Lithology and Stratigraphy of Lower Paleozoic Strata: New Information from Cores in the Cumberland Lake Area, East-Central Saskatchewan

F.M. Haidl

Haidl, F.M. (1988): Lithology and stratigraphy of lower Paleozoic strata: new information from cores in the Cumberland Lake area, east-central Saskatchewan; *in* Summary of Investigations 1988, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 88-4.

Lower Paleozoic strata outcrop at a number of localities in the Cumberland Lake area of east-central Saskatchewan (Kupsch, 1952). Correlation of these outcrops with strata in the subsurface of southern Saskatchewan is hampered by limited exposures in the field and by a paucity of subsurface information north of Township 50. In the summer of 1988, four new cores and supplementary data from recent drilling projects were kindly made available to Saskatchewan Energy and Mines by Cominco Ltd. This new information should facilitate stratigraphic correlation in the area.

The locations of the four Cominco cores are shown in Figure 1. Cores SR1 and SR3 were taken by Cominco in the winter of 1986 as part of the Squaw Rapids drilling project (in the Cumberland Delta area, north of Squaw Rapids). Both cores are continuous from near the top of the Lower Interlake to a few metres below the Paleozoic/Precambrian contact (Figure 2). Cores from the Berland project (Ber3 and Ber4) were taken from holes drilled through the ice on Cumberland Lake in March 1988. A cursory examination of these cores suggests that they encompass strata from uppermost Precambrian to at least as high as the Stonewall Formation, and possibly even part of the lowermost Lower Interlake. All four cores have a diameter of 4.5 cm and were taken from directionally drilled holes; all depth and thickness values given here have been corrected to true vertical depth.

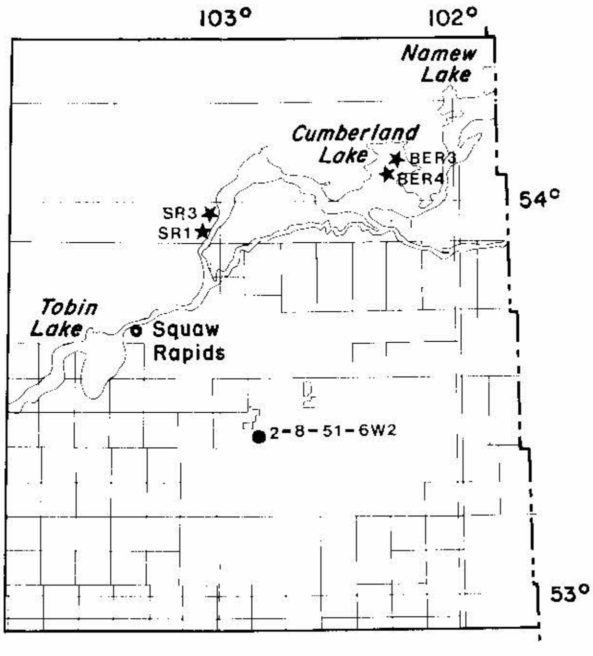

Figure 1 - Map showing the location of cores SR1, SR3, Ber3 and Ber4, as well as that of California Standard Pasquia Hills 2-8-51-6W2, the reference well used in correlation of cores to subsurface stratigraphic units (Figure 2). Also shown is the location of the Namew Island outcrop on Namew Lake.

Data from these cores will be incorporated in an ongoing regional study of Silurian strata in Saskatchewan, initiated by the author in 1986 (Haidl, 1987). Probable stratigraphic correlations and a brief description of lithologies in SR1 and SR3 are presented here.

1. Stratigraphic Correlation

The correlation of stratigraphic units in SR1 and SR3 with those in the subsurface of southern Saskatchewan is illustrated in Figure 2 and is based on the presence of marker beds observed in core and defined on geophysical well logs in Ordovician and Silurian strata (Kendall, 1976; Haidl, 1987), as well as on lithologic similarities to Ordovician and Silurian strata described by other workers (e.g., Paterson, 1971; Kendall, 1976; Jamieson, 1979).

The quartz sandstone of the Winnipeg Formation (Middle Ordovician) is the lowermost Paleozoic unit in the Cumberland Lake area. Weathered Precambrian rocks are unconformably overlain by a silty sandstone at the base of the Winnipeg Formation.

The clastics of the Winnipeg Formation are disconformably overlain by the burrow-mottled dolomites of the Yeoman Formation (Upper Ordovician). This contact is sharp in SR1 where a basal Yeoman dolomite bed, with only scattered quartz sand grains, directly overlies the argillaceous burrowed siltstone in the upper Winnipeg Formation. In SR3 there is a much more gradational change from clastics to carbonates and, therefore, the contact is more difficult to define. Using the criteria of Paterson (1971), the Yeoman/Winnipeg contact is placed at the point where grain-supported sandstones change to matrix-supported dolomites.

The Herald/Yeoman contact is not well defined in SR1 and SR3. Kendall (1976, p.15) stated that the Herald/Yeoman contact "is transitional with only slight evidence for any break in deposition" and is "one of the most difficult to locate in cores". In the Cumberland Lake area, the top of the Yeoman Formation is placed at the top of

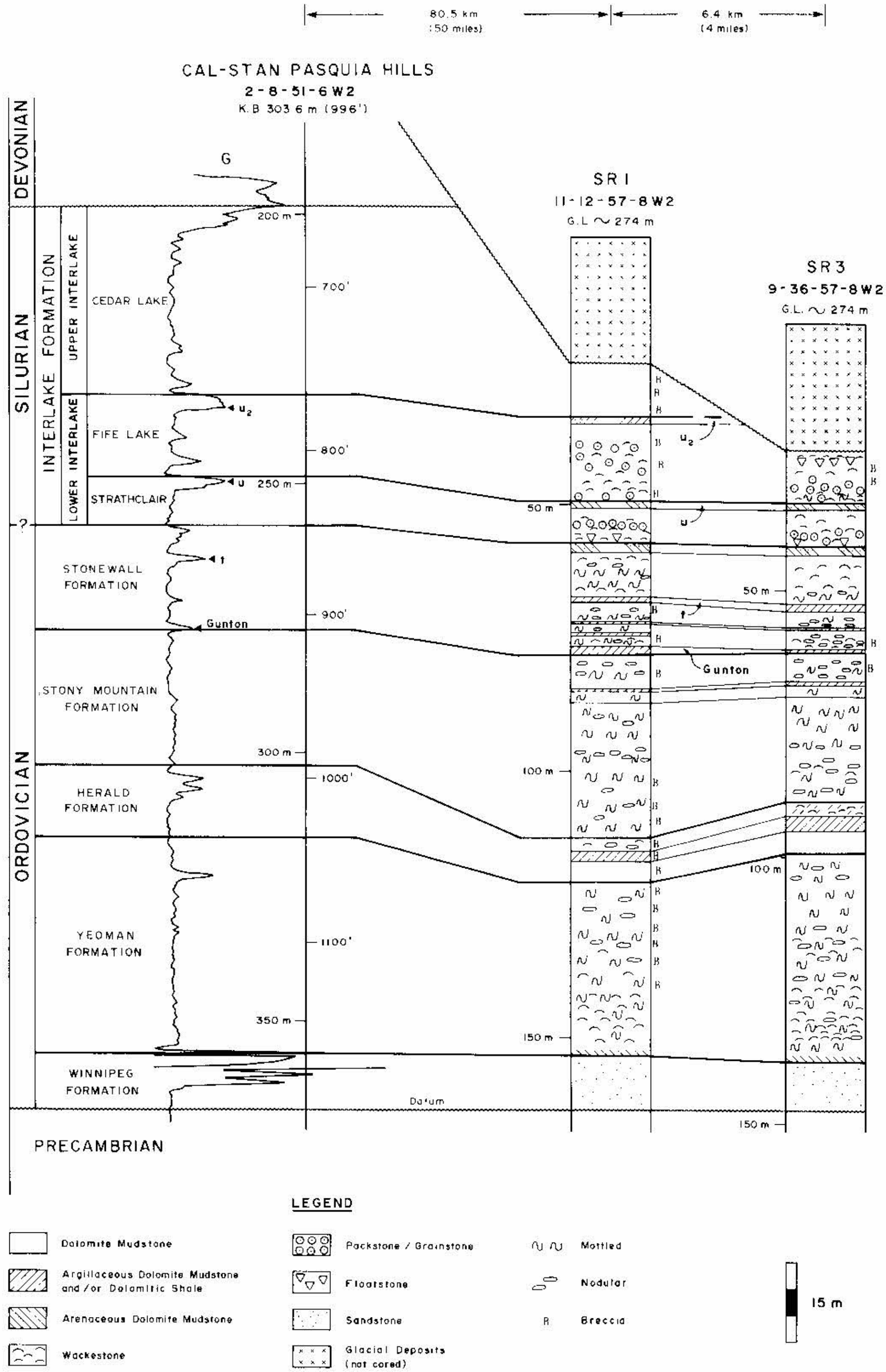

Figure 2 – Lithologies of cores SR1 and SR3 and the stratigraphic correlation of these cores to Cal-Stan Pasquia Hills 2-8-51-6W2, a reference well for which gamma ray (illustrated), neutron and electrical geophysical logs are available. The land locations (Western Canada Survey System) of SR1 and SR3 have been estimated from a location map provided by Cominco Ltd. Core depths have been corrected to true vertical depth.

the uppermost burrow-mottled dolomite unit which lies below the argillaceous strata of the Herald Formation.

The Stony Mountain/Herald contact is also poorly defined in this area. Neither the laminated microdolomite unit at the top of Herald nor the argillaceous marker bed which defines the base of the Stony Mountain Formation in Kendall's study area are present in cores SR1 and SR3. However, in SR3 a prominent truncation surface coincides with the base of a mottled nodular dolomite interval interpreted as Stony Mountain strata; the contact between the Stony Mountain and Herald is placed at this truncation surface. Brecciation of this zone in SR1 precludes the accurate delineation of the Stony Mountain/Herald contact; the pick is based on comparison with the lithologic sequence in SR3.

The remainder of the contacts between stratigraphic units are delineated by argillaceous and/or arenaceous marker beds. The top of the Stony Mountain Formation is picked at the base of a well-defined unit of argillaceous dolomite mudstones, correlative with the Gunton marker bed in southern Saskatchewan. The contact between the Stonewall Formation and the Strathclair subunit of the Interlake Formation is marked by the top of an interval of interbedded quartz sandstone and dolomite mudstones (Figure 2). The top of a marker bed ("u" marker, Figure 2) of similar lithology delineates the Fife Lake/Strathclair contact in the Lower Interlake unit. The top of the Fife Lake subunit is defined by the top of the "u_2" marker bed (Figure 2). In SR1, this contact is tentatively picked at the top of an interval of argillaceous dolomites with thin interbeds of sandstone. However, as this portion of the core is badly weathered, the validity of this pick is in question. In SR3, the erosion surface below the glacial drift truncates the Fife Lake subunit several metres below its projected top (Figure 2).

The intense weathering of the upper 10.1 m of the SR1 core precludes correlation of lithologies in this locality with those in cores in southern Saskatchewan, where the Guernsey subunit is the uppermost unit of the Lower Interlake (Haidl, 1987). Correlation of geophysical logs from the Calc-Stan Pasquia Hills well (2-8-51-6W2) with those from more southerly wells suggests, however, that the Guernsey subunit is absent in the northern portion of the province (Figure 2). Therefore, the upper 10.1 m of SR1 probably correlate with the Cedar Lake subunit of the Upper Interlake (Figure 2).

Thickness values for the Yeoman, Herald, Stony Mountain and Stonewall Formations, as defined in Figure 2, are in good agreement with those extrapolated from data in Kendall (1976). The combined Yeoman and Herald Formations appear to correlate with the Red River Formation as described in core and outcrop in Manitoba (McCabe, 1984, 1985, 1987).

2. Lithology

Lithologies within the Lower Paleozoic sequence in SR1 and SR3 are illustrated in Figure 2 and are briefly described below. Secondary breccias, abundant in SR1 and sparsely scattered in SR3, are discussed separately following the description of other lithologies in the stratigraphic sequence. The sequence is dominated by dolostones, all of which appear to be secondary. Nevertheless, original textures prior to dolomitization can be recognized in most cases and these allow the use of Dunham's classification of carbonate textures (Dunham, 1962), as modified by Embry and Klovan (1971). The carbonates are all dolomite, so its repetitive use as a lithologic adjective with the textural terms has been eliminated, except for the substitution of "dolomite" for "lime" in mudstone units.

a) Winnipeg Formation

The Winnipeg Formation is a sandstone unit composed predominantly of subangular to well-rounded quartz grains ranging in size from silt to coarse-grained sand. Sorting ranges from moderately well sorted in fine to medium sands, to poor to fair in intervals with a higher silt content (commonly burrowed). The uppermost portion (<1 m) of the Winnipeg Formation consists of argillaceous burrowed siltstone with abundant sand intercalations.

Pyrite is fairly abundant throughout the Winnipeg Formation in SR1 and SR3. The most interesting occurrence is as bands of concentrically laminated pyrite spherules ("ooids") near the Precambrian contact in the SR3 core. Similar grains have been reported in other Winnipeg cores (Paterson, 1971). The mechanism responsible for the formation of these spherules is not known. Binda et al. (1985) speculated that sulphide ooids in a Proterozoic arenite had an authigenic chemical origin and formed during early diagenesis. The spherules in the Winnipeg Formation may reflect a similar genesis.

b) Yeoman Formation

The thin (<0.35 m) basal unit of the Yeoman Formation is a sandy dolomite. The remainder consists of burrowed, mottled, commonly nodular, skeletal dolomite mudstones and wackestones (Plates 1A and B). The skeletal material is finely comminuted and recrystallized; crinoid ossicles are the only recognizable allochems. Porosity resulting from the dissolution of fossil fragments is best developed in a 5 m interval near the base of this formation in SR3.

The burrowed, mottled nature of the Yeoman Formation observed in these cores is characteristic of this stratigraphic unit throughout the Williston Basin. Complex variations in the appearance of this relatively homogeneous lithology can be attributed to changes in 1) color, 2) shape, size and frequency of the mottles, and 3) the character of the burrows (Kendall, 1976). The depositional and diagenetic events responsible for these variations are discussed at length in Kendall (1976, 1977, 1985). Possible diagenetic pathways and related changes in appearance are summarized in Figure 3.

c) Herald Formation

The basal unit of the Herald Formation consists of cryptocrystalline to finely microcrystalline dolomite mudstones. This unit is overlain by a middle unit

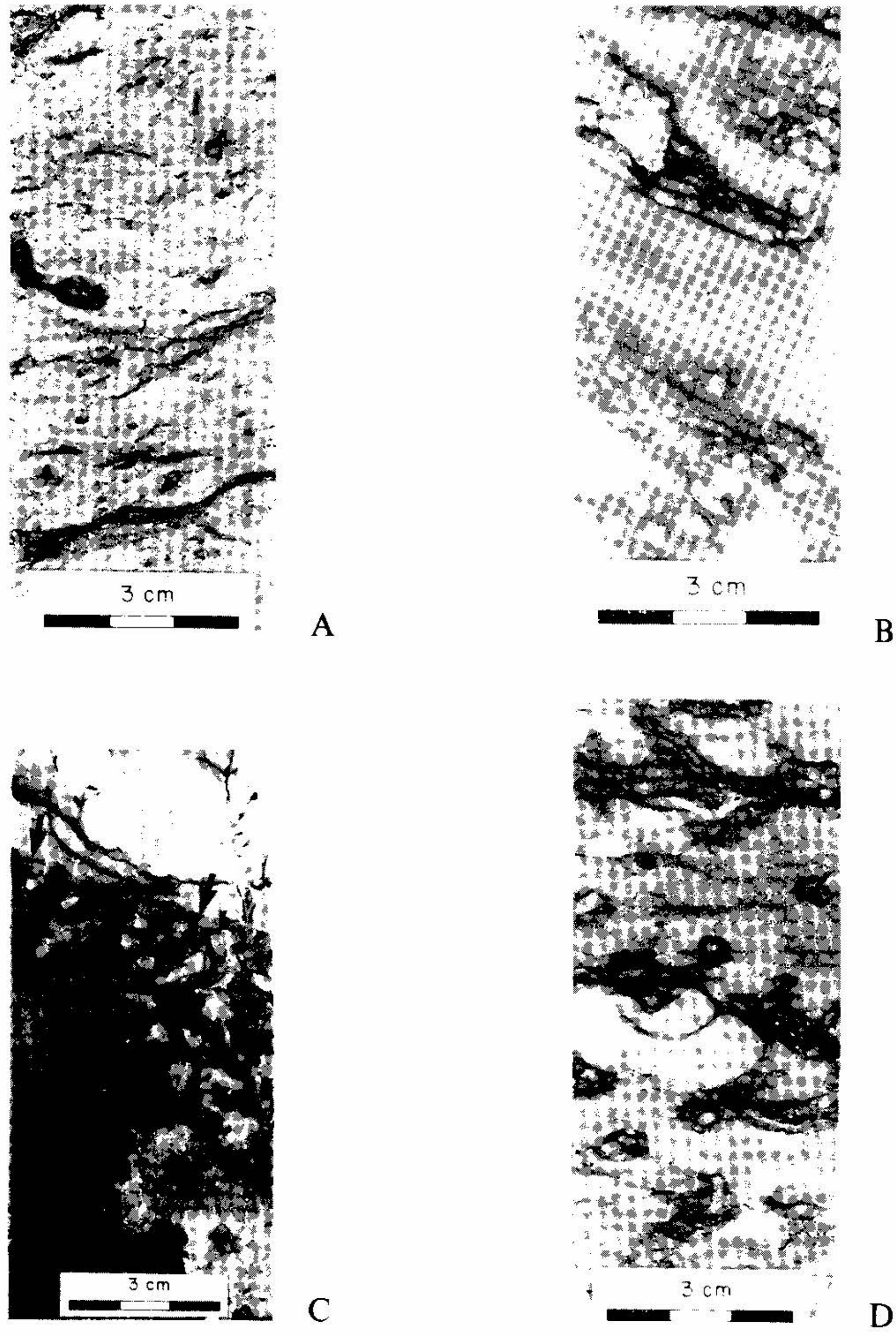

Plate 1 - A) Pyritic nodular skeletal wackestone with abundant solution stringers, Yeoman Formation, SR3, 134.7 m; note that cores SR1 and SR3 were taken from holes drilled at an angle of 65 to 68° to horizontal; all depths quoted have been corrected to true vertical depth. B) Dolomite mudstone with prominent burrow systems within large well-defined mottles, Yeoman Formation, SR3, 104.6 m. C) Sharp contact (arrows) between a mottled dolomite mudstone and an overlying nodular mudstone is interpreted as the contact between the Stony Mountain and Herald Formations, SR3, 89.5 m; note the highly irregular contact between distinctly mottled dolomite and unmottled burrowed dolomite near the top of the Herald Formation. D) Hematite-stained, mottled skeletal wackestone with small burrows within the mottles, Stony Mountain Formation, SR3, 84.1 m; fossils include a small rugose coral (upper left) and a cast of a large gastropod(?) at left centre.

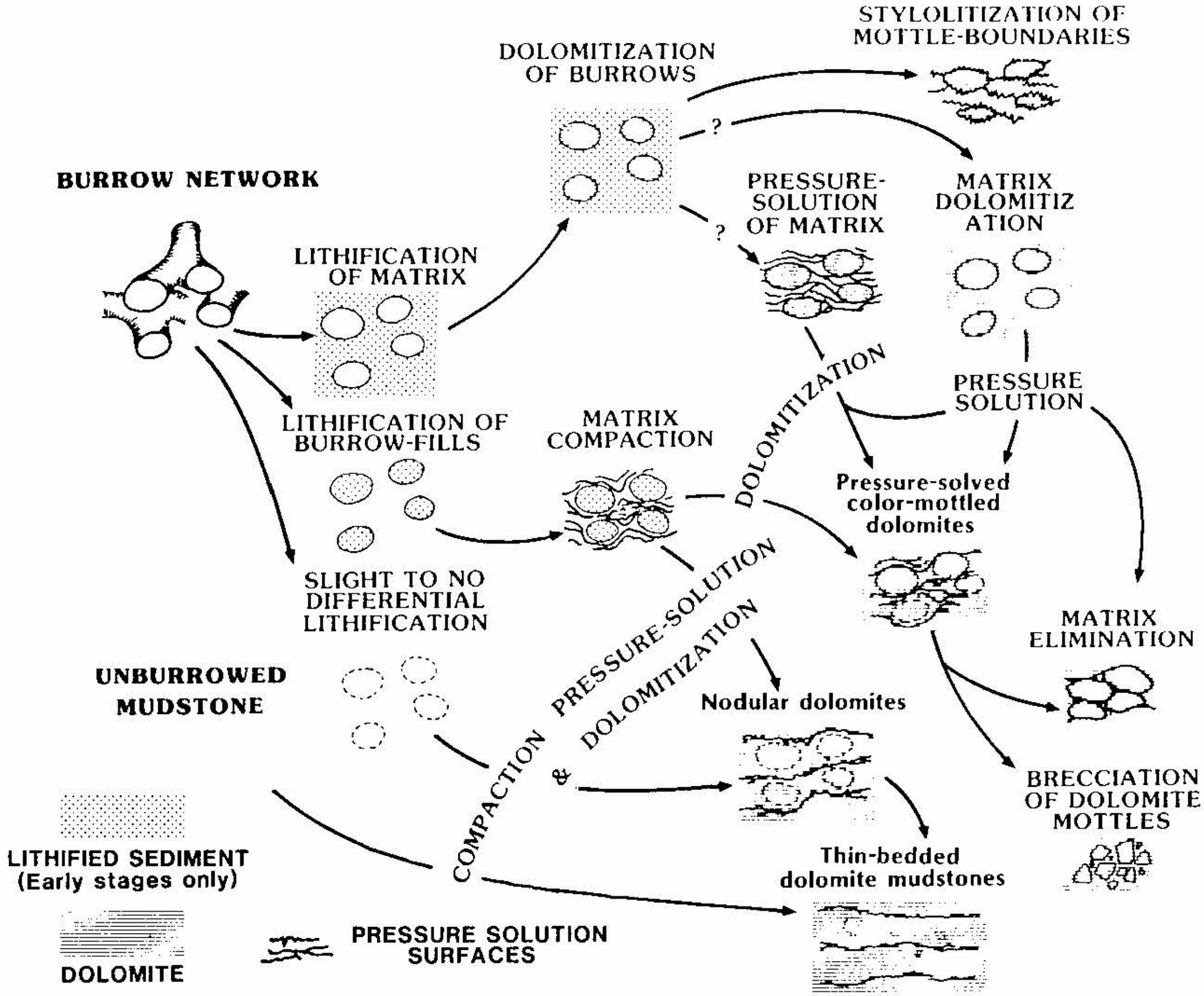

Figure 3 – Modification of Yeoman carbonates by diagenetic processes (from Kendall, 1985). The entire Lower Paleozoic carbonate sequence in SR1 and SR3 has been subjected to similar diagenetic processes.

characterized by laminated to bedded, argillaceous to highly argillaceous dolomites, which display several sharp contacts and are locally overlain by thin (<0.5 cm) laminae of small dolomite clasts. Molds of skeletal halite crystals are present near the top of the middle unit. Abundant microfractures, infilled with pyrite, are present in these lower two units of the Herald.

The upper unit of the Herald Formation is composed of interbeds of dolomite wackestone, argillaceous dolomite mudstone and dolomitic shale. In SR3, the top of the Herald Formation is placed at a sharp contact between a mottled dolomite in the Herald Formation and a nodular dolomite in the Stony Mountain Formation (Plate 1C).

d) Stony Mountain Formation

The burrowed, mottled and commonly nodular dolomite mudstones and wackestones comprising the basal unit (<25 m) of the Stony Mountain Formation are very similar to those of the Yeoman Formation (Plates 1D and 2A; Figure 3). Fossil fragments, generally less abundant than in the Yeoman, include crinoid ossicles, gastropods and rugose corals. Mottling decreases upward into nodular to massive dolomite mudstones which are overlain by laminated and/or argillaceous dolomite mudstones and dolomitic shales. The upper unit of the Stony Mountain Formation consists of nodular and indistinctly mottled dolomite mudstones.

e) Stonewall Formation

The lower unit of the Stonewall Formation consists of repetitions of subunits comprising the following lithologic sequence: 1) basal argillaceous, laminated to bedded dolomite mudstones, 2) nodular, commonly burrowed dolomite wackestones and mudstones with minor brachiopods, favositid corals and other skeletal material, and 3) massive to bedded dolomite mudstones. Four

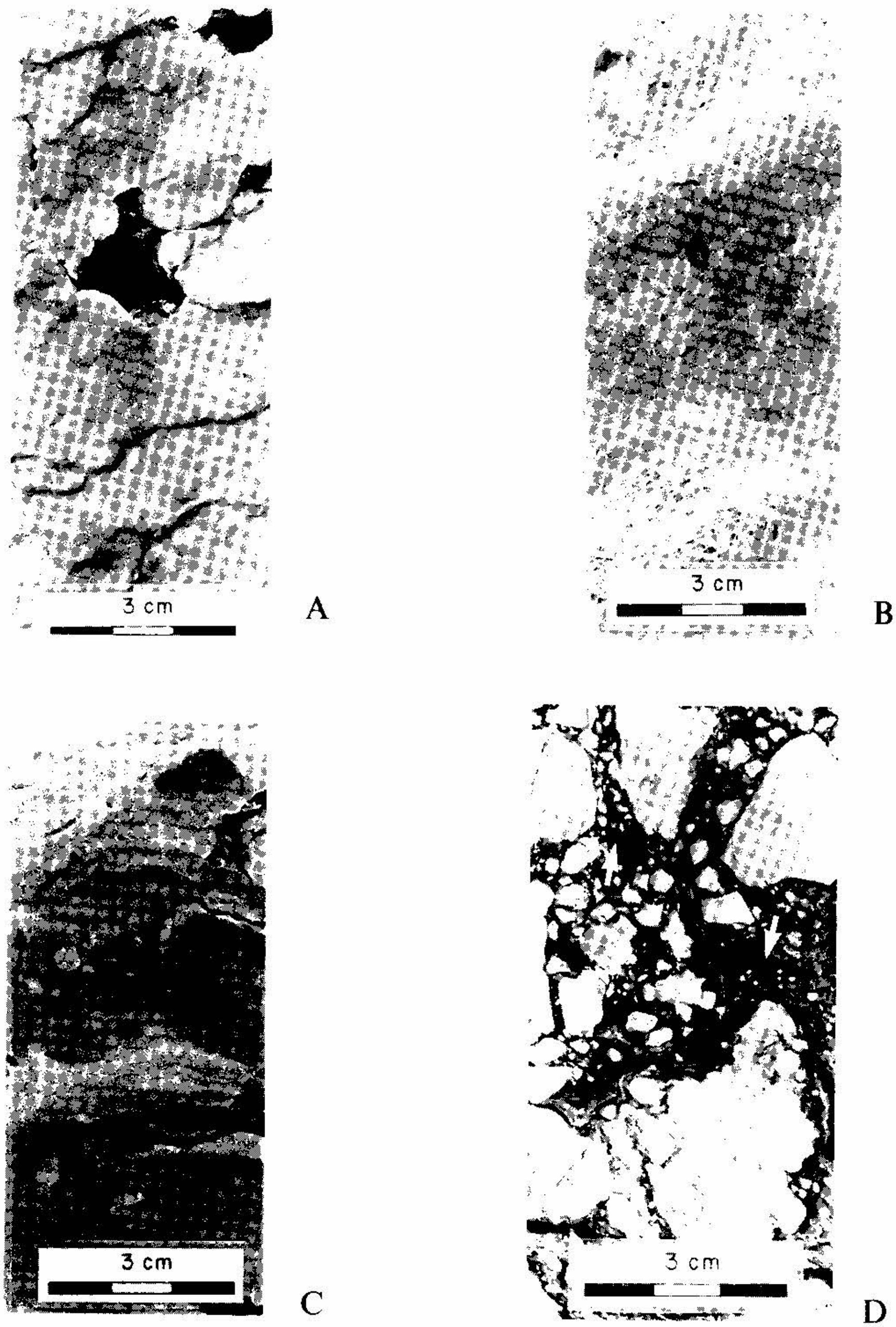

Plate 2 - A) Nodular dolomite mudstone with pressure solution stringers, Stony Mountain Formation, SR1, 96.0 m; solution cavities have developed along boundaries between a few nodules; cavities are commonly infilled with greenish-grey clay (c), although much of the clay has washed out during slabbing of the core. B) Coral floatstone, Strathclair subunit, Lower Interlake, SR1, 57.6 m; large favositid coral fragments in a skeletal wackestone matrix; other fossils in this unit include stromatoporoids, rugose corals and small brachiopods. C) Stromatoporoid floatstone in a mudstone matrix, Fife Lake subunit, Lower Interlake, SR3, 24.7 m; internal structures within stromatoporoids are extremely well preserved; fragments of rugose and favositid corals are also present in this unit. D) Matrix-supported breccia associated with fracturing, Yeoman Formation, SR1, 131.9 m; clasts composed of nodular dolomite mudstone display abundant microfractures; matrix consists of silt-sized dolomite and quartz sand grains, pyrite and kerogenous material (arrows).

subunits are present in SR1 and three in SR3. The basal mudstones (subunit 1) are especially well developed in the Gunton marker bed at the base of the Stonewall and in the "t" marker at the base of the thick (approximately 10.5 m) uppermost subunit (Figure 2).

The upper unit of the Stonewall Formation comprises thin interbeds of fine- to medium-grained quartz sandstone and dolomite mudstone. Contacts between the two lithologies are seldom sharp, with floating quartz sand grains commonly intercalated within the dolomites. In a few dolomite beds, irregular lenses of sandstone protrude into the dolomite, at times producing dolomite "clasts". The origin of this disruption in bedding is uncertain; it may be related to bioturbation and/or fluid escape. At the base of this upper unit in SR3, discrete lenses of quartz sandstone occur within a peloidal oolitic grainstone.

f) Interlake Formation

A thin exposure (2.1 m) of probable Interlake strata at Pine Island on Cumberland Lake (see below) represented the only accessible Lower Interlake strata north of Township 50 in Saskatchewan before the acquisition of the Cominco cores,. The cores provide valuable new information on this stratigraphic interval, as well as fossils and depositional textures which are significantly better preserved here than in most Interlake cores from southern Saskatchewan.

Lower Interlake, Strathclair Subunit:

The lowermost bed (<2 m) in the Strathclair is composed of fossiliferous floatstones and wackestones/packstones (Plate 2B). Fossils include favositid and rugose corals, hemispherical, bulbous and tabular stromatoporoids and abundant small disarticulated brachiopod(?) shells. Above this bed is a unit dominated by skeletal peloidal wackestones, packstones and grainstones with thin (<0.25 m) interbeds of dolomite mudstone. This in turn is overlain by a unit (<3.5 m) consisting of sublithographic dolomite mudstone, commonly làvinated, particularly towards the top. The laminae are irregular, and coupled with the presence of interlaminar porosity, this suggests an algal origin.

The uppermost unit of the Strathclair is the "u" marker bed (Figure 2). In SR3, this bed consists of two thin (<0.25 m) intervals of interbedded quartz sandstone and dolomite mudstone separated by an argillaceous dolomite mudstone bed. The mudstone bed is characterized by numerous erosion surfaces overlain by small clasts of dolomite and scattered quartz grains. In SR1, no quartz sandstone is present near the top of the marker bed but the remainder of the sequence is similar to that in SR3.

Lower Interlake, Fife Lake Subunit:

The basal bed (0.35 m) of the Fife Lake subunit in core SR3 is a crossbedded peloidal grainstone with good porosity. The well-rounded and well-sorted carbonate grains have been completely recrystallized; more detailed petrographic studies may facilitate interpretation of their depositional history. In SR1, the lowermost Fife Lake bed consists of interbeds of skeletal, peloidal grainstone and dolomite mudstone. Above the basal bed in both cores is a fossiliferous wackestone unit (<3 m) which contains orthoconic cephalopod shells, brachiopods, crinoids and favositid corals. This lithology is also an important component of the overlying unit which, in both cores, consists of interbeds of skeletal wackestones, oolitic peloidal packstones/grainstones and dolomite mudstones. Laminated mudstones, which include intervals of intraclasts stacked almost vertically (Plate 2C) and zones of fenestral porosity, dominate the upper part of this interbedded unit.

Correlation between the two cores breaks down at this level because of intense weathering in SR1. In SR3, in which original textures are well preserved over the entire cored interval, the interbedded unit is overlain by a stromatoporoid floatstone which displays excellent preservation of internal structure within tabular, bulbous and hemispherical stromatoporoids. The uppermost interval is a skeletal packstone/wackestone which includes crinoid, coral and brachiopod fragments. The remainder of the Lower Paleozoic sequence at this location has been removed by erosion associated with the subglacial unconformity.

The upper 19 m of SR1 are so intensely weathered that it is difficult to ascertain original textures and lithologies above the middle of the interbedded unit. A sequence of argillaceous dolomites with interbeds of sandstone (33.9 to 35.1 m) is tentatively interpreted as the "u_2" marker bed that occurs at the top of the Fife Lake subunit (Figure 2). The sandstones are composed of very fine sand and silt quartz grains, fine to medium dolomite sand grains, and authigenic quartz (including numerous euhedral bipyramidal crystals). Although this interval is in the correct stratigraphic position to be the "u_2" marker bed, it is difficult to determine whether the sandstone beds are part of the original depositional sequence. Their proximity to the unconformity and the brecciated nature of the overlying beds suggest that the sandstones may represent cavity-fill material which has been transported from the unconformity surface.

Upper Interlake, Cedar Lake Subunit:

Based on geophysical well log correlations, the uppermost 10.1 m in SR1 correlate to the Cedar Lake subunit of the Upper Interlake (Figure 2). The lower 2.3 m are composed of intensely weathered dolomite mudstone(?). The remainder of the core consists of matrix-supported breccias composed of weathered angular to subrounded clasts in an argillaceous silt matrix.

g) Secondary Breccias

The SR1 core is characterized by extensive intervals of brecciation from approximately 11 m above the base of the Yeoman Formation to the top of the core. A few brecciated zones are also present in SR3. Clasts within the breccias are subrounded to angular and range in diameter from less than 2 mm to more than 4.5 cm (i.e., greater than the diameter of the core). Textures range from tightly packed clast-supported breccias with virtually no matrix to those with clasts floating in abundant matrix.

Thin beds or laminae of matrix-supported dolomite clasts (commonly above erosion surfaces) occur as minor constituents in dolomite mudstone units in stratigraphic intervals above the Yeoman Formation, and are interpreted as primary breccias (i.e., part of the original depositional sequence). However, the majority of the brecciated intervals are interpreted as secondary breccias related directly to one or more of 1) diagenetic processes, 2) natural fractures, and 3) coring-induced fractures. This interpretation is based on the following: a paucity of sharp contacts between breccias and adjacent beds except where bounded by well-defined fracture planes; an abundance of clasts with fresh broken surfaces; an abundance of brecciated intervals with very little to no matrix; common discordance of bedding in matrix-supported breccias to the bedding in adjacent beds.

The texture and distribution of the secondary breccias appear to be controlled primarily by the degree and nature of chemical compaction (Figure 3) and also the intensity of fracturing. Chemical compaction is controlled in part by the original lithology and previous diagenesis (Kendall, 1985). The much more extensive brecciation observed in SR1 compared to SR3 can be ascribed to an abundance of oblique and vertical natural fractures in SR1 and a paucity of such fractures in SR3.

Matrix-supported breccias are most extensive in the Yeoman Formation in SR1 and appear to have formed in solution cavities developed along fracture planes. The majority of clasts appear to have been derived *in situ* and are likely the product of 1) fracturing and 2) dissolution of intervening material from between mottles or nodules in the mottled dolomites which characterize the Yeoman Formation. The matrix is commonly composed of silt-sized dolomite grains, subrounded to rounded quartz grains and pyrite. Kerogenous material is common in the matrix of breccias from 131.7-137.7 m in SR3 (Plate 2D). The presence of the quartz grains and concentrations of kerogenous matter suggest transport of matrix material from external sources along fracture planes and possibly joints.

Solution cavities have also developed along fracture planes in the Stony Mountain Formation. One such unit in SR1, approximately 0.35 m thick, is filled with greenish-grey argillaceous siltstones with only a few intraclasts of dolomite near the highly irregular upper and lower contacts. If the irregular contacts with adjacent beds and the associated clasts had not been preserved in core, this bed could be interpreted as part of the depositional sequence rather than as a cavity fill. Similarly, thin beds of claystone, which are common as cavity fills in nodular dolomites (see below), may appear to be primary deposits when observed in outcrop or core.

Nodular dolomites, characterized by an almost total absence of original matrix material, are also commonly brecciated in SR1. Small solution cavities, typically infilled with greenish-grey, generally silty clay, commonly develop at the boundaries between the nodules (Plate 2A). These cavities, while producing some clasts, are rarely extensive enough to account for the abundance of clasts in these breccias. Rather, when subjected to stresses induced by coring, boundaries between the nodules appear to have acted as planes of weakness and the rock has fractured into large irregular clasts with abundant fresh broken surfaces. Coring-induced stress is also likely to be responsible for breccias formed in rocks displaying 1) abundant natural irregular hairline fractures, 2) little evidence of chemical compaction, and 3) no evidence of matrix material.

3. Correlation of Cores with Outcrop

The author has not examined outcrops in the Cumberland Lake area; comments on possible correlations are based on lithologic descriptions in Kupsch (1952) and on geophysical log correlations of wells in Kupsch's study area with those in Kendall's study area (Kendall, 1976).

Many outcrops in the area are of limited vertical extent and are composed entirely of dolomites which are burrowed and mottled. This same lithology is seen in core to be typical of both the Yeoman Formation and the lower Stony Mountain Formation; thus it is difficult, if not impossible, to assign stratigraphic position of each outcrop on lithological grounds alone. *Receptaculites*, commonly recorded from the Red River Formation (e.g., Baillie, 1952), has not been reported however, from Stony Mountain strata and it seems most likely that the *Receptaculites*-bearing strata belong to the Yeoman Formation (previously the Yeoman Member of the Red River Formation).

One of the thickest sections of Lower Paleozoic strata exposed in this area (Section 10 in Kupsch, 1952) is found on Namew Island at Namew Lake (Figure 1). Correlation of this lithologic sequence with that in cores SR1 and SR3 suggests that this outcrop includes the strata of the uppermost Herald and lower Stony Mountain Formations. Kupsch placed this entire section in the Stony Mountain Formation and correlated the lower argillaceous strata (Units 1 to 11) with argillaceous strata in the subsurface at the Gronlid No.1 well (15-32-47-17W2). However, correlation of well logs from Kendall's study area (e.g., 5-29-46-18W2) with the Gronlid No.1 well indicates that this argillaceous unit correlates with the Herald Formation as now defined in the subsurface in southern Saskatchewan. Accordingly, it appears that the lower 3.8 m (Units 1 to 11) at the Namew Island outcrop correlates with the Herald Formation and the upper 12.2 m (Units 12 to 18) with the Stony Mountain Formation.

Two outcrops at MacDonald's Bay on Namew Lake have been identified as strata of the Stonewall Formation (Sections 18 and 19 in Kupsch, 1952). The Gunton marker bed at the base of the Stonewall in SR1 and SR3 appears to correlate with Unit 6 in Section 18, as well as with Units 2(?) and 3 in Section 19.

The only known outcrop of Interlake strata is located at Pine Island on Cumberland Lake (Section 20 in

Kupsch, 1952) where the lithologies described in the thin (2.1 m) exposure are similar to those in the middle of the Strathclair subunit in cores SR1 and SR3.

4. Further Work

Much more information is required to fully understand Lower Paleozoic strata in the Cumberland Lake area. The four new cores (SR1, SR3, Ber3 and Ber4), when studied in detail and correlated with outcrops and other cores in Saskatchewan and Manitoba, should establish more definitive stratigraphic correlations. The information provided by well-preserved Interlake strata in the new cores will also greatly facilitate the author's ongoing study of the detailed stratigraphy and lithologies of Silurian strata in Saskatchewan.

5. References

Baillie, A.D. (1952): Ordovician geology of Lake Winnipeg and adjacent area, Manitoba; Manit. Dep. Mines Nat. Resour., Publ. 51-6, 64p.

Binda, P.L., Koopman, H.T. and Schwann, P.L. (1985): Sulphide ooids from the Proterozoic Siyeh Formation of Alberta, Canada; Mineral. Deposita, v20, p43-49.

Dunham, R.J. (1962): Classification of carbonate rocks according to depositional texture; *in* Ham W.E. (ed.), Classification of Carbonate Rocks; Am. Assoc. Petrol. Geol., Mem. 1, p108-121.

Embry, A.F. and Klovan, J.E. (1971): A Late Devonian reef tract on northeastern Banks Island, N.W.T.; Bull. Can. Petrol. Geol., v19, p730-781.

Haidl, F.M. (1987): Stratigraphic and lithologic relationships, Interlake Formation (Silurian), southern Saskatchewan; *in* Summary of Investigations 1987, Sask. Geol. Surv., Misc. Rep. 87-4, p187-193.

Jamieson, E.R. (1979): Well data and lithologic descriptions of the Interlake Group (Silurian) in southern Saskatchewan; Sask. Dep. Miner. Resour., Rep. 139, 67p.

Kendall, A.C. (1976): The Ordovician carbonate succession (Bighorn Group) of southeastern Saskatchewan; Sask. Miner. Resour., Rep. 180, 185p.

________ 1977: Origin of dolomite mottling in Ordovician limestones from Saskatchewan and Manitoba; Bull. Can. Petrol. Geol., v25, p480-504.

________ 1985: Depositional and diagenetic alteration of Yeoman (Lower Red River) carbonates from Harding Co., South Dakota; *in* Longman, M.W., Shanley, K.W., Lindsay, R.F. and Eby, D.E. (eds.), Rocky Mountain Carbonate Reservoirs – A Core Workshop; Soc. Econ. Paleon. Mineral., p95-124.

Kupsch, W.O. (1952): Ordovician and Silurian stratigraphy of east-central Saskatchewan; Sask. Dep. Miner. Resour., Rep. 10, 62p.

McCabe, H.R. (1984): Stratigraphic mapping and stratigraphic and industrial minerals core hole program; *in* Report of Field Activities 1984, Manit. Energy Mines, p136-143.

________ (1985): Stratigraphic mapping and stratigraphic and industrial minerals core hole program; *in* Report of Field Activities 1985, Manit. Energy Mines, p216-225.

________ (1987): Stratigraphic mapping and stratigraphic and industrial minerals core hole program; *in* Report of Field Activities 1987, Manit. Energy Mines, p151-161.

Paterson, D.F. (1971): The stratigraphy of the Winnipeg Formation (Ordovician) of Saskatchewan; Sask. Dep. Miner. Resour., Rep. 140, 57p.