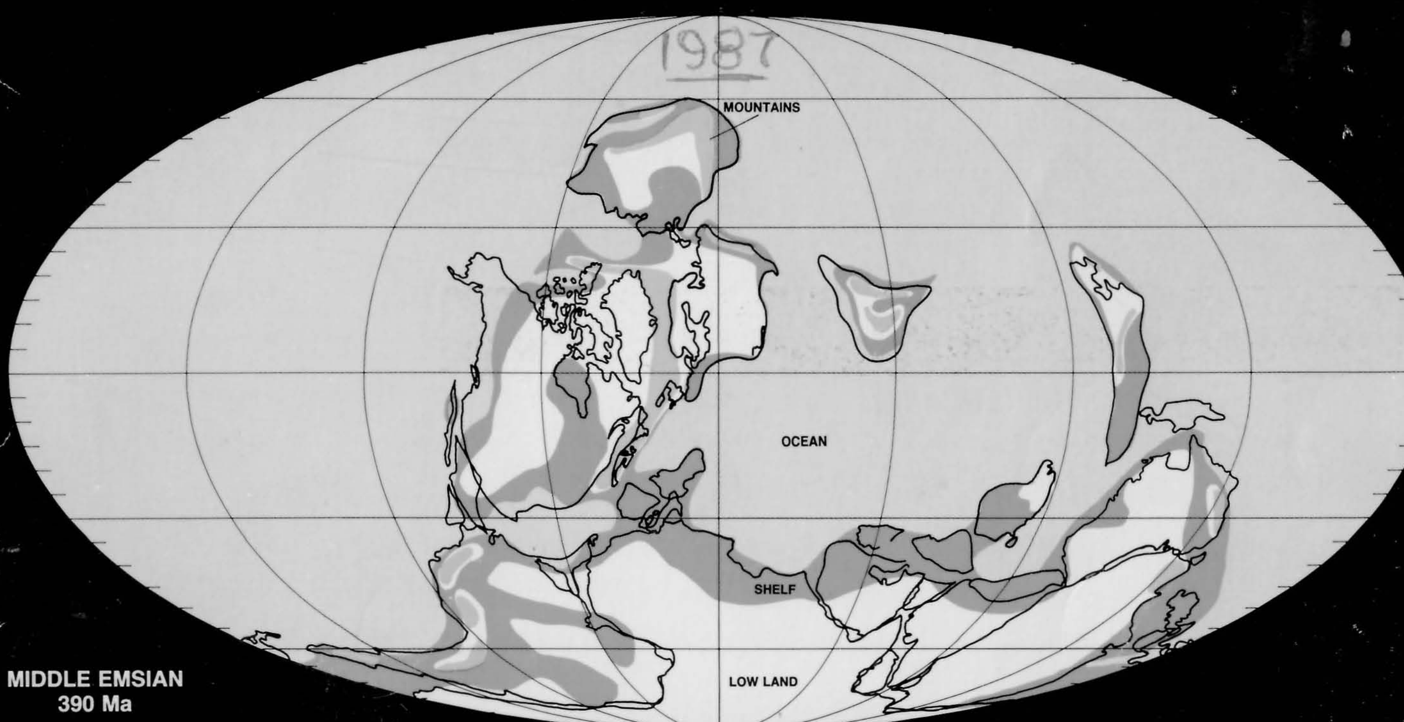
SECOND INTERNATIONAL SYMPOSIUM ON THE

DEVONIAN SYSTEM

CALGARY, ALBERTA, CANADA – AUGUST 17-20, 1987



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EXCURSION B2

THE MIDDLE AND UPPER DEVONIAN CARBONATE AND EVAPORITE SEQUENCE OF SOUTHERN MANITOBA

THE CANADIAN SOCIETY OF PETROLEUM GEOLOGISTS

NOTE: The original hard copy publication of “Excursion B2” was misprinted without a page numbered 25. No pages are missing from this PDF document.

SECOND INTERNATIONAL SYMPOSIUM ON THE DEVONIAN SYSTEM
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FIELD EXCURSION B2

THE MIDDLE AND UPPER DEVONIAN CARBONATE AND EVAPORITE SEQUENCE OF SOUTHERN MANITOBA

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FOREWORD

This field guide has been prepared as a comprehensive guide to the Devonian outcrops of southwestern Manitoba. It supersedes an earlier "Field Guide to Devonian Outcrops of Southwestern Manitoba" prepared for the 1967 First International Symposium on the Devonian System, sponsored by the Alberta Society of Petroleum Geologists.

The present guide has been compiled specifically for two proposed field trips, one for June 5-7, 1986, in conjunction with the annual meeting of the Canadian Society of Petroleum Geologists, and the second in conjunction with the August 1987 Second International Symposium on the Devonian System, also sponsored by the CSPG.

Almost all significant road accessible outcrops have been included in the present guide as well as a number of shoreline and island outcrops on Dawson Bay, accessible only by boat. A number of recently opened quarries and roadcuts included in this guidebook have not been described in any of the earlier reports or guidebooks.

In addition to the road log and general outcrop descriptions, an introductory section is included which reviews the regional subsurface stratigraphy and tectonic framework of southwestern Manitoba, in order to provide the field trip participant with some background for interpretation of the outcrop exposures.

For additional lithologic descriptions and faunal studies of Devonian outcrops not included in this guide the reader is referred to Baillie (1951, 1953), McCammon (1960) and Norris et al (1982).

The writer is greatly indebted to Dr. A.D. Baillie, who carried out much of the early field mapping of Paleozoic strata in Manitoba.

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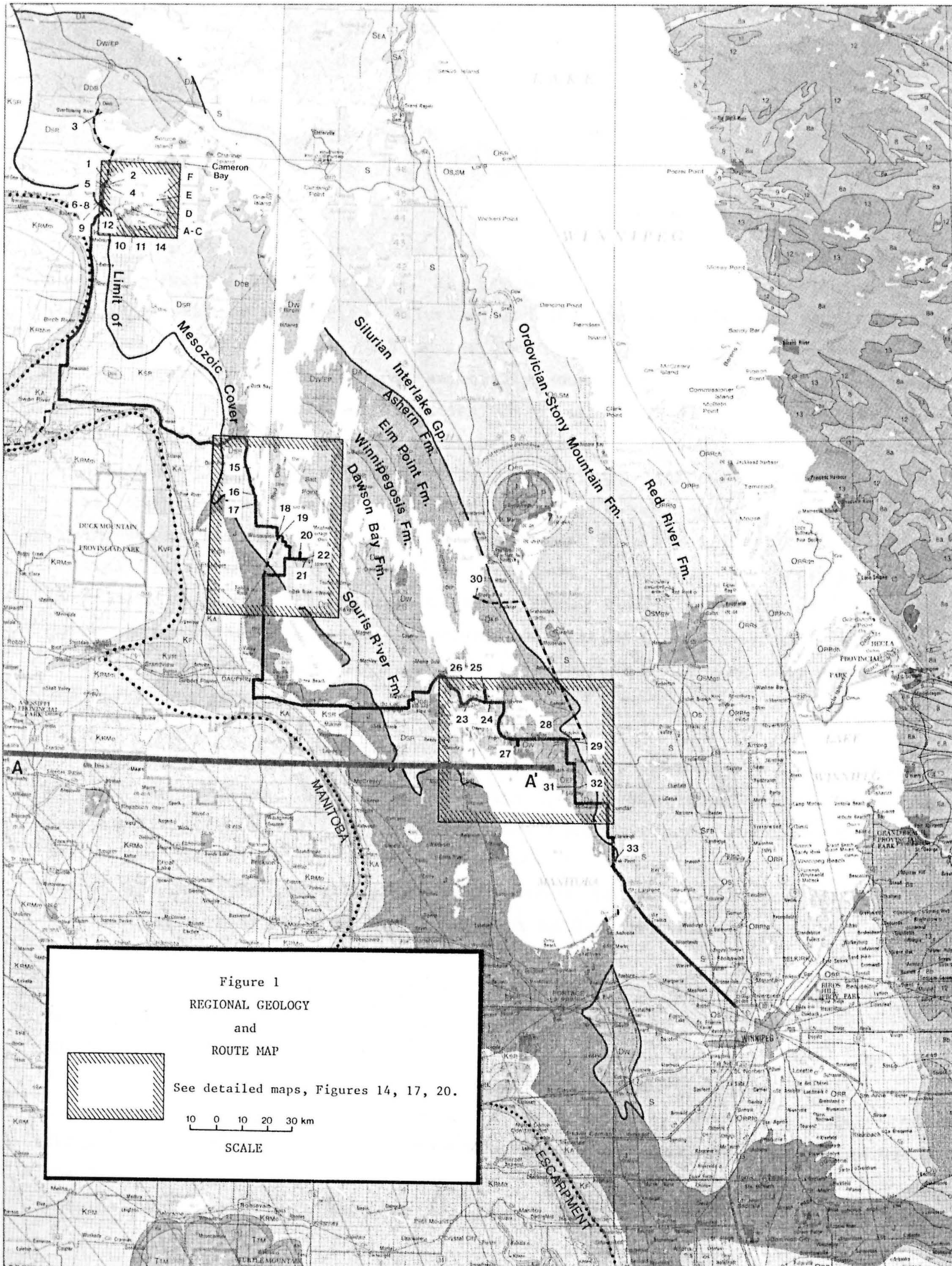


Figure 1
REGIONAL GEOLOGY
and
ROUTE MAP

INTRODUCTION TO THE DEVONIAN STRATIGRAPHY OF SOUTHERN MANITOBA

1.0 Regional Setting

1.1 Physiographic setting

The Devonian outcrop belt of Manitoba occurs within the Manitoba Lowland or First Prairie Level (Figs. 1, 2). This Lowland is underlain principally by Paleozoic rocks of Ordovician, Silurian, and Devonian age which dip gently to the southwest at approximately 2.8 m per km. Jurassic strata also underlie the southwestern part of the Lowland, especially south of Winnipeg where a large area of Jurassic rocks occurs as infilling of a major pre-Mesozoic channel in the Paleozoic erosion surface. The Manitoba Lowland is bounded on the east by the Precambrian Shield, and on the west by the Manitoba Escarpment. The Escarpment forms the eastern edge of the Second Prairie Level, which is underlain by Cretaceous strata dipping gently to the southwest at 1.5 - 1.9 m per km (Fig. 2). Several broad valleys interrupt this escarpment, especially the Assiniboine and Swan River valleys. The presence of soft, easily eroded sands and shales in the lower part of the Cretaceous, underlying a relatively more resistant shale cap (the Odanah siliceous shale), accounts for the abrupt escarpment near the edge of the Cretaceous strata.

The entire area has been glaciated, probably several times, and a mantle of till and moraine, largely of the latest, Wisconsin glaciation, covers the bedrock almost completely so that few good rock exposures occur, except along creeks and rivers cutting through the escarpment, and along the shores of lakes within the Manitoba Lowland. This drift mantle ranges in thickness from a few metres to as much as 260 m in some areas such as Duck Mountain.

In addition to the cover of drift material, the entire area of the Manitoba Lowland, as well as much of the Shield area, was covered by glacial Lake Agassiz, and a thick blanket of lake clays and silts was laid down over the southern part of the Lowland. These lake beds account for the extremely flat topography in the general Winnipeg area. To the north, however, the lake beds thin, and north of approximately the southern ends of Lakes Winnipeg and Manitoba, the Lowland is underlain by a relatively thin mantle of glacial drift (ground moraine) which has been modified and reworked by wave action in Glacial Lake

Agassiz. The present Lakes Winnipeg, Manitoba, and Winnipegosis are remnants of this ancestral glacial lake.

A series of beach ridges occurs around the periphery of the Manitoba Lowlands, especially along the Manitoba Escarpment, and mark the abandoned strand lines of Lake Agassiz. Late glacial and post-glacial rebound has resulted in tilting and differential uplift of the beaches in the northern part of the area, amounting to as much as 100 m.

For more detailed information on surficial geology the reader is referred to Johnston (1934, 1946), Elson (1961), Klassen et al. (1970), and the series of Soils Reports published jointly by the Manitoba Department of Agriculture and Conservation and the Canada Department of Agriculture (in particular, Reports 5, 8, 9, 12 and 13).

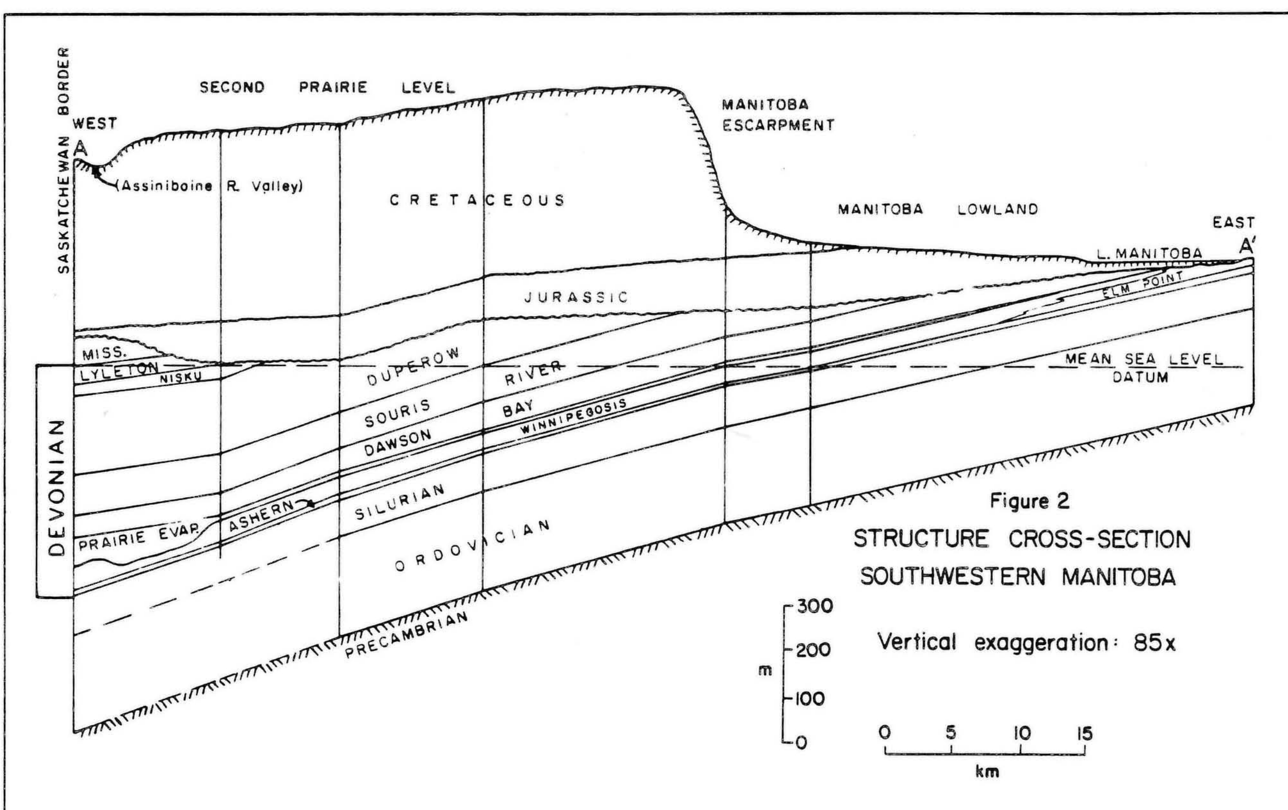


Figure 2. Structure cross-section, southwestern Manitoba

1.2 Stratigraphic Setting

To place the various Paleozoic outcrops of southwestern Manitoba in their proper perspective and to provide a basis for interpretation of the various features shown in outcrop it is necessary to review briefly the changing paleogeographic patterns through geologic time. The Manitoba outcrop belt is located on the northeastern edge of the Western Canada Sedimentary Basin - a composite feature which includes both the Elk Point Basin, centred in south-central Saskatchewan, which controlled deposition only during Devonian time, and the Williston Basin, centred in northwestern North Dakota, which controlled the depositional pattern throughout the remainder of post-Cambrian time (Figs. 4, 5, 6). Because the Manitoba outcrop belt appears to be situated on the northeastern edge of the sedimentary basin, and roughly parallels the regional structure contours, one might logically surmise that the strata comprising the outcrop belt would be relatively uniform in lithology, and would represent marginal stable shelf type deposits relative to the thicker, more basinal sedimentary sequence found to the southwest in the subsurface. This is not the case for most Paleozoic formations in southwestern Manitoba. The outcrop belts, particularly the Ordovician and Devonian, show marked changes in both thickness and lithology, indicating a complex and changing tectonic and depositional framework.

If any generalization can be made with respect to the nature of both the Devonian and Ordovician outcrop successions of southwestern Manitoba, it is that the outcrop successions are not marginal to the depositional basin but rather expose a series of dip sections of the basin which show the maximum possible isopach and lithofacies variation. Furthermore, the directions of the dip sections are opposite; basinal Ordovician outcrops occur at the southern end of the outcrop belt, whereas basinal Devonian outcrops occur at the northern (or northwestern) end of the outcrop belt. The following discussion will attempt to outline briefly how this complex pattern evolved, and will suggest a possible regional tectonic control for apparent anomalies in facies trends, as well as other related structural and stratigraphic anomalies.

ERA	PERIOD	EPOCH		FORMATION	MEMBER	MAX THICK (m)	BASIC LITHOLOGY
CENOZOIC	QUATERNARY	RECENT					TOP SOIL, DUNE SANDS
		PLEISTOCENE		GLACIAL DRIFT		140	CLAY, SAND, GRAVEL, BOULDERS, PEAT
	TERTIARY	PLIOCENE					
		MIOCENE					
		OLIGOCENE					
		EOCENE					
		PALEOCENE		TURTLE MTN.	PEACE GARDEN GOODLANDS	120	SHALE, CLAY AND SAND. LIGNITE BEDS LOCATED ONLY IN TURTLE MOUNTAIN
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS		BOISSEVAIN		30	SAND AND SANDSTONE, GREENISH GREY, LOCATED ONLY IN TURTLE MOUNTAIN
				RIDING MTN.	COULTER ODANAH MILLWOOD	310	GREY SHALES—NON-CALC. LOCAL IRONSTONE BENTONITE NEAR BASE. GAS FOUND
				VERMILION RIVER	PEMBINA	155	SHALE DARK GREY CARBONACEOUS NON-CAL BENTONITE BANDS
					BOYNE		SHALE GREY SPECKLED CALC. BENTONITIC SLIGHTLY PETROLIFEROUS
					MORDEN		SHALE DARK GREY NON-CALC. CONCRETIONS LOCAL SAND AND SILT
				FAVEL		40	GREY SHALE WITH HEAVY CALCAREOUS SPECKS BANDS LIMESTONE AND BENTONITE
				ASHVILLE ASHVILLE SAND		115	SHALE, DARK GREY, NON-CALC. SILTY "SAND ZONE" 27m F.G. QTZ. S. OR SS.
		LOWER CRETACEOUS		SWAN RIVER		75	SANDSTONE AND SAND, QTZ. PYRITIC SHALE—GREY, NON-CALC.
	JURASSIC	UPPER JURASSIC		WASKADA		200	BANDED-GREEN SHALE AND CALC.SANDSTONE
				MELITA			BANDS OF LIMESTONE, VARI-COLORED SHALE
		MIDDLE JURASSIC		RESTON		45	LIMESTONE, BUFF, AND SHALES, GREY
				AMARANTH	UPPER: EVAPORITE	45	WHITE ANHYDRITE AND/OR GYPSUM AND BANDED DOLOMITE AND SHALE
					LOWER: RED BEDS	40	RED SHALE TO SILTSTONE-DOLOMITIC
	TRIASSIC	(?)		ST. MARTIN COMPLEX		300	CARBONATE BRECCIA, TRACHYANDESITE (CRYPTO-EXPLOSION STRUCTURE)
PALEOZOIC	PERMIAN						
	PENNSYLVANIAN						
	MISSISSIPPIAN		MADISON GROUP	CHARLES		20	MASSIVE ANHYDRITE AND DOLOMITE
				MISSION CANYON	MC–5 MC–4 MC–3 MC–2 MC–1	120	LIMESTONE—LIGHT BUFF, OOLITIC, FOSS. FRAG., CHERTY, BANDS SHALE AND ANHYDRITE. OIL PRODUCTION
				LODGEPOLE	FLOSSIE LAKE WHITEWATER LAKE VIRDEN SCALLION / ROUTLEDGE	185	LIMESTONE & ARG. LIMESTONE LIGHT BROWN AND REDDISH MOTTLED. ZONES OF SHALEY. OOLITIC, CRINOIDAL & CHERTY OIL PRODUCTION
				BAKKEN	UPPER MIDDLE LOWER	20	2 BLACK SHALE ZONES — SEPARATED BY SILTSTONE OIL SHOW HIGH R.A. KICK
	DEVONIAN		[illegible]	LYLETON		35	RED SILTSTONE AND SHALE DOLOMITIC.
			SASK GROUP	NISKU		40	LIMESTONE & DOLOMITE, YELLOW-GREY FOSS. POROUS. SOME ANHYD.
				DUPEROW		170	LIMESTONE & DOLOMITE. ARG & ANHYDRITIC IN PLACES
			MAN GROUP	SOURIS RIVER 1-ST RED		120	CYCLICAL SHALE, LIMESTONE & DOLOMITE. ANHYDRITE
				DAWSON BAY 2-ND RED		65	LIMESTONE & DOLOMITE, POROUS, ANHYDRITE—LOCAL SHALE RED & GREEN
			ELK POINT G.	PRAIRIE EVAP		120	SALT POTASH & ANHYDRITE. DOLOMITE INTER-BEDDED
				WINNIPEGOSIS		75	DOLOMITE, LIGHT YELLOWISH BROWN REEFY
				ELM POINT			LIMESTONE—FOSS. HIGH CALCIUM
				ASHERN		12	DOLOMITE AND SHALE—BRICK RED
	SILURIAN			INTERLAKE GROUP		135	DOLOMITE YELLOWISH—ORANGE TO GREYISH—YELLOW FOSS. SILTY ZONES
	ORDOVICIAN			STONEWALL		15	DOLOSTONE, GREYISH YELLOW, BEDDED
				STONY MOUNTAIN	WILLIAMS GUNTON	30	DOLOMITE—YELLOWISH—GREY SHALEY
					PENITENTIARY		DOLOMITE—DUSKY—YELLOW FOSS
					GUNN	20	SHALE RED-GREEN FOSS. LIMESTONE BANDS
				RED RIVER	FORT GARRY SELKIRK CAT HEAD DOG HEAD	170	DOLOMITIC LIMESTONE, MOTTLED AND DOLOMITE
				WINNIPEG	UPPER UNIT	60	SHALE, GREEN, WAXY, SANDSTONE INTERBEDDED
					SANDSTONE		SAND, SANDSTONE, QUARTZOSE
	CAMBRIAN			DEADWOOD		60	SAND. BLACK TO GREEN-GREY WAXY. GLAUCONITIC SILTSTONE & SHALE, GREEN-GREY TO BLACK. VERY EDGE OF S.W. MANITOBA ONLY
PRECAMBRIAN							ACID & BASIC CRYSTALLINES & METAMORPHICS

Figure 3. Geological formations in Manitoba.

2.0 Pre-Devonian Tectonic/Depositional Framework

Paleozoic deposition in Manitoba and in the Western Canada Sedimentary Basin in general was initiated by deposition of the westward- thickening wedge of clastic sediments of the Cambro-Ordovician Deadwood Formation, which rests with profound unconformity on eroded Precambrian basement. During Deadwood time there was apparently no paleotopographic expression of the Williston Basin. Deadwood strata were subjected to a major erosional episode during early Ordovician time, and are overlain with angular unconformity by the basal clastics of the Middle Ordovician Winnipeg Formation, which overstep eroded Cambrian to rest directly on eroded Precambrian throughout most of Manitoba.

The Winnipeg Formation, along with the later Ordovician Red River, Stony Mountain and Stonewall Formations, all show a distinct isopach and lithofacies expression of the early Williston Basin. The isopach pattern, however, (Fig. 5) is somewhat anomalous relative to the regional Williston Basin pattern in that the isopach trend in Manitoba does not conform to the present structural configuration of the Williston Basin (compare Figs. 5 and 6), or to the later Paleozoic (e.g. Mississippian) expression of the basin, where isopach and lithofacies patterns are generally concentric to the basin depocentre. In Manitoba the Ordovician isopachs trend northeasterly, cutting directly across the regional structural trends (Fig. 5). This northeasterly trend appears to continue as far as the Hudson Bay Basin area, where identical Ordovician lithofacies are present. The isopach trend is mirrored by the lithofacies trend, so that the outcrop belt also is seen to cut directly across the facies trend, exposing a relatively thin shelf (dolomitic) facies to the north and a relatively thicker basinal (limestone) facies to the south.

The reason for the apparently anomalous depositional trends in the Manitoba portion of the Williston Basin possibly can be related to the nature of the underlying Precambrian basement. The writer (McCabe, 1971) has suggested that the Superior crustal block (the area east of the Churchill/Superior boundary zone, Figs. 4, 5) has behaved somewhat differently in response to the tectonic pulses that gave rise to both basin subsidence and basin uplift. That portion of the Williston basin underlain by the Superior Crustal Block appears to have undergone relatively greater subsidence during depositional episodes, and subsequently relatively greater uplift and erosion during episodes of emergence. A similar but rather more complex situation appears to have affected Devonian deposition in the Manitoba portion of the Elk Point Basin.

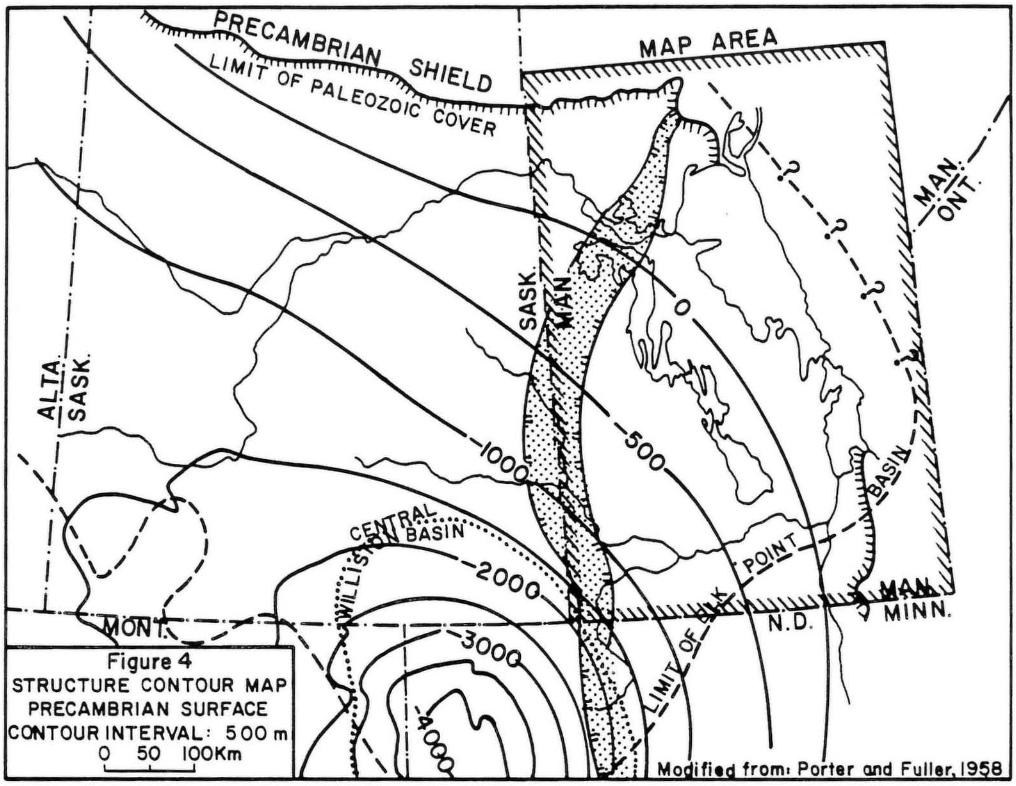


Figure 4. Structure contour map, Precambrian surface, Williston Basin area

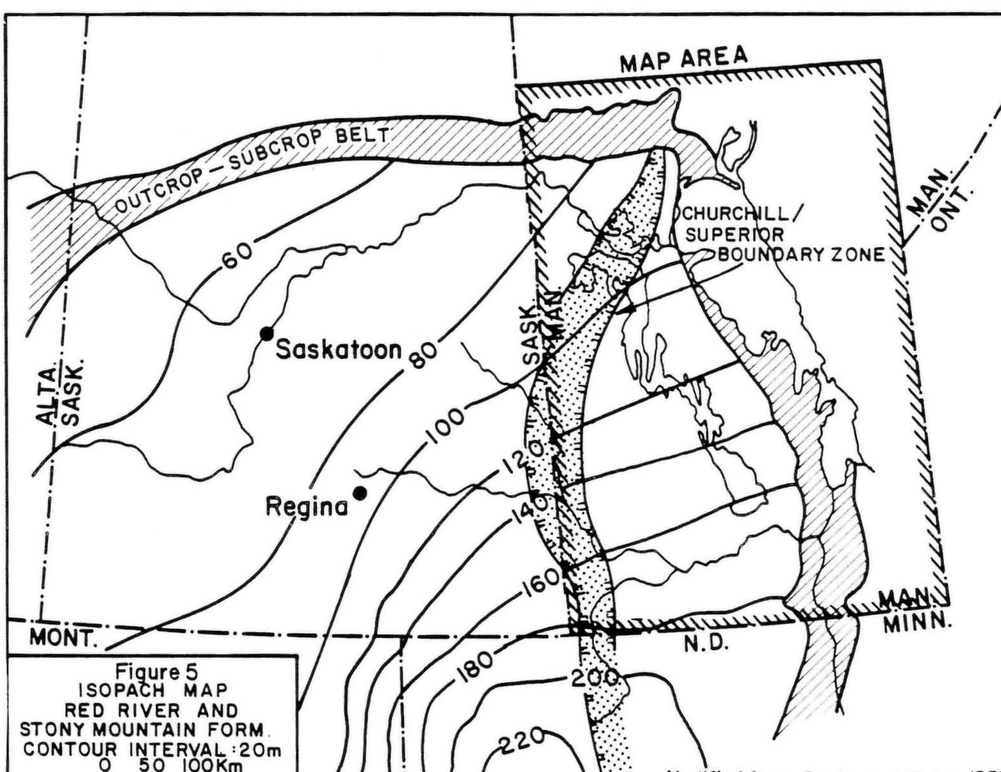


Figure 5. Isopach map, Red River and Stony Mountain Formations, Williston Basin area

Following the period of subsidence during Ordovician time, when differential subsidence of the Williston Basin gave rise to fairly distinct isopach and lithofacies basinal patterns, Silurian deposition showed a much more subdued pattern of basin subsidence with widespread development of relatively uniform shallow-water dolomitic deposits showing only minor lithofacies variation.

Subsequent to Silurian deposition, another major episode of erosion removed much of the Upper Silurian sequence on the flanks of the Williston Basin, prior to deposition of the Middle Devonian Elk Point strata.

3.0 Devonian Depositional Framework

Devonian deposition was marked by a major change in the tectonic framework of the Western Canada Sedimentary Basin. The Williston Basin, which had been the centre of subsidence during Ordovician and Silurian time, was no longer the centre of subsidence, but rather, Devonian deposition was related to the Elk Point Basin, centred in south-central Saskatchewan, approximately 500 km northwest of the depocentre of the Williston Basin (Fig. 6). Because of extensive late Paleozoic erosion, and also because of complex facies changes and associated isopach anomalies affecting Devonian strata, it is difficult to determine the precise depositional trends for the Manitoba portion of the basin. Isopachs for the outcropping Devonian formations are shown in Figures 7 and 8.

In general, the outcropping portion of the Devonian sequence comprises a series of complex carbonate-evaporite cycles, although in all cases the evaporites have subsequently been dissolved from the outcrop areas (Figs. 7c, d). The first, thickest and best defined cycle comprises the Elk Point Group (Fig. 13). The basal unit of this cycle consists of a red bed unit, the Ashern Formation, succeeded by the Winnipegosis/Elm Point Formation and the Prairie (evaporite) Formation. The second depositional cycle is represented by the Dawson Bay Formation, initiated by the Second Red Beds and culminating with the Hubbard Evaporite (in the central portion of the basin). The third cycle comprises the Point Wilkins Member of the Souris River Formation (Davidson Member of Saskatchewan), initiated by the First Red Beds and culminating with the Davidson Evaporite (in the central portion of the basin).

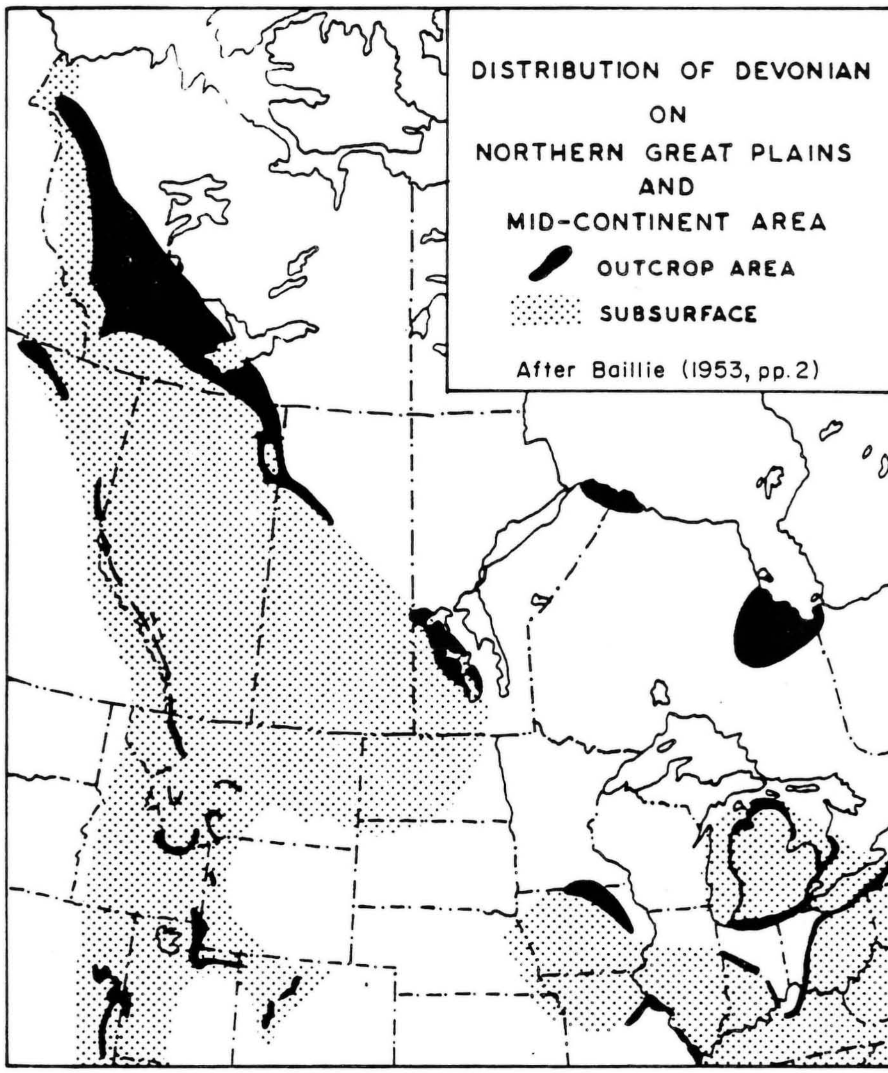


Figure 6. Distribution of Devonian, northern great plains and mid-continent area.

3.1 Elk Point Group

The red dolomitic shales and breccias of the Ashern Formation represent the basal deposits of the major Middle Devonian transgressive sequence. The irregular isopach pattern of the Ashern Formation (Fig. 7a) reflects the gentle irregularity of the underlying Silurian erosion surface. The major period of uplift and erosion in late Silurian to early Devonian time, resulted in complete removal of the Upper Interlake strata, which attain a maximum thickness of about 175 m in the central part of the Williston Basin. However, despite the probable erosion of up to several hundred metres of upper Silurian strata in Manitoba, there is no evidence of any appreciable angular truncation of Silurian beds in southern Manitoba. Locally, in the subsurface, some suggestion of incipient karst development has been noted at the erosion surface, although this is not evident in the outcrop belt. Minor infiltration of Ashern-related shale into the upper Silurian beds can be seen locally, as at Stop 29. The uniformity of the pre-Devonian erosion surface is well shown at Stop 29, where the unconformity is exposed in the middle of the quarry section.

The rather poorly defined depositional trends of the Elk Point Group, as shown by the Winnipegosis isopach (Fig. 7b), appear to be approximately northeast. The general pattern is one of a gradual, fairly uniform thickening to the west and northwest, up to a maximum of about 55 m. This facies was deposited in a shelf to fringing bank environment. West and northwest from this bank, the Winnipegosis is seen to thin, in places very abruptly, to as little as 12 m, but with local areas of thickening to as much as 105 m. This latter area of variable thickness represents a basinal reef-interreef complex. Apparently basin subsidence and differentiation was sufficiently rapid so that only in certain areas (original organic mounds?) was organic growth able to keep pace with subsidence. Reefs developed in these areas, but in the intervening interreef areas the only (remaining) deposits are a thin sequence of dark, organic rich (5-6% T.O.C.) finely banded to laminated sediments, referred to as bituminous laminites.

Stratigraphically, the Winnipegosis can be subdivided into two units, a Lower Winnipegosis Member which comprises a relatively uniform blanket type of deposit, or platform, and an Upper Winnipegosis Member which, in the more basinal areas, consists of either thick "reefal" carbonates or a thin sequence of interreef bituminous laminites.

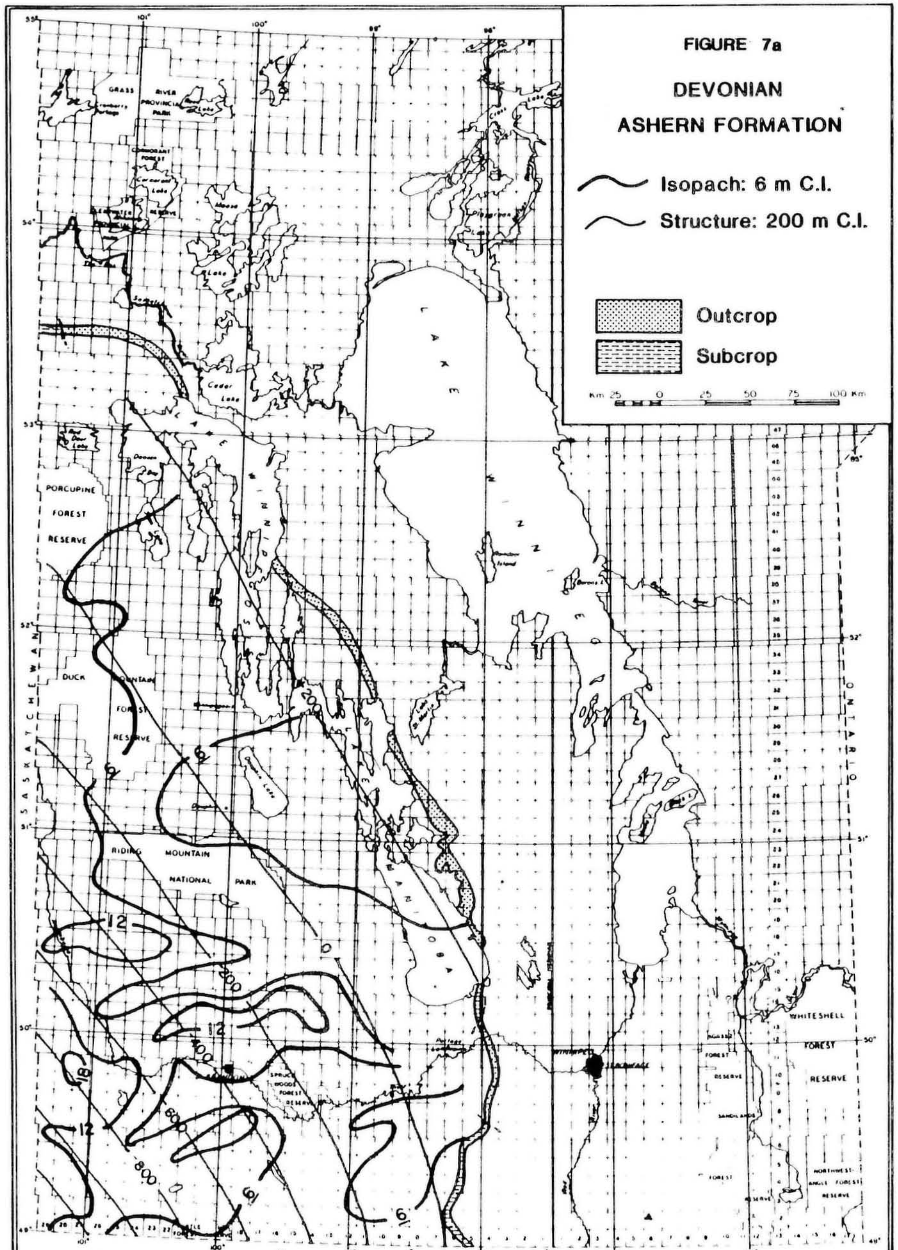


FIGURE 7a
DEVONIAN
ASHERN FORMATION

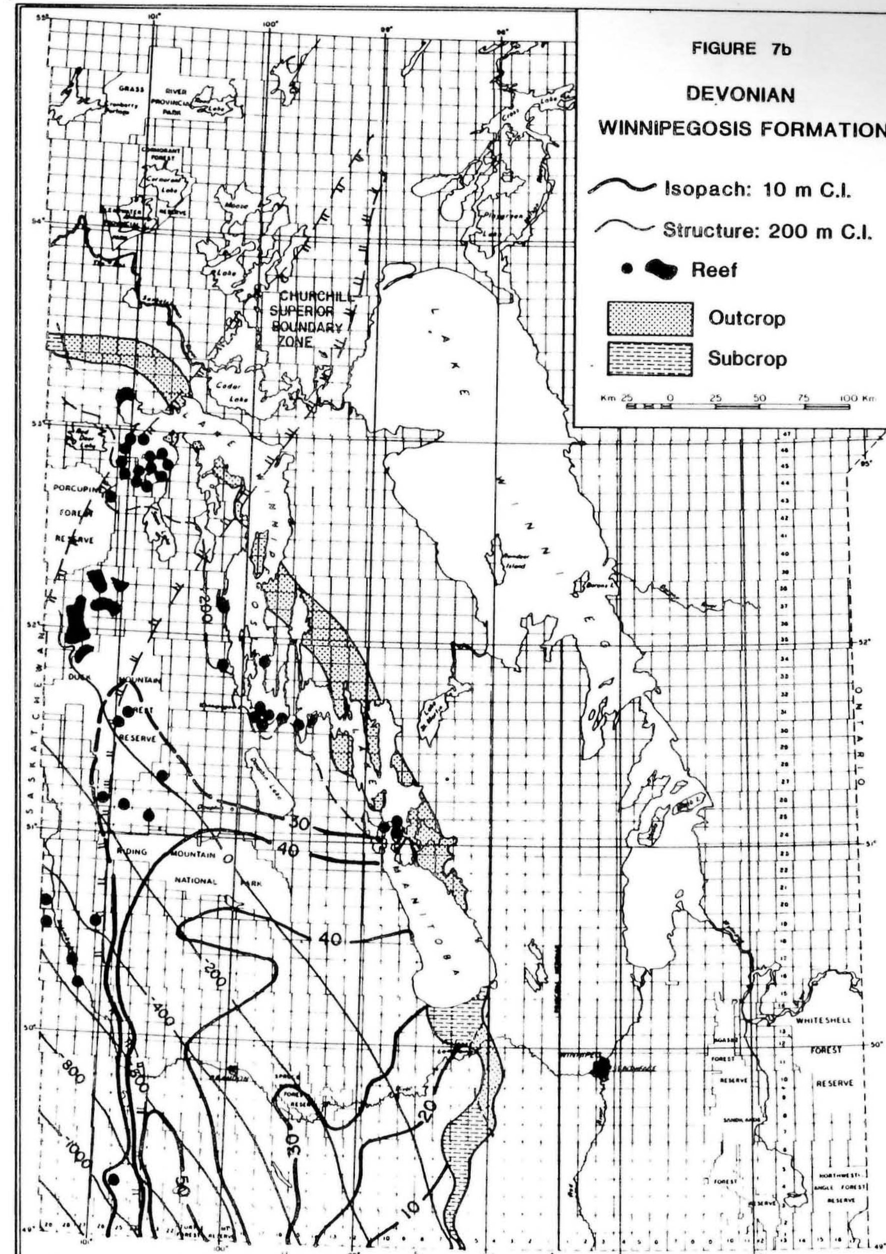


FIGURE 7b
DEVONIAN
WINNIPEGOSIS FORMATION

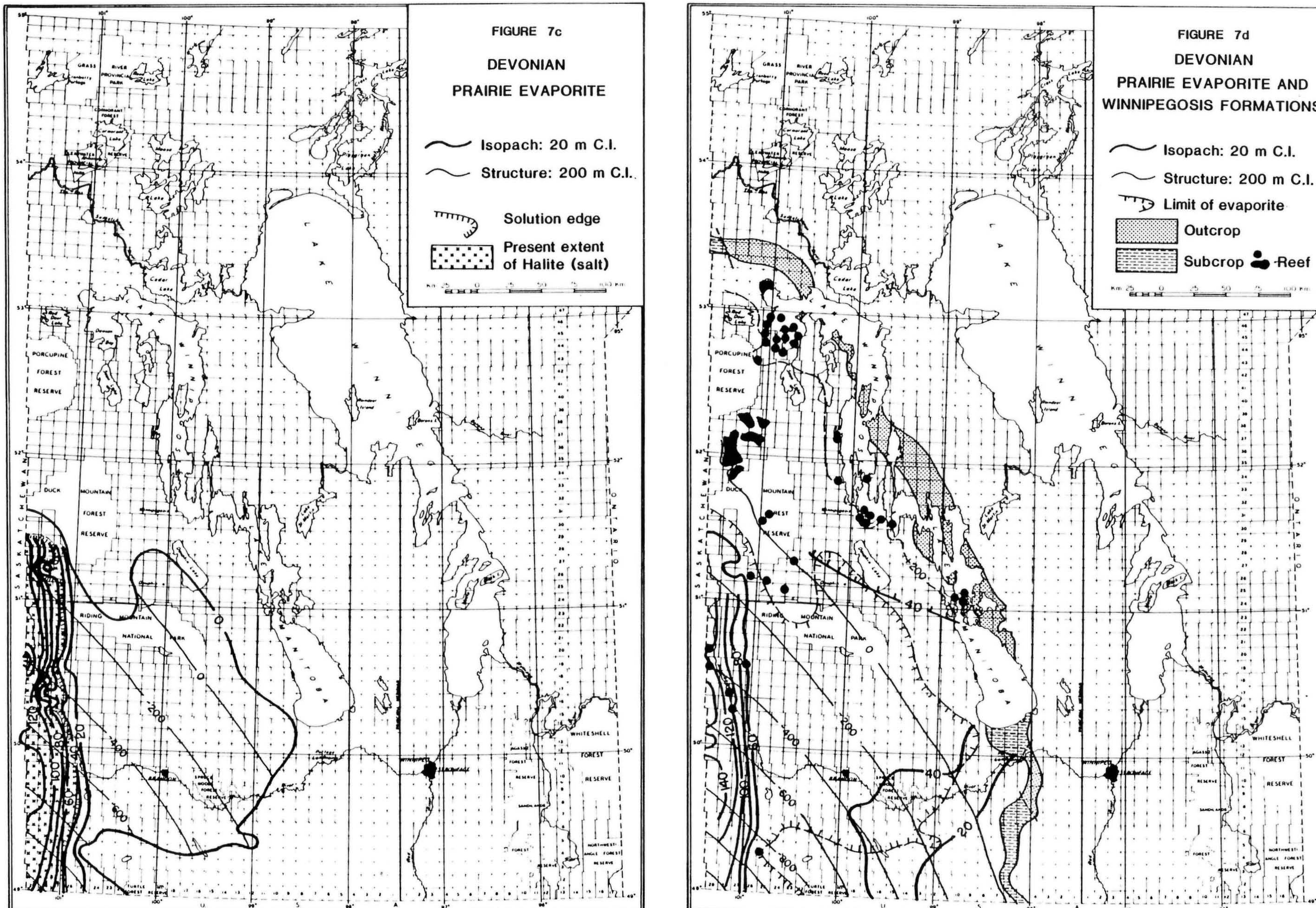
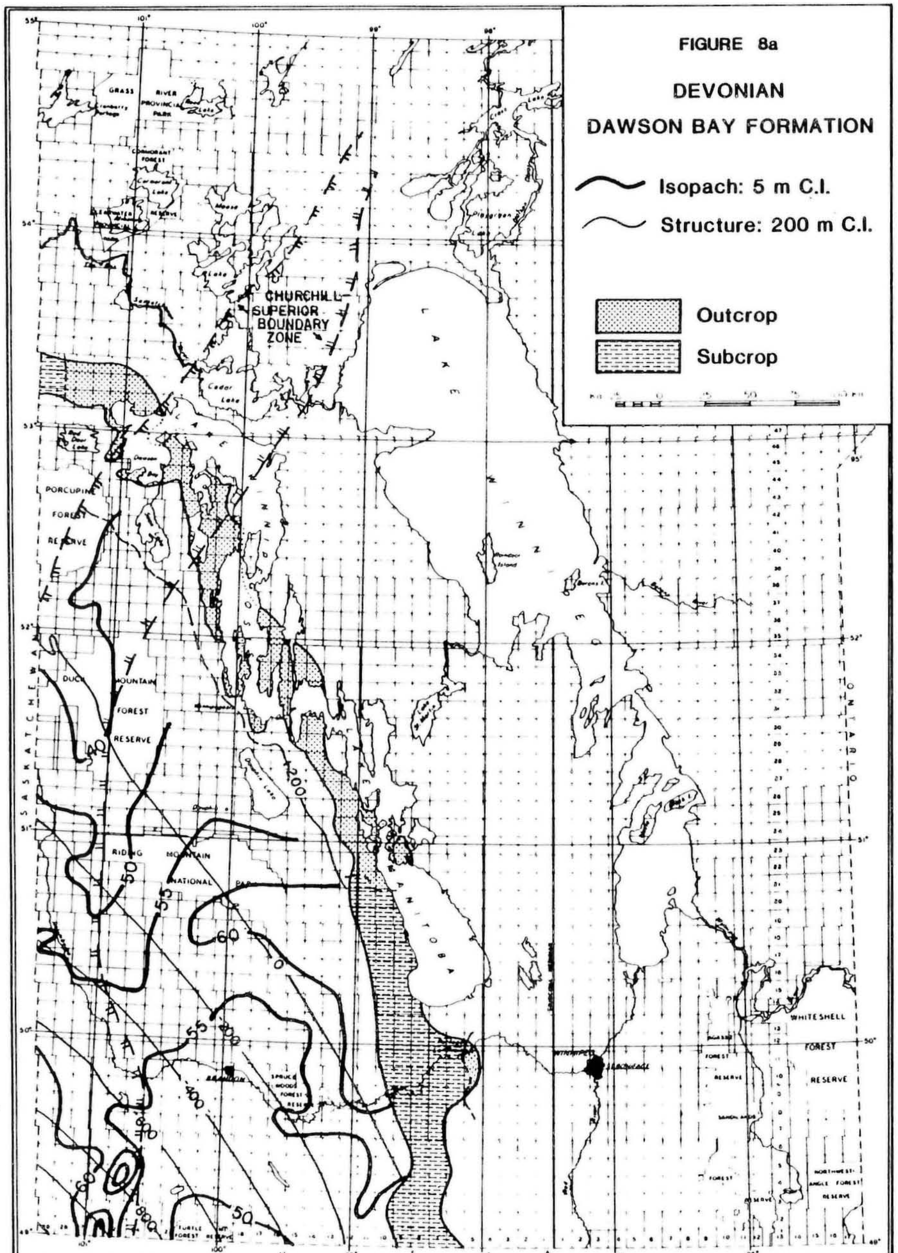


Figure 7 Isopach-structure contour maps (Ashern, Winnipegosis, Prairie Evaporite, Prairie Evaporite and Winnipegosis)



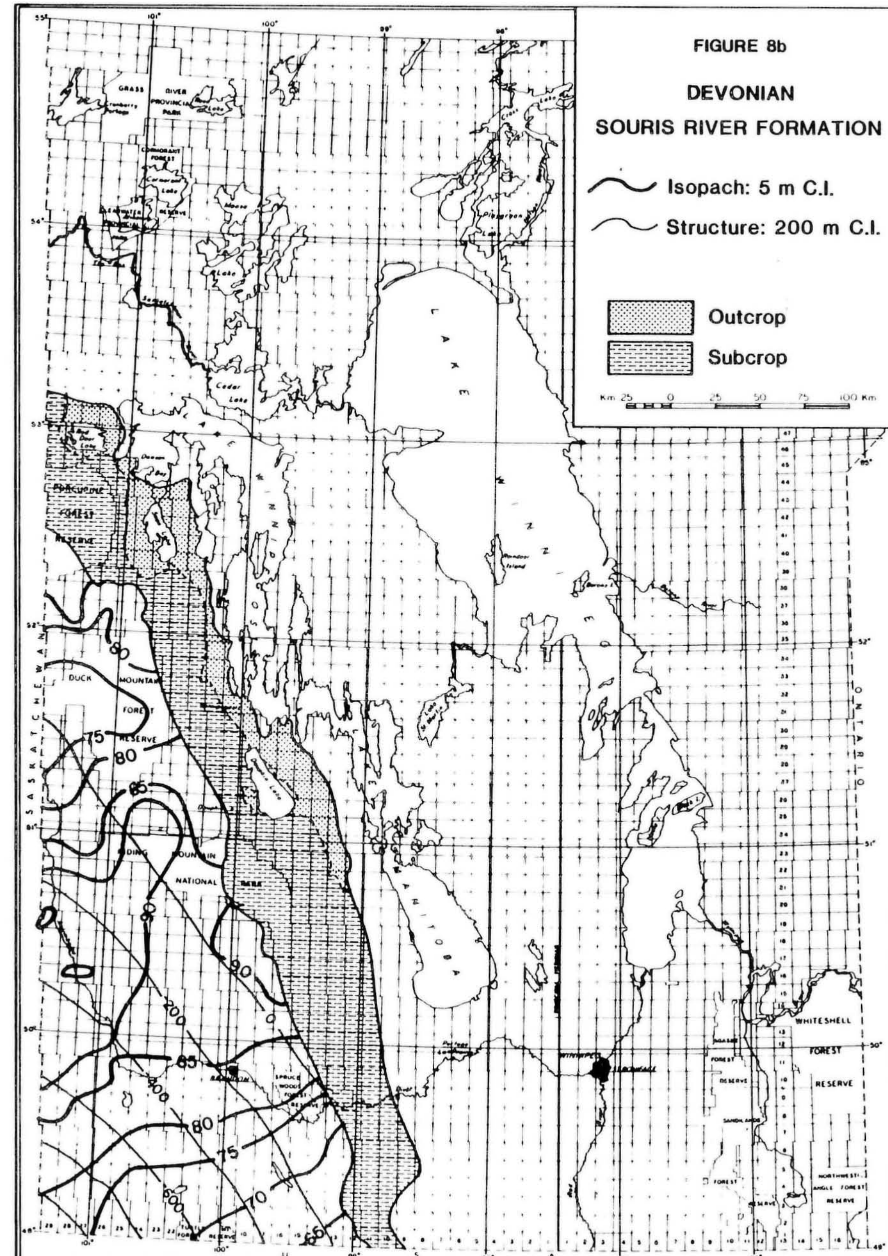


Figure 8. Isopach structure contour maps (Dawson Bay, Souris River)

3.1.1 Lower Winnipegosis (Elm Point)

Throughout the northern part of the outcrop belt, and in almost all of the subsurface, the Lower Winnipegosis consists entirely of a medium to coarsely crystalline granular to sub-saccharoidal, vuggy, sparsely fossiliferous, rather nondescript dolomite. In the southern part of the outcrop belt, however, application of the term Lower Winnipegosis poses a problem. From the Oak Point Quarry (Stop 33, Fig. 1) to Waterhen Lake, north of the town of Winnipegosis, the Lower Winnipegosis has not been completely dolomitized, and consists of strata ranging from partially dolomitized fossiliferous micrite (Lily Bay quarry, Stop 31), to pure, high-calcium biomicrite (Steep Rock quarry, Stop 30; Bannatyne, 1975). This relict limestone facies of the Lower Winnipegosis has been named the Elm Point Formation. Limited core hole data suggest that the degree of dolomitization of the platform beds (i.e. Lower Winnipegosis/Elm Point) may have been controlled by proximity to reef sites in the overlying Upper Winnipegosis.

The common occurrence of limestone in the Lower Winnipegosis (i.e. Elm Point) of the Manitoba outcrop belt probably is significant, inasmuch as this is the only area in the Elk Point Basin where such relict limestones are common, if not dominant. A possible explanation is that this area comprises the distal end of the Elk Point Basin, farthest removed from the area of influxing brines, which is believed to have been in northwestern Alberta. Consequently, the tendency for brine circulation and resultant dolomitization would have been minimized. Dolomitization possibly was reduced further by influx of fresh meteoric water from the hinterlands to the east or southeast. Also, the paleogeography of the northeastern flank of the basin is completely unknown. The preservation of a thick section of Elm Point limestone as a tectonic slump block within the Lake St. Martin crater structure (the most northeasterly known occurrence of Devonian strata) is additional evidence of reduced brine circulation on this flank of the basin.

3.1.2 Upper Winnipegosis Formation

Distinction between the Upper Winnipegosis and the Lower Winnipegosis is obvious in the basinal interreef areas where the massive granular, vuggy dolomites of the Lower Winnipegosis platform pass sharply into the distinctive thinly bedded argillaceous-bituminous laminites of the Upper Winnipegosis. In marked contrast, for reefal areas, there is generally no appreciable lithologic change between Lower Winnipegosis platform beds and Upper Winnipegosis "reefal" facies. An increase in fossil content, especially corals and stromatoporoids, may be evident but the extreme effects of dolomitization have, for the most part, destroyed the primary textures, making stratigraphic separation of Lower and Upper Winnipegosis beds difficult. In effect, the Upper Winnipegosis reefs appear to comprise local thickening of the Lower Winnipegosis platform. Details of Winnipegosis reef morphology and development will be discussed in sections 3.1.5. to 3.1.8.

Interpretation of the origin of the "bituminous laminites" of the interreef facies of the Upper Winnipegosis is somewhat controversial, and the differences in interpretation pose considerable question as to the evolution of the reefs, and in particular the precise correlation between the reefs and the off reef deposits - the bituminous laminites and evaporites. It is important to note that the Prairie Evaporite beds have been totally dissolved from the outcrop area so that the precise relationship between the reefs and the complete interreef sequence cannot be determined definitively in the outcrop belt.

In part, the different interpretations of the "bituminous laminites" arise from the fact that these beds actually consist of at least two distinctly different lithologies, indicative of two different modes of origin. The lower part of the "bituminous lamite" unit consists of finely banded or laminated bituminous mudstone, in places containing carbonate (detrital) interbeds (Fig. 22/9,10). The upper part of the unit consists of finely laminated, almost varvitic carbonate with fine black, bituminous, in part microstylolitic partings. Laminae average about 2 mm in thickness and range from very uniform in the lower part (Fig. 22/11,12) to increasingly irregular in the upper part (Fig. 22/13,15). Relict enterolithic structure is evident in some laminae, and some thin interbeds of detrital carbonate also are present. Lithologically these varvitic laminites appear to be correlative with the laminated carbonate-anhydrite beds defined in Saskatchewan as the Ratner Member (Wardlaw and Reinson, 1971), but with all traces of anhydrite removed by subsequent solution.

Baillie (pers. comm) and others note that "bituminous laminites" associated with comparable Devonian reefs in the Rainbow, Zama and Virgo areas of Alberta are postulated to be very shallow, intertidal algal-matte, sabkha type deposits. They suggest a similar origin for some of the bituminous laminites associated with the Winnipegosis reefs in the Manitoba outcrop belt. Other workers (e.g. Wardlaw and Reinson, 1971; Kendall, 1975) have postulated a deep-water, starved-basin environment for deposition of at least the lower portion of the bituminous laminite sequence.

A detailed discussion of deep-water/shallow-water origin for the bituminous laminites is beyond the scope of this guide, as is a detailed comparison with comparable Devonian reefs in other areas (Rainbow, Zama, etc.).

Although the shallow water/deep water problem has not been resolved, most workers currently dealing directly with the Winnipegosis reefs of the Elk Point Basin favour a deep-water, euxinic, starved-basin origin for at least the lower portion of the bituminous laminite sequence (Kendall, 1975; Kent, pers. comm., Christopher, pers. comm.). The writer also favours this interpretation; and most of the suggestions as to reef development presented in this guide are based on the premise of a deep water origin for the bituminous mudstone, and consequently a deep-water setting for the reefs.

One of the principal factors favouring a deep-water origin is the interfingering of the thin bituminous mudstones with progressively thicker interbeds of reef-derived carbonate detritus as the reef is approached, suggesting that the reefs and bituminous mudstones are contemporaneous lithologies. Kendall (1975) reports an outcrop occurrence in Saskatchewan "where steeply-dipping, fore-bank deposits pass downward and laterally into a thin-bedded laminated styliolinid-rich argillaceous unit." The same situation is shown by core hole drilling in the Manitoba outcrop belt. Kendall also points out that the bituminous, argillaceous interreef lithology "must have accumulated under water at least as deep as the thickness of the neighbouring banks, up to 75 m. It therefore represents a starved-basin deposit." Comparable water depths are indicated for the Dawson Bay and Winnipegosis portions of the Manitoba outcrop belt (Fig. 12).

The relatively unknown effect of differential compaction could possibly affect the aforementioned water depth estimates and thickness estimates. The bituminous sediments may well have undergone a higher degree of compaction than the carbonate reef complexes, in particular bioconstructed reef framework (assuming such framework exists). This factor would reduce the estimates of true water depths during Winnipegosis time. (A possible example of the effect of differential compaction is noted in Norris *et al.* (1982) (p. 124) where spherical *Tasmanites* is preserved in a thin carbonate interbed whereas *Tasmanites* in the enclosing bituminous sediments are totally compressed and flattened). Differential compaction within the reef complexes could also have given rise to apparent (present) variation in reef thickness. Possibly the thinner sequences associated with the central portions of the reef complexes (e.g., Salt Point) may result, in part, from differential compaction of finer grained lagonal deposits.

The origin of the varve-like bituminous laminites of the upper part of the Upper Winnipegosis interreef facies (i.e. Ratner Member) is somewhat uncertain. Both relatively deep subtidal, and shallow water to supratidal (Sabkha) origins have been proposed, but most workers in the area appear to favour a subtidal origin. However, all would indicate a considerable shallowing of water relative to the level maintained during organic reef growth. (Wardlaw and Reinson, 1971; Kendall 1975). Kendall's (op. cit.) suggestion that the Ratner Beds (i.e. the upper part of the Upper Winnipegosis interreef facies in Manitoba) should more properly be designated as the basal unit of the Prairie Evaporite appears to be valid, but is difficult to apply to the Manitoba outcrop belt because of evaporite solution. These laminated beds probably postdate biogenic reef development, although inorganic reef "growth" (e.g. caliche development and concurrent reef erosion) probably continued throughout deposition of the interreef evaporitic laminites and the lower halites of the Prairie Evaporite, until such time as the upper Prairie Evaporite salts buried the Winnipegosis reefs.

3.1.3. Relation of Outcrop Stops to Regional Depositional Framework

Examination of the Winnipegosis isopach map (Fig. 7b) shows that the northwesterly strike of the outcrop belt cuts directly across the northeasterly depositional trend of the basin. The outcrop belt thus constitutes a dip section of the basin, a situation similar to that noted for the Ordovician outcrop belt. However, in marked contrast to the Ordovician pattern, the Devonian sequence thickens to the north rather than to the south - a complete reversal of the tectonic/stratigraphic framework.

The effect of the changing tectonic framework is well shown in outcrop. The southeastern portion of the outcrop belt, in the vicinity of the Oak Point quarry (Stop 33), falls within the shelf or fringing bank facies. The edge of the fringing bank appears to intersect the outcrop belt just south of The Narrows of Lake Manitoba, and the gentle mound-like "reefs" seen in The Narrows area (Stops 23, 25, 26, Fig. 16) probably represent a shelf-edge complex. Flanking dips on the reefs are only a few degrees (Narrows West quarry, Stop 23), although primary bedding in reef-flank beds (foreset beds) can be much steeper (Rosehill quarry, Stop 25). Regional data suggest approximately 35 m of reef-interreef relief with maximum Winnipegosis thicknesses of about 70 m. The presence of a zone of sand-filled (Cretaceous?) solution caverns (Stop 28) throughout much of The Narrows area has severely limited drilling for deeper structural/stratigraphic data, and in particular has prevented deep drilling of reefal occurrences to determine if dolomitization of the platform beds is associated with reefal occurrence in the overlying Upper Winnipegosis.

The configuration of the numerous reef-related structures near the town of Winnipegosis suggests a basin-flank facies compared to the shelf-edge reefs of The Narrows area. Flank dips on the reef structures are steeper, averaging about 10^{o}. On the basis of limited core hole data, reefal sections appear to be about 85 m in thickness (total Winnipegosis), and interreef sections about 28 m. Maximum reef-interreef relief is thus approximately 60 m, as compared to only 35 m in The Narrows area.

The estimated thickness of 105 m for a reef drilled near the Camperville junction (Stop 15, Hole M-9-79, 16-32-33-19W; McCabe, 1980) is anomalously high and suggests a relatively deep-water setting in contrast to the relatively gentle, shallow-water reef configuration typical for most reefs in this general area. Surprisingly, the outcropping Lower Dawson Bay beds overlying the Camperville junction reef are relatively flat lying with no evidence of the typical domal structures characteristic of most reef-supported outcrops (see following section on salt collapse).

The Dawson Bay portion of the Winnipegosis outcrop belt represents a relatively deep basinal facies. The indicated reef thicknesses (total Winnipegosis) range from 82 m to 98 m. Interreef thicknesses are about 25 m, reef-interreef relief 50-74 m, and flank dips up to 20^{o} (Stop 10). The indicated reef thicknesses in the Dawson Bay area are approximately the same as those reported for the central portion of the Elk Point Basin, in central Saskatchewan (Wardlaw and Reinson, 1971), testifying to the relatively deep basinal facies developed in the Dawson Bay area.

Figure 12 presents a diagrammatic summary of the various Winnipegosis reef configurations outlined above.

3.1.4 Salt Collapse Structures

Before further discussion of the relation of Devonian outcrops to the depositional basin, it is necessary to note the extreme effect of salt solution and collapse on the outcrop geology. As noted above, Devonian reefs occur from the Dawson Bay area south to The Narrows. During late Elk Point time, all of these reefs were buried by evaporites (primarily halite) of the Prairie Evaporite, which overlapped an unknown distance over the fringing bank and shelf area. Flat-lying, uniform Dawson Bay strata were then deposited over the evaporites, with no evidence of any influence by underlying reefs. The uniformity of the Dawson Bay beds shows that burial of Winnipegosis reefs was complete. In western Manitoba and Saskatchewan, within the remaining portion of the salt basin, reefs are overlain by from 60 m to as much as 100 m of salt, but there is no way to accurately estimate the original salt thickness (and hence the amount of salt collapse) in the area of the Manitoba outcrop belt.

Subsequent to burial by Dawson Bay strata, the Prairie Evaporite was dissolved from the entire outcrop area as well as a large portion of the subsurface (Fig. 7c,d). Most of this solution is believed to have occurred during the period of late Paleozoic to early Mesozoic uplift and erosion, but localized episodes of evaporite solution also occurred throughout late Paleozoic and Mesozoic time. The earliest (Late Devonian and Mississippian) collapse episodes appear to have been local features, possibly fracture or fault controlled, whereas the main pre-Mesozoic solution episode appears to have resulted from widespread regional solution, possibly related to regional groundwater flow through the underlying Winnipegosis and Interlake strata. The salt solution process is continuing at the present time, as evidenced by the outflow of brine from the numerous salt springs along the Devonian outcrop belt (e.g., Stop 4).

As a result of salt solution, all of the post-evaporite strata collapsed and were draped over the underlying Winnipegosis reef-interreef complexes. The minimum amount of subsidence or collapse in a given area is equal to the reef-interreef relief. All of the Dawson Bay and Souris River outcrop occurrences have thus been subjected to varying degrees of salt collapse, and more importantly, the structural configuration shown by these strata reflects precisely the topography of the underlying Winnipegosis surface. Local, reef-controlled structural relief ranges from about 35 m in The Narrows area to 75 m in the Dawson Bay area. This superficial structure effectively masks the gentle uniform true structural dip, which averages only about 2.0 m/km (0.1 degrees). To date there is no evidence of true structural deformation associated with local Winnipegosis reef development, but a possible regional tectonic control for reef development will be suggested later.

Not only can the Winnipegosis reef configuration be determined from the structural configuration of the overlying Devonian strata, but the thickness of the Winnipegosis can be estimated if the precise stratigraphic position of the post-Winnipegosis outcropping strata is known. Several Dawson Bay and Souris River beds form excellent markers for such estimates of Winnipegosis thickness, and estimates will be noted wherever possible for outcrop stops.

The process of salt collapse has been, in places, a series of two or more collapse events, rather than a single event. Evidence for multiple-event collapse will be seen in the Winnipegosis quarry (Stop 18). Collapse can be extremely uniform with no visible evidence of structural deformation, or it can be a "catastrophic" event giving rise to a chaotic megabreccia. Both types are seen at the Winnipegosis Quarry.

The salt collapse scenario is complicated further by the probable original occurrence of multiple salt horizons. In the deeper parts of the Basin, additional evaporite units occur both at the top of the Dawson Bay Formation and at the top of the Point Wilkins Member of the Souris River Formation (Fig. 13). Breccia zones at these horizons in the Manitoba outcrop sequence indicate that these evaporites as well as the Prairie Evaporite extended throughout most of the outcrop belt. Solution of these younger evaporites occurred as well, but identification of collapse structures related specifically to these younger evaporites is not possible because of the lack of pre-evaporite paleotopographic relief.

3.1.5 Winnipegosis Reef Morphology, Subsurface, Swan River Area

Although some of the regional variations in Upper Winnipegosis reef configuration have been noted, the details as to size, shape and distribution of individual buildups are largely unknown. In the outcrop belt we have only a very limited insight, and even this is largely indirect as will be described later. The only area where the size and shape of a portion of a reef complex can be determined (other than in seismic studies* to which the writer does not have access) is in the Swan River area, 80 km southwest of the Dawson Bay outcrop belt, where, in 1951-52, Shell Oil Co. drilled 108 shallow structure test holes to Devonian markers, mainly the Upper Devonian Souris River and Duperow beds. Two deep test holes were subsequently drilled by Shell to test structural highs outlined by this study, and still later 5 additional deep test holes were completed (including 4 holes completely cored). All deep holes indicate a very uniform regional dip for pre-Winnipegosis strata, but complex structure is evident in the younger Devonian beds (Fig. 9). All of this shallow structure can be attributed to variations in Winnipegosis thickness, as a result of younger Devonian strata being draped over Winnipegosis reefs as a result of post-Devonian solution of the Prairie Evaporite.

A "Winnipegosis anomaly map" can be derived from structure test hole data for the Swan River area (Fig. 10). The "anomaly value" represents the local reefal thickening of the Winnipegosis, a maximum of 200 - 300 feet (61-70 m), and is effectively the reef-interreef paleotopographic relief at the end of Winnipegosis time. The deep test holes indicate that the 0 anomaly values correspond to a Winnipegosis thickness of about 80 feet (24 m). This represents the average interreef thickness and includes both Lower Winnipegosis platform beds and Upper Winnipegosis interreef beds. Several distinct reef characteristics can be derived from the anomalies outlined in Figure 10, and it seems reasonable to suggest that these characteristics may also apply to the Dawson Bay outcrop area covered by this field trip. These characteristics possibly are applicable to the entire Central Elk Point Basin area.

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* Seismic interpretations for salt solution areas are questionable because of the extremely complex velocity anomalies resulting from both primary lithofacies variations and secondary brecciation effects (McCabe, 1985).

A) The reefs are relatively small and sharply defined. Even with the closely spaced drilling (1-5 km) the individual reef configuration cannot be defined precisely. Maximum reef size is in the order of 5 km by 15 km, and the reefs appear to be elongate, but no preferred reef orientation is evident from the limited data available.

B) All reefs in this limited map area show approximately the same relief of about 61 - 67 m (total thickness 85 - 91 m). This characteristic is shown even more clearly by the sharply defined bimodal nature of the histogram plot of the Winnipegosis anomaly values (Fig. 11a). The same type of thickness plot can be derived for well data compiled for the entire central portion of the Elk Point Basin of Saskatchewan (Wardlaw and Reinsen, 1971) (Fig. 11a), the implication being that the reef model shown for the Swan River Area possibly is applicable to the entire Elk Point Basin area. The slope or spread of the "reefal" values in the histograms for the Saskatchewan basin could be interpreted as the range of "uniform" reef thickness (82 - 107 m) over a broad basinal area, as contrasted to the more sharply defined maximum for the locally derived Swan River data (85 - 91 m).

It is worth noting that reef thickness in the Swan River area falls well within the thickness range of the central-basin reefs of Saskatchewan, supporting the suggestion that the Swan River-Dawson Bay area of Manitoba represents a central basinal facies. In fact, the thickest reef sections in Manitoba (Shell Swan River 9-1-37-28, 107 m; Camperville South Quarry, Stop 15, 105 m estimated) are close to the maximum reported for Winnipegosis reefs anywhere in the southeastern part of the Elk Point Basin.

The distribution of Winnipegosis reefs and reef-controlled structures, as seen in the outcrop areas, supports the concept of a relatively uniform reef height or thickness.

C) The Winnipegosis reefs, in their final configuration, appear to be at least in part flat-topped, as suggested by the cumulative histograms for both the Saskatchewan and Swan River areas. The cumulative histogram can be interpreted, in general terms, as an average reef profile. It must be noted, however, that the data from which these histograms are derived are not completely representative, and may be rather strongly biased. The

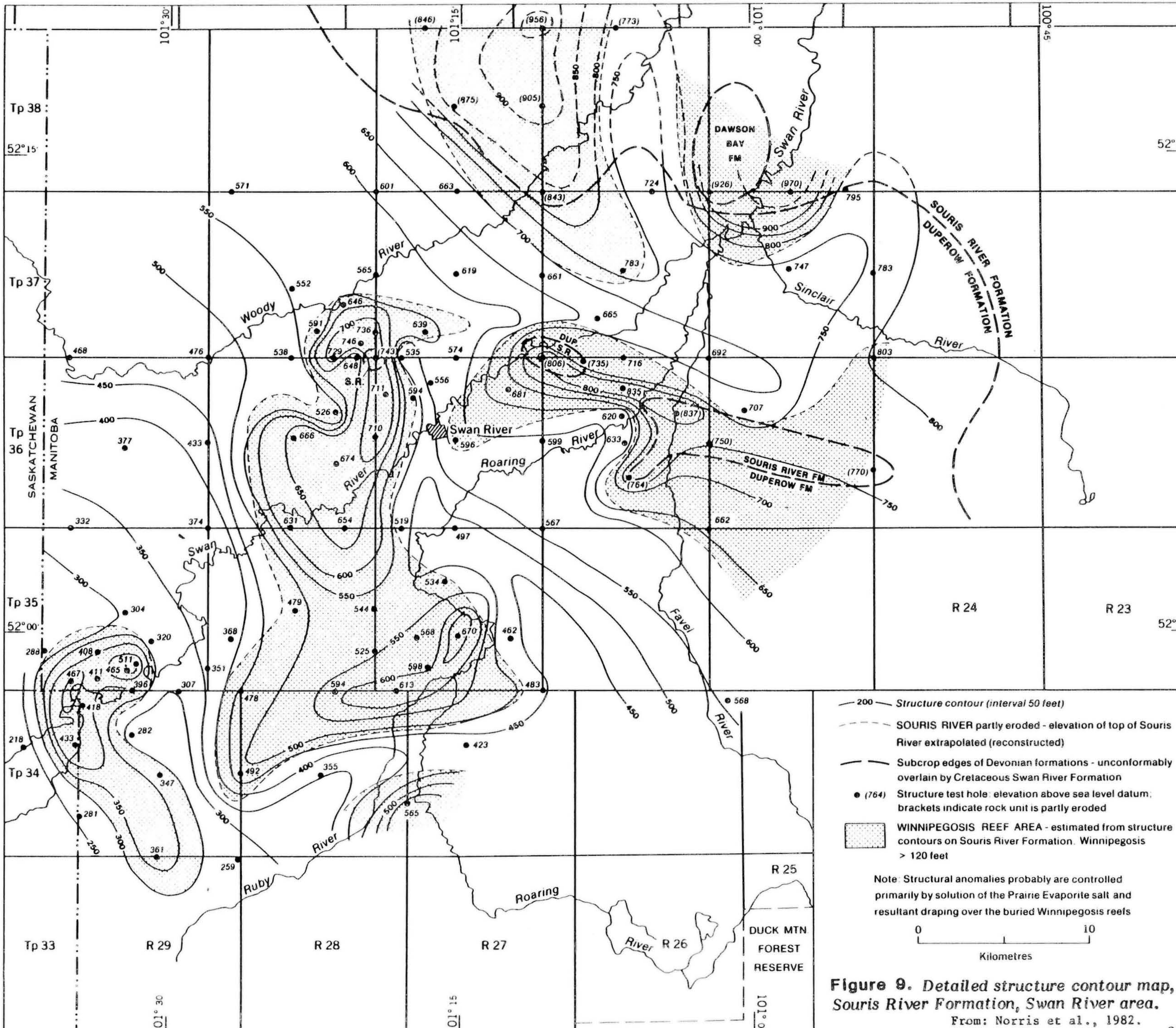


Figure 9. *Detailed structure contour map, Souris River Formation, Swan River area.*
From: Norris et al., 1982.

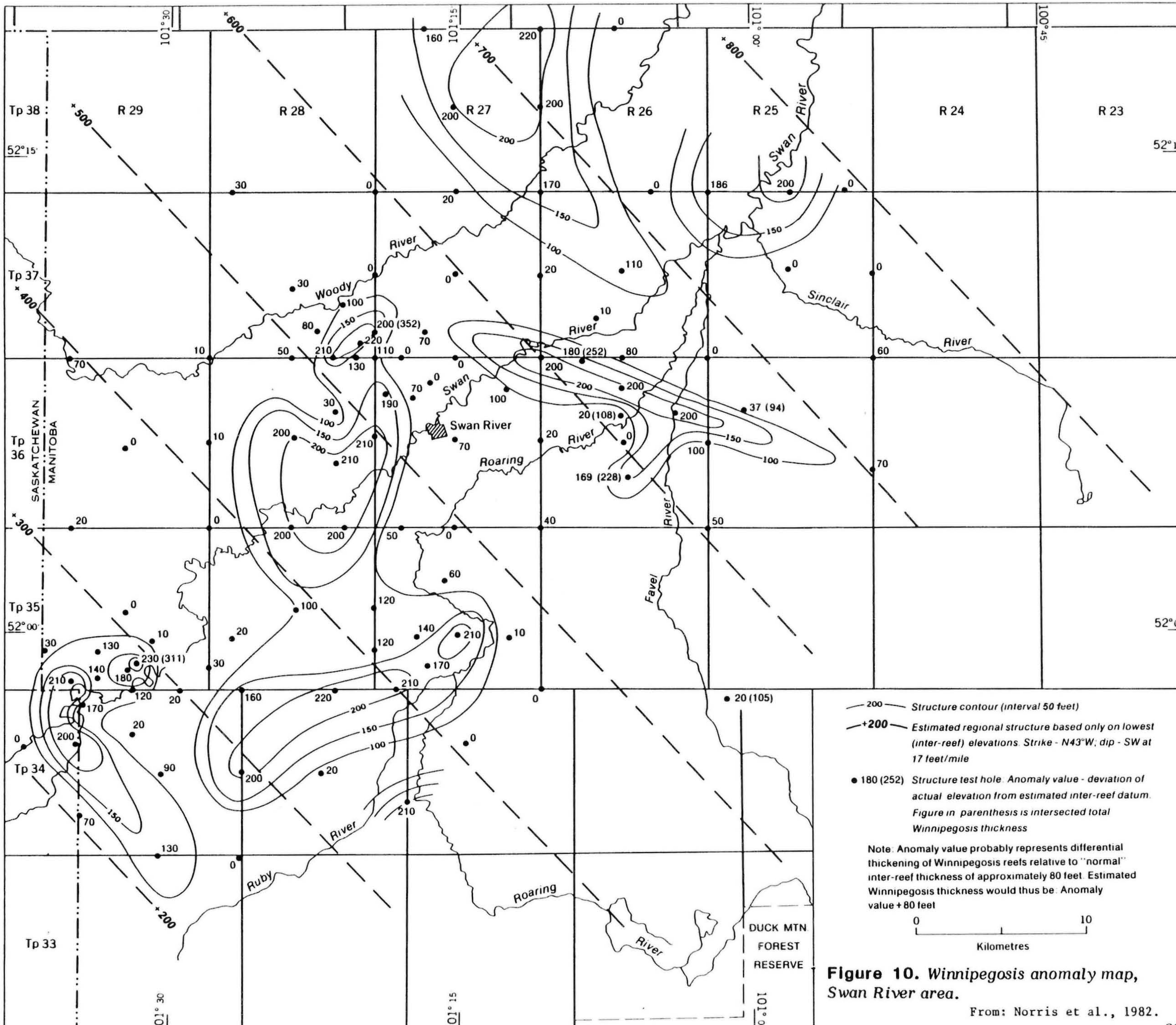


Figure 10. *Winnipegosis anomaly map, Swan River area.*

From: Norris et al., 1982.

very low percentage of reef-flank (intermediate thickness) values in the Saskatchewan data probably results in part from the selective drilling of seismically determined structural highs, in which case the histogram is largely a measure of seismic accuracy. This does not invalidate the concept of uniform reef thickness, but severely limits the suggestion that the cumulative plot reflects a flat-topped reef profile. In the case of the Swan River area data, however, most of the structure test holes were drilled on a systematic grid so data are relatively unbiased, although even in the Swan River map area infill drilling in the vicinity of the structural highs will have introduced some degree of bias.

Some Winnipegosis reefs appear to be small isolated "pinnacle type" reefs, whereas others, in particular the larger reef complexes (e.g. Salt Point area), appear to be partly flat-topped, possibly atoll-like in configuration.

3.1.6 Effects of Reef Morphology on Outcrop Patterns

The above noted reef characteristics, as determined for the Swan River Area, especially the uniformity in reef thickness, have had a pronounced effect on the Devonian outcrop patterns. Specifically, for the Dawson Bay area, where the regional dip is only 1.8 m per km, the 60 m of structural relief associated with reef development (and as reflected by subsequent salt solution) can give rise to an updip or downdip shift of about 32 km in expected location of an outcrop unit. Because of the uniformity of reef thickness, two completely separate "outcrop belts" can be established for each unit; a structurally high, reef-supported belt, and a structurally low (normal) interreef outcrop belt. Thus the interreef outcrop belt of the Souris River, Point Wilkins Member (Stops 6, 9) coincides with the reef-supported outcrop belt of the lower member of the Dawson Bay Formation (Stops 1, 5, 11). Most Lower Dawson Bay occurrences along this reef-supported outcrop belt consist of structural/topographic domes, providing direct evidence of the underlying "pinnacle-type" reef. A few Lower Dawson Bay outcrops along this belt are seen to be flat lying (Stop C), indicating that they are underlain by flat-topped portions of a reef complex. Flat lying Lower Dawson Bay outcrops, in a "normal" or interreef setting, occur 32 km to the northeast, on Cameron and Pelican Bays (Fig. 1). Very few other stratigraphic intervals are represented within this "composite outcrop belt" indicating the relative scarcity of reef flank deposits or reefs of other than "normal" thickness.

On the same basis, an outcrop belt of Upper Dawson Bay reef-supported structural-topographic domes (Stops 8, 10) occurs immediately downdip from the belt of Lower Dawson Bay domes, and coincident with the interreef outcrop belt of the upper part of the Point Wilkins Member. Similar outcrop patterns can be shown throughout the Devonian outcrop belt, but are not as well defined as in the Dawson Bay area because of the sparse outcrop control.

An important inference can be made if the Winnipegosis reefs of the Dawson Bay area are of a uniform height. As the reefal outcrops exposed on the islands of Dawson Bay are traced to the northeast, up regional dip (Stops A to F), the partially eroded reefal outcrops should expose sections that become progressively lower, stratigraphically, within the reefal succession. Thus, the Steeprock Bay Reef (Stop 12) is the most southwesterly, structurally lowest and stratigraphically highest reef occurrence; the outcropping strata represent beds at the apex of the reef, with essentially no post-reef erosion. In contrast, the Mason Island outcrop (Stop F), the most updip of the reefal stops to be visited, probably represents a section relatively low stratigraphically within the reef, with an estimated 25 - 30 m of upper reefal beds having being removed by (Pleistocene?) erosion. Regional structural extrapolation would place the Mason Island section 25 - 30 m above the base of the reef (i.e. platform).

It should be noted that most reefal island outcrops show some evidence of domed bedding, suggesting that most or all of these occurrences represent central reef or reef core positions. The sequence of island outcrops could possibly be considered to represent the evolution of a reef core through time, from an earlier dominantly crinoid-*Amphipora* phase (Mason Island, Stop F) through a dominantly coral-stromatoporoid phase (Simon Island, Stop D) to a final algal-stromatolitic phase (possibly in part supratidal) at the Steeprock Bay Reef (Stop 12).

3.1.7 Detailed Reef Morphology, Outcrop Belt

Some larger-scale aspects of reef morphology have been outlined, based largely on the test hole data from the Swan River area. Within the Devonian outcrop belt, a reflection of some of these aspects of reef morphology can be seen, but only indirectly and incompletely. Most Winnipegosis reef outcrops are small isolated occurrences that provide almost no clue as to the original size, shape or extent of the reef. These reef characteristics can only be determined where the Winnipegosis surface is mirrored by structure in the overlying strata, which have been draped over uneroded Winnipegosis reefs as a result of salt solution and collapse. It will be seen that even where outcrops are relatively abundant, as in the Dawson Bay area, reef configuration is so complex and small scale that determination of reef morphology is almost impossible.

By far the best insight into local complexity of reef morphology is seen along the Pelican Rapids Road where, for considerable distances, the road bed consists of an undulating bedding-plane surface of Lower Dawson Bay limestone that is believed to mirror precisely the shape of the underlying reef complex (Fig. 16h). This complex appears to extend for approximately 16 km along a northwesterly trend.

A second, northeasterly trending reef complex appears to underlie Salt Point (Fig. 14) and a third complex appears to trend northeast, coincident with the lower reaches of the Red Deer River and continuing through to the Bluff. Discrete dome-like structures along these trends indicate the presence of isolated pinnacle-type reefs (of a concordant height), but elsewhere on these trends, closely spaced undulating structures such as those seen on the Pelican Rapids Road suggest a more or less continuous reef complex possibly formed by merging of smaller, closely spaced reefs. In a few places, these complexes appear to have developed into flat-topped "atoll-like" complexes, as shown by the flat-lying Dawson Bay strata seen on Salt Point (Stop C).

The above comments apply primarily to the morphology of reefs occurring in the relatively deep basinal facies of the Dawson Bay area, where reefs probably attain a maximum complexity. In the shallower basin-flank areas (town of Winnipegosis area) and the basin margin areas (The Narrows area) the outcrop configuration generally is not as complex, but even in these latter areas the outcrop data are not sufficient to fully define the reefs or reef complexes.

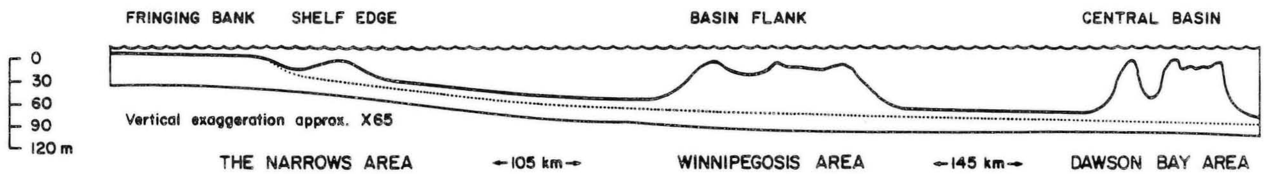
3.1.8 Internal Structure of Reefs and Implications for Pattern of Reef Growth

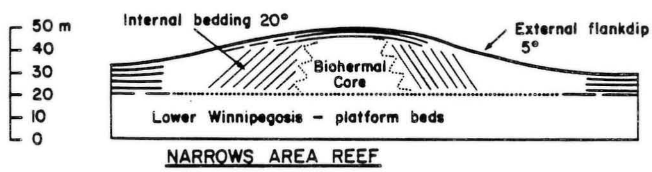
The writer has noted the differences in reef configuration as the reefs are traced from the shelf edge (Narrows Area) to the deeper basinal areas of

Dawson Bay (Fig. 12). The inference could be that the basic type of "reef" development changed from gentle bioclastic mounds in the Narrows area to possibly true bioconstructed "pinnacle-type" reefs in the Dawson Bay area. This scenario may be true, but limited data on internal structure of the reefs suggest a somewhat different hypothesis. The above scenario is based on the present gross reef configuration, the final shape immediately prior to burial by the Prairie Evaporite.

Almost certainly the final reef configuration differs from its configuration during earlier stages of reef development. At the Rosehill Reef, in the Narrows area (Stop 25), we see evidence for development of a massive "reef" core with flanking beds of well bedded reef flank detritus dipping off at about 20^{o}. An earlier reef configuration thus must have had flank dips of at least 20^{o}, but the final configuration as shown at Stop 23 is that of a gentle mound with flank dips of only a few degrees. Interestingly, the early flank dips in the Narrows area are the same as the final reef configuration of some of the "pinnacle type" reefs in the Dawson Bay area. The difference in final reef configuration as noted for the progression from the Narrows (shelf edge) to Dawson Bay (basin) (Fig. 12) may thus represent largely a measure of the degree of lateral reef growth or accretion in these areas, which in turn was controlled by the amount of subsidence. Late Winnipegosis (or early Prairie Evaporite) erosion also may have affected final reef configuration.

From the above one could infer that all Winnipegosis reefs were essentially the same in their initial stages of growth - all probably sharply defined bioconstructed true reefs. The overall configuration of the reefs, however, changed through time as lateral accretion occurred, subduing the reef profile and eventually developing broad gentle bioclastic mounds in the basin margin areas. Lateral accretion would have had much less effect on the small isolated pinnacle reefs in the deeper basinal areas, because the supply of detritus was not sufficient to cause significant lateral accretion in deeper-water conditions. Subsidence during Upper Winnipegosis time may thus have been marked by a strong initial episode of subsidence (giving rise to sharply defined pinnacle-type bioconstructed reefs), followed by a prolonged period of relatively stable or gently subsiding conditions dominated by lateral accretion. This model accounts for the relatively steep flanking dips and bioconstructed core in the shallow basin-margin setting at the Narrows.



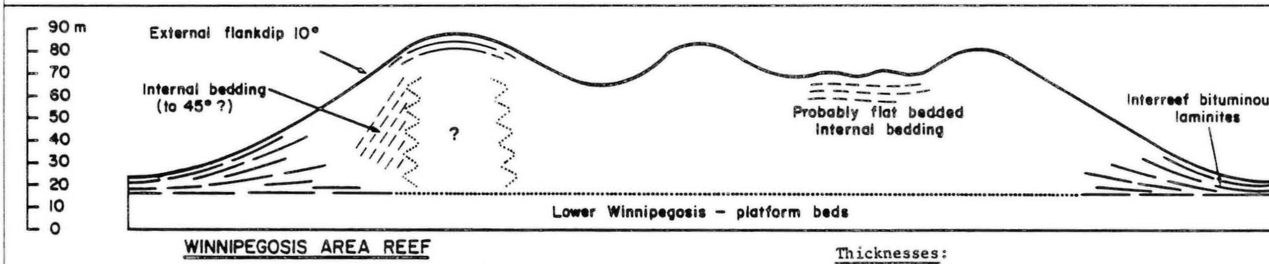


Configuration: Broad gentle mound, well bedded at top with algal/fenestral cap

- external flank dip 5°
- internal flank dip ± 20°
- massive biohermal (?) core
- interreef, pale finely laminated dolomite

Thicknesses:

Total Winnipegosis, reefal	65 - 70 m
" " , interreef	± 32 m
Relief	30 - 35 m
Upper Winnipegosis, reefal	40 - 50 m
" " , interreef	5 - 10 m
Lower Winnipegosis, platform	20 - 25 m

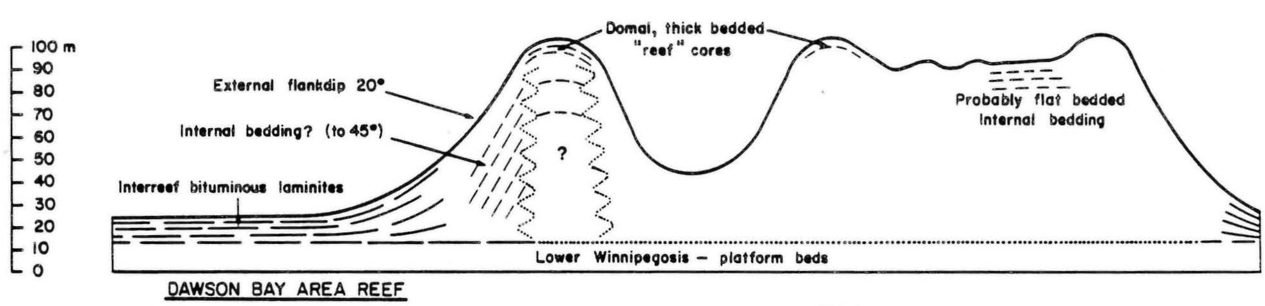


Configuration: Moderate domal structure, well bedded at top, algal/fenestral cap.

- external flank dips ± 10°
- internal flank dips uncertain (in cores, variable to 40°), in places flat topped, atoll-like
- interreef, fine bituminous laminite

Thicknesses:

Total Winnipegosis, reefal	82 - 94 m
" " , interreef	± 28 m
Relief	54 - 66 m
Upper Winnipegosis, reefal	65 - 77 m
" " , interreef	± 11 m
Lower Winnipegosis, platform	± 17 m



Configuration: Sharply defined domal structures

- uppermost strata thick bedded, gently domal with algal/fenestral cap in places
- external flank dips ± 20°
- internal flank dips uncertain (in core to 45°), known reef flank breccias
- in places undulating, flat-topped, atoll-like complexes
- interreef, fine bituminous laminite interbedded with reef flank detritus

Thicknesses:

Total Winnipegosis, reefal	82 - 98 m
" " , interreef	24 - 33 m
Relief	50 - 74 m
Upper Winnipegosis, reef	65 - 88 m
" " , interreef	13 - 15 m
Lower Winnipegosis, platform	10 - 17 m

Figure 12. Winnipegosis reef configuration (inferred) and known reef parameters.

Indirect evidence for sharply defined initial reef growth also can be noted for the more basinal areas in the vicinity of Winnipegosis town and Dawson Bay. In proximal reef flank locations, a thin interbed of bituminous mudstone is present above the platform, but is buried beneath a thick sequence of reef flank carbonates. This seems to reflect initial deposition of relatively deep-water* bituminous sediments very close to the shallow-water reef core, with subsequent burial of the bituminous beds during lateral reef growth. In stratigraphic core hole S-5-75 (Fig. 14) one such bituminous interbed occurs within 75 m of the centre of the reefal structure (Stop 11). This provides some measure of the rapid differentiation into reef and interreef facies. Several other core holes have intersected reef flank deposits which include large reef-derived detrital blocks mixed with fine interreef bituminous beds. Such occurrences, combined with internal flanking dips of up to 45°, also suggest sharp reef/interreef differentiation and development of a true wave resistant, possibly bioconstructed reef framework, although such a framework is only rarely distinguishable in outcrop.

A diagrammatic basin profile is shown in Figure 12, based on the above model. It must be stressed that this profile is based on very limited internal structural data for the reefs.

Supplemental Note

One of the probelms with interpretation of widely spaced oil well cores for the Manitoba-Saskatchewan portion of the Elk Point Basin is that the precise location of the core in relation to the reef is difficult or impossible to determine. At some localities in the Manitoba outcrop belt, however, the precise relation of the core holes to the reef is known, and it is hoped that closely spaced core hole profiles may eventually define the precise reef-inter reef relation ships.

In this regard, and subsequent to compilation of this guidebook, two core holes were drilled in 1986 on the flank of the Steeprock Bridge Reef. (Stop 11:

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* With regard to water depth, the alternative explanation for the bituminous beds as supratidal algal mattes has been noted. Even for a "deep-water" model, depths estimates are uncertain.

McCabe, 1986). These holes, along with two previously drilled core holes provide a detailed 4-hole profile on approximately 100 m spacing, on the western flank of the above reef. A summary profile is shown in Figure 15b. To the writer's knowledge, this is the only detailed profile available for a Winnipegosis reef in the southern portion of the Elk Point Basin area. Although detailed bed-by-bed correlations are not possible, the general stratigraphic relationships strongly suggest tht the laminated bituminous mudstones and interbedded fragmental carbonates (reef flank detritus) are equivalent to the active biogenic phase of reef growth.

The almost complete lack of varvitic laminites in the section suggests that these laminites are not formed during the biogenic phase of reef growth, and most probably are younger, possibly deposited during the earliest phases of Prairie Evaporite deposition.

Hopefully, further core hole data will help to clarify reef-interreef relationships, and provide a more accurate model for reef development. Specifically, additional core holes are planned for 1987 for the Salt Point Area (Stops A, B, C). These holes, possibly completed before this trip is run, will provide data for one of the larger platform-type reef complexes and may help to ascertain if these features developed as larger complexes, or evolved from a series of closely spaced pinnacle-type reefs.

3.1.9 Post-reef Erosion, Sedimentation, and Diagenesis

One final comment must be made regarding reef morphology as reflected in the structure of the overlying beds. It has been noted that such structure reflects only the final configuration of the Winnipegosis reef. This configuration probably reflects some degree of post-Winnipegosis/pre-Prairie Evaporite erosion, depending on how much sea level drop (evaporitic drawdown?) occurred in the basin before and during Prairie Evaporite time. Some workers (Porter and Fuller, 1969) have suggested that the lower part of the Prairie Evaporite sequence was deposited under sabkha conditions, in which case virtually the entire Winnipegosis reef succession would have been subaerially exposed and subjected to erosion and vadose diagenesis. Evidence of limited drawdown and associated vadose diagenesis, including development of vadose pisolites, has been documented for the upper parts of Winnipegosis reefs (Maiklem, 1971; Wardlaw and Reinson, 1971).

With regard to vadose diagenesis, the reported occurrence of stratigraphically defined halos of anhydrite (Wardlaw and Reinson, 1971) surrounding some central basin reefs in Saskatchewan may be highly significant. Such halos must reflect locally reduced salinity and a local increase in the supply of Ca^{++} ions in solution in waters surrounding the reef. Inasmuch as the reefs are completely enclosed in salt deposits, there can have been no "reduced restriction" in these areas. The entire basin sea was saturated and precipitating halite at the same time the anhydrite halos were being emplaced. One explanation for the locally reduced salinity and anhydrite precipitation would be a supply of fresh (or less saline) water and Ca^{++} ions from the reef itself. This could have been supplied by at least two mechanisms. The first would involve a regional flow of subsurface formation waters (normal marine?) through underlying strata, presumably the Winnipegosis platform beds, with discharge from these beds through overlying reefs subaerially exposed due to evaporitic drawdown. Introduction of this lower salinity water into the evaporite basin would give rise to a halo of reduced salinity and anhydrite precipitation, and the stratigraphic level of the anhydrite beds should reflect the approximate position of sea level, and show the extent of reef exposure above sea level. The input area for this subsurface flow system could have been the Presqu'ile barrier reef complex in northwest Alberta, which is believed to have caused regional restriction of the Elk Point Basin. The driving force for the subsurface flow system could have been the difference in "sea level" between the oceanic source and the drawdown level established in the Elk Point Basin (Maiklem, 1971). Alternatively, Jodry (1969) suggested that compaction of carbonates, especially in interreef areas, resulted in expulsion of pore fluid, with the fluid discharging through the reefs and causing dolomitization of the reefs. This expelled connate water also could have given rise to anhydrite halos around the reefs.

A second explanation for the anhydrite halos would be to have the reefs subaerially exposed (by evaporitic drawndown) so that the reef acted as a freshwater catchment for rainfall, which would percolate through the reef, pick up Ca^{++} ions while subjecting the reef to vadose diagenesis, and then precipitate the Ca^{++} as $CaSO_4$ on contact with the brines surrounding the reef. Brines saturated to the point of precipitation of NaCl are in effect supersaturated with respect to SO_4^{--}, relative to normal sea water, so any Ca^{++} ions introduced into such a saline environment would be precipitated immediately as $CaSO_4$, at the same time reducing the salinity in the area surrounding the reef to a point below the NaCl saturation level.

Both of the above mechanisms could have been operative at the same time. The apparently considerable areal extent of the anhydrite halos around the reefs would require a relatively large flow of "fresher" water, which would probably have been supplied more easily by a regional subsurface flow system.

A diagenetic model also has been suggested for formation of the reef-flank anhydrites, with the anhydrite being formed by replacement of reef-flank dolomites (as has been proposed for the Keg River reefs of Alberta). However, Kendall (1975) notes that there is little evidence of a replacement origin for the anhydrites associated with the Winnipegosis reefs in the Saskatchewan portion of the Elm Point Basin. He also notes that the halite beds of the Lower Prairie Evaporite (Whitkow Member) interfinger with the reef flank anhydrites, which provides further evidence of a primary origin for the reef-flank anhydrites.

The foregoing rather long and involved discussion of the origin of the Winnipegosis reefs is based on limited data and hence is rather speculative. Nevertheless, in view of the sparsity of outcrops and lack of definitive reefal exposures, the writer thought it necessary to provide a framework in which the field trip participants might better evaluate the fragmentary features seen in outcrop.

3.2 Dawson Bay Formation

Dawson Bay strata comprise the second of the series of Devonian evaporite cycles. The formation is subdivided into the four units shown and described in Figure 13. These units show pronounced differences in resistance to erosion. The soft recessive shales of the Second Red Bed and the Middle Dawson Bay unit almost never occur in outcrop, whereas outcrops of the hard resistant strata comprising the brachiopod biomicrite zone of the Lower Dawson Bay, and the Upper Dawson Bay coral-stromatoporoid beds are common. Because these resistant beds are thin, uniform, persistent and easily identified, precise stratigraphic and structural data can be determined from these outcrops.

The interbedding of resistant and recessive units coupled with reef-related salt solution collapse structures, has had a pronounced affect on the Devonian outcrop pattern. The soft shales overlying the resistant beds have been removed by glacial erosion, exposing a smooth bedding-plane surface of the underlying resistant beds. These bedding surfaces conform to the underlying Winnipegosis reef configuration, with the result that throughout much of the outcrop belt, the exposed bedrock topography reflects the structure of the Winnipegosis reefs. This effect is quite spectacular along the Pelican Rapids road, in the Dawson Bay area (e.g. Stops 11,13), where the road-bed in many places is a bedding-plane surface and the road undulations directly reflect the reef topography (Fig.16A/h).

Because of differential erosion of Dawson Bay strata, outcrop occurrences are limited to the resistant beds; consequently, Dawson Bay outcrops along the outcrop belt do not show any appreciable lithologic variation. However, lithologic changes, determined from core hole drilling appear to reflect the presence of a distinct sub-basin during Dawson Bay time, more or less coincident with the southern portion of the outcrop belt, as indicated by isopach trends (Fig. 8a). The middle calcareous shale member, although very persistent and uniform throughout the outcrop belt, disappears rapidly to the west in the subsurface by thinning and facies change to relatively clean carbonates. This fossiliferous shaly unit is not recognizable in the Saskatchewan succession (Lane, 1959), and probably represents a deeper-water, lower-energy deposit directly related to the sub-basin.

Considerable thickening of the Lower Dawson Bay Member is evident to the south, along the outcrop belt. This is due primarily to thickening of the lower part of the unit, which consists largely of dark brown, partly laminated and partly bituminous microgranular dolomites and slightly argillaceous micritic limestones. The latter are seen in outcrop at Stop 24. These beds also are indicative of deposition under relatively deeper-water, low-energy, more basinal conditions in a depositional sub-basin. The interbedding of relatively deeper water deposits (lower part of Lower Dawson Bay and Middle Dawson Bay) with shallower water deposits (upper part of Lower Dawson Bay and Upper Dawson Bay) indicates a subdued cyclical pattern of deposition during Dawson Bay time.

3.3 Souris River Formation

Only the lower portion of the Souris River Formation outcrops in Manitoba. Two members have been defined (Fig. 13), a lower Point Wilkins Member, and an upper Sagemace Member. Both units represent "evaporite cycles" comparable to the Dawson Bay cycle, and the Ashern-Winnipegosis-Prairie Evaporite cycle.

3.3.1 Point Wilkins Member

Outcrops of Souris River strata are sparse. The best exposures of the Point Wilkins Member are in the general area of "The Big Rock" (previously named Point Wilkins). The most accessible exposure is in the Mafeking quarry of Inland Cement (Stop 9). Point Wilkins strata consist of a basal red shale unit, the First Red Bed, overlain by a sequence of extremely fine grained, sparsely fossiliferous, micritic/intraclastic high-calcium limestones. Some admixture of argillaceous and silty material is evident in the Lower Point Wilkins. The very fine sediment grain size and the delicate nature of the contained fauna suggest deposition under quiet, low-energy conditions, with periodic disruption indicated by the intraclastic beds. These strata probably were deposited under relatively deep water conditions, with periodic storm effects.

In the southern part of the outcrop belt exposures are sparse, and lithologic data have been obtained primarily from core. The Point Wilkins beds thin markedly to the south, from over 50 m in the Dawson Bay area to about 35 m in the Winnipegosis area, although correlations based on shaly marker beds are somewhat uncertain. The apparent southward thinning of the Point Wilkins portion of the Souris River Formation, shown by the core holes, is not evident in the regional isopach pattern for the total Souris River sequence (Fig. 8b). Correlations and isopach variations are further complicated by extensive salt-collapse brecciation that occurs in many core holes. Nevertheless, the lithology of the Point Wilkins strata appears to change markedly to the south, where stromatoporoidal calcarenitic limestones become abundant, in places including coral biolithites and calcirudites. Local dolomitization is common but erratic, and lithofacies are quite variable. The lithology of this southerly area reflects a shallower-water, higher-energy environment than for the Dawson Bay area. This is consistent with the pattern of regional basinward thickening to the north suggested for the Winnipegosis, but inconsistent with the pattern of local sub-basin development indicated for Dawson Bay strata. Additional core hole studies are required before the regional lithofacies and isopach patterns of the Point Wilkins strata can be established with any degree of confidence.

3.3.2 Sagemace Member

The Sagemace Member comprises the second full depositional cycle of the Souris River Formation (Fig. 13). It occurs only in that portion of the outcrop belt near the town of Winnipegosis. The only significant exposures are the Pine River Road quarry (Stop 16), the Winnipegosis quarry (Stop 18) and possibly the exposure at the Mossy River Bridge in the town of Winnipegosis (Stop 19).

The lithology of the Sagemace Member is highly variable, but is generally similar to that of the Point Wilkins Member in the same area; the Sagemace beds also are brecciated to varying degrees. An excellent example of a salt-collapse plug is seen in the central part of the Winnipegosis quarry (Stop 18); it is the result of several separate episodes or periods of salt collapse, as outlined diagrammatically in Figure 18.

4.0 Possible Basement Control of Devonian Tectonic Framework

The possible effect of the Churchill/Superior boundary zone on the Ordovician tectonic framework has been noted, and the same feature appears to have influenced the Devonian framework as well. The well defined north-trending edge of the Winnipegosis fringing bank (approximately Tp. 1-15, Rge. 25WPM; Fig. 7b), and the coincident limit of the Prairie Evaporite salt beds (Fig. 7c) both fall on the projection of the boundary zone. Furthermore, the clusters of Winnipegosis reefs in the Swan River and Dawson Bay areas also occur along this boundary zone, although reefs are by no means limited to this zone. Also, the only known early salt collapse events, evidenced by local thickening of specific Devonian to Mississippian intervals, fall along the Churchill/Superior boundary zone.

A prominent isopach thinning (Fig. 8a) of the Dawson Bay Formation occurs roughly along the boundary zone, and a well defined thickening is present to the east, centred on the southern portion of the outcrop belt. Local thickening of the Second Red portion of the Dawson Bay, probably related to very early salt solution, occurs along the southern part of the boundary zone. The area of thickened Dawson Bay and the associated lithofacies variations suggest that a sub-basin existed east of the Churchill/Superior boundary zone, and as a result the carbonate thickness of the Dawson Bay Formation along the southern part of the outcrop belt exceeds the maximum reported Dawson Bay carbonate thickness in the central part of the basin (Lane, 1959). This is further evidence for greater subsidence in that greater portion of the basin underlain by the Superior crustal block.

There is little evidence for basement control of the Souris River isopach (Fig. 8b) although slight thickening is evident in the same area as for the Dawson Bay Formation.

System	Group/Formation	Member	Stop No.	Depositional thickness (metres)	Summary lithology
CRET. / JUR.					
DEVONIAN	SOURIS RIVER FORMATION	Sagemace Member	16, 18, 19	20+	Limestone, pale yellowish brown to reddish grey, microcrystalline, dense, minor argillaceous interbeds. Passes laterally to totally dolomitized sequence.
		basal shale		2-14	Shale, dolomitic, massive, medium brownish red with some greenish mottling.
		Point Wilkins Member: (evaporite dissolved)			**(Davidson Evaporite)**
		Point Wilkins Member: Upper Point Wilkins	9, G	10	Dolomite and dolomitic limestone, light grey to medium yellowish brown, partly mottled, coarsely microcrystalline, subsaccharoidal with remnant calcareous biomicrite.
		Point Wilkins Member: Middle Point Wilkins	9, G, 17, 6	14-21	Limestone (pure high-calcium), pale yellowish brown, faintly mottled, finely microcrystalline to cryptocrystalline, dense and tight (sublithographic), fossiliferous, in part intraclastic.
		Point Wilkins Member: Lower Point Wilkins	9, G	9-15	Limestone, slightly to moderately argillaceous with some interbeds calcareous shale, medium to light reddish and purplish grey, fossiliferous intramicrite, locally calcarenitic.
		First Red Beds	7	3-14	Shale, dolomitic, medium reddish grey to dark brownish red, in part mottled and brecciated. Several interbeds buff argillaceous limestone to brown argillaceous dolomite.
	DAWSON BAY FORMATION	(evaporite dissolved)			**(Hubbard Evaporite)**
		Upper Dawson Bay	9, 8, 20b, 22	6-17	Limestone, white to pale yellowish brown, highly fossiliferous with corals and stromatoporoids, in places grading to stromatoporoid biolithite. In part extremely pure high-calcium limestone (99.8% $CaCO_3$), but in places variably dolomitized, especially lower part of unit.
		Middle Dawson Bay	21	11-18	Calcareous shale, fossiliferous, medium grey to dark greyish red, massive (recessive).
		Lower Dawson Bay	5, 1, 24, 11; 3,4,13,15,20a	9-25	Gradational sequence passing upward from brown partly laminated and bituminous dolomite to grey and reddish grey dense slightly argillaceous micrite and fossiliferous micrite, which in turn grades upward to highly fossiliferous brachiopod biomicrite at top. Lower two zones thin markedly to the north.
		Second Red Bed		6-15	Red to greenish grey dolomitic shale, commonly brecciated as a result of salt collapse.
	ELK POINT GROUP: WINNIPEGOSIS FORMATION	PRAIRIE EVAPORITE	A, B, C, D, E, F, 2, 3, 12	0-129	Prairie Evaporite: dominantly salt with potash interbeds and minor anhydrite in basinal areas; entirely anhydrite in shelf areas (at present). Originally present throughout the entire Devonian outcrop belt, but subsequently removed by subsurface salt solution. Where preserved in subsurface, overlaps and completely buries Winnipegosis reefs with resultant thinning of evaporite section.
		Upper Winnipegosis (reef)	23, 25, 27	0-90	Reefal facies: dolomite, very fine to medium crystalline, ranges from compact dense to subsaccharoidal, massive to medium/thick bedded, variably fossiliferous but texture largely obscured by dolomitization. Reef thicknesses tend to be relatively uniform in a given area.
		Upper Winnipegosis (interreef)		35	Interreef facies: dolomite, brown to black, finely laminated with black bituminous partings, in places calcareous. Lamination best defined towards top of unit.
		Lower Winnipegosis	28, 30	10-20	Lower Winnipegosis: dolomite, fine to medium crystalline, moderately granular to saccharoidal, medium to thin bedded. In part calcareous and grades laterally to Elm Point limestone facies.
	ELK POINT GROUP	ELM POINT FM.	30, 31, 33, 32	10-20	Elm Point: Limestone, pale yellowish brown dense fine grained biomicrite. In part shows lighter yellowish dolomitic mottling. Pure high-calcium limestone to calcareous dolomite
	ELK POINT GROUP	ASHERN FORMATION		3-18	Argillaceous dolomite and dolomitic shale, medium to dark greyish and brownish red, in places reduced to greenish grey. Local basal dolomite breccia.
SIL.	INTERLAKE GROUP		29		Dolomite, white to pale yellowish buff, mostly microcrystalline dense, thin bedded, sublithographic, in part stromatolitic. Some porous biostromal interbeds towards top.

Figure 13. Detailed stratigraphic succession and lithology, Devonian formations.

Part II: General Road Log and Outcrop Descriptions

1.0 Introduction

Stops include portions of all Devonian stratigraphic units known to occur along the 400 km length of the the Manitoba outcrop belt, although exposures are widely scattered and generally are incomplete. Figure 13 shows the detailed stratigraphic succession comprising the Devonian outcrop belt, the general lithology of each unit, and the approximate stratigraphic portion of the section exposed at each of the various outcrop stops.

Only the lower portion of the Devonian succession is exposed in outcrop in southern Manitoba, that is, the section ranging from Middle Devonian (upper Eifelian) to early Upper Devonian (early Frasnian). The remainder of the Devonian succession (upper Frasnian and Famennian) is known only from the subsurface, because of overstep and burial by the thick sequence of Mesozoic clastics at the Paleozoic unconformity (Fig. 2). Lower Devonian (Emsian) strata are not present in southwestern Manitoba, and were not deposited in the Williston Basin area. The earliest Devonian strata in southwestern Manitoba, the Ashern Member of the Elk Point Group, are Middle Devonian in age, probably upper Eifelian. The Elifelian/Givetian boundary is believed to occur within the Winnipegosis Formation, possibly near the top of the Lower Winnipegosis (Elm Point) platform beds. The boundary between Middle and Upper Devonian (Givetian/Frasnian) is believed to occur within the Souris River Formation, possibly near the top of the lower argillaceous unit of the Point Wilkins Member (Norris et al., 1982).

Faunal lists for the various stratigraphic units are not included in this guide, but comprehensive listings for all formations and most outcrops are included in Norris et al. (1982). Earlier faunal lists are presented in Baillie (1951) (1953) and in McCammon (1960).

The itinerary for this field guide originates in the town of Swan River but the guide is not intended to be route specific. All significant outcrops have been included and can be visited in any desired sequence. Because of uncertainties introduced by the effects of weather on the boat portion of the trip, a considerable number of alternative stops have been included, and a specific detailed itinerary with available options will be made available for each participant. The following trip sequence is presented as a full 3-day trip (Manitoba portion only), assuming good weather conditions.

Note: Re: Winnipegosis reef lithofacies

> "It should be noted that the lithofacies described by Baillie (1949) for each individual build-up in outcrop were from one point only because of limited accessibility, landing sites and drift cover. Probably each build-up would include much more lithofacies diversity if it were studied more intensively. The lithofacies association in a composite build-up could include colonial corals of several types, amphipora concentrations, stromatoporoids, algal stomatolites with fenestral porosity, dolomite muds with large brachiopods, algal-mat organic-rich laminites and calcarenites; all of these lithofacies were observed in at least one outcrop. In several outcrops, in the upper part, a cavernous horizon with pisolites and "cave pearls" separated the more massive "reef" rock from a more bedded limestone, presumably a "vadose" phenomenon. A paleoecological pattern may be present in these isolated build-ups as in several places certain lithofacies such as the colonial coral groupings and the algal stromatolites seemed to be confined to certain parts of the build-up. Although erosion has removed much of the flanking and marginal parts the region offers an excellent easily accessible area for a study of these outcrops that have in many respects markedly similar aspects to Middle Devonian isolated reefs at Rainbow, Zama and the occurrences northeast of Senex Creek reef in Alberta."

"A.D. Baillie"/1986.

2.0 Comprehensive Trip Itinerary - all stops included

Preliminary: Saskatoon to Swan River

Visit to Potash Mine. Overnight at Swan River

Day 1: SWAN RIVER - DAWSON BAY AREA - SWAN RIVER (FIG. 14)

Stop No./Location/Formation/Priority

1)	Highway 10 Dome; Lower Dawson Bay Formation	Stop
2)	The Bluff Reef; Upper Winnipegosis, reefal facies	Stop
3)	Overflowing Bay Area; Lower Dawson Bay/ Winnipegosis	Optional
4)	Red Deer River Salt Spring; Lower Dawson Bay	Optional/view only
5)	Red Deer River River Bridge; Middle/Lower Dawson Bay	Optional/view only
6)	Highway 10 Tower Roadcut; Point Wilkins Member	Stop
7)	Highway 10 Borrow Pit; First Red Bed Member	Optional
8)	Highway 10 Roadcut; Upper Dawson Bay	Stop
9)	Mafeking Quarry; Middle Point Wilkins Member	Optional/view only
10)	Steeprock Road Dome; Upper Dawson Bay	Optional/view only
11)	Steeprock Bridge Dome; Lower Dawson Bay	Optional/view only
12)	Steeprock Bay Reef; Lower Dawson Bay/Upper Winnipegosis, reefal facies	Stop
13)	Pelican Rapids Road; general topography and structure	Optional/View only
14)	Bell River Bay Reef; Lower Dawson Bay/Upper Winnipegosis	Optional

Day 2: SWAN RIVER - DAWSON BAY (BOAT TRIP) - DAUPHIN (FIG. 14)

A) Salt Point West; Lower Dawson Bay/Winnipegosis

B) Salt Point Central; Upper Winnipegosis, reefal

C) Salt Point East; Lower Dawson Bay/Winnipegosis, reefal

D) Simon Island; Upper Winnipegosis, reefal

E) Rock Island; " " "

F) Mason Island; " " "

G) "Point Wilkins"; Souris River Formation, Point Wilkins Member

15)	Camperville South Quarry; Lower Dawson Bay	View only
16)	Pine River Road Quarry; Souris River, Sagemace Member	Optional
17)	Sagemace Bay Highway; Point Wilkins Member	Optional
18)	Winnipegosis Quarry; Sagemace Member	Stop
19)	Mossy River Bridge; Souris River Formation	Optional/view only
20)	Paradise Beach Road; (a) Lower Dawson Bay	Optional/view only
	" " " (b) Upper Dawson Bay	Optional/view only
	" " Quarry; (c) Upper Dawson Bay	Optional
21)	Volga Ditch; Middle Dawson Bay	Optional/view only
22)	Centennial Beach; Upper Dawson Bay	Optional/view only

Day 3 DAUPHIN - THE NARROWS AREA - WINNIPEG (FIG. 17)

23)	Narrows West Quarry; Upper Winnipegosis, reefal	Stop
23a)	Narrows East Quarry	View only
24)	Narrows Ditch; Lower Dawson Bay	Optional/view only
25)	Rosehill quarries; Upper Winnipegosis, reef/ reef flank	Stop
26)	Gunnlaugson Farm, Upper Winnipegosis, reefal	Optional
27)	Dog Lake Quarry; Winnipegosis (upper?)	Optional
28)	Overton Quarry; Lower Winnipegosis (platform)	Stop
29)	Oatfield Quarry; Ashern/Interlake	Stop
30)	Steeprock Quarry; Elm Point/Ashern	Optional
31)	Lily Bay Quarry; Elm Point	Optional
32)	Lily Bay East Quarry; Elm Point/Ashern	Stop
33)	Oak Point Quarry; Elm Point	Optional/view only

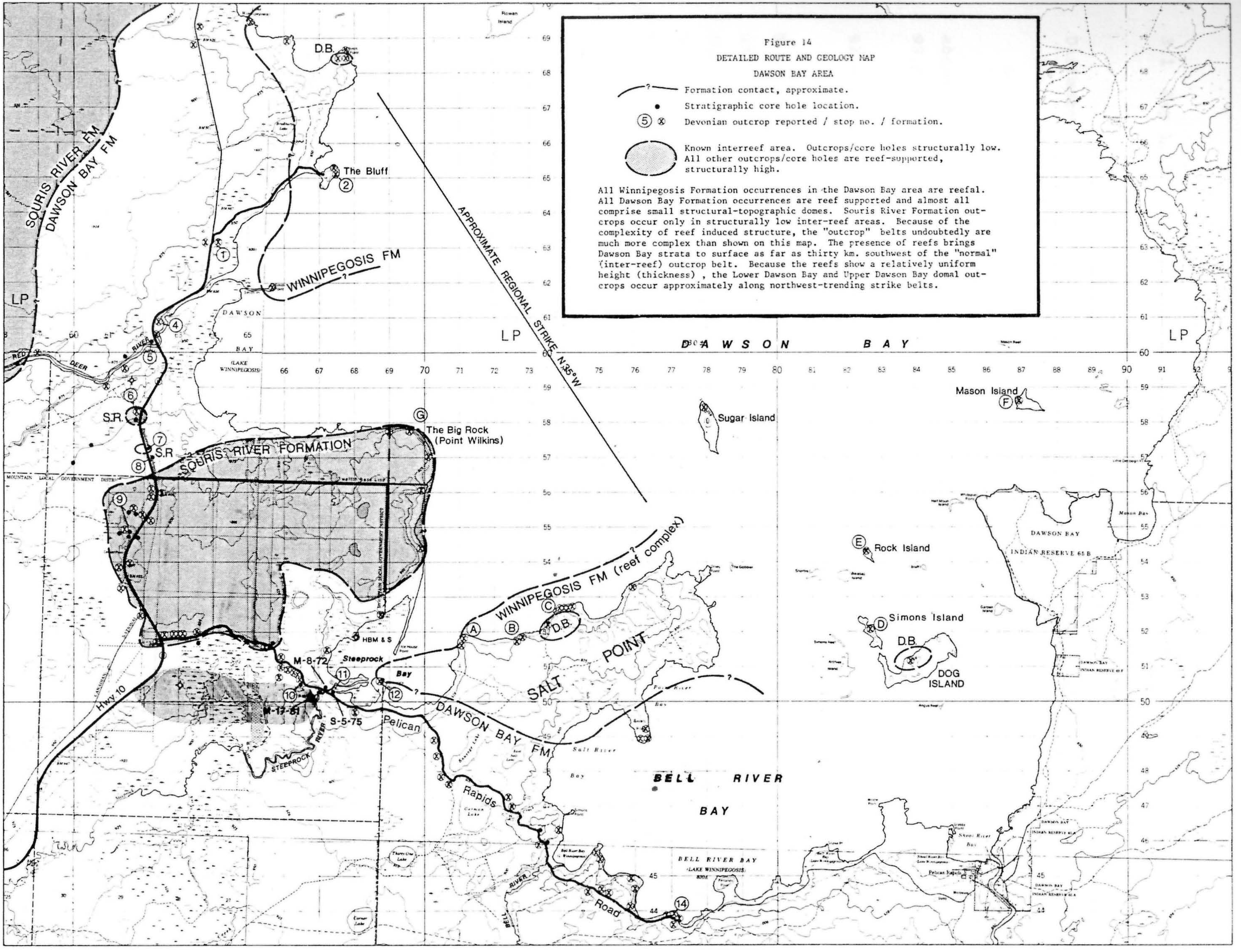


Figure 14
DETAILED ROUTE AND GEOLOGY MAP
DAWSON BAY AREA
Formation contact, approximate.
Stratigraphic core hole location.
Devonian outcrop reported / stop no. / formation.
Known interreef area. Outcrops/core holes structurally low. All other outcrops/core holes are reef-supported, structurally high.
All Winnipegosis Formation occurrences in the Dawson Bay area are reefal. All Dawson Bay Formation occurrences are reef supported and almost all comprise small structural-topographic domes. Souris River Formation outcrops occur only in structurally low inter-reef areas. Because of the complexity of reef induced structure, the "outcrop" belts undoubtedly are much more complex than shown on this map. The presence of reefs brings Dawson Bay strata to surface as far as thirty km. southwest of the "normal" (inter-reef) outcrop belt. Because the reefs show a relatively uniform height (thickness), the Lower Dawson Bay and Upper Dawson Bay domal outcrops occur approximately along northwest-trending strike belts.
SOURIS RIVER FM
DAWSON BAY FM
D.B.
The Bluff
WINNIPEGOSIS FM
APPROXIMATE REGIONAL STRIKE N35°W
LP
DAWSON BAY
S.R.
SOURIS RIVER FORMATION
The Big Rock (Point Wilkins)
Sugar Island
Mason Island
Rock Island
Simons Island
DOG ISLAND
WINNIPEGOSIS FM (reef complex)
SALT POINT
HBM & S
M-8-72
Steeprock Bay
M-17-81
S-5-75
Pelican Rapids Road
DAWSON BAY FM
BELL RIVER BAY
STEEPROCK RIVER
Hwy 10

3.0 General Road Log

3.1 Day 1, Stops 1-14, Dawson Bay Area (Fig. 14)

Distance - km

0 *Proceed north from Swan River on Highway 10 (Figs. 1, 14). Road skirts edge of Porcupine Mountains (Cretaceous shales), following along abandoned beach ridges of Glacial Lake Agassiz. Red Deer River bridge at 93.9 km. Continue north for 4.1 km to small road-cut.*

97.9 STOP 1. Highway 10 Dome, DAWSON BAY FORMATION. Lower (biomicrite) Member and basal Second Red Bed (Fig. 16A,a).

Road-cut through well defined structural/topographic dome exposes an upper 6 m unit of light grey, thin bedded, dense, highly fossiliferous brachiopod biomicrite (high-calcium limestone). A lower unit consists of 2.6 m of reddish to yellowish brown and greenish grey argillaceous dolomite and dolomitic shale - the Second Red Beds. The domal configuration, with flank dips of up to 20°, is due to salt solution and resultant collapse of the Dawson Bay beds, which are draped over an underlying Winnipegosis reef. The top of the reef occurs within 5 m of the roadbed. Note the minor faulting and brecciation resulting from collapse; also that the topography conforms roughly with the structure; such structural/topographic domes are common features of the Devonian outcrop belt. The structure of the Dawson Bay strata closely reflects the configuration of the uppermost part of the underlying reef. Note the asymmetry of the structure, with a secondary small structural roll immediately north of the main dome. Estimated underlying reef thickness is about 80 m.

References: Baillie (1950); Norris et al. (1982).

Proceed north on Highway 10 for 0.2 km to intersection with road to "The Bluff". Turn east and follow main road. Road is gated and permission to enter must be obtained from the Conservation Officer at Mafeking. Continue to abandoned fish station, then proceed on foot through open woodland to north end of peninsula forming "The Bluff".

102.3 STOP 2. The Bluff Reef, WINNIPEGOSIS FORMATION, Upper Member, reefal facies.

Accessible shore cliffs occur on the eastern and northern extremities of the Bluff (Fig. 14), and several small but clean outcrop mounds can be seen on the top of the Bluff, at the northern end. The Bluff comprises a slightly eroded reefal mound, or klint, although, as is typical for almost all Winnipegosis outcrops, dolomitization has largely obscured the primary organic textures. In places, however, excellent samples of bioconstructed lithologies can be seen, especially in the open area on top of The Bluff. The maximum exposed section consists of 9 m of white to pale yellowish brown, massive, compact, tough dolomite. At one place, a relatively thin-bedded zone is seen to occur between two massive (reefal?) abutments, and flanking dips to the south can be seen at the south end of the outcrop. Large talus blocks along the foot of the cliff are representative of the outcrop lithology. During periods of low water, bedrock pavement extends about 20 m from the foot of the cliff.

Pisolitic features can be seen filling cavities in the upper part of the outcrop. These are believed to be vadose pisolites, formed in the vadose (meteoric) zone during early diagenesis (Dunham, 1969) as a result of lowered sea level conditions subsequent to reef development but prior to burial of the reefs beneath salt beds of the Prairie Evaporite.

Configuration of the reef comprising the Bluff is indeterminate, but it probably is similar to that shown by the Lower Dawson Bay dome at Stop 1. Estimated remaining Winnipegosis thickness is approximately 88 m, and probably not more than a few metres of uppermost reefal beds have been removed by erosion.

References: Baillie (1950), Norris et al. (1982).

(Optional): *Return to Highway 10. Turn right (north) and proceed for 34 km to Overflowing River.*

STOP 3 (optional): Overflowing Bay Reef: Upper Winnipegosis reefal beds and flanking Lower Dawson Bay limestones.

Several poorly exposed Winnipegosis outcrops occur on the broad topographically high area north and east of Overflowing River. The Stadnick logging road, which runs east from Highway 10 approximately 1 km north of Overflowing River, provides access to a network of logging roads that cover this high. In addition, approximately 4.7 km north of Overflowing River and 1/4 km east of Highway 10, a large north-trending topographic ridge with a relief of 7-10 m provides some additional outcrop. A short distance south of Overflowing River, at the microwave tower, gently dipping Lower Dawson Bay strata occur on the southwestern flank of the topographic high.

These Winnipegosis outcrops are the northernmost known reefal outcrops and appear to comprise either a single large reef or a reef complex. Drilling at this site indicates a minimum Winnipegosis thickness of 84 m, with the uppermost Winnipegosis beds eroded. Hole M-7-73, drilled near the centre of the "reef" (topographic high) intersected 64 m of massive dolomites but was not drilled deep enough to intersect Lower Winnipegosis platform beds. Hole M-6-78, located on the Dawson Bay outcrop on the flank of the "reef", intersected 45 m of Upper Winnipegosis generally massive dolomite (local dips to 45^{o}, Fig. 22/6) and breccia beds, with a thin zone of black bituminous laminite at the base, overlying 10.8 m of Lower Winnipegosis platform beds, suggestive of lateral reef growth over flanking deeper-water bituminous laminites.

Return south on Highway 10 to Junction with The Bluff road. Continue south for 2.8 km to small salt flat adjacent to Red Deer River and 1.0 km north of Red Deer River bridge.

109.5 STOP 4. Red Deer River Salt Spring. Lower Member DAWSON BAY FORMATION.

One of the smaller salt springs or salt flats that occur throughout the Devonian outcrop belt, from the Dawson Bay area southeast as far as Toutes Aides (Tp. 29, Rge. 15W). This is one of the few salt springs where associated outcrop permits identification of the statigraphic source of the brine flow. A small outcrop of Lower Dawson Bay limestone, similar to Stop 1, occurs on the river bank, indicating the presence of a partly truncated domal structure, and hence the presence of an underlying Winnipegosis reef with, at most, a thin cover of basal Dawson Bay Second Red Beds. It seems probable that most salt springs are indicative of underlying Winnipegosis reefs with only a thin cover of basal Dawson Bay strata. (Drilling of salt flats to confirm this has not yet been undertaken because of potential problems involving control of heavy flows of artesian water from shallow depths). Deeper Silurian strata also may be involved in the artesian flow system.

Analysis of the brine indicated a salinity of 45,000 ppm with a variable flow rate of ± 10 litres per minute. The numerous salt springs along the Dawson Bay/Winnipegosis outcrop belt probably represent the discharge area for a regional subsurface flow system which is continuing the process of subsurface salt solution initiated in late Paleozoic time.

References: Baillie (1951), McCammon (1960), Norris et al. (1982).

Continue south on Highway 10 for 1.0 km to picnic area at Red Deer River bridge.

110.5 STOP 5. Red Deer River Bridge. Middle and Lower Members of DAWSON BAY FORMATION.

North bank of Red Deer River approximately 100 m west of bridge. Outcrop extends for about 30 m with beds dipping to the southwest at about 6°, exposing a 10 m section of fossiliferous limestone, argillaceous limestone and calcareous shale. These strata represent a portion of a truncated structural (reef-supported) dome comparable to those seen at Stops 1 and 4. Estimated minimum thickness of underlying Winnipegosis reef is about 80 m. A small brine flow is evident at the edge of the picnic area.

Two test holes were drilled a short distance upstream, one (M-18-77) on the top of a reef-supported structural dome of Lower Dawson Bay strata, and the other (Husky Mafeking 11-8-45-25) on a large salt flat. Both holes intersected Winnipegosis reefs 96 m thick. In contrast, two other holes drilled 7 km upstream intersected thin interreef Winnipegosis sequences of 24.1 and 32.7 metres. Thus minimum reef-interreef relief in this area is 72 m.

Several other Lower Dawson Bay reef-supported structural domes can be seen in this general area, as ditch outcrops along Highway 10 and as riverbank outcrop a short distance downstream from the bridge.

References: Baillie (1951, p. 40); McCammon (1960); Norris et al. (1982); Stratigraphic core hole M-10-72.

Continue south on Highway 10 for 2.2 km to large roadcut at microwave tower.

112.9 STOP 6. Tower Roadcut. Middle unit, Point Wilkins Member, SOURIS RIVER FORMATION.

Roadcut exposes a 5 m section of medium- to thin-bedded pale yellowish brown faintly mottled finely microcrystalline dense to sublithographic fossiliferous micrite. The mottling reflects, in part, an intraclastic texture. Fossils, dominantly brachiopods, are fragile and thin shelled, and the rock is a pure high-calcium limestone. Strata are flat-lying to gently undulating in the roadcut, but back from the highway, on the northern edge of the bedrock ridge, the beds fold upward sharply with dips of up to 33^{o}, exposing basal Souris River-First Red Beds. Recent drilling has shown that the beds also rise sharply to the south, exposing Upper Dawson Bay strata a short distance south of the road-cut. The flat-lying Point Wilkins strata thus represent an isolated, structurally low (collapsed) "outlier" of Souris River strata surrounded by a complex of structurally high, reef-supported Dawson Bay strata. Estimated thickness of the underlying Winnipegosis interreef strata is 44 m.

Detailed outcrops and core hole descriptions and analyses for the Point Wilkins strata are presented by Bannatyne (1975).

References: Baillie (1951), Bannatyne (1975), McCammon (1960); Norris et al. (1982). Stratigraphic core holes M-11-71, M-13-71, M-15-81.

Continue south on Highway 10 for approximately 0.8 km to small borrow pit east of highway.

113.7 STOP 7. Highway 10 Borrow Pit. First Red Beds, Point Wilkins Member, SOURIS RIVER FORMATION.

Bedrock pavement at the edge of a small abandoned borrow pit east of the highway exposes an undulating slightly truncated domal bedding plane surface. The thinly bedded strata show a fairly wide range of lithologies; brown granular mottled dolomitic limestone, light grey dense fossiliferous micrite, platy yellowish buff granular dolomitic limestone, and white to buff argillaceous fossiliferous micrite. In places irregularity of bedding suggests coarse brecciation. Total thickness of the First Red Beds in this area is approximately 10 m, and a core hole at this location (M-18-81) intersected 5.5 m of First Red Beds overlying Dawson Bay strata, indicating that the outcrop section comprises a more resistant interval near the middle of the Red Bed sequence.

The First Red Beds at this locality are structurally about 22 m high relative to the Point Wilkins strata at Stop 6. Estimated thickness of the underlying Winnipegosis is approximately 67 m. This is one of the few instances of a Winnipegosis build-up of intermediate thickness. This location is on regional strike with the Lower Dawson Bay domes noted previously on the Red Deer River, but "reef" thickness has only been sufficient to bring First Red Beds to surface.

Continue south on Highway 10 for 0.1 km to small road-cut.

114.7 STOP 8. Highway 10 Roadcut: Upper Member, DAWSON BAY FORMATION.

Roadcut through small structural dome exposes approximately 2 m of limestone and dolomite of the Upper Dawson Bay Member. This is the only outcrop of Upper Dawson Bay strata in the Dawson Bay area to expose any appreciable thickness of section; all other outcrops approximate bedding plane surfaces. The upper 1 m consists of relatively coarsely crystalline (recrystallized) brownish buff fossiliferous (coral-stromatoporoid) limestone, and is underlain by approximately 1 m of finely crystalline brown granular dolomite with numerous calcite-lined vugs.

Core hole data show that the dolomite content in the lower part of the Upper Dawson Bay is extremely variable, and the dolomite is believed to be entirely secondary in origin. Core hole M-14-81 at this location intersected an upper Dawson Bay sequence consisting of 4.75 m of limestone overlying 2.05 m of granular porous dolomite. These beds are structurally about 7 m higher than at Stop 7 indicating an underlying Winnipegosis thickness of about 75 m.

References: Norris et al. (1982); stratigraphic core hole M-14-81.

Continue south on Highway 10 for 3.0 km to access road to quarry west of highway.

116.8 STOP 9. Mafeking Quarry, Genstar Limited. Active quarry; permission required to enter. Quarry supplies high-calcium limestone used in manufacture of Portland Cement by Genstar Limited at Regina.

POINT WILKINS MEMBER of the Souris River Formation. There are two quarries at this location. The original, deeper quarry is now abandoned and mostly flooded and infilled (rehabilitated). It provides a good view of the gentle structural undulation affecting Point Wilkins strata; this structure reflects Winnipegosis interreef paleotopography. Detailed descriptions of the 27 m of section exposed in the old quarry are presented by Bannatyne (1975).

The new quarry exposes the same sequence as seen in the upper part of the old quarry, except for a 3 m cap of brown granular dolomite that occurs above the limestone and forms the uppermost unit of the revised Point Wilkins Member (Norris et al., 1982) (Fig. 13). These dolomites are the youngest Devonian strata known to occur in the area. The main quarry beds consist of light yellowish brown faintly mottled dense micritic limestones similar to the beds at Stop 6, which are correlative with the upper part of the quarry section approximately 5 m below the dolomite cap (Bannatyne, op. cit.). The lower part of the Point Wilkins Member consists of 10 m of reddish to purplish grey mottled argillaceous limestone, which was quarried in the old quarry. However, these argillaceous beds are of lower grade and are not being utilized in the new quarry.

Note the presence of the large sand-filled cave in the north quarry wall. Numerous such caves have been intersected during quarry operations and are believed to represent pre-Mesozoic karstic solution, with infilling by Cretaceous (Swan River?) quartzose sand. (The fissure breccias exposed at Point Wilkins - Day II, Stop G - possibly represent comparable but collapsed karst features).

The quarry beds have been subjected to a minimum of about 70 m of salt collapse, but associated disruption is relatively minor. Estimated thickness of the underlying Winnipegosis (interreef) strata is approximately 44 m. This thickness is somewhat unusual in comparison with the "normal" interreef thickness of 25-35 m. No core holes have been drilled to the base of the Devonian in the quarry area because of potential problems with high pressure artesian salt water.

References: Bannatyne (1975); Norris et al. (1982); Stratigraphic core holes M-9-70, M-9B-70.

Continue south on Highway 10 for 3.2 km to junction with Pelican Rapids road. Turn east on Pelican Rapids Road.

For the first 3.4 km the road traverses or skirts an upland underlain primarily by Point Wilkins strata, although one inlier of reef-supported stromatoporoidal Upper

Dawson Bay limestone occurs at 1.0 km. The low swampy area to the south is underlain, at least in part, by Mesozoic channel-fill deposits resting on structurally low (i.e. interreef), deeply eroded Dawson Bay strata as indicated by Husky Mafeking DDH #1 (6-16-44-25) (Norris et al., 1982). From 3.4 to 5.6 km, the road becomes undulating as it traverses a topographically high bedding-plane pavement of reef-supported Upper Dawson Bay strata. The sharp topographic drop off to the east also conforms to a bedding dip, as can be seen along the power line right-of-way.

Stop at 5.5 km and walk west on trail to top of large dome.

125.5 STOP 10. Steeprock Road Dome: Upper Member, DAWSON BAY FORMATION.

Outcrop forms a broad, irregular, dome-like topographic high exposing a bedding surface roughly paralleling the topographic surface. This structural/topographic dome is similar to the Lower Dawson Bay dome at Stop 1, but is broader, asymmetrical, and generally more irregular. Drilling at this location intersected a total of 5.2 m of Upper Dawson Bay strata consisting of an upper unit 2.3 m thick of yellowish brown medium crystalline limestone, variably fossiliferous with corals and stromatoporoids. This is underlain by 2.9 m of yellowish brown finely crystalline granular dolomite. Estimated thickness of the underlying Winnipegosis reef is 80 m.

References: Norris et al. (1982); stratigraphic core hole M-7-72.

Continue east on Pelican Rapids road for 0.5 km to picnic area beside Steeprock River.

A small riverbank outcrop at the west end of the picnic area exposes a dolomite bed, part of the First Red Beds of the Point Wilkins Member. A core hole drilled at this location (M-17-81) encountered high artesian flow from Winnipegosis strata, forcing abandonment of the hole before reaching the base of the Winnipegosis. However, comparison with a hole drilled at Stop 11, immediately east of the picnic area, indicates an interreef Winnipegosis thickness of only 42 m, including several interbeds of relatively coarse reef-derived detritus. Hole M-17-81 not only provides one of the few measures of interreef thickness in this area but also permits, for the first time, establishment of the structural profile of an individual reef - the large "pinnacle-type" reef underlying the Lower Dawson Bay dome at Stop 11. The true-scale profile is shown in Figure 15.

Continue east from picnic area, across Steeprock River bridge. Stop at foot of structural/topographic dome 0.2 km past bridge.

126.5 STOP 11. Steeprock Bridge Dome. Lower Member, DAWSON BAY FORMATION.

Outcrop forms a sharply defined structural/topographic dome, circular in configuration and approximately 150 m in diameter. Bedding dips on the flanks of the dome are uniformly 20^{o}, except for the north side which has been truncated. A small salt flat occurs below the truncated flank. This feature is similar to the dome seen at Stop 1, but has a much more prominent topographic expression.

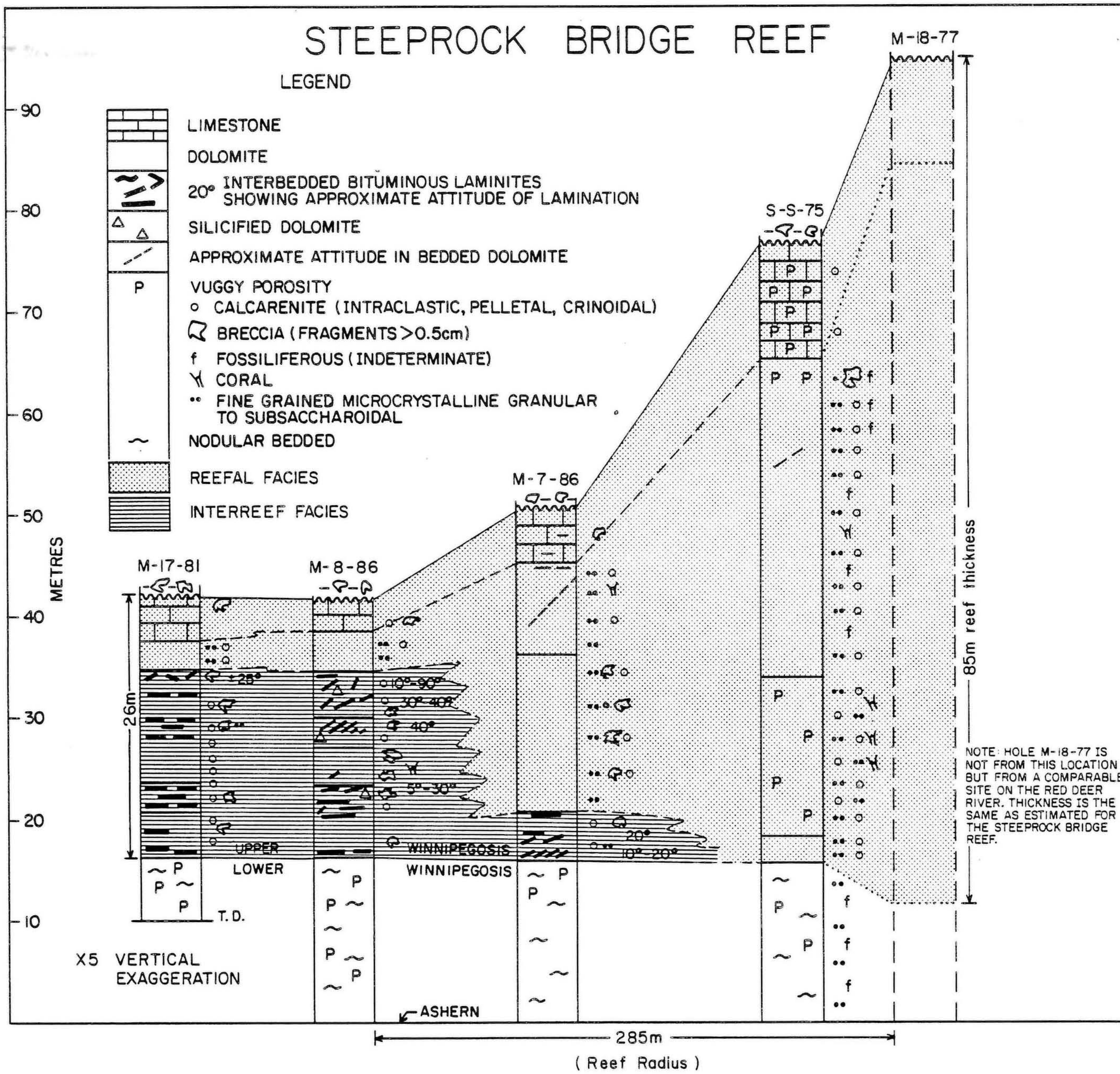
A total of 5 m of variably fossiliferous brachiopod biomicrite is exposed on the truncated face. The top of the underlying reef is not exposed but occurs approximately at lake level. Core hole S-5-75, drilled on the edge of the dome, intersected 76 m of Winnipegosis strata (massive, mostly textureless dolomite) indicating a total reef thickness, at the centre of the dome, of almost 90 m. True reef shape is shown in Figure 15. True diameter of the reef probably is about 400 m. Hole M-17-81 shows a Winnipegosis thickness of approximately 42 m, slightly greater than the estimated "normal" interreef thickness of about 30 m. This particular reef appears to be an isolated, symmetrical, pinnacle-type feature.

Looking northwest from the viewpoint on the top of the dome, several other Lower Dawson Bay reef-supported structural/topographic domes can be seen; the highland in the background is underlain by Point Wilkins strata (indicative of an interreef setting). To the northeast, the mound-like peninsula (Stop 12) is an exhumed Winnipegosis reefal structure, probably comparable to, but somewhat thicker than, the reef underlying this stop. (Figure 16A,g).

References: Baillie (1951); Bannatyne (1975); Norris et al. (1982); stratigraphic core holes S-5-75, M-8-72, M-17-81.

Continue east on Pelican Rapids road.

At 0.7 km past bridge, the road rises over an undulating bedding pavement of Lower Dawson Bay beds comprising the flank of a large, somewhat irregular reef-supported



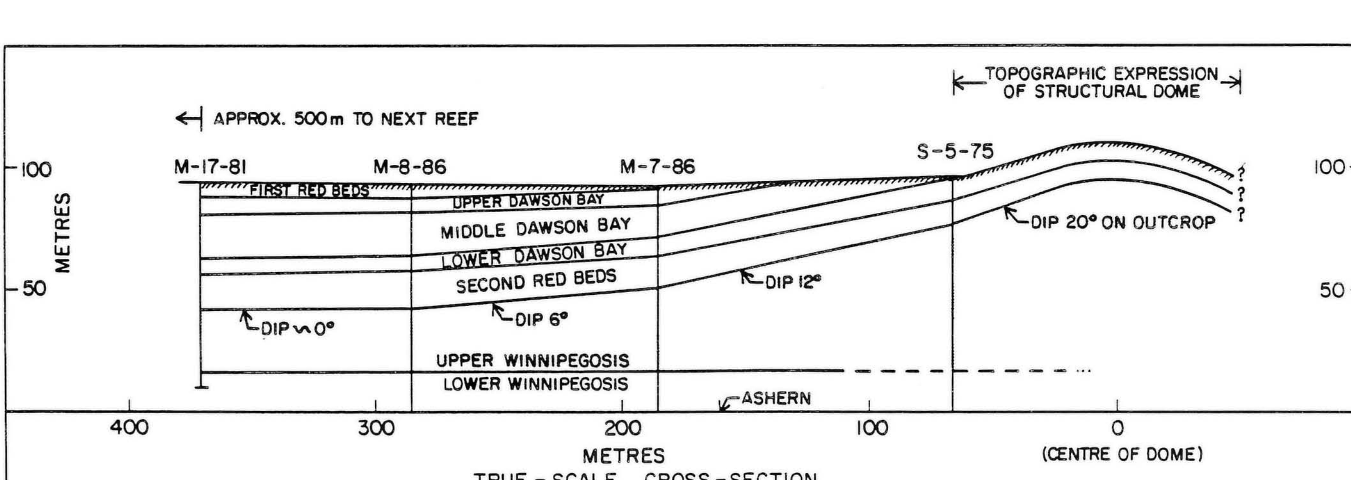


Figure 15. True-scale and exaggerated Devonian reef profiles, Steeprock Bridge Dome (Stop 11)

dome just south of the road (Fig. 16A,h). The irregular shape of this dome (reef) is more similar to that of the dome at Stop 10 than to the dome at Stop 11.

At 2.1 km past bridge, intersection with trail leading north. Turn north and follow right hand trail to shoreline. Caution please; this is a private trail to cottages and access may be limited. Proceed north on foot along shore to shore cliff at north tip of peninsula.

129.1 STOP 12. Steeprock Bay Reef. Lower Member DAWSON BAY FORMATION and Upper Member (reefal facies) WINNIPEGOSIS FORMATION

At the end of the trail, on the southern flank of the reefal dome, truncated Lower Dawson Bay strata are preserved. These beds are seen to dip to the south at about 20^{o}, comparable to the flank dips seen at Stop 11. Although no actual outcrop can be seen between the flanking Dawson Bay outcrop and the shoreline reef exposure, reddish soil between these two outcrops indicates the presence of the recessive shales of the Second Red Beds, and excavation on the top of the mound would probably expose the true cap rock of the reef. Extrapolation of flank dips indicates that at most a few metres of uppermost Winnipegosis strata have been eroded from the shore cliff, although there is no sign of the thin sequence of calcareous transition beds commonly found at the top of the Winnipegosis.

The outcropping Winnipegosis strata thus represent the stratigraphically highest occurrence of any known Winnipegosis beds, and must reflect the final stage in "reef" growth, possibly even a post-reefal stage developed after the main episode of organic development had ceased. The uppermost algal and fragmental beds may possibly have been deposited during the initial stages of increased salinity (and possibly lowered sea level) associated with eventual deposition of the Prairie Evaporite. Compare the lithology of the uppermost beds of this reef with the uppermost preserved, highly organic beds at The Bluff Reef (Stop 2).

A newly exposed, relatively fresh and clean shore cliff consists of approximately 7 m of massive to thick bedded dolomite, relatively flat lying but with a slight dip away from the centre of the outcrop. Dolomitization has largely obscured the primary texture, but the relatively clean weathered surface shows a complex relict texture with laminated algal stromatolites(?) at the top of the section, considerable calcarenite, patches of coarse intraclastic algal breccia forming small channel-type deposits, and several mudstone seams showing contortion and rip-up deformation. Fossils are common, including corals, gastropods and brachiopods (including *Stringocephalus)*. Except for the stromatolitic content, especially in the cap rock, evidence of bioconstruction is not generally apparent, although some loose blocks of coral biolithite, possibly derived from flanking beds, have been noted. Algae may have been the principal sediment-binding factor in this late stage of reefal development.

The Steeprock Bay Reef apparently is a "pinnacle-type", similar in configuration to the reef underlying the Lower Dawson Bay dome at Stop 11. Diameter of the reef, at this level of erosion, as indicated by the diameter of the peninsula, is approximately 300 m, and the estimated total Winnipegosis thickness is approximately 97 m.

Return to junction with Pelican Rapids Road. Turn left (east) and continue on Pelican Rapids Road for 11.4 km to abandoned borrow pit on left side of road, adjacent to Bell River Bay.

"STOP 13": This "stop" includes all outcrops and salt flats on the stretch of road between the Steeprock River and the Bell River Bay Reef, and is intended for viewing only. Most of the outcrops along this portion of the road consist of undulating bedding-plane pavement of Lower Dawson Bay strata, reflecting a complex series of reef-supported structural domes. A number of large salt flats, similar to that seen at Stop 4, occur adjacent to the road and probably are indicative of truncated Lower Dawson Bay domes, although outcrops are lacking.

This stretch of road runs roughly along regional strike for a strike distance of about 12 km, and apparently traverses a large reef complex. Unlike the isolated pinnacle-type reefs seen at Stops 10 and 11, this area appears to consist of a series of closely spaced mounds. The close spacing of these mounds would seem to rule out the possibility that they are individual pinnacle-type reefs, and suggests the presence of a broad, gently undulating but relatively flat-topped reef complex, estimated to average 76-95 m in thickness.

Drilling just north of the Bell River Bridge has shown that the structure of the pre-Winnipegosis strata (i.e. Ashern) is uniform, and that the complex structures seen in the post-Winnipegosis strata are purely "superficial" and related to draping of the Upper Devonian strata over Winnipegosis reefs as a result of solution of post-Winnipegosis - pre-Dawson Bay evaporite beds. (McCabe, Report of Field Activities, 1985).

References: Norris et al. (1982); McCabe (1984, 1985); stratigraphic core holes M-2-84, M-3-84, M-3-85.

Park in borrow pit and proceed on foot to shore. Walk north along winter trail just inshore from beach. Note bedrock pavement along the shore, and small cliffs a few metres inshore.

140.5 STOP 14. Bell River Bay Reef. Lower Member of DAWSON BAY FORMATION and Upper Member of WINNIPEGOSIS FORMATION (reefal facies).

The first outcrop consists of approximately 3 m of typical biomicrite limestone of the Lower Member of the Dawson Bay Formation. These beds are dipping steeply to the southwest at approximately 46^{o}, and represent flanking beds on a partially truncated reef-supported dome. The 46^{o} dip is considerably higher than any dip noted elsewhere for Dawson Bay strata flanking Winnipegosis reefal structures. The outcrop is small and it seems likely that the apparent dip has been oversteepened by slumping. The northernmost shoreline outcrop also consists of Lower Dawson Bay strata on the northwestern flank of the dome. A small cliff approximately 15 m inshore exposes 3 to 5 m of beds dipping to the west at 16^{o}. Shaly dolomites at the base of the cliff represent the upper part of the Second Red Beds.

Between the two Dawson Bay outcrops, in the central portion of the truncated domal structure, are a number of scattered, poorly exposed Winnipegosis outcrops. At the shore, pavement outcrop exposes up to 0.5 m of gently domal bedded dolomite, apparently at the centre of the reefal structure. A short distance inshore, and about 2 m above lake level, is a small poorly exposed 1 m section of almost flat-lying vuggy dolomite (algal calcarenite?). These beds must occur very close to the top of the Winnipegosis reef and possibly are stratigraphically equivalent to the Winnipegosis beds seen at the Steeprock Bay Reef (Stop 12).

246.2 Return on the Pelican Rapids Road to the junction with Highway 10. Turn left (south) and proceed to the town of Swan River. Overnight stop. End Day 1.

Figure 16A. Selected photographs - Dawson Bay Area

(A) Stop No. 1. Roadcut through structural-topographic dome. Structure of Lower Dawson Bay strata, with flanking dips of up to 20^{o}, conforms to configuration of underlying Winnipegosis reef. Topographic dome conforms approximately to structural dome. Note minor normal faulting.

(B) Stop No. 4. Typical small salt flat beside Red Deer River. Small outcrop of truncated Lower Dawson Bay on river bank indicates that salt flat probably is underlain by Winnipegosis reef. Flats range from sterile grey boulder till to black mud with multi-coloured algal coating.

(C) Stop No. 6. Roadcut through Middle Point Wilkins Member, Souris River Formation. Strata form isolated occurrence of Souris River in structurally low interreef setting. Gentle structural undulation reflects Winnipegosis interreef paleotopography.

(D) Stop No. 9. Mafeking Quarry (new), Genstar Ltd. The relatively uniform flat-lying Point Wilkins strata are structurally low, and have been collapsed by a minimum of 70 m as a result of salt solution. The structure reflects the uniformity of Winnipegosis interreef paleotopography. Small upper bench consists of brown granular dolomites of the Upper Point Wilkins.

(E) Stop No. 9. Mafeking Quarry (old), Genstar Ltd. Excavated beds include Point Wilkins argillaceous limestone (lower bench) as well as purer limestones of Middle Point Wilkins.

(F) Stop No. 9. Mafeking Quarry. Typical mottling of the dense micritic limestones of the Middle Point Wilkins Member. Mottling is not indicative of dolomitization.

(G) View northeast from top of structural-topographic dome 0.5 km past Stop 11 on Pelican Rapids Road. Bedding surface of Lower Dawson Bay strata in foreground conforms to configuration of underlying Winnipegosis reef. large mound-like peninsula in right background is exhumed Winnipegosis reef (Stop 12). Several Lower Dawson Bay domes are present in the far left background, and the upland in the distance (on strike) is flat-lying Point Wilkins strata in a structurally low interreef setting.

(H) ("Stop 13"). Undulating roadbed formed by bedding surface of Lower Dawson Bay limestone where road skirts the flanks of the large structural-topographic dome shown in (g) above. Similar bedding plane pavements are common along the Pelican Rapids Road for the next 12 km.

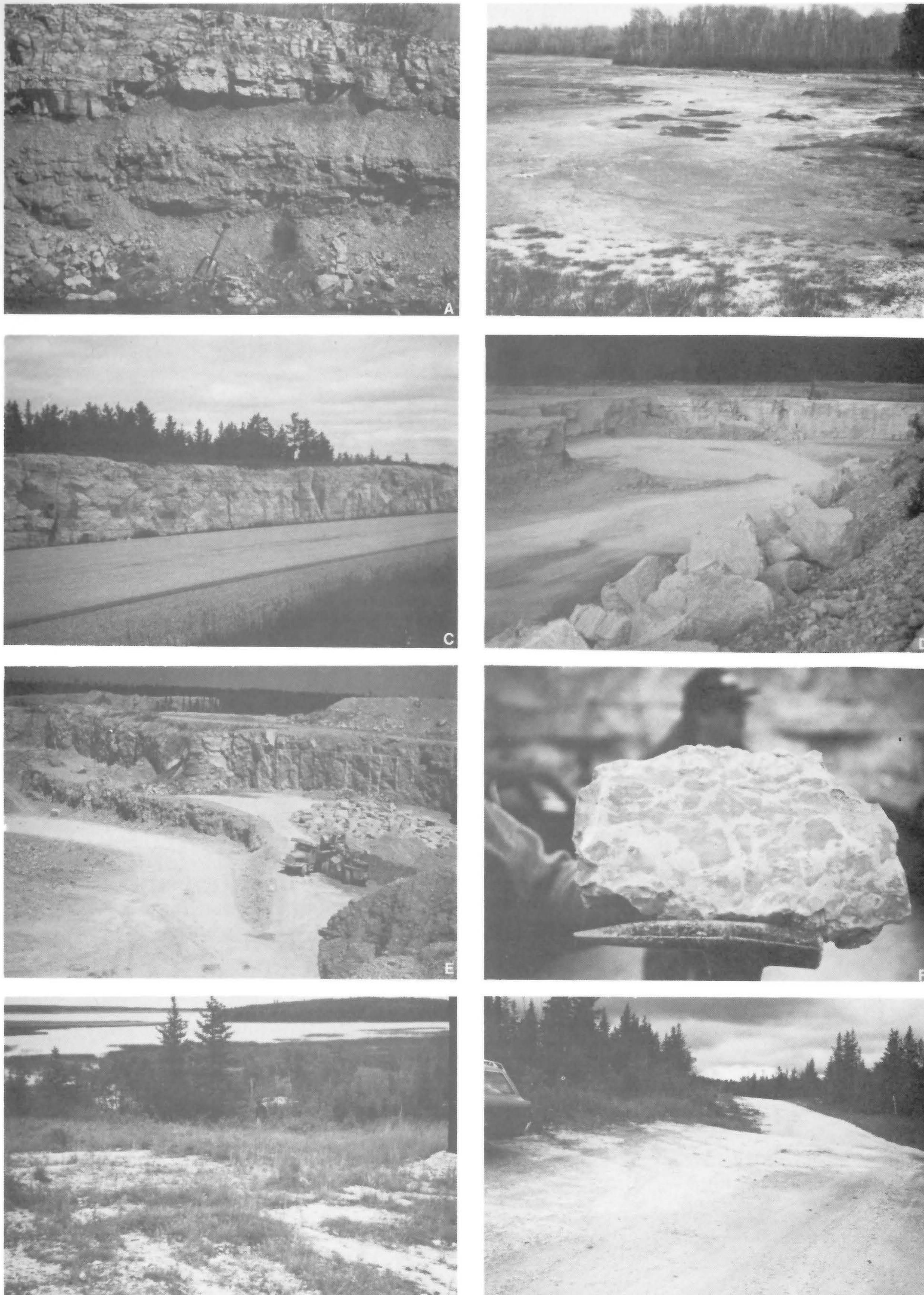


Figure 16A. Selected photographs - Dawson Bay area.

Figure 16B. Selected photographs - Dawson Bay Area

(A) Stop No. 9. Mafeking Quarry. One of the dozen or more large solution (karst) caverns in the Point Wilkins limestones. Cavern was filled with very fine white quartzose sand and clay, probably of Cretaceous age.

(B) Stop A. Salt Point West. Winnipegosis Formation, reef facies. Uppermost strata include 1.5 m limestone cap with prominent cave development at base. Gently domal bedding.

(C) Stop C. Salt Point East. Winnipegosis Formation, reef facies. Gently domal bedding. Nearby flat-lying Dawson Bay strasta indicate reefal mound formed part of a flat-topped reef complex including knobs such as this.

(D) Stop D. Simon Island. Winnipegosis Formation, reef facies. Massive dolomite is the most highly organic of any reef occurrence (dominantly coral-stromatoporoid). Typical exposure is lichen-covered, largely obscuring the textural characteristics.

(E) Stop E. Rock Island. Winnipegosis Formation, reef facies. Another typical klint of highly resistant dolomite showing fair domal bedding. Fauna dominantly coral-stromatoporoid.

(F) Stop F. Mason Island. Winnipegosis Formation, reef facies. Faint bedding shows gently domal structure but with flank dips as much as 30°. Occurrence is typical of the isolated, resistant "klintar" or eroded reef mounds that are found throughout the Dawson Bay area. Dominantly crinoidal.

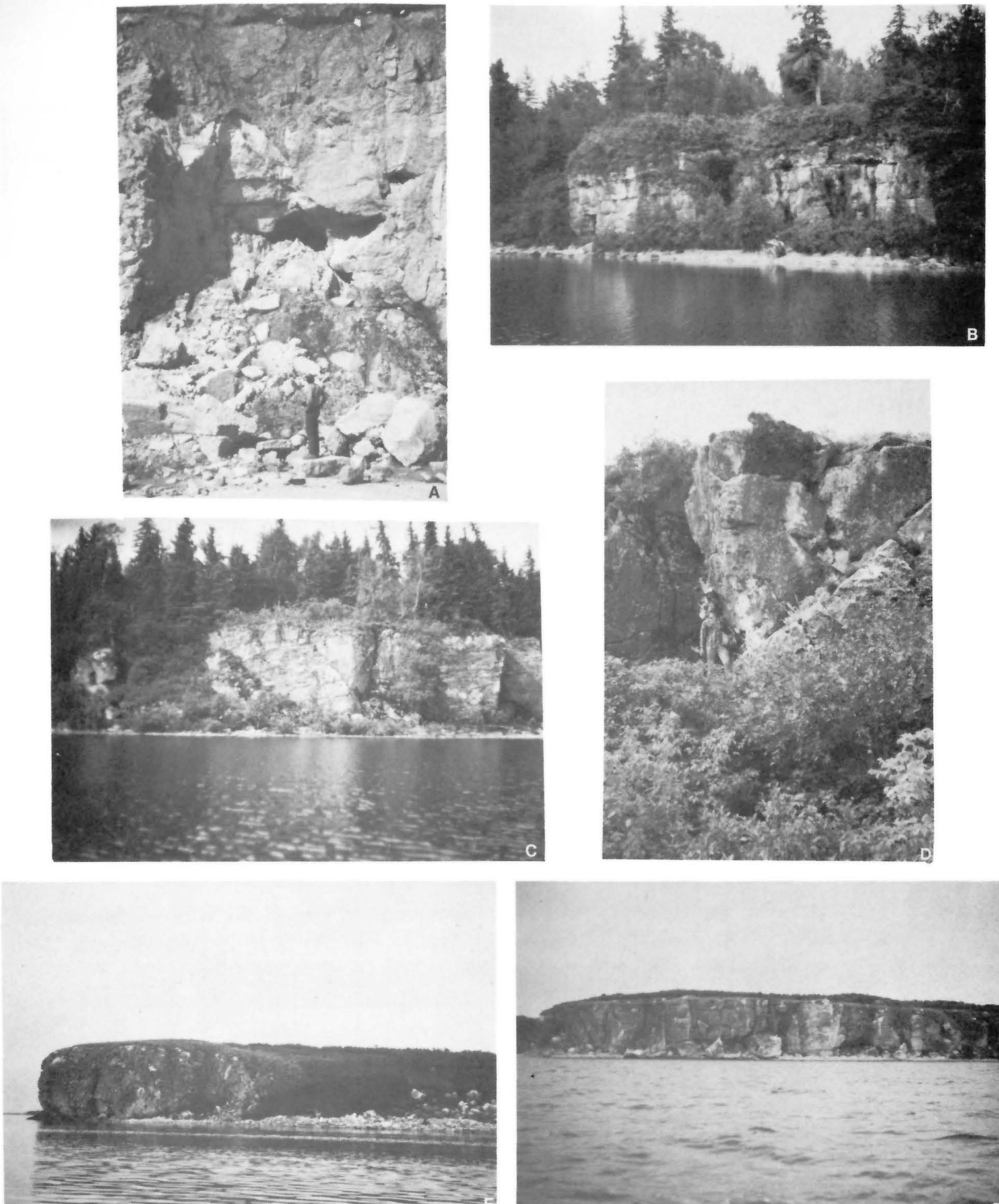


Figure 16B. Selected photographs - Dawson Bay area.

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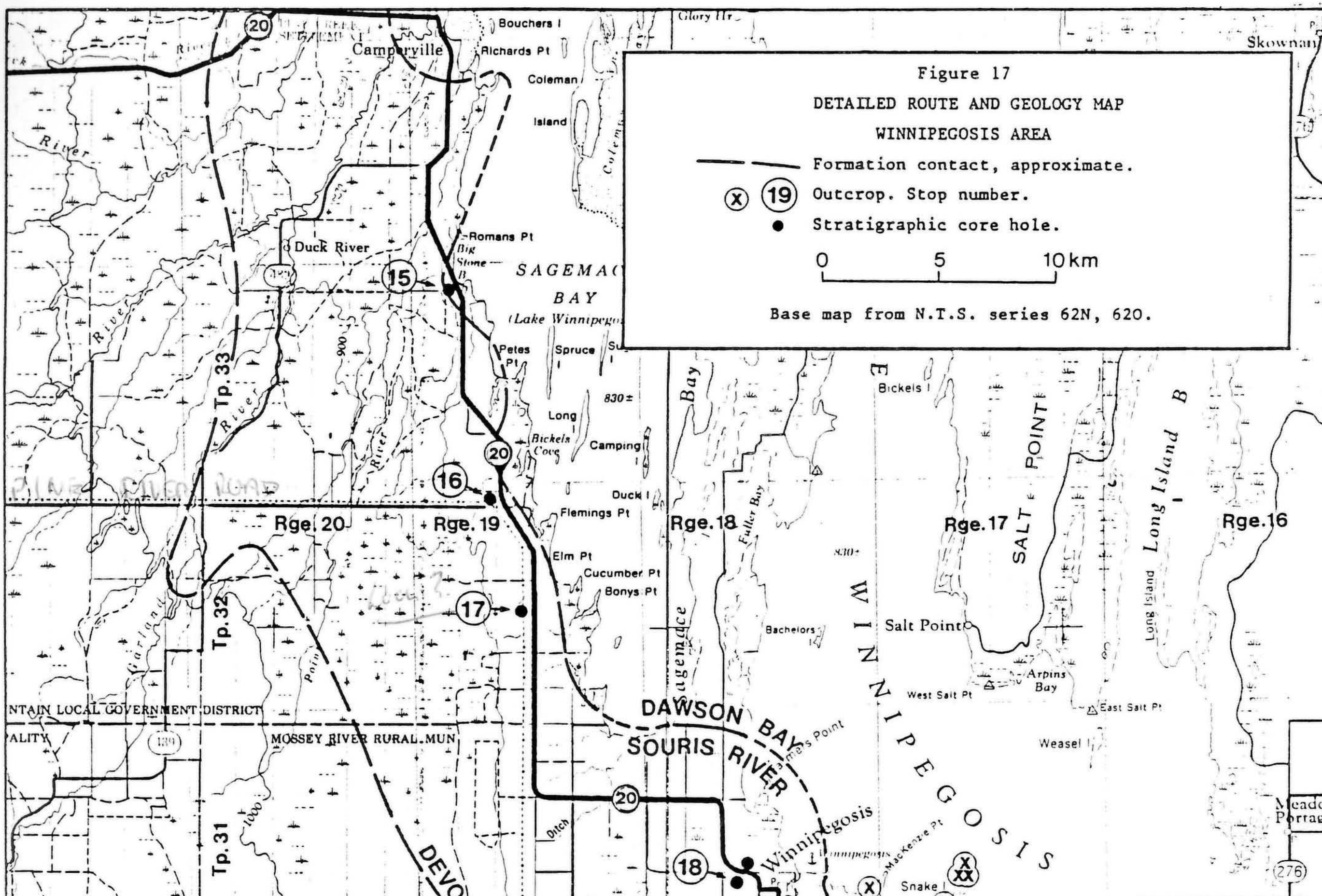


Figure 17. Detailed route and geology map, Winnipegosis area.

3.2 DAY II, Stops A-G, 15-22 (Fig. 14)

Distance

Note: *At this point the sequence of stops becomes conditional on time available and on weather conditions. Weather permitting, a boat trip will proceed from the dock on the west side of the Steeprock Bay peninsula (Stop 12) to selected Winnipegosis reefal outcrops on Salt Point and/or the islands of Dawson Bay. If weather is not suitable for a boat trip, the alternative will involve a walking tour on the Salt Point trail, to Winnipegosis reefs exposed along the north shore of Salt Point (approximately 2 km round trip). These are the same outcrops (Stops A-C) that would be visited by boat. If weather is not suitable for either boat trip or walking trip, continue with Stops 15-22.*

94.0 *Return to Steeprock Bay peninsula by way of Highway 10 and Pelican Rapids Road. On peninsula, take left branch of trail (if not fenced off) and proceed to boat dock.*

This is private property and permission to enter must be cleared with the local Conservation Office at Mafeking. Boat transport will be supplied by chartered fishing boat.

STOP A. Salt Point West. Upper Member, WINNIPEGOSIS FORMATION, reefal facies and transition beds.

Shore cliff 10 m high exposes 7.3 m of Winnipegosis beds showing gently domal structure. The upper 1.5 m consists of rubbly weathering limestone with prominent cave development at the base of the unit. These beds apparently represent uppermost Winnipegosis "transition beds", a zone of limestone and limestone/shale breccia commonly but not always found at the top of the Winnipegosis. The limestones overlie a 6 m section of thick bedded vuggy fossiliferous dolomites, somewhat pisolitic and accretionary in appearance, possibly reflecting vadose diagenesis. In places the dolomite shows thin banding of the fossil content, and the vuggy porosity in large part reflects fossil solution. Caves also occur in this part of the section. A short distance to the south is a moderate sized salt spring with no associated outcrop, then just south of the salt spring a small cliff exposing 3 m of relatively flat-lying Lower Dawson Bay limestones, and south of this another, large salt spring.

STOP B. Salt Point Central: Upper Member, WINNIPEGOSIS FORMATION, reefal facies; salt spring.

A small 6 m cliff about 10 m inshore (behind bushes) exposes a 3.6 m section of dolomite, light grey buff, medium to thick bedded to almost massive, approximately flat lying. Some samples show a very good relict fine calcarenite or intraclastic texture. Approximately 60 m to the west is a small salt spring flowing at an estimated 20-40 litres per minute from gravel immediately back of a bedrock pavement of Winnipegosis dolomite. To the writer's knowledge this is the only natural salt spring directly associated with Winnipegosis outcrop.

STOP C. Salt Point East. Lower Member DAWSON BAY FORMATION and Upper Member WINNIPEGOSIS FORMATION, reefal facies.

This outcrop area provides one of the most important occurrences for determination of Winnipegosis reef-interreef relations and reef configuration.

A number of shore cliffs, up to 14 m high, expose up to 11 m of "reefal" Winnipegosis dolomites showing a gentle domal structure. To the west, an extensive outcrop scarp exposing 6 m of Lower Dawson Bay strata occurs high above lake level (approx. 20 m) and about 60 m inshore. These beds are uniformly flat lying to the southwest, but towards the northeast they rise abruptly at about 15^{o} before being truncated on the flank of the Winnipegosis reef. Although Winnipegosis beds are not exposed beneath the flat-lying Dawson Bay strata, extrapolation indicates that the top of the Winnipegosis should occur about 4-5 m above lake level, and the top of the Winnipegosis must be flat. Thus the Winnipegosis configuration in this area is that of a domal reef structure attaining a height of at least 14 m above lake level (estimated thickness +95 m), dropping off with flank dips of $\pm 15^{o}$ to a flat-topped reefal platform approximately 4-5 m above lake level (estimated thickness 85 m).

The implication of the above is that the Salt Point reef complex (and others?) may comprise a relatively flat-topped reef with scattered (possibly fringing?) mounds rising only 10-15 m above the bank level. This configuration would seem to agree with the previously outlined configuration in the Swan River area (Part I: 3.1.5), and could be likened to an atoll. This contrasts markedly with the apparently isolated pinnacle-type of reef seen at Stops 1, 2, 11 and 12. It also points out the possibility that some of these apparently isolated pinnacles could be merely small mounds sitting on a flat-topped reef complex. Core data for the reef at the Steeprock Bridge Dome, however, (Stop 11, Fig. 15) show that, at least on the west flank of this reef, the Winnipegosis drops off to relatively deep interreef depths. In all probability both "pinnacle" and "atoll" type reefs occur. Further core hole drilling is planned for the Salt Point area to obtain additional data on reef configuration.

Compare the reef configuration for the Salt Point area with the configuration seen to the south, on the Pelican Rapids Road ("Stop 13") and also with the configuration noted for the Paradise Beach area (basin flank) (Stop 20).

Lithologically the Winnipegosis strata consist of buff, microcrystalline to finely crystalline dolomite with some calcareous patches. Bedding ranges from thick to thin bedded, and strata are mostly sparsely fossiliferous with a few moderately fossiliferous interbeds and some coarsely fragmental intraclastic beds. Algal laminations have been noted along with *Favosites* and Stromatoporoids, and abundant large *Stringocephalus* in flanking beds.

Winnipegosis strata exposed at this locality occur close to the top of the Winnipegosis section, probably slightly lower stratigraphically than the sections seen at Stop 12 and Stop A, but with only a few metres of uppermost beds eroded.

STOP D. Simon Island: Upper Member (reefal facies), WINNIPEGOSIS FORMATION

A dome shaped knob of Winnipegosis exposes approximately 7-8 m of massive hard dense, very finely crystalline dolomite with fair to good pinpoint to medium vuggy porosity largely resulting from fossil solution. In places a hint of poor irregular thin bedding can be seen but in general no appreciable internal reef structure is discernible, unlike most other Winnipegosis reefal occurrences, so the exact portion of the reef represented by this outcrop is uncertain.

This Winnipegosis occurrence is the most highly organic of any of the exposed reefs in the Dawson Bay area with large massive and abundant *Hexagonaria* up to 1 m thick (in life position), numerous stromatoporoid colonies and large tabulate coral colonies of *Alveolites*. The rock is almost totally organic where texture is discernible, and is demonstrably bioconstructed - a true reef. Some fine calcarenite interbeds are also present.

The estimated remaining thickness of Winnipegosis at this location is ± 81 m, with approximately 15 m of uppermost reefal beds having been removed by erosion. Estimated stratigraphic position is approximately 65 m above the platform beds.

STOP E. Rock Island. Upper Member (reefal facies), WINNIPEGOSIS FORMATION

Outcrop exposes a total of almost 16 m of section, and has the shape of an elongate dome truncated at the north end. Faint internal bedding indicates a true domal (reef core?) structure, although not well defined. Sedimentary textures are largely obscured and access is difficult, especially with high water conditions (Fig. 16B,f). The Winnipegosis dolomite is pale yellowish brown, microcrystalline, dense to slightly granular with fair pinpoint to medium vuggy porosity. In places a good relict calcarenite texture is evident.

According to Baillie (field notes), the lowest 2 m of beds in the middle of the structure consist of a mass of fragmentary corals along with large crinoid stems and stromatoporoids up to 0.3 m in diameter. Bedding is poorly defined, 2-5 cm, and rock is porous as a result of fossil solution. Towards the top of the section, the rock becomes more massive with abundant corals, and stromatoporoids to 0.6 m diameter. Trilobites, brachiopods etc. also are reported.

Estimated remaining Winnipegosis section is ± 80 m, approximately the same as at Simon Island, with an estimated 10-15 m of upper reefal beds having been eroded. The stratigraphic position of the Rock Island strata is thus the same as or possibly slightly lower than at Simon Island. The difference in lithology may reflect either the slight difference in stratigraphic (paleotopographic?) position or a different position (facies) relative to the overall reef configuration, which is uncertain in this instance. The outcropping strata probably occur stratigraphically ± 65 m above the platform beds.

The occurrence of flat-lying Dawson Bay strata on Dog Island, 3.5 km to the south, should be noted. This indicates the presence of flat-topped Winipegosis reefs similar to those inferred for Salt Point (Stop C) but with a thickness of only about 60 m.

STOP F. Mason Island. Upper Member (reefal facies), WINNIPEGOSIS FORMATION

One of the classic occurrences of a Winnipegosis "bioherm", used by J.B. Tyrrell as the frontspiece in his 1892 monograph on the geology of northwestern Manitoba (Fig. 16B,e). The shore cliff exposes 10-12 m of generally massive dolomite showing fair flanking dips on both sides of dome (reported by Tyrrell as anticline), indicating that the structure represents a reef core facies. Near the south end, dips to the south are as much as 30°.

The core of the dome is richly crinoidal with abundant large intact crinoid stems to 8 cm, and abundant solution cavities to 3 cm. Slump blocks from the inaccessible top portion of the cliff are especially abundant with *Amphipora* in association with crinoids. Tyrrell also reported stromatoporoids, bryozoa, brachiopods, bivalves and trilobites. Section becomes thin bedded and recessive at base of cliffs.

Estimated remaining Winnipegosis thickness is approximately ± 67 m with approximately 30 m of uppermost Winnipegosis beds removed by erosion (assuming uniform reef thickness). These are stratigraphically the lowest Winnipegosis reefal beds that will be seen on this trip, in this area. The exposed strata are estimated to occur ± 50 m above the platform beds.

STOP G. The Big Rock (formerly Steeprock Point, formerly Point Wilkins) Point Wilkins Member (type section) of the SOURIS RIVER FORMATION

Point Wilkins strata form an extensive shore cliff, exposing a total of 28 m of section and extending along the north and east shores of the point for a distance of about 9 km. Almost the entire area of the point consists of Point Wilkins limestone, extending as far west as the Mafeking Quarry. The strata are flat lying to gently undulating, and occur on strike with the previously noted reefal complexes on Red Deer River and Salt Point. This area of Point Wilkins outcrop thus reflects an extensive, relatively uniform and flat interreef area, all of which has been subjected to a minimum of 60 m of salt solution and collapse. The amount of associated deformation is minor, but several occurrences of "fissure breccia" have been reported. The estimated thickness of the underlying Winnipegosis interreef strata is ± 35 m.

The writer has not yet examined these breccia occurrences in detail, but they have been referred to as originating from either salt collapse or karst collapse. From available descriptions it seems more probable that the Point Wilkins breccias represent karst collapse features. Most notably the occurrence of (only?) Point Wilkins strata as breccia fragments, and the occurrence of sand as a matrix material would seem to relate the breccias to the sand-filled karstic solution caves seen at the Mafeking Quarry (Stop 9). Compare also with the chaotic, mixed-lithology megabreccia to be seen at the Winnipegosis Quarry (Stop 18), which can definitely be attributed to salt collapse.

The exposed section consists of a basal unit of 3 m of soft red shale (First Red Beds), overlain by approximately 7 m of buff fossiliferous limestone interbedded with relatively soft fossiliferous shaly beds (Lower Point Wilkins), in places coarsely brecciated, and is overlain by 15 m of light grey to buff mottled dense micritic limestone with abundant fossil fragments (Middle Point Wilkins), also in part brecciated.

Return to dock at Steeprock Bay Reef. End of boat trip.

Optional road or walking trip - Salt Point

If weather conditions prevent the previously outlined boat trip on Dawson Bay, an alternative ground trip can provide access to the Salt Point outcrops (Stops A, B, C). Proceed east on the Pelican Rapids Road (from junction with trail to Steeprock Bay Reef) for 1.1 km to point where road turns right at intersection with newly opened logging trail. Proceed east on logging trail. Follow left (north) branch of logging trail to north shore of Salt Point. Refer to Figure 14 for route of logging trail. In dry weather this trail can be travelled by a truck, 4x4, or A.T.V., but prior to attempting trail one should check with the local Conservation Office at Mafeking. See previous descriptions for Stops A, B and C. Return to junction with Pelican Rapids Road. Total walking/driving distance on logging trail is approximately 15 km.

Return via Pelican Rapids Road to junction Highway 10. Turn right and proceed south on Highway 10 to Town of Swan River. Rest Stop. Continue south on Highway 10 for 48 km to junction with P.R.20. Turn left and proceed east on Highway 20 for 50 km to small abandoned and flooded quarry 24 km south of the village of Camperville.

286.0 STOP 15. Camperville South Quarry. Lower Member, DAWSON BAY FORMATION

A small abandoned and now totally flooded (overflowing) quarry formerly exposed $\pm$ 3 m of dense fossiliferous brachiopod biomicrite, typical of the Lower Dawson Bay. The beds are flat lying. Regional data indicate a very thick, and from the attitude of the quarry beds, flat topped Winnipegosis reef estimated to be $\pm$ 105 m thick. A core hole was attempted at this location but a very heavy flow of brackish artesian water forced abandonment and plugging of the hole before the base of the Winnipegosis could be reached. A large number of salt springs occur in this general area and several can be seen adjacent to the highway.

Continue south on Provincial Road 20 for 11.3 km to junction with road from Pine River. Stop at abandoned quarry on northwest side of intersection.

286.0 STOP 16. Pine River Road Quarry. Sagemace Member, SOURIS RIVER FORMATION

Quarry exposes 2.5 m of slightly calcitic dolomite, mottled yellowish to greyish buff, dense to moderately granular with some blade-like and cubic pores (evaporite solution?), in places finely banded to laminated, with some fossiliferous calcarenite. Beds are medium- to thin-bedded with considerable structural undulation, showing dips of up to 15^{o}. These are stratigraphically the highest known Devonian beds outcropping in southwestern Manitoba (Fig. 12). The quarry is located in a structurally low interreef setting, and core hole M-6-80 at this location intersected a total Winnipegosis section of only 27.7 m. Note the presence immediately north of the quarry of a large salt flat, probably indicative of a thick underlying Winnipegosis reef comparable to that believed to underlie the Dawson Bay strata at Stop 15.

References: Norris et al. (1982); Stratigraphic core hole M-6-80.

Continue south on Provincial Road 20 for 17.7 km to small dry creek bed immediately west of road.

315.0 STOP 17. Sagemace Bay Outcrop: Point Wilkins Member, SOURIS RIVER FORMATION

A poorly exposed intermittent pavement outcrop along the dry creek bed provides one of the very few outcrop occurrences of Point Wilkins strata south of the type section at "Point Wilkins". Beds dip ± 15° to the southwest, exposing approximately 2 m of section consisting of pale yellowish brown slightly mottled and slightly dolomitic, micritic, dense to slightly granular fossiliferous limestone with reddish argillaceous interbeds. Core hole M-6-71 at this location shows that the outcropping strata occur approximately 30 m above the base of the Point Wilkins, and probably within 5 m of the top of the unit. Lithologically the outcropping strata are not greatly different from the type Point Wilkins strata in the Dawson Bay area, but cores from this and nearby holes show rather pronounced lateral lithologic variation in degree of dolomitization, development of stromatoporoidal, laminated and calcarenitic limestones, and in places highly fossiliferous coral biolithite. This contrasts markedly with the apparently uniform lithology in the Dawson Bay area; also, the thickness of the Point Wilkins sequence is considerably less in this southern area (30 m as compared with 45 m). These data suggest a considerably shallower-water, higher-energy environment of deposition for the southern area.

References: Baillie (1951); McCammon (1960); Norris et al. (1982); stratigraphic core hole M-6-71.

Continue south on Provincial Road 20 for 19.3 km to abandoned quarry on south side of road. This is now private property and permission to enter is required.

334.3 STOP 18. Winnipegosis Quarry. Sagemace Member, SOURIS RIVER FORMATION

Two quarries immediately south of Highway 20 expose approximately 6 m of light buff to reddish and purplish grey limestone, medium- to thin-bedded, very fine grained, dense (sublithographic), in part fossiliferous and stylolitic. Beds show gentle structural undulation with up to 2 m of relief. The Winnipegosis quarry beds are about 5 m stratigraphically below the dolomites of Stop 16, so the lithologic difference between the two locations is not unexpected. However, core hole data shows pronounced differences in lithology throughout the entire Sagemace Member; the unit is almost totally dolomitic at Stop 16, whereas at the Winnipegosis Quarry the unit is predominantly limestone. The limited data do not permit an explanation of the pronounced lithologic change.

Note especially the large abutment on the west side of the eastern quarry, directly opposite the entrance ramp. Much of this abutment consists of a chaotic megabreccia resulting from open-cavern salt collapse. The exposed dimensions of this breccia "plug" are 10 x 40 m. The plug does not extend to the east face of the quarry, but another poorly exposed occurrence of breccia near the centre of the western quarry possibly represents a continuation of the breccia plug.

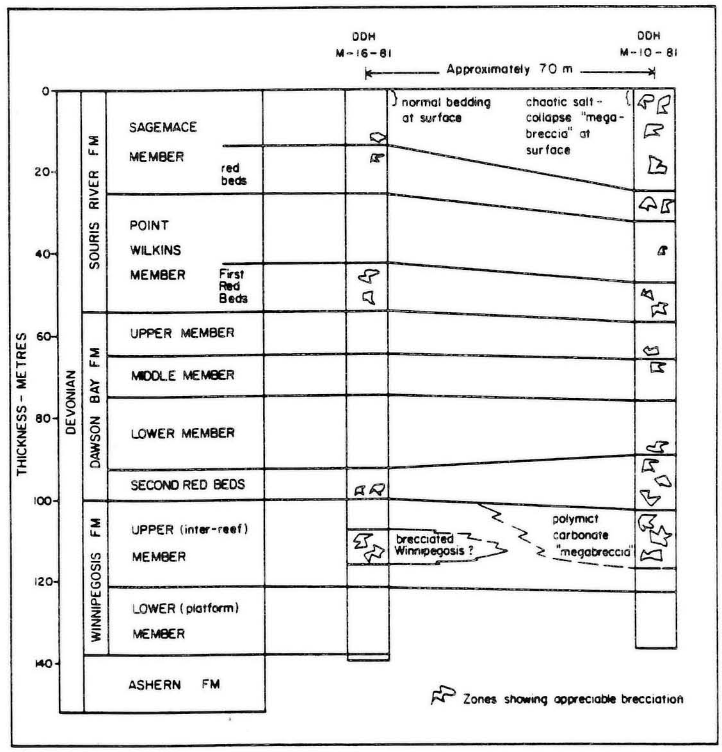
Two core holes have been drilled at this location, one in the centre of the breccia plug and a second in a "normal" area about 40 m north of the plug. Figure 18 shows a cross-section of the two holes and a sketch of the probable sequence of salt collapse. The upper part of the breccia plug consists of monomict breccias that can be correlated stratigraphically with the normal hole; little evidence of vertical mixing is seen. However, the monomict breccias are underlain by a well defined basal unit of mixed breccia containing fragments derived from zones up to 50 m stratigraphically above the mixed breccia zone. This mixed breccia could only have been formed by collapse into an open salt-solution cavern. The "normal" quarry beds also have collapsed (a later event), but with relatively little disruption. The core holes confirmed the presence of a relatively thin interreef Winnipegosis section of only about 25 m, indicating salt collapse in excess of 70 m.

References: Baillie (1951); McCammon (1960); McCabe (1981 Report of Field Activities); Norris et al. (1982); Stratigraphic core holes M-7-70, M-10-81, M-16-81.

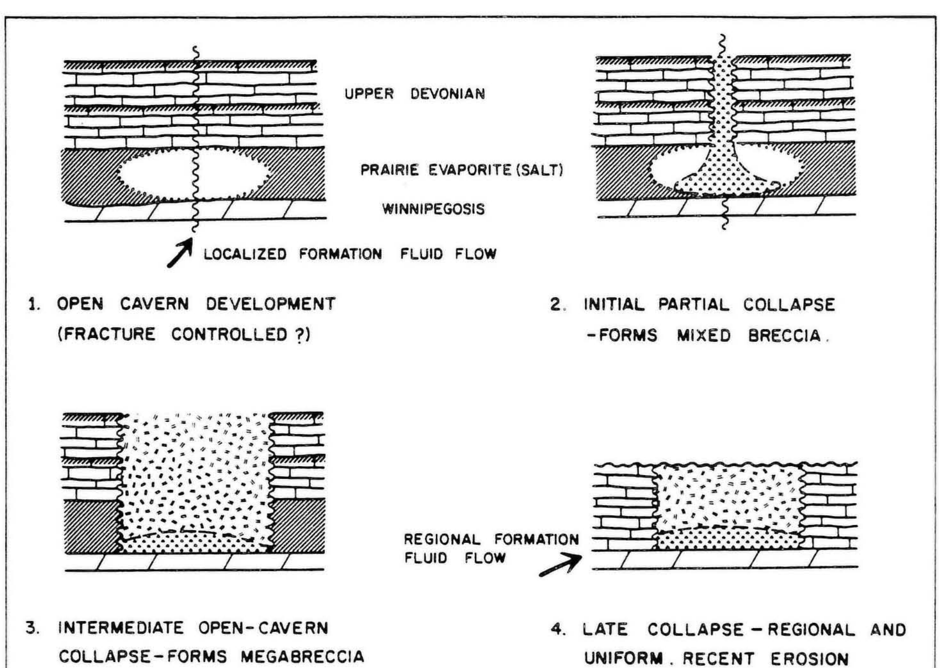
Continue south on Provincial Road 20 for 1.7 km to town of Winnipegosis. Turn lef t (east) a P.R. 364. At south side of town stop at Mossy River Bridge.

337.2 STOP 19. Mossy River Bridge. Sagemace Member ??, SOURIS RIVER FORMATION

Immediately east of the bridge is an exposure of 3 m of thick to thin bedded, light brown to yellowish brown, dense to finely saccharoidal limestone of the Souris River Formation. Exact correlation of these beds is not yet known. Strata dip easterly at about 10°, but downstream outcrops show dips as high as 50°. Minor faulting is evident at the bridge outcrop. The dip of the strata at the bridge suggests draping over a buried Winnipegosis reef, but the 50° dips downstream probably do not reflect reef flank dips. At least some of the structural disturbance in the area must reflect faulting and distortion associated with the salt collapse process, rather than simple draping over a buried reef (compare with collapse megabreccia of Stop 18). Karst collapse also could be involved, as at Stops 9 and G.



Correlation profile, Winnipegosis quarry



Possible sequence of salt collapse events.

Figure 18. Multiple-sequence salt collapse, Winnipegosis Quarry (Stop 18)

This location has not been drilled, but core hole M-4-72 was located a short distance downstream where a small outcrop showed 50° dips. The upper beds of this core are highly brecciated, with dips to 90°, but below about 17 m, the section becomes relatively more massive and uniform with dips of only 10-20°. Although this hole was not drilled deep enough to establish firm correlations, the upper 17 m of the hole is tentatively correlated with the Sagemace Member, and the underlying section with the Point Wilkins. The entire sequence probably represents a collapse breccia, but with little of the chaotic mixing that is evident at Stop 18.

The outcropping beds at the Mossy River Bridge probably are correlative with those in the upper part of hole M-4-72 and are tentatively identified as Sagemace Member.

References: Baillie (1951); Norris et al (1982); stratigraphic core hole M-4-72.

Continue on P.R. 364 for 11.9 km to junction with P.R. 269. Turn left and proceed east on P.R. 269 for 3.2 km to intersection with section road. Turn north on section road for 2.4 km to intersection. Turn right (east) for approximately 1 km to fork in road. Keep left and follow road past an abandoned borrow pit and over several structural topographic domes to Paradise Beach picnic area, on the south shore of Lake Winnipegosis. Three separate outcrop occurrences can be accessed from the Paradise Beach Road.

357.0 STOP 20A. Paradise Beach. Lower Member, DAWSON BAY FORMATION

Pavement outcrops of the Lower Dawson Bay occur along the shore. Beds dip gently to the east and represent flank beds of the broad gentle structural/topographic, reef-supported dome underlying the broad open grassy meadow behind the beach. A second, somewhat higher dome/meadow underlain by Lower Dawson Bay pavement occurs a short distance inshore, along the trail. Several offshore islands also show similar structural/topographic domes, with flank dips commonly in the order of 10°. All Dawson Bay outcrops in this area are reef-supported, and most occur on domal structures, as was the case in the Dawson Bay area. Note, however, the more gentle structural (reef) configuration in the Winnipegosis area as compared to the Dawson Bay area.

The Lower Dawson Bay strata consist of hard, dense, tight brachiopod biomicrite (wackestone), a high-calcium limestone. This lithology is almost identical to that seen in the Dawson Bay area (e.g., Stop 1).

A core hole at this site (M-6-76) intersected 87.5 m of Winnipegosis reefal beds underlying 24.4 m of Lower Dawson Bay red beds and limestone. In contrast, hole M-5-76, located about 8 km to the east intersected only 27 m of Winnipegosis strata including 10.9 m of Upper Winnipegosis bituminous laminites (interreef facies) and 16.1 m of Lower Winnipegosis platform beds. Minimum reef-interreef relief is thus 60.5 m.

Return on Paradise Beach road for 0.8 km to top of highest topographic rise, adjacent to abandoned borrow pit.

357.8 STOP 20B. Paradise Beach Dome. Upper Member. DAWSON BAY FORMATION.

Coral-stromatoporoid limestones of the Upper Dawson Bay form a domal bedrock pavement. The topographically low area between this outcrop and the Lower Dawson Bay meadow is the recessive "outcrop" of the Middle Dawson Bay calcareous shale beds. Although the Upper Dawson Bay beds occur approximately 8 m above the beach outcrop of Lower Dawson Bay, the Upper Dawson Bay strata are 25 m stratigraphically above the Lower Dawson Bay. The Winnipegosis strata underlying this location are thus approximately 17 m thinner than at the beach site (i.e. approximately 70 m).

The coral- and stromatoporoid-rich limestones are almost identical to the correlative Upper Dawson Bay strata seen at Stops 8 and 10 in the Dawson Bay area.

STOP 20C. Paradise Beach Quarry. Upper Member, DAWSON BAY FORMATION

A trail leading northwest from site (b) leads to a broad flat area of bedrock pavement consisting of Upper Dawson Bay strata. These beds appear to be flat lying, but are structurally almost as high as the beds at site (b). The implication is that these beds represent flat-lying strata on top of a flat-topped Winnipegosis reef estimated to be approximately 67 m thick. We thus must have both discrete dome-like reefs and broad, flat-topped, atoll-like reefs in the Winnipegosis area comparable to those seen in the Dawson Bay area but with slightly less reiief and a more gentle configuration (Fig. 12).

A small abandoned quarry (approximately 12 x 24 m) in the broad area of flat-lying Upper Dawson Bay strata exposes 3 m of light brown dense very finely crystalline limestone that is almost totally stromatoporoidal (i.e. a stromatoporoid biolithite). Regional maps show no appreciable thickness variations for the Upper Dawson Bay strata, so the unit must be biostromal in nature rather than biohermal. These stomatoporoidal limestones are exceptionally pure high-calcium limestones, with $CaCO_3$ contents as high as 99.8%.

References: Baillie (1951); Bannatyne (1975, p.75); Norris et al. (1982); stratigraphic core hole M-6-76.

Return on Paradise Road to junction with P.R. 269. Turn left and proceed west for 3.2 km to intersection with road north to Centennial Beach. Stop at intersection.

364.7 STOP 21. Volga Ditch. Middle Member, DAWSON BAY FORMATION

Bedrock pavement in the ditch on the south side of P.R. 269, just past the junction with the Centennial Beach Road exposes approximately 0.5 m of calcareous shale and highly argillaceous limestone, medium greyish red to orange-grey, faintly mottled, poorly bedded with some fossiliferous bands. The Middle Dawson Bay beds are soft and highly recessive, and are rarely exposed in outcrop. The only other known outcrop is at the Red River Bridge (Stop 5) where the basal beds of the unit are exposed. Core drilling at this stop (M-5-71) indicates that approximately 8.5 m of shale beds are present. Total thickness of the Middle Dawson Bay shale, as cored in the Centennial Beach hole (M-6-74) is 12 m. Regional data indicate that the outcrop is structurally high, reef-supported, with an estimated underlying Winnipegosis thickness of 79 m. Attitude is indeterminate.

The presence of this soft, easily eroded shale above the hard resistant Lower Dawson Bay limestones has permitted development of the structural/topographic domes of Lower Dawson Bay seen both in this area and in the Dawson Bay area.

References: Norris et al. (1982); stratigraphic core hole M-5-71.

Turn north on section road to Centennial Beach and proceed north for approximately 1 km to picnic area on a small bedrock knoll.

365.7 STOP 22. Centennial Beach. Upper Member, DAWSON BAY FORMATION

The small open topographic knoll on which the picnic site is located is bedrock supported and, although actual outcrop is limited to a small nearshore occurrence on the northeast flank of the knoll, it is believed to represent another structural-topographic dome comparable to that seen at Stop 20b. Similar gentle structural domes are common on the islands and shoreline of the southern part of Lake Winnipegosis (Fig. 19c). Flank dips on the structures generally are about $\pm 10^{o}$. At one locality, in the southeast corner of the lake, a Lower Dawson Bay dome has been truncated, exposing the uppermost beds of the underlying Winnipegosis reef (Fig. 19d).

Core hole M-6-70 intersected 8 m of Upper Dawson Bay strata of which the upper 2 m consist of fossiliferous stromatoporoidal limestone, and the lower 6 m of granular completely dolomitized limestone. This hole also intersected Upper Winnipegosis reefal beds consisting of vuggy calcarenitic algal and breccia material in places showing bedding inclined at up to 45^{o} to the core axis. High artesian head (estimated 20 m) of salty water forced abandonment of the hole.

Regional data indicate that this stop is structurally high (reef-supported) with an estimated Winnipegosis thickness of about 67 m.

References: Norris et al. (1982); stratigraphic core hole M-6-70.

429.5 *Return to Provincial Road 269. Turn right (west) and continue on 269 to junction with Highway 20. Turn left (south) and proceed on Highway 20 to town of Dauphin. Overnight stop.*

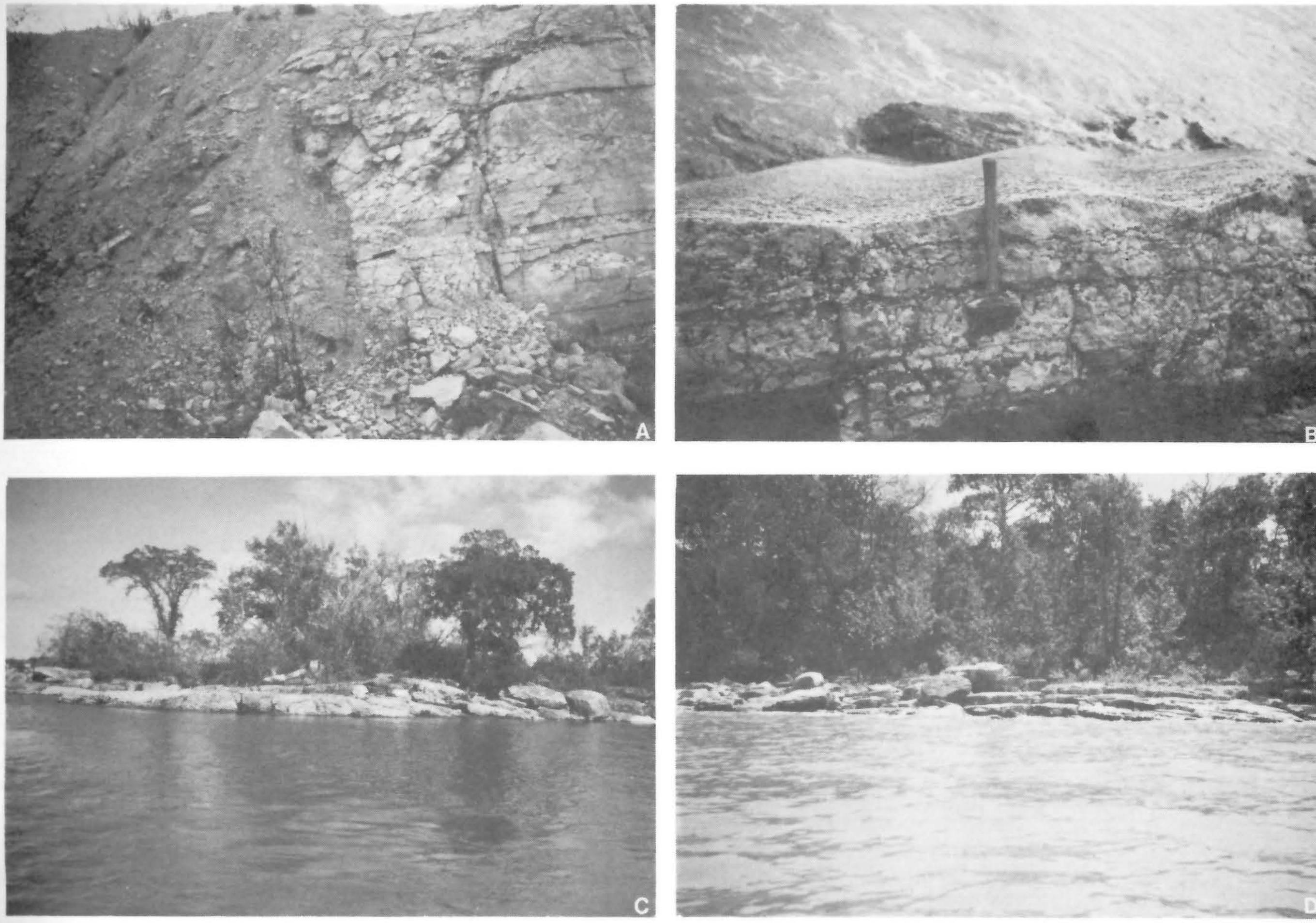


Figure 19. Selected photographs, Winnipegosis Area

(a) Stop 18. Winnipegosis Quarry. Vertical contact between chaotic megabreccia (early salt collapse) and normal, relatively flat-lying Souris River strata (refer to Figure 18), which have also undergone subsequent salt solution and collapse.

(b) Lower Dawson Bay, medium-bedded brachiopod biomicrite (wackestone) showing ripple marked bedding plane surface. From Snake Island at south end of Lake Winnipegosis (2-16-31-17WPM, Fig. 17).

(c) Pine Island, south end of Lake Winnipegosis (3-34-30-17WPM, Fig. 17) showing gentle domal structure in Lower Dawson Bay limestones. Configuration reflects underlying Winnipegosis reef top, comparable to those shown for Dawson Bay area, but with flank dips of only $\pm 10^{\circ}$.

(d) Meadow Portage Reef, southeast corner Lake Winnipegosis (11-33-30-16WPM, Fig. 17). Medium-bedded Winnipegosis ("reefal") strata showing well defined domal structure with flanking dips of $\pm 10^{\circ}$. Truncated Lower Dawson Bay strata occur on both flanks of the reef indicating only slight erosion of the uppermost Winnipegosis beds. Estimated reef thickness is ± 94 m, almost as thick as the Dawson Bay area reefs.

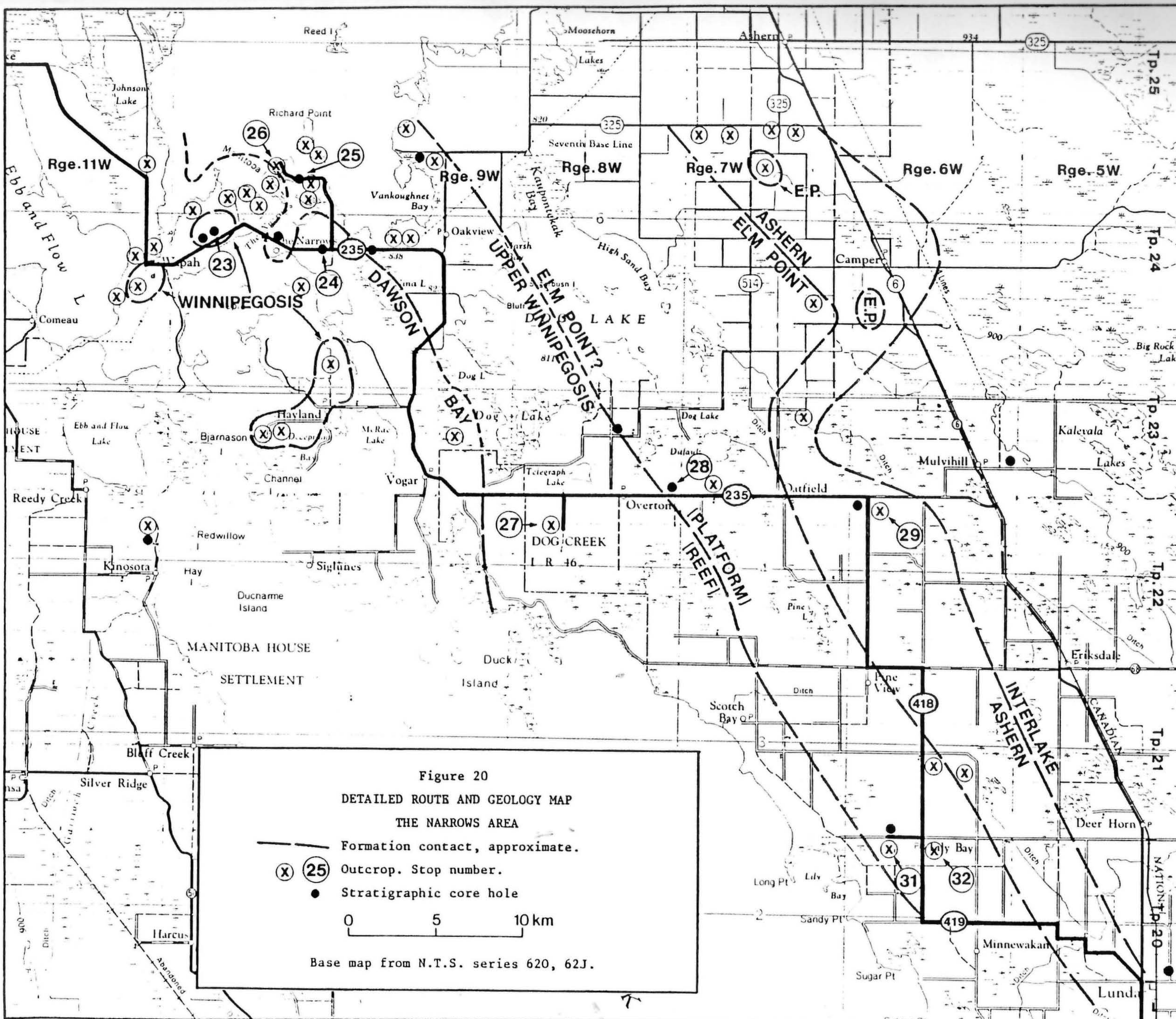


Figure 20. Detailed route and geology map, the Narrows Area

DAY III

Distance - km

0 *Proceed east from Dauphin on Highway 5 to junction with P.R. 235. Continue east on P.R. 235 for 67.1 km to quarry 1.6 km west of The Narrows causeway.*

114.7 STOP 23. Narrows West Quarry. Upper Member (reefal facies), WINNIPEGOSIS FORMATION

Quarry located on top of a broad gentle topographic dome exposes approximately 4 m of medium- to thick-bedded dolomite showing gentle structural undulation that probably reflects primary depositional topography. The lower beds are fine grained sparsely fossiliferous, and pass upwards to increasingly fossiliferous orange-brown wackestone, with several interbeds of packstone dominated by molds of the large brachiopod *Stringocephalus*, and showing excellent fossil solution porosity. The section is capped in places by fine grained, finely laminated algal (?) dolomite showing fenestral porosity. Detailed mapping of the quarry by Davison (1981) showed that significant lateral and vertical lithofacies changes occur within the bedding-defined units. Skeletal wackestones and boundstones are associated with the structurally higher locations, and mudstones are common in the depressions, which also may contain lenses of packstone. The abundant fauna include corals *(Disphyllum, Favosites, Coenites, Mesophyllum)*, stromatoporoids *(Amphipora, Actinostroma, Stromatoporella)*, brachiopods *(Stringocephalus)*, molluscs, cephalopods, bryozoa and echinoids.

The broad topographic rise on which the quarry is located probably reflects a structural/topographic dome similar to those seen in the Dawson Bay and Winnipegosis areas, but with a much more gentle configuration. Poorly exposed ditch outcrops to the southwest suggest a gentle dip in that direction (less than 5°), and flanking Lower Dawson Bay strata can be seen to the north, on the lakeshore (Fig. 21b), and also to the southwest. Drill holes at the site failed to reach the base of the Devonian because of drilling problems associated with sand-filled caves, but regional data indicate a total Winnipegosis thickness of only about 30-35 m. This broad gentle reef or mound apparently occupies a shelf-edge position, a short distance northwest of the fringing bank (Fig. 7b).

Compare the gentle "reef" configuration (dips $\pm$ 5°) and low relief (30-35 m) with the progressively more pronounced reef topography seen to the northwest in the more basinal areas of southern Lake Winnipegosis and Dawson Bay.

Very little erosion of Winnipegosis strata has occurred at this locality as shown by preserved flanking deposits of Lower Dawson Bay. The preserved quarry beds probably are close to the true depositional top of the "reef" and must represent a late stage in "reef" growth. Most likely they represent a post-bioherm stage of biostromal development, as suggested in the introductory section. Contrast this occurrence with the section to be seen at the Rosehill Quarry (Stop 25) where a massive biohermal core with flanking beds dipping at 20° possibly reflects an earlier, possibly biohermal phase of "reef" development.

References: Davison (1981); Norris et al. (1982); stratigraphic core hole M-5-69 (3-21-24-10 WPM).

Continue east on P.R. 325 for approximately 7.2 km. Stop just before intersection with Richards Point Road (north).

121.9 STOP 24. Narrows Ditch. Lower Member, DAWSON BAY FORMATION

Ditch pavement exposes a flat bedding-surface of greyish red to yellowish brown microcrystalline dense, almost lithographic limestone, thin bedded and fossiliferous in some beds. Note particularly the delicately frilled brachiopod *Atrypa*. These beds were not present in the Lower Dawson Bay section seen in the Dawson Bay area (e.g. Stop 1). In this southern area, highly fossiliferous brachiopod biomicrites, the same as seen in the north, are underlain by sparsely fossiliferous micrites, as seen at this stop, which are in turn underlain by brown, partly laminated micrograined dolomites (Fig. 13). This added section results in southward thickening of Lower Dawson Bay strata from about 10 m in the northern area to 20 m in the south.

At this location, Dawson Bay strata are preserved in a structurally low interreef setting. Estimated Winnipegosis thickness is only about 35 m.

References: Baillie (1951); McCammon (1960); Norris et al. (1982); stratigraphic core hole M-9-69.

Turn north on Richards Point Road for 4.2 km, then west for 1.0 km to abandoned lime kiln adjacent to small abandoned and largely overgrown quarry.

127.1 STOP 25. Rosehill Quarry. Upper Member (reefal facies), WINNIPEGOSIS FORMATION

Small quarry approximately 2 m deep, immediately south of road exposes medium-bedded reef-flank dolomites dipping north at approximately 20°. About 150 m to the south, just east of a newly cleared section line, a small pit exposes a massive, tough fossiliferous dolomite probably representing a "reef core". A core hole at the quarry site (M-1-72) intersected 27 m of Upper Winnipegosis dolomite underlain by 20 m of partly dolomitized Elm Point limestone (i.e. Lower Winnipegosis platform beds). Partial dolomitization of the Elm Point beds possibly may reflect proximity to the Winnipegosis reef core.

This is the only known outcrop exposure showing well developed internal reef flank structure. Another small quarry just east of the Narrows causeway at one time provided an even better example of internal reef structure, showing beds dipping off at 20° on both the western and southern flanks of a relatively massive core. This quarry unfortunately has been partially infilled, and the bedding almost entirely obscured, but it nevertheless provides evidence that the reef flank bedding seen at Rosehill is probably the normal reef structure in this area.

The occurrence of such relatively steep internal dips within the gentle mound-like "reefs" in the Narrows area seems highly significant. Such bedding seems to suggest that even in this relatively shallow basin-margin environment, the early stages of reef growth were truly biohermal. These bioherms subsequently evolved by lateral reef growth or accretion into the broad gentle mounds we see today.

Continue west on the Richards Point Road for about 2 km to the Gunnlaugson farm. This is private land, the road is gated, and permission to enter is required.

129.1 STOP 26. Gunnlaugson Farm Reef. Upper Member (reefal facies), WINNIPEGOSIS FORMATION

Several small bedrock mounds are exposed in the pasture, and others occur in the nearby woods. Baillie (1951) reports that a total of about 20 such mounds occur in the area, some up to 10 m long and 1 m high. The mounds appear to trend northeasterly at approximately 25° roughly parallel to the postulated depositional trends in this area (Fig. 7b). They are believed to be algal in origin, and stromatolitic structures are evident, particularly in the middle mound. The small algal mounds scattered around the Gunnlaugson farm represent minor features within the larger mound or reefal structure, reflected topographically by the Gunnlaugson peninsula. The "Gunnlaugson Reef" appears to represent a separate reefal feature, as do the Rosehill Reef (Stop 25), the Narrows East Reef, and the Narrows West Reef (Stop. 23).

Drilling at the nearby Rosehill Reef suggests that the total Winnipegosis thickness at Gunnlaugson Farm is approximately 45 m (partly eroded). The relief of this mound above the interreef areas is in excess of 15 m, as evidenced by the occurrence of Lower Dawson strata in the structurally low (salt solution) interreef areas (Stop 24).

The relative stratigraphic position of the Gunnlaugson Reef beds is uncertain. The structurally updip position of the reef would seem to indicate that the algal dolomites of the Gunnlaugson Reef should occur stratigraphically below the biostromal beds of the Narrows West reef (assuming uniform reef thicknesses). However, the occurrences of algal beds at the top of the Narrows West reef section suggests that the algal dolomites could be younger. This would seem to fit the model noted for the Dawson Bay area. The dipping reef flank beds at the Rosehill Quarry definitely appear to be older than either the Gunnlaugson or Narrows West beds. More data are required, however, to determine a definite sequence of reef evolution in this area.

Return to P.R. 235 and continue east and south for 34 km (7 km past town of Vogar) to intersection with trail to south (soft when wet). Optional side trip. Proceed south for 1.9 km to access trail to quarry west of road.

163.0 STOP 27. Dog Lake Quarry. Upper Member(?), WINNIPEGOSIS FORMATION

Quarry exposes approximately 3 m of medium- to thin-bedded, very finely crystalline, sparsely fossiliferous dolomite. No drill data are available for this location, but regional data indicate a Winnipegosis thickness of about 35 m. This is appreciably greater than the 20 m of Lower Winnipegosis strata intersected at the Rosehill Reef or the 26 m at the Dolly Bay core hole, and suggests that the

Dog Lake quarry beds probably are Upper Winnipegosis, but near the base of the section.

A Lower Dawson Bay limestone outcrop occurs almost on strike 6.4 m to the northwest, suggesting a "reefal" setting for the Dog Lake beds, but the lithology does not appear to be reef related. Possibly these strata represent Upper Winnipegosis interreef beds that are thicker than normal due to nearby reef buildup (i.e. proximal facies).

Return to P.R. 235 and continue east for 8.0 km to access trail to abandoned quarry, north of road.

170.0 STOP 28. Overton Quarry. Lower Member (platform facies), WINNIPEGOSIS FORMATION

Quarry exposes approximately 5 m of dolomite, medium light yellowish brown, mottled, finely crystalline slightly granular with large yellowish coarsely granular patches as well as small darker grey mottles (burrows?) and faint relict fine calcarenite texture. It is thick bedded to massive in upper part, becoming thinner bedded towards base. A large sand-filled channel occurs in the northeast corner, overlain by till, and several other lenses and pockets of sandy shaly material have been noted; this material possibly represents Cretaceous infill of incipient karst solution features.

Core hole M-8-81 at this location intersected 13.3 m of vuggy granular dolomites underlain by 7.6 m of dolomitic limestone grading downward to dolomite. Regional data indicate that the entire section is Lower Winnipegosis and represents a dolomitized facies of the Elm Point Formation. (Dolomitization possibly reflects proximity to a reef site that is now eroded.)
References: Stratigraphic core hole M-8-81.

Continue east on P.R. 235 to intersection with north-south road 4.9 km past junction with P.R. 418. Turn south on section road for 0.6 km to large inactive quarry, east side of road, completely fenced off.

183.3 STOP 29. Oatfield Quarry. SILURIAN DEVONIAN Unconformity

Quarry exposes 1.5 m of red argillaceous dolomite or dolomitic shale of the basal

Devonian Ashern Formation, resting with sharp but uniform unconformity on 2 m of massive to faintly thin bedded hard dense finely crystalline dolomite of the Silurian Interlake Group. The dolomite appears highly organic, but the texture has been obscured by dolomitization. Only slight gentle relief is evident on the unconformity surface, a maximum of about 1 m for the entire quarry area. A thin zone of basal dolomite breccia can be seen in places, and unusual large (1-2 cm) clay-filled vermiform solution channels cut the underlying dolomite. The red Ashern coloration has been reduced locally to pale greenish grey along fractures, and where the quarry face consists largely of bleached fracture faces, the unconformity is largely obscured.

The unconformity spans the stratigraphic interval from Middle Silurian to Middle Devonian, and as much as several hundred metres of Upper Silurian strata may have been eroded.

From this point an optional side trip can be taken to the large limestone quarries in the Elm Point Formation at the town of Steep Rock.

Return to Provincial Road 235 and continue east to the junction with Highway 6. Turn left and proceed north for 58 km to junction with road to Steep Rock. Turn left and proceed west to town of Steep Rock where two large quarries are located.

STOP 30. Steep Rock Quarry. ELM POINT FORMATION (Lower Member, Winnipegosis Formation)

Two large quarries as well as shoreline outcrops can be seen in the Steep Rock area. About 3 km southeast of the town of Steep Rock, is the Faulkner Quarry of Steel Brothers Ltd., where high-calcium limestone is quarried and burned to produce high-calcium lime (quicklime).

Along the lakeshore west and north of town, shoreline cliffs expose up to 6 m of the Elm Point Limestone. Elm Point itself is located on the lake about 6 km south of the town of Steep Rock, so this area is the type section area for the Elm Point Formation as defined by Kindle (1914, pp. 231-255).

The oldest quarry in the area is the Canada Cement LaFarge quarry immediately east of town. High-calcium limestone has been produced for many years for the cement plant at Fort Whyte in Winnipeg, and now more recently for the Genstar plant in Winnipeg. Detailed descriptions of the quarry are provided in Baillie (1951), Bannatyne (1975) and Bannatyne and Watson (1982).

The quarry exposes approximately 13 m of high-calcium limestone (0.7% MgO), pale yellowish brown with faint variable yellowish grey mottling, variably fossiliferous with corals, brachiopods and bryozoa, very finely crystalline and dense (a sparse biomicite or wackestone).

Mottling apparently reflects incipient recrystallization associated with the earliest stages of dolomitization. The rock is still a high-calcium limestone but a few fine crystals of secondary dolomite occur in the lighter mottles. Compare this with the more intense mottling and much higher degree of dolomitization to be seen at the Lily Bay quarry (Stop 31). Strata are medium to thin bedded, at places stylolitic, and bedding shows minor gentle undulation but is essentially flat lying. A small pit at the northeast corner of the quarry exposes argillaceous beds of the underlying Ashern Formation, but the pit is usually full of water.

References: Baillie (1951); Bannatyne (1975); Norris et al. (1982).

Return via Steep Rock Road, Highway 6 and P.R. 235 to Oatfield Quarry.

Continue south for 3.8 km to intersection with P.R. 418. Proceed south on P.R. 418 for 17.7 km, to east-west section road (just north of small abandoned church). Turn west on section road for 1.7 km to inactive quarry, south side of road.

206.8 STOP 31. Lily Bay Quarry. ELM POINT FORMATION (= Lower Member, Winnipegosis Formation)

Now abandoned, the quarry previously supplied high-calcium (but not high quality) limestone to the Cement LaFarge cement plant in Winnipeg. Quarry exposes 4.5 m of limestone. The upper 3 m is prominently mottled yellowish grey to yellowish brown, with the brownish granular patches strongly dolomitized. Intensity of mottling and degree of dolomitization decrease downward. The limestone is a hard dense fossiliferous micrite. Note the thin 8-10 cm interbed of undolomitized conglomeratic limestone. Approximately 1.5 m above the base of the exposed section a fairly sharp change occurs, to a faintly mottled, slightly reddish grey, almost non-dolomitic limestone. Brachiopods are abundant at the top of this unit.

Note the clean glaciated bedrock surface exposed near the quarry ramp. When wet, this bedding surface can be seen to be almost totally coralline.

A core hole immediately northeast of the quarry (M-2-70) intersected a total of 12.8 m of Elm Point limestone above the Ashern Formation. These limestones showed an appreciably lower overall degree of dolomitization. The beds in the Lily Bay quarry are thus seen to represent an intermediate stage of dolomitization of the Lower Winnipegosis platform beds, part way between the almost pure high-calcium limestone quarried at Steep Rock (Bannatyne, 1975), and the almost totally dolomitized strata seen at the Overton Quarry (Stop 14).

References: Core hole M-2-70; Bannatyne (1975).

Return to P.R. 418. A short distance southeast of intersection is a small abandoned aggregate quarry just recently excavated.

208.7 STOP 32. Lily Bay East Quarry. ELM POINT/ASHERN Contact

This is a new quarry and has not yet been examined in detail. Approximately 5 m of thinly bedded variably mottled, slightly dolomitic limestone (biomicrite) of the Elm Point Formation (Lower Winnipegosis equivalent) overlies 2 - 3 m of grey to red dense argillaceous dolomite and dolomitic shale of the Ashern Formation. The contact between the two units is smooth and gently undulating but appears to mark a (minor?) unconformity as evidenced by a thin clayey break, a pronounced change in lithology, and partial bleaching and colour alteration of the underlying dense argillaceous dolomites, which show a distinct intraclastic texture in places.

Continue south and east on P.R. 418 to junction with Highway 6 at Lundar. Proceed south for 22 km on Highway 6. Small abandoned quarry and kiln immediately east of Highway.

254.4 STOP 33. Oak Point Quarry. ELM POINT FORMATION

The small quarry exposes approximately 2 m of thin bedded yellowish brown mottled slightly dolomitic limestone (fossiliferous micrite). The degree of dolomitization is about the same, or possibly slightly less than seen in the upper part of the Lily Bay quarry. A core hole at this location (M-2-80) intersected 5.75 m of Elm Point strata above Ashern red beds.

References: Core hole M-2-80; Baillie (1950); Bannatyne (1975).

329.0 *Continue south on Highway 6 to junction with Winnipeg Perimeter Highway 101. End of log.*

Figure 21. Selected photographs, The Narrows Area

(a) Stop 31. Lily Bay Quarry. Thin-bedded, prominently mottled Elm Point Formation (i.e. Lower Winnipegosis equivalent), partially dolomitized facies. Darker patches are medium brown dense high-calcium biomicrite. Lighter patches are finely crystalline moderately granular dolomite with scattered relict calcareous fossil fragments.

(b) Thin-bedded Lower Dawson Bay strata outcropping on lake shore north of Stop 23, dipping gently to the north ($\pm$ 5°). These strata occur on the flank of the Narrows West Reef, about 2.5 km northeast of the quarry. Flat-lying Lower Dawson Bay limestone representing structurally low interreef strata occur a short distance to the northeast, on Manitoba Island.

(c) Stop 22. Lily Bay East Quarry. Flat-lying medium- to thin-bedded mottled dolomitic limestones of the basal Elm Point Formation resting with slight unconformity on red argillaceous dolomites and dolomitic shales of the Ashern Formation.

(d) Stop 29. Oatfield Quarry. Red argillaceous dolomites of the Ashern Formation, partially bleached (reduced) to light grey-buff along fractures, resting unconformably on fossiliferous dolomites of the Silurian Interlake. The large Silurian block in the foreground shows unusual vermiform, clay-filled solution channels. The unconformity is relatively uniform around the perimeter of the quarry.

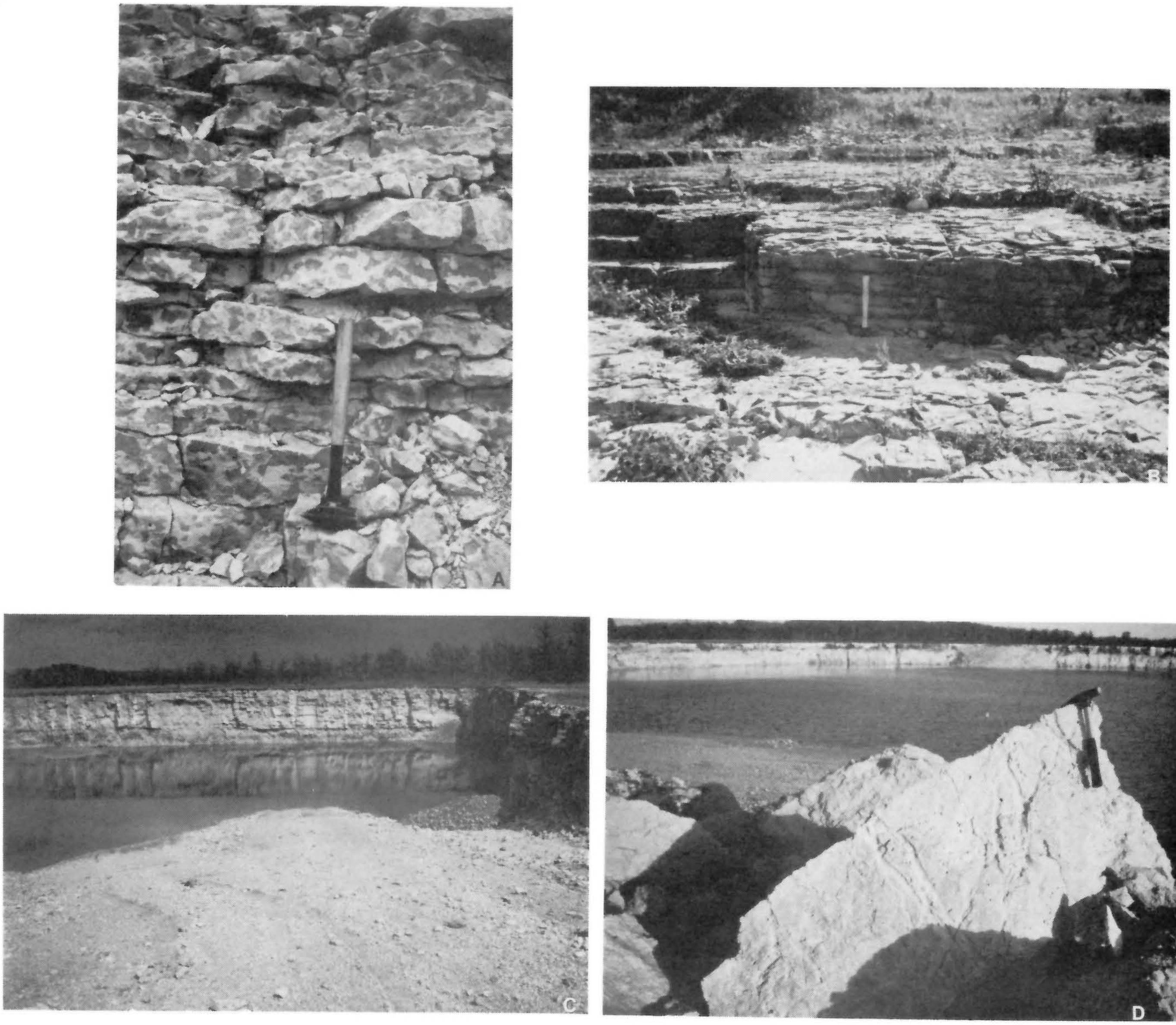


Figure 21. Selected photographs, The Narrows area.

Figure 22. Selected photographs, Winnipegosis and Elm Point Formations, core samples.

Elm Point Formation (= Lower Winnipegosis Platform)

Sample 1. M-1-72/45.3 m (Rosehill reef, Stop 25): Limestone, dolomitic, mottled light grey to slightly darker brown, biomicrite. The lighter patches are highly dolomitized except for contained fossil fragments, The darker patches are limestone with only minor disseminated dolomite grains. Dolomite content is much higher than normal for the Elm Point, and is transitional to Winnipegosis-type lithology.

Sample 2. M-1-72-39.1 m: Limestone, dolomitic, as above, but with somewhat sharper delineation of mottling. Dark patches are pure high-calcium limestone with only about 1 per cent disseminated dolomite crystals.

Sample 3. M-1-72-29.9 m: Dolomite, mottled, calcareous, biomicritic, as above but with much higher degree of dolomitization (approx. 75%). Sample from interbed within the Elm Point, about 3 m below the contact with the Winnipegosis.

Winnipegosis Formation, Upper Member, Reef Facies

Sample 4. M-7-73/18.1 m (Overflowing Bay Reef, Stop 3, central location): Dolomite, massive, pale grey-buff, very finely crystalline, highly granular with good pinpoint and intergranular porosity. Faint relict fine calcarenite texture with scattered, poorly preserved fossil fragments. Lithology is typical of much of the central reef deposits.

Sample 5. M-7-73/37.8 m: Dolomite, stromatoporoid (fragment?), very pale buff, microcrystalline, fair pinpoint porosity. Stromatoporoidal structure is barely visible as vertical, curved laminae on stained face of core. Typical of poor preservation in dolomitized beds.

Sample 6. M-12-71/17.1 m: (Overflowing Bay Reef, Stop 3, flank location): Dolomite, light buff, microcrystalline, dense but with good pinpoint to fine vuggy porosity aligned parallel to faint banding. Faint relict fine to medium calcarenite texture suggestive of algal remains. This type of lithology occurs near the tops and flanks of reefs. Inclination 45° to core, internal flank dip.

Sample 7. M-6-70/48.2 m (Centennial Beach Dome, Stop 22, near-flank location): Dolomite, as above, but texture better preserved; medium to coarse algal calcarenite. Inclination 40° to vertical core axis, internal flank dip.

Sample 8. M-7-73/4.0 m: Dolomite, biorudite, medium light buff, massive, recrystallized to microcrystalline, dense, but with excellent fine to medium interfragmental porosity. Abundant fossil fragments, especially corals (cf. *Coenites*) and brachiopods.

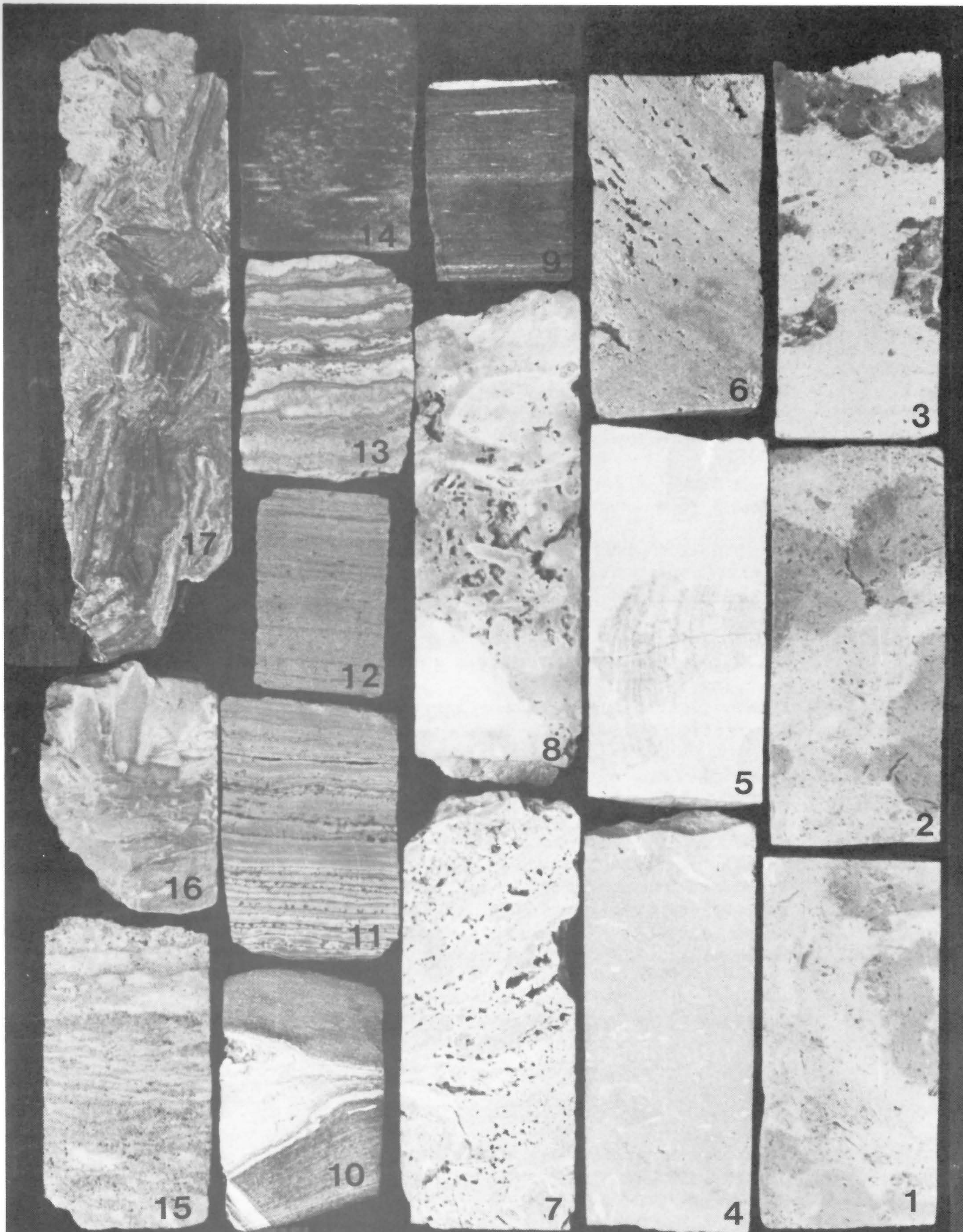


Figure 22. Selected photographs, Winnipegosis and Elm Point Formations, core samples.

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Winnipegosis Formation, Upper Member, Interreef Facies

Sample 9. M-3-73/26.5 m (Cameron Bay, see Figure 1): Dolomite, dark grey to black; fine lenses and streaks of dolomite throughout black bituminous matrix; carbonate lenses grade from microscopic to 2 mm in thickness; lamination horizontal. Thicker dolomite bands, as at top of sample, show fine bladelike pores, probably due to solution of gypsum porphyroblasts.

Sample 10. M-3-73/25.9 m: Dolomite, bituminous laminite as above, with 3 cm thick dolomite lens showing faint relict fine intraclastic texture. Bituminous laminae wrap uniformly around the lens and extend into lens. Configuration suggests differential compaction.

Sample 11. M-3-73/22.9 m: Dolomite, varvitic laminite, light buff, microcrystalline, dense. Fine dark bituminous, in part microstylolitic partings define clean carbonate laminae 0.5 to 3 mm thick. Lamination very uniform, slightly undulating. Probably equivalent to Ratner beds of Saskatchewan.

Sample 12. M-3-73/20.9 m: Dolomite, uniform varvitic laminite, as above, but partings less sharply defined and not appreciably bituminous.

Sample 13. M-3-73/20.1: Dolomite, laminite, similar to above but lamination coarser (up to 6 mm) and much more irregular, with microstylolitic character becoming pronounced.

Sample 14. M-3-73/18.6 m: Limestone, dark brown to black, finely crystalline, dense, faint fine banding; bituminous.

Sample 15. M-3-73/16.9 m: Limestone, medium crystalline, moderately granular with good intergranular and pinpoint porosity; irregular fine lamination, in part microstylolitic.

Winnipegosis Formation, Upper Member, "Transition beds"

Sample 16. M-12-71/14.3 m: Limestone breccia. Medium light grey, finely crystalline to microcrystalline, dense angular fragments, some showing faint fine lamination, in grey argillaceous matrix. Brecciation probably due to evaporite solution, suggesting beds may represent interbeds in original evaporite sequence hence correlatable with Prairie Evaporite?

Sample 17. M-12-71/13.1 m: Limestone breccia, similar to above, with fragments somewhat larger and showing well developed fine lamination. Considerable patchy interstitial pyrite.

Note: Samples are arranged in approximate stratigraphic sequence, from bottom right to top left. All samples are x1 magnification. Sample numbers denote corehole number and depth. For detail refer to Norris et al., 1982.

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