THE PLEISTOCENE STRATIGRAPHY AND SURFICIAL GEOLOGY OF THE ASSINIBOINE RIVER TO LAKE MANITOBA AREA, MANITOBA

A Thesis

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of

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by

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ABSTRACT

The area contains 80 to 275 feet of sediment deposited on a southward sloping Palaeozoic and Jurassic bedrock surface. Three tills are present with stratified units above and below each and a fluvial unit overlying the uppermost stratified unit. The upper till forms an asymmetric ridge in the northern one-third of the area. The tills are carbonate rich loams and clay loams. The lower till and middle and lower stratified units were deposited prior to the last ice advance and the middle and upper till by the ice which melted to form Glacial Lake Agassiz. Lacustrine and prodeltaic units were deposited in Lake Agassiz and the fluvial unit after the lake drained.

CHAPTER I

INTRODUCTION

Studies of the Quaternary stratigraphy in the Manitoba portion of the Lake Agassiz basin are limited. Interest in the Portage La Prairie area was aroused when work by Gilliland (1963), in connection with a flood control structure, suggested a possible ice frontal position in the area and stratified drift below the till underlying the Lake Agassiz sediments. The purpose of this study is to describe the Quaternary stratigraphy and surficial geology of the area and present tentative correlations with the stratigraphy and history of the surrounding region.

The location of the study area is shown in Figure 1. It includes all or portions of townships 11 to 14 and ranges 5 to 9 W1.

The climate is subhumid with precipitation averaging 18.46 inches a year. The warmest month is July, with an average temperature of 67.4^{o}F (Portage La Prairie Meteorological station). The area lies within the Aspen Grove forest belt (Gill, 1960) and the trees include poplar, aspen, oak, elm and alder.

Studies of Glacial Lake Agassiz commenced in the 1800's

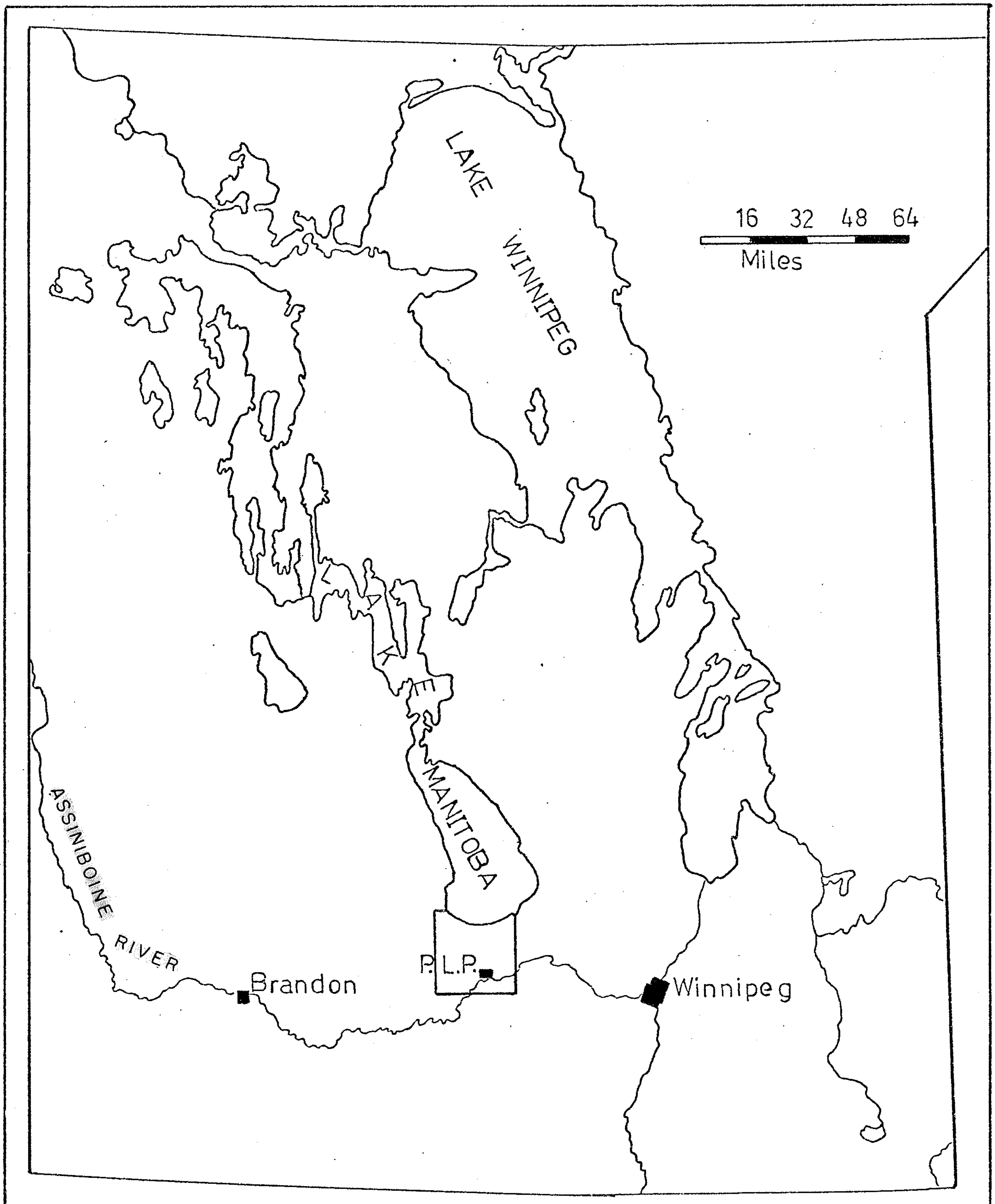

Fig I Location of study area

and many of the studies are listed in Life, Land and Water (Mayer-Oakes, 1967). Previous studies including all or portions of the study area include those by Johnston (1934), Ehrlich et al. (1957), Elson (1958, 1967) and Gilliland (1963).

ACKNOWLEDGEMENTS

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While conducting the field work the author resided at the University of Manitoba Field Station (Delta Marsh) by permission of Dr. J. M. Walker, the director. Unpublished data was supplied by Mr. B. B. Bannatyne, Manitoba Mines Branch, Dr. J. A. Gilliland, Inland Waters Branch, and Mr. L. Gray, Manitoba Water Control and Conservation Board. Some of the mineralogical analyses were performed in the laboratory of the Department of Fisheries and Forestry. One test hole was sidewall sampled by Dr. J. E. Wyder, Geological Survey of Canada.

The field work was supported by Geological Survey of Canada grant 3-68, obtained by Dr. D. T. Anderson. The drilling program was also supported by Geological Survey of Canada grant 24-65 and the Inland Waters Branch in

connection with a groundwater study by Dr. J. G. Gilliland.

METHOD OF INVESTIGATION

A preliminary air photo interpretation and literature search was carried out during the spring of 1969. The field work was conducted during the summer. The lithology and distribution of the surficial deposits was determined by surficial examination, the manual augering of about 300 holes 3 feet (≈1m) deep, and air photo interpretation. The subsurface data was collected from 32 truck mounted power auger holes 8 to 87 feet (≈3 to 29m) in depth and 8 rotary drill holes 105 to 275 feet (≈35 to 92m) in depth. The rotary drill was used to extend 8 power auger holes to bedrock and yielded the greatest amount of stratigraphic information. Auger flight, rotary chip, and in one hole side wall samples were collected. The drilling program was combined with that for a groundwater study being conducted in the area by Lutchman (1970) to assure most efficient use of all available funds.

The laboratory data was obtained from textural, carbonate and x-ray diffractometer analyses of representative samples. A description of the methods used and the results are given in Appendix A.

PHYSIOGRAPHY

The Westlake and Interlake Till Plains (Figure 2) have

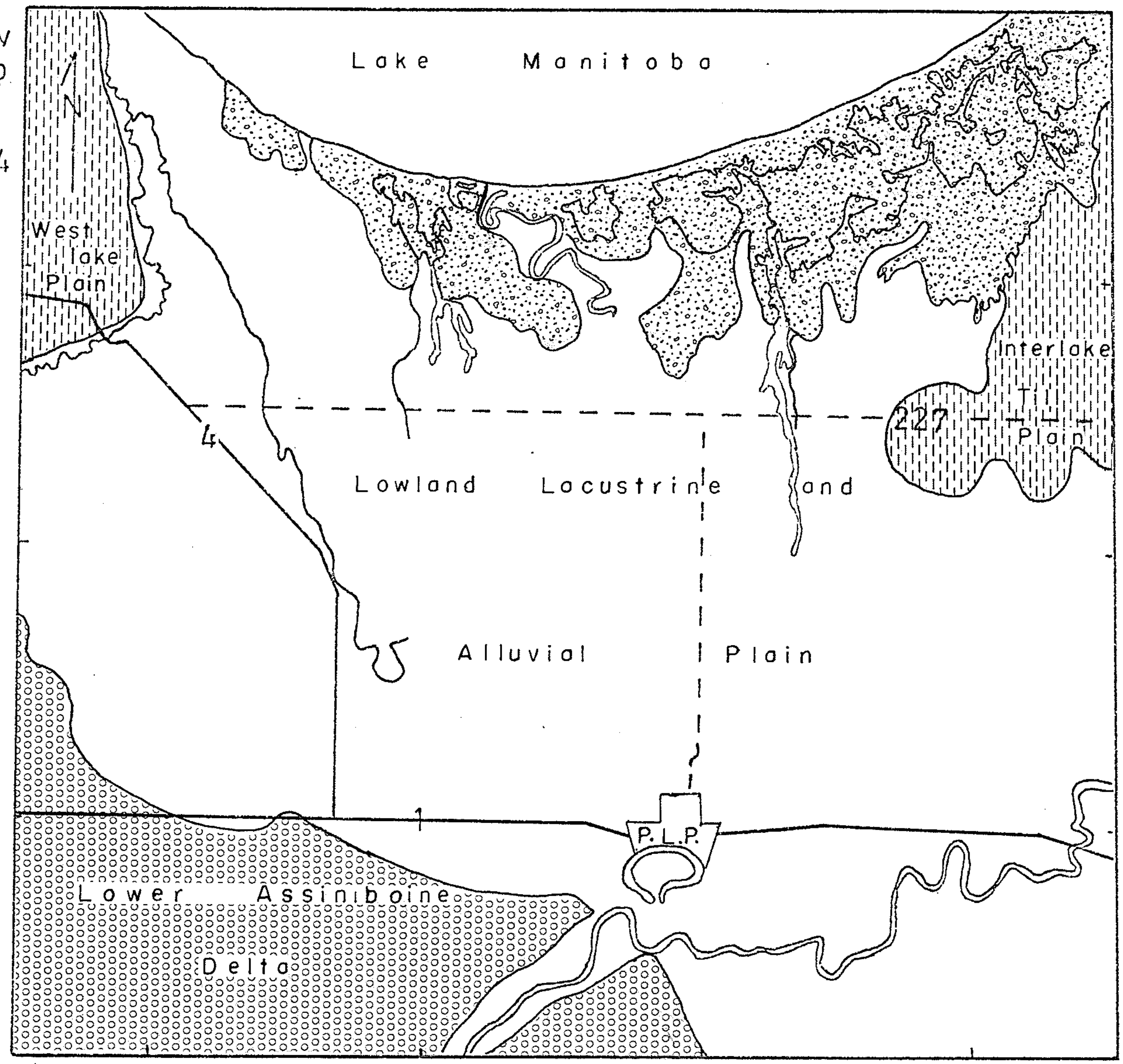


Fig. 2 Physiographic map of study area (modified from Ehrlich et. al. 1957)

0 1 2 3 4 5
Miles

Highway ———

Road gravel – – – –

low local relief, less than 10 feet (≈3m), and decrease in elevation from approximately 830 feet (≈280m) at their respective west and east boundaries to 815 feet (≈272m) near Lake Manitoba. The Lowland Plain decreases in elevation from approximately 875 feet (≈292m) in the southwest to 815 feet (≈272m) near Lake Manitoba. Local relief is caused by a number of abandoned river channels less than 10 feet (≈3m) deep. The lower Assiniboine Delta is a unit with low to moderate local relief, up to 25 feet (≈8m), and decreases in elevation from approximately 930 feet (≈310m) in the southwest to 875 feet (≈292m) at the contact with the Lowland Plain.

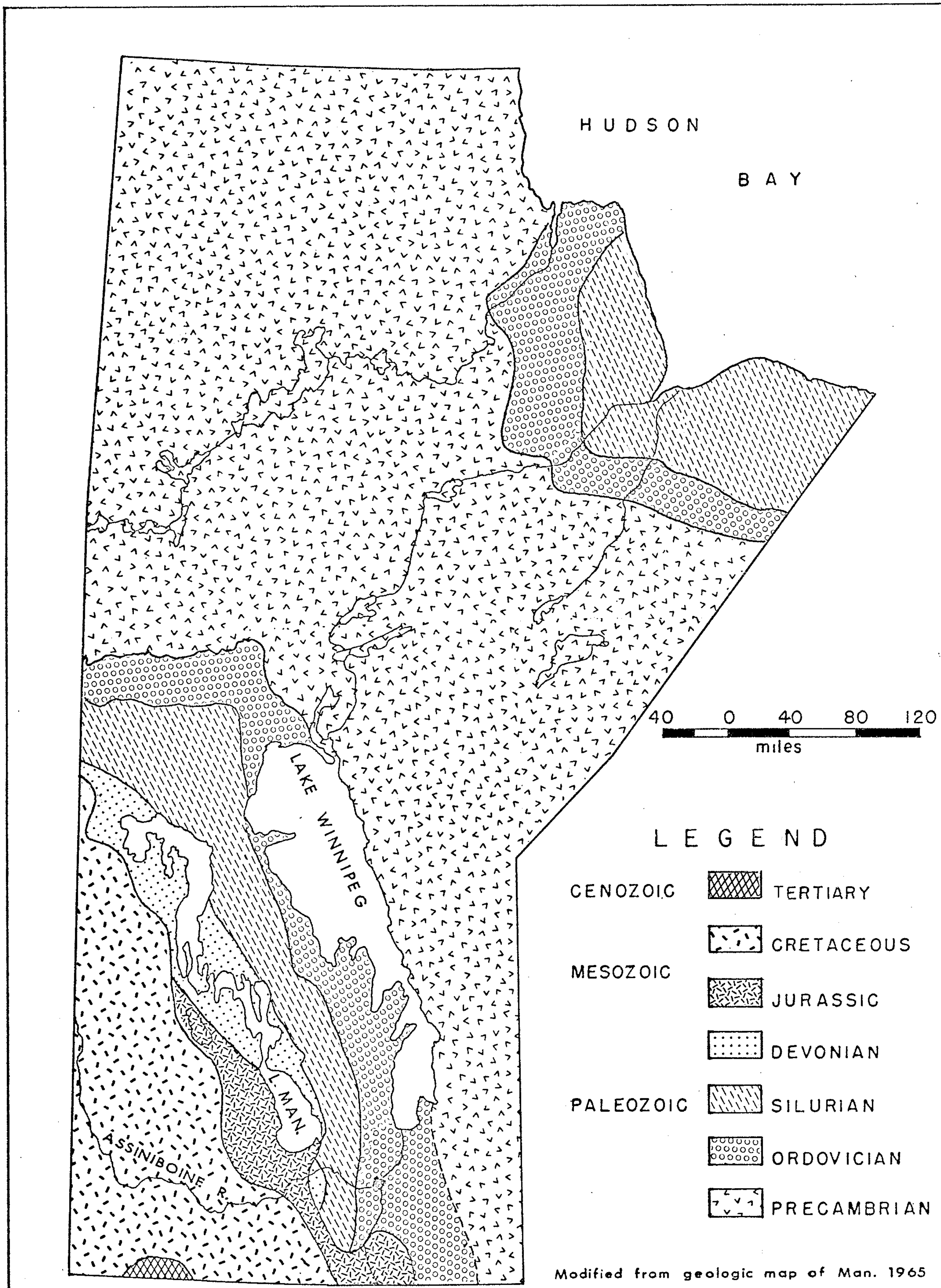


Fig. 3 Bedrock geologic map of Manitoba

Table 1: Bedrock formations present in the study area (from Davies et al., 1962)

AGE	FORMATION	BASIC LITHOLOGY
JURASSIC	Melita	Varicoloured shale, limestone
	Reston	Gray shale, argillaceous limestone
	Amaranth	Upper: anhydrite, gypsum, minor dolomite and shale Lower: red dolomitic shale, argillaceous dolomite, anhydrite
DEVONIAN	Dawson Bay	Argillaceous limestone, anhydrite, basal red shale
	Winnipegosis	Buff dolomite, reef and off reef

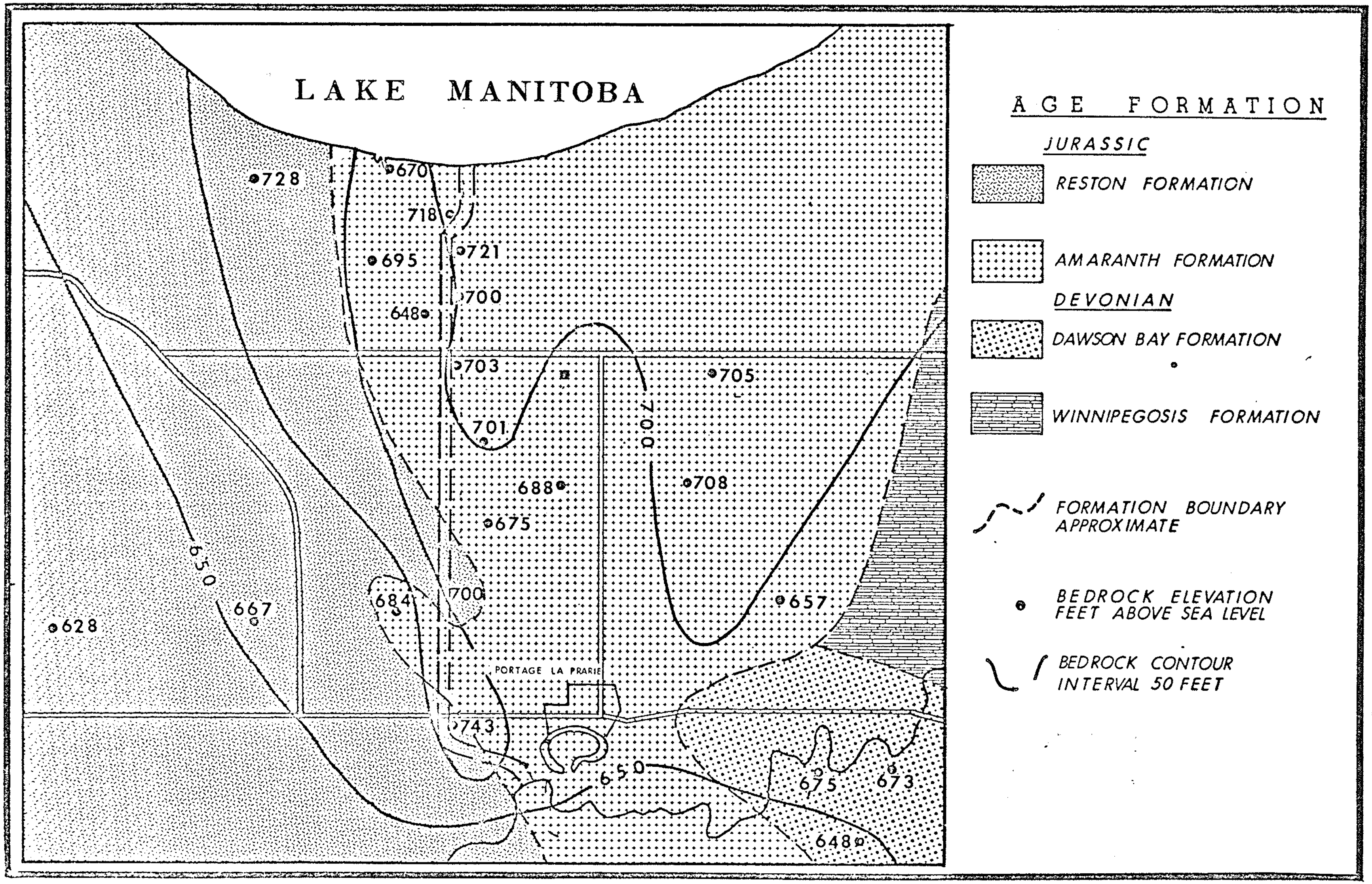


Fig. 4 Local bedrock geology and bedrock topography

intersected bedrock, unpublished data, and descriptions in Davies et al. (1962), Stott (1955), and McCabe (1967).

The Jurassic formations include the Amaranth Formation and the younger Reston Formation, and are the only units penetrated during the drilling program. The Amaranth Formation consists predominantly of interbedded gypsum or anhydrite, buff dolomite and greenish-gray shale in the west (hole P13, for example, Appendix B) and pink to white gypsum, buff dolomite and red to green shale in the east (Bannatyne, unpublished data, 1969). These two lithologies resemble the Upper and Lower Amaranth respectively as described by Stott (1955). The Reston Formation consists predominantly of limestone, dolomitic limestone and greenish-gray shale with some minor dolomite and gypsum (hole P7, for example).

The Melita Formation, a younger varicoloured shale and limestone unit (Table 1), was reported in two drill holes in the south central part of the area (Gilliland, 1963). The identification is regarded as uncertain because the Reston may also vary in colour (Stott, 1955), the reported thickness is only five feet and the formation was not intersected elsewhere in the area.

The Devonian formations include the Winnipegosis Formation and the younger Dawson Bay Formation (Table 1). The Winnipegosis Formation consists of white to buff dolomite. The Dawson Bay Formation is composed of argillaceous, white to buff limestone and dolomitic limestone and red and green shale.

The major portion, if not all of the bedrock sulphates intersected during the drilling program are believed to be gypsum; and X-ray diffractogram of one sample indicated pure gypsum. The gypsum is often intersected near the bedrock surface. Where the Reston forms the bedrock much of this gypsum is believed to be because of glacial transport from the Amaranth Formation.

An interpretation of the bedrock topography in the area is shown in Figure 4. The topography appears to be rolling with low relief. This is to be expected because the surface has been periodically subjected to erosion since the end of Jurassic time and scoured by multiple glaciations. The regional slope is to the southwest. This may be due to the presence of the buried preglacial Red or Missouri channels southwest of the study area (Wyder, oral communication, 1969). The topographic interpretation in Figure 4 suggests a north-south alignment of ridges and troughs. This may be owing to sculpture of the land surface by a southward-moving glacier as suggested by Wardlaw et al. (1969) for a portion of the bedrock in the Interlake area of Manitoba, northeast of the study area.

	GEOMORPHOLOGY		LITHOLOGY							
UNIT	MORPHOLOGY	PHOTO PATTERN	TEXTURE	COLOUR	MINERALOGY 0.062 mm	CARBONATE Dolomite (Weight Percent)	Calcite		THICKNESS (feet)	OTHER FEATURES
Beach	ridge, <10 ft. high, along lake shore series of bars offshore	ridge, light toned	sand; medium to fine-grained, well sorted, well developed cross bedding	grayish-brown to brown	quartz dominant				0-<15	
Marsh	flat, approximately 50% of the area submerged	light toned vegetation, areas of open water	silt and clay, organic rich	gray to brown					0-<15	
Fluvial -alluvial channel	flat, <10 ft relief; channels only relief, meandering, most abandoned	even, light tone particularly near channels; meandering channels	variable, sand in and adjacent to channels, silt and clay farther away	light grayish-brown to grayish-brown to olive gray, to dark gray in organic rich samples	quartz,dolomite,calcite, feldspar,illite,montmorillonite,chlorite and/or kaolinite	13 8	8 4	<0.062 mm <0.002 mm	0->40	iron staining plant,mollusk and ostracod fragments
-lake plain channel	angular channels cut into lacustrine unit	angular channels	sediment confined to channels, silt and clay	gray to brown	similar to that for alluvial channels				likely <20	
Strandline	low relief, <10 ft. discontinuous	ridge or scarp, light toned lineament	Sand, medium to very fine-grained, massive, occasional pebbles. scarps-erosional, some sand at base and crest	yellow-brown to grayish-brown	quartz dominant					iron staining
Lacustrine -silt	low relief, <10 ft. discontinuous	light to medium, blotchy tone, straight and curvilinear lineations	clayey silt	grayish-brown to olive brown	quartz,dolomite,calcite, feldspar,illite,montmorillonite,chlorite and/or kaolinite				0-<15 discontinuous	iron staining
-upper clay	low relief, <10 ft. angular drainage channels	light and dark blotchy tone, fine texture, angular stream pattern occasional straight & curvilinear lineaments	clay; silty, colour banded, laminated to massive, occasional pebbles and silt and till clasts	light grayish-brown to dark grayish-brown to olive gray	quartz,dolomite,calcite, feldspar,illite,montmorillonite,chlorite and/or kaolinite	7 undetectable in	5	<0.062 mm <0.002 mm	10-30	iron staining
-lower clay	not exposed		clay; silty, colour banded, laminated to massive, occasional pebbles and silt and till clasts slightly coarser than upper clay	grayish-brown to dark grayish-brown to olive gray, to dark gray, occasional blue cast	quartz,dolomite,calcite, feldspar,illite,montmorillonite,chlorite and/or kaolinite	11 undetectable in	9	<0.062 mm <0.002 mm	0-<80	
Prodeltaic -sand	northeast sloping highland; relief moderate, 5-25 ft. in dunes in south, low <10 ft. in north	light tone, coarse texture, irregular vegetation distribution	sand; fine to very fine grained, massive, occasional pebbles in the lower portion	grayish-brown	quartz dominant				0-<20 thins northward	
-silt	low relief, <10 ft. infrequently exposed	light and dark tone	clayey, laminated, each cycle a gradation clay to silt	very dark gray	quartz,dolomite,calcite, feldspar,illite,montmorillanite,chlorite and/or kaolinite,coal in+0.062mm	19	6	<0.062 mm	0->50	
Upper Till	predominantly subsurface unit, outcrops on N (minor) and NE, NE well developed lineations	well developed NW-SE lineation	loam to clay loam	light grayish-brown to grayish-brown to olive brown	dolomite,calcite,quartz, feldspar,illite,montmorillonite,chlorite and/or kaolinite	35	18	<0.062 mm	15-50	
Middle Till	not exposed		loam with gravel at upper contact	light grayish-brown to grayish-brown	dolomite,calcite,quartz, feldspar,illite,montmorillonite,chlorite &/or kaolinite	38	21	<0.062 mm	10-50	
Middle Stratified	not exposed		interbedded silt and clay with minor sand	light grayish-brown to dark gray	quartz,dolomite,calcite, feldspar,illite,montmorillonite,chlorite and/or kaolinite	47 5	11 5	<0.062 mm <0.002 mm	0-80	
Lower Till	not exposed		clay loam	grayish-brown to brown	dolomite,calcite,quartz, feldspar,illite,montmorillonite,chlorite and/or kaolinite	33	21	<0.062 mm	10-20	
Till + Stratified	not exposed		till interbedded and/or mixed with sand, silt and clay	till-grayish-brown to olive gray, strat.-grayish-brown to dark grayish-brown	similar to other till and stratified units	similar to other till and stratified units			0-60	
Lower Stratified	not exposed		interbedded sand, silt and clay	light grayish-brown to grayish-brown, to light olive gray to olive gray	quartz,dolomite,calcite, feldspar,illite,chlorite and/or kaolinite montmorillonite	28	26	<0.62 mm	0-60	

Table 2 Summary of unit properties

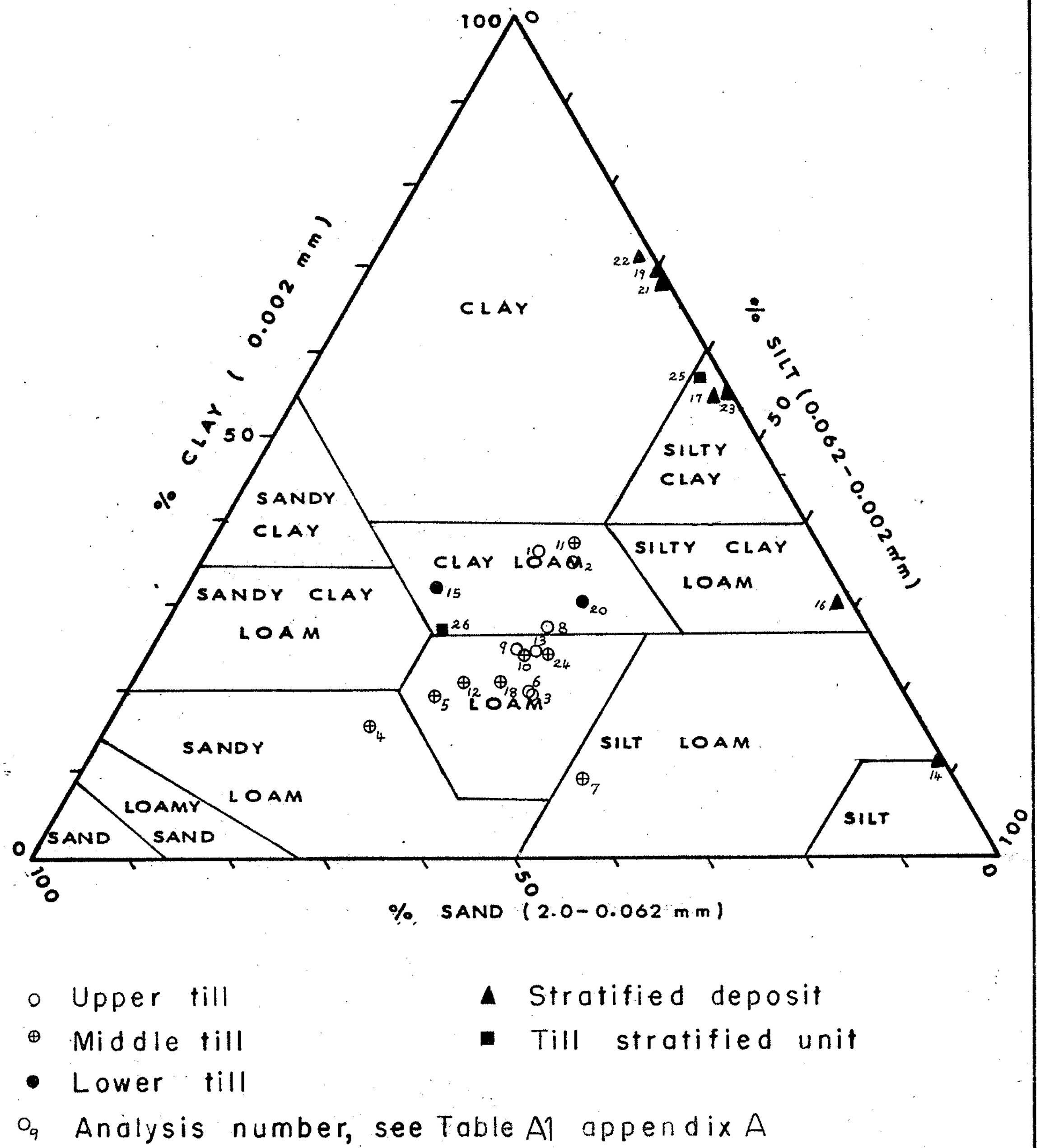


Fig. 8 Results of textural analyses

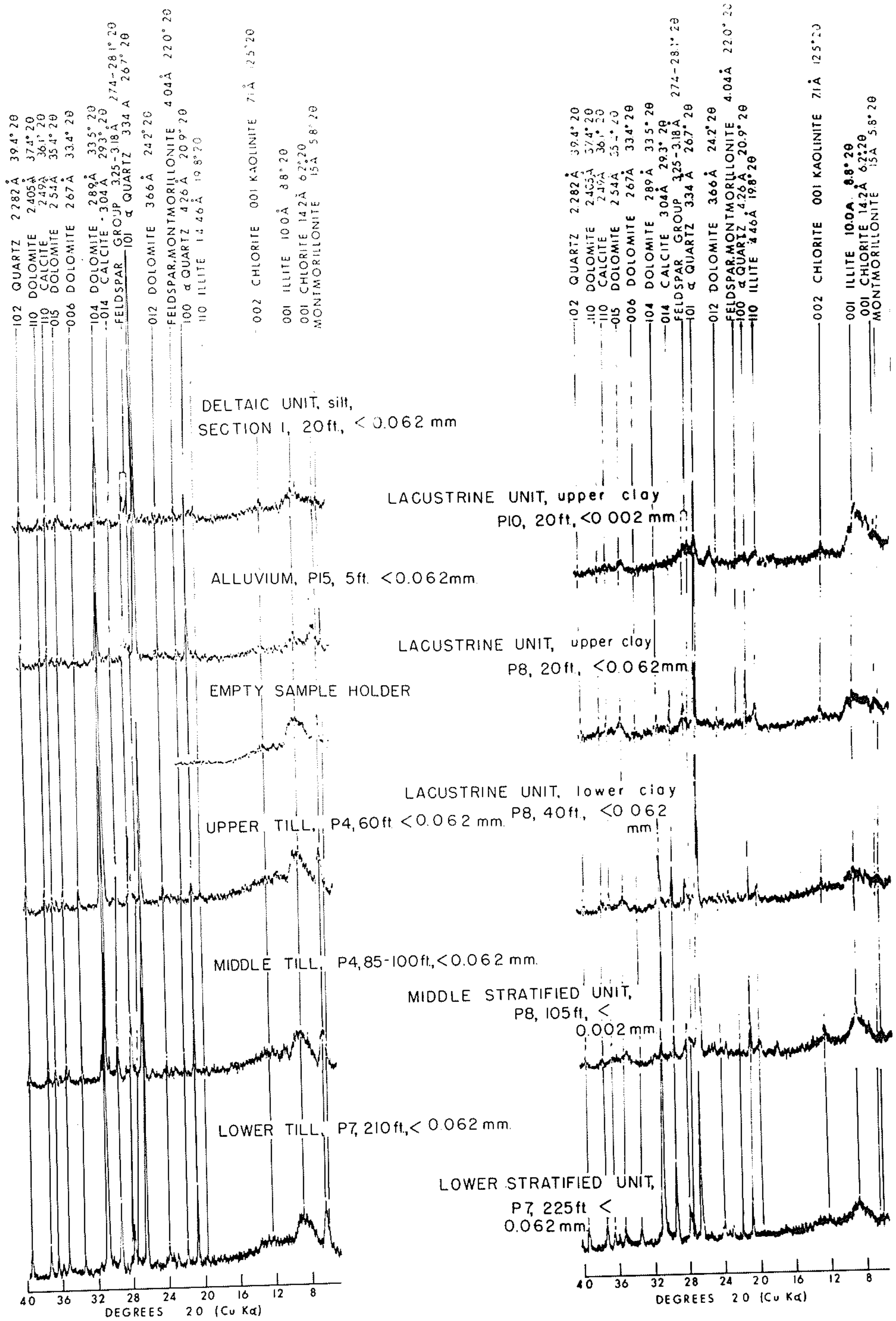


Fig. 9 X ray diffractometer patterns from selected samples.

Table 3

Weight Percent Dolomite and Calcite for Selected Specimens

All. = alluvial unit
L,uc = upper lacustrine unit
L,lc = lower lacustrine unit
D,ss = deltaic silt
MS = middle stratified unit
LS = lower stratified unit
LT = lower till
MT = middle till
UT = upper till
b = brown
r = red

Hole No.	feet	Unit	Grain Size (mm)	Dolomite	Calcite	Unit Average Dolomite wt.%	Unit Average Calcite wt.%
P13,	000-015	All.	0.002	08%	04%		
P15,	0- 5		0.062	13	08		
P 8,	20- 30	L,uc	0.062	07	05		
P 8,	40- 45	L,lc	0.062	11	09		
Sec. I,	20	D,ss	0.062	19	06		
P 8,	100-105	MS	0.002	05	05		
P 7,	180-185	MS	0.062	47	11		
P 7,	215-220	LS	0.062	32	20	28%	26%
P 7,	220-225	LS	0.062	23	32		
P 8,	140-145	LT	0.062	36	18	33	26
P 7,	205-210	LT	0.062	29	24		
P 1,	55- 65	MT	0.062	40	18		
	70- 75	MT	0.062	28	18		
	75- 80	MT	0.062	34	19		
	75- 80	MT,b	0.062	46	23	38	21
	80- 87	MT	0.062	50	22		
P 4,	60- 65	MT,r	0.062	36	20		
	85-100	MT	0.062	36	19		
P 7,	105-100	MT	0.062	31	27		
P 1,	20- 30	UT	0.062	30	18		
	40- 50	UT	0.062	33	17	35	18
P 4,	30- 31	UT	0.062	38	18		

mineralogy of the less than 0.062mm fraction is characterized by a lower carbonate and a higher clay mineral content than the tills (Figures 8 and 9). A portion of this unit could not be sampled with either a tube or a sidewall sampler because the sediment failed to remain in the samplers (hole P7). This suggests the sediment to be a fairly clean unconsolidated sand. This unit is identifiable only in the southwestern part of the area and appears to grade into the till + stratified unit to the north and east.

Till + Stratified Unit

This unit consists of till interbedded or mixed with stratified silt, sand and clay. All information on this unit comes from rotary chip samples and because of this the detailed character is not known. This unit occurs in the west central portion of the area (Figures 6 and 7) and grades southward and westward into the lower stratified unit.

Lower Till Unit

This till is a grayish-brown to brown clay loam having a higher carbonate content than the stratified deposits (Tables 2 and 3, Figures 8 and 9). It has been recognized only in the southwest (Figures 6 and 7).

Middle Stratified Unit

This unit is composed of interbedded deposits of silt, clay and sand (see Table 2). Sidewall samples show the deposits, particularly the silts, to be very well sorted (Figure 8, analyses numbers 14 and 19). There is a marked variation in carbonate content with grain size, the silts being carbonate rich and the clay being carbonate poor (Table 3). This unit is present only in the southwest (Figures 6 and 7).

Middle Till Unit

This is a loamy till (Table 2, Figure 8). The average carbonate content, of the less than 0.062mm fraction, is greater than in any other unit. In one hole analyzed in detail, the dolomite content increases with depth (Table 3, hole P1). The drilling indicates a boulder concentration often occurs at the upper surface of this unit (Figures 6 and 7). The unit varies from light grayish-brown to grayish-brown though there is no pronounced darkening with depth. In the north, where it is overlain by the upper till, the middle till is distinguished by its lighter colour.

This unit forms a fairly level surface in the southern two-thirds of the area (Figure 10). The major feature is a broad southeast trending depression which deepens eastward from the center of the area. The elevation of the top of this unit in one hole, SW-35-12-7W1, is anomously low. Without additional data the veracity of this identification is uncertain.

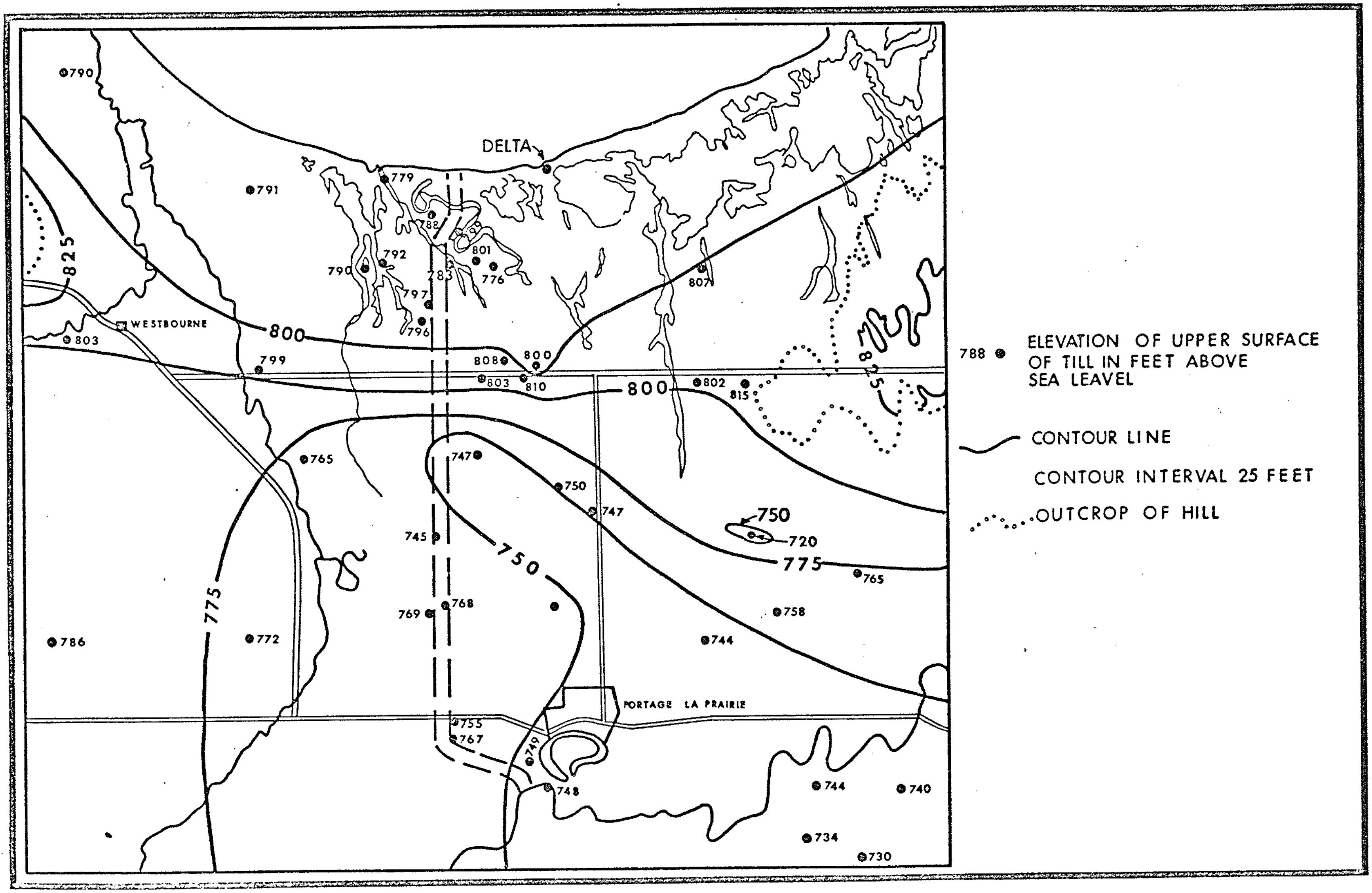


Fig. 10 Contour map on shallowest tills

Upper Till Unit

This till is a loam to clay loam (Figure 8). The mineralogy of the less than 0.062mm fraction, is characterized by a higher carbonate content and lower clay mineral content than most of the stratified units (Table 2, Figure 9). The average carbonate content is similar to that of the middle till. This unit is present in the northern one-third of the area forming an asymmetric, arcuate, roughly east-west trending ridge with the south slope much steeper than the north (Figure 10). The central part of the ridge is low with the till surface increasing in elevation to outcrops in the northwest and northeast (Figures 5 and 10).

The morphology is characterized by prominent northwest-southeast trending lineations consisting of parallel to subparallel ridges and troughs less than 10 feet from ridge crest to trough base and less than 500 feet from crest to crest. These lineations are most obvious on air photographs, the pattern being accentuated by the vegetation growth (Plate I). A further comment on the lineations can be found in the section on discussion of geomorphology.

Prodeltaic Unit

Silt Subunit

This deposit is composed of clayey silt. The distribution of this unit is shown on Figure 5 and the properties

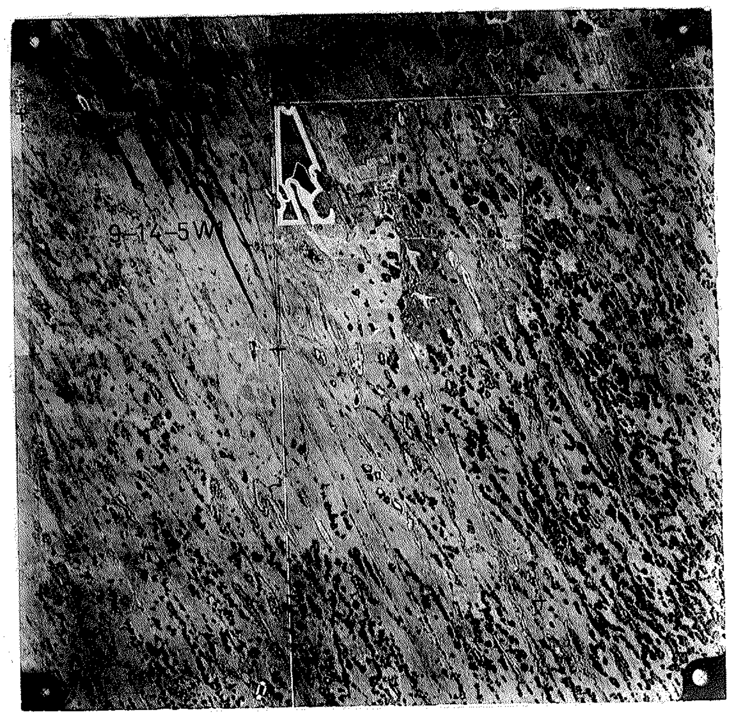


Plate I. Lineated till northeast part of the study area, 9-14-5W1.

summarized in Table 2. The most characteristic feature of this subunit is that the beds are repetative. This subunit, as determined in Section 1 (Appendix B), consists of thinly laminated beds one foot thick. The base of each bed is composed of a laminae of pure dark gray clay, less than 1 inch (≈25mm) thick. This grades upwards into thin 0.25 inch (≈7mm) thick, parallel laminated clayey silts and then into cross laminated, thinly laminated, often contorted and faulted clayey silts, the upper surface of which may show cut and fill structures. The upper surface of each bed is generally level and the next layer of pure clay begins with a sharp contact (Plate II). In one particular bed there was additional parallel laminated silt between the cross laminated and deformed portion and the clay of the next cycle. The basal clay layer decreases to less than 0.1 inch (≈2mm) near the top of the section. Textural analysis of one sample of the parallel laminated silt showed the sand fraction to contain more than ten percent very fine-grained coal by volume. Mineralogically, the deltaic silts are intermediate between the carbonate rich tills and the clay mineral rich clays (Table 2, Figure 9). The thickness of the silts is uncertain because the contact with the underlying lacustrine unit is gradational. The two holes which completely penetrate the subunit contain 30 feet (hole P7) and 50 feet (hole P12) of silt.

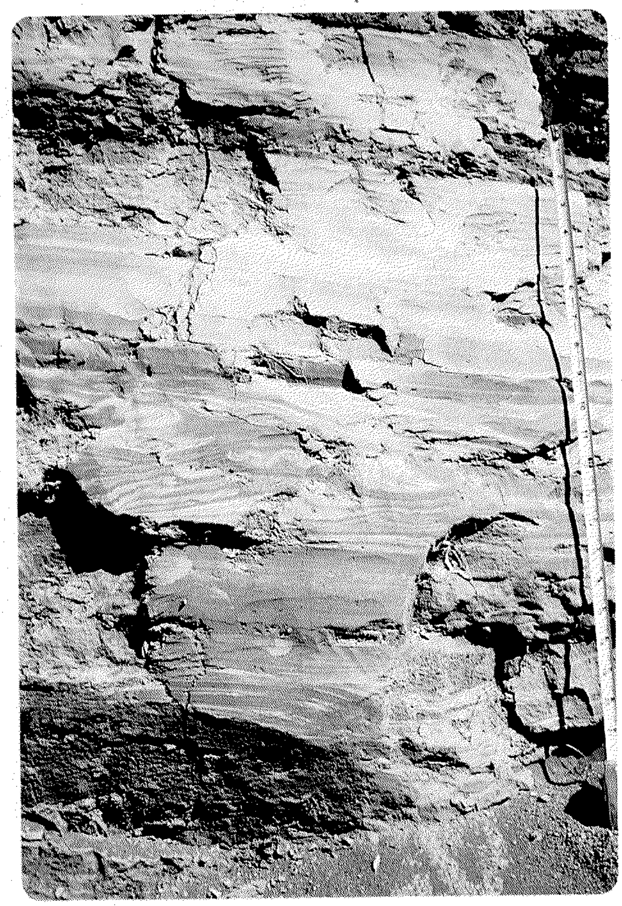


Plate II. Prodeltaic silt subunit showing repetative bedding, EC-29-11-8W1.

Sand Subunit

This deposit is composed of fine to very fine grained sand. The distribution is shown on Figure 5 and the subunit's properties are summarized in Table 2. In section 1 the lower portion of the deposit is grayer in colour and contains occasional pebbles while the upper part is brown and pebble free. This change was also noted in some of the hand auger holes (less than 3 feet, (≈1mm), deep) drilled in the area. The contact with the underlying silt appears gradational over a number of feet although the weathered condition of section 1 made the determination of the exact boundaries impossible. Dunes, stabilized by vegetation, occur in the southern portion of the subunit (Plate III).

Lacustrine Unit

This unit can be divided into a lower and upper clay and an overlying silt (Table 2, Figures 5, 6 and 7). The lacustrine silt is a minor division of this unit. It forms a thin discontinuous deposit in the southwest. The upper and lower clays are distinguished mainly by their colour. The lower clay is generally darker than the overlying clay, within a particular hole, and occasionally has a bluish cast. The colour of each clay is not constant within the area (Table 2). The lower clay is often softer and appears massive when fresh. The limited laboratory data indicates the lower clay to be slightly

Plate III. Prodeltaic sand subunit showing stabilized dunes, 15-11-7W1.

coarser and more carbonate rich (Table 2, Figure 8, Numbers 21, 22 upper clay, and 23 lower clay). The contact between the two clays is gradational over at least three feet and in some samples contains fragments of the upper and lower clay (Plate IV). In some holes the contact could not be distinguished.

The clays contain both laminations and colour bands though the laminations in the lower clay are visible only in a dry specimen. Though the exact nature of the bedding is uncertain because of the distortion by the auger, the colour bands are generally 0.25 to 0.5 of an inch (≈6 to 12mm) thick and may be massive or contain thin laminations, less than 0.1 of an inch (≈3mm) thick. Stones ranging from granule to boulder size occur throughout the unit with the proportion increasing to more than fifteen percent as the till contact is approached. Clasts of till and light grayish-brown to light olive-brown silt (Plate V) up to six inches in diameter, and light gray to buff to pink clay to silt up to 0.5 of an inch (≈12mm) in diameter (Plate VI) are occasionally present in the clays. The quantity and size of the till clasts increases as the till contact is approached. The small silt to clay and larger silt clasts were seen in situ but in these cases bedding plane deformation could not be determined because of the weathered nature of the outcrops. The clasts themselves are angular and show no sign of deformation.

Plate IV. Upper and lower lacustrine clay, NW-15-11-6W1, hole P18. The upper clay is on the right.

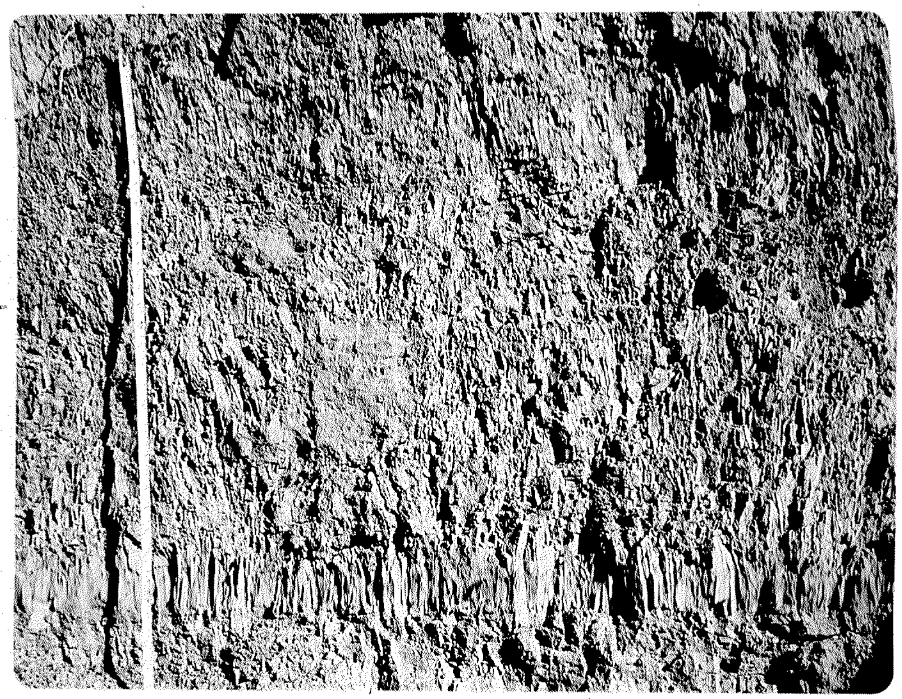


Plate V. Upper clay showing grayish-brown silt clasts, 22-13-9W1.

Plate VI. Lower clay showing light gray silt clast, NW-15-11-6W1.

Another type of inclusion is large masses, 3 x 4 x 9 feet (≈1 x 1 x 3m) of thinly laminated, highly contorted olive-gray sandy to clayey silt. These were seen in the excavation for the inlet structure for the Portage La Prairie Diversion (27-11-7W1) enclosed in what appeared to be the lower clay at a depth of approximately 30 feet (≈10m). The inclusions resemble the material comprising the prodeltaic silt subunit in colour, grain size and bedding - such as can be determined from the distorted inclusions.

Strandline Features

Two strandlines can be distinguished in the area. The higher and older occurs at the contact of the deltaic and lacustrine units, and the younger northeast of this on top of the lacustrine unit (Figure 5). The properties of this unit are summarized in Table 2. The older strandline, except in the extreme western part where it is undetectable, consists of a low scarp 5 to 10 feet (≈2 to 3m) high, cut into the deltaic unit. A low ridge trends parallel to the scarp northeast of it. As this ridge extends from the sand area at the northwest end of the scarp and is only slightly lower in elevation than the scarp it is interpreted as a barrier bar. The bar is massive, lacks bedding, and contains less than 1% pebbles (Plate VII). The bar has been split into segments by later stream erosion.

The more northerly strandline forms an asymmetric

Plate VII. Portion of barrier bar showing lack of bedding and low pebble content, NE-26-11-8W1.

ridge, 5 to 10 feet (≈2 to 3m) high on the seaward side, and changes eastward to a north facing scarp (Figure 5). The feature decreases in height westward and becomes undetectable. Immediately north of the Assiniboine River the scarp has been removed by later alluvial activity. South of the Assiniboine it reflects through a thin veneer of alluvium. The beach deposits consist of sand and gravel whereas the scarps being erosional have only a limited amount of storm-deposited sand on the crest and lag debris at the base.

Post Glacial Deposits

Fluvial Unit

The sediment grouped in the fluvial unit was deposited in and adjacent to two types of channels. These two channel types are informally referred to as the alluvial channels and the lake plain channels.

Alluvial Channel Deposits

The distribution of the alluvium is shown in Figure 5, and the properties of the material in Table 2. The most striking feature of this deposit is the alluvial channels themselves which are broad and sinuous, and with the exception of the Assiniboine and the Whitemud Rivers, are abandoned or contain underfit streams. There are about a dozen of these channels and channel fragments and the majority extend north from the vicinity of Portage La Prairie. The channels can be divided into older, or

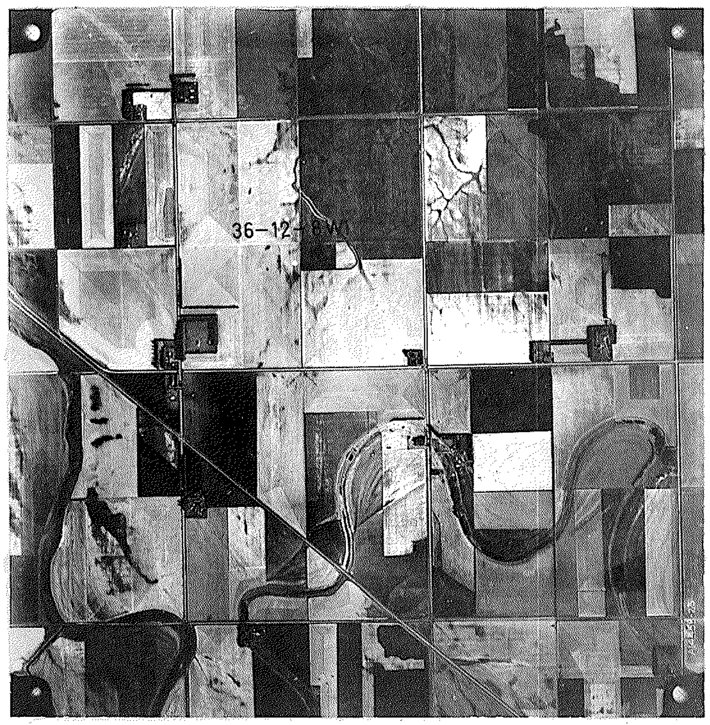


Plate VIII. Alluvial channels; older in the northwest and younger in the extreme west and south, 12-8W1.

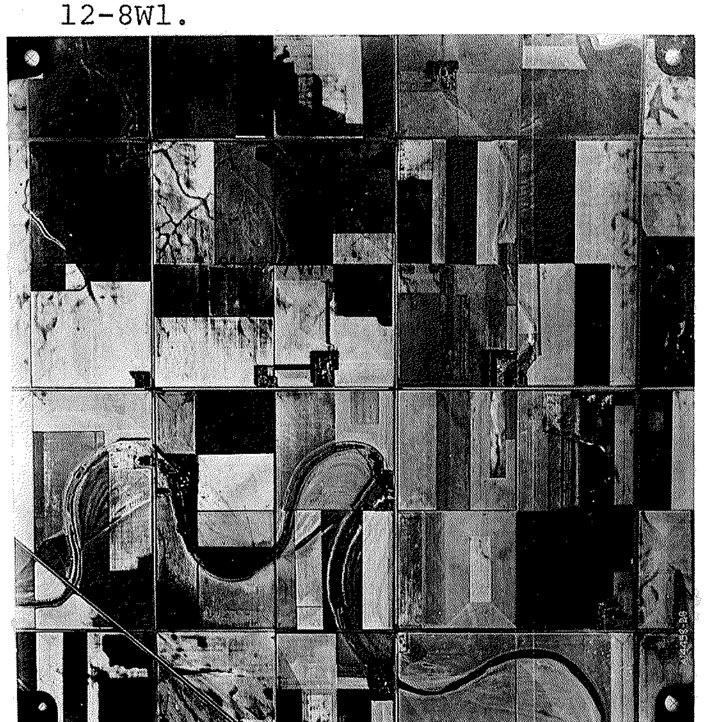


Plate IX. Straight, older channel, partially buried by alluvium from a meandering, younger channel, 12-7W1.

oral comm., 1969). The sample came from clay 20 to 26 feet below ground level and below 20 feet of sand and silt. The mineralogy is listed in Table 2.

The contact between the alluvial and lacustrine units is difficult to determine because the alluvium thins gradually away from the channels creating a "feather edge" surface at the contact and the lithology of the two units is often similar at the contact, a grayish-brown, slightly silty clay. Criteria used to determine the contact include: (i) photo pattern, the alluvium having the sinuous channels while the lacustrine clay has angular channels (Plate VIII), (ii) the degree of compaction, the alluvium being softer, (iii) the presence of till and silt pockets in the lacustrine clay, and (iv) the presence of plant and animal material in the alluvium.

Lake Plain Channel Deposits

These include all the material deposited in the channels cut into the lacustrine clays. The channels themselves are relatively angular (Plate VIII), have no recognizable flood plains and truncate the alluvial channels (Plate X). The sediment, impure clay and silt, is essentially confined to the channels themselves.

Marsh Unit

This unit includes the material deposited in the marsh south of Lake Manitoba. The distribution of the unit is

Plate X. Lake plain channel cutting through an alluvial channel in the southwest portion of the photo, 25-13-8W1.

shown in Figure 5 and the properties listed in Table 2. The unit is composed of organic-rich clays and silts. A radiocarbon date of 2,400 ± 230 years B.P. was obtained from a sample of organic material recovered from the lower part of the unit in Cadham Bay (Walker, oral comm., 1969).

Recent Beach Unit

This unit forms a discontinuous ridge along the south shore of Lake Manitoba (Figure 5). A summary of the properties is given in Table 2. A second ridge south of, and parallel to, the first is recognizable only in 15-14-7Wl. The deposit is composed of well sorted and cross-bedded sand. The submerged portion of the beach was not investigated but pre-existing data indicates that moving lakeward from SE-17-14-7Wl there are a series of offshore bars with the bottom sloping gradually to approximately 15 feet 3,000 feet offshore (Vascatto, written comm., 1969). Beyond this the bottom is smooth for a number of miles.

CHAPTER IV

DISCUSSION

UNIT COMPOSITION

Information on the composition variation between the different units is based upon grain size, calcite and dolomite, and X-ray diffractometer analyses (Table 3, Figures 8 and 9). Though the limited number of analyses preclude a unit by unit comparison, a comparison of the till to non till units does yield information about the source of these deposits. In general, the carbonate content decreases and the clay mineral content increases from the tills to the silts to the clays (Table 3). The high carbonate content of the tills reflects their origin from glaciers which passed over a minimum of one hundred miles of Palaeozoic carbonates and/or calcareous till. The higher clay mineral content of most of the silts suggests part of their source area contained a greater abundance of clay minerals. The closest region meeting this condition is the Manitoba Escarpment, and westward, which is composed dominantly of shales. The major silt deposit, the deltaic silt subunit, likely formed from material carried off the top of the Escarpment and the lower stratified units probably also received a portion of their sediment from this source area. One exception is the silt from the middle stratified unit (Table 3, hole P7, 180 to 185 feet). This sediment contains the greatest amount of carbonate recorded for any unit, 58 wt.%. An explanation for this is suggested by: (i) the high silt content of the unit, 88 wt.% silt, (ii) a study by Dreimanis and Vagnar (1969) of tills in southern Ontario which showed that the terminal mode, the grain size in which a particular comminuted mineral concentrates, for dolomite and calcite is the silt size, and (iii) the source material available for comminution is mainly carbonates. The deposition of a very silt-rich sediment, likely from a carbonate-rich till, determined the material would also be very carbonate-rich. The available data is, however, insufficient to determine why the material is silt-rich. The much lower carbonate content of the clays, approximately 10 wt.% total, is because their grain size is below the terminal mode of the carbonates.

The slight variation in carbonate content between the individual till units is indicative of their source. The respective calcite and dolomite values for each till are within a few percent of each other (Table 3). This indicates the tills were formed by glacial advances from the same direction. Each glacier incorporated similar bedrock material or the pre-existing till. The high carbonate content of the tills, approximately 50%, suggests the glaciers advanced from the north over the expanse of Palaeozoic carbonates.

In hole P1 where carbonate variation with depth was determined the dolomite content of the middle till, below 50 feet, varies from 28% near the upper contact to 50% near the bottom contact (Table 3). The bedrock in this area is the dolomite rich Amaranth Formation. The increase in the dolomite with depth is believed the result of a greater component of local bedrock in the till. This is supported by a distinct pink colour in the lower twenty feet of the till due to the comminution of the Amaranth red beds. The fact the calcite content varies only a few percent over the interval suggests that the calcite was incorporated from a more distant source. Dreimanis and Vagner (1969) found that the dolomite content of a till in southern Ontario increased slightly away from the dolostone contact and then decreased to a value which remained constant for more than forty miles.

PRODELTAIC SILT SUBUNIT

This subunit is characterized by repetitive bedding, each bed consisting of a thin pure clay laminae at the base and overlying thin parallel and cross laminated silts (see stratigraphy section for further description).

The subunit is believed to be the prodeltaic sediment deposited in front of the Assiniboine Delta. The cycles within the unit may be due to turidity currents dislodged from the Assiniboine Delta to the west. The turbidity current hypothesis has been proposed for other glacial sequences (Banerjee, 1965; Agaterberg and Banerjee, 1969; and Lajtai, 1966). The gradual upward increase in grain size within each bed is not entirely explained by turbidity currents however. The deposits may also be the result of yearly cycles with the pure clay being deposited during the winter and the coarser material during the spring runoff.

PRODELTAIC SAND UNIT

This subunit consists of sand with the upper part being pebble free (see stratigraphy section for further description). The entire subunit is attributed to redeposition of sand eroded from the upper part of the Assiniboine Delta by wave action as Lake Agassiz fell from its highest level (Elson, 1966). The presence of stabilized dunes in the south (Plate III) and the pebble free nature of the upper part of the subunit suggests it to be an aeolian reworking of the original sand after Lake Agassiz drained from the area.

pretation is supported by their lithologic resemblance to the silt subunit, the close proximity of the subunit front - immediately to the west of the location of the inclusions, and the highly contorted condition of the inclusions.

Upper and Lower Clay Division

The lacustrine clays have been divided into an upper and lower clay (see stratigraphy section for a description). This division is believed similar to the division into "brown" and "gray" clay made by Riddel (1950), Baracos and Bozozak (1958), Wicks (1965), and others in the Winnipeg area. The author used the terms upper and lower because of the colour variation within each division. The clays differ somewhat from those around the Winnipeg area. Wicks (1965) describes the gray (lower) clay as massive while it is at least partially laminated in the study area. The difference may be because of the sample location or Wicks examination of a fresh surface only in which the laminations are undetectable. The brown (upper) clay is described as thinly varved, varves 0.3 of an inch thick (Wallace and Maynard, 1924). In the study area the upper clay contains thin laminations but nothing which appears to be varve couplets. The thin laminated beds alternate irregularly with massive beds.

The upper clay is generally light grayish-brown to grayish-brown while the lower clay is dark gray to very dark grayish-brown. The cause of these colour differences is uncertain. Weller (1960) states that colour depends upon mineralogy, grain size and packing, organic content, and oxidation state of the iron cations. The author's analyses indicate the difference in mineralogy and grain size are insignificant. The organic content could effect only the shade, not the colour. The only remaining source is the oxidation strata of the iron. The brown colour is likely due to iron in the ferric state in the upper clay. This oxidation could have taken place in either the source area of the clay or after deposition due to oxygen rich groundwater. Oxidation in the source area is more likely as the clays are in a groundwater discharge area (Lutchman verbal comment, 1970). It is unlikely groundwater oxidation is the cause as the clays are located in a groundwater discharge area (Lutchman MSc. thesis in preparation, 1970). The colour of the clay is most likely due to oxidation in the source area.

STRANDLINE FEATURES

The higher more southerly strandline is composed of a beach and scarp at the shoreline and a barrier bar. The exact method of formation of the bar is uncertain. Bird (1964) states that a barrier bar can be formed by either the extension of a spit across a bar or shoreward migration of a foreshore bar. The straight nature of this bar and the absence of recurves, typical of many spits, suggests it originated from an offshore bar. The sand area to the west (Figure 5) could have furnished material for the southward construction of a spit by longshore currents. This origin is supported by assuming the present prevailing wind direction, from the northwest, was the same during construction of the bar. Elson (1967) makes a similar assumption when discussing the direction of storm winds on Lake Agassiz.

WATER PLANE IDENTIFICATION

The location of several Lake Agassiz water planes was determined using isobase location, and water plane elevation and uplift data from Johnston (1946) and Elson (1967). The higher strandline intersects the Gladstone water plane and the lower, northern strandline intersects the Burnside water plane. The Ossawa water plane intersects the land surface along a northwest-southeast trending line through the central portion of the area. There is, however, no evidence of the development of the Ossawa strandline in the area because the southeast half of the strandline is buried by more recent alluvium and the northwest half is on the flat lacustrine plane. Johnston (1946) identified the Ossawa strandline west, south and east of the area. Failure of the strandline to develop is likely because of a lack of sand from which to build a beach and to a shallow gently sloping littoral zone which prevented the development of waves large enough to cut a scarp. Ehrlich et al. (1957) interpreted a southeast trending strandline in 3-14-9W1 and 34-13-9W1. This feature is not included in this study because it is very poorly defined on air photos and is not marked by a ridge or a scarp in the field.

GEOMORPHOLOGY

Lineations

Lineations are very well developed on the exposed till in the northeast and are visible to a lesser extent on the adjacent lacustrine unit for approximately three miles beyond the lacustrine clay till contact (Figure 5). Lineations also occur on the northwest portion of the lacustrine unit. The northeast lineations are parallel to subparallel ridges and troughs of low relief, less than 10 feet from crest to trough, less than 500 feet wide, from trough to trough, and extending up to six miles in length (Plate II). These lineations occasionally have minor ridges on the slopes between the crests and the troughs. The northwest lineations are of very low relief, less than 3 feet, and 50 feet wide, and extend up to three miles and may be straight or curvilinear (Plate XI). These lineations occur much less frequently than those in the northeast.

Lineations occur in many areas of the Agassiz Basin but are concentrated in the lower, last drained portion, extending from North Dakota (Clayton, 1965) to well north of Lake Winnipeg. They were first studied by Horberg (1951) who interpreted them as fracture fillings in lake ice or permafrost features. Later authors have made other interpretations; Nikiferoff (1952) the product of wave and running water, Mollard (1957) the product of the downward movement of groundwater through joints in the bedrock, Elson (1961) the upward movement of groundwater through joints in the bedrock, Colton (1958) the product of the squeezing of sediment up into cracks in the lake ice. More recently, Clayton et al. (1965) suggested the lineations were formed by lake ice being blown over the shallower parts of the lake and gouging furrows in the bottom. Wardlaw et al. (1969) interpreted the lineations in the Gypsumville area (central part of the Interlake area, Manitoba) to be due to giant grooves in the carbonate bedrock or reflections thereof through the thin till.

The lineations in the northwest are probably due to wind driven ice blocks as proposed by Clayton (1965). In many places they occur on top of 40 to 90 feet of lake clay, eliminating the possibility of reflections of bedrock or till topography. Also, some of the lineaments are curvilinear and others intersect at angles of 40° or more, features noted by Clayton (1965) for ice drag lineations elsewhere in the basin and by Weber (1958) for recent ice drag lineations on Great Slave Lake.

to Lake Manitoba. This discussion will deal with certain aspects of these channels relating to the geomorphic development and history of the area.

As mentioned in the stratigraphic description these channels vary from shallow, poorly defined slightly sinuous channels to relatively deep, well defined, meandering channels. An example of a straight channel, hereafter referred to as the MacDonald Channel, is that passing through the MacDonald airfield (Plate XII, Figure 5). An example of a meandering channel is the Fort La Reine Channel (Plate XIII) which extends from Lake Manitoba at least as far south as the center of 12-7W1. An examination of the surficial geology map (Figure 5) suggests an evolution of channel type from the straight to the meandering. The straight channels are older being truncated and buried by the younger channels as at 25-12-8W1 (Plate VIII) and 13-13-7W1. The youngest channel in the area is the Fort La Reine which truncates older, both straight and meandering channels, in at least four places. This channel also has the greatest sinuosity, 1.95. The sinuosity of the MacDonald channel is only 1.15. The fact that all these channels extend north from the vicinity of Portage indicates a common water source and therefore a closely related history.

The development of these channels is related to the development of the marsh and the beach on the south shore

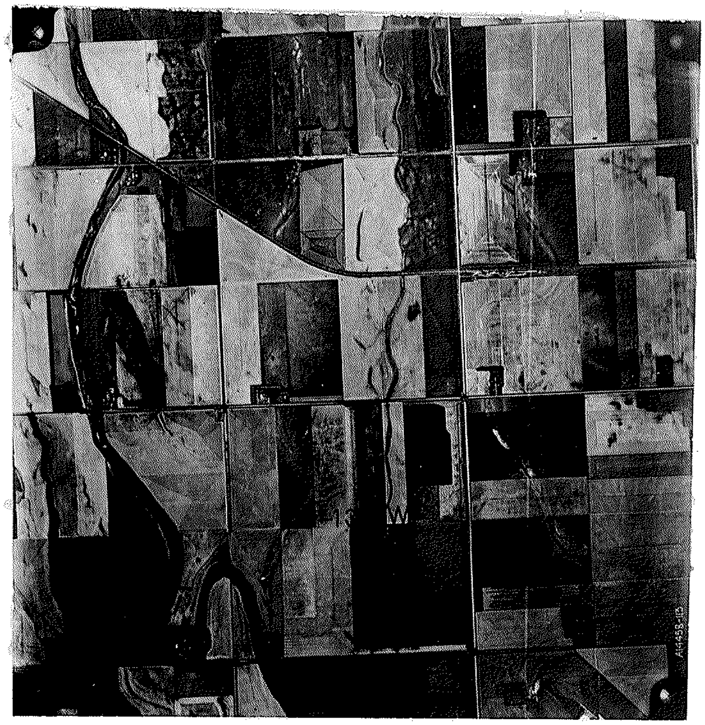


Plate XII. (a) Air photograph of straight channel, 13-8W1.

Plate XII. (b) Ground photograph of a portion of the channel, SW-23-13-8W1.

Plate XIII (a) Air photograph of a meandering channel, 13-7W1.

Plate XIII (b) Ground photograph of a portion of the channel, SW-24-13-7W1.

of Lake Manitoba. The straight channels and the older meandering channels which extend into the marsh have a submerged or drowned appearance as at 7-14-6W1 (Plate XIV) and 14-14-6W1 (Figure 5). The Fort La Reine channel, however, truncates the marsh extending to the beach at 17-14-7W1 and as an isolated part of this channel in 18-14-7W1 indicates extended into the present Lake Manitoba (Plate XV). If these two channel sections are joined using approximately the same radius of curvature as the meanders immediately to the south the missing portion of the channel extends approximately one half mile into the present lake. A hole drilled in the Fort La Reine channel immediately south of the present lake shore shows the base of the channel to be at 795 feet (≈263m) MSL. A transect north into the lake indicates the elevation of the present lake bottom to be 800 feet (≈266m) MSL about 3000 feet (≈1000m) from shore (Vascatto, written comm., 1969).

This evidence indicates a fairly complex history of channel evolution and shoreline development in the area. The water source for the channels is believed to be the Assiniboine River with the flow turning north, from the present river, immediately southwest of Portage. The age relationships suggest originally there was only one, slightly sinuous, northward flowing channel. The other channels formed by the sudden abandonment of part or the whole of the channel carrying the flow at that time. This

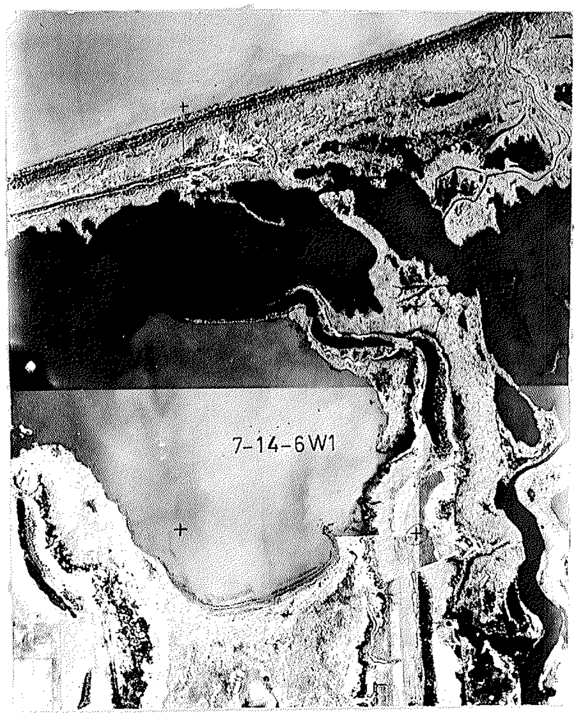


Plate XIV. Drowned mouth of an alluvial channel entering Cadham Bay, 7-14-6W1.

Plate XV. Air photograph showing truncation of the present northernmost bend of the Fort La Reine channel, 14-7W1.

process has been described for recent streams such as the Mississippi (Fisk, 1947), the Meander, Anatolia (Russel, 1954), and Texas streams (LeBlanc and Hodgsen, 1959).

The degree of sinuosity increases in the younger channels. The factors causing meandering are uncertain. Different authors (Schumm, 1963; Friedkin, 1945; and Shulits, 1941) have tried to relate it to a number of factors and it is likely that sinuosity results from the interaction of a number of factors with one or two being dominant in each case. Friedkin (1945), by a number of laboratory experiments, found that the radius of curvature of the meander bends increases with an increase in gradient or an increase in discharge. The younger channels, especially the Fort La Reine, show a decrease in the radius of curvature of the meander bends (Figure 5). If the reverse of Friedkin's findings can be assumed, the channel evolution in the area may be the result of a decrease in gradient and/or discharge. A northward decrease in gradient, with time, is to be expected due to the post glacial uplift in the area. Measurement of the amount of uplift on a north south trending part of the Gimli beach, which formed after Lake Agassiz drained from the study area, indicates a northward increase in elevation of 0.7 feet/mile (0.15 m/km) in the region east and slightly north of the study area. Using a figure of 0.5 feet/mile yields an uplift of 8 feet (≈2m) between the Assiniboine River and Lake Manitoba. A decrease in discharge is to be expected as Lake Agassiz drained and the modern climate developed. The thermal maximum associated with the Hypsithermal interval (Deevey and Flint, 1957) may have contributed to the decrease in discharge.

The southward migration of the south shore of Lake Manitoba (discussed previously) also effected the channels. This migration caused the development of the marshes and the drowning of the older channels. A radiocarbon date of 3,375 ± 250 years BP for organic material near the bottom of the Fort La Reine Channel (Gilliland oral comm., 1969) indicates the date of the development of the last channel and a radiocarbon date of 2,400 ± 230 years BP from the sediment on the north side of Cadham Bay (Walker oral comm., 1969) indicates the approximate time of development of the marsh in that area. The Fort La Reine channel appears to have formed before the present marsh and since it truncates the marsh deposits, functioned after the present development began. The erosion of the northern meander bend of the Fort La Reine Channel and the development of the present shoreline took place after 2,400 years BP. The 795 foot (≈265m) elevation of the base of the Fort La Reine Channel, immediately south of the present lake shore, together with the elevation of 800 feet for the present lake bed indicate an infilling of the channel during the southward migration of the shore.

The bases of the different channels vary from 10 to

30 feet (≈3 to 10m) below the present land surface. This requires an initial period of down cutting after the development of each new channel. The youngest channel is 20 feet (≈7m) deep immediately south of the present lake shore indicating the base level was low enough throughout the period of channel development to allow down cutting to the previously mentioned depths. The channels also contain 10 to 25 feet (≈3 to 8m) of sediment. Why this thickness of sediment should be deposited in a channel which originally down cut is uncertain, but, it is likely because of (i) deposition resulting from diminished discharge during the time the channel was being abandoned, and (ii) deposition after abandonment by use of the channel during flood periods. Great volumes of sediment can be deposited by the present Assiniboine during flood. After recession of the flood water of the Assiniboine River in the Portage area (1969) the author observed 4 to 6 feet (≈1 to 2m) of sand and gravel deposited in an abandoned part of the channel which was isolated before and after the flood.

Whether these channels carried the entire flow of the Assiniboine River is uncertain. There is a possibility the flow may have been split between these channels and one extending eastward to the Red River. Discharge of the entire river into Lake Manitoba is considered more plausible however. The trend of the Assiniboine River from the base of the Manitoba Escarpment to west of Portage is approximately N30°E which approaches the direction of maximum uplift for the Agassiz Basin, N27°E (Johnston, 1946). This suggests the Assiniboine River followed the post glacial slope of the land east of the Escarpment. When the river reached Portage La Prairie it flowed northward over the low lacustrine plain between the comparative highlands of the Westlake and Interlake Plains (Figure 2). The present Assiniboine River also changes direction suddenly, from N30°E to due east immediately east of the place the alluvial channels intersect the Assiniboine River suggesting a change in the direction of flow of the river after it had established its course into Lake Manitoba. Also the concept of the Assiniboine River flowing simultaneously into Lake Manitoba and the Red River during the entire period the norther channels functioned does not seem probable.

The reason for the eventual abandonment of the Fort La Reine Channel is because of the downcutting of the Assiniboine River, when it commenced to flow eastward, lowered the water level below that of the channel. The reason for the diversion of the Assiniboine is, most probably, that it was captured by a headward eroding tributary of the Red River. The development of this tributary may have been aided by the eastward flow of the Assiniboine River during times of flood. The abrupt change in direction of the Assiniboine from N30°E to due east at the point the abandoned channels meet the Assiniboine suggests river capture.

Another meandering stream not directly associated with those discussed above is the Whitemud River. This stream flows along the southern and eastern boundary of the lacustrine silt unit in the northwest. The only age relationship between the Whitemud River and the channels on the Lowland plain is the apparent piracy by a tributary of the Whitemud of one of the older meandering streams in 24-14-9Wl and the meander pattern of the Whitemud is as complex as that of the Fort La Reine Channel. The location of the Whitemud River appears strongly influenced by the distribution of the lacustrine silt unit, but since the silt is thin in the area it is more likely a reflection of control by the underlying till.

Lake Plain Channels

These channels appear geomorphically distinct from the alluvial channels. As mentioned, these channels are water filled, cut into the lacustrine clay, comparatively narrow and angular, and have no noticeable flood plains. They are short, extending south only one-half of the distance to Portage. The mouths of the channels empty directly into the marsh with no drowned appearance (Plate X). A lake plain channel truncates one of the older straight alluvial channels at 25-13-8Wl (Plate X). Because of these features the lake plain channels are believed to have developed contemporaneously with or later than the marsh.

CHAPTER V

GLACIAL HISTORY

Four major glaciations occurred during the Pleistocene Epoch in North America. The latest of these was the Wisconsin Glaciation which advanced over the continent about 50,000 years ago. Melting ice of the last glacial advance furnished the water to form Glacial Lake Agassiz.

EARLY GLACIAL ADVANCES

On the basis of the limited data available the units below the middle till indicate one if not two glacial advances - the till + stratified unit and the lower till, and two periods of retreat with the formation of pro-glacial lakes - the lower and middle stratified units separating the tills. The high carbonate content indicates the advancing glacier(s) crossed the Palaeozoic rock to the north and the east of the area. The comparatively high clay mineral content of the stratified deposits indicates a drainage component from the Manitoba Escarpment in the west. The mixed till + stratified unit suggests a possible ice frontal position during the earliest ice advance.

There is no data to indicate the age of these deposits. Bluemle (1967) interprets stratified deposits and till in a similar stratigraphic position in North Dakota as Pre-Wisconsin in age. The author believes the deposits in the study area are more probably Wisconsin in age. They may be related to the advances which deposited the Lennard or the Minnedosa Till in western Manitoba (Klassen, 1969) and the Battleford or Floral Formations in Saskatchewan (Christiansen, 1968).

THE LAST ADVANCE AND GLACIAL LAKE AGASSIZ

Phase 1

The ice advanced through the area and into North Dakota depositing the middle till. This advance is late Wisconsin, perhaps related to that which deposited the Lennard Till in western Manitoba (Klassen, 1969) or the Battleford Formation in Saskatchewan (Christiansen, 1968) about 20,000 years ago.

Phase 2

Between 12,500 and 12,000 years ago the ice began to retreat from the Big Stone Moraine forming Glacial Lake Agassiz (Clayton, 1966). Prior to 11,700 years ago the ice retreated to the northernmost position of the Hermin beach (Clayton, 1966). The ice margin lay north of the Assiniboine Delta and the study area was submerged to a depth of about 600 feet ($\approx$200m).

As the remaining glacial history of the area concerns Lake Agassiz, the lake history proposed by Elson (1967) will be referred to frequently. The sequence of lake levels proposed by Elson is shown in Figure 11.

As soon as the region was free of ice the deposition of the Assiniboine Delta began to the west and gray clay was laid down in the study area. The moraine in the northern one-third of the area, the upper till, was formed during this retreat either during a pause in the retreat, corresponding to the rising Lake Agassiz phase of Elson (1958), or during a minor readvance of the ice sheet as suggested by the thin lacustrine clay which appears to underlie the upper till in some places.

Phase 3

The lake level fluctuated over the next 1,000 to 1,500 years, falling as the southern outlet was eroded down, and later as continued retreat opened lower outlets in northwestern Ontario, and rising as readvance blacked these outlets (Figure 11). The study area was submerged during this time and deposition continued on the Assiniboine Delta and in the lake basin.

Phase 4

Ice retreat in northwestern Ontario opened northward, successively lower outlets allowing Lake Agassiz to drain through Lake Nipigon into Lake Superior about 10,500 years

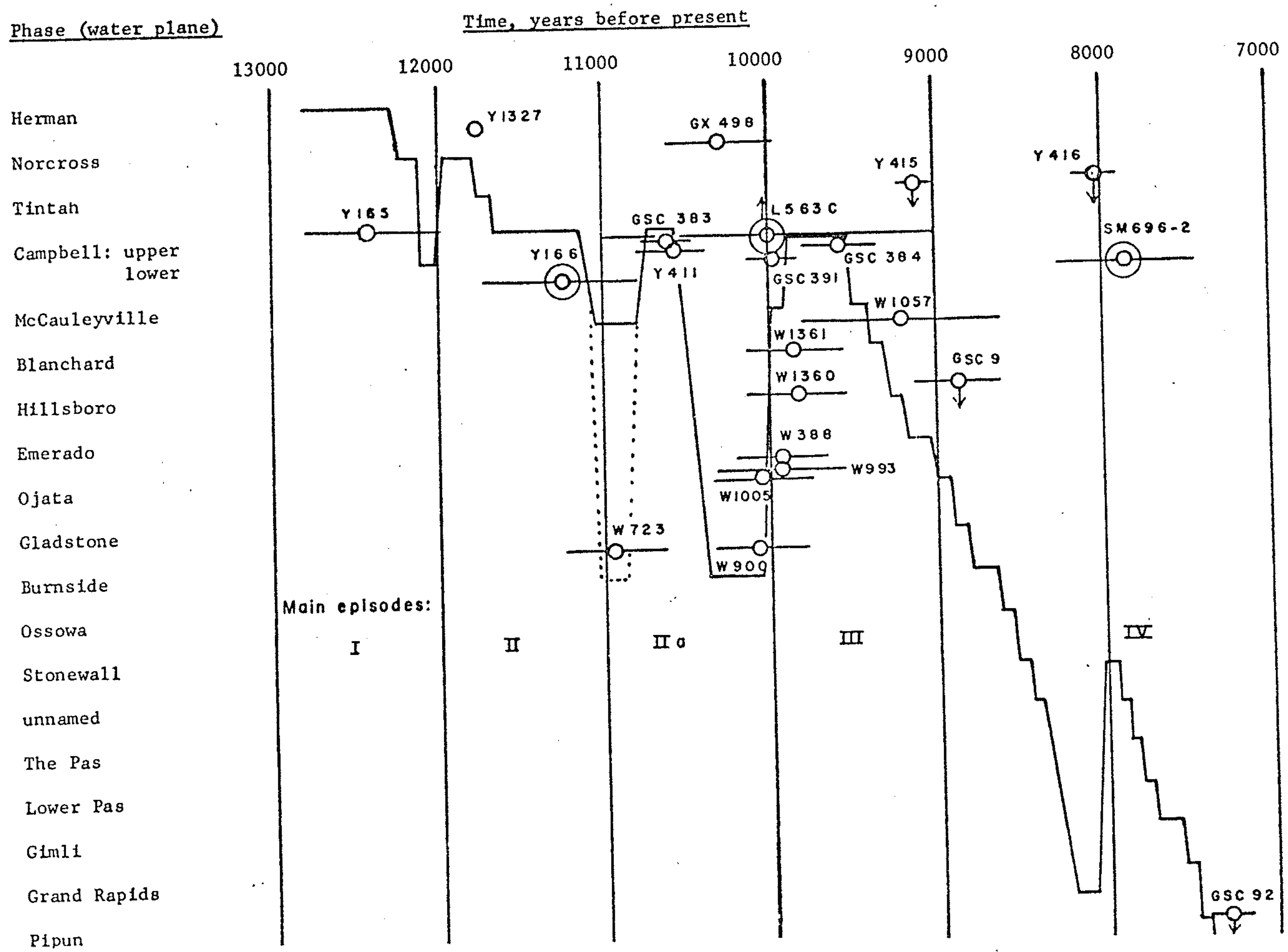


Fig. 11 Hypothetical sequence of water levels of Glacial Lake Agassiz (after Elson, 1967)

ago. The lake level fell perhaps as low as the Burnside water plane exposing the southern one-third of the study area. The level remained low for a long enough time to allow the incision of the Assiniboine River into the upper part of the Assiniboine Delta and the oxidation of the exposed till. The duration of the low level was long enough for the Burnside strandline to form as no lacustrine clay was found overlying beach deposits. Sand may have been eroded form the Upper Delta as the water level fell but it did not reach the study area as the Deltaic silt subunit was later eroded.

Phase 5

A readvance of the ice in the east closed the outlets and caused the lake level to rise to the Campbell strandline about 10,000 years ago. Oxidized material was brought in from the source areas and the upper clay was deposited.

Retreat in northwestern Ontario again caused the lake level to fall (Figure 11). During this period of falling water level sand eroded from the upper part of the Assiniboine Delta was transported eastward, the deltaic silt subunit was eroded depositing the lacustrine silt and before the lake level the Gladstone water plane the deltaic sand was brought into the area. The strong strandline with its associated near shore features was formed in the area when the water level reached the Gladstone water plane.

The lake level then fell to the Burnside water plane forming the Burnside strandline.

The lake level continued to drop and about 8,000 years ago the study area was drained. A later, minor readvance of ice raised the lake level slightly but the study area was not resubmerged. About 7,500 years ago Lake Agassiz drained into Hudson Bay (Elson, 1967) and nearly the present distribution of lakes was formed.

Phase 6 (Alluvial Phase)

Shortly after the water drained from the study area the southern part of Lake Manitoba assumed approximately its present shape except that the southern shore was north of its present position. The Assiniboine River began to flow across the study area and into the lake. With time the river formed other more meandering channels until about 3,375 years ago the Fort La Reine Channel, the youngest, developed.

During this time post glacial uplift tilted Lake Manitoba contributing to a southward migration of the shoreline. Approximately 2,400 years ago the southward flooding lake formed at least the northern part of the present marsh drowning the downstream portions of those older channels extending into the present marsh.

Sometime after the previous event the Assiniboine River commenced to flow eastward and eventually abandoned the Fort La Reine Channel. Continued southward migration of the shoreline later eroded the northern meander bend of the Fort La Reine Channel. The angular lake plain channels formed when or after the marsh reached its maximum extent.

A period of aeolian activity some 2,000 years B.P. (Klassen, 1969) formed the dunes in the southwest of the area. A second barrier beach may have been built north of the first, after the shoreline reached about its present position, by an east moving longshore current - the product of the prevailing northwest wind.

Sometime after 2,000 years B.P. the study area assumed its present appearance.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The area contains 80 to 275 feet of sediment deposited on the southward sloping Paleozoic and Jurassic bedrock surface. The major stratigraphic units are three tills, stratified units above and below each of them and a fluvial unit overlying the uppermost stratified unit. The upper till form an asymmetric ridge in the northern one-third of the area. The tills are carbonate rich clay loams and loams and the stratified and fluvial units, mainly silts and clays.

Locally the lower till and the lower and middle stratified units are believed to have been deposited prior to the last glacial advance. The middle and upper till were deposited by the ice advance which melted to form Glacial Lake Agassiz. The moraine in the north, the upper till, formed either during a hault or a minor readvance of the retreating ice. Lake Agassiz formed as the ice melted and remained until about 8,000 years ago. While Lake Agassiz was present the Assiniboine Delta built eastward into the southwest portion of the area and the lacustrine clays were deposited. After drainage of Lake

Agassiz the Assiniboine River flowed north, from near Portage La Prairie, into Lake Manitoba depositing the fluvial unit. The river commenced to flow east into the Red River sometime after 2,400 years B.P..

Regionally the lower till is believed to have been deposited by one of the Wisconsin glaciations likely that which deposited the Lennard or the Minnedosa till in southwestern Manitoba and the Saskatoon Group in Saskatchewan. The upper and middle tills were deposited by the last major Wisconsin glaciation, which formed the Bigstone moraine in North Dakota. The moraine in the north may correlate with one of the ice frontal positions postulated by Elson (1959) for the retreat of the Red River lobe from the top of the Manitoba Escarpment. The lacustrine clay corresponds to the clay unit of McPherson (1970) in the Winnipeg area. The fluvial unit is a local deposit.

LIST OF REFERENCES

AGATERBERG, F. P. and BANERJEE, I. 1969. Stochastic model for the deposition of varves in glacial Lake Barlow-Ojibway, Ontario, Canada. Can. Jour. Earth Sci., v. 6, pp. 625-652.

BANERJEE, I. 1965. Turbidites in a glacial sequence: A study from the Talchir Formation, Raniganj coalfield, India. Jour. Geol., v. 74, pp. 593-606.

BARACOS, A. and BOZOZUK, M. 1958. Seasonal movements in some Canadian clays. Proc. 4th Internat. Conf. Soil Mech. and Foundation Engineering, London, pp. 264-268.

BIRD, E. C. F. 1964. Coastal landforms. Australian National University Press, pp. 63-90.

BLUEMLE, J. P. 1967. Geology and groundwater resources of Trail County, part 1 geology. N. Dak. Geol. Surv., Bull. 49, pp. 18-34.

BRICE, J. C. 1964. Channel patterns and terraces of the Loup Rivers in Nebraska. U.S. Geol. Surv., Prof. Paper 422D.

CHRISTIANSEN, E. A. 1968. Pleistocene stratigraphy of the Saskatoon area, Saskatchewan, Canada. Can. Jour. Earth Sci., v. 5, pp. 1167-1173.

CLAYTON, L., LAIRD, W. M., KLASSEN, R.W. and KUPSCH, W.O. 1965. Intersecting minor lineations on Lake Agassiz Plain. Jour. Geol., v. 73, pp. 652-656.

CLAYTON, L. 1966. Notes on the Pleistocene stratigraphy of North Dakota. N. Dak. Geol. Surv., Rept. of Invest. 44.

COLTON, R. B. 1958. Notes on the intersecting minor ridges in the Lake Agassiz Basin, North Dakota. In Guidebook 9th Ann. Field Conf. Mid-Western Friends of the Pleistocene. N. Dak. Geol. Surv., Misc. Ser., No. 10, pp. 74-77.

DAVIES, J. F., BANNATYNE, B. B., BARRY, G. S. and McCABE, H. R. 1962. Geology and mineral resources of Manitoba. Man. Mines Branch, Pub. 62-1, pp. 132-149.

DREIMANIS, A. and VAGNERS, U. J. 1969. Lithologic relationship of till to bedrock. In Quaternary Geology and climate (H. E. Wright, Jr. Ed.). Nat. Acad. Sci., Pub. 1701, pp. 93-98.

EHRLICH, W. A., PAYSER, E. A. and PRATT, L. E. 1957. Report of reconnaissance soil survey of Carberry map sheet area. Manitoba Soil Surv., Soils Rept. No. 7, pp. 1-69.

ELSON, J. A. 1958. Pleistocene history of Southwestern Manitoba. In Guidebook 9th Ann. Field Conf. Mid-Western Friends of the Pleistocene. N. Dak. Geol. Surv., Misc. Ser., No. 10, pp. 62-73.

______ 1961. Soils of the Lake Agassiz Basin. In Soils in Canada, geological pedological and engineering studies (R. F. Legget Ed.). Royal Soc. Can. Spec. Pub. No. 3, pp. 51-79.

______ 1967. Geology of Glacial Lake Agassiz. In Life Land and Water (W.J. Mayer-Oakes, Ed.), Proc. 1966 Conf. on Environmental Studies of the Glacial Lake Agassiz Region. Univ. of Man., Dept. of Anthropology, Occasional Paper No. 1.

FRIEDKIN, J. F. 1945. A laboratory study of the meandering of alluvial rivers. U.S. Waterways Experiment Station.

GILL, C. B. 1960. The forests of Manitoba. Man. Dept. Mines and Natural Resources, Forest Resources Inventory Rept. No. 10, p. 13.

GILLILAND, J. A. 1963. Groundwater investigation in the Portage La Prairie area. Unpublished report prepared for Manitoba Water Control and Conservation Branch, Man. Dept. of Hwys.

HORBERG, L. 1951. Intersecting minor lineations and periglacial features in the Lake Agassiz Basin, N. Dak. Jour. Geol., v. 59, pp. 1-18.

JOHNSTON, W. A. 1934. Surface deposits and groundwater supply of Winnipeg map-area, Manitoba. Geol. Surv. of Can., Mem. 174.

______ 1946. Glacial Lake Agassiz with special reference to the mode of deformation of the beaches. Geol. Surv. of Can., Bull. No. 7.

LAJTAI, E.Z. 1967. The origin of some varves in Toronto, Canada. Can. Jour. Earth Sci., v. 4, pp. 633-639.

LUTCHMAN, M. in preparation, 1970. Groundwater hydrology of the Portage Delta area, Manitoba. M.Sc. thesis, Univ. of Man.

McCABE, H.R. 1967. Field guide to Devonian outcrops of southwestern Manitoba. Prepared for Int. Symp. on the Dev. Syst. Man. Mines Branch pub., pp. 4-14.

McPHERSON, R.A. 1968. Pleistocene stratigraphy of the Winnipeg River in the Pine Falls-Seven Sisters Falls area, Manitoba. M.Sc. thesis, Univ. of Man.

MOLLARD, J.D. 1957. Aerial mosaics reveal fracture patterns on surface materials in southern Saskatchewan and Manitoba. Oil in Canada, v. 9, pp. 26-50.

NIKIFEROFF, C.C. 1952. Origin of microrelief in the Lake Agassiz Basin. Jour. Geol., v. 60, pp. 99-103.

PELLETIER, B.R. 1968. Submarine physiography bottom sediments and models of sediment transport in Hudson Bay. In Earth Science Symp. on Hudson Bay (P.J. Hood, Ed.). Geol Surv. of Can., Paper 68-53, pp. 100-135.

RIDDEL, W.F. 1950. Foundation conditions in Winnipeg and immediate vicinity. Nat. Res. Council of Can., Assoc. Comm. on Soil and Snow Mech., Tech. Mem., No. 17, pp. 3-9.

SCHUMM, S.A. 1963. Sinuosity of alluvial rivers of the Great Plains. Geol. Soc. Am. Bull., v. 74, pp. 1089-1100.

SHULITS, S. 1941. Rational equation for river bed profiles. Trans. Am. Geophy. Union., v. 22, pp. 622-629.

SKINNER, S.I.M., HALSTEAD, R.L. and BRYDON, J.E. 1959. Quantitative manometric determination of calcite and dolomite in soils and limestones. Can. Jour. Soil Sci., v. 39, pp. 197-204.

STOTT, D.F. 1955. Jurassic stratigraphy of Manitoba. Man. Mines Branch, Pub. 54-2.

WALLACE, R.C. and MAYNARD, J.F. 1924. The clays of the Lake Agassiz Basin. Royal Soc. Can. Trans., v.18, sec. 4, pp. 9-30.

WARDLAW, N.C., STAUFFER, M.R. and HOQUE, M. 1969. Striations, giant grooves, and superposed drag folds, Interlake area, Manitoba. Can. Jour. Earth Sci., v. 6, pp. 577-593.

WEBER, N.J. 1958. Recent grooving in the lake bottom sediments of Great Slave Lake, Northwest Territories. Jour. Sed. Pet., v. 28, pp. 333-341.

WELLER, J.M. 1960. Stratigraphic principles and practice. Harper and Rowe Pub., pp. 83-143.

WICKS, F.J. 1965. Differential thermal analysis of the sediments of the Lake Agassiz Basin in Metropolitan Winnipeg, Manitoba. M.Sc. thesis, Univ. of Man.

APPENDIX A

LABORATORY DATA

Textural Analyses

The grain size distribution in the <4mm fraction was determined for representative samples. The initial sample preparation consisted of weighing out 20 to 40 grams, wet weight, of sediment and placing the sample in a 10 - 15cm plastic sample bag with about 200mls of calgonated water (0.5gm of calgon/l). The sample was alternately kneaded and allowed to sit until it was completely disaggragated. The sample was then poured onto a 0.062mm sieve and the material retained on the sieve washed with calgonated water until the wash water was clean. The sediment retained on the sieve was retained for a sieve analyses and that which passed through the screen recovered for a pipette analyses.

The sieve analyses on the 0.062mm fraction was conducted according to the method proposed by Folk (1965, p. 34). The pipette analyses on the 0.062mm fraction was also conducted according to the method of Folk (1965, pp. 37-40). After the pipette analyses the remaining sediment was recovered for use in the X-ray and carbonate analyses.

The weight percent of sand silt and clay in each sample is shown in Table A1, following, and plotted on the textural triangle, Figure 8 in the text.

X-ray Diffractometer Analyses

X-ray diffractometer analyses were conducted on the silt + clay and clay fraction of selected specimens to help determine the mineral composition. The samples were taken from the sediment remaining from the pipette analyses. To obtain a silt + clay specimen the sediment used in a pipette analyses was evaporated and to obtain the clay specimen the clay fraction was decanted from the sediment and evaporated. The samples were crushed with a mortar and pestle and mounted in a dry sample holder in a Norelco X-ray diffractometer. Copper Kα radiation was used with a scanning rate of 1^{o}/min. between $4^{o}2\theta$ and $64^{o}2\theta$. The diffractograms were examined to determine the qualitative and to a limited extent the quantitative mineralogy of the samples. Further statistics on the equipment include: settings of 50 kV and 20 mA, a time constant of two seconds and slit size of $1^{o} \times 1^{o}$.

The results are shown in Figure 9 in the body of the thesis. Some difficulty was encountered in identifying the clay minerals because of the low broad peaks formed by the minerals and a peak between 4^{o} and $6^{o}2\theta$ which the

Table A1. Results of textural analyses of selected specimens.

Analysis No.	Hole No.	Sample Depth (ft.)	Unit	Grain Size Distribution Sand	Silt	Clay
1	P1	20- 30	UT	28	36	36
2	P1	40- 50	UT	24	38	38
3	P1	55- 65	MT	38	43	19
4	P1	70- 75	MT	57	26	17
5	P1	75- 80 b	MT	48	32	20
6	P1	75- 80 r	MT	38	42	19
7	P1	80- 81	MT	37	53	10
8	P4	30-	UT	33	40	27
9	P4	60- 65	UT	34	38	28
10	P4	85-100	MT	35	39	26
11	P5	28- 40	UT	24	37	39
12	P5	70- 75	MT	45	34	28
13	P7	105-110	MT	35	39	26
14	P7	185	MS	0	88	12
15	P7	210	LT	43	26	31
16	P7	220	LS	1	69	30
17	P7	225	LS	2	43	55
18	P8	80- 85	MT	41	38	21
19	P8	105-110	MS	0	32	68
20	P8	140-145	LT	27	42	31
21	P10	20- 30	L (l)	0	31	69
22	P10	20- 30	L (d)	1	28	71
23	P10	40- 45	L	1	43	56
24	P10	95-100	MT	32	42	26
25	P10	110-105	T + S	2	41	57
26	P10	120-125	T + S	43	29	29

instrument produced even when the sample holder was empty.

Carbonate Analyses

The calcite and dolomite content of the silt + clay and clay fractions was determined for selected samples remaining from the pipette analyses. The procedure used is that followed by the Canada Department of Fisheries and Forestry Laboratory, Winnipeg, a procedure based on the intercept method of Skinner et al.,1960. The powdered sample, in a small cup, is placed in a gas bottle containing 30mls of 4N HCl. The bottle is placed in a constant temperature bath and sealed with a stopper containing a hose leading to a manometer. The bottle is mechanically agitated allowing the sample and the acid to mix and the volume of the CO_2 evolved recorded at successively longer time intervals. This data is used to plot the solution curves for calcite and dolomite. The dolomite curve is projected to the ordinate to determine the number of milliters of CO_2 due to calcite. The results are then calculated in terms of weight percent calcite and dolomite. The results are shown in Table 3 in the body of the thesis.

APPENDIX B

LOGS OF TEST HOLES DRILLED AND SECTIONS EXAMINED

Hole No. P1 Location: NE-17-13-5W1

Type: Power auger Date: 13/6/69

Depth (ft.)	Lithology	Interpretation
0-2	Gravel; sandy, pebbles and granules, predominantly carbonate	Wave washed till
2-14	Till; silty, sandy, clayey, stoney, grayish-brown (2.5Y5/2 wet), calcareous	Upper till unit
14-30	Till; silty, sandy, clayey, stoney, dark grayish-brown to olive gray (3.75 4/2 wet) calcareous	Unoxidized till
30-40	No sample recovered	
40-42	Gravel; sandy, pebbles and granules, predominantly calcareous	
42-50	Till; silty, sandy, stoney, clayey, very dark grayish-brown (2.5Y3/2 wet), calcareous	
50-65	Till; sandy, silty, stoney, clayey, light grayish-brown (2.5Y6/2 wet), calcareous	Middle till unit
65-70	No sample recovered	
70-75	Till; sandy, silty, stoney, clayey, dark grayish-brown (2.5Y4/2 wet), calcareous	Unoxidized till
75-80	i) Till; as above ii) Till; sandy, silty, stoney, clayey, pale brown (10YR6/3 wet), calcareous	Incorporation of material from underlying Jurassic red beds
80-87	Till; sandy, silty, stoney, clayey, pale brown (10YR6/3 wet), calcareous	

Hole No.	P2	Location:	NW-14-13-6
Type:	Power auger	Date:	13/6/69

Depth (ft.)	Lithology	Interpretation
0-6	Clay; silty, occasional sand grains, olive-gray to grayish-brown (3.75Y5/2 wet), till clasts, laminated, calcareous	Lacustrine unit
6-10	Till; silty, sandy, stoney, clayey, grayish-brown (2.5Y5/2 wet), calcareous	Upper till unit

Hole No.	P3	Location:	NE-16-14-6W1
Type:		Date:	14/6/69

Depth (ft.)	Lithology	Interpretation
0-13	Interbedded sand, silt and clay; all impure, grayish-brown to olive-brown (3.75Y5/2 wet) laminated, soft, calcareous	Alluvial unit
13-17	Clay; very silty, occasional sand grain and granule, grayish-brown (2.5Y5/2 wet), occasional gastropod, soft, calcareous	
17-23	Clay; silty, very dark grayish-brown to dark olive-gray (3.75Y3/2 wet), calcareous	Lacustrine unit, upper clay
23-30	Till; silty, sandy, clayey, stoney, light grayish-brown (2.5Y6/2 wet), calcareous	Upper till unit
30-45	Till as above except grayish-brown (2.5Y5/2 wet) -from 45 ft rotary chips	Unoxidized till
45-46	Till as above	
46-53	Clay; silty, stoney, sandy (near 53 ft.), dark gray (5Y4/1 wet), calcareous	Lacustrine unit gray clay?
53-63	Till; silty, sandy, clayey, stoney, dark gray (5Y4/1 wet), calcareous	Upper till unit Unoxidized
63-68	Gravel, sandy, calcareous, permeable	Middle till unit
68-87	Till; sandy, silty, clayey, stoney, light grayish-brown (2.5Y6/2 wet), calcareous	
87-90	Boulder, dolomite	

Hole No.	P3 (cont.)	
90-105	Till; sandy, silty,stoney, clayey, light gray to grayish-brown (2.5Y5.5/2 wet), calcareous	
105-115	Till; sandy, silty, stoney, clayey, dark grayish-brown	Middle Till, oxidized
115-130	Interbedded gypsum, white; dolomite, buff; and shale gray-green	Bedrock, Amaranth Formation

Hole No. P4 Location: SW-22-13-7W1

Type: Power auger and rotary Date: 14/6/69

Depth (ft.)	Lithology	Interpretation
0-5	Interbedded sand and clay; sand medium to fine-grained, grayish-brown (2.5Y5/2 wet), clay olive-gray (5Y5/2 wet), soft, calcareous	Alluvial unit
5-10	Clay; silty, occasional granules and dark specks, olive-gray (5Y5/2 wet), calcareous, occasional iron staining	Lacustrine unit, brown clay
10-20	Clay; silty, dark grayish-brown (2.5Y4/2 wet), abundant pebbles and light grayish-brown silt clasts, thin colour banding, calcareous	
20-27	Clay; very silty, dark grayish-brown (2.5Y4/2 wet), abundant pebbles and silt and till clasts (<1/2 in.), massive, calcareous	
27-45	Till; sandy, stoney, silty, clayey, grayish-brown (2.5Y4/2 wet), calcareous	Upper till
	-from 45ft. rotary chips	
45-56	Till; as above	
56-74	Till; sandy, silty, stoney, clayey, dark grayish-brown to olive-gray (3.75Y4/2 wet), calcareous	Unoxidized till
74-75	Clay; silty, very dark gray (5Y3/1 wet), silt clasts, buff, laminated, calcareous	Lacustrine unit, lower clay?
75-120	Till; silty, sandy, clayey, stoney, light gray-brown (2.5 Y6/2 wet), calcareous	Middle till unit

Hole No. P5 Location: SW-22-13-8W1

Type: Power auger and rotary Date: 14/6/69

Depth (ft.)	Lithology	Interpretation
0-5	Silt; clayey, olive-gray to grayish-brown (3.75Y5/2 wet), occasional iron staining, thin colour banding, soft, calcareous	Alluvial unit
5-10	Clay; silty, interbedded dark gray (5Y4/1 wet), organic rich and olive-gray (5Y5/2 wet) layers, occasional granules and shell fragments, soft, calcareous	
10-15	Clay; silty, grayish-brown (2.5Y5/2 wet), occasional stone and buff clay clasts and gypsum crystals	Lacustrine unit, upper clay
15-28	Clay; silty, grayish-brown (2.5Y5/2 wet), occasional stones and buff clay clasts colour banded; each band laminated, the silt, stones and clasts concentrated in the lighter bands	
28-30	Till; clayey, silty, stoney, sandy, grayish-brown (2.5Y5/2 wet),calcareous	Upper till unit
30-45	Till; sandy, silty, stoney, clayey, dark grayish-brown (2.5Y4/2 wet), calcareous	
	-from 45 ft. rotary chips	
45-60	Till; as above	
60-66	Clay? - drill break, no sample recovered	Lacustrine unit
66-75	Gravel; sandy, calcareous	Middle till unit

Hole No.	P6	Location:	SW-26-13-9W1
Type:	Power auger	Date:	14/6/69

Depth (ft.)	Lithology	Interpretation
0-23	Clay; silty, grayish-brown (2.5Y5/2 wet), occasional (i) stones, (ii) light grayish-brown silt and till clasts, and (iii) buff and pink clay clasts, colour banded, bands laminated with stones,etc., concentrated in the lighter bands, occasional gypsum crystals, calcareous	Lacustrine unit, upper clay
23-45	Till; sandy, silty, stoney, clayey, grayish-brown to dark grayish-brown (2.5Y4.5/2), calcareous	Upper till unit

Hole No. P7 Location: NE-10-12-9W1

Type: Power auger and rotary Date: 23/7/69

Depth (ft.)	Lithology	Interpretation
0-1	Clay; silty, grayish-brown (2.5Y5/2 wet), calcareous	Prodeltaic unit
1-5	Sand; fine grained, silty, very dark grayish-brown (2.5Y3/2 wet) calcareous	
5-18	Interbedded silt, clay and sand, grayish-brown (2.5Y5/2 wet) to 12 feet, dark grayish-brown (2.5Y4/2 wet) to 18 feet, occasional granule and iron stain streaks, calcareous	
18-30	Interbedded clay and silts dark olive-gray (5Y3/2 wet), colour banded, occasional buff and light gray clay clasts laminated, calcareous	Gradational contact between prodeltaic unit and lacustrine units
30-55	Clay; interbedded with thin laminated silts, dark gray (5Y4/1 wet), occasional stone and buff clay clasts, colour banding, calcareous	Lacustrine unit
55-60	Clay; interbedded with silt and very fine grained sand, thinly laminated, dark gray (5Y4/1 wet), calcareous	Sand slumped off delta front west of area
60-80	Clay; silty, dark gray (5Y4/1 wet), soft sticky, occasional thin silt lamination, occasional stone and buff or light gray clay clast	
80-94	Clay; as above, silt laminae more abundant (50%), clasts of silt and till and stones more abundant	
94-122	Till; silty,sandy, stoney, clayey, grayish-brown to dark	Middle till unit

Hole No.	P7 (cont.)	
	grayish-brown (2.5Y4.5/2), becomes sandier with depth, calcareous	
122-132	Sand; very fine grained, silty, grayish-brown (2.5Y5/2), occasional till layer? calcareous	Middle stratified unit
132-186	Silt; clayey, with occasional clay laminae, grayish-brown (2.5Y5/2 wet), abundant sand size grains of coal? calcareous	
186-204	Clay; silty, black (10YR2/1 wet), calcareous	
204-212	Till; sandy, silty, stoney, clayey, grayish-brown, calcareous	Lower till unit
212-225	Silt; clayey, olive-gray to grayish-brown (3.75Y5/2 wet), occasional sand, very fine grained,and silt laminae, occasional granule, calcareous	Lower stratified unit
225-250	No sample recovered, but likely sand	
250-251	Sand; fine grained, grayish-brown to olive-gray (3.75Y5/2 wet), clayey, occasional granule, calcareous	
251-257	Clay; silty, olive-gray to grayish-brown(3.75Y5/2 wet), calcareous	
257-260	Clay; geenish-gray	Bedrock, Jurassic Reston Formation
260-275	Interbedded greenish-gray clay, buff dolomite and minor anhydrite	

Hole No. P8 Location: SE-16-12-8W1

Type: Power auger and rotary Date: 16/6/69

Depth (ft.)	Lithology	Interpretation
0-5	Silt to very fine-grained sand; grayish-brown to olive-gray (3.75Y5/2 wet), laminated, calcareous	Gradation between beach and lacustrine deposit
5-20	Clay; silty, dark grayish-brown (2.5Y4/2 wet), colour banded, bands laminated, occasional gypsum crystals, light gray and pink clay clasts and pebbles, calcareous	Lacustrine unit, brown clay
20-50	Clay; silty, dark olive-gray (5Y3/2 wet), laminated, occasional silt rich laminae, buff and light gray clay clasts and pebbles, laminae in some cases appear to be rythmite couplets, calcareous	Lacustrine unit, gray clay
	-from 50 feet, rotary chips	
50-65	Clay, as above, silt content increasing with depth, calcareous	
65-78	Silt; clayey, dark gray (5Y4/1 wet), laminated, occasional silt and till clasts, stones at 74 ft,, calcareous	
78-80	Gravel; sandy, light grayish-brown (2.5Y5/2 wet), calcareous	Middle till unit
80-87	Till; sandy, silty, stoney, dark grayish-brown (2.5Y4/2 wet), calcareous	
87-130	Clay; silty, very dark grayish-brown (2.5Y3/2 wet), laminated, pink and buff clay clasts, calcareous	Middle stratified unit

Hole No.	P9	Location:	SW-15-12-7
Type:	Power auger	Date:	16/6/69

Depth (ft.)	Lithology	Interpretation
0-6	Silt; clayey, dark grayish-brown (2.5Y4/2 wet), iron stained spots, soft, calcareous	Alluvial unit
6-37	Sand; medium to coarse grained, well-sorted, dark grayish-brown (2.5Y4/2 wet), occasional mollusk and wood fragments, black organic and clay rich 25-27 feet, calcareous	
37-45	Clay; silty, olive-gray to grayish-brown (3.75Y5/2 wet), colour banding, bands laminated, occasional stones and buff and light gray clay clasts, calcareous	Lacustrine unit, upper clay
45-55	Clay; silty, dark olive gray (5Y3/2 wet), laminated, occasional buff clay and silt clasts	Lacustrine unit, lower clay

Hole No. P10 Location: NW-10-12-6W1

Type: Power auger and rotary Date: 16/6/69

Depth (ft.)	Lithology	Interpretation
0-3	Disturbed material	
3-10	Silt; clayey, grayish-brown, (2.5Y5/2 wet), soft, laminated, iron stained areas, calcareous	Alluvial unit
10-13	Sand; medium-grained, grayish-brown (2.5Y5/2 wet), calcareous	
13-35	Clay; silty, grayish-brown 2.5Y5/2 wet), colour banded, colour darkening to grayish-brown in lower part, laminated, occasional gypsum crystals, calcareous	Lacustrine unit, upper clay
35-50	Clay; silty, dark gray (5Y4/1 wet), occasional silt laminae, some internally bedded, occasional light gray and buff clay clasts, sticky, calcareous	Lacustrine unit, lower clay
	-from 50 feet, rotary chips	
50-86	Clay; silty, dark gray (5y4/1 wet), interbedded with light and dark laminated silt, occasional light gray and buff silt clasts increasing with depth, calcareous	
86-91	Gravel; sandy, calcareous	Middle till unit
91-107	Till; sandy, silty, stoney, light grayish-brown (2.5Y6/2 wet), calcareous	Middle till
107-116	Clay; very silty, gray-brown (2.5Y5/2 wet), laminated, calcareous	Till + Stratified unit

Hole No.	P10 (cont.)	
116-126	Till; sandy, silty, stoney, olive-gray to gray (5Y5/1.5 wet), calcareous	
126-129	Clay; greenish-gray, calcareous	Bedrock, Amaranth Formation
129-147	Interbedded white anhydrite and buff dolomite	

Hole No.	P11	Location:	SE-17-12-5
Type:	Power auger	Date:	16/6/69

Depth (ft.)	Lithology	Interpretation
0-5	Clay; silty, sandy, grayish-brown to olive-gray (3.75Y5/2 wet), laminated, calcareous	Alluvial unit
5-16	Sand; fine to medium-grained, grayish-brown to dark grayish-brown (2.5Y4.5/2 wet), occasional pebble, calcareous	
16-25	Clay; silty, very dark grayish-brown (2.5Y3/2 wet), colour banded, laminated, occasional buff and light gray clay clasts and gypsum crystals, calcareous	Lacustrine unit, upper clay
25-40	Clay; silty, dark gray (5Y4/1 wet), laminated, calcareous	Lacustrine unit, lower clay
40-65	Clay; very silty, dark olive gray (5Y4/2 wet), laminated, occasional pebbles and buff silt and sand clasts, calcareous	
65-72	Clay; silty, grayish-brown (2.5Y5/2 wet), occasional pebbles and silt and till clasts	

Hole No.	P12	Location:	SE-28-11-8
Type:	Power auger	Date:	16/6/69

Depth (ft.)	Lithology	Interpretation
0-10	Silt; clayey, olive (5Y5/3 wet) laminated, occasional buff pockets, and iron stained spots, calcareous	Prodeltaic units
10-20	Silt; clayey, dark grayish-brown to grayish-brown (2.5Y4.5/2 wet), colour banded, calcareous	Gradational contact with lacustrine unit
20-25	Interbedded silt and very fine sand, very dark gray to light gray, calcareous	
25-50	Silt; clayey, very dark gray (5Y3/1 wet), colour banded, occasional granule and light gray or brownish-yellow silt clasts, calcareous	
50-90	Clay; silty, very dark gray (5Y3/1 wet), colour banded, laminated, occasional granules and brownish-yellow clasts, calcareous	Lacustrine unit

Hole No. P13 Location: SW-34-12-7

Type: Power auger and rotary Date: 17/7/69

Depth (ft.)	Lithology	Interpretation
0-5	Silt; clayey, grayish-brown to light grayish-brown (2.5Y 5.5/2 wet), calcareous	Alluvial unit
5-11	Clay; silty, grayish-brown to light grayish-brown (2.5Y 5.5/2 wet), soft, laminated, iron stained spots, calcareous	
11-19	Sand; medium-grained, clayey grayish-brown (2.5Y5/2 wet), occasional pebble, calcareous	
19-25	Clay; silty, grayish-brown (2.5Y5/2 wet), laminated calcareous	Lacustrine unit Upper clay
	Below 25 feet rotary chip samples	
25-50	Clay; silty, grayish-brown (2.5Y5/2 wet) laminated, occasional buff silt clasts, calcareous	
50-80	Clay; silty, dark gray (2.5Y 5/2 wet), laminated, abundant silt and till pockets occasional stones, calcareous	Lacustrine unit, lower clay
80-81	Gravel, sandy, calcareous	Middle till
81-100	Till; silty, sandy, stoney, clayey, grayish-brown (2.5Y 5/2 wet), calcareous	
100-116	Till; silty, sandy, stoney, clayey, olive-gray (5Y4/2 wet)	Till unoxidized
116-119	Clay; silty, very dark grayish-brown to grayish-brown (3.75Y 411.5 wet) laminated calcareous	

Hole No. P13 (cont.) Location:

Type: Date:

Depth (ft.)	Lithology	Interpretation
119-123	Till? stones?	
123-127	Clay; (softer drilling)	
127-135	Till; sandy, silty, stoney clayey, very dark gray 5Y3/1 wet) calcareous	
135-140	Till; sandy, silty, stoney clayey, light grayish-brown (2.5Y6/2 wet) calcareous	
140-147	Silt; clayey, olive-gray (5Y5/2 wet)	
147-151	Gravel?	
151-155	Interbedded? till and clay - variable drilling	
155-163	Clay; greenish-gray, calcareous, occasional gypsum	Bedrock, Amaranth Formation
163-175	Interbedded buff dolomite and white gypsum	

Hole No. P14 Location: NE-9-14-8W1

Type: Power auger and rotary Date: 22-7-69

Depth (ft.)	Lithology	Interpretation
0-5	Silt; sandy clayey, gray to olive-gray, (5Y 5/1.5 wet) laminated iron stained, calcareous	Alluvial unit
5-12	Clay; silty, gray (5Y 5/1 wet) calcareous	
12-18	Clay; silty, dark gray to grayish-brown (3.75Y 5/1.5 wet) colour banded, occasional pebbles and buff clay clasts, stiff, calcareous	Lacustrine unit upper clay
18-29	Clay; silty, grayish-brown (2.5Y5/2 wet), colour banded occasional pebbles and buff clasts, calcareous, becomes very sandy and stoney 25-29	
29-40	Till; stilty, sandy, stoney clayey, light grayish-brown (2.5Y6/2 wet) calcareous	Upper till unit
40-45	Clay; silty, dark grayish-brown (2.5Y5/2 wet) colour banded, laminated, occasional till clasts and pebbles, calcareous	Lacustrine unit
45-50	Till; silty sandy, stoney, clayey, light grayish-brown (2.5Y6/2 wet), calcareous	Middle till
	Below 50 feet rotary chip samples	
50-55	Till as above	
55-70	Till; silty, sandy, stoney clayey, grayish-brown (2.5Y 5/2 wet) calcareous	

Hole No. P14 (cont.) Location:

Type Date:

Depth (ft.)	Lithology	Interpretation
70-75	Interbedded? light grayish-brown till and light gray sand to silt	Till + stratified unit
75-83	No sample recovered likely poorly consolidated sand	
83-87	Till; very sandy, silty, stoney, clayey, dark grayish-brown (2.5Y4/2 wet)	
87-100	Interbedded white limestone greenish-gray clay and minor anhydrite	Bedrock, Reston Formation
100-105	Interbedded buff to light gray dolomite	

Hole No.	P15	Location:	NW-27-12-6W1
Type:	Power auger	Date:	3/7/69

Depth (ft.)	Lithology	Intrepretation
0-14	Silt; clayey, grayish-brown (2.5Y5/2 wet), laminated, calcareous	Alluvial unit
14-25	Sand; medium to coarse-grained grayish brown, occasional mollusk fragment and clay lens, calcareous	
25-31	No sample recovered likely sand, calcareous	
31-40	Clay; silty, grayish-brown (2.5Y5/2wet) occasional stones and silt clasts, laminated, calcareous	Lacustrine unit
40-50	Clay; silty, grayish-brown (2.5Y5/2 wet), colour banded, occasional stones, and till clasts	

Hole No. P16 Location: NE-28-12-8W1

Type: Power auger Date: 31/7/69

Depth (ft.)	Lithology	Interpretation
0-20	Clay; silty, very dark grayish brown (2.5Y3/2 wet), colour banding, laminated, occasional stones, light gray and buff clay clasts, and gypsum crystals, calcareous	Lacustrine unit
20-40	Clay; silty, dark grayish brown (2.5Y4/2 wet) laminated, occasional stones and light gray and buff clasts, calcareous	
40-45	Clay; silty olive gray to grayish-brown (3.75Y5/2 wet), occasional light gray and buff clay clasts, laminated, calcareous	

Hole No.	P17	Location:	NE-33-13-6W1
Type:	Power auger	Date:	7/69

Depth (ft.)	Lithology	Interpretation
0-4	Sand; fine to medium-grained, clayey, silty, grayish-brown (2.5Y5/2 wet) colour banded, calcareous	Alluvial unit
4-5	Clay; silty, black (5Y2/1 wet) organic rich	
5-7	Interbedded clay, silty and silt, clayey, grayish-brown to olive gray (2.5Y 5/2 wet), laminated, iron stained, calcareous, soft	
7-17	No samples recovered likely clay and silt as above	
17-27	Clay; silty, very dark gray brown (2.5Y3.2 wet) colour banded, abundant stones and light grayish-brown till clasts, calcareous	
27-30	Till; sandy, silty, stoney clayey, grayish-brown (2.5Y 5/2 wet), calcareous	Upper till unit
30-48	Till; silty, sandy, stoney, clayey, calcareous	

Hole No.	P18	Location:	NW-15-11-6W1
Type:	Power Auger	Date:	8/69

Depth (ft.)	Lithology	Interpretation
0-5	Sand; very fine-grained, silty, olive gray (5Y5/2 wet), laminated, occasional mollusk fragments and medium-grained sand lenses, soft,calcareous	Alluvial unit
5-10	Silt; clayey, olive gray (5Y5/2 wet), laminated, occasional plant fragment, soft, calcareous	
10-13	Clay; silty,olive to olive gray,laminated, abundant specks of plant material, soft, calcareous	
13-15	Clay; silty, olive gray (5Y5/2 wet), contains approximately 50% fragments of dark olive clay, calcareous	Contact with lacustrine unit
15-29	Clay; silty, dark olive gray to grayish-brown (3.75Y4/2 wet), colour banding, occasional gypsum crystals and iron streaks, calcareous	Lacustrine unit, upper clay
29-30	Silt; clayey, olive gray (5Y5/2 wet), laminated, calcareous	Material slumped from delta to west
30-35	Clay; silty, dark olive gray (5Y3/2 wet), occasional fragments of olive gray clay occasional light gray silt clasts, calcareous	Contact between upper and lower clay
35-50	Clay; silty, dark olive gray (5Y3/2 wet), occasional granule and light gray or pink clay or silt clasts, calcareous	Lacustrine unit, lower clay

<u>Hole No.</u> P18 (cont.)

50-55	Clay; silty, gray (2.5YN5/ wet) laminated, calcareous	Lacustrine unit lower clay
55-65	Clay; silty, dark olive gray (5Y3/2 wet) colour banding, laminated ?, occasional pebbles and light gray and buff silt to clay clasts, calcareous	
65-70	Clay as above except occasional lenses or streaks of grayish-brown till, massive	
70-80	Clay; very silty, dark olive gray (5Y3/2 wet) buff and light gray silt to clay clasts, calcareous	

Hole No.	P19	Location:	SW-27-11-9W1
Type	Power auger	Date:	16/8/69

Depth (ft.)	Lithology	Interpretation
0-9	Sand; fine-grained, silty gray to olive-brown (2.5Y 4.5/2.5 wet) laminated	Prodeltaic unit sand subunit
9-10	Interbedded sand and silt, light gray (2.5Y N7/ wet), occasional pebble, calcareous	
10-15	Silt; clayey, olive-gray (5Y5/2 wet), laminated occasional sand lamination, calcareous	Prodeltaic unit silt subunit
15-20	Interbedded silt dark gray (2.5Y N4/ wet) and clay, dark olive-gray (5Y3/2 wet), laminated	

Hole No.	P20	Location:	SW-25-11-9W1
Type	Power auger	Date:	16/8/69

Depth (ft.)	Lithology	Interpretation
0-2	soil; black sandy	Prodeltaic unit sand subunit
2-5	Sand; fine-grained, well sorted, slightly silty, light yellow-brown (2.5Y614 wet) non-calcareous, massive	
5-10	Interbedded sand and clay gray (2.5Y N5/ wet), colour banded, calcareous	
10-17	Interbedded silt and clay; dark gray to dark olive-gray silt sandy in upper portion laminated, calcareous	Prodeltaic unit silt subunit
17-20	Silt; clayey, dark gray, occasional clay rich laminations, calcareous	
20-40	Interbedded silt and clay, dark gray (5Y5/1 wet), laminated, calcareous	

Hole No.	P21	Location:	SE-17-14-7W1
Type:	Power Auger	Date:	1/8/69

Depth (ft.)	Lithology	Interpretation
0-23	Sand; medium grained, silty, clayey, brown (10YR5/3 wet), calcareous	Alluvial unit
23-30	Clay; silty, dark olive-gray (5Y3/2 wet), occasional granules, calcareous	Lacustrine unit
30-40	Clay; silty, olive-gray (5Y4/2 wet), abundant pebbles, gypsum crystals and clay or silt clasts	

Hole No.	P22	Location:	SW-15-13-8W-1
Type:	Power Auger	Date:	17/8/69

Depth (ft.)	Lithology	Interpretation
0-5	Silt; clayey, grayish-brown to dark grayish-brown (2.5Y4/2 wet), colour banded, calcareous	Alluvial unit
5-13	Sand; very fine-grained grayish-brown (2.5Y5/2 wet), colour banded, iron stained soft, calcareous	
13-14	Clay; silty, olive-gray (5Y 5/2 wet), iron stained, soft, calcareous	Alluvial - lacustrine contact
14-15	Clay; silty, olive-gray to gray (5Y5/1.5 wet), firm, occasional pebble, calcareous	Lacustrine unit upper clay
15-25	Clay; silty, dark grayish-brown (2.5Y3/2 wet), colour banded, occasional pebbles and buff clasts, calcareous	
25-30	Clay; silty, olive-gray (5Y412, wet) occasional yellow-brown to pale brown till clasts and buff to light gray clay or silt clasts, laminated and colour banded, calcareous	Lacustrine unit lower clay
30-45	Clay; silty, dark olive-gray to olive-gray (5Y3.5/2 wet) occasional pebble and silt or clay pocket	

Hole No.	P23	Location:	NE-21-14-5W1
Type	Power auger	Date:	4/9/69

Depth (ft.)	Lithology	Interpretation
0-13	Clay; silty, sandy, stoney, grayish-brown to dark grayish-brown (2.5Y 4.5/2 wet) poorly developed laminations, occasional clasts of light grayish-brown till, calcareous	Lacustrine unit stoney, lake clay
13-15	Till, silty, sandy, stoney, clayey, light grayish-brown (2.5Y6/2 wet) dry, powdery	Upper till unit

Hole No.	P24	Location:	SE-13-12-9W1
Type	Power Auger	Date:	5/9/69

Depth (ft.)	Lithology	Interpretation
0-5	Disturbed sediment	
5-10	Clay, silty, dark grayish brown (2.5Y4/2 wet), occasional buff clasts, laminated ?, calcareous	Lacustrine unit silt
10-15	Clay, slightly silty, very dark grayish-brown (2.5Y 3/2 wet), occasional pebble and light gray or buff silt or clay clasts laminated, calcareous	Lacustrine unit clay

Hole No.	P25	Location:	SW-31-11-7W1
Type	Power Auger	Date:	5/9/69

Depth (ft.)	Lithology	Interpretation
0-5	Silt; clayey, grayish-brown (2.5Y5/2 wet), laminated, calcareous	Lacustrine Unit silt
5-10	Interbedded? silt and clay grayish-brown (2.5Y5/2 wet), calcareous	Contact between the lacustrine silt and clay
10-20	Clay; silty, grayish-brown, abundant silt clasts, calcareous	Lacustrine unit clay

Hole No.	P26	Location:	NE-17-11-6W1
Type:	Power auger	Date:	5/9/69

Depth (ft.)	Lithology	Interpretation
0-10	Clay; silty, olive-gray (5Y 4/2 wet) laminated? iron stained, occasional mollusk fragments, and yellow pockets soft, calcareous	Alluvial unit
10-14	Clay; silty, olive-gray (2.5Y5/2 wet) dark gray organic rich bands, occasional rootlet and mollusk fragment, low carbonate	
14-15	Clay; silty, olive-gray (2.5Y4/2 wet) occasional iron stained specks, soft, calcareous	Contact alluvial and lacustrine unit
15-19	Clay; silty, olive-gray to grayish-brown (3.75Y 5/2 wet), firm, occasional granules, calcareous	Lacustrine unit
19-20	Clay; silty, grayish-brown (2.5Y5/2 wet), occasional buff and pink clay and silt clasts, calcareous	

Hole No.	P27	Location:	NW-26-14-9W1
Type	Power Auger	Date:	13/9/69

Depth (ft.)	Lithology	Interpretation
0-3	Silt; clayey, light grayish brown to olive-gray (3.75Y 5.5/2 wet), occasional pebble	Lacustrine
3-5	Interbedded clay, dark grayish-brown to grayish-brown (2.5Y4.5/2 wet) and silt, light grayish-brown to olive-gray (3.75Y 5.5/2 wet), abundant till and silt, clasts and sand, concentrated mainly in the silt beds, calcareous	
5-15	Clay; silty, grayish-brown (2.5Y5/2 wet), colour banded, occasional grayish-brown till clasts and pebbles, calcareous	Lacustrine unit upper clay
15-25	Clay as above except very dark grayish-brown (2.5Y 3/2 wet)	
25-30	No sample recovered, likely clay as above	
30-35	Till; sandy, silty, stoney, clayey, grayish-brown (2.5Y5/2 wet)	
35-40	No sample recovered, likely till as above	
40-45	Till; sandy, silty, stoney clayey, grayish-brown	

Hole No.	P28	Location:	SE-1-13-6
Type	Minuteman auger	Date:	3/6/69

Depth (ft.)	Lithology	Interpretation
0-7	Clay; silty, olive-gray 5Y5/2 wet), calcareous	Lacustrine unit, upper clay
7-15	Clay; silty, olive-brown to grayish-brown (2.5Y 4.5/3 wet) occasional stones and silt clasts, laminated, calcareous	
15-24	Clay; silty, dark grayish-brown, (2.5Y4/2 wet, occasional pebbles, laminated	

Hole No.	P29	Location:	NE-12-13-6W1
Type:	Minuteman auger	Date:	3/6/69

Depth (ft.)	Lithology	Interpretation
0-6	Till;sandy silty stoney clayey, grayish-brown (2.5Y5/2 wet), calcareous	Upper till unit
6-13	Till; sandy silty stoney clayey, olive-gray (5Y5/2 wet), calcareous	

Hole No. P30 Location: SE-36-13-6W

Type: Minuteman auger Date: 4/6/69

Depth (ft.)	Lithology	Interpretation
0-2	Soil; silty, dark gray organic rich	Alluvial Unit
2-4	Sand; very fine-grained, silty, olive-brown (5Y5/2 wet), soft, laminated, occasional pebble, calcareous	
4-15	Clay; silty, olive to olive-brown (3.75Y 4/4 wet), occasional pebble	Lacustrine unit

Hole No. P31 Location: NW-19-12-5

Type: Minuteman auger Date: 4/6/69

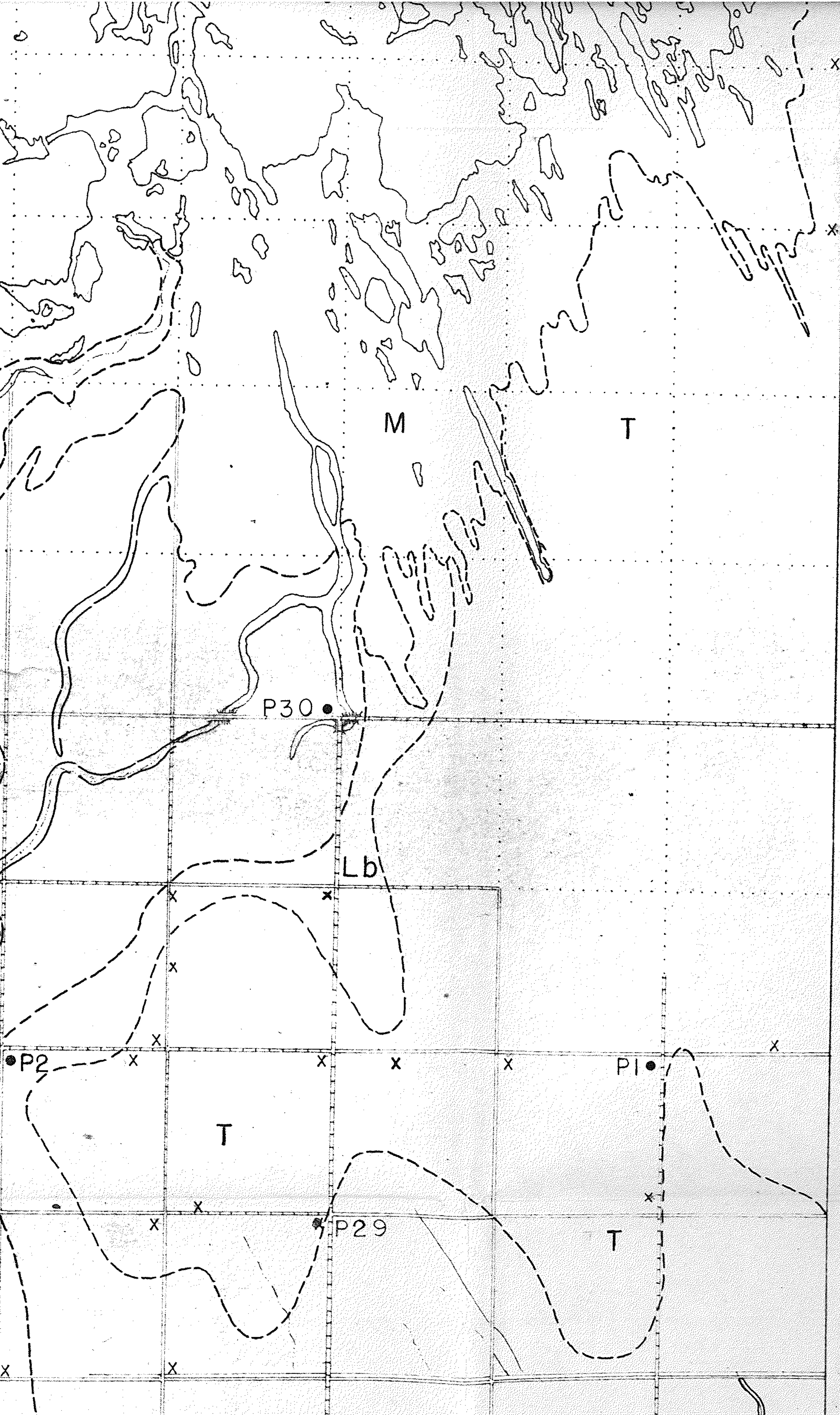
Depth (ft.)	Lithology	Interpretation
0-2	Soil; silty, clayey, dark gray	Alluvial unit
2-19	Silt to very fine-grained sand; olive-brown grayish-brown (2.5Y4.5/3 wet), laminated, soft, calcareous	
19-33	Clay; silty, dark grayish-brown (2.5Y5/2 wet), colour banded, laminated, calcareous	Lacustrine unit

Hole No.	P32	Location:	SE-22-14-9W1
Type:	Minuteman auger	Date:	8/6/69

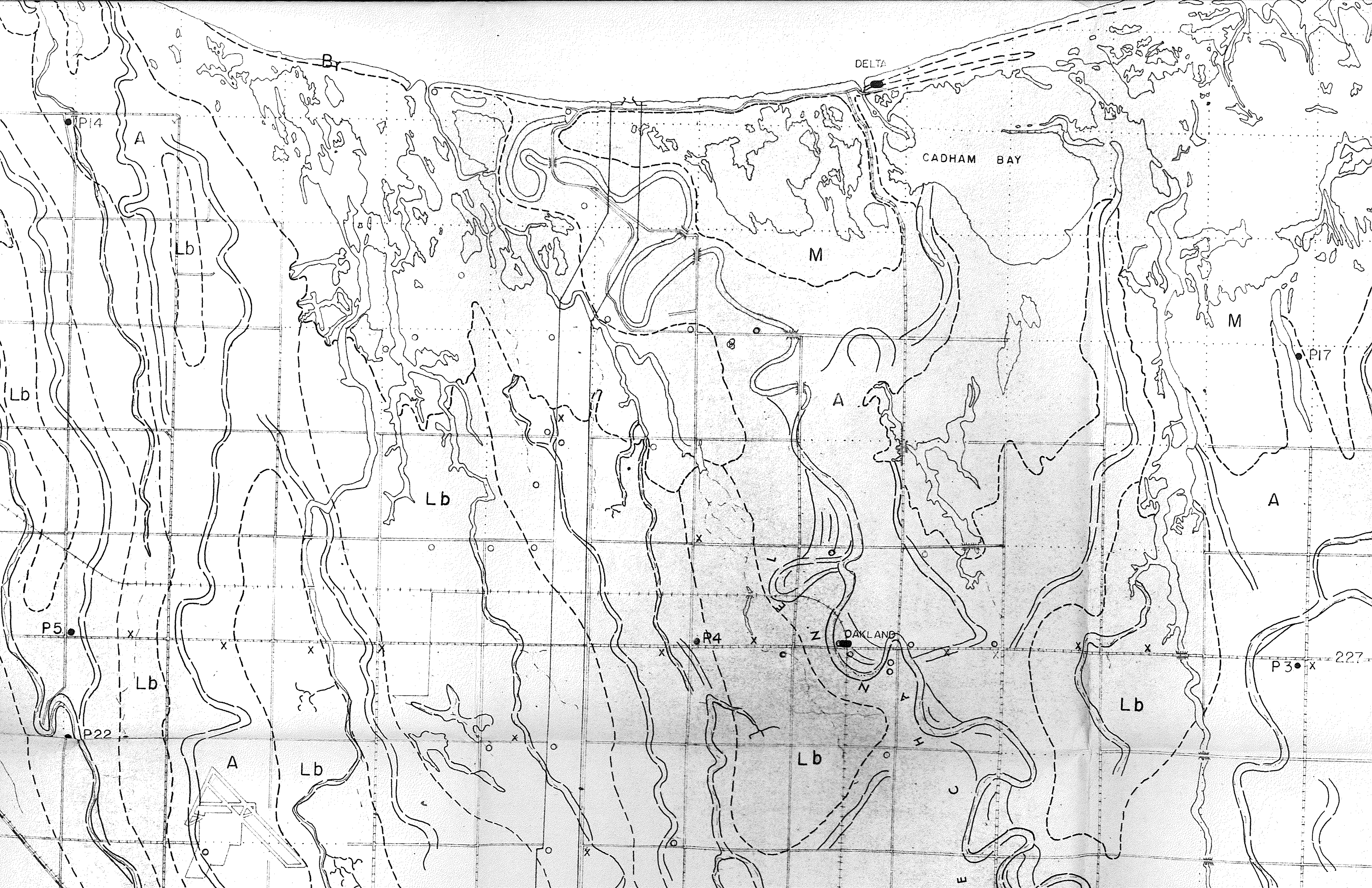
Depth (ft.)	Lithology	Interpretation
0-2	Soil; silty, sandy, dark gray	Lacustrine unit silt
2-7	Silt; clayey, grayish-brown (2.5Y5/2 wet), laminated, calcareous	
7-8	Clay; silty, sandy, grayish-brown, (2.5Y5/2 wet), occasional pebble	Lacustrine unit upper clay

Section No.	7	Location:	EC-29-11-8W1
Type:		Date:	July, 1969

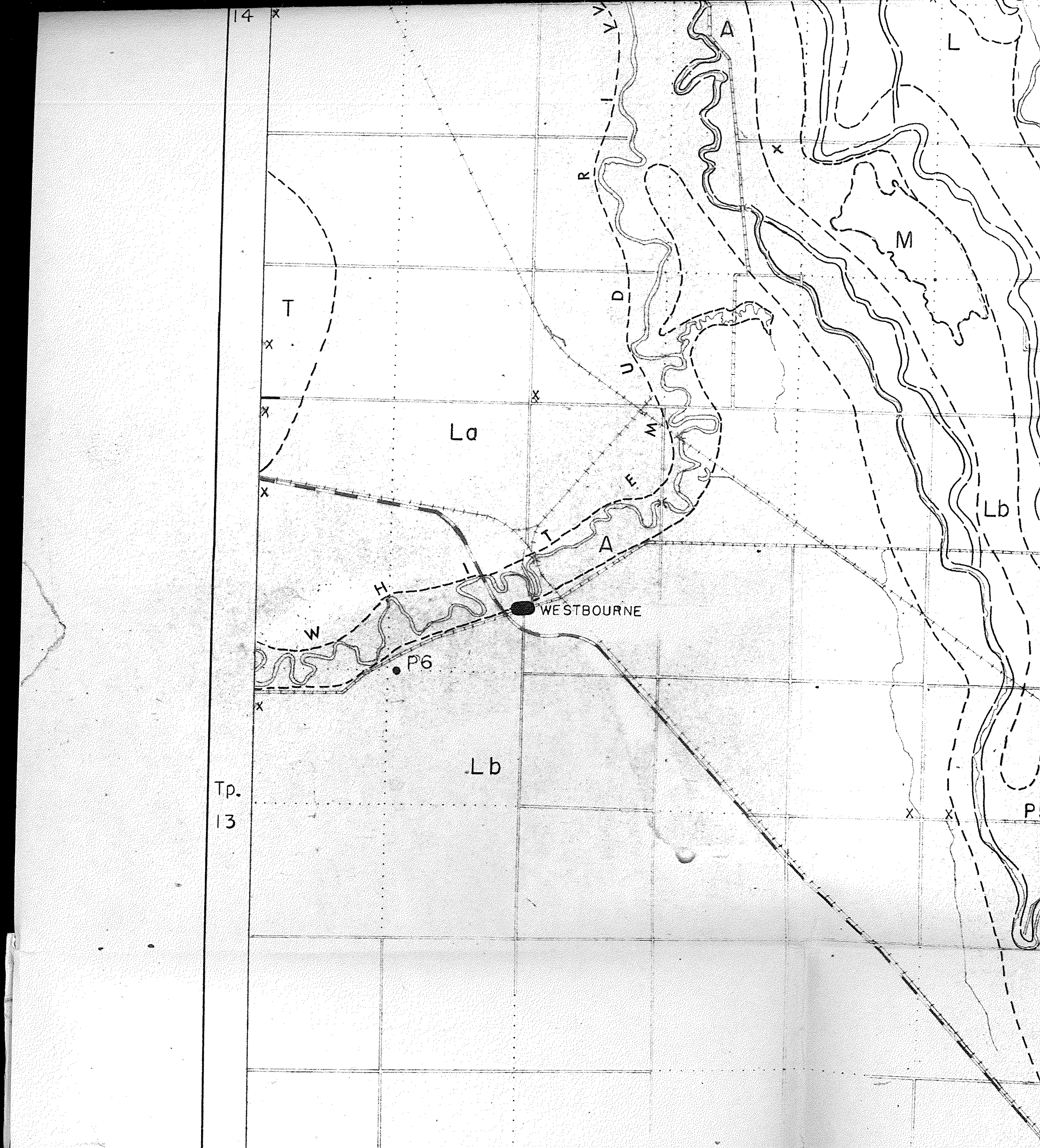
Depth (ft.)	Lithology	Interpretation
0-3	Sand; medium-grained organic rich, well sorted, black 5Y 2/1 wet), grading downward to light brownish-gray (2.5Y 6/2 wet)	Prodeltaic sand subunit, dune sand, also soil profile
3-6	Sand; medium-grained, light brownish-gray (2.5Y 6/2 wet) occasional pebbles with quantity increasing with depth	Prodeltaic sand subunit, lower portion lake deposited
6-11	Silt; grayish-brown (2.5Y 5/2 wet) laminated to massive weathered condition covers laminations, occasional thin clay laminae (<1mm) in lower portion, calcareous	Prodeltaic silt subunit, repeating units difficult to recognize due to thin clay
11-27	Repetative bedding; each unit consisting of pure clay at the base overlain by clayey silt. Clay silt changes upward from parallel laminated (1-5mm) to cross laminated often with cut and fill structures at the top of the cross laminated portion. In a few units parallel laminated clayey silt are present above the cross laminations. The units are about one foot (≈30 cm) thick. The contact between the repeating units is sharp. Clayey silt is calcareous.	



Br	Ridge, <10 ft. high along south shore of lake	Sand, fine to medium grained, well sorted, well devoloped cross bedding	Beach, produce by the action of the lake on the south shore
M	Flat, much of unit submerged	Silt and clay, organic rich	Marsh deposits, formed by southward flooding of Lake Manitoba
A	Low relief, (10ft.) channels are only relief	Sand, in and adjacent to channels Silt and clay, away from channels	Alluvium, deposited during period of fluvial activity following drainage of Lake Agassiz from the area
PLEISTOCENE			
Sp	Ridges, 5 to 15 ft. high. Scarps, 5 to 15 ft. high	Ridges, sand, fine to medium grained, massive, occasional pebbles Scarps, erosional some sand at base and crest.	Beaches bars and wave cut scarps form at the margin of intermediate levels of Lake Agassiz.
La Lb	Low relief (10 ft.) occasional very low straight to slightly curving linaments	(a) Silt, grayish brown, thin, discontinuous, (b) Clay, silty, grayish brown, occasional pebbles.	Lacustrine sediments deposited in Lake Agassiz, the clay during high lake levels, the silt at low lake levels shortly before the water drained from the area
Da Db	Forms northeast sloping highland. Relief moderate (5 to 25 ft.) in the stabalized dunes in the south, low (10 ft.) in the north	(a) Sand, very fine to fine grained, occasional pebbles in lower portion (b) Silt, clayey, thinnley laminated, underlies sand, infrequently exposed	Prodeltaic deposits form tne lower part of the Assiniboine Delta, deposited in Lake Agassiz by the eastward flowing Assiniboine River during highest lake level. Sand reworked along nothern boundary during lower water levels
T	Low relief (10 ft.) well developed	Till, grayish brown, loamy, stoney,	Moraine deposited during last north-



Br
DELTA
CADHAM BAY
P14
A
Lb
M
A
M
P17
Lb
Lb
A
A
OAKLAND
P5
R4
P3
227
Lb
Lb
P22
A
Lb
Lb
E L Z N A H C E


14
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WESTBOURNE
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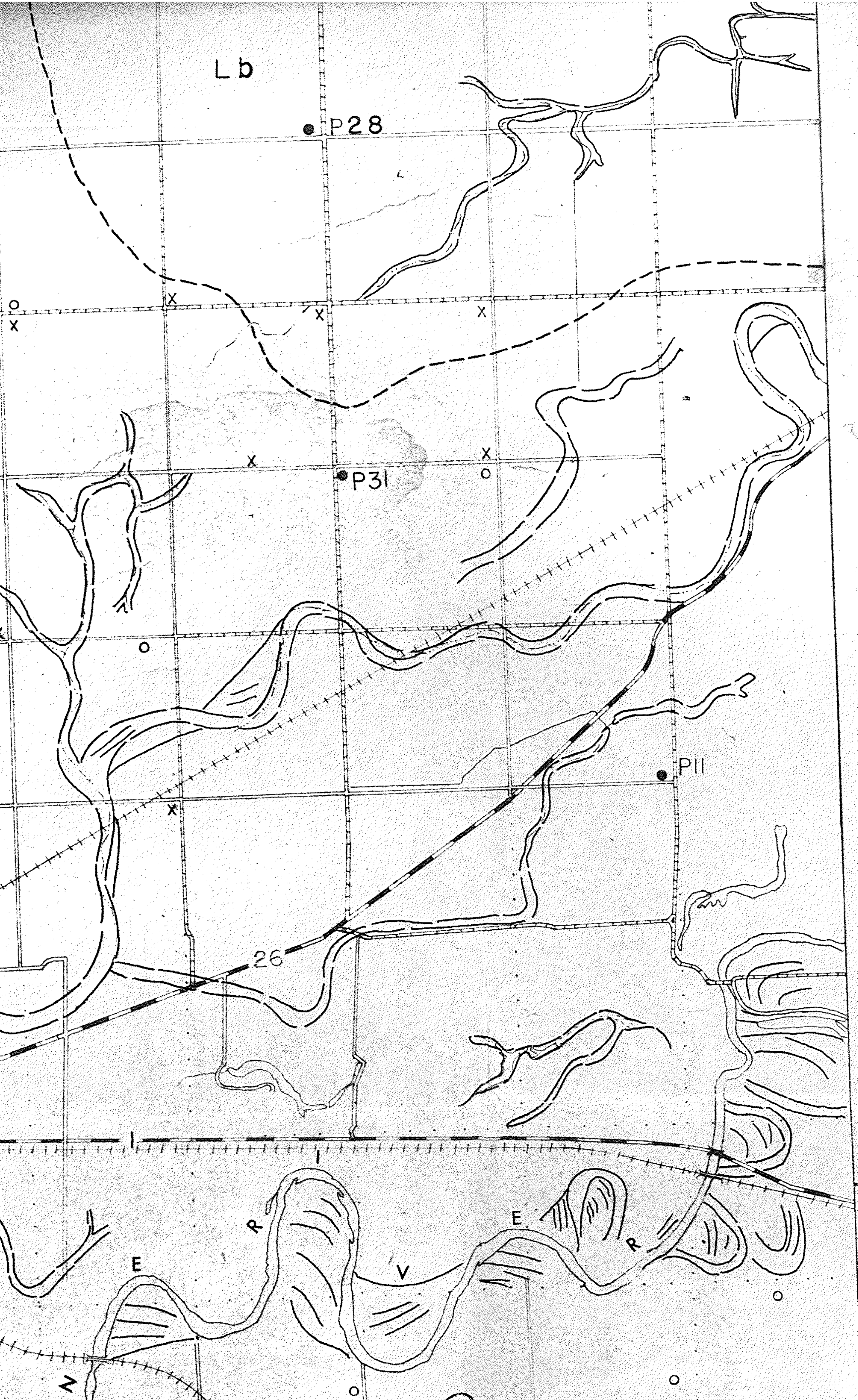
Lb
Tp.
13
P



trending linaments,
accentuated by
vegetation growth
parallel to them

Geologic boundary approximate
gradational

River channel, abandoned or containing underfit stream

River, Stream, Intermittent stream

Scarp

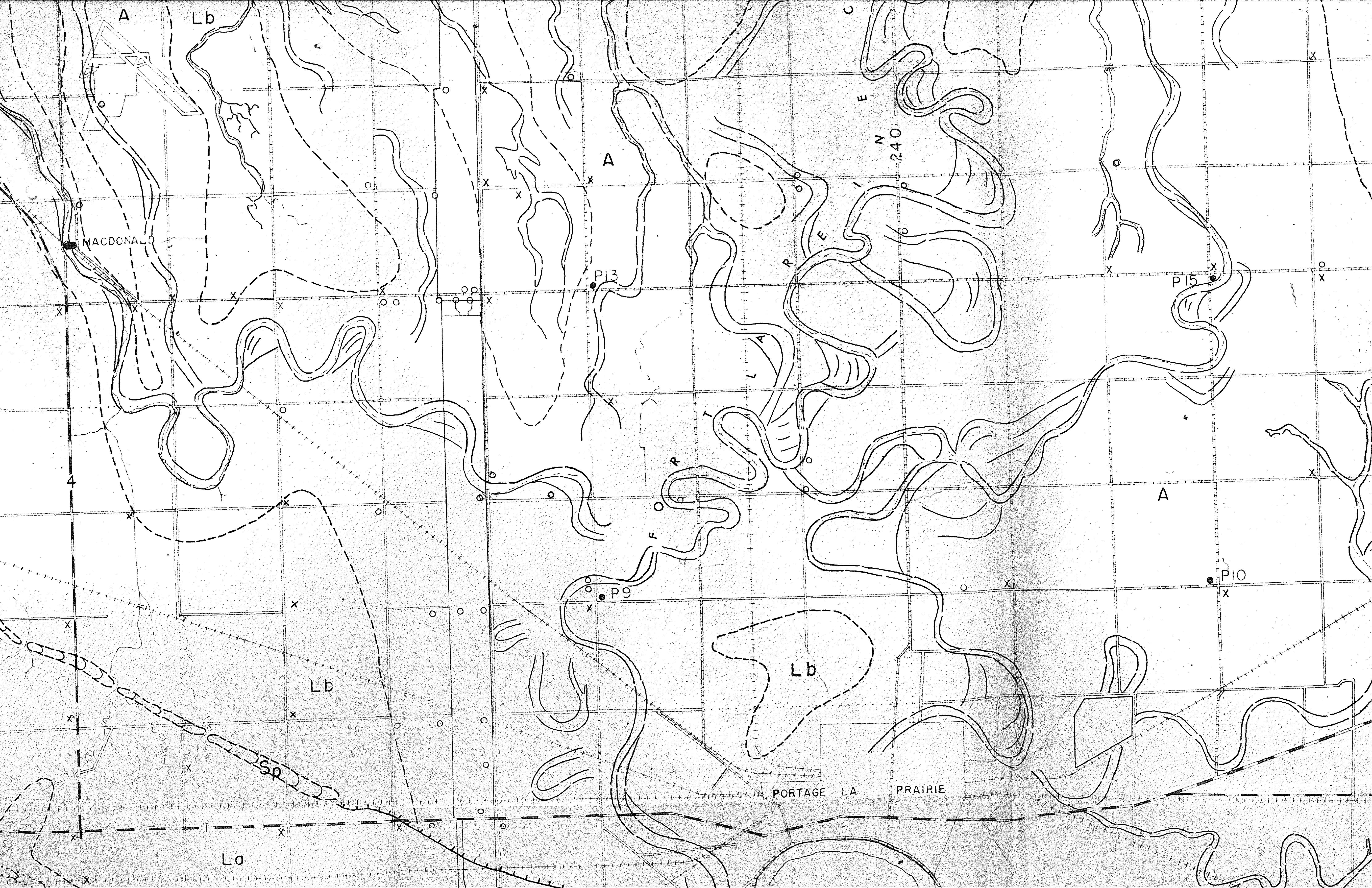
Ridge

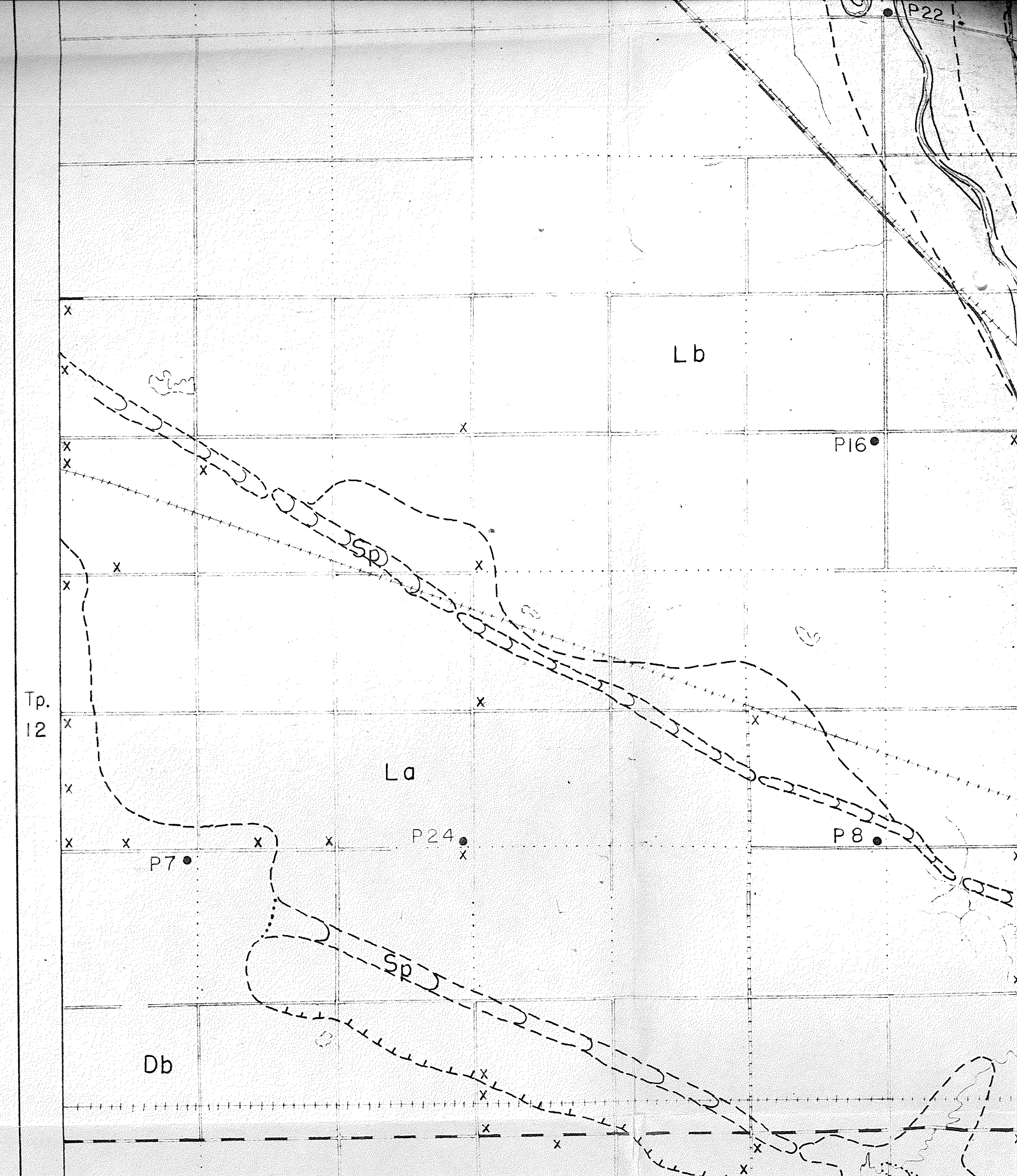
Hole drilled during study

Surface or hand auger sample

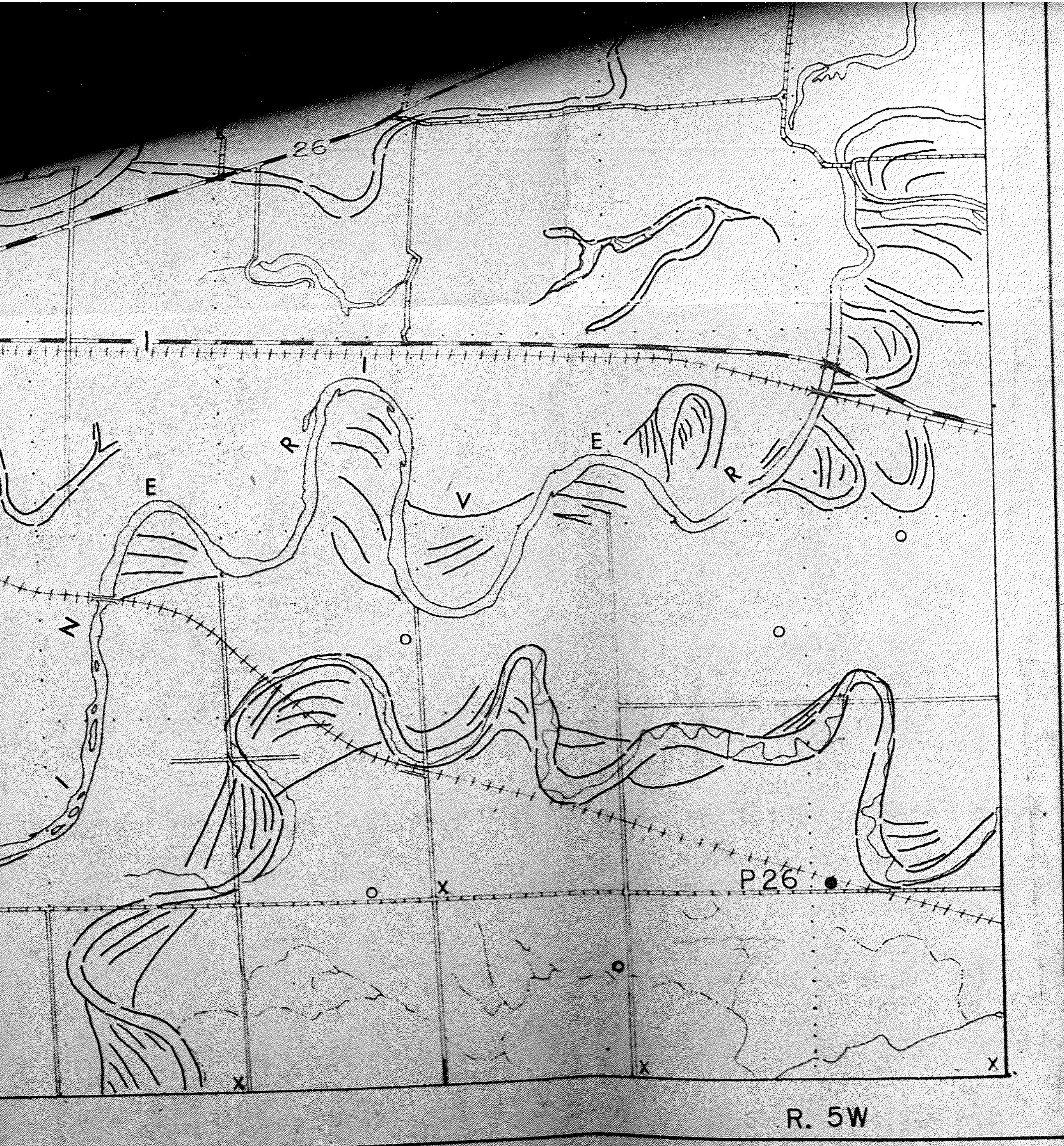
Preexisting drill hole

Geologic cross section


MACDONALD
PORTAGE LA PRAIRIE
FORT LA REINE
240
P9
P10
P13
P15
A
Lb
La
Sp
4
1



P22
Lb
P16
Sp
Tp.
12
La
P24
P8
P7
Sp
Db



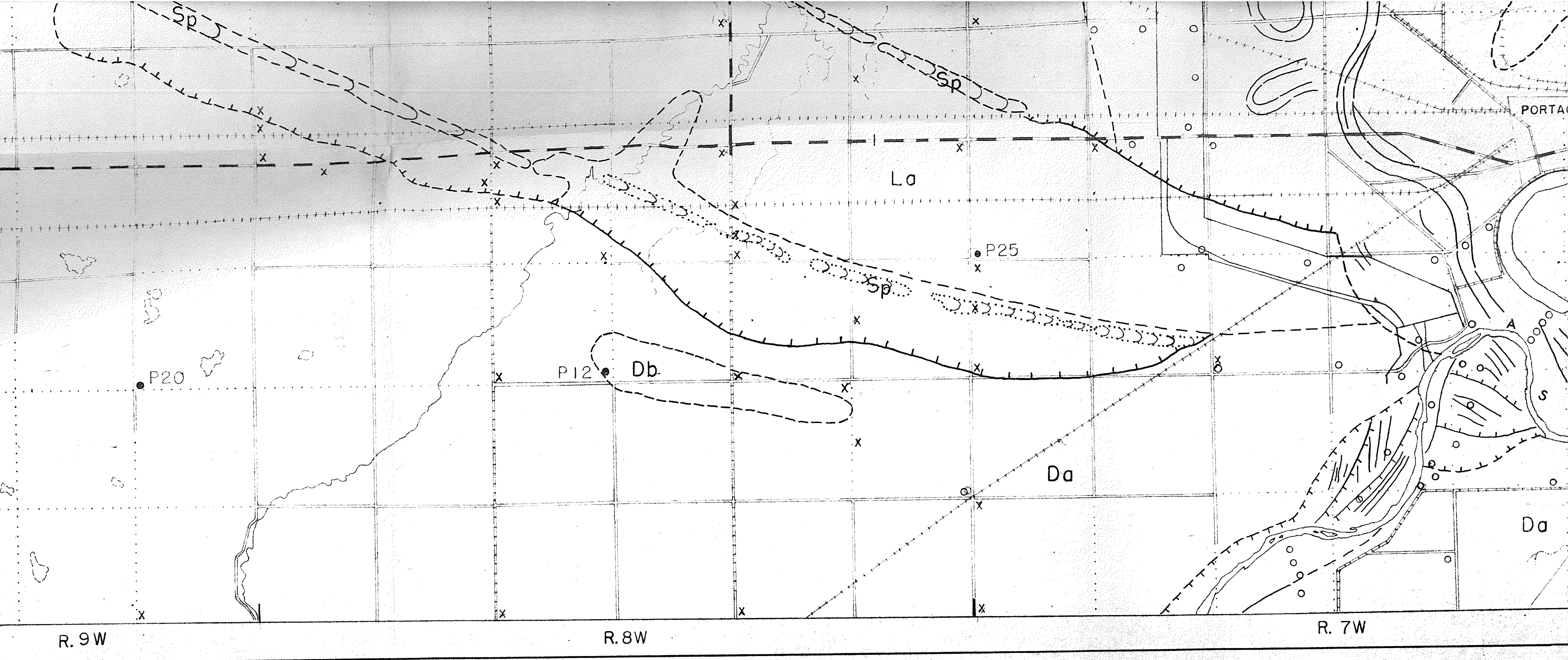
B A

Road, paved
gravel

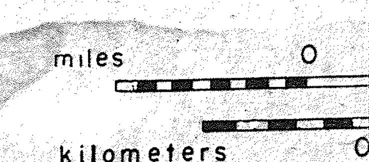
Railroad

Township or section line

Bridge



g. 5 SURFICIAL GEOLOGY ASSINIBOINE RIVER



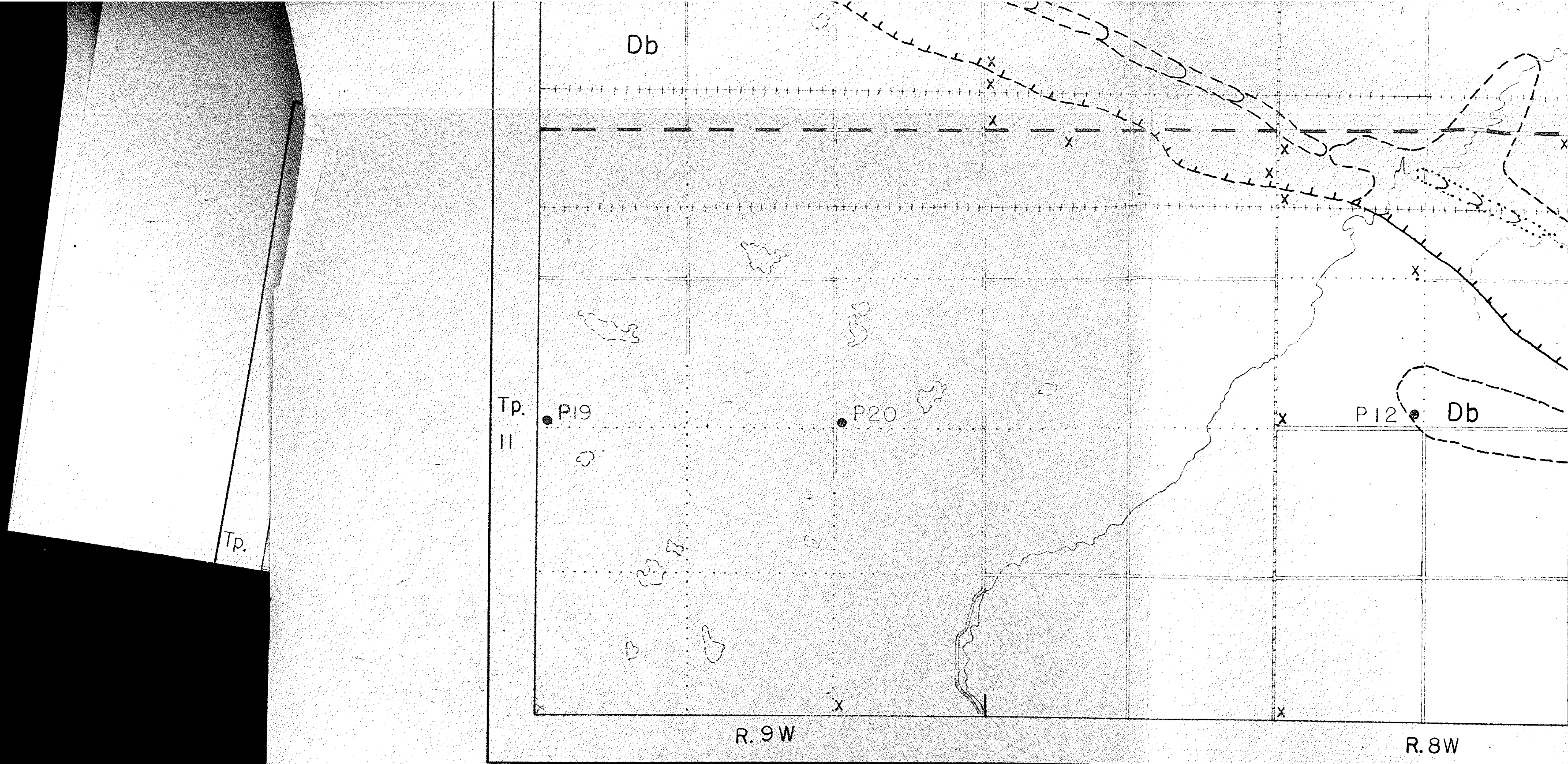
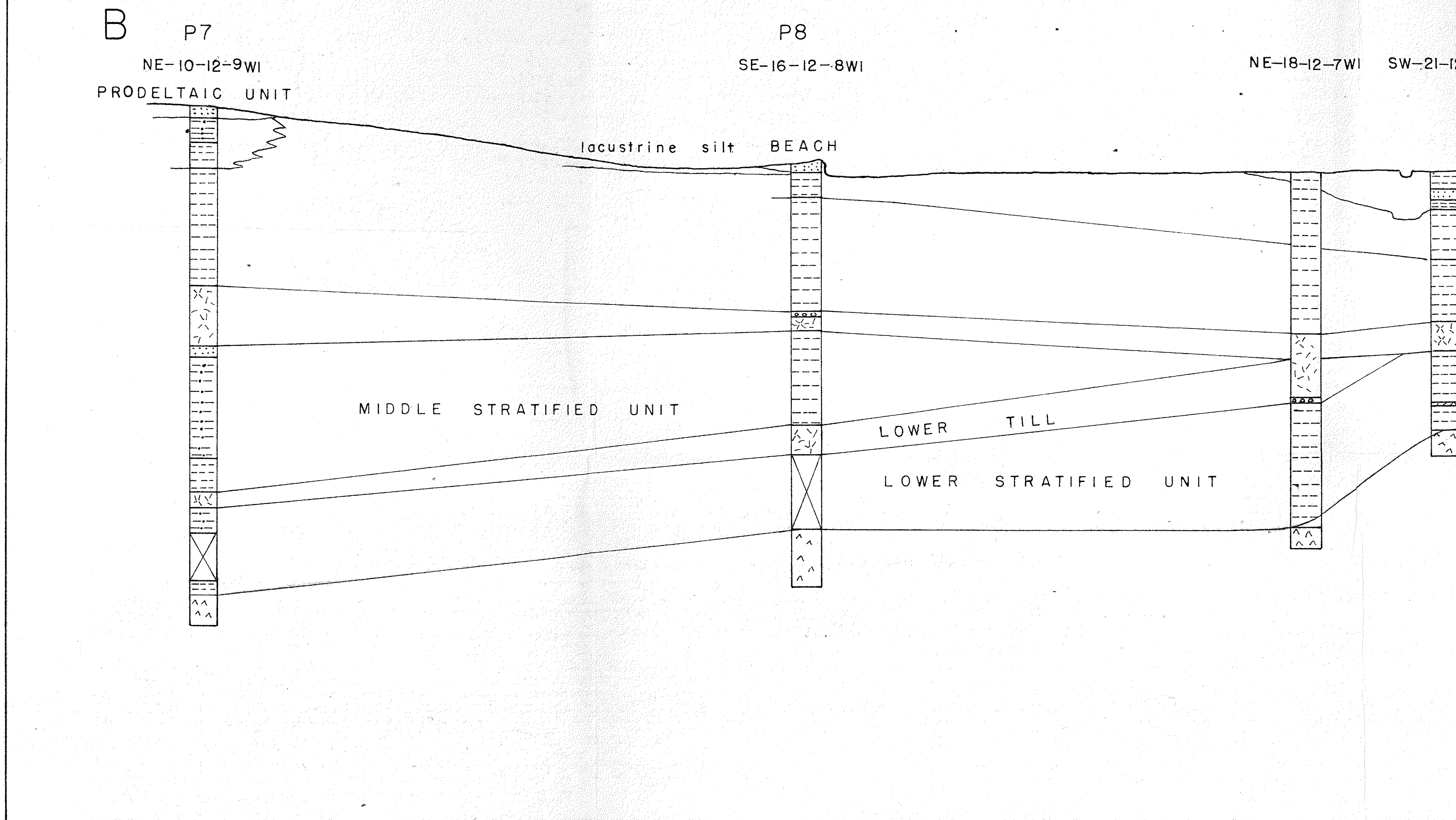
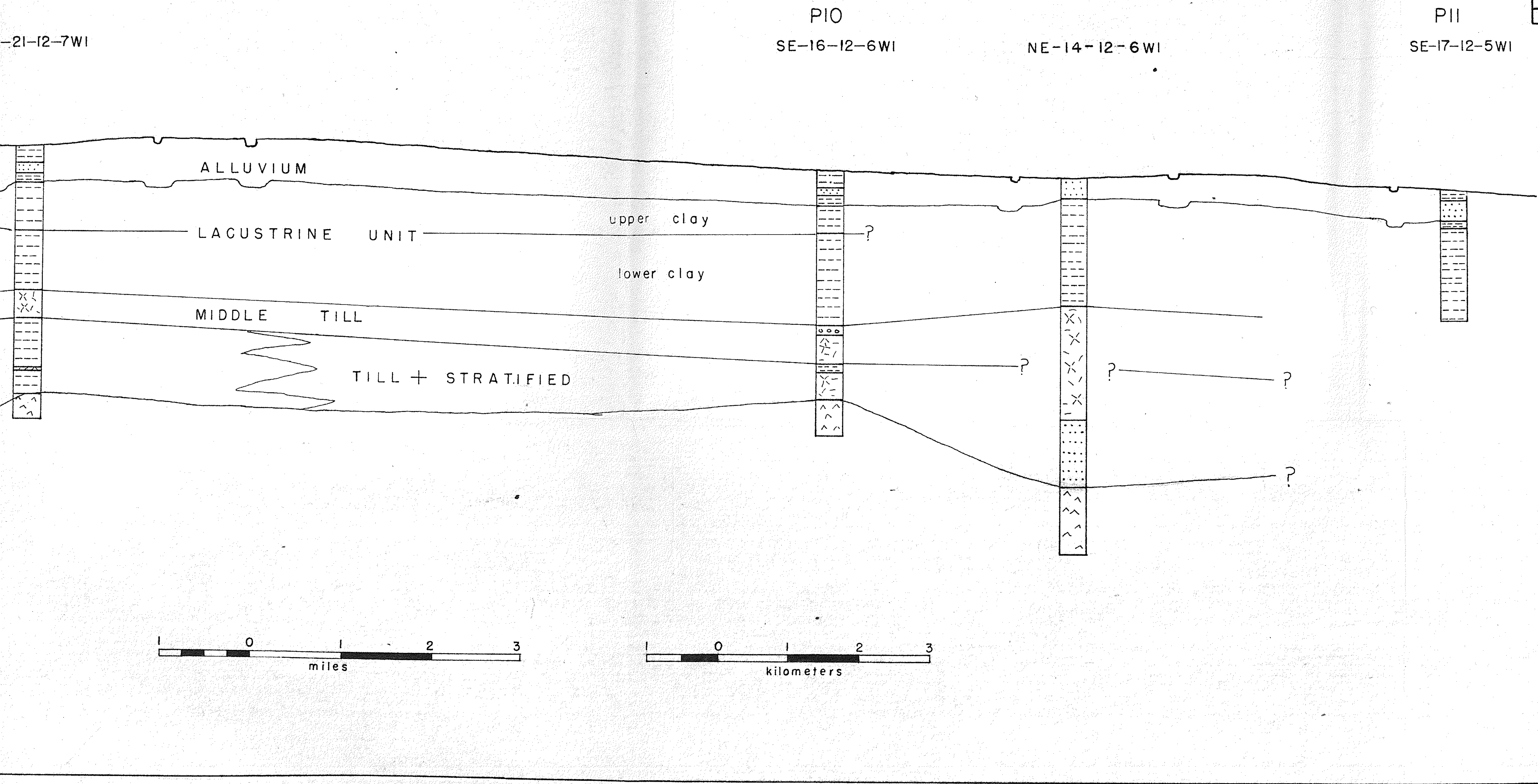


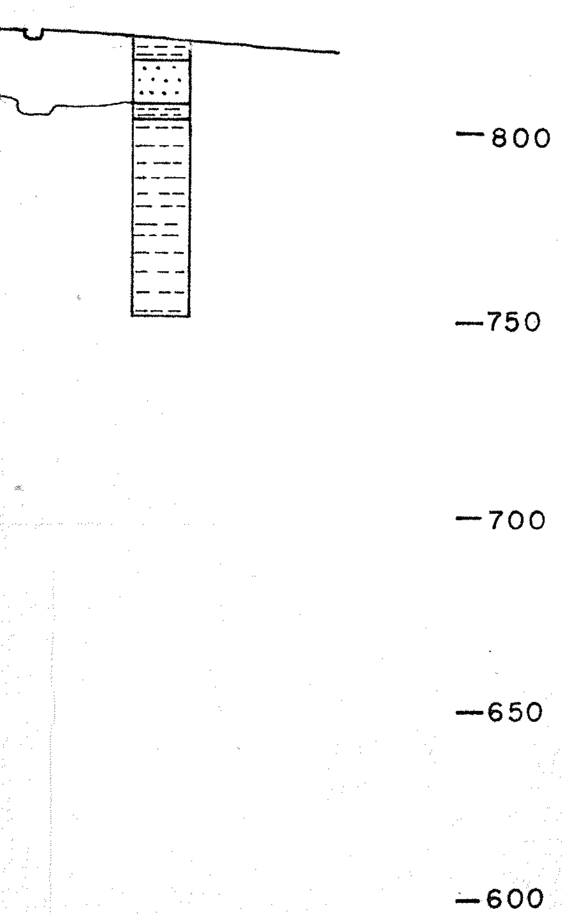
Fig. 5 SURFICIAL GE

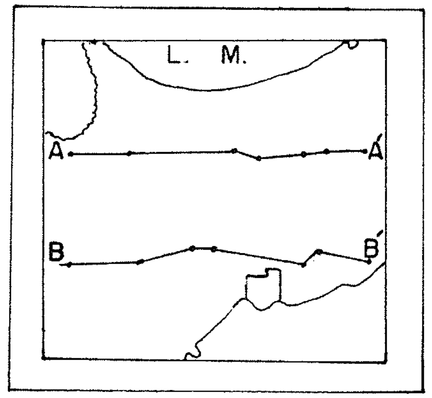

B
P7
NE-10-12-9WI
PRODELTAIC UNIT
P8
SE-16-12-8WI
lacustrine silt
BEACH
NE-18-12-7WI
SW-21-12
MIDDLE STRATIFIED UNIT
LOWER TILL
LOWER STRATIFIED UNIT


P10
P11
-21-12-7W1
SE-16-12-6W1
NE-14-12-6W1
SE-17-12-5W1
ALLUVIUM
upper clay
LACUSTRINE UNIT
lower clay
MIDDLE TILL
TILL + STRATIFIED
miles
kilometers

P11 B'

SE-17-12-5W1





LOCATION of SECTIONS

LEGEND

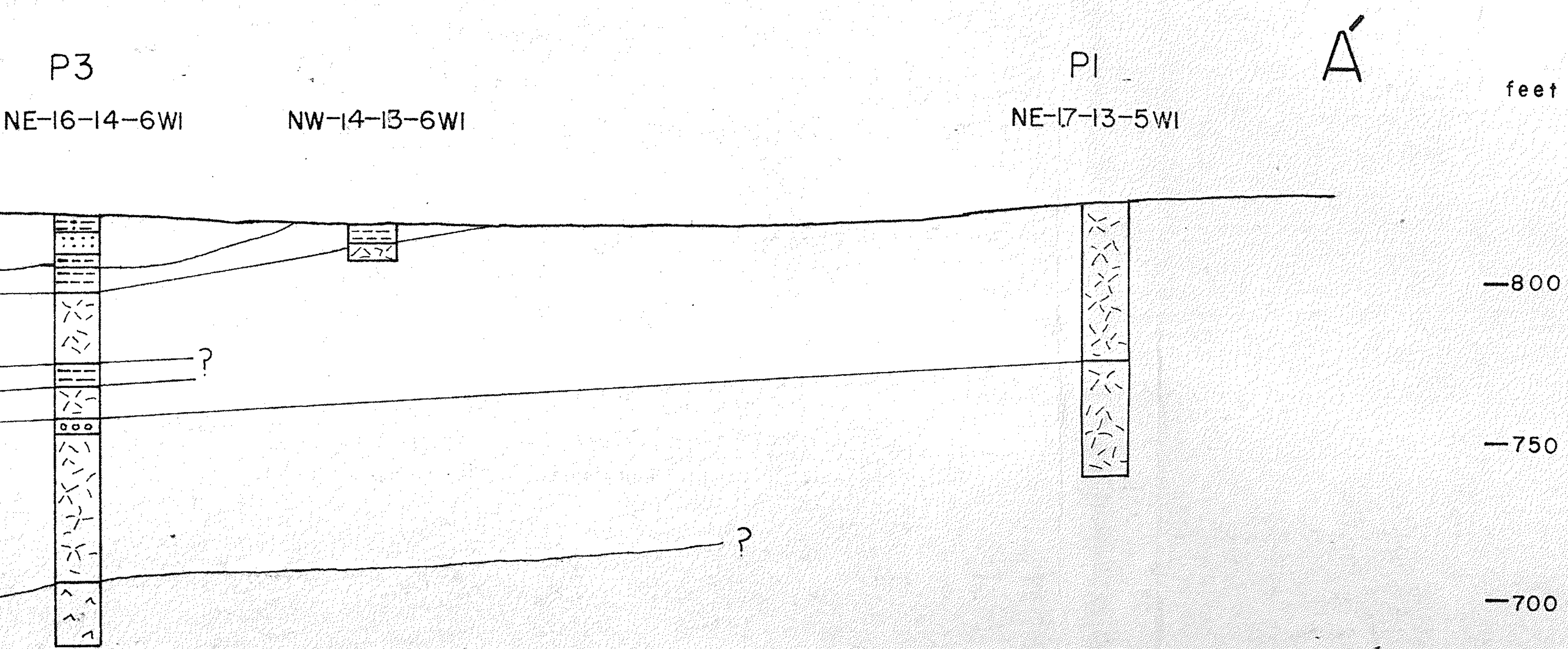
CLAY		GRAVEL	
SILT		TILL	
SAND		TILL and STRATIFIED	
		BEDROCK	

HORIZONTAL SCALE 1 in = 1 mi

VERTICAL SCALE 1 in = 50 ft

VERTICAL EXAGGERATION 100 X

REA, MANITOBA



EST EAST QUATERNARY CROSS SECTION PORTAGE-DELTA

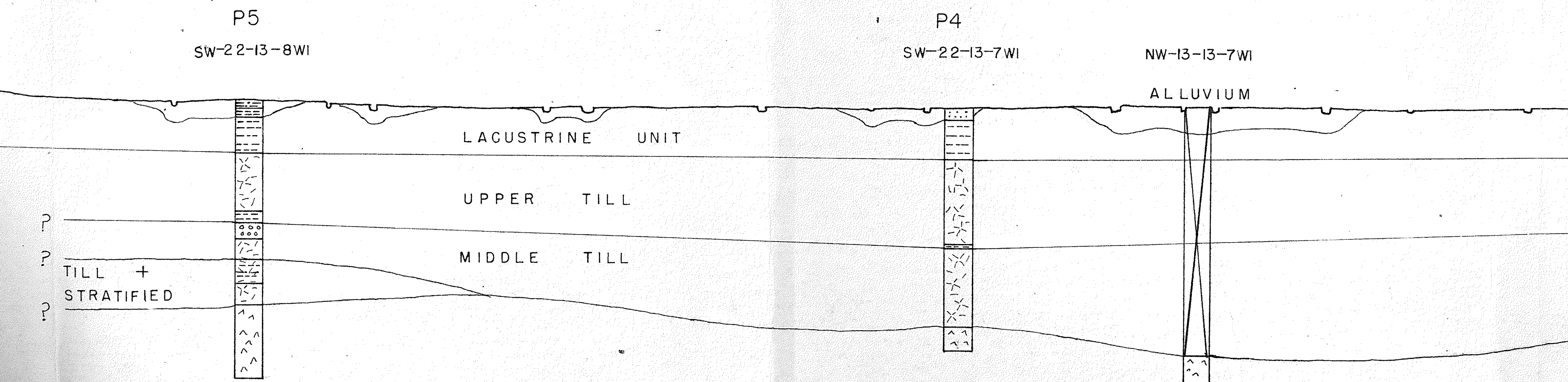
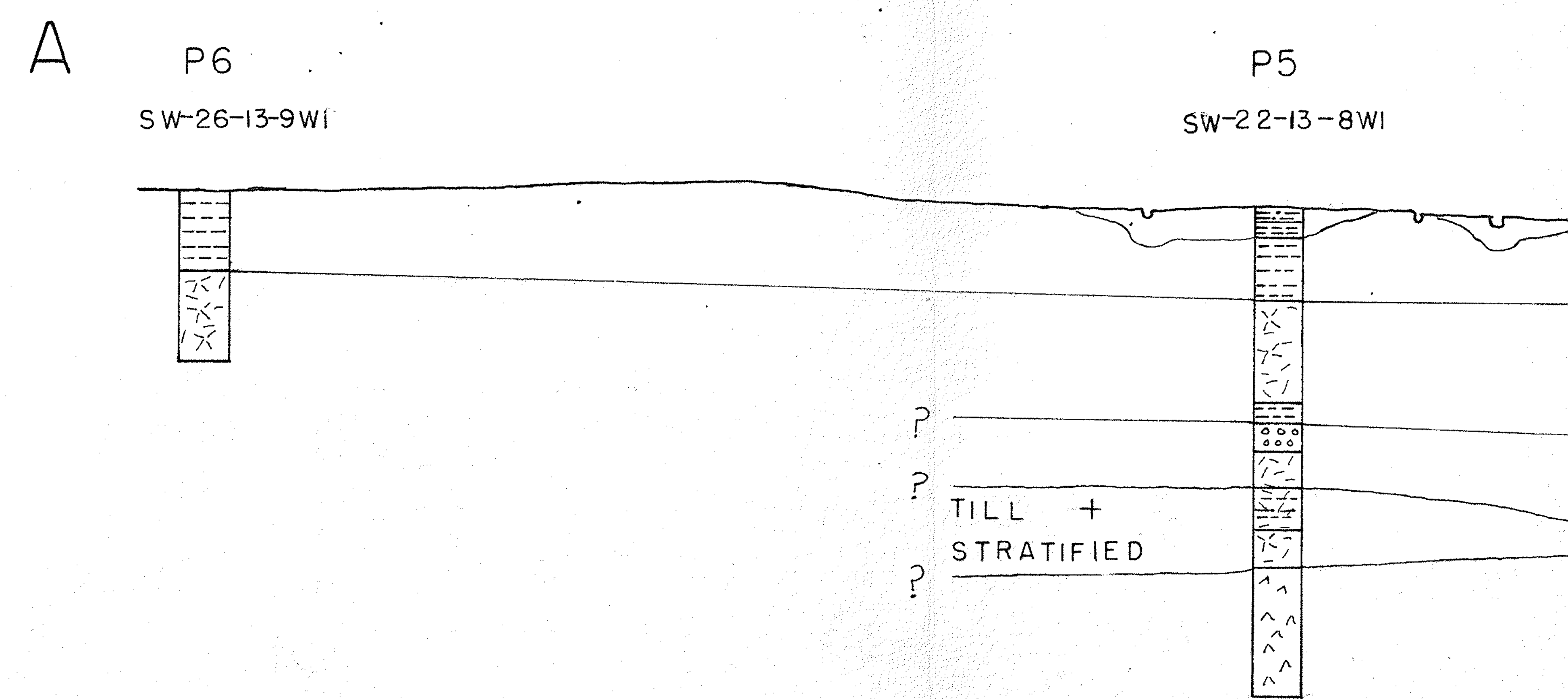


Fig. 7 WEST EAST QUA



SECTION PORTAGE DELTA AREA, MANITOBA

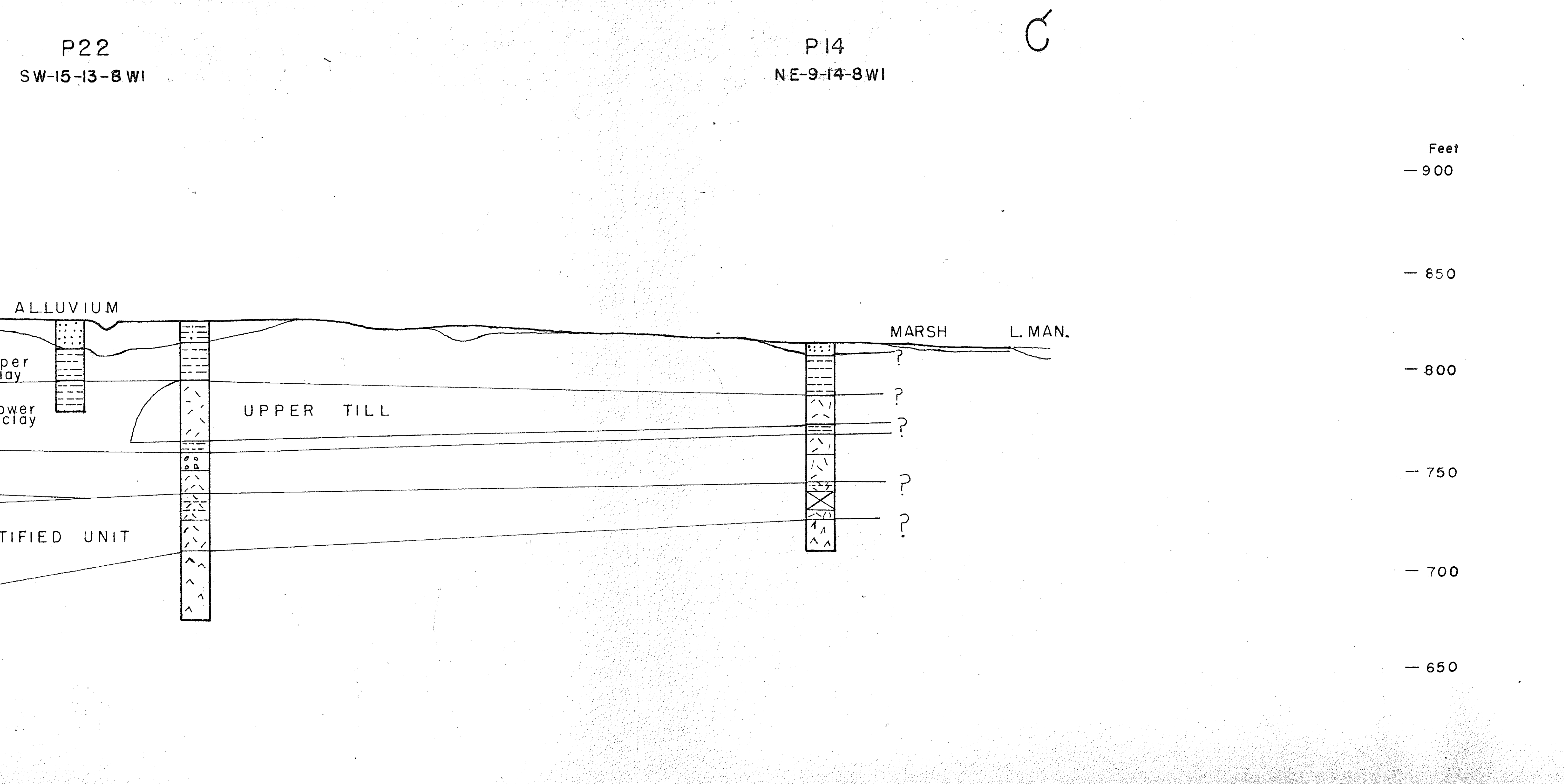
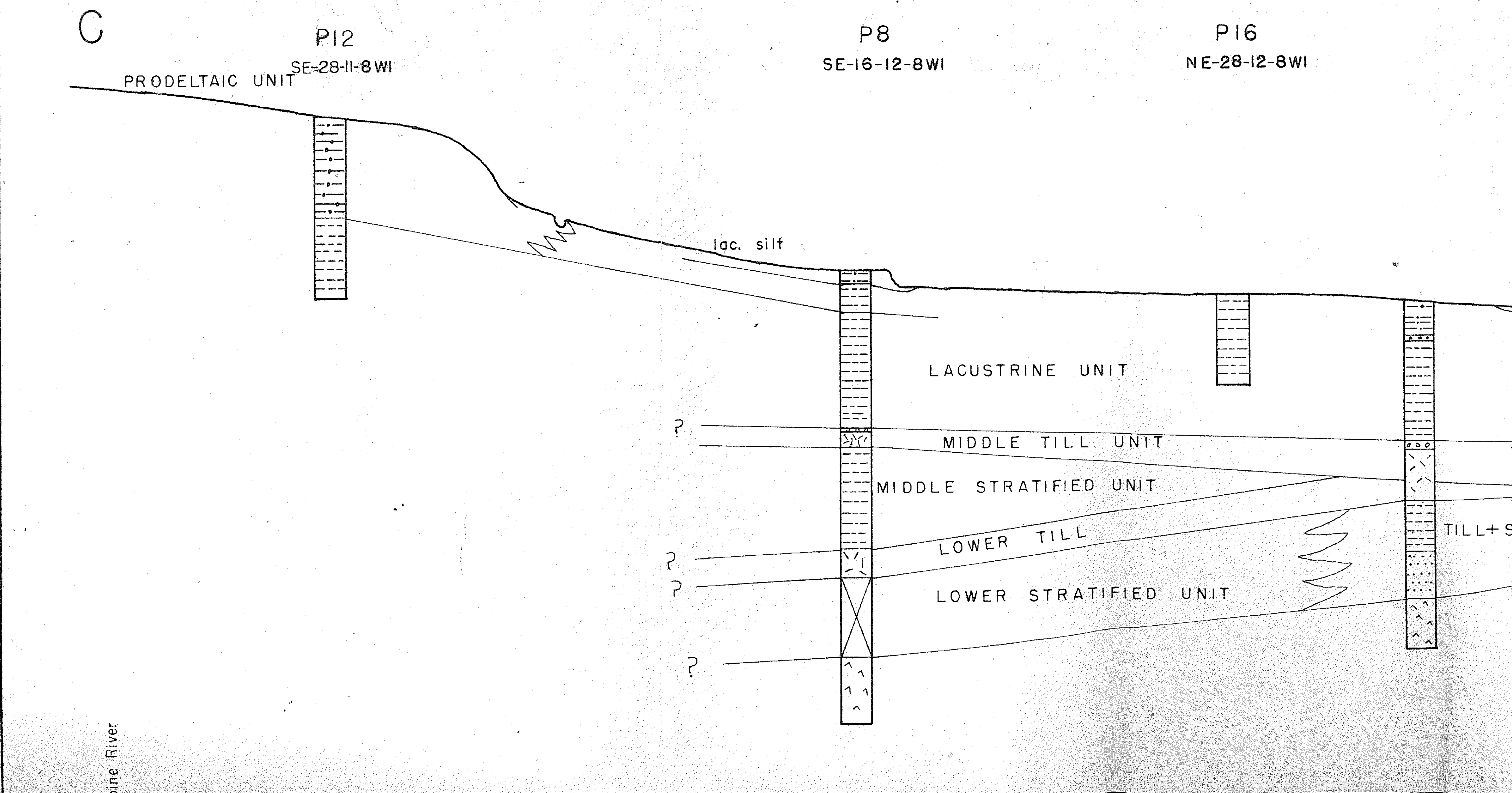
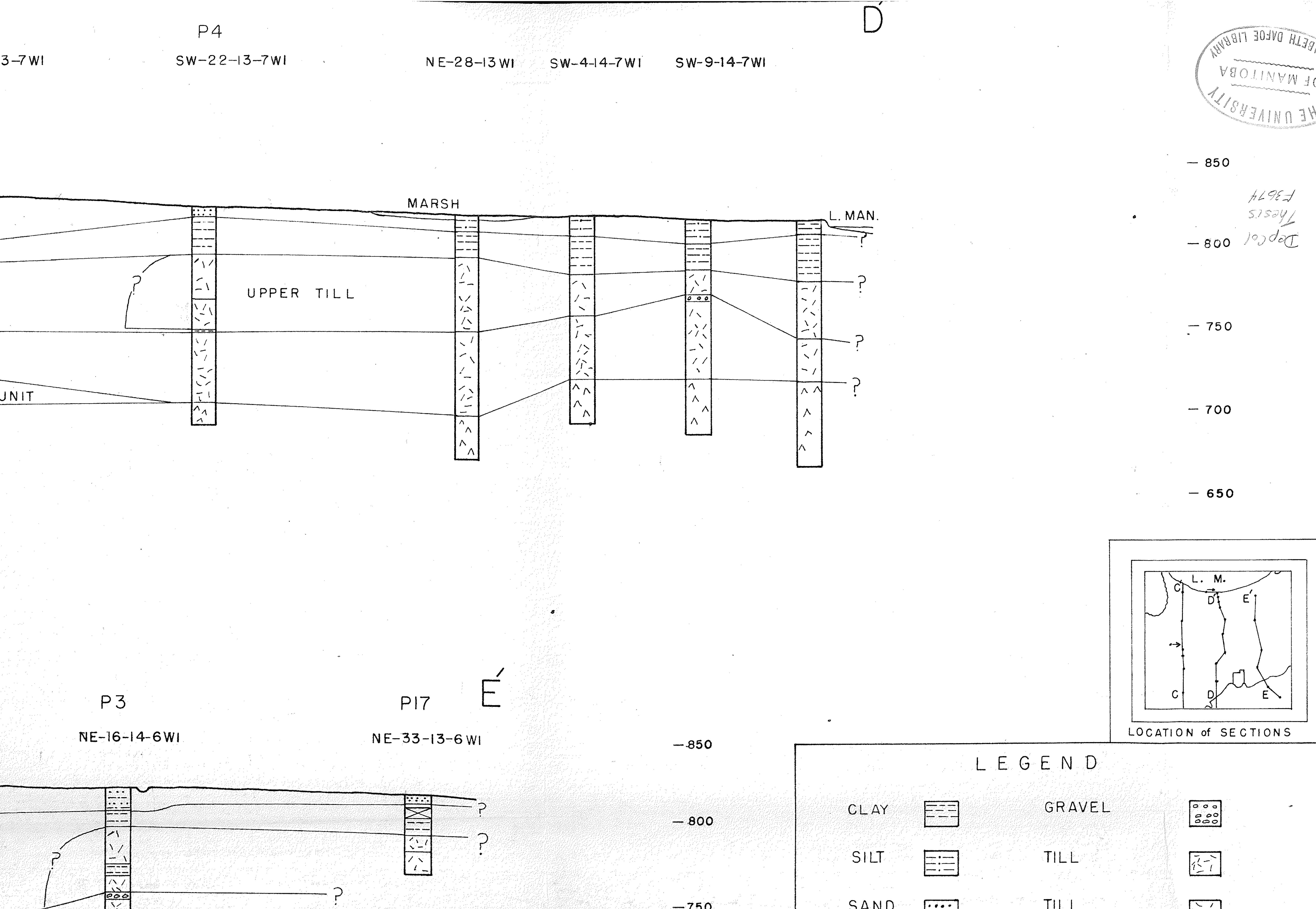
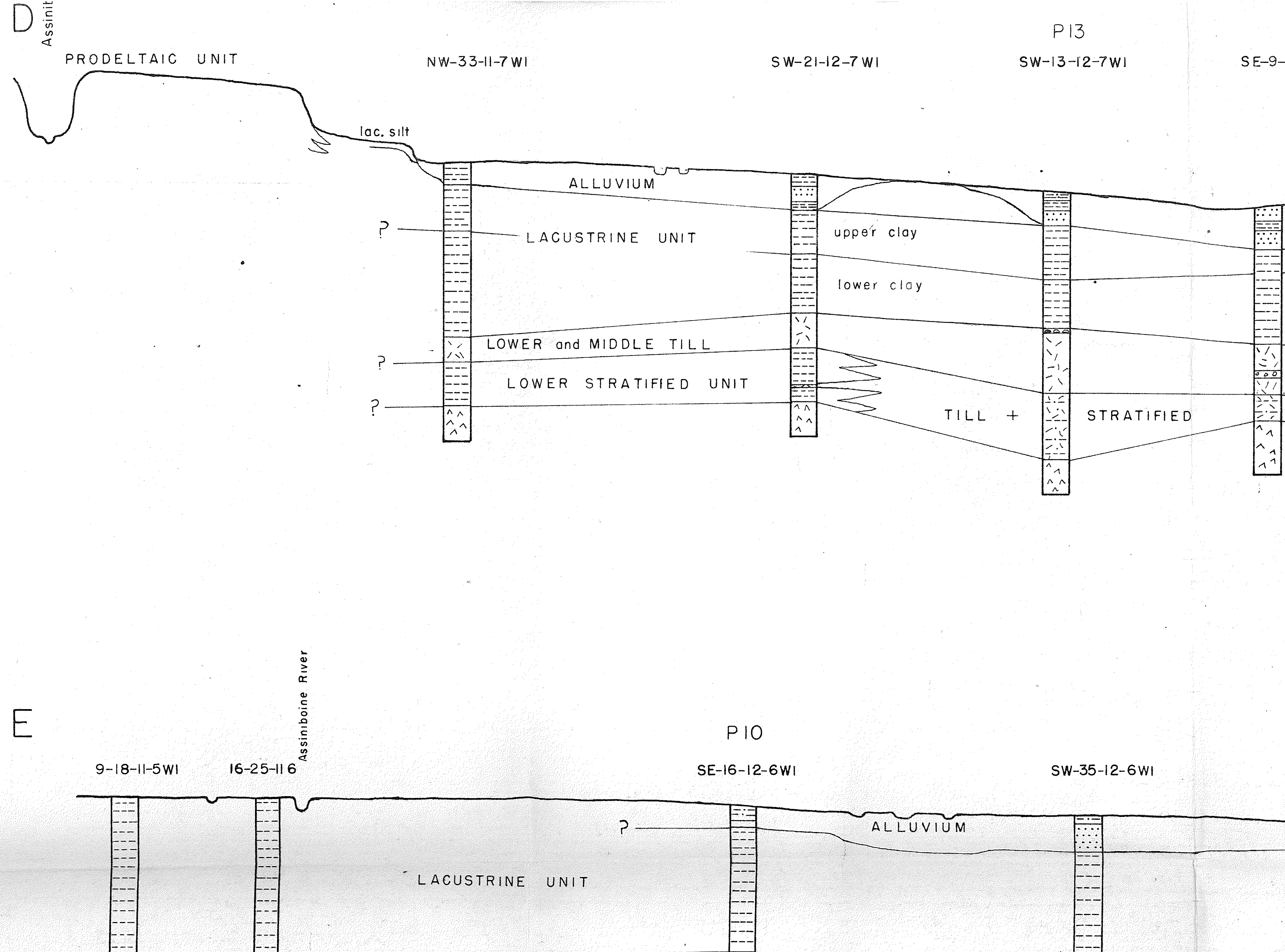
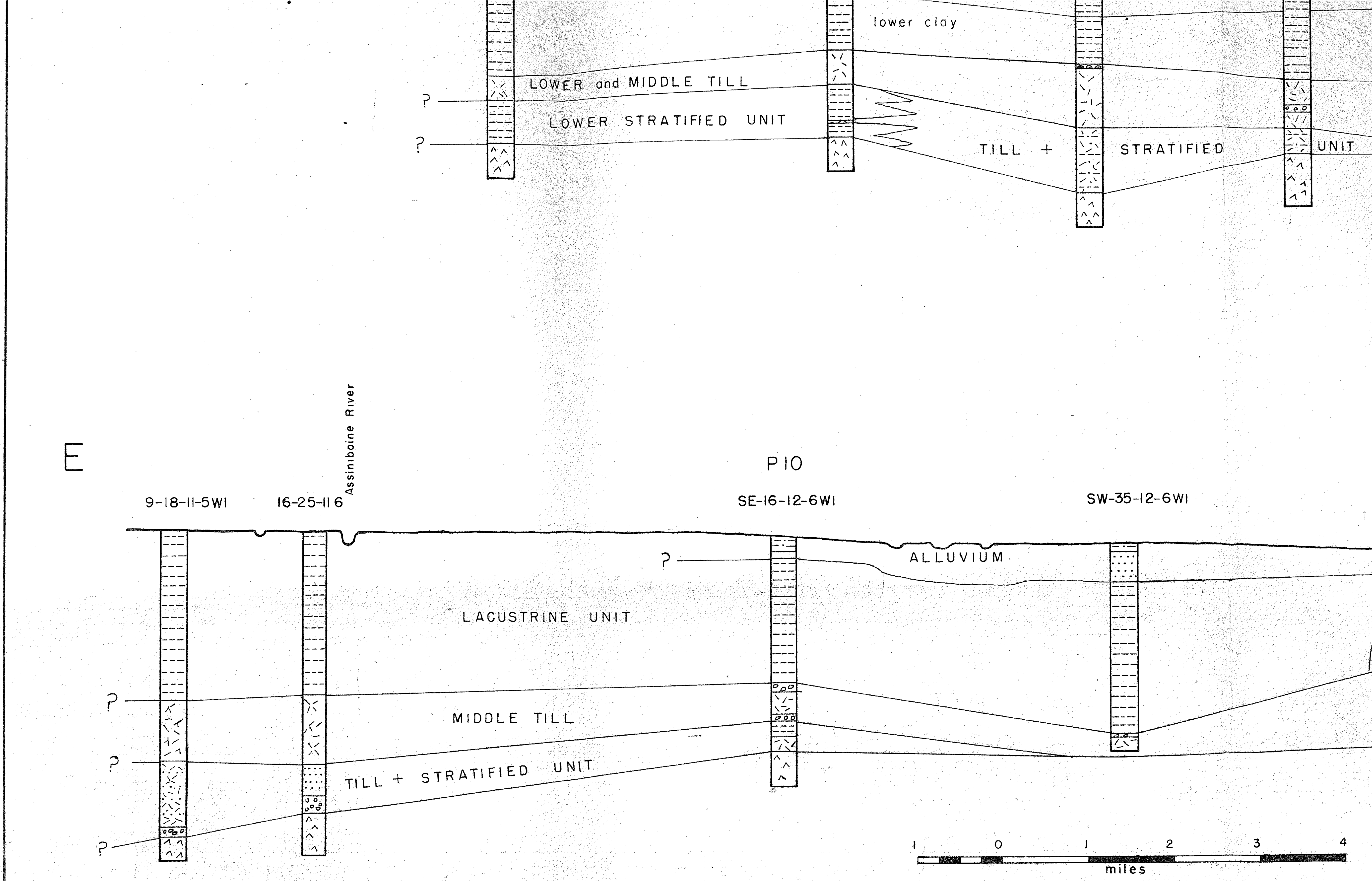


Fig. 6 NORTH SOUTH QUATERNARY CROS

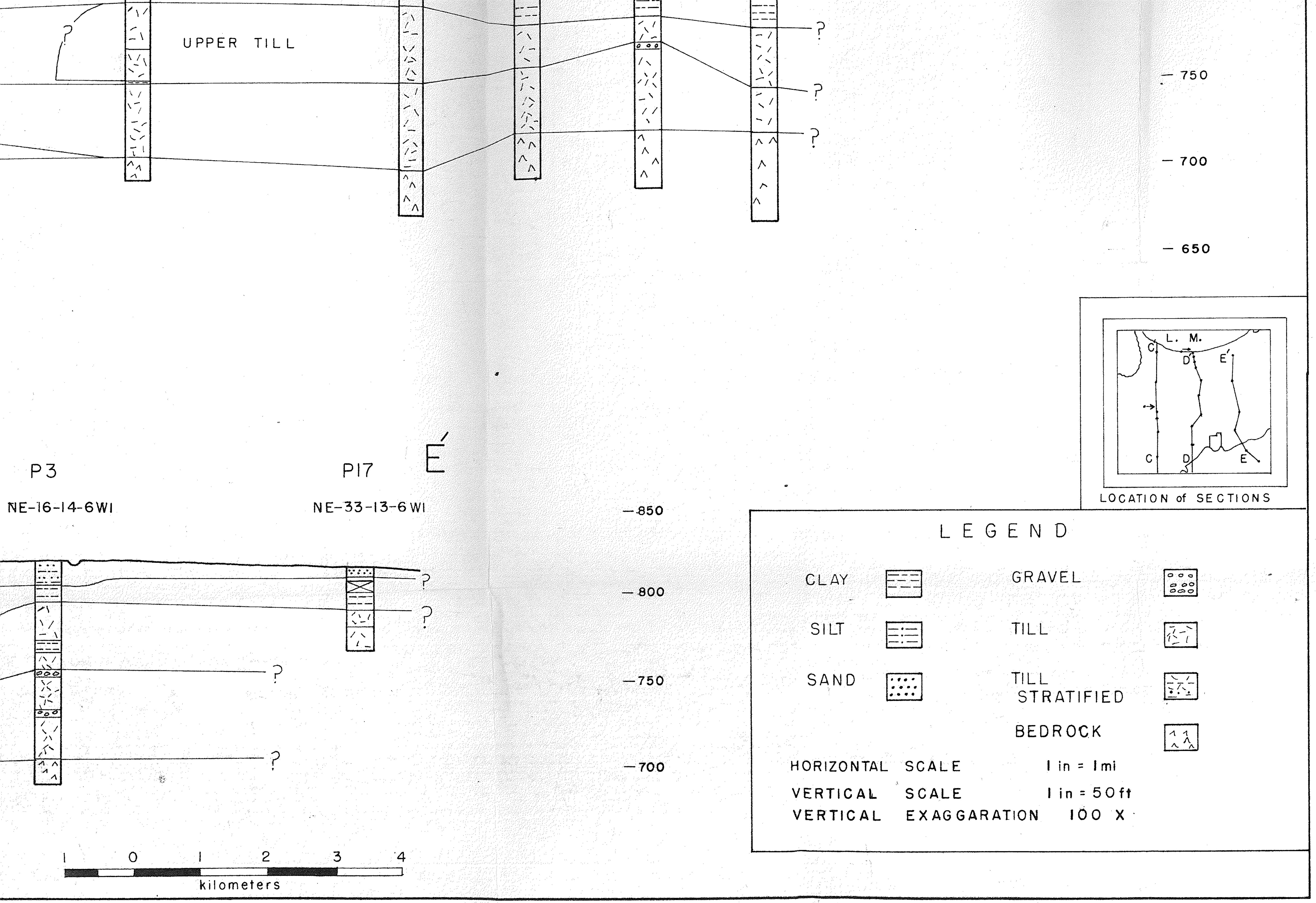



D′
P4
3-7WI
SW-22-13-7WI
NE-28-13WI
SW-4-14-7WI
SW-9-14-7WI
MARSH
L. MAN.
UPPER TILL
UNIT
850
800
750
700
650
?
P3
P17
E′
NE-16-14-6WI
NE-33-13-6WI
LOCATION of SECTIONS
L. M.
C
D
E
LEGEND
CLAY
SILT
SAND
GRAVEL
TILL


D
Assinit
PRODELTAIC UNIT
NW-33-11-7WI
SW-21-12-7WI
P13
SW-13-12-7WI
SE-9-
lac. silt
ALLUVIUM
?
LACUSTRINE UNIT
upper clay
lower clay
LOWER and MIDDLE TILL
?
LOWER STRATIFIED UNIT
?
TILL + STRATIFIED
E
Assiniboine River
P10
9-18-11-5WI
16-25-11 6
SE-16-12-6WI
SW-35-12-6WI
?
ALLUVIUM
LACUSTRINE UNIT



lower clay
LOWER and MIDDLE TILL
LOWER STRATIFIED UNIT
TILL + STRATIFIED UNIT
E
Assiniboine River
P10
9-18-11-5W1
16-25-11 6
SE-16-12-6W1
SW-35-12-6W1
ALLUVIUM
LACUSTRINE UNIT
MIDDLE TILL
TILL + STRATIFIED UNIT
1 0 1 2 3 4
miles



UPPER TILL
750
700
650
L. M.
C
C
D
D
E′
E
LOCATION of SECTIONS
P3
NE-16-14-6WI
P17
NE-33-13-6WI
E′
850
800
750
700
LEGEND
CLAY
SILT
SAND
GRAVEL
TILL
TILL STRATIFIED
BEDROCK
HORIZONTAL SCALE I in = I mi
VERTICAL SCALE I in = 50 ft
VERTICAL EXAGGARATION 100 X
1 0 1 2 3 4
kilometers