Distribution of Lower Paleozoic Strata in the Vicinity of the Meadow Lake Escarpment, West-Central Saskatchewan

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This study was undertaken to provide data necessary to delineate the northern limits of Ordovician and Silurian strata on maps generated for the New Geologic Atlas of Western Canada Sedimentary Basin, and to further ongoing research by the author on the Silurian sequence in Saskatchewan (Haidl, 1987, 1988). The paper summarizes results from 73 wells in an area encompassing Townships 47 to 64, Range 24W2 to the Alberta border (Figure 1). Stratigraphic correlations of Ordovician and Silurian carbonates were established using geophysical logs and drill cuttings. Data from the Cambrian and Ordovician clastic sequence are from Paterson (1971) and from an ongoing regional study by D.F. Paterson, who kindly made available these new data.

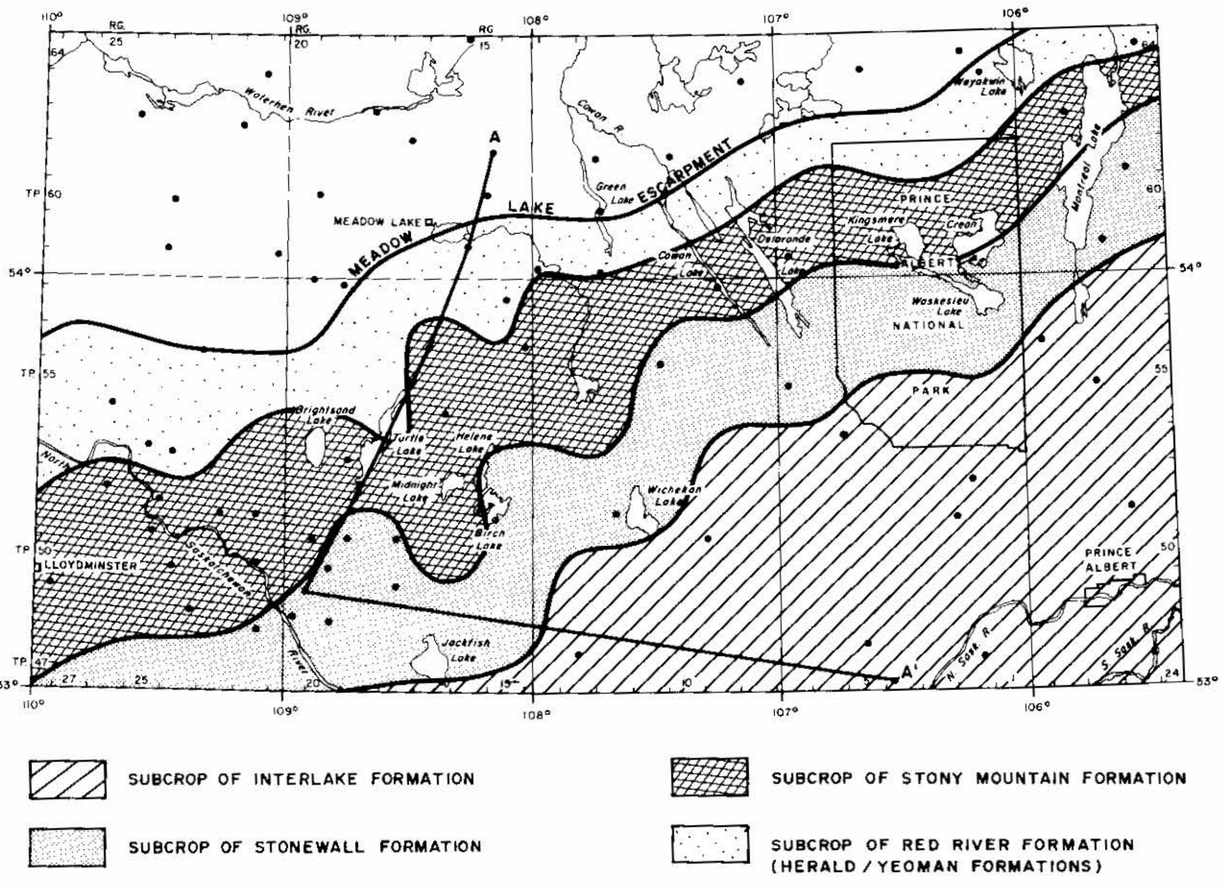

Figure 1 – Subcrop map of Lower Paleozoic carbonates in the study area. The erosional edge of the Red River Formation defines the Meadow Lake Escarpment, a northwest-facing slope formed by differential erosion of Red River carbonates and Deadwood/Earlie clastics. The location of cross section A-A' (Figure 2) is shown by a heavy black line.

1. Geologic Setting

Lower Paleozoic strata in Saskatchewan were deposited on the Interior Platform component of the Western Canada Sedimentary Basin (Aitken, in press; Osadetz and Haidl, in press). These deposits encompass the two lowermost major unconformity-bounded sequences of Sloss (1963), the Sauk Sequence and Tippecanoe Sequence. In west-central Saskatchewan, Sauk Sequence strata are composed entirely of clastics (Deadwood and Earlie Formations) of Middle Cambrian to Early Ordovician age. A major unconformity separates these clastics from the basal clastic unit of the Tippecanoe Sequence, the Winnipeg Formation (Middle Ordovician), which is present only in the eastern portion of the study area (Table 1). The remainder of the Tippecanoe Sequence is composed of carbonates of Late Ordovician to Early Silurian age. This carbonate sequence was deposited in the ancestral Williston Basin with northern depositional limits that probably extended well beyond the study area, but uplift on the northern margin during the pre-Devonian erosion period resulted in substantial truncation of Lower Paleozoic strata (van Hees, 1958, 1964). At the erosional margin of resistant Ordovician carbonates (Figure 2), more rapid erosion of less resistant Deadwood/Earlie clastics formed a relatively steep northwest-facing slope, the Meadow Lake Escarpment (van Hees, 1958). North of this escarpment, pre-Devonian erosion also removed up to 300 m of Sauk Sequence strata (van Hees, 1958, 1964).

Following the initial transgression of Middle Devonian seas, a complex sequence of evaporites, carbonates, and clastics (Meadow Lake Fm., Fuzesy, 1980; Meadow Lake Beds, van Hees, 1956; Buller, 1958) were deposited in the Lower Elk Point Basin. Distribution of these strata indicate that the approximate southern shoreline of this basin was, at that time, formed by the Meadow Lake Escarpment, along the northeast-southwest curvilinear trend of the erosional edge of the Red River Formation (van Hees, 1958). Later transgression of the sea southwards across the Escarpment resulted in deposition of the argillaceous dolomites, dolomitic shales, and minor anhydrites of the Ashern Formation (van Hees, 1958; Buller 1958; uppermost beds, Meadow Lake Fm., Fuzesy, 1980). At the close of Ashern deposition, the Meadow Lake Escarpment was buried by Devonian sediments (Figure 2).

In the northeast corner of the study area (wells in Twp. 61 and 64, Rge. 24W2; Twp. 63, Rge. 1W3, Table 1), truncation of Devonian and Lower Paleozoic strata occurred during the pre-Cretaceous erosion period. In this area, Lower Cretaceous sandstones of the Mannville Group overlie Ordovician carbonates.

2. Stratigraphy

a) Deadwood and Earlie Formations

Historically, the siltstones, shales, and sandstones which comprise the basal sedimentary sequence in western Saskatchewan have been assigned to the Deadwood Formation (Fyson, 1961; Fuzesy, 1980). Recent work by Paterson (1988; this volume) suggests that the lower portion of the sequence is Middle Cambrian in age and correlates with the Earlie Formation defined in eastern Alberta (Pugh, 1971). The remainder of the sequence correlates with the Deadwood Formation which is assigned a Late Cambrian to Early Ordovician age (Paterson, 1988; Lefever *et al.*, 1987; Pugh, 1971).

In east-central Alberta, the Earlie Formation is composed of "interbedded, glauconitic siltstones and fine-grained sandstones and shales" (Pugh, 1971, p7) and the Deadwood Formation consists of interbedded

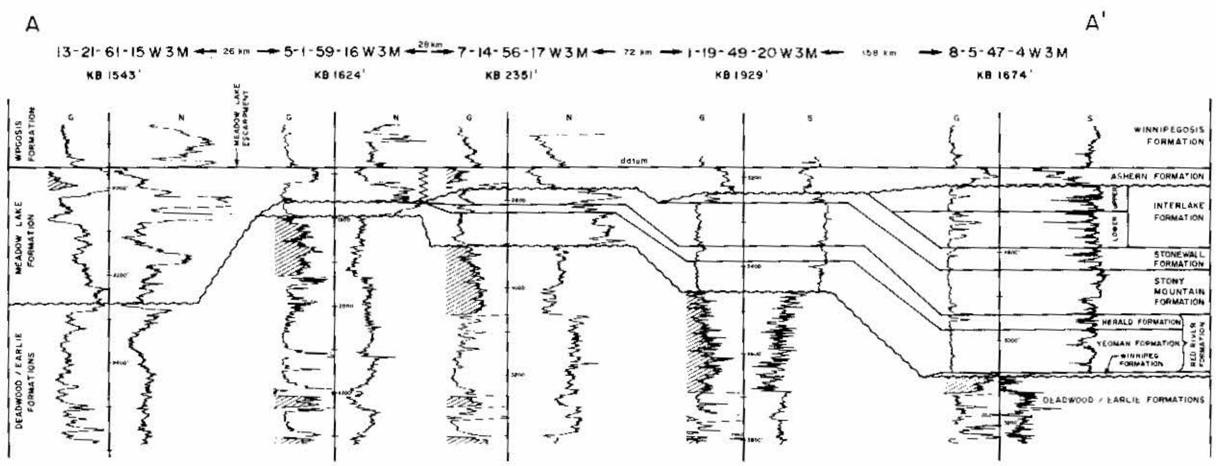

Figure 2 – Cross section showing progressive truncation of Lower Paleozoic carbonates from south to north. North of the Meadow Lake Escarpment, which formed at the erosional edge of the Red River Formation, Middle Devonian strata (Meadow Lake Fm., Fuzesy, 1980; Meadow Lake Beds and Ashern Formation, van Hees, 1958) infill the erosional low on the Deadwood/Earlie Formations. Location of the cross section is shown in Figure 1. Logs used are gamma (G) and neutron (N) or sonic (S). Datum is the top of the Ashern Formation..

Table 1 – Well data. Well location, kelly bushing elevation, and depth of tops of the Ashern Formation, Meadow Lake Beds, Upper Interlake unit, Lower Interlake unit, Stonewall Formation, Stony Mountain Formation, Red River Formation, Winnipeg Formation, Deadwood/Earlie Formations, and Precambrian in metres. A dash indicates that a unit is not present; a blank space indicates no data are available because well is not deep enough.

WELL LOCATION	K.B.	ASH TOP	MLB TOP	U.INT TOP	L.INT TOP	STW TOP	STM TOP	RR TOP	WPG TOP	DWD TOP	PC TOP
02-05-61-24W2	524.6	---	---	---	---	235.6	244.4	275.2	311.5	319.4	537.4
08-15-64-24W2	504.7	---	---	---	---	---	---	158.5	170.7	204.2	384.7
07-26-51-25W2	479.5	522.4	---	529.1	541.0	568.1	582.2	609.6	654.7	671.8	882.7
16-07-55-25W2	521.8	432.5	---	---	437.4	463.6	478.5	509.3	549.9	555.3	793.4
03-04-59-25W2	507.2	288.6	---	---	---	296.6	309.1	339.5	380.1	386.8	
05-22-62-26W2	589.5	268.8	---	---	---	---	273.1	294.4	330.4	374.3	556.0
04-15-56-27W2	558.1	442.6	---	---	451.7	459.3	476.4	506.3	544.4	552.6	810.2
03-18-63-01W3	648.3	---	---	---	---	---	---	372.2	378.0	433.1	640.4
16-26-47-02W3	503.5	730.3	---	741.6							
13-19-51-02W3	509.6	591.9	---	598.0	600.5	630.3	650.1	675.7	714.1	718.7	1007.1
08-15-52-02W3	539.8	585.2	---	591.6	597.4	622.7	637.6	667.2	705.9	709.9	990.0
08-08-64-02W3	635.8	474.6	491.6	---	---	---	---	---	---	577.6	610.5
08-05-47-04W3	510.2	794.3	---	806.5	824.5	849.8	865.0	896.1	938.5	940.3	
08-03-48-05W3	512.7	762.9	---	770.2	789.7	810.8	827.2	856.8			
14-31-53-05W3	512.1	549.6	---	---	556.9	570.0	585.2	612.6	646.8	648.3	
01-36-63-05W3	557.8	459.3	468.8	---	---	---	---	---	---	548.0	581.9
05-10-55-07W3	498.7	508.4	---	---	---	518.8	535.8	563.3	595.9	597.4	
12-35-58-07W3	505.7	382.2	---	---	---	---	388.0	415.4	444.4	445.9	
09-21-63-08W3	524.9	492.6	503.8	---	---	---	---	---	---	589.5	620.3
07-05-51-09W3	642.2	826.6	---	---	834.2	846.7	865.9	898.6	931.5	933.3	
02-01-58-09W3	490.1	420.6	---	---	---	---	429.2	453.2	485.9	489.2	842.8
04-31-55-10W3	596.5	628.5	---	---	---	637.6	646.8	672.4	702.6	705.6	
02-16-60-10W3	485.2	383.1	392.0	---	---	---	---	---	414.8	416.4	775.7
16-21-61-10W3	499.0	427.3	438.0	---	---	---	---	---	---	467.0	
13-18-65-11W3	491.0	495.3	507.8	---	---	---	---	---	---	594.4	615.1
13-25-51-12W3	591.6	777.8	---	---	---	788.8					
06-14-58-12W3	549.2	534.3	---	---	---	---	---	548.0	570.3	571.8	
02-02-60-12W3	505.1	468.8	481.6	---	---	---	---	---	---	486.2	
10-20-61-12W3	467.3	511.5	523.6	---	---	---	---	---	---	583.4	
14-34-47-13W3	729.7	1056.7	---	1065.6							
10-16-56-14W3	586.4	671.5	---	---	---	---	687.6	693.1	719.3	721.2	
06-23-58-14W3	548.0	554.1	---	---	---	---	---	564.8	---	596.2	
05-25-57-15W3	565.1	608.1	---	---	---	---	---	620.3			
01-16-60-15W3	482.5	605.6	620.3	---	---	---	---	---	---	671.5	
13-21-61-15W3	470.3	597.4	610.5	---	---	---	---	---	---	688.8	839.7
08-30-64-15W3	476.7	580.3	598.3	---	---	---	---	---	---	708.1	731.2
05-19-54-16W3	730.0	900.1	---	---	---	---	914.4	939.1	---	967.7	1399.0
05-01-59-16W3	495.0	513.6	523.3	---	---	---	---	537.1	---	547.4	970.2
07-14-56-17W3	716.6	830.9	---	---	---	---	845.5	856.8	---	885.4	1318.3
01-33-61-17W3	470.6	601.7	619.4	---	---	---	---	---	---	712.6	885.1
03-27-49-18W3	576.1	910.7	---	---	---	925.1	932.1	963.8	---	1003.7	
16-02-51-18W3	682.1	970.5	---	---	---	985.1	990.0	1021.4	---	1056.4	
07-28-62-18W3	499.0	662.3	685.5	---	---	---	---	---	---	789.4	
10-05-51-19W3	649.8	964.4	---	---	---	981.5					
06-09-53-19W3	681.8	930.6	---	---	---	---	940.9				
12-04-58-19W3	564.8	677.9	691.0	---	---	---	---	---	---	715.1	
08-26-48-20W3	558.1	955.5	---	---	---	972.9	983.3	1017.0	---	1050.6	
01-19-49-20W3	588.0	968.7	---	---	---	986.0	992.4	1022.3	---	1054.3	1511.8
02-11-50-20W3	585.5	929.0	---	---	---	945.8	948.8	983.0	---	1014.7	
06-05-51-20W3	615.4	947.3	---	---	---	---	961.3	993.6	---	1026.6	1481.3
15-10-58-20W3	530.7	724.8	731.5	---	---	---	---	---	---	822.7	1147.6
02-13-60-20W3	520.3	731.8	755.9	---	---	---	---	---	---	814.7	1052.2
07-35-48-21W3	553.2	954.6	---	---	---	969.6	977.2	1007.7	---	1042.4	
04-34-58-21W3	562.1	809.2	840.0	---	---	---	---	---	---	881.5	1184.5
12-34-63-21W3	594.4	766.9	793.1	---	---	---	---	---	---	915.3	
10-23-48-22W3	566.0	992.7	---	---	---	1008.9	1014.4	1046.1	---	1083.3	
10-23-50-22W3	573.0	934.5	---	---	---	---	947.0				
01-25-51-22W3	657.5	989.1	---	---	---	---	1000.4	1034.2	---	1065.3	
08-11-62-22W3	520.6	731.2	762.6	---	---	---	---	---	---	874.8	1051.9
06-25-51-23W3	591.6	936.7	---	---	---	---	945.8	953.4			
12-10-56-23W3	655.0	887.9	905.3	---	---	---	---	---	---	925.4	
06-01-49-24W3	644.0	1081.7	---	---	---	---	1094.8	1122.6	---	1163.4	1646.8
10-09-50-24W3	602.0	1004.9	---	---	---	---	1017.1				
10-07-51-24W3	575.2	967.7	---	---	---	---	978.4	1001.3	---	1039.4	1533.1
06-05-52-24W3	654.9	1016.5	---	---	---	---	1030.8				
01-16-53-24W3	569.1	895.2	---	---	---	---	---	911.7	---	954.9	
10-02-59-24W3	568.8	802.8	833.6	---	---	---	---	---	---	1001.3	
15-13-60-24W3	556.6	753.5	786.1	---	---	---	---	---	---	1007.1	
10-24-53-25W3	634.6	966.8	---	---	---	---	---	986.3	---	1005.2	1518.8
01-25-62-25W3	553.5	748.0	780.3	---	---	---	---	---	---	1056.1	1147.3
10-23-52-26W3	573.9	962.3	---	---	---	---	981.5	987.6	---	1021.4	1522.7
01-25-54-26W3	667.2	1011.0	1033.3	---	---	---	---	1036.0	---	1055.2	1548.4
12-30-49-27W3	646.5	1138.7	---	---	---	---	1149.1	1172.0	---	1205.0	1711.0

micaceous shales and micaceous and glauconitic siltstones (Pugh, 1971).

Preliminary log correlations suggest that similar lithologies are present over much of western Saskatchewan. In the vicinity of the Meadow Lake Escarpment, stratigraphic correlation is less certain. The Deadwood Formation in this area contains coarse-grained siltstones and fine-grained sandstones (Pugh, 1971) thus making it difficult to delineate the Deadwood/Earlie boundary. An additional correlation problem occurs at the base of the clastic sequence directly overlying rocks of Precambrian age. The Basal sandstone unit described by Pugh (1971) has not been defined in Saskatchewan and, therefore, the oldest Cambrian rocks are included in the Deadwood/Earlie sequence.

In this study the Deadwood and Earlie Formations have not been differentiated. An isopach map of net thickness of the two formations illustrates both depositional and erosional patterns associated with these strata (Figure 3). Deposition of this sequence took place in the "Lloydminster Embayment", a shallow depression which developed on the Interior Platform of the Western Canada Basin during the Middle Cambrian (van Hees, 1964; Aitken, in press). South of the Meadow Lake Escarpment the distribution of strata reflects deposition within this embayment with maximum thickness (513.6 m) present in 10-24-53-25W3 in the southwest corner of the study area. Two periods of erosion have affected Deadwood/ Earlie strata. The dramatic thinning of Deadwood/Earlie rocks north of the Escarpment is attributed primarily to pre-Devonian erosion. However, pre-Ordovician uplift and erosion on the eastern margin of the basin (van Hees, 1964) also contributed to removal of a portion of this sequence.

b) Winnipeg Formation

The Winnipeg Formation (Middle Ordovician) unconformably overlies the Deadwood Formation in the eastern half of the study area. It is composed predominantly of quartz sandstone with sub-angular to rounded grains ranging from very fine to coarse. The contact with the overlying carbonates of the Red River Formation is described as conformable by some authors (e.g. Vigrass, 1971) and as unconformable by others (e.g. Paterson, 1971; Kendall, 1976). The thin sheet (<3 m) of Winnipeg strata that blankets much of the study area (Figure 4 of Paterson, 1971), is interpreted by Kendall (1976) as the basal sandstone (or arenaceous dolomite) commonly present at the base of the Red River Formation. Maximum thickness (up to 55.1 m) of the Winnipeg Formation in the study area occurs in the northeast corner; the author's correlation of this thick sand unit as part of the Winnipeg Formation is tentative.

c) Herald and Yeoman Formations (Red River Formation)

A thin remnant (16 m) of the Yeoman Formation cored in California Standard Fort Pitt 1-25-54-26W3 is composed primarily of burrowed, mottled and commonly

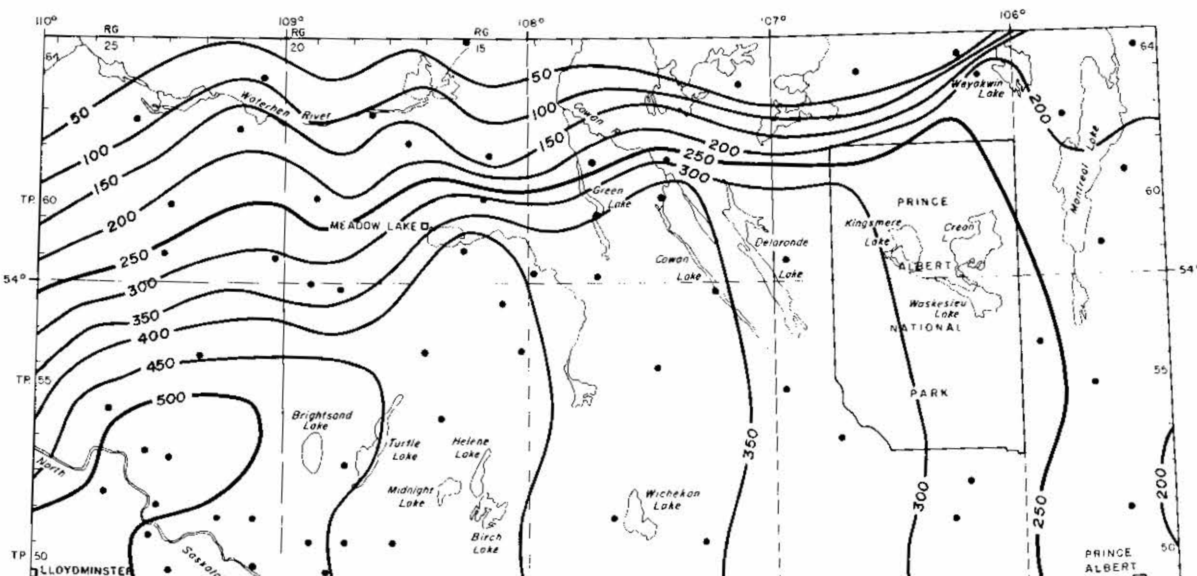

Figure 3 – Isopach map of undifferentiated Deadwood and Earlie Formations. Contour interval is 50 m.

nodular dolomite. Geophysical log response and samples suggest that this lithology is typical of the Yeoman throughout the study area. The burrowed and mottled nature is characteristic of this unit throughout the Williston Basin (Kendall, 1976, 1985; Haidl, 1988). In the Fort Pitt core (1-25-54-26W3) the dolomite sequence contains anomalous abundant lenses and irregular beds of reddish-brown dolomitic shale and anhydrite over a 3.5 m interval approximately 5 m below the top of the Yeoman. The contacts between the dolomite and the shale clearly indicate infiltration by the shale of the overlying Ashern Formation into fractures and solution cavities developed in the carbonate during the pre-Devonian erosional period. Anhydrite was probably precipitated in cavities in the Yeoman Formation at the same time as it formed in the Ashern Formation.

The Herald Formation has not been cored in the study area but geophysical log response and samples indicate that it is composed of microcystalline dolomite with interbeds of argillaceous dolomite. The contact between the Herald Formation and the overlying Stony Mountain Formation is placed at the base of a marker bed characterized by a marked deflection to the right (higher values) on gamma ray logs. This bed is composed of argillaceous dolomite, with interbeds of arenaceous dolomite. The presence of multiple argillaceous beds with similar log response within the Herald Formation and within the lower portion of the Stony Mountain Formation often makes correlation of this contact difficult (Figure 2).

In this study, the Yeoman and Herald Formations have been mapped as one unit. The contact between the two formations is described as gradational and is difficult to pick even in areas with good well and core control (Kendall, 1976; Haidl, 1988). For this reason the Herald/Yeoman contact has not been picked for the purpose of regional mapping. This undifferentiated Herald/Yeoman unit is equivalent to the Red River Formation in adjacent areas of the Williston Basin. In the study area, total thickness of Herald/Yeoman strata ranges from 45.1 m in 7-26-51-25W2 to zero along the erosional edge (Figure 1). Depositional thicknesses (where penetrated) range from the maximum of 45.1 m in 7-26-51-25W2 to a minimum of 28.1 m in 10-16-56-14W3.

d) Stony Mountain Formation

The subcrop of the Stony Mountain Formation also follows a northeast-southwest trend, roughly parallel to the Meadow Lake Escarpment (Figure 1). Data from wells which penetrate the depositional thickness of these strata indicate that maximum thickness of Stony Mountain strata (up to 34.2 m) occurs in the southwest portion of the map area. The two wells (13-19-51-2W3 and 4-31-55-10W3) with minimum thickness (25.6 m) are located along a line running northwest from the city of Prince Albert. In 13-19-51-2W3, the decreased thickness of the Stony Mountain coincides with a thick Stonewall interval. The gamma ray log over the Stonewall/Stony Mountain sequence in this well indicates a number of anomalously high gamma responses. However, no significant increase in argillaceous content is apparent in drill cuttings.

No cores were taken from this formation but samples and geophysical log response indicate that this interval is composed of burrowed mottled dolomite with minor interbeds of argillaceous dolomite, similar to the lithologies observed in Stony Mountain cores from the Cumberland Lake area in east-central Saskatchewan (Haidl, 1988).

The upper contact of the Stony Mountain Formation is placed at the base of a thin argillaceous dolomite bed (commonly with quartz grains) which, where well-developed, has a characteristic high gamma ray log reading. However, in several wells this marker bed is not well-defined, making accurate correlation of the Stonewall/Stony Mountain boundary difficult (Figure 2).

e) Stonewall Formation

In west-central Saskatchewan the Stonewall Formation is composed of microcrystalline, in places fossiliferous, dolomite and cryptocrystalline dolomite. Prominent marker beds are present at the base, in the middle ("t" horizon), and at the top of the formation. The marker beds consist of argillaceous dolomite with interlaminations of dolomitic shale. Quartz grains are commonly observed in samples, usually as scattered grains in argillaceous dolomite, but also as sandstone samples.

The entire Stonewall Formation is preserved in the southeastern portion of the study area where it ranges in thickness from 14.1 m in 7-26-51-25W2 to 19.8 m in 13-19-51-2W3. The subcrop of the Stonewall Formation is illustrated in Figure 1.

f) Interlake Formation

Rocks of the Interlake Formation are preserved in the southeastern portion of the study area. The erosional edge follows a northeast-southwest trend, parallel to the subcrops of other Lower Paleozoic carbonate units (Figure 1).

In Saskatchewan, the Interlake is subdivided into two informal stratigraphic units, Lower and Upper Interlake (Haidl, 1987). The Lower Interlake contains several well-defined marker beds, characterized by a high gamma ray log response, while there is a paucity of such beds in the Upper Interlake. In the study area, fossil fragments, coated grains, and microcrystalline,commonly laminated, dolomite observed in samples all suggest that the lithologic sequence is similar to that observed in cores in east-central Saskatchewan (Haidl, 1988). Samples and log response indicate the occurrence of a number of marker beds composed of argillaceous dolomite with interbeds of dolomitic shale, arenaceous dolomite and minor sandstone.

The basal metre of the Lower Interlake is cored in 11-7-58-21W2, a well just east of the study area. The cored interval consists of a dolomitized coral stromatoporoid(?) floatstone, a lithology characteristic of the basal Lower Interlake in the Cumberland Lake area (Haidl, 1988).

The full depositional thickness of the Lower Interlake unit is penetrated in only five wells where values range from 25.3 m to 29.8 m (Table 1). The erosional remnant of the Upper Interlake in these wells has a maximum thickness of 19.5 m in 8-3-48-5W3.

3. Structure

Structure contours on the top of the Precambrian basement define a homocline which dips to the southwest at approximately 4.5 m per kilometre (Figure 4). No major anomalies are observed on this surface in the map area and present well control is insufficent to define minor structures.

The map of structure contours on the top of Deadwood/Earlie Formations (Figure 5) illustrates strata in the southern portion of the study area dipping to the south-southwest at approximately 4.5 m per kilometre. Along the Meadow Lake Escarpment, erosional relief on these strata disrupts the regional trend. Here contours define a west-southwest trending "nose", roughly parallel to the Escarpment. A similar pattern is defined by contours on the top of the sub-Devonian unconformity (Figure 3 of Buller, 1958).

The principal reason for the trend of the Escarpment is not clear. There appears to be no evidence of significant faulting on the present-day Precambrian surface (Figure 4). There has been speculation that the Escarpment coincides with basement faulting which may have had both vertical and lateral movements (van Hees, 1958, 1964). D.M. Kent (pers. comm.) speculates that this feature, particularly at its northeast extremity, may be associated with an extension of the Stanley Fault (Figure 1 of Padgham, 1968).

4. Further work

This study was originally undertaken as a regional mapping project based primarily on geophysical logs. More detailed work is required to fully understand depositional and erosional features and their relationship to such factors as eustatic sea level changes and basement tectonics.

a) Stratigraphic correlation north of the Meadow Lake Escarpment

Interpretation of depositional and erosional features in this area requires detailed stratigraphic correlation based on comprehensive knowledge of the lithologies of the various formations. The basal clastic sequence requires further study in order to differentiate the "Basal sandstone", and the Deadwood, Earlie and Winnipeg Formations. The complex lithologies of the Meadow Lake Formation must also be mapped in detail in order that a sandy facies of the Meadow Lake Formation can more readily be distinguished from the underlying Deadwood or Earlie Formations, or a Meadow Lake dolomite from a remnant of the Red River Formation.

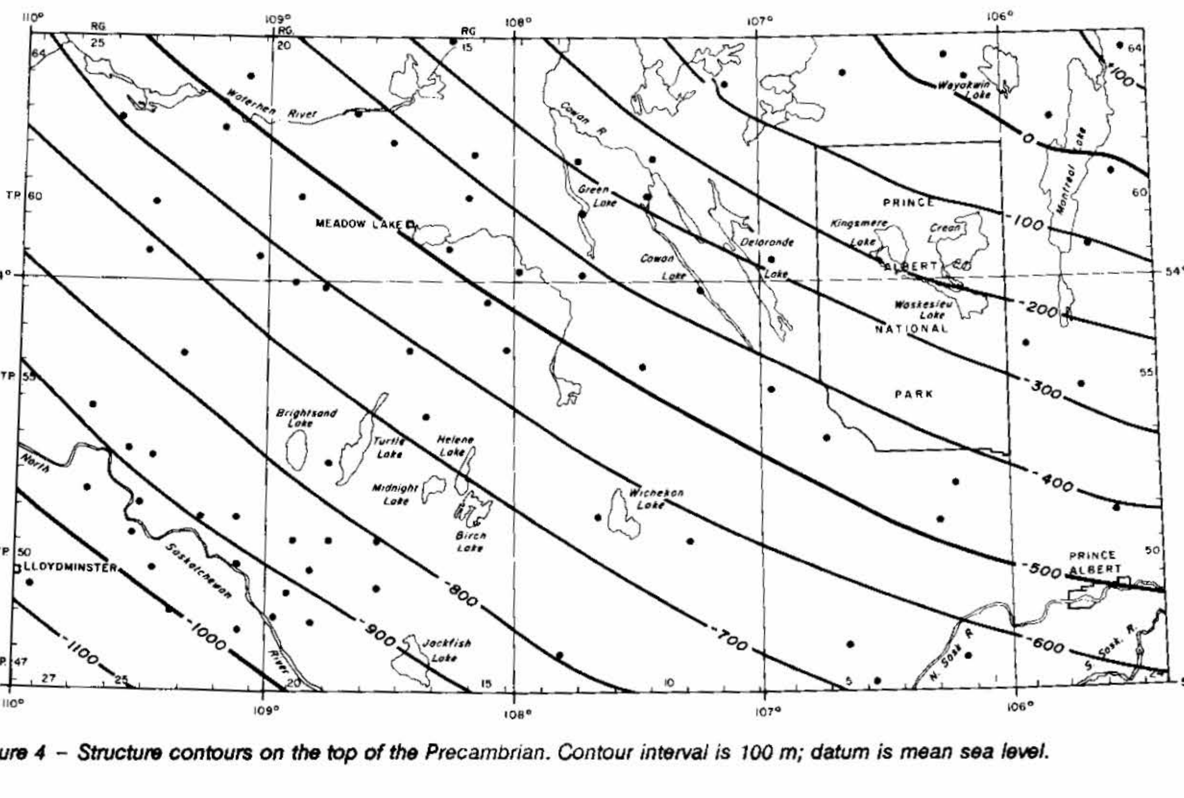

Figure 4 - Structure contours on the top of the Precambrian. Contour interval is 100 m; datum is mean sea level.

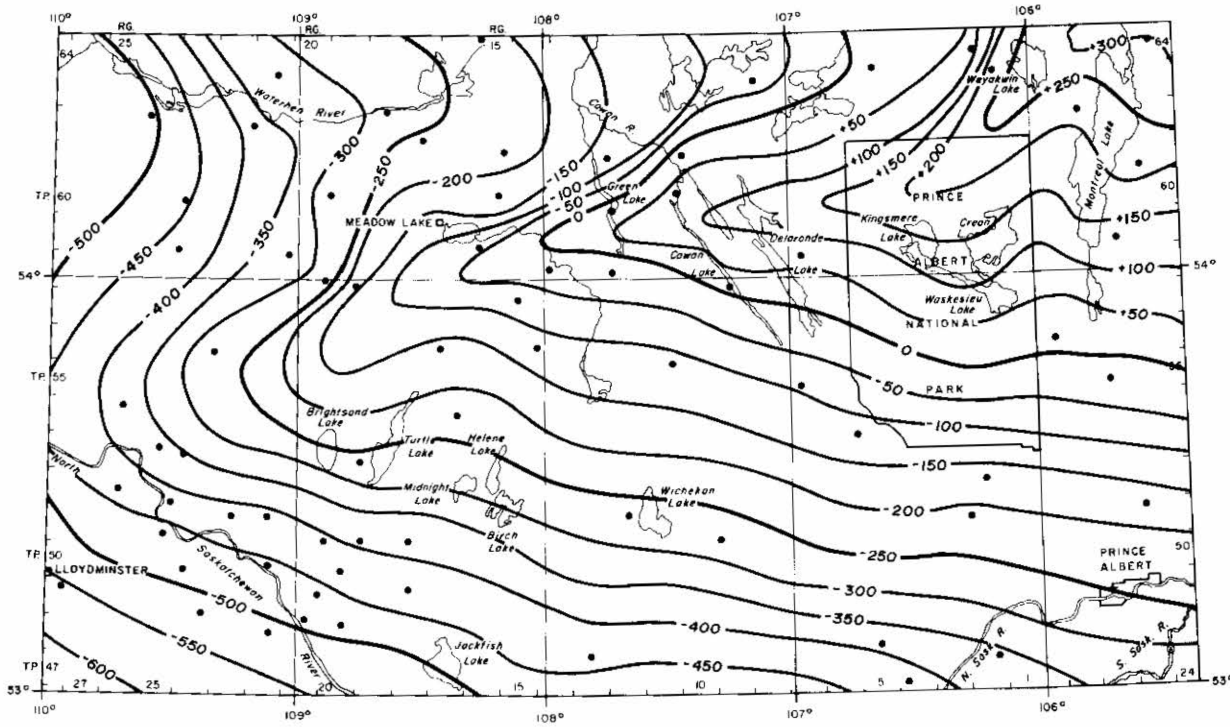

Figure 5 – Structure contours on the top of undifferentiated Deadwood/Earlie Formations. Contour interval is 50 m; datum is mean sea level.

b) Depositional Trends

Analysis of depositional trends requires that the area of study be extended away from the erosional edges of the various formations. More detailed lithologic data must be acquired to improve understanding of depositional sequences within both the clastic and carbonate units. Integration of these data with geophysical data may enhance understanding of the relationship of depositional and erosional features to basement tectonics.

One depositional trend observed in this study warrants more detailed analysis. The southeast-northwest trending depositional thin in the Stony Mountain Formation to the northwest of Prince Albert possibly extends to the southeast to Township 37, Range 9W2 where a similar feature exists (Figure 19 of Kendall, 1976). It is of interest to note that the Sturgeon Lake kimberlite discovery (Twp. 51, Rge. 1W3) lies along this trend.

5. References

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