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Tectonic Framework of Palaeozoic Formations in Manitoba

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ABSTRACT

The study of a detailed series of structure and isopach maps of the Palaeozoic strata of southwestern Manitoba indicates that the principal Palaeozoic tectonic elements — the Williston Basin and Elk Point Basin — have been modified to a considerable extent by major tectonic features of the Precambrian basement. The principal basement feature is the break between the Churchill and Superior provinces, which coincides roughly with the Manitoba-Saskatchewan border. East-west-trending orogenic belts within the Superior crustal block may also be reflected to some extent in later Palaeozoic movements. In addition, the Superior crustal block, as a whole, appears to have had a slightly different response to the tectonic forces, giving rise to both basin subsidence and basin uplift. During periods of deposition, especially during Ordovician time, the Manitoba portion of the basin appears to have undergone a relatively higher rate of subsidence, whereas during periods of erosion relatively greater amounts of uplift and truncation have occurred. As a result, the depositional and erosional patterns for most of the Palaeozoic formations in southwestern Manitoba are somewhat anomalous relative to the regional basin framework.

Some prominent Palaeozoic structures probably are the result of salt solution and differential compaction caused directly or indirectly by relatively minor tectonic movements related to Precambrian basement features. In particular, the prominent hinge line at the edge of the Devonian Prairie Evaporite salt basin may be due, in large part, to salt solution. Numerous other small structural lows, structural highs and isopach thicks, probably resulting from salt solution, occur along the salt edge and have been important in modifying and controlling Mississippian oil accumulation in the Daly-Virden producing area.

Introduction

THIS study is based on the examination of a detailed series of isopach and structure contour maps* for all Palaeozoic formations of southwestern Manitoba, as well as all available geophysical data. Selected references to the regional geologic setting are listed at the end. Southwestern Manitoba is located on the northeastern edge of both the Williston and Elk Point Palaeozoic sedimentary basins (*Figure 1*). The regional structure contours on the Precambrian basement reflect not only the composite effect of these two Palaeozoic tectonic elements but also later Mesozoic and Cenozoic subsidence. For Manitoba, only about 20 per cent of the present structure is due to Palaeozoic tectonic activity; this makes direct interpretation of the tectonic framework difficult.

*Most of these maps are included in the Stratigraphic Map Series, issued by the Mines Branch.

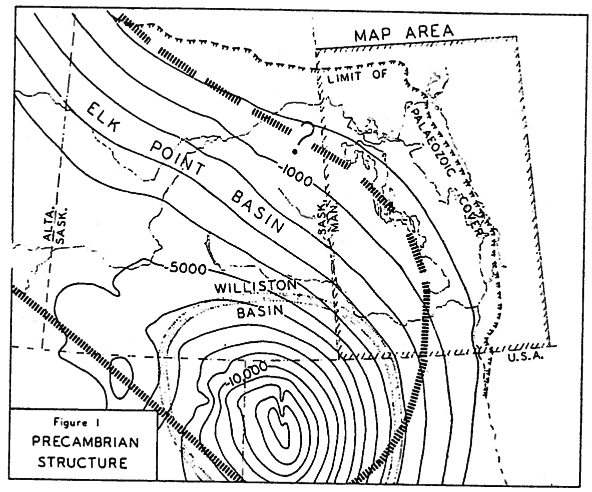


Figure 1
PRECAMBRIAN STRUCTURE

Although the over-all structural pattern appears to be rather uniform, an examination of the isopach maps for the various Palaeozoic formations shows that there are a considerable number of anomalous features throughout the stratigraphic succession, and that the Manitoba portion of both the Williston and Elk Point basins appears to have formed an anomalous area within the regional basin framework. The writer believes that the tectonic framework has been directly affected by major structural features of the Precambrian basement (*Figure 2*). The most prominent basement feature and the one that appears to have had the greatest effect on the Palaeozoic tectonic framework is the discontinuity or boundary zone between the Churchill and Superior Precambrian provinces. This zone is fairly well defined in the Shield area, and its southwestward extension beneath the Palaeozoic cover is indicated by the associated high and low gravity anomalies, as shown in *Figure 2*. A prominent magnetic low is also seen to occur along this break in the southern part of the map-area. The Manitoba portion of the Williston and Elk Point basins is thus underlain principally by rocks of the Precambrian Superior block, whereas Saskatchewan is underlain principally by rocks of the Churchill block.

As the Churchill and Superior blocks are known to differ considerably in age, lithologic character, tectonic grain and even in average crustal thickness, it is possible that these two major Precambrian blocks may have had a somewhat different tectonic response to the forces giving rise to both basin subsidence and basin uplift.

A further and very important factor to consider in evaluating the tectonic framework is the existence of prominent superficial or sedimentary structures which are not formed as a result of basement deformation, but rather are the result of either salt collapse or differential compaction. Differentiation between superficial structures and true tectonic structures presents a major problem in the map-area.

Precambrian

The structure map on the *Precambrian* surface (*Figure 2*) shows a relatively uniform dip to the southwest, ranging from 17 to 50 feet per mile. Although most of this reflects post-Palaeozoic deformation, any Palaeozoic tectonic features should nevertheless show on the structure map, but the relatively high superimposed dip coupled with the sparse deep well control make it difficult to delineate any but the most prominent structures. The principal feature shown by this map is the pronounced high in the vicinity of Lake St. Martin, west of the Lake Winnipeg narrows, where granitic and volcanic rocks are exposed at surface. Available data indicate that this feature is a topographic high on the erosion surface with a local relief in excess of 700 feet, and that there has been little or no associated post-Precambrian tectonic deformation. The volcanic rocks, however, are very fresh looking and not at all similar to the typical greenstones of the Superior province, which suggests that they may possibly represent late Precambrian or even younger activity. Two radioactive age determinations for these volcanics, by the K-Ar whole-rock method, gave an age of only 200-250 million years. However, because of the crystalline and vesicular nature of the material used, these results may be totally unreliable and need to be checked. The associated granitic rocks gave a normal "Superior" age of approximately 2.4 billion years. Assuming that the basement high is of Precambrian age, it must have remained emergent throughout Ordovician time, and all of the Ordovician strata must pinch out against the high.

Another prominent feature on the Precambrian map is the northeast-trending Moose Lake syncline or flexure located immediately northwest of the north end of Lake Winnipeg. This pronounced flexure also shows up as a prominent bend in the outcrop belt of Ordovician and Silurian strata, as shown in *Figure 3*. Because of extensive post-Palaeozoic erosion in this area, the age of this feature cannot be determined except that it has affected the youngest strata in the area and consequently in post-Middle Silurian. The synclinal flexure is seen to be coincident with the boundary zone between the Churchill and Superior Precambrian provinces and with the trace of the gravity anomalies where this boundary zone extends beneath the Palaeozoic cover. This is the most direct evidence available that the Churchill-Superior boundary zone represents a zone of post-Precambrian tectonic movement.

Palaeozoic

The Precambrian of southwestern Manitoba is overlain by up to 4,000 feet of *Palaeozoic* strata which dip gently to the southwest. This wedge of Palaeozoic strata was uplifted and partially truncated by pre-Jurassic erosion so that the Palaeozoic formations now outcrop or subcrop in a series of northwest-trending belts (*Figure 3*). The Palaeozoic erosion surface has, in turn, undergone post-Middle Jurassic subsidence, but the pattern of subsidence, and hence the post-Palaeozoic tectonic framework, is markedly different, with the result that the outcrop-subcrop belts are seen to be discordant to the present structure contours on the Palaeozoic erosion surface, and show a pronounced structural rise to the northwest. The stratigraphic succession and formation names are noted in the legend. The structure and isopach patterns for each of these units will be discussed briefly.

Most of the Palaeozoic formations of southwestern Manitoba are para-time-stratigraphic units delimited by marker horizons, and consequently the isopach of such units reflects the relative amount of tectonic subsidence and the structure contours reflect true structural deformation.

Ordovician

Ordovician strata comprise the first record of Palaeozoic sedimentation in Manitoba except for a small area in the extreme southwestern corner of the Province where Cambrian strata may be present. The *Total Ordovician* isopach (*Figure 4*) shows a relatively uniform and rather rapid thickening to the south, with surprisingly few thickness variations. This indicates deposition on a very smooth, flat Precambrian surface, with differential subsidence apparently having occurred along an east-trending axis. The Williston Basin, however, was the principal tectonic element at this time, and the pattern of subsidence in southwestern Manitoba is markedly discordant to the regional Williston Basin trends. The isopach pattern of southwestern Manitoba appears to result from a relatively greater amount of subsidence in the Manitoba portion of the basin. The area of thickening is delimited approximately by the Churchill-Superior boundary zone, and the isopach trends are similar to the trend of the orogenic belts within the Precambrian Superior province.

Although the Total Ordovician isopach is uniform, the isopachs of the constituent units are not, and most if not all of the isopach anomalies shown by these units can be attributed to differential compaction of the basal Ordovician *Winnipeg formation* (*Figure 5*), which shows rapid lateral lithologic changes from sand to shale. The thickest and most persistent sandstone unit within the Winnipeg is the Carman Sand, which occurs as an east-trending bar-like body south of Winnipeg. Differential compaction around this area of high sand content has given rise to the isopach thick in this area as well as the structural high associated with the isopach thick. It is possible, however, that slight tectonic movement, as evidenced by the flexure of the Precambrian structure contours, may have helped to localize deposition of the Carman sand body. The easterly trend of the Carman Sand is seen to parallel the trend of the Precambrian orogenic belts, although no magnetic data are available to determine if the sand body is coincident with a Precambrian feature.

The isopach of the *Red River formation* (*Figure 6*) shows an anomalously thin area coincident with the area of Winnipeg thickening. This indicates that most of the differential compaction of the Winnipeg shales occurred during Red River time. The relatively rapid southward thickening of the Red River is accompanied by a facies change from dolomite to limestone and dolomitic limestone. This suggests relatively rapid subsidence and tectonic differentiation of the basin during Red River time.

Also worth noting is the pronounced discordance between the isopach trend and the trend of the outcrop belt. The isopach trend is seen to be almost at

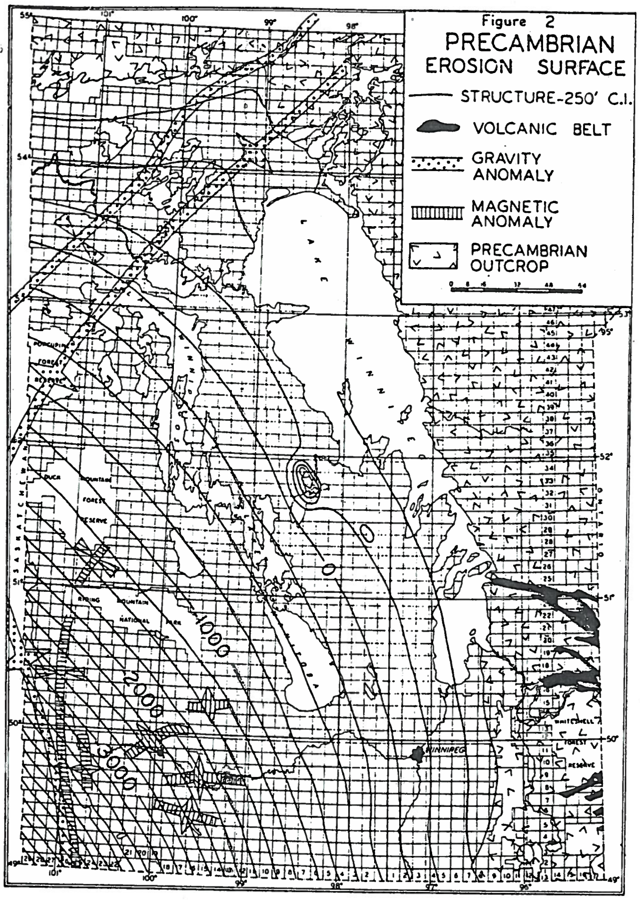


Figure 2
PRECAMBRIAN
EROSION SURFACE
STRUCTURE-250' C.I.
VOLCANIC BELT
GRAVITY ANOMALY
MAGNETIC ANOMALY
PRECAMBRIAN OUTCROP
LAKE WINNIPEG
WINNIPEG
1000
2000
3000

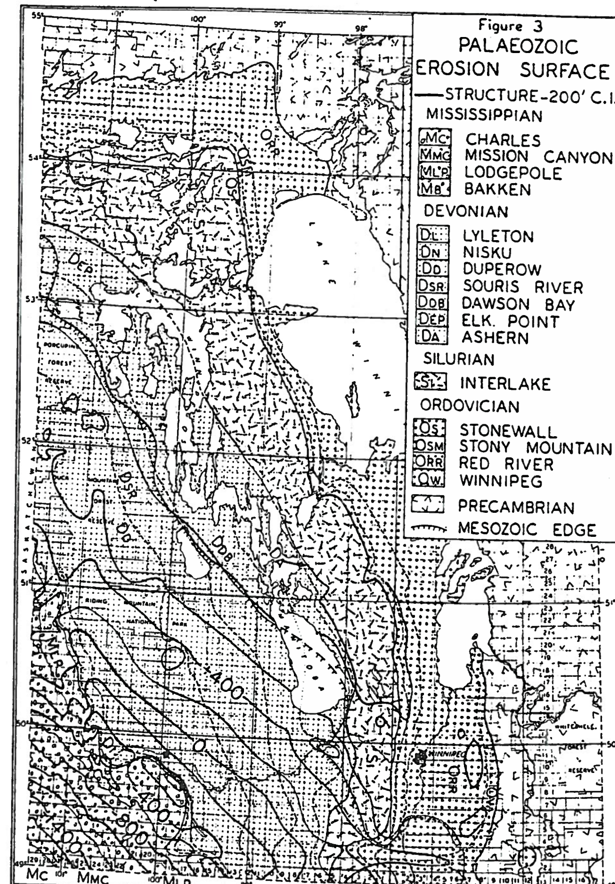


Figure 3
PALAEOZOIC
EROSION SURFACE
STRUCTURE-200' C.I.
MISSISSIPPIAN
Mc CHARLES
MMC MISSION CANYON
MLP LODGEPOLE
MB BAKKEN
DEVONIAN
DL LYLETON
DN NISKU
DD DUPEROW
DSR SOURIS RIVER
DDB DAWSON BAY
DEP ELK. POINT
DA ASHERN
SILURIAN
SI INTERLAKE
ORDOVICIAN
OS STONEWALL
OSM STONY MOUNTAIN
ORR RED RIVER
OW WINNIPEG
PRECAMBRIAN
MESOZOIC EDGE
400
800
Mc MMC MLP

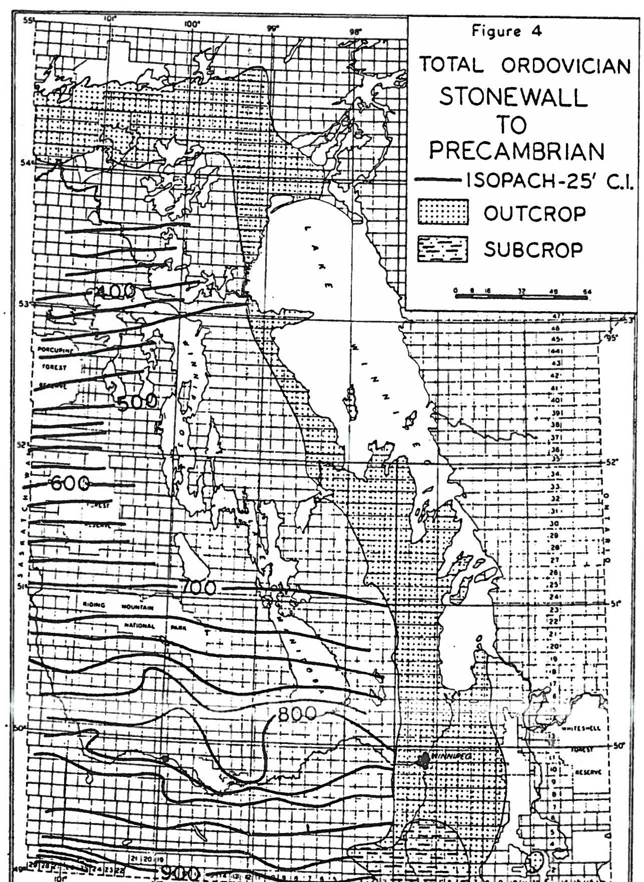


Figure 4
TOTAL ORDOVICIAN
STONEWALL
TO
PRECAMBRIAN
ISOPACH-25' C.I.
OUTCROP
SUBCROP
400
500
600
700
800
900

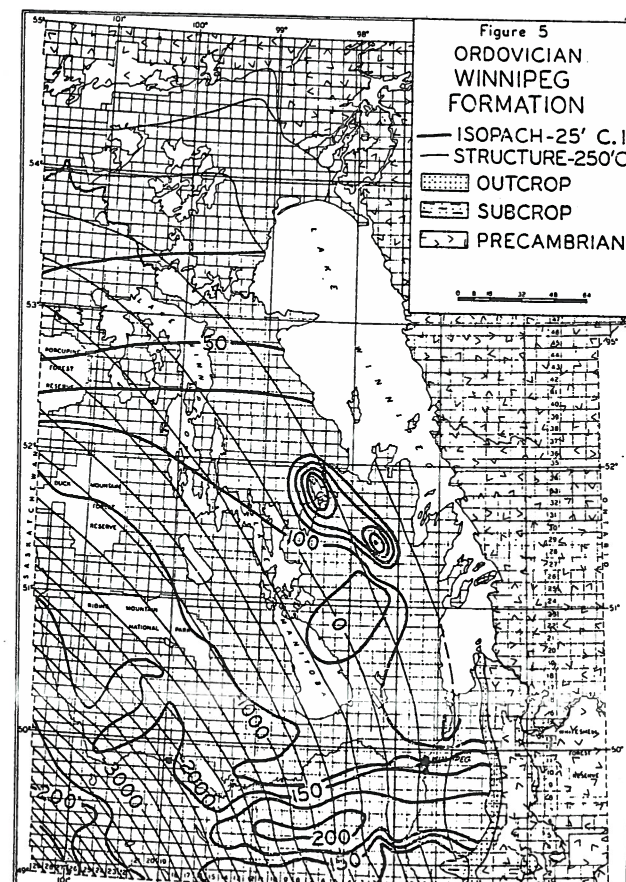
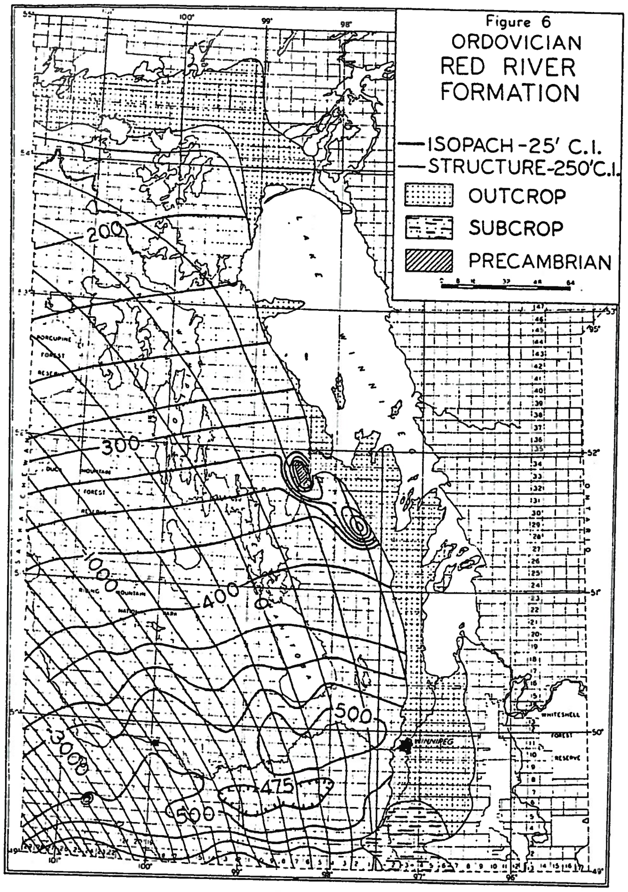


Figure 5
ORDOVICIAN
WINNIPEG
FORMATION
ISOPACH-25' C.I.
STRUCTURE-250' C.I.
OUTCROP
SUBCROP
PRECAMBRIAN
50
100
150
200
1000
2000
3000



right angles to the outcrop belt, so that the maximum rate of change of thickness and also the maximum rate of lithofacies change occur along the outcrop belt. The outcrop belt of the Red River formation thus represents essentially a dip section rather than a strike section, as might be expected on the periphery of the basin. This marked discordance between isopach and outcrop or subcrop belts is evident to a greater or lesser extent for all Palaeozoic formations and is in part the result of a post-Palaeozoic shift in the tectonic framework; it has been an important factor in controlling oil migration and accumulation in Mississippian strata, and is also a highly important consideration for any other exploration involving similar stratigraphic traps at the Palaeozoic erosion surface.

The isopach of the *Stony Mountain formation* (*Figure 7*) reflects a continuation of the previously established tectonic framework, but with a somewhat more gradual and irregular thickening to the south, and a small area of thickening near the Saskatchewan border. The southward thickening is accompanied by an increase in argillaceous content and a decrease in degree of dolomitization.

The *Stonewall formation* (*Figure 8*) comprises the uppermost Ordovician strata and may possibly include some basal Silurian strata as well, although there is no appreciable break in the stratigraphic succession. The isopach pattern differs markedly from the previously described Ordovician strata in that the unit thickens to the west rather than to the south. This indicates a significant change in tectonic framework during latest Ordovician or earliest Silurian time, with the Manitoba portion of the Williston Basin no longer undergoing differential subsidence.

The area of gypsum shown in *Figures 8* and *9* as occurring within the outcrop belts of the Stonewall and Interlake strata is of uncertain age (possibly Jurassic), and the exact configuration of the outcrop belts relative to the occurrences of both the gypsum and the adjacent Precambrian inlier is uncertain.

Silurian

The top of the next unit, the *Silurian Interlake Group* (*Figure 9*), marks a major unconformity, with all of the upper part of the Silurian strata having been eroded from southwestern Manitoba. The Silurian isopach thus reflects primarily the topography of the erosion surface, and shows an almost dendritic pattern. There is, however, little evidence of progressive truncation of Silurian strata, and this suggests that post-Silurian uplift was relatively uniform. Tentative isopachs of marker-defined units within the Interlake also are relatively uniform throughout the map-area. Apparently, a relatively stable tectonic framework was maintained in the Manitoba portion of the basin both during Interlake deposition and during subsequent pre-Middle Devonian uplift and erosion. This relative tectonic stability may account in part, for the highly dolomitized nature of the Interlake strata.

Devonian

Deposition of the basal Devonian Ashern formation of the Elk Point Group marks the beginning of a major new depositional cycle and the establishment of a completely different tectonic framework in southwestern Manitoba. Whereas the Williston Basin was the controlling tectonic element during Ordovician and Silurian time, the Elk Point Basin became the controlling element during Devonian time. However, the tectonic framework of the basin is obscured to a considerable extent by "superficial" salt collapse features.

The most prominent feature of the Devonian maps is the Birdtail-Waskada Axis, which comprises a north-trending zone approximately 20 miles east of the Saskatchewan border (*Figure 10*). As is shown in subsequent figures, this axis is the locus of a large number of local structure and isopach anomalies in Devonian and later strata. It marks the present eastern edge of the Prairie Evaporite salt basin; it marks the western edge of the Winnipegosis fringing reef; and it is coincident with the projected Churchill-Superior boundary zone of the Precambrian basement. All of these factors probably are closely inter-related.

The complex local structures located along this axis have been important in controlling or modifying most of the known oil accumulations in the shallower Mississippian strata of Manitoba, and a correct interpretation of the origin and extent of these features will be even more important in determining the prospects for oil accumulation in the deeper Devonian and earlier strata along this zone. In any case, regardless of the origin of these structures, whether they are superficial salt collapse features or true tectonic features, the Birdtail-Waskada Axis certainly appears to offer the best possibilities for future oil exploration within the map-area.

The isopachs of the basal Devonian *Ashern formation* (*Figure 10*) are markedly irregular and represent, in large part, an infilling of the previously noted topographic lows on the eroded Silurian surface. The structure contours on the top of the Ashern are of particular importance, as they are uniform and show no evidence of any appreciable tectonic differentiation across the Birdtail-Waskada Axis. This suggests that the structure and isopach anomalies evident in the overlying strata may be merely superficial features.

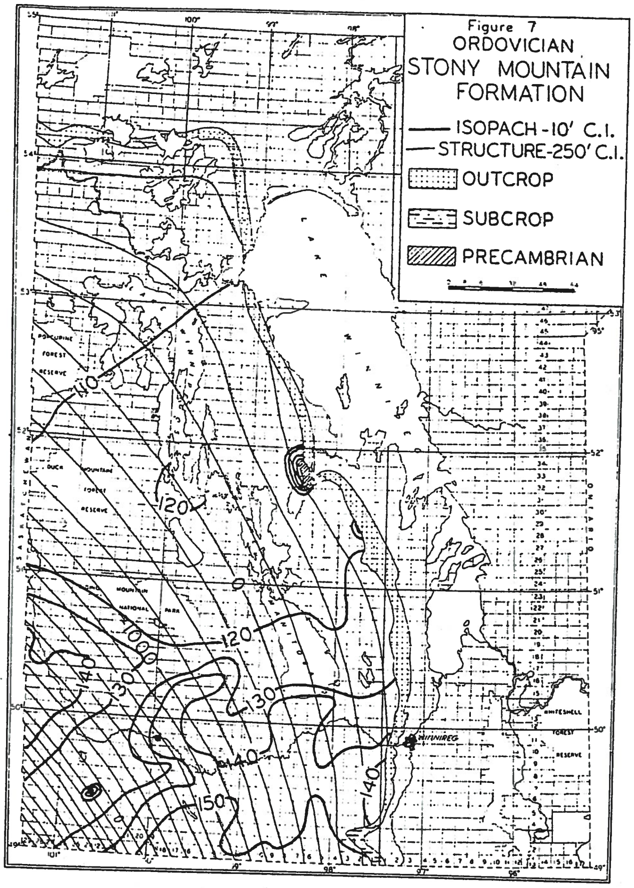


Figure 7
ORDOVICIAN
STONY MOUNTAIN FORMATION

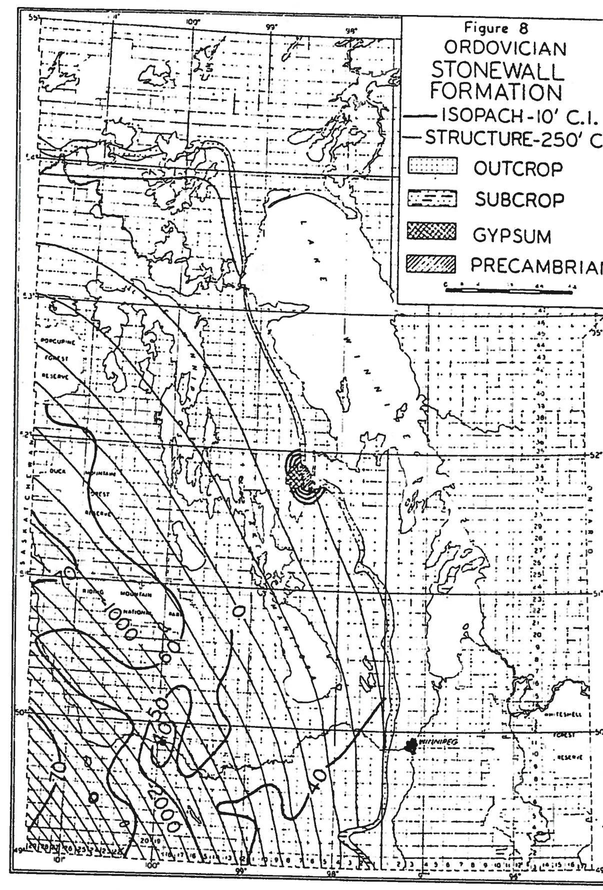


Figure 8
ORDOVICIAN
STONEWALL FORMATION

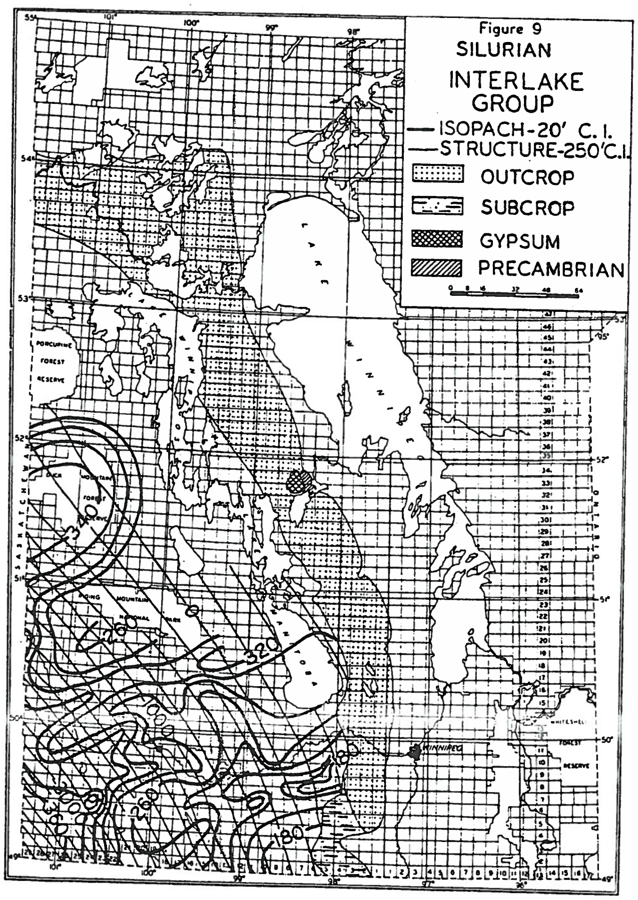


Figure 9
SILURIAN
INTERLAKE GROUP

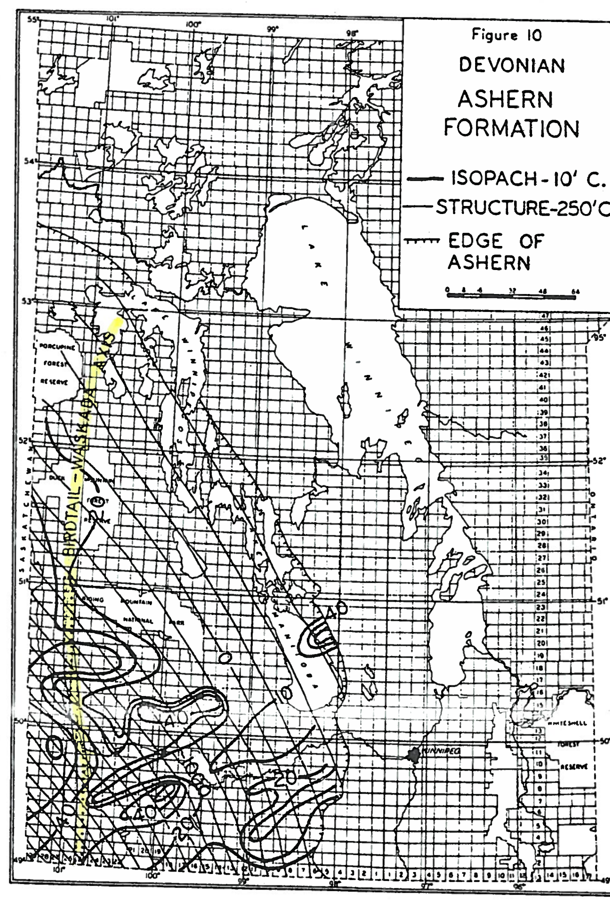


Figure 10
DEVONIAN
ASHERN FORMATION

Neither of the next Devonian units, the Winnipegosis or overlying Prairie Evaporite, is a marker-defined unit, and the tectonic framework cannot be interpreted directly from the isopachs. The top of the Winnipegosis reflects the topography of a reef and inter-reef complex having local depositional relief of as much as 200 to 300 feet. The Prairie Evaporite represents an infilling and overlapping of the Winnipegosis basin and is in large part a lateral equivalent of the Winnipegosis. Despite this, the isopach of the *Winnipegosis formation* (*Figure 11*) shows several important features. The unit thickens rather uniformly toward the west and northwest, to a maximum of 160 to 180 feet. This probably represents sedimentation on a relatively stable shelf area building up to a fringing reef or bank along the southeastern edge of the Elk Point Basin. West of the Birdtail-Waskada Axis, the Winnipegosis thins abruptly, coincident with a thickening of the Prairie Evaporite. This thinning is interpreted as a facies thinning rather than a tectonically controlled feature. The trend of the reef edge along the Birdtail-Waskada Axis is seen to be discordant to the general basin framework, and it seems likely that some minor tectonic movement associated with the Churchill-Superior boundary zone occurred along the Birdtail-Waskada Axis during Winnipegosis time and was sufficient to localize reef growth along the axis, but was not sufficient to show on the structure of the underlying Ashern.

In the deeper part of the Elk Point Basin, along the northward continuation of the Churchill-Superior boundary, further reef development is evident in the Duck Mountain, Swan River and Dawson Bay areas, where a series of patch reefs rise 250 to 300 feet above the inter-reef platform. The original extent of the Elk Point Basin to the northeast is uncertain, but it must have extended for a very considerable distance inasmuch as the outcrop area on Dawson Bay represents a basinal facies.

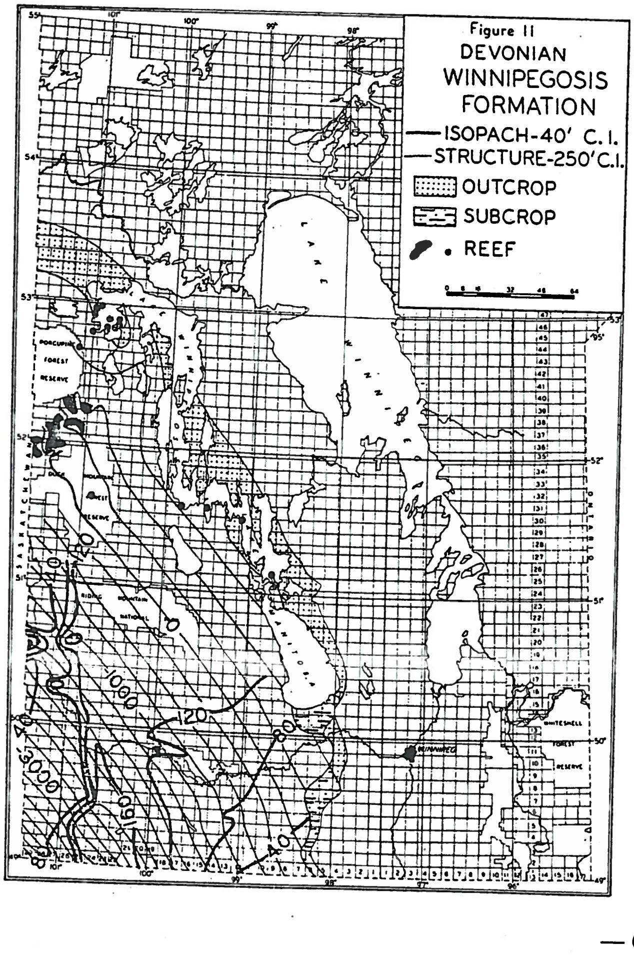


Figure 11
DEVONIAN
WINNIPEGOSIS
FORMATION

The principal feature shown by the *Prairie Evaporite* isopach (*Figure 12*) is the abrupt thinning along the Birdtail-Waskada Axis, coincident with the edge of the fringing Winnipegosis reef. Additional deep well control probably would show the salt edge to be much more irregular than indicated on this map.

The composite unit consisting of the *Winnipegosis + Prairie Evaporite* (*Figure 13*) is an approximate marker-defined unit; consequently, the isopach reflects the true depositional framework, except for areas where salt solution has occurred. It shows a number of features that are not evident on either of the Winnipegosis or Prairie Evaporite maps. A very abrupt thinning occurs at the present salt edge, and this thinning is associated with a synclinal hinge or flexure which is down-warped to the east. (This feature is more easily seen if data are extended into Saskatchewan). The synclinal flexure of the top of the unit coupled with the previously mentioned lack of structure on the underlying Ashern strongly suggests that extensive salt solution has occurred along the present eastern edge of the salt basin.

A number of factors probably have tended to localize the area of salt solution — notably the presence of a thick underlying section of porous Winnipegosis reef or bank deposits that provided an aquifer for the circulating formation waters which have dissolved the salt. Also, minor tectonic movement along the Birdtail-Waskada Axis may have caused fracturing which would favour salt solution. The sharply defined, linear and cross-cutting structural lows in the Mississippian strata of the field areas (*Figure 21*) are believed to be due to salt collapse, and are certainly suggestive of fracture-controlled solution channels.

Direct evidence for salt solution is noted in the several wells along the southern part of the Birdtail-Waskada Axis, where the total section of Winnipegosis + Prairie Evaporite is locally thin. It will be seen in *Figures 15, 17* and *19* that this thinning is compensated for by a thickening of certain overlying strata. The northern limit of the Prairie Evaporite is also a solution edge, because Upper Palaeozoic strata are seen to be draped over the Winnipegosis reefs with no evidence of any change in thickness. This draping is best shown in the Swan River area, where the structure on the top of the *Souris River formation* reflects the underlying "reef topography" (*Figure 14*). At least 200 to 300 feet of salt must have been removed from the inter-reef areas, largely during the post-Palaeozoic pre-Mesozoic erosion interval.

The Prairie Evaporite is overlain by the normal marine strata of the *Dawson Bay formation* (*Figure 15*). Re-establishment of normal marine conditions almost certainly must have resulted in some solution of salt from the top of the Prairie Evaporite, and the apparent truncation of the Prairie Evaporite potash beds by the Dawson Bay is one piece of evidence for this.

The basal red shales of the Dawson Bay probably represent, in part, the insoluble residue from this salt solution, and the previously mentioned areas of local salt solution on the southern end of the Birdtail-Waskada Axis do in fact show a thickened Dawson Bay section, due entirely to a thickening of the basal red beds.

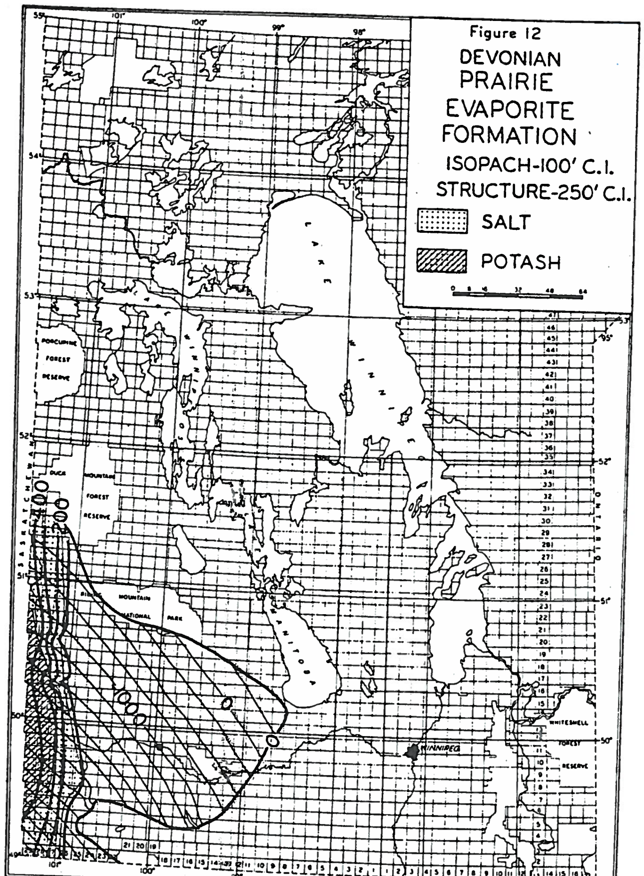


Figure 12
DEVONIAN
PRAIRIE
EVAPORITE
FORMATION
ISOPACH-100' C.I.
STRUCTURE-250' C.I.
SALT
POTASH
WINNIPEG

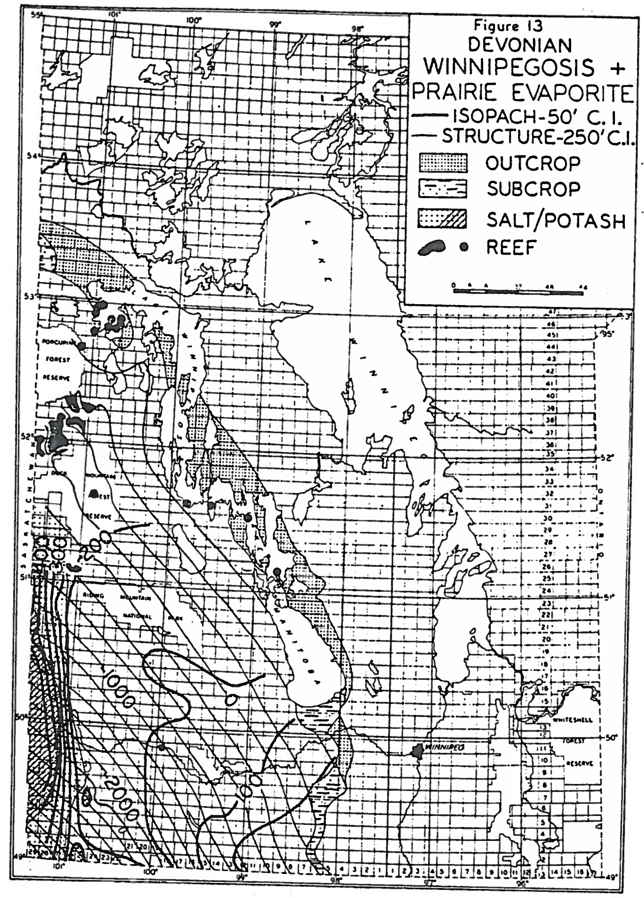
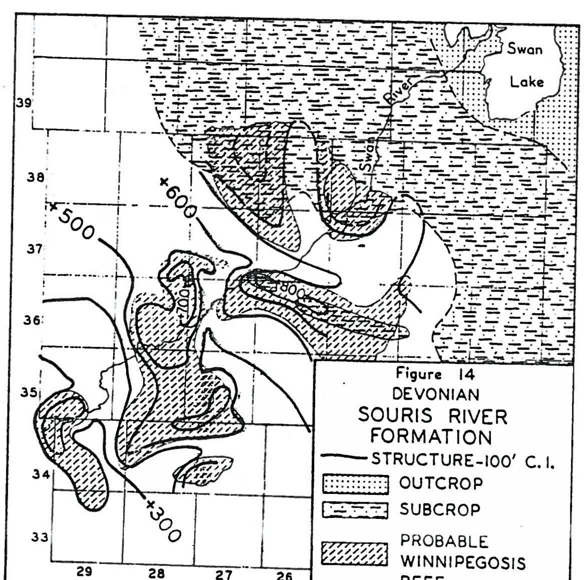


Figure 13
DEVONIAN
WINNIPEGOSIS +
PRAIRIE EVAPORITE
ISOPACH-50' C.I.
STRUCTURE-250' C.I.
OUTCROP
SUBCROP
SALT/POTASH
REEF
WINNIPEG


Swan
Lake
Swan River
+600
+500
+300
Figure 14
DEVONIAN
SOURIS RIVER
FORMATION
STRUCTURE-100' C.I.
OUTCROP
SUBCROP
PROBABLE
WINNIPEGOSIS
REEF
29
28
27
26

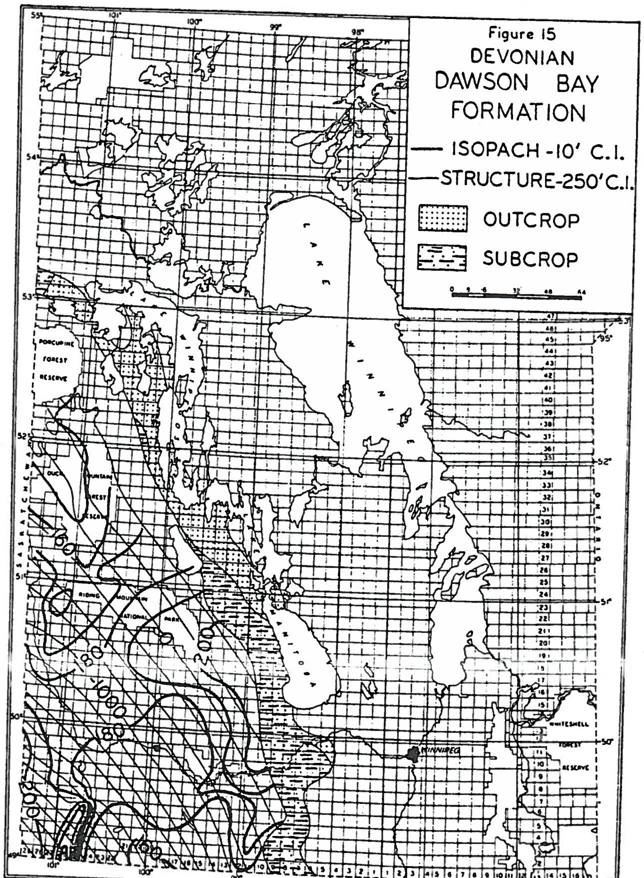


Figure 15
DEVONIAN
DAWSON BAY
FORMATION
ISOPACH -10' C.I.
STRUCTURE-250' C.I.
OUTCROP
SUBCROP
WINNIPEG

In general, the Dawson Bay isopachs are quite erratic and bear little relation to the over-all basin framework, as might be expected if pre-Dawson-Bay salt solution had occurred. In particular, note the thickening to the northeast of the Birdtail-Waskada axis, where Dawson Bay strata attain their maximum thickness at their erosional limit.

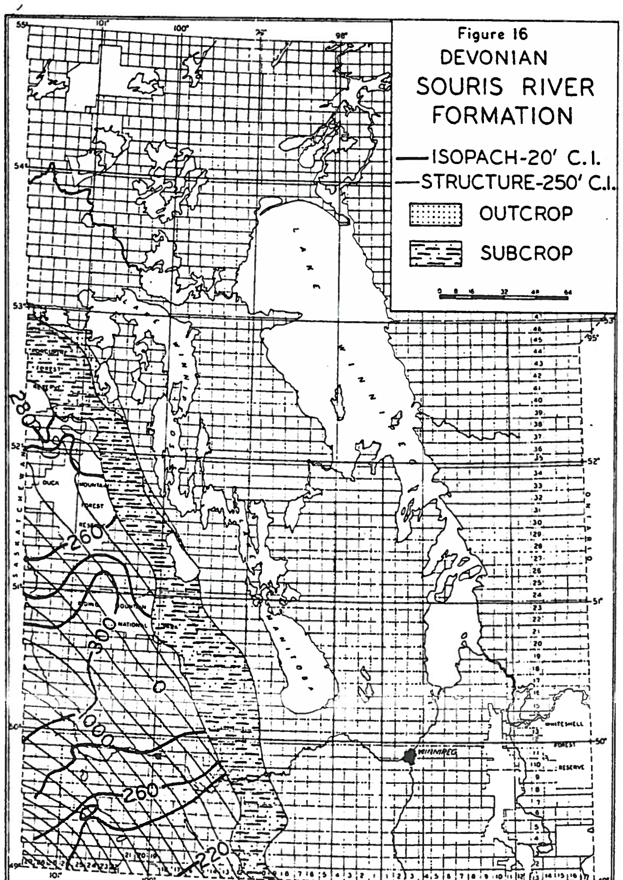
This thickening could possibly indicate relatively greater subsidence in the Manitoba portion of the Basin, but more likely it may represent thickening due to solution of Prairie Evaporite salt immediately prior to or during Dawson Bay time. Structure contours once again indicate a synclinal flexure along the salt edge.

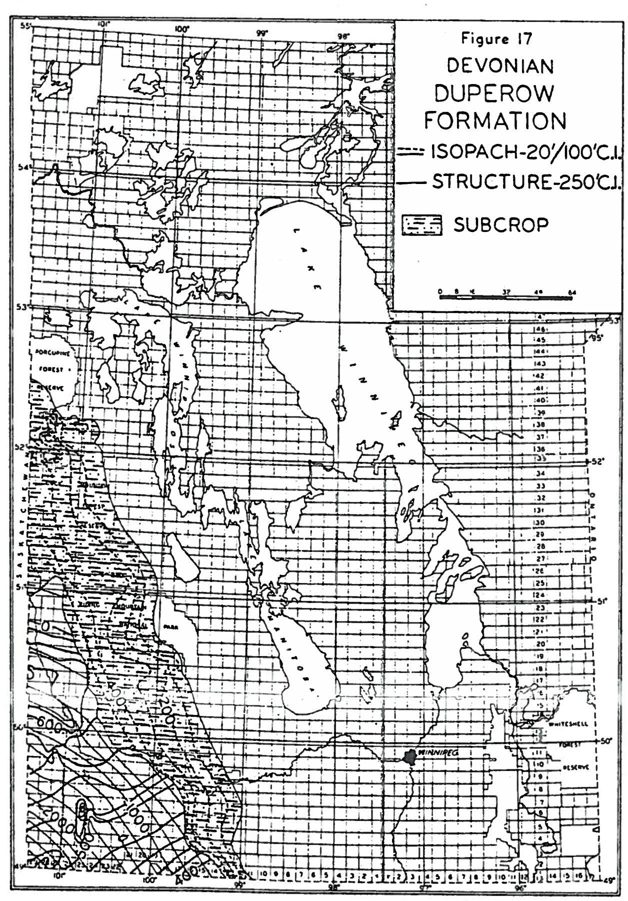
The isopach of the *Souris River formation* (*Figure 16*) shows a relatively normal tectonic framework with uniform thickening toward an east-trending zone of maximum subsidence in the central part of the map-area. This probably represents the eastern end of the Elk Point Basin, but to the east of the Birdtail-Waskada-Axis it is possible that salt collapse was a contributing factor, as the area of thick Souris River coincides with the approximate edge of the Winnipegosis reef. Structure contours once again show the synclinal flexure at the salt edge, and complex local structures are evident in the northern area where Souris River strata are draped over the buried Winnipegosis reefs.

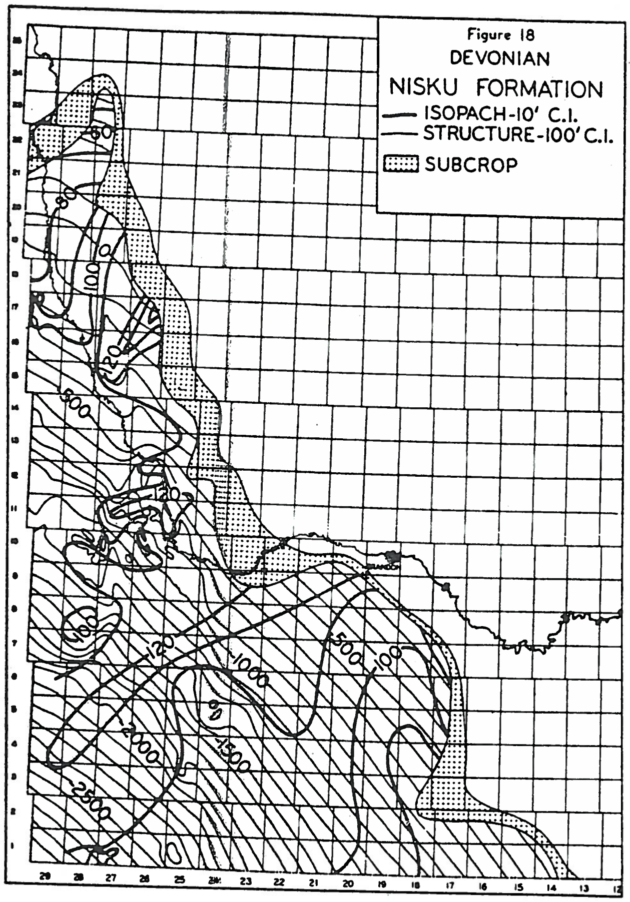
The isopach of the *Duperow formation* (*Figure 17*) is similar to that of the Souris River. However, a sharply defined local thick is evident along the southern part of the Birdtail-Waskada Axis. This is the same area where a thinning of the combined Winnipegosis - Prairie Evaporite isopach indicated salt solution, and the local thickening of the Duperow by over 100 feet is almost certainly the result of salt collapse during Duperow time. In the northern part of the subcrop belt, the marked irregularities in isopach pattern are the result of differential truncation over the reef-controlled structural highs noted previously in *Figure 14*.

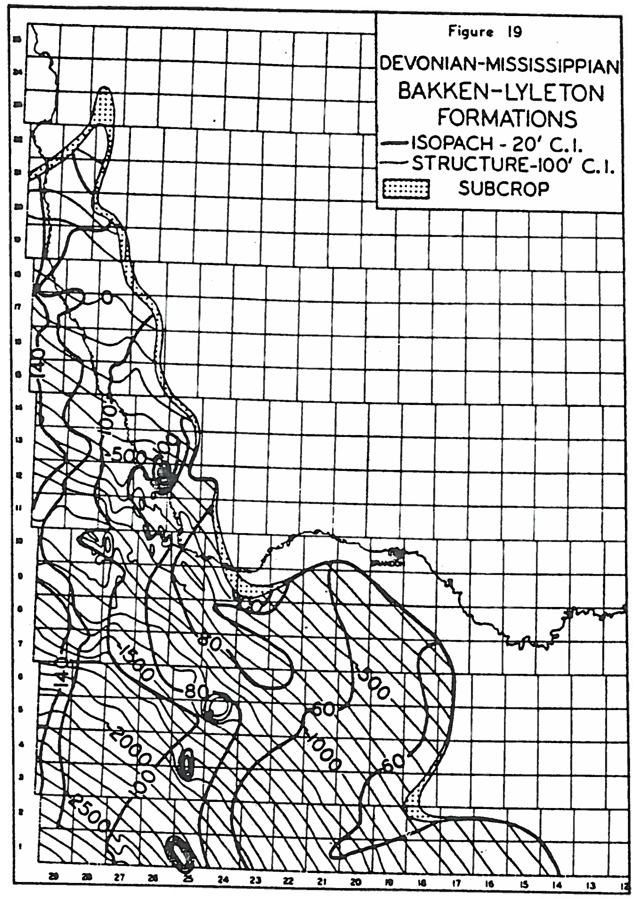
For the *Nisku formation* (*Figure 18*), the isopach pattern is seen to be quite irregular, possibly reflecting the biostromal nature of the unit, but there are no noticeable regional trends. This suggests a relative stabilization of the tectonic framwork toward the end of the Devonian depositional cycle.

The most prominent feature of this map is the large number of synclinal structures occurring along or near the Birdtail-Waskada Axis, especially in the vicinity of the Mississippian oil fields where at least fourteen prominent structural lows are evident. In all probability, these structures are also present in most of the underlying Devonian strata, but they do not appear on the preceding maps because of the lack of well control for pre-Nisku strata. Because of this lack of deep well control, it is not possible to ascertain directly that these structures represent salt collapse features; however, this appears highly probable. Two closed structural highs occur along the southern part of the Birdtail-Waskada Axis and are coincident with areas of earlier salt collapse. It seems likely that they are structural highs because of later salt solution in surrounding areas; such multiple-stage salt solution, giving rise to local structural highs in the area of early salt solution, would appear to offer excellent possibilities for oil entrapment.





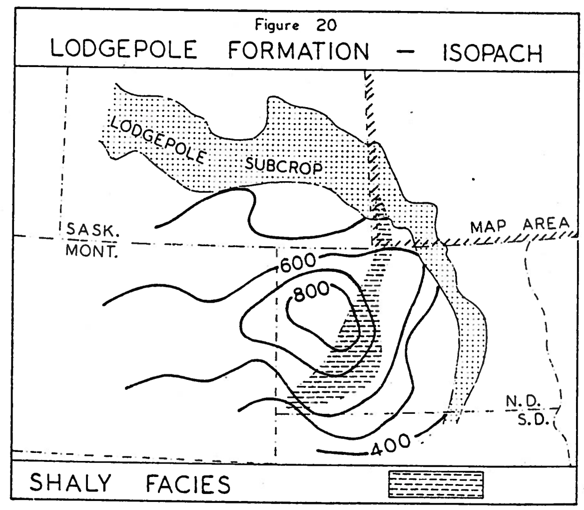




Mississippian

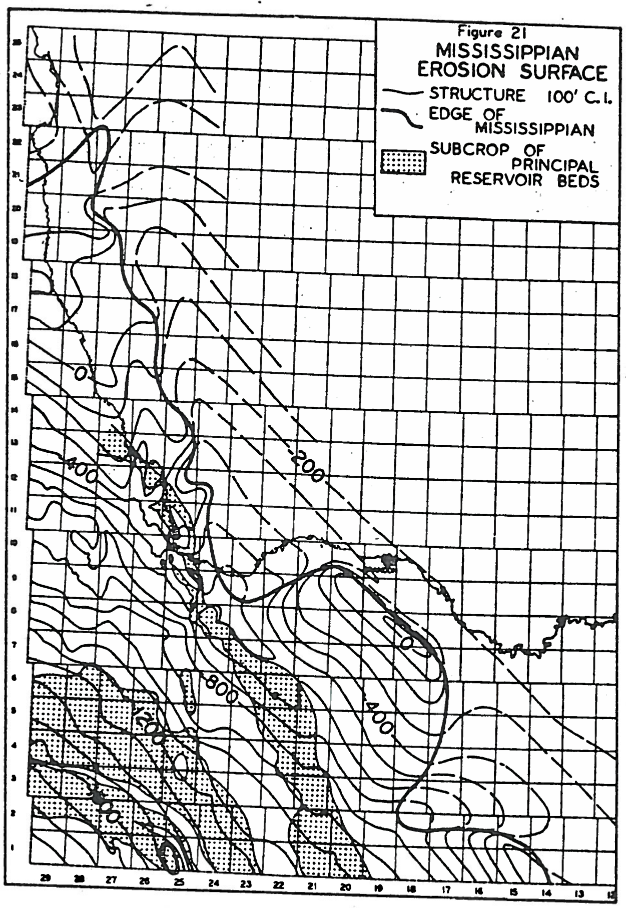
The *Bakken-Lyleton* interval (*Figure 19*) represents a composite unit of uppermost Devonian shales and basal Mississippian shales, and includes the unconformable contact between the two. The isopach reflects primarily the eastward truncation of the Lyleton formation, but it also marks the beginning of a major shift in the tectonic framework so that the Williston Basin rather than the Elk Point Basin was the dominant tectonic element during Mississippian time.

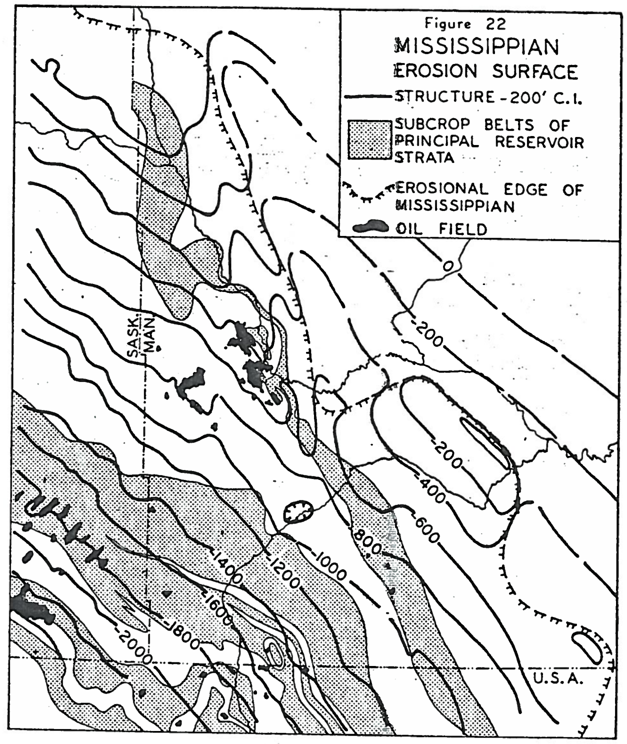
The main feature of the map once again is the large number of synclinal lows along the Birdtail-Waskada Axis. In addition, three local isopach thicks occur along this axis, probably as a result of salt collapse during Bakken-Lyleton time. Two of these areas are now structural highs, indicating that later salt collapse has occurred in surrounding areas.



Direct interpretation of the Mississippian tectonic framework in Manitoba is uncertain because of the extensive erosion of these strata during the pre-Jurassic erosion interval. However, regional isopachs of the lower Mississippian *Lodgepole formation* (*Figure 20*) indicate that, once again, the Manitoba portion of the Williston Basin, especially along the Birdtail-Waskada Axis, underwent a slightly greater degree of subsidence than adjacent parts of the basin. The distribution of the peripheral shale facies shows the effect of this differential subsidence.

The subcrop map of the *Mississippian erosion surface* (*Figure 21*) shows two windows of Mission Canyon and Lodgepole strata along the southern part of the Birdtail-Waskada Axis. These are the result of truncation of the previously mentioned local structural highs formed by early salt collapse. In addition, a well-defined change in orientation of the subcrop belts is evident. Whereas the subcrop belts of the Lodgepole and earlier strata show a structural rise to the northwest, the Mission Canyon and Charles subcrop belts show a rise to the southeast. A possible explanation for this can be seen if the map is extended to include a somewhat larger portion of the basin (*Figure 22*). A pronounced up-dip flexure of the subcrop belts occurs along parts of the Birdtail-Waskada Axis, indicating a synclinal structure which has been truncated at the Mississippian erosion surface. This structure may possibly be due to post-Mississippian salt collapse, or it may indicate further tectonic subsidence along the Churchill-Superior boundary zone.





Although the Manitoba portion of the Williston Basin underwent greater subsidence throughout a considerable portion of Palaeozoic time, most notably during deposition of Ordovician and Mississippian strata, this same area has been subjected to a greater degree of pre-Jurassic uplift and erosion, so that the thicker and more basinal facies of these strata are now exposed at the erosion surface. This accounts in part for the pronounced discordance between the isopach trends and the subcrop belts previously noted for all Palaeozoic formations, and may be the result of a greater response of the Superior block to the tectonic forces giving rise to both basin subsidence and basin uplift.

In summary, then, the major tectonic elements of the Precambrian basement, especially the discontinuity between the Churchill and Superior provinces, and to a much lesser degree the east-trending orogenic zones within the Superior block, apparently have been centers of continued tectonic activity during Palaeozoic time. In addition to having had a direct effect on sedimentation at certain times, minor movements associated with these features have served to localize superficial isopach and structural features of a much greater magnitude, resulting from differential compaction and salt solution. Differentiating between true tectonic structures and superficial structures, where the two are superimposed, is of critical importance in evaluating the Palaeozoic tectonic framework and the possibilities for oil accumulation in the Palaeozoic strata of Manitoba.

Acknowledgment

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