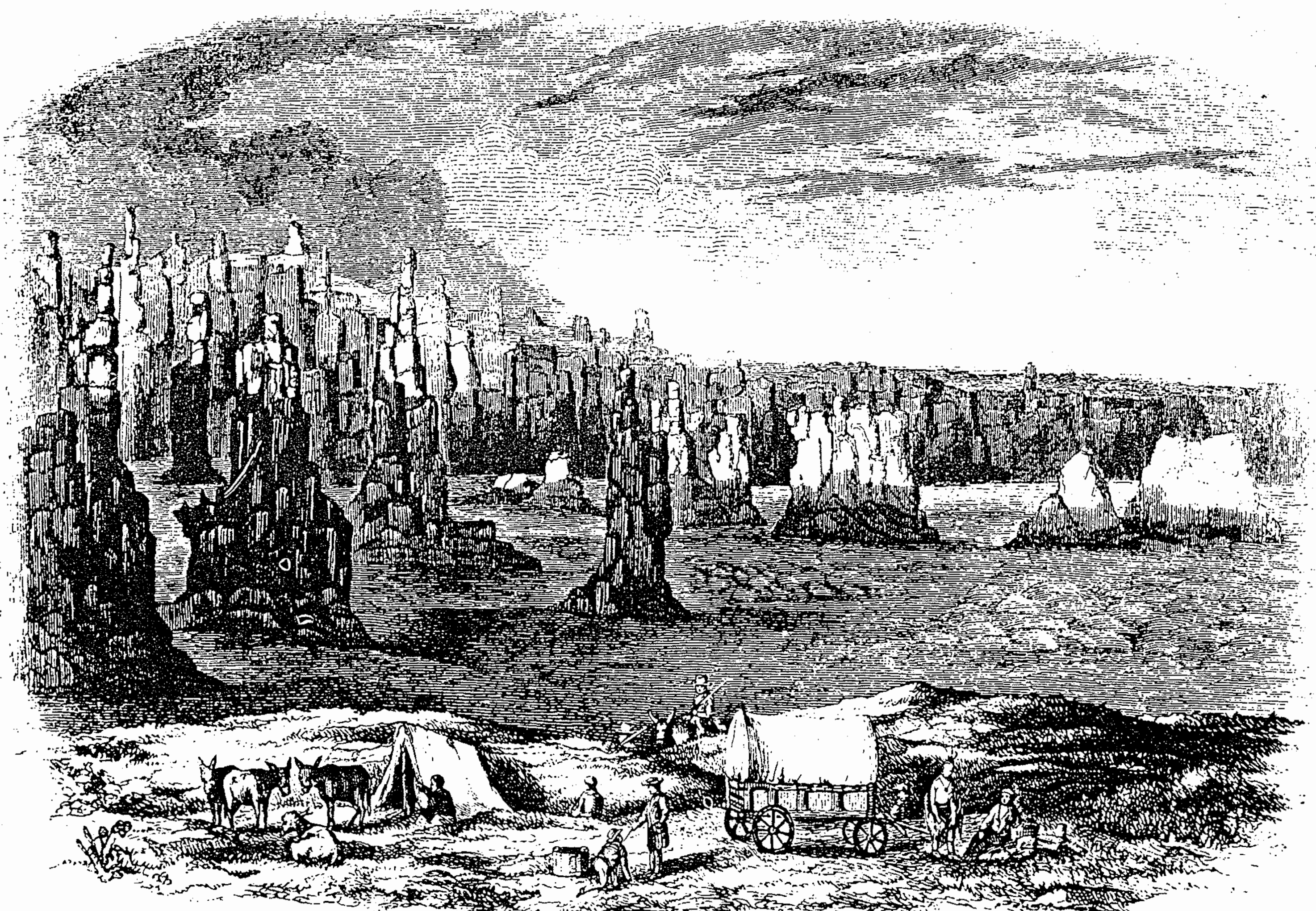
GUIDEBOOK
to the
MAJOR CENOZOIC DEPOSITS
of
SOUTHWESTERN SOUTH DAKOTA

Guidebook 2
South Dakota Geological Survey



MAUVAISES TERRES

by J.C. Harksen & J.R. Macdonald

STATE OF SOUTH DAKOTA
Frank Farrar, Governor

SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

GUIDEBOOK 2

GUIDEBOOK TO THE MAJOR CENOZOIC DEPOSITS OF SOUTHWESTERN SOUTH DAKOTA

by
J. C. Harksen
South Dakota Geological Survey

and

J. R. Macdonald
Los Angeles County Museum of Natural History

Science Center
University of South Dakota
Vermillion, South Dakota
1969

WELCOME

On behalf of the personnel of the South Dakota Geological Survey and, indeed, all of the citizens of South Dakota, I extend to you greetings and welcome you to this field conference.

You are here to exchange greetings and to renew acquaintances one with the other. You as vertebrate paleontologists and stratigraphers in attending a field conference such as this can and are getting nearer together, thus enabling all of you to greater harmony of opinion and unity on general principles, although each may differ on detail. It may be next to impossible for all of you to agree on everything that is said at this conference; each of you will have your differences and well that you should. Without your honest differences and the conveyance of them, all advancement and progress would cease and your science certainly would enter retrogression.

In your hands you hold a guidebook entitled "Guidebook to the major Cenozoic deposits of southwestern South Dakota" by J. C. Harksen and J. R. Macdonald which will provide you with information concerning the program of the field conference. The authors are to be commended for their efforts in the preparation of the guidebook. Those of you who have prepared similar documents know what a task it is to take the voluminous amount of available data on an area and try to summarize it into usable form.

Hopefully your stay in our State will be a pleasant one and you will want to return sometime in the future. Upon your return home, think about the field conference and if the spirit moves you, convey your comments, ideas, suggestions, and recommendations to the authors. They would be most happy to receive them.

Again, it is a pleasure to have you in our State. May your time spent with us be both rewarding and profitable.

Duncan J. McGregor
State Geologist

ACKNOWLEDGMENTS

The writers would like to extend their thanks to Bob Wilson, Morton Green, and George Callison of the South Dakota School of Mines and Technology for the assistance they have given in the preparation of this guidebook. We would also like to thank Roger Barker for measuring the three sections that are credited to him later in this guidebook. We also extend our thanks to the professional and clerical staff of the South Dakota Geological Survey for the help that they rendered during the preparation of this guidebook. A special vote of thanks goes to Dennis Johnson who did all the drafting included herein.

Major use was made of Keroher (1966), Agnew and Tychsen (1965), Bump (1951), and Anonymous (1941) without specific reference at all points in the text. The United States Geological Survey one by two degree topographic maps of the Rapid City, Hot Springs, Martin, and Alliance areas were used as basemaps in the preparation of figures 12, 34, 51, 52, 59, and 64.

DEDICATION

This guidebook is dedicated to the Loup Fork, Oak Creek, Little White River, Marsland, Titanotherium Beds, and all other lithologic names which have disappeared into the oblivion of synonomy.

CONTENTS

TABLES

FIGURES

FIGURES – continued.

FIGURES – continued

FIGURES – continued.

THE GEOLOGIC EXPLORATION OF SOUTHWESTERN SOUTH DAKOTA

by
J. R. Macdonald

Introduction

The unraveling of the Tertiary history of South Dakota and the naming of its geologic units has played a major part in the historical development of the stratigraphic and paleontologic studies of the Great Plains. Today the geologic situation is obscured by stateline unconformities, a plethora of names and the bickerings of egocentric protagonists quarreling over philosophical differences of interpretation, the goring of their favorite oxen, or the defense of their youthful errors. In this context, rest assured that the writer has carefully presented his own biased viewpoint.

Surely all will agree that the best area for study of the middle and late continental Tertiary history of North America is here in the "Fossiliferous Circle" – southwestern South Dakota, southeastern Wyoming, western Nebraska, and northeastern Colorado. Nowhere else can such a complete sequence of fossiliferous continental sediments (spanning early Oligocene through Pliocene) be found. This area should be the universal standard for this segment of time, as represented by continental sediments and faunas. Continuing concentrated study will eventually expand our knowledge of this important region not only because of its rich fossil bearing sequences but because it is unlikely that any area has produced so many dogmatic students with opposing views who would rather fight than most anything else. In such a healthy, inquiring atmosphere the truth will eventually out.

To the best of our knowledge, the first man to "see" and "tell" was the Mountain Man, James Clyman who (in a party led by Jedadiah Smith) followed the White River from the Missouri through the Badlands, across country to the Cheyenne River, and then into the Black Hills during September and October of 1823. The great vertebrate paleontologist and western historian, Charles L. Camp (Clyman, 1950), tells the story in Clyman's own words (pp. 15-19) in his beautiful book, *James Clyman, Frontiersman*.

> ". . . . .in (the) evening we camped on White Clay Creek (White River) a small stream running thick with a white sediment and resembling cream in appearance but of a sweetich pu(n)gent taste our guide warned us from using this water too freely as (it) caused excessive costiveness which we soon found out. . . . ."
>
> "Continued up the vally of this stream to Sioux encampment of the Bois Brulie (Burnt Wood) tribe. . . . .so far the country is dry not fit for cultivation (tere may) However there may be and pro(b)a(b)ly is better soil and better gr(a)ising higher up amongst the hills. . . . ."
>
> "We packed up and crossed the White Clay river and proceeded north westernly over a dry roling Country for several days meting with a Buffaloe now and then which furnished us with provision for at least one meal each day our luck was to fall in with the Oglela tiribe of Siouxs whare (we) traded a few more horses and swaped of(f) some of our more ordinar(r)y"
>
> "Country nearly the same short grass and plenty of cactus untill we crossed the (South Fork of) Chienne River a few miles below whare it leaves the Black Hill range of Mountains here some aluvial lands look like they might bear cultivation we did not keep near enough to the hills for a rout to travel on and again fell into a tract of country whare no vegetation of any kind existed beeing worn into knobs and gullies and extremely uneven a loose grayish coloured soil verry soluble in water running thick as it could move of a pale whitish coular and remarkably adhesive there (came) on a misty rain while we were in this pile of ashes (Pierre Shale beds west of the South Fork of the Cheyenne River) and it loded down our horses feet (feet) in great lumps it looked a little remarkable that not a foot of level land could be found the narrow revines going in all manner

> of directions and the cobble mound(s) of a regular taper from top to bottom all of them of the percise same angle and the tops sharp the whole of this region is moveing to the Misourie River as fast as rain and thawing of Snow can carry it by enclining a little to the west in a few hours we got on to smoothe ground and soon cleared ourselves of mud at length we arived at the foot of the black Hills which rises in verry slight elevation above the common plain we entered a pleasant undulating pine Region cool and refreshing so different from the hot dusty planes we have been so long passing over and here we found hazlenuts and ripe plumbs a luxury not expected"

The White River Badlands

(See Table 1)

Not until 1846 was a fossil bone described from the Tertiary deposits of the area. In that year Dr. Hiram Prout (1846) of St. Louis published a brief description of a fragment of the jaw of a Brontothere, one of the great rhinoceros-like beasts so common to the early Oligocene Chadron Formation of the Badlands. Picked up somewhere in the Badlands by an American Fur Company employee, the specimen eventually reached St. Louis, then the jumping-off place for all western adventures. Prout called his animal "a gigantic Palaeotherium," understandably mistaking it for a member of a closely related family of ungulates found in the Eocene and Oligocene of Eurasia. The following year another article appeared in *The American Journal of Science* expanding the preliminary report and figuring the specimen. At this point Dr. Prout dropped the subject. His only other dabble in vertebrate paleontology was the description of a brontothere tooth for which he gave a Virginia locality. This is certainly an error.

In the same year, a more important figure entered the scene when Dr. Joseph Leidy, the father of North American vertebrate paleontology, published (1847) his second paper on fossil vertebrates. In this case it was the skull of a camel from the Badlands which had made its way to Philadelphia before falling into the hands of an interested student.

Curiosity about the Badlands was sufficiently aroused by this time for David Dale Owen, United States Geologist, to send his assistant, John Evans, to the White River Badlands in 1849 and again in 1853. Evan's report on the 1849 trip was published as "Incidental Observations on the Missouri River, and on the Mauvaises Terres" in Owen's (1852) large work on the geology of Wisconsin, Iowa, and Minnesota. Fossil materials collected by Evan's party were sent for description to Joseph Leidy, as he was now the established authority on vertebrate fossils from the western territories.

The flood gates of exploration soon opened, and the 1850's saw Meek and Hayden making several (1853, 1855, 1857) trips into the area to explore and evaluate its potential. They returned with valuable collections of fossils from the Badlands, the Pine Ridge, and the valley of the Little White River for Leidy to describe.

The Civil War recessed this endeavor, as the main characters were busy with other matters: Hayden, for example, was an army surgeon.

With the end of hostilities the bone rush resumed. The Western Territories were open for exploitation and our culture was learning to live with and within The Great Plains (see Webb, 1931).

1870 saw Othniel C. Marsh enter the Badlands to collect specimens that were to place the Yale Peabody Museum ahead of the Philadelphia Academy of Sciences as a center of study for Oligocene fossils from the West. Marsh's collector, John Bell Hatcher, was among the first to collect intact and complete specimens, developing the beginnings of the collecting techniques used today.

In 1882 Princeton University moved into the field when Henry Fairfield Osborn and William Berryman Scott decided that fossils were "IN" and adventure was to be found in the fossil fields of the West. Adventure was certainly there. The Princeton party of 1882 was accompanied by a protective detachment of soldiers from the 9th Infantry. Upon returning home, they (Scott and Osborn) were much surprised to hear that the infantry detachment had been wiped out by Indians.

Table 1. Nomenclature chart for White River Badlands and Wounded Knee area.

Age	Hayden	OLDER WRITERS	WANLESS, 1923	MATTHEW, 1907 OSBORN, 1907,1909,1918	OTHER MODERN WRITERS	THIS PAPER
Lower Pliocene						Ogallala Group Undifferentiated Ash Hollow Formation
Middle Miocene			Rosebud Beds	Upper Rosebud Beds	Marsland Formation Schultz and Falkenbach 1940, 1950 Skinner, Skinner, and Gooris, 1968	Rosebud Formation
Lower Miocene		Sharps Formation considered Brule Formation or ignored. Hayden collected type of Palaeocastor nebrascensis in 1857. Specimen in typical Sharps nodule.		Lower Rosebud Beds		Harrison Formation
						Monroe Creek Formation
			White Ash Layer	Leptauchenia Zone	Gering Formation Schultz and Falkenbach 1941, 1954, 1956	Sharps Formation Harksen and Others, 1961 Rockyford Ash Nicknich and Macdonald, 1962
Upper and Middle Oligocene	Horizon "C" of Hayden	Leptauchenia Zone with Protoceras Sandstone Wortman, 1893	Leptauchenia — Protoceras Beds Upper Oreodon Red Clays Middle Oreodon Green Sandstones Upper Nodular	Matthew mistook the cemented zone in the Sharps Formation at St. Johns (see Osborn, 1918, fig. 7) for the White Ash Layer (Rockyford Ash) or base of the Miocene, i.e., Rosebud Beds.	Brule Formation Darton, 1899a	Brule Formation Darton, 1899a Poleslide Member Bump, 1956 Scenic Member Bump, 1956
	Horizon "B" and "C" of Hayden	Oreodon Beds Hayden, 1867 Oreodon Beds including Metamynodon Sandstone Wortman, 1893	Metamynodon Channels Lower Oreodon Banded Silts Lower Nodular Layer			
Lower Oligocene	Horizon "A" of Hayden	Palaeotherium Beds Evans, 1852 Titanotherium Beds Hayden, 1867	Limestone Sheet Titanotherium Beds		Chadron Formation Darton, 1899a Peanut Peak Member Clark, 1954 Crazy Johnson Member Clark, 1954 Ahearn Member Clark, 1954	Chadron Formation Darton, 1899a

Princeton students and graduates continued working in the Badlands into the present century, although the University's Museum's interests have now basically shifted to other fields.

By the turn of the century all of the large Eastern universities and museums had taken a turn at collecting White River fossils.

In 1899 the South Dakota School of Mines began taking students into the Badlands for short field trips. Slowly a fine collection of fossils was built up and a formal museum established. Under the direction of Glenn L. Jepsen and later James D. Bump, the School of Mines took over the major interest in the Badlands and was most actively engaged in fossil collecting.

The Chadron and Brule Formations were formally named by Darton (1899a) without the designation of a type section. Although describing rocks in western Nebraska he referred to the "typical" beds in the Big Badlands. Osborn (1929), in his monumental review of the "Titanotheres" i.e., Brontotheres, designated a type section for the Chadron Formation on Bear Creek northeast of the town of Scenic (**mile 41.9**).

When Wanless (1922, 1923) published a definitive study of the lithology and stratigraphy of the Badlands, he used lithologic and biostratigraphic names but did not use or equate his units to the formal formational names.

Schultz and Stout (1938) provided the names Orella Member and Whitney Member for the lower and upper parts of the Brule Formation in western Nebraska. These members have become the temporal bases for two North American Continental Provincial Ages, the Orellan and Whitneyan, but lithologically cannot be equated to rocks in the Badlands. In 1955 these authors designated a section at Toadstool Park, Nebraska, as the type section for the Brule Formation, but as Darton and earlier authors had already indicated the South Dakota Badlands as the typical area, the Toadstool Park section cannot be considered valid.

Bump (1956) described the Scenic and Poleslide Members of the Brule Formation in South Dakota, basing the Scenic Member on a section just south of Scenic, South Dakota (**mile 50.1**) and the section for the Poleslide Member at the south end of Sheep Mountain Table (**mile 59.5**). It is suggested elsewhere by Harksen and Macdonald (in preparation) that these be designated as the type section for the Brule Formation.

Although Bump (1951, fig., p. 34) included the White Ash Layer that caps the higher tables of the Badlands in his Brule Formation, it has traditionally been considered the base of the Miocene section (and the overlying Sharps Formation).

The Wounded Knee Area
(See Table 1)

In 1906 William D. Matthew and Albert Thomson of the American Museum of Natural History crossed the Badlands to prospect for early Miocene fossils on the Pine Ridge Indian Reservation. They hoped to find a fauna lying temporally between the White River (Brule) and the Agate Springs, Nebraska (Harrison) faunas. Deciding that the White Ash Layer (Rockyford Ash) (**mile 182.5**) was the boundary between Oligocene and Miocene, they moved south up Wounded Knee Creek where they lost the ash in the jumble of landslides and vegetation south of Windmill (Chimney) Butte. Mistaking the Sharps Formation for the Brule Formation, they did not begin prospecting until they reached Manderson.

At Manderson they decided the contact between the Brule and the Miocene beds was gradational, recognizable only by the fossil fauna. Actually they were looking at the Sharps-Monroe Creek gradational contact. Continuing south to Wounded Knee they collected up the section as they turned northeast and down Porcupine Creek, to Porcupine Butte. Matthew felt the whole post-Brule section should be referred to Gidley's (1904) Rosebud Beds and divided the local sequence into upper and lower moieties. The Lower Rosebud began near the top of the Sharps Formation, included all of the Monroe Creek Formation and the lower part of the Harrison Formation. The base of the sequence was the heavily cemented exposures of Sharps Formation (**mile 198.8**) just north of Bear Creek Hill. Thomson mistook this zone for the Rockyford Ash. The Upper Rosebud included the upper part of the Harrison Formation and the Rosebud Formation. Matthew published on the fauna in 1907.

The nomenclatural confusion resulting from the transference of the name "Rosebud Beds" to include all of the post-Sharps Formation sequence and the mistaking of the Sharps Formation for the Brule Formation on both Wounded Knee Creek and Porcupine Creek effectively stalled further study for many years. Occasional casual collecting in the area produced a few new taxa but no renewed study of the geology.

A careful collecting program begun by Macdonald in 1953 resulted in the discovery of the large vertebrate fauna from what was to be called the Sharps Formation. Detailed geologic mapping began in 1959 when Harksen joined the project. The naming of the Sharps Formation and the restriction of the name Rosebud Formation to the early middle Miocene portion of the sequence (which is a lithic continuation of the rocks exposed in Gidley's type area) straightened out the stratigraphy but raised howls of anguish in certain quarters.

The type section of the Sharps Formation is in two parts: the lower may be seen in the bluffs facing north toward the White River on the Wolff Ranch **(mile 182.5)**, and the upper part to the south of the Gooseneck Road on the west side of the divide between Porcupine and Wounded Knee Creeks **(mile 204.7)**.

In the "continuous" sequence of Chadron Formation–Brule Formation–Sharps Formation–Monroe Creek Formation–Harrison Formation–Rosebud Formation we have an extraordinary picture of the succession of terrestrial (i.e., mammal) life during the middle Tertiary in North America. This sequence is unique; its nearest approach is the Nebraska section south of the Chadron Arch, which is broken by an erosional interval between the "Miocene" portion of the "Brule Formation" and the overlying Gering Formation as defined by Darton (1899a).

The arbitrary use of the base of the Rockyford Ash as the Oligo-Miocene boundary may be open to debate. However, as the standard epoch boundaries are based on breaks in the European section, in a continuous North American sequence arbitrary boundaries must be selected. This ash is a prominent feature in the White River Badlands and has a tradition as a boundary marker. Until such a time as an absolute date has been determined for this boundary, one and all are invited to bring their bosun's chairs and buckets of red paint to mark their choice on the face of Sheep Mountain Table, Cedar Pass, the Pinnacles, and the cliffs on the south side of the White River.

The Monroe Creek Formation, which has a gradational contact with the Sharps Formation, is the prominent cliff-forming unit in southeastern Wyoming, western Nebraska, and southwestern South Dakota. It forms high bluffs wherever the Pine Ridge escarpment is seen. Named by Hatcher in 1902 out of Darton's (1899a) Arikaree Formation, it has enjoyed little controversy. Cook and Cook (1933) placed it in the Oligocene but this was generally ignored. Most of the scant fauna has been described from Nebraska. Macdonald (1963 and in press) recorded a few taxa from the Wounded Knee–Monroe Creek fauna. Bryant (MS) has identified some fifty taxa from a lot-sized concentration of ant hills about five miles east of Sharps Corner. In the Wounded Knee area the Monroe Creek Formation is largely composed of angular glass shards, which has some interesting but unstudied implications concerning its source and mode of deposition.

The Harrison Formation, also named by Hatcher (1902), is broken up by a series of concretionary layers at Bear Creek Hill and on the divide between Porcupine Creek and Wounded Knee Creek. This concretionary zone was Matthew's boundary between the Upper and Lower Rosebud Beds.

The Harrison Formation has produced an amazing fauna from near Agate, Nebraska. The remarkable Agate Springs *Diceratherium* Quarry and the nearby *Stenomylus* Quarry have recently become the center of a National Monument. The scientific exploitation of this site and the development of the Agate Springs Ranch into a paleontologists' rendevous and second home is a monument to the courtesy, hospitality, and keen scientific interest of Harold J. and Margaret Cook and Harold's father, Captain James H. Cook (see J. H. Cook, *Fifty Years on the Old Frontier*). At the time of her death in 1968, Margaret had completed editing some of the tapes left by Harold in 1962 to form a sequel to his father's work. This book has recently been published as *Tales of the 04 Ranch* (Cook, 1968).

A modern historic note should be included before leaving the Wounded Knee area.

Wounded Knee was the site of a tragic encounter between the Ogallala Sioux and the U. S. Army on the 29th of December 1890. Big Foot's band was headed into Pine Ridge after hiding out in the Badlands during the tension of the Ghost Dance period. They were met at Wounded Knee by a military detachment whose mission was to escort them to the Agency headquarters. An attempt was made to disarm the Sioux. The Medicine Man, Yellow Bird, was "inciting to riot." A shot was fired and when the smoke cleared away 146 Indians and 31 soldiers were dead. Many of the Indians were shot down at some distance from Wounded Knee when they attempted to flee the fight. Locally published accounts of this affair may be purchased at the Wounded Knee Store or Museum, and in Pine Ridge at the Pejuta Tepee (Medicine Lodge, Drug Store).

The Miocene and Pliocene of the Border – Pine Ridge to Martin
(See Table 2)

To the south of Wounded Knee lies the large east-west paleovalley bordered by the White Clay fault, the Pine Ridge and the Sand Hills to the south and the updip slopes of pre-valley early to middle Miocene sediments to the north. This valley was carved in post Rosebud Formation times (late middle and late Miocene) and filled with early Pliocene sediments as evidenced by the Ash Hollow Formation capping Porcupine Butte. Subsequent erosion removed much of these deposits. The sediments in this valley were not exploited for fossils by early workers as much more productive equivalent beds were available in northern Nebraska along the drainages of the Niobrara and Platte Rivers.

In 1855 Hayden was in the valley of the Little White River but until Gidley worked the Pliocene deposits at and near Big Spring Canyon in 1903 the area was virtually ignored. Formational names for these beds were readily given: Ash Hollow, Loup Fork, Nebraska Beds, Oak Creek Formation, and Little White River Beds. In general, most of these rocks are either lumped together into the Ogallala Group or occasionally the Ash Hollow and Valentine Formations are separated and identified.

University of California Museum of Paleontology parties, under the direction of R. A. Stirton, opened the Big Spring Canyon quarries in 1933 and continued their work in 1934. This fauna was described by Gregory (1942). While prospecting the underlying Rosebud Formation they discovered the Flint Hill quarry in beds that have now been designated as the Batesland Formation by Harksen and Macdonald (1967). A middle Miocene fauna equivalent in age to the Running Water fauna of Sioux County, Nebraska, was collected in 1936. This fauna has not yet been described although parts have been covered or listed in papers by Miller and Compton (1939), Miller (1944), Macdonald (1951b), Repenning (1967), Stirton (1967), and Harksen and Macdonald (1967).

Green (1956) described a small early Pliocene fauna from the Wolf Creek Drainage west of Pine Ridge.

The Miocene and Pliocene of the Border – Martin to Mission
(See Table 3)

In 1902 Gidley of the American Museum of Natural History went into South Dakota and along the Niobrara River in northern Nebraska. He returned in 1903 to collect along the Little White River in what he was to name the Rosebud Beds. In 1904 and 1906 Gidley published on some of the fossils and the geology of the area while Matthew described the remainder of the fossils.

Two actions were to cause a great deal of further confusion. Gidley (1904) did not designate a type section for the Rosebud Beds and Matthew (1907) (while describing the faunas collected the previous year on the Wounded Knee and Porcupine Creek drainages) used the name Rosebud Beds to include not only the Rosebud Formation in the Wounded Knee area but all the lower rock units down into the top of the Sharps Formation. It is not known whether Gidley concurred with this usage or not. The dividing out of the various formations in the Wounded Knee area was done by Harksen and others in 1961 and Macdonald in 1963. The selection of a type section for the Rosebud Formation was a horse

Table 2. Nomenclature chart for the Big Spring Canyon, Flint Hill, and Martin areas.

	MATTHEW AND GIDLEY 1904,1906	GREGORY, 1942	VARIOUS WRITERS	THIS PAPER
Lower Pliocene	Loup Fork	Ogallala Group		Ogallala Group
Lower and Middle Miocene		Arikaree Formation	Marsland Formation Skinner, Skinner, and Gooris, 1968	Batesland Formation Harksen and Macdonald, 1967
				Rosebud Formation
			Mellette facies Collins, 1960	Monroe Creek Formation ?
Oligocene				Not exposed.

Table 3. Nomenclature chart for the Rosebud Agency and Mission areas.

	VARIOUS WRITERS	SKINNER, SKINNER, AND GOORIS, 1968	THIS PAPER
Early Pliocene	Loup Fork Nebraska Beds Little White River Oak Creek Formation		Ogallala Group
Early, Middle and (?)Late Miocene	Mellette Formation Agnew, 1957 Mellette Facies of Arikaree Formation Sevon, 1959	Marsland Formation ? ? Rosebud Formation ? ? ?	Rosebud Beds Gidley, 1904
Oligocene			White River Group: Brule Formation Chadron Formation

In 1904 Gidley proposed the name "Rosebud Beds" for the pink silts exposed along the Little White River and in the vicinity of Rosebud Agency. In 1967 Skinner and Taylor indicated a preference for a type section which would have greatly restricted the temporal span of the Formation. Their preference was at Rosebud Agency and had neither top nor bottom. In 1968 Macdonald and Harksen, utilizing the entire sequence of pink beds exposed in this area along the Little White River selected a different type section. Both sets of Authors are second guessing Gidley. Macdonald and Harksen believe that theirs is a broader view and closer to Gidley's intent. Their selection puts the name Marsland Formation in jeopardy and expands the temporal span of the Rosebud Formation.

race due to some basically different philosophical concepts. Skinner and Taylor (1967), in what was essentially a footnote in a paper on the Bijou Hills, designated a type area near Rosebud Agency, representing a small portion of the total sequence. Macdonald and Harksen (1968) rewrote a completed paper describing the problem and presented their selection, the entire sequence of the lithic unit in the type area including the exposures on the Little White River. Their Rosebud Formation in the type area ranges in age from early Miocene into possibly the early part of the late Miocene.

Macdonald and Harksen believe that this sequence reflects local climatic conditions and depositional environments which did not exist further west until middle Miocene times. Thus their Rosebud Formation in the Rosebud Agency area is the temporal equivalent of the Sharps–Monroe Creek–Harrison–Rosebud sequence in the Wounded Knee area. They believe that the formations may vary in time laterally and should not be based on taxonomic units to the exclusion of lithology. Skinner and Taylor apparently were disregarding lateral lithologic variation as a geologic fact and were striving to preserve the term Marsland Formation as a unit name despite its spotted history and roving type section. Must we always be reminding our colleagues that rock units are no respectors of time boundaries and need not be confined to a designated piece of time, be the same age from one end to the other, nor be defined on the basis of contained fossils?

In 1915, Yale parties visited the Mission area to collect Pliocene mammals and Troxell (1916) published on part of the collection. Frick Laboratory parties frequently visited this area and collected along the whole of the Pine Ridge–Mission axis.

Macdonald (1960) described a small early Pliocene fauna from the Joe Thin Elk Gravel Pit north of Mission. Most of this fauna was collected at the base of the discard chute with a garden rake while the channel was being screened for select borrow during the rebuilding of U. S. 83 from Mission to the Nebraska border.

Prospecting and collecting continues in all these areas. It is unlikely that any more concentrations like Big Spring Canyon, Flint Hill, or the Thin Elk Gravel Pit will be found, but fossil hunters are an optimistic breed and may be seen working the outcrops on almost any hot summer day.

THE CENOZOIC HISTORY OF SOUTHWESTERN SOUTH DAKOTA

by
J. C. Harksen

The geologic history of the southwestern portion of South Dakota is a record told by a thickness of over 34,000 feet of exposed igneous, metamorphic and sedimentary rocks. Over 30,000 feet of exposed rock are representative of pre-Cenozoic time while the remaining 4,000(+) feet represent the Cenozoic. Darton and Paige (1925), Page and others (1953), Slaughter (1968), and many other authors including C. C. O'Harra, J. P. Connolly, and J. P. Gries have presented a wealth of information on the pre-Cenozoic geology of the Black Hills region. To aquaint the reader with the local nomenclature figure 1 shows the rock column for the Black Hills region, figure 2 shows the Cambrian and later deposits in greater detail, and figure 3 presents the Tertiary strata present in southwestern South Dakota. As this field trip is primarily involved with the Cenozoic we shall begin our story with the Laramide Revolution.

Western South Dakota (fig. 4) in late Cretaceous time was covered by a large inland sea. The sediments deposited during this inundation are now represented in ascending order by the Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Chalk, Pierre Shale, and Fox Hills Sandstone (see fig. 2). The Fox Hills represents the last marine deposit of the Cretaceous while the top of the Hell Creek Formation (a swamp and brackish water type of deposit complete with coal and dinosaur bones) marks the end of the Cretaceous in South Dakota. As the Cretaceous Period was drawing to a close a general uplift was taking place in the areas that were to become the Black Hills and Rocky Mountains. As soon as these areas rose above base level, wind and stream erosion began to remove the soft Cretaceous rock that had just been deposited.

While the Black Hills area was rising the Williston Basin (fig. 5) continued to receive sediments. There is little difference between the lithology of the upper Hell Creek (Brown, 1907) and the lower Fort Union (Meek and Hayden, 1862). The contact between the two is usually drawn at the base of a prominent coal bed (the Shadehill Coal facies of Stevenson, 1954) or just above the last occurrence of dinosaur remains.

During the Paleocene the Williston Basin received sediments which formed the Ludlow, Cannonball, and Tongue River Formations of the Fort Union Group. The Cannonball Formation represents the last positive marine invasion of South Dakota. Recently shark material has been collected from the Tongue River Formation of South Dakota by Pipiringos and others (1965). This find probably represents sharks temporarily entering a brackish water environment rather than sharks in their normal marine environment. Figure 6 shows the outcrop area of the Fort Union Group in South Dakota – note that it does not extend into the area covered on this field trip.

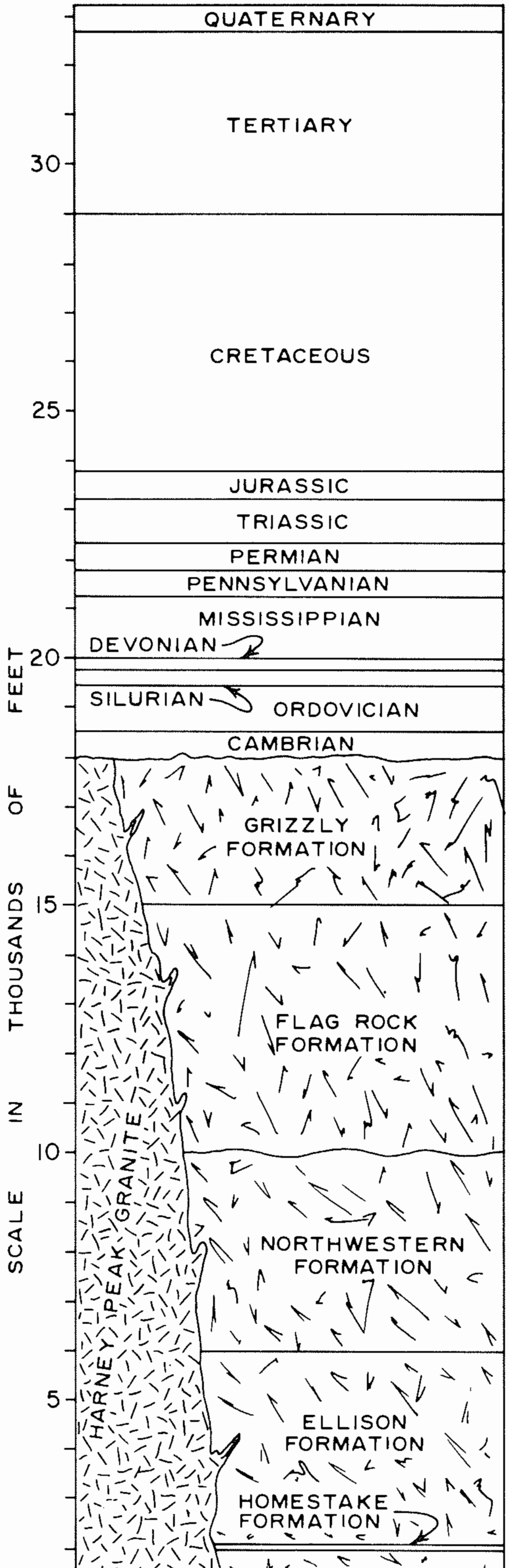
Very little is known of the Eocene history of South Dakota. In Harding County, there are two stratigraphic units which have been referred to the Eocene.

Bjork (1967) reports that in the Slim Buttes area there are deposits which are quite similar, lithically, to the Golden Valley Formation of North Dakota. The Golden Valley Formation has been assigned to the Wasatchian (early Eocene) by Jepsen (1963). The Golden Valley is the same unit that has been mapped by Petsch (1955a, 1955b) as the "golden zone."

A second stratigraphic unit, also of very limited extent, is the Slim Buttes Formation of Malhotra and Tegland (1960). This unit has been assigned an age of Duchesnean (latest Eocene) by Bjork (1967).

These two units, both probably restricted to Harding County, are the only remnants we have of the 20,000,000+ years of the Eocene Epoch in South Dakota. Undoubtedly there was a tremendous amount of deposition, evolution, and erosion that took place in South Dakota during this time – but at present we can do little more than infer the history from what is known of adjacent regions.

During the Eocene the Black Hills region was subjected to continued erosion. The



This is an attempt to compare, with some trace of realism, the relative thickness of the Precambrian lithic units of the northern Black Hills with the thickness of strata deposited during each subsequent period in western South Dakota. This figure was drawn primarily from material presented by Schoon (1968) and Slaughter (1968). The Harney Peak Granite is shown as a "time" rather than as a true thickness or lithic relationship.

Figure 1. Columnar section of the Black Hills region.

PERIOD / EPOCH	GROUP / FORMATION	DESCRIPTION	THICKNESS
QUATERNARY	PLEISTOCENE	Sand, gravel, boulders.	0-60
TERTIARY — MIOCENE	ARIKAREE GROUP	Clay and silt, light colored, soft to cemented, white ash bed at base.	0-500
TERTIARY — OLIGOCENE	WHITE RIVER GROUP	Clay, pink, sandy and silty, chalcedony veins, massive.	0-600
TERTIARY — PALEOCENE	FORT UNION — TONGUE RIVER	Clay and sand, light colored, minor thin coal beds.	0-400
	FORT UNION — CANNONBALL	Shale, greenish gray, sandstone, yellow to buff as concretions and channel filling.	0-225
	FORT UNION — LUDLOW	Clay and sandstone, somber gray with some thin lignite beds. Shadehill (?) coal at base.	0-350
CRETACEOUS	HELL CREEK FORMATION	Shale, drab, soft brown (somber beds) and sandstone gray. Sandstone increases toward base. Thin lenses of lignite in upper part.	0-325
	FOX HILLS FORMATION	Sandstone, grayish white to carbonaceous gray shale. Ironstone concretions at top.	0-200
	PIERRE SHALE	Shale, light gray to dark gray.	2800
	NIOBRARA FORMATION	Chalk, light to dark gray, white speckled, microfossiliferous.	270
	CARLILE SHALE	Shale, medium to dark gray plastic to fissile - scattered ironstone concretions.	320
	GREENHORN LIMESTONE	Limestone, white to light gray, slabby, very fossiliferous with dark gray, white speckled shale at top and at base.	70
	BELLE FOURCHE SHALE	Shale, dark gray, dolomite and ironstone concretions.	370
	MOWRY SHALE	Shale, medium gray, siliceous, bentonite marker at top.	275
	NEWCASTLE SANDSTONE	Sandstone, white to light gray, fine-grained in part, very shaley.	0-100
	SKULL CREEK SHALE	Shale, dark gray with thin glauconitic siltstone near middle of interval.	200-250
	INYAN KARA GROUP (FALL RIVER AND LAKOTA SANDSTONE)	Sandstone, white to light gray, fine to medium-grained quartz, predominately friable.	320
JURASSIC	MORRISON FORMATION	Shale, medium gray, interbedded with sandstone, white, fine grained, glauconitic.	180
	SUNDANCE FORMATION	Sandstone, white, fine to medium grained, glauconitic, interbedded with shale, gray, green and brown.	320
TRIASSIC	PIPER LIMESTONE	Limestone, white to brown, fine grained, interbedded with shale, green, red and brown.	90
	SPEARFISH FORMATION	Shale, silty, orange, brick red, green and minor gray. Interbedded with anhydrite, gypsum and salt.	0-600
PERMIAN	MINNEKAHTA LIMESTONE	Limestone, white to lavender, fine, dense.	0-50
	OPECHE SHALE	Shale, brick red, silty.	0-50
	MINNELUSA — CASSA[3]	Sandstone, white, brick red, clayey.	0-80
	MINNELUSA — BROOM CREEK[3]	Anhydrite, white to light brown, limestone and dolomite, white to light gray, silty.	80-300
PENNSYLVANIAN	MINNELUSA — WENDOVER-MEEK[3]	Limestone, dolomite, light gray, fine, silty, anhydrite, light brown and gray. "Red Shale Marker" at top.	175-200
	MINNELUSA — HAYDEN[3]	Limestone, light gray to brown interbedded with black radioactive shale.	140-170
	MINNELUSA — ROUNDTOP[3]	Shale, green to minor red, plastic, sands up eastward	100-160
	MINNELUSA — RECLAMATION[3]	Ls. white to black, lithographic, varicolored shale	0-80
	MINNELUSA — FAIRBANK[3]	Sandstone, white to red, in part shaley.	0-100
MISSISSIPPIAN	KIBBEY SANDSTONE	Sandstone, white to gray, medium to coarse grained.	0-120
	CHARLES FORMATION	Limestone, white to light tan, lithographic, interbedded with anhydrite, white to light blue and light brown.	0-400
	MISSION CANYON FORMATION	Limestone, white to light tan, fine to oolitic, in part anhydritic.	120-320
	LODGEPOLE FORMATION	Limestone, light to medium brown, gray, fine to medium grained, in part sucrosic.	120-550
	ENGLEWOOD	Dolomitic siltstone and varicolored shale	0-60
DEVONIAN	DUPEROW	Light brown, fine grained limestone and dolomite, interbedded with thin gray shale.	0-240
	SOURIS RIVER	Varicolored shale and red dolomitic siltstone	0-30
SILURIAN	INTERLAKE	Light tan to brown dolomite, fine grained clastics at base.	0-250
ORDOVICIAN	STONEWALL	Light tan to pale dolomite, locally sandy.	0-75
	STONY MOUNTAIN	Brownish gray fine grained dolomite at top with green waxy shale and siltstone at base.	0-155
	RED RIVER (UNIT A)	Light brown to pale red	0-115
	RED RIVER (UNIT B)	limestone, in part dolomitized, and light colored chert. Threefold subdivision is mainly based	0-320
	RED RIVER (UNIT C)	E-log characteristics.	0-100
	WINNIPEG	Fine grained quartz sandstone at base, green, splintery to subwaxy shale with small vitreous black phosphate nodules interbedded with siltstone at top.	0-150
CAMBRIAN	DEADWOOD	White to reddish-orange, fine to medium grained quartz sandstone and dolomite, contains green shale partings and locally abundant glauconite.	0-630
PRECAMBRIAN		Igneous and metamorphic rock.	

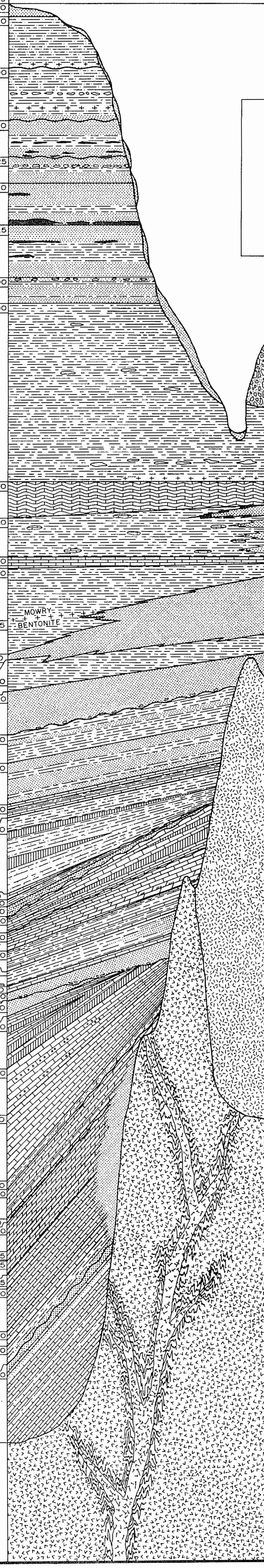


Figure 2. Stratigraphic section of northwestern and central South Dakota. This section is taken from Schoon, 1968.

THICKNESS	DESCRIPTION	GROUP / FORMATION	PERIOD / EPOCH
0-500	Clay, sand, pebble and boulder mixture.	PLEISTOCENE	QUATERNARY
1000-1300	Shale, medium to dark gray with limestone and ferruginous concretions. Many thin bentonites. Shale, dark gray, carbonaceous. Bentonite at base.	PIERRE SHALE	CRETACEOUS
120-150	Chalk, light to dark gray, white, speckled, microfossiliferous	NIOBRARA FORMATION	
0-70	Sandstone, white to gray, glauconitic.	CODELL SANDSTONE	
330	Shale, medium to dark gray, plastic, ironstone concretions and stringers of fine grained sandstone.	CARLILE SHALE	
40	Limestone, white to light gray, fossiliferous.	GREENHORN LIMESTONE	
110	Shale, dark gray, fissile to blocky, ironstone concretions.	GRANEROS SHALE[1]	
450	Sandstone, white, fine to medium grained, friable to well consolidated.	DAKOTA SANDSTONE[2]	
0-150	Sandstone, dark gray, glauconitic, siltstone near middle part.	SKULL CREEK SHALE	
0-225	Sandstone, white, fine to coarse grained quartz.	INYAN KARA GROUP	
0-7000 ?	Sioux Ridge composed of pale maroon to red orthoquartzite.	SIOUX QUARTZITE	PRECAMBRIAN
	Igneous and metamorphic rock.		

1 As defined by Hattin, D.E., 1965. Stratigraphy of the Graneros Shale (Upper Cretaceous) in Central Kansas. Kansas Geological Survey, Bull. 178, 83 pp.

2 As described by Meek, F.B., and Hayden, F.V., 1861. Philadelphia Academy of Natural Resources Proceedings, v. 13, p. 419-20.

3 Condra, G.E., Reed, E.C., and Scherer, O.S., 1940. Correlations of the Formations of the Laramie Range, Hartville Uplift, Black Hills and western Nebraska. Nebraska Geological Survey Bull. 13, 52 pp.

In view of the equivalency of the Hartville "Formation" and the Minnelusa, the Hartville subdivisions are employed in the Minnelusa in South Dakota.

SOUTH DAKOTA GEOLOGICAL SURVEY

DJ

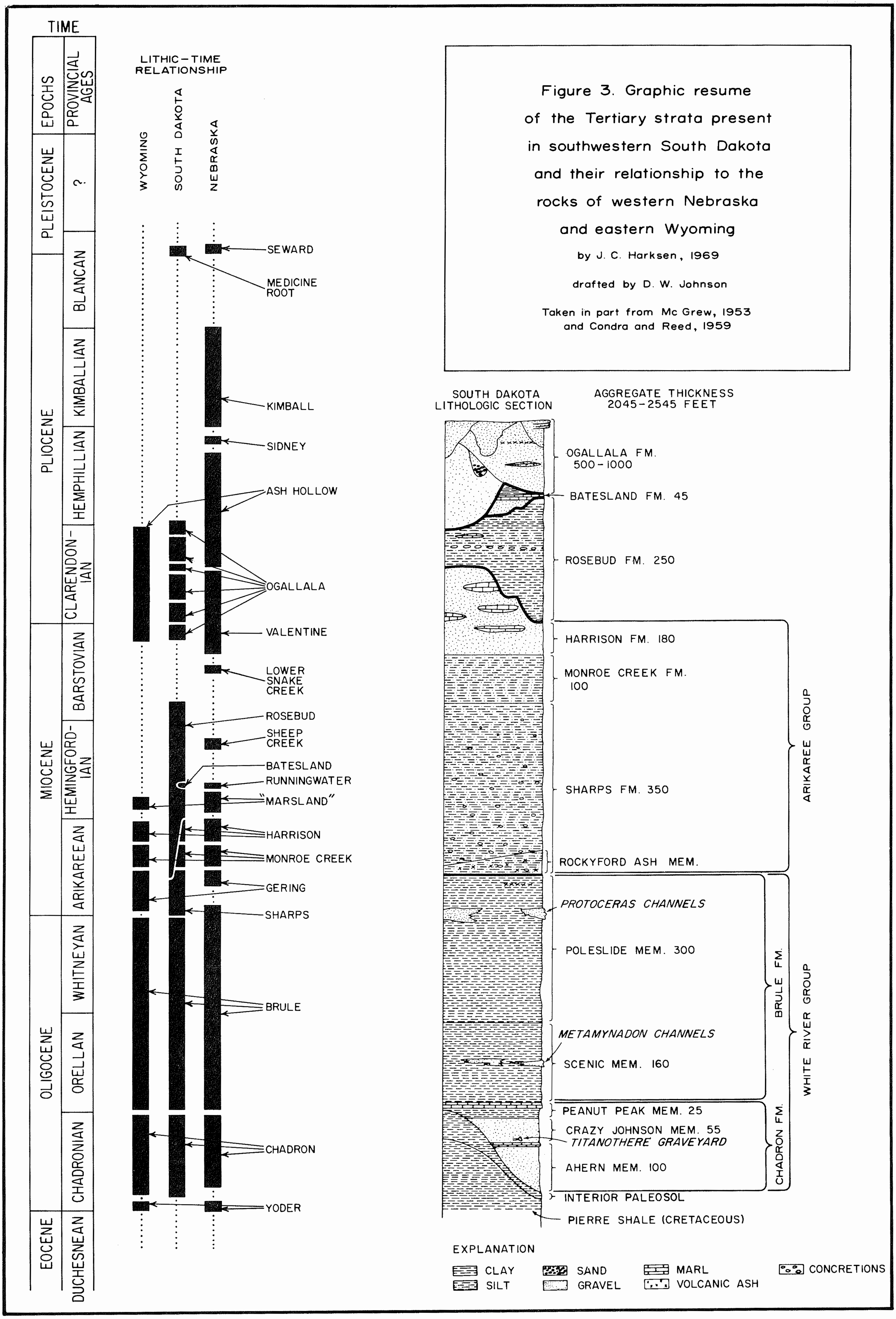


Figure 3. Graphic resume of the Tertiary strata present in southwestern South Dakota and their relationship to the rocks of western Nebraska and eastern Wyoming

by J. C. Harksen, 1969

drafted by D. W. Johnson

Taken in part from Mc Grew, 1953 and Condra and Reed, 1959

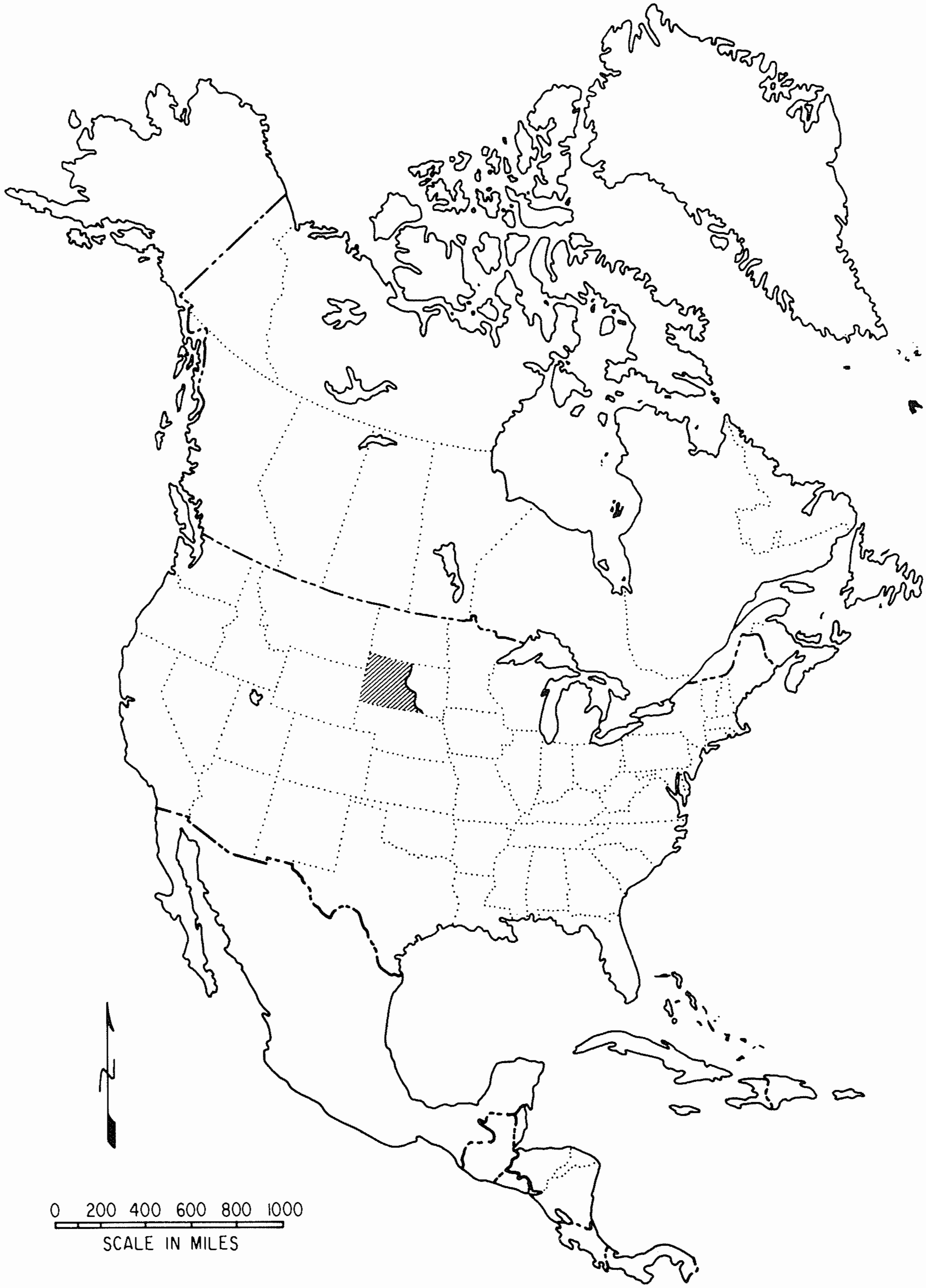


Figure 4. Outline map of North America with western South Dakota (that area of South Dakota west of the Missouri River) shaded in.

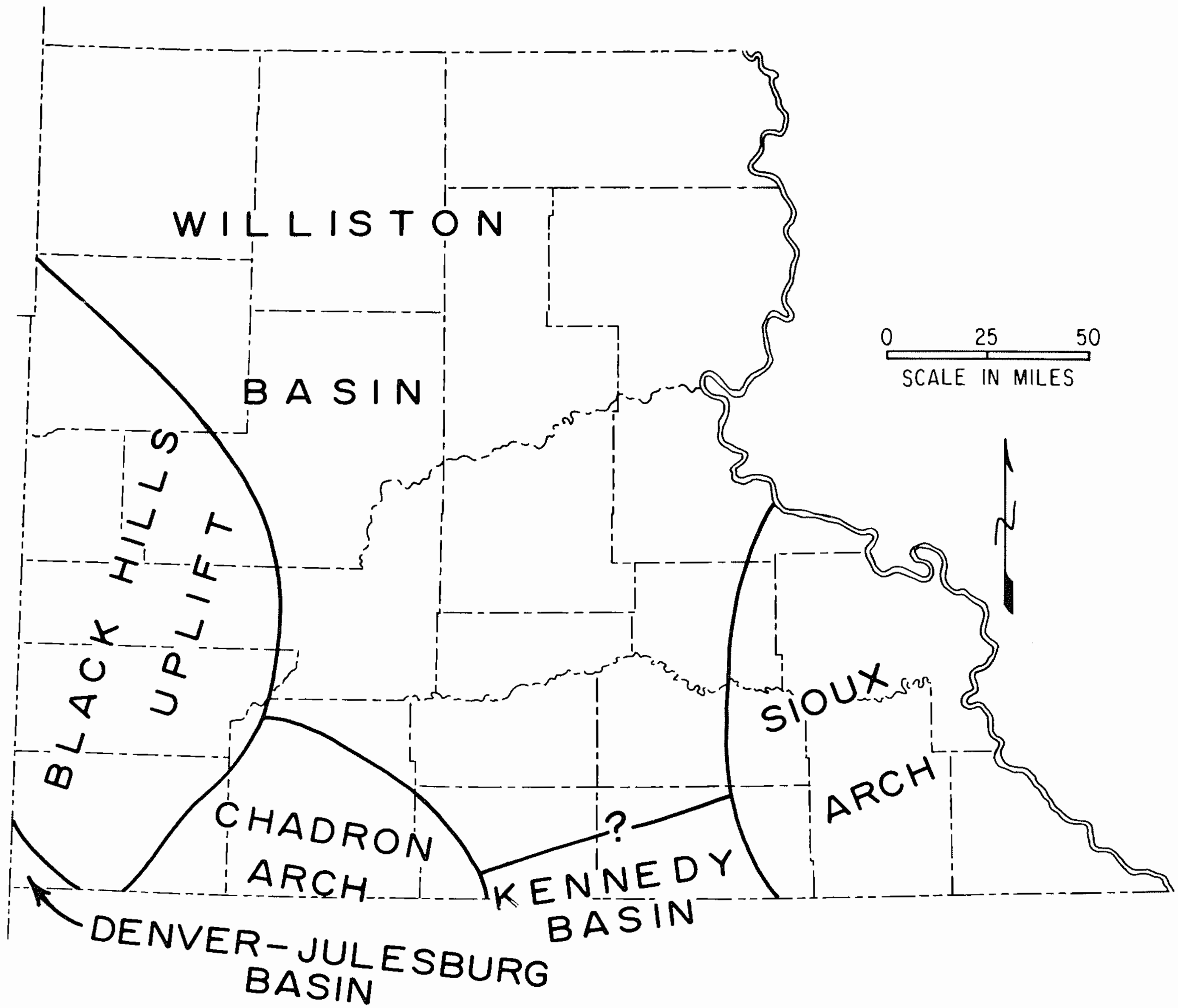


Figure 5. County outline map of western South Dakota showing the relative positions of the Black Hills Uplift, Chadron Arch, Sioux Arch, Williston Basin, Denver-Julesburg Basin, and the Kennedy Basin.

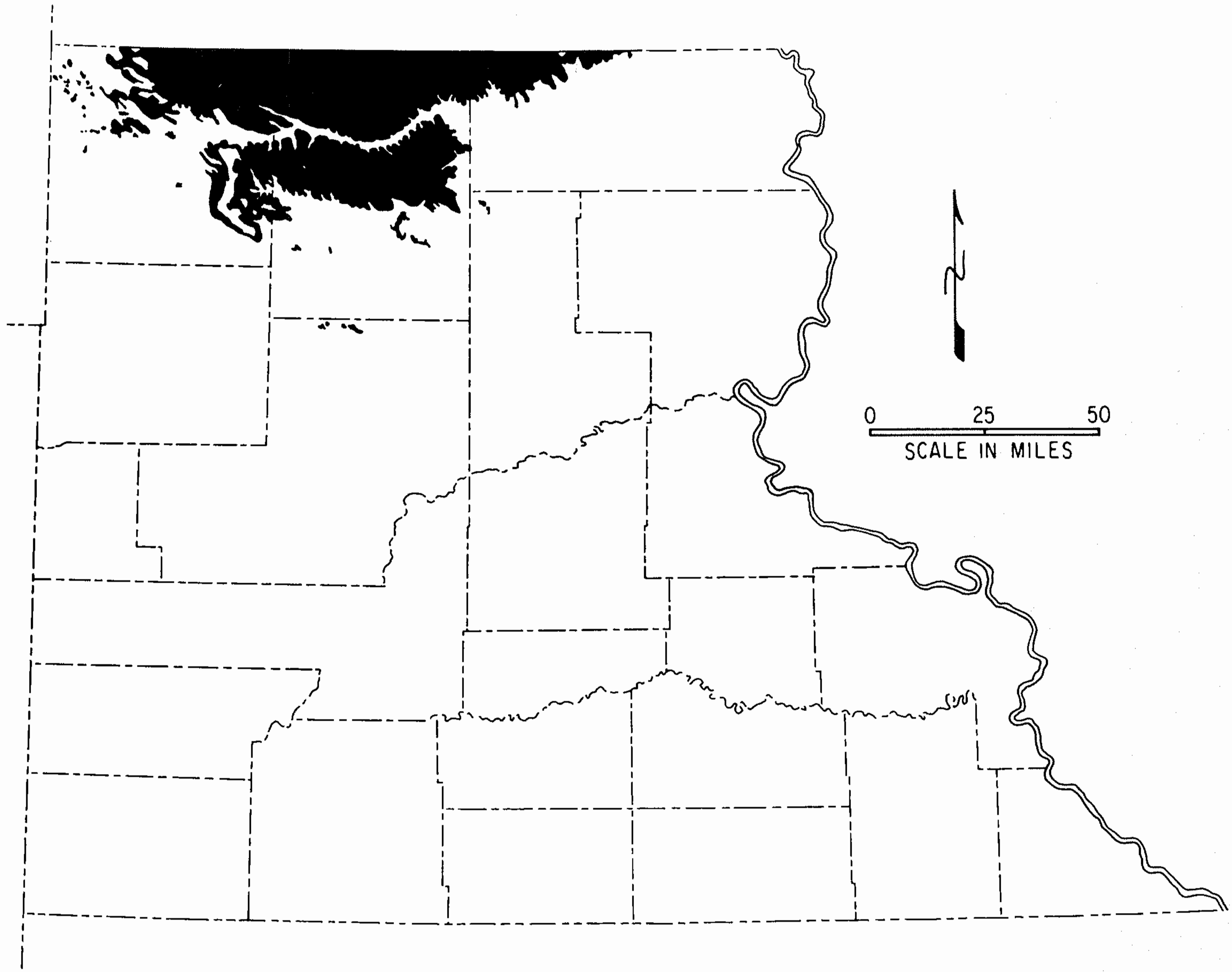


Figure 6. County outline map of western South Dakota showing the outcrop area of the Fort Union Group.

streams radiated away from the center of the Black Hills much like the spokes on a buggy wheel. Weathering, soil formation, and erosion continued at a rapid rate with erosion probably stripping away the soil as fast as it was formed.

At approximately the Eocene–Oligocene boundary the erosion of the low lying areas slowly came to a halt and the deposition of sediments began. Near Yoder, Wyoming, the first deposition of Oligocene sediments began with the deposition of the Yoder Formation (Schlaikjer, 1935). The Yoder Formation is Oligocene and yet is older than the Chadron Formation as found in North Dakota, South Dakota, Nebraska, Eastern Colorado, or eastern Wyoming (Wood and others, 1941).

Weathering and erosion were going on in South Dakota while the Yoder Formation was being deposited in Wyoming. During early Oligocene time the Interior Paleosol of Ward (1922) was formed. Pettyjohn (1966) concluded that the Interior Paleosol was of Eocene age. However, the writer believes that the formation and removal of any soil, in either a depositing or eroding environment, is a continuing, never-ending process. The writer also believes that the time represented by the Yoder Formation is sufficient for removal of all the soil formed during the Eocene and replacement of it with soil formed during the Oligocene.

This hypothesis is further strengthened by Bjork (MS) who reports an Interior-like soil formed on the Slim Buttes Formation (latest Eocene) and by the writer's observation that seldom is the paleosol very well developed below the earliest Chadron in the Big Badlands of South Dakota. It should be noted however that Clark and others (1967) believe the Ahern Member of the Chadron to be an age equivalent of the Yoder Formation. If this is true it would invalidate the writer's conclusions on the age of the Interior Paleosol.

At the end of the Eocene the rim of the Black Hills had about the same relief as today. The writer believes this is well displayed by the location and elevation of the many deposits of the White River Group which are scattered throughout the Black Hills (Darton and Paige, 1925).

Inside Wind Cave National Park in the "racetrack," Roger Barker and the writer measured one 240-foot section of the White River Group. This shows to what extent the racetrack of the southern Black Hills had been excavated in Eocene or very early Oligocene time, filled with Oligocene sediments, and finally reexcavated in fairly recent time. This observation brings into focus a very interesting problem. If the Black Hills were essentially excavated to their present state by late Eocene time then where was the origin of the major part of the volume of sediments forming the Oligocene, Miocene, and Pliocene of southwestern South Dakota?

The Chadron Formation (Darton, 1899a) is the lower of the two formations in the White River Group (Meek and Hayden, 1958) of South Dakota. Figure 3 shows the stratigraphic relationships of the subdivisions of the White River. Henry Fairfield Osborn (1929) designated a type section for the Chadron along Bear Creek in Pennington County, South Dakota, the area from which the Chadron (Titanotherium or Paleotherium beds) had been classically studied, collected, and named. The Chadron reaches a maximum thickness of about 180 feet in the Indian Creek–Battle Creek Draw area of the Badlands (Hatcher, 1893). It should be noted that badlands (uncapitalized) refers to any area of badlands but Badlands (capitalized) refers to the White River Badlands of South Dakota (Macdonald, 1951a).

The Chadron of the Indian Creek–Battle Creek area has proven to be the thickest as well as the most fossiliferous Chadron in the Badlands. In addition this is the area where Clark (1937, 1954) named the Ahern, Crazy Johnson, and Peanut Peak members. It is unfortunate that this area apparently is a structural trap and as such the sediments from this immediate area are lithically dissimilar to the rest of the Chadron. The Ahern, Crazy Johnson, and Peanut Peak lithologies can only be traced for a few miles in any direction.

The Chadron was deposited in what can only be interpreted as a paleovalley. This valley was on the magnitude of 175 feet deep and it took the better part of Chadronian time to fill it with sediments. In places only a few feet of Chadron separate the Brule Formation from the Pierre Shale.

The Brule Formation (Darton, 1899a) is the uppermost formation in the White River

Group (fig. 3). The Brule Formation is about 460 feet thick in the vicinity of Sheep Mountain Table where Bump (1956) placed the type sections for the Scenic and Poleslide Members.

The Brule is a combination of fluviatile and eolian deposits. Streams, with the help of wind, deposited this great thickness of highly fossiliferous pink sands, silts, and clays. A change in the climate between Chadron and Brule time is shown by certain differences in the faunas. For example while alligator fossils are relatively common in the Chadron only one has been reported from the Brule (Wilson and Tucholke, 1967). The beds have varying hardness and so the Brule weathers into a tread and riser type of topography in opposition to the haystack topography of the Chadron. The river channels in the Scenic Member are called *Metamynodon* channels because the remains of the river rhinoceros *Metamynodon* are found in them. The river channels in the Poleslide member are called *Protoceros* channels because that is the only place where the artiodactyl *Protoceras* has been collected. It may be noted here that *Protoceras* channels are only found in certain areas of the Brule of South Dakota.

The Arikaree Group was named by Darton (1899a) and redefined by Hatcher (1902). In western Nebraska the Arikaree Group is composed of the Gering, Monroe Creek, and Harrison Formations while in South Dakota (fig. 3) it is composed of the Sharps, Monroe Creek, and Harrison Formations. The Arikaree Group was deposited during the first third of Miocene time.

The Sharps Formation was named by Harksen and others (1961) for about 350 feet of pink silts which overlie the Brule Formation and in turn are overlain by the Monroe Creek Formation. At the base of the Sharps Formation is the Rockyford Ash Member (Nicknish and Macdonald, 1962) which is a light-colored band of impure volcanic ash.

At the beginning of Miocene time volcanic eruptions in northwestern Wyoming produced vast quantities of volcanic ash which were wind carried into South Dakota. Apparently the ash was deposited on a surface where the wind was able to move it around before final burial by later sediments. The Rockyford, because of the wind reworking, is an impure ash with gradational upper and lower contacts. Also its thickness is highly variable ranging up to 55 feet on the south end of Sheep Mountain Table.

The remaining thickness of the Sharps Formation is made up of pink silt and clay, mostly wind deposited, that typically contains a great many small, randomly spaced concretions. A great many of the animals that lived during Sharps time have been preserved in the concretions. This gives us an excellent picture of the vertebrate life of the early Miocene of South Dakota.

After the deposition of the Oligocene Brule Formation deposition of sedimentary rocks continued in the northern Great Plains. The basal Miocene unit is the Rockyford Ash, a unit apparently not reported from the states surrounding South Dakota. The remainder of the Sharps Formation was deposited on top of the Rockyford Ash. Part way through Sharps time a period of erosion took place. This erosion is shown in Nebraska by the unconformity between the Brule and the Gering and in South Dakota by the Godsell Ranch Channel (Macdonald, 1963) in which one Sharps channel cuts down through older Sharps into the Brule Formation. A channel within the Miocene rocks capping Cedar Pass may also be related to these phenomenon. At any rate the earliest Miocene rocks of Nebraska are called Gering Formation while those of South Dakota are called Sharps Formation. These two stratigraphic units are lithically dissimilar, the Gering is a sand and the Sharps is basically a silt, and are separated by the uplift called the Chadron Arch. Some authors (Schultz and Stout, 1961, and Schultz and Falkenbach, 1968) who confuse time units and rock units regard the Sharps Formation as a synonym of the Gering Formation.

The Monroe Creek Formation (Hatcher, 1902) of South Dakota varies in thickness from 100 feet along Porcupine and Wounded Knee Creeks to a considerably increased thickness in the area around Martin. The Monroe Creek is a tan to grayish-buff, massive well compacted series of sandy silts. It is a paleo-loess type of deposit and therefore in typical outcrops it is vertical weathering. This phenomenon is well exhibited between Manderson and Wounded Knee and between Sharps Corner and Porcupine.

As is mentioned above, the Monroe Creek is a paleo-loess. This may be a misnomer to some extent as the formation is composed of a high percentage of volcanic ash (see Bryant, MS) which is mixed with non-volcanics of clay through sand size. The high percentage of volcanic material in the Monroe Creek (as high as 80% in some samples) indicates that there was tremendous volcanic activity, probably in northwestern Wyoming, at this time.

The Harrison Formation (Hatcher, 1902) is the upper formation in the Arikaree Group. The Harrison is represented in the area of Porcupine and Wounded Knee Creeks by about 160 feet of gray, noncalcareous, moderately consolidated silty sand. Calcareously cemented channels, concretionary ledges and bedded marls give the exposures a bedded or step-like appearance.

The lithology of the Harrison is typically exposed in a roadcut (mile 228.7) a short distance north of Wounded Knee. At this point one sample of Harrison was analyzed. Mechanical analysis indicated 0.14% medium sand, 3.53% fine sand, 62.50% very fine sand, and 33.80% silt and clay. True mechanical analysis is difficult because of the high percentage of bubbles and shards of volcanic ash. These are right next to sand-sized agglomerations of silt particles. Breaking down the sand-sized agglomerations of silt particles without crushing the shards and bubbles is a difficult operation. Volcanic materials constitute 70-80% of the fine sand and 30-40% of the very fine sand in the one sample on which mechanical analysis was run.

A cyclic depositional phenomenon is described in the sediments of the Harrison Formation by Harksen (1965, 1968b). The marls in the Harrison represent chemical and clastic deposition in small bodies of water. However, the big picture of the deposition environments of the Harrison is at present unknown.

The Rosebud Formation was named by Gidley (1904) and further defined by Macdonald and Harksen (1968). The Rosebud of South Dakota extends from western Gregory County to near Ogallala in Shannon County, a distance of about 150 miles. The Rosebud reaches its maximum thickness near Rosebud, South Dakota, where it is in excess of 300 feet.

Contrary to Harksen (1965, 1967b) the Rosebud Formation unconformably overlies the Harrison Formation. The Rosebud is in turn unconformably overlain by later deposits such as the Batesland and Ogallala.

The Rosebud Formation of the Porcupine Butte area was deposited during a restricted portion of Hemingfordian time. Apparently the time represented by the formation expands greatly as one travels to the east until at the type section the formation is representative of time ranging from early Arikareean to early Barstovian (see fig. 3). The depositional environment apparently expanded from east to west and then retreated. This type of expanding and shrinking environment has allowed the Rosebud to be in part time equivalent of the Sharps, Monroe Creek, and Harrison Formations and at the same time overlie them!

The exact type of environment represented by the Rosebud Formation is not known at this time. The writer feels that some type of swamp or lowland-alluvium type of deposition is represented in contrast to the loess-like deposition of the Monroe Creek or the river channel deposition of the Batesland. It is hoped that future work on the Rosebud of South Dakota and Nebraska will shed some light on both the age and depositional environment of this interesting and controversial unit.

Lying unconformably upon the Rosebud Formation in Bennett and Shannon Counties is a stratigraphic unit, the Batesland Formation (Harksen and Macdonald, 1967), which is essentially an age equivalent of the Runningwater Formation (Cook, 1965) of Nebraska. The Batesland Formation, while small in areal extent, is definitely a mappable unit (see Harksen, in preparation) and meets all other criteria for being a valid unit as set forth by the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1961).

At the type section, the Batesland is about 45 feet thick. The upper contact is unconformable but the elevation of distant outcrops indicates that possibly 250 feet of Batesland was once present in this area.

The Batesland Formation at one area has produced a wealth of vertebrate fossils. This area, discovered by P. O. McGrew, was quarried by the University of California during the 1930's and was given the designation of the "Flint Hill" quarry. An exceptionally large fauna was collected from this site as has been abstracted by Macdonald (1951b) and

Harksen and Macdonald (1967).

The Batesland Formation is a stream deposit filling a paleovalley. Varied types of lithologies are present from clay-pebble conglomerates to limestones and clays. The color is generally light green with outcrops appearing white from a distance. Morton Green of the South Dakota School of Mines and Technology is at present collecting and studying a micro-mammal fauna from both the site of the "Flint Hill" quarry and the type section of the Batesland Formation.

The Pliocene is represented in southwestern South Dakota by the Ogallala Group. Three extensive faunas have been collected and reported from these rocks by Gregory (1942), Green (1956), and Macdonald (1960). While the Ogallala is seldom cited as being thicker than 300 feet (Sevon, 1961, gave a maximum thickness of 350 feet for the Ogallala Group in the Vetal quadrangle) the writer believes that when the history of cut and fill during Ogallala time is unraveled a thickness of well over 1000 feet will be represented.

The modern pioneer work of mapping the Tertiary of southwestern South Dakota was done by Allen F. Agnew, former State Geologist of South Dakota. Agnew mapped the White River and Mission quadrangles (Agnew 1957, 1964) and directed work done by Sevon, Collins, and Harksen in the late 1950's and early 1960's. Agnew's concept of the Ogallala (Agnew and Tychsen, 1965) was that it consisted of the Valentine (lower) and Ash Hollow Formations. The Bijou Formation of Stevenson (1953) has been considered invalid since a flurry of papers – Agnew (1958a), Stevenson (1958a), and Green (1958) – appeared in print. The Valentine (according to Agnew and Tychsen, 1965, who cite Agnew, 1958b) is generally loose and uncemented sand and silt in contrast to the Ash Hollow which is generally well cemented and possessing a network of calcareous plant rootlets and clumps of *Celtis* seeds.

In addition Agnew (1958b) states, "A bed of volcanic ash at the contact of Valentine and Ash Hollow is widespread." Sevon (1961) states that the Valentine was conformably overlain by the Ash Hollow Formation. He further states, "A creamy white thin-bedded limestone locally occurs in the lower part of the Ash Hollow. The limestone is hard, contains small black dendritic structures, weathers brilliant white, and ranges from 6 inches to 1½ feet in thickness. Skeletons of small fish are locally present in this unit. A 1-2 foot zone of diatomaceous earth is locally associated with the limestone. . . . .The limestone and the diatomaceous earth have been used arbitrarily to mark the base of the Ash Hollow Formation."

The diatomaceous earth and limestone deposits found in the Ogallala are indicative of small lakes which were present throughout Ogallala time and are scattered throughout the section. Two of the most interesting diatomaceous deposits are at **mile 295.0**. At this point there is one on each side of the road and the one on the north side of the road is 61 feet higher than the one on the south side of the road.

The Sharps and Gering Formations along with the Batesland and Runningwater Formations show that different lithologies can be deposited at the same time in the neighboring states of Nebraska and South Dakota. Indeed the Rosebud Formation suggests that different lithologies were being deposited, only a short distance apart, in one depositional basin during most of the Miocene. It was possibly a mistake to transpose the Nebraska names, Ash Hollow and Valentine, to the South Dakota section without a lot more study. By this the writer does not mean to criticize Skinner and others (1968) – quite the contrary, the writer lauds their work on the Ogallala. In addition the cemented Ogallala is an indication of either a slowing of deposition or a cementation due to subsurface water flow and can be found throughout the section.

During the Tertiary the main geological factor in western South Dakota (figs. 4 and 5) was deposition. Although periods of erosion were interspersed with periods of deposition, deposition nevertheless far exceeded erosion. Near the end of the Pliocene Epoch the states of Texas, Oklahoma, Kansas, Nebraska, South Dakota, Wyoming, Colorado, and New Mexico were to a greater or lesser extent buried beneath a flood of sediments (mostly poorly consolidated sand) which spread eastward from the Rocky Mountains and Black Hills. These alluvial sediments, sometimes several hundred feet thick, were called "Mortar beds," "Tertiary grit," or "Magnesia beds" until Darton (1899a) designated these sediments as the Ogallala Formation.

Apparently a state of near equilibrium was reached in the midcontinent region in late Pliocene time. The depositional surface on top of the Ogallala became a very flat area of very low gradient which stretched as a gently sloping plain from southern Texas to South Dakota. This flat depositional surface is called the High Plains. A paleotopographic map showing the surface of South Dakota in late Pliocene time is shown as figure 7. It is to be noted that the altitudes given in figure 7 are the altitudes that the High Plains would have today if uplift without erosion had taken place. The gradient on the Ogallala, as shown in figure 7, is about 9.75 feet per mile. The actual depositional gradient was probably only about half this figure. See Frye and Leonard (1964) for comments on the deposition surface on the Ogallala of Texas.

In late Pliocene time the Rocky Mountain Region began to experience uplift. This uplift is noted from eastern Montana and western North Dakota by Witkind (1959), the High Plains by Frye and Leonard (1959) and throughout the Rocky Mountain Region by Atwood and Atwood (1948) and Richmond (1965). The magnitude of this uplift in the Black Hills area was from several hundred to several thousand feet.

As uplift began the area streams became rejuvenated and began to dissect the High Plains. Only scattered remnants of the High Plains remain undissected today. The largest remnant is the Staked Plains of Texas and New Mexico where an area of 20,000 square miles is almost untouched by erosion (Fenneman, 1931).

The last uplift of the Rocky Mountains and Black Hills began as much as 4.5 million years ago. That the largest undissected remnant of the High Plains occurs near the southern edge of its area (see Johnson, 1901, pl. 113) may mean that uplift began in the north and progressed south or that uplift has been of a greater magnitude in the north than in the south or both. The postulation that uplift has been of a greater magnitude in the north than in the south is supported by Harksen (1967a) who states post Ogallala downcutting by streams in western South Dakota is 1200 feet and in Western Nebraska is 600 feet while Frye (1945) states post Ogallala downcutting by western Kansas streams amounts to only slightly over 200 feet.

Frye and Leonard (1957) feel that dissection of the High Plains in Texas began in Nebraskan time. If uplift began in western South Dakota 4.5 million years ago, this would indicate that uplift of the High Plains tended to move from north to south.

Defining the Pliocene-Pleistocene boundary has in the past been a problem. What criteria should be used and where should we draw the line? A symposium by the Geological Society of America (Colbert, 1948) outlined the problem. Lately the Commission on Nomenclature and Correlation of the International Congress for Quaternary Research has established a type section for the Pliocene-Pleistocene boundary at Le Castella (Emiliani, 1967). However, drawing a line in Europe does little to alleviate the boundary problems in western South Dakota.

The writer, after some years of research, believes that the Medicine Root gravel (Harksen, 1966) is Nebraskan in age (Harksen, 1968a). In this paper we are going to assume that the Pliocene-Pleistocene boundary in western South Dakota lies at the base of the Medicine Root gravel. Also the writer and his associates will continue to do research and publish modifications, clarifications, and solidifications of the ideas presented herein.

With the advent of the Pleistocene came an increase in surface water. This is noted by Frye and Leonard (1959) and by Bryan (1944) who states, "It should, however, be borne in mind that the Platte and Missouri Rivers and all their Rocky Mountain tributaries, were in Pleistocene time over-loaded, glacially-fed streams." Many other workers share these views. Indeed a sea of ice only a few hundred miles to the east should have brought about some drastic changes in the weather of the Black Hills area.

When western South Dakota began to undergo uplift about 4.5 million years ago this brought the deposition of the Ogallala Group to a halt and initiated a period of erosion. The streams had relatively low gradients and the area received probably only a moderate amount of rainfall. Erosion progressed in a rather slow methodical manner up until the advent of the Pleistocene.

When the Nebraskan Glaciation reached into eastern South Dakota the streams of the

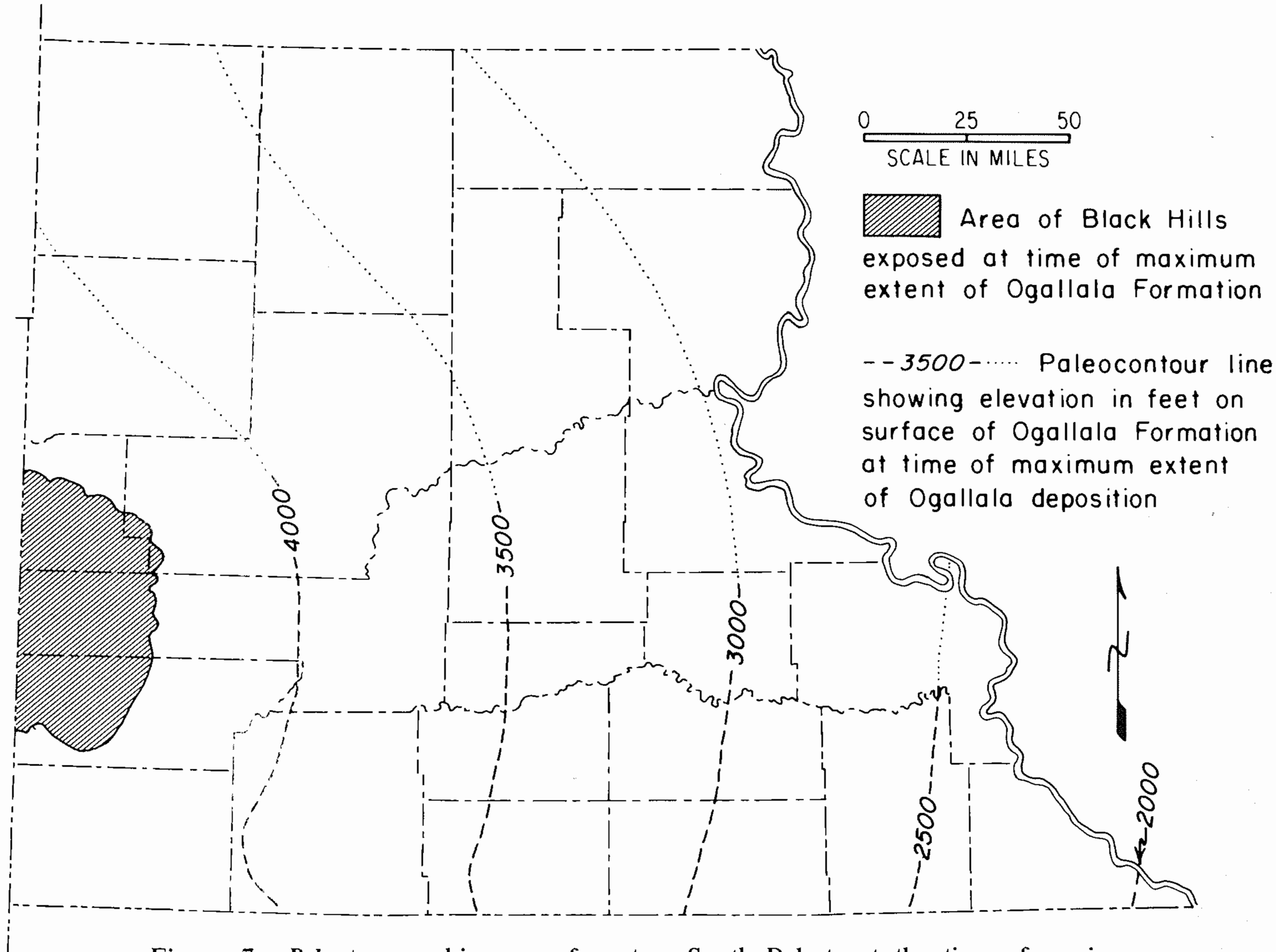


Figure 7. Paleotopographic map of western South Dakota at the time of maximum Ogallala deposition. Contour lines are dashed where some control is available and dotted where they are only estimations.

Black Hills were affected and turned into raging torrents. During this time great amounts of very coarse materials from the core of the Black Hills were washed far out onto the plains.

The Medicine Root gravel (Harksen, 1966) is a coarse gravel which was deposited under these conditions. When the Nebraskan Glaciation came to a halt and conditions returned to normal the stream valleys were choked with coarse sediments. Because the Tertiary rock was more easily eroded than the valley fillings, the streams eroded the Tertiary rock and left the gravel behind. Continued erosion brought about a topographic reversal which left the gravel capping the interfluves.

The Medicine Root gravel is found capping hills across Shannon, Washabaugh, and Mellette Counties (see fig. 8). The high area on the south edge of Cuny Table marks the most westerly known exposure of the Medicine Root gravel. The most easterly exposure known is in Sec. 32, T. 44 N., R. 31 W., Mellette County, and was brought to the writer's attention by Everett White (personal communication).

A second exposure of rocks in western South Dakota which the writer believes to be Nebraskan in age is a thick deposit of gravel in Meade County. This gravel was mapped by Pettyjohn (MS) in the area to the west of Enning (fig. 8). At present there is no concrete evidence for assigning these gravels to Nebraskan age. However, the elevation and stratigraphic position of these gravels seem to infer a Nebraskan age and therefore they are mentioned in this paper.

One additional stream deposit of Nebraskan age is the Sand Draw locality (McGrew, 1944, and Taylor, 1960) of northern Nebraska (fig. 9). When viewing the known deposits of Nebraskan age along with the uplifted areas and postulated divides everything seems to fit together quite well – therefore, it must be wrong.

The writer knows of no deposits in western South Dakota that should be referred to the Aftonian. One possible exception is the loess, underlying a deposit of Pearlette Ash, that is found in Secs. 2 and 3, T. 37 N., R. 34 W., Bennett County, South Dakota. However at present all that can be said about this loess is that the wirter thinks it is pre-late Kansan.

With the approach of the Kansan ice into the eastern part of the State the Black Hills drainages again became torrential streams. Once again boulders were carried from the Black Hills far out onto the plains. The coarse boulder gravel on the east end of Cuny Table was deposited at this time. In fact the general surface of Cuny Talbe marks the general level of the low area of this region during Kansan time. This level is approximately 200 feet below the deposits of Nebraskan age (Medicine Root gravel) which are found on the south edge of the table. As precipitation returned to normal the rivers were unable to erode the coarse gravels and instead cut new courses off to the side through the softer Tertiary bedrock. Figure 10 shows deposits of Kansan age which are present on Cuny and Red Shirt Tables and the stream courses they probably represent.

Near the end of the Kansan, volcanoes in northern New Mexico emitted the Pearlette Ash (Cragin, 1896). The Pearlette Ash is considered to be Kansan in age by Reed and Dreeszen (1965) while Miller (1964) and Miller and others (1964) consider the Pearlette to be Kansan–Yarmouthian in age. The writer does not wish to enter into this controversy or into the controversy over multiple "Pearlette Ash" beds in the Great Plains (M. J. Tipton, personal communication). In this paper the writer will remain constant with the classical concepts that the Pearlette Ash is the only widespread Pleistocene ash of the northern Great Plains and that it is late Kansan in age. Deposits of Pearlette Ash are noted in southwestern South Dakota by Harksen (1968a) who cites the three deposits shown in figure 10.

The deposits of Pearlette Ash give some indication of the rate of erosion, date the surface of Cuny Table, and also date the capture of the Black Hills drainages by the South Fork of the Cheyenne River. The history of the drainages has been discussed by Todd (1902), Wanless (1923), Harksen (1966) and others. The writer believes that the Pearlette Ash on the west end of Cuny Table is a "benchmark" that can be used in the study and dating of terrace deposits across western South Dakota.

Not much is known or has been reported in western South Dakota on the Yarmouthian, Illinoian, and Sangamonian with the exception of a few papers such as those by Green (1962) who gives the geologic inferences of *Bison latifrons* from near Midland, South Dakota, and White (1964) who comments on the age of the terrace levels near the mouth of

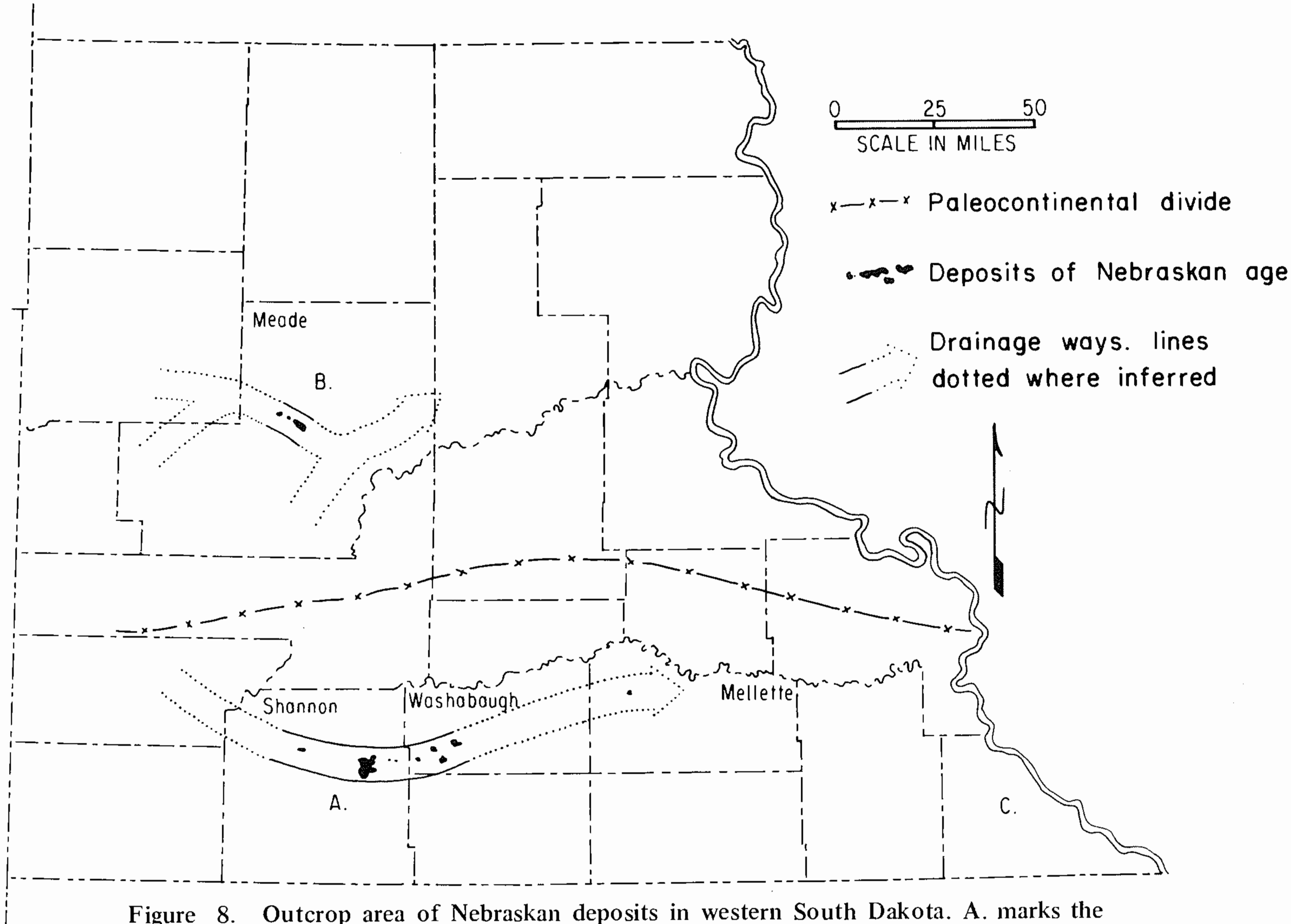


Figure 8. Outcrop area of Nebraskan deposits in western South Dakota. A. marks the exposures of the Medicine Root gravel and the stream course that they infer. B. marks the deposits of gravel mapped by Pettyjohn (MS) and a highly inferred stream course. C. marks the area where the Herrick gravel is exposed (Stevenson, 1958b). The age of the Herrick gravel is discussed by Green and Lillegraven (1966). The placement of the continental divide was made after considering the evidence presented by Laird (1967) and Hedges (1969).

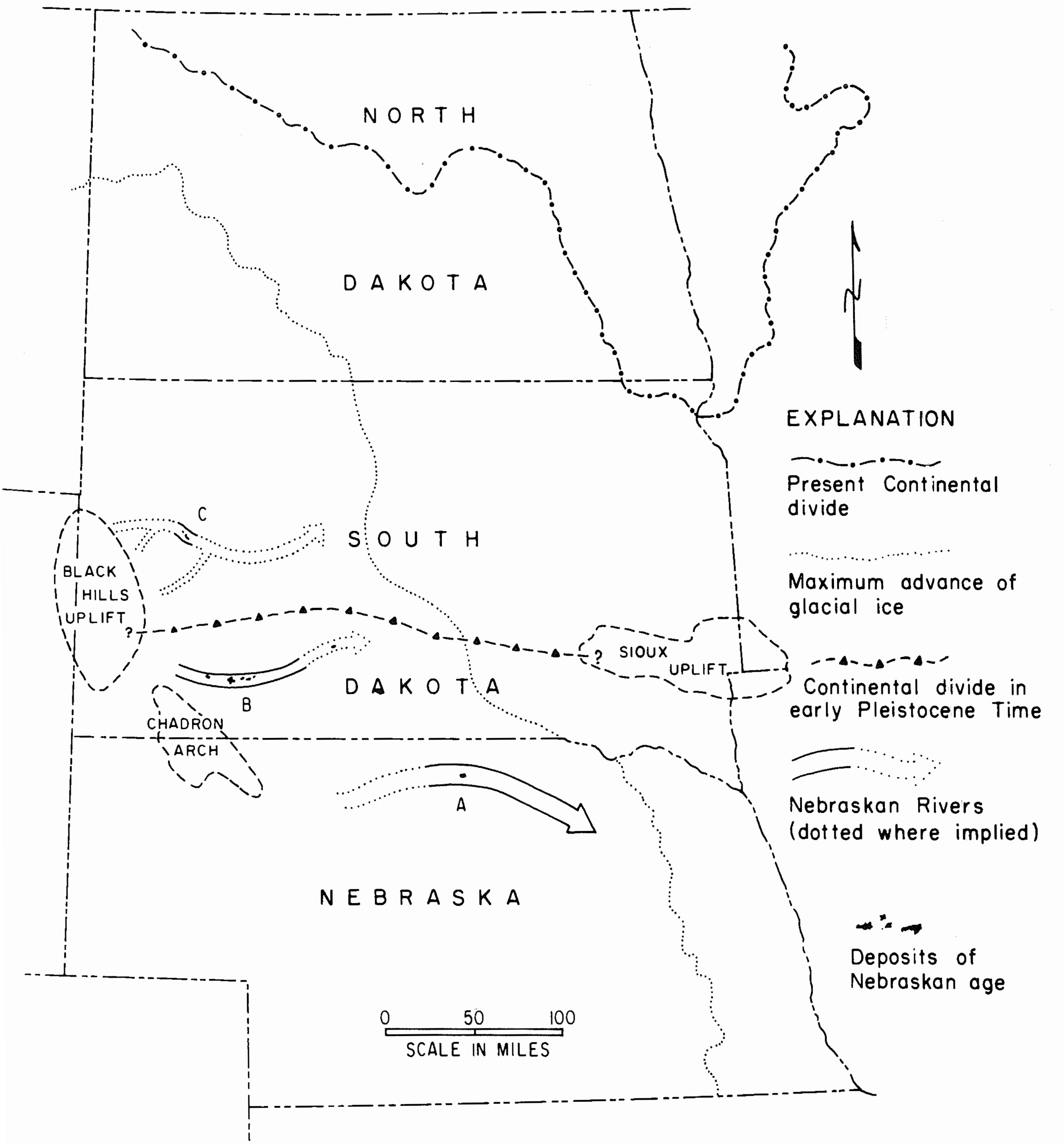


Figure 9. Outline map of North Dakota, South Dakota, and Nebraska showing the relations between uplifted areas, present and paleo continental divides, the maximum advance of glacial ice, and three stream deposits of Nebraskan age. A. The Sand Draw locality. B. The Medicine Root gravel. C. Unnamed gravel mapped by Pettyjohn (MS).

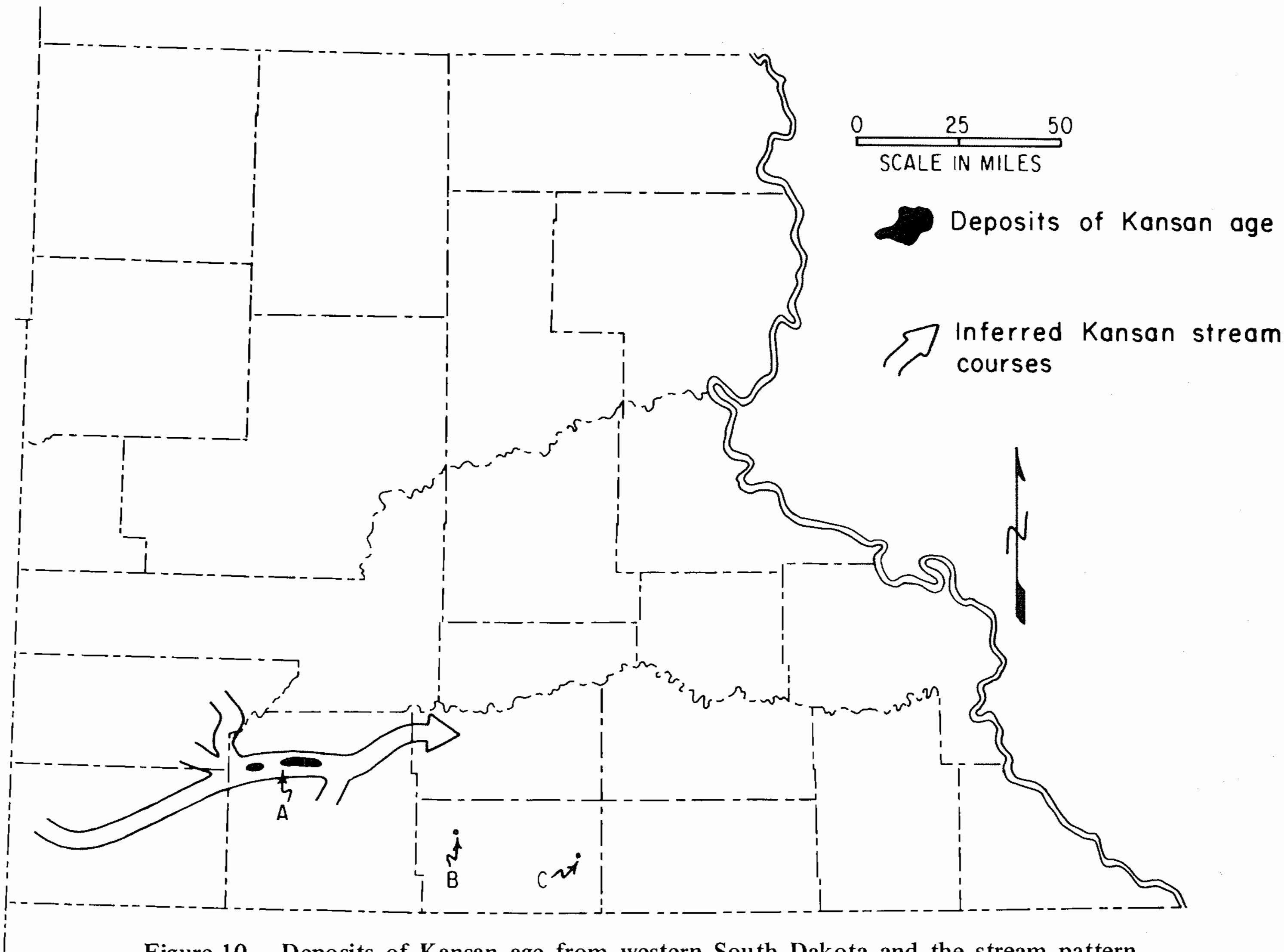


Figure 10. Deposits of Kansan age from western South Dakota and the stream pattern they infer. Points A, B, and C mark the three deposits of Pearlette Ash now known in this area.

the White River. A lot of time is represented and the history, once unraveled, will undoubtedly prove to be an interesting one.

The Wisconsin deposits of western South Dakota are represented by terrace deposits, dune sand, and loess. Despite papers by Harksen (1967a, 1968a) very little is known about the loess and even less about the dune sand. However, recent studies in Bennett County have allowed the writer to date one terrace deposit.

One of the broadest and most interesting of the low level terraces in this area of the State is the terrace found near Tuthill (Harksen, in preparation). The terrace is about 20-35 feet above the level of La Creek and the Little White River. The portion of this terrace which occurs in the Martin quadrangle was mapped, at a scale of 1:62,500, by Collins (1959). An eastward continuation of these terrace deposits was mapped by Sevon (1961).

In addition Morton Green (personal communication) informed the writer that a partial cranium of a musk ox had been collected from the terrace deposits of this area by Don Rice, a local rancher.

Mr. Rice was contacted and he allowed the writer to examine and photograph the musk-ox skull (part of Mr. Rice's rock and fossil collection) which proved to be of the genus *Symbos*. Mr. Rice informed the writer that he had found the skull on his ranch in the NE¼ Sec. 8, T. 37 N., R. 35 W., Bennett County, South Dakota. In addition he gave the writer permission to prospect for vertebrate fossils on his ranch. Intensive prospecting yielded some muskrat material (Harksen, 1968c) and the third skull of *Bison occidentalis* known from South Dakota (Harksen, in preparation). These fossils, especially the *Symbos* and the *Bison*, indicate a definite Wisconsin age and probably early Wisconsin age for these deposits.

Our present knowledge of the Cenozoic History of South Dakota is but an outline of the big picture. Each year our knowledge is expanded through continued mapping and fossil collecting. Each year field parties from the South Dakota School of Mines and the South Dakota Geological Survey make discoveries which further illuminate and expand our knowledge of the geological history of this area. Future work is now being planned to gather information that will further our quest for knowledge and write another chapter in the Cenozoic History of Southwestern South Dakota.

ROADLOGS

by
J. C. Harksen and J. R. Macdonald

FIRST DAY: Rapid City to Cedar Pass.

000.0 00.0 Assemble at the southeast corner of the Family Thrift Center parking lot (fig. 11). When leaving lot take a left turn and go east on St. Patrick Street. A map of the day's travel is presented as figure 12.

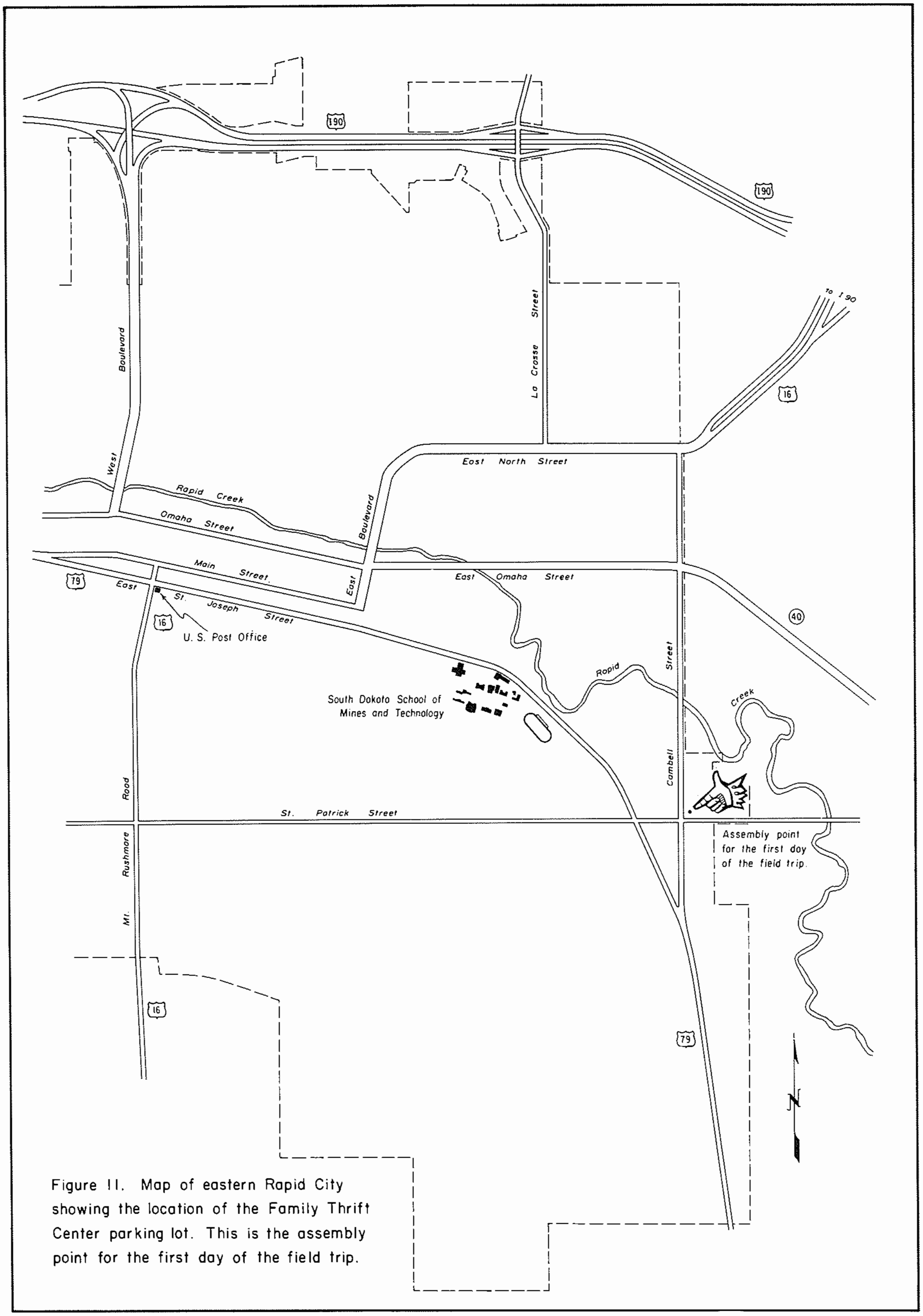


Figure 11. Map of eastern Rapid City showing the location of the Family Thrift Center parking lot. This is the assembly point for the first day of the field trip.

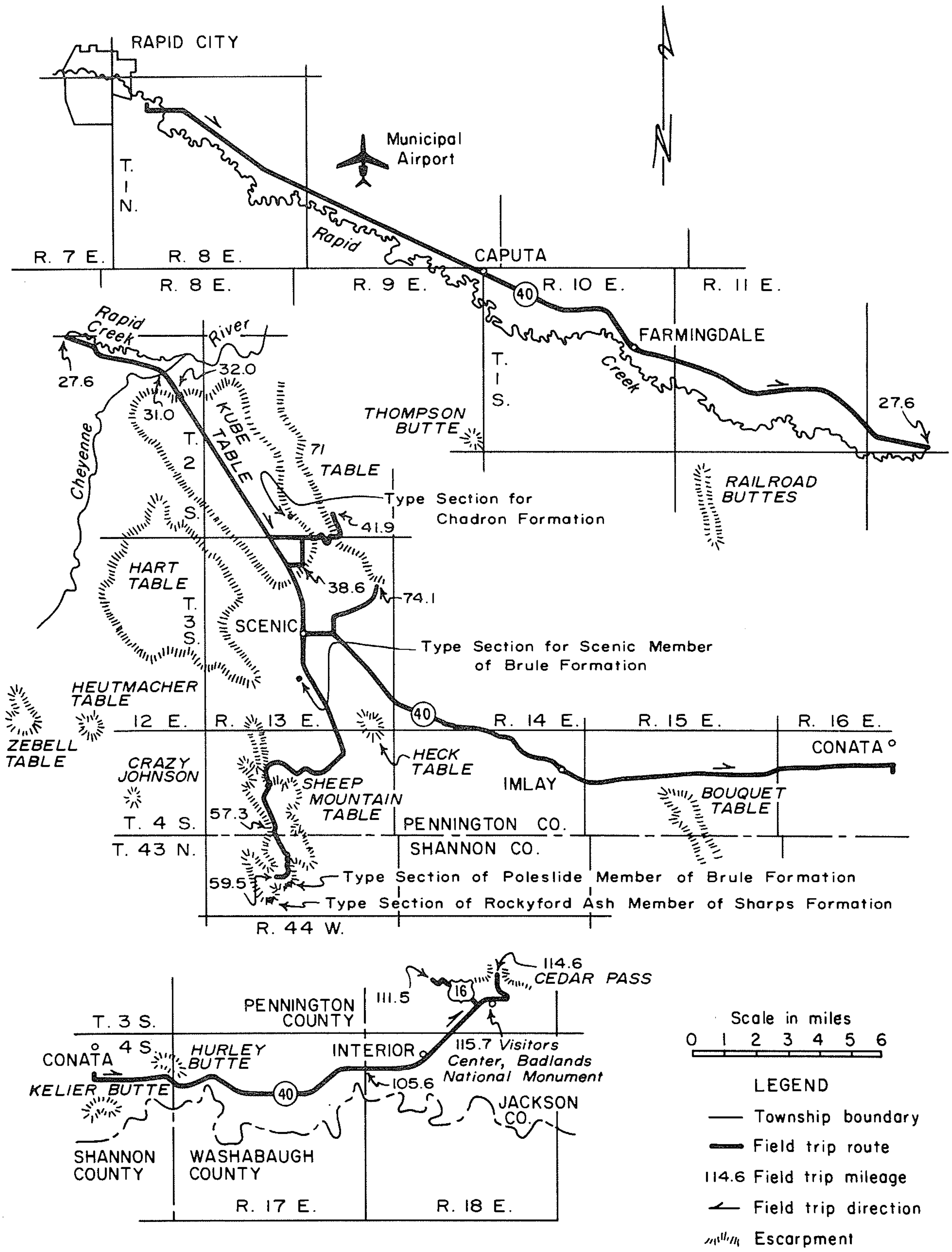


Figure 12. Map of the route to be followed on the first day of the field trip.

000.5 00.5 Cross Rapid Creek.

Rapid Creek is a translation of the Sioux name for this creek which meant literally "Water Swift Creek." The name was given it because of the steep gradient of the creek and therefore the swift flow of the water.

001.2 00.7 Road junction, turn right onto Highway 40.

002.1 00.9 Outcrop of the Niobrara Chalk to the left. Note the spherical concretions that are weathering out. Thomson Butte ahead (13 miles) on the right.

The Niobrara Chalk was named by Meek and Hayden (1862) from exposures along the Missouri River near the mouth of the Niobrara River in Knox County, Nebraska.

004.7 02.6 Rapid City waste-water plant to the south.

006.9 02.2 Rapid City Municipal Airport entrance on left.

008.9 02.0 H. O. Siding on right—named for H. O. Ranch on the left.

011.7 02.8 Caputa.

Caputa is a Latin word meaning "head camp." The town was laid out in 1907 by the Milwaukee railroad and settlement began in 1908.

013.2 01.5 Thomson Butte to the south (figs. 13 and 14).

This butte was named for Thomas Thomson, father of Albert (Bill) Thomson of the American Museum of Natural History. The family ranch was east of the butte.

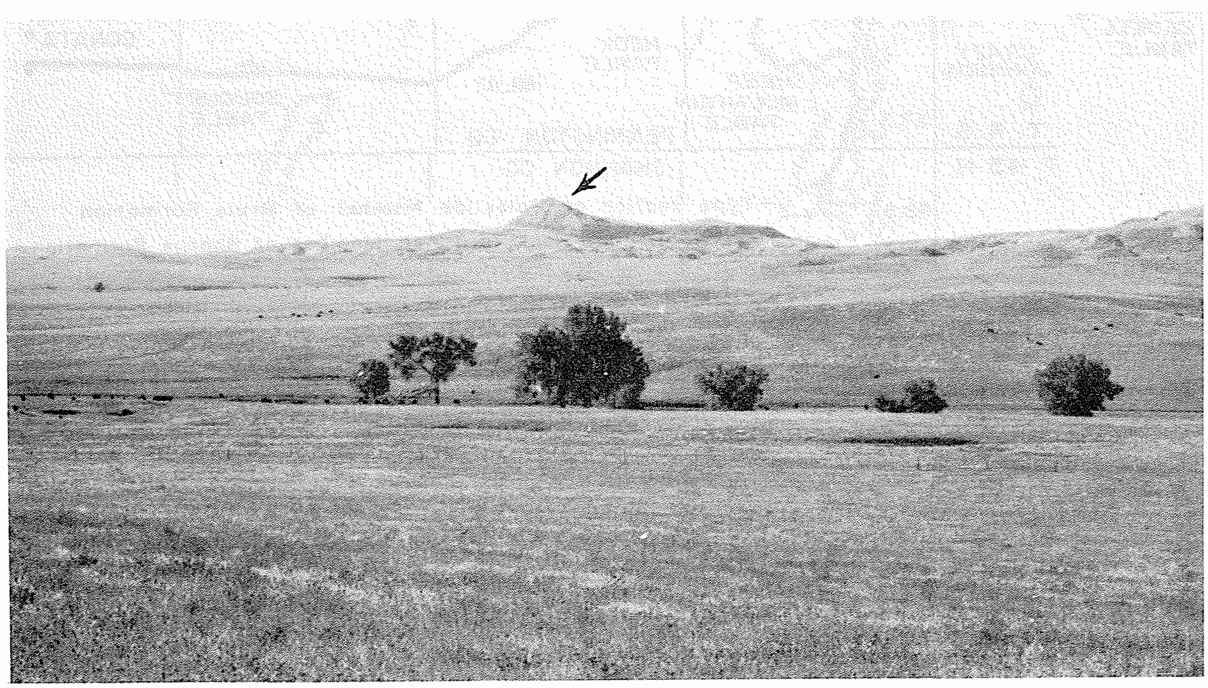


Figure 13. Thomson Butte (arrow) was named for Thomas Thomson, father of Albert (Bill) Thomson of the American Museum of Natural History.

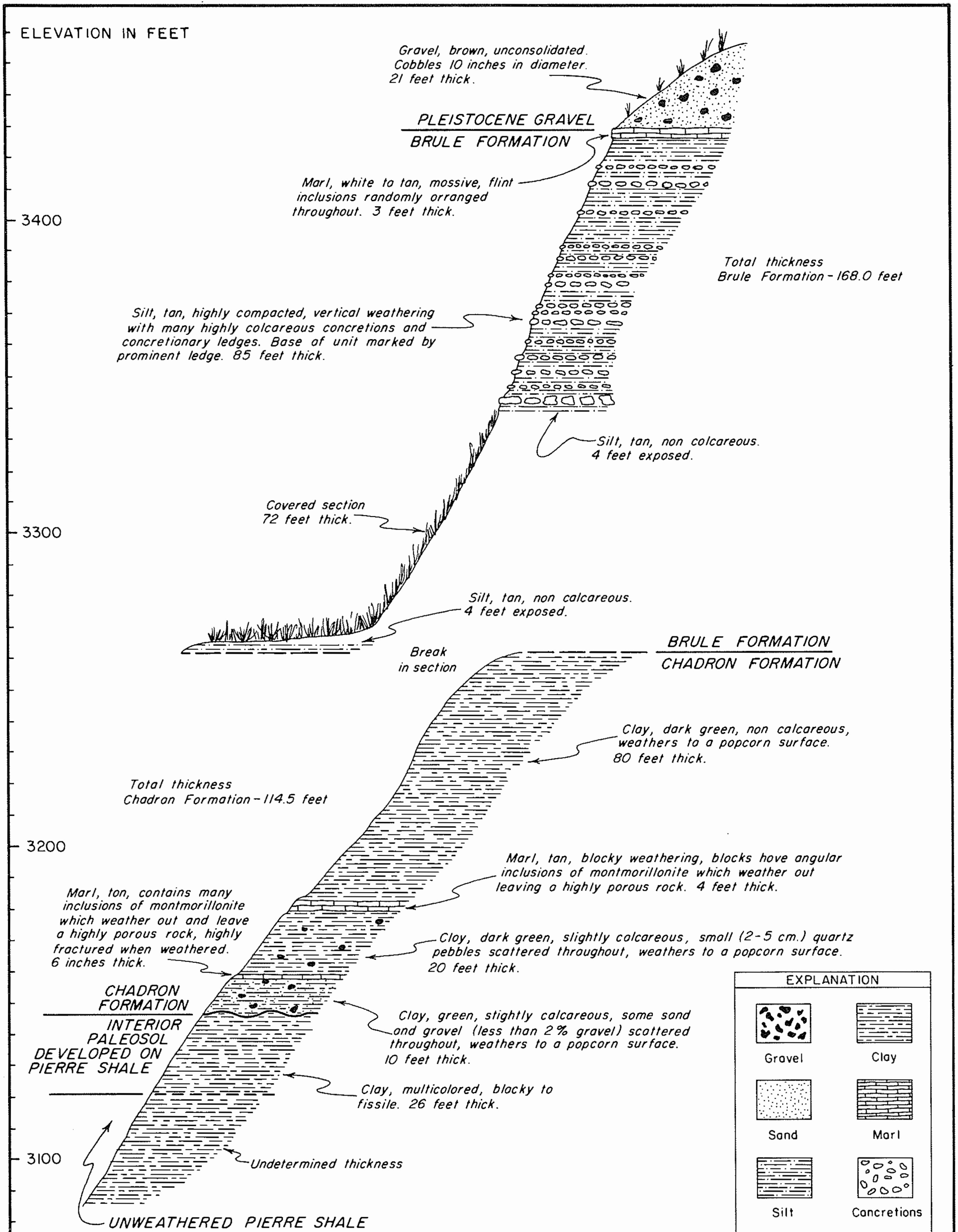


Figure 14. Columnar section of Thomson Butte. This section was measured by and is used with the permission of Roger Barker of Fort Hays Kansas State College.

015.3 02.1 Terrace gravels on both sides of the road. Also note the terrace levels on both sides of Rapid Creek to the south (right).

016.2 00.9 We are now driving on the Sturgis Terrace of Plumley (1948). Railroad Buttes straight ahead on horizon (figs. 15 and 16).

To the west of Railroad Buttes is the locality where the skeleton of *Archelon ischyros* Wieland was collected in 1895.

017.5 01.3 Farmingdale, note old foundations.

Farmingdale was so named by Americus Thomson, the first postmaster, because of the great influx of farmers into this region in the olden days. The town was originally located half a mile from the present site.

024.8 07.3 We are now driving on the Farmingdale Terrace of Plumley (1948). Note Mount Rushmore to the right. Begin the descent of a long grade.

025.3 00.5 Note slumping of Pierre Shale ahead across Rapid Creek.

The Pierre Shale was named the Fort Pierre Shale by Meek and Hayden in 1862 and the name subsequently shortened to its present length. While no type locality was designated the name was derived from Fort Pierre, Stanley County, South Dakota.

Figure 15. Railroad Buttes. This is the area where the skeleton of *Archelon ischyros* Wieland was collected in 1895. *Archelon*, the largest turtle known, was 12 feet in length and was collected from the late Cretaceous Pierre Shale.

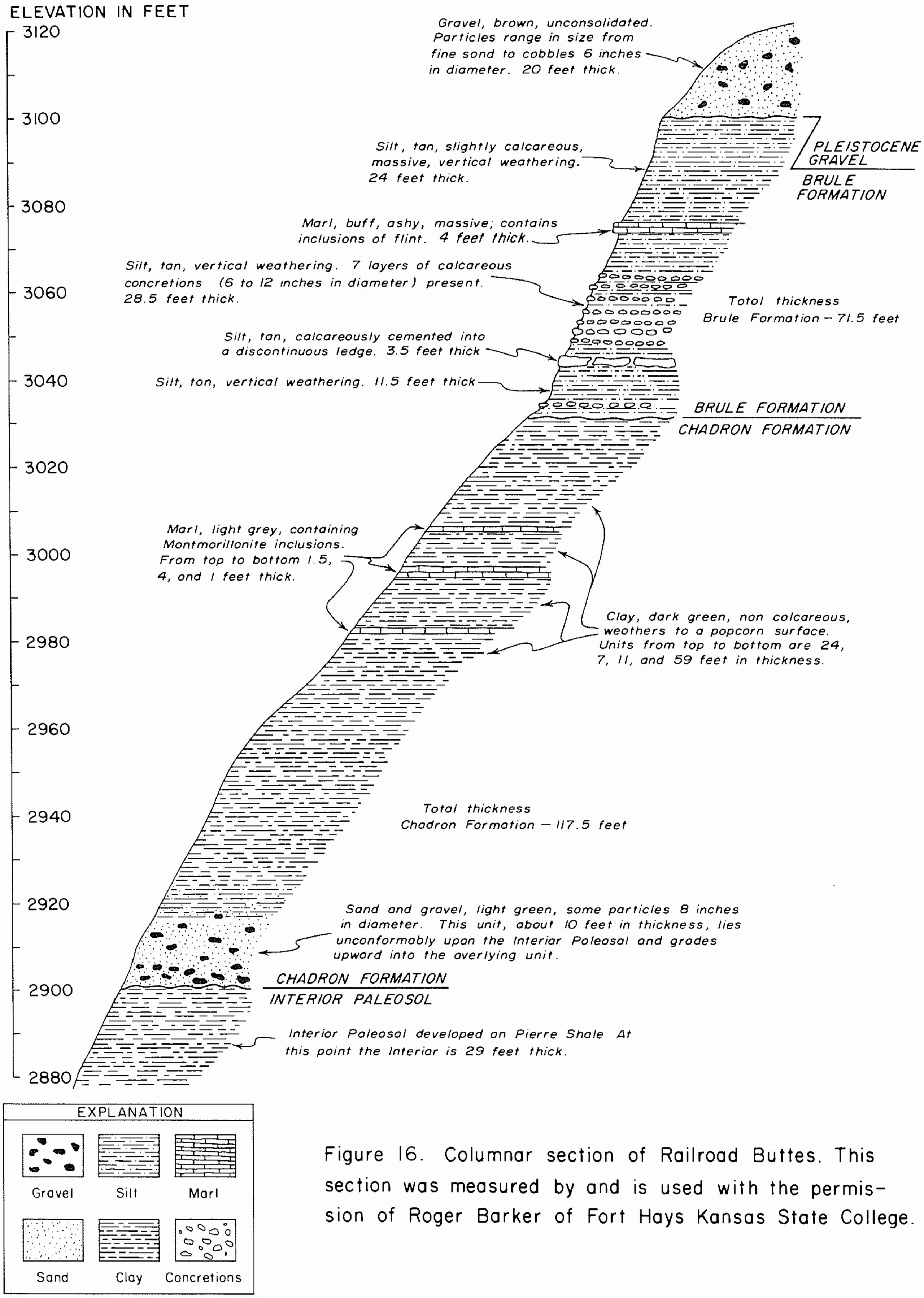


Figure 16. Columnar section of Railroad Buttes. This section was measured by and is used with the permission of Roger Barker of Fort Hays Kansas State College.

027.6 02.3 Cross Rapid Creek.
Just before crossing the bridge note the sign on the gatepost to the left (fig. 17).

Figure 17. Sign marking entrance to ranch road just to the west of Highway 40 crossing of Rapid Creek at field trip mileage 027.6.

028.0 00.4 Creston siding. Note the wire and plaster dinosaur, which is the last remnant of the town of Creston, to the left (fig. 18).
Creston was named for Creston, Iowa, by the first homesteader, Jake Allison, who arrived in 1880.

029.1 01.1 Cut Hill, named for a large railroad cut.

029.3 00.2 Note slumping in the Pierre Shale on the south side of the Cheyenne River.

030.6 01.3 Historic Marker to the left denotes "OGALLALLA FUR POST."
The post was located south of the marker where at one time Rapid Creek entered the Cheyenne River. The post operated from the winter of 1829-30 until 30 January 1832 when an inept worker dropped a lighted candle into a keg of gunpowder. The resultant explosion killed the factor, Thomas L. Sarpy, and destroyed the post. Lt. G. K. Warren passed this point on 6 October 1857.

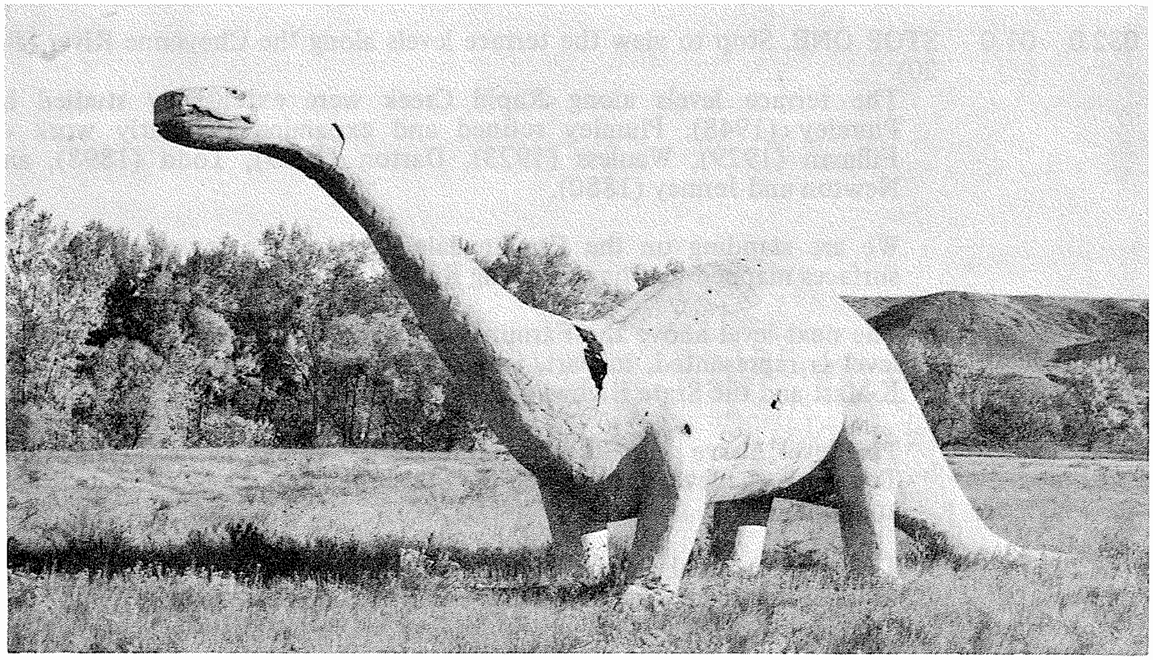


Figure 18. A wire and plaster dinosaur marks the site of the now defunct town of Creston. Dinosaur has been refurbished since the picture was taken.

031.0 00.4 Cross Cheyenne River (fig. 19).
The Cheyenne River was named for the Cheyenne tribe of Indians who at one stage in their migrations lived along this river.

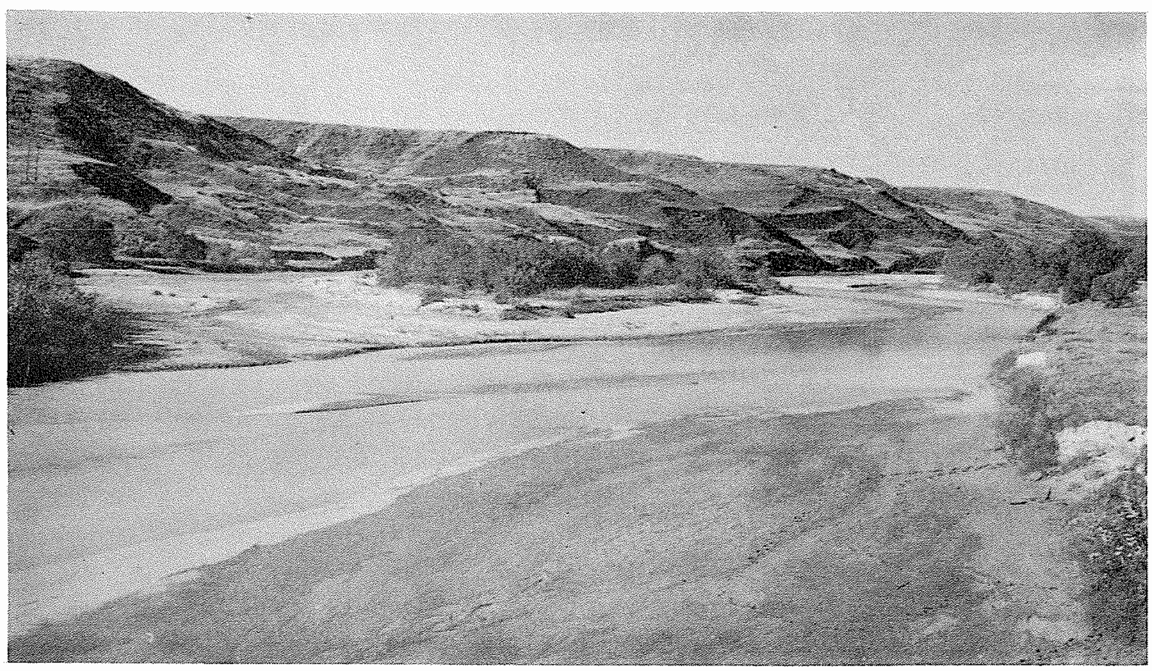


Figure 19. Slumping in the Pierre Shale along the Cheyenne River as seen from the Cheyenne River Bridge at field trip mileage 031.0.

032.0 01.0 **STOP ONE.** Stop to view the terrace levels along the Cheyenne River (fig. 20).

The terrace levels along Rapid Creek were extensively studied by Plumley (1948). Plumley refined and expanded the early work of Fillman (1929), Wanless (1923), Darton (1909), Todd (1898), and Newton and Jenney (1880).

We are standing on the Farmingdale Terrace, the lowest of the four surfaces mapped by Plumley along Rapid Creek.

The next level above the Farmindale Terrace is the Sturgis Terrace. This level is represented, in part, in Rapid City by the flat area around the K-Mart and the State Highway Shop.

The level above the Sturgis Terrace is the Rapid Terrace. The Rapid Terrace is the level upon which the Star Motel and the Municipal Airport are built.

The highest level is the Mountain Meadow surface which is found topping the divide between Rapid and Box Elder Creeks.

Plumley mentions the asymmetrical form of the north-south profiles of the streams flowing eastward out of the Black Hills. The southern slopes of the majority of the creek valleys are very steep compared to the gentle northern slopes. This is true of Rapid Creek and as a result the terraces are more extensively developed on the northern side of the valley.

More material on terraces is presented both in the section on the geological history of the region and at field trip mileage 133.9.

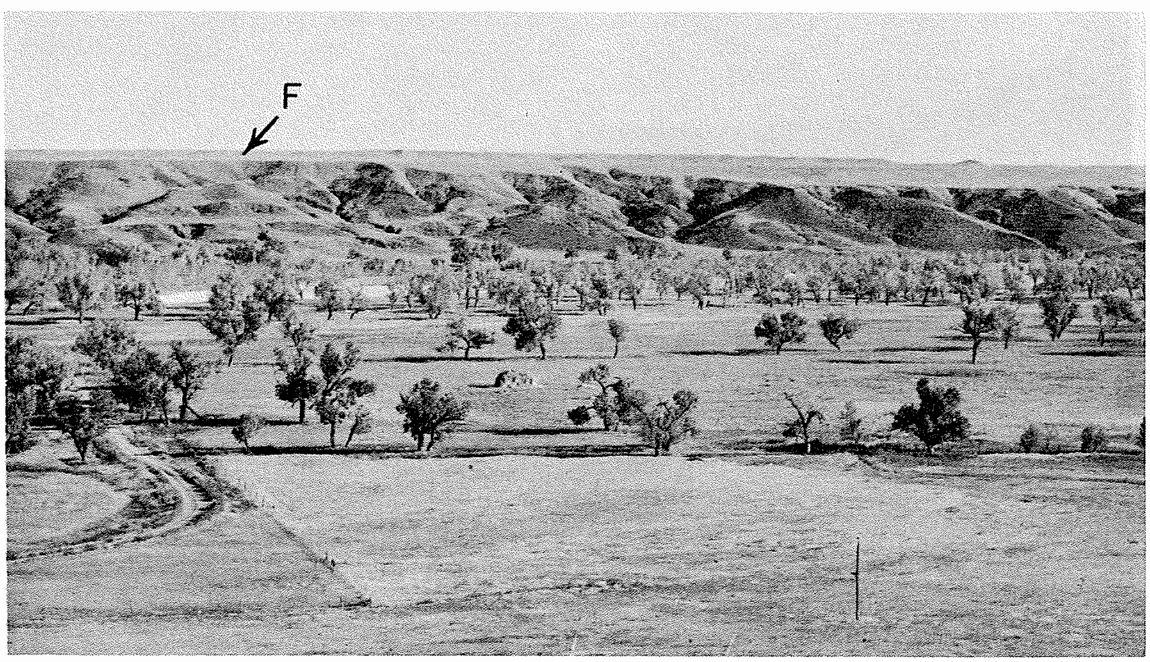


Figure 20. Terrace levels along the Cheyenne River. "F" marks the position of the Farmingdale Terrace.

032.2 00.2 Kube Table (fig. 12). We are climbing up through the Pierre Shale and advancing from younger through older terraces.

Kube Table is named for an early day sheepman of this region who went by the name Kuba.

038.4 06.2 Turn left toward Scenic overlook.

038.6 00.2 **STOP TWO.** Stop at Scenic overlook for introductory talk on the Badlands.

The White River Badlands is probably the most productive collecting area for terrestrial vertebrate fossils in the world. The more than 600 feet of sediments span the 10,000,000 years of the Oligocene epoch. Since the first description of a fossil from this region was published in 1846, there has been a constant stream of collectors into the Badlands. Representative collections may be found in museums throughout the world. Museum and university field parties still collect here every year. Unfortunately, present day irresponsible collecting by uninformed hobbyists is interfering with the scientists' work. Although the fossils from this sequence present perhaps the best view we have of an ancient fauna, heretofore unknown forms are being described each year, and we will never know the entire fauna.

Following post-Cretaceous uplift of the Great Plains, the Pierre Shale and minor areas of other Late Cretaceous rocks were slightly eroded (maximum relief 180 ft.) and subjected to deep tropical weathering during the early Tertiary. The resulting lateritic zone was named the "Interior Formation" by Ward (1922).

In early Oligocene time the "Titanothere Channels," green bentonitic clays and pond limestones of the Chadron Formation, were deposited on this gently rolling surface. The Middle and Late Oligocene are represented by the Brule Formation. The lower portion (Scenic Member) is often called the Oreodon Beds with *Metamynodon* channels. The upper portion (Poleslide Member) has been best known as the "*Leptauchenia* Clays" and "*Protoceras* Channels."

The Brule Formation is here conformably overlain by early Miocene sediments.

038.7 00.1 After leaving Scenic overlook turn right onto gravel road and drive east.

039.8 01.1 Road junction—turn right.

040.4 00.6 Start down grade into Bear Creek Valley.

Bear Creek was named for an animal once common to this region.

040.7 00.3 Pierre Shale in roadcut.

041.0 00.3 Cross Bear Creek.

041.9 00.9 **STOP THREE.** Stop to comment on the type section of the Chadron Formation (fig. 21). After the discussion turn around and retrace route toward Highway 40.

The Chadron Formation is the lower formation in the White River Group. It was named by Darton (1899a) as a replacement for the Titanotherium beds as used by Meek and Hayden (1858), Wortman (1893), Hatcher (1893), and others. As Darton (1899a) did not indicate

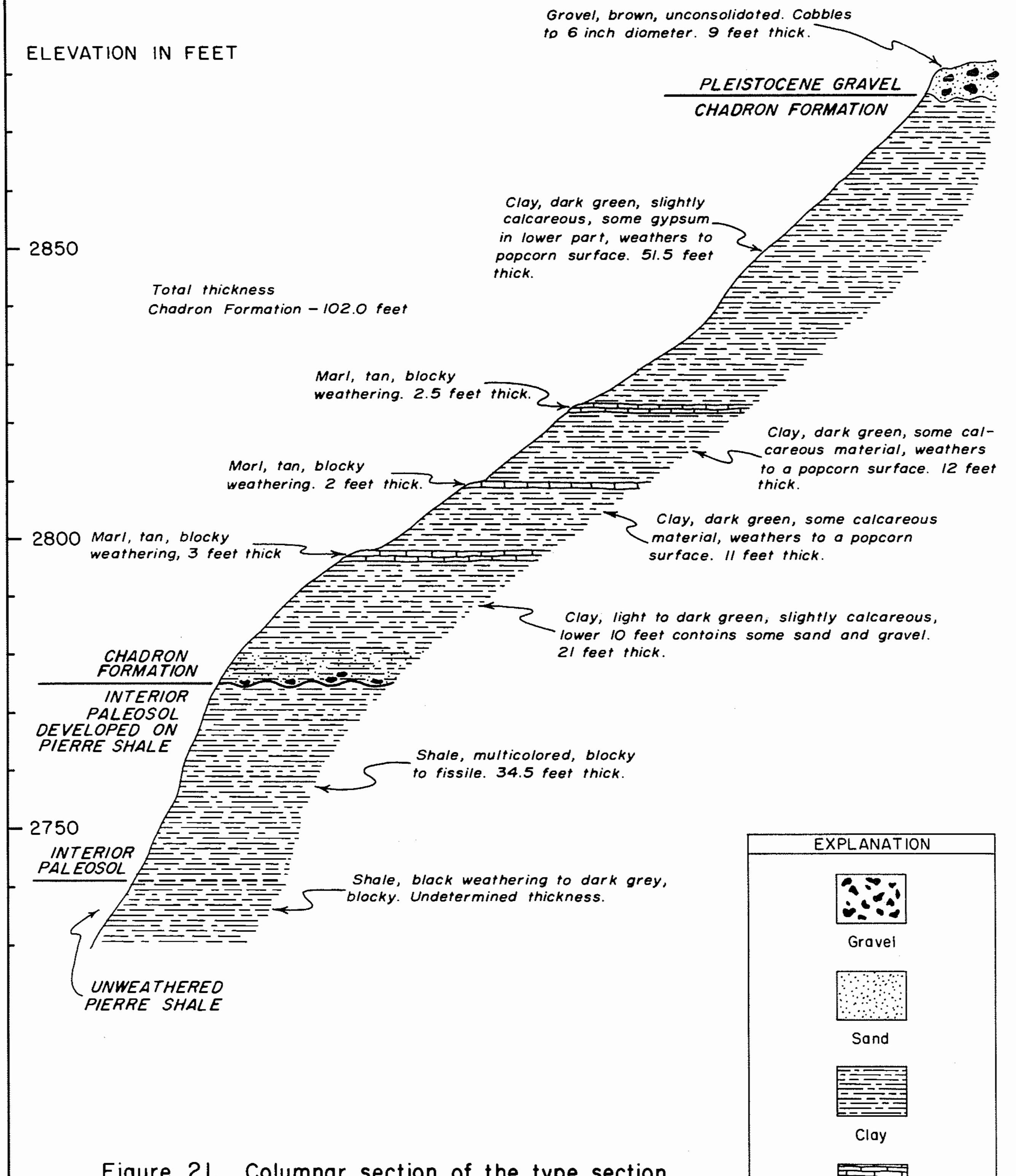


Figure 21. Columnar section of the type section of the Chadron Formation in the SW 1/4, SW 1/4, SE 1/4, sec. 28, T. 2 S., R. 13 E., Pennington County, South Dakota. This section was measured by and is used with the permission of Roger Barker of Fort Hays Kansas State College.

one, Osborn (1929) chose to establish a type section for the Titanotherium beds (Chadron Formation) along Bear Creek in an area mentioned by many early workers. The section presented as figure 21 was measured along Bear Creek near the point where the photographs in figure 72 of Osborn (1929) were taken. The authors believe that figure 21 of this report represents the type section for the Chadron as intended by Osborn (1929).

042.8 00.9 Cross Bear Creek. Note terraces of reworked White River along the road.

044.0 01.2 Continue west to Highway 40. Mount Rushmore and Harney Peak are visible on the horizon straight ahead.

044.3 00.3 Well house for Scenic water supply on the right side of the road. The well is 34 feet deep and draws water from the Quaternary gravels which cap Kube Table.

044.9 00.6 Turn left (south) onto State Highway 40.

046.0 01.1 We are now leaving Kube Table and dropping down into the Scenic Basin.

047.1 01.1 The road is essentially at the level of the top of the Chadron Formation.

047.6 00.5 Take right fork—continue south through Scenic.

048.0 00.4 Note circa-1935 campground on right.

048.1 00.1 Longhorn Bar on right (fig. 22).

Figure 22. The Longhorn Saloon in Scenic. Note the "squaw cooler" to the left of the saloon.

048.2 00.1 Cross Chicago, Milwaukee, and St. Paul Railroad tracks—proceed south on road toward Pine Ridge Indian Reservation.

048.3 00.1 To right is Hart Table named for Frank Hart, a rodeo rider who homesteaded on it. The break in the wall to the southwest is Saddlehorse Pass. To the left of the Pass is Sheep Mountain Table so named because a flock of big horn sheep lived there until about 1910. The road is approximately at the Chadron–Brule contact level. Note the low grass-covered Pleistocene terraces along the road.

050.1 01.8 **STOP FOUR**. Stop to see the type section of the Scenic Member of the Brule Formation (fig. 23). The section measured and published by Bump (1956) is presented as table 4. This is also the type section for the lower part of the Brule Formation.

The Scenic Member of the Brule Formation was named by Bump (1956) in order to assign local geographic names to the subdivisions of the Brule Formation in the Badlands. Bump felt that this 159 foot section (table 4) was representative of the lower Brule in the area from which "these deposits were studied and described." Harksen and Macdonald are proposing (Harksen and Macdonald, in preparation) that the type section for the Scenic Member be considered the type section for the lower half of the Brule Formation.

Table 4. The measured section for the Scenic Member of the Brule Formation as presented by Bump (1956).

Feet	Description
	Upper Nodular Zone
12	Light cream-colored clays with narrow layer of fossiliferous clay-lime concretions. Lime content of latter higher than in those of the lower nodular zone and with little oxidation on their surfaces. Overlain by upper Brule clays.
22	Gray clays with scattered and rounded silt concretions containing few fossils. Near-vertical weathering.
89	Mostly gray clays but with irregularly spaced brown banding and containing bedded, lens-shaped silt concretions. Fossils rare.
	Lower Nodular Zone
36	Pink-gray clays weathering on the surface to brown-gray color. Contains numerous clay-lime concretions which oxidize to rusty color on surface. Highly fossiliferous. Underlain by Chadron limestone and clays.

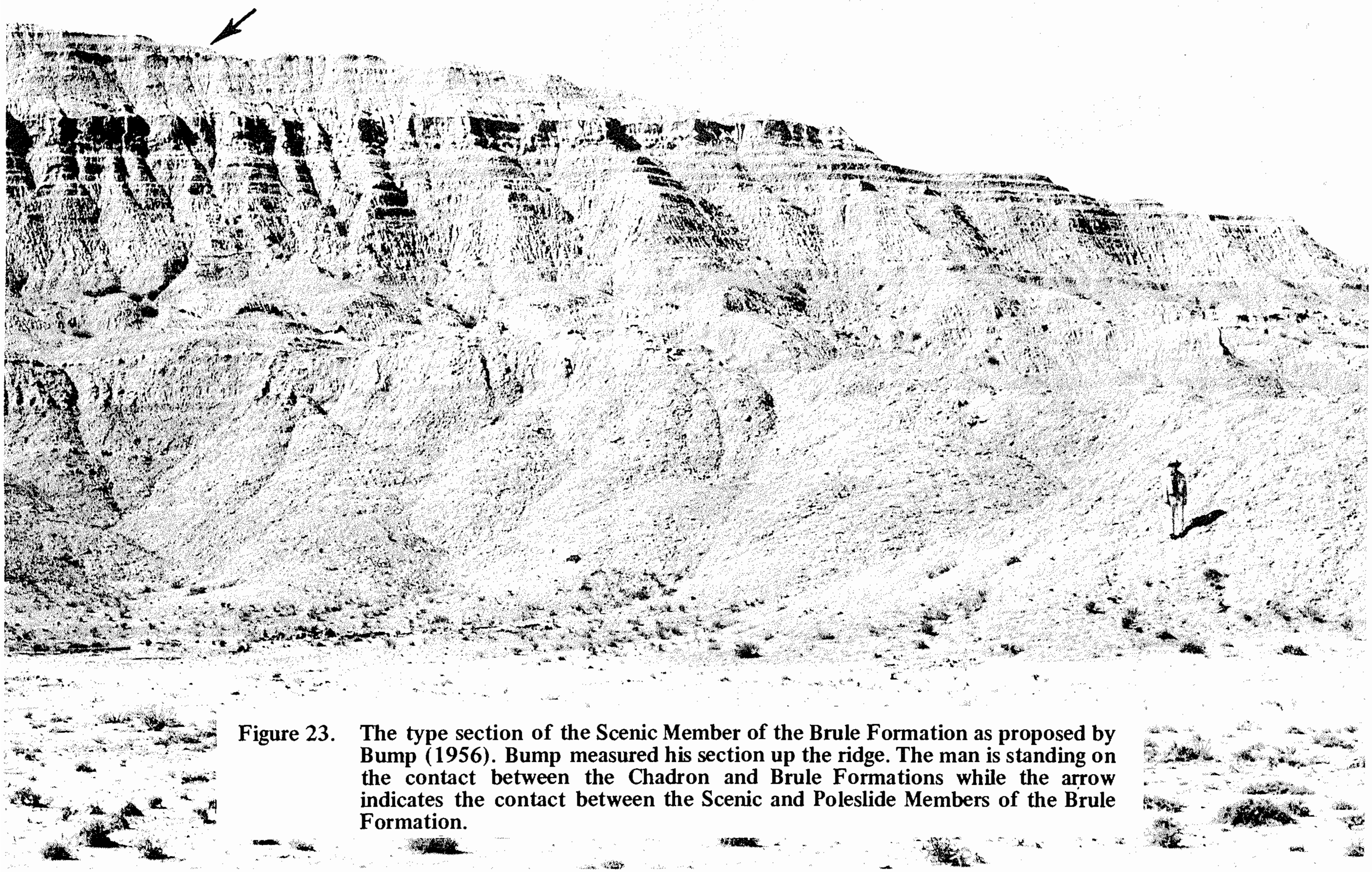


Figure 23. The type section of the Scenic Member of the Brule Formation as proposed by Bump (1956). Bump measured his section up the ridge. The man is standing on the contact between the Chadron and Brule Formations while the arrow indicates the contact between the Scenic and Poleslide Members of the Brule Formation.

051.5 01.4 Note the extensive development of Quaternary terraces along the road (fig. 24).

Figure 24. Extensive development of late Pleistocene terraces near Sheep Mountain Table. Arrow indicates man included for scale.

052.3 00.8 Turn right onto gravel road. Note chalcedony dike material on outcrops.

053.5 01.2 Thin *Metamynodon* Channels developed on left side of road.

054.0 00.5 Nodules of the lower nodular zone are strongly developed at this point.

054.6 00.6 Note clastic dikes on both sides of the road.

055.3 00.7 At this point we are turning left and starting up the grade toward the top of Sheep Mountain Table.

055.6 00.3 **STOP FIVE**. Stop to examine the contact between the Scenic and Poleslide Members of the Brule Formation (fig. 25).

East of the road at this stop is the contact between the Scenic and Poleslide Members of the Brule Formation.

055.8 00.2 Note the characteristic *Leptauchenia* nodules in the Poleslide.

056.1 00.3 Top of Sheep Mountain Table.

056.4 00.3 Excellent view of the Black Hills to the right.

The Black Hills are so named because from a distance their pine-covered slopes appear black.

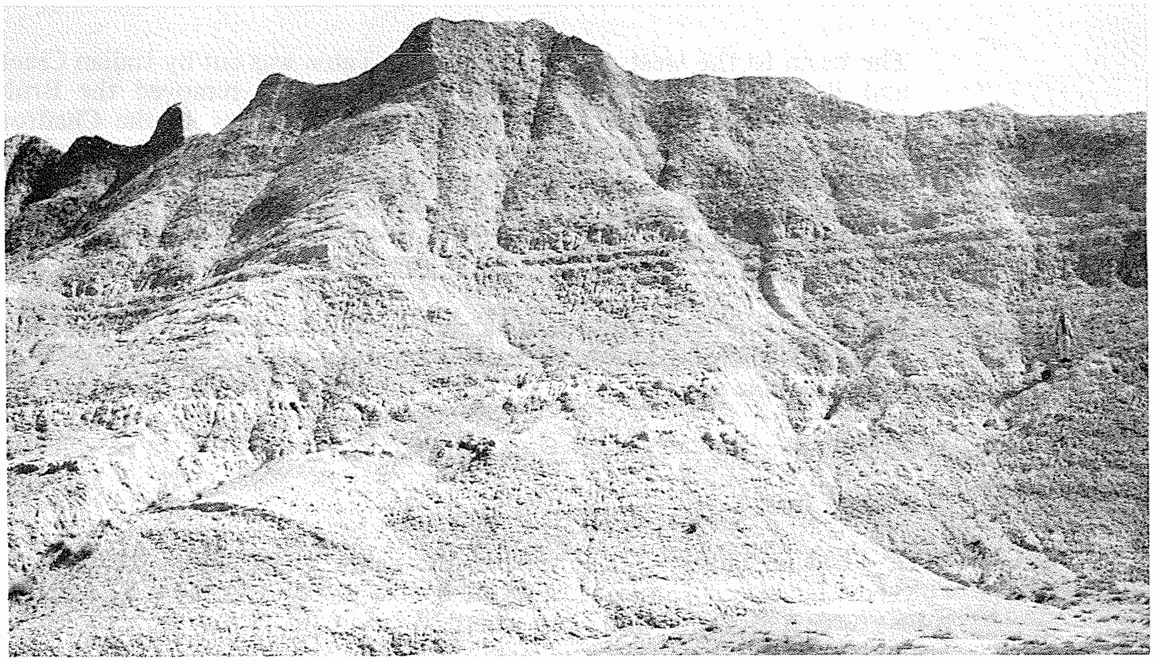


Figure 25. The contact between the Scenic and Poleslide Members of the Brule Formation on the northeast edge of Sheep Mountain Table. The man is standing on the contact.

057.3 00.9 **STOP SIX.** Stop to discuss the Chadron Formation along Indian Creek (fig. 26). After talk continue south along dirt road.

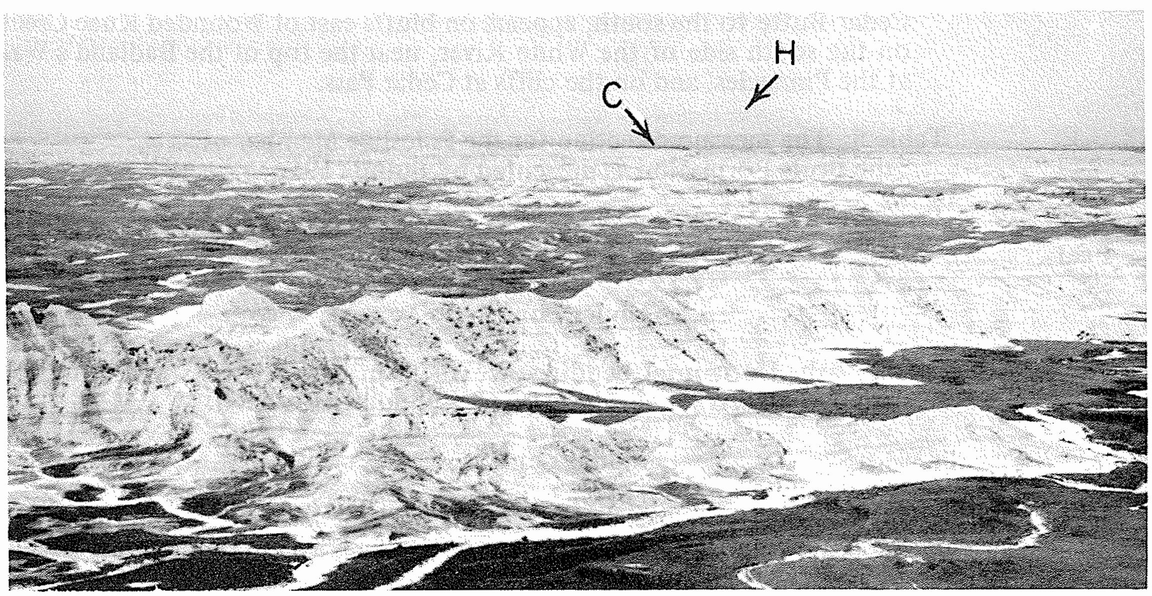


Figure 26. View to the west from the top of Sheep Mountain Table. "C" marks the Crazy Johnson while "H" marks Harney Peak (elevation 7242). The area to the north of Crazy Johnson is where Clark (1937, 1954) named the Ahern, Crazy Johnson, and Peanut Peak Members of the Chadron Formation.

The basin to the west of Sheep Mountain Table was cut by Indian Creek and its tributaries. Deep erosion has effectively removed the Brule Formation in this area and exposed broad expanses of the Chadron Formation. The "haystack" weathering of the clays is typical of the Chadron Formation. Extensive development of channel deposits, often containing large accumulations of Brontothere bones, has made this a prime prospecting area since Hatcher came into the Badlands in the late 1800's.

To those interested in erosional cycles and land forms in flat-lying sediments, their evolution can be seen on scales ranging from square yard to square mile samples.

In the valley directly below is an excellent example of stream piracy.

059.0 01.7 Take right fork.

059.5 00.5 **STOP SEVEN**. This stop is to see and discuss the type sections for both the Poleslide Member of the Brule Formation (fig. 27 and table 5) and the Rockyford Ash Member of the Sharps Formation. After stop return to Scenic.

Sheep Mountain Table provides the most spectacular vistas in this part of the Badlands. One of the best accessible sections of the upper Brule is displayed in canyons cutting into the south end of the table. Bump (1956) selected the type section of the Poleslide Member in one of these canyons, and Harksen and Macdonald (in preparation) are designating it as the type for the upper portion of the Brule Formation.

The base of the white ash layer capping the south end of the table has been the classical division between the Oligocene and the Miocene in this region. Nicknish and Macdonald (1962) formally named it the Rockyford Ash, the basal member of the Sharps Formation. It caps Cedar Butte to the south, appears on bluffs east of Wounded Knee Creek on the south side of the White River, near the top of the Badland's Wall at the Pinnacles, and on the cliffs at Cedar Pass.

Table 5. The measured section for the Poleslide Member of the Brule Formation as presented by Bump (1956).

Feet	Description
	Upper Zone
85	Gray silty ash. Horizontal bedding. Weathers in vertical walls and columns. Overlain by basal Arikaree white ash (Rosebud of Matthew).
	Middle Zone
111	Buff and gray-colored clays. *Protoceras* channel sandstone at several layers in upper 40 feet but not within 10 feet of upper gray ash. Sandstones highly fossiliferous. Clays moderately fossiliferous.
	Lower Zone
13	Light gray color with narrow brown band above and below (Light weathering band of Wanless).
90	Gray clays with brown hue. Least fossiliferous horizon of the Brule Formation. Underlain by the upper nodular zone.

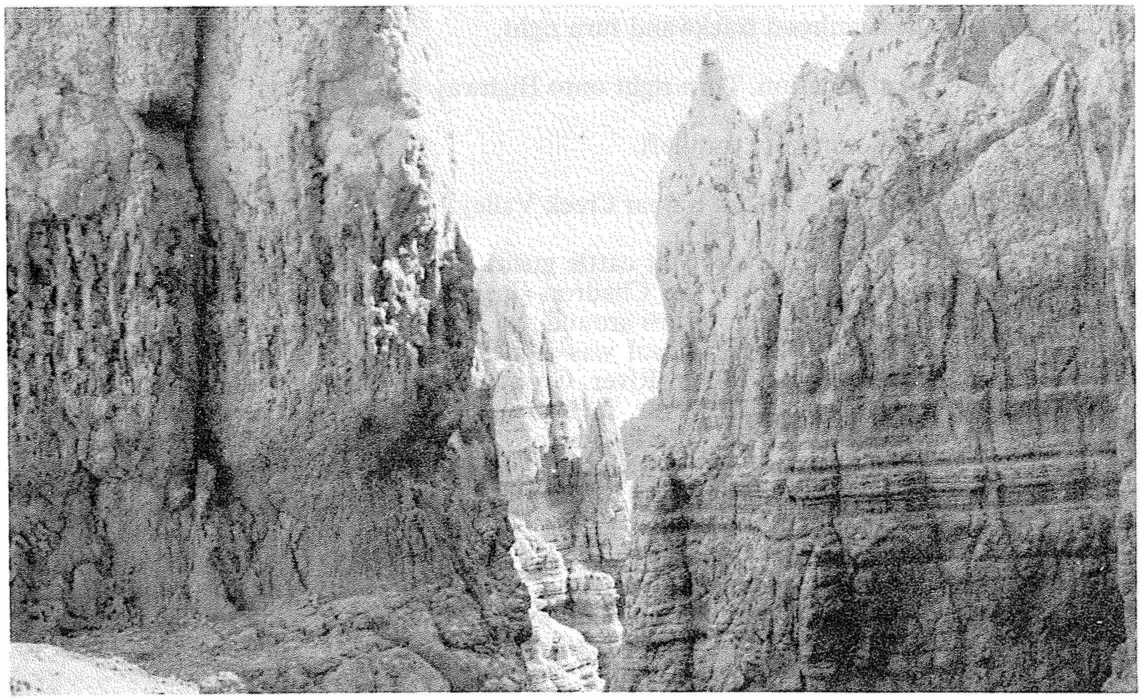


Figure 27. This area marks the top of the Poleslide type section as measured by Bump. Note the nodules that are present in the Rockyford Ash.

066.7 07.2 Turn left at road junction. Note the contact between the Scenic and Poleslide on the side of Heck Table (fig. 28).

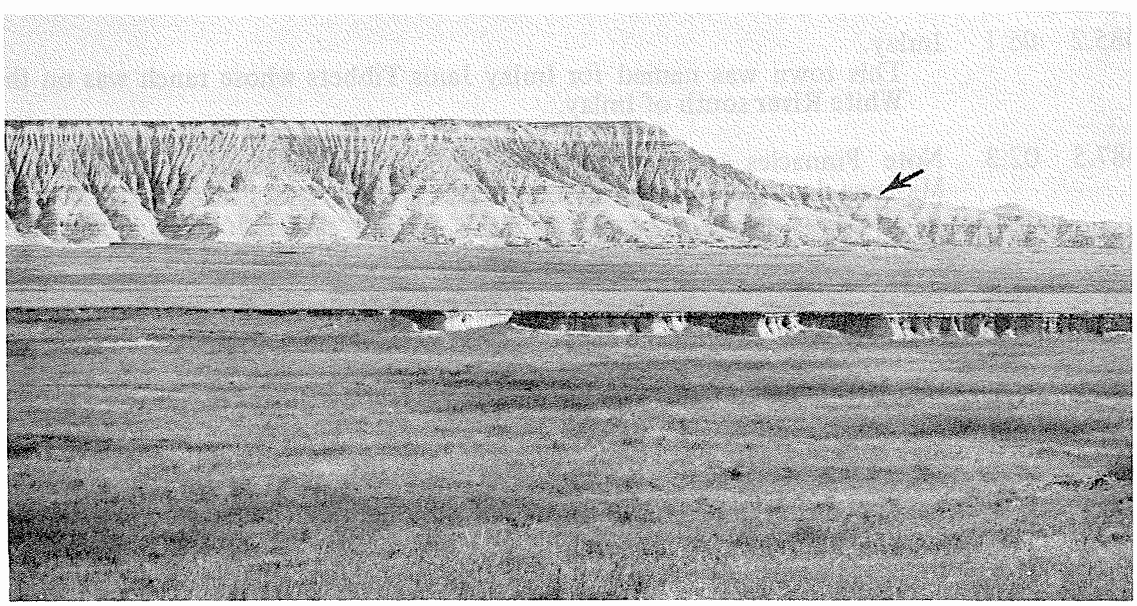


Figure 28. South end of Heck Table with the arrow indicating the contact between the Scenic and Poleslide. Note the finer system of drainages that is developed on the Poleslide.

070.8	04.1	Cross railroad tracks and turn right.
071.3	00.5	Road junction. Turn right onto Highway 40.
071.7	00.4	Road junction, turn left.
072.2	00.5	Ahead on horizon is Bear Creek Valley.
074.1	01.9	**STOP EIGHT**. Stop at cattle guard marking Badlands National Monument boundary to see the Chadron–Brule contact and the Chadron–Interior contact. After stop turn around and return to Highway 40. The Interior Paleosol was named by Ward in 1922. It is usually found below the White River Group where it is developed on the Pierre Formation. However, in tracing the White River deposits east from the Black Hills the Interior Paleosol can be found developed on many other lithic units. At field trip mileage 569.2 we will see it developed on the Graneros Shale, at 582.8 on the Greenhorn Limestone, and at 487.2 on the Niobrara Chalk. At this particular stop one can see and examine the whole Chadron exposed from the contact with the underlying Interior Paleosol to the contact with the overlying Brule Formation.
076.4	02.3	Turn left onto Highway 40.
078.2	01.8	Cross cattle guard marking boundary of Badlands National Monument. Both Scenic and Poleslide Members of the Brule Formation are exposed to the left of the road.
078.7	00.5	Note extensive development of lower nodular zone.
080.1	01.4	Note extensive development of dune sand on left front horizon. Leave Badlands National Monument.
085.2	05.1	Imlay. This town was named for Imlay Janis Tibbets whose ranch was on the White River south of Imlay.
087.5	02.3	Note Pinnacles on left front horizon. The Rockyford Ash and other Miocene deposits occur at the Pinnacles.
090.9	03.4	Blowout in dune sand to the right has a vertical exposure of 82 feet.
091.9	01.0	Excellent view of Badlands wall to the left front. To the front is the ruggedly eroded, Miocene capped Cedar Pass area.
097.1	05.2	Note structure to right. The butte ahead is Hurley Butte (fig. 29).
099.7	02.6	Pink sediments on both sides of the road are basal Chadron Formation.
100.8	01.1	Agate beds developed on both sides of the road.
102.6	01.8	Interior Paleosol developed on the Pierre to the left.

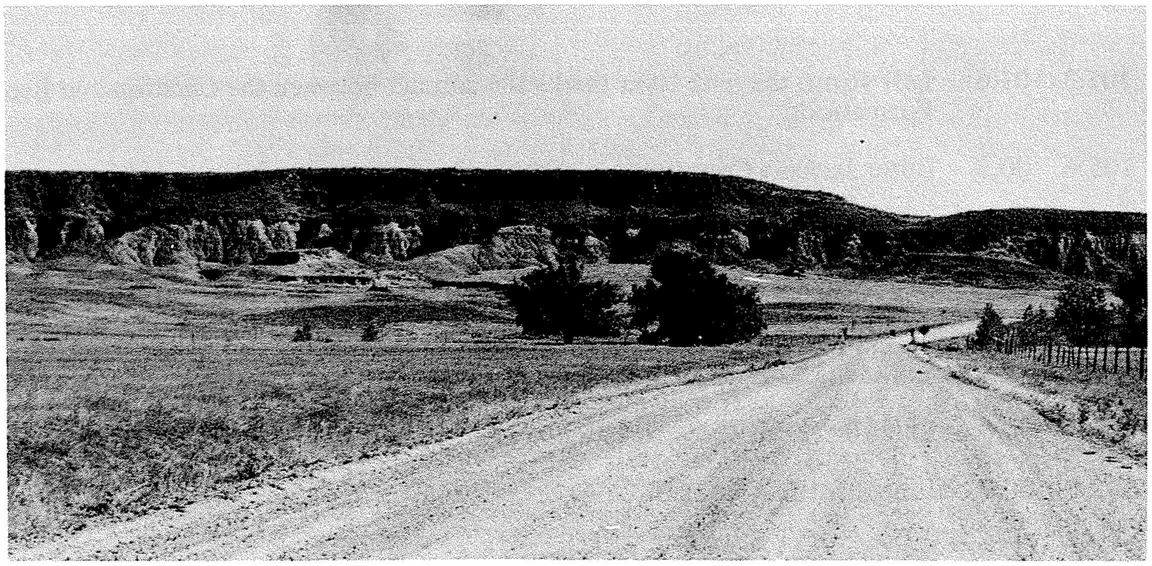


Figure 29. Hurley Butte, named for one of the pioneer settlers of this region.

103.7 01.1 Note white channels (fig. 30), ahead right, which are developed between the Interior Paleosol and the typical clays of the Chadron Formation. Clark and others (1967) refer these channels to the Slim Buttes Formation of Malhotra and Tegland (1960). However, these sandy channels in no way lithically resemble the Slim Buttes Formation (verigated silts and clays) of northwestern South Dakota. No diagnostic fossils have been collected from these white channels.

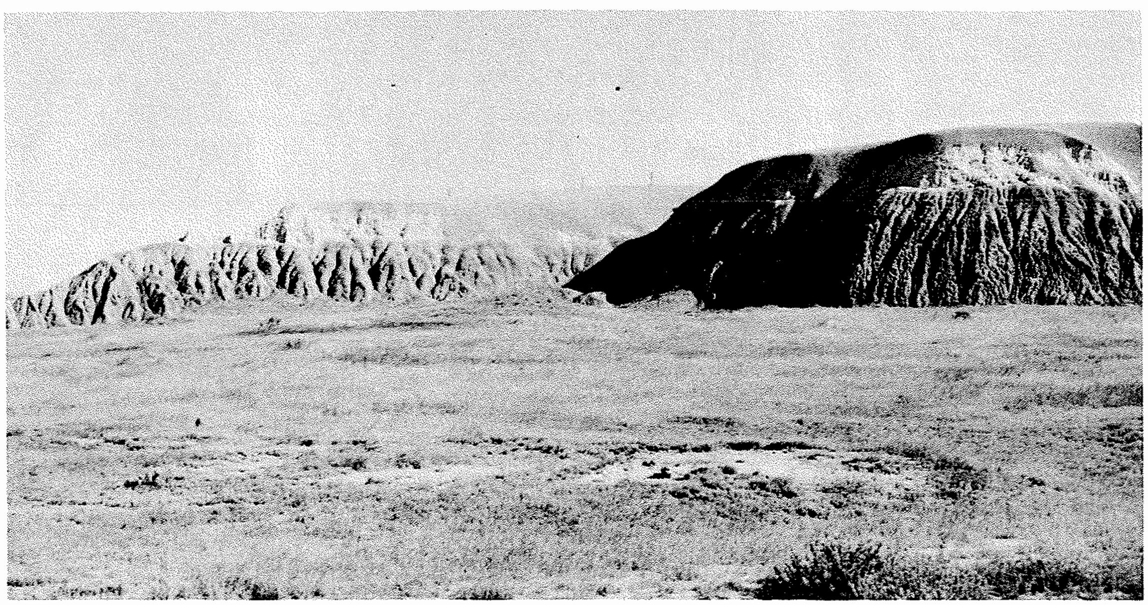


Figure 30. White channels (basal Chadron Formation) lying unconformably upon the Interior Paleosol. This area is in sec. 12, T. 4 S., R. 17 E., Pennington County.

105.3	01.6	Left front, the pink layer marks the contact between the Chadron and Brule Formations.
105.6	00.3	Enter Jackson County.
107.2	01.6	Enter Interior.
107.7	00.5	Standard station on left.
108.3	00.6	Prominent bench two-thirds of the way up the outcrop in the foreground marks the Rockyford Ash.
109.2	00.9	Enter Badlands National Monument.
109.9	00.7	Junction 16A—turn left.
110.5	00.6	Note fault to right.
111.2	00.7	Note fault ahead—this is Pass Creek Fault (fig. 31).

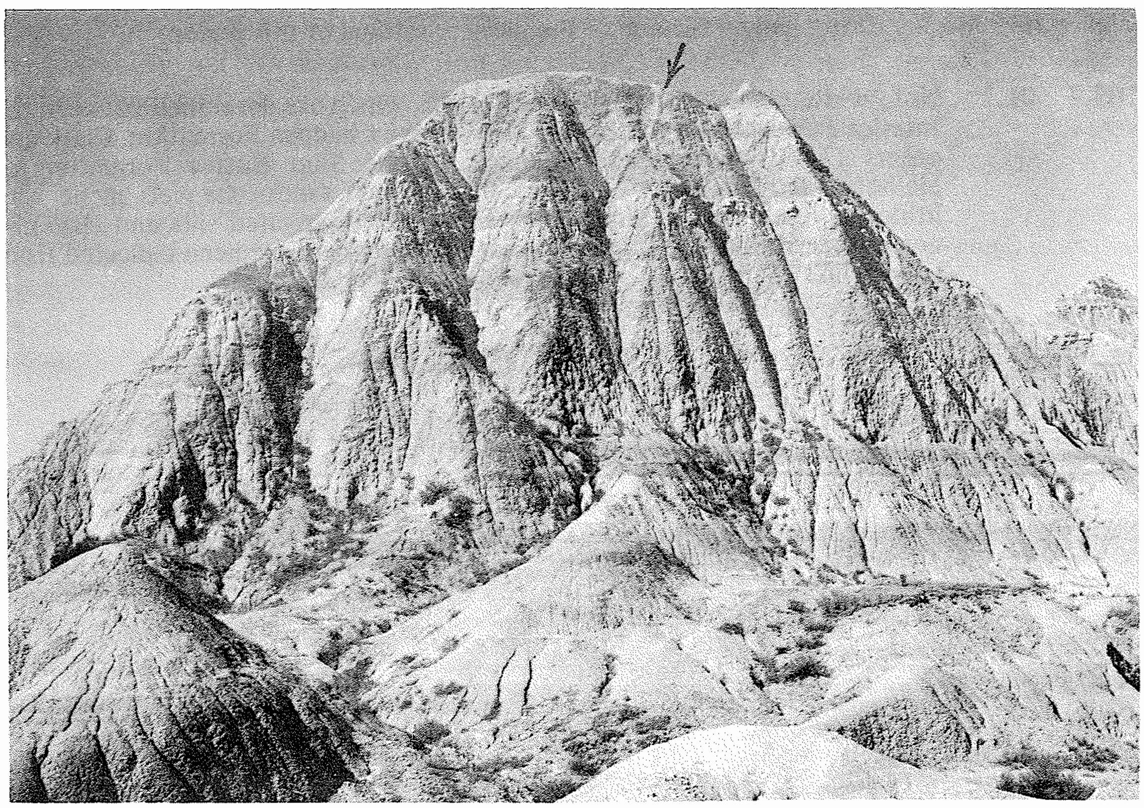


Figure 31. Pass Creek Fault marked by arrow. Road is to the left of the photograph.

111.5	00.3	Turn around. Remain on 16A for remainder of day.
113.3	01.8	Cedar Pass Lodge on right.
113.5	00.2	Badlands National Monument Visitors Center on right.

114.2 00.7 **STOP NINE.** Cliff Shelf Nature Trail parking lot. Stop to see the contact between the Scenic and Poleslide Members of the Brule Formation (fig. 32). After talk continue north on Highway 16A.

The contact between the Scenic and Poleslide Members of the Brule Formation is exposed at the junction of the red clay of the "Upper Oreodon" level and gray ashy clay of the "Leptauchenia Beds." The typical lithic zones of the Brule Formation in the type area tend to become somewhat obscured as the formation is traced eastward.

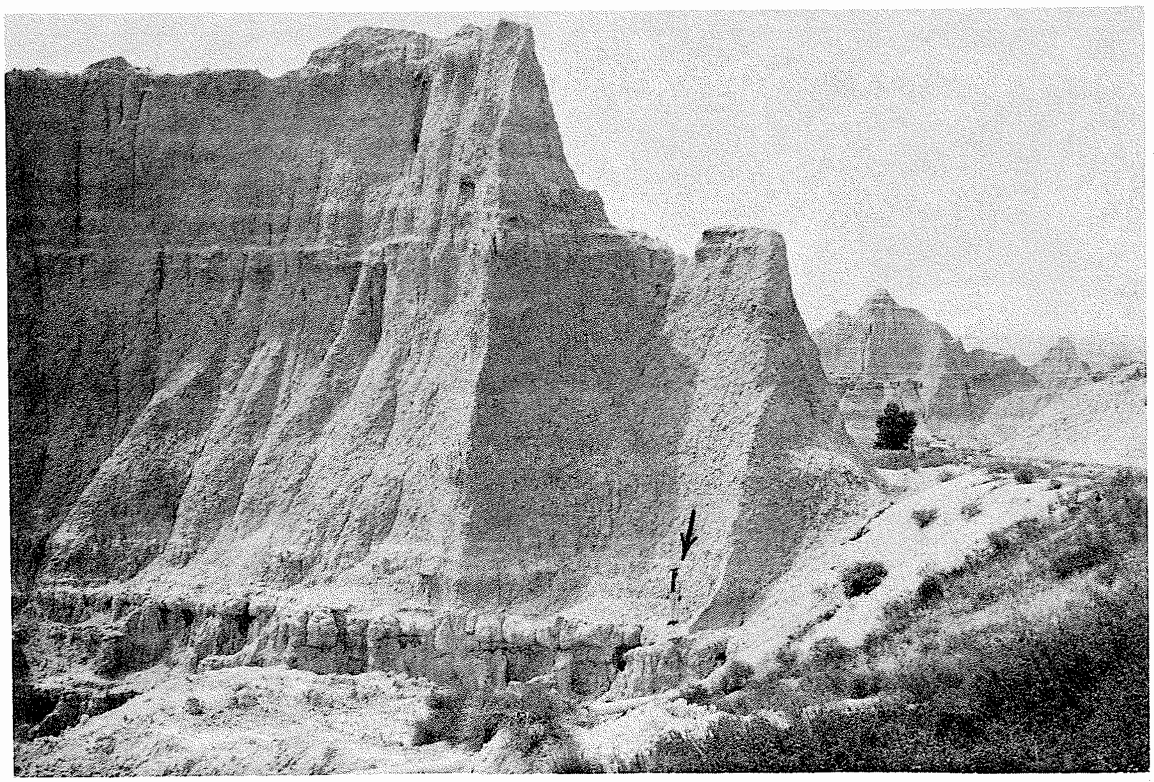


Figure 32. The arrow points to a man standing on the contact between the Scenic and Poleslide Members of the Brule Formation. This spot is just to the southwest of the Cliff Shelf Nature Trail parking lot of the Badlands National Monument.

114.6 00.4 **STOP TEN.** Stop to examine the Rockyford Ash at Cedar Pass (fig. 33). After stop turn around and return to the Visitors Center of the Badlands National Monument.

The Rockyford Ash is the prominent hard white layer about 22 feet thick beginning about 20 feet above the road surface. This is the most persistent marker bed in the Badlands. Above the Rockyford Ash are about 130 feet of early Miocene sediments which may be referred to the Sharps Formation. These erosional remnants are not continuous with the nearest Sharps exposures to the southwest. They do not show the typical number of potato nodules, and the lithology is slightly different. However, as the former is a ground water phenomenon and the latter a possible shift of facies, there is no reason not to refer these strata to the Sharps Formation.

115.7 01.1 Visitors Center of the Badlands National Monument and the end of Day Number One.

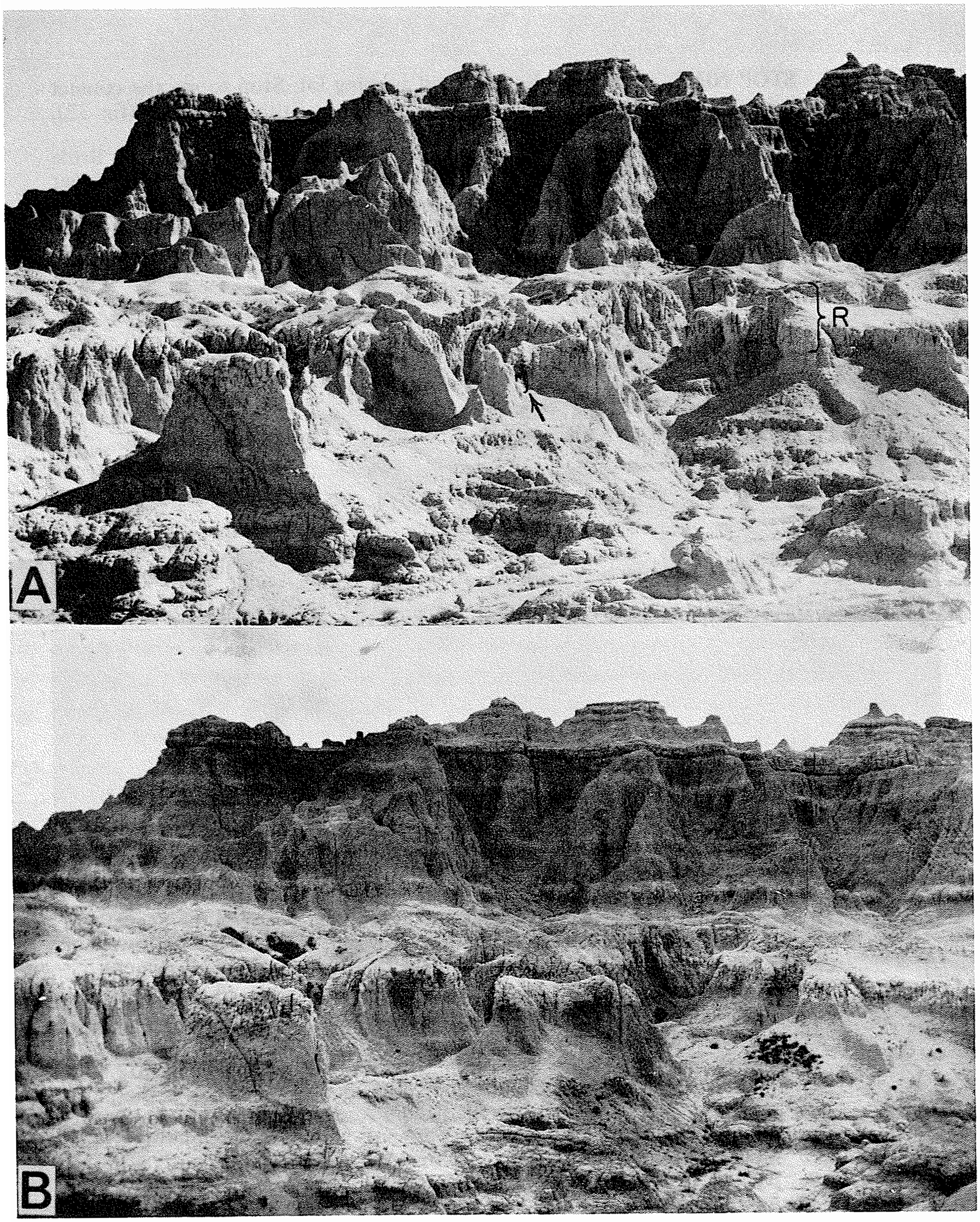


Figure 33. Rockyford Ash along with underlying and overlying deposits at Cedar Pass, Badlands National Monument. A. "R" marks the Rockyford Ash while the arrow indicates a man included for scale. This photograph was taken in 1968. B. This photograph, taken from the same spot as the one above, was taken by Dr. E. P. Rothrock in about 1930.

SECOND DAY: Cedar Pass to Mission

115.7 00.0 Assemble at the Visitors Center of the Badlands National Monument. Begin day by heading west on Highway 16A (fig. 34).

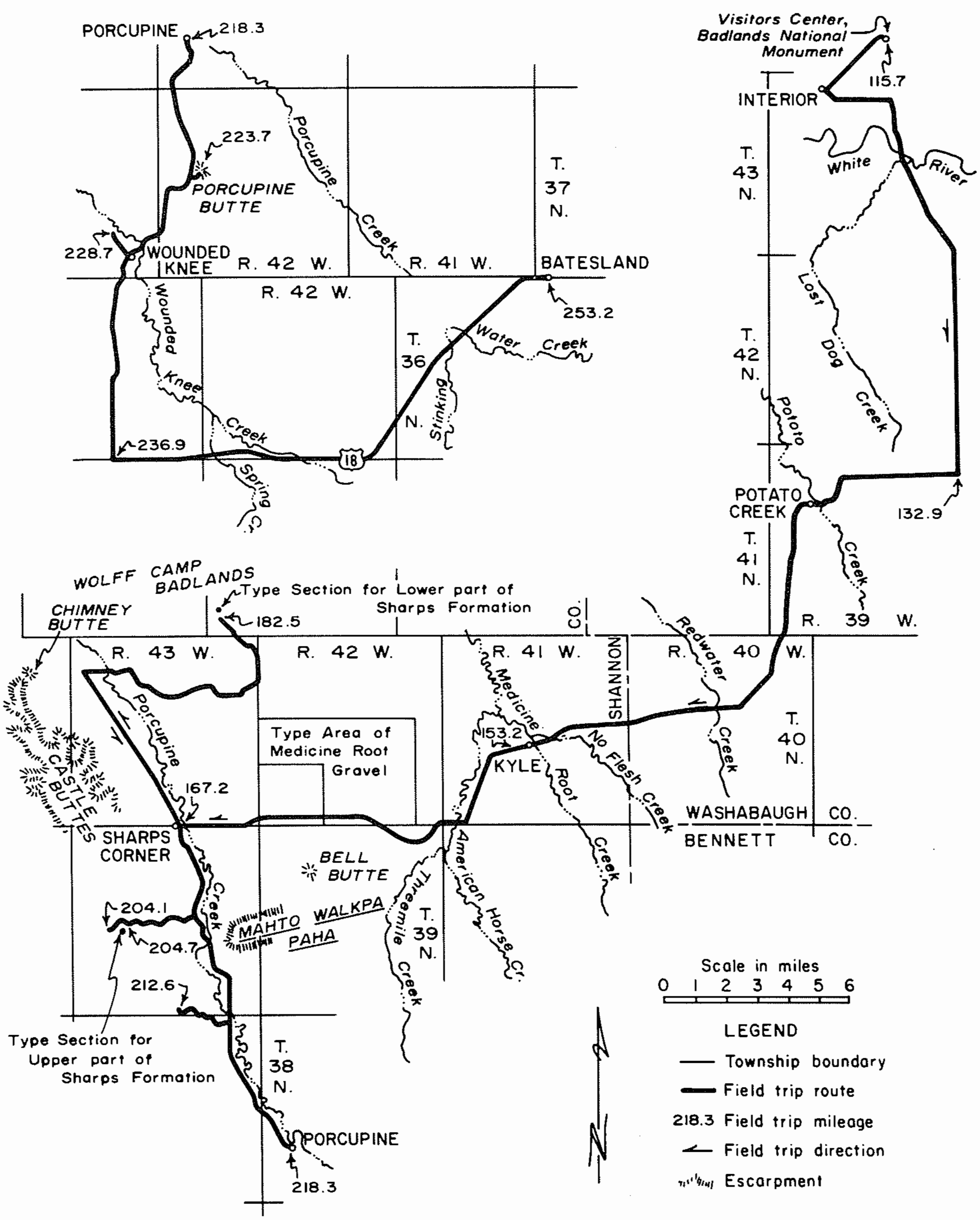


Figure 34. Map of the route to be followed on the first half of the second day of the field trip.

116.1	00.4	Road Junction–40 and 16A. Turn left onto Highway 40 toward Interior.
118.3	02.2	Standard station in Interior. Turn left onto unmarked road.
119.8	01.5	Cedar Pass to left front.
120.6	00.8	Quaternary terraces and Brule Formation along road.
122.3	01.7	Cross the White River. The White River is so called because of suspended clay which gives a milky color to its water.
128.5	06.2	Anticline in Brule to left.
129.0	00.5	Eagles Nest and Buzzard Buttes visible to the left front. The names are descriptive.
132.9	03.9	Road junction–turn right (west).
133.0	00.1	Sharps Formation in roadcut. The Sharps Formation was named by Harksen, Macdonald, and Sevon (1961). More information is presented at mileage 182.5 and 204.7.
133.9	00.9	The broad expanse of gravels capping this upland are Medicine Root gravel. The Medicine Root gravel was named by Harksen (1966). The gravel forms a discontinuous string of deposits from Cuny Table east to this area. The Medicine Root gravel is believed to be Nebraskan in age and large boulders of Black Hills origin found in this gravel hint of icerafting at high water in spring breakup (fig. 35).

Figure 35. This boulder of white sandstone and orthoquartzite (?Lakota Formation) was found in the Medicine Root gravel in sec. 11, T. 41 N., R. 39 W., Washabaugh County. This boulder has been moved about 70 miles from the Black Hills out onto the plains. 12½ inch geology pick for scale.

135.5 01.6 Medicine Root gravel in roadcut. The photograph presented as figure 35 was taken about a mile to the southwest.

137.3 01.8 Sharps Formation in roadcut.

137.6 00.3 Cross Potato Creek.
According to legend Potato Creek was so named because of wild potatoes which grew along the stream.

137.8 00.5 Defunct town of Potato Creek to the left.
For local color and history, see the books by Will Spindler who was stationed at the Wounded Knee and Potato Creek Day Schools for many years.

138.3 00.5 Sharps Formation in roadcut.

141.2 02.9 Medicine Root gravel capping hills on both sides of the road.

144.6 03.4 Monroe Creek Formation outcrops to the left of the road. Note the bare slopes and the vertical weathering.
The Monroe Creek Formation was named by John Bell Hatcher (1902) for exposures in Monroe Creek Canyon, Sioux County, Nebraska.

148.9 04.3 Medicine Root gravel capping hills to the right. Photograph presented as figure 36 was taken there.

Figure 36. Medicine Root gravel in a gravel pit in sec. 7, T. 40 N., R. 40 W., Washabaugh County. This gravel pit is about 1½ miles to the north of field trip mileage 148.9. 12½ inch geology pick for scale.

152.7 03.8 Kyle Day School on the right.
Kyle was named for former United States Senator James H. Kyle of Aberdeen.

153.2 00.5 Well developed nodular Sharps Formation exposed in roadcut to the left (fig. 37).

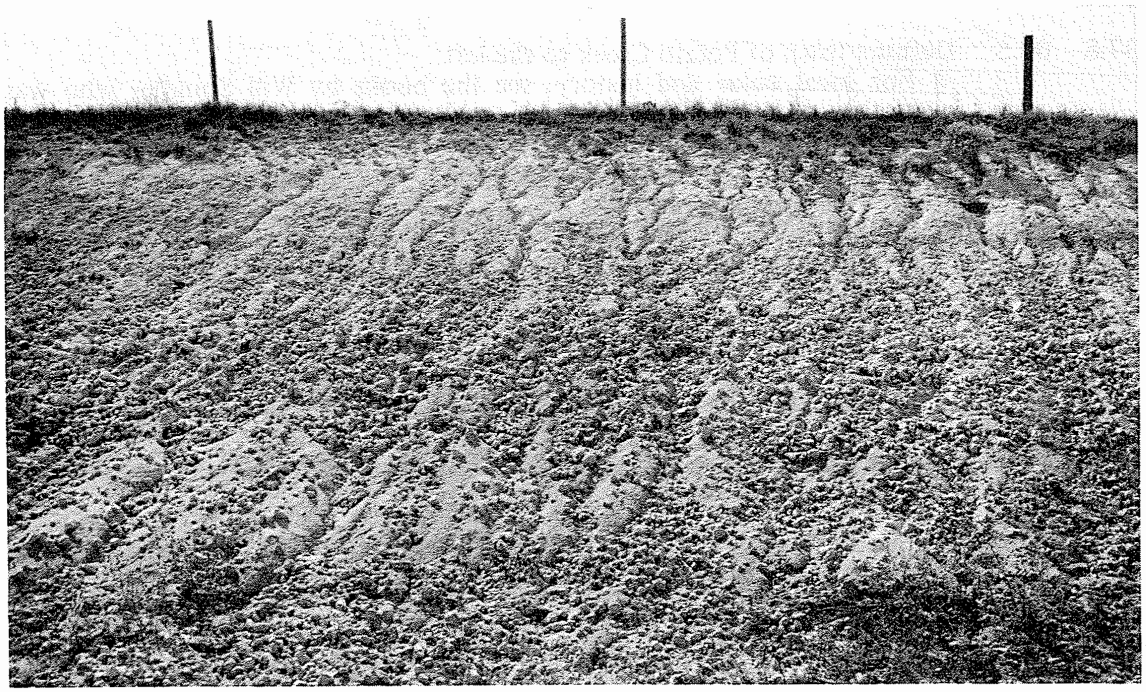


Figure 37. Roadcut in the Sharps Formation west of Kyle. This roadcut well exemplifies the nodular character of the Sharps.

156.8 03.6 Cliff forming formation to the southeast is the Monroe Creek Formation.

157.3 00.5 Turn right toward Sharp's Corner. Sign says "Sharps 10 mi."

160.6 03.3 Monroe Creek outcrops to the left.

162.1 01.5 Good view of Black Hills on far horizon and Castle Buttes in middle distance. Castle Buttes are Sharps Formation capped with grass covered eolian deposits. The Sharps Formation forms cliffs in this area due to heavy cementation. This led early geologists and paleontologists to believe it was part of the Brule Formation because the Rockyford Ash was obscured by the cementation. The cliffs on the southwest horizon are formed by the vertical weathering Monroe Creek Formation capped with Harrison Formation.
Castle Buttes were so named because portions of it have a resemblance to a medieval castle. The Harrison Formation was named by John Bell Hatcher (1902) for outcrops in Monroe Creek Canyon (north of Harrison) in Sioux County, Nebraska.

167.2 05.1 Road junction at Sharps Corner—turn right (north) following the valley of Porcupine Creek.
Sharps Corner was named after its founder, Grover Sharp.

169.5 02.3 Castle Buttes on the left (fig. 38). This is the approximate area where the Rockyford Ash disappears underground.

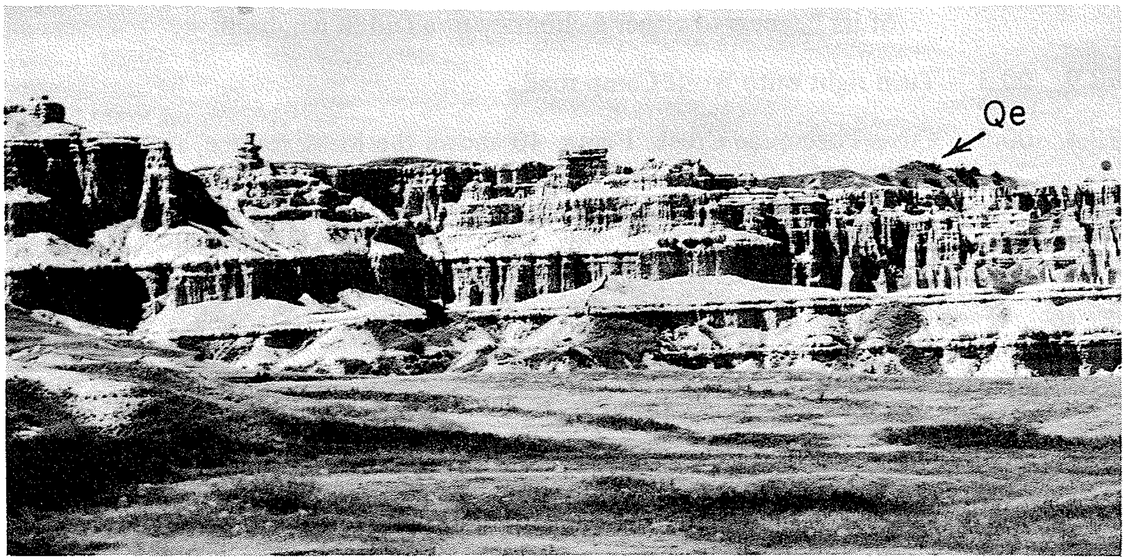


Figure 38. Photograph of a part of the Castle Buttes complex taken from a point in the NW¼, sec. 20, T. 40 N., R. 43 W., Shannon County. "Qe" marks one of the many deposits of Quaternary eolian material which cap the high points of the buttes.

170.0 00.5 Cedar Butte to the left front. The Rockyford Ash is just below the tree line. Sheep Mountain Table is to the right front.

Cedar Butte is so named because of the junipers which grow upon it.

171.5 01.5 Log cabin-dugout on left side of the road (fig. 39).

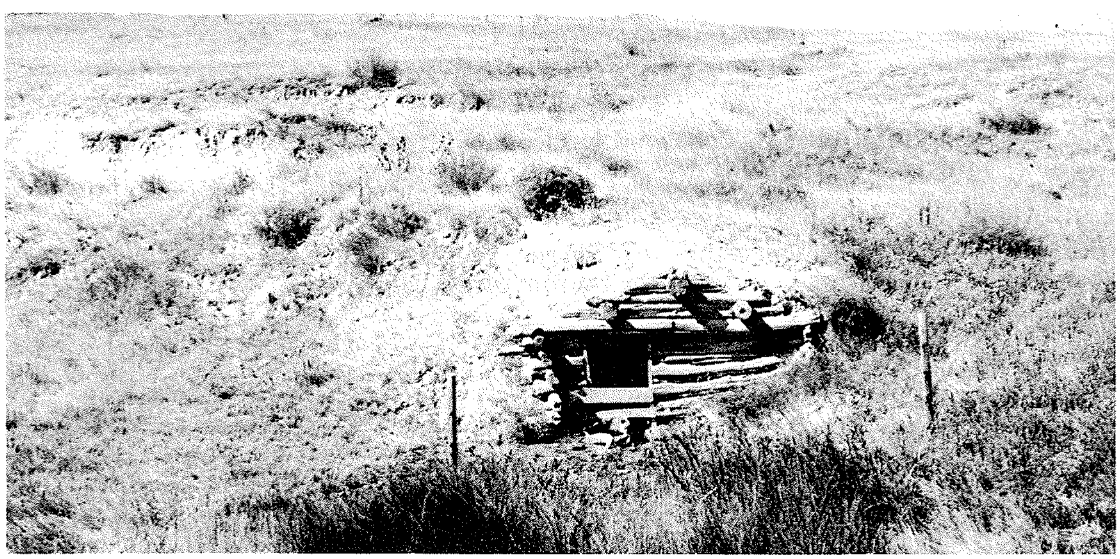


Figure 39. Dugout cabin along the highway about four miles north of Sharps Corner.

171.9 00.4 The grass-covered butte straight ahead on the horizon is Stirk Table.

172.6 00.7 Chimney Butte to the left.
Chimney Butte (sometimes called Windmill Butte) was so named because of its likeness to either a chimney or a Dutch windmill.

172.9 00.3 Turn right onto Wolff Camp road.

173.4 00.5 Cross Porcupine Creek. Figure 40 shows the loess, terrace, and Brule found at this point.
Porcupine Creek was so named because it originates near Porcupine Butte.

Figure 40. Loess (Ql), Brule (Tob), and terrace deposits (Qt) exposed to the northeast of the field trip crossing of Porcupine Creek (mileage 173.4).

176.2 02.8 Extensive exposures of Sharps Formation to the right. Some Brule Formation exposed in the bottom of the canyon.

179.2 03.0 Road junction, take left fork.

180.0 00.8 Go through wooden gate. Fifty feet beyond gate take the left fork in the road.

180.8 00.8 Take left fork in road.

181.5 00.7 Go through wooden gate.

181.8 00.3 Take left fork.

182.5 00.7 **STOP ELEVEN.** Leave trail and veer to the right (north). CAUTION: do not walk or drive over cliff. Park 100 feet north of the trail and walk to the edge for a talk on the type section for the lower half of the Sharps Formation (figs. 41 and 42). After talk retrace route to Sharps Corner.

When Matthew and Thomson crossed the White River in 1906 to prospect for early Miocene vertebrates, they used the White Ash Layer (Rockyford Ash) as their epoch boundary. Losing the ash in a jumble of slides and vegetation in Wounded Knee Creek they did not begin prospecting until they reached Manderson and the gradational contact between the Sharps Formation and the Monroe Creek Formation. Working south to Wounded Knee and then north to Porcupine Butte they collected up section through the Monroe Creek, Harrison, and Rosebud Formations. Continuing north down Porcupine Creek they stopped on a surface of cemented Sharps Formation to the north of Bear Creek Hill (mile 198.8). This surface, which they mistook for the Rockyford Ash, is 100 feet below the Sharps–Monroe Creek contact and 250 feet above the base of the Sharps Formation. Thus, they missed most of the Sharps Formation in their collecting. Matthew (1907), when describing the fauna, brought Gidley's (1904) name Rosebud Beds westward and referred the entire sequence to these formations dividing the section into two parts – Lower Rosebud Beds including the top 100 feet of the Sharps, the Monroe Creek and the lower moiety of the Harrison Formations; the Upper Rosebud Beds containing the remainder of the Harrison and the Rosebud Formation (senu stricto). The lower 250 feet of the Sharps Formation was believed to be Brule Formation.

In 1953 Macdonald (1963) discovered the richly fossiliferous nature of the Sharps Formation and Matthew's error in levels at the base of Bear Creek Hill. Harksen joined the project in 1959 and began mapping the area. The unit between the top of the Brule Formation and the base of the Monroe Creek Formation was named the Sharps Formation (Harksen and others, 1961) with the exposures below, beginning at the base of the Rockyford Ash, chosen as the type section for the lower part of the formation.

192.1 09.6 Asphalt road–turn left (south).

197.8 05.7 Sharps Corner–continue south on unnumbered asphalt road.

198.8 01.0 Pine covered hill is *Mahto Wakpa Paha* (Bear Creek Hill). The bare area below the hill-mass is highly cemented Sharps Formation. This area was shown in Osborn (1918) and Harksen (1968b).

200.5 01.7 **STOP TWELVE.** Stop to examine cemented Sharps Formation along the side of the road (fig. 43). After stop continue south on the asphalt road.

The heavily cemented Sharps Formation sediments exposed on the surface at the base of Bear Creek Hill were believed by Matthew and Thomson to be the Rockyford Ash and marked the end of their down section prospecting in this area. An ironic note was the discovery of one of the richest vertebrate microfaunal sites in the Sharps Formation at the edge of this cemented area in 1953.

201.1 00.6 Turn right onto the Gooseneck Road. The Gooseneck Road was first mentioned in print by Macdonald (1963).

201.9 00.8 The farthest north outcrops of Monroe Creek Formation on Wounded

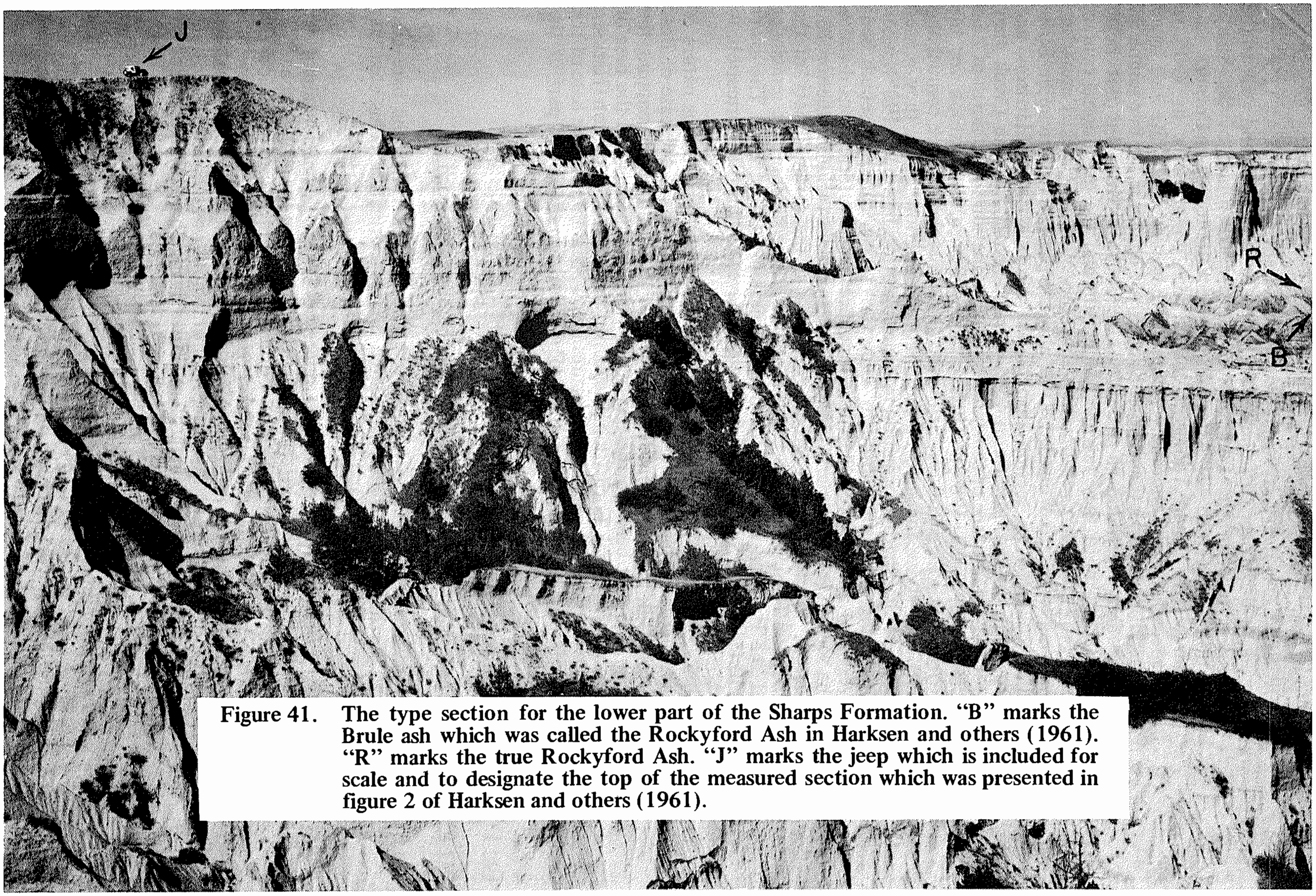


Figure 41. The type section for the lower part of the Sharps Formation. “B” marks the Brule ash which was called the Rockyford Ash in Harksen and others (1961). “R” marks the true Rockyford Ash. “J” marks the jeep which is included for scale and to designate the top of the measured section which was presented in figure 2 of Harksen and others (1961).

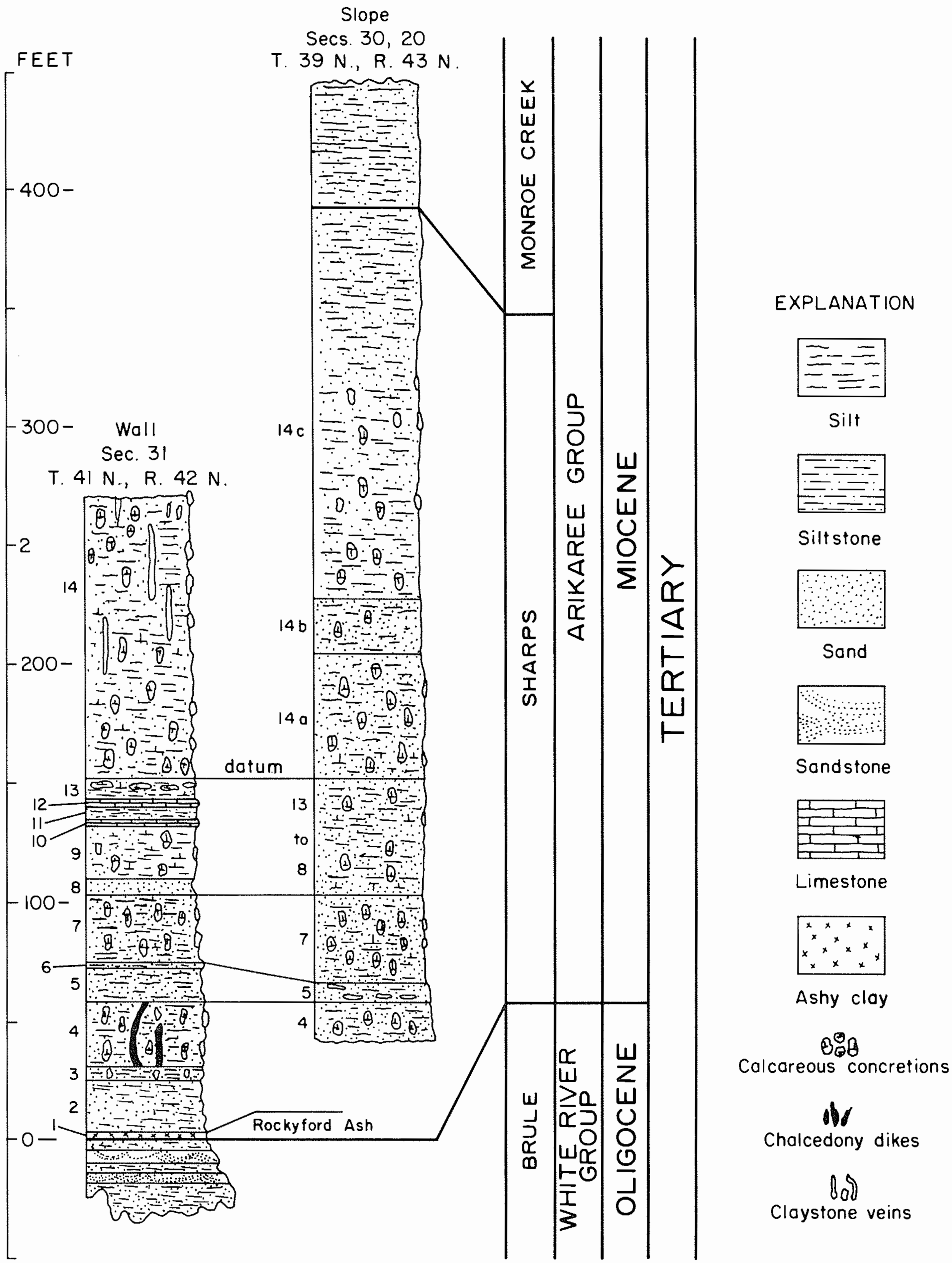


Figure 42. Columnar sections originally presented as Figure 2 of Harksen and others (1961). *Please note that bed 3 is the Rockyford Ash, not bed 1.*

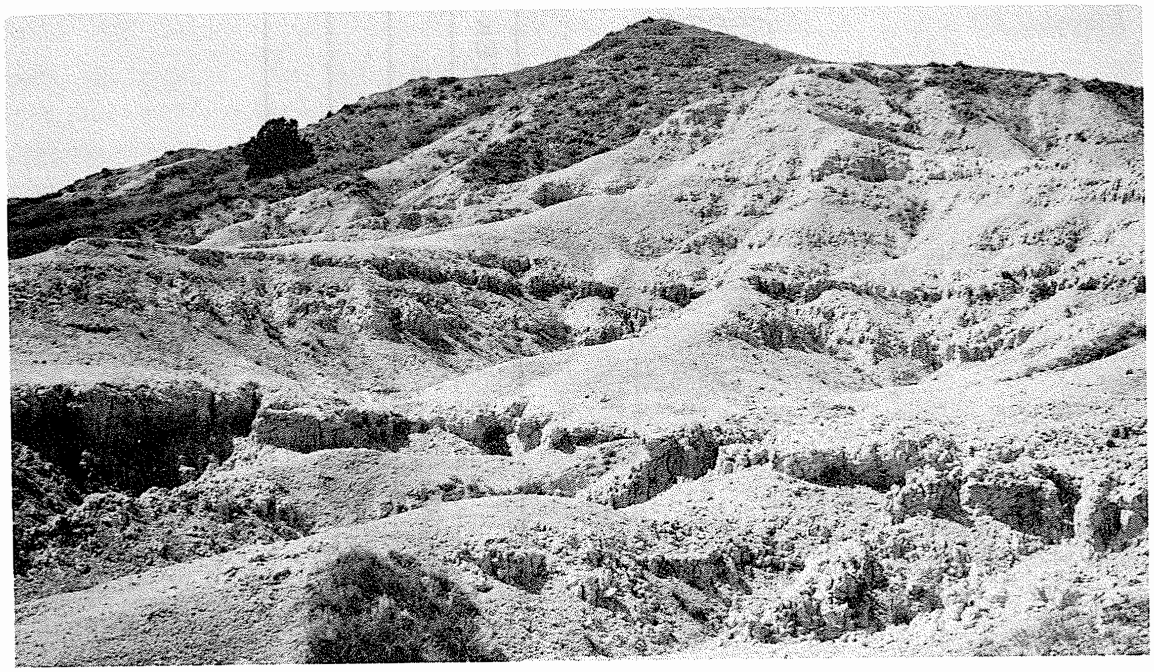


Figure 43. Highly cemented Sharps Formation exposed along the highway about two and one-half miles south of Sharps Corner.

Knee–Porcupine Creek divide are visible to the left front. Irregular grass covered knobs on top of the Monroe Creek are remnants of the Harrison Formation.

Wounded Knee Creek bears a name which is a translation of the Sioux name for this creek. Somewhere along its course a Sioux was wounded in the knee by an arrow in a fight with Crow Indians.

204.1 02.2 **STOP THIRTEEN**. Stop just to the west of the Sharps cutoff and walk to the crest of a small hill. There will be a short talk on the local geology. After the discussion return to the cars, turn around, and retrace route to asphalt road.

Exposed on the road and the side of the small hill are typical fossiliferous Sharps nodules. To the west is Wounded Knee Creek, to the south is the town of Manderson, to the southeast is the beginning of bluffs formed by the Monroe Creek Formation with a thin capping of Harrison Formation.

204.7 00.6 **STOP FOURTEEN**. Stop at cattle guard. Walk south along fenceline for 150 yards. At this point is the type section for the upper half of the Sharps Formation (see figs. 42 and 44). After discussion and examination return to cars and proceed east.

At this stop we are at the top of the type section for the upper half of the Sharps Formation. The type section was measured down the valley to the west.

In 1959 when we were writing the original description of the Sharps Formation we wanted one complete section of Sharps but none was to be found. We finally chose two areas in which the Sharps was relatively vertical, accessible, and free of vegetation, representative of the upper and lower Sharps, to be the standard bearers. Sevon, who measured and described the section for the original description (Harksen and others, 1961), measured a 325.5 foot section of Sharps down this canyon.

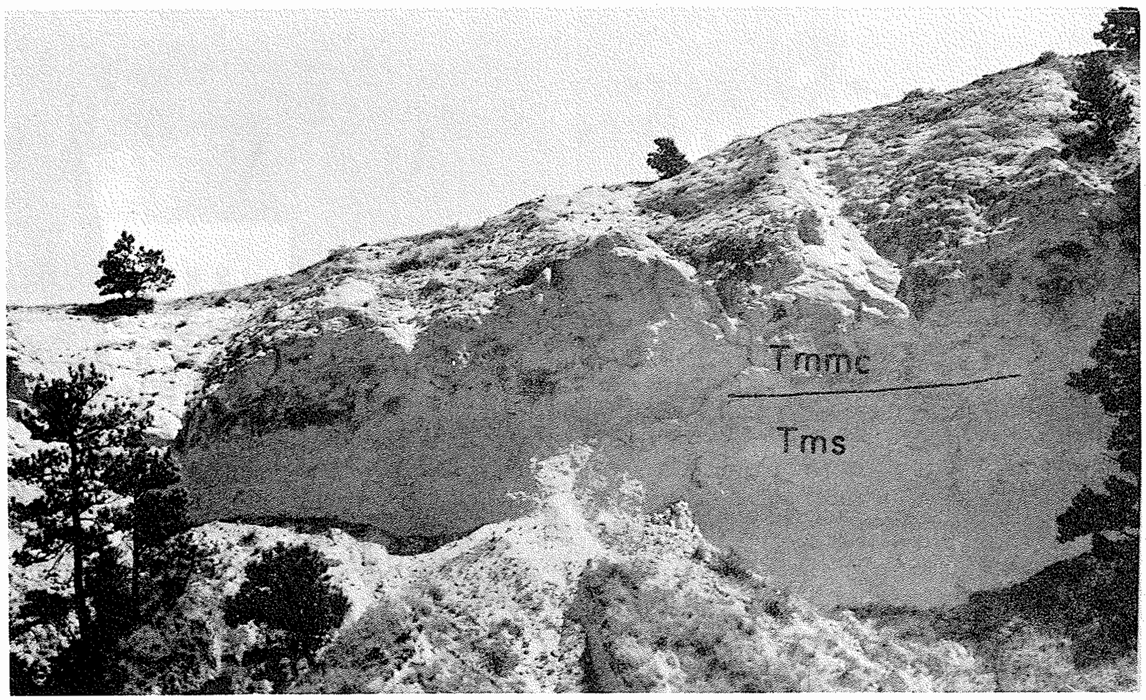


Figure 44. Contact between the Sharps and Monroe Creek Formations at the top of the type section for the upper part of the Sharps Formation.

207.1 02.4 Road junction, turn right onto asphalt road. The cemented layers in the Harrison Formation (to left) mark the boundary between Matthew's upper and lower Rosebud.

210.3 03.2 Cross Porcupine Creek.

210.5 00.2 Turn right in front of a large corrugated steel quonset hut and then immediately turn left and go through the gate southeast of the quonset hut. After going through the gate turn to the right and follow the road to the west.

210.8 00.3 Go through the gate.

211.2 00.4 Cross cattle guard. Note window (natural arch) in the Monroe Creek Formation to the left.

211.5 00.3 Take left fork in the trail.

211.8 00.3 Go through gate by corral.

211.9 00.1 Note massive channels in the Monroe Creek to the right front.

212.4 00.5 Turn right in the bottom of the valley and drive towards the Gieser Geyser.

212.6 00.2 **STOP FIFTEEN**. Stop and walk remainder of way to base of Gieser Geyser. Discussion and examination of geyser and window (figs. 45, 46, and 47). Then return to cars and return to asphalt road.

The Gieser Geyser was named by Harksen (1965). The ridge to the south is where the first specimen of *Allomys harkseni* was collected.

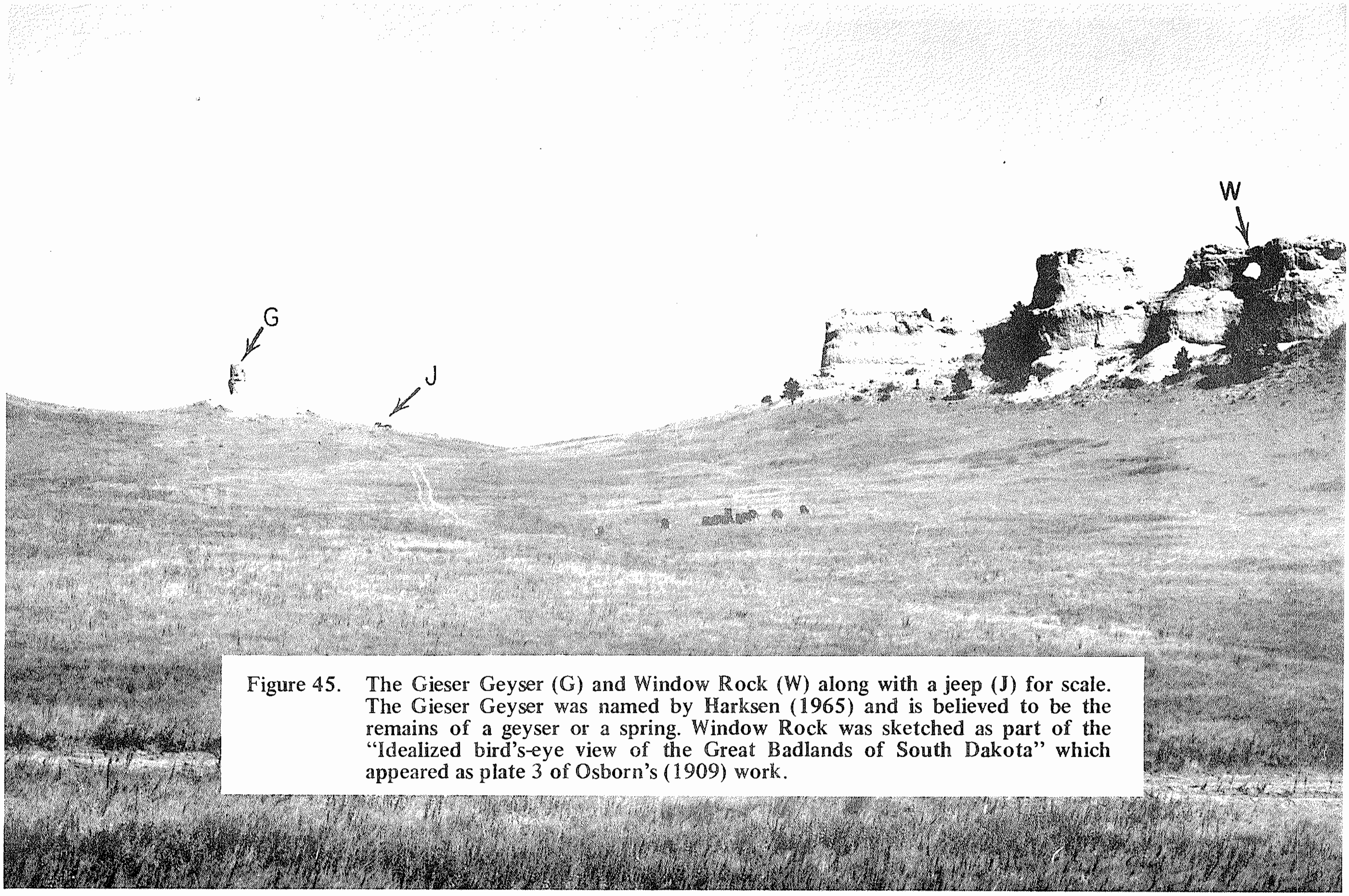
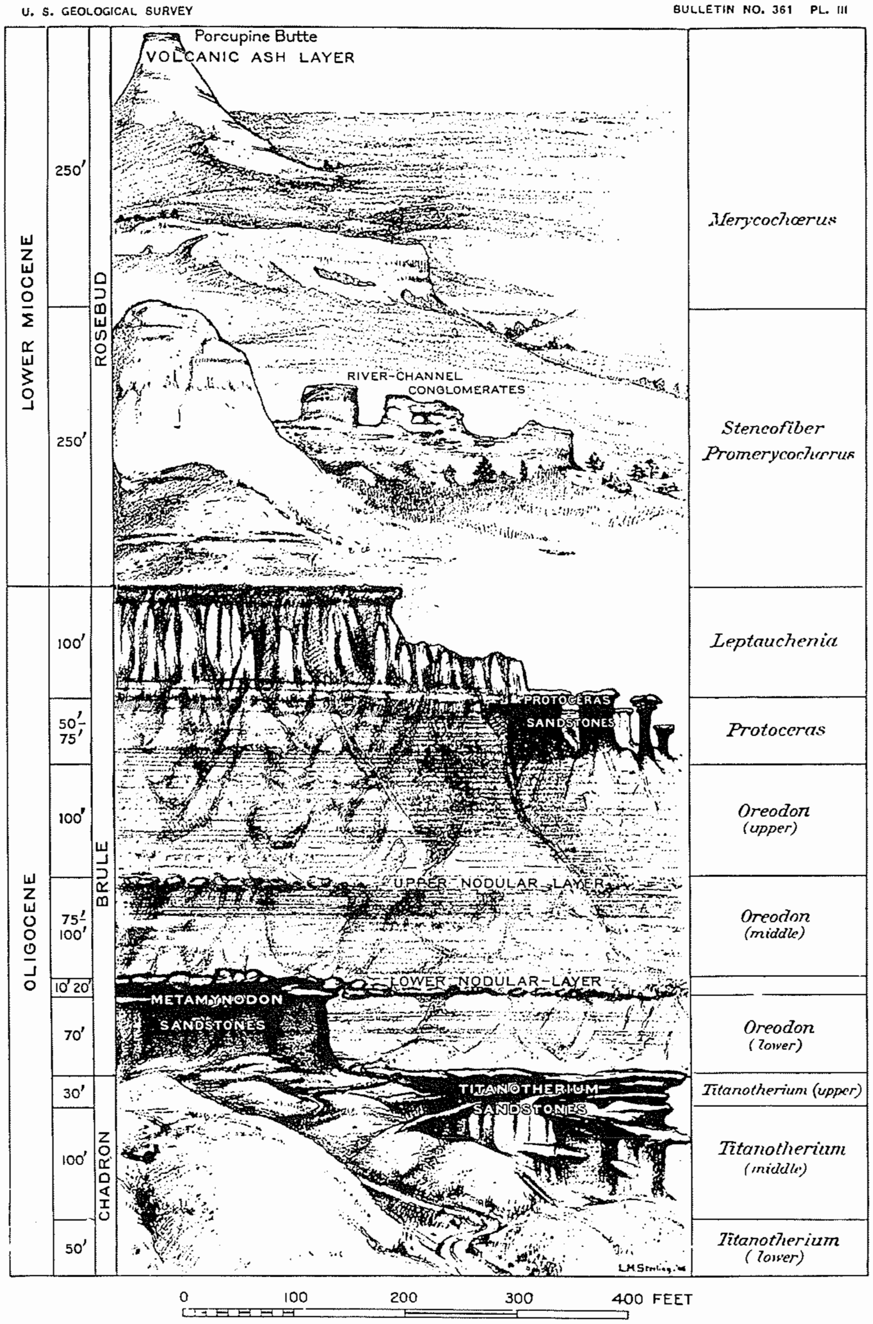


Figure 45. The Gieser Geyser (G) and Window Rock (W) along with a jeep (J) for scale. The Gieser Geyser was named by Harksen (1965) and is believed to be the remains of a geyser or a spring. Window Rock was sketched as part of the "Idealized bird's-eye view of the Great Badlands of South Dakota" which appeared as plate 3 of Osborn's (1909) work.



IDEALIZED BIRD'S-EYE VIEW OF THE GREAT BADLANDS OF SOUTH DAKOTA, SHOWING CHANNEL AND OVERFLOW DEPOSITS IN THE OLIGOCENE AND LOWER MIOCENE.

Looking southeast across Cheyenne and White rivers to Porcupine Butte, on Porcupine Creek, Pine Ridge Reservation. The location of the panorama is shown in Pl. II, approximately on the line of section B. The ancient river-channel deposits in the successive levels are the "*Titanotherium* sandstones," "*Metamynodon* sandstones," and "*Protoceras* sandstones." River-channel conglomerates appear in the Rosebud levels also.

Figure 46. Plate 3 of Osborn's (1909) work is here reprinted for the benefit of the people on the field trip.

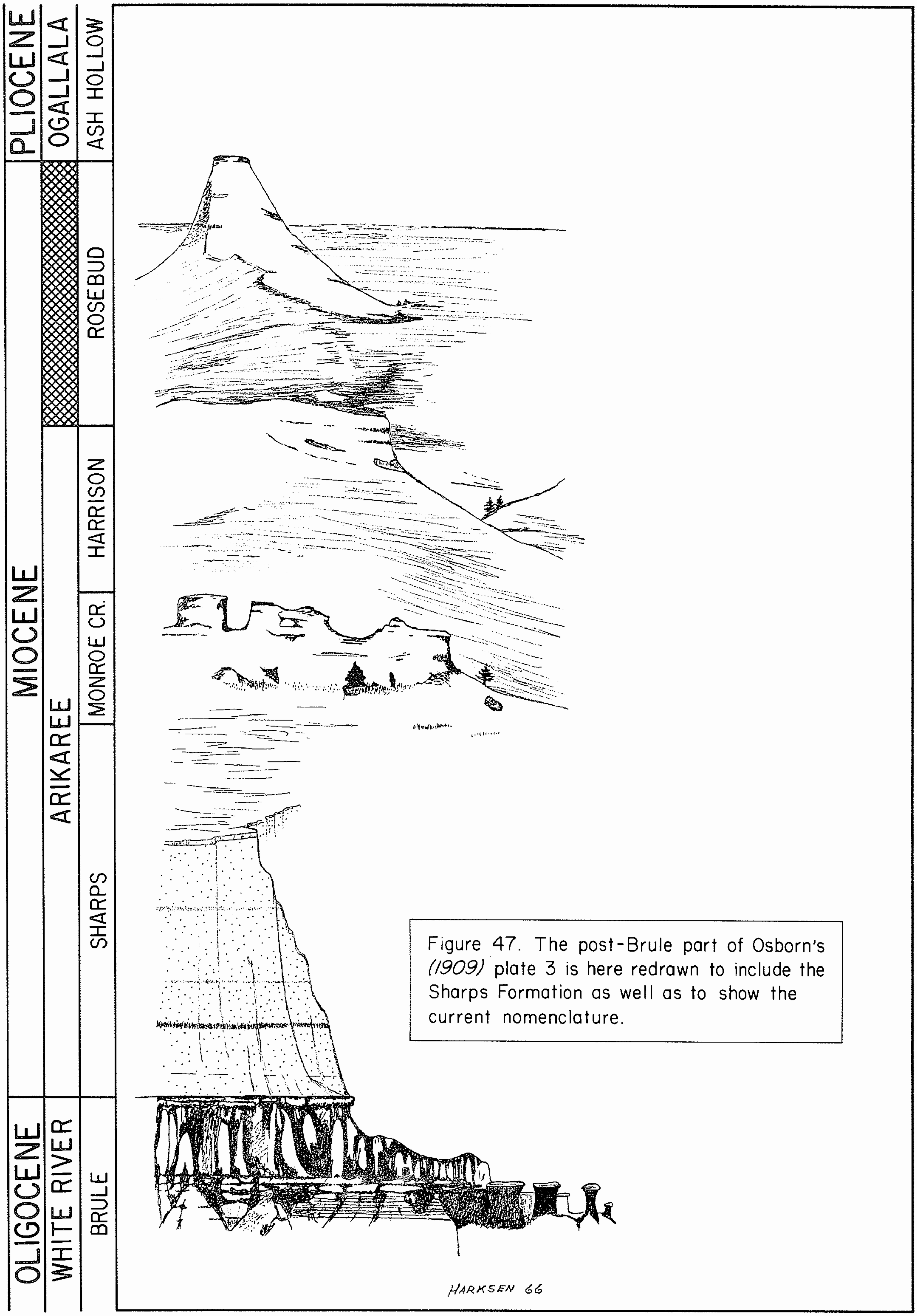


Figure 47. The post-Brule part of Osborn's *(1909)* plate 3 is here redrawn to include the Sharps Formation as well as to show the current nomenclature.

214.6 02.0 Turn right onto asphalt road.

215.9 01.3 Road surface at approximate level of Sharps–Monroe Creek contact.

217.8 01.9 Lady of Lourdes Mission on right. Note the varved beds on the southeast side of the exposure of Monroe Creek.

Children have made slides in the Monroe Creek cliffs. These are artificial and are not yardangs which are found elsewhere in the Monroe Creek Formation.

218.3 00.5 Porcupine–take right fork in the road.

218.9 00.6 Approximate Harrison–Rosebud contact.

The Rosebud Formation was named by Gidley (1904) for exposures along the Little White River in Todd County, South Dakota. A type section for the formation was selected by Macdonald and Harksen (1968).

220.3 01.4 Rosebud Formation in roadcuts on both sides of the road.

223.5 03.2 Turn left into Porcupine Butte parking lot.

223.7 00.2 **STOP SIXTEEN.** Park at base of butte and walk up to the top of the butte (fig. 48). After talk return to cars and then return to asphalt road.

Porcupine Butte is composed of Rosebud Formation capped with about 30 feet of the Ogallala Group. About 18 feet below the top of the butte is a layer of volcanic ash. As the basal Ogallala is composed of reworked Rosebud the contact is hard to spot. About 230 feet of Rosebud is present in this area.

Figure 48. Porcupine Butte is composed of Rosebud Formation capped with Ogallala.

223.9 00.2 Turn left onto highway.

225.2 01.3 Skyline to the south is the Nebraska Sand Hills.
The Sand Hills Formation was named by Lugn (1934).

227.3 02.1 **STOP SEVENTEEN.** Stop at historical markers (each tells a different version of the same incident). Then proceed to Sacred Heart Church on top of the hill to the northwest.

227.5 00.2 **STOP EIGHTEEN.** Stop at entrance to cemetery. This is the site of the mass grave where the victims of the Wounded Knee massacre were buried (fig. 49). After stop continue west on dirt trail.

The Wounded Knee Massacre was the last confrontation between the American Indians and the U. S. Army in the Great Plains. In 1890 the Ghost Dance "Craze" spread from the Great Basin and western Rockies onto the Great Plains. Tensions rose and white settlers anticipated trouble. To avoid an incident Big Foot took his band into the Badlands to hide. Late in December he headed his group toward Pine Ridge Agency to surrender. They were met at Wounded Knee by an army detachment sent to escort them to Pine Ridge. Colonel Forsythe instructed his troops to collect the Indians' arms. A shot was fired and when the day ended 31 soldiers and 146 braves, women, and children were dead. The marker over the mass grave on the hill was erected by Joseph Horncloud, Sr., in memory of his father and two brothers.

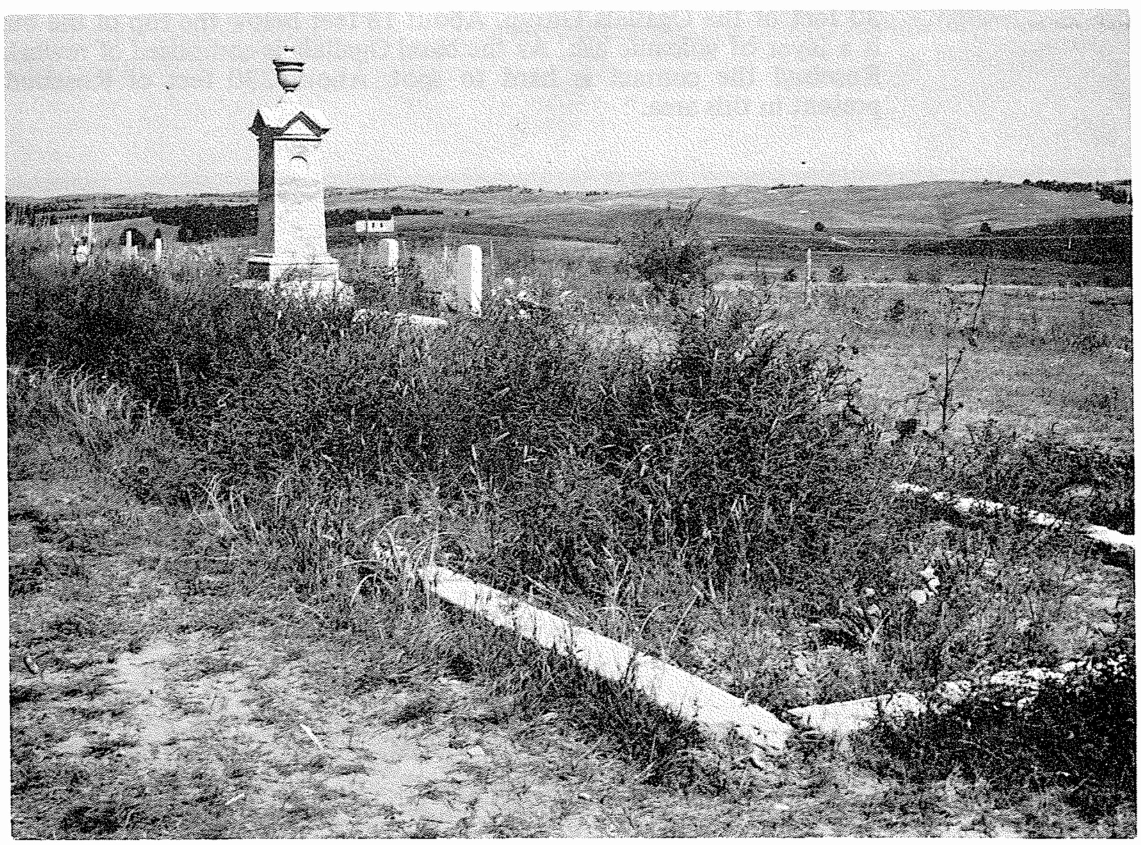


Figure 49. Mass grave where the victims of the Wounded Knee Massacre – some 146 to 240 Indian men, women, and children – are buried.

227.6	00.1	Wounded Knee–Manderson road. Turn right onto this road and drive north.
228.2	00.6	Former Wounded Knee Day School on left.
228.7	00.5	**STOP NINETEEN.** Stop to examine the Harrison Formation exposed in the roadcut on the left side of the road (fig. 50). After stop continue north for a short distance. The Harrison Formation is coarser and more friable than the underlying Monroe Creek Formation. Also, while the Monroe Creek tends to form vertical cliffs the Harrison forms rolling hills covered with pine trees and bunch grass. After stop continue to the north for a short distance.

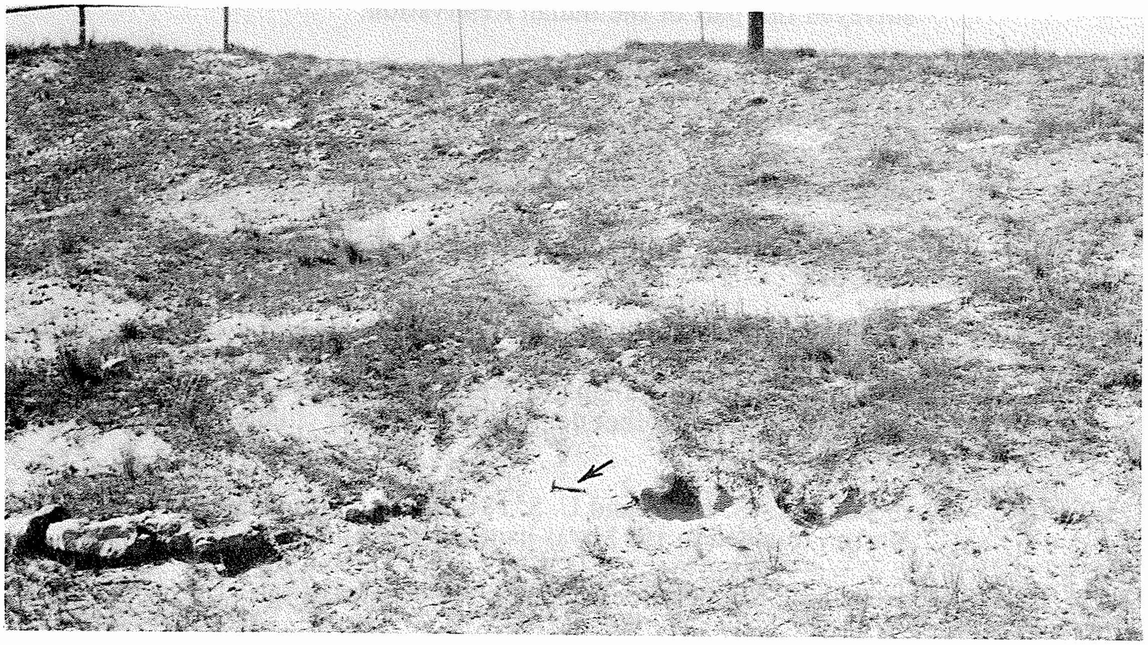


Figure 50. Exposure of "typical" Harrison Formation in roadcut along the Wounded Knee – Manderson road. Arrow points to 12½ inch geology pick.

228.8	00.1	Turn around and return to the south.
230.1	01.3	Road junction at Wounded Knee. Turn right and proceed toward Highway 18.
234.9	04.8	The northernmost of the pine trees to the south marks the White Clay fault. The White Clay Fault was named by Dunham (MS). Dunham's name has been used in print by Harksen (1967) and Skinner and others (1968).
236.9	02.0	Road junction, turn left onto U. S. Highway 18.
240.2	03.3	Cross Spring Creek.
242.7	02.5	Cross Wounded Knee Creek.
244.4	01.7	Outcrops of the Ogallala Group along the road. The Ogallala Group (Formation) was named by Darton (1899a). While no type section was specifically given, the name was taken from Ogallala,

Keith County, Nebraska.

It is to be noted that confusion may result from the fact that there is an Oglala, South Dakota; an Ogallala, Nebraska; and an Ogallah, Kansas.

245.0	00.6	Junction of State Highway 75 and U. S. Highway 18. Continue east on U. S. 18.
249.7	04.7	Cross Stinking Water Creek.
250.1	00.4	Ogallala exposed in roadcuts on both sides of the road.
253.2	03.1	Entering Batesland. Batesland was named for C. A. Bates, Government Surveyor, who surveyed this part of the Indian Reservation. For those following the progess of the field trip on the maps, switch from fig. 34 to fig. 51.
261.9	08.7	Swett. Swett was founded in 1931 by a farmer of that name.
262.9	01.0	Big Spring Canyon due south beyond end of farm to market (teepee to tavern) road.
270.2	07.3	Roadside park on left side of road. This park is favored by the presence of a hand-operated water pump. The pump is an outstanding tourist attraction as on almost any summer day you can see a mother demonstrating to her children how it was when she was a girl.
273.0	02.8	Road junction–S. D. 73 and U. S. 18–in Martin. Continue east on U. S. 18. Martin, founded in 1911, was named for Eben Martin of Hot Springs.
275.3	02.3	Monroe Creek Formation crops out on both sides of the road.
278.3	03.0	Buttes to the north are Eagles Nest and Buzzard.
279.3	01.0	Loess in roadcut on right side of road.
282.7	03.4	Deadman's Lake to right. Deadman's Lake was so named because in the olden days a man was found near the lake, shot to death.
285.5	02.8	Road junction–S. D. 73 and U. S. 18–continue on U. S. 18.
288.2	03.2	Little White River to the right. There are some outcrops of Ogallala Group along the river.
290.9	02.7	Buttes to the left are Ogallala Group.
292.0	01.1	Vetal. Vetal was named for Vetal Valandry, an early settler.
294.3	02.3	Outcrops along the road are Ogallala. The white exposures are diatomaceous lake deposits.

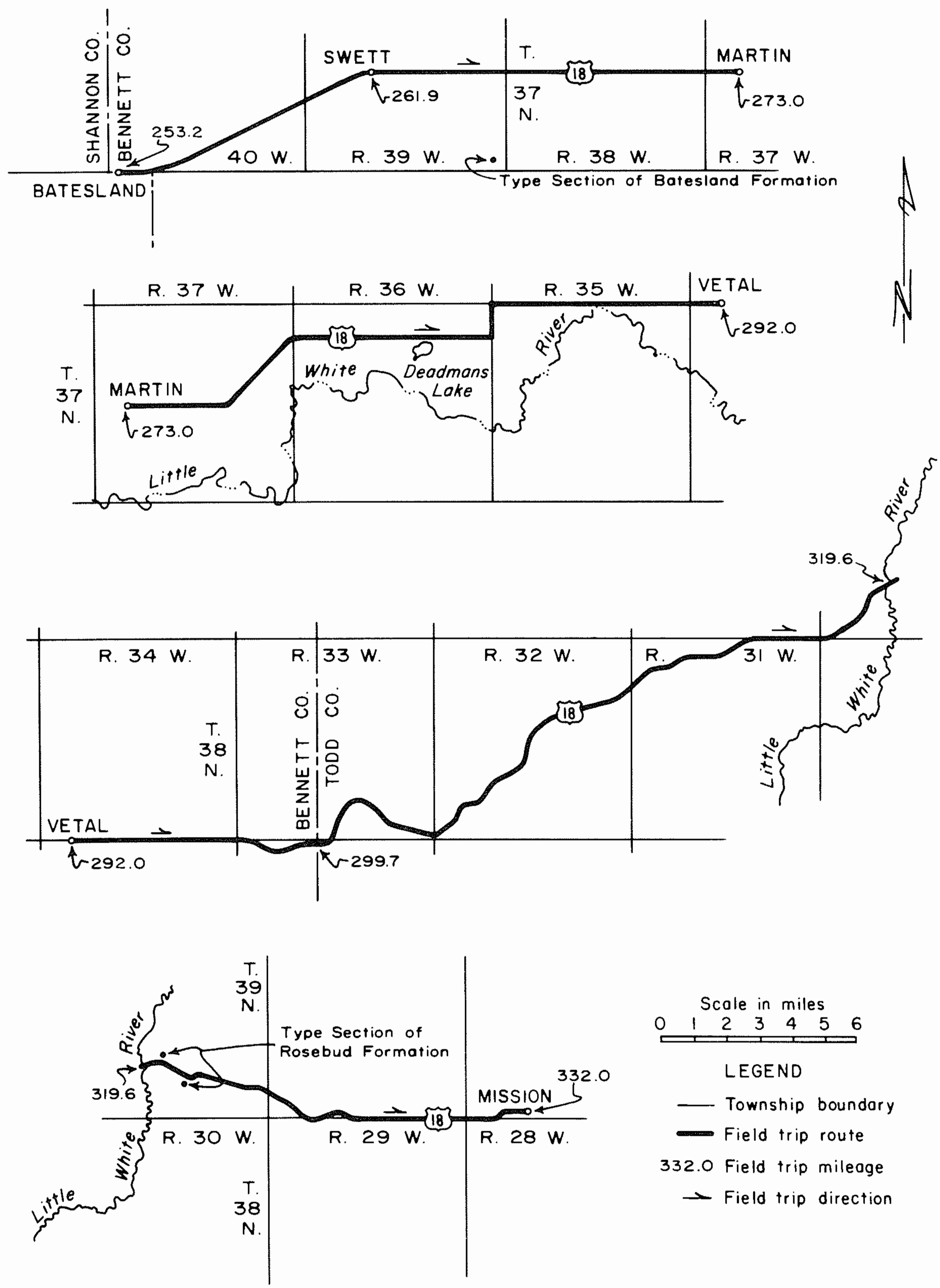


Figure 51. Map of the route to be followed on the last half of the second day of the field trip.

295.1	00.8	Presbyterian Community Church. The Pearlette Ash is exposed three-fourths mile to the south. The Pearlette Ash was named by Cragin in 1896 with the type section in southwestern Kansas.
299.7	04.6	Enter Todd County. Todd County was named for John Blair Smith Todd who was a cousin of Abraham Lincoln's wife and the first delegate to Congress from Dakota Territory.
302.7	03.0	Cemented beds in Ogallala Group to the left of the road. We will be traveling across the Ogallala for the next several miles.
309.9	07.2	Rosebud Formation exposed on the right side of the road.
313.8	03.9	Junction S. D. 63 and U. S. 18. Continue on 18.
318.3	04.5	Roadside park to the right.
319.3	01.0	"By the Way."
319.6	00.3	Cross the Little White River.
319.9	00.3	Approximate contact of the Brule and Rosebud Formations. For the next few miles we will be following the approximate type section for the Rosebud Formation as given by Macdonald and Harksen (1968).
326.4	06.5	Road junction–stay on U. S. 18.
326.8	00.4	Road junction–stay on U. S. 18.
328.8	02.0	Junction S. D. 83–stay on U. S. 18.
331.2	02.4	Entering Mission. Continue east through Mission.
332.0	00.8	Antelope Motel and the end of Day Number Two.

THIRD DAY: Mission to Hot Springs

332.0 00.0 Assemble at Antelope Motel. Leave parking lot and start west on U. S. 18 (fig. 52).

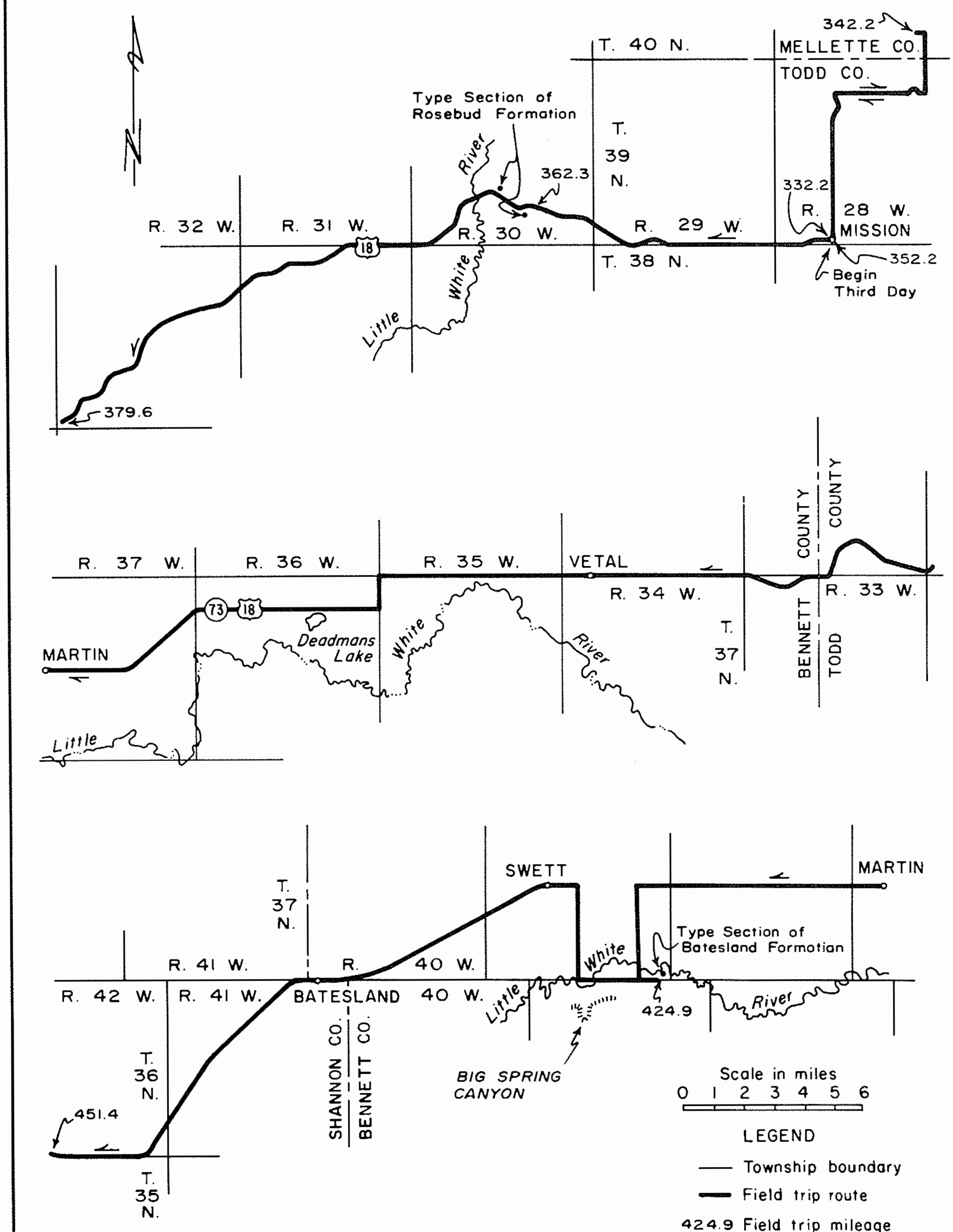


Figure 52. Map of the route to be followed on the first half of the third day of the field trip.

332.2	00.2	Turn right (north) onto section line road.
337.1	04.9	Road junction, turn right.
339.6	02.5	Veer to left around butte.
340.1	00.5	Road junction, turn left (north). Flat-topped buttes are capped by limestone beds in the Rosebud Formation.
341.3	01.2	Limestone bed crosses road.
341.5	00.2	Caution, limestone bed crosses road.
342.2	00.1	**STOP TWENTY.** Thin Elk Gravel Pit (named in Schultz and Falkenbach, 1941, p. 30). After discussion and inspection turn around and retrace route into Mission.

The Thin Elk Gravel Pit was an early Pliocene stream channel deposit about 25 feet thick. Outside the great east-west paleovalley the stream depositing these sediments was certainly an important tributary to the main river. Casual surface collections were made for many years by various museum parties. The main collection was made by Macdonald in 1956 while the Summit Construction Company of Rapid City was working the pit for select borrow during the reconstruction of U. S. 83 south of Mission. Collecting was done with a garden rake at the base of the discard chute (see fig. 53). Macdonald (1960) published on the vertebrate fauna.

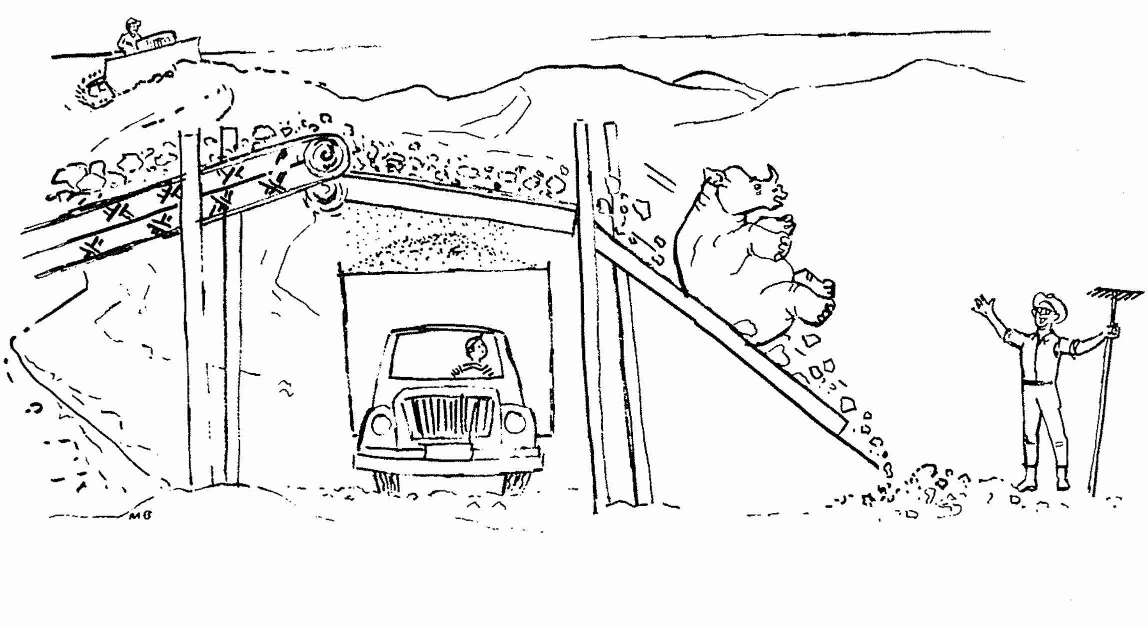


Figure 53. This drawing by Mary Butler of the Los Angeles County Museum of Natural History is a tongue-in-cheek version of the method used to collect the Mission fauna.

352.2 10.0 Highway 18 at Mission. Turn right and continue west through Mission.

358.1 05.9 Deposits of the White River Group can be seen in the distance to the right front.

361.2 03.1 This flat terrace-like area is mainly deposits of the Ogallala Group.

362.3 01.1 **STOP TWENTY-ONE**. Examine the Rosebud Formation near the top of the Type Section (fig. 54).

Gidley (1904) named the Rosebud Beds without giving a type section but stated, "The lower formation above mentioned, for which we propose the local term Rosebud Beds, is best exposed along the Little White River and in the vicinity of the Rosebud Agency." Skinner and Taylor (1967) chose to restrict the Formation to some 100 feet of rocks exposed near the Agency Headquarters. Harksen and Macdonald (1968), in their second-guessing of Gidley's intent, chose the bigger picture and published a type section encompassing the entire sequence exposed on the Little White River.

Figure 54. The Rosebud Formation exposed along Highway 18. This is the site for stop 21 of the field trip.

364.4 02.1 Cross Little White River.

379.6 15.2 **STOP TWENTY-TWO**. Examine sediments of the Ogallala Group (fig. 55).

In the roadcut at this point the Pliocene strata of the Ogallala Group are exposed. The gray and tan sands, with local deposits of volcanic ash, as seen here, are fairly typical of this unit as it is found in southwestern South Dakota. The writers and their associates are loth to give names such as Ash Hollow and Valentine to units in this part of South Dakota. Therefore, until further studies can be made they prefer to call the early and middle Pliocene deposits of this immediate area the Ogallala Group.

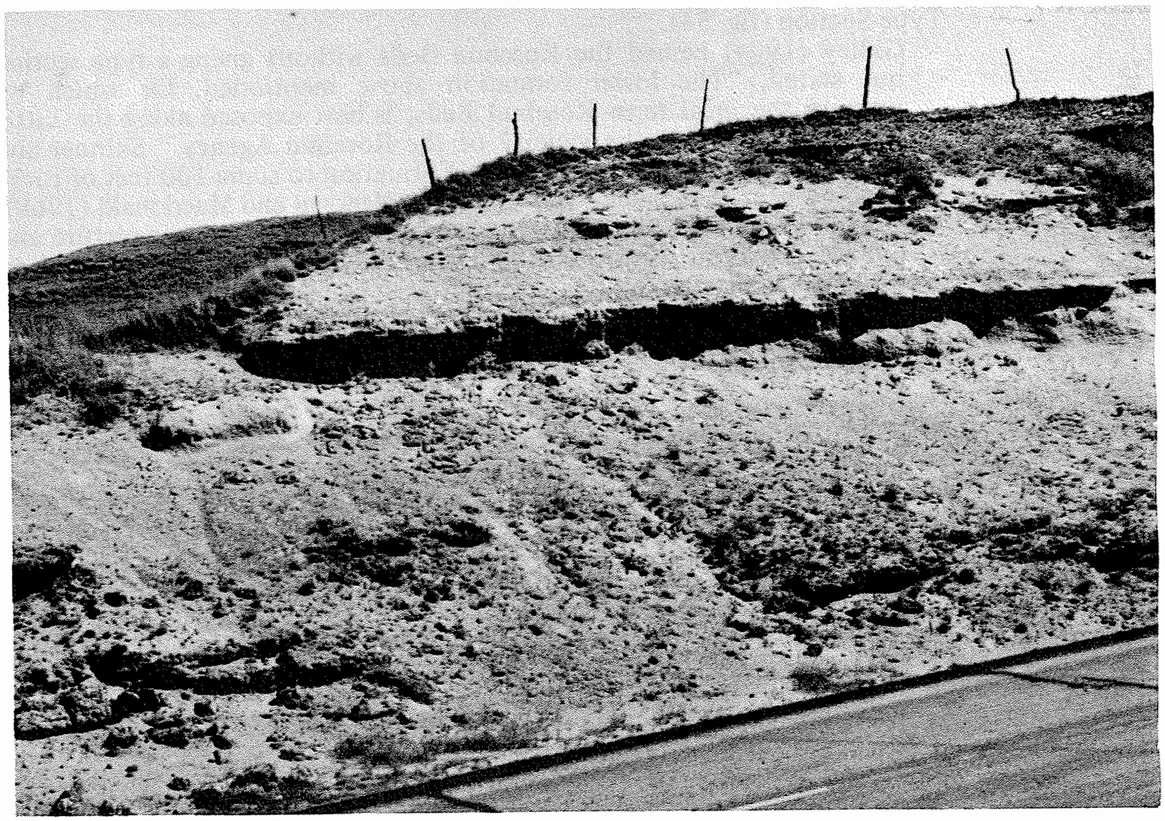


Figure 55. Ogallala Formation along Highway 18 at stop 22 of the field trip (mileage 379.6).

386.0 06.4 Enter Bennett County.

393.6 07.6 Vetal.

413.2 19.6 Junction 18–73 in Martin. Continue west on U. S. 18.

421.3 08.1 Turn left onto gravel road – drive south.

423.3 02.0 Sand Hills ahead on horizon. White outcrops to the left front are Batesland Formation. Big Spring Canyon is large canyon in Sand Hills to the right front.

The Batesland Formation was named by Harksen and Macdonald (1967); the type section is located at field trip mileage 424.9.

424.2 00.9 Cross Little White River.

424.4 00.2 Road junction, turn left.

424.9 00.5 **STOP TWENTY-THREE.** Walk across pasture to type section for the Batesland Formation (fig. 56). After discussion and examination of the Batesland return to cars and go west back down the gravel road.

The Flint Hill fossil locality was discovered in 1934 by P. O. McGrew, then a graduate student with the University of California field party. The fauna is in Batesland Formation, but some material is found in the underlying Rosebud Formation. The avifauna was described by Miller and Compton (1939) and Miller (1944). The mammals have been described (but not published) by Stirton and Gregory. The fauna is approximately equivalent to the Runningwater fauna of Nebraska. Skinner (1968), in his work on North American chalicotheres, briefly mentions the Batesland Formation.

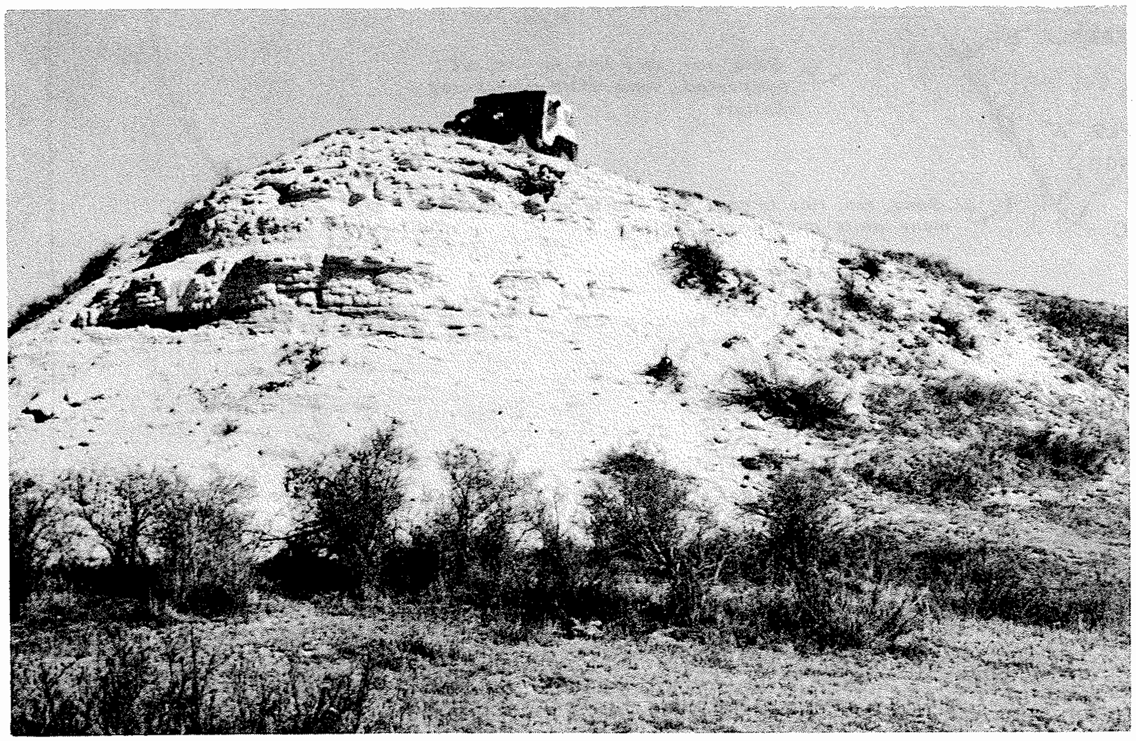


Figure 56. The type section of the Batesland Formation.

427.2 02.3 Cross Little White River.

427.4 00.2 Big Spring Canyon approximately one mile to the left (fig. 57, table 6).

These Pliocene deposits were Hayden's "Bed F." Mentioned by Matthew and Gidley in publications of 1904 and 1906 resulting from field work in 1903. The first extensive quarrying of this site was done by the University of California field parties under the direction of R. A. Stirton in 1933 and 1934. The definitive faunal study was published by J. T. Gregory in 1942.

427.5 00.1 Road junction, turn right (north).

430.5 03.0 Junction with Highway 18, turn left (west).

431.5 01.0 Swett.

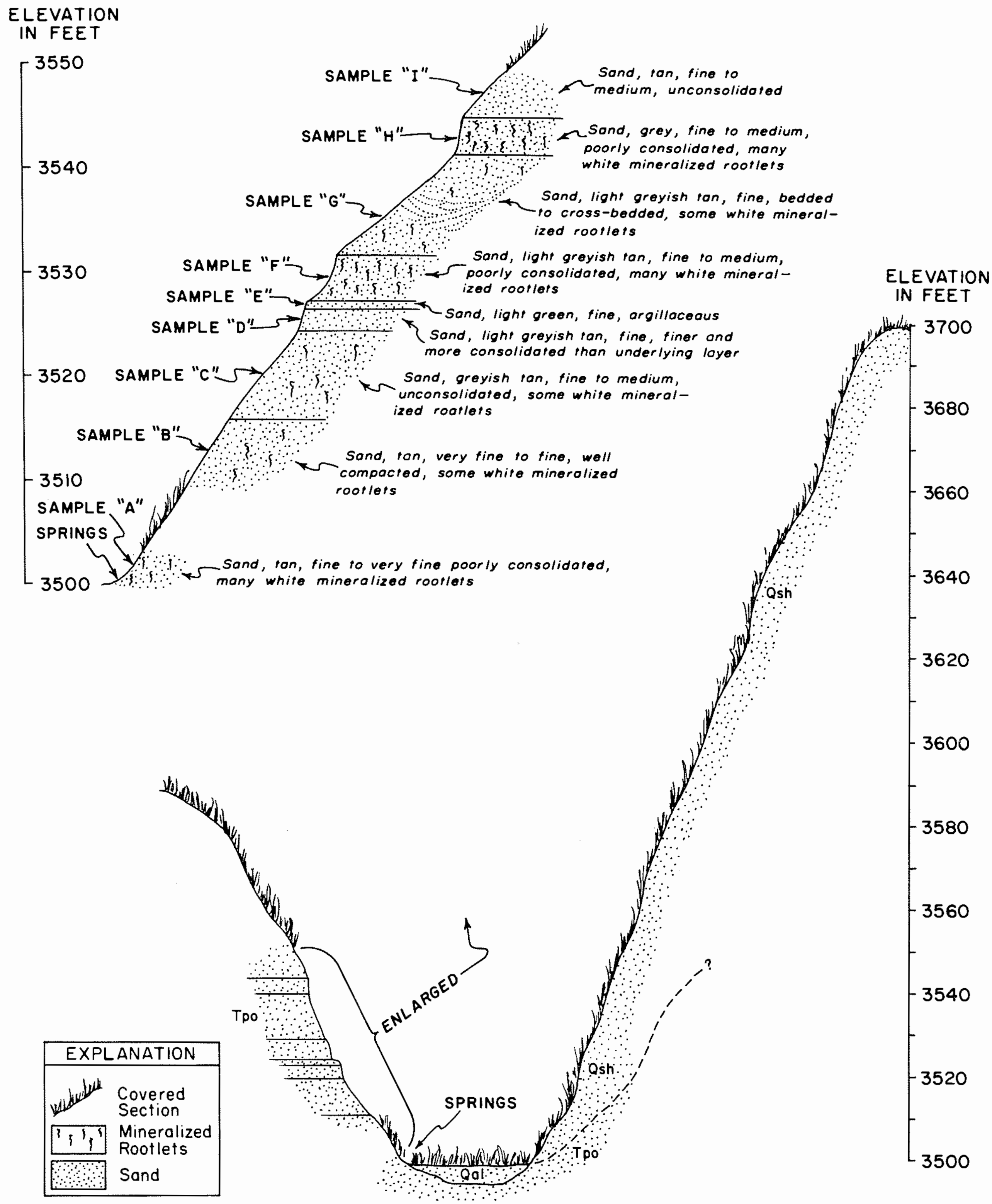


Figure 57. Columnar section of the Ogallala Group in Big Spring Canyon. This section was measured along the line between sections 5 and 8, T. 36 N., R. 39 W., Bennett County. On the lower drawing east is to the left while on the upper drawing east is to the right. The abbreviations used are Tpo, Ogallala Group; Qsh, Sand Hills Formation; Qal, Alluvium. The mechanical analysis of the samples indicated above are presented in Table 6.

Table 6. Mechanical analysis of nine samples of sand from Big Spring Canyon. Sample letters correspond with those on figure 57.

SAMPLE	A	B	C	D	E	F	G	H	I
GRAVEL 2.0 mm and coarser	2.03				2.22	2.10		3.21	0.94
VERY COARSE SAND 1.0–2.0mm	1.04	0.71		0.12	4.38	0.51	0.02	1.26	0.22
COARSE SAND 1/2–1.0 mm	1.23	1.46	0.19	0.66	4.59	0.71	0.51	1.86	3.10
MEDIUM SAND 1/4–1/2 mm	8.11	7.88	25.40	20.75	15.95	33.53	22.63	25.50	35.59
FINE SAND 1/8–1/4 mm	32.16	27.30	62.83	59.29	40.34	58.72	60.31	60.08	51.70
VERY FINE SAND 1/16–1/8 mm	33.70	33.86	10.37	15.46	18.39	3.08	15.28	6.81	6.97
SILT AND CLAY finer than 1/16 mm	20.67	28.79	0.58	3.21	13.52	0.62	1.00	0.74	0.51

440.0	08.5	Batesland.
448.5	08.5	Junction of U. S. 18 and S. D. 76. Continue west on 18.
450.2	01.7	Mt. Denby (Rosebud Formation) ahead on horizon. Mt. Denby is a ludicrous name for a small hill near Denby. Denby was founded in 1921 and was named after Edwin Denby, U. S. Secretary of the Navy from 1921 to 1924.
451.4	01.2	Beaver dam to right (fig. 58). Those following the map of the field trip should switch from figure 52 to figure 59.

Figure 58. Beaver dam along Highway 18 at field trip mileage 451.4.

453.3	01.9	Cross Spring Creek. Mt. Denby visible to right front.
454.2	00.9	Pine Ridge visible to left front.
454.3	00.1	Both Mt. Denby and Porcupine Butte visible to the right.
456.6	02.3	Road junction, continue west on U. S. 18.
463.7	07.1	Cross Wolf Creek. Green's (1956) early Pliocene Wolf Creek fauna was collected to the south of the road.
465.4	01.7	Oglalla Sioux Sundance Grounds to right. This is one of the last authentic Indian celebrations in the United States. It is held the first week in August.
465.6	00.2	Enter Pine Ridge.

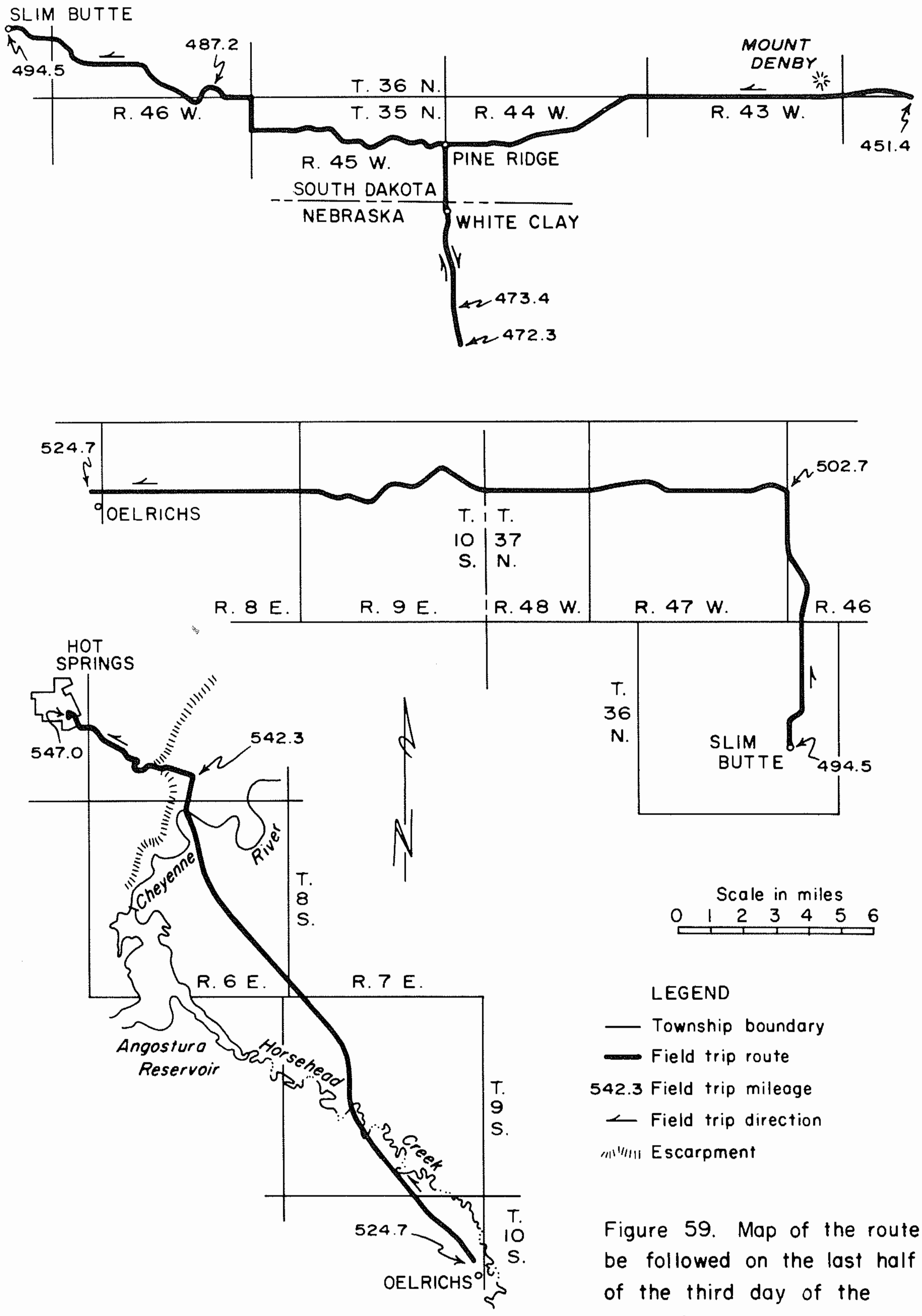


Figure 59. Map of the route to be followed on the last half of the third day of the field trip.

466.0 00.4 Four-way stop sign. Turn left and head for White Clay, Nebraska. This short teepee to tavern road is one of the most dangerous in South Dakota.

466.7 00.7 Entrance to Three Moccasin Park. Continue south on asphalt road.

467.3 00.6 Cross White Clay Fault.

467.8 00.5 Cross state line, enter White Clay, Nebraska. Follow Nebraska No. 87 to the south.

468.3 00.5 Jumping Eagles Inn on right.

472.3 04.0 Road junction. Turn around and retrace route to north.

473.4 01.1 **STOP TWENTY-FOUR.** Examine Brule-Monroe Creek contact on the east side of the road (fig. 60). After discussion and examination retrace route to Pine Ridge.

Uplift of the Chadron Arch at the end of the Oligocene blocked the southern movement of sediments which were to become the Sharps Formation. South of the arch the earliest Miocene deposition is a continuation of Brule-like sediments, followed by at least one erosional interval and the deposition of Darton's (1899a) Gering Formation. Uplift and erosion along the Chadron Arch has caused deposition of the Monroe Creek Formation directly on top of the Brule Formation at this point.

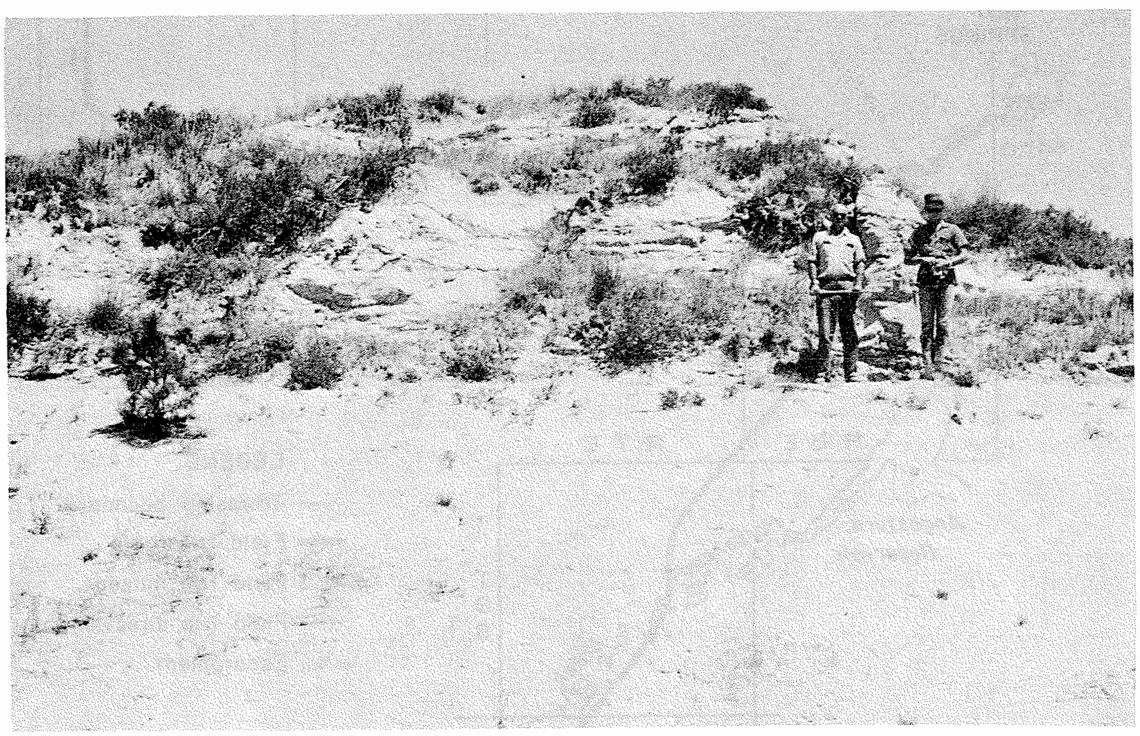


Figure 60. The Brule and Monroe Creek Formations exposed along the highway south of White Clay, Nebraska, at stop 24 (field trip mileage 373.4). The two figures are standing on the contact.

475.5	02.1	Knobs of gravel on the skyline to the left front mark the course of the White Clay Fault.
476.8	01.3	Re-enter South Dakota.
478.6	01.8	Stop at four-way stop sign in Pine Ridge. Turn left.
478.8	00.2	Stop sign, highway hooks slightly to the left.
479.1	00.3	Bridge. Turn right on the gravel road just beyond the bridge.
479.6	00.5	Cinder block church on right.
480.2	00.6	Take right fork. The left fork leads to the Pine Ridge city dump.
481.5	01.3	Rosebud Formation crops out along road.
483.0	01.5	Windmill on right side of road.
485.9	02.9	In the valley ahead the Interior Paleosol is developed on the Niobrara Chalk. The red band marks the base of the Chadron Formation, of which the dull green clays form the major part. The tan deposits on the Chadron Formation are either Pleistocene or Recent loess.
487.2	01.3	**STOP TWENTY-FIVE.** The Interior Paleosol is developed on the Niobrara Chalk (fig. 61). After discussion continue west on the dirt road.

The Interior Paleosol was named by Freeman Ward (1922) from colored exposures of Pierre Shale or Fox Hills Formation near Interior, South Dakota. This paleosol is developed on sedimentary rocks underlying the White River Group in North Dakota, South Dakota, Nebraska, and Wyoming. Cook (1922) refers to the Interior Paleosol as the "Ainsworth Formation." While usually only the Late Cretaceous strata is thought of as being affected by the Interior Paleosol, Bjork (MS) reported alteration on the Slim Buttes Formation, late Eocene, which apparently represents the Interior Paleosol. Bjork (1967) assigns an age of latest Eocene to the Slim Buttes Formation. In addition Pettyjohn (1966) reports the Paleosol being developed on the Golden Valley Formation (early Eocene), the Fort Union Formation (Paleocene), the Pierre, Fox Hills, and Lance (all Cretaceous) and probably developed on the Skull Creek and Hell Creek Formations (both Cretaceous). At this stop the Interior

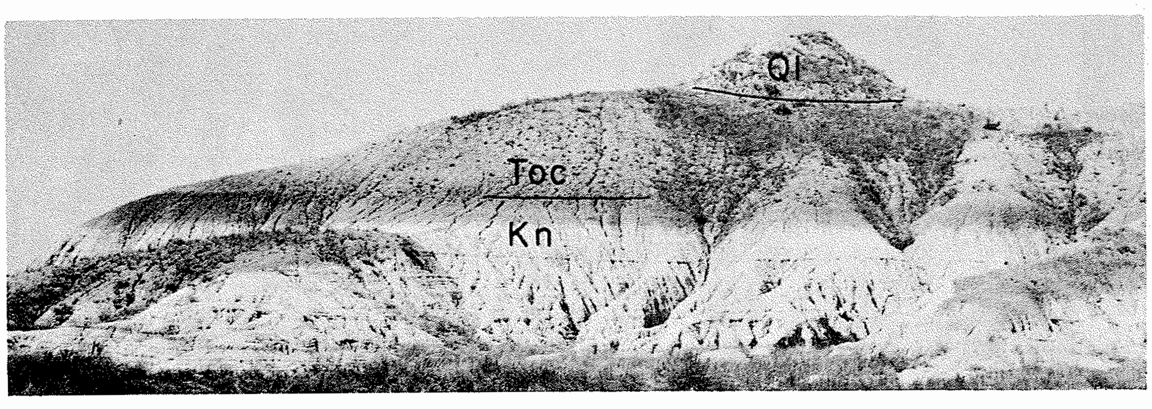


Figure 61. In this area the Interior Paleosol is developed on the Niobrara Chalk (Kn) and the bright red band marks the contact between the Niobrara and the Chadron Formation (Toc). Small deposits of loess (Ql) are present in this area.

Paleosol is developed on the Niobrara Chalk and later on this trip we will see the paleosol developed on both the Greenhorn Limestone and the Graneros Shale. While there is no present evidence to support this contention, future work will probably show the Interior to be developed on almost all units from the Deadwood to the Slim Buttes Formations in western South Dakota. Pettyjohn (1966) calls the Interior Paleosol the "Eocene Soil Profile" intimating a change of nomenclature. The senior author believes that the name Interior Paleosol should be retained and questions the validity of giving the Interior an Eocene rather than an early Oligocene age.

490.7 03.5 Cattle guard. To the southwest are two small buttes capped with porcelanite. This was apparently caused by lightning or prairie fires igniting oil-rich layers in the Sharon Springs Member of the Pierre Shale.

493.4 02.7 Pinkish outcrops ahead are the Brule Formation.

494.2 00.8 Bridge across the White River.

494.5 00.3 Road junction, turn right.
This is the site of the now defunct town of Slim Butte.

495.0 00.5 Roadcut is Brule Formation.

495.5 00.5 Roadcut is loess. While in this immediate area the loess cover is quite thin, on Babby Butte, some 18 miles to the northeast, the loess is well over ninety feet thick (fig. 62).

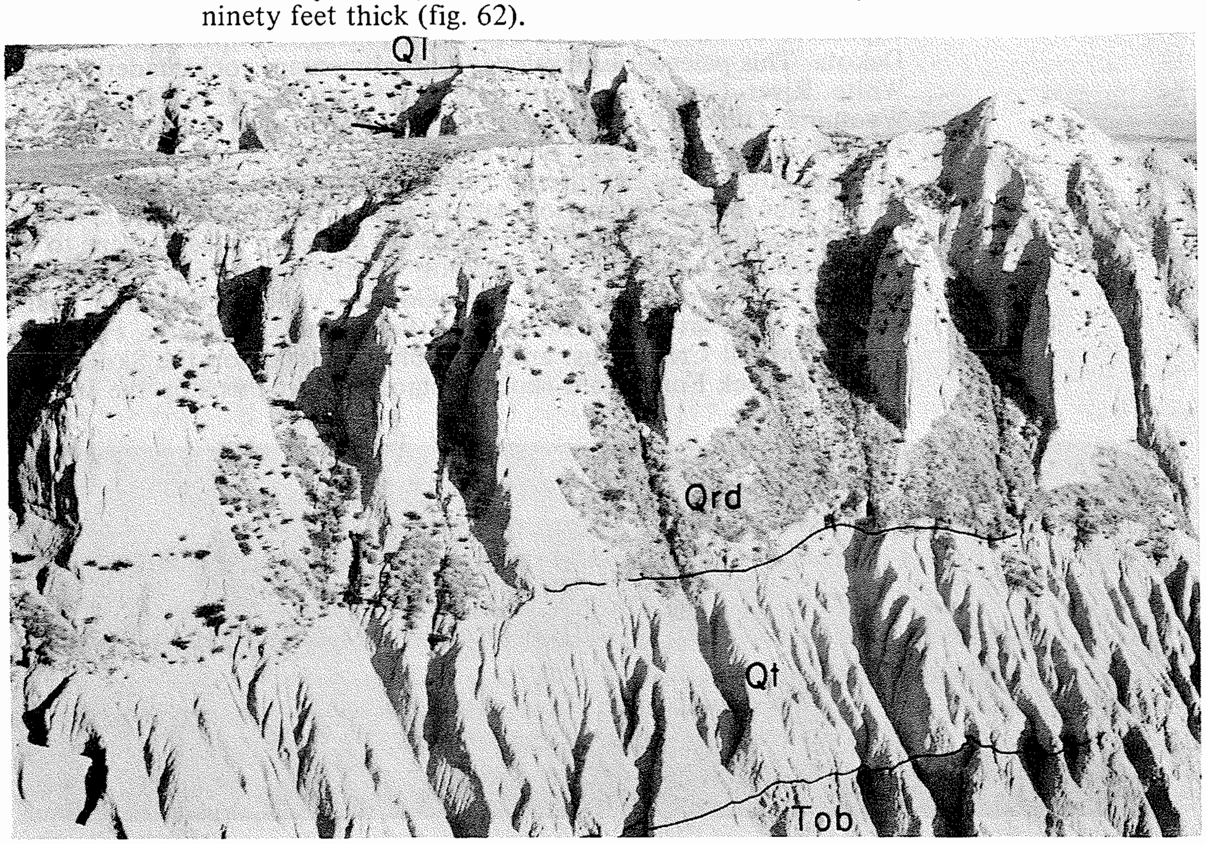


Figure 62. Babby Butte showing the Brule Formation (Tob), Terrace deposits (Qt), Red Dog Loess (Qrd), and undifferentiated loess (Ql). On Babby Butte the Red Dog Loess is 90 feet thick (Harksen, 1968a). Arrow points to a 5-foot 3-inch figure included for scale.

495.7 00.2 Pink Cliffs to the right are the Monroe Creek Formation.

495.9 00.2 The gravel pit to the left is in late Pleistocene gravel.

496.2 00.3 The exposure on the northwest horizon is the Poleslide Member of the Brule Formation.

501.5 05.3 Note the structure in the Brule Formation about three miles ahead and on the far side of the White River.

502.7 01.2 Junction with U. S. 18. Turn left and head west down 18.

503.3 00.6 Note terraces along road. Brule to the west with unaged, unnamed unit above (fig. 63).

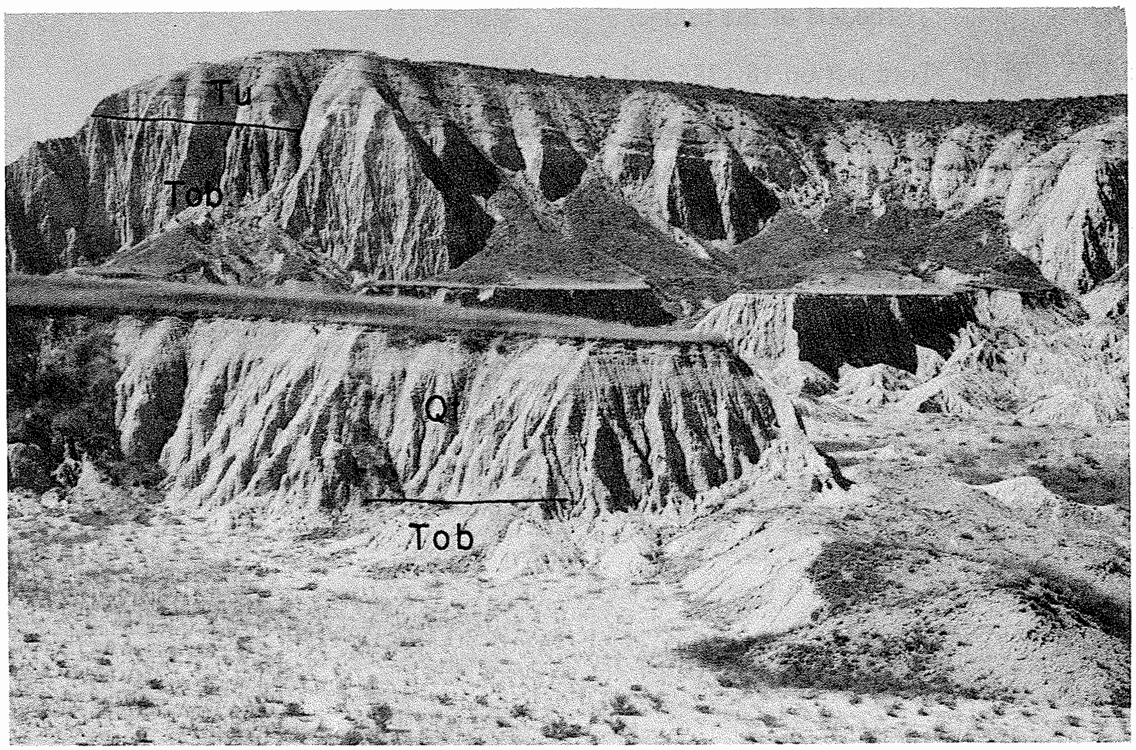


Figure 63. Exposures to the right of the road are the Brule Formation (Tob), terrace deposits (Qt), and an unnamed, unaged Tertiary unit (Tu).

512.1 08.8 Enter Fall River County.

515.6 03.5 Slim Butte to the southeast.
Beware of a confusion of names as there is a "Slim Buttes" in northwestern South Dakota.

516.0 00.4 To the left of the road the basal Chadron gravels are weathering down over the Interior Paleosol developed on the Pierre Formation.

517.0 01.0 Limestone Butte ahead on the horizon.

517.8	00.8	Teepee buttes ahead on horizon.
524.7	06.9	Stop sign at junction of 385 north of Oelrichs. Turn right and proceed towards Hot Springs on 18-385.
539.3	14.6	Cross irrigation canal. The water comes from Angostura Reservoir. Angostura Dam is located approximately two miles to the southwest. This canal was laid out through the sand dunes. Much to the surprise of the Bureau of Reclamation, it did not hold water. A jaw of the Pleistocene camel, *Camelops*, was recovered during the subsequent bentonite lining operations.
540.0	00.7	Note dip on Cretaceous strata to the right front.
541.2	01.2	Cross Cheyenne River. The confluence of the Cheyenne River and Fall River is located just to the left of the bridge.
542.3	01.1	Turn left on 18–385 and continue towards Hot Springs.
543.1	00.8	Crossing the "Dakota" hogback through the water-gap formed by Fall River.
546.9	03.8	Turn left on Highway 71 and cross Fall River.
547.0	00.1	El Rancho Court and the end of Day Number Three.

FOURTH DAY: Hot Springs to Rapid City

547.0 00.0 Assemble at El Rancho Court (fig. 64). Drive north and cross Fall River.

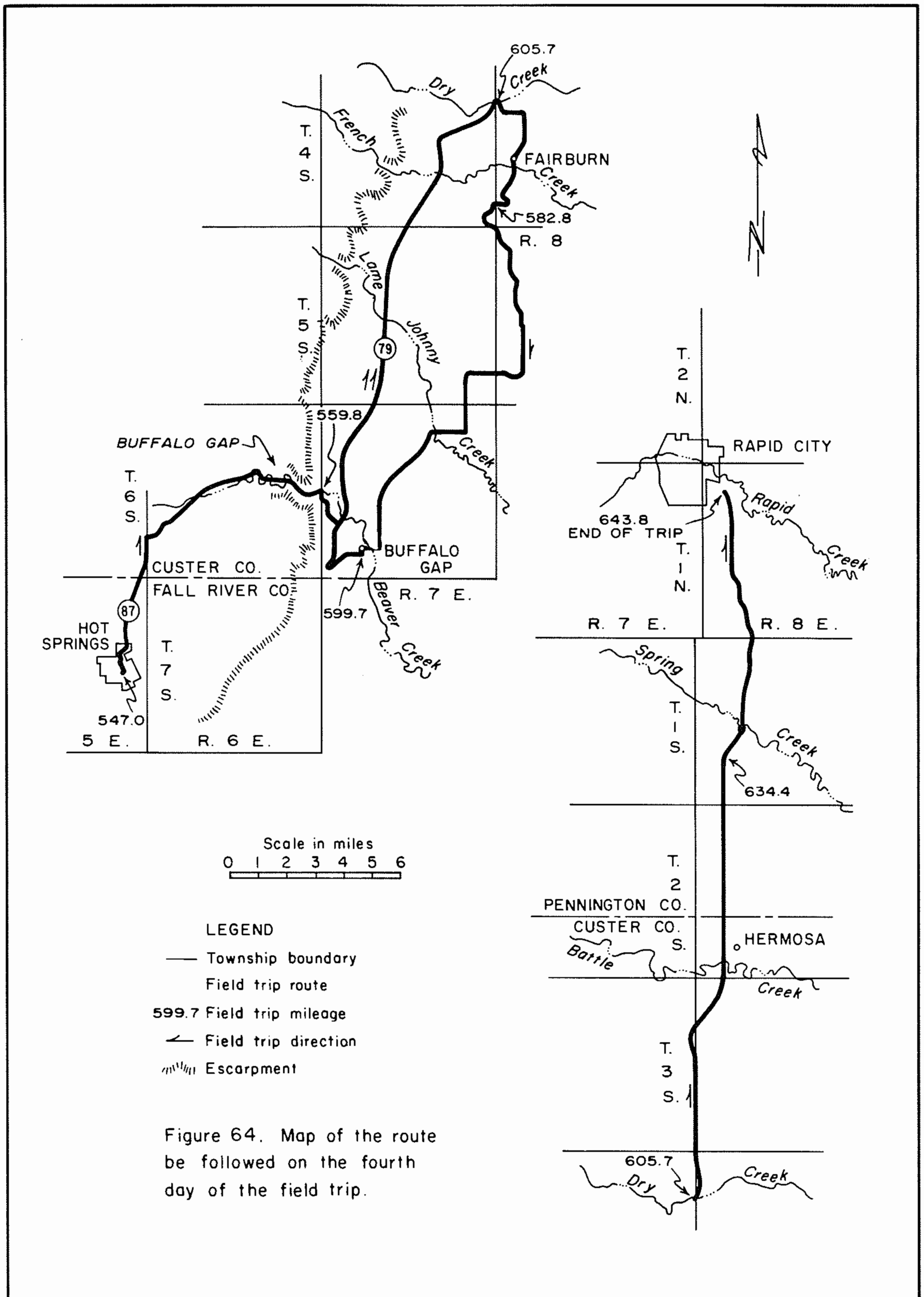


Figure 64. Map of the route be followed on the fourth day of the field trip.

547.1	00.1	Turn onto Highway 385 and follow it north through town.
547.8	00.7	Note waterfall over Cenozoic conglomerates (fig. 65). There are huge goldfish thriving in the warm creek waters.

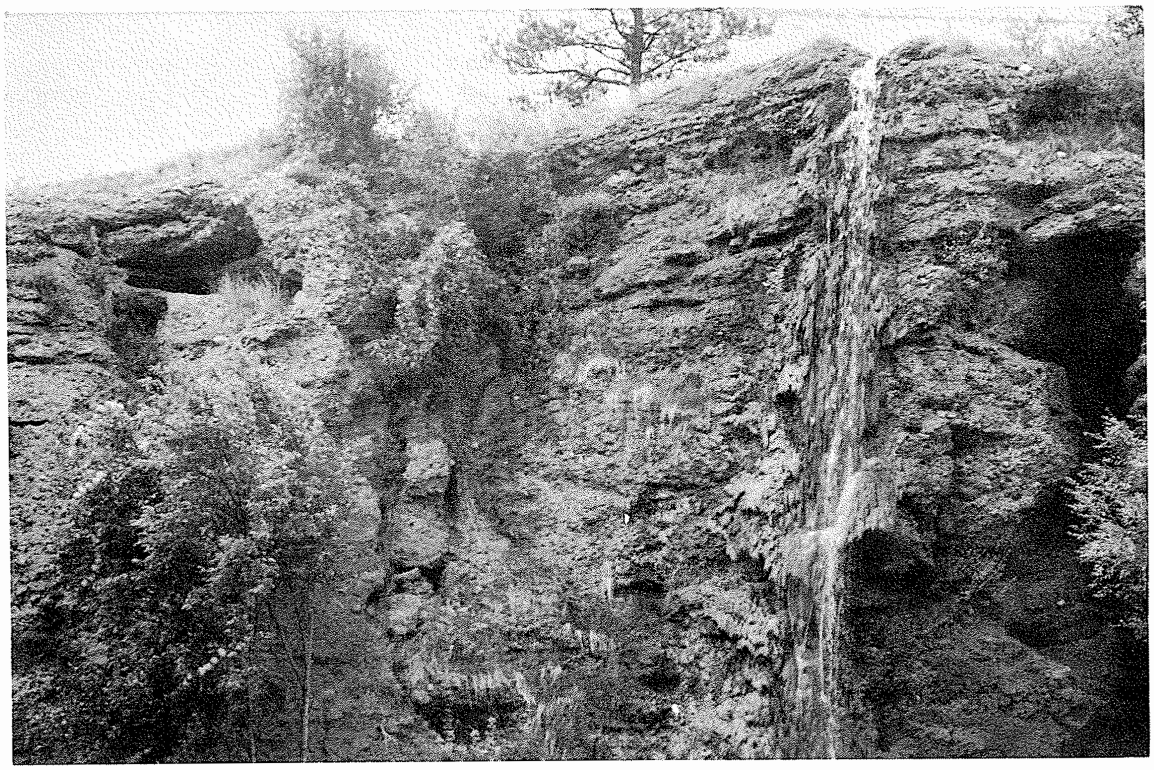


Figure 65. Waterfall over Cenozoic conglomerates in downtown Hot Springs.

548.0	00.2	Century House (Evans Hotel) - built out of locally quarried Unkpapa Sandstone. The Unkpapa Sandstone was named by N. H. Darton (1899b) for Unkpapa Peak, Custer County, South Dakota.
548.1	00.1	Cenozoic conglomerates ahead and across Fall River.
548.2	00.1	Cross the Fall River.
548.3	00.1	Turn right.
548.4	00.1	Cross railroad tracks and Fall River.
548.5	00.1	Turn left.
549.6	01.1	KOBH transmitter on left.
551.2	01.6	Enter Custer County. Custer County is named for General George Armstrong Custer whose men discovered gold along French Creek (three miles below the present town of Custer) in 1874.

551.8 00.6 **STOP TWENTY-SIX.** Stop on drive-off on right side of road. Short talk on Red Valley or Racetrack and then tour will continue.

The racetrack or red valley, the valley we are now in, extends completely around the Black Hills. The Black Hills has been formed from a domal uplift which has been subjected to intense erosion. The softer strata has been more intensely eroded than the harder strata forming a series of concentric ridges around the Precambrian core. The most noticeable valley to be formed is the one we are now in. This valley was formed because erosion has moved great quantities of the Triassic Spearfish Formation while removing lesser amounts of the underlying Minnekata Limestone and the overlying Inyan Kara Group.

552.6 00.8 Turn right onto "Custer 101," a gravel road.

554.6 02.0 Buffalo Gap, the water gap by which we will leave the Black Hills, is on the right front.

555.9 01.3 Entrance to 7-11 Ranch.

556.8 00.9 Dropping down through the Minnekata Limestone. Note the irregular surface caused by collapse features.

The Minnekata Limestone was named by N. H. Darton (1901) with the type area near Hot Springs – a region known to the Indians as Minnekahta.

557.7 00.9 Note the cemented Cenozoic conglomerates on the right of the road.

559.1 01.4 Sundance Formation along the right side of the road. However, no belemnites are to be found.

The Sundance Formation was named by N. H. Darton (1899b) for outcrops in Lawrence County, South Dakota.

559.4 00.3 Passing through the water gap, known as Buffalo Gap, cut by Beaver Creek (fig. 66). Believed to be the gap through which Jedadiah Smith and James Clyman entered the Black Hills in 1823.

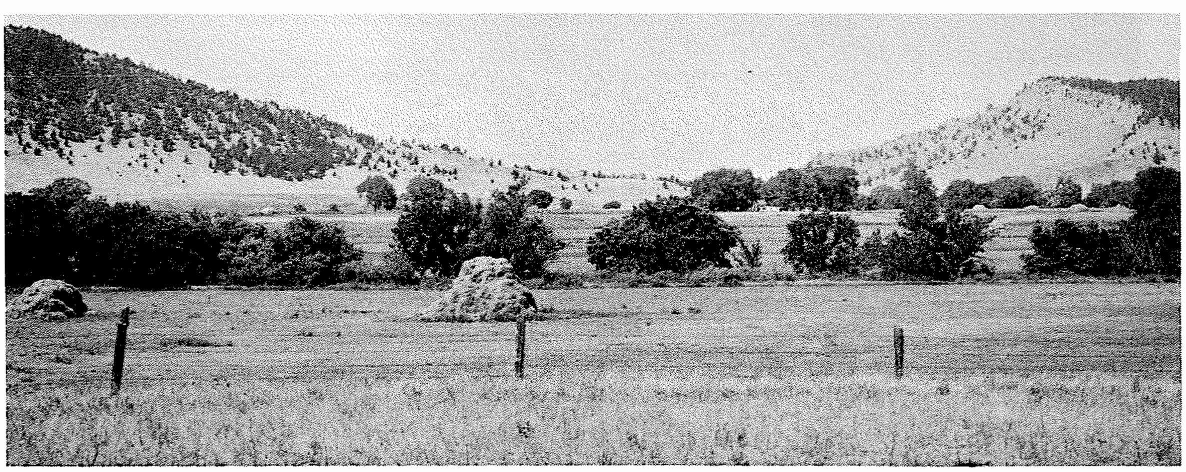


Figure 66. Buffalo Gap. Photograph taken from field trip mileage 561.7.

559.8 00.4 Leaving water gap, take right fork in the road.

560.6 00.8 To the right, at the corner, is Calico Canyon.

Calico Canyon is named for a variety of Unkpapa Sandstone. This thin-bedded, variegated sandstone is highly faulted and heavily cemented. A polished, cross-sectioned specimen is on display at the Museum of Geology of the School of Mines and Technology in Rapid City.

561.1 00.5 Junction of Highway 79, turn left (north).

561.7 00.6 **STOP TWENTY-SEVEN**. Stop at roadside park for talk on Buffalo Gap (fig. 66).

Buffalo Gap is a "textbook" example of a water gap. It was in the past a passageway for herds of bison into the Black Hills. In 1823 a party of Mountain Men led by Jedadiah Smith entered the Black Hills probably by this route. James Clyman, a member of the party, chronicled the events of the trip. His observations on land forms and conditions from Ft. Kiowa on the Missouri, up the White River, overland to the Cheyenne River and through the Black Hills make his route easy to follow. The other gap through which Highway 18-385 and Fall River leave the hills is the other choice. As Fall River is warm, and Clyman did not mention this fact, Buffalo Gap is the best choice (see Clyman, 1950).

562.6 00.9 Greenhorn Hogback on right (fig. 67).

The Greenhorn Limestone was named by G. K. Gilbert (1896); the type area is near Greenhorn Station, Colorado.

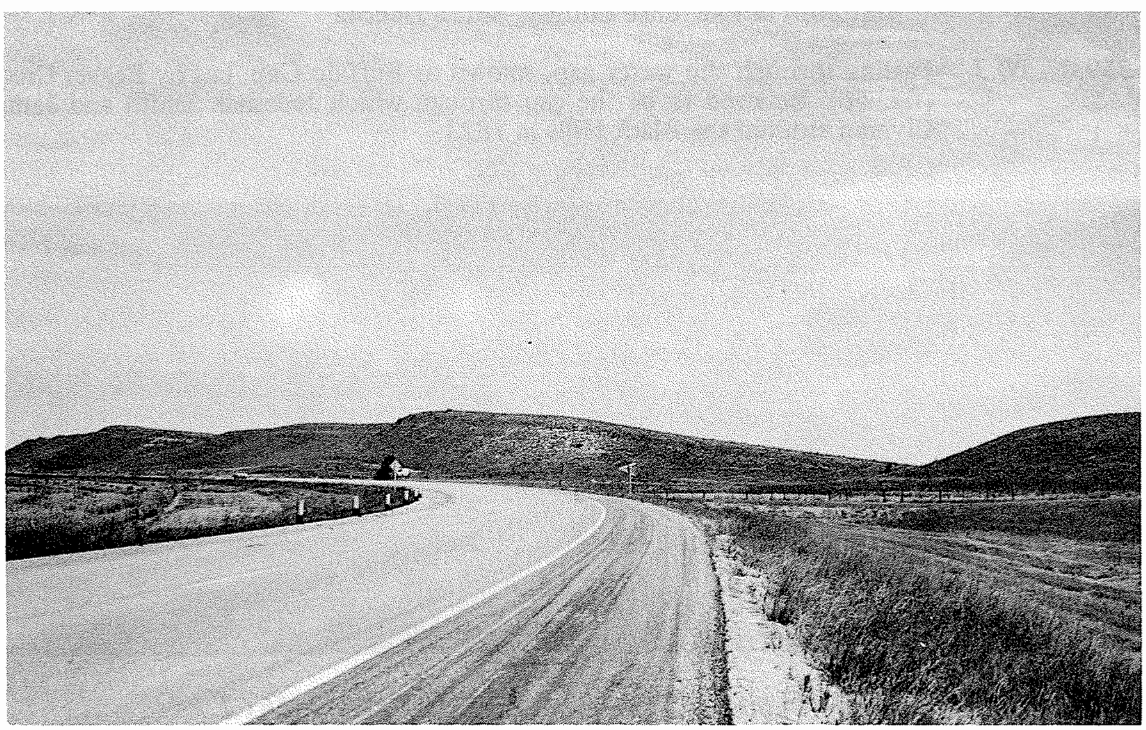


Figure 67. Greenhorn hogback. Photograph taken from field trip mileage 561.7.

564.7 02.1 Cross Dry Creek.

569.2 04.5 Note Interior Paleosol developed on the Graneros to the right front (fig. 68). The Graneros Shale was named by G. K. Gilbert (1896) for exposures near Graneros Creek, Pueblo County, Colorado.

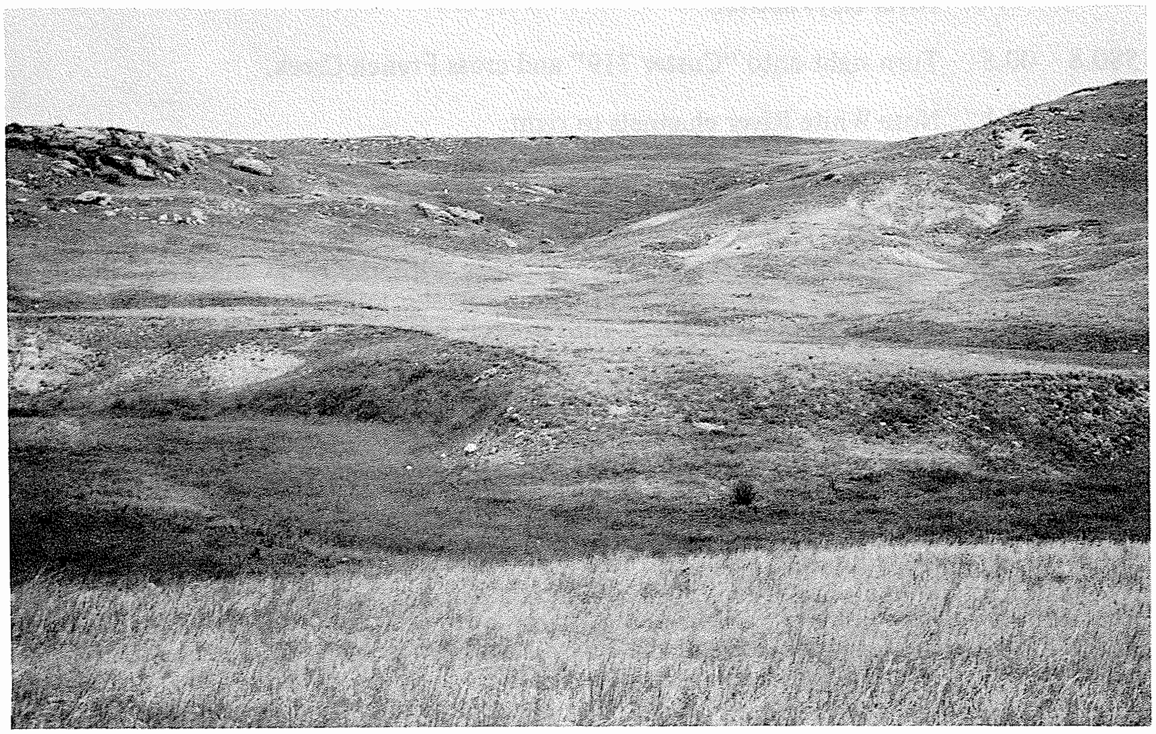


Figure 68. Cemented channels of the White River Group lying unconformably upon the Graneros Shale. The Interior Paleosol is well developed on the Graneros at this point.

569.6 00.4 We are now crossing one of the many highly cemented channels of the White River Group which are common along the southeastern edge of the Black Hills.

571.1 01.5 Brule Formation on right – front horizon.

574.2 03.1 Cross French Creek.

574.7 00.5 Fairburn to right.
Fairburn, platted in 1886, has a name which is a combination of "fair," the adjective, with "bourn" (spelled burn), the Scottish name for stream, brook, or creek.

575.2 00.5 Custer State Park road on left.

577.6 02.4 Turn right on "Custer 18," a gravel road.

578.2 00.6 Cross Chicago Northwestern Railroad tracks.

578.5 00.3 Small hill on right is the Greenhorn hogback.

579.6 01.1 From this spot we can see to the southwest a breached anticline with the Greenhorn Limestone forming the cap.

579.9 00.3 Greenhorn Limestone in railroad cut to right.

580.3 00.4 Fairburn city limit. On right are cemented White River channels with White River clays above.

580.8 00.5 Turn right onto "Custer 719" and cross French Creek.

580.9 00.1 Note White River channels to right.

582.0 01.1 Flowing well to right.

582.8 00.8 **STOP TWENTY-EIGHT.** Stop at top of anticlinal structure. At this stop we will see bedded White River deposits with the same strike and dip as the underlying Greenhorn. This indicates the Fairburn structure was formed much later than the Black Hills proper, probably post mid Oligocene.

583.3 00.5 **STOP TWENTY-NINE.** Poleslide Member of the Brule Formation exposed in roadcut to left (note the green mottling and the *Leptauchenia* nodules). A snail, *Helix leidyi*, can be found here.

It is surprising to see this unique lithology so well developed this close to the supposed source of the sediments.

587.5 04.2 Pierre Shale in roadcut to left.

589.0 01.5 **STOP THIRTY.** Stop to see Sharon Springs Member of the Pierre Shale.

This exposure of the Sharon Springs Member of the Pierre Shale has produced fish, mosasaur, and bird remains. The seal-like wingless bird, *Hesperornis*, is usually associated with the Niobrara Chalk in Kansas. In South Dakota *Hesperornis* is found in the Pierre Shale but is unknown in the Niobrara Chalk.

590.2 01.2 Top of hill is top of Niobrara Chalk.

591.6 01.4 Carlile Shale to left.

The Carlile Shale was named by G. K. Gilbert (1896) for exposures near Carlile Spring and Carlile Station in Pueblo County, Colorado.

594.4 02.8 Cross Lame Johnny Creek.

Named for Lame Johnny, the notorious Black Hills bandit. His last crime was the robbery of a stagecoach in 1882 at the crossing of this creek. While being transferred from one jail to another he was seized by a body of vigilantes, taken to the spot where the coach was robbed, and there hanged from a tree.

596.5 02.1 Niobrara exposure on the right side of the road.

599.2 02.7 Join "Custer 656."

599.4 00.2 Cross Beaver Creek.

599.5 00.1 Enter Buffalo Gap.

599.7 00.2 **STOP THIRTY-ONE.** Stop at Hussong's Museum. After stop continue west.

Turn south at the Southern Hills Bank and back to the west on Cedar Street.

599.9 00.2 The school building to the northwest is constructed of Unkpapa Sandstone.

600.9 01.0 Junction with Highway 79, turn right (north).

601.8 00.9 Note steep dips in strata to the left.

602.7 00.9 Roadside park on left.

603.6 00.9 Greenhorn hogback on right.

605.7 02.1 Cross Dry Creek.

610.6 04.9 We are now crossing one of the many highly cemented channels of the White River Group along the southeastern edge of the Black Hills.

612.1 01.5 Brule Formation on right-front horizon.

615.2 03.1 Cross French Creek. Just across the bridge note a narrow gravel road to the left. 1.5 miles down this road is Scored Rock (fig. 69).

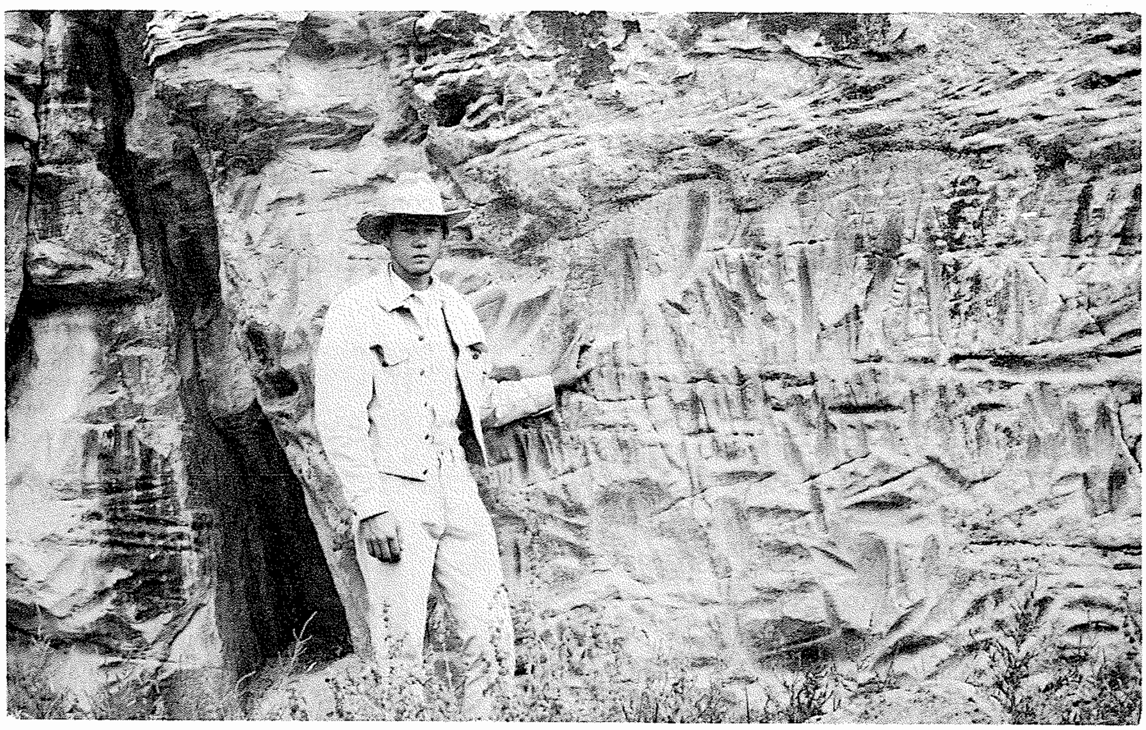


Figure 69. Scored Rock where Sioux Indians once sharpened their implements and tools.

615.7 00.5 Fairburn to right.

616.2 00.5 Custer State Park road on left.

619.5 03.3 Brule Formation in roadcut on right.

620.7 01.2 Brule Formation in roadcut on right.

623.9 03.2 Cemented White River Channels capping hills to the right.

624.3 00.4 Graneros Shale in railroad cut on right.

627.8 00.5 Cross Battle Creek – Hermosa on right. Battle Creek was so named to commemorate a battle between the Sioux and an unrecorded pre-European enemy.

Hermosa was founded in 1886 by the Pioneer Town Site Company. It was first called Strater Post Office and then the Battle River Stage Station. The present name is a Spanish word meaning beautiful. Hermosa was an early shipping point for Yale Museum vertebrate fossils and is often incorrectly cited as a collecting locality for White River fossils (Macdonald, 1956).

627.8 00.5 Graneros Shale along road.

629.9 01.1 Enter Pennington County. Pennington County was named for John L. Pennington, governor of Dakota Territory from 1874 to 1878.

632.4 03.5 Tree line on left marks the lower contact of the Graneros Shale. The trees are growing on the underlying Inyan Kara Group.

633.3 00.9 The butte to the left front (Molly's Nipple; Morton Green, personal communication) is capped with Oligocene limestone.

634.4 01.1 **STOP THIRTY-TWO.** Stop to look at Brule Formation exposed in roadcut (fig. 70). Note the size of some of the constituent particles and the contact between the Brule Formation and the Graneros Shale. It is interesting to see the similarities between the Brule of the Badlands and the Brule of this outcrop.

Figure 70. Brule Formation exposed along Highway 79 at field trip mileage 634.4.

636.4	02.0	Buttes ahead are composed of Graneros Shale capped with cemented White River channels.
641.4	05.0	KOTA transmitter on right.
642.3	00.9	Rapid City city limits.
643.8	01.5	Junction of Highway 79 and St. Patrick Street. **END OF FIELD TRIP!**

LITERATURE CITED

Agnew, A. F., 1957, Geology of the White River quadrangle, South Dakota: S. Dak. Geol. Survey map and text.

________1958a, Bijou Formation – A stream deposit?: S. Dak. Acad. Sci. Proc. (1957), v. 36, p. 129-133.

________1958b, Miocene and Pliocene rocks of southern South Dakota: Geol. Soc. America Bull., v. 69, p. 1721.

________1964, Geology of the Mission quadrangle, South Dakota: S. Dak. Geol. Survey map and text.

Agnew, A. F., and Tychsen, P. C., 1965, A guide to the stratigraphy of South Dakota: S. Dak. Geol. Survey Bull. 14, 195 p.

American Commission on Stratigraphic Nomenclature, 1961, Code of Stratigraphic Nomenclature: Am. Assoc. Petroleum Geol. Bull., v 45, p. 645-665.

Anonymous, 1941, South Dakota Place Names: University of South Dakota, 689 p.

Atwood, W. W., and Atwood, W. W., Jr., 1958, Tertiary-Pleistocene transition at the east margin of the Rocky Mountains: Geol. Soc. America Bull., v. 59, p. 605-608.

Bjork, P. R., MS, Stratigraphy and paleontology of the Slim Buttes Formation in Harding County, South Dakota: South Dakota School of Mines and Technology unpublished masters thesis (1964).

________1967, Latest Eocene vertebrates from northwestern South Dakota: Jour. Paleo., v. 41, p. 227-236.

Brown, B., 1907, The Hell Creek beds of the Upper Cretaceous of Montana, their relation to continental deposits, with faunal and floral lists and a discussion of their correlation: Am. Mus. Hist. Bull., v. 23, p. 823-845.

Bryan, K., 1944, Glacial versus desert origin of loess: Am. Jour. Sci., v. 243, p. 245-246.

Bryant, Laurie, MS, Early Miocene Lagomorphs and Rodents from the Wounded Knee Area, South Dakota: South Dakota School of Mines and Technology unpublished masters thesis (1969).

Bump, J. D., ed., 1951, Guidebook, Fifth field conference of the Society of Vertebrate Paleontology in western South Dakota: Museum of Geology of the South Dakota School of Mines and Technology, 85 p.

________1956, Geographic names for the members of the Brule Formation of the Big Badlands of South Dakota: Am. Jour. Sci., v. 254, p. 429-432.

Clark, J., 1937, The stratigraphy and paleontology of the Chadron Formation of the Big Badlands of South Dakota: Annals of the Carnegie Museum, v. 25, p. 261-350.

________1954, Geographic designation of the members of the Chadron Formation in South Dakota: Annals of the Carnegie Mus., v. 33, p. 197-198.

Clark, J., Beerbower, J. R., and Kietzke, K. K., 1967, Oligocene Sedimentation, Stratigraphy, Paleoecology, and Paleoclimatology in the Big Badlands of South Dakota: Field Museum of Natural History, Fieldiana - Geology Memoirs, v. 5, 158 p.

Clyman, J. (*Posthum*), 1950, James Clyman, Frontiersman (Edited by C. L. Camp): Champoeg Press, Portland, Oregon, 352 p.

Colbert, E. H., 1948, Pleistocene of the Great Plains: Geol. Soc. America Bull., v. 59, p. 541-542.

Collins, S. G., 1959, Geology of the Martin quadrangle, South Dakota: S. Dak. Geol. Survey map and text.

________ 1960, Geology of the Patricia quadrangle, South Dakota: S. Dak. Geol. Survey map and text.

Condra, G. E., and Reed, E. C., 1959, The geological section of Nebraska: Nebr. Geol. Survey Bull. 14A, 92 p.

Cook, H. J., 1922, Basic Tertiary conglomerate of the Black Hills: Pan-Am. Geologist, v. 37, p. 421-424.

________(*Posthum*), 1965, Runningwater Formation, middle Miocene of Nebraska: American Museum Novitates 2227, 8 p.

________(*Posthum*), 1968, Tales of the 04 Ranch: Univ. Nebr. Press, 221 p.

Cook, H. J., and Cook, M. C., 1933 Faunal lists of the Tertiary Vertebrata of Nebraska and adjacent areas: Nebr. Geol. Survey Paper 5, 58 p.

Cragin, F. W., 1896, Preliminary notice of three late Neocene terranes of Kansas: Colo. College Studies, v. 6, p. 53-54.

Darton, N. H. 1899a, Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U. S. Geological Survey 19th Ann. Rept., p. 719-785.

________1899b, Jurassic formations of the Black Hills of South Dakota: Geol. Soc. America Bull., v. 10, p. 383-396.

________1901, Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey 21st Annual Report, p. 489-599.

________1909, Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Prof. Paper 65, 105 p.

Darton, N. H., and Paige, S., 1925, Central Black Hills Folio, South Dakota: U. S. Geol. Survey Atlas 219, 34 p.

Dunham, R. J., MS, Geology of uranium in the Chadron Area, Nebraska and South Dakota: U. S. Geol. Survey open-file report (1961).

Emiliani, C., 1967, The Plio-Pleistocene boundary: Science, v. 156, p. 410.

Fenneman, N. M., 1931, Physiography of western United States: McGraw-Hill Book Co., New York, 534 p.

Fillman, L., 1929, Cenozoic History of the Northern Black Hills: Univ. Iowa Studies in Nat. Hist., v. 13, p. 1-48.

Frye, J. C., 1945, Valley erosion since Pliocene "Algal Limestone" deposition in central Kansas: Kansas Geol. Survey Bull. 60, p. 85-100.

Frye, J. C., and Leonard, A. B., 1957, Ecological interpretations of Pliocene and Pleistocene stratigraphy in the Great Plains Region: Am. Jour. Sci., v. 255, p. 1-11.

________1959, Correlation of the Ogallala Formation (Neogene) in western Texas with type localities in Nebraska: Univ. Texas, Bureau Econ. Geol., Rept. Inv. 39, 46 p.

________1964, Relation of Ogallala Formation to the southern High Plains in Texas: Univ. Texas, Bureau Econ. Geol., Rept. Inv. 51, 25 p.

Gidley, J. W., 1904, New or little known mammals from the Miocene of South Dakota. American Museum expedition of 1903. Part 1, Geological notes: Am. Mus. Nat. Hist. Bull., v. 20, p. 241-246.

________1906, New or little known mammals from the Miocene of South Dakota. American Museum expedition of 1903. Part 4, Equidae: Am. Mus. Nat. Hist. Bull., v. 22, p. 135-153.

Gilbert, G. K., 1896, The underground water of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey 17th Annual Report, p. 551-601.

Green, M., 1956, The lower Pliocene Ogallala-Wolf Creek fauna, South Dakota: Jour. Paleo., v. 30, p. 146-169.

________1958, *Gomphotherium friki* from the Bijou Hills, South Dakota: S. Dak. Acad. Sci. Proc. (1957), v. 36, p. 139-142.

________1962, Comments on the geologic age of *Bison latifrons*: Jour. Paleo., v. 36, p. 557-559.

Green, M., and Lillegraven, J. A., 1966, Significance of *Rangifer* in the Herrick Formation of South Dakota: S. Dak. Acad. Sci. Proc., v. 44, p. 48-51.

Gregory, J. T., 1942, Pliocene Vertebrates from Big Spring Canyon, South Dakota: Univ. Calif. Pubs., Bull. Dept. Geol. Sci., v. 26, p. 307-446.

Harksen, J. C., 1965, Geology of the Sharps Corner quadrangle, South Dakota: S. Dak. Geol. Survey map, text, and auxillary sheet.

________1966, The Pliocene-Pleistocene Medicine Root gravel of southwestern South Dakota: Southern Calif. Acad. Sci. Bull., v. 65, p. 251-257.

________1967a, Quaternary loess in southwestern South Dakota: S. Dak. Acad. Sci. Proc. 1967, v. 46, p. 32-40.

________1967b, Geology of the Porcupine Butte quadrangle, South Dakota: S. Dak. Geol. Survey map and text.

________1968a, Red Dog Loess named in southwestern South Dakota: S. Dak. Geol. Survey Rept. Inv. 98, 17 p.

________1968b, Geology of the Sharps Corner quadrangle, South Dakota, second edition: S. Dak. Geol. Survey map and text.

________1968c, *Ondatra* from the Pleistocene of South Dakota: S. Dak. Acad. Sci. Proc. [1969], v. 47, p. 46-49.

________in preparation, The geology of the Martin Area, South Dakota: S. Dak. Geol. Survey Bull.

Harksen, J. C., and Macdonald, J. R., 1967, Miocene Batesland Formation named in southwestern South Dakota: S. Dak. Geol. Survey Rept. Inv. 96, 10 p.

________in preparation, Type sections for the Chadron and Brule Formations of the White River Oligocene in the Big Badlands, South Dakota.

Harksen, J. C., Macdonald, J. R., and Sevon, W. D., 1961, New Miocene Formation in South Dakota: Am. Assoc. Petroleum Geol. Bull., v. 45, p. 674-678.

Hatcher, J. B., 1893, The Titanotherium beds: Am. Naturalist, v. 27, p. 204-221.

________1902, Origin of the Oligocene and Miocene deposits of the Great Plains: Am. Philos. Soc. Proc., v. 41, p. 113-131.

Hedges, L. S., 1969, Geology and water resources of Beadle County, South Dakota, Part I: Geology: S. Dak. Geol. Survey Bull. 18, 66 p.

Jepsen, G. L., 1963, Eocene vertebrates, coprolites, and plants in the Golden Valley Formation of western North Dakota: Geol. Soc. America Bull., v. 74, p. 673-684.

Johnson, W. D., 1901, The High Plains and their utilization: U. S. Geol. Survey 21st Annual Report, p. 601-741.

Keroher, Grace C., 1966, Lexicon of geologic names of the United States for 1936-1960: U. S. Geol. Survey Bull. 1200, 4341 p.

Laird, W. M., 1967, A note on preglacial drainage in the Northern Great Plains: N. Dak. Geol. Survey Misc. Series 30, p. 167-170.

Leidy, J., 1847, On a new genus and species of fossil Ruminantia; *Poebrotherium wilsoni*: Phila. Acad. Nat. Sci. Proc., v. 3, p. 322-326.

Lugn, A. L., 1934, Outline of the Pleistocene geology of Nebraska: Univ. Nebr. State Museum Bull., v. 1, p. 319-356.

Macdonald. J. R., 1951a, The history and exploration of the Big Badlands of South Dakota , in Bump, J. D., ed., Guidebook, fifth field conference of the Society of Vertebrate Paleontology in western South Dakota: p. 31-33.

________1951b, The fossil vertebrata of South Dakota, in Bump J. D., ed., Guidebook, fifth field conference of the Society of Vertebrate Paleontology in western South Dakota: p. 63-74.

________1956, The North American Anthracotheres: Jour. Paleo., v. 30, p. 615-645.

________1960, An early Pliocene fauna from Mission, South Dakota: Jour. Paleo., v. 34, p. 961-982.

________1963, The Miocene faunas from the Wounded Knee area of South Dakota: Am. Mus. Nat. Hist. Bull., v. 125, p. 139-238.

________in press, Review of the Miocene Wounded Knee Faunas of southwestern South Dakota: Los Angeles Co. Museum Nat. Hist. Bull.

Macdonald, J. R., and Harksen, J. C., 1968, Rosebud Formation in South Dakota: S. Dak. Geol. Survey Rept. Inv. 97, 13 p.

McGrew, P. O., 1944, An early Pleistocene (Blancan) fauna from Nebraska: Field Mus. Nat. History, Geol. ser., v. 9, p. 33-66.

________1953, Tertiary deposits of southeastern Wyoming: Wyoming Geol. Assn. and Univ. Wyo. Guidebook, 8th Ann. Field Conference, p. 61-64.

Malhotra, C. L., and Tegland, C. L., 1960, A new Tertiary formation in Harding County, South Dakota: S. Dak. Acad. Sci. Proc. (1959), v. 38, p. 263-274.

Matthew, W. D., 1907, A lower Miocene fauna from South Dakota: Am. Mus. Nat. Hist. Bull., v. 23, p. 169-219.

Matthew, W. D., and Gidley, J. W., 1904, New or little known mammals from the Miocene of South Dakota: Amer. Mus. Nat. Hist. Bull., v. 20, p. 241-268.

________1906, New or little known mammals from the Miocene of South Dakota: Amer. Mus. Nat. Hist. Bull., v. 22, p. 135-153.

Meek, F. B., and Hayden, F. V., 1858, Descriptions of new Species and Genera of Fossils, collected by Dr. F. V. Hayden in Nebraska Territory under the direction of Lieut. G. K. Warren, U. S. Topographical Engineer; with some remarks on the Tertiary and Cretaceous formations of the northwest and the parallelism of the latter with those of other portions of the United States and Territories: Acad. Nat. Sci. of Phila. Proc. 1857, v. 9, p. 117-148.

________1862, Descriptions of new lower Silurian, (Primordial), Jurassic, Cretaceous, and Tertiary fossils, collected in Nebraska, by the Exploring Expedition under the command of Capt. Wm. F. Raynolds, U. S. Top. Engrs.; with some remarks on the rocks from which they were obtained: Acad. Nat. Sci. Phila., Pr. 1861, p. 415-447.

Miller, A. H., 1944, An avifauna from the lower Miocene of South Dakota: Univ. Cal. Pub., Dept. Geol. Sci., v. 27, p. 85-100.

Miller, A. H., and Compton, L. V., 1939. Two fossil birds from the lower Miocene of South Dakota: Condor, v. 41, p. 153-156.

Miller, R. D., 1964, Geology of the Omaha-Council Bluffs Area, Nebraska-Iowa: U. S. Geol. Survey Prof. Paper 472, 70 p.

Miller, R. D., Van Horn, T., Dobrovolny, E., and Buck, L. P., 1964, Geology of Franklin, Webster, and Nuckolls Counties, Nebraska: U. S. Geol. Survey Bull. 1165, 91 p.

Newton, E., and Jenney, W. P., 1880, Report on the geology and resources of the Black Hills of Dakota: U. S. Geog. G. S. Rocky Mtn. Reg. (Powell), 566 p.

Nicknish, J. M., MS, Investigation of the basal ash of the Arikaree Formation in northern Shannon County, South Dakota: South Dakota School of Mines and Technology unpublished masters thesis (1957).

Nicknish, J. M., and Macdonald, J. R., 1962, Basal Miocene Ash in White River Badlands, South Dakota: Am. Assoc. Petroleum Geol. Bull., v. 46, p. 685-690.

Osborn, H. F., 1907, Tertiary mammal horizons of North America: Am. Mus. Nat. Hist. Bull., v. 23, p. 237-253.

________1909, Cenozoic mammal horizons of western North America: U. S. Geol. Survey Bull. 361, p. 1-90.

________1918, Equidae of the Oligocene, Miocene, and Pliocene of North America; Iconographic type revision: Am. Mus. Nat. Hist. Mem. (n. s.) v. 2, p. 1-330.

________1929, Titanotheres of ancient Wyoming, Dakota, and Nebraska: U. S. Geol. Survey Monograph 55, 2 vols.

Owen, D. D., 1852, Report of a geological survey of Wisconsin, Iowa, and Minnesota and incidentally of a portion of Nebraska Territory: Philadelphia, 638 p.

Page, L. R., and others, 1953, Pegmatite investigations 1942-1945, Black Hills, South Dakota: U. S. Geol. Survey Prof. Paper 247, 228 p.

Pettyjohn, W. A., MS, Geology of the Stoneville quadrangle, South Dakota: S. Dak. Geol. Survey unpublished map and text.

________1966, Eocene soil profile in the northern Great Plains: S. Dak. Acad. Sci. Bull., v. 44, p. 80-87.

Petsch, B. C., 1955a, Areal geology of the Reva quadrangle: S. Dak. Geol. Survey map and text.

________1955b, Areal geology of the Govert quadrangle: S. Dak. Geol. Survey map and text.

Pipiringos, G. N., Chisholm, W. A., and Kepferle, R. C., 1965, Geology and Uranium deposits in the Cave Hills Area, Harding County, South Dakota: U. S. Geol. Survey Prof. Paper 476-A, 64 p.

Plumley, W. J., 1948, Black Hills Terrace gravels, a study in sedimentary transport: Jour. Geol., v. 56, p. 526-577.

Prout, H. A., 1846, Gigantic *Palaeotherium*: Am. Jour. Sci., ser. 2, v. 2, p. 288-289.

Reed, E. C., and Dreeszen, V. H., 1965, Revision of the classification of the Pleistocene deposits of Nebraska: Nebraska Geol. Survey Bull. 23, 65 p.

Repenning, C. A., 1967, Subfamilies and Genera of the Soricidae: U. S. Geol. Survey Prof. Paper 565. 74 p.

Richmond, G. M., 1965, Glaciation of the Rocky Mountains, in Wright, H. E., Jr., and Frey, D. G., eds., The Quaternary of the United States: Princeton University Press, p. 217-230.

Schlaikjer, E. M., 1935, Contributions to the stratigraphy and palaeontology of the Goshen Hole Area, Wyoming, part three, A new basal Oligocene Formation: Museum of Comparative Zoology Bull., v. 76, p. 71-93.

Schoon, R. A., 1968, Stratigraphic section for northwestern and central South Dakota: S. Dak. Geol. Survey hand out sheet.

Schultz, C. B., and Falkenbach, C. H., 1940, Merycochoerinae, a new subfamily of oreodonts: Am. Mus. Nat. Hist. Bull., v. 77, p. 213-306.

________1941, Ticholeptinae, a new subfamily of oreodonts: Am. Mus. Nat. Hist. Bull., v. 74, p. 1-105.

________1950, Phenococoelinae, a new subfamily of oreodonts: Am. Mus. Nat. Hist. Bull., v. 95, p. 91-149.

________1954, Desmatochoerinae, a new subfamily of oreodonts: Am. Mus. Nat. Hist. Bull., v. 105, p. 143-256.

________1956, Miniochoerinare and Oreonetinae, two new subfamilies of oreodonts: Am. Mus. Nat. Hist. Bull., v. 109, p. 377-482.

________1968, The Phylogeny of the oreodonts, parts 1 and 2: Am. Mus. Nat. Hist. Bull., v. 139, p. 1-498.

Schultz, C. B., and Stout, T. M., 1938, Preliminary remarks on the Oligocene of Nebraska (Abs.): Geol. Soc. America Bull., v. 49, p. 1921.

________1955, Classification of Oligocene sediments in Nebraska: Univ. Nebr. State Museum Bull., v. 4, p. 17-52.

________1961, Field conference on the Tertiary and Pleistocene of western Nebraska, Guidebook for the ninth field conference of the Society of Vertebrate Paleontology: Lincoln, Univ. Neb. State Mus., 55 p.

Sevon, W. D., 1961, Geology of the Vetal quadrangle, South Dakota: S. Dak. Geol. Survey map and text.

Skinner, M. F., 1968, A Pliocene chalicothere from Nebraska, and the distribution of chalicotheres in the Late Tertiary of North America: American Museum Novitates 2346, 24 p.

Skinner, M. F., Skinner, S. M., and Gooris, R. J., 1968, Cenozoic rocks and faunas of Turtle Butte, south-central South Dakota: Amer. Mus. Nat. Hist. Bull., v. 138, p. 379-436.

Skinner, M. F., and Taylor, B. E., 1967, A revision of the Geology and Paleontology of the Bijou Hills, South Dakota: American Museum Novitates 2300, 53 p.

Slaughter, A. L., 1968, Homestake mine, in Wulf, G. R., ed., Wyoming Geological Association 20th Field Conference Guidebook: p. 157-171.

Stevenson, R. E., 1953, The Bijou Formation in south central South Dakota: S. Dak. Acad. Sci. Proc. (1953), v. 32, p. 86-90.

1954, Areal geology of the Morristown quadrangle: S. Dak. Geol. Survey, map and text.

1958a, Revision and interpretation of the Bijou Formation: S. Dak. Acad. Sci. Proc. (1957), v. 36, p. 134-138.

1958b, Geology of the Gregory quadrangle, South Dakota: S. Dak. Geol. Survey map and text.

Stirton, R. A., 1967, Relationships of the Protoceratid Artiodactyls, and description of a new genus: Univ. Calif. Pubs., Bull. Dept. Geol. Sci., v. 72, p. 1-35.

Taylor, D. W., 1960, Late Cenozoic molluscan faunas from the High Plains: U. S. Geol. Survey Prof. Paper 337, 94 p.

Todd, J. E., 1898, The first and second biennial reports on the geology of South Dakota with accompanying papers, 1893-1896: S. Dak. Geol. Nat. Hist. Survey Bull. 2, 139 p.

1902, Hydrographic history of South Dakota: Geol. Soc. America Bull., v. 13, p. 27-40.

Troxell, E. L., 1916, An early Pliocene one-toed horse, *Pliohippus lullianus* sp. nov.: Am. Jour. Sci., ser. 4, v. 42, p. 335-348.

Wanless, H. R., 1922, Lithology of the White River sediments: American Philos. Soc. Proc., v. 61, p. 184-203.

1923, The stratigraphy of the White River beds of South Dakota: Am. Philos. Soc. Proc., v. 62, p. 190-269.

Ward, F., 1922, The geology of a portion of the Badlands: S. Dak. Geol. Nat. Hist. Survey Bull. 11, p. 7-59.

Webb, W. P., 1931, The Great Plains: Grossett and Dunlap, New York, 525 p.

White, E. M., 1964, Post-Illinoian age for Missouri River in South Dakota proposed from relationship to a White River terrace: Am. Jour. Sci., v. 262, p. 494-496.

Wilson, R. W., and Tucholke, B. E., 1967, A first record of an alligator from the middle Oligocene of the Big Badlands of South Dakota (abs.): S. Dak. Acad. Sci. Proc. (1966), v. 45, p. 287.

Witkind, I. J., 1959, Quaternary geology of the Smoke Creek–Medicine Lake–Grenora area, Montana and North Dakota: U. S. Geol. Survey Bull. 1073, 80 p.

Wood, H. E., II, and others, 1941, Nomenclature and correlation of the North American Continental Tertiary: Geol. Soc. America Bull. v. 52, p. 1-48.

Wortman, J. L., 1893, On the divisions of the White River or lower Miocene of Dakota: Am. Mus. Nat. Hist. Bull., v. 5, p. 95-105.