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The stratigraphy of the Sperati Point Quadrangle, McKenzie County, North Dakota

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THE STRATIGRAPHY OF THE SPERATI POINT QUADRANGLE, McKENZIE COUNTY, NORTH DAKOTA

by

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This thesis submitted by Michael B. Clark in partial fulfillment of the requirements for the Degree of Master of Arts in the University of North Dakota is hereby approved by the Committee under whom the work has been done.

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ABSTRACT

The Sperati Point Quadrangle is in McKenzie County, northwestern North Dakota, about 30 miles south-southwest of Watford City, North Dakota. The quadrangle is bounded by Ts. 146-148 N., Rs. 100-101 W., and encompasses an area of about 54 square miles. The topography consists of weakly dissected upland plains and, adjacent to the Little Missouri River and tributaries, well dissected, well drained, badland areas characterized by extensive slumping. About 570 feet of the Sentinel Butte Member of the Tongue River Formation of Paleocene age is exposed in the quadrangle. The lower 200 to 250 feet is dominantly grayish, fine to medium-grained graywacke sandstone and siltstone. The remainder of the section is dominantly gray, yellow, and brownish claystone, siltstone, shale and lignite. Characteristic sedimentary structures are "cannonball" and "log-like" siltstone and claystone concretions. A blue bentonitic claystone, the "blue bed", which occurs about 200 feet below the top of the member, and a yellow clayey siltstone, the "yellow bed", 45 to 60 feet above the "blue bed", were correlated in measured sections of the member. Fresh-water pelecypods and gastropods occur throughout the member, but most of these mollusks are found in the "yellow bed". Plant fossils occur in bentonitic claystones, siltstones, lignitic shales and lignites. The Sentinel Butte Member is comprised of alluvial, fluviatile, and lacustrine sediments deposited on a vast alluvial

or coastal plain. Major source areas for these sediments were presumably in the Rocky Mountains to the west and the Black Hills to the south. Conformably overlying the Sentinel Butte Member is about 100 to 160 feet of yellow silty clay and micaceous sandstone of the Golden Valley Formation of Eocene age. Wisconsinan (?) glacial outwash deposits and preglacial Wiota Gravel (?) are also present in the quadrangle.

ACKNOWLEDGMENTS

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Michael B. Clark

INTRODUCTION

Location and Physiography

The Sperati Point Quadrangle is located in McKenzie County, northwestern North Dakota (fig. 1). Regionally, the quadrangle is a part of the Missouri Plateau, glaciated, of the Great Plains province. According to Fenneman (1931, p. 61), "The Missouri Plateau comprises all that part of the Great Plains province which lies north of the High Plains to an undetermined boundary in Canada." The quadrangle is bounded by Ts. 146-148 N., Rs. 100-101 W., and includes an area of approximately 54 square miles. About 20 square miles of the extreme western portion of the North Unit of Theodore Roosevelt National Memorial Park are covered by the northeast portion of the quadrangle. The area of study is approximately 30 miles south-southwest of Watford City, North Dakota.

The topography consists of poorly dissected upland plains and, adjacent to the Little Missouri River and its tributaries, well dissected, well drained, badland areas

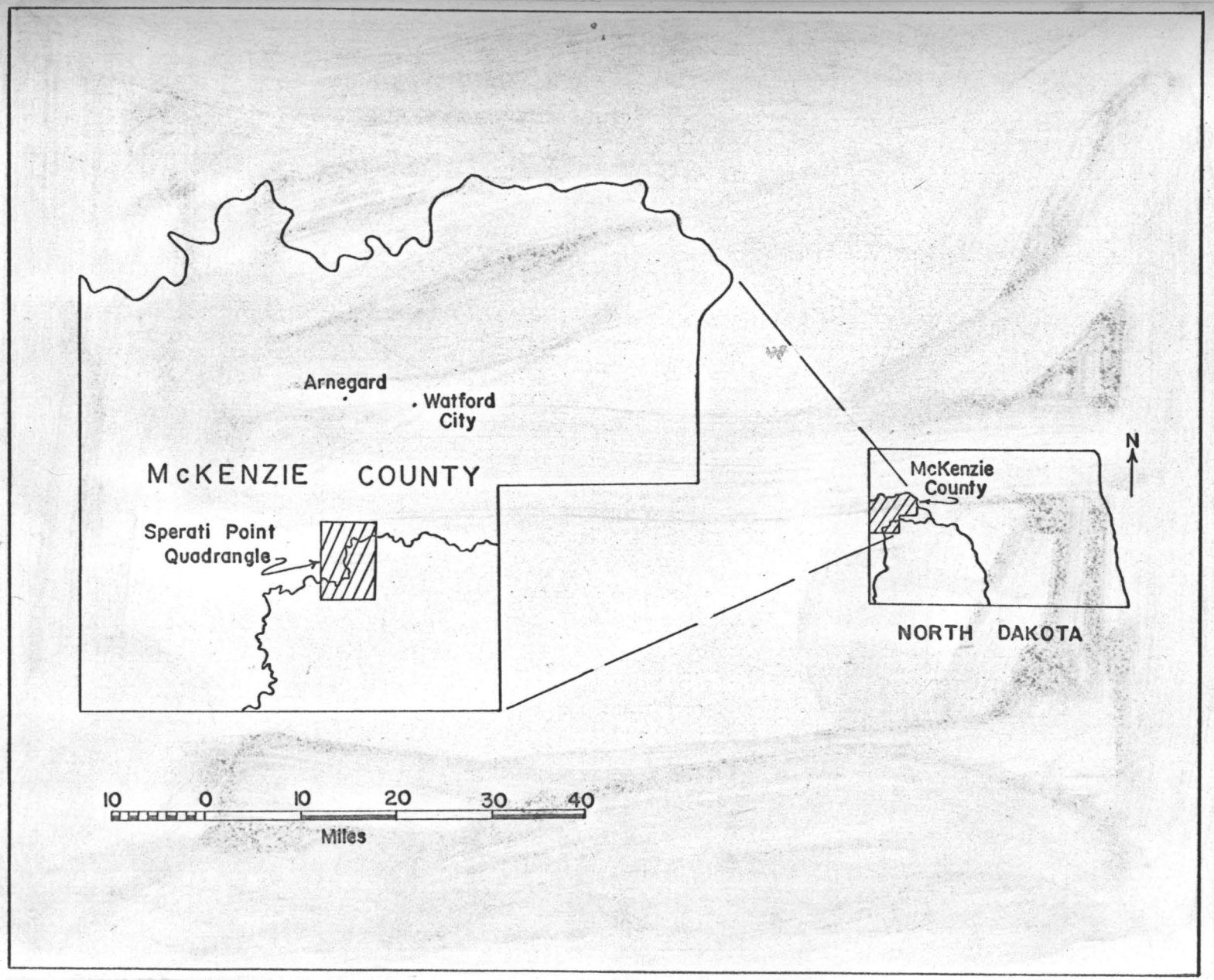

Figure 1. Index map showing location of the Sperati Point Quadrangle, McKenzie County, northwestern North Dakota.

characterized by extensive slumping (fig. 2). Slump areas are typically rough, irregular, and accentuated by the presence of heavy vegetation. Fluted weathering produced by surficial runoff gives the badlands an interesting sculptured appearance (fig. 3). Maximum relief is about 650 feet.

The Little Missouri River and its tributaries are integrated into a dendritic drainage system. The drainage is best developed in the badland areas and rather poorly developed on the upland plains.

The climate is typical of a prairie grassland with an average annual precipitation of 18 inches from 1963 through 1965 (U.S. Weather Bur., Annual Summary, 1963 to 1965). Rainfall is heaviest from April through early July, generally as short rain storms or heavy cloudbursts. Runoff is severe and the tributaries of the Little Missouri River are frequently swollen by these rains. The average temperature is 43 degrees Fahrenheit from 1963 through 1965 (U.S. Weather Bur., Annual Summary, 1963 to 1965). The intensity of the heat is magnified by radiation and reflection from the sedimentary rocks in the badland areas.

The upland plains are extensively covered by prairie grasses; in the immediate proximity of the Little Missouri River, the badland areas support thick stands of juniper, aspen and elm. Wildlife, in addition to the western prairie rattlesnake, includes squirrel, rabbit, fox, coyote, bobcat, lynx, deer, and buffalo. These animals are protected

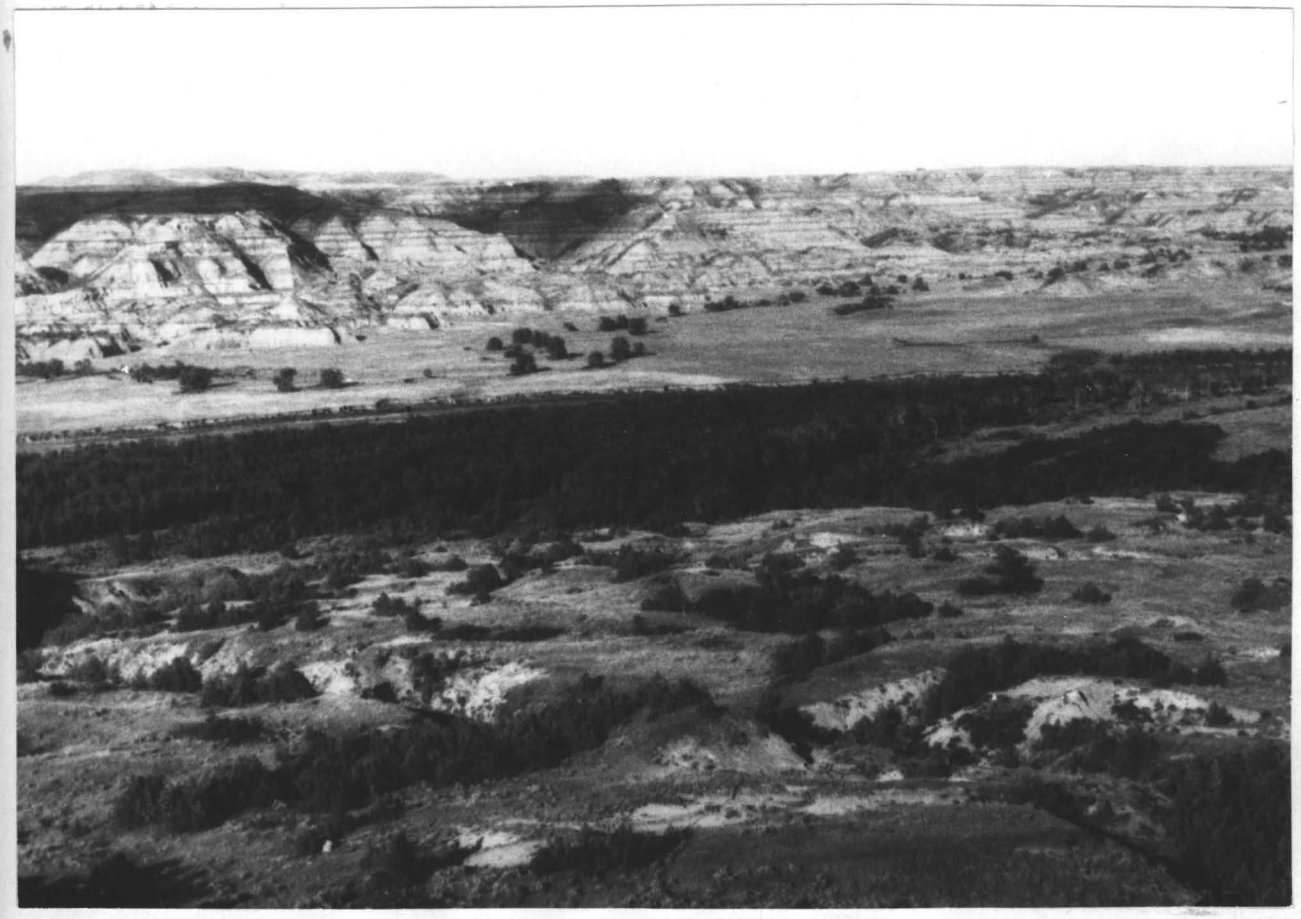

Figure 2. View to the north-northeast from the top of the Kellogg Ranch Section (NW¼ sec. 20, R. 100 W., T. 147 N.) showing the typical badland topography of the area. Note the slumped area in the foreground.

Figure 3. Fluted weathering produced by surficial runoff (near Sperati'Point South Section, SE¼ sec. 6, R. 100 W., T. 147 N.).

in Theodore Roosevelt National Memorial Park.

Farming and ranching are the major occupations. The North Unit of Theodore Roosevelt National Memorial Park is a noted attraction for the visitor traveling through the area. Watford City, with a population of about 2,000, is located about 18 miles north of the east entrance of the North Unit of the park on U.S. Highway 85.

Objectives

The objectives of this study are as follows: to make a geologic map and a fence diagram showing the distribution of the lithologic units present in the Sperati Point Quadrangle, to describe the stratigraphy of the Sentinel Butte Member of the Tongue River Formation of Paleocene age and other lithologic units present in the quadrangle, to determine if it is possible to correlate units of the Sentinel Butte Member in the quadrangle, and to discuss the depositional environments that may have prevailed during deposition of the sediments comprising the Sentinel Butte Member.

Field Work and Methods

The field work was done during June, July, and August, 1965.

Stratigraphic sections were chosen on the basis of maximum exposure and isolation from slumped areas (fig. 4). Sections were measured with a hand level mounted on a 5 foot staff.

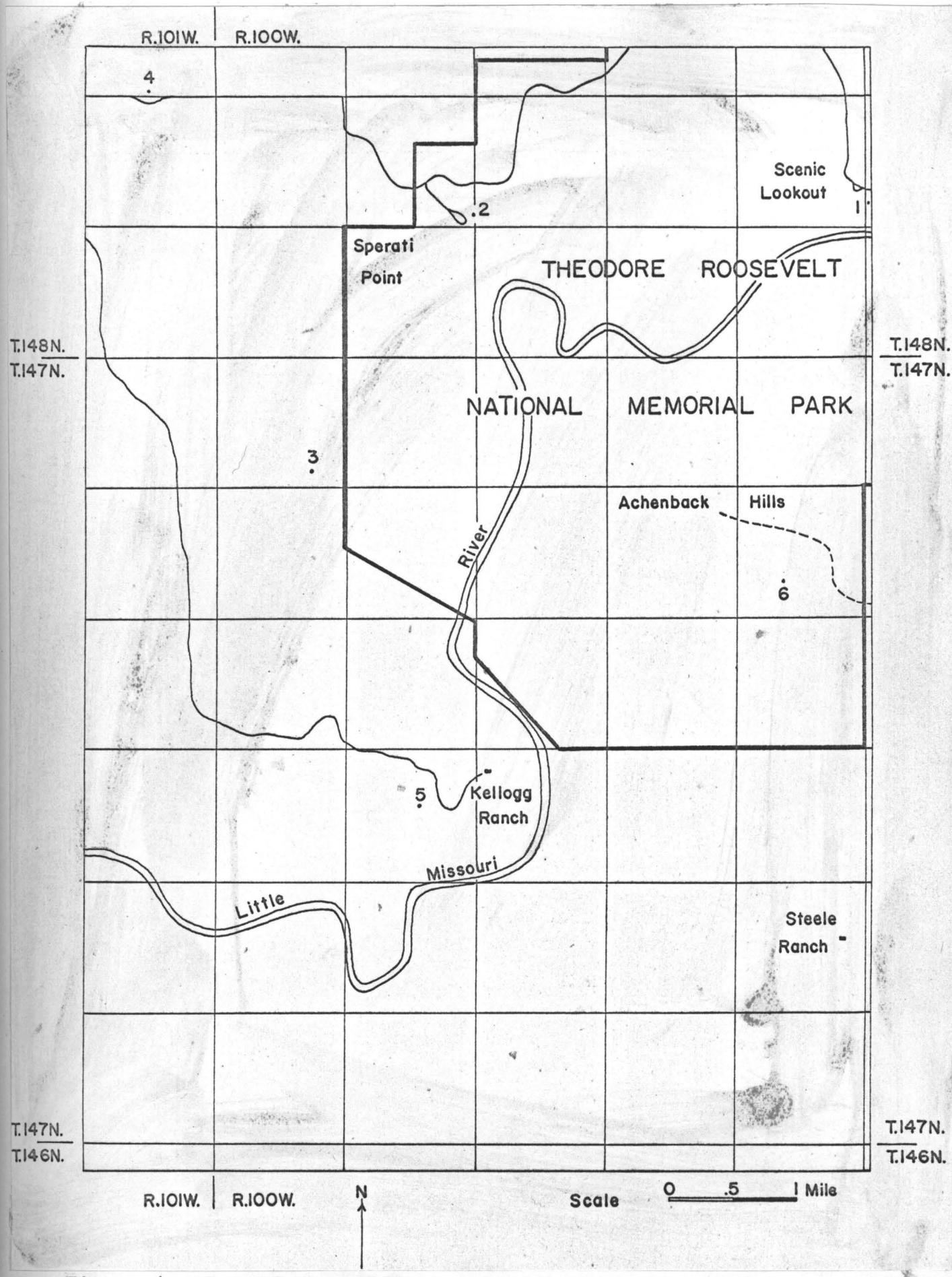

Figure 4. Location map of stratigraphic sections in the Sperati Point Quadrangle.

The following is a list of measured sections in the Sperati Point Quadrangle:

Measured Section No.	Section Name and Location
1	Scenic Lookout Section (SE¼ sec. 26, R. 100 W., T. 148 N.)
2	Sperati Point North Section (SW¼ sec. 28, SE¼ sec. 29, R. 100 W., T. 148 N.)
3	Sperati Point South Section (SE¼ sec. 6, NE¼ sec. 7, R. 100 W., T. 147 N.)
4	Sperati Point West Section (SW¼ sec. 24, NW¼ sec. 25, R. 101 W., T. 148 N.)
5	Kellogg Ranch Section (NW¼ sec. 20, R. 100 W., T. 147 N.)
6	Achenback Hills Section (SE¼ sec. 11, R. 100 W., T. 147 N.)

Samples from each section were taken from each different lithology and at 5 foot intervals if a lithologic unit was thicker than 10 feet.

The classification of sedimentary rocks is that of Pettijohn (1957). Color descriptions are from the Rock-Color Chart distributed by the Geological Society of America.

The samples were fractionated by using the Frantz

Isodynamic Magnetic Separator following procedures of H. H. Hess (Princeton University). The heavy minerals so obtained were identified by binocular examination.

Particle size and X-ray diffraction analyses were made using procedures outlined by Dr. Frank R. Karner (personal communication, 1966).

The Sperati Point Quadrangle topographic map (U.S.G.S. topographic series) was enlarged from a scale of 1:24,000 to 1:12,000 and used as a base for a geologic map of the quadrangle. Contacts were determined in the field and further supplemented by data taken from aerial photographs (Fairchild Aerial Survey, 1958) of the quadrangle.

The geologic map shows the distribution of the Sentinel Butte Member (undifferentiated), two distinctive "key" beds of the Sentinel Butte Member, the "blue bed" and the "yellow bed", the Golden Valley Formation of Eocene age, Wisconsinan (?) glacial outwash deposits, preglacial Wiota Gravel (?), alluvium and slumped areas in the quadrangle (Plate I).

STRATIGRAPHY

General Introduction

Within the Sperati Point Quadrangle are found rocks of Paleocene and Eocene age. The Paleocene is represented by the Sentinel Butte Member of the Tongue River Formation and the Eocene by the Golden Valley Formation. Also present in the quadrangle are Wisconsinan (?) glacial outwash deposits and preglacial Wiota Gravel (?).

Tongue River Formation

Taff (1909) applied the name Tongue River to a sequence of lignite-bearing beds that crop out along the Tongue River in the Sheridan Coal Field, Wyoming. Thom and Dobbin (1924) referred to the Tongue River in western North Dakota as a member of the Fort Union Formation. Dorf (1940) reclassified the member of Thom and Dobbin as a formation of the Fort Union Group, and this nomenclature has been retained by the North Dakota Geological Survey. The upper portion of the Tongue River Formation has been referred to as the Sentinel Butte Member (see section dealing with the Sentinel Butte Member for further discussion).

The formation is found in northeastern Wyoming, much of eastern Montana, throughout the western half of North Dakota, western South Dakota, northwestern Nebraska, and southern Canada. Only the Sentinel Butte Member of this formation occurs in the Sperati Point Quadrangle.

Tongue River strata in North Dakota are mainly fine-

grained sandstone, siltstone, shale, claystone, bentonitic claystone, and lignite beds. The distribution varies considerably both laterally and vertically.

B. Hanson (1955) reported a thickness of about 1600 feet for the formation (including the Sentinel Butte Member) in Golden Valley and Billings Counties, western North Dakota. Thom and Dobbin (1924) reported a thickness of about 1100 to 1350 feet (including the Sentinel Butte Member) in the Williston-Minot area of North Dakota.

The strata in southwestern North Dakota are essentially horizontal with a regional dip to the northeast of only a few feet per mile (Bergstrom, 1956). However, generally north-south trending anticlines and synclines with closures ranging from 30 to 60 feet reflect the possibility of faulting in the Precambrian basement rocks followed by subsequent disruption of the overlying sediments. Structures due to the possibility of faulting in Precambrian basement rocks are pronounced in the Williston Basin area (Meldahl, 1956). These small structures may also reflect larger subsurface structures developed as a consequence of unequal deposition on a slowly subsiding Paleocene coastal plain (Meldahl, 1956).

A fresh-water fauna comprised mainly of gastropods and pelecypods has been described by Meek and Hayden (1862), Meek (1876), Russell (1931 and 1934), Tozer (1956), Yen (1946, 1947, and 1948), and others. The bones of small mammals, fish, turtles, and the aquatic reptile, Champsosaurus

laramiensis, have also been identified (Leonard, 1908).

Lignite beds, sandstone beds (Hennen, 1943) and color changes have been used in correlating measured sections of the formation.

Tongue River strata consist of alluvial, fluviatile, and lacustrine sediments and sedimentary rocks deposited on a vast alluvial or coastal plain that originated as a consequence of the erosion of the Rocky Mountains to the west and the Black Hills to the south. Volcanic ash in Tongue River sediments and sedimentary rocks is an indication of volcanic activity in the Rocky Mountains.

Sentinel Butte Member

Name and Definition

The Fort Union Group in North Dakota was regarded by Leonard (1908) as a formation. He divided the Fort Union into a lower, middle, and upper member. The middle member was referred to as the Tongue River Member of the Fort Union Formation by Thom and Dobbin (1924), but reclassified as a formation of the Fort Union Group by Dorf (1940). Leonard measured a section near Sentinel Butte, North Dakota, which he designated as the "Sentinel Butte group of coal beds." The lower contact of this "coal group" was designated as the "S" bed, a lignite bed about 3 feet thick and 40 to 50 feet below the "R" bed, a bed of lignite about 15 feet thick. The contact between the middle and upper members was defined as the base of this "R" bed. Leonard (1908, p. 106) said, "The bed which lies at the base of the upper Fort Union, R,

can be readily traced by its red clinker horizon in the bluffs and ridges of the Little Missouri badlands as far as the eye can see."

Hares (1928) referred to the "R" bed as the HT lignite which he designated as the basal bed of the Sentinel Butte Member of the Fort Union Formation. There was some question at this time as to whether the member was Paleocene or Eocene in age. Hares' Meyer lignite, about 80 feet below the HT lignite in the Marmarth, North Dakota area (Hares, 1928, p. 50), may be the equivalent of Leonard's "S" bed. The HT lignite and the "R" lignite supposedly correspond with the Roland coal of Taff's Tongue River sequence; however, the Roland coal bed was included with Taff's Tongue River sequence and not the overlying strata.

Differentiation between Leonard's "middle and upper members" has also been based on a color change; the upper member has a more somber appearance than the lighter colored middle member. Leonard (1908, p. 52) stated that the color change was so pronounced it could be traced without difficulty whenever exposed. This color change, although quite distinctive in the vicinity of Leonard's section near Sentinel Butte, becomes less pronounced when traced to the north. Brown (1948) stated that in the vicinity of the mouth of the Yellowstone River and the northern part of the Little Missouri badlands, the color of the member is so light it is virtually indistinguishable from the underlying strata of the Tongue River Formation.

The top of the Sentinel Butte Member at Sentinel Butte, North Dakota, is defined by 60 to 80 feet of well consolidated, gray and brownish sandstone. Overlying the sandstone is a sequence of about 40 feet of greenish conglomerate and a white, compact limestone (Leonard, 1908). According to Brown, fossil fish in the limestone and teeth and other vertebrate remains in the conglomerate have been identified as Oligocene in age. The sequence of greenish conglomerate and white, compact limestone has been shown to be the White River Formation of Oligocene age. Leonard said nothing about the nature of the contact, but Brown (1948) stated that the contact between Paleocene and Oligocene strata at Sentinel Butte is unconformable. Brown (1948) put the contact at the base of the 60 to 80 feet of massive, coarse, gray and brownish, cliff-making sandstone considered by Leonard as the top of the Sentinel Butte sequence. As evidence supporting this designation, Brown mentions the presence of a Fort Union fauna below this massive sandstone, but not within it.

Fisher (1954), stated that according to Brown (1948), the Sentinel Butte sediments are the upper facies member of the typical Tongue River Formation and the entirety is now recognized to be of Paleocene age. However, Brown (1948, p. 1271) stated that "Southwest of Broadus, Montana, a considerable dark sequence near the top of the Tongue River, but beneath lignitic strata containing Wasatch fossils, appears to be correlatable northeastward with the dark Sentinel

Butte shale and lateral equivalents." Brown mentioned difficulties encountered in mapping the Paleocene sequence east of the Rockies because of color changes accompanied by extensive lateral and vertical changes in lithologic composition. However, at no point did he specifically mention the Sentinel Butte as a member of the Tongue River Formation. Other workers in North Dakota have followed Fisher's nomenclature by referring to the Sentinel Butte as a member of the Tongue River Formation (B. Hanson, 1955, Meldahl, 1956, and Bergstrom, 1956). As this is presently the position of the North Dakota Geological Survey, at least tentatively, this nomenclature will be retained in this paper. It is not felt that nomenclatorial problems of Paleocene strata in North Dakota can be resolved on the basis of a study within a single quadrangle.

Occurrence

The Sentinel Butte Member is found in North Dakota, Wyoming, and Montana.

In the eastern portion of the Sperati Point Quadrangle on the Achenback Hills, the member is conformably overlain by the Golden Valley Formation of Eocene age. The contact, which appears to be gradational, has tentatively been placed at the base of the lower of two beds of purplish, shaly claystone in a sequence of yellow, silty claystone.

The base of the Sentinel Butte Member is not exposed in the quadrangle but can be observed at a locality about

4 miles west and 5 or 6 miles due south of the unofficial west entrance of the North Unit of Theodore Roosevelt National Memorial Park. The contact in this area is based on the presence of the HT (?) lignite bed (C. F. Royse, personal communication, 1965).

The distinctive "key" beds previously mentioned were most useful in correlating measured sections in the quadrangle. The "blue bed" is found throughout the quadrangle except in the extreme southern part where it gradually changes color and interfingers with the surrounding strata to eventually disappear. The bed has been traced east about 25 miles from the east boundary of the North Unit of Theodore Roosevelt National Memorial Park, and north to about 3 miles south of Arnegard, North Dakota (Plates I and IV).

The "yellow bed" has a fairly wide lateral distribution and is found throughout most of the quadrangle (Plates I and IV).

Lithology

In the Sperati Point Quadrangle, the lower 150 to 200 feet of the Sentinel Butte Member is dominantly grayish, fine to medium-grained graywacke sandstone, very fine to coarse-grained siltstone, and silty claystone. Most of the graywacke is lithic graywacke because it contains a greater abundance of dark minerals than feldspar; however, this is difficult to establish without detailed analyses. Quartz and chert are common constituents of the sandstones

and siltstones. The upper part of the section is dominantly gray, yellow, and brownish graywacke sandstone, siltstone, claystone, bentonitic claystone, shale, and lignite.

Heavy mineral analyses of graywacke sandstone from the lower part of each measured section reveal an abundance of the platy minerals with lesser amounts of amphibole, pyroxene, pyrite, tourmaline, epidote, garnet, barite, and magnetite (table 1). Most of the mineral grains are angular with sharply defined edges and surfaces showing little apparent evidence of weathering or transportation.

Characteristic sedimentary structures found throughout the member include ferruginous, calcareous claystone "cannonball" concretions (fig. 5), and ferruginous, calcareous siltstone, and claystone "log-like" concretions or concretionary-like lenses (fig. 6). Also present are limonitic, siltstone concretions which are friable, subspherical, and 1 to 6 inches in diameter, with marcasite filling the interiors (fig. 7).

The "blue bed" (called the "blue bed" because of its blue color) is a good example of a bentonitic claystone. X-ray analyses show that the major clay mineral present is montmorillonite. Also found in this bed are quartz, potassic and sodic-calcic feldspar, calcite and dolomite (table 2). Weathered exposures typically have a "popcorn-like" surface due to the expansion of the montmorillonite when wet and the shrinkage upon drying (fig. 8). The "blue bed" is comprised of about 73% clay, 26% silt, and 1% sand (table 3). The

Table 1. Representative mineral frequencies from sandstone beds in the base of the Sentinel Butte Member

Section No.	1	2	2	3	4	5	6
Unit No.	31	1	8	1	3	30	6
Mineral							
Amphibole and/or pyroxenes	S	R	C	R	S	R	R
Epidote and/or clinozoisite	S	S	R	S	S	S	S
Corundum	N	S	N	S	S	S	N
Garnet	R	R	C	R	R	S	S
Tourmaline	S	R	R	R	R	R	R
Magnetite and/or ilmenite	S	R	S	S	S	R	R
Platy minerals*	C	C	R	C	C	C	C
Barite	S	R	R	S	R	S	S
Pyrite	R	S	R	R	R	R	C
Kyanite	N	N	S	N	S	N	N

C = common, greater than 8%
R = rare, 1 to 8%
S = scarce, 0 to 1%
N = did not observe

** Includes biotite, muscovite and chlorite

Figure 5. Claystone "cannonball" concretions about 2 feet above the "blue bed", Sperati Point North Section (SW¼ sec. 28, SE¼ sec. 29, R. 100 W., T. 148 N.)

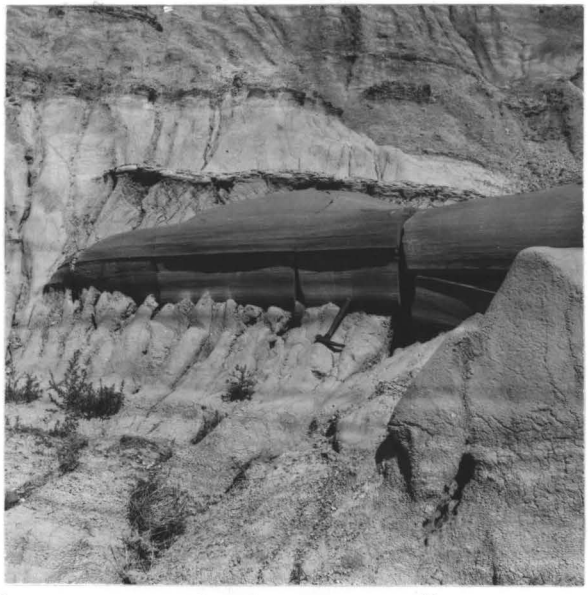

Figure 6. Siltstone and claystone "log-like" concretions or concretionary-like lenses about 12 feet above base of Sperati Point West Section (SW¼ sec. 24, NW¼ sec. 25, R. 101W., T. 148 N.).

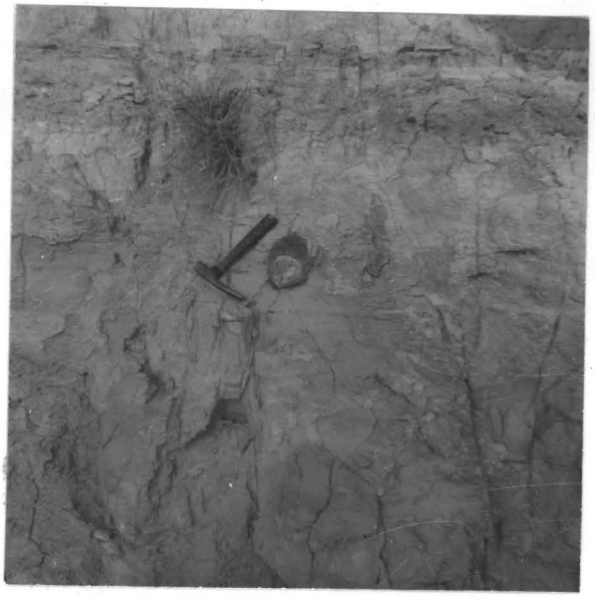

Figure 7. Friable, limonitic siltstone concretions in the "yellow bed", Scenic Lookout Section (SE¼ sec. 26, R. 100 W., T. 148 N.).

Figure 8. "Popcorn-like" surface developed on a weathered exposure of the "blue bed", a bentonitic claystone, Scenic Lookout Section (SE¼ sec. 26, R. 100 W., T. 148 N.).

Table 2. X-ray diffraction analyses of the "blue bed"

Sperati Point North Section (Section No. 2)

Mineral	Percentage
Quartz	15
* Clay minerals	81
Potassic feldspar	2
** Sodic-calcic feldspar	3
Calcite	1
Dolomite	2

Sperati Point South Section (Section No. 3)

Mineral	Percentage
Quartz	16
* Clay minerals	83
Potassic feldspar	1
** Sodic-calcic feldspar	2
Calcite	3
Dolomite	2

Sperati Point West Section (Section No. 4)

Mineral	Percentage
Quartz	15
* Clay minerals	82
Potassic feldspar	1
** Sodic-calcic feldspar	4
Calcite	2
Dolomite	1

* About 90% montmorillonite and/or mixed layer clays with minor amounts of illite and kaolinite.

** Percentage may be high due to presence of cristobalite and/or sanidine.

Table 3. Particle size analyses of the "blue bed"

Sperati Point South Section (Section No. 3)

% Sand	% Silt	% Clay
0.5	28.5	71.0

Sperati Point West Section (Section No. 4)

% Sand	% Silt	% Clay
1.0	28.0	71.0

Kellogg Ranch Section (Section No. 5)

% Sand	% Silt	% Clay
2.0	20.0	78.0

claystone generally is fairly well consolidated with blocky to shaly partings. The source of the blue color in this bed has not been determined.

The "yellow bed" is a fine to medium-grained, poorly consolidated clayey siltstone that may be locally sandy or grade laterally and vertically into sandstone. Particle size analyses reveal an average composition of about 63% silt, 36% clay, and 1% sand (table 4).

Microscopic studies reveal the presence of volcanic ash in the form of glass shards throughout much of the Sentinel Butte Member. The shards are most abundant in siltstones, sandstones, and especially bentonitic claystones. These shards range from accicular fibrous shapes to splinters, are 0.25 to 1.00 mm long, and colorless, greenish, brown and black.

Detailed lithologic descriptions of measured sections in the Sperati Point Quadrangle are included in the Appendix. Plates II and III are columnar illustrations of measured stratigraphic sections.

Structure and Thickness

The beds of the Sentinel Butte Member are essentially horizontal with a regional dip to the northeast of only a few feet per mile. Elevations obtained on the top of the "blue bed" in the quadrangle indicate a dip of 15 to 45 feet per mile in this direction. Localized complex folding and faulting of strata including the "blue bed" in an area southwest of Watford City have been reported by the late Vaughn

Table 4. Particle size analyses of the "yellow bed"

Scenic Lookout Section (Section No. 1)

% Sand	% Silt	% Clay
1.0	65.0	34.0

Sperati Point North Section (Section No. 2)

% Sand	% Silt	% Clay
1.5	67.5	31.0

Kellogg Ranch Section (Section No. 5)

% Sand	% Silt	% Clay
0.5	57.5	42.0

Russom (M. Hansen, 1954).

Extensive slumping is evident in areas immediately adjacent to the Little Missouri River and its tributaries. Presumably, this slumping takes place when a block of strata saturated with water becomes too heavy to support its own mass. It then slides down the face of an escarpment or butte along a glide plane. Slumping does not seem to be typical of, or confined to, any one type of lithology. Small scale slumping (10 to 30 cubic feet) is common, and takes place whenever the conditions outlined in the preceding discussion have been met.

Thom and Dobbin (1924) reported the thickness of the Sentinel Butte Member as: 1100 to 2500 feet in the vicinity of Sheridan-Buffalo, Wyoming; 200 to 500 feet in the vicinity of the Poplar-Culbertson area and the Crow Indian Reservation, Montana, respectively; about 300 feet in the Glendive, Montana, area, about 400 feet in the Sentinel Butte, North Dakota, area, and about 550 feet in the Williston-Minot, North Dakota, area.

In the Sperati Point Quadrangle, the member is about 570 feet thick.

The member appears to thicken when traced northward from the Sentinel Butte, North Dakota, area.

Paleontology

The flora and fresh-water fauna of the Sentinel Butte Member have been described in detail by Brown (1962), Dorf (1940), Yen (1946, 1947, and 1948), Meek and Hayden (1862),

Meek (1876), Russell (1931 and 1934), Tozer (1956), and others. The fauna is comprised mainly of gastropods of the genera Viviparis and Campeloma, and pelecypods of the genus Unio.

The most fossiliferous bed in the member, as it occurs in the quadrangle, is the "yellow bed". In locales where the "yellow bed" is dominantly siltstone, many fairly well preserved gastropods and pelecypods have been found. A good collecting site from this bed is at the Kellogg Ranch Section (NW¼ sec. 20, R. 100 W., T. 147 N.). Faunal collections taken at this site include the following species:

? Campeloma sp.
? Viviparis sp.
Plesielliptio priscus ? (Meek and Hayden)
Sphaerium formosum ? (Meek and Hayden)
? Unio (Elliptio) sp.

A fossil leaf from the "yellow bed" at the Kellogg Ranch Section site is identified as Ampelopsis acerifolia (Newberry).

Although mollusks are found throughout most of the section, they are rare, poorly preserved, and usually confined to claystone or clayey siltstone beds. No mollusks were found in any of the sandstone beds.

Plant fossils are found in greatest abundance in bentonitic claystone, lignitic shale and claystone, and lignite beds. The plant remains are woody and partially carbonized

in bentonitic claystone, lignitic shale and claystone, and partially carbonized to totally carbonized in the lignite.

Excellent leaf impressions can be found in some lignitic shale and claystone beds; most of the plant remains in bentonitic claystone are highly fragmented and aligned parallel to bedding planes. Clayey siltstones directly underlying lignite beds sometimes have woody root fragments aligned perpendicular to bedding planes in what appears to be their original growth position.

Correlation

Considerably question existed in the late 1940's regarding the age of the Sentinel Butte Member. The chief worker responsible for the modern chronologic assignment of the member is Brown (1948), on the basis of paleontological evidence.

Thom and Dobbin (1924) correlated the member with the "Intermediate Coal Group" (Taff, 1909) that directly overlies the Tongue River Coal Group (the Roland coal bed marks the top of the Tongue River Coal Group). They also correlated the member with the Kingsbury Conglomerate (Darton, 1906) which is found on the east side of the Big Horn Mountains in Wyoming. The Kingsbury has been assigned to the Eocene on the basis of the occurrence of the floating fern, Salvinia preauriculata. However, according to Brown (1948), the interfingering of the Kingsbury Conglomerate with the "Intermediate Coal Group", as implied by

Thom and Dobbin in their correlations, has not been demonstrated. The implication is that the Kingsbury Conglomerate and the Sentinel Butte Member are not correlative. The Sentinel Butte Member has also been correlated with the "Clark Fork Beds" of the Big Horn Basin (Brown, 1948). The "Clark Fork Beds" contain a mammalian fauna that unquestionably assigns them to a late Paleocene age.

Brown (1948) identified the first occurrence of Salvinia preauriculata at a level about 200 to 250 feet above the Roland coal bed in an area east and northeast of Buffalo, Montana. This establishes that at least a portion of the "Intermediate Coal Group" is Paleocene in age. Brown mentions that he has never identified Salvinia preauriculara in strata of known Paleocene age. All fossil plants of the Sentinel Butte sequence and lateral equivalents are Paleocene in age (Brown, 1948, p. 1272).

Two "key" beds, the "blue bed" and the "yellow bed" (figs. 9 and 10) occur at about the same stratigraphic level throughout most of the quadrangle. These beds were used as an aid in correlating measured sections of the member (Plates II and III). A fence diagram shows the distribution of these beds (Plate IV). The beds attract one's attention almost immediately because of their bright color which contrasts distinctively with the somber appearance of other beds in the member.

From a casual observation at a distance, the horizontality of the strata gives the impression of lateral and

Figure 9. Looking southwest toward the Sperati Point North Section (SW¼ sec. 28, SE¼ sec. 29, R. 100 W., T. 148 N.) showing the "blue bed" capping the ridges.

Figure 10. Looking east toward the Scenic Lookout Section (SE¼ sec. 26, R. 100 W., T. 148 N.) showing the "yellow bed" that caps the ridge. Note the thin lignite bed followed by a sequence of claystone that directly overlies the "yellow bed".

vertical persistence, and correlations with many prominent-appearing beds seem possible. However, upon closer observation (which by necessity involves walking-out as much of the outcrop as possible), the beds are observed to vary in thickness, disappear under wash and slump, and rarely continue at the same stratigraphic level for any great distance--10 miles at the most. For this reason, sections in the quadrangle were chosen as close together as possible; the greatest distance between any two sections correlated with each other is 3.9 miles (fig. 4).

Lignite beds in the quadrangle cannot generally be used successfully as an aid in correlating measured sections of the member. An exception to this is a single lignite bed, about 2.5 to 6.0 feet thick, that appears to be laterally persistent over an area of about 18 to 20 square miles in the northern part of the quadrangle. Other lignites are not as persistent and pinch out or disappear within a much smaller area.

Depositional History

The following discussion is the author's interpretation of the depositional history of the Sentinel Butte Member based on evidence gathered in the Sperati Point Quadrangle. The member is comprised of alluvial, fluviatile, and lacustrine sediments deposited on a vast alluvial or coastal plain. Numerous streams meandered across this low surface and deposited great thicknesses of detrital debris derived from the Rocky Mountains to the west and the Black

Hills to the south. Shallow-water lakes or swamps, large and small, served as sites of deposition for claystone, siltstone, shale and lignites. Volcanoes, in the vicinity of the Rocky Mountains, ejected large amounts of volcanic ash that was carried many miles by the wind to settle eventually on the alluvial or coastal plain. Bentonitic claystones and the apparent lack of chemical weathering of the particles in the sedimentary rocks of the Sentinel Butte Member suggest a relatively cool, fairly dry climate?

The thick basal sequence of graywacke sandstone and siltstone probably represents stream channel deposits. However, due to lateral shifting of the streams and consequent partial destruction of the deposits, well-marked channel sands are not very evident in this lower basal sequence. As the streams shifted from their courses, much of the sediment was reworked: such reworking is indicated by the presence of cross-bed sets in the sandstone and siltstone.

The greater relative abundance of dark minerals over feldspar seems to suggest either a source area of thoroughly weathered crystalline rocks or derivation from older sediments, possibly from the Hell Creek Formation. Another possibility is that much of the material may have been derived directly from volcanoes to the west as volcanic ash and glass. The presence of large amounts of relatively unaltered mica, pyrite, garnet, and tourmaline as subhedral to euhedral particles suggests that the weathering during transportation must have been minimal. Much of the sediment may have been

locally derived before complete lithification of the sediments.

"Cannonball" and "log-like" ferruginous, calcareous, siltstone and claystone concretions are found throughout the Sentinel Butte Member; however, most of these are found in the lower 300 feet of the section. Low spots in former stream channels may have been filled with silty and clayey sediment during periods of high stream flow. Ground water percolating through the sediment could have contained dissolved iron which precipitated and aided in the cementation of the silt and clay. The concretions may have further consolidated and eventually lithified because of case-hardening, a process whereby porous sediment becomes cemented on the surface by minerals precipitated from ground water or surface-water infiltration.

The wide areal distribution and uniform lithologic composition of the "blue bed" suggests a lacustrine environment of deposition. The "blue bed" and many other claystone beds are bentonitic. Wind-blown volcanic ash from the Rocky Mountains to the west may have settled in many of the shallow-water lakes or swamps. Devitrification of the volcanic ash produced the montmorillonite; devitrification is favored by relative dryness in regions where little leaching can occur (Weller, 1960, p. 344). Partially carbonized plant remains are present in many of the bentonitic claystones. Rapid accumulations of wind-blown ash could have killed plant life that lived in the lakes or swampy areas

where the clays were accumulating.

Fairly well preserved pelecypods and gastropods found in the "yellow bed" appear to be little transported and in no particular orientation with regard to their long axes (fig. 11). Very likely, the "yellow bed" is dominantly a lacustrine deposit and the mollusks are found at or near their place of origin. Erosion would have removed the fossils from their original place of burial and resulted in their subsequent fragmentation. If they had lived in a stream environment and are in their original place of burial, they probably would be in some pattern of preferred orientation. The absence of the "yellow bed" in the vicinity of the Sperati Point South Section (Plate I) may be due to removal of the bed from the area by stream erosion or, the bed may never have been deposited in this area.

Stagnant shallow-water lakes or swamps were suitable environments for the formation of lignite, lignitic claystone and siltstone. These deposits could cover tens or hundreds of square miles. Deposits of a smaller scale could have their origin in ox-bow lakes that later became swampy areas. Deoxidation and dehydration of dead vegetation in an anerobic environment produced accumulations of peat which, with the passage of time and under the compaction of the overlying sediments, was converted to lignite.

Beds of irregularly cross-bedded, fairly well consolidated sandstone may represent deltaic deposits formed where a stream entered a lake (fig. 12). However, deltas that formed

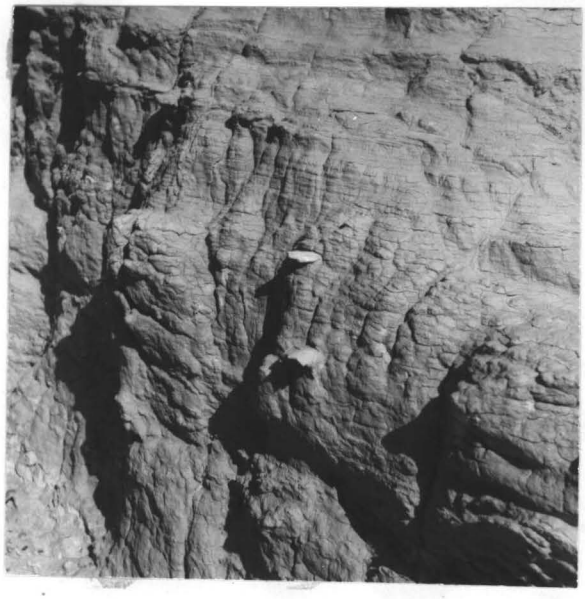

Figure 11. Pelecypods in place in the "yellow bed" in the Kellogg Ranch Section (NW¼ sec. 20, R. 100 W., T. 147 N.).

Figure 12. Prominent irregularly cross-bedded sandstone ledge former about 100 feet below top of the Scenic Lookout Section (SE¼ sec. 26, R. 100 W., T. 148 N.).

in this manner would most likely have been destroyed by stream erosion if the lakes were drained. According to Weller (1960, p. 183), few, if any fresh-water deltaic deposits, even when preserved, are large enough to constitute prominent stratigraphic features.

Many of the sediments were probably floodplain deposits. These deposits would shift from fine to coarse in what might seem to be a repetitive type of deposition. In the basal 200 to 250 feet of the Sentinel Butte Member in the quadrangle, there is evidence of repetitive deposition. From the base up, sandstone alternates with siltstone and/or claystone which is overlain by lignite. Overlying the lignite is another sequence of sandstone alternating with siltstone and/or claystone followed by lignite (Plates II and III).

Where great bodies of continental sedimentary rocks have accumulated, lacustrine and fluvial strata are commonly interlayered. Streams flowing across an alluvial or coastal plain could be expected to shift laterally; such meandering and changes in stream courses could produce complex associations between lacustrine and fluvial sediments. Such interlayering and complex associations between sediment types is characteristic of the Sentinel Butte Member in the Sperati Point Quadrangle. It is difficult, if not impossible, to trace any one particular bed over a great distance. Very rarely will any one bed continue laterally for any distance at the same stratigraphic horizon or with the same thickness.

Golden Valley Formation

Name and Definition

The Golden Valley Formation of Eocene age was named by Benson and Laird (1947) for a sequence of micaceous silts, sands and minor light-colored clays and shales near the town of Golden Valley in Mercer County, North Dakota. The sequence includes beds formerly assigned to the "unnamed formation" of the Wasatch Group (Seager, et al., 1942).

The formation generally is conformable with the underlying Sentinel Butte Member and disconformably underlies the White River Formation of Oligocene age.

Occurrence

This formation has a spotty occurrence in northwestern, southwestern, and southern North Dakota. Large boulders (lag gravel?) of well-indurated "pseudo-quartzite" on the higher portions of the hillsides on Achenback Hills marks the presence of the formation in the eastern part of the quadrangle (figs. 13 and 14). The "pseudo-quartzite" contains numerous plant impressions and root and stem molds; similar "pseudo-quartzites" are known to occur in the Tongue River Formation in North Dakota (Hares, 1928, Laird and Mitchell, 1942). Benson (1954b) reported the presence of the "pseudo-quartzite" (referred to by Benson as a silicified sandstone) in the Golden Valley Formation in western North Dakota. Removal of a portion of the upper member may possibly have resulted in the collapse and subsequent accumulation of the "pseudo-quartzite" as lag gravel (?) on the underlying Sentinel Butte

Figure 13. Looking due west on Achenback Hills showing the topography developed on the Golden Valley Formation (secs. 10 and 11, R. 100 W., T. 147 N.).

Figure 14. Large "pseudo-quartzite" boulders (lag gravel?) of the Golden Valley Formation on Achenback Hills (sec. 10, R. 100 W., T. 147 N.).

Member.

Lithology

This formation has been divided into a lower and upper member (Benson, 1949). The lower member consists of purple-gray carbonaceous shale with interbedded white sandy kaolinitic clays that weather to an orange color. The middle portion of the lower member weathers a characteristic reddish-yellow and has a mottled appearance; these beds comprise the "marker bed" (Benson and Laird, 1947) that is used as an aid in mapping structure in Mercer, Dunn, McKenzie and Stark Counties, western North Dakota. The upper member is largely fine to coarse-grained micaceous sand, sandstone, silt and siltstone with small clay lenses.

Structure and Thickness

The beds of the Golden Valley Formation in southwestern North Dakota are essentially horizontal, with a slight dip of less than one degree to the northeast. Exposures of the formation are present on a northwest-southeast trending anticline in the vicinity of Grassy Butte, North Dakota (Meldahl, 1956).

The overall thickness of the Golden Valley Formation in the Sperati Point Quadrangle is about 100 to 160 feet. The formation is about 175 feet thick in the type area near Golden Valley, North Dakota (North Dakota Geol. Soc., 1954, p. 9).

Paleontology

The fauna and flora of the Golden Valley Formation are rich and varied. Fossil fish, amphibians, reptiles, croco-

dilians, birds, mammals, riparian and aquatic animals, ferns, cycads and conifers have been identified by Jepsen (1963) and fellow workers. Eighteen orders, 29 families, 38 genera and 37 species of vertebrates from the formation are in collections at Princeton University (Jepsen, 1963). The base of the formation is marked by the occurrence of the floating fern, Salvinia preauriculata (Benson and Laird, 1947).

Correlation

The Golden Valley Formation has been correlated with the Kingsbury Conglomerate found on the east flank of the Bighorn Mountains in Wyoming (Jepsen, 1963). The Kingsbury has been identified as Eocene in age on the basis of the occurrence of the floating fern, Salvinia preauriculata (Brown, 1948), and fresh-water invertebrates identified by Yen and reported by Hose (1955).

Depositional History

The gradational contact between the Golden Valley Formation and the underlying Sentinel Butte Member suggests that during the early Eocene, deposition must have been quite similar to that during the late Paleocene. According to Benson (1952 and 1954a), the lower kaolinitic beds may have been deposited in a large, very shallow, fresh-water lake. The kaolin in the sediments was probably transported as kaolin from a source area to the west (Benson, 1952). The beds of the upper member may represent deposits laid down by streams flowing across a low, flat plain, possibly a coast-

al plain. The fauna and flora of the formation suggest a warm, humid climate with swampy lowlands and subtropical forests (Jepsen, 1963).

Pettyjohn (1966) described a soil profile that is well developed on rocks of late Eocene through Cretaceous age and possibly even older. The profile is evident in western North Dakota, South Dakota, southeastern Wyoming, and northwestern Nebraska. The profile is characterized by brightly colored purple, yellow and greenish-gray sediments. The lack of calcium carbonate compared to that of unweathered strata suggests a lateritic climate at the time of its development. The youngest rocks on which the profile is found are of late Eocene age and directly underlie the Chadron Member of the White River Formation of Oligocene age.

Wiota Gravel

Preglacial gravel deposits, younger than the Flaxville Gravel and found about 25 miles west of the Wolf Point Quadrangle in Montana (Colton, 1955), were named the Wiota Gravel by Jensen (1951, p. 17).

In the type area, the gravel deposits overlie rocks ranging in age from late Cretaceous to Miocene or Pliocene. In the Wolf Point Quadrangle, the gravel overlies the Fox Hills, Hell Creek, and Flaxville Gravel. Oldest and highest terrace remnants are found at an altitude of 2,550 feet; several other terrace remnants are present at 2,200 to 2,300 feet.

Gravel deposits overlie Paleocene and Eocene bedrock in the western, northwestern, and extreme southeastern parts of the Sperati Point Quadrangle (Plate I). The base of the gravel occurs at an elevation between 2,500 and 2,520 feet. These deposits are tentatively referred to as the Wiota Gravel.

The gravel consists primarily of fairly well-rounded to well-rounded fragments of very fine to medium-grained, brown, green, yellow, and gray quartzite. Agate, chalcedony, chert, many varieties of basic and acidic igneous rocks, local sedimentary rock, and petrified wood fragments are present in minor amounts. The fragments range in size from a fraction of an inch to as large as 5 inches in diameter. Jensen (1951) said the gravel may vary laterally from deposits of almost entirely sand to deposits dominantly of coarse gravel. Jensen said the deposits range in thickness from 1 to 30 feet. In the Sperati Point Quadrangle, thicknesses are estimated to range between 15 and 35 feet.

Bone fragments and mammoth teeth have been found in Wiota Gravel pits (Colton, 1955).

Howard (1960) named gravels near the Yellowstone-Missouri confluence (5 to 6 miles north of Cartwright, North Dakota, in north-western McKenzie County) as the Cartwright Gravel. Patches of the Cartwright Gravel are known to be present along the Missouri River, the Little Missouri River, and other streams, as well as in the inter-

fluve areas. Howard (1960, p. 21) stated that the Cartwright Gravel is, at least in part, equivalent to the Wiota Gravel.

Wiota Gravel deposits probably mark the presence of former streams or higher levels of present streams. The topographic expression of remnant stream terraces as "perched" deposits may be due to topographic inversion.

Outwash Deposits

Wisconsinan (?) glacial outwash deposits are found underlying Wiota Gravel (?) deposits in the western and northwestern parts of the Sperati Point Quadrangle (Plate I).

These deposits differ from the Wiota Gravel (?) deposits as they are comprised of unstratified, angular (rather than well-rounded), dominantly gravel-sized, fragments of limestone, dolostone and Canadian Shield-type igneous and metamorphic rocks, with lesser amounts of sand, silt, and clay. Numerous large boulders of granite and granite gneiss, 1 to 4 feet in diameter, are scattered over the hillsides. The angular shapes and large sizes of these boulders, is an indication of ice, rather than stream transportation prior to their arrival in the vicinity of the Sperati Point Quadrangle.

POST-EOCENE HISTORY

Oligocene through Miocene

Oligocene deposits in North Dakota are known as the White River Formation. The formation is not present in the quadrangle. Either it was not deposited in this area, or it has since been removed by erosion.

Miocene deposits, other than terrace gravel deposits, have not been positively recognized in North Dakota. However, Denson and Gill (1965) have assigned a sequence of dominantly carbonaceous rocks with cross-bedded sandstone, shale, and conglomerate, present in the Killdeer Mountains and possibly in the Sentinel Butte, North Dakota, area, to the Arikaree Formation of Miocene age.

Heavy minerals in these rocks were derived from extrusive igneous rocks mainly of pyroclastic origin. Large amounts of disseminated volcanic ash and relatively pure ash are evidence for volcanic activity during Miocene time.

Miocene deposits, if they were present in the Sperati Point Quadrangle, have since been removed by erosion.

Pliocene through Pleistocene

In the western and northwestern parts of the quadrangle, the Wiota Gravel (?) deposits appear to have been cut through or dissected by a glacial outwash channel. Mixed deposits of outwash and Wiota Gravel (?) are present in secs. 6 and 7, R. 100 W., T. 147 N. (fig. 15).

The following discussion is based mainly on the ideas of Laird (1956) and Schmitz (1955).

During the Pliocene, the present-day Killdeer Mountains acted as a drainage divide. Streams that flowed east off the divide joined other streams of which the exact courses are not now known. Streams that flowed west off the divide joined the Little Missouri River which flowed north near Ray, North Dakota, and then west to eventually join the Yellowstone River (Leonard, 1916, p. 301). The Yellowstone River, in turn, joined the preglacial Big Missouri River near Crosby, North Dakota; the Big Missouri River emptied into Hudson Bay by way of Lake Winnipeg and the Nelson River. The gravel deposits of these Pre-Pleistocene streams that flowed west off the Killdeer Mountains may be represented by the Wiota Gravel (?) found in the quadrangle.

In late Pliocene to early Pleistocene time, the area to the east of the Killdeer Mountains was uplifted (Schmitz, 1955). Streams flowing east off the divide became entrenched and, through renewed downcutting and headward erosion, captured the tributaries of the Little Missouri River. Eventually, the Little Missouri was captured by the Medicine Stone River: this is probably the course now occupied by the Little Missouri River east of the bend in the Sperati Point Quadrangle.

During the Pleistocene, glaciers entered the area. When the ice retreated to the north, meltwater and debris from the wasting ice could have been channeled across the Wiota Gravel (?) deposits. Later, the gravel deposits could

Figure 15. Mixed deposits of glacial outwash and Wiota Gravel (?) (SW¼ sec. 6, R. 100 W., T. 147 N.).

have been cut through by the outwash streams. Such a process could result in mixed deposits of outwash and Wiota Gravel (?).

Extensive field work would be necessary to establish clearly the relationship between the Wiota Gravel (?) and the glacial outwash deposits. The preceding discussion outlines a possible explanation based on limited field observations.

Recent

Slumped areas border the Little Missouri River and nearly all the streams in the Sperati Point Quadrangle. Since the recession of the glaciers through the present,

slumping has probably been taking place. For this reason, the age of the slumping is given as Recent (?) (Plate I). Slump areas that formed prior to the Recent may have since been removed or altered by the erosion of the Little Missouri River Valley.

Alluvial deposits are quite extensive on the meandering flood plain of the Little Missouri River. Elevated meander scars (sec. 33, R. 100 W., T. 148 N., and secs. 4 and 5, R. 100 W., T. 147 N.), and high, steep-sided river banks may be an indication that the river is presently downcutting. The meander scars are occupied by the river during periods of high flow.

SUMMARY AND CONCLUSIONS

1. In the Sperati Point Quadrangle, bedrock consists primarily of the Sentinel Butte Member of Paleocene age. The Golden Valley Formation of Eocene age occupies a small area in the eastern part of the quadrangle.

2. The Sentinel Butte Member in the quadrangle consists of about 570 feet of poorly consolidated sedimentary rocks characterized by great horizontal and vertical irregularity. These rocks contain large amounts of volcanic ash. The lower 200 to 250 feet of the section is dominantly graywacke sandstone and siltstone with an abundance of platy minerals. The upper part of the section consists of graywacke sandstone, siltstone, claystone, shale, and lignite. The sedimentary rocks of the member were probably deposited on an alluvial or coastal plain.

3. Two "key" beds of the Sentinel Butte Member present in the quadrangle are a bentonitic claystone, the "blue bed", and a clayey siltstone, the "yellow bed", both of which have a relatively wide areal distribution. These beds continue laterally at about the same stratigraphic horizons and can be traced throughout the quadrangle.

4. Although some workers have found lignites to be useful in correlating Paleocene sedimentary rocks, lignite beds

in the Sentinel Butte Member in the quadrangle are not very extensive and cannot be used with any measure of success for this purpose.

5. There appears to be a general lack of fossil mollusks in the Sentinel Butte Member in the quadrangle; however, they are locally common in the "yellow bed".

6. Glacial erratics and outwash deposits (Wisconsinan ?) in the northern and northwestern parts of the quadrangle are evidence for the former presence of glaciers in the area. Outwash deposits are found mixed with western gravel (Wiota Gravel ?) in the quadrangle in secs. 6 and 7, R. 100 W., T. 147 N.

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APPENDIX

Included in this Appendix are detailed lithologic descriptions of stratigraphic sections measured in the Sperati Point Quadrangle, McKenzie County, North Dakota.

1. Scenic Lookout Section

SE¼ sec. 26, R. 100 W., T. 148 N., about 26 miles south-southeast of Arnegard, McKenzie County, North Dakota. Base of section in NE¼, SE¼ sec. 26, at base of southwest-facing butte about 100 feet east of stream cut and 2500 feet southeast of Scenic Lookout, North Unit, Theodore Roosevelt National Memorial Park. Section measured by M. Clark, June, 1965; elevation at top of section, 2449 feet: Plate I.

Description

Top of section

Sentinel Butte Member

Unit		Feet
58	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, very poorly consolidated, light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2). Caps the butte. Supports prairie grass vegetation. Selenite crystals abundant	3.0
57	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly consolidated, dark yellowish orange (10YR 6/6) to moderate yellowish brown (10YR 5/4), weathers grayish orange (10YR 7/4). Claystone concretions, elliptical, 2.0 to 6.0 inches in diameter. Heavily washed	13.5
56	CLAYSTONE, silty, slightly bentonitic, fairly	

Unit		Feet
	well consolidated, olive black (5Y 2/1), weathers yellowish gray (5Y 8/1) to light olive gray (5Y 6/1), shaly partings. Poorly developed "popcorn-like" surface on weathered exposures. Washed	7.0
55	SILTSTONE, sandy, clayey, fine to medium grained, very poorly consolidated, dark yellowish orange (10YR 6/6) to light brown (5YR 5/6), weathers very pale orange (10YR 8/2) to grayish orange (10YR 7/4). Supports sparse vegetation . .	19.0
54	CLAYSTONE, silty, slightly calcareous, poorly consolidated, olive gray (5Y 4/1) to dark greenish gray (5GY 4/1), weathers light olive gray (5Y 6/1). Contacts obscured due to heavy washing	3.5
53	SILTSTONE, clayey, medium to coarse grained, poorly consolidated, olive gray (5Y 4/1), weathers light olive gray (5Y 6/1) to yellowish gray (5Y 8/1). Washed	3.0
52	SILTSTONE, calcareous, ferruginous, very fine to fine grained, fairly well consolidated, light brown (5YR 5/6) to moderate brown (5YR 4/4), weathers same. Ledge former. Manganese dendrites	2.0
51	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly to fairly well	

Unit		Feet
	consolidated, yellowish gray (5Y 8/1) to light olive gray (5Y 6/1), weathers light olive gray (5Y 6/1) to greenish gray (5GY 6/1). Numerous beds of claystone, silty, ferruginous, poorly to fairly well consolidated, moderate yellowish brown (10YR 5/4), weathers same. Fluted and washed	19.5
50	SHALE, medium light gray (N6), weathers light gray (N7), fissile, lignitic partings 1/8 to ¼ inch thick	1.0
49	CLAYSTONE, silty, fairly well consolidated, brownish gray (5YR 4/1), weathers yellowish gray (5Y 8/1) to light olive gray (5Y 6/1). Woody. Leaf and stem impressions . . .	3.8
48	LIGNITE, grayish black (N2) to black (N1), weathers very dusky red (10R 2/2) to dark gray (N3). Exposure obscured due to slumping and heavy washing	5.5
47	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly consolidated, light gray (5Y 5/2), weathers yellowish gray (5Y 7/2). Caps the ridge. Washed . . .	9.6
46	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly consolidated, and CLAYSTONE, silty, slightly calcareous, poorly consolidated; unit is light olive gray (5Y 5/2)	

Unit		Feet
	to oliv gray (5Y 4/1), we ers yellowish ay (5Y 7/2 o yellowish gray Y 8/1). Lignit bed, 0. to 0.3 feet thick bout 1.0 feet below p of unit. Heavil ashed . . .	6.9
45	LIGN..., black (N1), weath dusky brown (5YR 2/2). Carbonized plan emains . .	4.0
44	SILTSTONE, clayey, very fi to medium grained, poorly consolidated, olive ray (5Y 4/1), weathers greenish gray (5GY 6/1) . . .	6.0
43	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly to fairly well consolidated, dark yellowish orange (10YR 6/6) to light olive gray (5Y 6/1), weathers same. Sandstone bed, feldspathic graywacke, calcareous, fine to medium grained, well consolidated, medium olive gray (5Y 5/1) to light brownish gray (5YR 6/1), weathers light olive gray (5Y 6/1) to brownish gray (5YR 4/1), some cross-bedding apparent; 1.5 feet thick, about 16 feet above base of unit, ledge former. Sandstone lenses, 0.2 to 0.4 feet thick. Hard crust on washed surfaces. Fluted with pinnacles common . .	24.0
42	LIGNITE, black (N1) to olive black (5Y 2/1), weathers same	0.6
41	CLAYSTONE, bentonitic, fairly well to well consolidated, pale blue (5B 6/2), weathers pale	

Unit		Feet
	blue (5PB 7/2). Partially carbonized plant remains	1.5
40	SILTSTONE, clayey, slightly calcareous, coarse grained, poorly consolidated, and SANDSTONE, lithic graywacke, slightly calcareous, very fine grained, poorly consolidated; unit is pale olive gray (10Y 6/2) to light olive gray (5Y 6/1), weathers yellowish gray (5Y 7/2) and (5Y 8/1) to pale greenish yellow (10Y 8/2), laminations 1/8 to ¼ inch thick. Siltstone is 65% silt, 34% clay and 1% sand. Siltstone concretions, "log-like", 2.0 to 6.0 feet long, 1.0 to 2.0 feet thick, and "cannonball", 0.2 to 1.5 feet in diameter. Heavily washed. Caps the ridge. Referred to as the "yellow bed"	16.5
39	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly consolidated; basal 4.0 to 5.0 feet is light olive gray (5Y 6/1) to brownish gray (5YR 4/1), weathers very pale orange (10YR 8/2) to very light gray (N8); upper part dark yellowish orange (10YR 6/6) to moderate yellowish brown (10YR 5/4), weathers grayish orange (10YR 7/4) to dark yellowish orange (10YR 6/6). Washed	15.0
38	LIGNITE, grayish brown (5YR 3/2) to black (N1), weathers grayish red (10R 4/2) to dusky brown	

Unit		Feet
	(5YR 2/2). Selenite crystals common. Partially carbonized to carbonized plant remains. Leaf and stem impressions	6.0
37	CLAYSTONE, silty, poorly consolidated, and SILTSTONE, clayey, very fine to fine grained, poorly consolidated; unit is greenish gray (5GY 6/1) to olive gray (5Y 4/1), weathers light olive gray (5Y 6/1) to brownish gray (5YR 4/1). Becomes more silty in upper 2.0 to 2.5 feet	5.0
36	CLAYSTONE, bentonitic,silty, fairly well consolidated, dark greenish gray (5GY 4/1), weathers light gray (N7). Carbonized plant remains. Leaf and stem impressions . . .	1.0
35	CLAYSTONE, bentonitic, silty, poorly to fairly well consolidated, olive gray (5Y 4/1), weathers light gray (N7). Caps the ridge. Heavily washed. Poorly developed "popcorn-like" surface on weathered exposures	5.8
34	CLAYSTONE, bentonitic, silty, slightly calcareous, poorly consolidated, moderate brown (5YR 3/4) to grayish brown (5YR 3/2), weathers dark yellowish brown (10YR 4/2) to moderate yellow (5Y 7/6), shaly partings upper 0.2 feet. "Popcorn-like" surface on weathered exposures	2.5
33	SILTSTONE, clayey, medium to coarse grained,	

Unit		Feet
	fairly well consolidated, light bluish gray (5B 7/1), weathers same to medium bluish gray (5B 5/1). Washed	4.7
32	CLAYSTONE, bentonitic, silty, fairly well consolidated, dark greenish gray (5GY 4/1), weathers light bluish gray (5B 7/1). Becomes more silty in upper 0.5 feet. "Popcorn-like" surface on weathered exposures	4.5
31	CLAYSTONE, bentonitic, poorly to fairly well consolidated, olive gray (5Y 4/1) to dark greenish gray (5GY 4/1), weathers medium bluish gray (5B 5/1) to bluish gray (5B 7/1). X-ray analyses reveal presence of montmorillonite, quartz, potassic feldspar, sodic-calcic feldspar, calcite and dolomite. Very plastic and sticky when wet. "Popcorn-like" surface on weathered exposures. Caps the ridge. Heavily washed. Woody to carbonized plant remains in lower 0.2 to 0.4 feet. Referred to as the "blue bed"	5.0
30	SILTSTONE, clayey, slightly calcareous, very fine to fine grained, well consolidated, dusky yellow (5Y 6/4) to light olive gray (5Y 5/2), weathers same. Heavily washed near base	23.0
29	SANDSTONE, lithic graywacke, fine to medium grained, poorly to fairly well consolidated, medium olive gray (5Y 5/1), weathers light olive	

Unit		Feet
	gray (5Y 6/1). Hard crust on washed surfaces	27.6
28	SANDSTONE, lithic graywacke, medium to coarse grained, poorly to fairly well consolidated, moderate yellowish brown (10YR 5/4), weathers pale yellowish brown (10YR 6/2). Sandstone bed well consolidated, 0.4 feet thick, marks top of the unit; ledge former. Heavily washed	7.4
27	SANDSTONE, lithic graywacke, very fine to medium grained, poorly consolidated, moderate yellowish brown (10YR 5/4), weathers yellow orange (10YR 6/6). Sandstone bed, cross-bedded, well consolidated, moderate yellowish brown (10YR 5/4), weathers pale yellowish brown (10YR 6/2); 5.5 feet thick, marks top of the unit, ledge former. Hard crust on washed surfaces . .	39.0
26	LIGNITE, grayish black (N2), weathers brownish black (5YR 2/1). Some shale, lignitic, dark reddish brown (10R 3/4), weathers grayish brown (5YR 3/2), 2.0 feet at base. Partially carbonized to carbonized plant remains . . .	5.0
25	SANDSTONE, lithic graywacke, very fine to fine grained, poorly consolidated, light olive gray (5Y 6/1), weathers yellowish gray (5Y 8/1). Fluted, hard crust on washed surfaces . .	17.4
24	SANDSTONE, lithic graywacke, very fine to fine grained, poorly to fairly well consolidated,	

Unit		Feet
	medium olive gray (5Y 5/1), weathers light olive gray (5Y 6/1) to moderate yellowish brown (10YR 5/4). Numerous claystone beds, ferruginous, moderate brown (5R 4/4), weather very dark red (5R 2/3) to moderate red brown (10R 4/6), 0.2 to 1.0 feet thick. Fluting pronounced near base. Heavily washed, hard crust on washed surfaces	35.5
23	CLAYSTONE, silty, slightly calcareous, poorly consolidated, dark yellowish brown (10YR 4/2), weathers moderate yellowish brown (10YR 5/4). Caps the ridge. Has washed over underlying sandstone	0.5
22	SANDSTONE, lithic graywacke, very fine to fine grained, poorly to fairly well consolidated, medium olive gray (5Y 5/1), weathers light olive gray (5Y 6/1). Fluted, hard crust on washed surfaces	9.0
21	SILTSTONE, clayey, medium to coarse grained, poorly consolidated, greenish gray (5GY 6/1), weathers light olive gray (5Y 6/1). Washed	1.0
20	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly consolidated, dark yellowish brown (10YR 4/2) to light olive brown (5Y 5/6), weathers to light olive gray (5Y 6/1) to moderate yellowish brown (10YR 5/4)	1.3

Unit		Feet
19	CLAYSTONE, ferruginous, calcareous, fairly well indurated, and SILTSTONE, clayey, calcareous, very fine to medium grained, poorly to fairly well consolidated; unit is light brown (5YR 5/6) to very dusky red (10R 2/2) to olive gray (5Y 6/1), weathers dark reddish brown (10R 3/4) to light olive gray (5Y 6/1)	1.0
18	CLAYSTONE, silty, poorly consolidated, dark yellowish orange (10YR 6/6) to dusky yellow (5Y 6/4), weathers moderate yellowish brown (10YR 5/4), shaly partings, 1/8 to ¼ inch thick	0.8
17	CLAYSTONE, silty, poorly consolidated, olive gray (5Y 4/1), weathers light olive gray (5Y 6/1). Heavily washed	1.0
16	LIGNITE, black (N1), weathers same to dark gray (N3). Shale, lignitic, grayish brown (5YR 3/2), weathers grayish red (10R 4/2), 0.5 feet at top. Carbonized plant remains, plant stem and leaf impressions . . .	1.8
15	SILTSTONE, clayey, very fine to fine grained, well consolidated, greenish gray (5GY 6/1), weathers light olive gray (5Y 6/1), blocky partings. Plant stem and leaf impressions .	2.5
14	SILTSTONE, clayey, fine to medium grained,	

Unit		Feet
	poorly consolidated, grayish brown (5YR 3/2), weathers dark yellowish brown (10YR 4/2). Washed	1.2
13	SHALE, and SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly to fairly well consolidated; unit is light olive gray (5Y 6/1), weathers olive gray (5Y 4/1), plant leaf and stem impressions . . .	1.8
12	SHALE, lignitic, blackish red (5R 2/2), weathers very dusky red (10R 2/2). Partially carbonized plant remains	0.4
11	SILTSTONE, clayey, slightly calcareous, very fine to fine grained, poorly consolidated, light olive gray (5Y 6/1) to medium olive gray (5Y 5/1), weathers same. Caps small ridge. Supports sparse vegetation	4.0
10	SILTSTONE, clayey, slightly calcareous, very fine to coarse grained, poorly to fairly well consolidated, light olive gray (5Y 5/2), weathers light olive gray (5Y 6/1). Fluted in lower 3.0 feet	10.0
9	LIGNITE, brownish black (5YR 2/1) to black (N1), weathers same. Shale, lignitic, dark reddish brown (10R 3/4), weathers moderate reddish brown (10R 4/6), 0.4 feet at base. Partially carbonized plant remains	1.7
8	SILTSTONE, clayey, medium to coarse grained,	

Unit		Feet
	fairly well consolidated, olive gray (5Y 4/1) to olive black (5Y 2/1), weathers light olive gray (5Y 6/1)	1.0
7	SANDSTONE, lithic graywacke, very fine to medium grained, fairly well consolidated, moderate yellowish brown (10YR 5/4), weathers same to light olive gray (5Y 6/1). Fluted	3.5
6	SANDSTONE, lithic graywacke, micaceous, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, yellowish gray (5Y-8/1), weathers light olive gray (5Y 6/1). Sandstone concretions, elliptical, 4.0 to 8.0 inches in diameter	4.5
5	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly consolidated, dusky yellow (5Y 6/4), weathers light olive gray (5Y-5/2). Selenite crystals scarce	2.0
4	LIGNITE, brownish black (5YR 2/1), weathers same to olive black (5Y 2/1). Selenite crystals common	5.0
3	SILTSTONE, clayey, slightly lignitic, very fine to medium grained, poorly to fairly well consolidated, grayish brown (5YR 3/2), weathers same to moderate brown (5YR 4/4). Carbonized plant remains	1.0
2	SILTSTONE, clayey, micaceous, medium to coarse	

Unit		Feet
	poorly consolidated, dark yellowish brown (10YR-4/2), weathers light olive gray (5Y 6/1). Contacts obscured by slumping. Fluted and washed.	5.5
1	SANDSTONE, lithic graywacke, very fine to medium grained, poorly consolidated, dark yellowish brown (10YR 4/2), weathers pale yellowish brown (10YR 6/2). Washed and fluted . . .	8.2

Base of section not exposed; covered by stream deposits.

2. Sperati Point North Section

SW¼ sec. 28, SE¼ sec. 29, R. 100 W., T. 148 N., about 24 miles south of Arnegard, McKenzie County, North Dakota. Base of section in SW¼, SW¼ sec. 28, at base of northeast-facing butte, about 1800 feet northeast of park road "turn-around" that is about ½ mile southeast of the west unofficial entrance, North Unit, Theodore Roosevelt National Memorial Park. Section measured by M. Clark, June, 1965; elevation at top of section, 2415 feet: Plate I.

Description

Top of section

Sentinel Butte Member

Unit		Feet
45	SILTSTONE, clayey, slightly calcareous, fine to medium grained, poorly consolidated, dusky yellow (5Y 6/4) to light olive brown (5Y 5/6), weathered yellowish gray (5Y 7/2). Sandstone lenses, fairly well indurated, irregularly cross-bedded, 4.0 to 10.0 feet long, 3.0 to 4.0 feet thick; forms ledges about 12.0 feet below top of unit. Top capped by prairie grass vegetation. Base obscured due to heavy washing . . .	18.5
44	CLAYSTONE, silty, poorly consolidated, olive gray (5Y 4/1), weathered light olive gray (5Y 6/1)	3.4
43	CLAYSTONE, lignitic, poorly consolidated, and SILTSTONE, lignitic, fine to medium grained,	

Unit		Feet
	poorly consolidated; unit is grayish brown (5YR 3/2) to black (N2), weathered pale yellowish brown (10YR 6/2) to moderate brown (5YR 4/4). Some claystone and siltstone beds have shaly partings	3.0
42	SILTSTONE, clayey, very fine grained, poorly consolidated, olive gray (5Y 4/1), weathered light olive gray (5Y 6/1)	13.2
41	SILTSTONE, clayey, very fine to medium grained, light olive brown (5Y 5/6) to medium olive brown (5Y 4/4), weathers light olive gray (5Y 5/2). Claystone and siltstone concretions, ferruginous, elliptical to subspherical, 0.5 to 1.0 feet in diameter, 1.0 to 2.0 feet below top of unit. Gastropods, scarce, poorly preserved, fragmental	8.6
40	CLAYSTONE, slightly silty, slightly calcareous, bentonitic, well consolidated, dusky yellow (5Y 6/4) to medium olive gray (5Y 5/1), weathers yellowish gray (5Y 7/2) to light olive gray (5Y 6/1), shaly partings	7.2
39	LIGNITE, black (N1), weathered same. Clay, 0.2 feet at base. Selenite crystals common. Covered by wash from overlying unit . .	1.7
38	SILTSTONE, clayey, slightly calcareous, very fine to coarse grained, poorly consolidated,	

Unit		Feet
	light olive brown (5Y 5/6), weathered dusky yellow (5Y 6/4). Heavily washed, some slumping, caps ridge for about 100 feet. Referred to as the "yellow bed"	26.5
37	SANDSTONE, lithic graywacke, slightly calcareous, very fine grained, poorly consolidated, and SILTSTONE, sandy, slightly calcareous, coarse grained, poorly consolidated; unit is dusky yellow (5Y 6/4) to light olive brown (5Y 5/6), weathers yellowish gray (5Y 7/2). Heavily washed, some slumping	18.0
36	SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poor to fairly well consolidated, light olive gray (5Y 6/1), weathers yellowish gray (5Y 8/1). Top of unit marked by siltstone bed, ferruginous, indurated, 0.5 feet thick. Hard crust on weathered surfaces	5.0
35	SILTSTONE, clayey, slightly calcareous, fine to medium grained, olive gray (5Y 5/1), weathers light olive gray (5Y 6/1). Carbonized plant remains	9.2
34	SHALE, lignitic, brownish gray (5YR 4/1) to brownish black (5YR 2/1), weathers same, fissile	0.6
33	SILTSTONE, clayey, fine to medium grained,	

Unit		Feet
	fairly well consolidated, olive gray (5Y 4/1), weathers light olive gray (5Y 6/1). Numerous beds of siltstone and claystone, ferruginous, indurated, 0.2 to 0.4 feet thick. Claystone concretions, ferruginous, "cannonball-like", 2.0 to 3.0 feet in diameter. Becomes less clayey in upper 1.5 feet	10.0
32	LIGNITE, brownish black (5YR 2/1) to black (N1), weathers same. Clay, 0.2 to 0.4 feet at base; Shale, 0.2 to 0.4 feet at top. Some ash and carbonized plant remains . . .	3.3
31	SILTSTONE, clayey, fine to medium grained, poorly to fairly well consolidated, light olive gray (5Y 5/2), weathers light olive gray (5Y 6/1). Partially carbonized plant remains	2.3
30	CLAYSTONE, silty, bentonitic, poorly consolidated, olive gray (5Y 4/1), weathers light olive gray (5Y 6/1). "Popcorn-like" surface on weathered exposures. Caps small ridge. Numerous glass shards	2.0
29	CLAYSTONE, silty bentonitic, slightly calcareous, poorly consolidated, medium olive gray (5Y 5/1), weathers light gray (N7). Numerous beds of claystone, ferruginous, 0.2 to 0.4 feet thick. Selenite crystals. Glass shards scarce. Gastropods, scarce, poorly preserved, fragmental	2.3

Unit		Feet
28	SHALE, well consolidated, olive gray (5Y 4/1) to brownish gray (5YR 4/1), weathers light olive gray (5Y 6/1) to brownish gray (5YR 4/1). Partially carbonized plant remains . . .	1.2
27	SILTSTONE, clayey, bentonitic, very fine to medium grained, poorly consolidated, olive gray (5Y 4/1), weathers light olive gray (5Y 6/1) to greenish gray (5GY 6/1). "Popcorn-like" surface on weathered exposures. Glass shards fairly common	1.7
26	CLAYSTONE, silty, bentonitic, slightly calcareous, poorly to fairly well consolidated, dark greenish gray (5GY 4/1), weathers medium light gray (N6). "Popcorn-like" surface on weathered exposures. Heavily washed; contact with underlying unit is gradational and hard to pick .	4.0
25	CLAYSTONE, silty, bentonitic, poorly to fairly well consolidated, medium dark gray (N4), weathers light gray (N7). Claystone concretions, ferruginous, laminations, ¼ to ½ inch thick, elliptical to subspherical, 1.0 to 3.0 feet in diameter. Contact with underlying unit is gradational and ill-defined. Numerous glass shards	3.5
24	CLAYSTONE, bentonitic, slightly calcareous, poorly to fairly well consolidated, olive gray (5Y 4/1) to dark greenish gray (5GY 4/1), weathers	

Unit		Feet
	to medium bluish gray (5B 5/1). X-ray analyses reveal presence of montmorillonite, quartz, potassic feldspar, sodic-calcic feldspar, calcite, and dolomite. "Popcorn-like" surface on weathered exposures. Plastic and very sticky when wet. Caps the ridge. Heavily washed. Basal 0.5 feet are well consolidated. Referred to as the "blue bed"	2.0
23	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, well consolidated, medium gray (N5), weathers light gray (N7) to light olive gray (5Y 6/1), fissile in places. Heavily washed	6.1
22	SILTSTONE, clayey, coarse grained, poorly consolidated, and CLAYSTONE, silty, poorly consolidated; unit is medium olive gray (5Y 4/1), weathers light olive gray (5Y 6/1). Siltstone concretions, ferruginous, elliptical, 1.0 to 1.5 feet in diameter. Numerous beds of siltstone and claystone, ferruginous, indurated, dark yellowish orange (10YR 6/6) to light brown (5YR 5/6), weathers same, 0.2 to 0.5 feet thick, present in upper 6.0 feet of unit. Fluted with pinnacles, common and well developed . .	20.5
21	SHALE, lignitic, poorly consolidated, pale brown (5YR 5/2), weathers same, partings, 1/8	

Unit		Feet
	to ½ inch thick	1.0
20	LIGNITE, brownish black (5YR 2/1) to black (N1), weathers same	2.0
19	SILTSTONE, clayey, lignitic, very fine to coarse grained, poorly consolidated, olive gray (5Y 4/1) to olive black (5Y 2/1), weathers light olive gray (5Y 6/1) . . .	1.3
18	CLAYSTONE, silty, poorly consolidated, medium olive gray (5Y 5/1), weathers light gray (N7)	9.0
17	CLAYSTONE, silty, poorly consolidated, light olive gray (5Y 6/1), weathers medium gray (N6)	0.5
16	SILTSTONE, clayey, coarse grained, poorly consolidated, medium olive gray (5Y 5/1), weathers light olive gray (5Y 6/1). Occasional beds of claystone and siltstone, ferruginous, indurated, 0.2 to 0.4 feet thick. Washed, slightly fluted	8.3
15	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly consolidated, dusky yellow (5Y 6/4), weathers pale olive (10Y 6/2). Numerous beds of claystone and siltstone, ferruginous, indurated, moderate brown (5R 4/4), weathers very dark red (5R 2/6) to moderate red brown (10R 4/6), 0.2 to 0.4 feet thick. Washed and fluted	11.0
14	LIGNITE, brownish black (5YR 2/1) to black (N1), weathers same. Siltstone, clayey, lignitic, very	

Unit		Feet
	fine to medium grained, well consolidated, baked, blocky partings, 0.5 feet at base. Carbonized plant remains	3.5
13	SILTSTONE, clayey, medium to coarse grained, poorly to fairly well consolidated, light brown (5YR 6/4) to pale yellowish brown (10YR 6/2), weathers light olive gray (5Y 6/1). Caps higher part of ridge. Heavily washed	3.0
12	SANDSTONE, lithic graywacke, very fine grained to fine grained, fairly well consolidated, light olive gray (5Y 6/1), weathers yellowish gray (5Y 8/1). Caps part of a small ridge, washed	2.0
11	SANDSTONE, lithic graywacke, very fine to medium grained, fairly well consolidated, light olive gray (5Y 6/1), weathers yellowish gray (5Y 8/1). Hard crust on washed surfaces, fluted	17.0
10	SILTSTONE, clayey, lignitic, micaceous, coarse grained, poorly consolidated, light olive gray (5Y 6/1) to olive black (5Y 2/1), weathers same to brownish gray (5YR 4/1), laminations ¼ to ½ inch thick	3.0
9	SANDSTONE, lithic graywacke, very fine to medium grained, fairly well consolidated, light	

Unit		Feet
	olive gray (5Y 6/1) to greenish gray (5GY 6/1), weathers light olive gray (5Y 6/1). Hard crust on washed surfaces	10.0
8	SILTSTONE, lignitic, coarse grained, poorly to fairly well consolidated, grayish brown (5YR 3/2) to dusky brown (5YR 2/2), weathers moderate yellowish brown (10YR 5/4), shaly partings .	2.0
7	SANDSTONE, lithic graywacke, very fine to medium grained, fairly well consolidated, light olive gray (5Y 6/1) to greenish gray (5GY 6/1), weathers light olive gray (5Y 6/1). Claystone concretions, ferruginous, elliptical to subspherical, ½ to 3.0 inches in diameter. Sandstone beds, cross-bedded, and lenticular sandstone bodies of unknown dimension, form ledges throughout the unit. Prominent sandstone bed, cross-bedded, 3.0 to 5.0 feet thick, is ledge former about 6.0 feet below top	50.6
6	SHALE, slightly lignitic, moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2), weathers pale yellowish brown (10YR 6/2), quite fissile	1.0
5	SHALE, medium brown (5YR 3/4) to grayish brown (5YR 3/2), weathers pale yellowish brown (10YR 6/2), poor fissility	1.5
4	SHALE, moderate yellowish brown (10YR 5/4) to	

Unit		Feet
	dark yellowish brown (10YR 4/2), weathers pale yellowish brown (10YR 6/2). Claystone bed, ferruginous, 0.2 feet thick at top of unit	1.7
3	SHALE, lignitic, moderate brown (5YR 4/4) to grayish brown (5YR 3/2), weathers pale yellowish brown (10YR 6/2) to dark yellowish brown (10YR 4/2), very fissile. Partings 1/8 to ½ inch thick. Carbonized plant remains in lower 0.5 feet	1.5
2	SILTSTONE, clayey, slightly calcareous, coarse grained, poorly consolidated, moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2), weathers pale yellowish brown (10YR 6/2). Washed	3.5
1	SANDSTONE, lithic graywacke, very fine to medium grained, fairly well consolidated, medium olive gray (5Y 4/1), to greenish gray (5GY 6/1), weathers light olive gray (5Y 6/1). Siltstone concretions, limonitic, elliptical, 1.0 to 4.0 inches in diameter	15.0
	Base of section not exposed; covered by stream deposits.	

3. Sperati Point South Section

SE¼ sec. 6, NE¼ sec. 7, R. 100 W., T. 147 N., about 25 miles south of Arnegard, McKenzie County, North Dakota. Base of section in NE¼, NE¼, sec. 7, about 20 feet from stream cut at base of south-facing butte, about 1.3 miles due east of Kellogg Ranch road and 0.5 mile due west of the boundary of the North Unit, Theodore Roosevelt National Memorial Park. Section measured by M. Clark, August, 1965; elevation at top of section 2410 feet: Plate II.

Description

Top of section

Glacial outwash (Wisconsinan ?)

Unit		Feet
53	GLACIAL OUTWASH, unstratified, dominantly gravel-sized debris of dominantly limestone, dolostone, and Canadian Shield-type igneous and metamorphic rocks, with lesser amounts of sand, silt, and clay. Many angular shaped boulders of granite and granite gneiss, 1.0 to 4.0 feet in diameter, are scattered over the hillsides. Debris from this unit has accumulated as talus on the "blue bed" and other stratigraphically lower units.	17.5

Sentinel Butte Member

Unit		Feet
52	SILTSTONE, clayey, slightly calcareous, fine to	

Unit		Feet
	medium grained, poorly consolidated, light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2). Numerous claystone beds, ferruginous, calcareous, fairly well indurated, light brown (5YR 5/6), weather dark yellowish orange (10YR 6/6). Sandstone concretions, cross-bedded, elliptical to subspherical, 0.5 to 2.0 feet in diameter. Pelecypods, common, poor preservation, fragmental	17.5
51	SHALE, lignitic, moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2). Woody and carbonized plant remains . . .	1.0
50	SILTSTONE, clayey, very fine to medium grained, poorly consolidated, light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2). Heavily washed	1.7
49	SHALE, lignitic, pale red (10R 6/2) to pale yellowish brown (10YR 6/2), weathers same. Woody to carbonized plant remains . . .	0.5
48	CLAYSTONE, silty, poorly consolidated, light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2). Heavily washed. Woody plant remains	2.8
47	SANDSTONE, lithic graywacke, very fine to medium grained, poorly consolidated, light olive gray (5Y 6/1), weathers same. Fluted . .	5.0
46	SILTSTONE, clayey, slightly calcareous, very	

Unit		Feet
	fine to fine grained, light olive gray (5Y 5/2), weathers light olive gray (5Y 6/1). Washed	1.7
45	SILTSTONE, clayey, slightly calcareous, fine to medium grained, fairly well consolidated, light olive gray (5Y 5/2) to (5Y 6/1), weathers same. Washed	2.5
44	CLAYSTONE, bentonitic, slightly calcareous, poorly to fairly well consolidated, olive gray (5Y 4/1), weathers light gray (N7). Washed. Woody and partially carbonized plant remains. Fresh surfaces moist	1.0
43	SANDSTONE, feldspathic graywacke, slightly calcareous, very fine grained, poorly to fairly well consolidated, light olive gray (5Y 6/1) to yellowish gray (5Y 8/1), weathers same. Laminations, 1/8 to ¼ inch thick. Hard crust on washed surfaces	1.6
42	SANDSTONE, lithic graywacke, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, light olive gray (5Y 6/1), weathers yellowish gray (5Y 8/1). Sandstone lenses, cross-bedded, 0.5 to 1.2 feet thick. Fluted, hard crust on washed surfaces	3.7
41	CLAYSTONE, bentonitic, fairly well to well consolidated, olive gray (5Y 4/1), weathers same to light olive gray (5Y 6/1). Woody and par-	

Unit		Feet
	tially carbonized plant remains. Gastropods scarce, poor preservation, fragmental . .	3.6
40	CLAYSTONE, bentonitic, silty, slightly calcareous, poorly to fairly well consolidated, olive gray (5Y 4/1), weathers light gray (N7). "Popcorn-like" surface on weathered exposures. Heavily washed	1.7
39	CLAYSTONE, bentonitic, slightly calcareous, poorly to fairly well consolidated, olive gray (5Y 4/1) to dark greenish gray (5GY 4/1), weathers bluish gray (5B 5/1). X-ray analyses reveal presence of montmorillonite, quartz, potassic feldspar, sodic-calcic feldspar, calcite, and dolomite. 71.0% clay, 28.5% silt, and 0.5% sand. Very plastic and sticky when wet. "Popcorn-like" surface on weathered exposures. Caps the ridge. Heavily washed. Referred to as the "blue bed".	5.6
38	CLAYSTONE, bentonitic, slightly silty, slightly calcareous, fairly well consolidated, light olive gray (5Y 6/1) to light gray (N7), weathers same. "Popcorn-like" surface on weathered exposures. Heavily washed. Pelecypods, scarce, poor preservation, fragmental	6.7
37	SHALE, lignitic, moderate brown (5Y 3/4) to dusky brown (5YR 2/2), weathers dark yellowish	

Unit		Feet
	brown (10YR 4/2) to dusky yellowish brown (10YR 2/2). Very lignitic in basal 0.5 feet. Leaf impressions and carbonized plant remains	2.2
36	SILTSTONE, clayey, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, medium olive gray (5Y 5/1), weathers yellowish gray (5Y 7/2). Numerous claystone beds, ferruginous, 0.2 to 0.4 feet thick. Sandstone lenses, cross-bedded, 0.4 to 0.6 feet thick, ledge formers	8.2
35	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly to fairly well consolidated, medium olive gray (5Y 5/1), weathers yellowish gray (5Y 7/2). Claystone concretions, ferruginous, elliptical to subspherical, 2.0 to 6.0 inches in diameter, several "log-like", 2.0 to 3.0 feet long, 0.2 to 0.5 feet thick. Pelecypods, scarce, poor preservation, fragmental	18.1
34	SHALE, lignitic, grayish brown (5YR 3/2), weathers dark yellowish brown (10YR 4/2). Woody and partially carbonized plant remains	0.2
33	CLAYSTONE, silty, slightly bentonitic, slightly calcareous, poorly consolidated, olive gray (5Y 4/1), weathered light gray (N7). "Popcorn-like" surface on weathered exposures.	

Unit		Feet
	Resembles the "blue bed"	6.8
32	LIGNITE, brownish black (5YR 2/1) to black (N1), weathers same to olive black (5Y 2/1). Shale, lignitic, 0.4 feet at top. Woody. Petrified stumps in the lignite, 1.0 to 3.0 feet in diameter	3.0
31	CLAYSTONE, lignitic, silty, fairly well consolidated, dark yellowish brown (10YR 4/2), weathers pale yellowish brown (10YR 6/2). Petrified wood from overlying lignite. Woody, plant remains	1.3
30	SILTSTONE, clayey, very fine to medium grained, poorly to fairly well consolidated, medium olive gray (5Y 5/1), weathers light gray (N7) to light olive gray (5Y 6/1). Partially carbonized petrified wood fragments. Fluted	7.3
29	SILTSTONE, clayey, slightly calcareous, very fine to fine grained, fairly well consolidated, medium olive gray (5Y 5/1) to dark yellowish orange (10YR 6/6), weathers light olive gray (5Y 6/1) to grayish orange (10YR 7/4). Occasional claystone beds, ferruginous, indurated, medium olive gray (5Y 5/1) to dark yellowish orange (10YR - 6/6), weathers same to dusky red (5R 3/4) to very dark red (5R 2/6)	16.2
28	LIGNITE, brownish black (5YR 2/1) to black	

Unit		Feet
	(N1), weathered same to olive black (5Y 2/1). Clay, lignitic, dark yellowish brown (10YR 4/2), weathers pale yellowish brown (10YR 6/2), 0.3 feet at base. Woody and carbonized plant remains	4.9
27	SILTSTONE, clayey, lignitic, very fine to fine grained, poorly to fairly well consolidated, light olive gray (5Y 6/1), weathers very pale orange (10YR 8/2). Woody and partially carbonized plant remains	1.3
26	CLAYSTONE, bentonitic, poorly consolidated, light olive gray (5Y 6/1), weathers yellowish gray (5Y 8/1) to light gray (N7). Caps the ridge. "Popcorn-like" surface on weathered exposures. Iron-manganese nodules, elliptical, 2.0 to 8.0 inches in diameter	4.5
25	CLAYSTONE, silty, slightly calcareous, poorly to fairly well consolidated, light olive gray (5Y 5/2) to medium olive gray (5Y 5/1), weathers yellowish gray (5Y 7/2) to light olive gray (5Y 6/1). Blocky partings. Woody . . .	2.8
24	SHALE, lignitic, grayish brown (5YR 3/2), weathers dark yellowish brown (10YR 4/2). Woody and carbonized plant remains . . .	0.5
23	CLAYSTONE, bentonitic, slightly lignitic, poorly to fairly well consolidated, light olive gray	

Unit		Feet
	(5Y 6/1) to medium olive gray (5Y 5/1), weathers same to light gray (N7). Selenite crystals common. Woody	1.6
22	SILTSTONE, clayey, very fine grained, poorly consolidated, olive gray (5Y 4/1), weathers light olive gray (5Y 6/1). Washed . . .	0.5
21	SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poorly to fairly well consolidated, yellowish gray (5Y 7/2) to grayish yellow (5Y 8/4), weathers same. Occasional claystone beds, ferruginous, 0.1 to 0.2 feet thick. Sandstone lenses, cross-bedded, 0.2 to 0.8 feet thick, ledge formers. Fluted and washed, pinnacles common	9.4
20	CLAYSTONE, bentonitic, slightly calcareous, poorly consolidated, light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2). Supports sparse vegetation	14.8
19	CLAYSTONE, bentonitic, slightly calcareous, poorly to fairly well consolidated, medium olive gray (5Y 5/1), weathers yellowish gray (5Y 8/1) to light olive gray (5Y 6/1). Well-developed "popcorn-like" surface on weathered exposures. Washed	7.9
18	SANDSTONE, lithic graywacke, fine to medium grained, fairly well consolidated, light olive	

Unit		Feet
	gray (5Y 6/1), weathers same. Sandstone lenses or lenticular bodies, cross-bedded, 1.0 to 1.5 feet thick, ledge formers about 1.0 foot above base. Hard crust on washed surfaces. Fluted	12.8
17	CLAYSTONE, silty, slightly calcareous, poorly consolidated, medium olive gray (5Y 5/1) to dusky yellow (5Y 6/4), weathers light olive gray (5Y 5/2) to light olive gray (5Y 6/1). Fluted, pinnacles common	7.2
16	LIGNITE, and CLAY, lignitic, poorly consolidated; unit is olive black (5Y 2/1) to black (N1), weathers same to pale yellowish brown (10YR 6/2). Fuller's earth (?) in the lignite, powdery and unconsolidated, moderate yellow (5Y 7/6), weathers same. Selenite crystals common .	3.9
15	CLAYSTONE, silty, slightly calcareous, poorly consolidated, olive gray (5Y 4/1), weathers light olive gray (5Y 6/1). Heavily washed .	4.0
14	SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poorly consolidated, moderate yellowish brown (10YR 5/4), weathers dusky yellow (5Y 6/4). Washed .	5.0
13	LIGNITE, brownish gray (5YR 4/1) to black (N1), weathers same. Clay, lignitic, 0.2 feet at base. Woody and carbonized plant remains. Selenite crystals common.	1.2

Unit		Feet
12	SILTSTONE, clayey, slightly bentonitic, fine to medium grained, poorly consolidated, dark yellowish brown (10YR 4/2), weathers pale yellowish brown (10YR 6/2). Poorly developed "popcorn-like" surface on weathered exposures. Washed	1.6
11	CLAYSTONE, bentonitic, poorly to fairly well consolidated, medium olive gray (5Y 5/1), weathers light olive gray (5Y 6/1) to greenish gray (5GY 6/1). Numerous glass shards. "popcorn-like" surface on weathered exposures. Washed	4.5
10	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, fairly well consolidated, light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2), blocky partings	3.9
9	LIGNITE, brownish gray (5YR 4/1) to brownish black (5YR 2/2), weathers same. Shale, lignitic, dark yellowish brown (10YR 4/2), weathers pale yellowish brown (10YR 6/2), 0.2 feet at top. Clay, lignitic, 0.5 feet at base. Woody to partially carbonized plant remains . . .	2.0
8	SILTSTONE, clayey, coarse grained, poorly consolidated, medium olive gray (5Y 5/1) to light olive brown (5Y 5/6), weathers same to light olive gray (5Y 6/1) to dark yellowish orange	

Unit		Feet
	(10YR 6/6). Washed	1.6
7	SANDSTONE, lithic graywacke, fine to coarse grained, poorly to fairly well consolidated, light olive gray (5Y 6/1) to medium olive gray (5Y-5/1), weathers to light olive gray (5Y 6/1). Sandstone lenses or lenticular bodies, cross-bedded, slightly calcareous, medium olive gray (5Y 5/1), weathers moderate brown (5YR 4/4), 6.0 to 8.0 feet long, 0.2 to 0.5 feet thick, ledge formers. Hard crust on washed surfaces	25.2
6	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly consolidated, light olive gray (5Y 6/1) to medium olive gray (5Y-5/1). Limonitic claystone concretions, sub-spherical, 1.0 to 8.0 inches in diameter, friable, marcasite interiors. Washed, pinnacles common. Gastropods, scarce, poor preservation, highly fragmental, found in lower 1.0 foot of unit.	3.7
5	SILTSTONE, clayey, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, light olive gray (5Y 6/1) to dark yellowish orange (10YR 6/6), weathers same. Occasional claystone beds, ferruginous, calcareous, indurated, 0.2 feet thick	6.5
4	SHALE, lignitic, dark yellowish brown (10YR 4/2),	

Unit		Feet
	weathers same to pale yellowish brown (10YR-6/2). Lignitic partings, 1/8 to ¼ inch thick	0.4
3	CLAYSTONE, slightly calcareous, fairly well consolidated, greenish gray (5GY 6/1) to medium olive gray (5Y 5/1), weathers same to light olive gray (5Y 6/1). Shaly partings in basal 0.2 feet. Washed	3.4
2	SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poorly to fairly well consolidated, light gray (N7), weathers same. Hard crust on washed surfaces	4.0
1	SANDSTONE, lithic graywacke, slightly calcareous, very fine to medium grained, fairly well consolidated, yellowish gray (5Y 8/1) to light olive gray (5Y 6/1), weathers same. Sandstone, lithic graywacke, slightly calcareous, cross-bedded, well consolidated, yellowish gray (5Y-8/1) to light olive gray (5Y 6/1), weathers same to moderate brown (5YR 4/4); 1.5 feet thick, 4.0 feet below top of unit, ledge former. Fluted, pinnacles common. Hard crust on washed surfaces	46.5

Base of section not exposed; covered by stream deposits.

4. Sperati Point West Section

SW¼ sec. 24, NW¼ sec. 25, R. 101 W., T. 148 N., about 24 miles south of Arnegard, McKenzie County, North Dakota. Base of section in NE¼, NW¼ sec. 25, at base of south-facing butte, about 20 feet north of east-west road that leaves west unofficial entrance of North Unit, Theodore Roosevelt National Memorial Park. Section measured by M. Clark, July, 1965; elevation at top of section, 2310 feet: Plate I.

Description

Top of section

Sentinel Butte Member

Unit		Feet
17	SANDSTONE, lithic graywacke, slightly calcareous, very fine grained, poorly consolidated, and SILTSTONE, ferruginous, slightly calcareous, coarse grained, poorly consolidated; unit is grayish orange (10YR 7/4) to dark yellowish orange (10YR 6/6) to light brown (5YR 5/6), weathers grayish orange (10YR 7/4) . . .	2.3
16	SHALE, lignitic, pale brown (5YR 5/2) to moderate brown (5YR 3/4), weathers pale yellowish brown (10YR 6/2) to pale brown (5YR 5/2), fissile, carbonized plant stems and leaves, more lignitic than underlying mudstone	1.1
15	MUDSTONE, lignitic, well consolidated, pale yellowish brown (10YR 6/2), weathers same, blocky, carbonized plant stems and leaves .	0.4

Unit		Feet
14	LIGNITE, shiny, black (N1), weathers dusky brown (5YR 2/2), selenite crystals common .	2.5
13	CLAY, grayish red (10R 4/2), weathers same, powdery	1.0
12	CLAYSTONE, slightly lignitic, poorly to fairly well consolidated, light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2), carbonized plant remains, supports sparse vegetation	2.3
11	SANDSTONE, lithic graywacke, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, light olive gray (5Y 6/1) to yellowish brown (10YR 6/2), weathers light olive gray (5Y 6/1). Siltstone concretions, limonitic, friable, elliptical to subspherical, 1.0 to 6.0 inches in diameter	5.0
10	CLAYSTONE, bentonitic, slightly calcareous, poorly consolidated, light olive gray (5Y 6/1), weathers same to light gray (N6). Numerous beds of claystone, calcareous, shaly, indurated, 0.1 to 0.4 feet thick	2.1
9	CLAYSTONE, bentonitic, slightly calcareous, fairly well consolidated, light olive gray (5Y 6/1), weathers same to light gray (N6). Numerous beds of claystone, ferruginous, calcareous, indurated, 0.1 to 0.4 feet thick. Gastropod	

Unit		Feet
	fragments, scarce, poorly preserved; some fossil shell coquina comprised mainly of gastropod and pelecypod fragments present as float. "Popcorn-like" surface on weathered exposures . .	2.4
8	CLAYSTONE, bentonitic, slightly calcareous, poorly to fairly well consolidated, medium olive gray (5Y 4/1) to dark yellowish brown (10YR 4/2), weathers same. "Popcorn-like" surface on weathered exposures; heavily washed . .	0.9
7	CLAYSTONE, bentonitic, slightly calcareous, poorly to fairly well consolidated, olive gray (5Y 3/2), weathers olive gray (5Y 4/1). X-ray analyses reveal presence of montmorillonite, quartz, potassic feldspar, sodic-calcic feldspar, calcite, and dolomite; 71% clay, 28% silt, and 1% sand. "Popcorn-like" surface on weathered exposures. Referred to as the "blue bed" .	2.1
6	SANDSTONE, lithic graywacke, calcareous, very fine to fine grained, poorly to fairly well consolidated, light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2). Numerous beds of claystone and siltstone, ferruginous, indurated, light brown (5YR 5/6), weathers dark yellowish orange (10YR 6/6), 0.1 to 0.3 feet thick. Claystone concretions, common, calcareous, ferruginous, subspherical, 0.1 to 0.4 feet in diameter;	

Unit		Feet
	some concretions are lenticular, 2.0 to 4.0 feet long, 2.5 to 5.0 feet above base of unit	23.9
5	SHALE, calcareous, pale brown (5YR 5/2), weathers pale yellowish brown (10YR 6/2), not very fissile	0.9
4	SANDSTONE, lithic graywacke, slightly calcareous, micaceous, very fine grained, poorly consolidated, yellowish gray (5Y 7/2) to light olive gray (5Y 6/1), weathers same . . .	3.3
3	SANDSTONE, lithic graywacke, slightly calcareous, very fine grained, poorly consolidated, yellowish gray (5Y 7/2) to light olive gray (5Y 6/1), weathers yellowish gray (5Y 7/2). Numerous ferruginous, calcareous, sandstone, siltstone and claystone concretions or "log-like" concretionary-like lenses, indurated, irregularly cross-bedded, 1.0 to 25.0 feet long, 1.0 to 5.0 feet thick	5.4
2	SILTSTONE, clayey, calcareous, medium to coarse grained, poorly consolidated, light olive gray (5Y 6/1) to light gray (N7), weathers light olive gray (5Y 6/1). Top of unit marked by claystone bed, ferruginous, indurated, dark yellowish orange (10YR 6/6) to moderate yellowish brown (10YR 5/4), weathered same, 0.2 to 0.4 feet thick. Washed and slightly fluted. Glass shards	

Unit		Feet
	scarce	1.0
1	SILTSTONE, slightly calcareous, medium to coarse grained, poorly consolidated, yellowish gray (5Y 7/2) to light olive gray (5Y 6/1), weathers same. Numerous glass shards	7.8

Base of section begins at base of unit 1.

5. Kellogg Ranch Section

NW¼ sec. 20, R. 100 W., T. 147 N., about 27 miles south of Arnegard, McKenzie County, North Dakota. Base of section in NE¼, NW¼ sec. 20, about 20 feet east of stream cut, at base of southwest-facing butte, about 1000 feet due south of Kellogg Ranch road. Section measured by M. Clark, June, 1965; elevation at top of section, 2485 feet: Plate II.

Description

Top of section

Sentinel Butte Member

Unit		Feet
33	SILTSTONE, clayey, slightly calcareous, fine to medium grained, poorly consolidated, dark yellowish brown (10YR 4/2), weathers same. Many well-rounded pebbles of red, brown, gray, and yellow quartzite in upper 2.0 feet. Caps the butte. Glass shards fairly common . . .	13.5
32	LIGNITE and SHALE, lignitic; unit is brownish gray (5YR 4/1) to black (N1), weathers light brownish gray (5YR 6/1) to medium dark gray (N4). Clay, lignitic, moderate brown (5YR 3/4), weathers dark yellowish brown (10YR 4/2), 0.7 feet at base. Woody and carbonized plant remains	5.8
31	SILTSTONE, clayey, fine to medium grained, poorly consolidated, light olive gray (5Y 5/2),	

Unit		Feet
	weathers yellowish gray (5Y 7/2). Washing has obscured contacts. Caps part of the ridge. Supports sparse vegetation	4.3
30	SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poorly to fairly well consolidated, and SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly to fairly well consolidated; unit is yellowish gray (5Y 7/2) to light olive gray (5Y 6/1), weathers same. Prominent sandstone beds, cross-bedded, well consolidated, ledge formers; 2.5 feet above base is bed 2.5 feet thick, 9.5 feet above base is bed 1.5 feet thick. Sandstone lenses, cross-bedded, 1.0 to 3.0 feet long, 0.2 to 0.8 feet thick, in upper 15 to 20 feet of the unit. Washed and fluted. Leaf impressions in the siltstone . . .	29.0
29	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, fairly well consolidated, yellowish gray (5Y 7/2) to dusky yellow (5Y 6/4), weathers same. Slightly fluted. Pelecypods and gastropods, scarce, poorly preserved, fragmental	8.4
28	LIGNITE, black (N1), weathers same to medium dark gray (N4). Clay, lignitic, powdery, moderate brown (5YR 3/4), weathers dark yellowish brown (10YR 4/2), 0.3 feet at base; Shale, lig-	

Unit		Feet
	nitic, 0.2 feet at top. Selenite crystals common	1.4
27	CLAYSTONE, slightly calcareous, poorly to fairly well consolidated, yellowish gray (5Y 8/1), weathers very pale orange (10YR 8/2). Highly washed. Supports sparse vegetation	2.6
26	SILTSTONE, clayey, slightly calcareous, coarse grained, poorly consolidated, and SANDSTONE, feldspathic graywacke, slightly calcareous, very fine to fine grained, poorly to fairly well consolidated; unit is grayish yellow (5Y 8/4) to dusky yellow (5Y 6/4), weathers grayish yellow (5Y 8/4). Sandstone concretions or "concretionary-like" bodies, common, subspherical, 2.0 to 4.0 inches in diameter. Caps the point. Supports prairie grass vegetation	21.0
25	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly to fairly well consolidated, dusky yellow (5Y 6/4), weathers yellowish gray (5Y 7/2). 57.5% silt, 42.0% clay, and 0.5% sand. Pelecypods and gastropods, fairly abundant, poorly to fairly well preserved. Referred to as the "yellow bed"	12.5
24	LIGNITE, black (N1), weathers medium dark gray (N4). Clay, lignitic, 0.2 feet at base.	

Unit		Feet
	Contacts obscured by wash and slump from overlying siltstone	1.8
23	SILTSTONE, clayey, slightly calcareous, coarse grained, poorly consolidated, yellowish gray (5Y 7/2), weathers very pale orange (10YR 8/2). Weathered surfaces are powdery. Supports sparse vegetation	2.0
22	SILTSTONE, clayey, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, dusky yellow (5Y 6/4), weathers yellowish gray (5Y 7/2). Heavily washed. Fresh surfaces moist. Woody plant remains	3.0
21	SILTSTONE, lignitic, clayey, very fine to fine grained, poorly to fairly well consolidated, olive gray (5Y 4/1) to black (N1), weathers light olive gray (5Y 6/1). Contacts obscured by wash and slump from overlying siltstone . . .	1.1
20	CLAYSTONE, slightly silty, poorly consolidated, olive gray (5Y 4/1), weathers light olive gray (5Y 6/1). Washed. Calcareous deposits on weathered surfaces produce a mottled appearance .	5.5
19	SILTSTONE, clayey, very fine grained, poorly consolidated, dusky yellow (5Y 6/4), weathers yellowish gray (5Y 7/2). Shaly partings, ¼ to ½ inch thick. Numerous beds of claystone, ferruginous, 0.2 feet thick. Slightly washed .	5.5

Unit		Feet
18	CLAYSTONE, bentonitic, slightly calcareous, fairly well consolidated, olive gray (5Y 4/1), weathers yellowish gray (5Y 8/1) to light olive gray (5Y 6/1). Shaly partings 1/8 to ¼ inch thick. Woody plant remains . . .	1.4
17	SANDSTONE, lithic graywacke, slightly calcareous, very fine to medium grained, poorly to fairly well consolidated, yellowish gray (5Y 8/1) to light olive gray (5Y 6/1), weathers same. Sandstone lenses, 0.2 to 0.5 feet thick. Sandstone concretions, cross-bedded, 2.0 to 6.0 inches in diameter	5.0
16	CLAYSTONE, bentonitic, slightly calcareous, poorly to fairly well consolidated, medium olive gray (5Y 5/1), weathers light olive gray (5Y 6/1). "Popcorn-like" surface on weathered exposures. Fresh surfaces moist . . .	2.1
15	LIGNITE and SHALE, lignitic, brownish gray (5YR 4/1) to black (N1), weathers light brownish gray (5YR 6/1), blocky to shaly partings. Selenite crystals common. Woody to carbonized plant remains	2.2
14	CLAYSTONE, lignitic, fairly well consolidated, olive gray (5Y 4/1), weathers yellowish gray (5Y 8/1) to light olive gray (5Y 6/1). Woody to partially carbonized plant remains . .	2.0

Unit		Feet
13	LIGNITE and SHALE, lignitic, black (N1) to grayish black (N2), weathers medium dark gray (N4). Clay, lignitic, powdery, 0.2 feet at base	0.8
12	CLAYSTONE, bentonitic, poorly consolidated, olive gray (5Y 4/1), weathers pale yellowish brown (10YR 6/2). Woody to partially carbonized plant remains	1.1
11	SILTSTONE, clayey, fine grained, poorly consolidated, yellowish gray (5Y 8/1), weathers very light gray (N8). Upper 0.2 feet is shaly with lignitic partings. Selenite crystals scarce	1.2
10	CLAYSTONE, bentonitic, poorly consolidated, olive gray (5Y 4/1), weathers light gray (N7). "Popcorn-like" surface on weathered exposures. Fresh surfaces moist. Glass shards scarce .	1.5
9	SILTSTONE, clayey, fine grained, poorly consolidated, yellowish gray (5Y 8/1), weathers very light gray (N8). Selenite crystals scarce	1.3
8	CLAYSTONE, silty, calcareous, slightly bentonitic, poorly consolidated, brownish gray (5YR 4/1) to olive gray (5Y 4/1), weathers light olive gray (5Y 6/1). "Popcorn-like" surfaces on weathered exposures. Fresh surfaces moist. Slightly washed	1.5

Unit		Feet
7	CLAYSTONE, bentonitic, slightly calcareous, poorly to fairly well consolidated, olive gray (5Y 4/1), weathers medium light gray (N6). X-ray analyses reveal presence of montmorillonite, quartz, potassic feldspar, sodic-calcic feldspar, calcite, and dolomite. 78% clay, 20% silt, and 2% sand. "Popcorn-like" surface on weathered exposures. Plastic and very sticky when wet. Fresh surfaces moist. Referred to as the "blue bed"	1.5
6	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, poorly consolidated, and CLAYSTONE, silty, slightly calcareous, slightly bentonitic; unit is olive gray (5Y 4/1), weathers light olive gray (5Y 6/1) to yellowish gray (5Y 7/2). Sandstone lenses, cross-bedded, 0.2 to 1.0 feet thick. Poorly developed "popcorn-like" surface on weathered exposures. Fluted with pinnacles common	17.5
5	SHALE, lignitic, pale red (10R 6/2) to pale yellowish brown (10YR 6/2) to dusky brown (5YR 2/2), weathers pale red (10R 6/2) to pale yellowish brown (10YR 6/2), fissile. Partings 1/8 to ¼ inch thick. Carbonized plant remains . .	2.0
4	SANDSTONE, lithic graywacke, slightly calcareous, fine to medium grained, poorly to fairly well con-	

Unit		Feet
	solidated, light olive gray (5Y 6/1) to yellowish gray (5Y 7/2) to medium olive gray (5Y 5/1), weathers light olive gray (5Y 6/1) to yellowish gray (5Y 7/2). Limonitic siltstone concretions, subspherical, 2.0 to 6.0 inches in diameter. Occasional beds of siltstone and claystone, ferruginous, calcareous, indurated, 0.2 to 0.4 feet thick. Sandstone lenses, cross-bedded, 0.4 to 0.8 feet thick. Washed, slightly fluted	13.5
3	SHALE, very pale orange (10YR 8/2) to grayish orange (10YR 7/4), weathers same. Lignitic partings, 1/8 to ¼ inch thick	0.6
2	CLAYSTONE, silty, slightly calcareous, poorly consolidated, olive gray (5Y 4/1), weathers light gray (N7). Partings ¼ to ½ inch thick. Slumped and heavily washed	1.5
1	SILTSTONE, clayey, slightly calcareous, very fine to medium grained, fairly well consolidated, dusky yellow (5Y 6/4) to medium olive gray (5Y 5/1), weathers light olive gray (5Y 6/1) to yellowish gray (5Y 7/2). Washed . . .	7.9
	Base of section not exposed; covered by stream deposits.	

6. Achenback Hills Section

SE¼ sec. 11, R. 100 W., T. 147 N., about 28 miles south-southeast of Arnegard, McKenzie County, North Dakota. Base of section in NW¼,SE¼ sec. 11, at base of south-facing butte about 500 feet south of east-west road on south side of Little Missouri River in North Unit, Theodore Roosevelt National Memorial Park. Section measured by M. Clark, July, 1965; elevation at top of section, 2586 feet: Plate II.

Description

Top of section

Golden Valley Formation

Unit		Feet
5	SANDSTONE, micaceous, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, dark yellowish orange (10YR 6/6) to pale yellowish orange (10YR 8/6), weathers same. Claystone concretions, ferruginous, calcareous, subspherical, 2.0 to 8.0 inches in diameter. Caps the Achenback Hills. "Pseudo-quartzite" (lag gravel?) found on hillsides rests on this unit. Supports abundant prairie grass vegetation. This unit, as present in Sperati Point Quadrangle, has maximum thickness of about 160 feet	10.5
4	SILTSTONE, clayey, slightly calcareous, medium grained, poorly to fairly well consolidated, grayish yellow (5Y 8/4) to yellowish gray	

Unit		Feet
	(5Y 7/2), weathers same. Very homogeneous unit.	5.0
3	CLAYSTONE, silty, slightly calcareous, poorly consolidated, light brownish gray (5YR 6/1) to pale red purple (5RP 6/2)	1.0
2	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly to fairly well consolidated, grayish yellow (5Y 8/4) to yellowish gray (5Y 7/2), weathers same. Very homogeneous unit. Resembles unit 4	2.5
1	CLAYSTONE, silty, slightly calcareous, poorly consolidated to fairly well consolidated, light brownish gray (5YR 6/1) to pale red purple (5RP 6/2), weathers same; may have shaly partings. Base of this unit picked as base of Golden Valley Formation in Sperati Point Quadrangle.	1.0

Contact with underlying Sentinel Butte Member believed to be gradational.

Sentinel Butte Member

Unit		Feet
24	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly consolidated, grayish yellow (5Y 8/4) to yellowish gray (5Y 7/2). Laminations ¼ to ½ inch thick. Glass shards scarce. Very homogeneous unit	10.0

Unit		Feet
23	LIGNITE, and SHALE, lignitic, light olive gray (5Y 6/1) to olive gray (5Y 4/1) to brownish black (5YR 2/1), weathers same. Contacts obscured by washing	0.5
22	SILTSTONE, clayey, slightly calcareous, coarse grained, poorly consolidated, and SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poorly to fairly well consolidated; unit is yellowish brown (10YR 6/2) to yellowish gray (5Y 7/2), weathers same. Heavily washed	16.0
21	LIGNITE, brownish black (5YR 2/1) to olive black (5Y 2/1) , weathers same. Clay, lignitic, 0.5 feet at base, lignitic partings. Selenite crystals common	2.0
20	SILTSTONE, clayey, slightly calcareous, very fine to coarse grained, poorly consolidated, light gray (N7) to light olive gray (5Y 6/1). Selenite crystals scarce	10.0
19	SILTSTONE, clayey, slightly calcareous, medium grained, poorly consolidated, yellowish gray (5Y 7/2) to light olive gray (5Y 6/1), weathers same. Heavily washed and slumped . . .	7.5
18	LIGNITE, brownish black (5YR 2/1) to black (N1), weathers same. Clay, lignitic, 0.5 feet at base. Shale, lignitic, 0.2 feet at top.	

Unit		Feet
	Woody and carbonized plant remains. Large selenite crystals up to 5.0 inches long. Contacts obscured by washing and slumping .	3.0
17	CLAYSTONE, silty, slightly bentonitic, poorly to fairly well consolidated, light gray (N7) to light olive gray (5Y 6/1), weathers same. Caps the ridge. Poorly developed "popcorn-like" surface on weathered exposures. Fresh surfaces moist. Selenite crystals scarce .	4.9
16	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly consolidated, light olive gray (5Y 6/1), weathers same to yellowish gray (5Y 7/2). Numerous beds of claystone, ferruginous, calcareous, poorly consolidated, 0.2 to 0.4 feet thick	5.0
15	SANDSTONE, lithic graywacke, slightly calcareous, very fine to medium grained, poorly to fairly well consolidated, light olive gray (5Y 6/1) to medium olive gray (5Y 5/1), weathers same. Hard crust on washed surfaces. Fluted	10.4
14	SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poorly to fairly well consolidated, and SILTSTONE, clayey, slightly calcareous, medium to coarse grained, poorly to fairly well consolidated; unit is light olive gray (5Y 6/1) to yellowish gray (5Y 7/2), weathers	

Unit		Feet
	same. Numerous limonitic siltstone concretions, subspherical 1.0 to 8.0 inches in diameter, friable, marcasite interiors	16.0
13	LIGNITE, brownish black (5YR 2/1) to black (N1), weathers same. Clay, lignitic, 0.8 feet at base. Selenite crystals common. Good quality lignite	3.8
12	CLAYSTONE, silty, poorly to fairly well consolidated, light olive gray (5Y 6/1) to greenish gray (5GY 8/1), weathers same to yellowish gray (5Y 7/2). Woody plant remains	3.5
11	SILTSTONE, clayey, slightly calcareous, fine to coarse grained, fairly well consolidated, and SANDSTONE, lithic graywacke, slightly calcareous, very fine to medium grained, poorly consolidated; unit is yellowish gray (5Y 7/2) to light olive gray (5Y 6/1), weathers same. Numerous beds of claystone, ferruginous, calcareous, poorly to fairly well consolidated, moderate yellowish brown (10YR 5/4) to dark yellowish orange (10YR 6/6), weathers same. Glass shards scarce	17.5
10	SILTSTONE, clayey, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, light olive gray (5Y 6/1), weathers same. Shaly to blocky partings, laminations 1/8 to ¼	

Unit		Feet
	thick.	3.5
9	SHALE, lignitic, pale red (10R 6/2) to pale yellowish brown (10YR 6/2) to dusky brown (5YR 2/2), weathers same. Lignitic partings, 1/8 to ¼ inch thick. Woody to partially carbonized plant remains	0.4
8	CLAYSTONE, silty, slightly calcareous, poorly to fairly well consolidated, yellowish gray (5Y 7/2), weathers same. Numerous claystone beds, ferruginous, calcareous, 0.1 to 0.2 feet thick	5.0
7	LIGNITE, grayish black (N2) to brownish black (5YR 2/1), weathers same. Clay, lignitic, 1.5 feet at base	5.0
6	SANDSTONE, lithic graywacke, very fine to fine grained, poorly consolidated, greenish gray (5GY 6/1) to light olive gray (5Y 6/1), weathers same. Laminations, ¼ to ½ inch thick . .	15.0
5	SANDSTONE, lithic graywacke, fine to medium grained, fairly well consolidated, and SILTSTONE, fine to medium grained, fairly well consolidated; unit is moderate reddish orange (10R-6/1) to light olive gray (5Y 6/1) to moderate reddish brown (10R 4/6), weathers same. Columnar jointing in sandstone; appears to be "scoritized"	7.0

Unit		Feet
4	SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poorly consolidated, light olive gray (5Y 6/1) to brownish gray (5YR 4/1). Washed and slumped . . .	16.0
3	SILTSTONE, clayey, slightly calcareous, medium to coarse grained, very poorly consolidated, and SANDSTONE, lithic graywacke, very fine to fine grained, poorly consolidated; unit is yellowish gray (5Y 8/1) to light olive gray (5Y 6/1), weathers same. Limonitic siltstone concretions, common, subspherical, 2.0 to 5.0 inches in diameter, friable, marcasite interiors. Hard crust on washed surfaces	7.5
2	SILTSTONE, clayey, slightly calcareous, fine to medium grained, poorly to fairly well consolidated, light olive gray (5Y 6/1) to moderate yellowish brown (10YR 5/4), laminations, ¼ to ½ inch thick. Numerous limonitic siltstone concretions, subspherical to elliptical, 2.0 to 8.0 inches in diameter. Washed and slumped. Referred to as the "yellow bed"	40.0
1	SANDSTONE, lithic graywacke, slightly calcareous, very fine to fine grained, poorly to fairly well consolidated, yellowish gray (5Y 7/2), weathers same. Claystone concretions, ferruginous, elliptical to subspherical, 2.0 to 4.0	

Unit		Feet
	inches in diameter. Supports some vegetation near the base. Heavily washed	27.0

Base of section is not exposed; covered by slump.

GEOLOGIC MAP OF THE SPERATI POINT QUADRANGLE

McKENZIE COUNTY, NORTH DAKOTA

By Michael B. Clark, 1966

THEODORE ROOSEVELT NATIONAL MEMORIAL PARK

R. 101 W. R. 100 W. — 27'30" — 25' — 103°22'30" — 103°30' — 47°37'30" — 35' — 32'30" — 47°30'

T. 148 N. — T. 147 N. — T. 146 N.

PARK BOUNDARY

Sperati Point — Achenback Hills — Kellogg Ranch — Steele Ranch

Appel Creek — Scenic Lookout — Cirral Creek — Bennett Creek — Sheep Creek

MISSOURI RIVER — LITTLE MISSOURI RIVER

Ttr — Ttrb — Ttry — Tgv — Qo — Qw — Qal — Qlsd

SCALE 1:12,000

0 — ½ — 1 MILE

Qal	Qlsd	Qo	Qw	Tgv	Ttr	Ttry	Ttrb
Alluvium	Slump	Outwash	Wiota gravels (?)	Golden Valley Formation	Sentinel Butte Member (undifferentiated)	Yellow bed	Blue bed
RECENT (?)		PLEISTOCENE		EOCENE	PALEOCENE		
QUATERNARY							

Geologic contact (dotted where concealed)

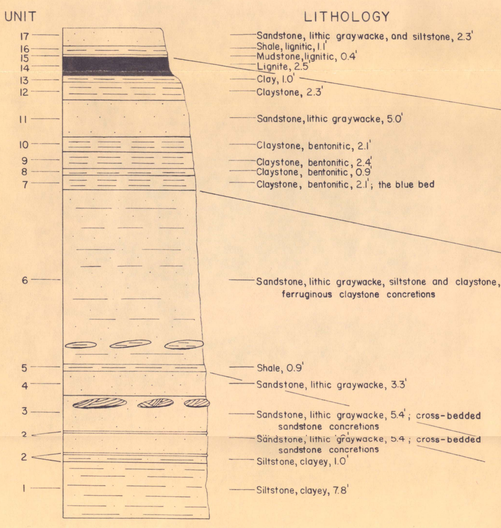
Inferred geologic contact

Unimproved road

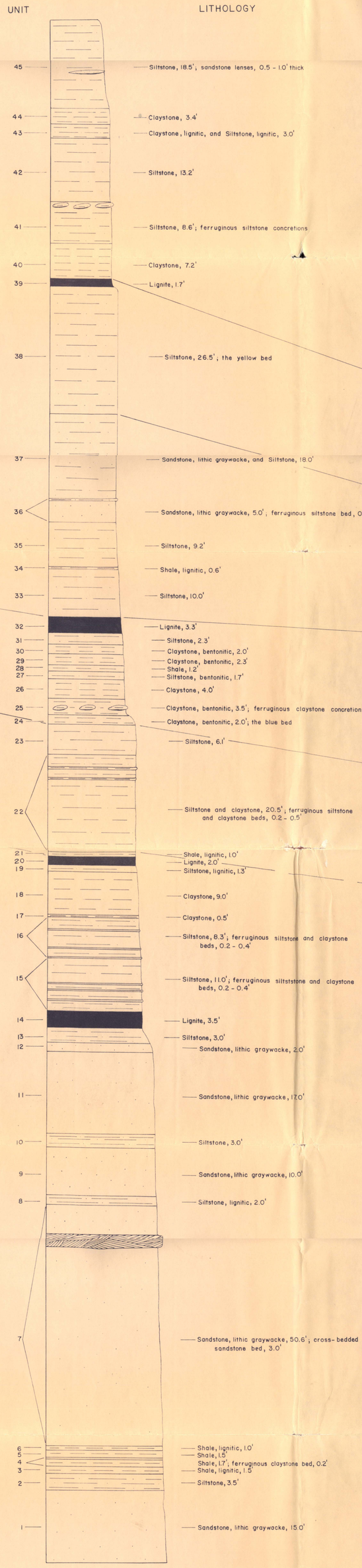
Trail

Intermittent stream

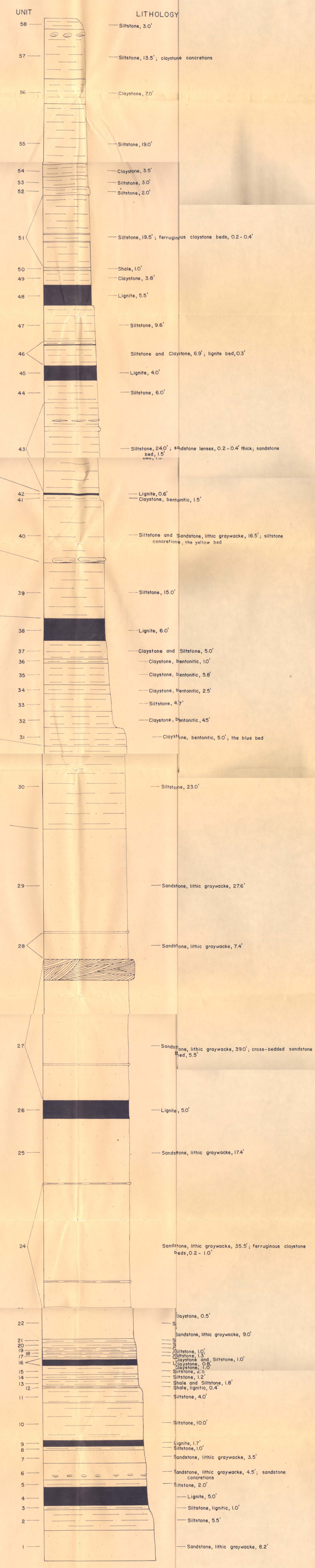
SPERATI POINT WEST SECTION
-4-



SPERATI POINT NORTH SECTION
-2-



SCENIC LOOKOUT SECTION
-1-



LEGEND

- Sandstone
- Sandstone, cross-bedded
- Siltstone
- Claystone or Shale
- Lignite
- Concretions
- Lenses

VERTICAL SCALE 1": 10'

HORIZONTAL SCALE 1": 1,500'

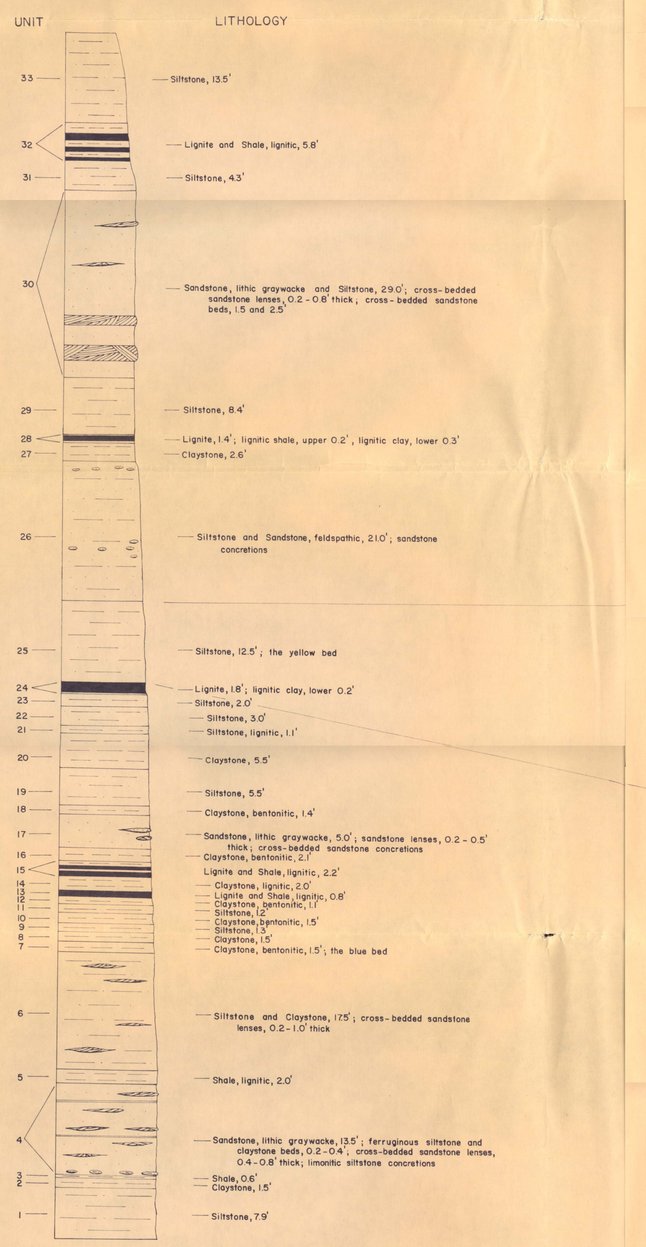
(sections positioned on sea level datum)

PLATE II. STRATIGRAPHIC SECTIONS OF THE SENTINEL BUTTE MEMBER IN THE SPERATI POINT QUADRANGLE, McKENZIE COUNTY, NORTH DAKOTA

BY Michael B. Clark

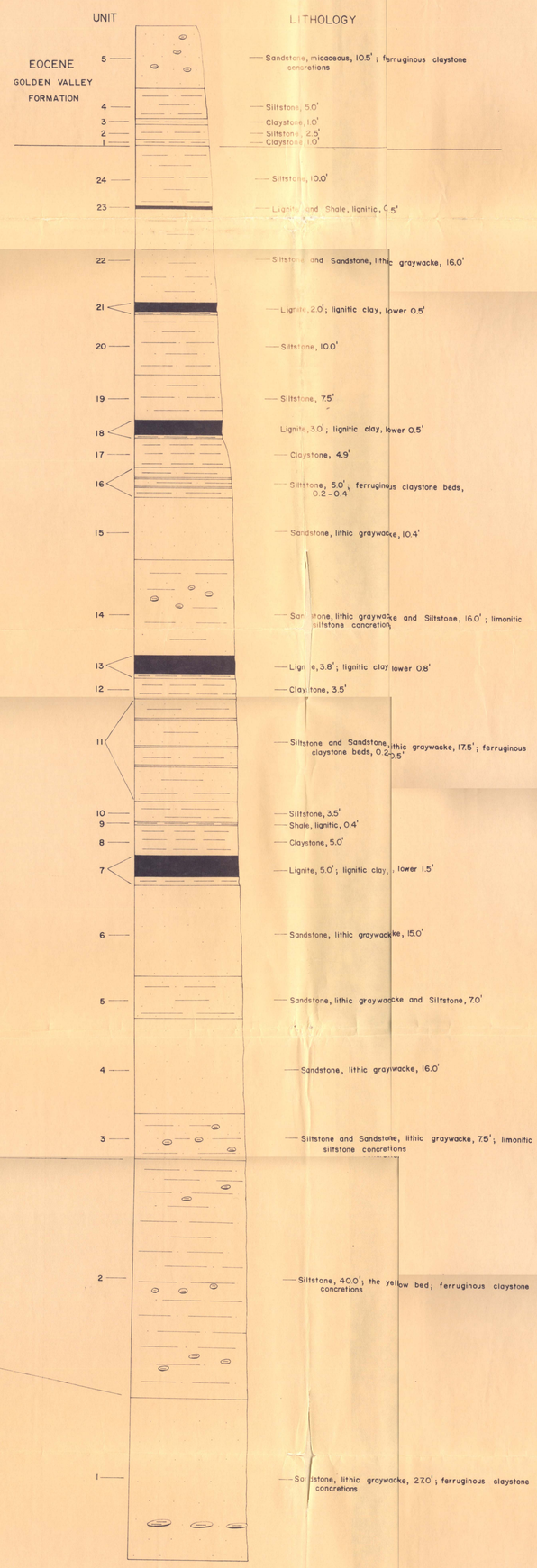
KELLOGG RANCH SECTION

-5-



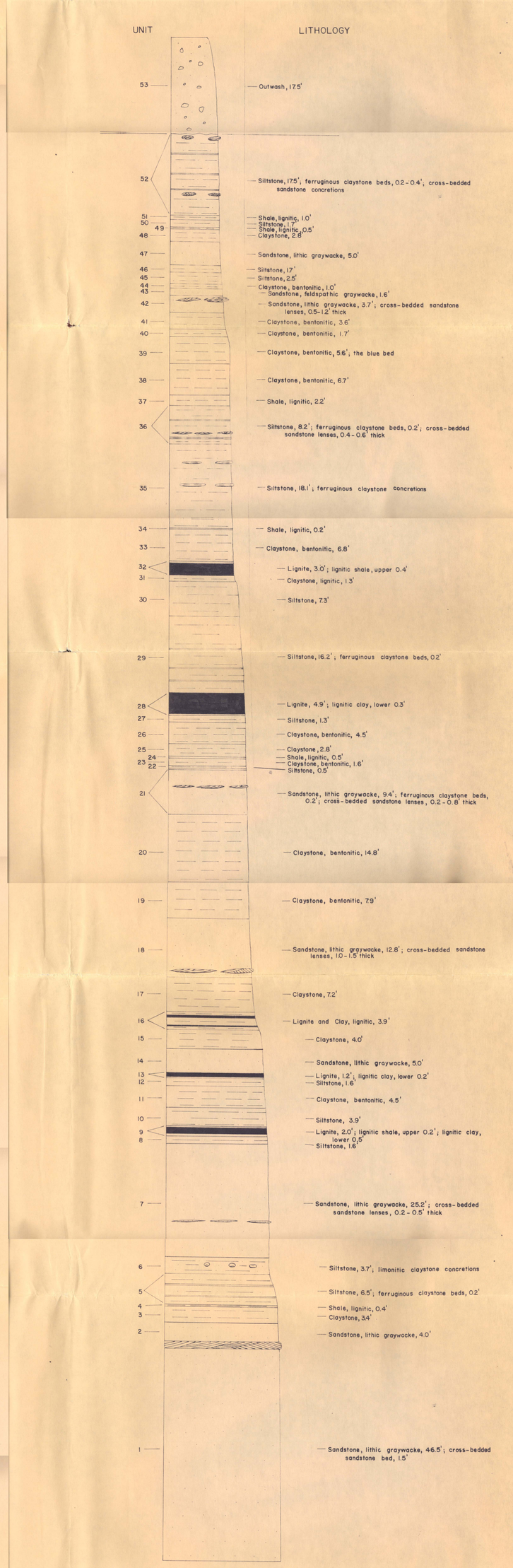
ACHENBACK HILLS SECTION

-6-



SPERATI POINT SOUTH SECTION

-3-



LEGEND

- Sandstone
- Sandstone, cross-bedded
- Siltstone
- Claystone or Shale
- Lignite
- Concretions
- Lenses

VERTICAL SCALE 1": 10'

20' 15 10 5 0

HORIZONTAL SCALE 1": 1,500'

(sections positioned on sea level datum)

PLATE III. STRATIGRAPHIC SECTIONS OF THE SENTINEL BUTTE MEMBER IN THE SPERATI POINT QUADRANGLE, McKENZIE COUNTY, NORTH DAKOTA

BY Michael B. Clark

LEGEND

Qo	Outwash
Tgv	Golden Valley Formation
Ttr	Sentinel Butte Member (undifferentiated)
Ttry	Yellow bed
Ttrb	Blue bed

Vertical Scale
200 Feet
100
50
0

Horizontal Scale
0 0.5 1.0 Mile

PLATE IV. FENCE DIAGRAM OF THE SENTINEL BUTTE MEMBER IN THE SPERATI POINT QUADRANGLE, McKENZIE COUNTY, NORTH DAKOTA

By Michael B. Clark, June 2, 1966