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## THE LATE TERTIARY HISTORY OF THE UPPER LITTLE MISSOURI RIVER, NORTH DAKOTA

A Thesis

Submitted to the Faculty

of the

Graduate School

of the

University of North Dakota

bу

Charles K. Petter, Jr.

In Partial Fulfillment of the Requirements for the Degree of Master of Science

June 1956

This thesis submitted by Charles K. Petter, Jr. in partial fulfillment of the requirements for the Degree of Master of Science in the University of North Dakota, is hereby approved by the Committee under whom the work has been done.

Hondon & Bell Hilson M. Laid

J. D. Halland J.

Dean of the Graduate School

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# THE LATE TERTIARY HISTORY OF THE UPPER LITTLE MISSOURI RIVER, NORTH DAKOTA

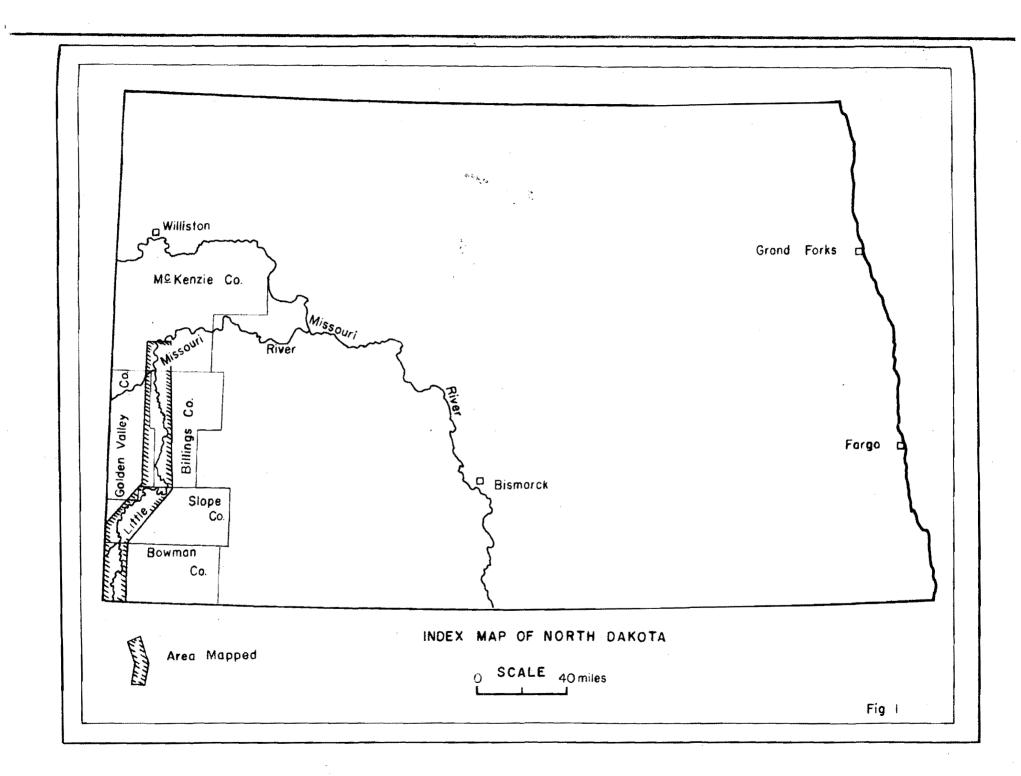
#### General Statement

The upper Little Missouri River valley, southwestern

North Dakota, described within this report, contains approximately 1800 square miles (see Figure 1). Erosional remnants situated on the partially dissected Miocene-Pliocene peneplain, border the Little Missouri River valley. The gravel deposits which veneer this upland surface are herein designated as Flaxville and are correlated with the Flaxville gravel of northeastern Montana. Within the valley, the picturesque Badlands of North Dakota are subdued by vestiges of a former flood plain of the Little Missouri River, designated as Little Missouri Terrace No. 4. Below this high terrace level, terraces of Pleistocene age are well developed and indicate multiple cycles of erosion.



Figure 2. Typical landscape along Little Missouri River Valley



The erosional processes which have sculptured the landforms of southwestern North Dakota were initiated and influenced by numerous factors and agents, such as broad uplifts,
stream captures, climate, lithologic variations and similarities, and isostatic adjustment. Figure 2 shows a typical
view of the landscape along the Little Missouri River valley.

#### Acknowledgments

I wish to express my appreciation to the North Daketa Geological Survey, Dr. Wilson M. Laird, Director, for the use of equipment which made possible the study of this area. Special thanks are extended to Dr. W. M. Laird, Dr. G. L. Bell, Mr. N. N. Kowhanowski and Mr. F. D. Holland, Jr., of the Department of Geology, University of North Daketa, for awarding me the Critchell Parsons Graduate Fellowship in Geology, which enabled me to operate in the field. I am deeply indebted to Dr. Gordon L. Bell for suggesting the problem, his invaluable suggestions, assistance, criticisms, and continued interest in the field and in the preparation of this report. To Mr. Emmett R. Schmitz, Skelly Gil Co., Casper, Wyoming, I express deep appreciation for his helpful suggestions and aid.

#### Previous Work

In the early 1900's, Dr. A. G. Leonard, former State Geologist, did extensive work describing much of the geology of southwestern North Dakota. Hares (1928), did extensive mapping south of Billings County, to the South Dakota state line along the Little Missouri River and its tributaries.

Alden (1932), outlined the physiography and glacial geology of northeastern Montana and the adjacent areas. Laird (1950), Benson (1952), Fisher (1953), Hanson (1955), Meldahl (1956), have mapped in some detail either the geomorphology, stratigraphy, or structure of portions of western North Dakota. The most recent extensive geomorphic work in the immediate area was done by Schmitz (1955), in which he describes the geomorphic history of the lower Little Missouri River.

#### Methods of Field Work

Reconnaissance of the area mapped was conducted during May and June 1955. Field work was begun during the latter part of July 1955, and was completed by mid-September of the same year.

Areal index photographs to the scale of approximately one inch to the mile were used as base maps and for control in mapping. North Dakota State Highway maps of McKenzie, Billings, Golden Valley, Slope, and Bowman counties were of great assistance in locating possible routes of travel and for identifying local landmarks. River Survey maps, published by the United States Geological Survey, 1949, for the area south of Medora to the state line were of great help in locating bench marks and for topographic control along the Little Missouri River. However, a Paulin altimeter was used to obtain the altitudes of terraces and higher surfaces along the river

valley.

Accessibility -- The area can be reached from the south or north by either United States Highway 35 on the east side of the area or North Dakota State Highway 16 on the west side of the area. Access to the Little Missouri valley from the east or west can be accomplished by following either United States Highway 10, passing through Medora, or United States Highway 12, through Marmarth (Plate 1). Many secondary roads and seismic survey trails provide ample routes through the area, although at places these roads become impassable as the result of rainfall. Fords for river crossing are designated on county road maps, but it is advisable to consult with the local ranchers before attempting a crossing.

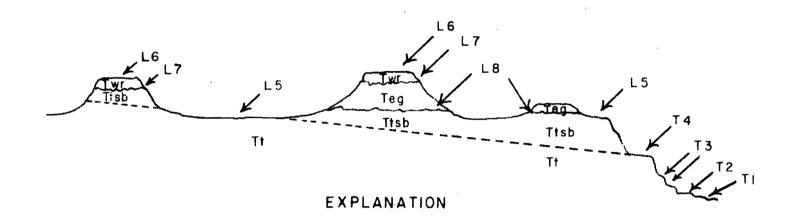
#### Terrace Levels

The upland or peneplain surface is designated as Level 5. Other prominent levels will be defined below. All terraces and levels are indicated on Figure 3.

Level 5 was mapped far enough back on both sides of the river to include all younger terraces and their graded conditions along the more extensive tributaries of the Little Missouri River. Beaver, Little Beaver, Third, Magpie, and Biecegel Creeks are exceptions and no attempt was made to include these tributaries (see Plate 1).

The terrace classification used in this report conforms with that of Laird (1950), and Schmitz (1955).

## Composite Sketch of Erosion Surfaces



L = Level

T = Terrace

- L8 Post Paleocene erosion surface
- L7 Late Eccene early Oligocene surface
- L6 Late Oligocene early Miocene surface
- L5 Miocene Pliocene peneplain \_\_\_ (Flaxville surface)
- T4 Pliocene Pleistocene terrace
- T3 Pleistocene terrace
- T2 Pleistocene terrace
- TI Present Little Missouri River channel

#### Table 1

#### Terrace Classification

- Little Missouri Terrace No. 1 -- present stream level.
- Little Missouri Terrace No. 2 -- lowlands and flats along the present stream.
- Little Missouri Terrace No. 3 -- away from the main stream, developed as a combination cut terrace and cut and fill terrace. Matched portions at a minimum.
- Little Missouri Terrace No. 4 -- the Pliocene-Pleistocene strath of the stream.

#### Structure

The structural setting of southwestern North Dakota may be described as two major structures with superposed structures developed within their limits. The major structure of western North Dakota is a large basin called the Williston Basin. This almost elliptical basin appears to be an eastern extension of the Big Snowy Basin which was extensive during mid-Paleozoic time. During most of geologic time (beginning with the Paleozoic Era) this area was maintained as an unstable shelf which in association with basin conditions accumulated thousands of feet of sediments. Superposed on the western edge of the Williston Basin lies the nose of the Cedar Creek anticline with an axial trend of north 30° west. This structure in the Williston Basin is considered by Eardley (1951, p. 346) to be results of the Laramide orogeny and is

represented at the surface by folded Cretaceous formations.

The surface structure in the Tertiary rocks of the basin is comparatively simple, and consists of nearly flat-lying formations. As a result of post-Oligocene warping (Benson, 1952, p. 217), minor synclines and anticlines were superposed on the regional structure. According to Benson (1952, p. 236) the Little Badlands in Stark County and Chalky Buttes area of Slope County developed in synclines, which resulted during Miocene warping. Bullion Butte may also be situated near the center of a minor downfold, but according to Powers (1946, p. 58) this butte has only a slope to the east as do many of the buttes in southwestern North Dakota. Many minor folds in the Paleocene rocks have been outlined by Fisher (1953), Caldwell (1954), Hanson (1955), and Meldahl (1956).

### Cretaceous Stratigraphy

The cldest rocks exposed in southwestern North Dakota are of Cretaceous age, and they crop out where the Little Missouri River and its tributaries cross the Cedar Greek anti-cline. The cldest formation exposed is the Pierro shale, which is gray to black, marine shale composed of montmorillenite clay with thin lenses of bentonite. On exposure the shale becomes deeply weathered and produces rounded mud slopes.

Overlying the Pierre shale with a transitional contact, is the Fox Hills sandstone, a marine formation consisting of gray and green shaly sandstone and sandy shale. Many beds are glauconitic and weather to rust brown on the surface.

The Colgate sandstone member at the top of the Fox Hills is a light gray sandstone which contains some thin lignite lenses and yields a fluted surface upon weathering.

Disconformably overlying the Fox Hills sandstone is the Hell Creek formation, the uppermost Cretaceous formation in North Dakota. This formation is composed of non-marine calcareous gray sandstone and brown to black carbonaceous and bentonitic clay. Some persistent lignite beds are present in the lower one-third of the formation. Figure 4 shows a typical outcrop of the Hell Creek formation and also indicates the result of differential erosion.



Figure 4. Outcrop of Hell Creek formation, showing differential erosion along High-way 16, north of Marmarth, North Dakota

## Tertiary Stratigraphy

The lowest unit of the Paleocene series is the Ludlow formation of the Fort Union group. The yellow-gray sandstone, light to dark gray shale and clay, and thin beds of lighte of

#### Table 2

Cretaceous and Tertiary Stratigraphy of Southwestern North Dakota

Tertiary system

Pliocenc-Pleistocene series - gravel

Miocene-Pliocene series - Plaxville gravel

Unconformity

Oligocene series

White River formation

Unconformity

Eocene series

Golden Valley formation

Unconformity

Paleocene series

Fort Union group

Tongue River formation including the Sentinel Butte member.

Ludlow formation.

Cretaceous system

Hell Creek formation.

Fox Hills sandstone including

Colgate sandstone member.

Pierre shale.

- Certain Control Indio: formation conformably overlie the Unyer Cretacecus The color differences, and Tertiary fauna help to distinguish the Monta the think arous. Tell Creek でのながれのです Above the Ludlow formation lies the Tongue River formation. shale and clay with massive lensos of sandstone and alternating the underlying Tengue River strata. Coincident with this color unit. "S" bod. The best of the "I," bed along with the monteable is a prominent scorie bed designated by Tishor (1953) The opportion characteristically derien and more somber in appearance hash with interbodded lighto, scorie, petrified logs and Tongue River formation, the Sentinel Batte nomber, fragments, and bentonitic layers make up this upper tan beds color change mark the contact between these two units. beds of lightee and shale. It centains much scenia, fused sandstone which are distinctively red de mostag yellow do of baking by burning Lights beds. Tongue Hiver formation clay and 27 tie TO SELLE PROTE

Socene Co the middle of this unit, characteristically stained yellow to Tolden Valley formation. This fermation censists of a lesen clay member and an upper sandstons member. The lower member to the (D) (C) A persistent white clay bed to light purple-gray kholinitic clay mixed with Inconformably overlying the Paleocone series is ¢-7 by from onide, is prominent in the outerops The HOCKEDO The upper unit is variable amounts of haciln. #1.65° na proded Darling of orange

to yellow-brown micaceous silt and sand with a few lenses of gray clay and lignite. The coarse sand of the upper unit is cross-bedded with forset beds to the east.

The White River formation of Oligocone age disconformably overlies the Eccene sediments where present but in many buttes rests on the Paleocene rocks. This formation has been divided into three units (Benson, 1952, p. 94), the lower unit being composed of light gray to white, fine to coarse grained sandstone with lenses of rounded cobble-size gravel, interbedded with calcareous and siliceous clay. The coarse gravel was derived from the mountains to the west (Benson, 1952, p. 96). The middle unit consists predominantly of highly calcareous clay or marl, but it also contains highly siliceous beds. The upper unit consists of greenish gray shale and clay interbedded with green sandstone and fragments probably derived from the middle unit.

The lower unit described above, caps many of the buttes situated on the upland bordering the Little Missouri valley (Powers, 1945, p. 60). These buttes are Sentinel Butte, Flattop Butte, Bullion Butte, and H. T. or Black Butte.

A great amount of the White River deposits was removed from southwestern North Dakota by the erosive action of the streams which ultimately planated the major portion of western North Dakota. In the process of peneplanation, gravel was deposited in the channels of the planating streams. These gravel deposits consist of cobbles and pebbles, clay, and

some silt. The cobbles and peobles are rounded to well rounded and are composed of granite, granite porphry, quartzite (various colors), dacite, trachyte, chert, flint, limestone, sandstone, quartzose conglomerate, silicified wood, vesicular basalt, scoria and fragments of cemented sand grains which at one time were cementing material for some of these cobbles. The quartzite cobbles have some distinctive percussion markings. The lithologic composition of these Level 5 gravel deposits favorably corresponds with the description of the Flaxville gravel, given by Collier and Thom (1918, p. 181) and Alden (1932, p. 20).

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 of the Black Hills and Devils Tower areas. The ferruginous sandstone and quartzose conglomerate pebbles may have been derived from the outcrops of the Deadwood formation (Cambrian) in Wyoming and South Dakota.

A random sample of Flaxville gravel, taken from the type area Flaxville, Montana, was compared with a random sample taken from a gravel pit on Level 5, SW sec. 31, T. 141 N., R. 101 W., four miles north of Medora, North Dakota. Histograms of the selved portion below 16 mm shows a bimodal curve for each sample (see Figure 5).

Heavy mineral analysis of the seived fraction between  $\frac{1}{3}$  and  $\frac{1}{4}$  mm from both of the above mentioned samples was run and the heavy mineral suites of the respective samples are

shown in Table 3.

Table 3
Heavy Mineral Analysis of Flaxville Gravel

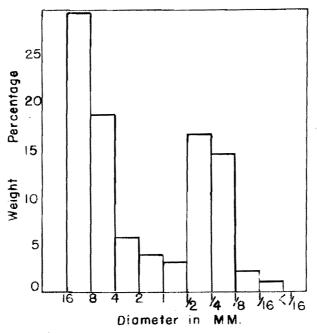
Heavy Minerals	.Sample ,			
	I.	IIC		
Actinolite	P			
Epidote	A			
Garnet	R	R		
H <b>ornbl</b> end <b>e</b>	P	R		
Iron oxide (cement and stained				
lithic fragments)	$\mathbf{A}$	r		
Iron stained quartz		G		
Mica	Ħ			
Pyroxene	T			
Rutile		O		
Zircon		P		

<sup>1</sup> Flaxville gravel, Flaxville, Montana 2 Level 5 gravel, SW a sec. 31, T. 141 N., R. 101 W.

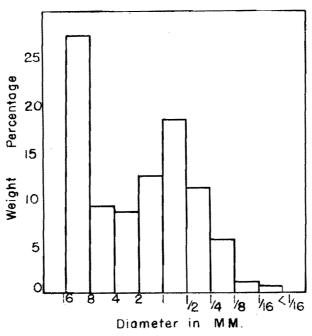
Amount of each specific mineral indicated by the following letters with corresponding percent: Flood F, 75 to 100%; Dominant D, 50 to 75%; Abundant A, 25 to 50%; Common C, 10 to 25%; Present P, 5 to 10%; Rare R, 1 to 5%; Trace T, less than 1%.

The heavy mineral suites indicate a different source area for the deposits but the large amount of iron oxide present as stain, portions of cement and lithic fragments indicates a similar depositional environment and climate for the two deposits.

On the basis of lithological similarities, heavy mineral analysis, stratigraphic and topographic position, these gravel deposits are herein designated as Flaxville in age



Histogram of Flaxville gravel Flaxville, Montana



Histogram of gravel from Level 5 TI4IN,RIQIW,Sec3I, North Dakota

and correlated with the Miocene-Pliocene deposits on the Flaxville Plain in northeastern Montana.

On the Little Missouri Terrace No. 4, the PliocenePleistocene strath of the Little Missouri River, is found a
great quantity of gravel and sand. This material has approximately the same composition as the Flaxville gravel. However,
Terrace No. 4 gravel appears to be reworked Flaxville gravel
with additions of local material, such as an added amount
of scoria and ironstone concretions from the local formations.

## Physiography and Topography

As a result of glaciation, isostatic rebound and structural control, five escarpments divide the state into six major physiographic divisions, which lie within the Central Lowlands Province and the Great Plains Province.

These are the Agassiz Lake Plain, Drift Prairie, Turtle Mountains, Souris and Devils Lake Plain, Coteau du Missouri and Hissouri Plateau. (Roth and Zimmerman, 1955, p. 84)

Only the Missouri Plateau division lies completely within the Great Plains Province, as the Coteau du Missouri is the boundary of the Central Lowlands Province.

|Glacial drift which covers the eastern two-thirds of
North Dakota, was deposited by the Kansan-Illinoian and
Wisconsin ice sheet. The boundary of maximum glacial advance
may be traced from T. 120 N., R. 83 W., on the North DakotaSouth Dakota border, north to Hebron, west to Gladstone,

north to Killdeer Mountains and thence along the north side of the Little Missouri River Vallay curving south as it leaves the state toward Glendive, Montana. (Schmitz, 1955, p. 14)

The area under discussion lies entirely within the unglaciated portion of the Missouri Plateau, which extends southwest from the Missouri River in western North Dakota, South Dakota, Montana and Wyoming. The surface of the Missouri Plateau is a gently rolling upland ranging in altitude from 2,700 to 3,000 feet above sea level and is designated as Level 5, the Miocene-Pliocene peneplain (see Figure 3). Numerous, conspicuous buttes rise above the general level of this surface, including Sentinel Butte, Bullion Butte, Plattop Butte, and H. T. or Black Butte, the latter being the highest point in the state, with an altitude of 3,468 feet. These buttes or monadnocks are degraded remnants of a late Oligocene-early Miocene plain which have been sculptured by the early and present Little Missouri drainage.

Epeirogenic uplifts and ensuing planations of the Cretaceous and early Pertiary formations culminated in the present upland surface, Level 5, indicated here as an extension of the Flanville Plain of northeastern Montana. Many rivers have carved mature valleys into this rolling upland. The Little Missouri River and its tributaries are bordered by an area of badlands which add a picturesque geomorphic form to southwestern North Dakota. These badlands extend on both

sides of the river in a belt 2 to 15 miles wide and have an average relief of 350 feet.

The unglaciated portion of the Missouri Plateau area is characterized by five main topographic forms or physiographic types. These forms will be discussed in the following order: buttes, peneplains, terraces, lowlands in stream valleys, and badlands and slopes.

#### Buttes

Many buttes, remnants of the late Oligocene-early Miccene surface Level 6 (see Figure 3), are situated on the Flaxville surface. These buttes represent old drainage divides of tributaries of the early Miocene river. Many of these higher buttes are capped with a resistant sandstone of the Oligocene White River formation, as are Sentinel Butte, Flattop Butte, Bullion Butte and Black Butte. Other buttes capped by resistant scoria whose summits actually represent structural benches and should not be confused with the prominent levels described in Figure 3, lie 125 to 175 feet above the upland surface, Level 5. Many remnants on Level 5 have sharp crests and concave slopes which are indicative of forms developed in a region reduced to the peneplain stage in the fluvial geomorphic cycle. The grading surface of the next lower erosion surface can be seen on the flanks of these buttes. Many of these higher buttes are covered by a thin veneer of flint and chert fragments and a minor amount of gravel.

### Peneplain

As the result of late Oligocene-early Miocene stream dissection initiated by uplift, these buttes began to take form. Soon the drainage fabric of the Little Missouri was established and the north flowing, early Little Missouri and its tributaries continued to shape these monadnocks. In consequence of the Miocene-Pliocene erosion of the existing interstream divides numerous structural benches were preserved because of the resistant nature of the baked clay and fused sandstone. Broad meandering streams flowed sluggishly northward often becoming dammed by their own sediments and shifted their courses back and forth as they planated the Flaxville surface. The gravel deposits present today which indicate these old channels have been designated as the Flaxville gravel (Collier and Thom, 1918, p. 182). By early Pliocene time



Figure 6. Miocene-Pliocene peneplain, Level 5 sec. 31, T. 141 N., R. 101 W., Billings County, North Dakota

southwestern North Dakota had the aspect of a peneplain with numerous monadnocks spotting the horizon. This surface is characterized by an undulating, rolling appearance. Where the surface is directly underlain by scoria the surface becomes a combination stripped plain and a peneplain. From Bullion Creek north, scoraceous knobs give Level 5 a grotesque appearance. The scoraceous surface actually appears as karst-like topography with sink holes, but north of Medora, North Dakota, the scoria dips below the upland surface, and Level 5 takes on the aspect of a grassy, rolling surface (see Figure 6).

#### Terraces

Vestiges of a former flood plain of the Little Missouri
River are the highest set of terraces within the river valley
and are developed below the main valley shoulder. (see Plate 1)
The cessation of downcutting and formation of this strath,
designated as Terrace No. 4 by Laird (1950, p. 11), and as
Little Missouri Terrace No. 4 by Schmitz (1955, p. 3), was
the end product of stream piracy. This pirating action occurred
in northeast Wyoming as the headwaters of the Belle Fourche
River breached the divide between the Little Missouri drainage
and that of the Belle Fourche River (see sequence of events,
p. 40).

Terrace No. 4 is a cut terrace, originally cut in bed rock, and in places it is covered in part by alluvial gravel

and colluvium (the result of sheet wash). This terrace ranges in altitude from 2,950 feet above sea level at the South Dakota state line to 2,330 feet above sea level at the mouth of Hay Draw Creek, where the river turns east. This terrace is a distinctive feature throughout the upper portion of the Little Missouri River valley in North Dakota and can be traced to the elbow of capture southeast of Alzada, Montana, just below the Montana-Wyoming state line, where the terrace has a very limited extent. From Marmarth, North Dakota, north, this former strath has an areal extent of many square miles and is used by local ranchers as a source area for wheat and hay (see Figure 7). Within the main river valley, Terrace



Figure 7. Broad expanse of Terrace No. 4 north of Medora, North Dakota

No. 4 is very distinct, whereas along the heads of many tributaries it is difficult to determine the exact contact in slope difference as Terrace No. 4 grades Level 5 at many places. However, Terrace No. 4 is developed extremely well along many of the larger tributaries to the Little Missouri River, such as Beaver, Little Beaver, Deep, Sand, Garner, Williams, Bullion, Whitetail, Wannigan, Biecegel, and Cannonball Creeks (see Figure 8).



Figure 8. Terraces along Cannonball Creek

From the South Dakota-North Dakota state line downstream, the terraces reflect the different types of the underlying bedrock. Where the Pierre shale is exposed in the Cedar Creek anticline, Terrace No. 4 exhibits a rounded, shale slope appearance. In the South Unit of Roosevelt National Memorial Park, a few scoria capped structural benches are developed above the general level of Terrace No. 4 and below Level 5. They are mapped as portions of Terrace No. 4, as theoretically, all the surface between the lip of Level 5 and the toe of Terrace No. 4 was cut during the Terrace No. 4 cycle. Of course, this does not hold true where No. 4 has been completely graded and modified by lower terrace development.

Characteristics of an old flood plain are evident in only a few places, one being an old meander scar on a portion of Terrace No. 4 west of the Park Headquarters and on the west side of the river in the South Unit of the Park, NW sec. 11, 7. 140 N., R. 102 W. Other features such as stream bars, swales and natural levees, may be present but have been modified by erosion to such an extent that they are not clearly distinguishable.

Marping or tilting of an area after terrace development may lessen the down-valley slope of a particular terrace as is indicated by Terrace No. 4 along the Little Missouri valley. By plotting the altitude of Terrace No. 4 graphically, it can be seen that the portion of this terrace below Bullion Butte has been subjected to warping (see Plate 2). In consequence of the ablation of glacial ice lobes the depressed area to the North of Bullion Butte rose. After a study of available literature on isostatic rebound, Schmitz and Kresl (1955, p. 93), placed a hinge line or boundary of equilibrium just north of Bullion Butte. From measurements obtained in the field, the limits of the zone of zero adjustment is calculated to be from the mouth of Third Creek to five miles south of Medora. As indicated on Plate 2, the amount of rebound at the "Bend" (Hay Draw Creek area) is about 120 feet.

Regional uplift caused the Little Missouri River to renew a cycle of downcutting. The gradient of the river was increased by stream piracy and inversion of drainage in the

lower portion of the Mittle Missouri River (Schmitz, 1)55, p. 31). With this increased gradient, the renewed cycle of downcutting was vigorous and the drainage of the newly formed system was firmly established.

As a result of rapid incision of Terrace No. 4, a new channel began to form; this channel was cut to a great depth in the loosely indurated, flat-lying sediments. Sheet wash and mass wasting accompanied downcutting and development of the badlands along the river was initiated.

As the Kansan-Illinoian ice sheet accumulated to the North, the actively downcutting Little Missouri acquired a temporary base level and began a short period of lateral planation and the development of cut Terrace No. 3. This terrace is cut in bed rock and has a gradual slope toward the river and lies about 120 to 140 feet below Terrace No. 4 in the South Unit of Theodore Roosevelt Memorial National Park. The terrace was incised by the Little Missouri River as a result of increased precipitation during the Misconsin Stage of glaciation. A deep trench was excavated which was soon to be apgraded as a result of sheet wash and mass wasting along the valley walls. Over-steepening of the valley walls, local ponding and alluviation aggraded the river valley in such a manner as to reduce the gradient of the river to that of an old age stream.

As this sluggish stream meandered over its flood plain, reworking and redepositing alluvial and colluvial material,

cut and fill Terrace No. 3 was developed. The upper or cut portion of Terrace No. 3 is matched in most places, and the cut and fill portion of Terrace No. 3 is characteristically unmatched.

#### Low-lands

At the base of the badland slopes in the main valley and below Terrace No. 3 is an extensive low-land area (or broad flats) which has been designated as Terrace No. 2. This alluvial terrace rises approximately 10 to 15 feet above Terrace No. 1, the present day river. The formation of Terrace No. 2 has resulted from the tilting of the area in response to isostatic rebound following the retreat of the glacial ice. Terrace No. 2 exhibits many meander scars and other typical features of a floodplain. Cottonwood trees, hay fields and ranches are numerous on Terrace No. 2 along the entire length of the lower Little Missouri River in North Dakota.

Terrace No. 1 or the present Little Missouri River is characterized by channel bars, meander loops, point bars and oxbow lakes. The overloaded river has a variable depth which may change markedly within a 2h-hour period depending on the amount of precipitation within the Little Missouri drainage basin. At times a braided pattern and ponded areas may develop during periods of low run-off. Aeolian action along the present flood plain is also active during these periods of

low run-off.

The longitudinal profile of the stream is indicative of a near graded stream with a nickpoint between the mouth of Williams Greek and the mouth of Third Creek, near the Slope-Billings county line, while the majority of the tributaries are ungraded. This nickpoint is considered to be the result of lithologic differences and also the result of the tilting caused by isostatic adjustment. The nickpoint migrated approximately 10 miles upstream from the zone of zero isostatic adjustment.

The valley of the Little Missouri River is asymmetrical with the more dissected badland area on the eastern side of the valley and the steeper valley wall being on the western side of the valley.

Terrace No. 2 disappears south of Camp Crook, South Dakota (50 miles south of Marmarth, North Dakota). Terrace No. 3 becomes indistinct south of Capital, Montana (11 miles southwest of Camp Crook), and Terrace No. 4, as mentioned above, is reduced to a 100 foot width near Alzada, Montana. Level 5 has a rolling surface, marred by channel scars and resembles a pediment slope as it grades remmants of Level 6 in the southeast Montana area, a few miles north of Alzada, Montana.

#### Badlands and Slopes

The badland and slopes developed along the terraced valley

of the Little Missouri River deserve special mention as do the geomorphic processes instrumental in their development.

Although streams cut and deepen valleys and transport the resulting loads of rock particles, the shaping of most of the land surface, including the sides of the valleys, results mainly from sheet runoff and mass wasting of weathered material. Mass wasting is regulated not only by the rate of weathering but also by the rate of stream erosion. Consequently the load increase of the stream, as the result of mass wasting, tends to retard stream velocity which results in retardation of stream erosion. The concept of sculptural evolution of a land mass is based on variations of precipitation, slopes, and rock types, resulting in sculptured forms of varying appearance.

In the case of the Little Missouri River Valley the slope gradient is dominated by the river, and the rainfall can course over every part of the channeled slope as sheet wash. For this reason it seems appropriate to call graded slopes of this kind wash-slopes (Meyerhoff, 1940, p. 251). In any given situation the wash-slope is the composite product of sheet volume and load, and the angle required by these local factors will develop on valley slopes.

The recession of the erosional escarpment at the head of the wash-slope profile depends on gradational processes. The gullying action is aided and abouted by gravity and the clopes will be torn down by slumping, soil creep and landslides. Hecause these slopes are the prey of varied effects of gravity, they may appropriately be called gravity-slopes (Meyerhoff, 1940, p. 251). The form of the slopes developed depends on the coherence of the material at hand and the local processes which act on them.

Rapid lateral planation by streams may broaden valley floors. When lateral planation is halted by entrenchment, sheet wash continues on the strath terraces which are left and the process is accompanied by the steady recession of the erosional valley shoulder, escarpment or gravity-slope. Interruptions in the planating cycle of a stream may result in the formation of valley-in-valley profile, which still holds the concave profile of a topographic form produced by the fluvial cycle of erosion (Bryan, 1940, p. 255).

With the incipient dissection of Terrace No. h, the actual sculpturing of the badlands of southwestern North Dakota was begun. All that seems necessary to start the process of badland sculpturing is a certain amount of relief, a semi-arid climate, a bare spot, weakly resistant rock, and concentrated rainfall. Once the process of steep down outting has begun and bed rock becomes exposed, the initiated rills develop into gullies which enlarge to form minor channels and the mass wasting is underway. The poorly indurated rocks of the Fort Union group are ideal for the process of masswasting and deep erosion. Consequently, the wash-slope and gravity slope are heavily gullisd and channeled until

the slope surface is heavily dissected.

Grassy uplands are soon incised by the headwaters of numerous tributaries and interstream divides are engulfed.

Steep slopes develop and vast amounts of sediment are carved from the valley walls.

The heterogeneous nature of the Fort Union group has yielded many strange and labyrinthic forms which characterize badland topography. Where headward erosion caused capture of tributaries, dissected portions of the upland were left as isolated salients or topographic unconformities, such as "mud buttes" resting on a grassy surface. Other forms, including demoiselles, pinnacles, stacks, chimney rooks, earth pillars and organ pipe fluting, are all developed on the surface of the outcrops. In consequence of hard sandstone lenses, scoria, and concretions, many ledges are preserved and add strange forms to the area. Adding to the variable types of forms present, in the Little Missouri Badlands, are the yellow, tan, brown, and gray, of the nearly horizontal strata.

#### Drainage

The master stream of this area is the Little Missouri River. The North Dakota portion of the drainage basin of this river is bounded by a narrow interstream divide on the east and an equally narrow divide on the west. The divide between the Little Missouri and the heads of southeast flow-

ing streams is 10 to 15 miles wide in places and appears to be shifting to the east. The divide between the Yellowstone River drainage on the west and the Little Missouri River drainage on the east is 2,800 feet above see level near Beaver Creek in Golden Valley county, but in the May Draw Creek area of southern McKenzie county, the divide is approximately 2,200 feet above sea level. This low divide is the result of erosion by the diverted Yellowstone River when it flowed through this channel (Leonard, 1916, p. 300). The main tributaries on the west are Boxelder, Little Beaver, Cannonball, Williams, Bullion, Garner, Andrews, Reaver, and May Draw Creeks. On the east side of the river the tributaries include Deep, Sand, Third, Whitetall, Magpie and Biscegel Creeks which supply most of the perennial water to the main channel.

From the South Dakota state line to Williams Creek the gradient of the river is about four feet per mile, while the total gradient in the mapped area is his feet per mile.

One curious feature of the river is the distinct loop as it flows north through Slope county. Just below the Billings-Slope county line, the river turns east, then curves west to continue its general northward course. From the terrace development in this area it is surmised that the river has followed this course since late Phicoene-early Plaistocene time. It appears that this loop is controlled to some extent by the stratigraphy and structure in the Palecoene

beds. The contact of the Imdlow formation and the Tongue River formation is followed somewhat by the eastern trend of the river in the big loop.

The conspicuous monnders, so characteristic of the Little Missouri River, are not static, but tend to migrate downstream. Field examination failed to preve structural control for the meanders, consequently they probably are the result of deflection by Terrace No. 3 and No. 2 and the exposed bedrock.

From the work of Banson (1955), and Moldahl (1956), it is apparent that portions of the Little Missouri River tend to follow moses of slightly plunging structures which trend to the north.

#### Sequence of Events

The sequence of events which culminated in the formation of the Little Hissouri Piver as we see it today is based on a series of uplifts, planations and stream captures. The geologic and geomorphic history of the Little Hissouri River is outlined diagrammatically in Figures 9 to 12 inclusive and described in the following stages:

# Stese No. 1

During the Paleocene epoch deposition was predominent in western North Dakota. The slightly different formations of the Fort Union group were deposited in an environment of low lying coastal swamps, with the exception of the Cannon-ball formation which was deposited in a shallow seaway.

In early Ecocome time western North Dakota was at a low altitude. At this time the process of erosion became dominant over the process of deposition, which had been prevalent during Paleccene time. Erosion of the high areas to the west soon resulted in deposition of fluviatile material in western North Dakota. In the western part of the state this deposition furnished the basal clay member of the Ecocome Golden Valley fermation, followed by the coarser sediment of the upper sandstone member. This member probably was deposited by streams flowing over a low, flat plain, possibly over a coastal plain (Benson, 1952, p. 92).

These two distinct series (the Fort Union group and the Golden Valley formation) are separated by an unconformity which is designated as Level 8 in Figure 3.

## Stage Mo. 2

Following the deposition of the Golden Valley formation, tilting of the Rocky Frantzin area and aplift of the Black Hills (Benson, 1952, p. 236), resulted in the crosion of much of the Fort Union group and the Golden Valley formation from weatern North Dakota. These epeirogenic aplifts occurred in middle and late Eccens time and resulted in the development of an erosion surface here designated as Level 7 in Figure 3. This unconformity is evident at the base of the White River formation where it is exposed in Schtinel Butte.

It is probable that the formation of the scoria, so prominent as a colorful marker bed in the Hongue River for-

mation of southwestern Morth Dakota, began as the streams dissected the soft, poorly indurated clay, shale, samistone and lignite of this formation. According to Benson (1952, p. 53), and Hares (1928, p. 52) the light beds began to burn as they were exposed by erosion. The unconformity (Level 7), evident at Sentinel Butte, shows clearly that scoria was present prior to the deposition of the White River formation in Cligocene time. In the basal mark beds of the White River formation on Sentinel Butte, red streaks of iron oxide and fragments of scoria picked up in the coze at the time of deposition indicate that the White River bode were deposited on an eroded scoria surface. Evidence has been cited by Benson (1952, p. 53), and Hares (1928, p. 52) that the basal conglomerate of the White River formation contains scoria fragments, which again indicate that the scoria had been formed prior to the White Rivor deposition.

#### Stale Mo. 3

Uplift followed the late Rocene period of presion and east-flowing streams developed which rose in the Montana Rocky Mountains, the Wyoming Rocky Mountains and the Black Hills. The generally fine texture of the Unite River deposits indicates deposition by streams of gentle gradient in local lakes and bayous. Coarse or basal conglomerate in the basal Cligocone White River beds indicates moderate relief of the source areas. The streams continued erosion and deposition over their meandering courses and thus initiated the develop-

ment of the Cypress Plain (Alden, 1932, p. 7) in northeastern Montana and southern Canada. In North Dakota at this same time, the White River formation was being deposited. According to Alden (1932, p. 7), the formation of the Cypress Plain and the deposition of the White River formation are of the same age.

The streams flowing east in North Dakota terminated in lakes. The fluctuating level of these lakes is evidenced by facies changes in the White River sediments. Both gross fossil evidence and lithologic evidence indicates oscillating shoreline development at different stages of these Oligocene lakes. The stream patterns and shore outlines at one stage in the development of the Oligocene lakes are indicated in Figure 9. Differences in the lithology of the outcrops present in the area seem to indicate either a series of transgressing and regressing shore lines, or the presence of several lakes.

The streams which flowed into this lake system left a gravel capped surface to the west and north. In North Dakota, this curface can readily be seen terminating the higher flattopped buttes, such as Sentinel Butte, Bullion Butte, and Flattop Butte. An eastern slope of the Oligocene land surface is indicated by feeble dips in these white River remnants (Powers, 1945, pp. 43,60). Perhaps this planed surface of the higher buttes is partially the remnant of a stripped plain in North Dakota, that was once a part of the gravel capped

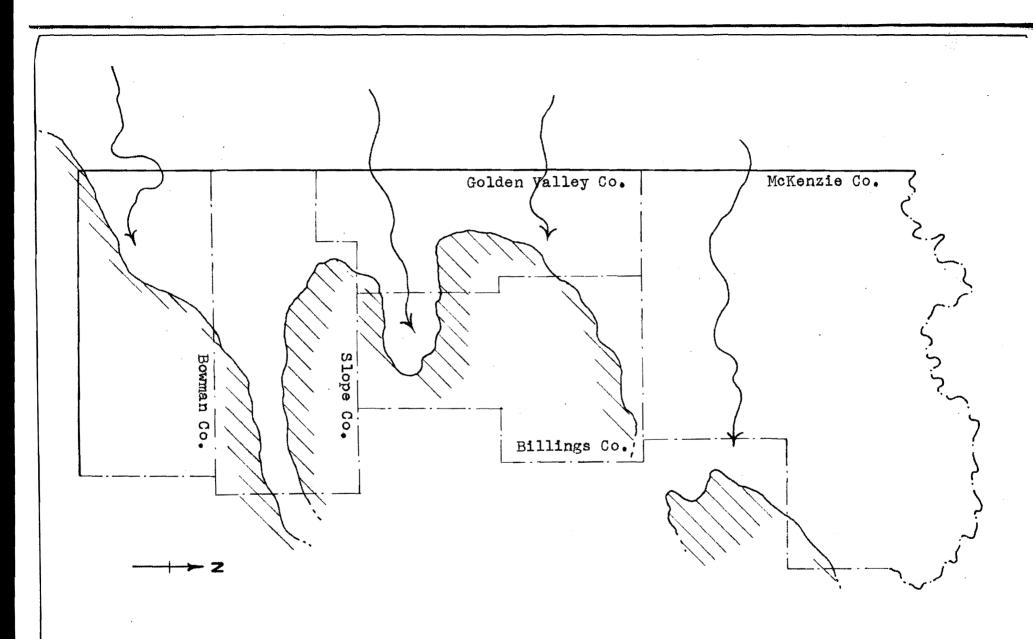


Figure 9. Stage No. 3

Early to middle Oligocene time. This figure indicates the direction of flow of the major streams and position of shore lines of lake system (ruled area) at one stage of development. Shore lines at this stage indicated by facies change from shore type environment to deep water environment.

depositional plain to the North and West. This surface is indicated in Figure 3 as Level 6.
Stage Ho. 4

In late Oligocome and early Miocome time major uplifts occurred to the South and West of the Morth Dakota area.

Hardley (1951, p. 362) gives the following figures indicative of the uplift:

- a. 2,000 to 3,000 feat in the Black Hills.
- b. About 5,000 feet in the Wyoning Rocky Mountains. Alden (1932, p. 12) states that 700 to 1,000 feet of uplift occurred east of the 1090 west longitude line. Plumley (1948, p. 535) also suggests an uplift of 2,000 to 3,000 feet in the Black Hills area. Folding and warping accompanied the uplifts. This folding may account for the deformation of the Tertiary beds in North Dakoba.

The east flowing streams in consequence of the uplift migrated to the north as they became superposed on the White River beds, as is indicated in Figure 13. These streams began the dissection of Level 6 and were the forerunners of the broadly meandering streams which were to produce the Flauville surface. Much of the White River formation was removed by the action of these streams. Many of these streams croded channels which are evident today and were the initial cause of the formation of many menadhooks or buttes which rise 300 feet to 500 feet above the present upland surface, Level 5.

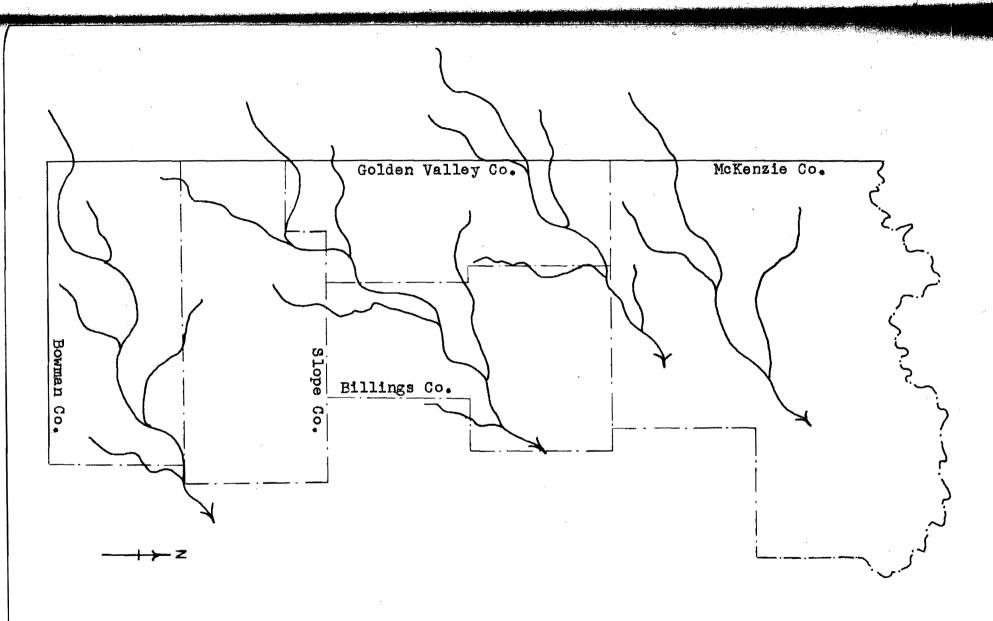


Figure 10. Stage No. 4 Late Oligocene-early Miocene time. Lakes had receded to the East and in response to the uplift streams migrated to the North and were superposed on Level 6. Erosion began to form monadnocks such as Sentinel Butte, Flattop Butte, and Bullion Butte, during the incipient stage of the Flaxville surface.

## Stage No. 5

By late Miocene time much of the area had been dissected. In response to regional uplift the northeast flowing streams began to migrate north and with the aid of tributary captures formed north flowing streams from which the Missouri, Yellowstone and the Little Missouri Rivers developed. Figure 11 indicates this pattern with respect to the Little Missouri River.

As the newly formed streams began downcutting of the partially eroded Oligocene surface, Level 6, they were aided in degradation by acolian and landslide action. These streams had broad floodplains and laid down thick beds of coarse gravel, sand, and clay. The heavily loaded streams frequently filled their shallow valleys with coarse debris and shifted their courses as the process of peneplanation continued into Pliocene time.

This surface which developed is the correlative of the Flaxville Plain of northeastern Montana. Deposition of the Flaxville gravel was being accomplished by the early Yellowstone, Missouri, and Little Missouri Rivers which were meandering over floodplains 20 to 30 miles in width. This surface is indicated by Level 5 in Figure 3. Gravel deposits on this surface indicate old channels of these Miocene-Pliocene rivers, while the interstream divides are covered by only a very thin veneer of gravel or may have no gravel cover. |

Russell (1950, p. 58) cites evidence which he believes indi-

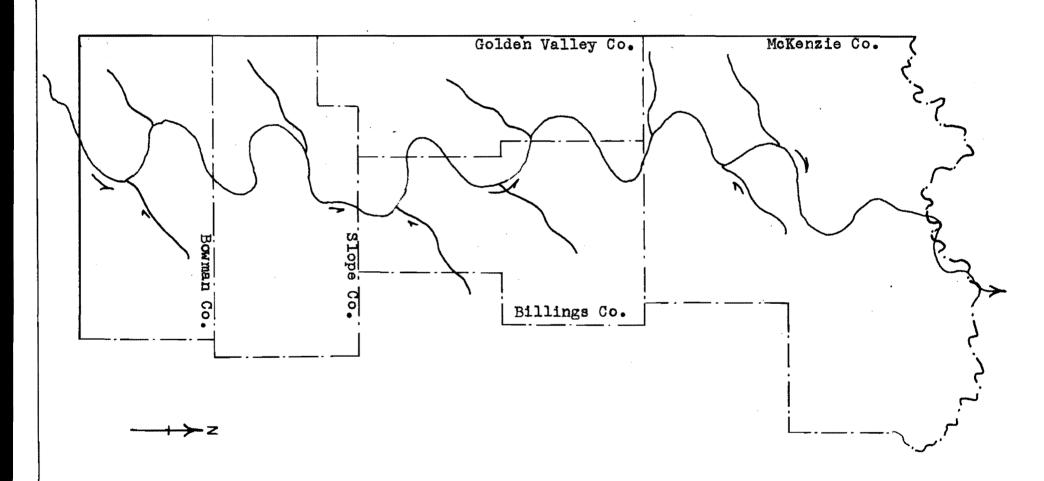


Figure 11. Stage No. 5 Late Miocene and early Pliocene time. In sympathy with broad uplift, northeast flowing streams migrated north and with the aid of tributary capture formed a broad meandering stream flowing north.

cates at least two periods of Flaxville deposition. He feels that the buried soil zone present in the type area of the Plaxville gravel accounts for a late Miccene deposition and also an early Plicene deposition. By mid-Plicene time the Flaxville surface had the aspect of a true peneplain and may be contiguous with both the Rocky Mountain peneplain (considered by Mackin, 1948, to be a real pediment surface) and the Mountain Meadow surface of the Black Hills.

Stage No. 6

Regional uplift at the close of Plicene or early Pleistocene time caused the north and northeastward-flowing streams to begin their dissection of the Flaxville Plain/ (Level 5). The downcutting to the present Little Missouri Terrace No. 4 was aided by this regional uplift. This uplift probably initiated and accelerated the headward erosion of the Belle Fourche River. This encroachment by the Belle Fourthe toward the main tributary of the Little Missouri River resulted in the breaching of the low interstream divide and terminated in the capture of a portion of the head waters of the Little Missouri River. The actual capture took place on Level 5 as the headward encroachment of the Belle Fourche River breached the divide between the tributaries of the two rivers. The elbow of capture is represented by the area designated as Stonewall Flats, NW sec. 11, T. 58 N., R. 86 W., on the Aladdin Quadrangle, Wyoming, South Dakota, and Montana, United States Geological Survey Topographic Sheet, 1903.

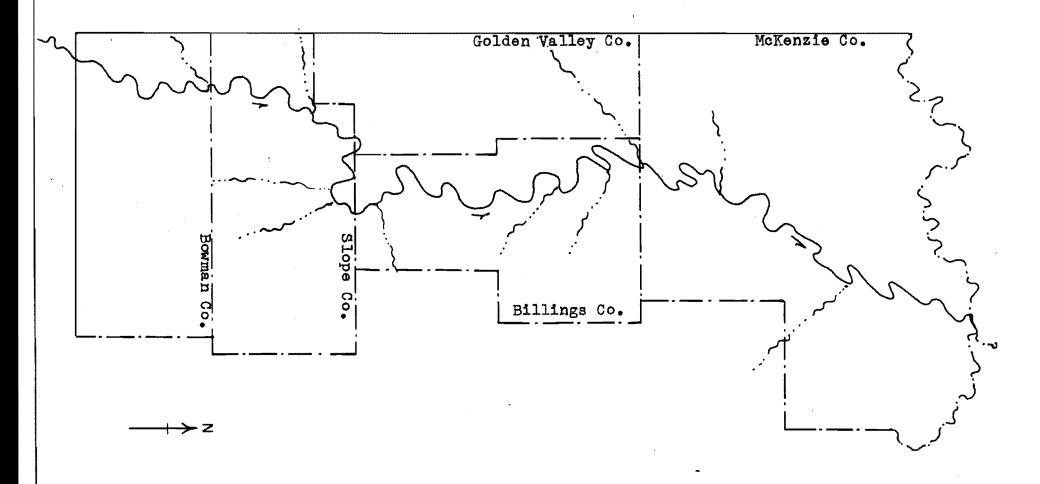


Figure 12, Stage No. 6 Late Pliocene-early Pleistocene time. The pattern of the Little Missouri River as it developed the strath which is designated as Little Missouri Terrace No. 4.

Piracy of the Little Missouri River's main tributary resulted in a loss of the Little Missouri River's main source of water and a consequent decrease in its eroding and transporting power. As a result the Little Missouri River was soon changed from an actively incising stream to a stream of lateral planation. This lateral cutting developed the strath known as Little Missouri Terrace No. 4. Another result of this capture was the decrease of transported material; so consequently, the gravel covering Terrace No. 4 is mostly reworked Flaxville gravel.

The Little Missouri River throughout its generation has been a superposed stream and may be considered as a superposed-consequent stream, as it cuts through previous formed structures and tends to follow the slope that resulted from a series of uplifts. The drainage pattern of the late Pliocene-early Pleistocene Little Missouri River is shown in Figure 12.

## Stage No. 7

As the Little Missouri River flowed north, renewed uplift and peripheral precipitation in advance of the Kansan-Illinoian ice sheet soon altered the lower course of the Little Missouri River (Schmitz, 1955, p. 31).

As a result of broad arching and increased stream gradients the Little Missouri River began rapid downcutting. It incised its former strath (Terrace No. 4) and produced a topographic unconformity or a valley-in-valley type of geomorphic form (Thornbury, 1954, p. 144). A temporary or local . base level was reached and the formation of another cut terrace followed. This cut terrace is designated as Terrace No. 3 in Figure 3. With increased precipitation, large scale mass wasting was initiated as the result of sheet wash, gullying and landslides. The Little Missouri River cut below the present river bed prior to a period of valley filling. The process of aggradation overtook that of degradation in the Little Missouri valley with a temporary base level being established. These periods of alluviation and local damming caused by sheet wash, which in turn was the result of oversteepening of the valley walls, interrupted the normal degradation cycle. As soon as the stream could again reach its cutting cycle, the lateral swinging of the stream produced unmatched terraces in the alluvium. This type of terrace is designated as a cut-and-fill terrace by Smith (1949, p. 1507). This group of terraces is indicated in Figure 3 as Little Missouri Terrace No. 3.

The laminations in alluvial material along the Little
Missouri River, which often have been interpreted as seasonal
varves, as a result of major ponding in the valley, may be
the result of cyclic interruptions of the delicate sedimentation processes, such as sheet wash, at that time. It is
possible that particles of sediment which reached the heavily
overloaded stream through the medium of mass wasting, settled
out and were planed to form this cut and fill terrace. Periodic

break-through of streams caused by change in stream velocity resulted in channel and fill deposits in the alluvium. These are evident in the cut slopes of Terrace No. 2 and No. 3 where present day erosion and slumping have exposed alluvium along tributaries of the main stream (see Figure 13). From the study of Terrace No. 3, it is evident that at least two periods of base leveling occurred as the result of static rejuvination of the stream (Malott, 1920, p. 183; Schmitz, 1955, p. 16). This is reflected in the two different and distinct origins of portions of Terrace No. 3.



Figure 13. View along Paddock Creek showing laminated alluvium, channel fill and slumping east of Medora, North Dakota

Reflections of fluctuations in local base level, caused by isostatic adjustment of the area in response to the ablation of glacial ice, are seen in the development of Terrace No. 2 and caused the river to again down cut and reach the overloaded meandering pattern it has today. The amount of rebound of this area following the retreat of the ice is

inferred by comparing the early Pleistocene profile of Terrace No. 4 and the present profile of Terrace No. 4 as depicted on Plate 2. It can be seen that the zero region of rebound coincides within reasonable limits to the hinge line inferred by the work of Schmitz and Kresl, (1955, p. 93).

#### Summary /

The upper portion of the Little Missouri River and the adjacent physiographic features of its valley and bordering uplands has a history characterized by several cycles of erosion. The late Tertiary history of this area may be outlined in seven main stages.

Stage No. 1. Deposition of the Paleocene Fort Union group and the Eccene Colden Valley formation.

Stage No. 2. Uplift and extensive erosion. Initial formation of scoria from burning lignite, during Eocene time.

Stage No. 3. Deposition of the Oligocene White River formation by east-flowing streams. Remnants of this formation evident in some of the high buttes in southwestern North Dakota.

Stage No. 4. Major uplift to the South and West resulting in drainage migration to the North and consequent development of the Flaxville surface.

Stage No. 5. Stream migration and tributary stream capture that aided development of the broad meandering streams which deposited the Flaxville gravel.

Stage No. 6. Dissection of the Flaxville Plain. Loss of the main tributary of the Little Missouri River as the result of stream capture and the formation of Little Missouri Terrace No. 4. Incipient badland development.

Stage No. 7. Increase in precipitation, broad arching, stream capture, and isostatic rebound all influenced the formation of lower terraces along the Little Missouri and aided the development of the present topography of the Little Missouri drainage basin.

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