NORTH DAKOTA GEOLOGICAL SURVEY

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The Geology of the Grassy Butte Area, McKenzie County, North Dakota

by

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ABSTRACT

The Grassy Butte area lies in southern McKenzie County, just southwest of the deepest part of the Williston Basin, and is bordered on the north by the North Unit of the Theodore Roosevelt National Memorial Park.

The purpose of this investigation was: (1) to prepare a geological map of the area; (2) to map the geologic structure of the area; (3) to measure and describe detailed stratigraphic sections which would aid in correlating rock units in this area with previously described rock units in adjacent areas; (4) to indicate lignite beds of possible economic value.

The western three-fifths of the Grassy Butte area is thoroughly dissected into badland topography, but the eastern two-fifths is an upland plain, the Missouri Plateau.

The Tongue River formation, including the Sentinel Butte member, and the Golden Valley formation are exposed at the surface. The Tongue River formation is Paleocene in age. The Golden Valley formation, of Eocene age, was determined to be more extensive in this area than was previously supposed, and the writer used as the base of the formation an horizon approximately 25 feet lower than the "orange marker bed" which had usually been used for mapping purposes before.

A series of north plunging noses and troughs was found to be present in the western part of the Grassy Butte area. To the south, in the adacent Elkhorn Ranch area, the plunge of the easternmost nose is reversed and anticlinal closure results. The village of Grassy Butte is located on the crest of another anticline, trending northwest-southeast. The Little Missouri River flows over the easternmost nose, which seems to exert directional control on the course of that river. The outcrop pattern also seems to be controlled to some extent by the structure of the Paleocene beds in this area.

INTRODUCTION

Location and accessibility:

The Grassy Butte area is located in the unglaciated part of the Missouri Plateau section of the Great Plains physiographic province. The northern boundary of the area is approximately the southern extent of Pleistocene glaciation in this vicinity. The area lies in southern McKenzie County, just southwest of the deepest part of the Williston Basin, and is bordered on the north by the North Unit of the Theodore Roosevelt National Memorial Park. It is situated mainly in Tps. 148 and 149 N., and Rs. 98 to 103 W.

United States Highway 85 extends north-south through the eastern part of the Grassy Butte area, and North Dakota State Highway 7, an east-west highway, intersects Highway 85 in the southwestern part of the area. Highway 85 passes through the village of Grassy Butte, which is located in secs. 11 and 12, T. 148 N., R. 99W.

The two highways mentioned above are the only all weather roads in the area, the others being county, township and private roads, usually with a clay surface, and at best surfaced with a thin layer of scoria. The secondary roads are practically impassable during and after showers.

The western three-fifths of the Grassy Butte area is dissected into mature or bad lands topography and cross country travel off the maintained roads is impossible with any wheeled vehicle except a jeep, and is then mostly limited to old trails. The writer was fortunate that during the time the field work for this report was being done, roads were being built throughout this area by a seismic crew, and the writer was able to reach many otherwise inaccessible places. The seismic roads are not maintained, however, and after several showers they usually wash out where they cross a gully or stream bed. Fire guard trails are maintained in this area by the McKenzie County Stock Grazers Association, and they were also of much help.

Purpose of investigation:

The purpose of this investigation was fourfold:

1. To prepare a geologic map of the area.
2. To map the geologic structure of the area.
3. To measure and describe detailed stratigraphic sections which would aid in correlating rock units within the area with previously described rock units in adacent areas.
4. To indicate lignite beds of possible economic value.

Previous geologic investigations:

The Tertiary stratigraphy and physiography of southwestern North Dakota have been described by many writers, including Alden (1932), Benson (1952), Brown (1948), Laird (1950), Leonard (1916, 1925), North Dakota Geologic Society (1954), Seager, et. al. (1942). Detailed mapping of adjacent areas has been done by Fisher (1953, 1954), and Hanson (1955). Schmitz (1955) has deciphered the history of the east-west portion of the Little Missouri River, and Petter (1956) has done the same for that portion of the Little Missouri River from the South Dakota-Wyoming border to its easerly bend.

Additional references to previous work are cited throughout this report.

Field work:

The field work for this report was done during the summer of 1955. Five stratigraphic sections were measured in detail for the purpose of correlating rock units within this area and with previously described and mapped rock units in adjacent areas. The sections were measured with an Abney hand level and with a Brunton compass used as a hand level.

Altitudes on beds used to construct the structure contour map were established with a Paulin altimeter calibrated in two foot units. The only established vertical control within the area is a United States Coast and Geodetic Survey second order level line located along U.S. Highway 85, extending from Belfield to Watford City, North Dakota. Temporary bench marks were established, with the altimeter, one to three miles apart, depending on the terrain. The temporary bench marks were all double checked, and often triple checked. A United States Coast and Geodetic Survey second order level line is located along old North Dakota Highway 16, extending from Junkin to Beach, a few miles west of the western boundary of Grassy Butte area. Just west of the Little Missouri River a line of temporary bench marks was established from the second order level line located along Highway 16.

Lignite beds are the most persistent of all Paleocene beds in western North Dakota, and for this reason most mapping is based on them. The key bed, upon which the structure contours are drawn in this report, is the base of a bed designated the "L bed" by Fisher (1953), which is generally lignite or scoria. The "L bed", locally at least, is the lower contact of the Sentinel Butte member of the Tongue River formation. This lignite bed was used as the key bed for structure mapping by Fisher in the Skaar-Trotters area (1954) to the west of the Grassy Butt area, in the West Central McKenzie County area (1953) adjacent to the northern limit of the Grassy Butte area, and by Hanson (1955) in the Elkhorn Ranch area directly to the south of the Grassy Butte area. The "L bed" is the base of the Sentinel Butte member in these areas and also in the South Unit of the Theodore Roosevelt National Park.

Where the "L bed" is not exposed altitudes were established on other strata of known interval from the key bed and that interval added or substracted from the measured altitude to determine the altitude of "L bed", the key bed.

Laboratory work:

Lithologic samples collected in the field were later examined with binocular and petrographic microscopes. When necessary and feasible chemical tests were run on the samples to facilitate identification of the minerals. Some bentonitic clay samples were examined microscopically to determine the presence or absence of shards of volcanic glass, and a sample was also tested with a differential thermal analysis apparatus to establish the composition of the clay.

Acknowledgements:

Thanks are due Dr. Wilson M. Laird, State Geologist of North Dakota and Head of the Department of Geology at the University of North Dakota, who provided economic assistance for the field work, supplied much of the equipment used in the preparation of this report, and who offered many helpful suggestions. Special thanks are extended Dr. Gordon L. Bell, Department of Geology, University of North Dakota, for guiding, criticizing, and giving valuable advice in the field and all other phases of preparation of this report. I also wish to express my appreciation to Mr. Nicholas N. Kohanowski, Department of Geology, University of North Dakota, for his helpful suggestions. Mr. Miller Hansen, Assistant State Geologist of North Dakota, along with Dr. Bell, briefed the writer on field methods and this was greatly appreciated. I also wish to thank the many ranchers in the Grassy Butte area and residents of the village of Grassy Butte who aided the writer during the time the field work for this report was being done.

PHYSIOGRAPHY

Topography:

The eastern two-fifths of the Grassy Butte area is an upland plain, the Missouri Plateau, except for a narrow margin of badlands along Charlie Bob Creek and Spring Creek, which drain into the Little Missouri River north of the Killdeer Mountains. In the very southeastern corner of the area are the head waters of the Knife River, which empties into the Missouri River. Several small buttes, such as Grassy Butte, rise 50 to 100 feet above the surrounding plain. The surface altitude in general ranges approximately from 2000 feet above sea level on the Little Missouri River to 2700 feet on the upland plain.

The western three-fifths of the Grassy Butte area is thoroughly dissected into badlands by headward erosion of the tributaries of the Little Missouri River. Badlands are characterized by mature topography, in contrast to the flat upland plain. The larger valleys have flat or broadly rounded bottoms but the smaller streams flow in steepsided ravines and gorges. The Little Missouri River tributaries form a dendritic pattern, and badlands along adjacent streams often coalesce, with the result that the dissected topography is virtually continuous for several miles away from the river.

The badland topography is formed both by headward stream erosion and sheet wash. Rain usually occurs in short cloudbursts and the water immediately runs off the impermeable clay surface to the stream channels. As a result the slopes are generally fluted by tiny rills. Some of the larger rills often form a "wine glass" pattern, with the "stem" terminating at the break in the slope. The steep sides are usually void of vegetation.

Another factor in the development of this topography is slumping of blocks of the horizontal strata. These slump blocks seem to be due mainly to the gliding down slope of deeply notched spurs of bedrock units whose basal member has become saturated and undercut (Schmitz, 1955). The writer has seen what appears to be blocks of strata developing slump. Lignite beds often act as aquifers and this seems to facilitate oxidation much further back from the outcrop than is ordinarily the case. On oxidation, lignite soon crumbles to a powder and is easily removed by the wind and percolating water. An overhanging ledge is developed, sometimes extending many feet into the face of the outcrop.

The width of the Little Missouri badlands ranges from a maximum of over 20 miles in the Grassy Butte area, to less than two miles in places along the east-west portion of the river, north of this area. The cause of the range in width will be discussed later.

The drainage divide between the Little Missouri and Yellowstone Rivers is included in the western part of the Grassy Butte area. West of the divide there is a very noticeable change in topography from the badlands found to the east. The tributaries of the Yellowstone in this area are not dissecting the strata into badlands and the valleys are generally shallow and broad. As a result cross country travel is much easier but there is also a corresponding scarcity of outcrops. Scoria beds consisting of fused and baked rocks overlying burned lignite beds, often cap the hills and are very useful for mapping purposes. Near the drainage divide are numerous pot holes which make travel off the roads extremely difficult. Where the pot holes were observed a lignite bed was always found near the surface. These holes are also found in lesser numbers in the badlands.

The cause for the variation of the topography between the Little Missouri River watershed and that of the Yellowstone River was the lowering of the base level of the Little Missouri River due to the relocation of its mouth just previous to the Kansan-Illinoian glaciation. This change was brought about by stream piracy by tributaries of the Little Missouri River and streams now tributary to the Missouri River (Schmitz, 1955), and the resulting increased gradient of the river initiated the development of badlands topography.

The Little Missouri River is a mature stream. It meanders broadly in a flood plain which varies in width from half a mile to one and a half miles. The river alternately erodes and deposits, always trying to establish equilibrium as conditions change. From evidence suggested by a recent cutoff meander the writer believes that on the whole the river is eroding. The last meander just south of the bend where the Little Missouri River turns east (see geologic map) has been cut off to form a small oxbow lake. The level of water in the oxbow is higher than that of the river, due to active downcutting by the river since the oxbow was formed.

The meanders of the Little Missouri River are usually rectangular in shape, with corresponding sides of the various rectangles oriented in the same direction. This pattern suggests structural influence (Bell, 1955). No field evidence of jointing or faulting has been found, but the sides of the meander rectangles generally seem to extend parallel or normal to the structural contours in the Grassy Butte area.

Pleistocene drainage changes:

Along the Little Missouri River at least five levels of erosion, deposition, and combination erosion and deposition are discernible (Laird, 1950; Fisher, 1953; Schmitz, 1955; Petter, 1956). The lowest level, Terrace No. 1, is the present stream channel. As described by Schmitz, (1955), Terrace No. 2 is an alluvial surface, while Terrace No. 3 is a combination cut in fill and planation terrace, being cut in fill nearest the river, and planation terrace away from the river. Terrace No. 4 is a planation terrace. The highest level, Level No. 5, is the Missouri Plateau and it represents the Miocene-Pliocene peneplain, correlated with the Flaxville plain by Schmitz (1955) and Petter (1956).

Study of the Little Missouri terraces has revealed the history of that river (Schmitz, 1955, Petter, 1956). It is generally agreed that the Little Missouri River once flowed north from its present easterly bend, through a wide strath, Little Missouri Terrace No. 4, now occupied by parts of Bowline, Redwing, Cherry, and Tobacco Garden Creek. This channel trends northeast from the mouth of Bowline Creek and joins the Missouri River at the mouth of Tobacco Garden Creek. This pre-diversion Little Missouri River was part of a former drainage system that flowed northeast to the Hudson Bay. Benson (1952) and Schmitz (1955) believe this pre-diversion river flowed north across the site of the present Missouri River trench and joined the ancient Yellowstone in the northwestern part of North Dakota.

The following is a summary of the sequence of events in the history of the Little Missouri River as determined by Schmitz.

Stage No. 1. Miocene epeirogenic movements in the Rocky Mountain region halted Oligocene deposition and initiated erosion which culminated in a peneplain, the present upland surface, by Pleistocene time. Across the plain the Little Missouri flowed north in a broad, shallow strath, which is present day Terrace No. 4.

Stage No. 2. Broad arching during early Pleistocene elevated the region and enabled tributaries of the Little Missouri River to capture that part of the river upstream from the present mouth of Bowline Creek. This established the easterly bend in the river, but the Little Missouri still flowed north, although for a distance it was in the channel of former tributaries.

Stage No. 3. The Little Missouri River of Stage No. 2 was captured by an east-west flowing stream, the pre-glacial Medicine Stone River. This completed the diversion to the present channel, and a change of base level and gradient due to a new mouth initiated rapid down cutting which deeply entrenched the new valley.

Stage No. 4. The Kansan-Illinoian ice sheet invaded the region and blocked the valleys of the northeasterly flowing rivers. Lakes were formed in the river valleys and deposition resulted.

Stage No. 5. Maximum glaciation was followed by re-trenching of the diverted channel and the resultant formation of Little Missouri Terrace No. 3, and later Terrace No. 2 and Terrace No. 1.

The development of badlands along the Little Missouri River must have begun with the diversion of the river and the lowering of its base level. The tributaries of the rejuvenated stream rapidly cut into the surrounding Little Missouri Terrace No. 4 along the north-south flowing portion of the river. Terrace No. 4 was not nearly as widely developed by the tributarties of the pre-diversion Little Missouri River and as a result the terrace is not as widely distributed along the east-west flowing portion of the river as it is along the north-south portion. The upland plain, which is approximately 150 feet above Terrace No. 4, is closer to the river along its east-west portion and this greater thickness of bedrock has hindered as extensive development of badlands along this portion of the river as along the north-south portion

STRATIGRAPHY

General Stratigraphy:

Strata present within the area described in this report include the Tongue River formation, the Sentinel Butte member of the Tongue River formation, and the lower member of the Golden Valley formation. The general classification of Tertiary rocks of western North Dakota is as follows (adopted from Schmitz, 1955):

Tertiary system
- *Pleistocene series
- *Wisconsin stage
- *Kansan-Illinoian stage
- ——Unconformity——
- Miocene-Pliocene series-Flaxville gravel
- ——Unconformity——
- *Oligocene series
- *White River formation
- ——Unconformity——
- Eocene series
  - Golden Valley formation
- Paleocene series
  - Fort Union group
    - Tongue River formation including the Sentinel Butte member.
    - *Cannonball-Ludlow formation

*Not present within the Grassy Butte area.

Tongue River formation:

The Tongue River formation was named by J. A. Taff (1907) of the United States Geological Survey. He used the term Tongue River Coal group to denote a series of lignite bearing strata along the Tongue River in the Sheridan Coal Field, Wyoming. The beds he described underlie the approximate equivalent of the Sentinel Butte shale, which was formerly considered to be of Eocene age. The North Dakota Geological Survey considers the Sentinel Butte shale to be a member of the Tongue River formation.

The Tongue River formation conformably overlies the Ludlow-Cannonball formation, the Ludlow member being the continental lignitic facies, and the Cannonball member is a marine facies. According to Benson (1952), the transitional contact between the Tongue River formation and the Cannonball marine member indicates that the Cannonball sea became shallow and was gradually replaced by low-lying coastal plain swamps. Benson further states that the fossil wood and the vertebrate fossils also indicate deposition in a coastal plain swamp, and that the sub-tropical floral assemblage indecates that the climate was moist and warm. The presence of fairly quiet waters is indicated by the well bedded, fine grained rocks.

Tisdale (1941) states that the heavy minerals in the Tongue River beds indicate the sediments were probably derived from a metamorphic complex such as the Black Hills or as may have existed in western Montana. He also believes that other sources may have contributed and that the sources of at least a portion of the sand were relatively near at hand.

The Tongue River formation consists of non-marine sand, sandstone, silt, clay, shale and lignite beds. On a fresh surface the beds are generally light gray or olive drab, but on a weathered surface the coloring is most often light tan or light gray.

The sand and sandstone beds in the Grassy Butte area are usually light gray in color, with a "salt and pepper" appearance. Many of the sand beds have a small amount of limonitic material which give the beds an overall tan or buff color.

The size of the sand grains ranges from medium to very fine and silt size, classified according to the Wentworth grade scale. The vast majority of the grains are very fine grained to silt. The sphericity of the grains ranges from angular to rounded, usually being subangular to subrounded.

The predominent mineral in the sand and sandstone beds is quartz, but gypsum, calcite, biotite, muscovite, mellite (?), organic fragments, limonite, unidentified dark minerals, and black opaque minerals are present in varying amounts. Several 10 feet to 20 feet thick sand beds are composed largely of gypsum present in the form of selenite grains. These beds contain too many impurities to be of economic importance. The "salt and pepper" appearance of many of the sand beds is due to organic fragments, biotite, the unidentified dark minerals. and the black opaque minerals.

Many of the sand beds are indurated to sandstone but within a sand bed the degree of induration changes both vertically and laterally, and the sandstone protrudes as ledges from the enclosing sand. Thin sandstone ledges are also present in many clay beds. The material cementing the sandstone grains is usually calcareous clay but in some beds the cement is entirely calcium carbonate and its percentage is in places so high that the rock would have to be classified as sandy limestone. Some of the sandstone is indurated with silica to the extent that it is a quartzite. The quartzite is gray and homogeneous in appearance. Limonite also cements some of the sandstone, usually in combination with calcareous clay. The character of the bedding of the sand and sandstone bed ranges from massive to thin bedded.

Sandstone concretions are prevalent in some beds. The concentric bands of the smaller concretions are stained with iron oxide, except for the center, which is usually gray in color and appears to be either leached of iron or else the iron present is not oxidized. These concretions range in size from a few tenths of an inch to several inches in diameter. They are found only in the outer part of an exposed sand bed, and this would indicate epigenetic origin. Marcasite or pyrite concretions are also found and these are not limited to exposed surfaces. The marcasite or pyrite is often oxidized to limonite and the concretion then appears much the same as the previously described concretions.

Well over half of the Tongue River formation consists of clay. The clay beds are predominately tan to gray in color but some are brown, white, and even purplish. The purest clay is found just above or below lignite beds, the rest usually being silty or sandy. Most of the clay is calcareous and limestone concretions are fairly common. Some thin clay beds are silicified and these crop out as resistant ledges and cap some of the small spurs. According to Benson (1952) most of the clay in the Tongue River formation is a mixture of illite type and kaolinite type clays, with a subordinate amount of montmorillonite type clay.

Many lignite and carbonaceous shale beds are present in the Tongue River formation. The color of the lignite is brown to dull or lustrous black. The lignite is woody in appearance and easily breaks along the grain. Selenite, pyrite, and concentrations of jarosite often occur in the lignite.

On exposed surfaces the lignite is oxidized and as a result is crumbly and powdery. Leonardite, an oxidized form of lignite, is present to some extent on nearly all exposed surfaces but was not found in commercial amounts in the Grassy Butte area. The oxidized powdery lignite is easily removed by wind and water, and this causes slumping of the overlying strata which often masks the true thickness of a lignite bed. Where completely covered, the lignite beds are often marked by a line of vegetation.

Although lignite beds are most persistent of all beds in the Tongue River formation they do rapidly thin and thicken, and often split into two or more beds separated by clay.

Scoria, formed by the baking and fusing of beds overlying burning lignite, is a prominent feature of the lignite bearing strata of western North Dakota. The scoria caps many of the smaller buttes and spurs and protects them from erosion. In this way, and by causing slumping of the overlying strata into the burned out coal, the formation of scoria influences the topography of the North Dakot badlands. The base of the red scoria is usually marked by a thin reddish white ash bed, and is quite distinct, but the upper surface of the scoria grades into the overlying strata. Scoria fragments often slide down the slope of the exposure, covering the base of the bed, and make it quite difficult to establish the base for mapping purposes.

Silicified wood occurs in many stratigraphic horizons in the Grassy Butte area. It is most plentiful in the lignite beds and bentonitic clay beds but is also present in other clay beds and in sand and sandstone beds. The original cell structure is well preserved and this has aided in the identification of the original trees. Benson (1952) states that they were coniferous type trees and probably swamp dwellers. Several "petrified forests" are present in the Grassy Butte area the largest being located in sec. 18, T. 145 N., R. 100 W.

The base of the Tongue River formation is not exposed in the Grassy Butte area, but according to the North Dakota Geological Society's 1954 Guidebook the thickness of the formation in the Golden Valley County-McKenzie County area is 980 feet, not including the Sentinel Butte member. The writer has established the thickness of the Sentinel Butte member as 650 ± 20 feet in the Grassy Butte area, which would indicate a total thickness for the Tongue River formation of about 1630 feet.

Sentinel Butte member of the Tongue River formation:

The upper division of the Fort Union was first described by Leonard and Smith (1907). They designated the lignite-bearing strata occuring in Sentinel Butte the Sentinel group of lignite beds. Thom and Dobbin (1924), and Seager et. al. (1942), correlated the Sentinel Butte strata with the Wasatch formation of Eocene age. Brown (1948) concluded that it is, as originally defined, an upper member of the Fort Union formation. The North Dakota Geological Survey considers it a member of the Tongue River formation of the Fort Union Group.

The contact of the Sentinel Butte member with the lower part of the Tongue River formation is essentially a color boundary with little lithologic difference. As previously described, the lower Tongue River strata are buff, light tan, and light gray in color. The Sentinel Butte member is generally darker and more somber in color, usually being dark to light gray. The color difference between the Sentinel Butte member and the rest of the Tongue River formation usually appears quite distinct from the distance, but is actually gradational and indefinite.

As mentioned earlier in this report the base of the Sentinel Butte member is marked by the "L bed" in this area, in the adjacent areas to the north, west, south, and in the South Unit of the Theodore Roosevelt National Park. In those areas the "L bed" is usually a prominent scoria, quite thick in the Park, and north of the Grassy Butte area, but generally only about four feet thick to the west of the Grassy Butte area and in the Elkhorn area to the south. In the northern half of this area the "L bed" is lignite, four feet thick, and only locally has it burned to produce scoria. In the southern half of the Grassy Butte area the lignite thins and in places is entirely absent. Here the "L bed" consists of bentonitic clay, which in places is underlain by the lignite. Both the bentonitic clay and the lignite generally contain petrified logs. Hanson (1955) also picked the color change at this stratigraphic horizon in the northern part of the Elkhorn Ranch area to the south.

In the Grassy Butte area the Sentinel Butte member contains more sand, sandstone, and bentonitic clay than do the standard Tongue River beds. The bentonitic clay is light gray when dry but almost black when wet. Upon drying, the surface clay contracts and forms a spongy, curdy layer, which is more resistant to erosion than the sand beds or other clay beds. This layer forms wide benches with characteristic rounded tops giving the benches a "bread loaf" shape. The curdy clay drops over the edge of the bench and often covers many feet of the underlying strata, giving a false impression of great thickness to the bentonitic bed. Silicified logs are often found in the bentonitic beds, and are generally more plentiful in all strata of the Sentinel Butte member than in the rest of the Tongue River formation.

Bentonite is usually considered to have been formed by the devitrification and chemical alteration of volcanic ash. Bentonite of such origin should contain shards of volcanic glass, but the bentonite examined from the Grassy Butte area was found to contain none. The bentonite beds usually occur directly above or below lignite beds and this association indicates that the origin of the bentonite might be closely related to that of lignite. As mentioned prevously, silicified wood is especially abundant in both bentonite and lignite beds. A sample of bentonitic clay from the Grassy Butte area was analyzed in a differential thermal analysis apparatus by Mr. Oscar E. Manz, who is conducting a clay research program for the North Dakota Geological Survey and for the University of North Dakota. This was done after it had been determined that the clay contained no shards, to verify that the clay was bentonitic. The differential thermal analysis curve was not typical for pure bentonite, but Mr. Manz was convinced that the clay was bentonite in part.

Golden Valley formation:

The Golden Valley formation was named by Benson and Laird (1947) from exposures near the town of Golden Valley, North Dakota. They discovered the floating fern **Salvinia preauriculata,** which is diagnostic of the Lower Eocene, near the base of this formation. Seager, et al (1942) called this series of strata the Unnamed unit and correctly placed it in the Eocene epoch, but as a member of the Wasatch formation.

Benson (1952) states that the Golden Valley formation is essentially conformable on the Tongue River formation, but that erosion and channeling are apparent in places. The Golden Valley-Tongue River contact seems conformable in the Grassy Butte area, and the writer suggests that the contact is gradational except where local unconformity can be shown. The Golden Valley formation is unconformably overlain by he Oligocene White River formation, which is not present in the Grassy Butte area.

The Golden Valley formation consists of two members, an upper and a lower. In the Grassy Butte area the lower member consists of approximately 50 feet of kaolinitic clay, shale and sand with kaolin binder. The sand is fine grained to silt size and subangular to subrounded. The grains consist mostly of quartz but a small amount of muscovite, gypsum and opaque black mineral which is possibly ilmenite, and a few lignite fragments are also present. The color of the sand is ashy white to light gray and tan.

The clay in the lower member of the Golden Valley formation is light gray, tan or dirty brown in color. One bed consists of carbonaceous shale and contains abundant selenite crystals. A light gray clay near the middle of the lower member is characteristically stained yellow to orange and is widely known as the "orange marker bed". This bed is usually mapped as the base of the Golden Valley formation but the writer used a dirty brown silty clay approximately 25 feet below the orange marker bed. The bed the writer used as the base of the Golden Valley formation was not found to contain the diagnostic fossil plant **Salvinia preauriculata** in the Grassy Butte area but it does grade imperceptibly into sediments that are definitely of Eocene age. This bed does not have the typical appearance of the Sentinel Butte beds below and it has a fairly definite contact with the underlying sediments which enables the bed to be traced quite easily in this area. As a result of using this bed as the lower contact of the Golden Valley formation, that formation was determined to be more extensive in this area than was previously supposed.

The upper member of the Golden Valley formation is present in this area only on the tops of several small buttes near the village of Grassy Butte. In this area the upper member consists of light gray to tan argillaceous sand. The sand is fine grained and angular to subrounded. It contains much muscovite, biotite, and quartz, and a little gypsum. The lower part of the sand bed is partially iron stained. Calcareous clay weakly binds the sand grains and the amount of calcium carbonate decreases toward the top.

Concerning the environment of deposition of the lower member of the Golden Valley formation, Benson (1952) states, "the suite of minerals in the sandy facies of this member and the lack of weathering of these minerals indicates that the kaolin was not weathered in situ but was transported from some source area. Crossbedding in both members dips generally to the east, indicating that this source area was to the west. The kaolin seems to have been transported as kaolin and deposited as one continuous or nearly continuous blanket over southwestern North Dakota. This suggests deposition in a broad, extremely shallow fresh water lake." Benson concludes that the upper sandy member of the Golden Valley formation was deposited by streams flowing over a low flat plain.

Flaxville gravel:

In northeastern Montana, remnants of a high level surface are capped by conglomerate. Collier and Thom (1918) assigned this conglomerate to Late Miocene or Early Pliocene on the basis of vertebrate fossils, and designated it as the Flaxville Gravel. Benson (1952), Schmitz (1955), and Petter (1956) correlate gravel on the high upland plain (Level No. 5) in North Dakota with the Flaxville gravel.

Petter (1956) states "These gravel deposits consist of cobbles and pebbles, some silt, and clay. The cobbles and pebbles are rounded to well rounded and are composed of granite, granite porphry, quartzite, dacite, trachyte, chert, flint, limestone, sandstone, quartzose conglomerate, silicified wood, vesicular basalt, scoria and fragments of cemented sand grains which were at one time cementing material for some of these cobbles." Mr. Petter further states "Much of the material was derived from the basal conglomerate of the White River formation, other portions of the gravel were derived from the volcanic and igneous terranes off the Black Hills and Devils Tower areas. The ferruginous sandstone and quartzose conglomerate pebbles may have been derived from outcrops of the Deadwood formation (Cambrian) in Wyoming and South Dakota."

Correlation:

The correlation of Tertiary strata from one locality to another is probably the most difficult task encountered by the surface geologist in western North Dakota. Due to the fluvial and lacustrine deposition of the sediments they grade laterally nearly as rapidly as they do vertically. It is an exceptional sand bed that can be traced for more than several miles. Most Tertiary structural mapping done in North Dakota is based on lignite beds because they are by far the most persistent and often burn to form prominent red scoria beds.

In the Grassy Butte area seventeen different beds were used for recording altitudes and all altitudes obtained were referred to the previously mentioned "L bed". The various beds have been designated by letters and when possible they were correlated with beds previously described and used for mapping by Fisher (1953, 1954) and Hanson (1955) in the adjacent areas to the north, west, and south. The L horizon was correlated in all three directions, and the other beds that the writer suceeded in correlating were traced from the West Central McKenzie County area to the North. These beds have been given their original designation in capital letters, and beds used for correlation within the Grassy Butte area only have been designated in alphabetical order with lower case letters.

"Lignite a" is present in stratigraphic sections 2, 3, and 4, and ranges up to six feet in thickness. Where exposed this bed has usually burned to produce a scoria up to 36 feet or more thick. The base of the scoria is usually marked by six inches of pinkish white ash and clinker. The lateral extent of this lignite bed is described later in this report in the section on lignite beds of possible economic value.

The "L bed" is the lower contact of the Sentinel Butte member of the Tongue River formation and was previously described in this report in the section describing the Sentinel Butte member. The "L bed" is present in stratigraphic sections 1, 2, 3, and 4. Altitudes were established on the "L bed" in Tps. 145 and 146 N., Rs. 101 and 102 W., and near the mouth of Bennett Creek.

"Lignite b" is exposed in stratigraphic section 2, where it is five feet thick. This lignite contains concentrations of jarosite and near the top of the bed selenite crystals are found. In most places the overlying clay has slumped over the lignite, but the bed can be distinguished by a line of vegetation growing along its base. Altitudes were established on "lignite b" only along Beicegel Creek in the vicinity of stratigraphic section 2.

"Lignite c" crops out in stratigraphic section 4, where it is three feet thick. This bed contains much carbonaceous shale but in places it has burned to form scoria three to four feet thick. Large petrified logs are found in this bed. Altitudes were established on "lignite c" only along Bennett Creek near the vicinity of stratigraphic section 4.

"Lignite d" is present in stratigraphic section 2, where it is four feet thick. The upper and lower parts of this lignite bed are quite shaley. It contains selenite crystals and concentrations of jarosite. In the vicinity of section 2, this lignite has usually burned to form a scoria bed which caps many of the adjacent hills. Altitudes were established on "lignite d" in the area south of Beicegel Creek in T. 145 N., Rs. 100 and 101 W.

"Lignite M" is exposed in stratigraphic sections 3 and 4, with a thickness of three to four feet in the vicinity of section 3, and a thickness of one to two feet in section 4. This lignite contains petrified wood and concentrations of jarosite. Altitudes were established on "lignite M" in the northern part of T. 146 N., Rs. 100 and 101 W.

"Lignite P" is exposed in stratigraphic sections 2, 3, and 4. It ranges in thickness from one to six feet, usually thinning to the south. In the northern part of the area this lignite bed has generally burned to form a scoria up to 11 feet thick. It is generally underlain by a burned bentonitic clay bed. Altitudes were established on "lignite P" in T. 146 N., Rs. 100 and 101 W., and in T. 145 N., R. 100 W.

"Lignite R" is exposed in stratigraphic sections 3 and 4 where it is six inches thick. This thin lignite bed lies in the basal part of the "lower yellow zone", a series of silt, silty clay and clay which weathers to yellow, buff, and tan. The color of the "lower yellow zone" is very distinct from the normal gray of the Sentinel Butte member and is easily traced in the north-central part of the Grassy Butte area.

"Lignite e" is exposed in stratigraphic section 5 and is generally four to five feet thick. This lignite bed always contains selenite crystals. In the southern part of the area it is represented by scoria in many places Altitudes were established on this bed in Tps. 145 and 146 N., R. 99 W., and T. 146 N., R. 98 W.

"Bed f" crops out in stratigraphic section 5, and consists of three feet of light bluish gray bentonitic clay. An altitude was established on this bed near the head of Beicegel Creek.

"Lignite g" is exposed in stratigraphic section 5, and consists of one foot of lignite. Stratigraphic section 5 is a composite section, comprised of five smaller sections. "Lignite g" is the base of one of the smaller stratigraphic sections, located in the center of T. 145 N., R. 99 W.

"Lignite U" is exposed in stratigraphic section 5, and consists of one foot of organic shale and lignite. This thin lignite bed is at the base of the "upper yellow zone", which consists of buff to tan silt and silty clay. Altitudes were established on "Lignite U" in the southeastern part of the Grassy Butte area.

"Lignite h" is exposed in stratigraphic section 5, where it is two feet thick. This lignite ranges up to four feet in thickness and locally has burned to form scoria.

"Bed j" is exposed in stratigraphic section 5, and is the base of the Golden Valley formation. This bed consists of light, dirty brown, slightly silty clay, with a few "ironstone" concretions. "Bed j" crops out only in the southeastern part of the Grassy Butte area.

"Bed k" is exposed in stratigraphic section 5. This bed is the "orange marker bed" mentioned earlier in this report, and consists of sandy tan and light gray clay, with many orange stains. The orange stains also extend into the ashy white sand below the clay. Altidudes were established on the top of "Bed k" in the southeastern part of the Grassy Butte area.

"Horizon O" is the base of the stratigraphic section 1. This is the lowest exposed part of a series of alternating thin to massive tan clay beds. The only altitude established on this horizon was the base of section 1.

"Horizon OO" is the base of stratigraphic section 5. It is the lowest exposed part of a light tan sand, and the only altitude established on this horizon was the base of section 5.

LIGNITE BEDS OF POSSIBLE ECONOMIC VALUE

The lignite beds in the Grassy Butte area range in thickness from a few inches to seven feet. The writer observed few beds that maintained a thickness of five feet or more for any distance and only two of these were in the lower part of the Tongue River formation strata, below the Sentinel Butte member. Lignite beds are more plentiful in the Sentinel Butte member than in the rest of the Tongue River formation in the Grassy Butte area but they are generally thin and contain much carbonaceous clay. The individual beds often show considerable range in thickness, thickening some places and thinning in others.

As mentioned previously some of these beds were correlated with beds described by Fisher (1953) and they have been given their original designation in capital letters. The beds not correlated with previously described strata are designated with lower case letters.

A lignite bed four feet to seven feet thick crops out along the Little Missouri River from the McKenzie County-Billings County line north to a point approximately one mile south of the mouth of Beicegel Creek. The thickest portion of this lignite bed observed by the writer was in section 11, T. 145 N., R. 102 W., where the bed was seven feet thick. Although this bed disappears below the level of the Little Missouri River just south of the mouth of Beicegel Creek, the structure of the strata brings this bed to the surface again a little over a mile upstream along Beicegel Creek.

Leonard (1925) mentions a five foot thick coal bed present in places in the northwestern part of T. 145 N., R. 101 W., and the southeastern part of T. 146 N., R. 102 W. This probably correlates with "lignite a" which crops out upstream along Beicegel Creek for about eight miles, and is included in stratigraphic sections 2, 3, and 4. "Lignite a" was observed along the Little Missouri River from the mouth of Beicegel Creek north and east of the southwest corner of sec. 21, T. 147 N., R. 100 W. It is also exposed for one or two miles upstream along Bummer Creek and Bennett Creek. "Lignite a" was observed to be up to six feet thick but is probably thicker in places. It is very often represented by a scoria bed that is in places over 30 feet thick. This lignite bed thins and splits to the west and south.

In the southwest corner of Sec. 36, T. 146 N., R. 101 W., "lignite b", which is five feet thick in stratigraphic section 2, splits into two beds, each approximately four feet thick. Here the lignite is easily accessible and is mined for local use by ranchers.

"Lignite P" is six feet thick in stratigraphic section 4 and is exposed for about seven miles upstream along Bennett Creek. This lignite thins to the east and is of good thickness in the northern part of the area only a few miles upstream along Bennett Creek and for several miles upstream, from the mouth of Bennett Creek, along the Little Missouri River. "Lignite P" is also exposed along Beicegel Creek and is of good thickness along most of that portion of the creek flowing through T. 145 N., R. 100 W.

"Lignite e" of stratigraphic section 5 is four feet to five thick along the upper portion of Beicegel Creek and along the head waters of Bennett Creek in Tps. 145 and 146 N., R. 99 W.

A 10 foot thick bed of good grade lignite in Sec. 1, T. 147 N., R. 98 W. was reported to the writer but not observed by him.

STRUCTURE

General Structure:

The structure contours in the Grassy Butte area are based on altitudes established by the writer. The contour lines in adjacent areas were established by Fisher (1953, 1954) and Hanson (1955). The contours drawn by Fisher and Hanson were slightly altered, immediately adjacent to the Grassy Butte area, to conform with the altitudes established by the writer.

The general dip of the strata in the Grassy Butte area is approximately 10 to 20 feet per mile to the northeast. The chief structural feature within the area is the series of north plunging noses and troughs in Tps. 145 and 146 N., R. 102 W. The easternmost nose, crossed by the Little Missouri River, terminates to the south in the Elkhorn Ranch area (Hanson, 1955) in a north-south trending anticline with at least 55 feet of closure. This anticline is situated largely in the Elkhorn Ranch area but its northern end extends into the area of this report.

The village of Grassy Butte is located on the crest of a northwest-southeast trending anticline with a minimum of 33 feet of closure. On his anticline and on the saddle to the southeast of it are Golden Valley formation remnants which are discussed below.

The subsurface structures in the Williston Basin seem to have inclined axial planes. The near surface center of the Keene Dome (Nevin, 1946) is located in sec. 28, T. 152 N., R. 96 W., whereas the subsurface high is located in secs. 5 and 7, T. 151 N., R. 95 W., an offset of approximately three miles to the south east (Anderson, 1956).

According to Benson (1952) many of the smaller near surface structures in North Dakota may be reflections of larger subsurface structures because the thickness of coastal plain beds, such as comprise the Tongue River formation, indicates the area must have been sinking during Paleocene time, and it is unlikely the amount or rate of downsinking would be the same over the entire region. Fisher (1953) states "The larger structures of the Williston Basin appear to have been formed by successive differential subsidences and uplifts, accompanied by faulting in the basement and deeper sedimentary rocks. Thus the dips on the flanks of the folds should steepen and closure should increase with depth. Such has been found to be the case of several structures within the basin. Some of the smaller structures also probably formed very early and in the same manner, but others may have resulted from shallow faults associated with the most recent vertical movements of the region."

GEOLOGICAL HISTORY

The geological history of the great plains province is intimately associated with that of the Rocky Mountains and the Black Hills. The following summary of events in western North Dakota since Cretaceous time is adapted from Benson (1952) and Schmitz (1955).

1. No major physical event marked the close of the Cretaceous period. The last Cretaceous formation to be deposited, the Hell Creek, was laid down on flood plains and in swamps.
2. During early Paleocene time the Cannonball sea advanced from the northeast across central North Dakota and the Cannonball marine member, which intertongues with the continental Ludlow member to the west, was deposited in coastal plain swamps. Local warping, accompanied by minor folding and faulting occurred during Paleocene time.
3. Rocky Mountain epeirogenic movements at the close of the Paleocene epoch transmitted minor uplift to the east. North Dakota remained low but received no deposits.
4. Eocene time is marked by erosion in the Montana Rockies due to continued uplift and by deposition of the lower member of the Golden Valley formation in North Dakota, in broad fresh water lakes. Over the lower member the upper fluvial sands were deposited.
5. Differential uplift and tilting away from the Black Hills occurred during post-Wasatch (early Eocene) and pre-Oligocene time. Large amounts of Early Eocene and Paleocene strata were eroded.
6. During Oligocene time the lacustrine White River formation was deposited. Much-worked volcanic ash indicates volcanism to the west.
7. The deposition of the White River formation was followed by a period of folding and warping with uplift and erosion. The Cypress Plain was developed in Montana and much of the White River formation was removed from North Dakota.
8. Miocene-Pliocene regional uplift resulted in the formation of the Flaxville Plain which is today's upland surface.
9. Dissection of the broad upland plain formed the gently sloping broad valley profiles that flank today's major stream valleys.
10. As Pleistocene glacation ended minor regional uplifts were caused by isostatic readjustment. Diversion of the former northeast flowing drainage occurred just previous to and during glaciation.

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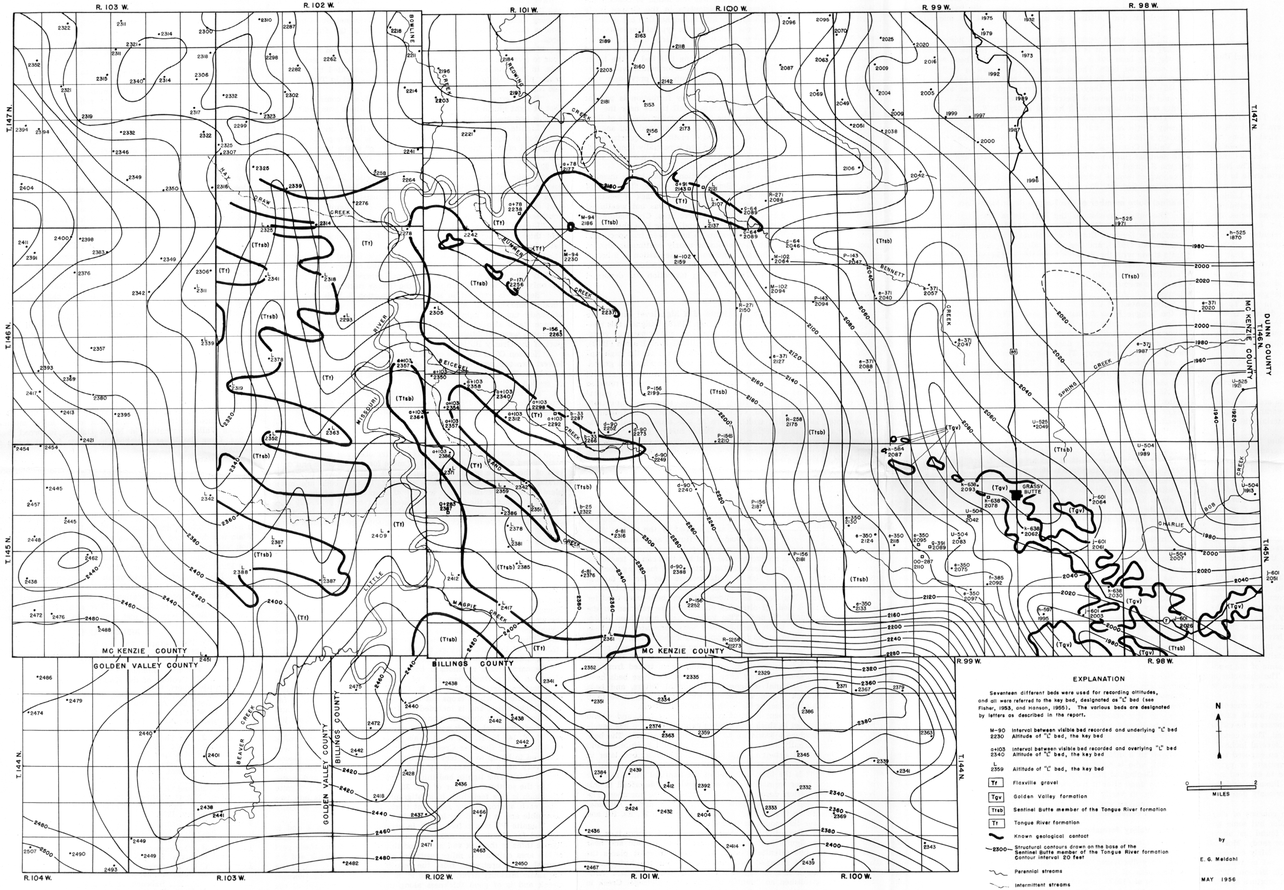


EXPLANATION

Seventeen different beds were used for recording altitudes, and on were referred to the key bed, designated as "L" bed (see Fisher, 1955, and Hanson, 1955). The various beds are designated by letters as described in the report.

M-90 Interval between visible bed recorded and underlying "L" bed
2230 Altitude of "L" bed, the key bed

o405 Interval between visible bed recorded and overlying "L" bed
2340 Altitude of "L" bed, the key bed

2359 Altitude of "L" bed, the key bed

Tf Flaxville gravel

Tgv Golden Valley formation

Ttsb Sentinel Butte member of the Tongue River formation

Tt Tongue River formation

Known geological contact

2500 Structural contours drawn on the base of the Sentinel Butte member of the Tongue River formation Contour interval 20 feet

Perennial streams

Intermittent streams

US United States Highways

ND North Dakota State Highways

N

0 1 2 MILES

by

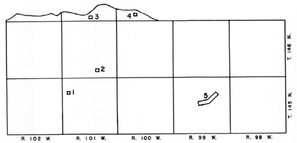
E. G. Maldoni

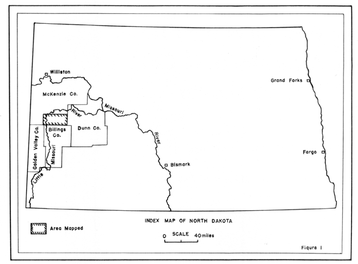
MAY 1956

GEOLOGIC MAP OF THE GRASSY BUTTE AREA, MCKENZIE COUNTY, NORTH DAKOTA
STRUCTURAL CONTOURS AT THE BASE OF THE SENTINEL BUTTE MEMBER OF THE TONGUE RIVER FORMATION

EXPLANATION

- Conglomerate
- Sand and silt
- Argillaceous sand and silt
- Sandy clay and shale
- Clay and shale
- Bentonitic clay
- Scoria
- Lignite





1
SEC. 7, T.145 N., R.101 W.

2
SEC. 34, T.146 N., R.101 W.

3
SEC. 33, T.147 N., R. 101 W.

4
SEC. 28, T. 147 N., R. 100 W.

5
SECS. 11, 15, 14, 21, T. 145 N., R.99 W.

STRATIGRAPHIC SECTIONS
GRASSY BUTTE AREA