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Tongue River - Sentinel Butte Contact

in

WESTERN NORTH DAKOTA

by
Chester F. Royse, Jr.

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ABSTRACT

The Tongue River-Sentinel Butte contact has been regarded by many workers as a vague color boundary of minor extent within a relatively homogeneous sequence of Paleocene strata. Consequently, the Sentinel Butte has come to be regarded as a subordinate unit of the "Tongue River Formation." As defined in this report, the contact is a distinctive horizon between two discrete lithogenetic units. It is characterized by three criteria: a lignitic horizon (HT Butte bed) at the top of the Tongue River sequence; a basal sandy unit in the Sentinel Butte sequence; and a marked change in color between buff-yellow Tongue River sediments below and somber gray Sentinel Butte sediments above.

This contact has been mapped (1:250,000) throughout the badlands of the Little Missouri River, and along the Missouri River from the Montana-North Dakota border to the mouth of the Little Missouri River. The contact is concealed in the central part of the Williston basin, but crops out on the eastern flank of the basin about 60 to 80 miles east of the mapped area. The extent of the contact along the eastern margin of the basin has not been determined, but outcrops in Morton County display lithologic relationships similar to those which distinguish the contact farther west. No evidence was found in support of the Tongue River-Sentinel Butte facies relationship postulated by previous investigators.

Recognition of distinctive stratigraphic relationships at the Tongue River-Sentinel Butte contact and documentation of their regional persistence demonstrate that the Sentinel Butte sequence is a mappable lithostratigraphic unit. It is therefore recommended that in western North Dakota and adjacent areas the Sentinel Butte sequence be assigned formational rank. The term Tongue River Formation should be applied only to beds underlying the Sentinel Butte Formation.

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INTRODUCTION

This report is an outgrowth of a sedimentological study of the Tongue River and Sentinel Butte Formations in western North Dakota, during which it was necessary to determine the stratigraphic position of samples collected for analysis. In regard to the names, ages, thicknesses, and stratigraphic relationships of these Paleocene strata, the literature contains many apparent ambiguities and contradictions and the stratigraphy is reliably documented in relatively few localities. Therefore, the writer began at the type locality of the Sentinel Butte Formation and traced its basal contact, which constitutes a good mapping horizon, throughout a large part of western North Dakota.

Scope and Objectives

The objectives of this report are threefold, (a) to describe the characteristics of the Tongue River-Sentinel Butte contact which permit its recognition throughout a large portion of western North Dakota, (b) to demonstrate the mappability of the Sentinel Butte Formation, and (c) to review the stratigraphic nomenclature applied to these and related units.

Fulfillment of these objectives should illustrate that the Sentinel Butte is a distinctive and mappable stratigraphic unit. In anticipation of such fulfillment, the writer freely refers to the Sentinel Butte as a formation. Other terminology, except that used in the context of previous investigators, is that currently accepted by the North Dakota Geological Survey. The lithostratigraphic nomenclature applied in this report to beds in the Paleocene Series in western North Dakota is given below.

Fort Union Group
- Sentinel Butte Formation
- Tongue River Formation
- Ludlow and Cannonball Formations

Quantitative data necessary to demonstrate a lithologic difference between the Tongue River and Sentinel Butte Formations are not given here; studies in progress are providing such data and these will be presented in a future report.

Methods of Investigation

Field observations which form the basis of this report were made during the summers of 1965 and 1966. The Tongue River-Sentinel Butte contact was delimited (Figure 1) by continuity throughout much of the study area, but similarity of stratigraphic sequence was utilized in correlation across broad expanses where the contact is concealed. The contact was inspected at numerous localities, its elevation determined, and the character of the adjacent beds recorded. Samples were taken 6 to 8 feet above and below the contact at many stations. Field locations were accurately plotted on county road maps (scale = 1/62,500) and later transferred to topographic sheets (scale = 1/250,000). These points, supplemented with additional data from published reports, were used to extrapolate the contact throughout the drainage of the Little Missouri and Missouri Rivers.

Previous Studies

Many of the "surface" geologic studies concerning Paleocene strata in western North Dakota involved classification of coal lands and are found in the Bulletins of the U.S. Geological Survey. Most of these investigations were conducted between 1900 and 1930, but an increasing potential of lignite for generation of electric power and the discovery of uranium compounds in lignitic strata has renewed economic interest in these beds. Extensive seismic and other subsurface geophysical surveys have been made by various oil companies, but results of these studies are not generally available to the public. Several recent studies involving the Paleocene Series in western North Dakota can be found among the publications of the North Dakota Geological Survey. Relevant studies are cited in the text and additional references are included in the selected bibliography.

The Conservation Branch of the U.S. Geological Survey is presently mapping a number of quadrangles in Morton and Grant Counties, but the greatest portion of the area of Figure 1 has not been mapped at a scale greater than 1/250,000 or a contour interval of less than 100 feet.

CHARACTER AND EXTENT OF THE CONTACT

General Statement

Strata of Paleocene age are widespread throughout the northern Great Plains. They conformably overlie the Hell Creek Formation of Cretaceous age and are unconformably overlain by the Golden Valley (Eocene) and White River (Oligocene) Formations and by late Tertiary gravels and assorted Pleistocene deposits. Collectively, beds of the Paleocene Series form a stratigraphic unit known as the Fort Union

Group, which extends in continuous outcrop over much of western North and South Dakota, eastern Montana, and across the Powder River basin of Wyoming. Fort Union beds are also recognized in northwestern Colorado.

Within North Dakota, Fort Union beds are widespread within the Williston basin. Major outcrops, however, are largely restricted to the non-glaciated area (and adjacent glaciated areas of thin drift) south and west of the Missouri River. Excellent exposures are present in the highly dissected badlands of the Little Missouri River and along the northern reaches of the Missouri River. The Turtle Mountains, in north-central North Dakota, are an outlier of Paleocene strata.

The Tongue River and Sentinel Butte Formations constitute the greatest Paleocene outcrop area within the state; the contact between the two is nearly continuous throughout the Little Missouri badlands. Stratigraphic exposures reach 300 to 500 feet, affording excellent opportunity for observation of stratigraphic relationships. Within the area here discussed (Figure 1), the base of the Tongue River Formation crops out only south of the vicinity of Bullion Butte where it overlies the Ludlow Formation. Elsewhere in western North Dakota it lies in the subsurface, except along the eastern flank of the Tertiary Williston basin where it appears above the Cannonball Formation. Much of this eastern area is mantled with drift, and the contact is largely concealed. Although Sentinel Butte strata are widespread in western North Dakota, the upper beds of the sequence have been widely removed by erosion and can be observed at relatively few localities.

Definition of the Contact

In locating and tracing the Tongue River-Sentinel Butte contact in western North Dakota, it was found that it can be distinguished on the basis of three criteria. These are a marked change in gross color, the presence of a lignitic horizon in the uppermost part of the Tongue River Formation, and the presence of a sandy basal Sentinel Butte unit.

Color

The first of these criteria, a distinctive color difference, is embodied in the original definition of the Sentinel Butte Formation given by Leonard and Smith (1909, p. 18) in their report on the Sentinel Butte lignite field.

> There is a very noticeable difference between the lower Fort Union beds, which outcrop in the bluffs bordering Little Missouri River, and the upper beds, occurring in the tops of

> the higher ridges, divides, and buttes, usually back some distance from the river. The lower member is composed of buff and light ash-gray clays and sands in alternate layers. The upper member is formed of strata considerably darker in appearance, mostly dark gray, with many brown, ferruginous, sandy nodules and concretions. The contrast between these members is so well marked and their contact so clearly defined that it can be readily distinguished at a distance and traced without difficulty wherever it is exposed. Over most of the eastern half of the field a thick bed of lignite or a layer of red clay formed by the burning of the lignite occurs just at the contact of the upper and lower members. But even where the coal or burnt-clay bed is wanting, the line of separation is readily discernible.

Leonard (1911, p. 534), in a discussion of the stratigraphy of North Dakota, again emphasized the marked contrast in color and the clarity of the contact between Tongue River and Sentinel Butte strata.

> In Billings County, North Dakota, an upper member [= Sentinel Butte] of the formation appears in the tops of the higher ridges, divides, and buttes, and resembles somewhat the Lance beds in its dark color and its many brown ferruginous, sandstone concretions. The lower member [= Tongue River] constitutes the typical yellow and light gray Fort Union and this is the only one present over most of the region. Where both occur, the contrast between the upper and lower members is so well marked and their contrast so clearly defined that it can be readily distinguished even at a distance and traced without difficulty, wherever it is exposed.

Although the color contrast between these stratigraphic units is real and persists regionally, it may fail locally as a sole means of distinguishing the contact. The lower Sentinel Butte beds, as discussed below, are rather uniform in both color and lithology. The Tongue River beds below the contact exhibit considerable variation in texture and are locally variable in color. Where fine-grained, drab beds are present in the uppermost Tongue River the color contrast with the Sentinel Butte is reduced (see Figures 5-C and 6-A). Because light colored beds invariably dominate any weathered section of Tongue River strata, the contact is most discernible where it occurs above a substantial section of Tongue River strata.

It must be emphasized that the light, buff-yellow color of Tongue River sediments is largely, if not entirely, a weathering phenomenon. Locally, as in steep bluffs along rivers (see Figure 7-B), where erosion proceeds rapidly, the Tongue River beds appear far more somber than in areas where oxidation has had ample time to operate. In fresh outcrops or in the subsurface, no color distinction can be made between these units. Despite these limited drawbacks, the color contrast remains perhaps the most useful single factor in field recognition of the Tongue River-Sentinel Butte contact in North Dakota.

HT Butte bed

A lignitic unit is present at the Tongue River-Sentinel Butte contact in virtually all localities visited by the writer, but it is frequently concealed in outcrop by slumping of overlying material. With the exception of Hares' (1928) term "HT Butte lignite," terms formerly or presently applied to this unit are not stratigraphic binomials. It is therefore recommended that the terminology of Hares (1928) be exclusively retained and applied to this stratigraphic interval in North Dakota. As understood and applied in the present report, the name HT Butte bed applies to a carbonaceous zone in the uppermost Tongue River Formation which may be represented by lignite, lignitic shale, or both, ranging in thickness from several inches to several tens of feet. Because of its great regional extent and distinctive stratigraphic relationships, this bed has great value in mapping.

The association of lignite with the contact has been noted by many workers. Taff (1909) placed the upper contact of his Tongue River coal group above the Roland coal bed. The likely persistence and great areal extent of this lignite was recognized by Thom and Dobbin (1924, p. 496).

> In northern Wyoming and southern Montana, and perhaps in Dakota areas as well, the base of the Sentinel Butte shale is marked by the Roland coal bed, which in thickness, persistence, and general genetic relationships resembles the Big Dirty coal of the Lebo.

In North Dakota this lignitic unit has received many designations, the most important of which are included in the synonymy of Table 1. Although an equivalence appears probable and the temptation to correlate is great, it is considered unwise to apply the term Roland coal in North Dakota until such correlation is more firmly established than it appears to be at present. Should definite correlation be established with the Roland coal bed of the Sheridan field in Wyoming, the term HT Butte should be superseded by Roland.

Table 1. Synonymy of terms applied to the lignitic interval at the Tongue River-Sentinel Butte contact.

Author	Nomenclature	Publication
Leonard (1908)	R	5th Bien. Rept. N.D.G.S.
Leonard and Smith (1909)	F and G	U.S.G.S. Bull. 341-A
Stebinger (1912)	K	U.S.G.S. Bull. 471
Hares (1928)	HT Butte	U.S.G.S. Bull. 775
Fisher (1953, 1954)	L	N.D.G.S. Rept. Inv. 11 & 15
Hanson (1955)	L	N.D.G.S. Rept. Inv. 18
Meldahl (1956)	L	N.D.G.S. Rept. Inv. 26

A note of explanation is necessary regarding consideration in this report of both the F and G beds of Leonard and Smith (Table 1) as a single stratigraphic unit. As originally stated by Leonard and Smith (1909, p. 31).

> The second member of the group, bed G, from 25 to 50 feet above the lowest member [which is bed F], shows to better advantage in the south-central part of the surveyed area, in the base of the higher buttes, where its outcrop is marked by a fringe of clinker. Both the lower members become thin and disappear toward the northwest. These beds have been so generally burned that few exposures showing their whole thickness can be found.

It appears that bed G is known with certainty to occur only at the base of Sentinel Butte where it was extensively mined in former years. Field inspection on the northeast flank of Sentinel Butte, at the site of the old Mammoth mine, indicates that bed F is about 6 feet thick and is separated from bed G by 18 feet of silty clay which constitutes a single stratigraphic unit. Bed G exceeds 20 feet in thickness and is overlain by a thick sequence of clayey sand.

Investigations by many workers since 1909 have resulted in the recognition and extension of bed F far beyond the limits of the Sentinel Butte field. Bed G, however, has received no such recognition. This writer feels that, although outcrop exposures are inadequate for

demonstration, it is most probable that the F and G beds comprise a single genetic unit parted by a wedge of clastic sediment. Correlation of the G bed with the lignite which burned to form the prominent red clinker capping ridges and buttes north of the village of Sentinel Butte (Leonard and Smith, 1909; Hennen, 1943) appears to be in error. The contact in this area is marked by a distinct color change (as can be seen on the northeast flank of Camel Hump Butte and near the center of section 4, T. 140 N., R. 104 W., Figure 4-C) associated with a lignitic zone and a basal Sentinel Butte sand, and underlies the clinker horizon by about 50 feet. The implications involving miscorrelation of the G bed are discussed in the following section.

Taff (1909) originally considered the top of Roland coal as marking the top of his Tongue River coal group. Subsequent workers (Leonard and Smith, 1909; Hares, 1928; Fisher, 1953; and others) have arbitrarily included this bed in the Sentinel Butte Formation, perhaps because its dark color contrasts less with this unit than with the underlying Tongue River Formation. It appears, however, that the HT Butte bed represents the culmination of a sequential accumulation of fine clastic material in which development of thick lignites was fairly common. As discussed below, the Sentinel Butte sequence was introduced by an influx of "basal" sand which spread across the "HT Butte swamps." Thus, the HT Butte bed is here considered a genetic unit of the Tongue River Formation.

The HT Butte bed is so variable in thickness that only general statements regarding thickness appear to have validity. As an example in point, it can be demonstrated that the thickness of the HT Butte bed decreases northward from more than 10 feet in the South Unit of Roosevelt Park to about one foot 10 miles northward on the divide south of Mikes Creek (Figure 5-C). A similar thinning occurs westward toward Twin Buttes (Figure 4-D), where the HT Butte bed consists of a few inches of lignitic shale. The thickness of lignites appears to be a relatively local phenomenon which has little bearing on their regional persistence and only minor significance regarding the regional conditions which favor their development. Field experience has demonstrated to the writer's satisfaction that lignites cannot and should not be correlated solely on the basis of thickness. Thus, thickness is considered a subordinate factor in recognition of the HT Butte bed.

Basal Sentinel Butte sand

Recognition of a persistent basal unit in the Sentinel Butte Formation has aided significantly in recognition of the Tongue River-Sentinel Butte contact. In its "typical" or "maximum" state of development, this basal unit is a silty, cross-bedded sand ranging from several tens of feet to over 100 feet in thickness (Figures 2 and 3). Cross-stratified sets

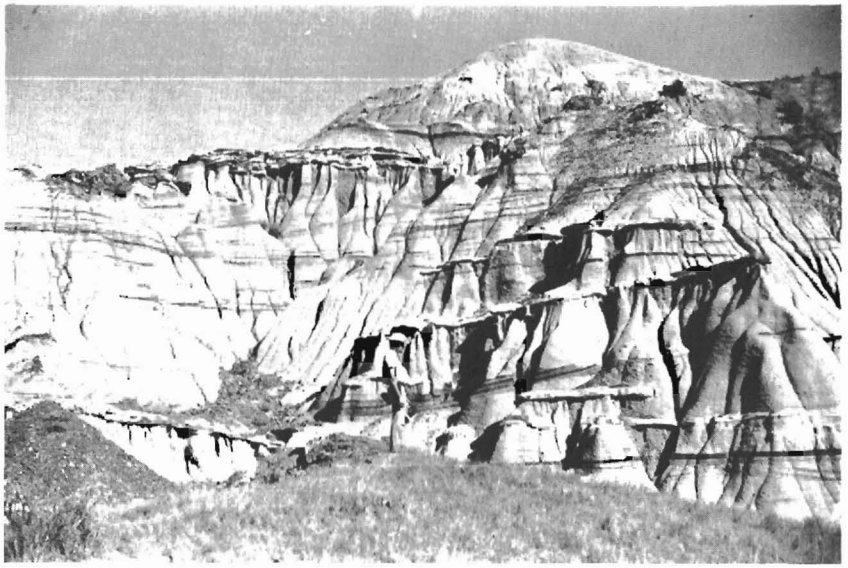
FIGURE 2.

A. Basal Sentinel Butte sand in upper Blacktail Creek drainage. Cross-beds are emphasized by concentrations of lignite fragments along bedding planes; man in foreground indicates scale.
Location: SE 1/4 sec. 10, T. 143 N., R. 101 W., Billings County, North Dakota.

B. Cross-bedded basal Sentinel Butte sand on West River road about 3 miles southwest of Medora. Sand is loosely cemented with iron oxides; hammer indicates scale.
Location: SW 1/4 sec. 31, T. 140 N., R. 102 W., Billings County, North Dakota.

C. Cross-bedding in fine basal Sentinel Butte sand along fire-guard trail south of Bear Creek. Cross-bed sets are emphasized by lignite fragments concentrated along bedding planes. Entrenching shovel indicates scale.
Location: SW 1/4 sec. 7, T. 137 N., R. 101 W., Billings County, North Dakota.

D. Concretionary bedding-planes developed in basal Sentinel Butte sand about 5 miles southwest of Medora. These surfaces are diastems and illustrate the periodic mode of accumulation of this unit; note similar structures in Figures 3-A and 3-B.
Location: SW 1/4 sec. 11, T. 139 N., R. 103 W., Billings County, North Dakota.



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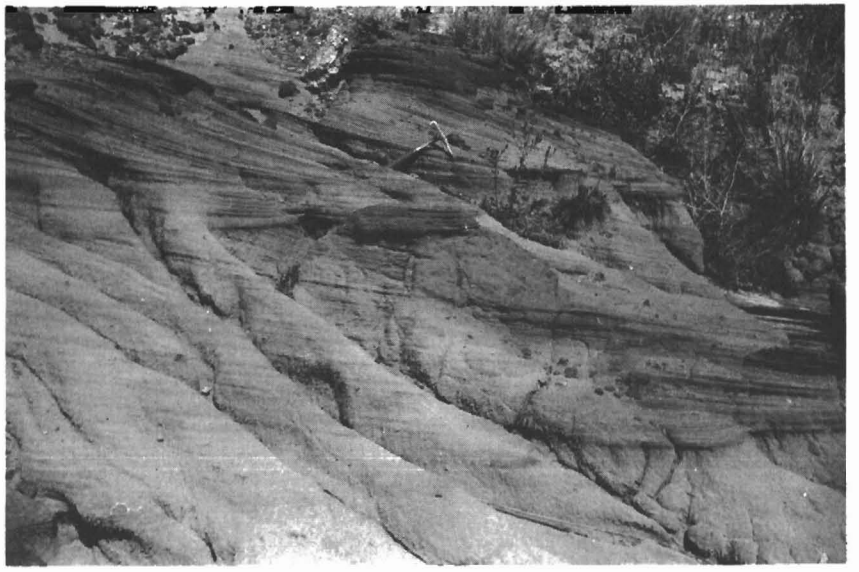

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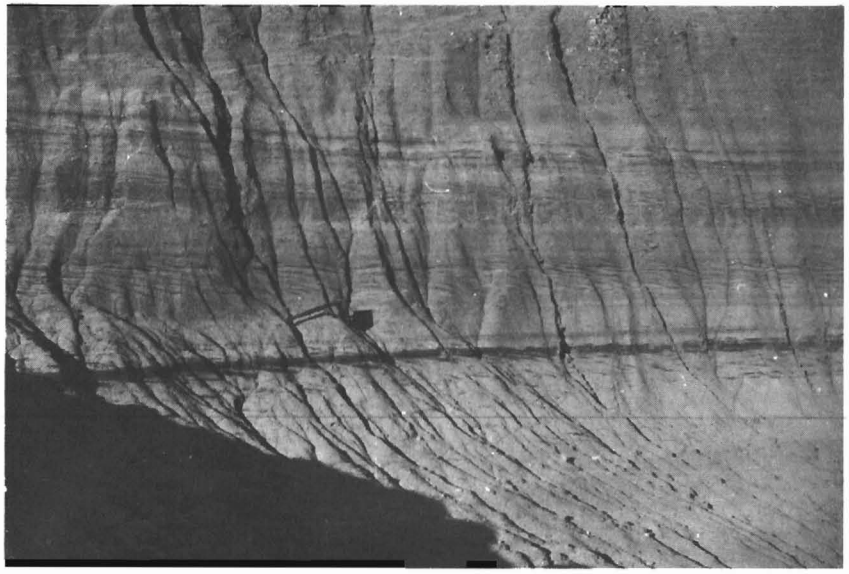

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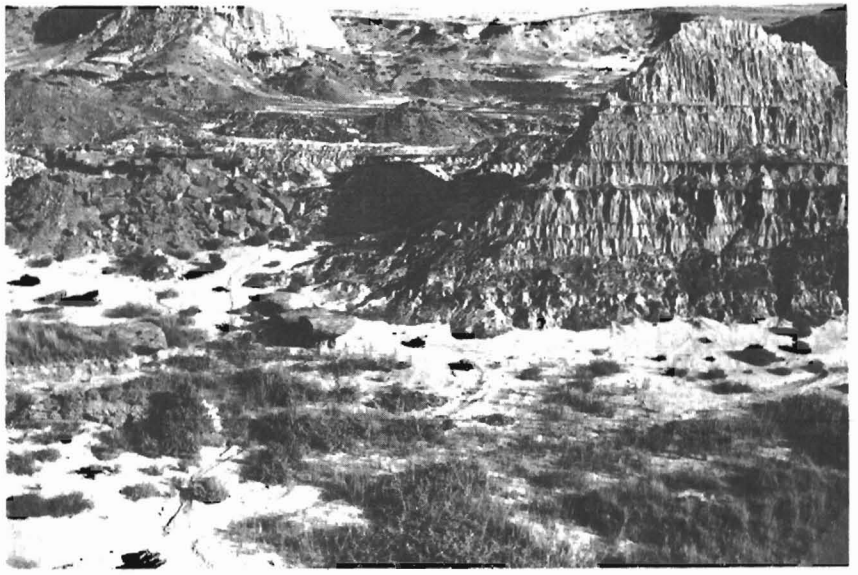

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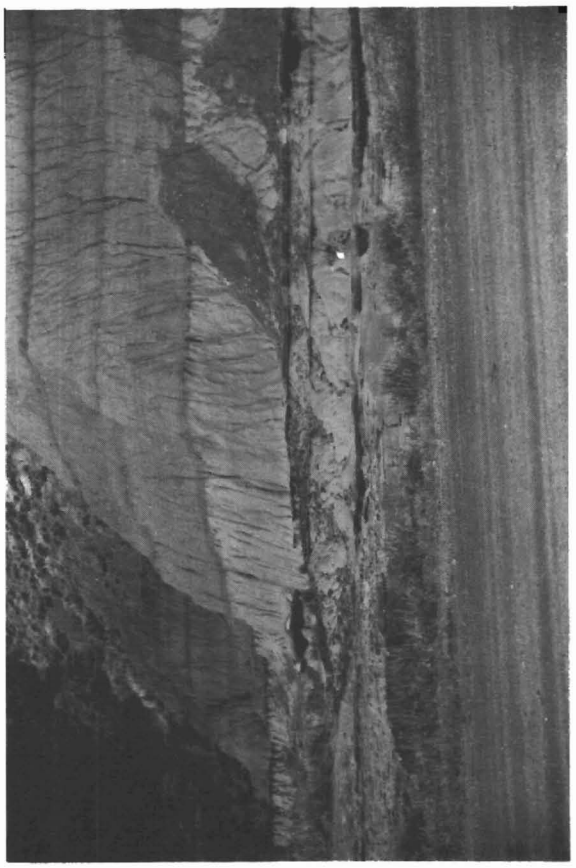
FIGURE 3.

A. Bedding planes, emphasized by concretionary iron oxide, show primary dip (note horizontal beds near top) in basal Sentinel Butte sand about 5 miles southwest of Medora. Fluted weathering reflects the high silt-clay content of this unit.
Location: SW 1/4 sec. 11, T. 139 N., R. 103 W., Billings County, North Dakota.

B. Concretionary horizons in basal Sentinel Butte sand near the entrance to Squaw Creek campground, North Unit of Roosevelt Park.
Location: NE 1/4 sec. 31, T. 148 N., R. 99 W., McKenzie County, North Dakota.

C. Large clasts of loosely consolidated siltstone in clayey matrix of basal Sentinel Butte "sand" about 8 miles southeast of Medora.
Location: NE 1/4 sec. 36, T. 139 N., R. 102 W., Billings County, North Dakota.

D. Petrified wood characteristic of the HT Butte bed of the Tongue River Formation adjacent to the road on the divide south of Mikes Creek.
Location: NE 1/4 sec. 36, T. 143 N., R. 102 W., Billings County, North Dakota.



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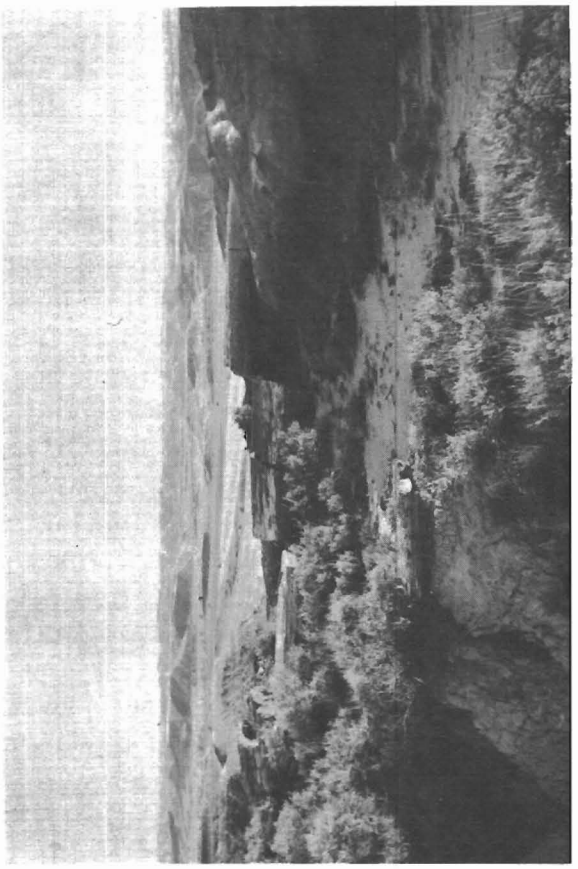

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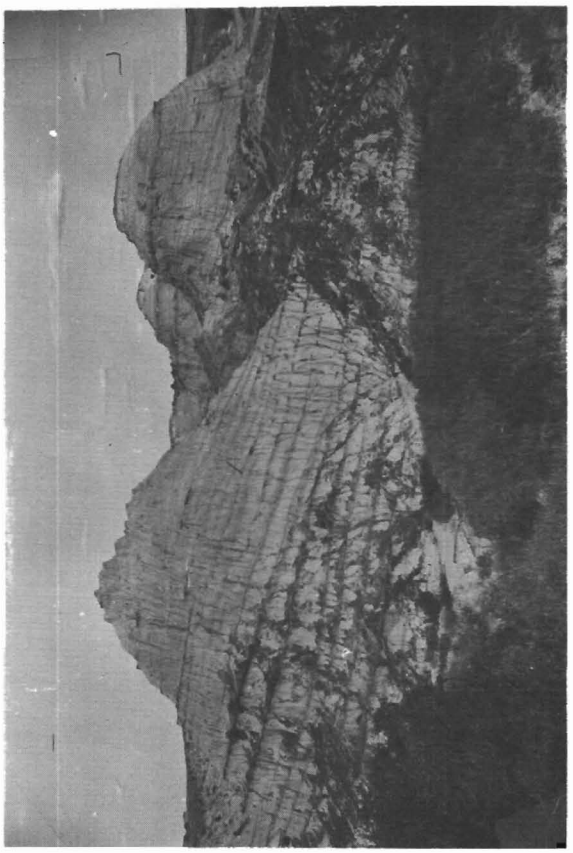


A

C

range from several inches to 3 feet or more in thickness, the average being about 18 to 20 inches, and are generally planar and wedge-shaped (Figures 2-A and 2-B). Lignite clasts are commonly concentrated in cross-laminae and emphasize cross-bed sets (Figures 2-A and 2-C). Co-sets are often bounded by ferruginous concretions of nodular or planar character (Figures 2-D, 3-A, and 3-B) with associated plant molds and desiccation features which indicate the diastemic nature of the bedding planes. In many outcrops, marcasitic or limonitic concretions are randomly scattered throughout the unit. Rarely, the clay-silt content is reduced and the sand is fairly well sorted and loosely consolidated.

Fine-grained equivalents of the basal unit exist, but appear to be less extensive than the sandy facies. These "fine" facies are typically thin-bedded sandy silt and silt (rarely clayey silt) (Figures 2-C, 4-C) which often grade upward into coarser sediment. Cross-bedding occurs but is of the "small-scale" type and is usually obscured in exposed outcrops due to the alternate swelling and shrinking of clay components. Fine-grained facies of the basal unit invariably coarsen laterally, usually in a relatively short distance. Thus, except in areas of extremely limited outcrops, the validity of the textural relationships suggested here can be readily checked in the field. In deference to the dominant facies, the unit is referred to here as the basal sand of the Sentinel Butte formation.

Occasionally the basal sand is separated from the HT Butte bed by a wedge of dark gray clay ranging in thickness from a few inches to as much as 4 or 5 feet. This clay is represented by dark horizons above the contact in Figures 4-D and 7-D. Both coarse- and fine-grained facies of the basal unit have been observed above and filling channels in this clay. Apparently the clay was widespread prior to deposition of the basal sand, and the latter may have incorporated much of this clay.

That the transport energies were high even for the finer-grained basal sediments is indicated by the presence of clay galls in many outcrops. These galls or clasts often swell or "check" on weathered surfaces and their character is not always clearly evident. Occasionally, clasts of coarser material were observed in a clay matrix, an example of which is shown in Figure 3-C.

With the possible exception of Hennen (1943), it appears that the persistence and correlative significance of the basal sand of the Sentinel Butte Formation has not been previously recognized. Hennen's observations appear to suffer from at least two errors. Hennen recognized a persistent marker bed in western North Dakota which he called "Sandstone 21" and which he described as follows (p. 1569).

> A persistent "marker-bed" for correlation has been recognized in the Fort Union formation by the writer. It is grayish white, flaggy to shaly sandstone, apparently containing a mixture of volcanic ash, with silicified fossil plant stems in abundance, and here and there silicified stumps of trees 3-5 feet in diameter . . . it is ordinarily less than 5 feet in thickness but westward at Sully Springs, it is more than 40 feet thick but still is grayish white to ash-gray, with the silicified tree zone at the top. It is believed that a great outpouring of volcanic ash took place at the time of its deposition . . . It is in this zone that the "Petrified Forest" occurs on the valley floor of Andrews Creek [Hennen means Sully Creek], 1.5 miles southwest of Sully Springs railway station. This zone may be observed also, in typical development, at the entrance gate to Roosevelt Park on Highway 10, 5 miles east of Medora.

In reference to thick occurrences in the vicinity of Sully Springs and the east gate of Roosevelt Park, Hennen's "Sandstone 21" is synonymous with the basal sand of this report. Hennen, however, places his "marker bed" in the Tongue River "member" about 70 feet below the horizon which he indicates as its upper contact. In order to resolve this discrepancy, it is necessary to consider how Hennen placed his "marker bed" in the Paleocene Series; this he elaborates in reference to his Sentinel Butte section (p. 1575-1576).

> At the point where the section was measured, formations were concealed directly below this lignite bed [20 feet in thickness] so that it was not possible here to determine its interval above Sandstone 21. However, immediately northeastward and northward at many places this lignite bed forms "scoria" at an elevation of 2,910 feet at the base, slightly more than a mile north of Sentinel Butte railway station . . . Here the top of Sandstone 21 with its characteristic silicified trees is 70 feet by hand-level lower in the measures, or at practically the same interval (75 feet) as at point 2 [Medora] below Lignite 22. Likewise, here a thin lignite bed immediately overlies Sandstone 21, as at the Sully Springs section . . .

The lignite is bed G of Leonard and Smith (1909) and, as stated in the previous section, the correlation with the "scoria" to the north and northeast appears invalid. Herein appears to lie the source of Hennen's first error. He correctly identified the basal sand north of Sentinel Butte, but miscorrelated the HT Butte bed. Thus, he was led to believe that the basal sand on Sentinel Butte was concealed in the subsurface below the F bed. In reality, it is well exposed and overlies the G bed.

A second error occurred as Hennen carried his marker bed eastward toward Medora (his point 2). Very few beds resembling the basal sand are present in the Tongue River Formation but, from about the Billings-Golden Valley County line to Medora and northward into the South Unit of Roosevelt Park, a locally persistent clayey sand bed does exist in the upper Tongue River section. This bed occurs about 70 to 80 feet below the Tongue River-Sentinel Butte contact and is about 5 feet thick along Highway 10 several miles west of Medora. It can be traced along the highway to Medora and is prominent in the west bluffs of the Little Missouri which extend northward into the park. The unit thickens considerably as it enters the park, as can be seen along the park road as it descends from Johnson Plateau to the valley floor. This unit Hennen confused with the "marker bed" of the Sentinel Butte locality. The stratigraphic occurrence of this sand bed is unfortunate, for it allowed Hennen to justify his first error with a second. The paradox is even more apparent when one realizes that clayey-sand beds are quite uncommon among Tongue River strata. Hennen's second error was recognized by Brown (1948a, p. 1269) who concluded,

> . . . it would seem that, between Sentinel Butte and Sully Springs Hennen confused two silicified zones in an interval of 100-125 feet.

It is unfortunate that Hennen's study received so little acceptance, for a closer inspection of his "Sandstone 21" might have aided in an earlier recognition of the basal Sentinel Butte sand. The writer confesses his own skepticism of Hennen's work during initial stages of field investigation. Only after the partial equivalence of Hennen's "marker bed" with the basal sand at Sully Springs was realized was an attempt made to resolve the conflicts which existed in his cross-section between Sentinel Butte and Medora. Whether Hennen's "Sandstone 21" is equivalent to the basal sand elsewhere in western North Dakota is not readily apparent. The two appear to be co-extensive as will be discussed below.

Regional Extent of the Contact

The extent of the Tongue River-Sentinel Butte contact in a significant portion of western North Dakota is indicated in Figure 1. The contact is essentially a line of best approximation connecting points at which the character and elevation of the contact was established in the field. The writer has utilized available literature in facilitating extrapolations through areas for which his field observations are limited. In this regard, reports of Leonard and Smith (1909), Hares (1928), Fisher (1953, 1954), and unpublished data of Clayton (in preparation) were of particular value. The reliability of all published sections and datum points utilized in establishing the contact was verified by a thorough field check. During the course

of six months spent in the field, the writer visited nearly every township in which the contact is indicated to be present. However, the probability exists that some outliers containing the contact have been overlooked and, to the extent that this is true, this map is incomplete. It is expected that future detailed mapping will correct these omissions; if the feasibility of such mapping is demonstrated by Figure 1, it has served its purpose.

Little Missouri badlands

The Tongue River-Sentinel Butte contact is essentially continuous throughout the badlands east of the Little Missouri River from northern Slope County to southern McKenzie County. West of the river, the contact is discontinuous and defines detached remnants of Sentinel Butte strata which form divides or buttes which rise above the regional level. This distribution is an expression of the regional dip of these beds toward the structural axis of the Williston basin (syncline) which lies to the east and northeast. For many miles east of the east "breaks" of the Little Missouri badlands, topography is developed almost entirely upon strata of "Sentinel Butte" and younger age. In the extreme southwest corner of the map area, all Paleocene and younger strata have been removed by erosion from the northeast flank of the Cedar Creek anticline.

Both time limitations and difficulties imposed by the gently rolling topography and paucity of outcrops prevented tracing of the contact south of Amidon and, with the exception of HT Butte, this locale constitutes the southern limit of investigation. Between Amidon and Medora the contact is readily apparent and can be inspected at many localities. The HT Butte bed and the basal sand are generally well developed but locally the HT Butte bed thins and the basal sand becomes fine grained. The HT Butte bed has burned throughout much of this area, as can be readily seen from the road into the "Burning Coal Vein" which follows the divide westward across the center of T. 136 N., R. 101 W. Outcrops of the contact along this divide (Figure 4-A) show the basal sand to be fine grained and the HT Butte bed to be rather thin.

Northward, on the divide south of Bear Creek the color contrast is marked and the contact is evident from a distance. At this locality the HT Butte bed is about 60 inches thick and the basal sand is well developed (Figure 4-B). The basal Sentinel Butte unit is silty above the HT Butte bed but coarsens upward, becoming sandy within a vertical interval of 6 feet.

On the west side of the Little Missouri, the contact is prominent on Bullion Butte and occurs in the bases of Sentinel and Square (Flat Top) Buttes. The contact dips easterly at Sentinel Butte and passes into the subsurface along Highway 10 (Interstate 94) about three miles east of Medora. The HT Butte bed is burned along most of this traverse and its descent into

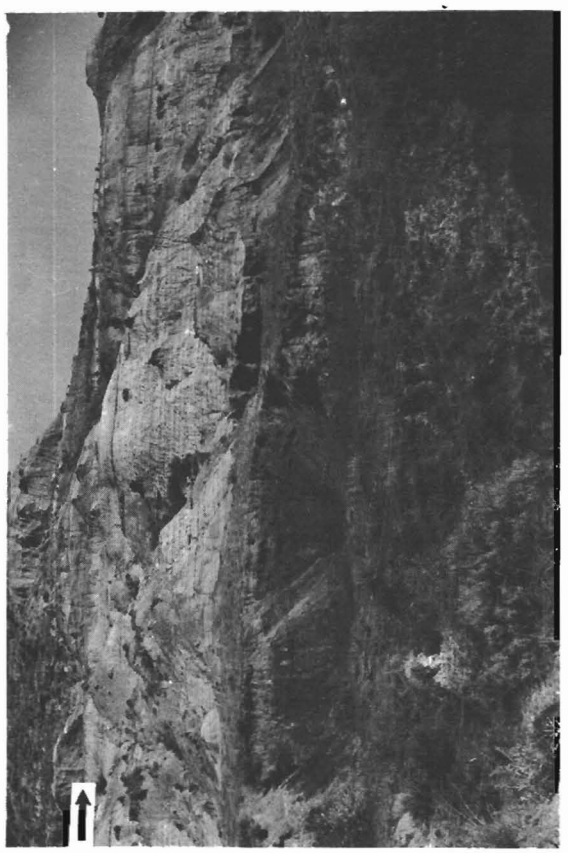
FIGURE 4.

A. Tongue River-Sentinel Butte contact (arrow) near road on the divide south of Second Creek, about 7 miles northwest of Amidon. The HT Butte bed measures 30 inches but is poorly exposed.
Location: NE 1/4 sec. 20, T. 136 N., R. 101 W., Slope County, North Dakota.

B. Tongue River-Sentinel Butte contact (arrow) near fire-guard trail about midway between Amidon and Medora. Forty inches of poorly exposed HT Butte bed underlies a thick sequence of basal Sentinel Butte sand.
Location: SW 1/4 sec. 7, T. 137 N., R. 101 W., Billings County, North Dakota.

C. Tongue River-Sentinel Butte contact (arrow) about 4 miles north of the village of Sentinel Butte. The basal unit is fine grained and conspicuously banded, the HT Butte bed is thin, but the color contrast above and below the contact is marked.
Location: NW 1/4 sec. 4, T. 140 N., R. 104 W., Golden Valley County, North Dakota.

D. Tongue River-Sentinel Butte contact (arrow) in the vicinity of Twin Buttes. The dark horizon above the contact is a dense clay which locally separates the basal sand and the HT Butte bed.
Location: E 1/2 sec. 16, T. 141 N., R. 103 W., Golden Valley County, North Dakota.



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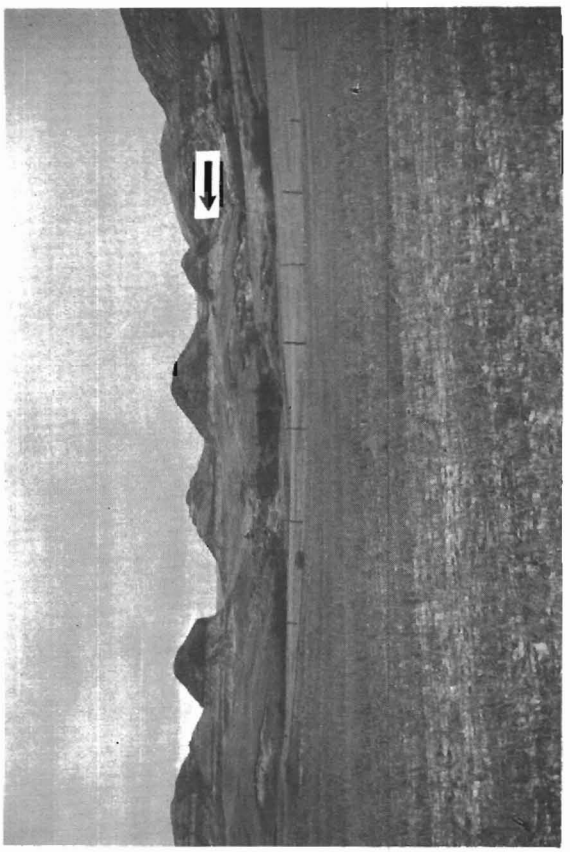

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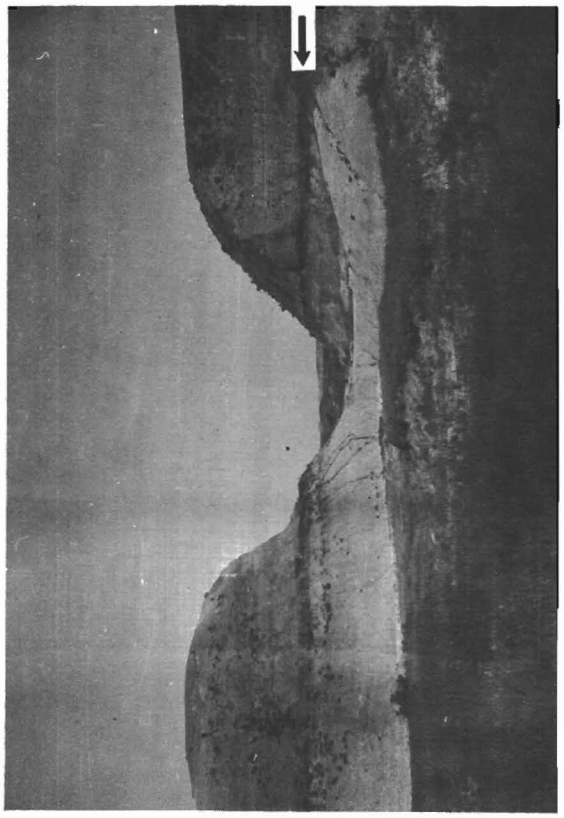

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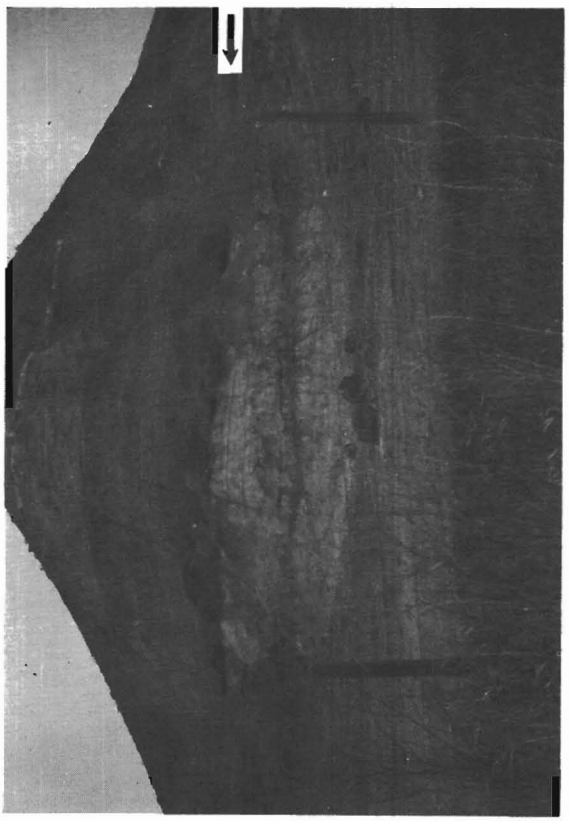

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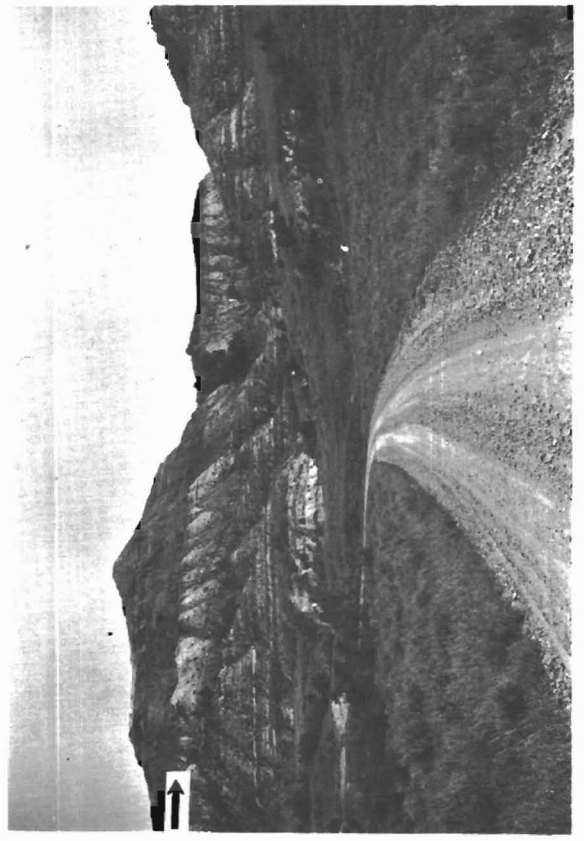
FIGURE 5.

A. Tongue River-Sentinel Butte contact (arrow) near the entrance to Techer's Ranch, about 13 miles north of Twin Buttes. The color contrast above and below the contact is very pronounced.
Location: NE 1/4 sec. 1, T. 143 N., R. 103 W., Golden Valley County, North Dakota.

B. Tongue River-Sentinel Butte contact (arrow) on the river road about 3 miles north of South Roosevelt Park. The HT Butte bed is largely covered but exceeds 13 feet in thickness.
Location: NW 1/4 sec. 8, T. 141 N., R. 103 W., Billings County, North Dakota.

C. Tongue River-Sentinel Butte contact (arrow) on the river road 13 miles north of South Roosevelt Park. The basal sand is fine grained and the color contrast above and below the contact is subdued by dark clays in the upper portion to the Tongue River Formation.
Location: NE 1/4 sec. 36, T. 143 N., R. 102 W., Billings County, North Dakota.

D. Tongue River-Sentinel Butte contact (arrow) in the valley of Blacktail Creek about 17 miles north of South Roosevelt Park. The basal Sentinel Butte sand is "typically" developed with large-scale cross-bed sets.
Location: SE 1/4 sec. 10, T. 143 N., R. 101 W., Billings County, North Dakota.



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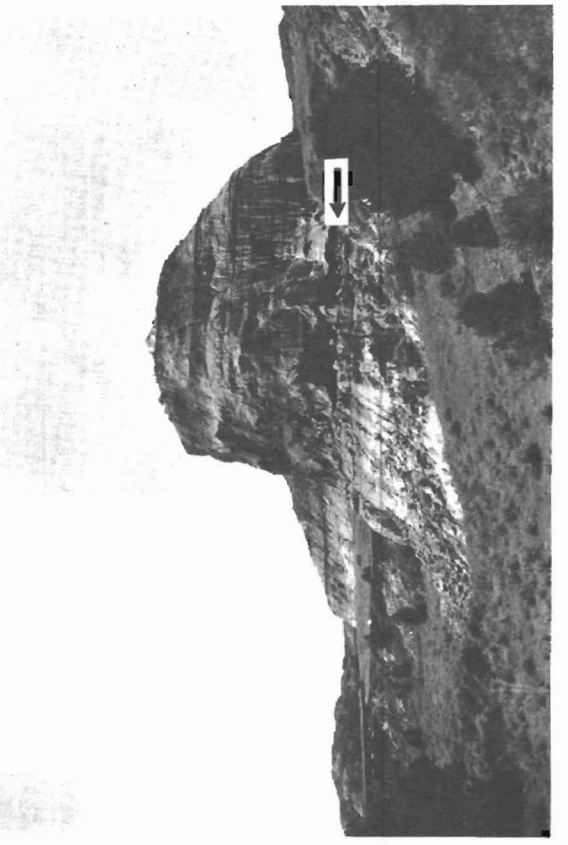

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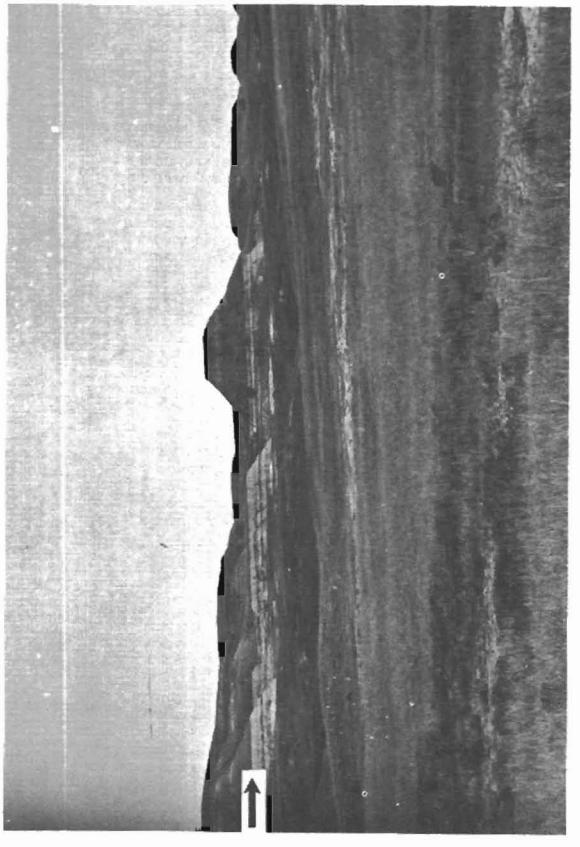

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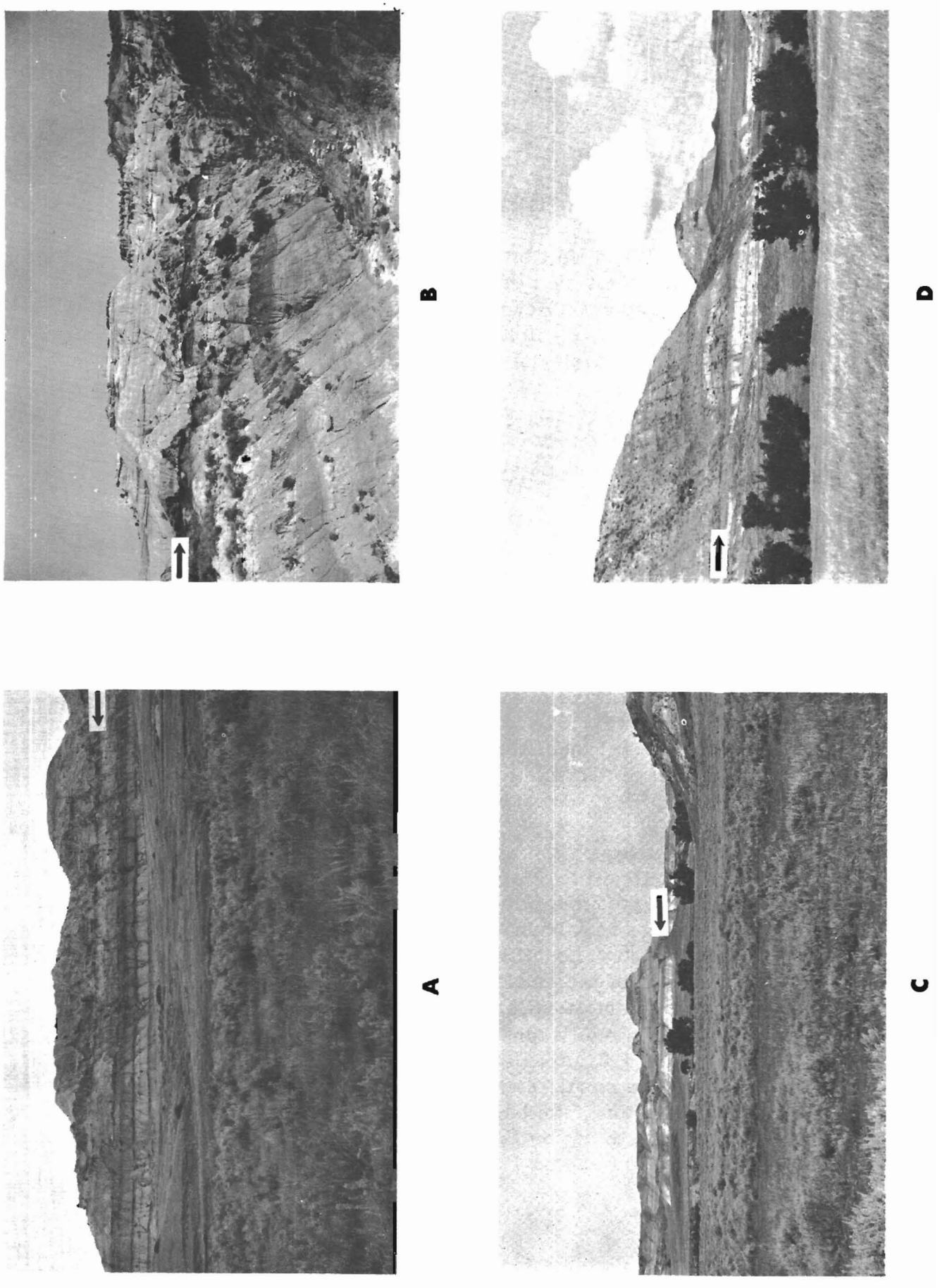
FIGURE 6.

A. Tongue River-Sentinel Butte contact (arrow) along Sand Creek about 13 miles west of Grassy Butte. The basal Sentinel Butte sand is well developed, but the color contrast above and below the contact is somewhat subdued by gray clay beds in the upper Tongue River Formation.
Location: sec. 10, T. 145 N., R. 101 W., McKenzie County, North Dakota.

B. Tongue River-Sentinel Butte contact (arrow) near the road on the divide above the Beicegel Ranch about 16 miles west of Grassy Butte. The basal Sentinel Butte sand greatly resembles that in outcrops to the south along Blacktail Creek (Figure 5-D).
Location: SE 1/4 sec. 6, T. 145 N., R. 101 W., McKenzie County, North Dakota.

C. Tongue River-Sentinel Butte contact (arrow) in the Bowline Creek drainage about 9 miles southeast of Sheep Buttes. The HT Butte bed is 6 to 7 feet thick and partially concealed by slumping of the basal Sentinel Butte sand.
Location: NW 1/4 sec. 18, T. 147 N., R. 101 W., McKenzie County, North Dakota.

D. Tongue River-Sentinel Butte contact (arrow) about 2 miles southwest of Sheep Buttes. The HT Butte bed is concealed but measures about 4 feet and is overlain by about 20 feet of silty basal Sentinel Butte sand.
Location: SW 1/4 sec. 21, T. 148 N., R. 103 W., McKenzie County, North Dakota.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the subsurface east of Medora is marked by a fringe of red clinker, but a minimum thickness of 7 feet was measured for the bed at a partial exposure in Sheep Creek. The basal sand is exposed on the northeast flank of Sentinel Butte and can be viewed along the "West River road" in the northeast portion of T. 139 N., R. 103 W., near Sully Springs, and just west of the east entrance to Roosevelt Park.

Within the South Unit of Roosevelt Park, the contact is present high in the bluff on the west side of the Little Missouri River across from Cottonwood campground. Here the HT Butte bed exceeds 9 feet in thickness and is overlain by a thick sequence of basal sand. The contact can also be seen in the vicinity of "Scoria Point," a scenic stop within the park. The HT Butte bed has largely burned to produce a spectacular red clinker, but an unburned remnant, nearly 12 feet in thickness, can be seen in the gully below the overlook. The co-called "Burning Coal Mine" in the park is in the HT Butte bed and clinker produced by earlier burns is widespread; good outcrops occur adjacent to the road near the park boundary north of Wind Canyon.

North of the village of Sentinel Butte, near Twin Buttes, the contact is exposed on numerous small buttes and divides (Figure 4-D). The HT Butte bed is represented by only 6 to 8 inches of lignitic shale, but the contrast in color between the formations is exceedingly good. This contrast is persistent northward and can be seen near the entrance to Techer's ranch (Figure 5-A), on the divide above the historic Elkhorn Ranch site. Throughout much of this area the basal Sentinel Butte sand is rather fine grained and at several localities it is separated from the HT Butte bed by as much as 4 feet of dark clay. At these localities, however, the clay grades upward and laterally into more "typical" basal sand.

Three localities on the east side of the Little Missouri north of the South Unit of Roosevelt Park appear representative of the contact. The first of these is a prominent bluff on the east side of the river road about 3 miles north of the park boundary (Figure 5-B). The HT Butte bed is well developed, measuring about 13.5 feet in thickness. The basal sand consists of 6 to 8 feet of rather clayey silt which grades upward into 20 feet of clayey sand. About 10 miles north of this outcrop, the contact is accessible near the road at the summit of the divide south of Mikes Creek (Figure 5-C). The HT Butte bed is only 16 to 18 inches thick and the lower portion of the basal sand is thinly bedded and fine grained. Despite its overall fine texture, the basal sand contains pods and lenses of medium sand and large clasts or "galls" of clay. Silicified wood (Figure 2-D) is particularly abundant at this locality.

The river road north of Medora terminates, after 30 scenic miles, at the ranches of Les and Jack Connel; exit from the badlands is gained along the Blacktail Creek drainage eastward to Gorham. Along the Blacktail Creek road occur some of the best examples of "typically" developed basal sand. The contact is conspicuous and nearly continuous along the north wall of the creek valley for 5 or 6 miles up Blacktail Creek from its mouth. Where the contact passes beneath the valley floor, erosional remnants of the resistant basal sand form numerous buttes which project above the valley alluvium (Figure 5-D). The HT Butte bed is generally thin, averaging 12 to 20 inches thick.

The basal sand is well developed north of the Blacktail drainage and was observed on the divide between Whitetail and Magpie Creeks and in the Magpie Creek valley. Excellent exposures also occur in the Beicegel and Sand Creek drainages, but the upper Tongue River beds become somewhat clayey and the color contrast with the Sentinel Butte Formation is less pronounced (Figure 6-A). The basal sand reaches thicknesses in excess of 100 feet in the upper reaches of Sand Creek.

At the summit of the road above the Beicegel Ranch, the basal sand is well exposed (Figure 6-B) and greatly resembles outcrops in the Blacktail Creek area. The HT Butte bed is generally thin along Sand Creek but thickens northward, as measured in a section near the Nelson Ranch (SW 1/4, sec. 18, T. 146 N., R. 101 W.), the bed is 7 feet thick.

Farther north, the contact can be seen in the bluffs of the Little Missouri in the vicinity of sec. 28, T. 147 N., R. 101 W., but it passes beneath slump debris and valley alluvium somewhere in the vicinity of the southern boundary of the North Unit of Roosevelt Park. The contact has not been observed within the park but its presence at shallow depths in the subsurface is indicated by the thick interval of basal sand which can be seen at many localities within the park, the most accessible of which are adjacent to the entrances to the Squaw Creek campground (Figure 3-B).

The northern limit of the contact within the north-south reach of the Little Missouri badlands appears to be in the Bowline Creek drainage (Figure 6-C). Here the contact is again distinct, despite the presence of a gray bentonite bed in the uppermost part of the Tongue River Formation. The basal sand is silty near the base and coarsens upward in the unit. The HT Butte bed is 6 to 7 feet thick. Additional outcrops occur along the road several miles south of this locality in the east half of sec. 25, T. 147 N., R. 102 W.

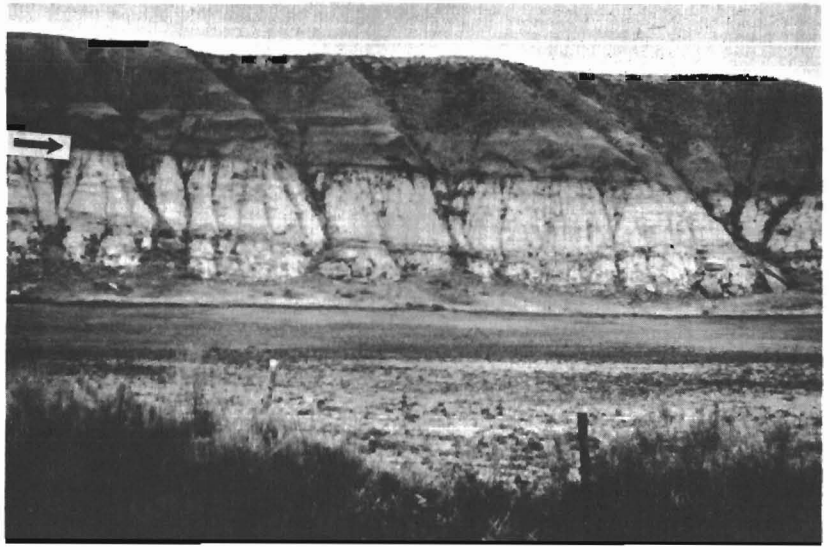
FIGURE 7.

A. Tongue River-Sentinel Butte contact (arrow) in bluffs of Yellowstone River about 8 miles southwest of Cartwright. The contact here is very distinct and lies within the type locality of the Fort Union Group.
Location: SE 1/4 sec. 31, T. 150 N., R. 104 W., McKenzie County, North Dakota.

B. Tongue River-Sentinel Butte contact (arrow) near Garrison Reservoir about 7 miles northwest of Newtown. The basal Sentinel Butte sand stands in high relief above less resistant Tongue River beds.
Location: Near center sec. 26, T. 153 N., R. 103 W., Mountrail County, North Dakota.

C. Tongue River-Sentinel Butte contact (arrow) near Garrison Reservoir about 8 miles northwest of Newtown. The HT Butte bed is about 9 feet thick and is overlain by about 50 feet of basal Sentinel Butte sand.
Location: SE 1/4 sec. 22, T. 153 N., R. 93 W., Mountrail County, North Dakota.

D. Tongue River-Sentinel Butte contact (arrow) about 2 miles southwest of Glen Ullin. The dark horizon above the contact is a dense clay; note the similarity of this outcrop with that of Figure 4-D.
Location: NE 1/4 sec. 2, T. 138 N., R. 89 W., Morton County, North Dakota.



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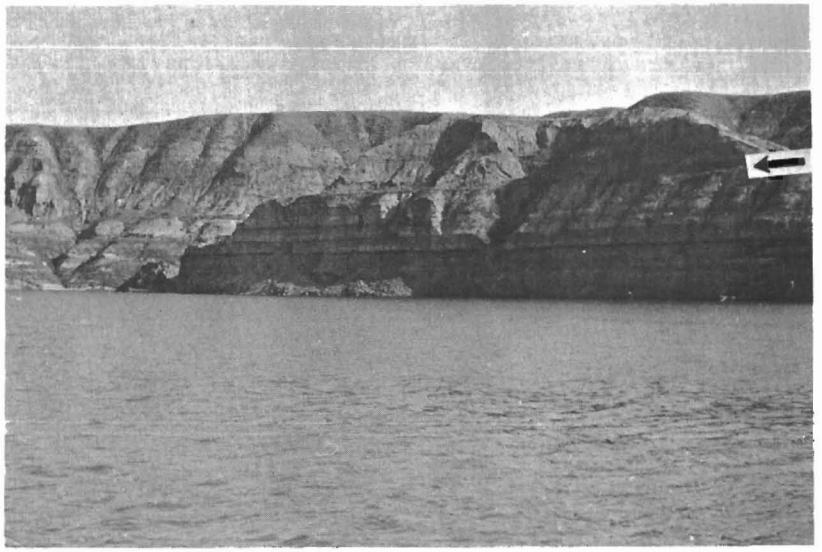

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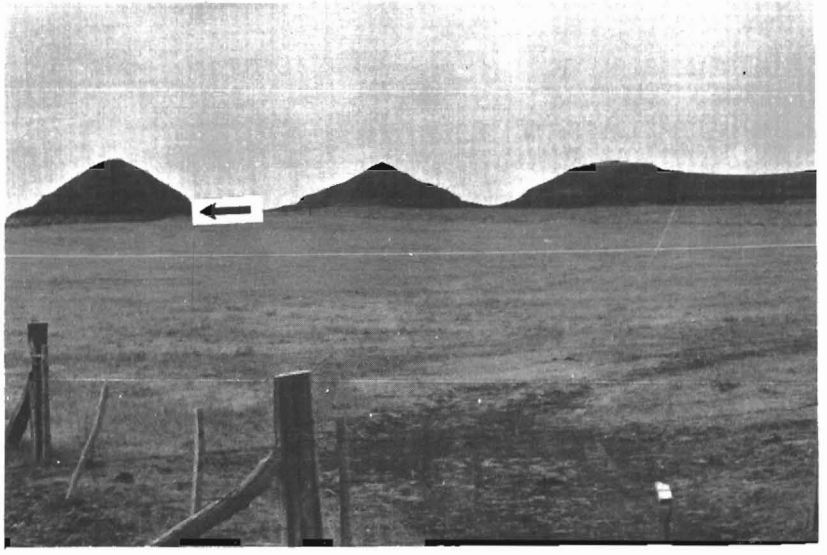

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Area north of the badlands

The area north of the Little Missouri badlands of western North Dakota has been glaciated, the topography is rather subdued, and bedrock is well exposed only in the deeper drainages. The contact can be extrapolated northwestward from Bowline Creek to the vicinity of Sheep Buttes. The "big blue" clay bed, which is so prominent in the North Unit of Roosevelt Park, aids correlation across this area of limited bedrock exposure. The contact is exposed about 2 miles southwest of Sheep Buttes (Figure 6-D) at the location of Fisher's (1953) "section 3." The HT Butte bed here is 4 feet thick and overlain by 20 feet of rather silty basal sand. Northward, the contact can be seen in the more prominent slopes of the Horse Creek drainage, particularly in the vicinity of Horse Creek school. Fisher (1953) has noted the HT Butte bed in this area which he designates as "L" in his "section 2."

The Sentinel Butte Formation appears to have limited extent in Montana, but it can be viewed at Blue Mountain in northern Wibaux County, in the east bluffs of the Yellowstone River northeast of Sidney, and at the Snowden railway siding on the Missouri River near the Montana-North Dakota state line. The latter localities are of particular interest because they lie within the general type locality of the Fort Union Group. On the river road about 8 miles southwest of Cartwright, North Dakota, the contact is marked by a 5-foot thickness of HT Butte bed and a marked color change. The basal sand is typical and ranges in thickness between 25 and 40 feet (Figure 7-A). The contact in this area is so distinct that it can be picked with ease from aerial photographs. Similar conditions exist at the contact 0.8 miles northwest of the road junction at Snowden, Montana, except that the HT Butte bed is represented by 40 inches of lignitic shale. Here 52 feet of Sentinel Butte strata overlie about 250 feet of Tongue River Formation. The basal sand is typically developed and silicified wood and stumps are abundant along the contact.

East of the Snowden-Buford area, the contact dips below the Missouri River and is believed to remain in the subsurface across most of southern Williams County. Near the Williams-Mountrail County line it rises to the surface along the east flank of the Nesson anticline. Good exposures can be seen in the bluffs along Garrison Reservoir just east of the Mountrail County line (Figure 7-B). An outcrop, accessible by car, occurs about 7 miles northwest of Newtown (Figure 7-C) where about 9 feet of lignite, lignitic shale, and carbonaceous clay constitute the HT Butte bed and are overlain by 40 feet of basal sand. The lower portion of the basal sand is better sorted than is "typical," but the clay-silt content increases upward in the unit.

The contact can be extrapolated up the valley of the White Earth river in western Mountrail County to its terminus near the Burke County line. East of the mouth of the White Earth valley, the contact can be traced in discontinuous outcrops along Garrison Reservoir to the Four Bears Bridge, west of Newtown, where it is well exposed at an elevation slightly above the bridge abutments. The contact cannot be traced beyond a sag filled with post-Paleocene sediments about 6 miles south of Newtown. Sentinel Butte strata only are present above the reservoir level for several miles south of the sag, and it is inferred that the contact has been displaced downward along a northwest trending fault (Clayton, in preparation). The writer has not inspected the bluffs along the reservoir beyond the Mountrail-Dunn County line, but Clayton (personal communication, 1967) has observed what he believes is the Tongue River-Sentinel Butte contact in the bluffs along the north shore of the reservoir opposite the mouth of the Little Missouri River. This occurrence seems plausible, because the contact is thought to occur due west of this locality in the vicinity of Lost Bridge.

At Lost Bridge, strata believed to contain the contact occur near flood-plain level where bedrock crops out adjacent to the river. Caution is required in evaluating these exposures, for many slump blocks (not all of which have been rotated) are present along the base of the high bluffs. The contact is believed to be present just west of the north abutment of the bridge. The HT Butte bed is locally burned but a single measurement indicates that it is thin, probably averaging less than 3 feet in thickness. The basal sand is present above the lignite but its stratigraphic position is locally occupied by flood-plain and alluvial-fan debris and its total thickness is undetermined. The absence of a well exposed section of Tongue River strata makes it difficult to demonstrate the validity of the contact at Lost Bridge. Supporting evidence is contained in the 450 feet of Sentinel Butte beds which extend above the presumed contact. This section contains marker beds (a "blue" bed and upper and lower "yellow" beds) which appear correlative with similar beds in the North Unit of Roosevelt Park. If the correlation of these beds is correct, and if their relative stratigraphic positions are constant, the contact should exist near river level at Lost Bridge.

Eastward extent of contact

The area of Figure 1 south of the Little Missouri River and east of North Dakota State Highway 85, which consists primarily of Dunn and Stark Counties, is not specifically included in the scope of this report. However, the writer has traveled most of the major roads of this region and is of the opinion that nearly all of the exposed strata are of Sentinel Butte age and younger. This observation is in accord with regional

structure, for the axis of the Williston basin (syncline) of North Dakota extends north-south through this area. For example, beds of Tongue River and older age are concealed by younger strata along Highway 10 (Interstate 94) between the east "breaks" of the badlands and the Glen Ullen-New Salem area 60 miles to the east.

Success in delimiting the Tongue River-Sentinel Butte contact throughout the areas discussed above leads to an important query - can the contact be delimited with equal facility farther east along the truncated flank of the Williston basin? Difficulties are imposed in this area by rolling terrain mantled with vegetation and glacial debris which conceal the bedrock. The composite thickness of Paleocene strata is considerably less in this area than in the badlands and greater altimetric control is necessary to correlate between the isolated outcrops. Questions concerning the differentiation of Tongue River and Sentinel Butte strata in this region will ultimately be answered by detailed geologic mapping of the units, an initial stage of which has already begun.

During the fall of 1966, the writer held a field conference with U.S. Geological Survey geologists[1] involved in surface mapping in Morton and Grant Counties. The contact, as defined by the writer, was inspected at many localities in Billings and Golden Valley Counties and compared with a persistent "marker" horizon in Morton County. Although the HT Butte bed is thin and poorly developed and the basal Sentinel Butte sand is fine grained, the writer (and apparently his companions; I express no formal commitment on their part) concluded that the "marker" horizon was in fact the Tongue River-Sentinel Butte contact. In regard to this horizon in Morton and Grant Counties, Barclay (personal communication, January, 1967) has stated:

> I am convinced that the horizon which you showed me on November 4 [1966] in the South Unit of the Theodore Roosevelt National Park and which you map as the Sentinel Butte/Tongue River contact is the same horizon I showed you on the following day in the Glen Ullin and Dengate Quadrangles, which I had mapped as a marker between two major lignite zones. I have seen the same horizon in the White Butte, Clark Butte, and the North Almont quadrangles. I'm sure it is present in the Heart Butte and Heart Butte NW Quadrangles.

[1] U.S. Geological Survey geologists were C. S. V. Barclay, G. D. Mowat, and K. Soward; the writer was accompanied by C. G. Carlson of the North Dakota Geological Survey.

> In the Glen Ullin and Dengate Quadrangles, the contact is marked by a dark olive to greenish gray montmorillonitic, locally silty to sandy claystone above, and a yellowish gray sandstone and siltstone sequence below. There is commonly a [thin] lignitic zone at the base of the clay [which may be] an HT Butte lignite equivalent. You stated, or at least implied, that the montmorillonitic claystone, with its locally high proportion of coarser material, is, at least in part, a lateral equivalent of the basal clayey sandstone [present in the Little Missouri badlands]. I concur in this also, except I tend to regard the montmorillonitic claystone with the characteristically high admixtures of coarser material as the "normal" contact and the clayey sandstone as the result of local emphasis on one aspect of sedimentological conditions during earliest Sentinel Butte time. Of course this local emphasis becomes more general as the source area for the coarser material is approached . . .
>
> I also believe that this "local" emphasis occurred in the Dengate-Glen Ullin area. Actually, I include 13 to 15 feet of sediment - the interval from the lignitic zone below the montmorillonitic clay to the base of the next lignitic zone - in a basal zone of the Sentinel Butte, the uppermost third or so of which is not uncommonly a clayey or silty sandstone to sandstone. As a matter of fact, there is a sandstone at least 40 feet thick above the contact that is exposed in a railroad cut in the Dengate Quadrangle [NE 1/4, sec. 21, T. 139 N., R. 87 W.]. This sandstone body is not well exposed but is of limited areal extent. Its outcrop pattern and primary dips on either side of its long axis indicate that it is a "channel" sand.

The writer is in essential agreement with Barclay's deductions. It appears that the basal Sentinel Butte "sand" contains greater admixtures of fine silt and clay, particularly near its base, in this eastern region and its dominant texture may be silty clay or clayey silt. The contact is mappable, however, and the criteria which aid in its recognition are essentially the same as those recognized farther west. Figure 7-D illustrates the contact in the Glen Ullin Quadrangle.

Previous Observations of the Contact

Numerous statements regarding the character and extent of the Tongue River-Sentinel Butte contact appear in the geological literature. Many of these are restatements of opinions expressed by earlier workers and most are intended to apply to relatively small study areas. Individually, they

add testimony to the persistence and character of the contact and, collectively, they appear to support the general conclusions of this report. A few of these statements have already been cited, others which relate to western North Dakota are reviewed below.

The most comprehensive and concise statement regarding the regional extent of the Sentinel Butte Formation noted by this writer, is given by Seager, and others (1942, p. 1417).

> The best exposures of Sentinel Butte are found in the badlands of the Little Missouri River in the vicinity of North Roosevelt Park, McKenzie County, North Dakota. In this locality, near the axis of the Williston Basin syncline, the unit as a whole is flat, and may exceed 550 feet in thickness. Its position in the syncline preserved it from pre-Oligocene erosion. The Sentinel Butte is the surface rock in most of McKenzie, Billings, Dunn, and Stark Counties, in eastern Slope County, and in parts of Mercer and Morton counties. It crops out along the Missouri and Little Missouri rivers as far east as Sanish and Elbowoods, and also may be observed in the drainage of the Knife River near Hebron . . .
>
> The Tongue River member of the Paleocene Fort Union Formation conformably underlies the Sentinel Butte. A clinker resulting from the burning of a lignite bed marks the contact of the Tongue River and Sentinel Butte members in many places. Numerous clinker beds occur both above and below the contact clinker. Thus, the presence of clinker should not be used indiscriminantly as the criterion for separating the two members.

Regarding the distribution of the Tongue River Formation, these writers state (p. 1417):

> The Tongue River . . . crops out extensively in the badlands of the Little Missouri River from the vicinity of Marmarth, North Dakota, to a point 100 miles north. At the latter locality, the general northeast dip of the strata into the Williston Basin syncline carries the member below river level. The member is exposed over a broad area along the Montana-North Dakota boundary, from northern Slope County at least as far north as the Missouri River. It reappears on the crest of the Nesson anticline in southern Williams County, and is exposed along the Missouri River on the east side of the Williston Basin syncline.

These statements are in essential agreement with the distribution of Paleocene strata as recognized by the writer. Although Seager, and others, allude to the HT Butte bed of the Tongue River Formation, no mention is made of the basal Sentinel Butte sand.

Hennen (1943) is apparently the only person who has attributed regional persistence to a sandstone horizon. As discussed above, the "Sandstone 21" of Hennen is equivalent in part to the basal Sentinel Butte sand of this report and, although Hennen placed it within the Tongue River Formation, its persistence suggests it may be largely synonymous with the basal sand of the Sentinel Butte. Regarding the distribution of his "Sandstone 21," Hennen (p. 1570) writes:

> It is persistent and widespread in the Dakota basin, as evidenced by exposures extending from the vicinity of Sentinel Butte, Golden Valley County, eastward to the vicinity of Almont, Morton County; from a point on the east bank of North Fork of Cannonball River, 10 miles northeast of Amidon, in eastern Slope County, northward to the steeply pitching flanks of the Nesson anticline in southern Williams County; and thence southeastward along the valley of the Missouri River to the vicinity of Coleharbor . . .
>
> Marker-bed SS_{21} is typically developed on both flanks of the Nesson anticline in southern Williams County with the same abundance of silicified plant stems and here and there a silicified tree stump.

With the exception of sections figured in Hennen's east-west cross-section from Sentinel Butte to Kidder County, locations given for "Sandstone 21" are too general for accurate field checks and the extent to which it is equivalent to the basal sand of this report has not been determined.

In reference to the distribution and stratigraphic relationship of Fort Union strata, Brown (1948a, p. 1270-1271) makes the following remarks.

> The dark Sentinel Butte shale, according to Hennen extends eastward across the Little Missouri River as far as Almont, about 115 miles from Sentinel Butte. Northward it comprises the higher strata of the badlands along the Little Missouri River and is part of the type section of the Fort Union formation on the north side of the Missouri River opposite the

> mouth of the Yellowstone River. Its color in these farther areas, however, is relatively light, so that in this respect it is practically indistinguishable from the underlying Tongue River member . . .
>
> Southwest of Broadus, Montana, a considerable dark sequence, near the top of the Tongue River but beneath lignitic strata containing Wasatch fossils appears to the writer to be correlatable northeastward with the dark Sentinel Butte shale and its lateral equivalents.
>
> The Tongue River member of the Fort Union in the type exposures along Tongue River in Wyoming and Montana is essentially a light-colored zone of sandstones, shales, clays and coals. Duller colors, however, prevail in its southwestern and northeastern extensions, and lenses or bands of darker-colored portions come and go both vertically and laterally so that its boundaries, except locally, are very indefinite, accounting perhaps for many of the variations in thickness attributed to the member . . .
>
> In some areas . . . the variation in thickness [of the Tongue River member] is caused by the lateral transition of light-colored into darker strata and vice versa which moves the color boundaries up and down in the section.
>
> In brief, the color changes match the equally great variations in lithologic composition, vertically and laterally, in the Paleocene sequence east of the Rocky Mountains, and render the definition and mapping of its several so-called members difficult or impossible, except locally. No reliance can be placed on distant lateral correlations made on this basis.

These statements appear to be, by and large, undocumented statements of opinion and intuition which may possibly have prejudiced concepts of the Tongue River-Sentinel Butte contact in North Dakota. Field observations upon which the present report is based do not support interpretation of a facies relationship between Tongue River and Sentinel Butte strata in western North Dakota. Brown's statement regarding the Sentinel Butte beds as "practically indistinguishable" from the Tongue River "member" near the mouth of the Yellowstone River appears questionable. As Figure 7-A illustrates, the color contrast across the contact is as marked here as can be observed anywhere in North Dakota.

The great variation in thickness recorded for the Tongue River "member" probably results more from differing opinions regarding its bounds than from lateral transition of light-colored into darker strata as suggested above by Brown. For example, Leonard (1911, p. 540) once stated:

> Where the uppermost beds of the [Fort Union] formation are found, as on the top of such high buttes as Sentinel, Flat Top, Bullion, and Black, they are seen to consist of a rather hard sandstone 80-100 feet thick . . . The White River beds are seen resting directly on this uppermost sandstone of the Fort Union.

This "uppermost" sandstone has since yielded fossils which reveal its true age as Oligocene (Brown, 1948a). Thus one must deduct 80 to 100 feet from the composite thickness cited for the Fort Union Group (or for the Sentinel Butte Formation) by Leonard around the year 1911. An error of similar magnitude is apparent in a later statement by Leonard (Leonard, and others, 1925, p. 35).

> The top of Sentinel Butte is 1163 feet above the bottom of the Little Missouri River valley at Medora so that in going from the river to the top of that butte it is possible to determine the number of coal beds present in this vertical section of over 1100 feet of strata.

This statement tacitly assumes that the strata are horizontal, an assumption which is good only as a "first" approximation. The eastward component of dip between Sentinel Butte and Medora is about 0.3 or 0.4 degrees eastward. This dip carries the HT Butte bed downward from the base of Sentinel Butte into the subsurface about 3 miles east of Medora, and the apparent composite section is reduced accordingly. Thus the composite section along this traverse is considerably less than 1100 feet, probably on the order of 650 to 700 feet. Many similar errors are present in the literature and citations of aggregate or composite thicknesses of Paleocene strata require careful evaluation.

That Paleocene units do vary in thickness, however, appears certain. For example, the thickness of the Sentinel Butte Formation increases from about 350 feet at Bullion Butte to 400 feet at Sentinel Butte and attains a maximum recorded thickness near the North Unit of Roosevelt Park of about 600 feet. In the writer's opinion, such variation in thickness reflects primary depositional control and, coupled with directional data, will eventually aid in evaluating both the structural character of the Tertiary basin of accumulation and the source of Paleocene sediments. This will be achieved, however, only after the stratigraphic units have been adequately differentiated.

Brown (1948a) does not stand alone in his contention that the color boundary between the Tongue River and Sentinel Butte Formations is migratory. Benson (1952, p. 41-43) summarizes his investigations conducted with Brown.

> At various times during the summers of 1947 through 1949 Brown and I together examined the Paleocene and Eocene formations in western North Dakota in an attempt to determine what happens to the Tongue River-Sentinel Butte contact east of Sentinel Butte and the Little Missouri River. We reached the following tentative conclusions:
>
> (1) The contact between the Tongue River and Sentinel Butte shale members of the Fort Union Formation is essentially a color boundary, with little lithologic difference between the two members.
>
> (2) This contact cannot be traced directly east because it dips in that direction into the Williston Basin and is concealed by younger formations. It can, however, be traced along the Little Missouri River north and south from the type locality of the Sentinel Butte shale near Medora. To the south, the Sentinel Butte shale can be identified as far as the Marmarth coal field (Hares, 1928), beyond which area erosion has removed all the late Paleocene beds. To the north, the color contact can be followed, at or near the same stratigraphic horizon, as far as southern McKenzie County, where the dip into the Williston Basin carries it below the floor of the Little Missouri Valley.
>
> (3) Beds representing the approximate stratigraphic horizon of the Tongue River-Sentinel Butte contact reappear at the surface on the east side of the Williston Basin in eastern McKenzie, northeastern Dunn and western Mercer counties. In this area, however, there is no color change. The section as a whole is dark, resembling the type Sentinel Butte shale; but it also contains numerous light beds that resemble the Tongue River.
>
> (4) The eastward darkening of the section is probably due to eastward thinning of the Fort Union formation, especially the Tongue River member. Near Medora the combined thickness of the Tongue River and Sentinel Butte members is between 1,000 and 1,500 feet and sand comprises about half of the section. In Mercer County, the thickness of the Tongue River-Sentinel Butte beds is probably less than 800 feet, and the

> section is 60 to 65% gray shale. Also, as the total volume of sediments decreases, the relative abundance of carbonaceous material increases, causing a darkening of the color. It is not surprising that the color contrast between the Sentinel Butte shale member and the Tongue River member does not persist as far east as the Knife River area.
>
> (5) The Sentinel Butte shale, therefore, is mappable as a separate member of the Fort Union formation only near its type locality in western North Dakota. To the east it appears to intertongue, both laterally and vertically, with the Tongue River member. We therefore suggest that the name "Sentinel Butte" be used only in western North Dakota; and that beds of equivalent age in the central part of the state be included in the Tongue River member of the Fort Union formation.

As interpreted in this report, the Tongue River-Sentinel Butte contact is not just a color boundary, it is a lithogenetic break between two rock stratigraphic units, the uppermost of which transgressed the lower. Preliminary evaluation of analyses of nearly 500 stratigraphic samples (Royse, in progress) demonstrates that these units are distinct in both texture and composition and that they record two different episodes of Paleocene history. Thus, statements regarding Tongue River and Sentinel Butte lithologies as "indistinct" appear to be erroneous.

Benson's failure to distinguish the Tongue River-Sentinel Butte contact within the Knife River drainage suggests to this writer that it is not exposed in much of this area. The contact is distinct south of Benson's map area in Morton County and efforts are presently underway to carry it northward (C. G. Carlson, in progress). The presence of light-colored horizons within the Sentinel Butte Formation is not denied. "Yellow" beds can be seen in the upper half of the section near the North Unit of Roosevelt Park and correlative strata appear to exist westward to Sheep Buttes, eastward to Lost Bridge, and southward at least as far as the Blacktail-Whitetail Creek divide. A light-colored bed occurs high in the local section just west of Fryburg, Billings County, which has considerable persistence and might correlate with one of the yellow beds mentioned above. The writer considers these beds similar to Tongue River strata and suggests they may represent a brief "return to Tongue River conditions," however no evidence exists to imply that they have physical continuity with the bulk of strata in the underlying Tongue River Formation.

The influence of Benson and Brown is evident in the reports of subsequent investigations. For example, Fisher (1953) makes the statement,

> The Sentinel Butte sediments are generally more somber than those below. Brown (1948), in his review of the Paleocene rocks of westcentral North Dakota, has shown them to be a facies of the Tongue River formation; a color change that moves vertically across the section. A similar condition is indicated in McKenzie County for the upper part of the river bluffs in the northwestern portion of the county contain beds which are probably high in the [Fort Union] section, but are chiefly buff in color. The writer cannot be certain of this fact because correlations were not carried into that area.

Fisher's uncertainty is justified by the writer's field check of the bluffs along the river north of the Nelson Bridge east of Fairview, Montana, which contain only Tongue River strata.

Fisher's success in tracing the HT Butte bed is of greater concern than his comments regarding facies. In regard to this horizon, which he designates as the L bed or "scoria," he states:

> The L lignite of this report can be traced over 30 miles southeast from the bend of the Yellowstone River [in northwestern McKenzie county].
>
> The L scoria forms the rimrock in much of the western half of the area. It is the thickest single scoria in the area, ranging up to 45 feet although usually less than half that thick.

In a southward continuation of his structural study in west-central McKenzie County, Fisher (1954) again uses the L bed as a datum.

> It was thought desirable to follow out the extensive L scoria which served as contour datum in that report [Fisher, 1953], and to locate the position of this bed in the sections measured by Leonard along the Little Missouri River.
>
> In McKenzie and northern Golden Valley counties at least, this scoria marks the contact between the light colored standard Tongue River sediments and the overlying somber Sentinel Butte facies.

Fisher's structural mapping was followed by similar studies to the southeast (Hanson, 1955) and east (Meldahl, 1956). In regard to the contact within the "Elkhorn Ranch area" Hanson (1955) comments:

> The contact between the Sentinel Butte member and the underlying beds of the Tongue River formation is quite pronounced because it is picked at a color change; dark brown Sentinel Butte shale is found resting on gray to tan Tongue River beds.
>
> In the southern part of the area a prominent clinker bed exists which has been designated by the writer by the letter "L." This clinker bed extends for about three miles north of the southern boundary of the area, and caps all the buttes in that vicinity. Although this clinker bed is not very extensive, and is much thicker than the clinker bed in the Skaar-Trotters area, it was determined that it is the same bed described by Fisher (1954) in the Skaar-Trotters area. The base of clinker bed "L" was used for the datum plane in structure contouring.

Although Hanson's report adds testimony to the color contrast between the Tongue River and Sentinel Butte Formations, his mapped contact between them does not agree well with Figure 1 of this report.

The following year, Meldahl (1956) mapped the "Grassy Butte area" which constitutes a northward extension of Hanson's and an eastward extension of Fisher's investigations. In reference to the character of the contact, Meldahl states:

> 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.

Such skepticism regarding recognition of the contact would presumably preclude its use as a structural datum, but Meldahl had success comparable to that of Fisher (1953, 1954) in tracing the "L bed":

> . . . 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 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 [Grassy Butte?] 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.

Meldahl's reference to replacement of the "L bed" by a "bentonitic" clay merits comment. This unit is a local wedge of fine material between the HT Butte bed and the basal Sentinel Butte sand. Where it was observed in Meldahl's and Hanson's map areas, it is discontinuous and ranges in thickness from a "feather edge" to 4 or 5 feet. It is distinct from, but usually grades abruptly upward into, the basal sand. It may have (in its original extent) been the source of clay in the basal sand.

In conclusion, brief consideration is given to Nevin's (1946) comments regarding the contact in the Keene dome area of eastern McKenzie County.

> Although the Sentinel Butte is conformable with the underlying Tongue River, and although the environment of sedimentation was very similar for both formations, it is possible to map them separately . . . Since the contact of the Sentinel Butte and Tongue River is completely gradational, some arbitrary horizon must be selected for the boundary. Seager (1942) states that a lignite or a burned clinker bed marks the contact in many places. Hennen places the contact at the top of lignite 22, a bed 20 feet thick, that is being mined on the north face of Sentinel Butte. If no mistake has been made in correlation, this horizon is equivalent to JK of the stratigraphic section, figured in this report.

Nevin, however, considered a more "logical" contact (his bed L) to exist about 200 feet stratigraphically higher than the JK bed to which he refers as the "approximate top" of the Tongue River. Spot checks of Nevin's datum points between Charlson and the Missouri River, where the contact (as defined by criteria of this paper) is known to exist, indicate to the writer that Nevin erred in his regional correlation of the contact by at least 200 feet. This error has no direct bearing on his local correlation and should not influence his structural interpretations. Nevin's failure to

include key marker beds (such as the "blue bed" and the "upper and lower yellow beds" of Fisher, 1953) which are believed to be present in his map area, limit the utility of his generalized stratigraphic section.

STRATIGRAPHIC NOMENCLATURE

In any penetrating study of early Tertiary continental deposits of the western interior, the geologist will find himself drawn into a voluminous literature full of nomenclatorial ambiguity and uncertainty. Few stratigraphic intervals in the United States have been subject to greater argument, debate, and disagreement than has the late Cretaceous-early Tertiary continental sequence of the western interior. The roots of controversy extend backward in time to the first comprehensive geological studies by the Territorial Surveys; duplication and confusion accompany and characterize the history of subsequent study. Only recently has our knowledge reached the degree of completeness necessary for clarification of the stratigraphic nomenclature. A brief résumé of uses (and misuses) of stratigraphic terms applied to the Cretaceous-Tertiary sequence appears desirable here in order to place the Tongue River and Sentinel Butte units in proper nomenclatorial perspective.

Early Nomenclature

Early geological reports (1852 to 1876 and later) referred to the Lignite (Lignitic) Group, now known to contain strata which range in age from late Cretaceous to early Tertiary. Meek and Hayden (1862) supplanted the "Lignitic Group"[2] of older reports with the "Fort Union Group" or the "Great Lignitic Group." Apparently, no need for consistent usage was felt and the terms were used interchangeably by Hayden during the following decade. A seed of synonymy had, however, been sown, for the term "Lignitic Group" was an abstraction applicable to carbonaceous strata anywhere; "Fort Union" was specific and applied to a definite sequence of strata with a designated "type" locality. The two were in no way entirely equivalent.

The term "Lignitic Group" was also replaced by the term "Laramie Group" in the vicinity of the fortieth parallel by King (1876). This duplication of terminology was soon recognized, and Hayden and King together agreed to replace the descriptive term "Lignitic" with the geographic term

[2]Formal stratigraphic terms, used in the context of previous workers, which are considered to embrace different stratigraphic intervals than current usage permits are placed in quotes. Likewise, obsolete rank terms are placed in quotes. Quotes are omitted for terms currently accepted by the North Dakota Geological Survey and the writer, and for terms used in general context without explicit stratigraphic connotation.

"Laramie." They included within the "Laramie Group" all strata between the "Fox Hills Sandstone" and "Vermillion Creek" (of King) or "Wasatch" (of Hayden) Group. It is not entirely evident that Hayden ever intended to replace the term Fort Union with Laramie; it would seem, rather, that he temporarily revised its age, considered it "Wasatch," and preserved its identity. Hayden (1878, p. iv) states,

> If objection is made to the use of Lignitic group I would say that in this work it is restricted to a series of coal-bearing strata lying above the Fox Hills group, or Upper Cretaceous, and these are embraced in the Laramie and Fort Union groups . . . It is also probable that the brackish-water beds on the upper Missouri must be correlated with the Laramie, and that the Wasatch group as now defined and Fort Union group are identical as a whole, or in part at least.

If King and Hayden ever agreed on the usage of Laramie, it is certain that they never agreed on its age. Controversy is apparent in King's (1878, p. 298) statement regarding the "Laramie Group" as the last of the conformable marine strata and equivalent to the "Lignitic series" of Meek and Hayden (1862) in the upper Missouri section:

> Dr. Hayden has successively considered these rocks as Tertiary and as transitional between Cretaceous and Tertiary . . . That there might be no misunderstanding as to stratigraphic position and nature of the rocks themselves, Dr. Hayden and I mutually agree to know them hereafter as the Laramie group, and to leave their age for present as debatable ground, each referring them to the horizon which the evidence seems to him to warrant. The result of our investigations leads me to the distinct belief of their Cretaceous age.

Hayden (1876, p. 26-27) was no less emphatic in his viewpoint:

> I still regard the lignitic group proper as transitional or Lower Eocene, and shall so regard its age until evidence to the contrary is much stronger than any which has been presented up to present time. When, however, the proof is sufficient to decide the Cretaceous age of the group I shall accept the verdict without hesitation. It is somewhat doubtful whether the age will ever be decided positively to the satisfaction of all parties.

In retrospect we realize that both men were largely correct, that the lignitic sequence in question contains strata of both Cretaceous and Tertiary age, and that King probably saw more of the former and Hayden more of the latter. That Hayden had the better perspective is indicated by his lack of dogmatism and by his statement (Hayden, 1878, p. iv) that

> . . . those who worked from the south and southwest toward the north have been thoroughly impressed with the Cretaceous age of the "Lignitic group," while those who have studied the deposits from the north and northwest toward the interior basin received their first impressions they were of Tertiary age.

Thus at the close of the Territorial surveys (1878) the term "Lignitic group" was passing into disuse and uncertainly existed as to the meaning and age of the terms Fort Union and Laramie. By 1900, the age, definition, and extent of the "Laramie Formation" was becoming a major issue (the Laramie Problem) in the burning debate over placement of the Cretaceous-Tertiary boundary in the western interior. As detailed studies were completed, additional terminology was introduced, older terms were revised and restricted, and the stratigraphic nomenclature rapidly attained a complexity capable of wearying the casually interested and frustrating the seriously involved geologist.

Weed (1893) made the first major subdivision of the "Fort Union" near Livingstone, Montana, in which he restricted the term "Fort Union Group" to an upper sequence of rather massive cross-bedded sandstones with gray silty shales and local lenses of impure limestone which he (p. 35)

> . . . believed to be a distinct formation, corresponding in lithology, stratigraphic position, and fossil contents to beds exposed along the Missouri River at the mouth of the Yellowstone, so long known in geological literature as Fort Union beds.

Beneath this "Fort Union" he recognized the "Livingstone beds" which unconformably overlay a thick sequence he regarded as equivalent to the Cretaceous "Laramie beds" of King and others. This appears to be the first clear recognition of the temporal and stratigraphic distinction between the "Laramie" and "Fort Union" formations. Subsequent work in adjacent localities resulted in further subdivision of these strata in which "Fort Union" was restricted to the youngest strata underlying the "Wasatch formation" and its equivalents.

Strata beneath the "Fort Union beds" received various new terms. In Converse County, Wyoming, the late Cretaceous sequence equivalent to the widespread dinosaur-bearing beds (Ceratops beds) between the "Fox Hills" and "Fort Union" formations were named "Lance Creek beds"

(Hatcher, 1903); similar strata in eastern Montana were named "Hell Creek beds" (Brown, 1907) and subsequently became known as the "Hell Creek member of the Lance formation."

Just as the term Fort Union became restricted to the upper portion of the lignitic strata of the Great Plains, the term Lance received wide application to the lower interval. From its inception, the term was equivalent in part to the "Laramie formation" of King and others. As a result of the uncertainty which attended usage of "Laramie formation" the U.S. Geological Survey, in 1910, restricted the use of Laramie to rocks of the Denver basin. As a result, "Lance formation" was extended to include strata throughout Wyoming and adjacent portions of Colorado, Montana, North Dakota, and South Dakota. Brown (1943) proposed that the term Laramie be expanded to include the "Arapahoe conglomerate" and the Cretaceous portion of the "Denver formation," thus making the Laramie formation" equivalent to the typical "Lance" and "Hell Creek" formations.

The base of the Lance Formation is marked in some localities by an unconformity with the Fox Hills Sandstone. The upper contact, however, is gradational with younger beds of variable character, many of which have been treated as members of the Lance Formation and considered to be of late Cretaceous age. In eastern Montana such units included the "Tullock member" (Rogers and Lee, 1923) and the "Lebo shale" (Stone and Calvert, 1910) and in adjacent North and South Dakota the "Ludlow Lignitic member" (Lloyd, 1914). The Paleocene age of each of these units has subsequently been recognized and they are now considered to be subordinate units within the Fort Union sequence (Keroher, 1966).

Because of the uncertain age relationship between the Lance and Laramie strata (the latter of which was considered to be of established Cretaceous age), the U.S. Geological Survey in 1935 elevated the Hell Creek and Tullock "members" to formational rank and restricted the age designation of the Lance to "Cretaceous" except where beds of demonstrated Tertiary age exist above those of Cretaceous age, in which case the age designation might be "Upper Cretaceous and Eocene." In North Dakota, the Ludlow and Cannonball continued to be considered members of the "Lance," their Paleocene affinities not yet having been demonstrated.

Tongue River and Sentinel Butte Formations

The "Fort Union" also underwent subdivision during the early part of the century, largely as a result of the many "coal surveys" of the U.S. Geological Survey. Taff (1909) divided the "DeSmet formation" of Darton (1906; equivalent in part to Fort Union) in the Sheridan coal field, Wyoming, into three groups. In descending order, these were the Ulm, Intermediate, and Tongue River coal "groups." The Tongue River coal "group" was named for exposures along the northward

flowing river of that name, and its upper contact was defined by the top of the Roland coal bed. On the basis of fossil plants and shells collected from the Tongue River "group" upward, Taff considered the coal-bearing rocks of the Sheridan field to be of "Fort Union" age; that is lower "Eocene" or "basal" Tertiary.

About the same time, Leonard (1908) and Leonard and Smith (1909) divided strata of the Sentinel Butte coal field of western North Dakota into an upper Sentinel Butte coal "group" and a lower Medora coal "group." Leonard (1908) is properly credited with the first stratigraphic application of the term "Sentinel Butte," however the stratigraphic interval assigned to the Sentinel Butte group in 1908 differs from that of Leonard and Smith the following year. In 1908, the Sentinel Butte coal "group" was recognized as containing, in its lower portion, lignite beds Q, R, and S. Bed Q marks the base of the group. In 1909, only two beds, F and G, were assigned to the lower part of this "group," bed F constituting its base. The equivalence of beds S and G is certain, both being reported as 20 feet in thickness. It is also certain that bed R equals F; thus the Q-R interval of the "1908" Sentinel Butte "group" was omitted from the 1909 section, apparently being relegated to the underlying Medora "group." Subsequent applications of the term Sentinel Butte appear to follow the revision of Leonard and Smith (1909).

Leonard's use of "Medora group" merits additional comment. In 1908 Leonard recognized the Beaver Creek and Medora coal "groups" as underlying the Sentinel Butte group of lignite beds. The partial equivalence of lignite beds of the Beaver Creek and Medora "groups" is evident to this writer. Perhaps it was this equivalence which caused Leonard and Smith (1909) to omit the Beaver Creek "group" and apply the term Medora "group" to the entire lignitic sequence (exclusive of the Ludlow Formation) below the Sentinel Butte "group." This revised Medora "group," as shown by Leonard and Smith, contains fewer lignite beds than did the 1908 combined sequence of Medora plus Beaver Creek "group."

Leonard (1908) regarded the Sentinel Butte "group" as part of the "Fort Union formation," and the entire sequence to be of early Eocene age (Eocene then included the Paleocene Epoch). Thom and Dobbin (1924) complied with the then current usage of the U.S. Geological Survey and treated it as Fort Union(?) although they state that they regard it to be of "Wasatch" age and equivalent to the Intermediate coal "group" (plus the Roland coal) of the Sheridan coal field. Likewise, Hares (1928) followed the same classification and expressed the same personal opinion as Thom and Dobbin. A subtle fact was becoming apparent, not only is the base of the Paleocene Series problematical but its upper boundary is also indistinct. The age of the Sentinel Butte Formation had become an issue.

Early opinions regarding the age of Sentinel Butte strata appear to result from two considerations; its relationship to the "Clark Fork beds" of the Big Horn basin and to the Intermediate coal "group" and the "Kingsbury conglomerate" in the Powder River basin. Simpson (1929) tentatively correlated Sentinel Butte with Clark Fork strata which he considered (paleontologically) transitional between late Paleocene (Torrejon) and true "Wasatch." The paucity of fossil material and the uncertain stratigraphic position of key specimens allowed Simpson (p. 7-8) to formulate only the following tentative conclusion.

> If this distinctly Paleocene type of fauna does belong in the Sentinel Butte, it would be much more satisfactory from a faunal point of view to retain this member in the Fort Union Formation or Group, rather than to follow Thom and Dobbin in placing it in the Wasatch. Equivalence with the Clark Fork fauna does not necessitate inclusion in the Wasatch. The known Clark Fork fauna may be slightly later than the Bear Creek fauna, . . . but it is still essentially of final Paleocene type.

In 1930 Jepsen, on paleontologic grounds, assigned the "Clark Fork formation" to the Fort Union and considered it to mark the summit of the Paleocene. Although Jepsen's study helped confirm the age of the "Clark Fork beds," their correlation with the Sentinel Butte Formation remained tenuous.

Darton (1906) named and described the "Kingsbury conglomerate" at Kingsbury Ridge on the east flank of the Big Horn Mountains in Wyoming and assigned it to the Cretaceous. In 1909, Knowlton, in his discussion of the Hell Creek, Ceratops, and Fort Union "beds," stressed the similarity of floras from the Kingsbury and the upper and lower "members" of the Fort Union, to which he considered the Kingsbury belonged. Likewise, Gale and Wegeman (1910) considered the "Kingsbury conglomerate" to be an upper member of their "Fort Union," although Wegeman (1917, p. 60) amended his views to the effect that:

> . . . It is the writer's opinion that the Kingsbury conglomerate is equivalent to part of the Wasatch, and that the unconformity at its base separates that formation, in the Kingsbury region at least, from all older rocks.

Apparently prompted by opinions of Thom and Dobbin (1924) and Hares (1928) favoring a "Wasatch" age for the Sentinel Butte "shale" and Intermediate coal "group" (which they correlated with the "Kingsbury conglomerate"), a number of subsequent workers followed suit and assigned the Sentinel Butte "shale" an Eocene age (Kline, 1942; Seager, and others, 1942; Laird and Mitchell, 1942; Hennen, 1943; Nevin, 1946; and others).

It appears relevant to mention that Thom and Dobbin also correlated the Sentinel Butte "shale" with the "Clark Fork beds" of the Big Horn basin which subsequently (as discussed above) have been regarded as uppermost Paleocene; thus the correlation remains valid although the age assignment of both has changed. In two related papers, Brown (1948a, 1948b) largely clarified the age relationships of the "Kingsbury conglomerate," Intermediate coal "group," and Sentinel Butte "shale." Faunal evidence has established the Eocene (Wasatch) age of the "Kingsbury conglomerate" and, as Brown (1948a, p. 1273) points out, although

> . . . the Kingsbury conglomerate . . . was said to occupy a position somewhat laterally of the Intermediate coal group with stringers into that group . . . neither Taff nor anyone else has succeeded . . . in establishing its stratigraphic level relative to the base of the Kingsbury conglomerate.

Thus the presumed correlation of the Intermediate coal "group" and the "Kingsbury conglomerate" cannot be physically demonstrated.

Subsequent workers (Sharp, 1948; Brown, 1948b; May, 1954) have recognized two conglomerates in this area, an upper Moncrief gravel (Sharp, 1948) which rests unconformably (in part) above the Kingsbury conglomerate. The two are lithologically distinct but both grade eastward into Wasatch strata of the Powder River basin. The "Wasatch" age of these gravels and their relationship to Tertiary strata in the Powder River basin and adjacent North Dakota has been clarified by Brown (1948a, p. 1273). Brown concludes:

> All the recent paleontologic and stratigraphic evidence points toward retention of the Sentinel Butte shale within the Fort Union formation of the Paleocene series. This evidence seems to be harmonious across the entire Paleocene-Eocene terrain east of the Rocky Mountains and permits the drawing of the Paleocene-Eocene boundary with reasonable assurance.

Further discussion of the Sentinel Butte Formation necessitates consideration of the Tongue River Formation. As previously mentioned, Taff (1909) divided the "DeSmet formation" (Darton, 1909) of the Sheridan coal field into upper and lower "members." The upper "member," in turn, was divided into (ascending) Tongue River, Intermediate, and Ulm coal "groups." The top of the Tongue River "group" was marked by (and included) the Roland coal bed; the base was (p. 127)

> . . . distinguished by the relative quantities of sandstone and shale and by the general color of the rocks . . . and is marked approximately by the Carney coal bed . . .

> The rocks below the Carney coal are essentially all shale or are shaley in character and prevailingly dull drab, bluish, and brown in color.

In North Dakota the same lithostratigraphic relationship exists. The top of the Tongue River Formation is defined by the HT Butte bed and the base (where observable) is separated from the somber Ludlow Formation by a well developed basal sand. It is conformably overlain by the Sentinel Butte Formation and is a discrete rock-stratigraphic unit.

In early publications, the U.S. Geological Survey regarded the Tongue River as a "member" of the Fort Union "formation" and the Sentinel Butte as a "member" of the Fort Union(?) "formation" (Hares, 1928; Wilmarth, 1938). About the same time that it formally accepted Paleocene as an epoch-series term (June 12, 1939) the U.S. Geological Survey omitted the interrogative and began to refer the Sentinel Butte "member" to the Fort Union "formation." This usage is still current.

North Dakota geologists have been less consistent in their assignment of stratigraphic rank to Sentinel Butte strata. Workers have variously referred to the "Sentinel Butte formation of the Wasatch group" (Nevin, 1946), "Sentinel Butte shale formation of Eocene (Wasatch) age" (Laird and Mitchell, 1942), "the Sentinel Butte member of the Wasatch formation" (Seager, and others, 1942; Kline, 1942; Hennen, 1943), or to the Sentinel Butte "member" of the Fort Union "formation." No sooner had the reassignment of the Sentinel Butte "shale" to the Paleocene (Brown, 1948a and 1948b) received general acceptance than its relationship to the underlying Tongue River began to be questioned. Two basic opinions developed; one considered the Sentinel Butte to be a "member" of the "Tongue River formation" and a second regarded the Sentinel Butte to be a facies of the "Tongue River formation." Neither of these opinions is supported in this report.

Classification of the Sentinel Butte as a subordinate interval (exclusive of a facies) within the Tongue River necessitates an extension of the upper contact of the Tongue River (which has been firmly placed at the Roland and HT Butte horizons) to include a greater stratigraphic interval than originally defined, and subsequently accepted, for the Tongue River. Such revision has never been proposed or adopted, and such an extension (with retention of original names) is discouraged both by precedent and by the accepted standards of the Stratigraphic Code of Nomenclature (A.C.S.N., 1961, Article 14). It has become increasingly difficult in recent years to understand an author's meaning of "Tongue River" and whether he is using original or modified terminology.

Consideration of the Sentinel Butte as an "upper member" of the Tongue River Formation creates an unnamed "lower member" (Crawford, 1967) occupying the interval formerly considered as Tongue River. Reference to this "lower member" is commonly made with some qualification. For example, Fisher (1953, 1954) refers alternately to "typical," "usual," and "standard" Tongue River rocks in discussing beds below the Sentinel Butte "member." Meldahl (1956) was forced to allude to the "lower part" of the Tongue River "formation." Other writers are equally vague about this stratigraphic interval which for years was known as Tongue River.

Consideration of the Sentinel Butte as a "facies" of the Tongue River Formation is even less acceptable to the writer than member status discussed above. This usage appears to have entered the literature largely as a result of Brown's (1948a) cross-section correlating lignitic strata between Sheridan, Wyoming, and Mandan, North Dakota, which schematically expresses facies relationships between light and dark strata. Benson (1952, 1954) regarded the

> . . . Sentinel Butte shale member as a facies of the Tongue River member.

His motives were apparently expressed by Brown (1948a, p. 1268),

> Benson, as a result of detailed mapping in the Knife River area in 1946 . . . found it impossible to distinguish one from another the sequences of strata that had there been called Tongue River member and Sentinel Butte shale.

As previously acknowledged, the writer has not thoroughly explored Benson's map area, but structural relationships imply that sediments of the Tongue River "member" should not be exposed throughout much of the area. It is probable that the Tongue River-Sentinel Butte sequence undergoes lithologic and textural change with increased distance from its source, such is certainly the case in many post-orogenic sequences. But evidence for a major facies relationship between Tongue River and Sentinel Butte strata (if it ever existed) has been removed by late Tertiary erosion and the relationship cannot be demonstrated within remaining outcrop areas in western North Dakota.

SUMMARY

This investigation has provided criteria for recognition of the Tongue River-Sentinel Butte contact and has documented its persistence throughout much of western North Dakota. It is hoped that differentiation of these units will encourage study of the lithogenetic and paleontologic aspects of

the individual units. Such studies should contribute significantly to a knowledge of Paleocene tectonics, geography, and ecology of the Rocky Mountains and Great Plains.

The Sentinel Butte has been accepted as a lithostratigraphic unit of a sub-formational rank since originally defined by Leonard and Smith (1909). The evidence appears to be unequivocal that the stratigraphic sequence presently referred to as Sentinel Butte is a distinctive and mappable stratigraphic unit and deserves formational rank. It is therefore recommended that the following lithostratigraphic terminology be applied to the Paleocene Series in western North Dakota and adjacent areas.

Fort Union Group
- Sentinel Butte Formation
- Tongue River Formation
- Ludlow and Cannonball Formations

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TONGUE RIVER-SENTINEL BUTTE CONTACT IN WESTERN NORTH DAKOTA

104° 103° 102°

48°

47°

WILLIAMS
MOUNTRAIL
McKENZIE
DUNN
BILLINGS
GOLDEN VALLEY
STARK
MORTON
SLOPE
HETTINGER
GRANT

Williston
Fort Union
Buford
Newtown
Keene
Watford City
Sheep Butte
Roosevelt Park North Unit
Lostbridge
Gorham
Twin Buttes
Sentinel Butte
Medora
Roosevelt Park South Unit
Sully Springs
Dickinson
Hebron
Glen Ullin
New Salem
Amidon
H.T. Butte
Marmarth

Little Muddy River
Missouri River
Yellowstone River
Garrison Reservoir
Little Missouri River

EXPLANATION

Sentinel Butte / Tongue River — Contact largely exposed, extrapolation based on abundant data.

Sentinel Butte / Tongue River — Contact approximate or poorly exposed, extrapolation based on sparse data.

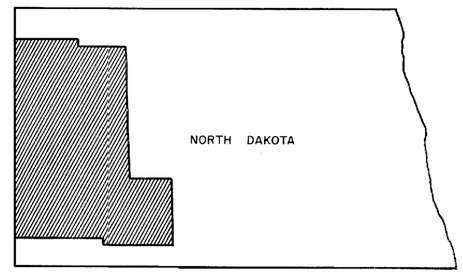
Sentinel Butte / Tongue River — Contact concealed or inferred.

X — Isolated exposure of Tongue River–Sentinel Butte contact.

SCALE

5 0 5 10 15 20 miles

5 0 5 10 15 20 25 30 kilometers



Index to map area.