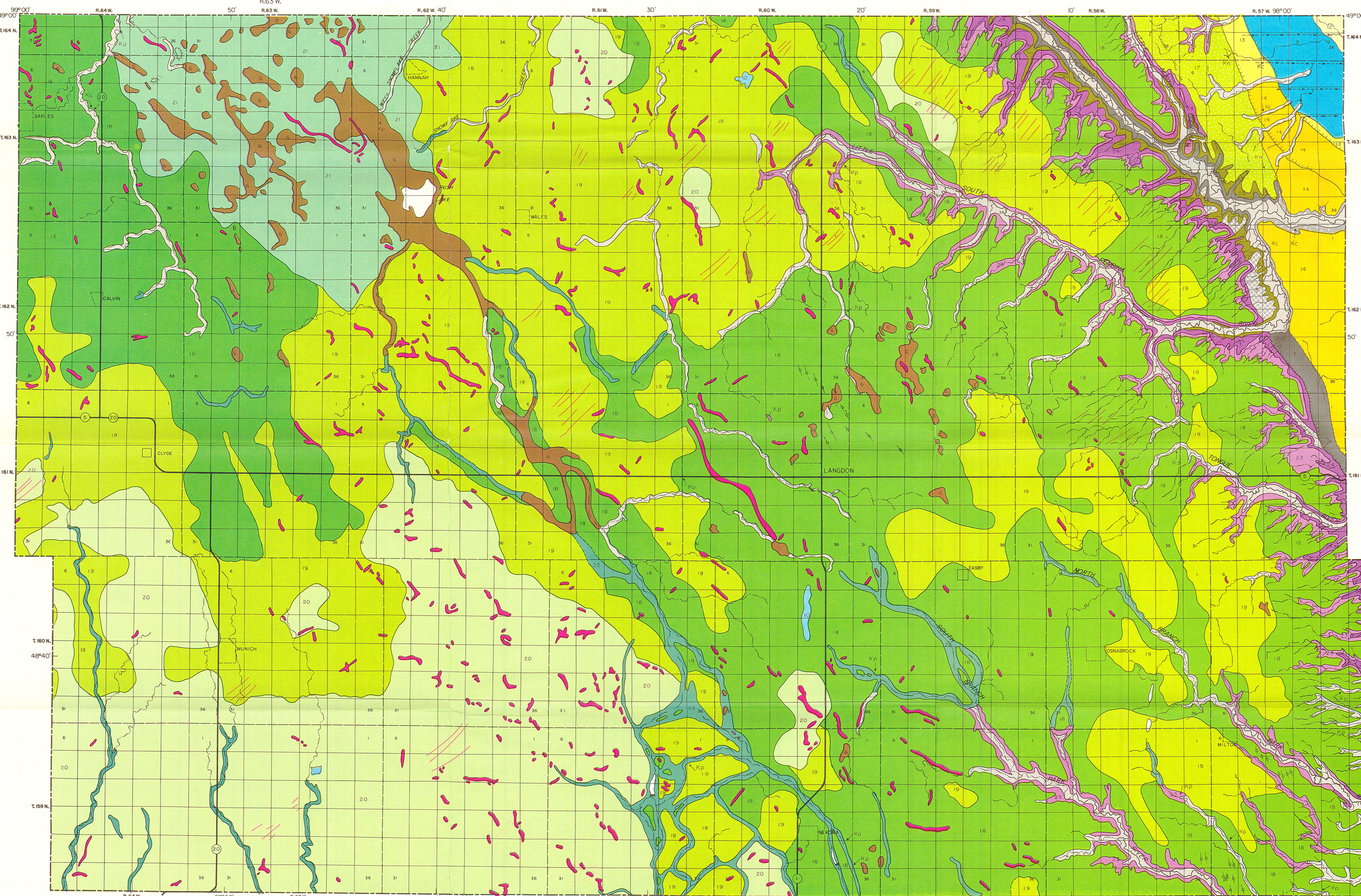


PLATE I. - GEOLOGY OF CAVALIER COUNTY

PART I PLATE I
COUNTY GROUND-WATER STUDIES 20
BULLETIN 62

NORTH DAKOTA GEOLOGICAL SURVEY
NORTH DAKOTA STATE WATER COMMISSION



Unit	Lithostratigraphic Unit	Description	Topography	Origin
1	Walsh Formation Sand and silt facies	Generally gray to black; bedding is horizontal although vague; organic fragments common.	Flat to gently sloping	Modern river overbank sediment; some river-channel sediment.
2	Walsh Formation Sand and silt facies	Light to very dark gray; bedding obscure; this rapidly away from rivers.	Flat to gently rolling	Modern river overbank sediment.
3	Walsh Formation Sand and silt facies	Clay and silt underlain by sand and gravel; cross-bedded; moderately sorted.	Flat to nearly flat	Pre-modern river overbank sediment; some river-channel sediment.
4	Walsh Formation Sand and silt facies	Mostly sand and gravel; large.	Steep slopes	Sediments deposited by the Pembina River during a time of very high discharge.
5	Walsh Formation Gravel facies	Heterogeneous mixture of sand silt clay and gravel; poorly sorted; generally dense and compact.	Moderate to steep slopes	Slopewash and creep sediment.
6	Walsh Formation Clay facies	Vague bedding; dark brown to black.	Flat	Slough and pond sediment.
7	Coleharbor Group Silt and clay facies	Laminated; yellowish-brown to light gray.	Nearly flat to gently undulating	Offshore sediment of Lake Agassiz.
8	Coleharbor Group Silt and clay facies	Laminated to massive yellowish-brown; snail and clam shells present.	Nearly flat to gently undulating	Offshore sediment of a lagoon near Lake Agassiz; the area containing this sediment was cut off from the rest of the lake by longshore bars and spits.
9	Coleharbor Group Silt and clay facies	Laminated; yellowish-brown to light gray locally overlain by thin veneer of clayey sand.	Nearly flat to gently undulating	Offshore sediment of Lake Agassiz modified by postdepositional processes such as slopewash and groundwater discharge.
10	Coleharbor Group Sand and gravel facies	Laminated; dark gray to black; snail shells present.	Nearly flat	Sediment deposited in lakes whose basins were enclosed by ice.
11	Coleharbor Group Silt and clay facies	Laminated; yellowish-brown to light gray; gypsum crystals abundant.	Nearly flat to gently undulating	Saline offshore sediment of Lake Agassiz; salinity is a result of groundwater discharge from underlying Paleozoic and Pleistocene sediments.
12	Coleharbor Group Silt and clay facies	Mostly silt and very fine sand; yellowish-brown to light-brown; bedding not apparent.	Nearly flat to gently undulating	Near-shore or shallow-water sediment of Lake Agassiz.
13	Coleharbor Group Sand and gravel facies	Mostly sand and gravel; well sorted; distinct cross-bedding; gravel is generally found in linear ridges.	Rolling to undulating	Shoreline, near-shore, and offshore sediments of Lake Agassiz.
14	Coleharbor Group Sand and gravel facies	Mostly medium to coarse sand; moderately to well sorted; grades from shaly sand in the west to clean sand in the east.	Rolling to hummocky	Near-shore and fluvial sediments that make up the Pembina Delta.
15	Coleharbor Group Sand and gravel facies	Fine sand; well sorted.	Rolling to hilly	Wind-blown sediments of sand dunes.
16	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam overlain by thin sand and gravel facies; locally thin veneer of laminated silt and clay; surface boulders abundant locally.	Nearly flat to undulating	Glacial sediment (till) deposited by wave action of Lake Agassiz.
17	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; generally thin; overlying Cretaceous Pierre and Niobrara Formations; locally minor amounts of sand and gravel; bedrock commonly exposed; abundant surface concentrations of boulders.	Hilly to undulating	Eroded glacial sediment (till) overlying lower Pierre and Niobrara Formations.
18	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; minor amounts clay, sand, and gravel; generally yellowish-brown to olive gray; few sloughs and depressions; occasional surface ridges of stratified sand and gravel (eskers) although most are too small to be shown on the map.	Nearly flat to gently undulating; local relief 5 to 15 feet	Glacial sediment (till).
19	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; discontinuous lenses of sand and gravel with depth; surface sand and gravel ridges (eskers) may be covered by thin veneers of silty clay loam; generally yellowish-brown to olive gray; abundant sloughs and depressions.	Gently undulating; local relief 10 to 20 feet	Glacial sediment (till).
20	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; discontinuous lenses of sand and gravel with depth; surface sand and gravel ridges (eskers) abundant although most are too small to be shown on the map; abundant sloughs and depressions generally in excess of 30 per square mile.	Undulating to hummocky; local relief 10 to 35 feet	Glacial sediment (till) deposited from stagnant ice mass.
21	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; minor amounts of sand and gravel; discontinuous lenses of sand and gravel with depth; locally may be overlain by 1 to 2 feet of poorly sorted sand; lag concentrate of boulders very common.	Flat to undulating; local relief less than 5 feet	Glacial sediment (till).
22	Coleharbor Group Sand and gravel facies	Pebbly, silty, clay loam; locally sand and gravel; may be underlain by shaly sand and gravel that is generally less than 5 feet thick.	Flat to gently undulating	Glacial sediment (till) deposited in former glacial meltwater channels.
23	Pierre Formation Upper Member	Shale; gray; hard; siliceous; jointed; iron-stained; thin yellow clay bands may be present; Marine offshore sediment.	Steep slopes	Marine offshore sediment.
24	Pierre Formation Lower Member	Shale; dark gray to black; soft; abundant yellow clay beds; upper portion weathers into a distinctive "popcornlike" surface; slumps easily.	Moderate slopes	Marine offshore sediment.
25	Niobrara Formation	Shale; yellowish-tan to light gray; calcareous; upper yellow member is jointed and fossils are common; lower gray member is speckled and has fine structure.	Steep slopes	Marine offshore sediment.
26	Carlisle Formation	Shale; black; soft; discontinuous limonite stringers; large ellipsoidal concretions common; generally non-calcareous; abundant gypsum crystals; fish scales common; slumps easily.	Moderate to steep slopes	Marine offshore sediment.

0 1 2 3 4 5 6 MILES

STRATIGRAPHIC UNITS

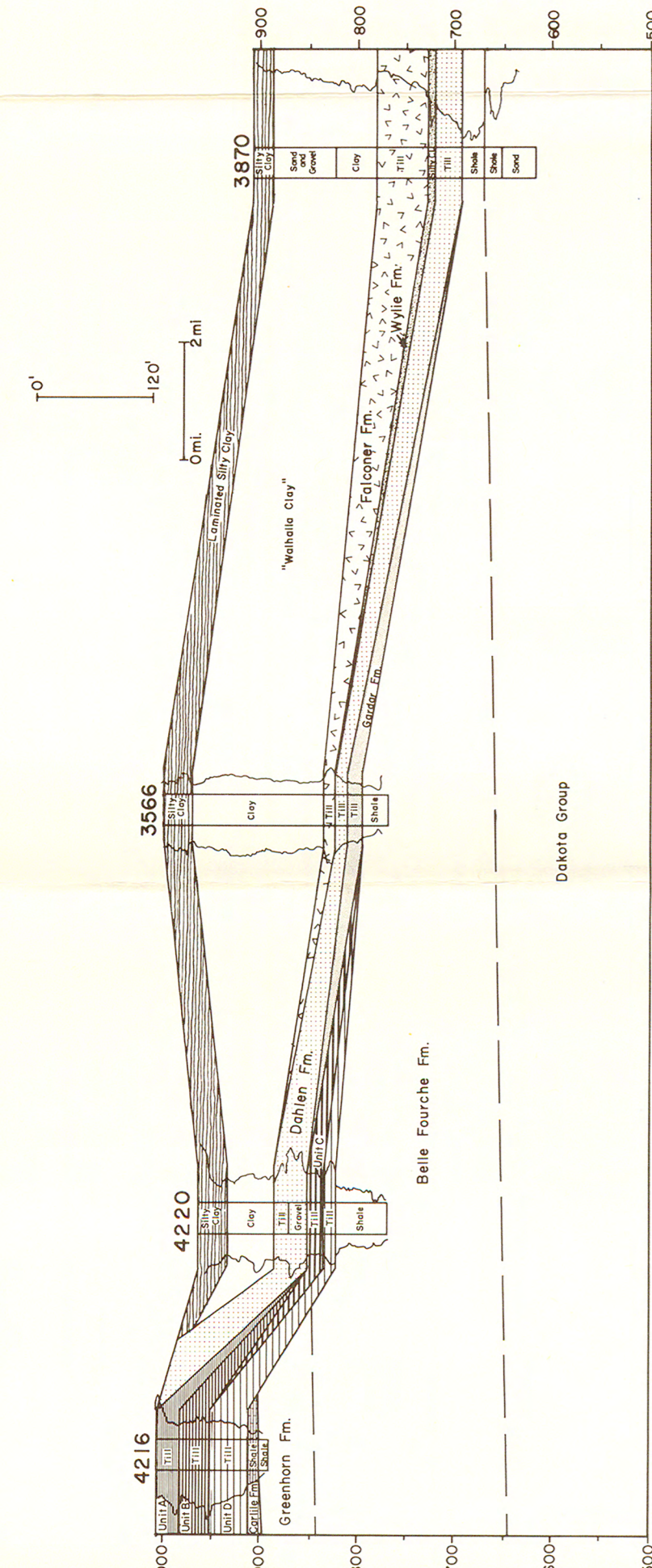
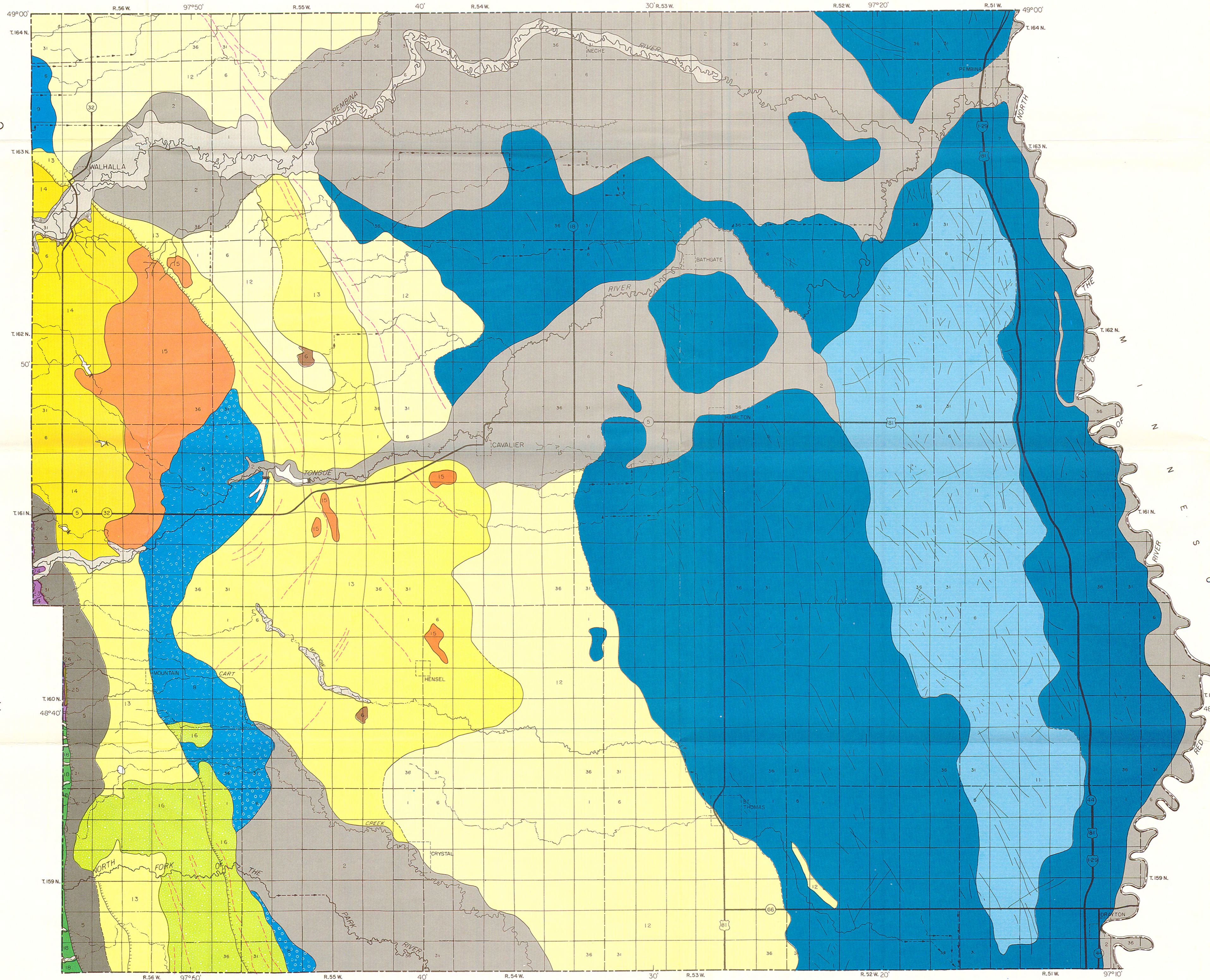
Formation or Group	Description	Map Units
WALSH FORMATION	Clay Facies Clay; dark brown to black; dispersed organic material; bedding planes difficult to recognize; Swamp, slough and pond sediment.	6
	Sand and Silt Facies Silty clay, clayey silt, sandy silt; dark brown-gray black; vague horizontal bedding; wood, shells, and bone fragments present; River sediment deposited along river valleys and floodplains.	1, 2, 3, 4
	Gravel Facies Gravel, sand, silt, clay; poorly sorted to coarsened; lithology and texture variable; commonly found along fringes of esker ridges; Deposited by slopewash, slumping, sliding, and earth creep.	5
COLEHARBOR GROUP	Stony Loam Facies Homogeneous mixture of clay, silt, sand, pebbles, cobbles, and boulders in yellow argillaceous, non-striae, poorly sorted; Glacial sediment.	16, 17, 18, 19, 20, 21, 22
	Sand and Gravel Facies Gravel, gravely sand, sandy silt, sand, sandy silt, vague to distinct bedding; well sorted to poorly sorted; Most deposited by rivers during glacial times; some deposited on beaches and in near-shore environments; some deposited by wind.	12, 13, 14, 15, 16, 22
PIERRE FORMATION	Silt and Clay Facies Clay, silty clay, clayey silt, silt, and some very fine sand; generally laminated but may be nonbedded; Deposited in lakes.	7, 8, 9, 10, 11, 12, 13, 16
	Upper Member Shale; gray; hard; siliceous; jointed; iron-stained; thin yellow clay bands may be present; Marine offshore sediment.	23
NIORRARA FORMATION	Lower Member Shale; gray to black; calcareous in upper part; abundant yellow clay bands throughout; may be several inches to two feet thick; slumps easily; Marine offshore sediment.	17, 24
	Shale, tan in upper part; light gray and speckled in lower part; highly calcareous; blocky structure in upper part; fine structure in lower part; fossiliferous; Marine offshore sediment.	17, 25
CARLISLE FORMATION	Shale; black; non-calcareous; abundant fish scales; slumps easily; Marine offshore sediment.	26

Map units 2, 7, 8, 15, and 16 are not included in Cavalier County

MISCELLANEOUS SYMBOLS

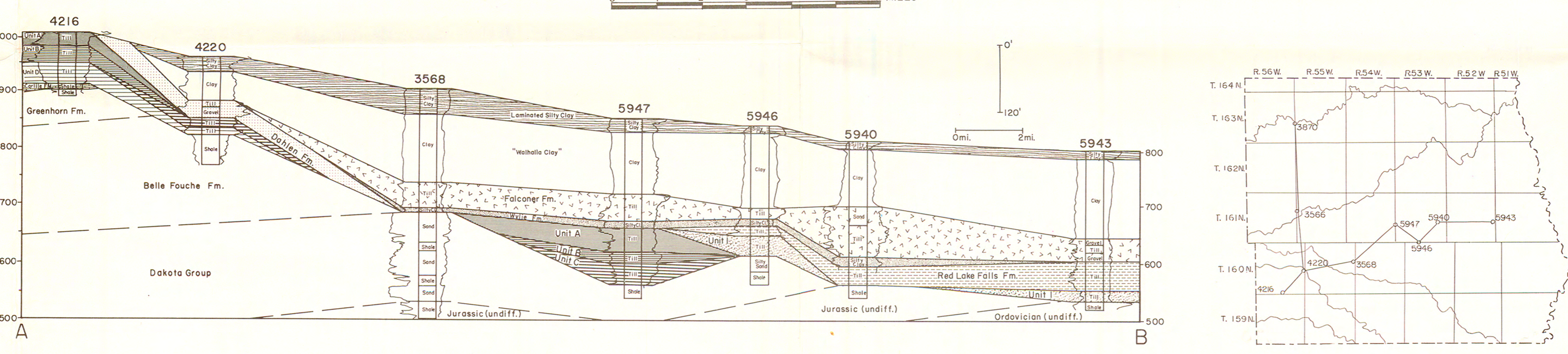
	Eskers		Ice-drag Marks		Cretaceous Pierre Formation Outcrop
	Geologic Contacts		Washboard Moraines		Cretaceous Niobrara Formation Outcrop
	Inferred Geologic Contacts		Drumlins		Cretaceous Carlisle Formation Outcrop
	Ponds and Lakes		Scarp		North Dakota State Road
	Beach Ridges		Compaction Ridge		United States Road

Unit	Lithostratigraphic Unit	Description	Topography	Origin
1	Wash Formation Sand and silt facies	Generally gray to black bedding is horizontal although wavy; organic fragments common.	Flat to gently sloping	Modern river overbank sediment; some river-channel sediment.
2	Wash Formation Sand and silt facies	Light to very dark gray; bedding obscure; thin rapidly away from rivers.	Flat to gently rolling	Modern river overbank sediment.
3	Wash Formation Sand and silt facies	Clay and silt underlain by sand and gravel; cross-bedded; moderately sorted.	Flat to nearly flat	Pre-modern river overbank sediment; some river-channel sediment.
4	Wash Formation Sand and silt facies	Mostly sand and gravel; large.	Steep slopes	Sediments deposited by the Pembina River during a time of very high discharge.
5	Wash Formation Gravel facies	Heterogeneous mixture of sand silt clay and gravel; poorly sorted; generally dense and compact.	Moderate to steep slopes	Slopewash and creep sediment.
6	Wash Formation Clay facies	Vague bedding; dark brown to black.	Flat	Slough and pond sediment.
7	Coleharbor Group Silt and clay facies	Laminated; yellowish-brown to light gray.	Nearly flat to gently undulating	Offshore sediment of Lake Agassiz.
8	Coleharbor Group Silt and clay facies	Laminated to massive yellowish-brown; snail and clam shells present.	Nearly flat to gently undulating	Offshore sediment of a lagoon near Lake Agassiz; the area containing this sediment was cut off from the rest of the lake by longshore bars and spits.
9	Coleharbor Group Silt and clay facies	Laminated; yellowish-brown to light gray locally overlain by thin veneer of clay sand.	Nearly flat to gently undulating	Offshore sediment of Lake Agassiz modified by postdepositional processes such as slopewash and groundwater discharge.
10	Coleharbor Group Silt and clay facies	Laminated; dark gray to black; snail shells present.	Nearly flat	Sediment deposited in lakes whose basins were enclosed by ice.
11	Coleharbor Group Silt and clay facies	Laminated; yellowish-brown to light gray; gypsum crystals abundant.	Nearly flat to gently undulating	Saline offshore sediment of Lake Agassiz; salinity is a result of groundwater discharge from underlying Paleozoic and Pleistocene sediments.
12	Coleharbor Group Silt and clay facies	Mostly silt and very fine sand; yellowish-brown to light-brown; bedding not apparent.	Nearly flat to gently undulating	Near-shore or shallow-water sediment of Lake Agassiz.
13	Coleharbor Group Sand and gravel facies	Mostly sand and gravel; well sorted; distinct cross-bedding; gravel is generally found in linear ridges.	Rolling to undulating	Shoreline, near-shore, and offshore sediments of Lake Agassiz.
14	Coleharbor Group Sand and gravel facies	Mostly medium to coarse sand; moderately to well sorted; grades from shaly sand in the west to clean sand in the east.	Rolling to hummocky	Near-shore and fluvial sediments that make up the Pembina Delta.
15	Coleharbor Group Sand and gravel facies	Fine sand; well sorted.	Rolling to hilly	Wind-blown sediments of sand dunes.
16	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam overlain by thin discontinuous bodies of sand and gravel; locally thin veneer of laminated silt and clay; surface boulders abundant locally.	Nearly flat to undulating	Glacial sediment (till) modified by wave action of Lake Agassiz.
17	Coleharbor Group Stony loam facies Pierre Formation and Niobrara Formation	Pebbly, silty, clay loam; generally thin; overlying Cretaceous Pierre and Niobrara Formations; locally minor amounts of sand and gravel; bedrock commonly exposed; abundant surface concentrations of boulders.	Hilly to undulating	Eroded glacial sediment (till) overlying lower Pierre and Niobrara Formations.
18	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; minor amounts clay, sand, and gravel; generally yellowish-brown to olive gray; few sloughs and depressions; occasional surface ridges of stratified sand and gravel (eskers) although most are too small to be shown on the map.	Nearly flat to gently undulating; local relief 5 to 15 feet	Glacial sediment (till).
19	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; discontinuous lenses of sand and gravel at depth; surface sand and gravel ridges (eskers) may be covered by thin veneers of silty clay loam; generally yellowish-brown to olive gray; abundant sloughs and depressions.	Gently undulating; local relief 10 to 20 feet	Glacial sediment (till).
20	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; discontinuous lenses of sand and gravel with depth; surface sand and gravel ridges (eskers) abundant although most are too small to be shown on the map; abundant sloughs and depressions generally in excess of 30 per square mile.	Undulating to hummocky; local relief 10 to 35 feet	Glacial sediment (till) deposited from stagnant ice mass.
21	Coleharbor Group Stony loam facies	Pebbly, silty, clay loam; minor amounts of sand and gravel; discontinuous lenses of sand and gravel with depth; locally may be overlain by 1 to 2 feet of poorly sorted sand; lag concentrate of boulders very common.	Flat to undulating; local relief less than 5 feet	Glacial sediment (till).
22	Coleharbor Group Stony loam facies Sand and gravel facies	Pebbly, silty, clay loam; locally sand and gravel; may be underlain by shaly sand and gravel that is generally less than 5 feet thick.	Flat to gently undulating	Glacial sediment (till) deposited in former glacial meltwater channels.
23	Pierre Formation Upper Member	Shale; gray, hard, siliceous non-calcareous; thin beds of yellow clay; iron and manganese concretions; fractures easily; weathers into distinct chips and flakes.	Steep slopes	Marine offshore sediment.
24	Pierre Formation Lower Member	Shale; dark gray to black; soft; abundant yellow clay beds; upper portion weathers into a distinctive "popcorn-like" surface; slumps easily.	Moderate slopes	Marine offshore sediment.
25	Niobrara Formation	Shale; yellowish-tan to light gray; calcareous; upper yellow member is jointed and fossils are common; lower gray member is speckled and has fluted structure.	Steep slopes	Marine offshore sediment.
26	Carlile Formation	Shale; black; soft; discontinuous limonite stringers; large ellipsoidal concretions common; generally non-calcareous; abundant gypsum crystals; fish scales common; slumps easily.	Moderate to steep slopes	Marine offshore sediment.



STRATIGRAPHIC UNITS

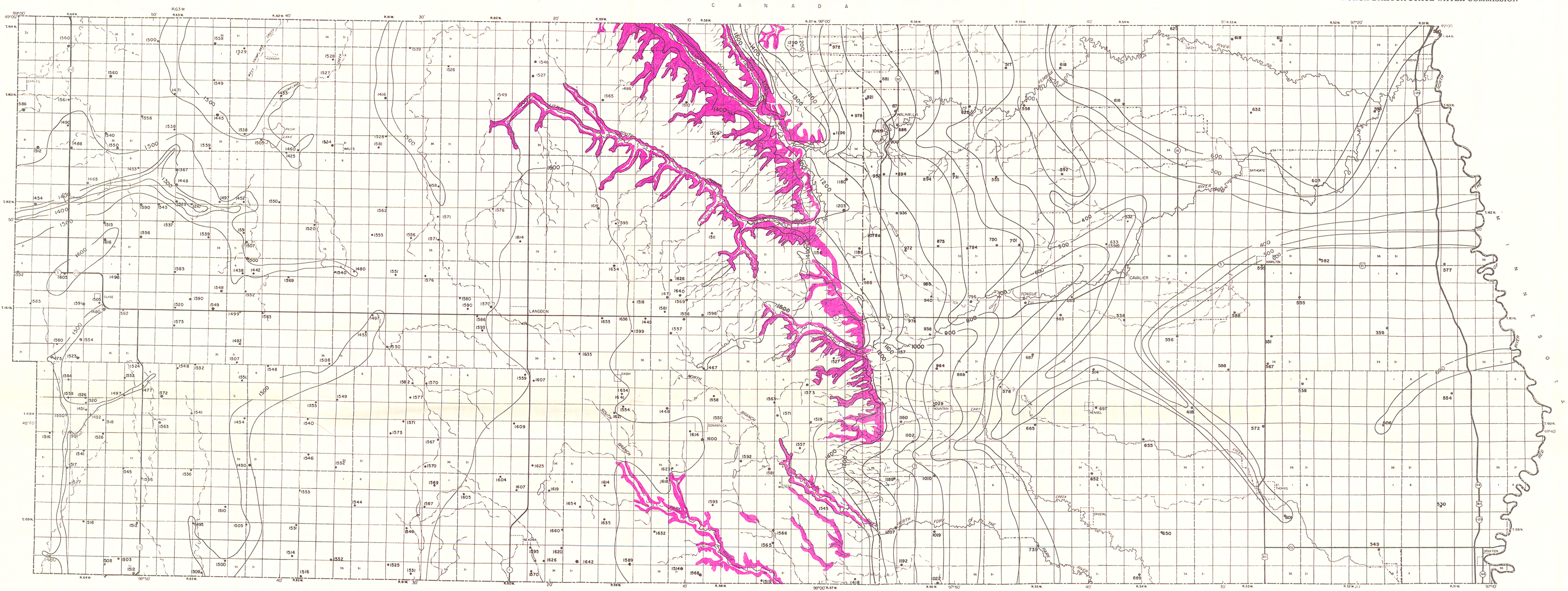
Formation or Group	Unit	Description	Map Units
WASH FORMATION	Clay Facies	Clay; dark brown to black; dispersed organic material; bedding planes difficult to recognize; heavy, tough and pond sediment.	6
	Sand and Silt Facies	Silty clay; clayey silt; sandy silt; dark brown gray black; vague horizontal bedding; wood, shells, and bone fragments present; bare sediment deposited along river valleys and floodplains.	1, 2, 3, 4
	Gravel Facies	Gravel; sand, silt, clay; poorly sorted to coarse; whitish and texture variable; commonly found along front of steep slopes; deposited by slopewash, slumping, sliding, and earth creep.	5
COLEHARBOR GROUP	Stony Loam Facies	Homogeneous mixture of clay, silt, sand, pebbles, cobbles, and boulders in various proportions; non-structured; poorly sorted.	16, 17, 18, 19, 20, 21, 22
	Sand and Gravel Facies	Gravel; gravelly sand; sand; silty sand; sandy silt; upper to distinct bedding; well sorted to poorly sorted; most deposited by trees during glacial times; some deposited on beaches and in near-shore environments; some deposited by wind.	12, 13, 14, 15, 16, 22
	Silt and Clay Facies	Clay; silty clay; clayey silt; silt; and some very fine sand; generally laminated but may be nonbedded; deposited in lakes.	7, 8, 9, 10, 11, 12, 13, 16
PIERRE FORMATION	Upper Member	Shale; gray; hard; siliceous; jointed; non-stained; thin yellow clay bands near base; Marine offshore sediments.	23
	Lower Member	Shale; gray to black; calcareous in upper part; abundant yellow clay bands throughout; may be several inches to two feet thick; slumps easily; Marine offshore sediments.	17, 24
NIORARA FORMATION		Shale; tan in upper part; light gray and speckled in lower part; highly fossiliferous; bedded in upper part; fluted structure in lower part; Marine offshore sediments.	17, 25
CARLILE FORMATION		Shale; black; non-calcareous; abundant fish scales; slumps easily; Marine offshore sediments.	26



MISCELLANEOUS SYMBOLS

			Cretaceous Pierre Formation Outcrop
			Cretaceous Niobrara Formation Outcrop
			Cretaceous Carlile Formation Outcrop
			North Dakota State Road
			United States Road

Map units 1, 10, 17, 19, 20, 21, 22, and 24 are not included in Pembina County



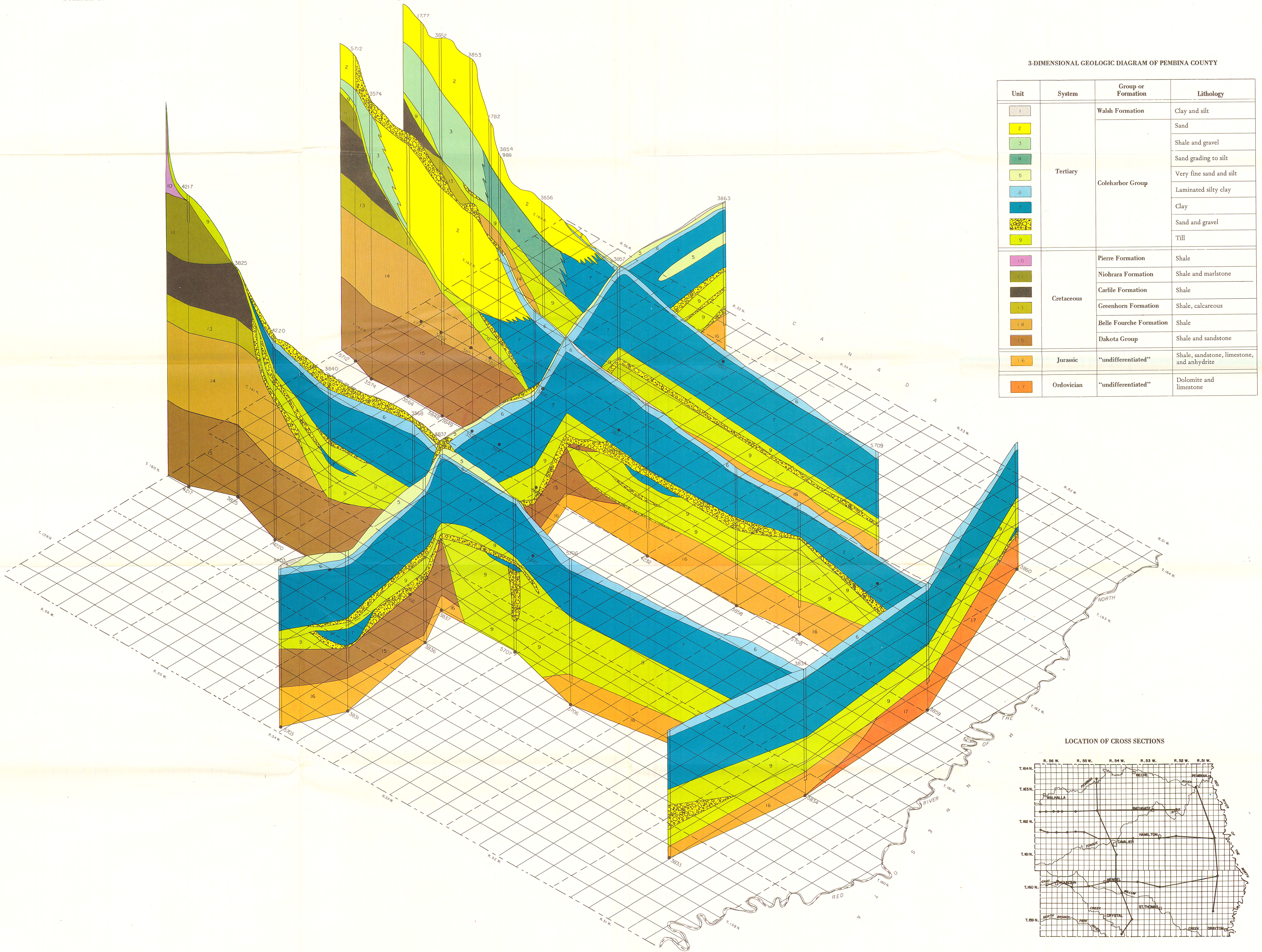
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Contour Interval=100 Feet

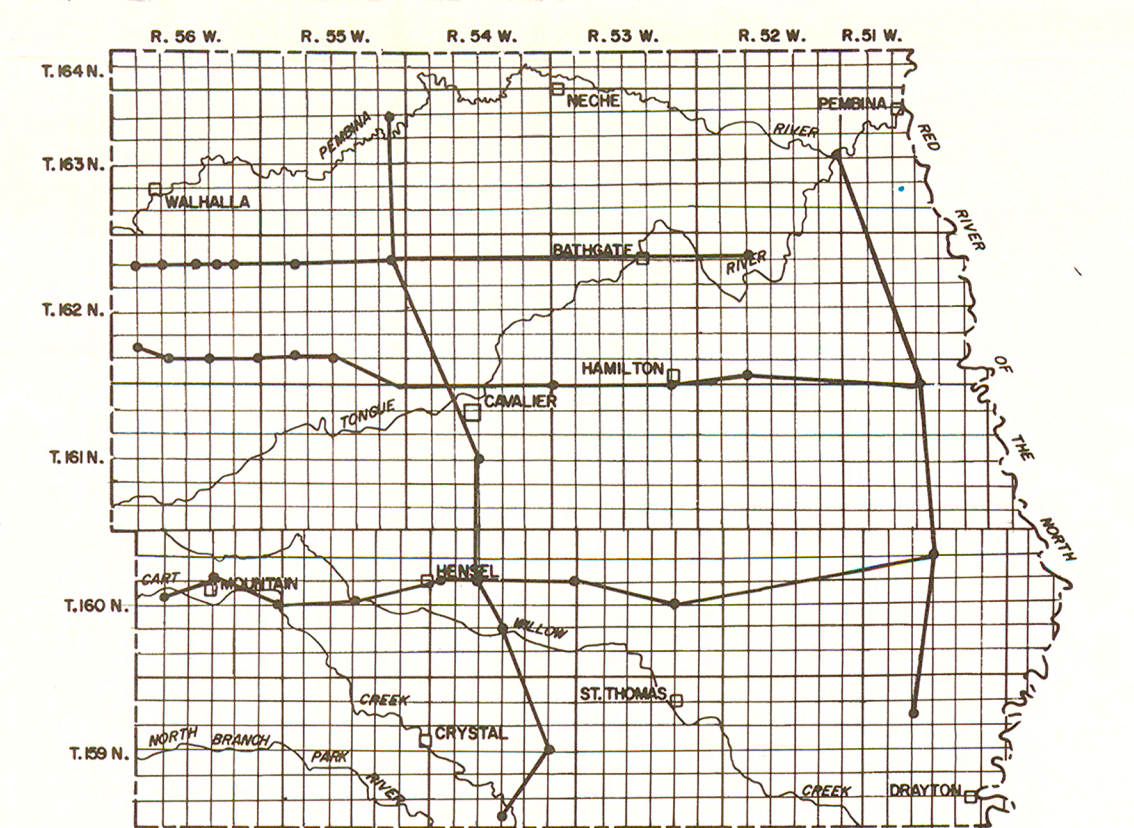
- 1500 Bedrock Elevation
- Shaded areas indicate surface exposure of bedrock.

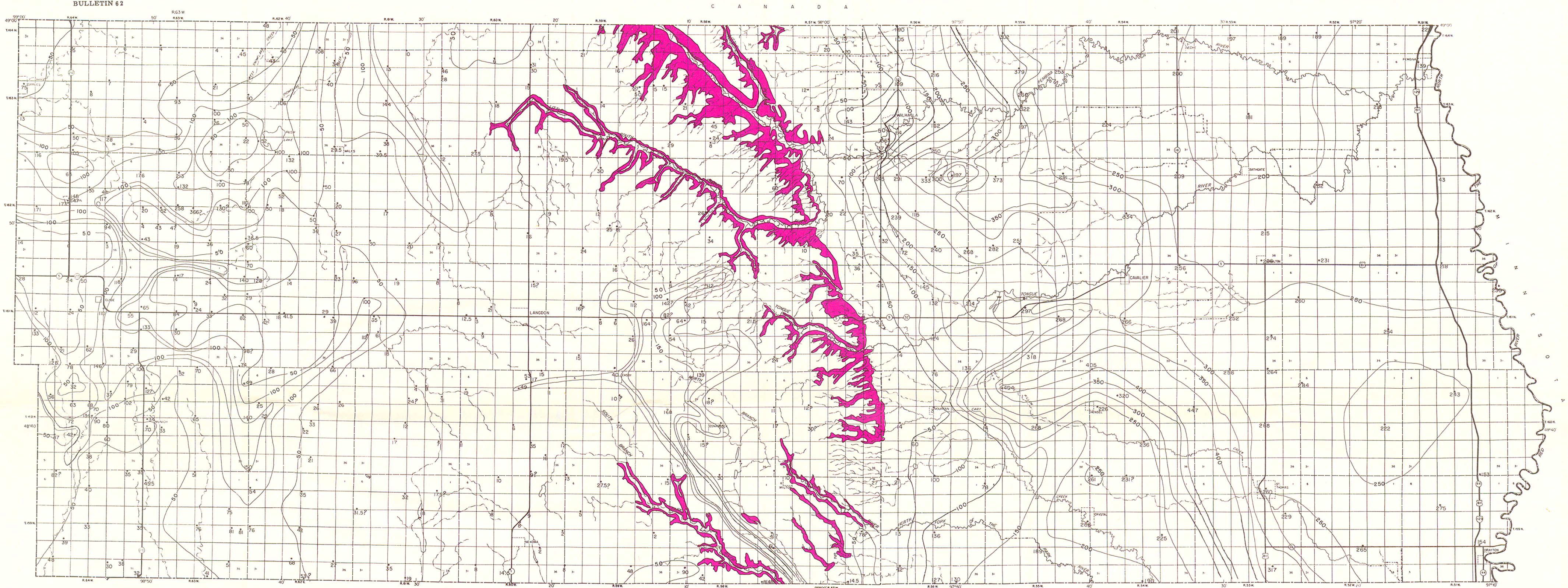
3-DIMENSIONAL GEOLOGIC DIAGRAM OF PEMBINA COUNTY

Unit	System	Group or Formation	Lithology	
1	Tertiary	Walsh Formation	Clay and silt	
2			Sand	
3			Shale and gravel	
4			Sand grading to silt	
5		Coleharbor Group		Very fine sand and silt
6				Laminated silty clay
7				Clay
8				Sand and gravel
9				Till
10	Cretaceous	Pierre Formation	Shale	
11		Niobrara Formation	Shale and marlstone	
12		Carlile Formation	Shale	
13		Greenhorn Formation	Shale, calcareous	
14		Belle Fourche Formation	Shale	
15		Dakota Group	Shale and sandstone	
16	Jurassic	"undifferentiated"	Shale, sandstone, limestone, and anhydrite	
17	Ordovician	"undifferentiated"	Dolomite and limestone	



LOCATION OF CROSS SECTIONS





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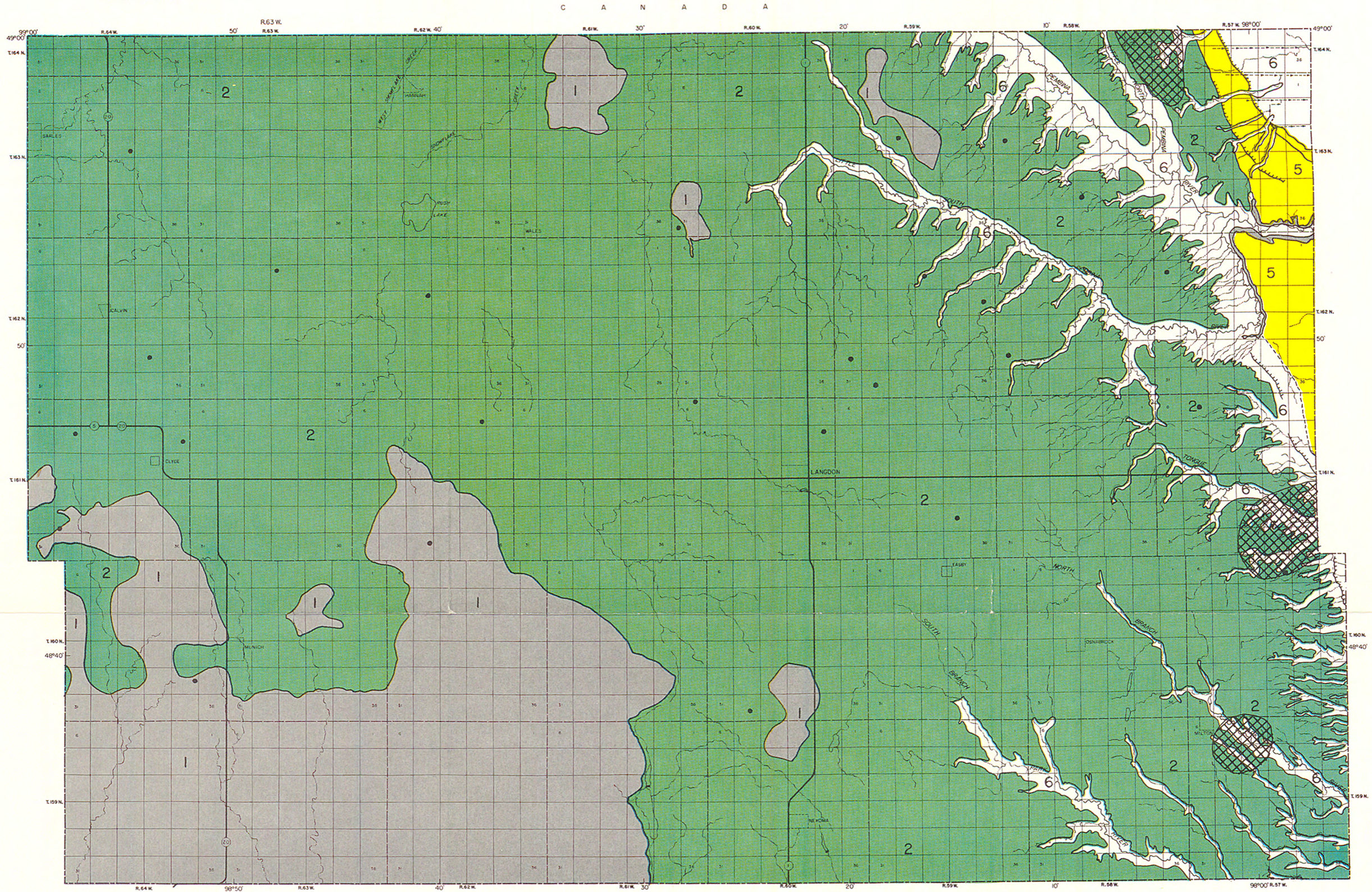
Contour Interval=50 Feet

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235

Thickness of Glacial Drift



Shaded areas indicate surface exposure of bedrock.



Potential Resources Map

Surface Sand and Gravel Resources

- 1 Small isolated deposits of variable quality for individual use. Usually found in sinuous ridges, rounded hills, and along streams.
- 2 Occasional isolated deposits of variable quality for individual use.
- 3 Small quantities of sand and gravel. Quality is variable but generally adequate for uses other than high quality aggregate.
- 4 Extensive sand and gravel deposits. Generally of excellent quality, although shale-pebble content may exceed 30%. Large quantities of sand present.
- 5 Extensive quantities of sand and little or no gravel. Sand generally well sorted and clean. May be of commercial quality.
- 6 No surface sand or gravel supplies.

Map units 3 and 4 are not included in Cavalier County.

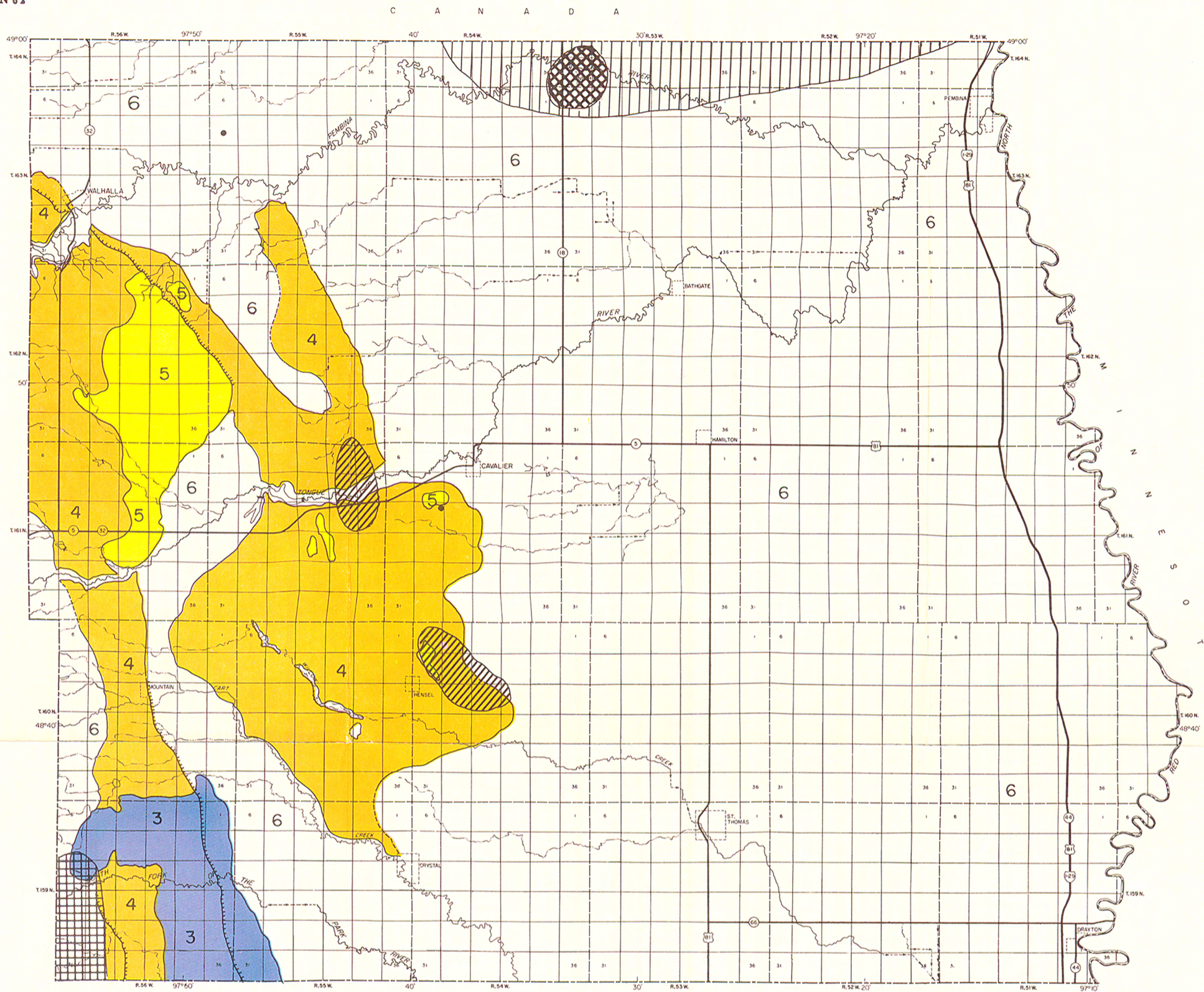
Areas that have been investigated for other resources

Resource	North Dakota Geological Survey Report of Investigations
Clays and shales	RI-17: Manz, O. E., 1954; Investigation of Lightweight Aggregate Possibilities of Some North Dakota Clays and Shales. RI-27: Manz, O. E., 1956; Investigation of Lake Agassiz Clay Deposits.

• Oil Exploration Tests

Miscellaneous Symbols

- Prominent scarp
- Contact, accuracy within .1 mile
- Inferred contact accuracy between .2 and .3 mile



Potential Resources Map

Surface Sand and Gravel Resources

- | | |
|---|---|
| 1 | Small isolated deposits of variable quality for individual use. Usually found in sinuous ridges, rounded hills, and along streams. |
| 2 | Occasional isolated deposits of variable quality for individual use. |
| 3 | Small quantities of sand and gravel. Quality is variable but generally adequate for uses other than high quality aggregate. |
| 4 | Extensive sand and gravel deposits. Generally of excellent quality, although shale pebble content may exceed 30%. Large quantities of sand present. |
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| 6 | No surface sand or gravel supplies. |

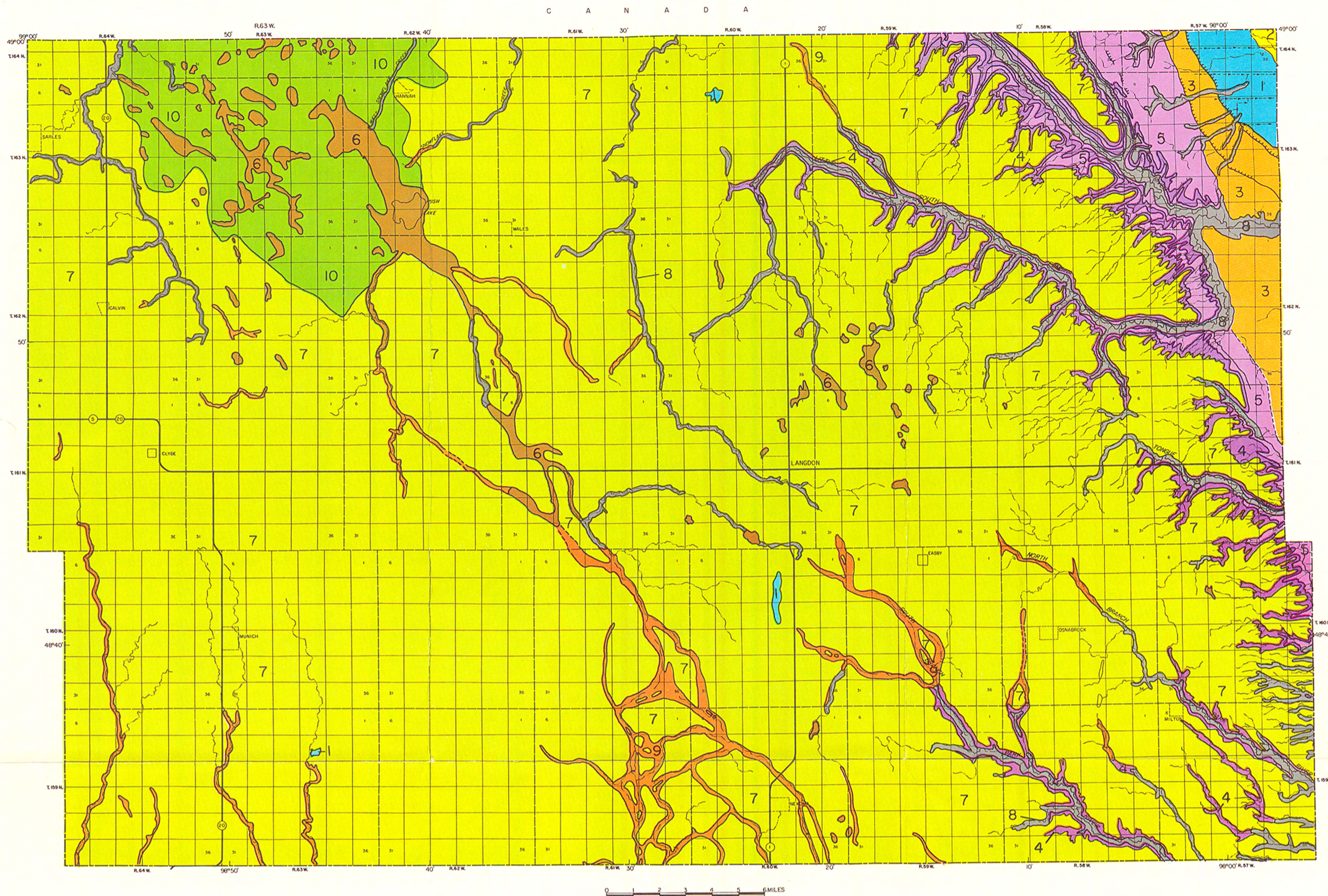
Map units 1 and 2 are not included in Pembina County.

Areas that have been investigated for other resources

Resource	North Dakota Geological Survey Report of Investigations
Clays and shales	RI-17: Manz, O. E., 1954; Investigation of Lightweight Aggregate Possibilities of Some North Dakota Clays and Shales. RI-27: Manz, O. E., 1956; Investigation of Lake Agassiz Clay Deposits.
Cement rock	RI-41: Carlson, C. G., 1964; The Niobrara Formation of Eastern North Dakota: Its Possibilities for use as a Cement Rock. RI-48: Anderson, S. B. and Haraldson, H. C., 1969; Cement Rock Possibilities in Paleozoic Rocks of Eastern North Dakota.
Magnetic Anomalies	RI-49: Moore, W. L. and Karner, F. R., 1969; Magnetic Anomalies in Pembina County, North Dakota.
Gypsum—Dolomite	Open File Report: Results of Gypsum—Dolomite Exploratory Drilling Project, Pembina County, North Dakota.
Oil Exploration Tests	

Miscellaneous Symbols

- Prominent scarp
- Contact, accuracy within .1 mile
- Inferred contact accuracy between .2 and .3 mile

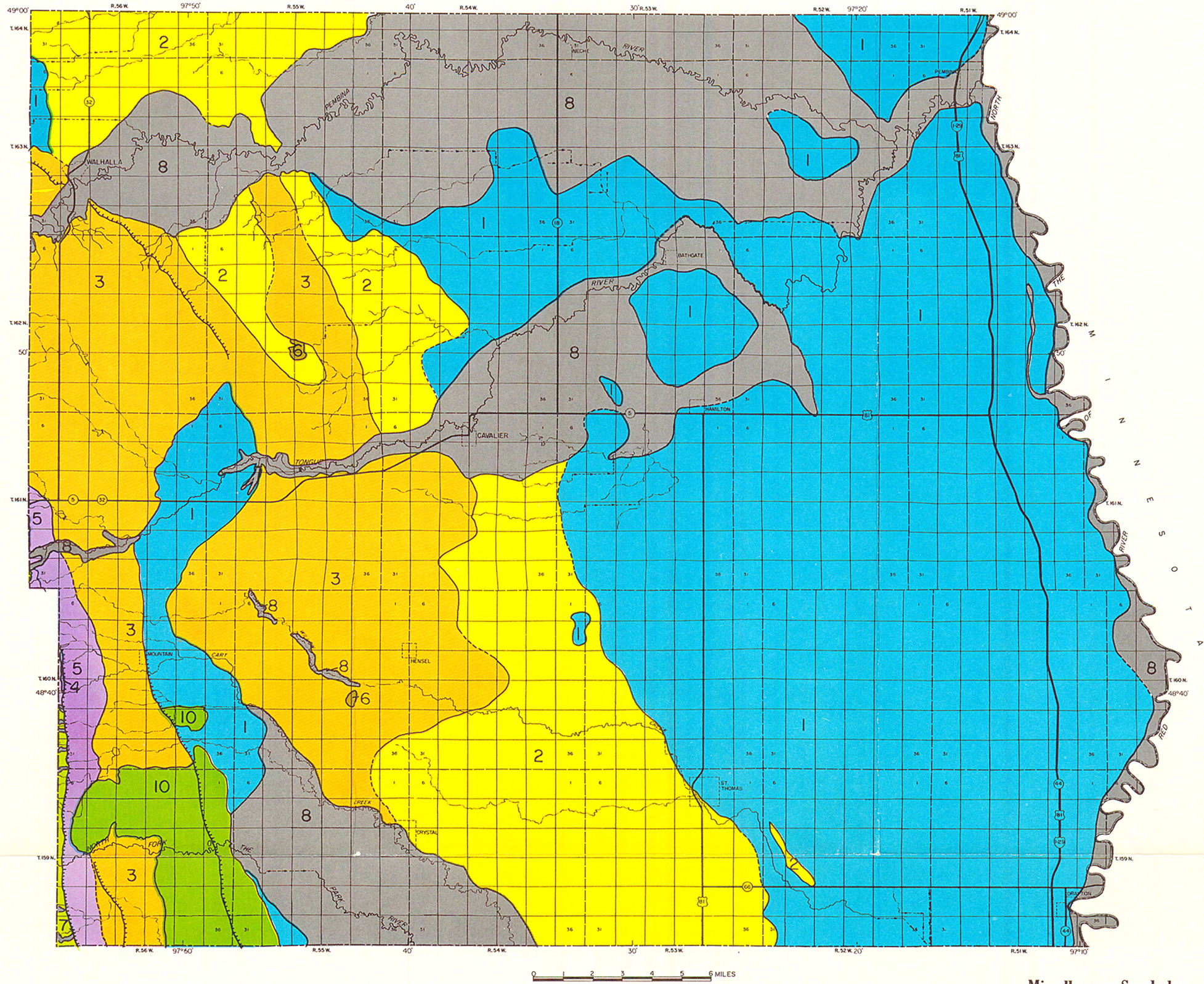


Miscellaneous Symbols

- Prominent scarp
- Contact, accuracy within .1 mile
- Inferred contact accuracy between .2 and .3 mile

General Construction Conditions

Unit	Geology	Water Table	Permeability	Slope Stability in Open Cuts	Compressibility	Bearing Strength	Comments
1	Clay, minor amounts of silt; Lake sediment	High	Low	Low	High	Low	1. Material susceptible to frost heaving. 2. Highly plastic. 3. Poor internal drainage.
2	Silt and very fine sand; Lake sediment	Low	Moderate to high	Low	Moderate	Low to moderate	1. Silt and sand are gradational with clay and that may be encountered during excavation.
3	Sand and gravel; Beach and delta sediments	Low	High	Low to moderate	Low	High	1. Stable on natural slopes but is easily erodable in unprotected cuts.
4	Shale; includes siliceous upper Pierre shale, and calcareous Niobrara Formation	Low	Low to high	High	Low	High	1. Siliceous shale usually highly fractured resulting in high permeabilities. 2. Shale may be subject to slaking when wet. 3. Suitable foundation material for most types of construction.
5	Shale, clay, silt, sand, and gravel; Shale, colluvium and glacial sediments—Till	Low	Low to high	Low	Low to high	Low	1. Shale is very bentonitic, therefore plastic and may slump readily. 2. Sand, silt, and gravel is landslide material at the base of slopes and is subject to continued sliding. 3. Thin glacial sediments over plastic shales and clay, boulders abundant.
6	Clay, highly organic; Slough deposits	High	Low	Low	High	Low	1. Highly plastic and unstable. 2. High water table and internal drainage may cause problems.
7	Sandy clay silt, locally sand and gravel; Glacial Sediments—Till	Generally greater than 10 feet	Low to high	High to moderate	Low to moderate	High	1. Occasional sand and gravel lenses encountered in excavation. 2. Suitable for most types of construction.
8	Clay and silt, sand and gravel; Alluvium	High	Low to moderate	Low to moderate	Moderate to high	Moderate to low	1. Areas underlain by these deposits subject to flooding. 2. Clay and silt facies are moderately plastic and are susceptible to frost heaving. 3. Internal drainage may be a problem.
9	Sandy clay silt and sand and gravel; Glacial Sediments and Alluvium	Low to high	Low to high	Moderate to high	Moderate to low	Moderate to high	1. Occurs in channels that may be filled during spring runoff. 2. Sand and gravel may be encountered at shallow depths. 3. These channels are avenues for groundwater flow.
10	Sandy clay silt, overlain by thin discontinuous bodies of sand and gravel; Surface boulders abundant, Glacial sediments	Generally greater than 10 feet	Low to high	Moderate to high	Moderate to low	Moderate to high	1. Good internal drainage where overlain by sand and gravel. 2. Boulder at or near the surface may cause problems of workability. 3. Generally suitable for most types of construction, although extensive site investigation may be necessary because the variability of the sediment.



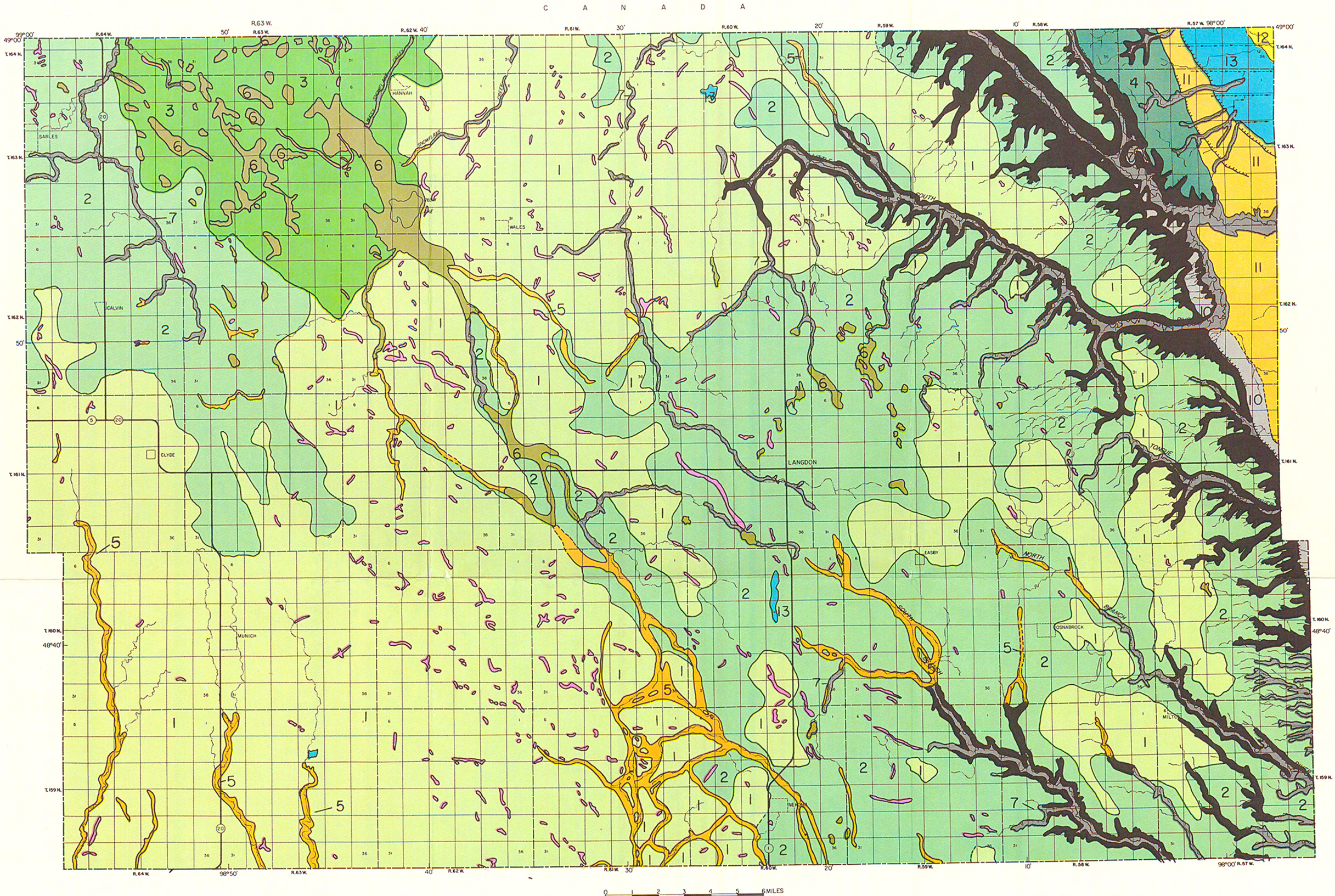
General Construction Conditions

Miscellaneous Symbols

- Prominent scarp
- Contact, accuracy within .1 mile
- Inferred contact accuracy between .2 and .3 mile

Unit	Geology	Water Table	Permeability	Slope Stability in Open Cuts	Compressibility	Bearing Strength	Comments
1	Clay, minor amounts of silt; Lake sediment	High	Low	Low	High	Low	1. Material susceptible to frost heaving. 2. Highly plastic. 3. Poor internal drainage.
2	Silt and very fine sand; Lake sediment	Low	Moderate to high	Low	Moderate	Low to moderate	1. Silt and sand are gradational with clay and that may be encountered during excavation.
3	Sand and gravel; Beach and delta sediments	Low	High	Low to moderate	Low	High	1. Stable on natural slopes but is easily erodable in unprotected cuts.
4	Shale; includes siliceous upper Pierre shale, and calcareous Niobrara Formation	Low	Low to high	High	Low	High	1. Siliceous shale usually highly fractured resulting in high permeabilities. 2. Shale may be subject to slaking when wet. 3. Suitable foundation material for most types of construction.
5	Shale, clay, silt, sand, and gravel; Shale, colluvium and glacial sediments—Till	Low	Low to high	Low	Low to high	Low	1. Shale is very bentonitic, therefore plastic and may slump readily. 2. Sand, silt, and gravel is landslide material at the base of slopes and is subject to continued sliding. 3. Thin glacial sediments over plastic shales and clay, boulders abundant.
6	Clay, highly organic; Slough deposits	High	Low	Low	High	Low	1. Highly plastic and unstable. 2. High water table and internal drainage may cause problems.
7	Sandy clay silt, locally sand and gravel; Glacial Sediments—Till	Generally greater than 10 feet	Low to high	High to moderate	Low to moderate	High	1. Occasional sand and gravel lenses encountered in excavation. 2. Suitable for most types of construction.
8	Clay and silt, sand and gravel; Alluvium	High	Low to moderate	Low to moderate	Moderate to high	Moderate to low	1. Areas underlain by these deposits subject to flooding. 2. Clay and silt facies are moderately plastic and are susceptible to frost heaving. 3. Internal drainage may be a problem.
9	Sandy clay silt and sand and gravel; Glacial Sediments and Alluvium	Low to high	Low to high	Moderate to high	Moderate to low	Moderate to high	1. Occurs in channels that may be filled during spring runoff. 2. Sand and gravel may be encountered at shallow depths. 3. These channels are avenues for groundwater flow.
10	Sandy clay silt, overlain by thin discontinuous bodies of sand and gravel; Surface boulders abundant, Glacial sediments	Generally greater than 10 feet	Low to high	Moderate to high	Moderate to low	Moderate to high	1. Good internal drainage where overlain by sand and gravel. 2. Boulder at or near the surface may cause problems of workability. 3. Generally suitable for most types of construction, although extensive site investigation may be necessary because the variability of the sediment.

Map unit 9 is not included in Pembina County.

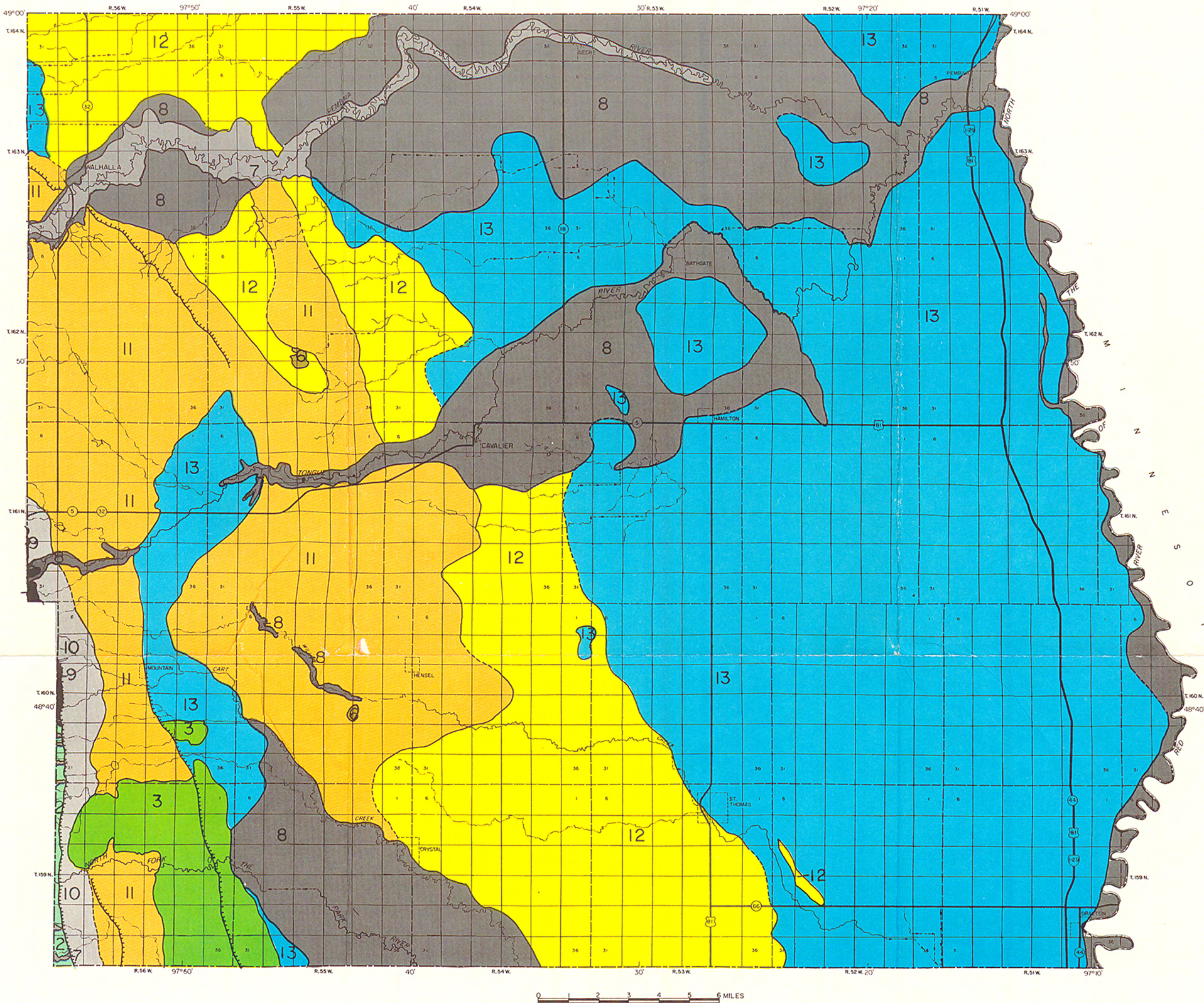


Geologic Map Relating to Sanitary Landfill Suitability

- Miscellaneous Symbols**
- Prominent scarp
 - Contact, accuracy within .1 mile
 - Inferred contact accuracy between .2 and .3 mile
 - Eskers

Unit	Geology	Topography	Degree of Variability	Permeability	Water Table	Ease of Workability	Comments Relating to Use as a Landfill Site
1	Sandy-silty clay; numerous sand and gravel ridges (larger ones marked in red) present; Glacial Sediment—Till	Hummocky	Contains lenses of sand and gravel at various depths. Surface sand and gravel ridges (eskers) may be covered by thin veneers of glacial till.	Generally low, high where sand bodies encountered	Low to high	Moderate to low	1. Lateral variability requires extensive site investigation. 2. Extensive network of potholes and sloughs indicate possible drainage problems.
2	Sandy-clay silt, locally sand and gravel; Glacial Sediment—Till	Undulating	Local lenses of sand and gravel may be encountered with depth. Surface ridges as above not as common.	Generally low except where sand and gravel encountered	Generally greater than 10 feet	Low to moderate	1. Lateral variability requires extensive site investigation. 2. Bedrock generally close to the surface and is highly fractured which may provide avenues for rapid leachate removal.
3	Sandy-clay silt, overlain by thin discontinuous bodies of sand and gravel. Surface boulders very abundant locally; Glacial Sediment—Till	Nearly flat to undulating	Sand is discontinuous both laterally and vertically. Boulder concentrations.	Low except where sand and gravel encountered	Generally greater than 10 feet	Low to high	1. Surface sand and gravel may provide rapid lateral leachate movement. 2. Extensive near surface boulder concentrations may cause problems of workability.
4	Sandy-clay silt, locally sand and gravel. Underlain by Cretaceous Shales; Glacial Sediment—Till	Hummocky	Sand is discontinuous. Till thickness varies and extensive surface concentrations of boulders.	Low except where sand and gravel encountered	Low to high	Low to high	1. Lateral variability requires extensive site investigation. 2. Boulder concentrations may cause a problem of workability. 3. Underlying shales are very clayey and may be difficult to work. 4. Underlying shales may be unstable in steep slopes.
5	Sandy-clay silt and sand and gravel; Glacial Sediment, and river channel deposits	Occurs as shallow to moderately deep linear troughs	High degree of variability ranging from clay to coarse shale gravels.	Low to high	Low to high	Moderate	1. Channel troughs may be filled with surface water during certain times of the year. 2. Groundwater flow may be rapid in these channels. 3. Where water content is high, soil would be difficult to work when frozen. 4. Wet conditions may be common in the bottom of pit.
6	Clay, silty to sandy, rich in organics; slough deposits	Flat	May grade to coarser sediments with depth. Usually very uniform.	Low	High; may be above ground surface	Low	1. High water table will mean constant wet conditions in the bottom of a pit. 2. Soil difficult to work when wet or frozen. 3. Clay is plastic and stability of pit walls will be a problem.
7	Clay, silt, sand and gravel; River alluvium	Flat to gently sloping toward the river	Highly variable both laterally and vertically. Type of sediments are usually reflected by the type of sediments the river flows over.	Low to moderate	High	Low to moderate	1. Lateral permeable zones may move leaching into river system. 2. Working conditions difficult because of high watertable. 3. Flooding susceptibility is high.
8	Clay and silt; River overbank deposits	Flat to gently rolling	Generally uniform and may grade finer away from the river.	Low	High	Low to moderate	1. May be susceptible to flooding during periods of high spring runoff. 2. Working conditions may be difficult when soil is frozen. 3. Locally lateral movement along higher zones of permeability may occur. 4. High water table conditions will mean wet conditions in the bottom of the pit.
	Clay and shale; Cretaceous bedrock (undifferentiated)	Moderate to steep slopes	Bedrock variable from hard, fractured Siliceous shale to bentonitic, soft clay.	Low to high	Low	Low to moderate	1. Highly fractured shale near the surface allows for rapid leachate removal. 2. Usually heavily vegetated. 3. Mostly exposed along the major river valleys where slopes are unstable and slumping and sliding may occur.
10	Clay, sand, silt, and gravel; Colluvium	Moderate to steep slopes	Highly variable.	Low to high	Low	Low to moderate	1. Lateral permeability may result in lateral leachate movement. 2. Material unstable and may slide.
11	Sand and gravel; Beach and Delta deposits	Rolling to hummocky	Sand and gravel generally well sorted and clean. Some areas almost exclusively medium coarse sand.	High	Low	High	1. High permeability. 2. Much of the area is a groundwater recharge area. 3. Suitable cover material not nearby.
12	Silt and very fine sand; Lake sediment	Flat to gently undulating	Uniform, laterally thins eastward.	Moderate to high	Generally greater than 10 feet	Moderate to high	1. Permeability may result in lateral leachate movement. 2. Where thin and underlain by clay, wet conditions may be a problem.
13	Clay and some silt; Lake sediment	Flat to gently undulating	Uniform, clay predominates.	Low	High	Low	1. Soil difficult to work when wet or frozen. 2. Difficult to keep pit dry because of high watertable.

Map unit 8 is not included in Cavalier County.



- Miscellaneous Symbols**
- Prominent scarp
 - Contact, accuracy within .1 mile
 - Inferred contact accuracy between .2 and .3 mile

Geologic Map Relating to Sanitary Landfill Suitability

Unit	Geology	Topography	Degree of Variability	Permeability	Water Table	Ease of Workability	Comments Relating to Use as a Landfill Site
1	Sandy-silty clay; numerous sand and gravel ridges (larger ones marked in red) present; Glacial Sediment—Till	Hummocky	Contains lenses of sand and gravel at various depths. Surface sand and gravel ridges (eskers) may be covered by thin veneers of glacial till.	Generally low, high where sand bodies encountered	Low to high	Moderate to low	1. Lateral variability requires extensive site investigation. 2. Extensive network of potholes and sloughs indicate possible drainage problems.
2	Sandy-clay silt, locally sand and gravel; Glacial Sediment—Till	Undulating	Local lenses of sand and gravel may be encountered with depth. Surface ridges as above not as common.	Generally low except where sand and gravel encountered	Generally greater than 10 feet	Low to moderate	1. Lateral variability requires extensive site investigation. 2. Bedrock generally close to the surface and is highly fractured which may provide avenues for rapid leachate removal.
3	Sandy-clay silt, overlain by thin discontinuous bodies of sand and gravel. Surface boulders very abundant locally; Glacial Sediment—Till	Nearly flat to undulating	Sand is discontinuous both laterally and vertically. Boulder concentrations.	Low except where sand and gravel encountered	Generally greater than 10 feet	Low to high	1. Surface sand and gravel may provide rapid lateral leachate movement. 2. Extensive near surface boulder concentrations may cause problems of workability.
4	Sandy-clay silt, locally sand and gravel. Underlain by Cretaceous Shales; Glacial Sediment—Till	Hummocky	Sand is discontinuous. Till thickness varies and extensive surface concentrations of boulders.	Low except where sand and gravel encountered	Low to high	Low to high	1. Lateral variability requires extensive site investigation. 2. Boulder concentrations may cause a problem of workability. 3. Underlying shales are very clayey and may be difficult to work. 4. Underlying shales may be unstable in steep slopes.
5	Sandy-clay silt and sand and gravel; Glacial Sediment, and river channel deposits	Occurs as shallow to moderately deep linear troughs	High degree of variability ranging from clay to coarse shale gravels.	Low to high	Low to high	Moderate	1. Channel troughs may be filled with surface water during certain times of the year. 2. Groundwater flow may be rapid in these channels. 3. Where water content is high, soil would be difficult to work when frozen. 4. Wet conditions may be common in the bottom of pit.
6	Clay, silty to sandy, rich in organics; slough deposits	Flat	May grade to coarser sediments with depth. Usually very uniform.	Low	High; may be above ground surface	Low	1. High water table will mean constant wet conditions in the bottom of a pit. 2. Soil difficult to work when wet or frozen. 3. Clay is plastic and stability of pit walls will be a problem.
7	Clay, silt, sand and gravel; River alluvium	Flat to gently sloping toward the river	Highly variable both laterally and vertically. Type of sediments are usually reflected by the type of sediments the river flows over.	Low to moderate	High	Low to moderate	1. Lateral permeable zones may move leaching into river system. 2. Working conditions difficult because of high watertable. 3. Flooding susceptibility is high.
8	Clay and silt; River overbank deposits	Flat to gently rolling	Generally uniform and may grade finer away from the river.	Low	High	Low to moderate	1. May be susceptible to flooding during periods of high spring runoff. 2. Working conditions may be difficult when soil is frozen. 3. Locally lateral movement along higher zones of permeability may occur. 4. High water table conditions will mean wet conditions in the bottom of the pit.
	Clay and shale; Cretaceous bedrock (undifferentiated)	Moderate to steep slopes	Bedrock variable from hard, fractured Siliceous shale to bentonitic, soft clay.	Low to high	Low	Low to moderate	1. Highly fractured shale near the surface allows for rapid leachate removal. 2. Usually heavily vegetated. 3. Mostly exposed along the major river valleys where slopes are unstable and slumping and sliding may occur.
10	Clay, sand, silt, and gravel; Colluvium	Moderate to steep slopes	Highly variable.	Low to high	Low	Low to moderate	1. Lateral permeability may result in lateral leachate movement. 2. Material unstable and may slide.
11	Sand and gravel; Beach and Delta deposits	Rolling to hummocky	Sand and gravel generally well sorted and clean. Some areas almost exclusively medium coarse sand.	High	Low	High	1. High permeability. 2. Much of the area is a groundwater recharge area. 3. Suitable cover material not nearby.
12	Silt and very fine sand; Lake sediment	Flat to gently undulating	Uniform, laterally thins eastward.	Moderate to high	Generally greater than 10 feet	Moderate to high	1. Permeability may result in lateral leachate movement. 2. Where thin and underlain by clay, wet conditions may be a problem.
13	Clay and some silt; Lake sediment	Flat to gently undulating	Uniform, clay predominates.	Low	High	Low	1. Soil difficult to work when wet or frozen. 2. Difficult to keep pit dry because of high watertable.

Map units 1, 4, and 5 are not included in Pembina County.