North Dakota Geological Survey
WILSON M. LAIRD, *Director*
Bulletin 14

The Geology of the Southern Part of Morton County, North Dakota

By

WILSON M. LAIRD
and
ROBERT H. MITCHELL

Grand Forks, North Dakota, 1942

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The Geology of the Southern Part of Morton County, North Dakota

WILSON M. LAIRD[1] and ROBERT H. MITCHELL[2]

INTRODUCTION

Abstract

In the southern part of Morton County the Fox Hills and Hell Creek formations of the Cretaceous period and the Ludlow, Cannonball, and Tongue River formations of the Paleocene series of the Tertiary period are exposed at the surface. These formations are described in detail. Elevations on various beds in the area were taken by means of a Paulin altimeter and a structure map was plotted from this information. The physiography of the area including possible erosion levels and pre-glacial drainage is described. The locations of coal, clay and gravel deposits are noted.

Location

The area of this report is located in the southern part of Morton County, North Dakota, in Townships 133 to 136 North, Ranges 79 to 84 West inclusive.

Geography of the area

In this part of Morton County there are primarily two industries, farming and ranching. In general, it can be said that the farming is carried on on the rolling upland formed by the Cannonball and Tongue River formations. Cattle raising is usually confined to the lowlands on the Hell Creek near the Cannonball River where the soil is not good enough for crops but raises enough grass for satisfactory pasture in moist years. Water and shelter are also available here for the cattle.

Both farming and cattle raising are largely dependent on the amount of rainfall the area receives. The average annual rainfall is about 15 inches per year. This amount would place this region in the middle latitude steppe type of climate according to the Köppen system of climatology as modified by Trewartha[3]. The soil on all the formations exposed in the area except that on the Hell Creek appears to be fertile and in many places still retains the native prairie sod.

This part of the county is served by a branch line of the Northern Pacific Railroad which runs from Mandan south to Cannonball and thence west through Flasher terminating at Mott. There are two gravelled state highways in this area: Route 6 connecting Breien and Mandan by way of St. Anthony; and Route 21 east from Flasher joining Route 6 about 6½ miles north of Breien. Numerous county roads on nearly every section line and prairie trails make most places in the area fairly accessible.

The towns in this part of Morton County are few. The largest is Flasher in the southwestern part, and the next larger is St. Anthony in the north-central part of the county.

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[1] State Geologist, North Dakota Geological Survey.

[2] Assistant Professor of Geology, Muskingum College, New Concord, Ohio.

[3] Trewartha, G. T., An introduction to weather and climate, Third edition, Plate I, New York, McGraw-Hall Book Co., Inc., 1937.

Field work

The purpose of the mapping of this area was to secure all possible information concerning the geologic formations and their structure. The geologic mapping done is of a detailed reconnaissance nature, as it was impossible for several reasons to use the telescopic alidade.

A base map of the area prepared by the State Highway Department on a scale of one inch to the mile was used. Contacts were sketched in directly on this map. Elevations were taken by means of a Paulin altimeter reading to 2 feet. To obtain as accurate control as possible for these elevations, frequent checks were made to the elevations established by the United States Coast and Geodetic Survey along the Northern Pacific Railroad and to the bench marks established by the United States Geological Survey in its topographic map of the Bismarck quadrangle. In some instances, however, particularly in the northwestern part of the map area, regularly established bench marks were so far away that frequent checks were difficult to make. In these cases temporary bench marks were established by altimeter as quickly as possible after setting it at a known bench mark. Because of this some of the elevations may not be as accurate as others. The field work was carried on during July and August of 1941 and June and July of 1942.

Acknowledgements

The writers are especially grateful to Mr. Ernest Tisdale who was in charge of the field party during the season of 1941. Thanks are also due to Mr. Howard Garaas and Mr. Kenneth Peterson who were field assistants during the summer of 1941. Mr. John Sullivan generously allowed the field party to camp on his ranch during the 1941 field season. Many of the geologists employed by the various oil companies operating in the State have given generously of their time and suggestions during the progress of the work. Particular thanks must be given to Mr. O. A. Seager and Mr. William Cobban of the Carter Oil Company. Mr. Cobban kindly read the manuscript and offered many valuable suggestions. Dr. G. A. Abbott, Head of the Department of Chemistry at the University of North Dakota kindly made the analysis of the manganiferous nodules from the Hell Creek formation.

PREVIOUS WORK

The United States Geological Survey has published a number of reports on the geology of areas immediately adjacent to this region[4].

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[4] Calvert, W. R., **et al.**, Geology of the Standing Rock and Sheyenne River Indian Reservations, North and South Dakota: U. S. Geol. Survey Bull. 575, 49 pp., 1914.

Stanton, T. W., The fauna of the Cannonball marine member of the Lance formation: U. S. Geol. Survey Prof. Paper 128A, 49 pp., 1920.

Hancock, E. T., The New Salem lignite field; Morton County, North Dakota: U. S. Geol. Survey Bull. 726A, 39 pp., 1921.

Dobbin, C. E., and Reeside, J. B., The contact of the Fox Hills and Lance formations: U. S. Geol. Survey Prof. Paper 158B, pp. 9-25, 1929.

The late Dr. A. G. Leonard[5] of the North Dakota Geological Survey did some work in this area incidental to more detailed work in other parts of the state. Lloyd and Hares[6] studied the Upper Cretaceous and Lower Tertiary stratigraphy of this and adjacent regions and published a small geologic sketch map.

STRATIGRAPHY

Stratigraphic terminology

The subject of the proper stratigraphic terminology to use is a most controversial one. It does not seem within the bounds of this report to discuss the various opinions expressed in the literature[7].

For this report the following rock and time terminology will be used:

Rock unit	**Time unit**
System	Period
Series	Epoch
Group	Age
Formation	Phase
Member	

The general classification of the rocks exposed in this area is as follows:

Tertiary system
Paleocene series
Fort Union group
Tongue River formation
Cannonball formation—Ludlow formation
Cretaceous system
Upper Cretaceous series
Hell Creek formation
Breien member
Montana group
Fox Hills formation

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[5] Leonard, A. G., The geology of southwestern North Dakota with special reference to the coal: North Dakota Geological Survey 5th Biennial Report, pp. 29-114, 1908.

—————,The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour Geol., vol. 19, pp. 507-547, 1911.

—————, U. S. Geol. Survey Geol. Atlas, Bismarck folio (no. 181) 8 pp., 1912.

—————, Pleistocene drainage changes in western North Dakota: Geol. Soc. America Bull., vol. 27, pp. 295-304, 1916.

[6] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geol., vol. 23, pp. 523-547, 1915.

[7] See Ashley, G. H., **et al.**, Classification and nomenclature of rock units: Geol. Soc. America Bull., vol. 44, pp. 423-459, 1933; Amer. Assoc. Petroleum Geologists Bull., vol. 17, 66. 843-868, 1933.

Tomlinson, C. W., **et al.**, Classification of Permian rocks: Amer. Assoc. Petroleum Geologists Bull., vol. 24, pp. 337-358, 1940.

Tomlinson, C. W., Technique of stratigraphic nomenclature: Amer. Assoc. Petroleum Geologists Bull., vol. 24, pp. 2038-2048, 1940.

Schenk, H. G., Muller, S. W., Stratigraphic terminology: Geol. Soc. America Bull., pp. 1419-1426, 1941.

Schenk, H. G., **et al.**, Stratigraphic nomenclature: Amer. Assoc. Petroleum Geologists Bull., vol. 25, pp. 2195-2211, 1914.

DETAILED STRATIGRAPHY

Cretaceous system

Name and definition

The Cretaceous was originally named by D'Halloy[8] for the terrain lying between the Tertiary and Jurassic strata in France. In the United States, the same usage is followed although there is some discussion as to the exact upper boundary. It is the last or youngest system of the Mesozoic Era.

Upper Cretaceous series

Name and definition

This series was originally called the Gulf series by R. T. Hill. In 1889[9], however, he made the term Gulf series synonymous with Upper Cretaceous. According to Schuchert and Dunbar[10] the base of the Dakota sandstone is the base of the Upper Cretaceous. The top of the Hell Creek formation constitutes the top of the series.

Montana group

Name and definition

G. H. Eldridge[11] apparently was the first to use the term Montana group as now understood. He included in this group the Fox Hills sandstone and the Pierre shale as now delimited. The group was named for the extensive development in Montana in the upper Missouri River region.

Fox Hills formation

Name and definition

The Fox Hills formation was named by Meek and Hayden[12] from Fox Ridge located in what is now northwestern Armstrong and southwestern Dewey Counties, South Dakota. It is the lowest member of the Cretaceous system which outcrops in this area. The Fox Hills formation described in this report includes the strata which appear to be equivalent to the Colgate member of the Montana and the other unnamed upper Fox Hills members. It is overlain in this region by the Hell Creek formation. The base is not exposed.

Occurence

Exposures of the Fox Hills member are confined to the bluffs and stream banks along the Cannonball River and along the Missouri River from the mouth of the Cannonball northward for a distance of about 8 miles to the vicinity of Fort Rice.

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[8] D'Halloy, J. J. O., Observations sur un essai de carte geologique de la France, des Pays — Bas et des contrees voisines: Annales des mines, vol. 7, pp. 373-374, 1822. (Reference from Wilmarth, Grace, The geologic time classification of the United States Geological Survey compared with other classifications: U. S. Geol. Survey Bull. 769, p. 56, 1925.)

[9] Hill, R. T., Relation of the uppermost Cretaceous beds of the eastern and southern United States: Am. Jour. Sci., 3rd ser., vol. 38, p. 469, 1889.

[10] Schuchert, C., and Dunbar, C. O., A Textbook of Geology, Part II—Historical Geology, 4th edition, p. 354, New York, John Wiley & Sons, Inc., 1941.

[11] Eldridge, G. H., Colo. Sci. Soc. Proc., vol. 3, pt. 1, p. 93 footnote.

[12] Meek, F. B., and Hayden, F. V., Philadelphia Academy of Sci. Proc., vol. 13, p. 419, 427, 1861.

Lithology

In general the Fox Hills formation of this area consists of three fairly distinct lithologic members. The lowest is a heavy buff sand which is overlain by a banded sandstone and shale sequence which is, in turn, overlain or replaced by a light grey sand that is probably the equivalent of the Colgate member of the Fox Hills formation farther west.

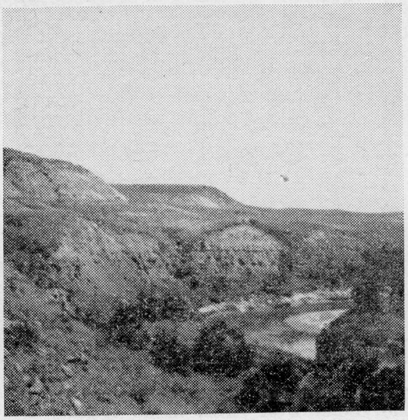

Fig. 1. The most completely exposed section of the Fox Hills formation in the area covered by this report. Located in the S½ Sec. 21, T. 134 N., R. 80 W. The two-fold nature of the upper Fox Hills is shown here; the lower, heavy, concretionary sand and the upper banded shale and sandstone.

The lower 90 feet of the Fox Hills in this area consists of poorly consolidated, cross-bedded sands. These sands are fine- to medium-grained. The color varies from brownish-green to grey which weathers to buff. At some horizons ferruginous sandstone concretions, some of which exhibit cross-bedding, are common. The sand, of which these concretions are composed, is apparently coarser than the sand surrounding them or the sand grains have been enlarged by the accretion of mineral matter due to deposition on them of silica from solution. This may have permitted a freer passage of iron-bearing ground water from which limonite was deposited. The deposition of limonite around the sand grains cemented them into harder masses that on weathering stand out as small ledges.

The upper 100 to 110 feet of the Fox Hills member consists of grey, clayey, medium-grained sand interbedded with thin, grey, shale partings. Concretionary layers, locally fossiliferous, are present throughout the member. In the Solen (Sioux County) railroad cut, the upper 34 feet of the section (section 2 in the part of this report entitled **Detailed sections**) is a banded shale and sandstone. The shales of this succession are mostly flaky with a few limonitic zones near the base. Fossils are present in this railroad cut in the bottom of the exposure of the heavy sand underlying the banded shale and sandstone; and Dobbin and Reeside[13] report a number of different species from this locality.

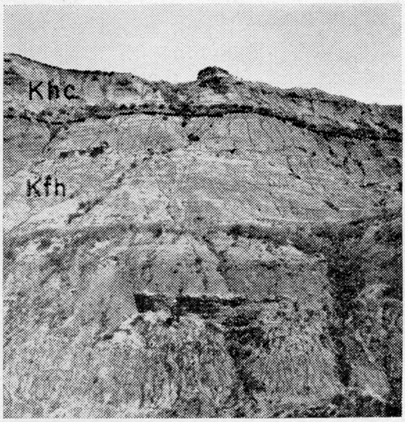

Fig. 2. Banded shale and sandstone of the upper Fox Hills. Same locality as Fig. 1. Kfh=Fox Hills; Khc=Hell Creek.

Overlying or sometimes partially replacing the upper banded sandstone and shale is a light grey to grey-white, fine-grained sand which is probably the equivalent of the Colgate member of the Fox Hills formation farther west. In the area mapped and on the south bank of the Cannonball across the river from the map area, the generalization can be made that where the Colgate is present the banded sandstone and shale is thin, and where the banded sandstone and shale is well developed the Colgate is thin or absent .This relationship is well shown along the south bank of the Cannonball River east and west of Solen. In the SE¼ Sec. 21, T. 134 N., R. 80 W., banded sandstone and shale measures 112 feet and is overlain by the Hell Creek formation with no Colgate present. In the railroad cut at Solen about 35 feet of the banded sandstone and shale are exposed. Three and one half miles west at the Crowghost cemetery (NW¼ Sec. 33, T. 134 N., R. 81 W.), the exposed banded sandstone and shale measures about 12 feet and the Colgate sandstone measures 36 feet. This would suggest that the Colgate possibly was a filling in a channel cut in the banded sandstone and shale.

The Colgate sandstone in this area is characterized by its grey-white color and its fluted appearance on weathering. It also makes

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[13] Dobbin, C. E., and Reeside, J. B., The contact of the Fox Hills and Lance formations: U. S. Geol. Survey Prof. Paper 158B, p. 12, 1929.

steep butte sides which may be due to a small amount of clay in the sand which tends to make the sand more resistant to erosion.

Thickness

The total thickness of fthe Fox Hills member cannot be measured in the area mapped since its base is not accessible. The most complete section measured in the SE¼ Sec. 21, T. 134 N., R. 80 W., exposes 174 feet[14].

Fossils

In a cutbank of the Cannonball River in the SE¼ Sec. 21, T. 134 N., R. 80 W., is a harder sandy layer which is so full of pelecypods that it is almost a coquinite. Fossils are also found throughout the less consolidated sands of the lower portion of the Fox Hills in this section, but are not abundant. It is nearly impossible to collect these fossils in the soft sands because they are so badly weathered and soft.

The following fossils were found in the upper part of member No. 1 of Section 1.

Calva ("Callista") nebrascana (Meek and Hayden)
Cymbophora formosa (Meek and Hayden)
Tancredia americana (Meek and Hayden)
Halymenites

Above this bed is another sandstone sequence containing sandstone concretions. These concretions are abundantly fossiliferous, particularly of certain species. The fauna of these concretions is as follows:

Anomia sp.
Cymbophora formosa (Meek and Hayden)
Ostrea aff. O. mesenterica Morton
Ostrea sp.
Protocardia subquadrata (Evans and Shumard)
Pteria linguaeformis (Evans and Shumard)
Tellina scitula Meek and Hayden
Fasciolaria (?) sp. (Evans and Shumard)
Polynices (?) sp.
Gastropod indet.
Discoscaphites cheyennensis (Owen)
Lamna cf. L. elegans Agassiz
Crocodile tooth indet.
Bone fragments
Halymenites

These fossils were kindly identified by John B. Reeside, Jr. through the courtesy of Dr. W. C. Mendenhall, Director of the United States Geological Survey.

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[14] In a personal communicaton from Mr. William Cobban to the senior author, dated November 17, 1942, the total thickness of the Fox Hills is given as 320 feet at Elk Butte in Sec. 15, T. 20 N., R. 27 E., Corson County, South Dakota. This is the nearest section to the Morton County area that can be completely and accurately measured.

Mr. Cobban (letter of November 17, 1942) states that in Morton and Sioux Counties, North Dakota, and in Corson and Dewey Counties, South Dakota, the heavy buff sandstone member of the Fox Hills (member No. 1 of section 1) is characterized by the abundance **Halymenites, Dosiniopsis nebrascensis** and **Tancredia americana.** The banded shale sequence is generally without fossils or contains only fragments of **Ostrea glabra** and **Dosiniopsis sp.** The Colgate sandstone in North Dakota is characterized by large **Halymenites** and in South Dakota it frequently contains solid oyster beds 30 to 35 feet thick.

Relation to adjacent formations

Within the area covered by this report, the base of the Fox Hills member is not exposed. Elsewhere it has been found that the Fox Hills lies conformably on the Pierre shale. Hares[15] states that in the Marmarth, North Dakota area "The sandstone grades downward into the typical Pierre shale, so that it is almost impossible to be sure that the lower limit as determined is everywhere at the same horizon." The contact between the Fox Hills and Hell Creek is sharp in this area because of the lignitic zone usually present at the base of the Hell Creek.

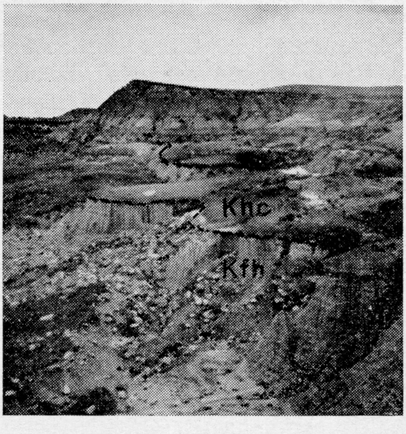

Fig. 3. Fox Hills-Hell Creek contact as exposed at the Crowghost cemetery in the center of Sec. 33, T. 134 N., R. 81 W., Sioux County.

Correlation

Leonard[16], and Calvert[17] and others have identified the Fox Hills in this area. The present authors accept the correlation of these

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[15] Hares, C J., Geology and lignite resources of the Marmarth field, southwestern North Dakota: U. S. Geol. Survey Bull. 775, p. 19, 1928.

[16] Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. of Geol., vol. 19, pp. 507-547, 1911.

[17] Calvert, W. R., **et al.,** Geology of the Standing Rock and Cheyenne River Indian Reservations, North and South Dakota: U. S. Geol. Survey Bull. 575, 49 pp., 1914.

workers and made no efforts to trace the Fox Hills from its type locality.

Historical interpretation

The fossil content of the Fox Hills together with the nature of the sediments would seem to indicate an open sea condition at the time of deposition. Local precipitation of iron compounds cemented the sands into hard, firm concretionary zones and nodules which still exhibit the original cross-bedding of the sands. The abundance of limonite, the presence of plant remains and the concretionary occurrence of the fossils and predominance of several types of pelecypods **(i. e., Protocardia subquadrata** and **Cymbophora formosa)** near the top of the Fox Hills suggests rather unusual living conditions near the close of the Fox Hills time.

Hell Creek formation

Name and definition

The Hell Creek formation was named by Barnum Brown[18] in 1907 for a sequence of strata typically exposed on Hell Creek in Garfield County, Montana, and nearby tributaries of the Missouri River. Thom and Dobbin[19] modified Brown's delimitation of the Hell Creek and included in the top of the formation about 100 feet of strata Brown had termed lignitic beds and had classified as Fort Union (?) in age. In the area mapped, the Hell Creek is underlain by the Fox Hills formation and overlain by the Ludlow formation of the Tertiary.

Occurrence

The Hell Creek beds are widely exposed in the area of this report. In the bluffs back from the Missouri River on the east side of the map area, the Hell Creek is well exposed. Also along the Cannonball River and for several miles north of that river are extensive exposures of the Hell Creek formation on the south side of the map area. On the north bank of the Cannonball, this formation forms extensive flats and badland areas. In the northwestern part of the map area a few feet of what is presumed to be upper Hell Creek outcrops along the banks of the Heart River.

Lithology

The Hell Creek is a formation containing several different lithologies. It consists predominantly of calcareous grey sand with numerous brown and black lignitic shales. Brown limonitic concretionary zones also are quite common in many places. It is this dark brown and grey appearance which early earned the name "Somber Beds" for this formation. Interbedded as a member of the Hell Creek formation is the Breien member which is described elsewhere in this report.

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[18] Brown, Barnum, The Hell Creek beds of the Upper Cretaceous of Montana: Amer. Mus. Nat. Hist. Bull., vol. 23, art. 33, pp. 829-834, 1907.

[19] Thom, W. T., Dobbin, C. E., Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. Amer. Bull., vol. 35, pp. 491-492, 1924.

The sands are fine to medium grained and contain abundant dark minerals. Because of the dark mineral content, the sands have a "salt and pepper" appearance. The sands are not entirely pure but often contain considerable amounts of clay. When the included clay is bentonitic, the sand shows the typical bentonitic type of weathering (**i. e.**, polygonal cracks). The sands commonly show extensive cross-bedding. This cross lamination is clearly shown in numerous planes due to the presence of thin (one-eighth inch or less) coatings of brown lignitic shale on the cross-bedding surfaces. The amplitude of the cross-bedding may be as much as 3 feet or more but often, however, it is less. The sands as well as the shales are lenticular and do not carry horizontally any great distance. Sandstone concretions cemented with calcite are often found in the Hell Creek and limonitic concretions in the shape of small cylindrical masses are also found which resemble the fossil **Halymenites** very closely. The sands are usually calcareous and it is probably because of this calcareous material in the sand that the formation erodes so readily, containing cavernlike openings on the sides of buttes.

The shales of the Hell Creek are predominantly of two types, lignitic and bentonitic. The lignitic shales are brown, thin-bedded and very fissile. Macerated plant fragments are often found on the bedding surfaces. Bentonite is a very common clay in the Hell Creek with some of the bentonite beds being 10 or more feet thick. Where present in the section, the bentonite beds, being quite resistant to erosion, form benches on the bluffs and slumps below the bluffs. Unaltered volcanic ash in the basal part of the Hell Creek is found in the SW¼ Sec. 31, T. 134 N., R. 81 W. in Sioux County southeast of Breien. This is apparently a channel deposit overlying or interfingering with bentonite. Bentonite, due to its faculty for swelling several times its size when wet, has a very characteristic appearance on outcrop. The dried surface of the bentonitic clays usually show polygonal weathering cracks but beneath this weathered shell the clay is damp, plastic, and sticky.

Three common minerals are found rather widely in the Hell Creek formation. These are limonitic, marcasite and gypsum. The first two are found commonly in concretionary zones and the last is characteristically found in the form of crystalline balls or rosettes. The "limonitic" concretionary zones (which also probably contain a small percentage of manganese) are locally fairly continuous. The "limonite" concretions are interesting in that the limonite appears to be only a weathering phenomenon. When one of the concretions is broken open, it will be found that usually the inside is a grey fine-grained sandy limestone or siliceous shale. The surfaces of these concretions have a dark "varnished" appearance often showing markings similar to septarian concretions.

Dr. G. A. Abbott, Head of the Chemistry Department of the

University of North Dakota, analyzed the black limonitic manganiferous coating of one of these concretions. His analysis follows:

	Per cent
Moisture, Water of Hydration, and Volatile Matter	9.04
Residue insoluble in HCl	10.28
Ferric Oxide, Fe_2O_3	47.37
Manganese Dioxide, MnO_2	8.01
Soluble Aluminum, Calcium Sulphate, and undetermined	25.30
	100.00

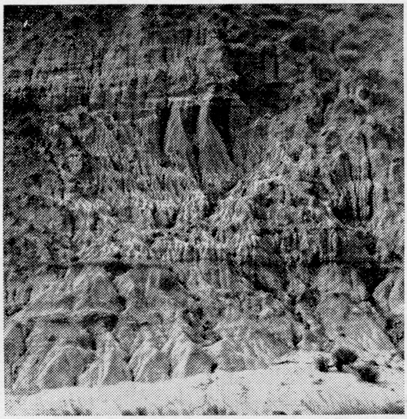

Fig. 4. Typical exposure of the Hell Creek formation. The picture was taken in the NW¼ Sec. 21, T. 134 N., R. 82 W.

The sands and clays both change very little in color on weathering, the greys and browns being retained. The sands of the Hell Creek, like those of the upper Fox Hills, have the propensity toward weathering into fluted columns. This fluting is really acute gully erosion on a small scale. The entire face of a sand section on the side of a bluff may be minutely dissected by these flutings. The deeper erosion plus the solution of any calcareous material in the sand of these flutings often excavates caverns which sometimes attain sizes up to 6 to 10 feet in diameter. Characteristically the sides of the buttes or bluffs meet the lowland at a rather high angle. It appears that the lowland is eroded right up to the side of the buttes much after the same fashion as pediments are produced in the arid basin regions of the West. These miniature pediments are covered by debris from the butte side in transit. The retention of the same angle of slope of the sides of the buttes is a fascinating geomorphic problem. The high clay content, particularly bentonite, of the Hell Creek formation makes it subject to extensive landslides. Such a slide on a large scale can be well seen along the bluffs back from the Missouri River south of the town of Huff.

Where flats are developed on the Hell Creek formation, they are usually characterized by bare spots where no vegetation grows. Thre are also at least two plants which are more commonly found on the Hell Creek formation than on the other formations of the vicinity. These have been determined by Dr. O. A. Stevens of the North Dakota Agricultural College to be Prairie Plantain and Red Mallow.

Thickness

The Hell Creek formation where exposed most completely is about 250 feet thick. Thicknesses elsewhere are difficult to obtain due to the lack of good exposures of upper and lower contacts.

Fossils

With the exception of the Breien member, the Hell Creek formation contains no marine fossils. Plant fossils are numerous but poorly preserved in the lignitic shales. Leonard[20] reports occasional bones of **Triceratops** and **Trachodon** although no well articulated skeleton has ever been found in this area.

Relation to adjacent formations

The contact of the Hell Creek with the underlying Fox Hills sandstone is usually quite sharp but conformable in this area. The contact with the overlying Ludlow is slightly more difficult to place due to the presence of lignites and lignitic shales in the upper part of the Hell Creek, similar in appearance to the Ludlow. Usually, however, the contact between the Hell Creek and Ludlow can be drawn at the base of a coal or lignitic shale at the base of the Ludlow. After becoming familiar with this contact it is fairly easy to trace if good exposures can be found. Often in the map area there is a heavy bentonite in the top of the Hell Creek below the Ludlow coal.

Correlation

The authors of the present report made no effort to trace these beds into their type area. However, numerous workers[21] who have studied these beds from a regional standpoint have carried the correlations to this area from the type sections. Therefore we are accepting their correlations.

Historical interpretation

The presence of abundant though badly broken plant fragments, fairly numerous fragmentary dinosaur remains, the presence of thin lignites and the irregular bedding of the Hell Creek formation would point to a continental mode of origin. This statement holds true except for the Breien member of the Hell Creek described elsewhere.

It might be reasonable to assume on the basis of lithology that this formation was deposited on a vast alluvial plain in front of the Rocky Mountains. Thin lignites and lignitic shales reflect a climate that was at least temperate to humid. Dorf[22] in speaking of the Lance (Hell Creek) flora says "The presence of palms and other low altitude forms indicates that the flora is a lowland subtropical to warm temperate assemblage." The large quantities of bentonite and bentonitic shale which are present would strongly suggest that there was volcanic activity not too far away to furnish volcanic ash. Tisdale[23] in his study of the heavy minerals of the basal Fort Union sandstone has suggested that the Black Hills region was possibly the source of much of the volcanic ash and heavy minerals incorporated in that formation. Possibly this and other sources were also active during the deposition of the Hell Creek.

Marie Lange[24] has recently studied the heavy minerals of the various formations exposed in this area. Her conclusion is that some area containing primarily igneous but including also some metamorphic and sedimentary rocks is the source of these minerals. She does not name any specific area for such a source. She also points out that most of the minerals have undergone little mechanical abrasion and are commonly angular or prismatic in shape.

The idea of deposition of a formation of this type on an alluvial plain is probably the traditional one. However, to the authors this idea, while probably the most reasonable, needs a great deal of clarification. The rather even grain size of the sands suggests that the material was well sorted even before it was available to the streams which distributed this material over the plain at the foot of the Rockies. Then, too, it is hard to grasp the idea of how even a number of streams meandering over a relatively flat surface at the foot of the mountains could deposit a formation several hundred feet thick. This, like many other sedimentation problems, awaits further study.

From the historical standpoint the presence of the Breien member in the basal part of the Hell Creek is most interesting. This

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[20] Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geol., vol. 19, p. 524, 1911.

[21] Dobbin, C. E., and Reeside, J. B., The contact of the Fox Hills and Lance formations: U. S. Geol. Survey Prof. Paper 158B, pp. 9-25, 1929.

Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geol., vol. 23, pp. 523-547, 1915.

Stanton, T. W., The fauna of the Cannonball marine member of the Lance formation: U. S. Geol. Survey Prof. Paper 128A, pp. 1-49, 1920.

Lloyd, E. R., The Cannonball River lignite field: U. S. Geol. Survey Bull. 541G, 51 pp., 1914.

[22] Dorf, Erling, Relationship between floras of type Lance and Fort Union formations: Geol. Soc. America Bull., vol. 51, p. 217, 1940.

—————, Upper Cretaceous floras of the Rocky Mountain region, II: Flora of the Lance formation at its type locality, Niobrara County, Wyoming: Carnegie Inst. Washington Pub. no. 508, p. 101, 1942.

[23] Tisdale, E. E., The geology of the Heart Butte quadrangle: North Dakota Geol. Survey Bull. 13, p. 31, 1941.

[24] Lange, M. L., Heavy mineral correlation of the Fox Hills, Hell Creek and Cannonball sediments, Morton and Sioux Counties, North Dakota: Unpublished manuscript in the files of the North Dakota Geological Survey, 1942.

means that the Fox Hills sea which had retreated from this area probably to the south returned for a brief interval shortly after the beginning of Hell Creek time. In other words, the contact between the two formations is a much more gradational one than has hitherto been reported in this area.

Breien member

Name and definition

Near the village of Breien in T. 134 N., R. 82 W., a thin, fossiliferous marine member is found interfingering with the basal part of the non-marine Hell Creek. Its base occurs on the average about 20 feet above the base of the Hell Creek with which it is apparently conformable and gradational above and below. For this member the name Breien is proposed. Reference to this member has already been made[25] but only a short description of it was published.

Occurrence

The Breien member is well exposed at only a few places within the area mapped, in the base of the bluffs in the SE¼ Sec. 17, T. 134 N., R. 81 W., where it occurs about 20 feet above the erosion level developed near the top of the Fox Hills, and in the SW¼ Sec. 21, T. 134 N., R. 80 W. It is also found in the central portion of Sec. 33, T. 134 N., R. 81 W., and center Sec. 35, T. 134 N., R. 81 W. The last two localities are across the Cannonball River in Sioux County. In other words, it is exposed along the Cannonball River from just east of Breien to Solen. It extends southward and has been reported[26] west of Fort Yates in Sioux County.

Lithology

The Breien member consists primarily of two beds of grey sand separated by a grey bentonite. The sands are fine grained, grey in color, weathering to buff. The upper sand is noticeable because of its greenish color which strongly suggests a marine origin. This color caused Mr. Cobban, its discoverer, to suspect its marine origin so he searched until he found marine fossils in it. Limonitic concretions and the fossil **Halymenites** are abundant in these sands and make definite zones.

The grey bentonite which separates the beds of sand contains abundant weathered marcasite concretions and gypsum crystals. These bentonites sometimes have a peculiar white coating on the surface which is probably alkali brought to the surface by evaporation. The typical polygonal cracks due to expansion of the bentonite on weathering are commonly seen on this member and in places the bentonite forms a small topographic bench.

Thickness

The greatest thickness of the Breien measured in this area totals 31 feet in the SW¼ Sec. 21, T. 134 N., R. 80 W.

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[25] Seager, O. A. **et al.**, Stratigraphy of North Dakota: Amer. Assoc. Petroleum Geologists Bull., vol. 26, p. 1418, 1942.

[26] Personal communication Mr. William Cobban.

Relation to adjacent formations

The Breien member interfingers with the undifferentiated Hell Creek above and below.

Fossils

The fossils of the Breien member have not been studied in detail. However, the following list which is only part of the fauna has been reported from the member by W. A. Cobban[27].

Halymenites
Ostrea glabra
Dosinopsis (?) sp.
Lingula sp.
Unidentified microfossils

Correlation

Although the transition is not seen, the Breien apparently passes into terrestial Hell Creek deposits not far west of this region. This is the only known occurrence of this bed.

Historical interpretation

The Breien member is of unusual interest because it represents a temporary return of the sea into an area of predominantly continental deposition. As the member has a small east-west extension but is found to the south of this area, it would appear that a seaway from the south or east apparently invaded this territory for a short distance depositing the sands and bentonite of the Breien. This return of the sea interrupted the typical continental deposition of the Hell Creek in this area. After a comparatively short time the sea again retreated and conditions of continental deposition were resumed. This marine member suggests that marine conditions were not far distant from this area from Fox Hills time until the end of Cannonball deposition.

Tertiary system

Name and definition

The name Tertiary was first applied to the rocks of this system overlying "Secondary" rocks by Arduino[28] in 1760. As a matter of fact, this name is a relic of the time when the Pre-Cambrian rocks were called Primary and the Paleozoic and Mesozoic rocks were called Secondary. Naturally the rocks overlying the Secondaries would be thought of as Tertiary in this type of classification.

Paleocene series

Name and definition

The term Paleocene was applied by Schimper[29] to the rocks in France lying above undoubted Cretaceous sediments and below those of undisputed Eocene age. W. D. Matthew[30] states that the

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[27] Seager, O. A., **et al.**, Stratigraphy of North Dakota: Amer Assoc. Petroleum Geologists Bull., vol. 26, p. 1418, 1942.

[28] Arduino, Giovanni, Nuova raccolta di opuscoli scientifici a filologici del padre abate Angiola Calogiera: tom 6, pp. 142-143, Venice, 1760. Reference from Wilmarth, Grace, U. S. Geol. Survey Bull. 769, p. 49, 1925.

[29] Schimper, W. P., Traiti de paleonotologie vegetale, vol. 3, pp. 680-682, 1874. Reference from Wilmarth, Grace, **op. cit.**, p. 54, 1925.

[30] Matthew, W. D., Status and limits of the Paleocene: Geol. Soc. American Bull., vol. 31, p. 221, 1920.

term Paleocene has been revived by the vertebrate paleontologists to cover several faunal zones previously known as basal Eocene.

Fort Union group

Name and definition

The term Fort Union was originally proposed by Meek and Hayden[31] for beds overlying the Fox Hills beds and underlying the Wind River deposits of Eocene age. More recent usage in North Dakota terms those beds lying between the Hell Creek of the Cretaceous and the Sentinel Butte shale of the Wasatch as the Fort Union formation. The Fort Union has been raised to the rank of a group by Dorf[32] and this usage is being followed in this report. It is named for the exposures at Old Fort Union near the mouth of the Yellowstone River near Buford, North Dakota.

Ludlow formation

Name and definition

Lloyd and Hares[33] gave the name Ludlow to the non-marine beds which interfingered with the Cannonball marine formation. The Ludlow overlies the Hell Creek formation in this area and underlies and is in gradational contact with the Cannonball formation which it replaces westward.

Occurrence

The Ludlow formation occurs over much the same area as the Hell Creek above which it lies. It is best seen in the southeastern part of this area where it is well exposed in numerous bluffs and buttes. Farther west and northwest in the area, exposures of unquestioned Ludlow are difficult to find since the area is overlain by glacial till and alluvium. However, some of the Ludlow has been mapped on the basis of known elevation and topography. Where it could no longer be traced justifiably by elevations or outcrop the stratigraphic interval which was mapped as Ludlow elsewhere was included in the area mapped as Hell Creek.

Lithology

Lithologically the Ludlow formation resembles the Hell Creek from which it is differentiated largely on the basis of its greater lignite and lignitic shale content. The sands are usually fine-grained to shaly, thin-bedded and sometimes cross-bedded. Often the sands are interbedded with brown to black lignitic shales. The shales are grey to chocolate brown in color, weathering to buff and occasionally show limonite staining along the bedding planes.

The Ludlow shales are sometimes sandy and often grade vertically into fine-grained, shaly sandstones but are usually clayey and occasionally bentonitic. When wet, these shales become very slippery, causing slumping on the steeper bluffs and even on some of the more gentle slopes. Many of the shales are lignitic in character and contain numerous more-or-less poorly preserved plant fragments. In the area mapped, the lignite present is of poor grade, is mostly lignitic shale, and has little economic value, although some minning has been done locally. The largest of the abandoned mine pits are located in SE¼ Sec. 23, T. 135 N., R. 81W.; SW¼ Sec. 9, T. 134 N., R. 81 W.; SW¼ Sec. 21, T. 134 N., R. 82 W.; NE¼ Sec. 18, T. 134 N., R. 81 W.

The base of the Ludlow is taken at the lowest prominent lignite bed above the Hell Creek. Some of the lignitic beds have been burned in place, forming a reddish clinker or "scoria" which is present in the Ludlow in the SE¼ Sec. 26, T. 135 N., R. 81 W.; SW¼ Sec. 26, T. 134 N., R. 84 W.; and SE¼ Sec. 3, T. 134 N., R. 81 W.

In the bluffs along the Heart River in T. 137 N., R. 84 W., a grey sandy shale containing much fragmentary petrified wood occurs near the top of what has been mapped as Hell Creek[34]. On the basis of its stratigraphic position, this zone may be the partial equivalent of the Ludlow which has been differentiated from the Hell Creek farther to the southeast in this area.

Thickness

In the area mapped the thickness of the Ludlow ranges from 17 to 49 feet but it averages about 20 feet thick. This formation increases in thickness to the west.

Fossils

No fossils except plants have been found in the Ludlow. The plants are usually so poorly preserved that identifications have not been attempted.

Relation to adjacent formations

The base of the Ludlow which apparently overlies the Hell Creek in most places is taken at the most prominent lignite bed above a thick grey bentonite commonly found at the top of the Hell Creek. In some places the contact seems to be unconformable due to the lenticularity of the sands and clays of the upper Hell Creek. The Cannonball-Ludlow contact is more difficult to draw since the upper portion of the Ludlow contains a transitional zone composed of interbedded thin lignitic shales and sands. The contact is usually so drawn as to include most of the lignitic material within the Ludlow.

Correlation

No effort has been made by the authors to trace the Ludlow outside the area mapped. Other workers[35] have traced the beds herein called the Ludlow westward into known Ludlow exposures.

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[31] Meek, F. B., Hayden, F. V., Phila. Acad. Nat. Sci. Proc. vol. 13, p. 433, 1862.

[32] Dorf, Erling, Relationship between floras of the type Lance and Fort Union formations: Geol Soc. America Bull., vol. 51, p. 230, 1940.

[33] Lloyd, E. R., Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geol. vol. 23, p. 523, 528, 1915.

[34] Hancock, E. T., The New Salem lignite field, Morton County, North Dakota: U. S. Geol. Survey Bull. 726A, p. 9, 1921.

[35] Personal communication from O. A. Seager.

Historical interpretation

The lack of marine fossils in the Ludlow and the presence of the lignitic material and plant remains reflect continental conditions of deposition during Ludlow time. Swamps in which abundant vegetation thrived and from which the lignite was formed, alternated with more active conditions of deposition under which the sandstones and shales were laid down. Sands and clays were being deposited in some places while nearby more quiet swamp conditions prevailed and lignite was being formed. The region must have been at a critical level so that a slight change in elevation was sufficient to make the difference between a region of active deposition and one of quiet swampy conditions.

Cannonball formation

Name and definition

The Cannonball formation was named by Lloyd[36]. It comprises the upper 250-300 feet of the old Lance formation and it is typically exposed along the Cannonball River. To the west it intergrades with the Ludlow formation and in the map area it overlies and is gradational with the Ludlow. The Tongue River formation conformably overlies the Cannonball formation.

Occurrence

The Cannonball is exposed in the bluffs along the west bank of the Missouri River in the northeastern part of the map area. It is also exposed in the bluffs which are some miles north of the Cannonball River. The formation forms the upland surface over much of the central part of the map area and is fairly well exposed along the banks of the Heart River in the northwestern part of the area.

Lithology

The Cannonball formation consists of two dominant types of lithologies, buff, fine-grained sand and grey, thin-bedded clay shales. The sands are buff in color and as a rule are poorly indurated and often show cross-bedding. Frequently they contain concretions, some of which are round while others are flat and lenticular. The round concretions are seldom observed more than 2 feet in diameter but the lenticular ones might be as much as 6 feet in the long diameter. The cementing material in these concretions appears to be calcium carbonate. The sand contains rather large amounts of heavy minerals but no study was made of the sands from this standpoint.

Due to the fact that the Cannonball interfingers with the continental Ludlow formation it is not strange that the base of the formation is sometimes difficult to define. Occasional thin, lignitic shales are present interbedded with the Cannonball sands. Such features can be seen in the section south of Huff (No. 6 in the

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[36] Lloyd, E. R., The Cannonball River lignite field: U. S. Geol. Survey Bull. 541A, p. 9, 1914.

portion of this report on **Detailed sections**) and in the section (No. 11) south and west of St. Anthony.

On weathering the sands are quite resistant and stand out making topographic benches. There appear to be at least three sands which form such benches, which benches, for the sake of convenience, have been numbered 1, 2, and 3 starting at the bottom. Number 1 averages from 75 to 89 feet above the base of the Cannonball. Number 2 is found about 104 feet above number 1. Number 2 makes a very prominent subupland bench or terrace and is a useful key bed. Number 3 averages about 65 feet above number 2. Numbers 2 and 3 form the upland over much of the central and west central part of the map area. These sands are separated by grey clay and buff, sandy shale. These topographic benches are well shown in the bluffs north of Breien and north of Gall Siding. Reference should be made to Section No. 11 south and west of St. Anthony for a more complete stratigraphic section of the Cannonball formation.

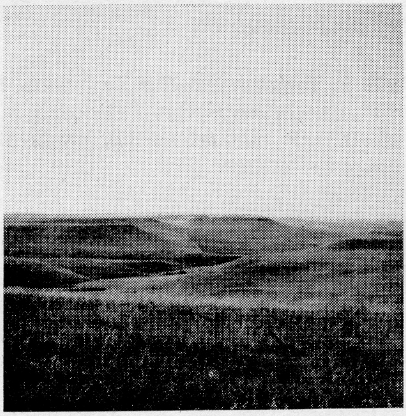

Fig 5. Bench held up by the middle Cannonball sand (the number 2 Cannonball sand of this report). Location of the picture is about 9 miles east of Flasher, Morton County, on Route 21.

Limonitic concretionary zones are present in the Cannonball sands particularly where the fossil **Halymenites** occurs. Such a zone is particularly well exposed in the section south of Huff.

The shales are grey, thin-bedded and slightly micaceous. Some of the shales, particularly where closely interbedded with the sands, are buff and sandy in nature. The shales of the Cannonball weather readily and are seldom seen in good exposures. The shales, being less resistant, generally form slopes between the sandstone benches.

Thickness

The thickness of the Cannonball is difficult to obtain due to the fact that its upper contact is not always well shown in this area. It would appear that in most places it averages approximately 300 feet thick. In the section west and south of St. Anthony (SE¼ Sec. 13, T. 136 N., R. 82 W.) the Cannonball measures 306 feet, 10 inches in thickness.

Relation to adjacent formations

The Cannonball formation is in apparently gradational contact with the Ludlow formation, but due to the facies nature of this contact, it is somewhat difficult to place exactly. As a rule the basal contact of the Cannonball was drawn so that most of the lignitic shales would be included in the Ludlow. The upper contact with the overlying Tongue River member is not so well shown but it appears to be conformable or even a gradational one. Such a gradational contact is shown in the SE¼ Sec. 13, T. 136 N., R. 82 W. where the uppermost Cannonball consists of grey, sandy shales. The basal Tongue River here consists dominantly of buff sand but some shale beds are interbedded at the base. The upper boundary of the Cannonball was drawn in this section at the top of the predominantly grey shale sequence.

Fossils

The Cannonball is famous for the fact that its fossils apparently relate it most closely with the Paleocene Midway formation of the Gulf Coast[37]. In this map area, the fossils of the Cannonball are not as abundant as elsewhere.

Schuchert and Dunbar[38] state that about 150 species of marine animals have been identified from these beds of which about 80 are molluscs and 70 are foraminifera. For a detailed list Stanton[39] and Fox and Ross[40] should be consulted.

Correlation

The correlation of the Cannonball member is a controversial issue. Stanton[41] on the basis of its fossil content would place the formation in the Cretaceous. Dorf[42] on the basis of its fauna would place it in the Paleocene, and suggests it can be correlated with the Midway of the Gulf Coast area. In this report the Paleocene age assignment of this formation is being accepted.

Historical interpretation

The marine fossils which are present in the Cannonball would indicate that most of the member was laid down in marine con-

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[37] Dorf, Erling, Relationship between floras of type Lance and Fort Union formations: Geol. Soc. America Bull., vol. 51, p. 213-236, 1940.

[38] Schuchert, Charles and Dunbar, C. O., A Textbook of Geology, Part II—Historical Geology, 4th edition, p. 398, New York, John Wiley and Sons Inc., 1941.

[39] Stanton, T. W., The fauna of the Cannonball marine member of the Lance formation: U. S. Geol. Survey Prof. Paper 128A, p. 10, 1920.

[40] Fox, S. K., and Ross, R. J., Foraminiferal evidence for the Midway (Paleocene) age of the Cannonball formation in North Dakota: Jour. Paleontology, vol. 16, pp. 660-673, 1942.

[41] op. cit., p. 18.

[42] op. cit., p. 233.

ditions. Stanton[43] lists five forms which suggest a brackish water environment for at least small parts of the Cannonball formation. Due to the isolated geographical position of the outcrops of this formation, it is difficult to ascertain where this shallow epicontinental sea connected with the oceans. The isolated position of this area with respect to the Eocene seas was one of the reasons why Stanton[44] assigned a Cretaceous age to these beds.

The Cannonball formation is thickest in this area thinning westward. This thinning is due to the westward replacement of the Cannonball by the Ludlow lignite member. From sections exposed farther west (as in Sections 31 and 32, T. 133 N., R. 88 W. in Grant County) this change in facies from the more sandy material of this map area to the predominantly shaly material can be seen. The grey shales of the Cannonball often contain badly macerated plant fragments suggesting a near-shore environment where plant fragments were washed into the sea and there incorporated with marine deposits.

Tongue River formation

Name and definition

The name Tongue River was applied by Taff[45] for the coal bearing rocks underlying beds approximately equivalent to the Sentinel Butte shale formation of Eocene (Wasatch) age. It is exposed along the Tongue River between Carneyville, Wyoming, and Bradenville, Montana. It is also seen on the Yellowstone and Missouri Rivers between Burns, Montana, and Fort Clark, North Dakota. Stratigraphically it is the highest formation outcropping in the area covered by this report and its upper contact is not exposed.

Occurrence

The Tongue River formation is exposed in this area primarily in T. 136 N. and Ranges 83 W. and 84 W. Another small area where only the most basal members are seen is found in T. 136 N., R. 80 W.

Lithology

In this region the Tongue River formation consists of grey clayey and silty shale, lignite and brown lignitic shale, volcanic ash and quartzitic sandstone, and buff, fine-grained sand. With the exception of the basal sand which is not well exposed, the lower 145 feet of the Tongue River of this area consists rather largely of thin-bedded clay and silty shale. Only one sizeable lignite bed was seen in this area and it averaged less than 2 feet thick. This lignite or its equivalent brown lignitic shale occurs 110 feet above the base of the formation. This compares favorably with the strati-

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[43] op cit., p. 11.

[44] op. cit., pp. 15, 18.

[45] Taff, J. A., The Sheridan coal field, Wyoming: U. S. Geol. Survey Bull. 341, p. 129, 1909.

graphic location of the **B** coal of Hancock[46] in the New Salem lignite field northwest of this map area.

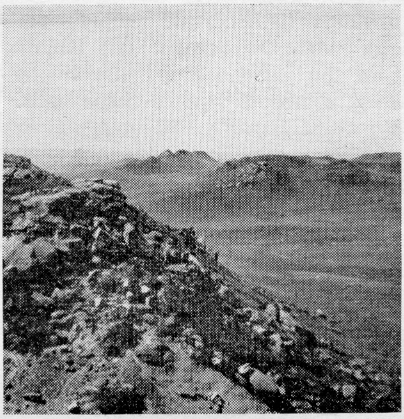

Fig. 6. Buttes held up by the heavy sandstone near the base of the Tongue River formation. The picture was taken in eastern Grant County just west of the area covered by this report.

The clay shales are thin bedded and the brown lignitic shales are often fissile. On weathering, the brown lignitic shales change to a lighter brown or purple color. The shales weather readily so that unless exposed by stripping operations they are seldom seen in outcrop.

The silty grey shale or volcanic ash underlying the **B** lignite deserves special mention because of the fact that its color makes it a prominent key horizon. In most places this is a silty shale but in the SE¼ of NE¼ Sec. 15, and the NW¼ Sec. 14, T. 136 N., R. 83 W. it is unweathered volcanic ash. In these localities, about 7 feet of the material is exposed. Quartzitic sandstone concretions are often found associated with this ash or silty clay but seldom, however, are they found in place. In the above mentioned localities the transition from the ash and silty clay to these concretions can be seen. This process is apparently one of case hardening which operates only on the outcrop but does not extend into the hill any appreciable distance. The presence of numerous quartzitic boulders on the surface is often an indication of the presence of this member but this criterion must be used with caution, as these quartzitic boulders are very common in the glacial drift of this area.

The buff, fine-grained sand which comprises the base of the Tongue River formation contains some lignitic shale stringers, particularly toward the base where it is in gradational contact with

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[46] Hancock, E. T., The New Salem lignite field, Morton County, North Dakota: U. S. Geol. Survey Bull. 726A, p. 13, 1921.

the underlying Cannonball. The buff sand whose base is approximately 145 feet from the base of the formation is fine-grained and is often concretionary. The concretions consist of sand cemented with calcium carbonate. They are lenticular and cross-bedded and have been observed to be as much as 10 feet in diameter in the map area. This upper sand, particularly where it is concretionary, makes the highest upland of the area and gives a rugged topography to the buttes which are capped by it.

Thickness

The total thickness of the Tongue River formation is not exposed in the area mapped. The best exposed section totals 180 feet.

Fossils

Plant remains are found in this member but none were identified in the course of this study. A few freshwater gastropods and pelecypods were also collected but both plant and animal remains are scarce in the area mapped.

Relation to adjacent formations

The contact with the underlying Cannonball formation is transitional but fairly sharp. The contact is drawn at a line below which the rocks are dominantly shale characteristic of the Cannonball formation. The upper contact is not seen in the area mapped.

Correlation

This member is being correlated with the basal part type Tongue River formation. The authors did not trace this formation from the type area but other workers[47] have.

Historical Interpretation

The transitional contact of the Tongue River with the underlying predominantly marine Cannonball formation would suggest that the Cannonball sea shoaled gradually until continental conditions were dominant. After the withdrawal of the sea, swampy conditions must have prevailed intermittently at which times the lignites and lignitic shales were deposited. At other times, fairly rapid erosion of some nearby sources provided the sands for the heavy, cross-bedded sandstones. Volcanism must have been active somewhere to provide the volcanic ash deposited below the **B** lignite. The abundance and fresh appearance of heavy minerals in all the sands would suggest the rapid erosion of igneous or metamorphic rocks.

Quaternary system

Name and definition

The name Quaternary was apparently first applied by J. Desnoyers [48] for beds which followed or overlay those of Tertiary age

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[47] See Thom, W. T., and Dobbin, C. E., Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., vol. 35, p. 499, 1924.

[48] Desnoyers, J., Observations sur en ensemble de depots marins plus recens que les terrains tertiares du bassin de la Seine, et constituant une formation geologique distincte; precedees d'un apercu de la non simultaneite des bassins tertiaires: Annales sci. nat., vol. 16, pp. 171-214, 402-491, 1829. Reference from Wilmarth, Grace, U. S. Geol. Survey Bull. 769, pp. 43-44, 1925.

deposited in the basin of the Seine River in France. The present usage is essentially the same in that all rocks of post-Tertiary age are included in this system.

Pleistocene series

Name and definition

The term Pleistocene as now understood was first used by Forbes[49] in 1846 for beds which were deposited during that part of geological time characterized by severe climatic conditions through the greater part of the northern hemisphere during which the formations that were called "Northern Drift" were formed. In North Dakota, the Pleistocene deposits are all directly related to the glacier. They are till, outwash or lake deposits associated with other glacial deposits.

General statement

The age of the glacial deposits in this part of North Dakota is a controversial issue. Leonard[50] referred to this drift as pre-Wisconsin and provisionally referred it to Kansan, although he suggests it might be younger than Kansan. Alden[51] referred these glacial deposits to the Illinoian or Iowan (?) stage of glaciation.

Character of the glacial deposits in the area of this report

The glacial deposits in this area can be divided into till, boulder beds and outwash. The till in most places is very thin, usually less than 10 feet in any exposure. It is not particularly stony and is grey to brown in color. Limestone pebbles are found in the till practically on the surface which suggests that leaching of calcium carbonate has not been a dominant process here.

Leonard[52] was of the opinion that this drift had undergone extensive erosion and that the boulder beds which are referred to later in this report are the residiuals after the clay and finer material had been carried off. He also notes that this drift never had any thickness except locally where moraines are formed.

The writers agree with Leonard that the drift was thick only locally but disagree with him on the extensive erosion of the till. The authors believe that the till was never much thicker than now and that the ice sheet simply blanketed the pre-glacial topography with a thin veneer of drift. Back a few miles from the main rivers the amount of erosion by running water has been slight. Therefore it seems the thinness of the till and its irregular distribution is probably due more to irregularities of glacial deposition than to erosion subsequent to deposition.

At several places there are only boulder beds of granite, other crystalline rockss, and Tongue River quartzites to indicate that the glacier had ever been present in this area. Such a bed is well shown in the SW¼ Sec. 5, T. 135 N., R. 79 W. The authors suggest that inasmuch as the drift which has been observed in this area is not particularly stony, that these boulder beds were deposited essentially as they are now found, **i. e.,** without any clay associated with them.

In a number of localities within this region glacial outwash gravels are found. All of these outwash deposits are associated with the pre-glacial drainage or glacial distributary channels. This is discussed in this report under the section entitled "Physiography."

Recent series

General statement

To the Recent series are alloted all beds which have been deposited since the ice withdrew from this area. At best this is an artificial division when the whole country or even the State of North Dakota is considered, as the ice did not withdraw evenly in a straight east-west line. Therefore it is hard to say where the line between Pleistocene and Recent deposits should be drawn. Usually the alluvium along the streams is thought of as being Recent in age. Due to the difficulty in differentiating between Pleistocene and Recent deposits and because it was desired to keep the number of symbols used on the geologic map to a minimum, the alluvium was not mapped separately from the glacial deposits in this area.

DETAILED SECTIONS

General statement

The following detailed sections are included in this report to illustrate the nature of the various formations described. It must be noted that in beds which are as lenticular and irregularly bedded as these formations are, there are bound to be considerable differences in stratigraphic sections measured only a few feet apart along the strike. Therefore these sections might not agree in every detail with others measured only a few feet away .

Section 1[53]

SE¼ Section 21, T. 134 N., R. 80 W.

Hell Creek formation	**Feet**	**Inches**
24. Bentonite: dull green, weathering to heavy grey gumbo	2	
23. Sandstone: whitish, soft	3	
22. Shale: lavender-brown, carbonaceous	1	

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[49] Forbes, E., On the connexion between the distribution of the existing fauna and flora of the British Isles, and the geological changes which have affected their area, especially during the epoch of the Northern Drift: Great Britain Geol. Survey Mem., vol. 1, pp. 402-403, 1846. Reference from Wilmarth, Grace, U. S. Geol. Survey Bull. 769, p. 48, 1925.

[50] Leonard, A. G., The Pre-Wisconsin drift of North Dakota: Jour. Geol., vol. 24, p. 532, 1916.

————————, The geology of North Dakota: Jour. Geol., vol. 27, pp. 22-23, 1919.

[51] Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, pp. 69-79, 1932.

[52] **op. cit.,** p. 522.

[53] This section was measured by Mr. William A. Cobban of the Carter Oil Company, who kindly allowed its publication in this report.

Breien member		
21. Sandstone: greenish-grey, soft, massive; contains shaly partings and small rusty-weathering ferruginous nodules	30	
20. Sandstone and shale: grey, soft; seamed with yellow limonite	1	
Undifferentiated Hell Creek formation		
19. Shale: lavender-brown, lignitic	1	
18. Shale: dull brown, sandy, earthy; contains carbonaceous partings	6	
17. Lignite and lignitic shale: brown to black; contains fossil wood	4	
Total thickness of exposed Hell Creek	48	
Fox Hills formation		
16. Bentonite: greenish-grey, sandy	3	
15. Sandstone: grey, soft, with yellow limonitic nodules	1	
14. Concretion zone: rusty-weathering clay iron-stone concretions and nodules in grey sandstone	1	
13. Sandstone: olive-grey, soft; some interbedded tan sandy shale and thin hard shaly ferruginous layers	8	
12. Shale: lavender-brown, carbonaceous	1	
11. Bentonite: dull green; weathers to grey gumbo		6
10. Sandstone: olive-grey, weathering to olive-grey gumbo	6	
9. Ferruginous layer: rusty-brown, shaly		3
8. Sandstone and shale: olive-grey, banded	8	
7. Concretion zone: brownish-weathering, white, cross-bedded, concretionary sandstone	2	
6. Sandstone and shale: alternating thin layers of olive-grey sandstone and brownish to grey shale. Weathers to olive-grey banded gumbo	40	
5. Sandstone: white, concretionary	2	
4. Sandstone: olive-grey, massive; weathers faintly banded olive-grey gumbo	20	
3. Sandstone: white, coarse, cross-bedded, concretionary	2	
2. Sandstone: greenish-buff, soft; contains a few small brown ferruginous sandstone masses	30	
1. Sandstone: greenish, soft; contains numerous odd-shaped, brown-weathering, ferruginous sandstone masses with some fossils	50	
Total thickness of exposed Fox Hills	174	9

Section 2

NE¼ Sec. 36, T. 134 N., R. 81 W.
Start section at level of railroad tracks in the railroad cut
west of Solen, Sioux County

Fox Hills formation	**Feet**	**Inches**
3. Banded shale and sandstone. Mostly flaky shale with few limonitic zones present toward base	34	
2. Buff, fine-grained sand containing numerous limonitic concretionary layers. **Halymenites** abundant in this zone. These forms grow at right angles to bedding as well as parallel to the bedding	9	6
1. Buff sand, unconsolidated. No fossils	9	1
Total thickness of exposed Fox Hills	52	7

Section 3

Center of Sec. 35, T. 134 N., R. 81 W.
West of Solen railroad cut 1.3 miles

Hell Creek formation	**Feet**	**Inches**
5. **Breien member.** Buff-weathering grey sand with some interbedded shale layers. **Halymenites** fairly abundant toward the top of the exposure. At top of the exposure is bentonitic shale which has a whitish alkali coating. Weathered marcasite concretions abundant. Gypsum crystals were also noted. Two poorly preserved gastropod molds, one **Halymenites** mold in a concretion, and one questionable pelecypod mold were found	9	
4. Chocolate-colored shale becoming quite lignitic toward the top of the member. Lignitic material flaky and thin-bedded	16	
3. e. Grey sand with limonitic concretions d. Brown shale c. Bentonite b. Brown shale a. Limonitic layer	12	2
Total thickness of exposed Hell Creek	49	2
Fox Hills formation		
2. Grey, fine-grained shale interbedded with grey sandstone. Sandstone contains little calcareous nodules. Surface of shale layers has bentonitic weathering appearance	20	5
1. Grey, buff-weathering, fine-grained sand. Large **Halymenites** very abundant. Shark teeth and bones found here	8	
Total thickness of exposed Fox Hills	28	5

Section 4

Center of Sec. 33, T. 134 N., R. 81 W., Sioux County
(Crowghost cemetery)

Start section at lowest exposure possible in creek bed not far from Cannonball River

	Feet	Inches
23. Sandy glacial till	11	
Hell Creek formation		
22. Buff-weathering, fine-grained sand	16	
21. Grey, flaky shale with some brown shale and interbedded sand. Probably part of member below but contains more shale	17	10
20. Grey, fine-grained, fluted sand with some interbedded shale	15	1
19. Lignitic shale	1	6
18. Grey and brown flaky shale interbedded with some grey sand	10	5
17. Brown, lignitic shale	2	5
16. Grey, bentonitic shale at bottom and top. Flaky shale with marcasite concretions in the middle	8	4
15. Grey, fine-grained sand, slightly fluted	7	4
14. Brown, lignitic shales and aboundant large limonitic concretions. Plant fragments abundant. Limonitic zone about 4 to 5 inches thick on top of lignitic shale	2	2
Breien member		
13. Grey, fine-grained sand. **Halymenites** common	10	6
12. Grey bentonite	1	7
11. Grey, fine-grained sand. Weathers buff grey. **Halymenites, Dosinopsis,** and gastroped molds found	6	5
10. Brown, sandy, limonitic zone. **Halymenites** present	2	10
Undifferentiated Hell Creek formation		
9. Grey-green, fine-grained sand. Perhaps slightly bentonitic. Weathers to a white-grey color	8	5
8. Brown, lignitic shale	1	
7. Grey, flaky shale almost black when weathered. Slightly sandy. Weathered marcasite concretions present	5	4
6. Brown lignitic shale	1	4
5. Grey, sandy, clayey shale. Slightly brown in color	3	5
4. Grey bentonite	1	10
3. Brown, lignitic shale. Somewhat concretionary in nature. Bottom of this zone may vary 20 feet where there has been channel filling in the top of the Fox Hills	2	
Total thickness of exposed Hell Creek	125	9
Fox Hills formation		
2. **Colgate member.** Grey, fine-grained sand with some interbedded bentonitic shale. Some sandstone concretions noted but apparently they are not laterally continuous. Sand making concretions apparently coarser than surrounding sand. (Perhaps this coarser sand allowed freer passage of the mineralized ground water allowing mineral matter to be deposited in the pores between the sand grains.) Limonitic material in center of concretion in lump form. Bottom and top of concretion apparently fine-grained sand. Bottom of concretion browner in color than the top. At 31 feet from the base locally prominent sandstone concretionary zone	36	
1. Grey, flaky, silty shale interbedded with grey sandstone, rather badly slumped	12	1
Total thickness of exposed Fox Hills	48	1

Section 5

SE¼ Sec. 17, T. 134 N., R. 81 W., NE of Breien, Morton County. Started as low as possible on flood plain of the Cannonball River.

Cannonball formation	Feet	Inches
19. Light brown, limonitic sand with some lighter sandstone concretionary layers in it. Mostly covered	101	
Ludlow formation (?)		
18. Brown, lignitic shales and sands, primarily shale. Black, lignitic shale at top of the member	24	5
Hell Creek formation		
17. Bentonitic grey shale and brown shale	8	
16. Grey, fluted, fine-grained sand	21	2
15. Buff-weathered, grey sand having speckled appearance	17	
14. Brown, thin-bedded shale with carbonized plant fragments. Interbedded with buff-colored, finer-grained sand. Lignitic zone about 2½ feet thick holds up small cliff. Base of lignitic zone 8½ feet from base of the member	14	2
13. Grey, fine-grained fluted sand. Large marcasite concretions present but weathered. Also some interbedded brown shale present	16	

12. Brown and grey shale interbedded. Brown shale band present right at base	17	
11. Grey, fine-grained sand with interbedded cross-bedded shale. Fluted sand makes small coverns	43	6
10. Concealed. Much slumping	35	
Breien member		
9. Buff, limonitic sand, with 1 foot bentonite layer near middle. **Halymenites** moderately abundant. Limonitic concretions common. The limonitic zone at the top of the Breien seems to be fairly continuous	17	6
Undifferentiated Hell Creek formation		
8. Brown, lignitic shales and sandstones	11	
7. Interbedded grey and brown, fine-grained sandy shale. Limonitic zone at the base. Scattered concretions elsewhere	5	6
6. Lignitic shale		6
5. Bentonite	1	
4. Grey, fine-grained sand, shaly in the upper portion	2	
3. Grey, sandy shale with abundant limonitic concretions	2	
2. Brown, lignitic shale	1	6
Total thickness of exposed Hell Creek	212	10
1. Top of the Fox Hills (?)		

Section 6

SW¼ Sec. 8, T. 136 N., R. 79 W.
Base of section badly slumped.

	Feet	Inches
23. Glacial till		
Cannonball formation		
22. Grey, clayey shale. Shale is thin-bedded and fissile but is more sandy toward top	38	6
21. Buff sand and lignitic shale. Marcasite and limonite concretions	1	2
20. Sandstone concretionary zone. Grey, not limonitic	1	8
19. Grey sand same as below. Very cross-bedded	10	3
18. Buff, fine-grained, grey sand with some thin shale partings. Limonitic concretions. Grey sand bed at top of member. **Halymenites** profusely abundant in top bed. Much calcareous material in joints. Base of **Halymenites** zone is 19 feet, 11 inches from base of the member. This zone is limonitic on surface and is 3 feet, 6 inches thick	23	5
17. Brown clay shale. Sandy. Upper part covered	33	6
16. Buff, fine-grained sand. Thin shale stringers interbedded at top and bottom. Gradational upper contact. Marcasite and limonitic concretions	12	9
15. Brown clay shale. Interbedded with sand. Gradational upper contact	5	3
14. Cover	12	9
Total thickness of exposed Cannonball	139	3
Ludlow formation		
13. Brown, sandy shale, interbedded with buff sand	2	2
12. Brown, lignitic shale. Fissile, thin-bedded. Much gypsum	4	
11. Buff, fine-grained sand. Gradational with bed below. Limonitic, concretionary. Gypsum crystals	3	2
10. Brown, lignitic shale. Fissile, thin-bedded	1	6
9. Black lignite. Ash at base		8
8. Brown, fissile, thin-bedded lignitic shale	3	2
7. Grey, fine-grained sand. Interbedded with lignitic shale at base	1	3
6. Lignitic shale. Marcasite at upper contact	2	
Total thickness of exposed Ludlow	17	11
Hell Creek formation		
5. Grey and brown bentonitic shale and clay. Gypsum crystals present. Badly slumped	17	
4. Buff-weathering, fine-grained grey sand. Speckled appearance. Some limonitic concretionary zones. Also some sandstone concretions showing cross-bedding. Whole member has irregularly bedded appearance	50	
3. Bentonitic sand, grey in color. Might belong to the member below. Abundant gypsum	10	
2. Grey, fine-grained sand containing some clay. Has speckled "salt and pepper" appearance on weathering. Fluting abundant. Some brown shale partings. Some grey sandstone concretions	21	10
1. Brown and grey lignitic and bentonitic zone causing springs. Mostly covered. Exposed	16	
Total thickness of exposed Hell Creek	114	10

Section 7

NE¼ Sec. 13, T. 134 N., R. 82 W.; NW¼ Sec. 7, and SW¼ Sec. 6, T. 134 N., R. 81 W., north of Breien, Morton County.

Start section at base of bluff.

Cannonball formation	Feet	Inches
13. Buff sand with sandstone concretions at top holding up general regional upland level in this area. Some limonitic concretions	10	
12. Dark grey and brown thin-bedded shale containing light grey fine-grained sandstone concretions at irregular intervals. (Some small amounts of ripple cross-bedding noted in the sandstone concretions.) Largely covered. Contacts dug out	50	
11. Buff, impure, fine-grained sand with sandstone concretions. Concretions form top of small bench at 16 feet and 48 feet from the base. Fossils found in the concretions at 48 feet from the base. This latter bench makes qutie a distinct topographic feature and is called the No. 2 sandstone or middle Cannonball sand in this report	51	
10. Grey and brown silty shale rather evenly bedded but badly slumped. Can't find exact bottom. Top can be readily dug out. Some of the shale is distinctly carbonaceous and contains considerable gypsum	31	
9. Sandy concretionary zone at the base. Impure, brown, fine-grained sand. Base of the member badly slumped and covered. At 32 feet from the base is another sandstone concretionary layer. Mostly covered	56	
Total thickness of exposed Cannonball	198	
Ludlow formation		
8. Brown, thin-bedded, fissile, lignitic shale. Lignite stringers. This part of the exposure is covered with about 16½ feet of glacial till. To get a continuous section at this locality the measurements were continued about 1 mile to the north sighting with the hand level. There is apt to be considerable error in this procedure	28	
7. Sand. Buff with lignitic shale partings	6	6
6. Brown clay shale		10
5. Sand. Buff, fine-grained. Concretionary	4	
4. Brown, thin-bedded, lignitic shale, containing plants. Coaly at base. Limonitic concretions in thin zones. Lignite stringers toward top	10	7
Total thickness of exposed Ludlow	49	11
Hell Creek formation		
3. Brown, lignitic shale interbedded with bentonitic sands and clays. Member is particularly bentonitic near base. Limonitic concretionary zone present 15 to 16 feet from the base is not apparently continuous. Weathered marcasite concretions also present	36	1
2. Brown, shaly sandstone with concretionary brown sand at the base. Grey and brown sandy shale. Few badly weathered marcasite concretions present	28	5
1. Medium-grained, grey, speckled sand with lignitic, brown shale partings. Cross-bedded. In irregular or gradational contact with the member above. Brown shale partings noted at the exposed base of the member. Exposed	11	7
Total thickness of exposed Hell Creek	76	1

Section 8

NW¼ Sec. 27, T. 136 N., R. 79 W.

Section base not exposed.

Glacial drift	Feet	Inches
10. Glacial till	2	
Cannonball formation		
9. Buff, calcareous sand weathering grey. Very cross-bedded. Limonitic zone toward the base. Sandstone concretions prominent in places. Exposed	25	
Ludlow formation (?)		
8. Grey, fine- to medium-grained sand interbedded with brown lignitic, silty shale showing plant fragments. Some weathered marcasite streaks. Fairly continuous limonitic concretionary layer at the top	30	
Hell Creek formation		
7. Grey to buff, fine- to medium-grained sand, some of it buff-weathering. Cross-bedded	23	
6. Grey, bentonitic clay with limonitic concretionary zone at the top. Some of the limonitic concretions are cemented together by additional limonite. Limonitized tree trunk in this zone	10	
5. Grey, fine-grained, cross-bedded, fluted sand. Silty shale stringers interbedded with the sand	17	
4. Brown, lignitic shale and brown shale. Black shale which is almost a lignite is present at the base	11	

3. Grey, fine-grained, fluted sand	3	6
2. Brown, lignitic shale grading upward into black shale. Top of this member also very irregular	4	6
1. Grey, fine-grained, fluted sand interbedded with silty shale. Some limonitic concretions present. Some sandstone concretions present at the top of the member. The top of the member is in very irregular contact with the overlying brown shale	17	
Total thickness of exposed Hell Creek	86	

Section 9

SE¼ Sec. 3, T. 134 N., R. 81 W.
Base of section in Hell Creek

Cannonball formation	**Feet**	**Inches**
16. Sandstone and shale poorly exposed. By aneroid to top of bluff	200	
Ludlow formation		
15. Brown-black lignitic shale. Very coaly	7	2
14. Scoria and ash. This bed not always found at the same level	1	
13. Brown-black lignitic shale, almost a lignite	1	10
12. Grey, fine-grained micaceous sand interbedded with lignitic shale. Round marcasitic concretions size of fist	5	9
11. Brown-black lignitic shale. Thin-bedded. Some thin lignitic stringers	9	7
Total thickness of exposed Ludlow	25	4
Hell Creek formation		
10. Shale, bentonitic, light and dark-grey with some sand	15	6
9. Sand, grey with light-brown streaks. Fine- to medium-grained. Cross-bedded. Transitional to shale at top. Lignitic layer near bottom in places	27	6
8. Sand, grey, buff-weathering, medium-grained, cross-bedded. Stands in vertical walls	23	6
7. Sand, fine-grained, grey, with some limonitic streaks and limonitic concretionary zone at top 6 inches thick	6	11
6. Sand and shale interbedded in thin beds. Grey in color	3	10
5. Cover, probably sand	13	
4. Shale, light brown, silty	3	6
3. Sand, fine-grained, argillaceous	3	
2. Shale, mostly grey, but with 1 foot lignitic zone near the middle	16	

1. Sand, fine-grey, argillaceous with shale breaks in upper part	14	
Total thickness of exposed Hell Creek	126	9

Section 10

Center of N. Line Sec. 19, T. 136 N., R. 79 W. (Square Butte)
Base of section in gully on west side of bluff where butte joins upland

Cannonball formation	**Feet**	**Inches**
15. Sand, buff, fine-grained with a little clay. Limonitic zone at base and another at 5 feet, 4 inches above the base. Exposed	8	5
14. Shale, yellow, flaky, with limonitic brown concretionary zone about 0.2 feet thick at the top	4	
Total thickness of exposed Cannonball	12	5
Ludlow formation		
13. Shale, brown, carbonaceous. Clay is partly bentonitic near middle but is mostly flaky. Some lignitic black shale near the top	14	6
Hell Creek formation		
12. Sand and shale interbedded. Grey with some carbonaceous material and plant stems. Weathered marcasite concretions common in sand layers imparting yellow color. Weathers giving banded appearance. Clay is bentonitic in part	30	
11. Sand, grey to brownish, thin-bedded. The sand layers are separated by very thin carbonaceous streaks	1	7
10. Sand, grey, medium- to fine-grained with numerous concretions of cobble size. Most concretions are limonitic yellow shale. Some are limonitic sand cemented around weathered marcasite concretions. Clay balls, ellipsoidal in shape, with long diameter up to 1½ inches are common in the lower half. Upper half of bed stands in nearly vertical walls and has less clay beds and concretions than lower portion which erodes as a slope. Hard brown sandstone commonly 4 inches in thickness but in some places thicker present at top of member	35	
9. Shale, yellow and brown, bentonitic, mottled. White efflorescence (?) along fractures	43	
8. Sand, medium-grained with considerable dark mineral. Shale breaks toward the top. Upper contact more or less gradational	8	

7. Shale, medium-grey to brown-grey. Stains brown at surface. Thin sandy streaks are discontinuous	2	7
6. Sand, grey, fine-grained, becoming finer in texture toward the top and finally grading into a silty shale. Color also somewhat changes from a grey in lower part to a light brownish-grey in the silty material at top. Shows fluted weathering	11	6
5. Bentonite, dark greenish to brownish grey. Thin brown clay at top	2	
4. Sand and shale, grey. Sand is impure and is interbedded with grey bentonite sandy clay. Top contact with overlying bentonite is indistinct and gradational	5	8
3. Sand and shale, brown, carbonaceous, lower 2 feet is sand and upper 1 foot brown shale with some grey streaks and blotches	3	
2. Sand, grey, fine-grained, argillaceous	5	6
1. Sand, grey, fine- to medium-grained, clayey, with thin lignitic streaks. Interbedded with grey bentonitic shale in upper part with some plant fragments. Top 6 or 8 feet is nearly all shale with about 1 foot of brown, lignitic shale at the top of the member	27	10
Total thickness of exposed Hell Creek	175	8

Section 11

SE¼ Sec. 13, T. 136 N., R. 83 W.
Base covered.

Tongue River formation	Feet	Inches
13. Buff, fine-grained sand and interbedded, thin, lignitic, brown to black shale. Lignitic shale stands out slightly on weathering. Some fluted weathering in sand. Top not exposed. The interbedded shale appears to be in general darker than underlying shale. Exposed	16	9
Cannonball formation		
12. Buff, fine-grained sand and grey shale interbedded. Not too well exposed. Sand more prominent at middle. More grey shale at top, but some of top shale is black. Transitional contact with overlying sand	48	2
11. Cover	11	
10. Grey shale. Thin-bedded, interbedded with fine- to medium-grained sand. Sand beds 4 to 5 inches thick. Sand more abundant toward top. Makes slight topographic bench	5	7
9. Grey, thin-bedded shale. Weathers readily to grey-white talus slopes. Some buff sand interbedded toward top	15	9
8. Cover. Possibly shale	78	2
7. Grey sand, poorly exposed. Some concretions here. General level here that of Cannonball sand No. 2. Sand not consolidated here	8	
6. Cover. Probably contains grey shale	69	6
5. Grey shale	5	7
4. Cover	14	9
3. Buff, fine-grained sand. Concretions of sandstone at top. Fossils: gastropods, plecypods. Bench maker	16	9
2. Cover	24	5
Total thickness of exposed Cannonball	306	10
Hell Creek or Cannonball formation		
1. Grey, bentonitic shale	9	2

Section 12

NE¼ Sec. 30, T. 136 N., R. 82 W.

Tongue River formation	Feet	Inches
6. Buff, yellow sand. Massive and cross-bedded. Lenticular concretions cemented with carbonate found with diameters of 10 feet or more in long dimension. The concretions show crossbedding very well. The sand of this member is fine grained	33	6
5. Grey, clay shale with limonitic concretions	10	
4. Buff, impure, clay sand. Limonitic concretions present. Sand shows fluted weathering	8	
3. Grey, hard, tough, clay shale with brown lignitic shale and black lignitic shale seams interbedded. Some lenses of buff sand also present. The member is poorly exposed	14	6
2. Lignite or brown-black lignitic shale. This has apparently been opened for a mine. Some slumping here, so the measurements are apt to be inaccurate	3	1
1. Light grey, tough, hard, silty shale. Covered at base. Poorly bedded. This interval is represented in other sections farther west by volcanic ash. Quartzitic sandstone concretions appear in place at top of this member	31	6
Total thickness of exposed Tongue River	100	7

Base covered.

STRUCTURE

A generalized structural map (Plate 2) has been drawn, using the base of the Ludlow formation as a datum plane. This horizon is one of the most prominent and satisfactory for this purpose in this area. In general, it will be noted that the strike of the rocks of the area is NE-SW and the regional dip of the beds is to the north or northwest. The rate of dip is variable, but in general the average dip in this area is about 15 feet per mile.

Elevations were taken on three beds and reduced to the datum. In the area north and east of Flasher the elevations were taken on the top of the No. 2 or Cannonball sandstone. North and west of Fallon the elevations were in general taken on the base of the **B** lignite of the Tongue River formation. All elevations were taken with a Paulin altimeter and corrected for diurnal pressure variations.

Taken as a whole, there are no large structures with much closure on this map. It is interesting that the small domes and noses which do show on the structure map in general trend in a northerly or northwesterly-southeasterly direction at nearly right angles to the regional strike. The most prominent of these noses is the one trending north through townships 135 and 136 in range 83.

Two suggestions as to the origin of these low folds can be made. They may be the Great Plains equivalent of the mountain building forces which were operative in the Rocky Mountain region during the pre-Wasatch- post Fort Union time in which case they are truly orogenic in nature or they may simply be due to differential compaction. In this latter case the "folds" might be caused by the structurally high areas being underlain by material which did not compact as readily as material on either side. Therefore the strata on either side of the high area settled more than the strata over the structural high giving rise to the present structures.

PHYSIOGRAPHY

General statement

Several interesting physiographic problems present themselves in this area. These are as follows: the erosion levels and their possible correlation; the pseudo-erosional levels held up by hard layers in several of the formations; and the preglacial drainage of the area.

Topography of the area

The area covered by this report is part of the Missouri Plateu which extends into Canada and is bounded on the south by the High Plains, on the east by the Missouri Coteau and on the west by the Rocky Mountains[54]. This area is part of that portion of the Missouri Plateu which has been subjected to continental glaciation although in the area of this report the effects of the glaciation were relatively slight.

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[54] Fenneman. N. M., Physiography of the western United States: pp. 72-75, New York, McGraw-Hill Book Co., Inc., 1931.

In general the area can be roughly divided into two parts: the northern and western part which is the upland area underlain by the Cannonball and Tongue River formations of the Fort Union; and the lowland and badland area in the southeast part of the map area which is underlain by the Hell Creek formation.

For purposes of discussion the upland area can be divided into two divisions according to the underlying formation. The higher of the two levels is for convenience called the Tongue River level in this report since it is underlaid by the Tongue River formation and ranges in elevation from 2100 to 2275 feet in elevation. It forms the long northwest-southeast trending upland lying in townships 135 and 136, ranges 82, 83, 84. In most places this level rises rather gently from the level formed on the top of the Cannonball formation and while it is usually held up by a sandstone member, poor exposures make it difficult to be certain that this is always the case.

Below this uppermost upland area is the level held up by the various sandstone members of the Cannonball formation. In this report this is being called the Cannonball level. This level fringes the base of the Tongue River level and lies mainly in the central and northern part of the map area. It ranges in elevation from 1950 to 2100 feet declining northward with the dip of the beds. It is held up by several of the sandstone concretionary zones which are present in the Cannonball (usually the one labelled number 2). The relief of this level is moderate, averaging about 50 feet (estimated). The break in slope from this upland to the Hell Creek lowland below is quite sharp and distinct. This bluff may be as much as 250 or more feet above the lowland formed on the Hell Creek formation. At several places, such as that immediately north of Breien, several of the sandstone concretionary zones in the Cannonball make very noticeable subsidiary levels below the main upland.

Probably the most noticeable level of all in the map area is the one nearest the Cannonball River. This level is developed in the Hell Creek formation and is for convenience termed the Hell Creek level. It is a true strath in that it is not developed on any one hard bed of this formation. In this respect it differs from the levels developed on the Tongue River and Cannonball formations. Since it is limited largely to one formation, some question might be raised as to whether the Hell Creek is a true strath. However, the top of the Fox Hills formation is also included in this level in the most southeastern part of the map area along the Cannonball River. Quite possibly, the Fox Hills sandstone may be the temporary base level which has held up and is holding up this level. This Hell Creek strath declines in elevation from 1742 feet just north of Timmer to 1732 feet at Breien to 1727 feet south of Solen to 1722 near the mouth of the Cannonball River. Thus it can be seen that this bench declines downstream with the present Cannonball River. This erosion level also rises northward from 1722 feet near the mouth of the Cannonball to about 1840 or more feet in the valley of Rice Creek.

While it is dangerous to suggest correlations without more detailed tracing to other areas, it is being tentatively suggested that this level might be the same as the outer gorge developed along the Little Missouri River in Billings County, North Dakota. Leonard[55] says that this outer gorge is about 160 to 200 feet below the upland there. In this map area, Hell Creek level is from 250 to 380 feet below the upland. Inasmuch as this level is widely developed near the mouth of the Cannonball (where it is 10 or more miles wide) and as it is covered with glacial gravel in many places, it would seem to be pre-glacial in age. Possibly this level might be late Pliocene or early Pleistocene in age and be equivalent to the first level below the Flaxville Plain of eastern Montana[56]. Such a correlation is only suggested and cannot be proved until much more detailed work in western North Dakota is done.

Pre-glacial drainage

Leonard[57] has suggested the course of several of the pre-glacial streams in this area. During the course of the present field work, it was found that there are many more glacial and pre-glacial drainage channels than Leonard noted. In general, these may be divided into two types, (1) those which were occupied by streams for a considerable period of time and were possibly pre-glacial river valleys, and (2) those which were glacial outwash channels or distributaries and which were used only when the ice was melting in the immediate vicinity of this area.

There are two of these old channels which probably represent pre-glacial streams. (See Plate III.) One of these extends northwestward from the Cannonball valley at Timmer, passes northeast of Flasher about one mile and continues northward to the valley of the Heart River. The southern part of this old channel is occupied by the valley of Chanta Peta Creek. From about the latitude of Flasher to the Heart River, the valley is not occupied by any permanent stream.

The other of these old valleys which was probably occupied by a fairly large stream is the one running southeast from St. Anthony. In the northern part of this valley flows the southeast branch of Little Heart River. The southern part is occupied by the northwest branch of Cantapeta Creek.

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[55] Leonard, A. G., The geology of southwestern North Dakota with special reference to the coal: North Dakota Geological Survey Fifth Biennial Report, pp. 33-41, 1908.

[56] See Collier, A. J., and Thom, W. T., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179-184, 1918.

Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, 133 pp., 1932.

[57] Leonard, A. G., U. S. Geol. Survey Geol. Atlas, Bismarck folio (no. 181), p. 45, 1912.

————————, Pleistocene drainage changes in western North Dakota; Geol. Soc. America Bull., vol. 27, pp. 295-304, 1916.

There are numerous old discharge channels. These are differentiated from the old valleys by the fact that they are less well-defined, and are broader and shallower. In general both the old valleys and the discharge channels trend in a northwesterly-southeasterly direction. As can be seen by reference to Plate III one of these channels lies east of Ambulance Butte and another lies west of Ambulance and Signal Buttes and is occupied by the north branch of Cantapeta Creek. Another old channel is found about 2½ miles east of the old pre-glacial valley occupied in part by Chanta Peta Creek and the Heart River. A smaller discharge channel occupied now by the east branch of Chanta Peta Creek and an unnamed stream flowing south-southeast joins the valley of the Cannonball northeast of Timmer.

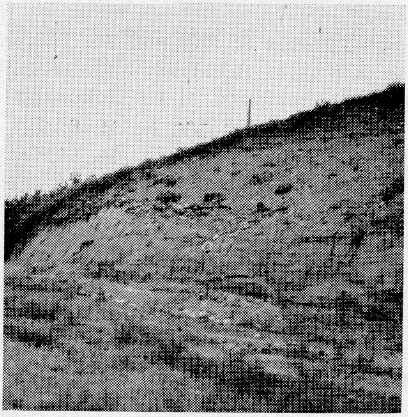

Fig. 7. High terrace gravels resting on lowest Cannonball sand in the SW¼ Section 13, T. 134 N., R. 83 W., north of Timmer, Morton County. These gravels are approximately 200 feet above the present Cannonball River.

These old valley and discharge channels should be kept in mind if gravel is desired as most of the gravel in the area occurs in these valleys. They also might prove valuable as ready sources of shallow ground water.

ECONOMIC GEOLOGY

General statement

This area is not particularly well endowed from the standpoint of natural resources. Possible natural resources are lignite, gravel, clay, and the possibility of oil.

Lignite

The lignite occurring in this area is found at two different horizons. One of these is the coal at the base of the Ludlow formation. In no place is it being extensively mined at the present time. There are a number of old abandoned pits, the largest of which are located as follows:

SE¼ Sec. 22, T. 135 N., R. 81 W.
NE¼ Sec 18, T. 135 N., R. 81 W.
SE¼ Sec. 10, T. 134 N., R. 84 W.

This coal averages 2 feet or less in thickness. It is irregular in distribution and does not always occur at the base of the Ludlow. In the places where it has been mined, it has been stripped and used apparently only by the farmer on whose land it occurs.

The other coal of the area is the coal occurring about 100 feet above the base of the Tongue River formation. This corresponds in stratigraphic position to the B lignite of the New Salem field to the north[58]. There are a number of abandoned openings in the area covered by this report mostly in the northwestern part of the area in township 136 north, ranges 82, 83, and 84. This coal is also thin, averaging less than 2 feet in thickness, and irregularly distributed. Abandoned openings can be found at the following locations:

Sec. 29, T. 136 N., R. 82 W.
NE¼ Sec. 1, T. 136 N., R. 84 W.
NE¼ Sec. 24, T. 136 N., R. 84 W.

Clay

Clay is an abundant constituent of several of the formations in this area. Bentonitic clay is abundant in the Hell Creek formation but the individual beds are thin and therefore the clay is not likely to have commercial importance. In association with, and near the base of the **B** lignite found in township 130 N., ranges 82, 83, and 84 is a light grey siliceous clay or volcanic ash which might be commercially important for abrasive or scouring powders. At one location (NE¼ Sec. 15, T. 136 N., R. 83 W.), 7 feet of this ash was measured in an old opening.

Gravel

As has been noted before, the gravel of this area is associated rather extensively with the old pre-glacial valleys and glacial discharge channels. Gravel pits have been observed at the following locations:

SW¼ Sec. 2, T. 135 N., R. 80 W.
SE ¼ Sec. 33, T. 136 N., R. 81 W.
NW¼ Sec. 33, T. 136 N., R. 81 W.
SE ¼ Sec. 33, T. 136 N., R. 83 W.
NE¼ Sec. 3, T. 134 N., R. 84 W.
SW¼ Sec. 12, T. 134 N., R. 84 W.

Another area where pits have not been opened but where gravel might be found is in the old channel present in township 135 N., ranges 82 and 83 W.

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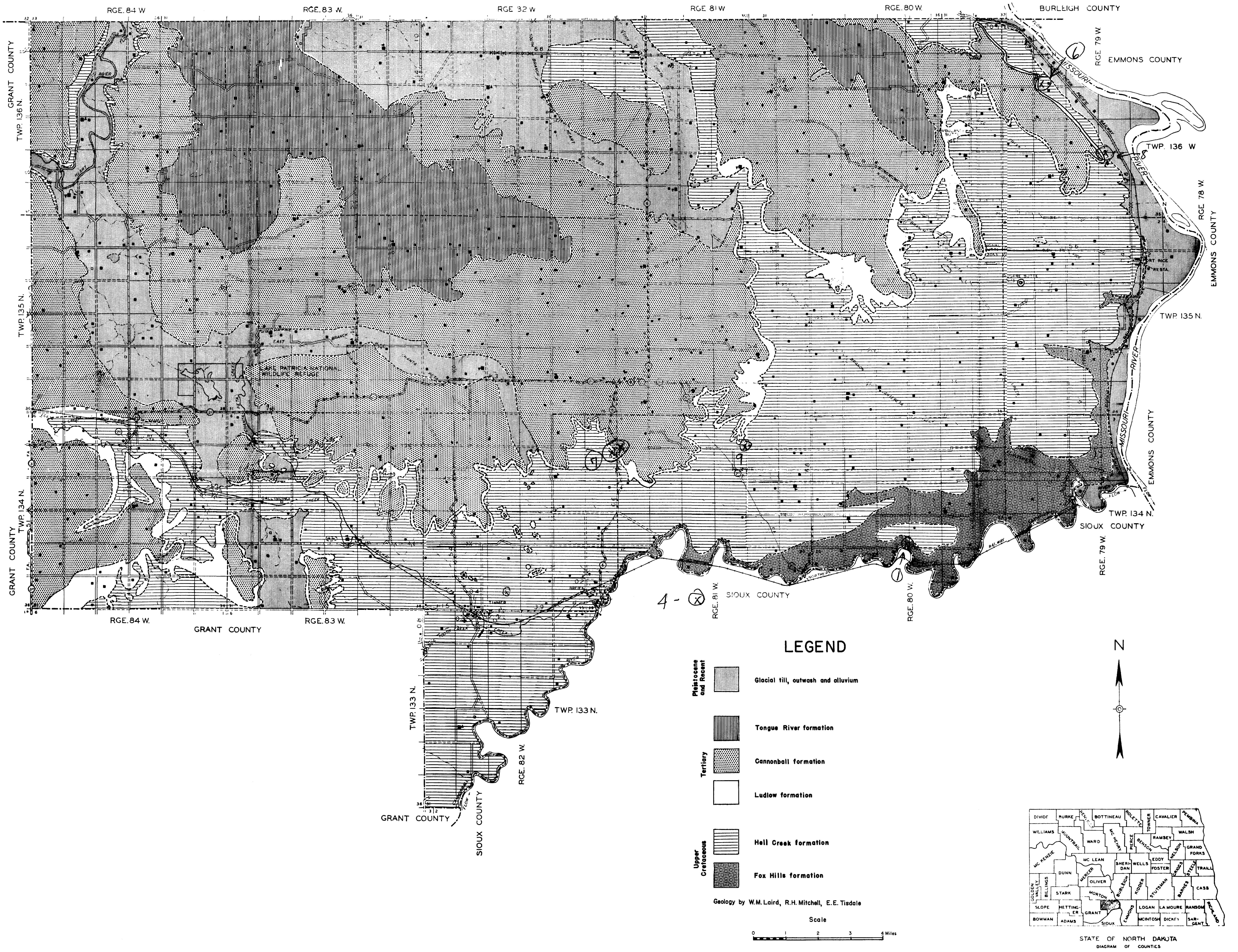
[58] See Hancock, E. T., The New Salem lignite field: U. S. Geol. Survey Bull. 726A, 39 pp., 1921.

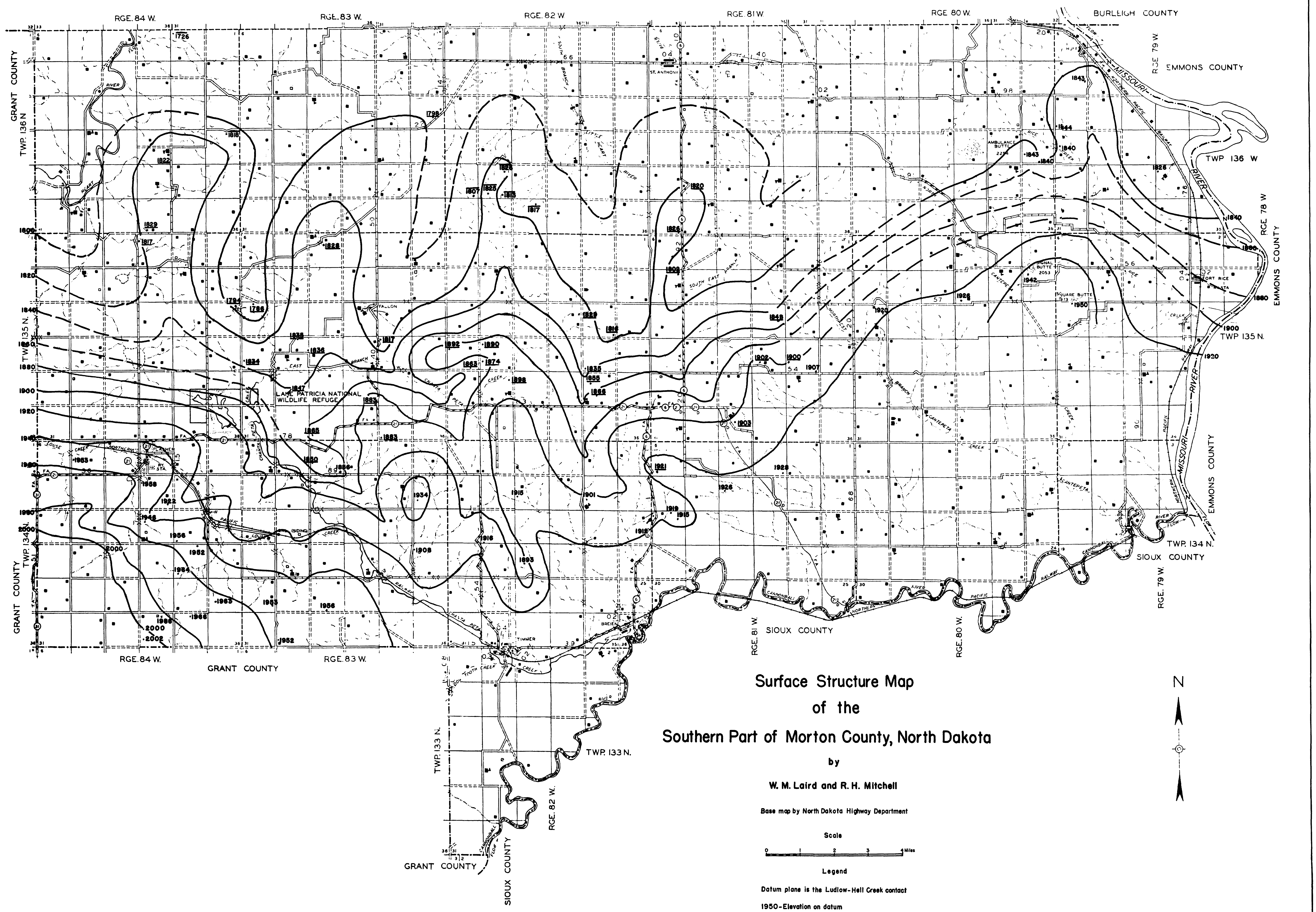
PLATE I



WML

MODIFIED POLYCONIC PROJECTION

PLATE 2



Surface Structure Map
of the
Southern Part of Morton County, North Dakota

by

W. M. Laird and R. H. Mitchell

Base map by North Dakota Highway Department

Scale

0 1 2 3 4 Miles

Legend

Datum plane is the Ludlow-Hell Creek contact

1950-Elevation on datum

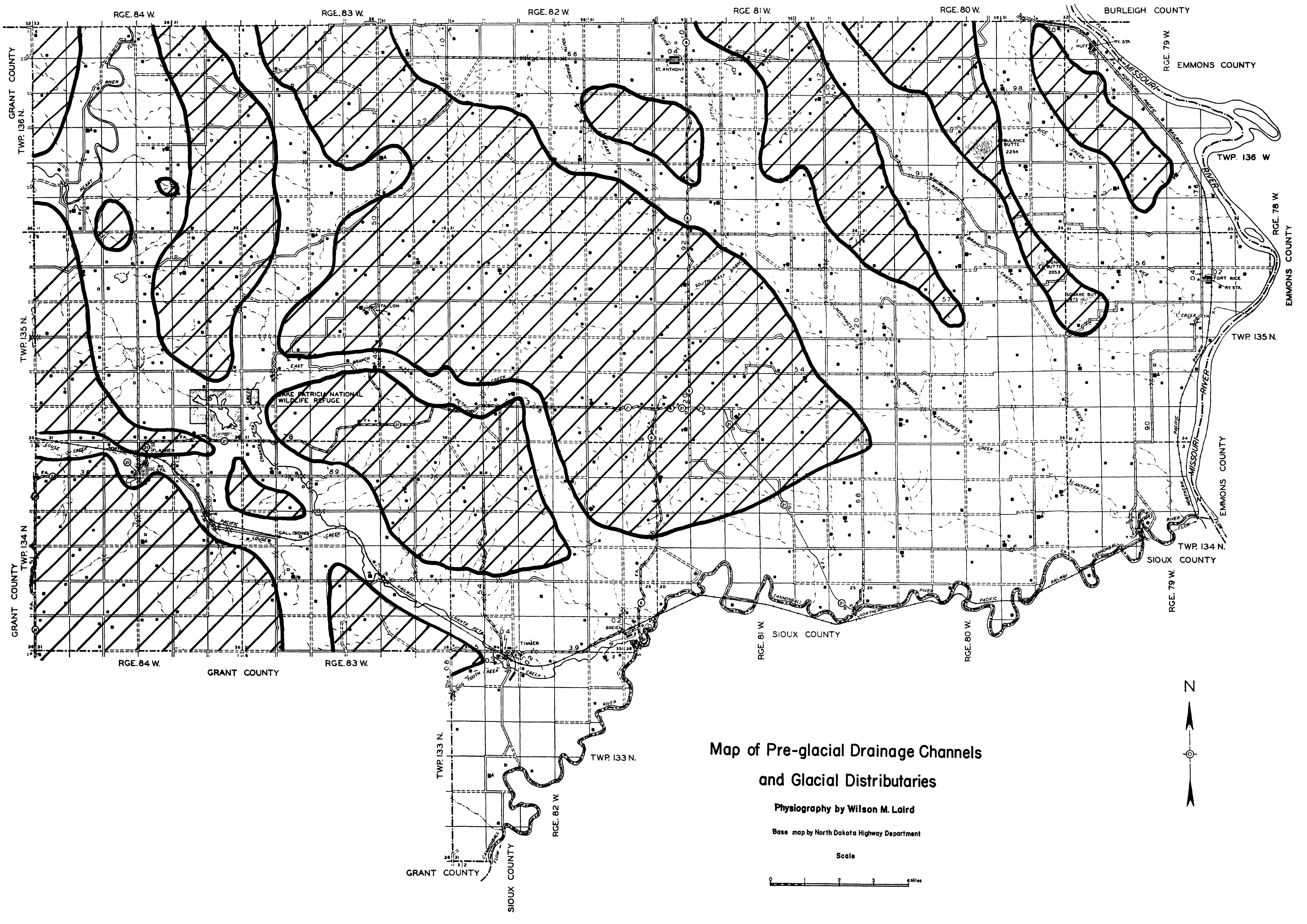
1950-Elevation on No.2 sand of the Cannonball reduced to datum

1950-Elevation on B lignite of the Tongue River reduced to datum

Contour interval - 20 feet

WML

PLATE 3



Map of Pre-glacial Drainage Channels and Glacial Distributaries

Physiography by Wilson M. Laird

Base map by North Dakota Highway Department

Scale

WML