

LATE CENOZOIC STRATIGRAPHY OF THE
LAKE SAKAKAWA BLUFFS NORTH AND WEST
OF RIVERDALE, NORTH DAKOTA

by
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INTRODUCTION

The late Cenozoic stratigraphy of central North Dakota is best exposed along the nearly continuous, 20-meter high (65 feet), vertical bluffs of Lake Sakakawa in Mercer and McLean Counties.

One Paleocene formation, the Sentinel Butte, outcrops in the study area. The six late Cenozoic formations that overlie the Sentinel Butte Formation are, from bottom to top, the Charging Eagle Formation (formally named herein), the Medicine Hill Formation (formally named herein), the Horseshoe Valley Formation (formally named herein), the Snow School Formation (formally named herein), the Coteau Formation (defined and described by Bickley, 1972), and the Oahe Formation (defined and described by Clayton, Moran, and Bickley, in preparation) (fig. 1).

| AGE | UNIT NAME | DOMINANT LITHOLOGY |
|-------------|---|---|
| | Riverdale Member | |
| Holocene | Oahe Formation | Pick City Member Coarse silt |
| | Aggie Brown Member Mallard Island Member | |
| ? | Coteau Formation | Dirty (containing organic material), poorly sorted, gravelly, sandy, silty clay |
| | Snow School Formation | Boulders, pebbly, sandy, silty clay |
| Pleistocene | Horseshoe Valley Formation | Boulders, pebbly, sandy, silty clay |
| | Medicine Hill Formation | Bouldery, pebbly, sandy, silty clay, with silt inclusions |
| ? | Charging Eagle Formation | Silty sand and sandy silt |
| Paleocene | Sentinel Butte Formation | Sandstone and shale |

FIGURE 1. Stratigraphic column and dominant lithology of formations in the area.

CHARGING EAGLE FORMATION

Source of name.

The Charging Eagle Formation is here named for Charging Eagle Bay of Lake Sakakawa in Dunn County, North Dakota.

The type section of the Charging Eagle Formation is in the SW⁴SE⁴N²E⁴ sec. 20, T. 147 N., R. 85 W., in a north-facing bluff of Lake Sakakawa, a few hundred meters north of the only farm buildings in that section (fig. 2). The type section location is indicated by the number 12 on the Mercer County cross section and map.



FIGURE 2. Contact (dashed line) of the Charging Eagle Formation with the overlying Snow School Formation at the type section of the Charging Eagle Formation.

Reference section.

Reference sections are located in the bluffs of Lake Sakakawa in the NE¹SE¹SW⁴ sec. 21, T. 147 N., R. 85 W., and the SE¹SE¹ sec. 15, T. 147 N., R. 85 W., Mercer County, North Dakota.

Description of type section.

The type section, from bottom to top, consists of the following: (1) 1 meter (3.25 feet) covered; (2) 0.7 meter (2.25 feet) of black, calcareous, partly laminated, silty clay, and clayey silt; (3) 1.4 meters (4.5 feet) of gray, calcareous, lignitic, poorly sorted, clayey, silty sand containing kappas and no cross stratification (classification of cross stratification from Allen, 1963); (4) 6.8 meters (22.25 feet) of gray, calcareous, lignitic, gypsum-bearing, very slightly pebbly, silty sand with predominantly large-scale, grouped cross bedding and some small-scale, grouped cross bedding; (5) 0.4 meter (1.25 feet) of gray, calcareous, lignitic, poorly sorted, clayey, silty sand containing kappas and no cross stratification; (6) 0.3 meter (1.75 feet) of yellowish, calcareous, lignitic, poorly sorted, clayey, silty sand containing some small-scale cross bedding; and (7) 4.1 meters (13.5 feet) of grayish-yellow, calcareous, lignitic, poorly sorted, very slightly pebbly, silty sand and sandy silt, both of which contain small-scale cross bedding and planar beds.

Description of the formation.

The Charging Eagle Formation is predominantly silty sand and sandy silt. At the type section, the lower 9 meters (29.5 feet) is composed of silty to 20 percent coarse to fine sand, 60 to 70 percent very fine sand, and 15 to 20 percent silt and clay. The next 4 meters (13 feet) at the type section is composed of 10 sand, and 50 percent very fine sand, and 50 percent silt and clay. Pebbles make up less than 1 percent of the sandy silt and silty sand facies of the formation. In general, there is a decrease in grain size from the bottom to the top. Most of the formation is poorly sorted (Sackreiter, 1973).

Color differences are due primarily to grain size and secondary mineral cementation. The sandier parts are typically whitish gray to grayish white. The siltier parts are grayish yellow to yellowish gray. White carbonate and gypsum concretions are scattered throughout the formation. Reddish iron-oxide stains are especially common in the flat-bedded sand and gravel. At the first reference section, large amounts of lignite disseminated through the sand give an overall black appearance to the sand.

The formation is generally unconsolidated, but some of the siltier parts of the formation are slightly consolidated.

The sand-sized portion of the formation is composed largely of feldspar, gypsum, quartz, lignite, and small amounts of igneous and metamorphic rock types. A handful of pebbles from the sandy part were about 50 percent limestone and dolomite, 25 percent locally derived sandstone and shale, and 25 percent granite and basalt. Strong reaction with dilute hydrochloric acid takes place throughout the formation. Secondary gypsum, locally in the form of large crystals, is scattered throughout the coarser parts of the formation.

Much of the unit has high-angle, small-scale and large-scale, trough-shaped, grouped cross bedding. Some high-angle, large-scale, erosional, irregular, solitary cross bedding is also present. No fossils have been found in the Charging Eagle Formation.

Nature of the contacts.

The contacts of the Charging Eagle Formation with the underlying Sentinel Butte Formation and the overlying Medicine Hill Formation are sharp. The contact of the Charging Eagle Formation with the overlying Snow School Formation (fig. 2) is sharp where the Medicine Hill Formation is missing.

Regional extent and thickness.

The Charging Eagle Formation occurs between the Sentinel Butte Formation and the Medicine Hill Formation or Snow School Formation. The lateral limits of this formation are not known. The Charging Eagle Formation may be equivalent to the upper unit of the Empress Group in southern Saskatchewan (Whitaker and Christiansen, 1972). The Charging Eagle Formation ranges in thickness from a few tens of millimeters to 14 meters (46 feet).

Differentiation from other units.

Stratigraphic position, lithology, and nature of the contacts distinguish the Charging Eagle Formation from other formations. An erosional contact on the Sentinel Butte Formation makes it possible to distinguish between the two formations. Sharply contrasting lithologies (poorly sorted sands and silts of the Charging Eagle Formation and unsorted pebble-loom of the Medicine Hill Formation and the Snow School Formation) make it possible to distinguish the Charging Eagle Formation from other overlying formations.

Origin.

On the basis of cross bedding, sorting, and nature of contacts, the Charging Eagle Formation is interpreted to be fluvial sediment.

Age.

The age is unknown. The presence of dolomite, limestone, basalt, and granite pebbles suggests that the Charging Eagle Formation was deposited some time after the first latest Cenozoic glaciation in the area.

Source.

The sediment was derived from the west (Black Hills and Rocky Mountains areas) and the northeast (Canadian Shield and Manitoba Lowland areas).

MEDICINE HILL FORMATION

Source of name.

The Medicine Hill Formation is here named for Medicine Hill Township, T. 148 N., R. 79 W., in McLean County, North Dakota.

Type section.

The type section of the Medicine Hill Formation (fig. 3) is 425 meters (1400 feet) south of the mouth of Dead Man Coulee Bay in the NW¹SE¹NW⁴ sec. 22, T. 147 N., R. 84 W., McLean County, North Dakota (point 10 on the McLean County cross section).

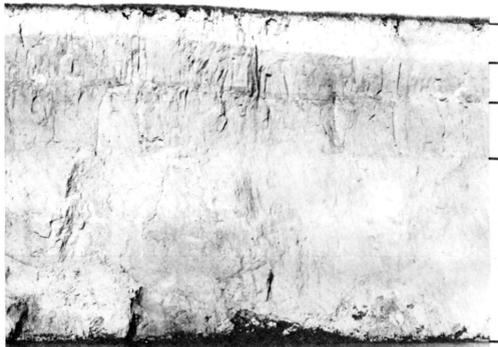


FIGURE 3. Photo of the Medicine Hill Formation (A), Horseshoe Valley Formation (B), Snow School Formation (C), and Oahe Formation (D), in the Bluffs along Lake Sakakawa 425 meters (1400 feet) south of the mouth of Dead Man Coulee Bay.

Reference section.

The reference section of the Medicine Hill Formation (fig. 3) is about 100 meters (325 feet) east of the mouth and along the shore of Dead Man Coulee Bay, in the SE¹NE¹NW⁴ sec. 22, T. 147 N., R. 84 W., McLean County, North Dakota (point 4 on the cross section). This section is the type section of the Coleharbor Group (Bluemle, 1971, Bickley, 1972).

Description of type section.

The type section of the Medicine Hill Formation (measured point 10 on the stratigraphic cross section of McLean County), from bottom to top, consists of the following (lower member of the Medicine Hill Formation is not present here): (1) 12 meters (39.25 feet) of yellow and gray, compact, nonjointed pebble-loom with silt inclusions, chips of lignite, and selenite crystals. The grain size ranges from clay to boulders as much as 1.5 meters (5 feet) in diameter. The coarse sand consists of limestone and dolomite, igneous and metamorphic rock types, shale, iron-stained concretions, and some siliceous rock types. When exposed and dry the surface is very compact, but when it is moist the pebble-loom flakes off in small polygonal plates (upper member of the Medicine Hill Formation); (2) 4 meters (13 feet) of pale olive pebble-loom that is fairly well jointed, compact, and peppered with iron oxide stain and a few lignite fragments. Grain size ranges from clay to boulders. The coarser grains are composed of limestone and dolomite, igneous and metamorphic rock types, shale, iron-stained concretions, and some siliceous rock types (upper member of the Medicine Hill Formation); (3) 1.5 meters (5 feet) of reddish, very sandy, not well consolidated pebble-loom which, in some places, contain alternating beds of silt, sand, and clay (middle member of the Snow School Formation); (4) 0.1 meter (0.25 foot) of fine, white, nonbedded sand (middle member of the Snow School Formation); (5) 4 meters (13 feet) of olive yellow, well jointed, very compact pebble-loom with a few lignite fragments. The grain size ranges from clay to boulders. The coarse sand consists of limestone and dolomite, igneous and metamorphic rock types, shale, iron-stained concretions, and some siliceous rock types (upper member of the Snow School Formation); (6) 1.7 meters (5.5 feet) of yellow to yellow brown silt (Mallard Island Member of the Oahe Formation); (7) 0.2 meter (0.75 foot) of dark brown to red brown clayey silt (Aggie Brown Member of the Oahe Formation); (8) 0.9 meter (3 feet) of gray silt (Pick City Member of the Oahe Formation); (9) 0.1 meter (0.25 foot) of gray silt containing dark organic matter (lower Riverdale Member of the Oahe Formation); (10) 0.1 meter (0.25 foot) of gray silt (middle Riverdale Member of the Oahe Formation); and (11) 0.3 meter (1 foot) of gray silt containing dark organic matter (upper Riverdale Member of the Oahe Formation).

Description of the formation.

The Medicine Hill Formation contains two distinct members, a lower member consisting of silt, sand, and gravel, and an upper member consisting of pebble-loom (silt).

Lower member.—The lower member of the Medicine Hill Formation is 0.5 meter (1.75 feet) to 2.0 meters (6.5 feet) of poorly sorted silt, sand, pebbles, cobbles, and boulders from 0.2 meter (0.75 foot) to 2.0 meters (6.5 feet) in diameter. The bedding within this member is obscure. The lithology of the pebbles, cobbles, and boulders includes quartz, chert, and scoria from western source areas (Black Hills and Rocky Mountains), and limestone, dolomite, granitic rock types, metamorphic rock types, and shale from northern source areas (Canadian Shield and Manitoba Lowland). This lower member is commonly cemented into a conglomerate and is stained reddish brown by iron oxide.

This member is seen in only a few outcrops because most of the lower Medicine Hill Formation is beneath lake level.

Upper member.—The upper member of the Medicine Hill Formation is pebble-loom with grain size ranging from clay to boulders (less than 0.001 millimeter to 3.0 meters [9.75 feet]). The pebble-loom is very compact and nonbedded. Textural analysis shows that the upper member of the Medicine Hill Formation averages 23 percent sand, 47 percent silt, and 30 percent clay. The pebbles (4 millimeters to 128 millimeters) average 45 percent limestone and dolomite, 18 percent light-colored igneous and metamorphic rock types, 9 percent dark-colored igneous and metamorphic rock types, 20 percent shale, 6 percent iron-stained concretions, and 4 percent siliceous rock types. On the basis of a coarse sand count the upper member of the Medicine Hill Formation contains 43 percent shale, 32 percent crystalline, and 12 percent carbonate. See Ulmer (1973) for more details on laboratory data.

The limestone and dolomite are generally only slightly weathered, whereas the granitic fragments are weathered enough to crumble when handled. The shale fragments, which are easily broken, are seldom larger than pebbles. The upper member of the Medicine Hill Formation contains many lignite fragments, selenite crystals, and large inclusions of clayey silt as much as 4 meters in diameter. The bedding within the clayey silt lenses is disrupted in almost all cases.

The color of the upper member of the Medicine Hill is very mottled. Fresh and dry the color ranges from pale yellow (2.5Y 8/4), to light brownish gray (2.5Y 6/2, Munsell Soil Color Charts). On a weathered outcrop the color ranges from olive yellow (2.5Y 6/6), to dark gray (N4).

Nature of the contacts.

The contact of the lower member of the Medicine Hill Formation with the underlying Sentinel Butte Formation is sharp. The contact of the lower member of the Medicine Hill Formation with the upper member of the Medicine Hill Formation is sharp. The contact between the lower and upper members is marked by a thin iron-oxide zone.

The contact of the upper member of the Medicine Hill Formation with the overlying lower member of the Horseshoe Valley Formation is sharp and undulating. Where the lower member of the Horseshoe Valley Formation is missing the contact with the upper member is sharp. The contact with the upper member of the Medicine Hill Formation with the upper member of the Horseshoe Valley Formation is often marked by a zone of iron oxide. The conspicuous jointing of the overlying upper member of the Horseshoe Valley Formation stops at the contact with the Medicine Hill Formation.

Regional extent and thickness.

The Medicine Hill Formation is well exposed in the study area. It ranges in thickness from 1 to 15 meters (3.25 to 49.25 feet) along the bluffs of Lake Sakakawa but may be thicker where its base is beneath lake level.

Differentiation from other units.

The pebble-loom, sand, silt, and gravel of the Medicine Hill Formation is readily differentiated from the sandstone, siltstone, and lignite of the underlying Sentinel Butte Formation. The Medicine Hill Formation differs from the overlying Horseshoe Valley and Snow School Formations in having a mottled more yellow color and numerous clayey silt lenses and in containing numerous selenite crystals. The Medicine Hill Formation is not jointed, whereas the overlying Horseshoe Valley and Snow School Formations have very conspicuous jointing. The Medicine Hill Formation has a higher shale content, lower crystalline content, and lower limestone and dolomite content in the coarse sand fraction than the two overlying formations. The nonmontmorillonite content of the Medicine Hill Formation is lower and the kaolinite content is higher than in the overlying Horseshoe Valley and Snow School Formations.

Age.

The age of the Medicine Hill Formation is unknown. The lower member is probably deposits of a proglacial stream and is slightly older than the upper member. The Medicine Hill Formation is older than late Cenozoic and probably not younger than late Wisconsinan.

HORSESHOE VALLEY FORMATION

Source of name.

The Horseshoe Valley Formation is here named for Horseshoe Valley Township, T. 149 N., R. 80 W., McLean County, North Dakota.

Type section.

The type section of the Horseshoe Valley Formation (fig. 4) is along the north shore of Dead Man Coulee Bay, 100 meters (325 feet) east of its mouth, in the SE¹N¹SE¹NW⁴ sec. 22, T. 147 N., R. 84 W., McLean County, North Dakota (point 4 on the McLean County cross section). This is also the type section of the Coleharbor Group (Bluemle, 1971, Bickley, 1972).

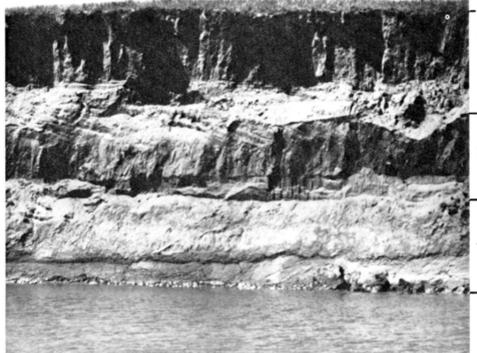


FIGURE 4. Photo of the Medicine Hill Formation (A), Horseshoe Valley Formation (B), and the Snow School Formation (C). Location of photo is 100 meters (325 feet) east of the mouth of Dead Man Coulee Bay.

Reference section.

The reference section of the Horseshoe Valley Formation (fig. 3) is 425 meters (1400 feet) south of the mouth of Dead Man Coulee Bay in the SE¹SE¹NW⁴ sec. 22, T. 147 N., R. 84 W., McLean County, North Dakota (point 10 on the McLean County cross section).

Description of type section.

The type section of the Horseshoe Valley Formation from bottom to top, consists of the following: (1) 2 meters (6.5 feet) of yellow to gray, compact, massive pebble-loom with silt inclusions, weathered lignite fragments, and selenite crystals. The grain size ranges from clay to boulders as much as 1.5 meters (5 feet) in diameter. The coarse sand consists of limestone and dolomite, igneous and metamorphic rock types, shale, iron-stained concretions, and some siliceous rock types (upper member of the Medicine Hill Formation); (2) 1.7 meters (5.5 feet) of cross-bedded and flat-bedded, well sorted, fine, white quartz sand. The bedding planes dip east-northeast. Weathered lignite fragments and rounded gypsum particles are concentrated along some of the bedding planes (lower member of the Medicine Hill Formation); (3) 3.5 meters (11.5 feet) of light brown, columnar jointed, compact pebble-loom that is peppered with grains stained with iron oxide and lignite fragments. The grain size ranges from clay to boulders (0.001 millimeter to 3.0 meters [9.75 feet]). The pebbles consist of limestone and dolomite, igneous and metamorphic rock types, shale, iron-stained concretions, and some siliceous rock types (upper member of the Horseshoe Valley Formation); (4) 0.5 meter (1.75 feet) of cross-bedded and flat-bedded, well sorted, fine, white sand. The bedding planes dip east-northeast. Some weathered lignite fragments and rounded gypsum particles are concentrated on the bedding planes (lower member of the Snow School Formation); and (5) 1 meter (3.25 feet) of a light brown, very compact, columnar jointed pebble-loom. The grain size ranges from clay to boulders (0.001 millimeter to 1.0 meter [3.25 feet]). The pebbles consist of limestone and dolomite, igneous and metamorphic rock types, shale, sandstone, iron-stained concretions, and some siliceous rock types. Small amounts of lignite fragments are found within this unit (upper member of the Snow School Formation).

Description of formation.

The Horseshoe Valley Formation consists of two members. The lower member is conglomerate, stained with iron oxide, and overlain by well sorted, fine, white, cross-bedded, and flat-bedded sand. The upper member is compact, well jointed pebble-loom.

Lower member.—At the base of the lower member of the Horseshoe Valley Formation is 0.5 meter (1.75 feet) to 1.0 meter (3.25 feet) of silt, sand, pebbles, cobbles, and boulders from 0.3 meter (1 foot) to 2.5 meters (8.25 feet) in diameter. These rocks are usually well cemented and stained reddish brown with iron oxide and when thoroughly washed from the modern Lake Sakakawa form a solid conglomerate. The lithology of the pebbles, cobbles, and boulders include limestone and dolomite, granitic and metamorphic rock types, sandstone, shale, iron-stained concretions, and siliceous rock types.

Overlying this conglomerate is 0.2 meter (0.75 foot) to 3.0 meters (9.75 feet) of cross-bedded and flat-bedded, well sorted, fine, white quartz sand. The bedding planes generally dip east-northeast. Weathered lignite fragments and rounded-gypsum particles are concentrated along some of the bedding planes.

Upper member.—The upper member of the Horseshoe Valley Formation is pebble-loom with grain size ranging from clay to boulders (0.001 millimeter to 3.0 meters [9.75 feet]). The pebble-loom is very compact and nonbedded. The textural analysis shows that the upper member of the Horseshoe Valley Formation averages 29 percent sand, 36 percent silt, and 34 percent clay. The lithology of the pebbles (4 millimeters to 128 millimeters) averages 53 percent limestone and dolomite, 18 percent light-colored igneous and metamorphic rock types, 8 percent dark-colored igneous and metamorphic rock types, 13 percent shale, 7 percent iron-stained concretions, and 1 percent siliceous rock types. In the coarse-sand fraction (1.0 millimeter to 2.0 millimeters) the upper member of the Horseshoe Valley Formation contains 24 percent shale, 48 percent crystalline, and 28 percent limestone and dolomite. The pebble-loom contains a few weathered lignite fragments.

The upper member of the Horseshoe Valley Formation is pale yellow (2.5Y 7/4) and has a peppered appearance resulting from staining with iron oxide. The upper member of the Horseshoe Valley Formation has distinct columnar jointing.

Nature of the contacts.

The contact of the lower member of the Horseshoe Valley Formation with the upper member is sharp and undulating. The contact of the upper member of the Horseshoe Valley Formation with the lower member of the Snow School Formation is sharp and undulating. Where the lower member of the Snow School Formation is missing the contact of the upper member of the Horseshoe Valley Formation with the upper member of the Snow School Formation is sharp, and marked by a thin zone of iron oxide.

Regional extent and thickness.

The Horseshoe Valley Formation ranges in thickness from 0.2 meter (0.75 foot) to 6 meters (19.75 feet). The lower member ranges in thickness from 0.5 meter (1.75 feet) to 4 meters (13 feet) and is present only in a few places in the study area (points 4 and 13 on the McLean County cross section) and in Wolf Creek. The upper member ranges in thickness from 0.2 meter (0.75 foot) to 6 meters (19.75 feet). The Horseshoe Valley Formation has been recognized only in McLean County.

Differentiation from other units.

The lower member of the Horseshoe Valley Formation is very difficult to distinguish from either the lower member of the Medicine Hill Formation or the lower member of the Snow School Formation. They can be distinguished only by the presence of the upper members of these formations.

The upper member of the Horseshoe Valley Formation is easily distinguished from the upper member of the underlying Medicine Hill Formation. The Horseshoe Valley Formation has a more uniform yellow as compared with the mottled color of the Medicine Hill Formation. The Horseshoe Valley is well jointed and contains less silt and more montmorillonite than the Medicine Hill Formation.

The upper member of the Horseshoe Valley Formation is hard to distinguish from the upper member of the Snow School Formation. Both formations are jointed. Where the upper members of both units are in disconformable contact in an outcrop, the jointing is continuous from one unit to the next. The upper member of the Horseshoe Valley Formation contains slightly more shale and less montmorillonite than the Snow School Formation. The main difference between the two units is that the Snow School Formation contains a middle sandy reddish member between the upper pebble-loom and lower sand and gravel, which the Horseshoe Valley Formation lacks.

Age.

The age of the Horseshoe Valley Formation is unknown. The Horseshoe Valley Formation is younger than the Medicine Hill Formation and older than the Snow School Formation. The Horseshoe Valley Formation is no older than late Cenozoic and no younger than late Wisconsinan.

SNOW SCHOOL FORMATION

Source of name.

The Snow School Formation is here named for the Snow School in sec. 8, T. 148 N., R. 83 W., McLean County, North Dakota.

Type section.

The type section of the Snow School Formation is in the bluffs along the east shore of Lake Sakakawa, in Dead Man Coulee Bay (fig. 5), SE¹NW¹NW⁴ sec. 22, T. 147 N., R. 84 W., McLean County, North Dakota (point 5 on the McLean County cross section).

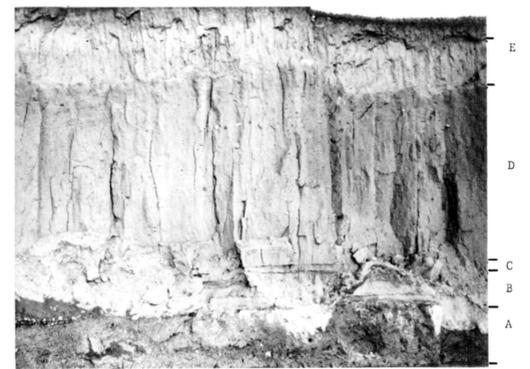


FIGURE 5. Photo of the type section of the Snow School Formation (A).

Reference section.

The reference section of the Snow School Formation is 425 meters (1400 feet) south of the mouth of Dead Man Coulee Bay (fig. 3), in the SE¹SE¹NW⁴ sec. 22, T. 147 N., R. 84 W., McLean County, North Dakota (point 10 on the McLean County cross section).

Description of the type section.

The type section of the Snow School Formation (point 5 on the McLean County cross section), from bottom to top, consists of the following: (1) 1.5 meters (5 feet) of patchy yellow to gray pebble-loom with inclusions of silt, lignite fragments, and selenite crystals (the upper member of the Medicine Hill Formation); (2) 0.5 meter (1.75 feet) of poorly sorted sand, pebbles, cobbles, and boulders of limestone and dolomite, igneous and metamorphic rock types, shale, sandstone, iron-stained concretions, and some siliceous rock types (middle member of the Snow School Formation); (3) 1.5 meters (5 feet) of pale olive (5Y 6/3), vertically jointed pebble-loom, which has a peppered appearance that is caused by iron oxide staining, and a few lignite fragments (lower subdivision of the upper member of the Snow School Formation); (4) 0.5 meter (1.75 feet) of light brown, columnar jointed, compact, vertically jointed, calcium carbonate stained pebble-loom, with lignite fragments (upper subdivision of the upper member of the Snow School Formation); (5) 1.5 meters (5 feet) of pale olive (5Y 6/3), vertically jointed pebble-loom, which has a peppered appearance that is caused by iron oxide staining, and a few lignite fragments (lower subdivision of the upper member of the Snow School Formation); (6) 1.8 meters (6 feet) of pale yellow (5Y 7/3), vertically jointed pebble-loom, with staining (middle subdivision of the upper member of the Snow School Formation); (7) 0.5 meter (1.75 feet) of a light brownish gray (2.5Y 6/2), oolitic-looking, compact, vertically jointed, calcium carbonate stained pebble-loom, with lignite fragments (upper subdivision of the upper member of the Snow School Formation); (8) 0.65 meter (2.25 feet) of olive gray (5Y 5/2), poorly jointed pebble-loom, which appears vaguely laminated on the weathered exposure (uppermost subdivision of the upper member of the Snow School Formation); (9) 1.2 meters (4.0 feet) of yellowish gray silt (Mallard Island Member of the Oahe Formation). Units 5 through 8 make up the upper member of the Snow School Formation. The grain size, rock type of the coarse sand and clay mineralogy are fairly consistent throughout this unit. The subdivisions are made on the basis of a color change which is seen from a distance, and a slight textural difference.

The contacts between these subdivisions are diffuse.

Description of the formation.

The Snow School Formation is subdivided into three members: a lower sand and gravel member, a middle reddish, sandy pebble-loom member, and an upper pale yellow to brown pebble-loom member.

Lower member.—The lower member of the Snow School Formation is poorly sorted silt, sand, pebbles, cobbles, and boulders from 0.2 meter (0.75 foot) to 1.0 meter (3.25 feet) in diameter. These rocks are usually poorly cemented and stained with iron oxide. This part of the lower member ranges in thickness from 0.2 meter (0.75 foot) to 1.5 meters (5 feet). The lithology of the pebbles, cobbles, and boulders includes limestone and dolomite, granitic and metamorphic rock types, sandstone, iron-stained concretions, shale, and a small amount of siliceous rock types.

Overlying the poorly cemented and iron-stained unit is medium to fine, well sorted, flat-bedded and cross-bedded, white quartz sand. The cross bedding dips east-northeast. Weathered lignite fragments and rounded gypsum particles occur on some of the bedding planes. Thin beds of gravel interfinger with, and overlie, the medium to fine sand. The lower member of the Snow School Formation is well exposed along the southwest shore of Wolf Creek Bay.

Middle member.—The middle member of the Snow School Formation contains several kinds of material. Alternating beds of sand, silt, and clay are found in places, but the most abundant material is reddish-brown, sandy pebble-loom. The grain size ranges from clay to boulders (less than 0.001 millimeter to 0.3 meter [1 foot]). The middle member averages 37 percent sand, 53 percent silt, and 12 percent clay. Generally this unit is not bedded, although some thin bedding has been seen in a few locations. In the pebble range, this member contains 64 percent limestone and dolomite, 25 percent granitic and metamorphic rock types, 28 percent shale, 3 percent iron-stained concretions, and 6 percent siliceous rock types.

This reddish-brown middle member is not jointed, but is massive, and is very compact in some places.

Upper member.—The upper member of the Snow School Formation is very compact, columnar jointed pebble-loom. The grain size ranges from clay to boulders (between 0.001 millimeter to 1.0 [3.25 feet]). This member is nonbedded. Textural analysis shows that the upper member of the Snow School Formation contains 28 percent sand, 38 percent silt, and 35 percent clay. The lithology of the pebble fraction averages 56 percent limestone and dolomite, 16 percent granitic and metamorphic rock types, 17 percent shale, 5 percent iron-stained concretions, and 4 percent siliceous rock types. On the basis of one coarse sand count, the upper member of the Snow School Formation contains 19 percent shale, 50 percent igneous and metamorphic rock types, and 26 percent limestone and dolomite. Small amounts of lignite fragments are found within the upper member.

The upper member of the Snow School Formation is pale olive (5Y 6/3) to grayish brown (2.5Y 5/2) where weathered and is much darker where freshly exposed. The upper member has very distinct columnar joints that are vertically continuous from top to bottom in most outcrops. These joints are commonly stained with calcium carbonate that has been leached down from the overlying soil horizon.

The upper member of the Snow School Formation is very hard on weathered, dry outcrops and is compact on fresh exposures.

Nature of contacts.

The contact of the lower member of the Snow School Formation with the middle member is sharp and undulating. The sand of the lower member has a tendency to slump out from under the middle member leaving the middle member slightly overhanging.

The contact of the middle member of the Snow School Formation with the upper member is sharp, but at times is almost gradational. Where the middle member of the Snow School Formation is missing the contact of the lower member and the upper member of the Snow School Formation is sharp. The contact of the upper member of the Snow School Formation and the Oahe Formation is sharp. In places small lenses of gravel lie in undulations on the surface of the upper member of the Snow School Formation.

Regional extent and thickness.

STRATIGRAPHIC CROSS SECTION OF THE LAKE SAKAKAWEA BLUFFS NORTH AND WEST OF RIVERDALE, NORTH DAKOTA

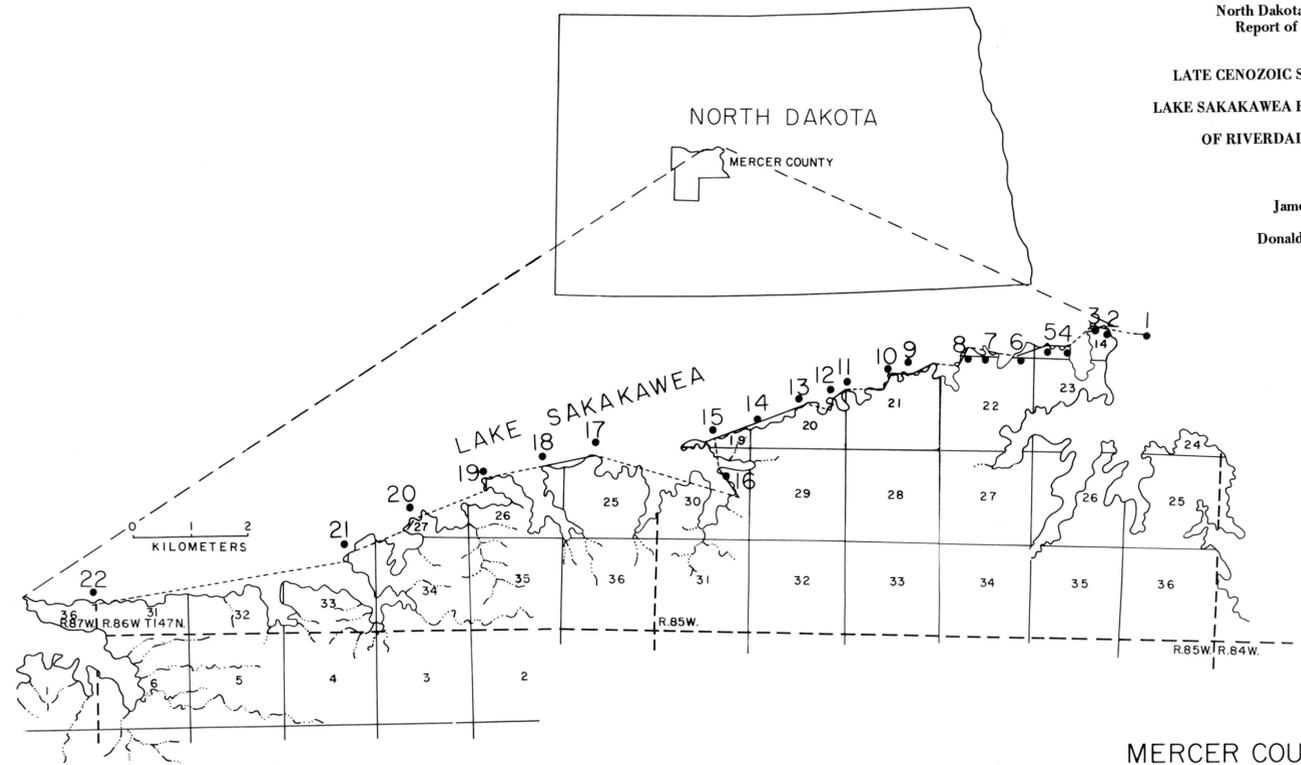
by
James H. Ulmer
and
Donald K. Sackreiter

1973

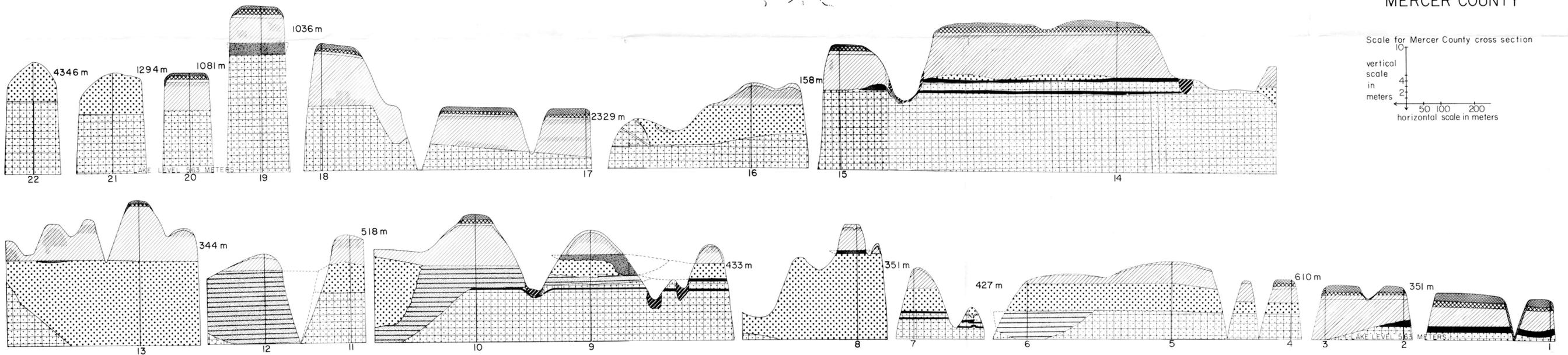
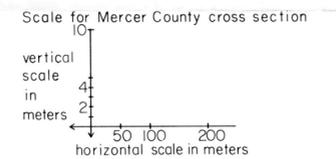
EXPLANATION

- | | | | |
|--|---|--|--|
| | Oahe Formation | | Silt |
| | Upper Member, includes the Pick City Member and the Riverdale Member (the heavy line represents the lowest bed of the Riverdale Member) | | Sand |
| | Lower Member, includes the Mallard Island Member and the Aggie Brown Member | | Sand and Gravel |
| | Coteau Formation | | Gravelly, Sandy, Silty, Clayey Organic-Rich Sediment |
| | Snow School Formation | | Pebble-Loam |
| | Upper Member | | Carbonate Accumulation |
| | Middle Member | | Lignite |
| | Lower Member | | Alternating Beds of Sand, Silt and Clay |
| | Horseshoe Valley Formation | | |
| | Upper Member | | |
| | Lower Member | | |
| | Medicine Hill Formation | | |
| | Upper Member | | |
| | Lower Member | | |
| | Charging Eagle Formation | | |
| | Sentinel Butte Formation | | |

The numbers between the bluffs are distances left out of the cross section.



MERCER COUNTY



McLEAN COUNTY

