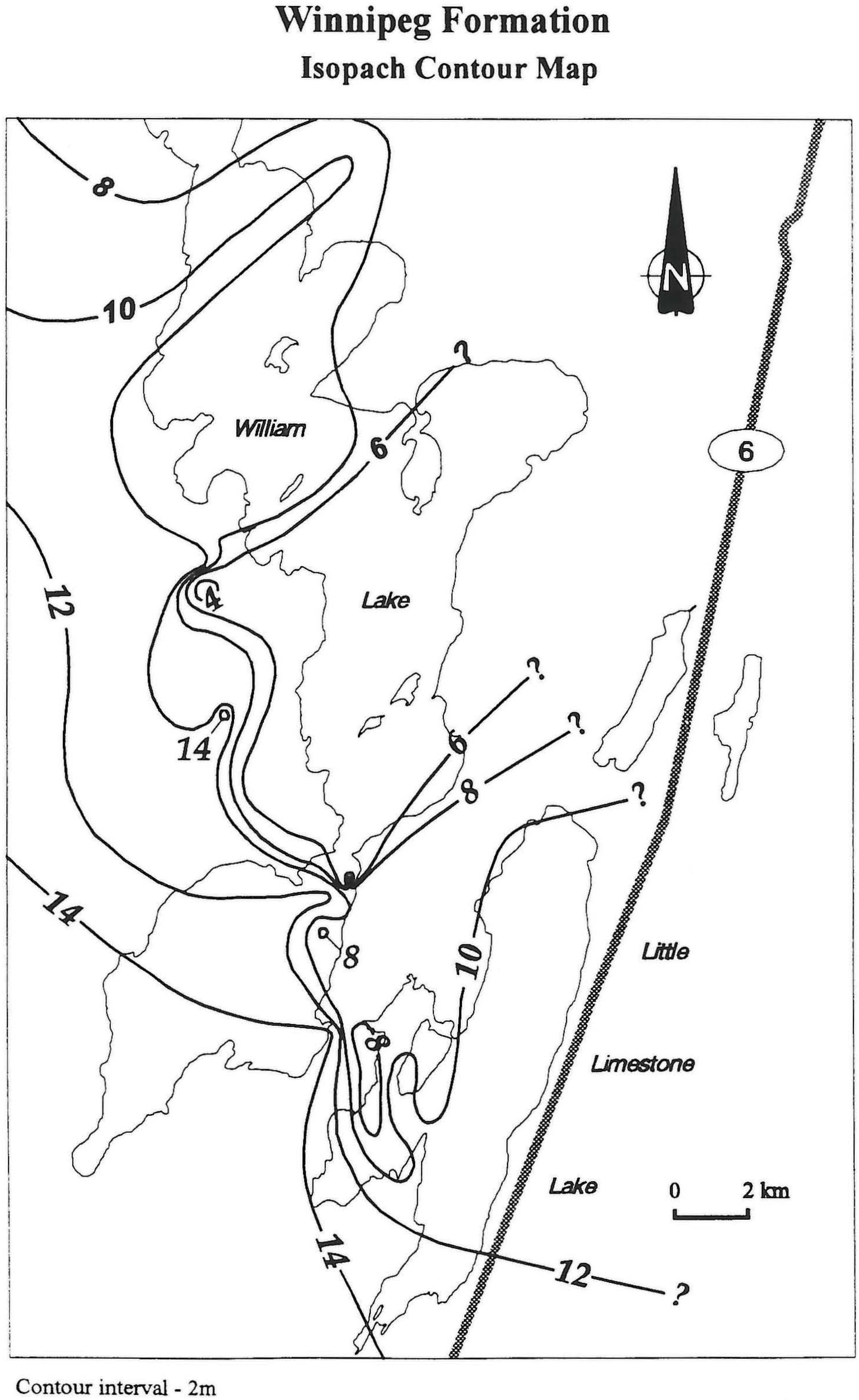
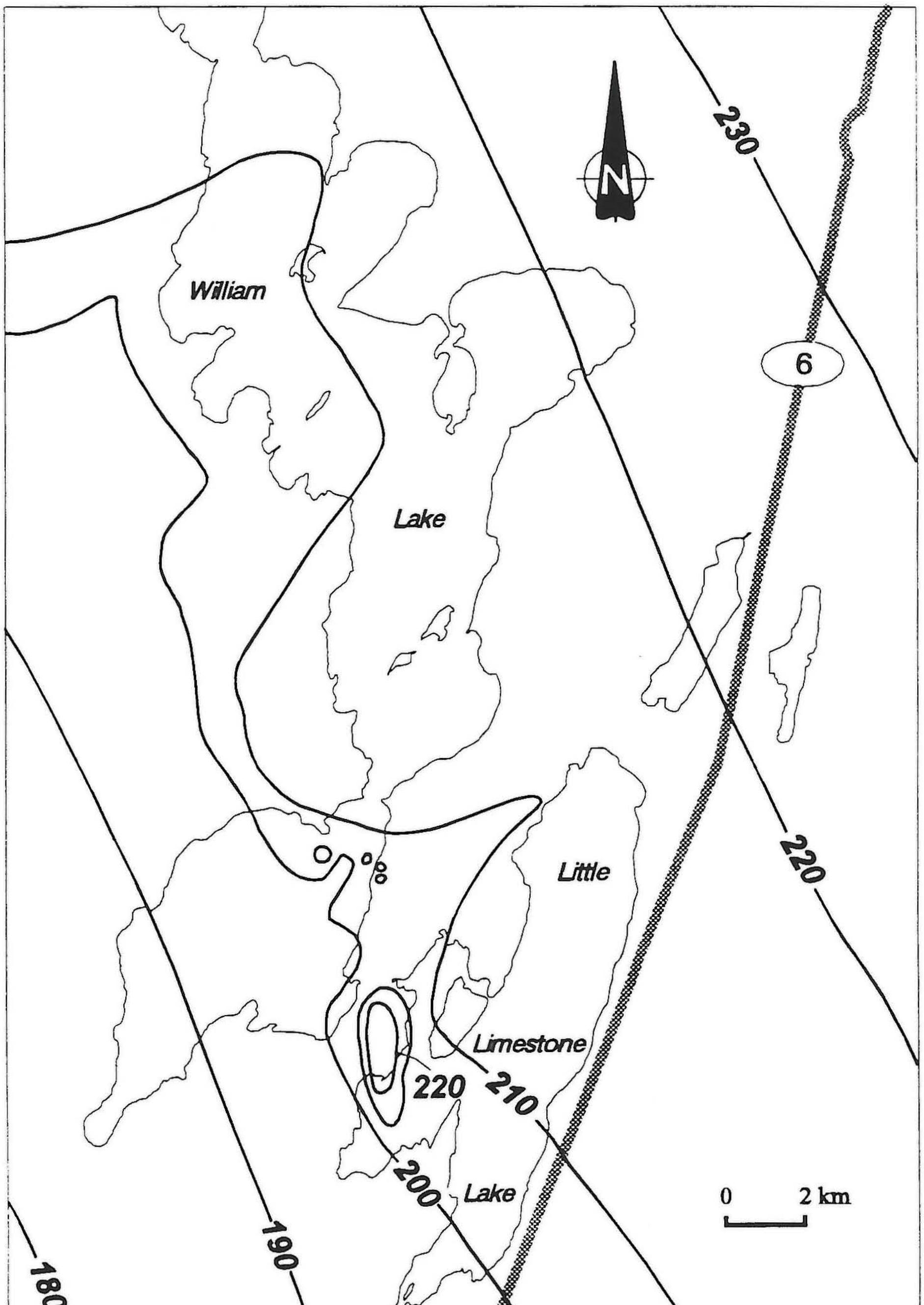


Figure 9: Winnipeg Formation isopach map of the William Lake area.

Upper Red River Formation

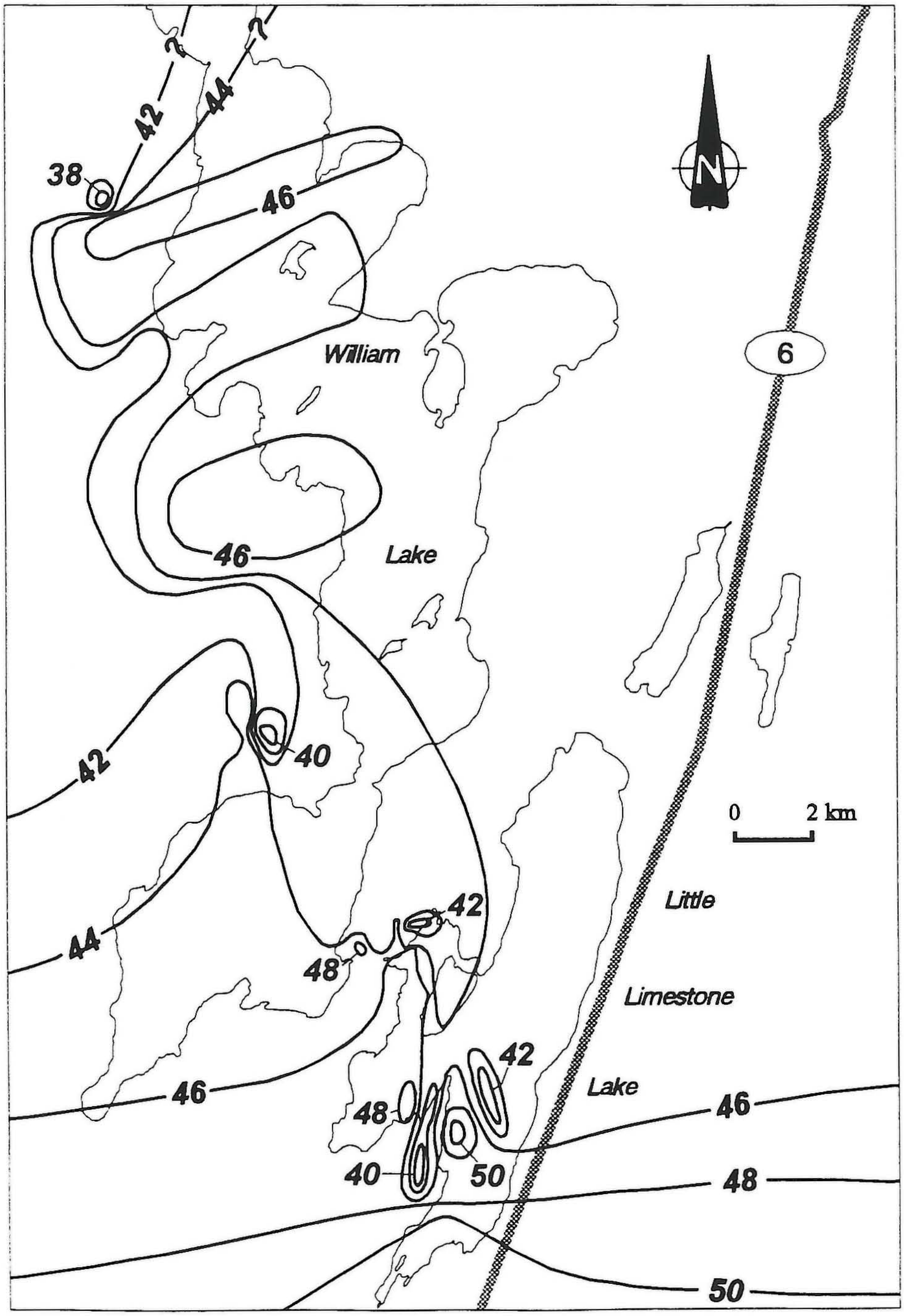
Structure Contour Map



Contour Interval - 10m

Figure 10: Upper Red River Formation structure contour map of the William Lake area (meters above sea level).

Red River Formation
Isopach Contour Map

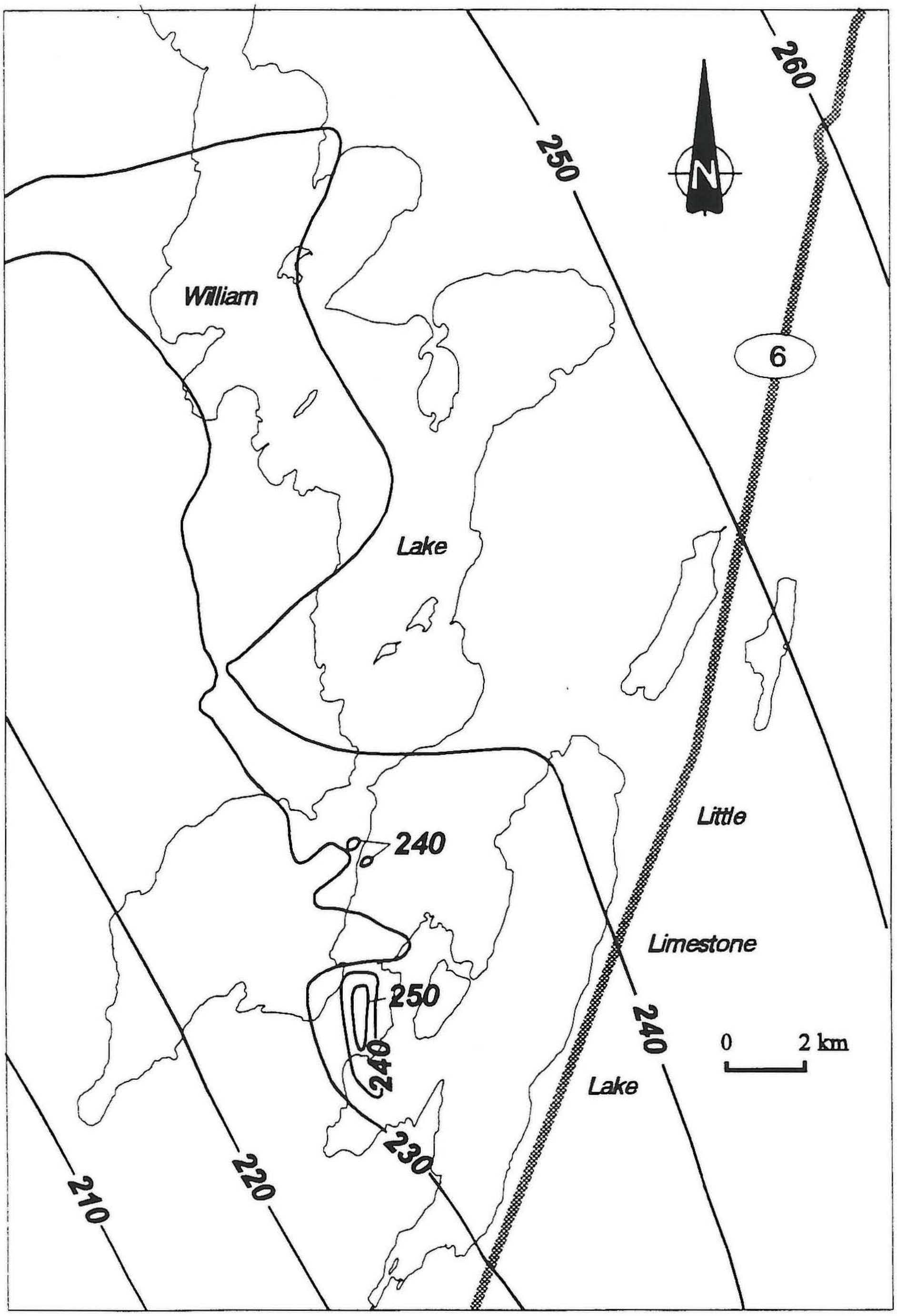


Contour interval - 2m

Figure 11: Red River Formation isopach map of the William Lake area.

Stony Mountain Formation

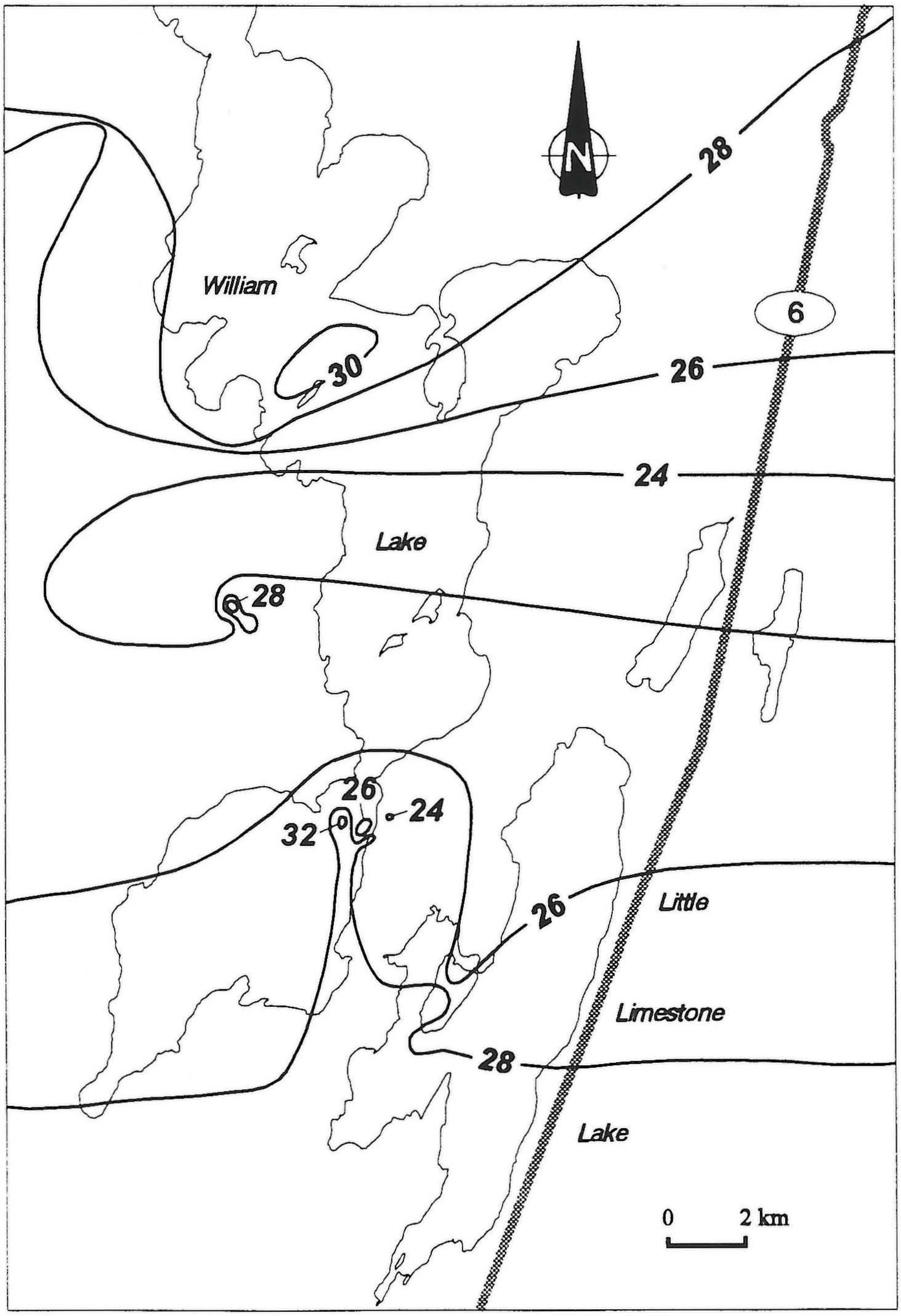
Structure Contour Map



Contour Interval - 10m

Figure 12: Stony Mountain Formation structure contour map of the William Lake area (meters above sea level).

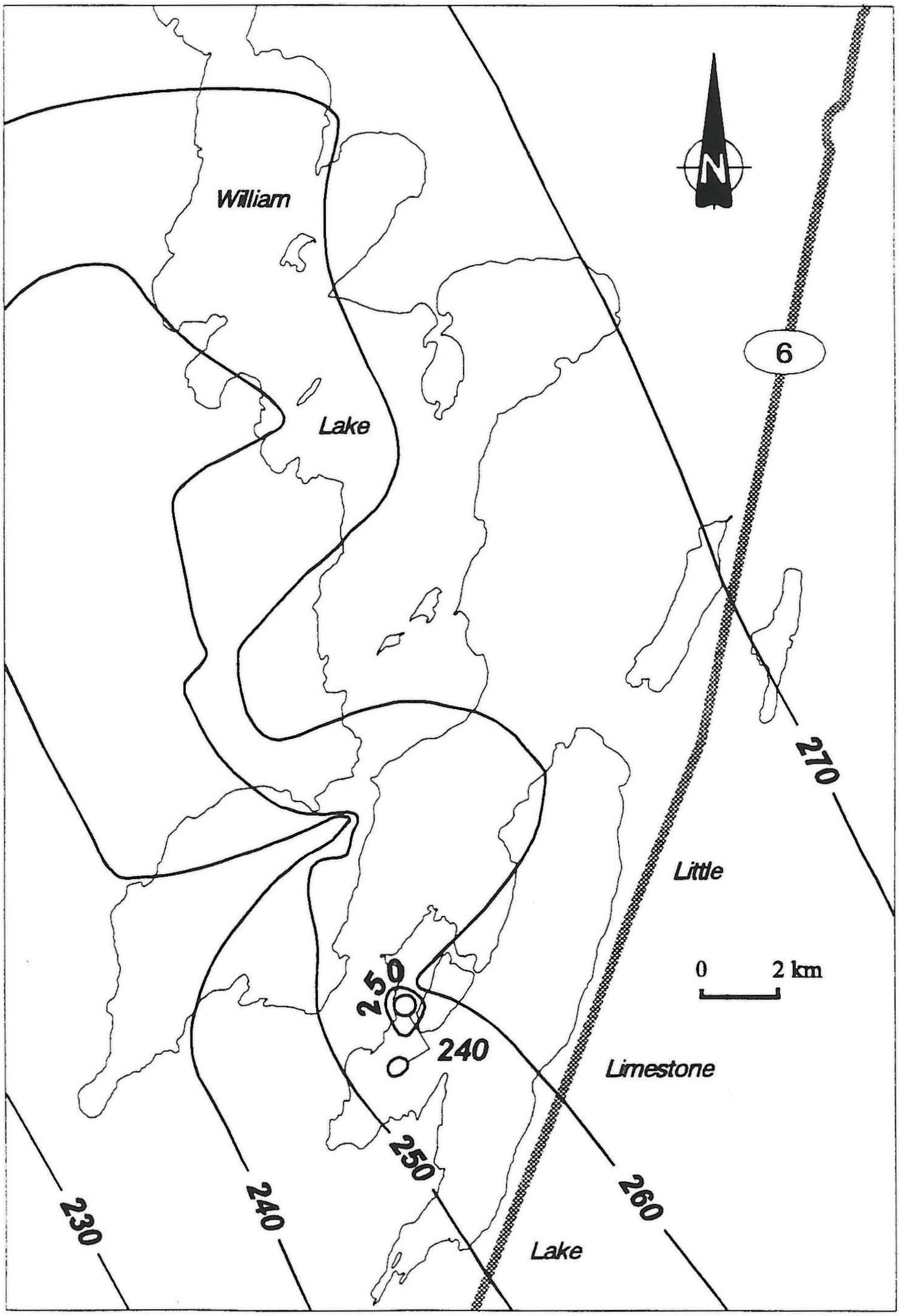
Stony Mountain Formation
Isopach Contour Map



Contour interval - 2m

Figure 13: Stony Mountain Formation isopach map of the William Lake area.

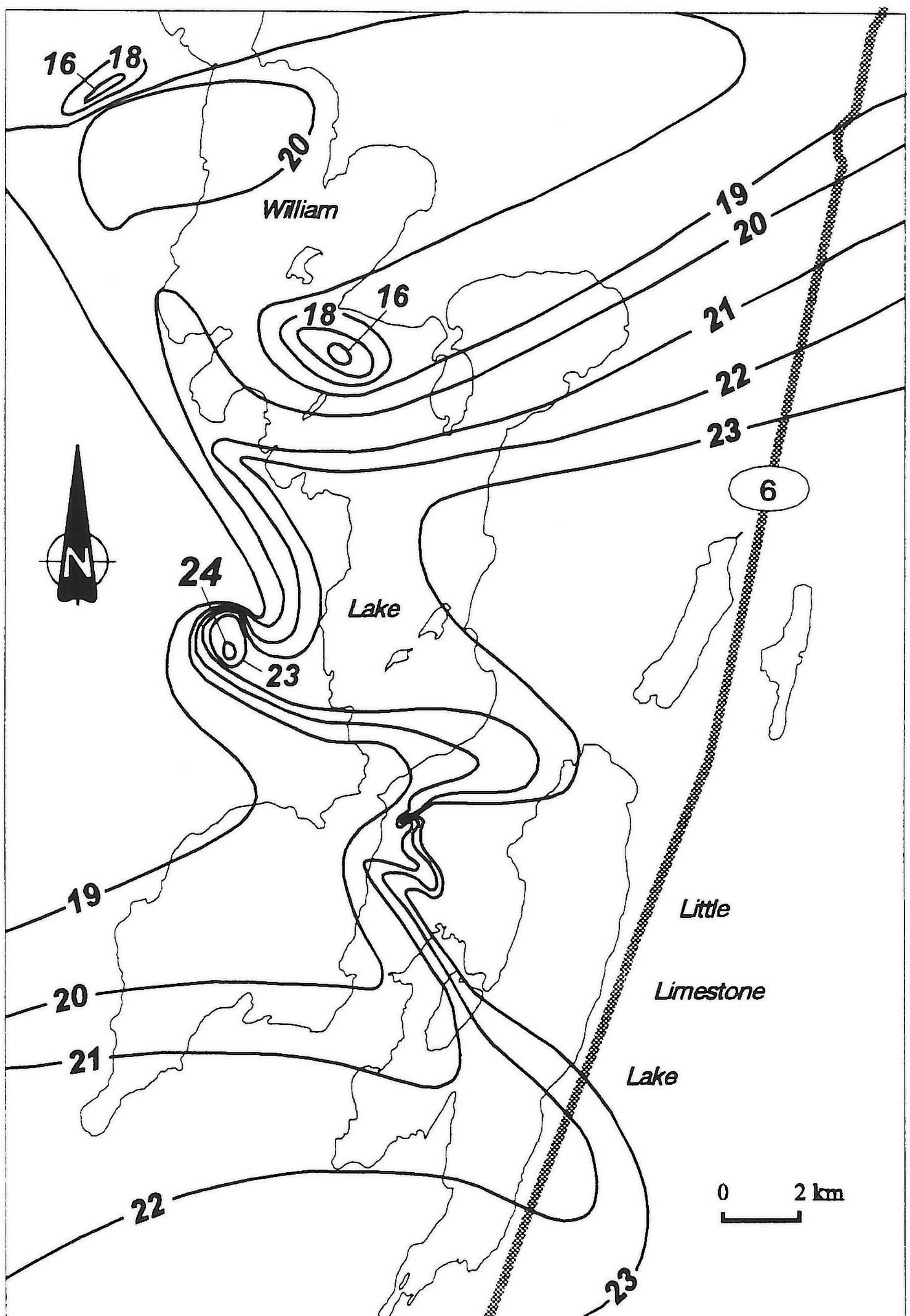
Stonewall Formation
Structure Contour Map



Contour Interval - 10m

Figure 14: Stonewall Formation structure contour map of the William Lake area (meters above sea level).

Stonewall Formation
Isopach Contour Map



Contour interval - 1m

Figure 15: Stonewall Formation isopach map of the William Lake area.

Location of Cross Sections
A - A[1] and B - B[1]

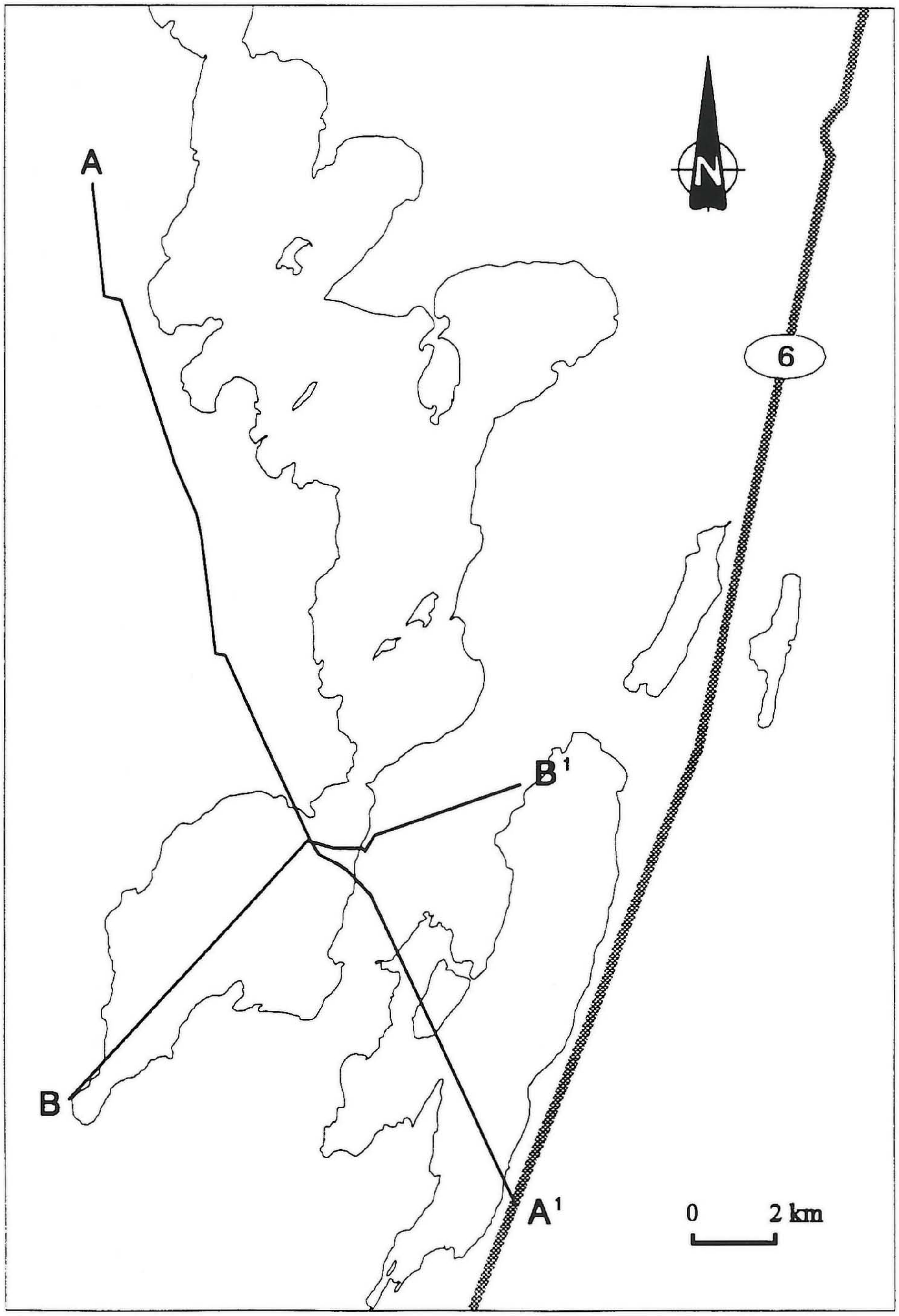


Figure 16: Location of stratigraphic and structural cross sections in Figures 17-20.

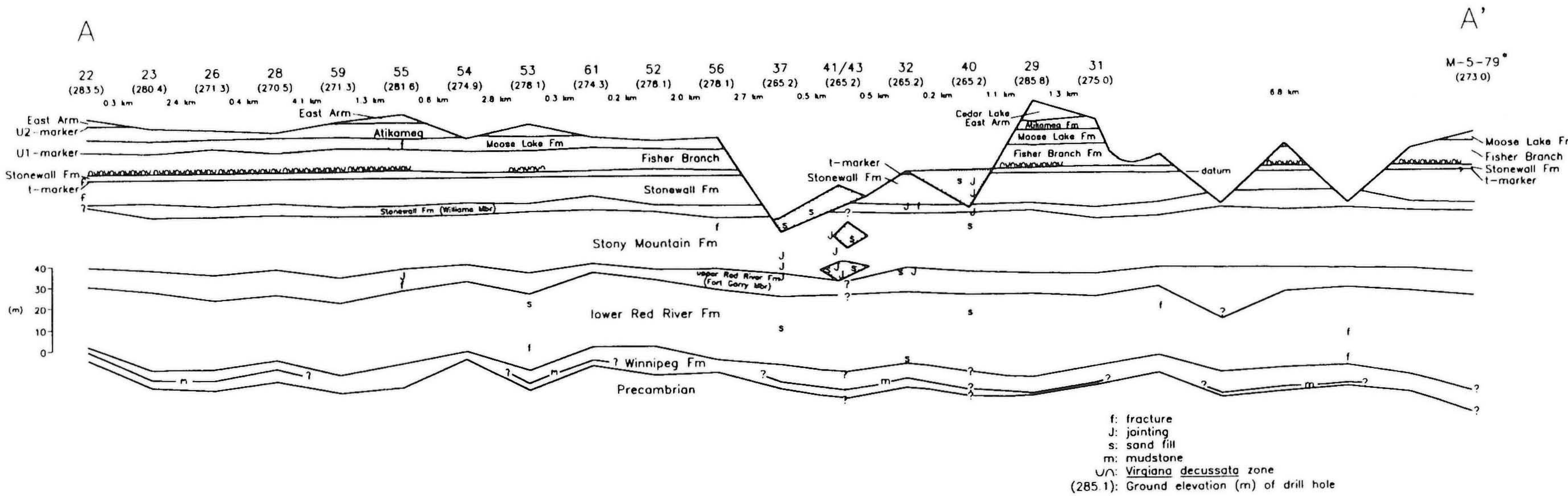


Figure 17: Stratigraphic cross section A-A', William Lake area. See Figure 18 for the equivalent structural section, Figure 4 for the detailed stratigraphic nomenclature chart, and Figure 16 for cross section location. All holes are directionally drilled diamond-drill holes, except M-5-79, which is vertical. See Appendix A for drillhole information.

CROSS SECTIONS

The stratigraphic and structural cross sections and their locations in the William Lake area are shown in Figures 16 to 20 and Map 10. Most drillholes were directionally drilled except those marked with an asterisk, which are vertical stratigraphic core holes drilled by the Geological Services Branch (core holes M-5-79 and M-12-90). For illustrative purposes, the cross section holes were spaced equidistant horizontally. Actual distances between drillholes are indicated in Figures 17 to 20.

Figure 17 shows the stratigraphic cross section for line A-A'. The t-marker was used as datum. This cross section portrays, stratigraphically, the deposition of the sedimentary sequence during the Lower Paleozoic. Structural highs on top of the Precambrian are evident in holes 22, 28, 54, 32, 61, 52 with a distinct structural high near Little Limestone Lake. Erosion is indicated by deep incisions at the top of the section.

The cross section (Fig. 17) also shows areas of thick sand beds and infill (indicated by *s*). The latter may be Quaternary sediments that are infilling a bedrock karst feature, or remnant Mesozoic material. Mudstone beds within the Winnipeg Formation (indicated by *m*) and absent on structural highs, may represent anoxic mud accumulations in structurally low areas.

Drillholes with the diagnostic brachiopod, *Virgiana decussata*, in the Fisher Branch Formation are indicated, as well as joints (*J*) and fractures (*f*).

Figure 18 is a structural cross section along line A-A'. It uses the same data points used in Figure 17, but was constructed using sea level as datum. Therefore, this depicts present subsurface stratigraphy. Holes 55 and 37 show a structural high; a fault is interpreted between holes 37 and 41/43. The Precambrian structural high in the Little Limestone Lake area (Fig. 7, Map 1) is apparent, and is transposed into the overlying units.

Figure 19 is a stratigraphic cross section along line B-B' and uses the same symbols as Figures 17 and 18. In this area there is no relief on the Precambrian surface and the overlying sedimentary sequence is flat lying. Figure 20, a structural cross section of B-B', shows a topographic high associated with hole 37 and a low with hole 36. Hole 36 penetrated Cretaceous sedimentary rocks.

CONCLUSIONS

The drill core data suggests that tectonic movements were active during Lower Paleozoic time in the William Lake area. Possible driving forces are unknown. Relief differences are as much as 29 m, on top of the Precambrian, between holes spaced half a kilometre apart. Some of these structures are aligned with topographic lineaments evident on airphotos.

Figure 21 is a photomosaic of the William and Little Limestone lakes areas. The dark lines indicate northeast-trending topographic lineaments. The longest lineament, the Reedy Lake lineament, is approximately 17 km long, and may extend further north of Little Limestone Lake.

Lineaments produced by glaciation are, in places, difficult to distinguish from those produced by bedrock fault movement. Fault lineaments are generally characterized by extreme lengths (10s of kilometres) and linearity. Linear features of glacial origin tend to be shorter (< 2 kilometres) and more irregular in pattern (Misra *et al.*, 1991).

Figure 22 is an airborne magnetic and topographic map (1:250 000) of the William Lake area. The hatched line indicates the approximate position the Reedy Lake lineament (Fig. 21). This lineament coincides with a trend formed by lakes and streams, and basement magnetic signatures. Drill core data (C. McGregor, pers. comm., 1994) suggest that the contact between Proterozoic Ospwagan Group and Archean granitoid rocks locally coincides with the lineament; this suggests that the contact may be a fault. Thus, available evidence indicates that the Reedy Lake lineament had a tectonic origin.

The suggestion that the Reedy Lake lineament is tectonic in origin is further supported by the presence of subvertical fracturing, which is highly unusual for Lower Paleozoic carbonates in Manitoba. This fracturing (Fig. 23) is exposed on the east shore of Reedy Lake (on the Reedy Lake lineament) and is similar to fracturing caused by quarry blasting.

Misra *et al.* (1991) suggest that structures in basement rocks produced by block faulting that result in a series of horsts and grabens are generally unrelated to structures and trends defined by magnetic data. Faults with significant vertical displacement may correlate with abrupt changes in magnetic values and trends.

A vertical corehole drilled by the Geological Services Branch (M-12-90 - south end of William Lake), intersected 35.0 m of vertically fractured Red River Formation (Fig. 24). The fractures, dilated 1 to 3 cm, are filled with sand, silt and clay breccia (Fig. 25). No lateral offset is evident in the core. The fractures suggest tectonic movement emanating from the Precambrian basement, although the site is not associated with any known topographic lineaments.

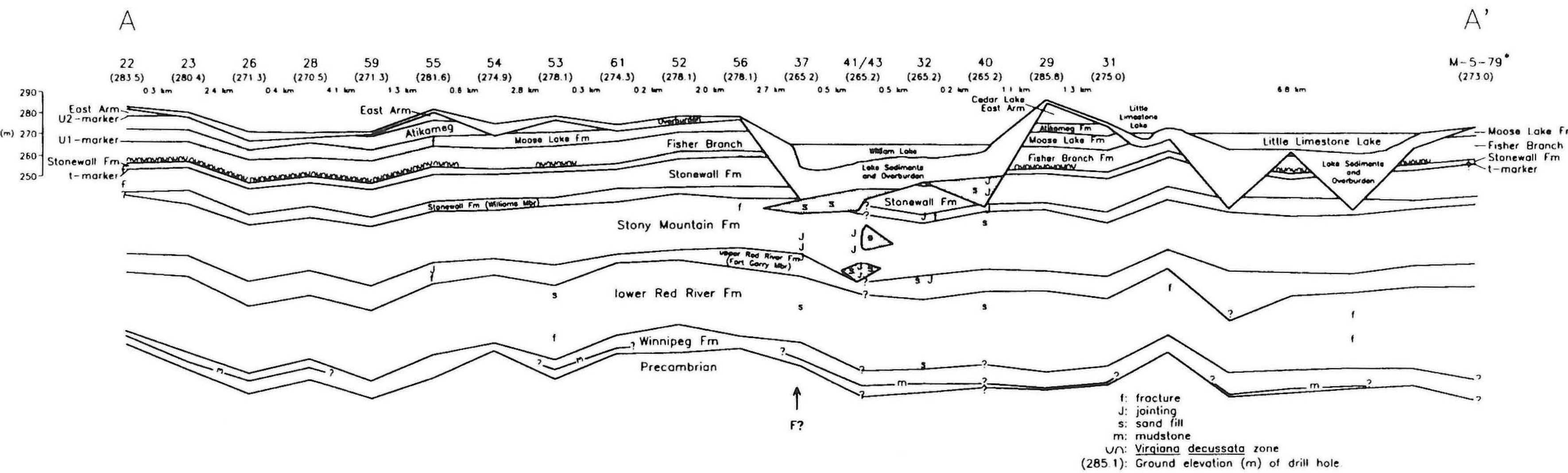


Figure 18: Structural cross section A-A', William Lake area. See Figure 17 for the equivalent stratigraphic section, Figure 4 for the detailed stratigraphic nomenclature chart, and Figure 16 for cross section location. All holes are directionally drilled diamond-drill holes, except M-5-79, which is vertical. (F) indicates the location of a possible vertical fault. See Appendix A for drillhole information.

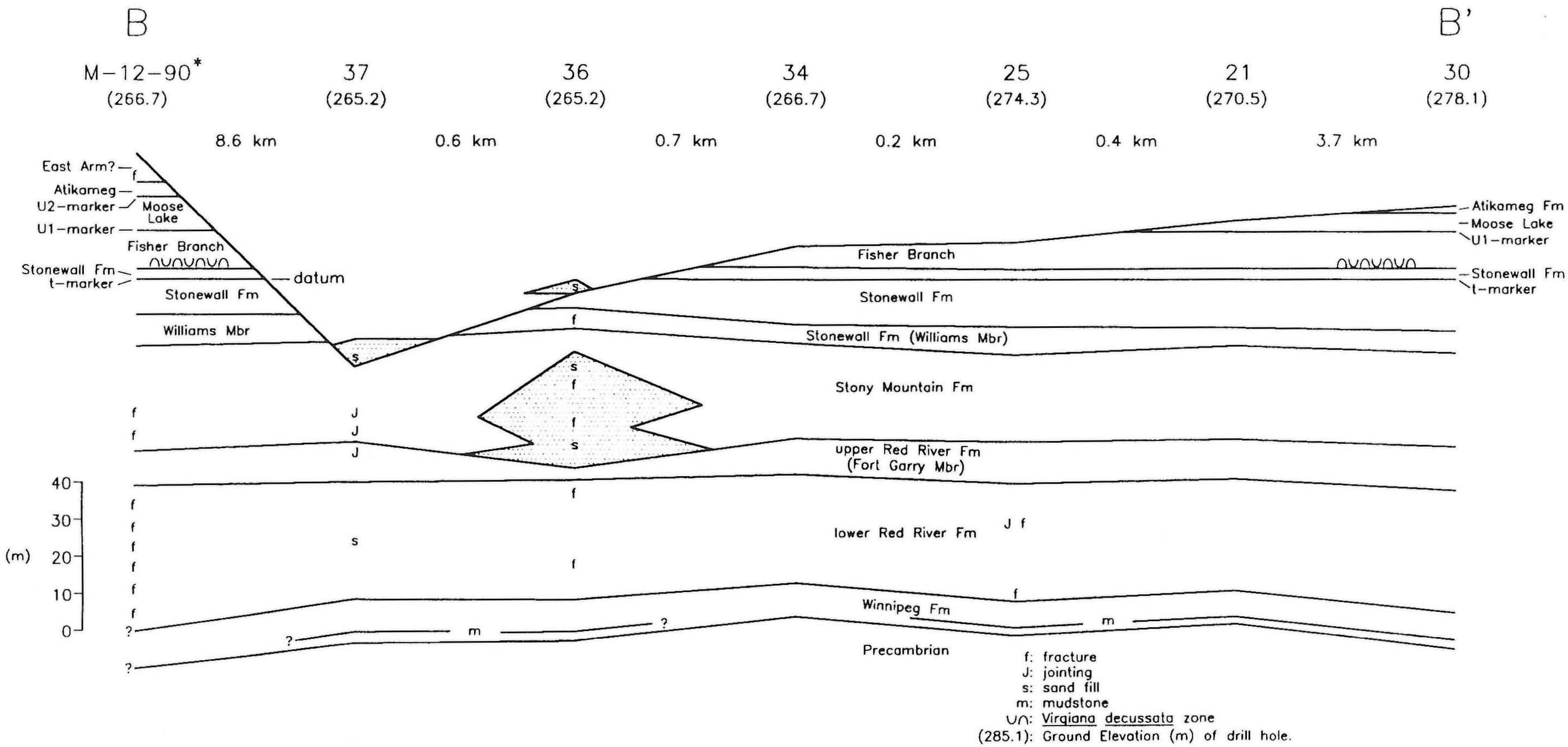


Figure 19: Stratigraphic cross section B-B', William Lake area. See Figure 20 for the equivalent stratigraphic section, Figure 4 for the detailed stratigraphic nomenclature chart, and Figure 16 for cross section location. All holes are directionally drilled diamond-drill holes, except M-12-90, which is vertical. See Appendix A for drillhole information.

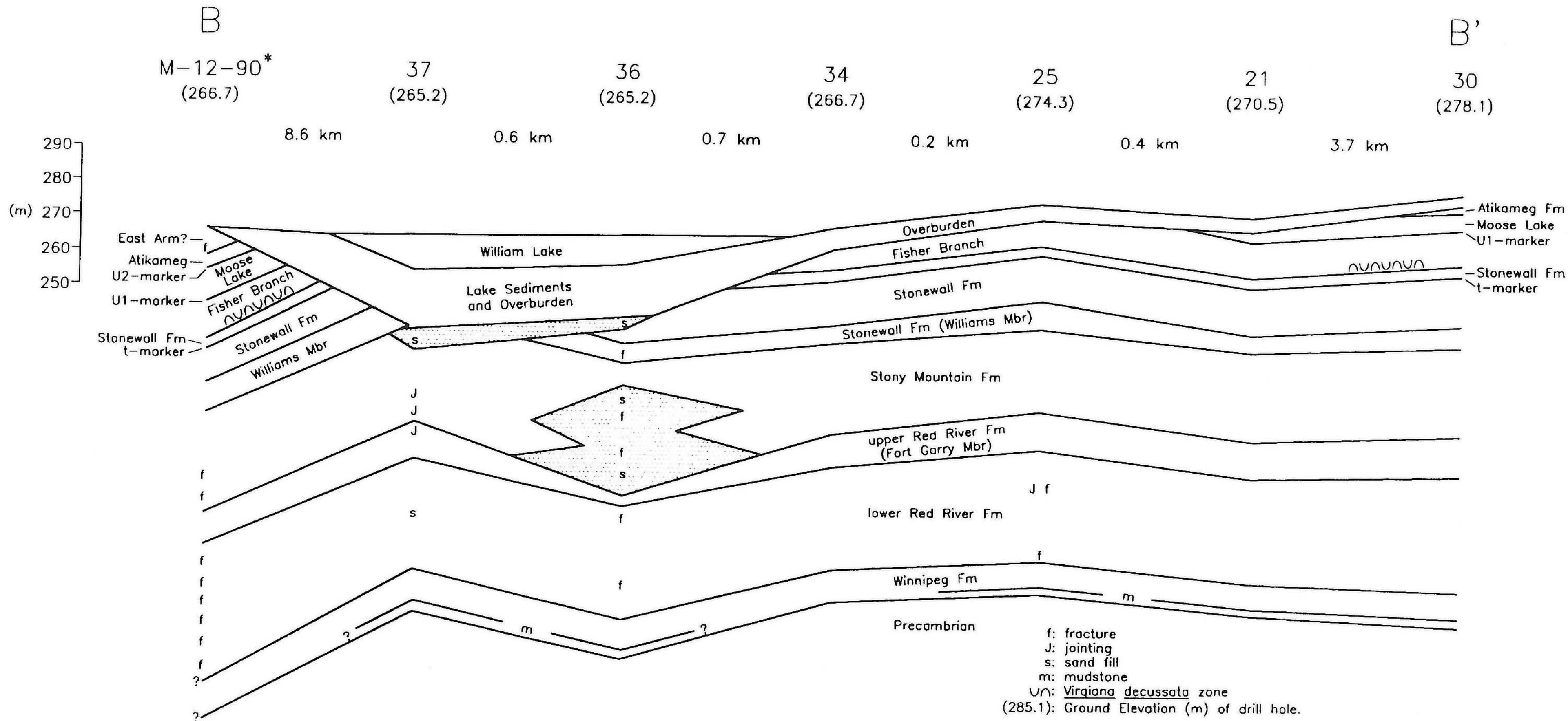


Figure 20: Structural cross section B-B', William Lake area. See Figure 19 for the equivalent stratigraphic section, Figure 4 for the detailed stratigraphic nomenclature chart, and Figure 16 for cross section location. All holes are directionally drilled diamond-drill holes, except M-12-90, which is vertical. See Appendix A for drillhole information.

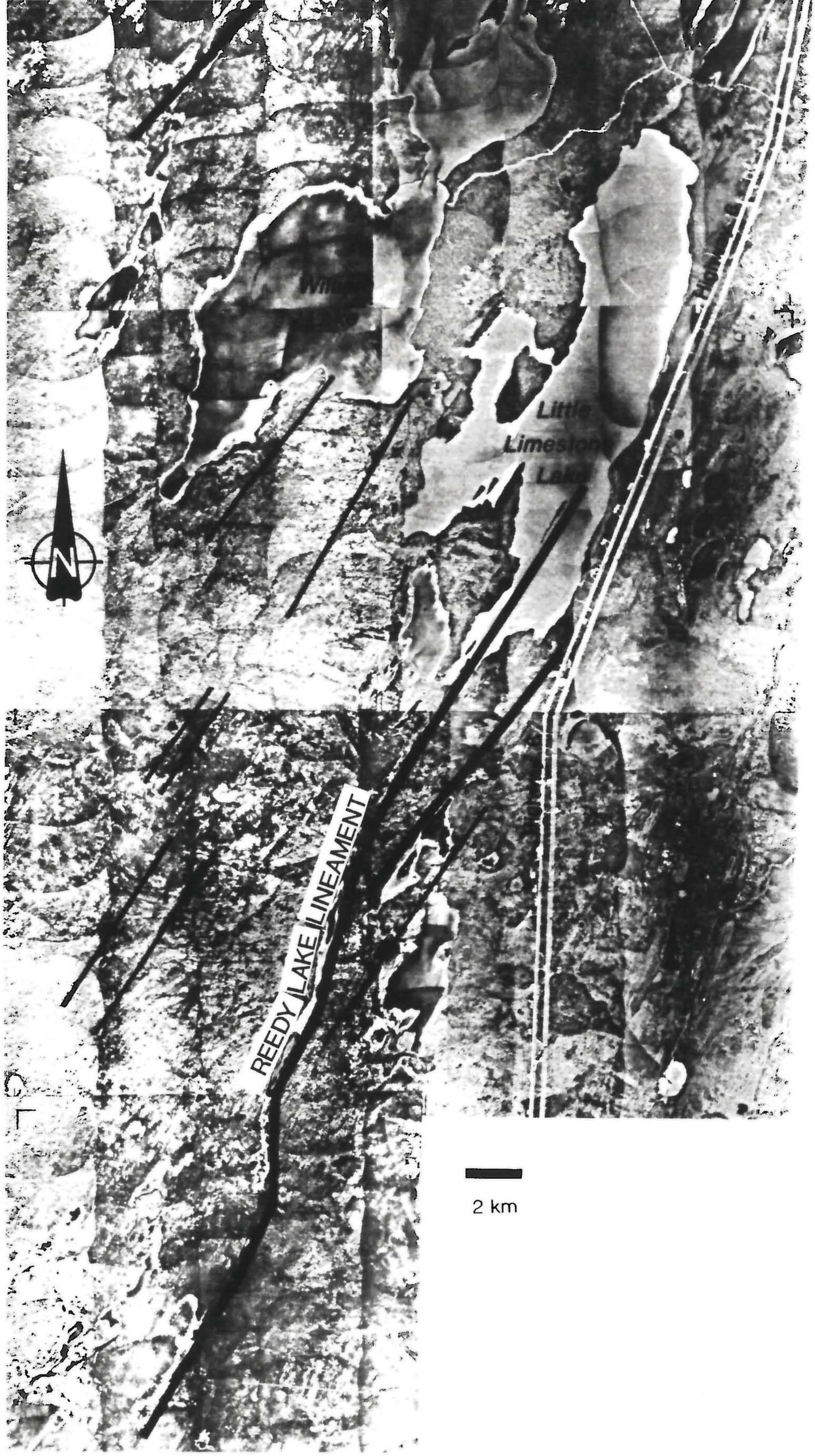


Figure 21: Photomosaic composite of the William Lake area showing major lineaments in black lines.

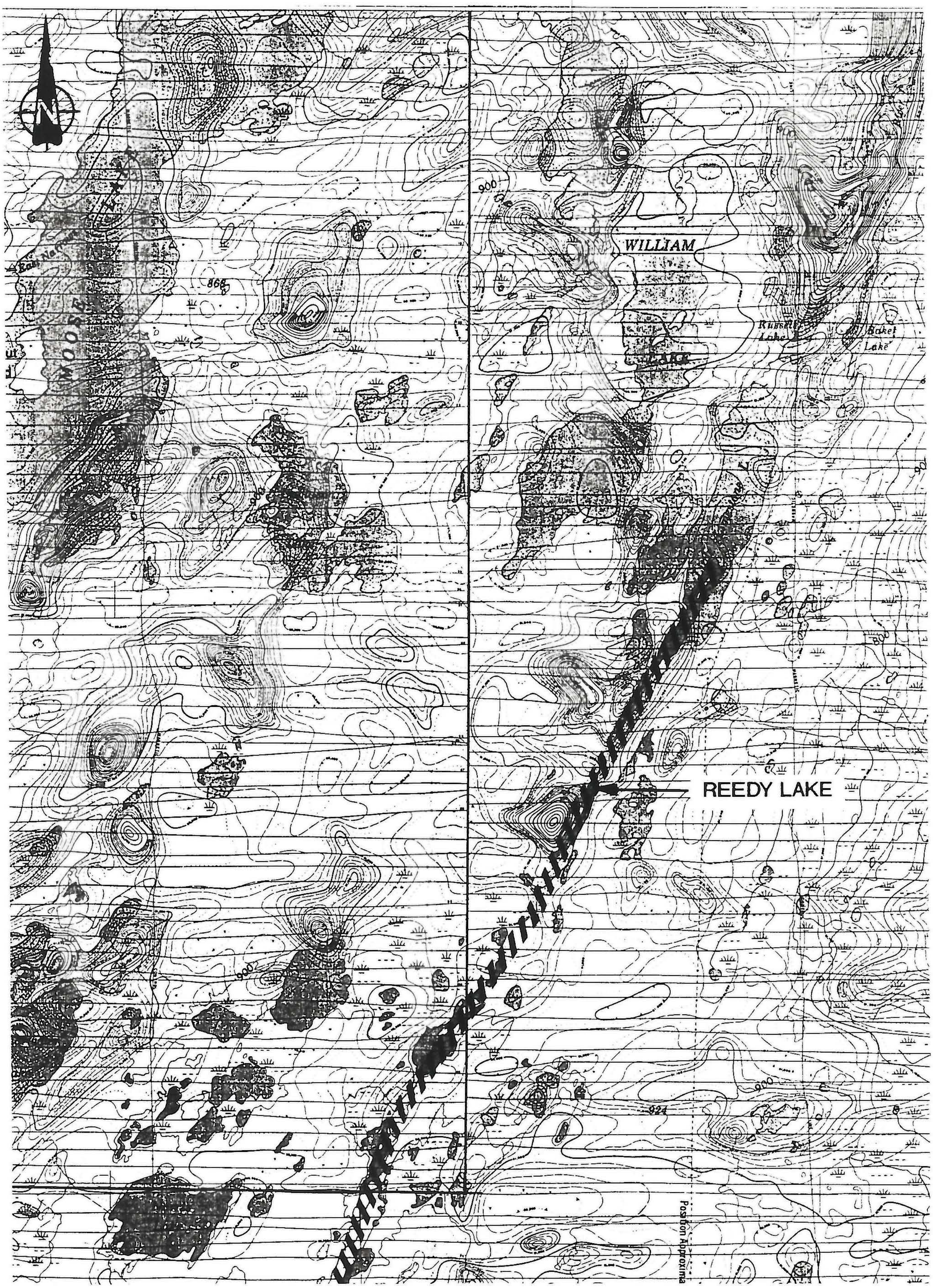


Figure 22: Aeromagnetic map (Geological Survey of Canada, 1969), scale: 1:250 000. Dashed line indicates the approximate location of the Reedy Lake lineament (see Figure 21).

Figure 23: Vertical fracturing in the Silurian East Arm Formation at Reedy Lake.

Figure 24: Vertically fractured Red River Formation core in stratigraphic core hole M-12-90 (William Lake). Top is to the left.

Figure 25: Close-up of fractured core from Figure 24 with clay infill in fracture.

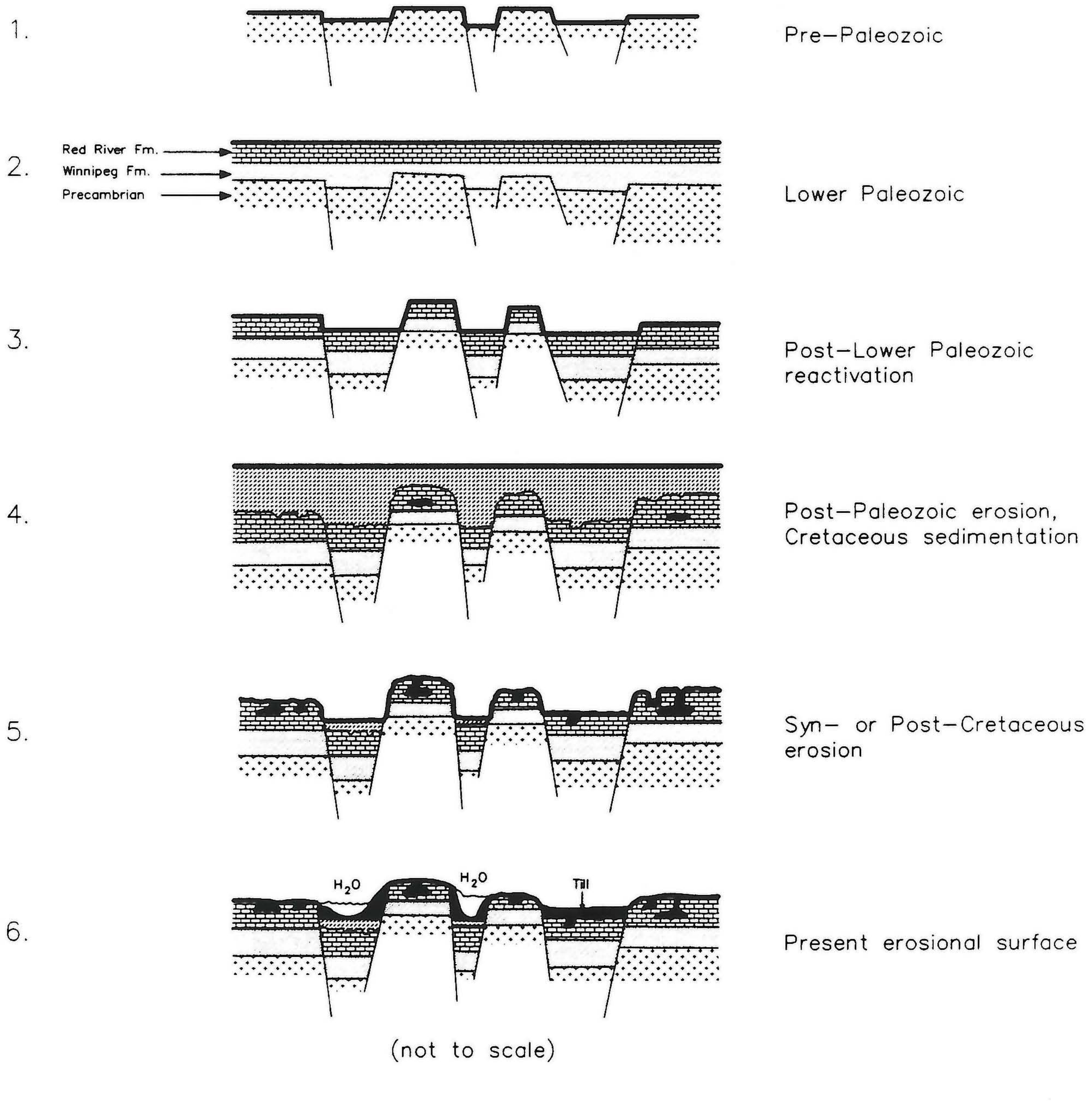


Figure 26: Schematic cross sections and hypothetical events affecting Paleozoic strata in the William Lake area (see text for details).

Figure 26 schematically summarizes the geologic events that may have taken place in the William Lake area. The cross sections are perpendicular to the CSBZ trend. It suggests that block faulting along the CSBZ may have resulted in a series of horst and graben structures perpendicular to the CSBZ during Precambrian time. Later reactivation of these structures affected Mesozoic and Paleozoic strata.

Figure 26 Summary:

1. The pre-Paleozoic surface is represented by a series of horsts and grabens, aligned perpendicular to the CSBZ trend;
2. Lower Paleozoic sedimentation (on top of the Precambrian) with preservation of Precambrian highs and lows; (Fig. 27 shows an alternate sequence of events, with early Lower Paleozoic sedimentation, renewed basement tectonic movement, followed later by Lower Paleozoic sedimentation);
3. Post-Silurian re-activation along basement lineament fault planes;
4. Post-Paleozoic erosion and Cretaceous (Mesozoic) sedimentation with extensive karst development (assuming no syn-Paleozoic tectonic movement);
5. Syn- or post-Cretaceous (Mesozoic) erosion with renewed tectonic movement (?);
6. Present-day topography with Quaternary erosion and sedimentation, with minor Cretaceous remnants.

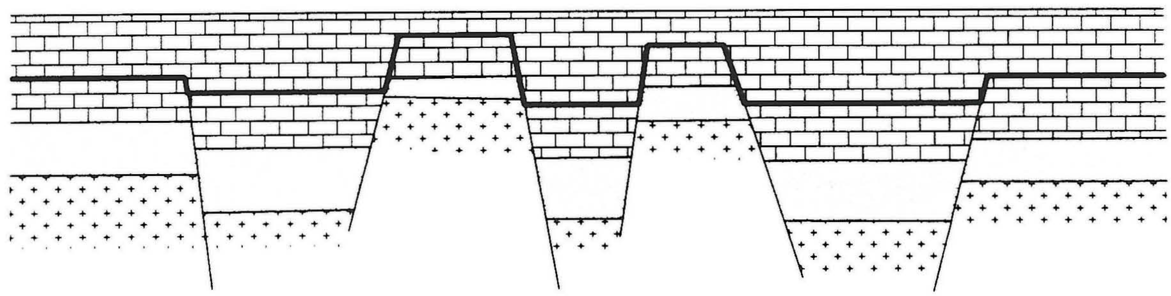


Figure 27: Early Lower Paleozoic Sedimentation with renewed basement tectonic movement, which is followed by later Lower Paleozoic sedimentation (See Fig. 26-3).

ECONOMIC IMPLICATIONS

An understanding of the Paleozoic and sub-Paleozoic structures along the southwestern extension of the CSBZ may be beneficial for the minerals industry in the following ways:

1. the geology on top of the Precambrian surface needs to be determined and understood for the placement of potential mine shafts;
2. structures emanating from the Precambrian may produce pathways for kimberlitic pipes into the Phanerozoic sequence (Lehnert-Thiel *et al.*, 1992), and;
3. Mississippi Valley Type lead-zinc mineralization may be preferentially located along and above reactivated structures (Sangster, 1988).

Basement structures, similar to the ones described in this report, may occur along the Birdtail-Waskada Axis in southwest Manitoba. These areas could be prime sites for the trapping of deep oil and gas or its release, depending on the time frame. Oil and gas well data from southwest Manitoba is sparse; however, evidence in southeastern Saskatchewan suggests that Precambrian structures have affected the Devonian Prairie Evaporite (Holter, 1969; McTavish, 1991). Faults, propagating from the basement, allow for the circulation of brines that have caused dissolution of the Prairie Evaporite and subsequently the collapse of overlying strata. These collapse structures represent potential oil and gas trap sites.

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REFERENCES

Bezys, R.K.
1991: Stratigraphic mapping (NTS 63F, 63K) and core hole program 1991; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1991, p. 61-73.

Bezys, R.K. and McCabe, H.R.
1990: Paleozoic Geology of the Grand Rapids area, NTS 63G; Manitoba Energy and Mines, Minerals Division, Preliminary Map 1990M-1, 1:250 000.

Brindle, J.E.
1960: The faunas of the Lower Paleozoic rocks in the subsurface of Saskatchewan; Saskatchewan Department of Mines, Research Report 52, 45p.

Dunham, R.J.
1962: Classification of carbonate rocks according to depositional texture; in Ham, W.E. (ed.), classification of carbonate rocks, American Association of Petroleum Geologists, Memoir 1, p. 108-122.

Embry, A.F. and Klovan, J.E.
1971: A Late Devonian reef tract on north-eastern Banks Island, N.W.T.; Bulletin of Canadian Petroleum Geology, v. 19, p. 730-781.

Foerste, A.F.
1929: The Ordovician and Silurian of the American arctic and sub-arctic regions. Denison University Scientific Lab Journal, v. 24, p. 27-79.

Fuller, J.G.C.M.
1961: Ordovician and contiguous formations in North Dakota, South Dakota, Manitoba and adjoining areas of Canada and USA; Bulletin of the American Association of Petroleum Geologists, v. 45, p. 1334-1363.

Geological Survey of Canada
1969: Aeromagnetic Series, Geophysics Paper 7740, Grand Rapids, Manitoba; Geological Survey of Canada, Department of Energy, Mines and Resources, Map 7740G, 1:250 000, NTS 63G.

Gerhard, L.E., Anderson, S.B., and Fisher, D.W.
1990: Petroleum geology of the Williston Basin; in M.W. Leighton, D.R. Kolata, D.F. Oltz and J.J. Eidel (eds.), Interior Cratonic Basin, American Association of Petroleum Geologists, Memoir 51, p. 507-559.
1979: Extension of the Superior-Churchill boundary into southern Canada; Canadian Journal of Earth Sciences, v. 16, p. 1691-1701.

Haidl, F.M.
1990: Ordovician hydrocarbon reservoirs, Herald and Yeoman Formations (Red River), southeastern Saskatchewan; in Summary of Investigations 1990, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 90-4, p. 176-186.

Holter, M.E.
1969: The Middle Devonian Prairie Evaporite of Saskatchewan; Department of Mineral Resources, Report No. 123, 133p.

Kendall, A.C.
1976: The Ordovician carbonate succession (Bighorn Group) of southeastern Saskatchewan; Saskatchewan Department of Mineral Resources, Report No. 180, 185p.

Lehnert-Thiel, K., Loewer, R., Orr, R.G. and Robertson, P.
1992: Diamond-bearing kimberlites in Saskatchewan, Canada: The Fort à la Corne case history; Exploration and Mining Geology, v. 1, p. 391-403.

Macek, J. J. and Nagerl, P.
1992: Sub-Paleozoic Precambrian Boundary Zone between the Hargrave and Minago Rivers (63J); Manitoba Energy and Mines, Open File Report OF92-3, 55p.

McCabe, H.R.
1967: Tectonic framework of Paleozoic formations in Manitoba; Transactions of the Canadian Institute of Mining and Metallurgy, v. 70, p. 180-189.
1971: Stratigraphy of Manitoba, an introduction and review; **in** Geoscience studies in Manitoba, A.C. Turnock (ed.); Geological Association of Canada, Special Paper no. 9, p. 167-187.
1978: Reservoir potential of the Deadwood and Winnipeg Formations, southwestern Manitoba; Manitoba Department of Mines, Resources and Environmental Management, Minerals Resources Division, Geological Paper GP78-3, 54p.
1988: Preliminary report on Ordovician - Silurian boundary rocks in the Interlake area, Manitoba, Canada; **in** Cocks, L.R.M. and Richards, R.B. (eds.): A global analysis of the Ordovician - Silurian boundary; Bulletin of the British Museum, Natural History, Geology Series, v. 43, p. 255-257.
1982: Paleozoic stratigraphy of southwestern Manitoba; Geological Association of Canada Field Trip Guidebook, 1982, No. 10, 48p.

McGregor, C. R. and Macek, J. J.
1992: Relogged drill core from the subPhanerozoic SW extension of the Thompson Nickel Belt (NTS 63J, NTS 63G); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1992, p. 110.
1993: Relogged drill core from subPhanerozoic Precambrian basement in 63J; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 126.

McGregor, C.R., Bezys, R.K. and McCabe, H.R.
1990: Subsurface Precambrian structure of the Grand Rapids and Wekusko Lake map sheets (NTS 63G and 63J); Manitoba Energy and Mines, Minerals Division, Preliminary Map 1990M-2, 1:250 000.

McIntyre, D.J.
1993: Report on palynology of three Cretaceous samples from northern Manitoba (NTS 63G/14); Geological Survey of Canada, Internal Report 4-DJM-1993, 1p.

McTavish, G.J.
1991: Role of salt dissolution in controlling outcrop distribution in south-central Saskatchewan; **in** Christopher, J.E. and Haidl F.M. (eds.): 6th International Williston Basin Symposium Proceedings, p. 244-249.

Misra, K.S., Slaney, V.R., Graham, D., and Harris, J.
1991: Mapping of basement and other tectonic features using seasat and thematic mapping in hydrocarbon-producing areas of the Western Sedimentary Basin of Canada; Canadian Journal of Remote Sensing, v. 17, p. 137-151.

Norford, B.S., Haidl, F.M., Bezys, R.K., Cecile, M.P., McCabe, H.R. and Paterson, D.F.
1994: Middle Ordovician to Lower Devonian strata of the Western Canada Sedimentary Basin; **in** Geological Atlas of the Western Canada Sedimentary Basin, G.D. Mossop and I. Shetsen (Compilers), Calgary, Canadian Society of Petroleum Geologists and Alberta Research Council, p. 109-127.

Porter, J.W. and Fuller, J.G.C.M.
1959: Lower Paleozoic rocks of northern Williston Basin and adjacent areas; Bulletin of the American Association of Petroleum Geologists, v. 43, p. 124-189.

Sangster, D.F.
1988: Breccia-hosted lead-zinc deposits in carbonate rocks; in James, N.P. and Choquette, P.W. (eds.), Paleokarst, Springer-Verlog, New York, p. 102-116.

Sloss, L.L.
1963: Sequences in the cratonic interior of North America; Geological Society of America, Bulletin, v. 74, p. 93-114.

Stearn, C.W.
1956: Stratigraphy and paleontology of the Interlake Group and Stonewall Formation of southern Manitoba; Geological Survey of Canada, Memoir 281, 162p.