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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 70-56

BEDROCK TOPOGRAPHY, BURIED VALLEYS AND NATURE OF THE DRIFT, VIRDEN MAP-AREA, MANITOBA

(Report, 1 figure and Map 14-1970)

R. W. Klassen and J. E. Wyder

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ABSTRACT

This report is based largely on field data obtained by sampling and electrical logging some 24,000 feet of drift and bedrock and from the results of surface (DC) resistivity surveys within a 4,000-square-mile area of southwestern Manitoba during the summers of 1967 and 1968.

A number of buried valleys of Tertiary and/or Pleistocene ages are filled with 300 feet to 500 feet of drift. The preglacial Missouri Valley can be traced from the Manitoba-Saskatchewan boundary diagonally northeastward across the study area as a broad bedrock depression 30 miles wide and 200 feet deep. A secondary valley (Pierson Valley) up to 6 miles wide and incised 100 to 250 feet below the level of the preglacial Missouri Valley, follows the latter except in the southwestern corner of the area where it is continuous to the south with the preglacial Souris Valley of North Dakota.

The lowest bedrock elevations are not necessarily coincident with preglacial drainage channels, for Pleistocene alluvium occurs in the deepest parts of buried valleys. It appears that, in this area, base level during later Tertiary time was probably 100 or 200 feet higher than it was in early Pleistocene time.

In the subsurface, the drift comprises mainly multiple tills and intercalated glaciolacustrine deposits. Of the drift penetrated in boreholes, about 75 per cent is till, 15 per cent is silt and clay and 10 per cent is gravel and sand.

Although this investigation does not provide an evaluation of the quality or quantity of groundwater in the area, it does provide a general framework for future groundwater investigations.

BEDROCK TOPOGRAPHY, BURIED VALLEYS AND NATURE OF THE DRIFT, VIRDEN MAP-AREA, MANITOBA

INTRODUCTION

This preliminary report describes the subsurface topography of the bedrock and the nature of the overlying drift within an area of 4,000 square miles in southwestern Manitoba. Prior to this study, published reports concerning drift thickness, drift stratigraphy and bedrock topography were not available. The bedrock had been mapped by Wickenden (1945) on the scale of 1 inch to 8 miles and the surficial deposits had been mapped by Elson (1962) on a scale of 2 inches to 1 mile. The new information presented in this report was obtained mainly as a result of stratigraphic drilling by the Geological Survey of Canada during the summers of 1967 and 1968. The bedrock topography (*see* Map 14-1970) is based on results of the drilling programs and on information obtained from various types of geological and geophysical well records, published and unpublished surficial and bedrock geology maps, surface direct current (DC) resistivity surveys, electrical borehole logs, and field observations made by the writers.

Drilling sites were selected by reference to a working map of the bedrock topography compiled from published surficial and bedrock geology maps and from water-well and drilling reports. As a rule, holes were drilled where available records indicated the drift to be more than one hundred feet thick or where information was lacking or appeared unreliable.

One hundred and three holes were drilled through 24,000 feet of drift and bedrock. A descriptive log, based on drill chips taken at 10-foot intervals, was kept by the well-site geologist as drilling progressed. Continuous resistivity and self-potential logs were run in each borehole, and the tills and most of the fine sediments were sampled at 5-foot or 10-foot intervals by means of a sidewall sampling device (Morrison, 1969), which provides undisturbed samples about one inch in diameter and two inches to four inches long. A final written log of each borehole was compiled on the basis of data derived from the descriptive well-site log, by visual examination of each sidewall sample, and by study of the electrical logs. Surface elevations at drilling sites and outcrops were either estimated from contours and/or spot elevations on 25-foot contour maps, or were determined by altimeter, using elevation benchmarks as control points.

The larger elements of the bedrock topography as determined from this project do not differ markedly from the original control map. Significant differences are evident, however, in the second order topographic elements, particularly the position of the Pierson Valley and occurrence of the Medora Valley.

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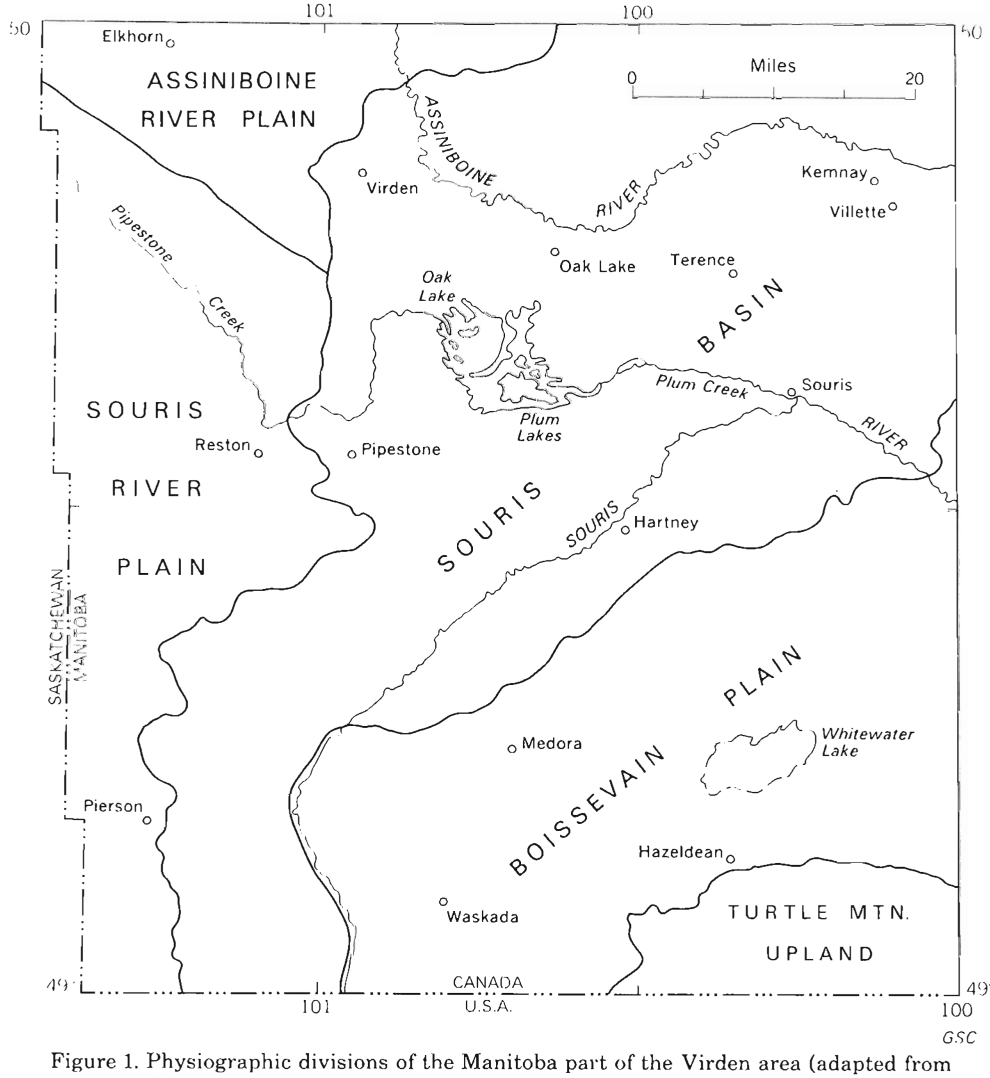

Figure 1. Physiographic divisions of the Manitoba part of the Virden area (adapted from Johnston, 1934; Elson, 1962; Economic Atlas of Manitoba, 1960).

Acknowledgments

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PHYSIOGRAPHY

The Virden area is largely gently undulating prairie consisting of till and lacustrine plains 1,400 to 1,900 feet in elevation, but it also includes, in the southeast, a wooded, hilly morainal upland up to 2,500 feet in elevation. The Souris Basin (Fig. 1) is a glacial lake plain underlain by sand, silt and clay. The Souris River Plain, Assiniboine River Plain and the Boissevain Plain consist of ground moraine interspersed with areas of end moraine and outwash. The Turtle Mountain Upland consists of hummocky moraine with local relief of up to 100 feet.

The principal rivers within the area, the Assiniboine, Souris, and Pipestone, occupy valleys up to 1 1/2 miles wide and 200 feet deep that originated as glacial meltwater channels and spillways of former glacial lakes.

BEDROCK STRATIGRAPHY

The principal bedrock units represented in the map-area are the Riding Mountain Formation of Upper Cretaceous age (Wickenden, 1945) and the Boissevain and Turtle Mountain Formations of Upper Cretaceous or Tertiary age. The Turtle Mountain and Boissevain Formations are present on Turtle Mountain; elsewhere in the area they are absent and have presumably been removed by erosion, for the Riding Mountain Formation is the uppermost bedrock unit.

The Riding Mountain Formation according to Wickenden (ibid.) consists of soft, greenish grey clay beds commonly overlain by medium to light grey, hard, siliceous shales. Tyrrell (1893, p. 141E) considered the soft shale and siliceous shale to be separate stratigraphic units and named the soft shale the Millwood Member and the siliceous shale the Odanah Member. Later studies led to the designation of these units as phases (Wickenden, ibid.; Kerr, 1949, p. 31) and beds (Tovell, 1951, p. 5). Wickenden (ibid.) described the Boissevain Formation as greenish grey or rusty yellow sandstone and sand, the Turtle Mountain Formation as a series of shale, sandstone and some coal beds.

The results of this study generally confirm earlier reports concerning the nature and distribution of the bedrock formations underlying the drift. Boreholes were commonly terminated 20 feet to 50 feet below the drift-bedrock interface. In the vicinity of Terence (SE 1/4 sec. 13, tp. 9, rge. 22) and Kemnay (NW 1/4 sec. 3, tp. 10, rge. 20) in the Souris Basin, boreholes penetrated a black, fairly soft, papery, calcareous or noncalcareous shale underlying sand and gravel of Pleistocene age. The physical properties and elevation of this shale suggest it to be the Pembina or Boyne Member of the Upper Cretaceous Vermilion River Formation, which underlies the Riding Mountain Formation elsewhere in this region (Wickenden, 1945, p. 35). The contact between the above formations in the vicinity of Brandon therefore is some 40 miles farther southwest than Wickenden (1945) assumed.

In the study area, the Riding Mountain Formation is not readily divisible on the basis of lithology into Millwood and Odanah Members. Based upon subsurface records it typically is a very dark grey, noncalcareous, soft, waxy shale that in places includes thin beds of hard shale or bentonite. The characteristic rotary drill "chatter" that signals the penetration of the Riding Mountain Formation throughout most of the Riding Mountain area was rarely noted during drilling in the Virden area. Interbeds of hard shale were most commonly penetrated in boreholes in the Boissevain Plain and Assiniboine River Plain and it is possible that equivalents of the hard, siliceous Odanah shale underlie these areas. Because of limited evidence for stratigraphic subdivisions within the Riding Mountain Formation none is shown on the accompanying map. The names Millwood shale and Odanah shale are used in the descriptive logs for soft shale and hard shale respectively.

The Turtle Mountain and Boissevain Formations were encountered in a borehole near Hazeldean (NW 1/4 lsd. 15, sec. 32, p. 1, rge. 22) on the Turtle Mountain Upland. The Boissevain Formation here consists of 100 feet of fine- to medium-grained "salt and pepper" sandstone with occasional shale interbeds. The overlying Turtle Mountain Formation consists of 260 feet of light grey sandstone and siltstone interbedded with grey to light grey shale and some lignite.

BEDROCK TOPOGRAPHY

Map 27-1970 is a generalized and subjective interpretation of relatively limited data. Elevation points on the bedrock surface obtained from boreholes and outcrops average about two sites per township but are not uniformly distributed. Therefore, the reliability of the map and the amount of detail shown on it vary from place to place.

The bedrock topography is considered primarily the result of Tertiary (preglacial) erosion and Pleistocene (glacial and interglacial) erosion. The broad aspects of the bedrock topography that are believed to reflect a somewhat modified preglacial land surface include the following topographic features: 1) the broad depression underlying the Souris Basin and southern part of the Souris River Plain; 2) the pediment-like bedrock slopes from 1,300 feet to 1,600 feet elevation underlying the Assiniboine River Plain and the Boissevain Plain; 3) the bedrock upland 1,600 to 2,100 feet in elevation underlying most of the Turtle Mountain Upland.

The separation of secondary topographic features of the bedrock surface into preglacial and glacial elements is generally rather conjectural. The concepts listed below, which were developed through similar studies in Alberta and Saskatchewan have served as guidelines for the interpretation of data and for separating some Tertiary erosional elements from Pleistocene ones:

> "Regional Tertiary (preglacial) drainage in the western Canadian plains was consequent, and flowed east and northeast toward Hudson Bay. Valleys, two to fifteen miles wide with gently sloping walls, formed a dendritic pattern on the underlying, generally soft, homogeneous Cretaceous shales (Kupsch, 1964, p. 275, Christiansen, 1962, p. 50 and Stalker, 1961, p. 4).
>
> "The preglacial drainage systems distributed gravels that contain distinctive rock types derived from the Rocky Mountains. These late-Tertiary sediments, commonly referred to as 'Preglacial gravels' (Stalker, 1963, p. 4, Christiansen, 1965a, p. 19) or 'Saskatchewan gravels and sands' (Stalker, 1968), are restricted to broad valleys incised in the Cretaceous bedrock. Where detected in the subsurface or in outcrop, they serve to identify and delineate these preglacial valleys. Older Tertiary gravels are known to cap or occur on the flanks of some present day uplands of the Interior Plains Region and are indicative of degradation during the Tertiary (Stalker, 1961, p. 2; Christiansen, 1962, p. 49).

"During the Pleistocene, meltwater streams incised steep-walled valleys one-quarter mile to three miles wide into drift and/or bedrock (Stalker, 1961, p. 4). The trends and positions of these valleys were controlled directly or indirectly by ice masses that blocked the natural consequent drainage routes and caused the cutting of new valleys in side-hill positions or across former divides. Many such valleys were later occupied by interglacial and postglacial streams."

BURIED VALLEYS

Buried valleys located within the study area include the broad valley of the preglacial Missouri River referred to in numerous earlier publications (Meneley *et al.*, 1957; Lemke and Colton, 1958, p. 43; Thornbury, 1965, p. 296; Lemke *et al.*, 1965, p. 19) and smaller valleys coincident with or tributary to the preglacial Missouri River valley as well as a narrow through-valley in side-hill position beneath the Boissevain Plain.

The valleys associated with the preglacial Missouri River valley were either incised during Tertiary time and served as drainage courses during early Pleistocene time, or else were first incised during the early Pleistocene. Clearly these valleys carried Pleistocene drainage, for in places along their thalwegs, glacial erratics are included in the alluvium. Yet the width (up to 6 miles) and the relatively gradual slopes of their sides are characteristic of preglacial valleys.

Preglacial Missouri Valley

The preglacial Missouri Valley, which is recognized as a broad swale ten to fifteen miles wide across the Missouri Plateau between Poplar, Montana and Grenora, North Dakota (Howard, 1960, p. 65), has been traced in the subsurface to a position some fifteen miles west of Estevan, Saskatchewan where it joins the buried Yellowstone Valley and follows an easterly course into Manitoba (Meneley *et al.*, 1957, pp. 441-447). The valley width in Saskatchewan appears to be about the same and its depth is about 250 feet (Meneley ibid.). Within the map-area the section of the depression about 1,200 feet to 1,400 feet above sea level area is continuous with the preglacial Missouri Valley in Saskatchewan, whereas a secondary or inner valley, 1,000 feet to 1,200 feet above sea level, within the depression is not continuous with the preglacial Missouri Valley in Saskatchewan and is considered a separate valley (see Pierson Valley).

The preglacial Missouri Valley in Saskatchewan as defined by Meneley *et al.* (1957), has been renamed "Estevan Valley" in a later publication by Christiansen (1965b). Detailed subsurface studies across the preglacial Missouri Valley in the Frobisher area, Saskatchewan (Wyder, 1968, and unpublished information) indicate that a distinctive inner or secondary valley occurs within the preglacial Missouri Valley and appears to swing southeastward across the International Boundary. The course it follows beyond this point may be similar to the broad glacially positioned loop of the modern Souris River in the northern United States. It is suggested the name Estevan Valley be restricted to this secondary valley within the preglacial Missouri Valley west of Frobisher. The "preglacial Missouri River" channel shown on the map prepared by Meyboom (1963) was not located by drilling along its projected course into Manitoba.

Typical 'preglacial gravels' were not encountered in boreholes drilled during the present survey. Gravel that outcrops at an elevation of about

1,350 feet above sea level along the east side of the valley near the town of Souris, is part of the 'Souris gravel and sand' deposit described in an earlier paper (Klassen, 1969). It contains a high percentage of 'preglacial' rock types (from Rocky Mountain source) mixed with glacial erratics. The former appear to have been derived from deposits related to the preglacial Missouri Valley and are apparently preserved in widely separated localities elsewhere along the valley. Results of detailed testhole drilling across the preglacial Missouri Valley near Frobisher, Saskatchewan (Wyder, 1968, Plates 4 and 5) indicate the occurrence of gravels similar to the Souris gravel and sand in both lithology and in their position along the valley side. In the study area glacial and fluvial erosion probably removed the typical 'preglacial gravels' that are preserved in similar buried valleys elsewhere in Saskatchewan and Alberta.

Pierson Valley

A secondary or inner valley within the preglacial Missouri Valley north of Pierson and continuous with the preglacial Souris Valley in North Dakota (Lemke *et al.*, 1965, p. 19) south of Pierson is here named the Pierson Valley. In the southwestern part of the area it is about 3 miles wide and less than 100 feet deep, and gradually widens and deepens towards the northeastern part where it is some 6 miles wide and 250 feet deep. Within the map-area the gradient is nearly 3 feet per mile.

Glacial gravels with a composition similar to the Souris gravel and sand (Klassen, 1969, p. 2) within the deepest parts of the Pierson Valley are overlain by 300 to 400 feet of drift comprising multiple till sheets, and glaciofluvial and glaciolacustrine deposits.

This study supports the contention that the Pierson Valley is of Pleistocene age. Although it occupies broad bedrock swales associated with Tertiary drainage courses, the deposits within it are of Pleistocene age and those deposits similar to Tertiary alluvium elsewhere on the western Plains occur at higher levels outside the Pierson Valley.

The elevation of the Pleistocene deposits within the Pierson Valley indicates that base level lowering that began during Tertiary time continued at least into early Pleistocene time in the study area. Howard (1960, pp. 60 and 97) and Ritter (1967, p. 467) cited evidence that base level lowering continued during most of the Pleistocene in the adjacent northern Great Plains Region of the United States. However, Christiansen (1962, p. 52) suggested that in southern Saskatchewan base level has in general been rising since the late Tertiary, because deposits of preglacial age within the buried valleys of this region commonly occur at lower elevations than associated sediments of Pleistocene age.

Virden Valley

A buried valley about 2 miles wide and 450 feet deep, here named the Virden Valley, enters the map-area from the north near Harmsworth (tp. 12, rge. 26) and continues southeastward to join the Pierson Valley near Oak Lake (tp. 8, rge. 25). North of the map-area, the Virden Valley appears to run parallel to and be nearly coincident with the modern valley of the Assiniboine River about as far as township 14, range 27 near Miniota. Beyond this, its trend can only be conjectured, but apparently the buried valleys shown south of Qu'Appelle River valley on the bedrock map of this area (Klassen, 1966b) are part of the Virden Valley. This inference would require that the valleys carried drainage south rather than north as originally assumed. Thus, the Virden Valley may trend northwestward from township 15, range 31, to join the valley of the Qu'Appelle River within township 17, range 2, W2. The presence of a buried valley in this locality is indicated by a borehole (GSC Testhole 18-67; SW 1/4 sec. 29, tp. 17, rge. 2, W2) in which 700 feet of drift and alluvium were penetrated above bedrock at elevation 1,185 feet. The gradient of Virden Valley between this borehole and the borehole near Harmsworth is about 14 feet per mile.

The Virden Valley appears to be of early Pleistocene age for, in its deepest known sections, glacially transported rock types are found in the alluvium and no significant percentage of 'preglacial' rock types have so far been detected. The narrowness of the valley and its position across a former divide between Moose Mountain and Riding Mountain Upland (Klassen, 1966a, p. 13) are further support for this assumption. The Virden Valley may have been incised when a river, flowing northeast across the northwestern part of the Riding Mountain area and between the Riding Mountain Uplands and the Duck Mountain Uplands was blocked by a continental glacier and diverted to the southeast. Thus the Virden Valley may be a "cross valley" of the type recognized in parts of the northern Great Plains Region of the United States (Laird, 1967).

Medora Valley

A buried valley less than one mile wide and more than 200 feet deep occurs between Medora (tp. 3, rge. 24) and Waskada (tp. 2, rge. 26). The limited information available suggests it continues in side-hill position northeast toward Lauder (tp. 5, rge. 24) whence its course coincides with the modern Souris River valley as far as the town of Souris. Beyond Souris its course is highly conjectural; possibly it continues roughly east-northeast from the town.

The side-hill position of the valley and deposits within it both indicate it is of Pleistocene age. The depth of this valley between Medora and Waskada is about the same as Pierson Valley to the northwest; thus this valley provides additional evidence that the lowest elevations are not necessarily coincident with the courses of preglacial river systems.

Other Buried Valleys

On Map 27-1970 a few minor buried valleys of preglacial age are shown as tributaries to the main buried valleys or to modern valleys. However very detailed subsurface information is required to detect and trace the course of such relatively minor valleys, and that on the basis of the generally scattered subsurface information presently available, only the continuous large buried valleys can be delineated with any degree of certainty.

NATURE AND THICKNESS OF QUATERNARY DEPOSITS

The drift consists mainly of widespread till deposits. In the Souris Basin, lacustrine sediments lie upon and are intercalated between till units which are themselves locally underlain by early Pleistocene alluvium. Typical drift sections penetrated in boreholes consist of about 75 per cent till, 15 per cent clay and silt, and 10 per cent gravel and sand. The average thickness of the drift in the Souris Basin and Souris River Plain is about 350 feet (*see* cross-sections). It is much thinner, commonly less than 50 feet, on the Boissevain Plain, where bedrock outcrops are common. On the Turtle Mountain Upland, drift thicknesses up to 500 feet are reported, although the drift thickness is variable over this bedrock upland.

Souris Gravel and Sand

Pleistocene gravel and sand informally named the Souris gravel and sand (Klassen, 1969), are exposed in gravel pits just above a low terrace at about 1,350 feet above sea level within the Souris River valley (NE 1/4 sec. 34, tp. 7, rge. 21). The base of the gravel is not exposed but nearby outcrops suggest it probably lies on bedrock. This deposit consists mainly of rock types derived from sources to the west and includes subrounded to well-rounded clasts of grey and brownish grey argillite, brown chert, jasper, agate, silicified wood and porphyritic volcanics deposited along valleys that carried Tertiary drainage from the west and southwest. Clasts from eastern sources, including mainly granitic, foliated metamorphic and carbonate rock types initially brought in by glaciers, comprise a small percentage of the rock assemblage. The carbonate rock types are commonly more weathered than typical glacial gravels in the area. Many of the boulders are glacially faceted. Some shale and sandstone of local origin are also included in this deposit.

In general, at least 75 per cent of the gravel-size material in the Souris gravel and sand are of western provenance. The quartzite and argillite rocks are similar to bedrock that outcrops in the Waterton Lakes area of Alberta (A.M. Stalker, 1965, pers. comm.). According to Elson (1956, p. 274) the assemblage, except for the granite rock types, is similar to the late Precambrian Belt Series and the late Tertiary? Flaxville gravel of Montana.

Gravel and sand, occur between the lowest till and shale bedrock along the deepest part of the Pierson Valley near Oak Lake, Villette and Pierson. Western rock types comprise between 20 and 30 per cent of the clasts in the gravel beds; the other rock types present are of eastern origin. This deposit appears to be somewhat younger than the Souris gravel and sand at the type section but is considered part of the same depositional sequence and the same name is applied.

Till

The till in the study area commonly consists of about 60 per cent clay and silt, 30 per cent sand, and 10 per cent gravel. Within the zone of surface oxidation that extends to a depth of 10 to 20 feet, the till is typically olive brown (2.5y 4/4 Munsell colour) when wet. Below the zone of oxidation it is typically very dark grey (5y 3/1) when wet. It is thickest in the southern part of the Souris River Plain where a massive blanket 300 to 350 feet thick overlies shale bedrock.

Multiple till sheets recognized by the occurrence of stratified interbeds, buried oxidized zones, or differences in colour and hardness were penetrated in most boreholes. Correlations between till units shown in the cross-sections will be presented in a later report when preliminary correlations have been confirmed by laboratory studies of borehole samples for texture and carbonate content.

Other Stratified Sediments

Gravel, sand, silt and clay are widely distributed within the Souris Basin where they accumulated largely in lacustrine and deltaic environments. Locally distributed gravel, sand, silt and clay deposited as outwash, or alluvium or as sediment in small lake basins, occur in the subsurface throughout the map-area.

The lacustrine sediments within the Souris Basin comprise the surface deposits in nearly half of the study area. They consist of a thick succession of dense laminated clay with silty and sandy interbeds, overlain by 10 to 50 feet of sand and silt. The deposits are 180 feet thick in the central part of the basin, near Oak Lake, and they thin gradually towards the basin margin. Along the southeastern edge of the basin, the surface is sandy and much of it has been worked into dunes. The upper sand and silt unit here includes zones high in coal pebbles, apparently derived from the lignite beds of the Turtle Mountain Formation that outcrops on the Turtle Mountain Upland to the southeast.

Gravel and sand of deltaic and outwash origin, in beds 20 to 100 feet thick, are distributed along the western margin of the Souris Basin. The thickest gravel was penetrated near Pipestone where it overlies silt and till.

IMPLICATIONS FOR GROUNDWATER

The 'Souris gravel and sand', particularly within the deepest parts of the Pierson Valley, may be capable of yielding industrial water supplies. Its coarse texture, its thickness (up to 100 feet), its depth (some 300 feet below the surface) near Pierson, Pipestone and Villette, suggest that it has considerable groundwater potential in these localities at least. The occurrence of the 'Souris gravel and sand' as a channel deposit within Pierson Valley suggests it is an elongate, relatively narrow deposit that could easily go undetected unless observations and borings were sufficiently detailed.

The sand, gravel and colluvium within the Medora Valley may also prove capable of providing water supplies adequate for nearby small towns.

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