SOUTH DAKOTA

STATE GEOLOGICAL SURVEY

E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 21

THE GEOLOGY

OF

CENTRAL PERKINS COUNTY, SOUTH DAKOTA

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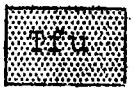
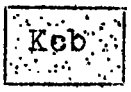
Legend



Fort Union



Cannonball member of the Lance

Ludlow member of the Lance

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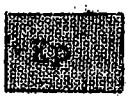
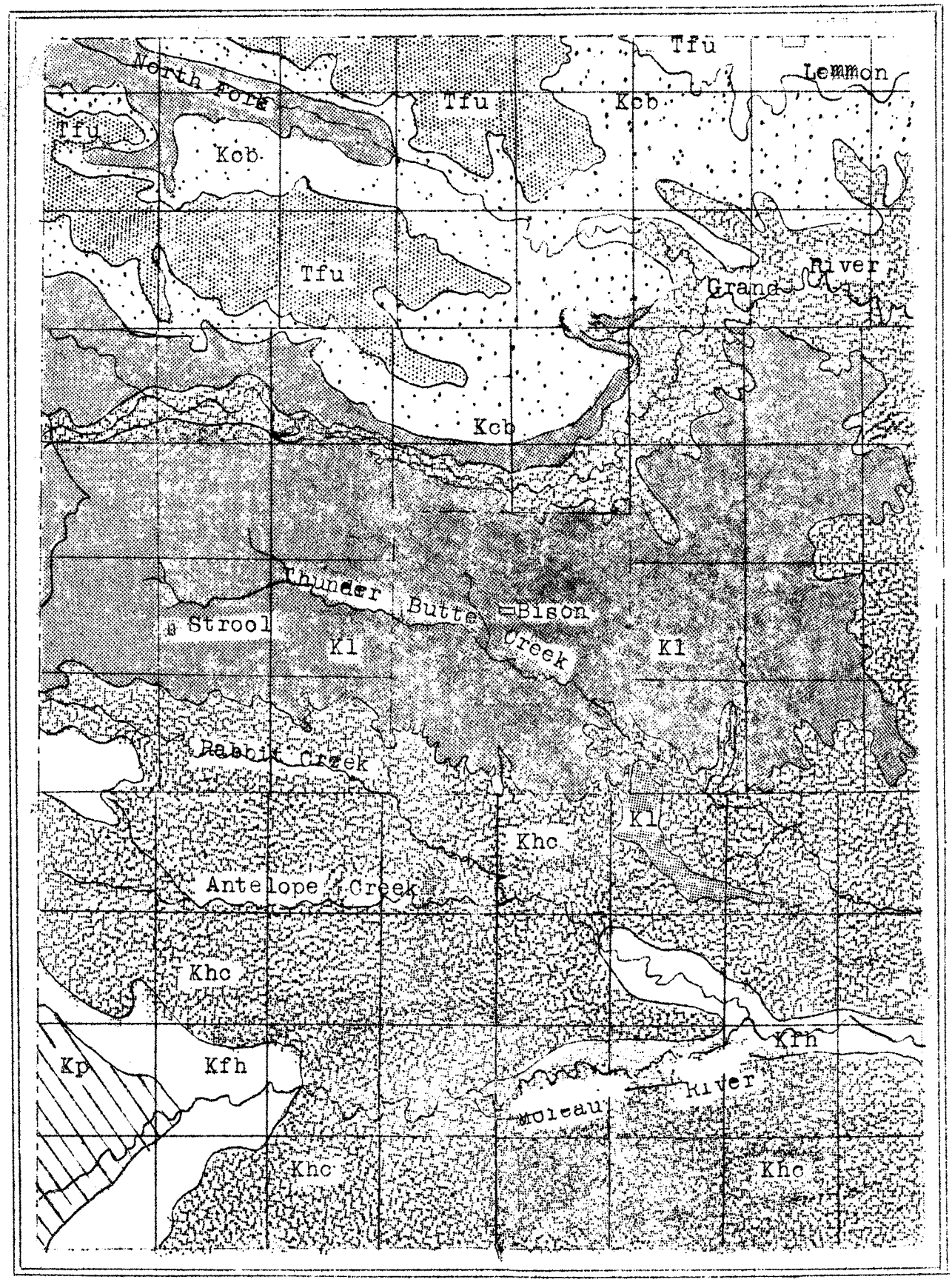
Fox Hills



Pierre



GEOLOGIC MAP OF PERKINS COUNTY

to show location and general relations of the central Perkins County Area, South Dakota

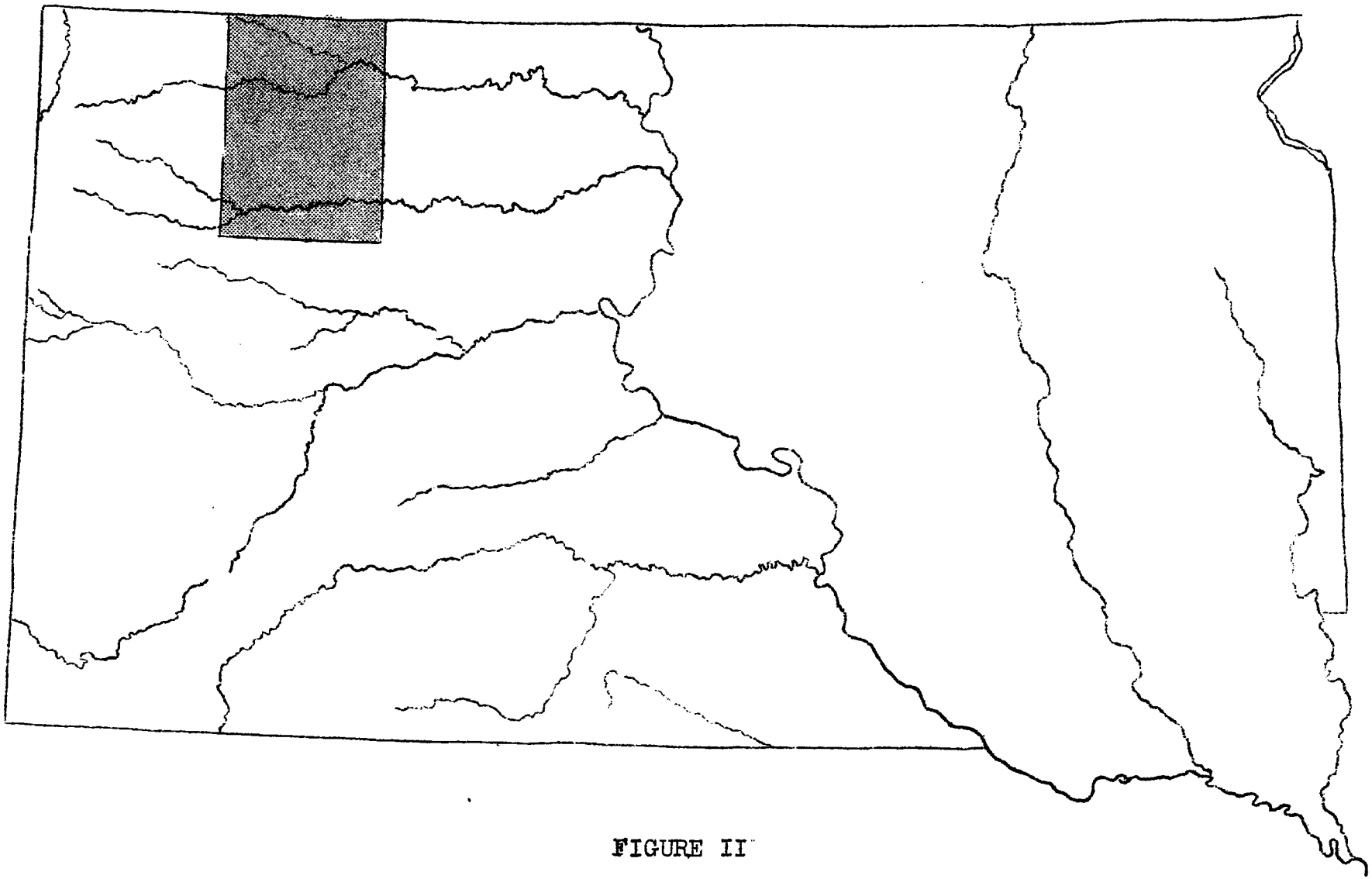


FIGURE II

Index map of South Dakota to show location of Perkins county.

THE GEOLOGY OF CENTRAL PERKINS COUNTY

INTRODUCTION

Location and area:

The Central Perkins county area lies at about the geographic center of Perkins county, South Dakota. Perkins county is in northwestern South Dakota and is bounded on the north by North Dakota and is separated from Montana to the west by Harding and Butte counties. The central Perkins county area, as mapped in this report, lies twenty-four miles south of the northern boundary of South Dakota and about seventy miles east of the western boundary. It occupies T. 17 and 18 and S½ 19, R. 13 E. and T. 17, 18, and S½ 19, R. 14 E., a total of 180 square miles, (fig.1). Bison, the county seat, somewhat north of the center of the mapped area, is approximately 130 miles northwest of Pierre, 100 miles almost due west of Mobridge, and approximately 110 miles north and somewhat east of Rapid City. (fig. 2).

Purpose of the Investigation:

Perkins county, South Dakota, is underlain by the most complete succession of beds to be found in the state representing the interval between the Fox Hills of the Cretaceous and the early White River of the Oligocene. In this county a succession including upper Pierre, Lance, lower Fort Union, and lower White River is exposed. A complete succession of the Lance, including the Hell Creek of early Lance age, the Ludlow of the late Lance, and its marine correlative, the Cannonball, is developed here.

The rocks of this county are thus important to the determination of the stratigraphy and the relations of these various formations in South Dakota. They are of particular importance to the Lance problem because the boundary of the continental and marine facies of the upper Lance, the Ludlow and Cannonball, lies across the county.

The area in central Perkins county was chosen for investigation because it contains upper Lance beds which lie approximately at the geographic boundary between the continental and marine facies. Detailed studies of these beds are necessary to further stratigraphic studies, to structural studies, and to economic studies such as those involving oil, gas, and coal.

The area was chosen also because of coal deposits in it which have been of much importance in the settlement of this and the surrounding area and which constitute the most important local source of fuel.

Previous Geologic Work:

The earliest geologists to investigate the general region in which the central Perkins county lies were N. H. Winchell[1] and Bailey Willis.[2] The former, with the Custer expedition, under William Ludlow passed to the westward in western Harding county in 1874. The latter, ten years later, made a preliminary investigation between Grand and Moreau Rivers which extended westward to Rabbit Butte. Todd, first State Geologist of South Dakota, in 1895 made a reconnaissance into northwestern South Dakota.[3] He approached the area as near as the Slim Buttes and the Cave Hills. He classified the rocks of the region, now known as the Lance, with the Laramie. He also recognized the beds of the White River in the Slim Buttes. The Lance was not subdivided nor the Fort Union differentiated. In 1900[4] and again in 1902, Todd made reconnaissance investigations.[4] At the later date he studied Rabbit Butte, made side trips to Bixby, and to the south and of Slim Buttes. He later visited Coal Springs. He made a generalized geologic section of the region, collected fossils from formations of the region, and made several sections, one of which he made at Rabbit Butte. His classifications remained the same as in his earlier report.

The first comprehensive and detailed geological survey was made for the purpose of land classification during the summers of 1911 and 1912, under the auspices of the United States Geological Survey.[5] The formations of Harding and Perkins county were first mapped in detail, coal beds were plotted, and sections made. This survey classified the formations of the region essentially as at present. The Lance was subdivided into lower Lance, Ludlow lignitic member, and the Cannonball marine member of the Lance. Numerous contributions by other authors have been made to the knowledge of the formations represented in the area. Studies of the general region, preliminary studies of the coal and its properties have been made by the South Dakota Geological Survey.

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1. Ludlow, William, Report of a Reconnaissance of the Black Hills of South Dakota, U. S. A., Washington, 1875.
2. Willis, Bailey, Lignites of the Great Sioux Reservation, U. S. Geological Survey, Bull. 21, 1885.
3. Todd, J. E., A reconnaissance into northwestern South Dakota. South Dakota Geological Survey Bull. No. 2, pp. 42-68, 1898.
4. Todd, J. E., Preliminary report on the geology of the northwest-central portion of South Dakota. South Dakota Geological Survey, Bull. No. 4, 1908.
5. Winchester, D. E., Hares, C. J., Lloyd, E. R., and Parks, E. M., The Lignite Field of Northwestern South Dakota. United States Geological Survey Bull. No. 627, 1916.

Field Work:

About six weeks during July and August, 1932, were spent in the study of the area. All parts of the area were investigated. The outcrops were plotted from speedometer readings and by pacing. Sections were made with the aid of hand level and by telescopic level and stadia rod.

Acknowledgements:

The Survey appreciates the kind cooperation of residents, land owners, and owners and operators of coal mines. Mr. Kirk M. Sandals rendered diligent and able assistance in the field. The literature on this and the surrounding region have been freely consulted. Analysis of coals were made at the South Dakota School of Mines through the kindness of Dr. C. C. O'Harra and Chas. Bentley, analyst.

PHYSIOGRAPHY AND GEOGRAPHY

Physiographic province

Central Perkins county is well within the Great Plains, the eastern boundary of the area being approximately 100 miles from the eastern edge of the Plains. The boundary between the Great Plains and the Glaciated Plains province is roughly marked by the valley trough of Missouri River.

Drainage and Relief

Drainage is to South Fork of Grand River and to Moreau River through its major tributaries, Thunder Butte Creek and Rabbit Creek. (Plate I). Thunder Butte Creek crosses the area diagonally from the western edge toward the southeastern corner and drains the central and southeastern part of the area, approximately 85 square miles. Most of T. 18 N., R. 13 E., excepting the northern corners, T. 18 N., R. 14 E., excepting the northern two tiers of sections, and all of T. 17 N., R. 14., excepting the southwestern corner drain to Moreau River through Thunder Butte Creek and its tributaries. The northern part of the area is drained by nearly parallel, short, deeply cut valleys which drain somewhat west of north into South Fork of Grand River. The valley trough of South Fork is from one to three miles north of the mapped area. Grand River tributaries drain all of T. 19 N., R. 13 E. and T. 19 N., R. 14 E., and in addition the northern corners of T. 18 N., R. 13 E. and the northern two tiers of sections of T. 18 N., R. 14 E., a total of approximately sixty square miles. Rabbit creek crosses

sec. 31, T. 17 N., R. 13 E. and with its southward draining tributaries drains most of this township, the southwestern part of the area, approximately thirty-five square miles.

All streams of the area are intermittent. They flow only after high precipitation or from the runoff of melting snow.

The relief of the area is related to the drainage. That of Rabbit Creek valley and Thunder Butte Creek valley is mostly low, averaging less than fifty feet from valley bottoms to butte tops. Maximum relief in these drainage areas is rarely, if in any case, more than 100 feet. Much of this part of the area is rolling grass and wheat land, known since early occupation as part of the "Big Meadow".

North of the divide between Thunder Butte Creek and South Fork of Grand River, relief is high, valleys are deeply cut, only small flattish areas occur, and butte and "breaks" topography prevails. In these "breaks", the common name on the plains for rough topography where numerous valleys cut into flattish areas, the maximum relief is over 400 feet. Between the prominent buttes along both sides of the southern boundary of T. 19 N., R. 14 E. and South Fork of Grand River, about five miles north, the elevation decreases more than 450 feet or an average of fifty feet or more per mile.

The relief to the north of the divide between Grand River and Thunder Butte drainage has been developed much more recently than that to the south. The buttes along the south line of T. 19 N., R. 14 E. mark a former position of a formerly higher divide which has since been shifted about two miles to the south. The old divide rises fifty to sixty feet above the present one. The old divide is approximately 2730 feet above sea level whereas the new divide is approximately 2680 feet above sea level. The lower parts of valleys at the northern edge of the mapped area probably have an elevation of about 2330 feet.

Culture

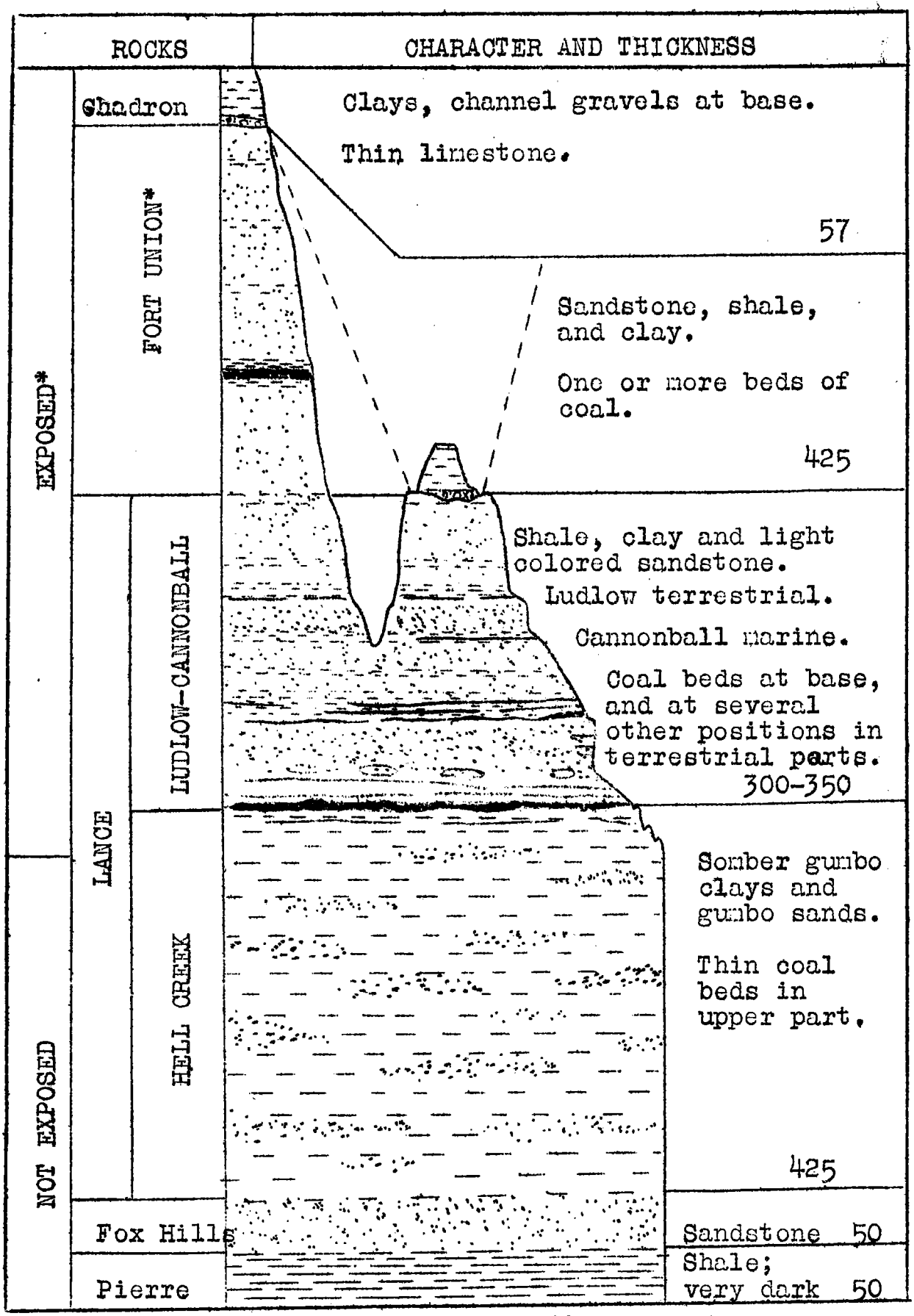
Towns:

Bison, the county seat of Perkins county, and the only town in the mapped area, with a population of 250 is on the Grand River-Thunder Butte divide in sec. 13, T. 18 N., R. 13 E. It is the distributing center for the surrounding territory.

Railways, Highways, and Roads:

No railways cross the central Perkins county area. The nearest railway is through White Butte at the northern boundary of Perkins county, but railway facilities at Lemmon in the northeastern corner of the county are commonly used by inhabitants of the region.

Figure 3. Generalized Section of the rocks at the Surface of Perkins county, South Dakota.



* The Fort Union is not exposed in the central Perkins county area.

Rocks indicated are exposed in the central Perkins county area.

State Highway No. 18 crosses the area and furnished highway connection with Mobridge to the east and through Buffalo to the west. About eight miles east of the area, State Highway No. 18 connects with State Highway No. 73 to Lemmon. Between Bison and Lemmon both Highway No. 18 and No. 73 are gravel surfaced, but west of Bison No. 18 is graded earth, and east of the junction with No. 73, there is more than forty miles of graded earth highway. Passage by car or truck is difficult over these earth roads during wet weather.

South of Grand River-Thunder Butte divide, roads and trails are abundant, mostly on section lines, so that this part of the area is readily accessible by car. North of the divide, roads are few, and access is difficult.

Water Supplies

Water supplies were not studied in detail in the area. On the divide, however, between Thunder Butte Creek and Grand River, where the surface is above the Scotch Cap sandstone of the Ludlow-Cannonball, water is accessible in shallow wells from 80-150 feet in depth. Other sandy lenses and beds furnish less certain supplies below this horizon. Catch-basins for impounding water have been made in many places by the construction of dams in small valleys, and "buffalo wallows" along the intermittent streams furnish water for stock in many places.

STRATIGRAPHIC GEOLOGY

Introductory Statement:

Rocks at the surface of the central Perkins county area consist of beds of late Cretaceous Lance, Oligocene White River, gravels of Pleistocene age, and alluvium, slope mantle, and residuum of latter date. Of these formations the Lance covers the greater portion of the area, later deposits occuring here and there as small patches, none of which cover as much as half a square mile. Although beds older (Lance) and younger (White River) than Fort Union outcrop in the area, the Fort Union is absent because of erosion following its deposition.

Unexposed Rocks:

Deposits as old as upper Pierre occur in Perkins county, only twenty miles southwest of the area. Between this outcrop

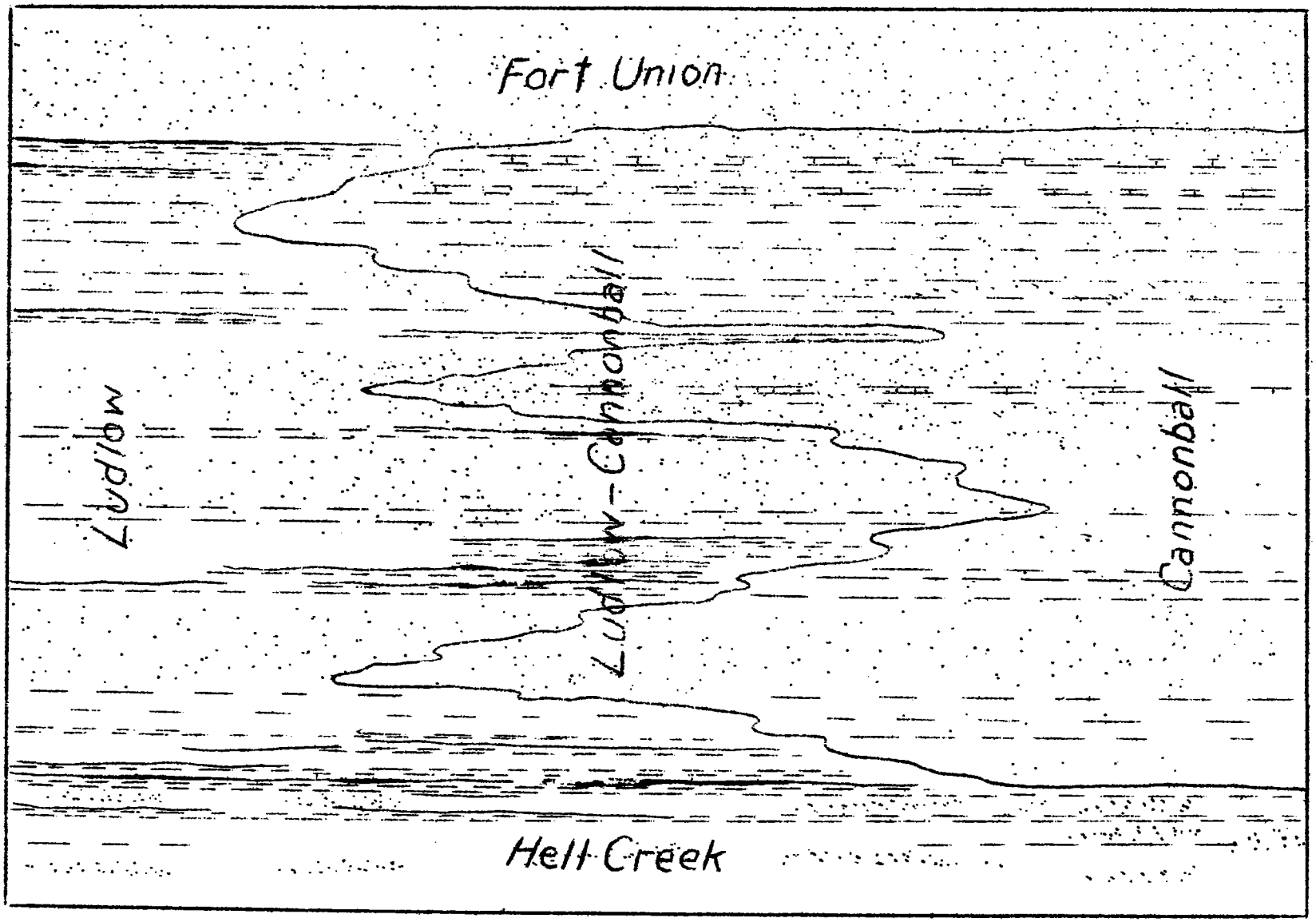


FIGURE IV

Diagrammatic representation of the relations between Ludlow, Cannonball, and Ludlow-Cannonball in Perkins County, South Dakota.

Pierre and that of the Hell Creek of lower Lance age, the Fox Hills sandstone occurs at its normal stratigraphic position. It is thus certain that Pierre and Fox Hills occur below the Lance in thicknesses and position common to the region. These formations are shown in the columnar section (Figure 3) in their relation to the rocks exposed in Perkins county.

Lance

Exposed Rocks:

Beds of the Lance are the oldest strata which outcrop in the area. (Plate I, Figures 1 and 3). In northwestern South Dakota the Lance is divisible into two members[1], a lower, the Hell Creek, and an upper of two facies, a continental and a marine facies. The continental development of the upper Lance is known as the Ludlow and the marine as the Cannonball. As suggested in a later page, it is suggested that where these facies interlense and where the environment of deposition is in doubt, the name Ludlow-Cannonball be used. (Figure 4)

Both Hell Creek and Ludlow-Cannonball outcrop in the area. Detailed descriptions of these beds are given in the pages which follow.

HELL CREEK MEMBER

Definition:

The Hell Creek Member of the Lance in northwestern South Dakota is the succession of clays, shales, and sandstones, mostly of subdued or somber colors, which lies, in the eastern part of the South Dakota coal field, between the marine and brackish water Fox Hills and the marine Cannonball member of the Lance. As thus defined, in South Dakota, it contains no marine or brackish water beds, these being included in the underlying Fox Hills or the overlying Cannonball marine member of the Lance. In the extreme northwestern counties of South Dakota, Harding and Perkins

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1./ The Lance should probably rank as a series and the subdivisions as formations, since the subdivisions of the Lance are as thick and as important stratigraphically as the Fox Hills formation which lies below the Lance.

counties, where the Fox Hills is mostly represented by relatively thin massive white sandstone, the Colgate sandstone[1], of somewhat doubtful marine origin, the Hell Creek member includes the beds immediately above these sandstones. The member in these counties continues upward to the base of the Ludlow or Cannonball members of the Lance, terrestrial and marine equivalents, which lie above the Hell Creek. The Hell Creek is the lower part of the Laramie Formation of Todd[2] and the lower part of the Lance of Winchester, Hares, Lloyd, and Parks[3]. The name "Ceratops beds" is also commonly used for the Hell Creek in older descriptions.

Distribution:

The Hell Creek member of the Lance occurs widespread in northwestern South Dakota, where it forms the outcrop between that of the Fox Hills and that of the Ludlow, Ludlow-Cannonball, or Cannonball members of the Lance. In the area mapped in central Perkins county (Plate I) only the upper portion of the member is exposed, and that only to the south of Grand river and north of Rabbit Creek. The largest outcrop lies in the southwest part of the mapped area along the valley of Rabbit Creek and its tributaries in the south and southwest sections of T. 17 N., R. 13 E. The member has been mapped along Thunder Butte Creek and its tributaries in the east half of T. 17 N., R. 14 E. Small outcrops extending southward from the outcrop area along South Fork of Grand River have been mapped into the area along tributaries for short distances.

Whenever possible, the boundary line between Hell Creek and Ludlow has been drawn at the base of a coal bed which lies at the base of the Ludlow member of the Lance in many places. Where coal outcrops at this position, the boundary has been drawn with definiteness. In many places, however, particularly in the southern part of the area, the coal is missing between the two members or it is hidden by grass covered slope mantle soil and residuum. In such cases the boundary has been drawn as careful-

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1./ Calvert, W. R., Geology of Certain Lignite Fields in Eastern Montana; U. S. Geol. Survey Bull. 471, p. 194, 1912.
Winchester, D. E., Hares, C. J., Lloyd, E. R., Parks, E. M., The Lignite Field of Northwestern South Dakota; U. S. Geol. Survey Bull. 627, p. 18, 1916.

2./ Todd, J. E., A Reconnaissance into Northwestern South Dakota; South Dakota Geol. Survey Bull. No. 2 pp. 48-60, 1898.
Todd, J. E., Preliminary Report on the Geology of the Northwest Central Portion of South Dakota; South Dakota Geol. Survey Bull. No. 4, pp. 32-37, 1908.

3./ Winchester, D. E., et al. loc. cit.

ly as possible on the basis of topography and on the character of the nearest exposed bedrock.

The boundary thus drawn is similar to that drawn by Winchester[1]., except in the southeast part of T. 17 N., R. 13 E.and in T. 17 N., R. 14 E., where the Hell Creek (Lower Lance) on Winchester's map covers a considerably larger area than on the present map. This difference is in part due to a difference in interpretation of topography and also apparently because of the assignment of a coal bed outcropping in Sec. 3, T. 17 N., R. 14 E. by Winchester to the lower Lance, now Hell Creek, and to the base of the Ludlow by the present survey.

Topographic Expression:

The Hell Creek, where accessible to erosion, is a badland former. In areas of high relief its badland forming character is most pronounced. Representative Hell Creek badland areas include the one which encircles the Slim Buttes to the west of Perkins county and the "Jumpoff" in western Harding county at the headwaters of South Fork of Grand River. Even where relief is low, as in the southwest and southeast corners of the central Perkins county area, badland topography developed on a small scale aids in identification of the Hell Creek. The topographic expression is in marked contrast to the butte producing character of the Ludlow-Cannonball.

Character and Lithologic Details:

The Hell Creek member of the Lance is composed of clays, shales, silts, sandstones, and thin coals. Clays and then beds of impure sandstone commonly predominate, although carbonaceous and lignitic shales are observed in greater or less amounts in most outcrops. Clays of the member tend to be more or less plastic or gumbo-like when wet, but become hard when dry, particularly on the surface of exposures. Many of the sands contain sufficient plastic clay to become gumbo-like and somewhat plastic when wet and hard and tough when dry. The gumbo-like character of Hell Creek sandstones is so notable that the sands have been called gumbo sands in sections of the member, such as those cited in the succeeding pages. The character is used also to distinguish isolated outcrops of the Hell Creek and in recognition of the boundary line between Hell Creek and Ludlow. Although consolidation is uncommon, here and there sandy beds are cemented into lenticular concretionary masses which project prominently from the faces of exposures.

Colors of the Hell member are distinctive in the general predominance of dull shades of gray, brown, drab, and buff. Shades of gray predominate. The characteristically lifeless hues are responsible for the old name "somber beds." These somber hues are a most ready means of recognition of the member and have been used as an important basis of definition and of

1. Winchester, D. E., The Lignite Field of Northwestern South Dakota: U. S. Geol. Survey Bull. 627, Plate II, 1916.

delimitation of these beds from the underlying and overlying strata in South Dakotaand elsewhere.

Bedding of the Hell Creek is commonly obscure. It is shown in large exposures chiefly by vertical changes in color, lithology, and texture. Clays and shales commonly show little evidence of lamination excepting in cases where carbonaceous materials alternate with beds of more or less structureless material or where carbonaceous material and fragmentary plant material is oriented in such a manner as to render the bedding conspicuous. Here and there, at various levels, bands of limonite or clay ironstone indicate partings between beds. Sandy lenses in many cases show distinct bedding, the bedding planes in many cases being ripplemarked, and cross-lamination on a small scale being observed in many places.

Lateral and vertical gradations in lithology and color are characteristic of the Hell Creek member of the Lance. The member can be traced throughout the South Dakota coal field by means of its general lithology and color, but lithologic units can be traced definitely over small areas only. A zone of beds containing thin coals and carbonaceous materials occurs in the upper part of the Hell Creek succession exposed near the mapped area, but even these beds of carbonaceous materials are not known to be continuous individually over any considerable area, although the carbonaceous zone appears to be widely distributed.

In the area mapped (Plate I), beds showing the characters described are poorly exposed because of the slope mantle and soil which conceal them. In order to determine the succession, sections have been studied outside of the mapped area in stiuations where there are more complete exposures. The upper part of the Hell Creek is excellently exposed along South F ork of Grand River westward from the junction with Flat Creek to and beyond the highway crossing South Fork north of Cash. Exposures are particularly good both east and west of this highway in bluffs north of South Fork and in cuts made by small southward draining tributaries east of the road. The table of succession which follows is a typical one exposed along undercut bluffs west of the roads in Secs. 33 and 28 T. 20 N., R. 12 E. It not only shows the upper part of Hell Creek succession, but is also shows the lower part of the Ludlow and the gradation between these two members of the Lance.

Section of Lance showing the upper part of the Hell Creek member and the lower part of the Ludlow-Cannonball member as exposed in secs. 33 and 28, T. 20 N., R. 12 E., together with overlying beds.

	Thickness Feet
Pleistocene	
38. Rubble band overlain by buff silt	8
Lance formation	
Ludlow-Cannonball member	

37. Shale, buff and gray, silty, micaceous, thinbedded, grades upward into silty sand.
Ledge of micaceous, gray, very thinbedded, silty, fine grained sandstone 12 feet above base, which is thicker and more firmly cemented in some places than in others. This ledge shows cross bedding and well developed ripple mark - - - - - - - - - - - - - - - 23 5/6

36. Shale, dark brownish gray, flaky in upper part. Contains small, sparsely distributed fragments of plant debris, grades into overlying bed - - - - - - - - - - - 16

35. Coal, black, glance and dull coal in approximately equal amounts, thin gypsum plates on vertical joints - - - - - - - - - - -1 1/2

34. Shale, dark brown to black, lignitic. Contains large selenite crystals to two inches in length - - - - - - - - - - - - - - - - - 1/4

33. Coal, mostly glance - - - - - - - - - - - - - - - - -1/3

32. Shale, sandy, silty, brown, gray and yellow mottled; highly lignitic and flaky in upper part - - - - - - - - - - - - - - -1 1/2

31. Sandy silt and silty sand, increasingly sandy toward top. Light gray and buff. Weathers to "Ludlow yellow"; colored by limonite in upper five feet. Bedding thin, tending toward thin lamination. Sandstone ledge of fine grained, gray, thinbedded sand, 0-5/6 feet in thickness occurs six to eight feet below top - - - - - - - - - - - - - - - - - -19 1/2

30. Shale, silty, micaceous, dark gray; weathers brown, sulphur yellow on joints. Grades upward into lighter colored brownish gray sandy silt. Shale gray and flaky - - - - - - - - - - - - - - - 4

29. Coal, black, brittle, horizontally laminated, vertically jointed, some fusain, both dull and glance coal - - - - - - - - - - - -1 2/3

28. Silty sand and sandy silt, contains plant debris and carbonized wood fragments. Buff, brown, and gray mottled. Some shale. Some identifiable leaves - - - - -1

27. Shale, rich brown to nearly black, much plant debris, occasional identifiable leaves, one inch of glance coal at top - - - -3/4-1

26. Shale and sandstone, silty, dark buff and brown. Laminae paper thin. Weathers yellowish or buff. Grades upward into beds which are dominantly sandy, some layers of clear sand up to one inch thick. Interbedded with thinbedded

		Feet
	shale, sand, and silt. The whole, however, very distinctly bedded. About eight feet below top, one or more beds of sand are consolidated into a hard concretion-like zone. These sandstone masses split into thin flaggy layers which show beautifully developed translation ripple-marks, mostly about one inch from crest to crest, but some two inches or more. Oriented in various directions on bedding planes. The whole exposure weathers Ludlow yellow - - - - -	14
25.	Shale, dark gray, flaky - - - - - - - - -	1/2
24.	Shale, dark brown, fissile - - - - - - -	2
23.	Shale, black and brown, highly carbonaceous, fissile, weathers into thin flakes - - - - - - - - - - - - - - - - - - -	1
22.	Shale, carbonaceous, "black jack", tough, shaly, bony, - - - - - - - - - - - - - -	1/4
21.	Coal, black, glance and dull in about equal amounts - - - - - - - - - - - - - - -	1/6
20.	Shale, brown, lignitic, plant debris abundant, slickensided - - - - - - - - -	1 1/2
19.	Sand, fine, gray and buff. Loose; uncemented. Contains rounded concretionary masses to three inches across at intervals -	1 1/4
18.	Shale and sandstone, interbedded, finely laminated for the most part but showing alternating zones in which first shale, then sand, predominate. Shale dark gray. Sand light gray, containing limonitic streaks and clay ironstone bands. Contains large concretionary sandstone masses 10 feet in diameter showing well developed translation ripple marks up to four inches from crest to crest. Concretions light gray, somewhat tough, loosely indurated and very thin bedded and lie between five and seven feet above the base - - - - - - - - - - - - - - - - - - -	14 3/4
17.	Shale, hard, gray, contains clay ironstone bands up to two inches thick - - - -	2 1/2
16.	Sand and clay, finely interbedded. Sand, yellow brown to buff in upper part; clay nearly brown, somewhat gray, becomes increasingly sandy toward top - - - - - - -	7
15.	Clay shale, gray, brown, finely micaceous. Contains yellow sulphur colored streaks - -	2
14.	Coal, black, brittle, much glance, horizontally bedded, vertically jointed. Some fusain. Gypsum on joints. - - - - - - - -	1/2-1 1/6

		Feet
13.	Clay shale, gray brown, yellow streaked in upper part. Upper part laminated, plant debris and glance coal on bedding planes - - - - - - - - - - - - - - - - - -	3 1/2
12.	Coal, mostly glance, black, brittle - -	1/12-1/4
Hell Creek Member		
11.	Clay shale, gray brown, somewhat brittle, slightly silty, structureless - - -	7
10.	Gumbo clays and silty gumbo sands, uniformly somber gray. Limonite concretions in thin horizontal bands. Very tough and hard. Contains large concretionary sandstone masses five feet above base and again few feet below top; these are light gray, silty, and soft. Upper five feet loose, friable, silty sand, not gumbo-like. Thin discontinuous lenses of coal to three inches at about the middle - - - - - - - - -	20
9.	Shale, brown, highly lignitic, abundant plant debris, somewhat fissile: contains some glance coal - - - - - - - - - -	1/4
8.	Coal, hard, black, horizontally laminated - - - - - - - - - - - - - - - - - - -	1/4
7.	Shale, gray, flaky, apparently structureless - - - - - - - - - - - - - - - - -	1
6.	Shale, brown, lignitic, considerable plant debris - - - - - - - - - - - - - - -	1
5.	Shale and sand alternating. Flaky shale and buff silty sand in following order: Shale, flaky - - - - - 2 feet Sand, silty - - - - - 3 1/2 feet Shale, flaky, gray - - 1 foot Sand, gray, silty - - 4 1/2 feet The two beds of silty sand differ in color; the lower is buff, the upper more gray. All beds weather gumbo-like. Gumbo-like character most notable in flaky shales which show it by hardness of dry weathered surface and gumbo fracture - - - - - - - - - - - - -	11
4.	Gumbo sand, friable and somewhat plastic when wet. Hard; gumbo jointing when dry. Color sulphur yellow in lower four inches, somber gray above. Contains large masses of light gray sandstone 2 1/2 feet thick and up to 15 feet in diameter two to three feet below the top. Beds above concretions are more silty than below and less gumbo-like - -	9 3/4
3.	Coal, weathered, flaky, apparently bony	1 1/2
2.	Clay, brownish gray, uniform and apparently structureless - - - - - - - - - - - - -	1
1.	Covered interval, estimated to river level -	25

The upper boundary of the Hell Creek member of the Lance, as indicated in this table of succession has been drawn at the base of the lowest coal above gumbo sands and gumbo clays of typical Hell Creek aspect. The boundary thus drawn lies also below beds of yellow buff, gray, and brown of shades notably more vivid than those below.

Stratigraphic Relations:

Both lower and upper contacts of the Hell Creek member of the Lance are gradational. The lower one is below the surface in this area, but elsewhere in South Dakota, wherever investigation of the contact has been made, the Fox Hills grades upward into the basal Lance without sedimentary interruption, except where cut and fill common in deposits of this type occur. Indeed, in many places, the boundary between the formations must be drawn arbitrarily unless brackish water fossils or a distinct change in lithology occurs at the top of the Fox Hills. These basal relations of conformity are probably the rule throughout the Dakotas, eastern Montana, and northeastern Wyoming.[1]

The upper contact of the Hell Creek with the Ludlow-Cannonball is also one of gradation and transition. Although suggestions of disconformable relations are suggested, as indicated in later pages, in the Lance of this area, these are not of great importance and occur well above the lithologic boundary in the Ludlow-Cannonball. In fact the boundary is drawn arbitrarily at a more or less gradual change in color, lithology, and physiographic expression.

Fossils:

Fossils were not observed in the Hell Creek of this area. They have been found, however, in many places in South Dakota and elsewhere. Several collections of fossils from the Hell Creek of Harding and Perkins county were made by the Winchester survey, three of which were in Perkins county. Those in

1./ Thom, W. T., Jr., and Dobbin, C. E., Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., vol. 35, pp. 496-497, 1924.
Ward, Freeman, The Lance Problem in South Dakota: Am. Jour. Sci., 5th ser., vol. 7, pp. 65-68, 1924.
Dobbin, C. E., and Reeside, J. B., Jr., Contact of Fox Hills and Lance formations: U. S. Geol. Survey Prof. Paper 158, pp. 9-25, 1929.

Perkins county consisted of two species of poplar, Celistrus, a woody vine or shrub, and Grewia, which belongs to the linden family.[1] Elsewhere in northwestern South Dakota the giant redwood, Sequoia, the soapberry, a beechlike tree, and a species of lotus-like waterlily were collected.

Dinosaurian remains and those of fresh water turtles, extinct alligator or crocodile-like reptiles, and other reptiles occur. Of the dinosaurs, the three-horned Triceratops and the duck-billed Trachodon are most characteristic. The Hell Creek includes the last of the dinosaurs, although other reptiles such as the alligator and crocodile-like Champsosaurus persists into the Fort Union.

Thickness:

Only the upper fifty or sixty feet of the Hell Creek are exposed in the area. An additional thickness of about 375 feet of Hell Creek beds is believed to lie below those exposed in central Perkins county.

Correlation:

The Hell Creek beds of the area have been traced from this region to the Hell Creek of eastern Montana and to the North Dakota boundary in Corson county. They continue northward at the surface nearly to Bismark, North Dakota.[2] Westward, the member crosses the boundary into Montana, and the outcrop continues into Wyoming. It is correlated with these beds in North Dakota, Montana, and Wyoming and with beds elsewhere which conformably overlie the Fox Hills and its equivalents.

LUDLOW-CANNONBALL MEMBER

Name and Definition:

The names Ludlow and Cannonball are applied to deposits believed to have been made contemporaneously in late Lance time. The Ludlow was named the Ludlow lignitic member from

1./ Winchester, et al., The Lignite Field of Northwestern South Dakota: U. S. Geol. Survey Bull. 627, p. 24, 1916.
2./ Lloyd, E. R., and Hares, C. J., Cannonball Marine Member of the Lance Formation: Jour. Geol. vol. 23, p. 527; map p. 525, 1915.

typical exposures near Ludlow, Harding county, South Dakota, approximately fifty miles northwest of Bison.[1] The Cannonball marine member of the Lance was first differentiated and named by Lloyd from significant outcrops along Cannonball River, North Dakota.[2] The Ludlow was first differentiated from the Lower Lance, now called the Hell Creek, by the prevailingly lighter color, greater proportion of sandstone, and by the coal it contains. It was separated from the Fort Union because of the intervening marine beds of the Cannonball member of the Lance over a part of the South Dakota coal field. The Cannonball was first defined in southwestern North Dakota as the upper 250 or 300 feet of the Lance.[3] After differentiation of the Ludlow from the lower Lance and further studies in Harding and Perkins counties counties, South Dakota, the Ludlow and Cannonball were found to be terrestrial and marine equivalents deposited during the same time.[4] In the area mapped in the present investigation, Lance beds above the Hell Creek lie near the geographic boundary between the terrestrial Ludlow and the marine Cannonball. Although most of the Lance of the area, above the Hell Creek, is probably terrestrial and therefore Ludlow, certain sandstones are possibly wholly or in part marine. Since fossils necessary to determine positively the marine or terrestrial origin of these beds have not been found, it seems advisable, at least at this time, to use the term Ludlow-Cannonball for the area rather than Ludlow for beds at this position. Indeed, the term Ludlow-Cannonball may well be used in all cases where terrestrial and marine beds of this age interlense as they do in many places near the boundary of the Cannonball sea. (Figure 4) The term Ludlow would thus be used to designate the beds lying in the interval between Hell Creek and Fort Union if represented by beds entirely of terrestrial facies, the Cannonball if the succescion is entirely marine, and Ludlow-Cannonball if marine and terrestrial beds alternate, or if terrestrial and marine alternations are suspected because of character of beds, distribution, or geographic position.

Thus defined, the term Ludlow-Cannonball member of the Lance is used in central Perkins county to include all beds including the basal coal and the uppermost beds of the Lance.

1./ Lloyd, E. R., and Hares, C. J., The Cannonball Marine Member of the Lance Formation of North and South Dakota and its Bearing on the Lance-Laramie problem; Jour. Geol. Vol. 23, p. 523, 1915.

2./ Lloyd, E. R., The Cannonball River Lignite Field, Morton, Adams, and Hittinger counties, North Dakota; U. S. Geol. Survey Bull. 541, p. 249, 1914.

3./ Lloyd, E. R., loc. cit. p. 249.

4./ Lloyd, E. R., and Hares, C. J., loc. cit. pp. 523-547, 1915.

Winchester, D. E., et al, The Lignite Field of Northwestern South Dakota: U. S. Geol. Survey Bull. t27, pp. 15-26, 1916.

The basal coal is defined as the lowest coal exposed in secs. 17 and 18, T. 17 N., R. 13 E., or strata correlated with it. Outside this area in many places where Fort Union occurs the contact between Lance and Fort Union marks the upper boundary. Elsewhere in South Dakota the line between Lance and White River beds of Oligocene age constitutes the upper boundary.

General Character:

The Ludlow and Cannonball, here treated as one member of the Lance formation for reasons previously explained, consist of sandstone, shale, clay and coal with small amounts of calcareous material and limestone. The sandstones and siltstones, which are the most commonly exposed parts of the member, are characteristically buff, yellow, and yellowish buff at the surface and hence are in rather striking contrast to the drab, dull browns, and gray of the Hell Creek member of the Lance. The sandstone and siltstone members are butte formers and under erosion produce a flat-topped butte topography very different from the "mud butte" and badland topography of the Hell Creek. The Ludlow in this portion of the South Dakota coal field differs from the Hell Creek also in the coal which it contains. The only workable coal beds of central Perkins county occur in the Ludlow, although thin beds of coal occur in the upper part of the Hell Creek near the central Perkins county area, and probably occur here also under cover.

Subdivisions:

In the central Perkins county area several subdivisions of the Ludlow-Cannonball have been identified and traced within the boundaries of the area mapped, and some of these have been observed and identified outside the area at considerable distance from it. For purposes of description these are designated by name. The names, however, are given for purposes of local description only, unless further work proves that they can be traced over a considerable portion of the Ludlow, Ludlow-Cannonball, and Cannonball outcrop areas. The subdivisions used here are as follows, arranged in the order of position, numbered from the base upward:

6. Bison silt and sandstone
5. Bison coal
4. Scotch Cap sandstone
3. Hillen coal zone
2. Lower sandstone
1. Basal coal zone

Of these subdivisions, the basal Coal zone and the Hillen Coal zone contain coal, carbonaceous clay, and shale, and clay with subordinate amounts of sandstone. Some shales and clays

are associated with the Bison coal in the places where exposures permit study. The lower sandstone, Scotch Cap sandstone, and the Bison silt and sandstone are clastics without carbonaceous materials. Thus the Ludlow-Cannonball consists of alternating zones of relatively fine materials associated with coal and carbonaceous shale alternating with zones dominantly of somewhat coarser elastic beds. It is of interest to note in this connection that the upper Ludlow, which contains several coal beds in the type area in the vicinity of Ludlow and around the Cave Hills, is not coal bearing here. Furthermore the sandstone beds within the Ludlow-Cannonball do not reach the thickness characteristic of the type Ludlow area. In the pages which follow, detailed descriptions of the several zones are given from the base upward in the order of their stratigraphic position.

Basal Coal Zone:

The basal coal zone of the Ludlow-Cannonball is a succession of beds of clay, coal, and shale which lies at the base of the Ludlow-Cannonball everywhere in the central Perkins county area. It has been identified in the mapped area wherever exposures are good, and it appears to be continuous outside the area eastward to the vicinity of Coal Springs and westward to the locality south of Strool. The zone is probably the same as a similar succession at this position around the Slim Buttes and may be the same as a zone of shale and carbonaceous material, outcropping above the Hell Creek as far west as along the South Dakota-Montana line about six miles northwest of Camp Crook, Harding County, and in many other places west of the Slim Buttes.

Where best exposed, the basal coal zone consists of four coal beds separated by clay, clay-shale, and clay, rarely sand, and in some places where shale overlies the uppermost coal, it also has been included. The coal beds are black in color. They vary in thickness from a few inches up to five feet. Identification of individual coal beds of the succession is not possible in widely separated outcrops, although in outcrops sufficiently close together, correlation appears to be possible. Thus, although the persistence of individual beds can rarely be demonstrated, the zone in which they occur appears to be persistent, at least over much of the South Dakota outcrop area.

The beds of clay, shale, and clay shale are mostly medium to dark gray, although drab and brownish drab beds occur. In many cases clays immediately underlying coal beds are siliceous, structureless, with bedding absent or obscure, in some cases slickensided and commonly containing carbonized rootlets. These clays appear to be of the true underclay or "fire clay" type such as those which underlie most of the coal beds of Illinois, Kentucky, and elsewhere in eastern coal fields. Presumably they constitute the soils in which the coal making plants grew. The shales are

laminated and contain carbonized detrital plant matter. These shales are thus the result of sedimentation rather than of soil forming processes such as those to which the underclays owe their character. The basal coal of the succession is commonly underlain by underclay. In many places in the South Dakota coal field, coal beds have been burned, and the overlying shales and clays have been baked to a brick red or yellow. This material is locally called "scoria", although geologists commonly refer to it as clinker. This material occurs rarely in this area, but outcrops south of the mines in Secs. 17, 18, 17 N., R. 13 E.

Clays and shales between the coal beds of the basal succession vary in thickness from a fraction of an inch up to eighteen feet. In a section made in 1929 in SE. ¼, Sec. 17, T. 17 N., R. 13 E., a shale above the lowest coal varied between nine and fifteen feet, and the shale above the second coal varied between 2½ and 18 feet. The thickness of the entire zone is also variable, although it can rarely be measured with certainty, since exposures occur only in strip mines, and these commonly expose but one or two coal beds whose position in the succession is uncertain. As nearly as could be determined, thickness varies from 14 7/12 feet up to 60± feet in central Perkins county. East of the area near Coal Springs, [1] the whole zone appears to be exposed in the Sundermeyer mine and is about 17 feet thick. West of the area, near Strool in the Van Lee mine[2], the basal zone varies between 8 1/12 and 17 5/6 feet. The common thickness is probably between 15 and 35 feet.

Details in the succession and variations in details are shown in the tables of succession which follow:

Section of basal coal zone of the Ludlow-Cannonball and beds overlying it exposed in the Hafner mine in the SE. ¼, NE. ¼, Sec. 18, T. 17 N., R. 13 E.

		Feet
8.	Soil, sandy	1
7.	Sandstone and sandy shale, contains large sandstone concretions to 15 feet or more in greatest diameter and more than one foot in thickness	5
6.	Coal, impure, thinly laminated; contains thin clay partings	1/3-1
5.	Shale, light medium gray to medium dark gray, plant leaves abundant in	

1./ Searight, W. V., Preliminary Report on the Coal Resources of South Dakota; So. Dak. Geol. Survey, Rept. of Inv. No. 3, p. 38; 1930.
2/ Searight, W. V., loc. cit., pp. 39-40.

		Feet
	thinner parts - - - - - - - - - - - - - - - -	2 1/2-18
4.	Coal, impure; contains thin clay partings -	3/4-1 1/4
3.	Shale, medium gray, prominently jointed throughout, fractured into angular pieces - - - - - - - - - - - - - - - - - -	9-15
2.	Coal, black, bright, horizontally bedded, hard, vertically jointed - - - - - - -	4 1/2-5
1.	Clay, tough, medium gray, jointed; contains carbonized rootlets - - - - - - - -	2
	Total exposed - - - - - - -	25 1/12-48 1/4

Section of basal Ludlow-Cannonball coal zone as exposed in the Carlson mine in the SE¼, SW¼, sec. 17, T. 17 N., R. 13 E.

10.	Soil, sandy - - - - - - - - - - - - - -	1	
9.	Shale, gray and brown, brown below -	14-15	
8.	Coal, laminated, bony - - - - - - - - -		1/3
7.	Shale, medium gray, horizontally banded - - - - - - - - - - - - - - - - -	6	
6.	Coal, black - - - - - - - - - - - - - -	1	1/2
5.	Shale, gray, thinly laminated - - - -	1/2-1	1/2
4.	Coal, black, hard, brittle - - - - -		5/6
3.	Shale, medium gray - - - - - - - - -		1/6
2.	Coal, black, vertically jointed into cubical blocks - - - - - - - - - - - -	4 1/2-5	
1.	Clay, hard, gray, somewhat siliceous, contains fossil rootlets (not exposed in 1932, but observed in a former visit) - - - - - - - - - - - -	5	
	Total exposed - - -	33 5/6-34 11/12	

Section of beds correlated with basal Ludlow-Cannonball coal zone and overlying beds exposed along the south section line in southeast corner of SW¼, SE¼, Sec. 10, T. 17 N., R. 14 E.

Pleistocene and Recent

5.	Silt -	2
4.	Gravel and sand, fairly clean - - - - -	2-3
3.	Ludlow-Cannonball silt, sandy, banded, buff, gray, and brown; thinly laminated. Contains sandstone concretions of gray, silty sand one foot thick 4 and 6 feet	

		Feet
	above base, with clay ironstone concretions just below each zone	11
2.	Shale, brown, silty, contains plant debris	1
1.	Coal, reported	2 1/2
	Total exposed	18 1/2–19 1/2

Section of lower Ludlow-Cannonball exposing basal coal zone in the Herzog mine in the NW.1/4, NE.1/4, Sec. 26, T. 19 N., R. 14 E.

		Feet
13.	Sand, gray to brown, silty, tough; contains large concretionary sandstone masses to 8 feet in length and 3 feet in thickness. Also contains large leaves of deciduous trees and plant debris	12
12.	Shale, mottled, yellow brown, gray, and lavender	1–3 1/2
11.	Coal, bony; shaly in places	1/12–5/6
10.	Shale, highly carbonaceous, dark brown to black, thinly laminated. Similar to bony coal in upper part	1/2
9.	Shale, brown, lignitic, flaky, sticks and stems on bedding planes	1 5/6
8.	Coal, black, brittle, about equally glance and dull	1/4–1/3
7.	Clay, brown to gray, gritty, micaceous, pyritic. Gypsiferous on joints; slickensided. Contains plant debris or rootlets.	2
6.	Shale, lignitic, flaky, brown to black	1/12–1/6
5.	Coal, black, thinly laminated, about equally glance and dull; vertically jointed. Appears bony in upper 1/6 foot	1 1/4
4.	Clay shale, gritty, light gray; diagonally jointed. Thin bedded in upper half. Clay ironstone concretions 1 1/2 feet above base. Contains rootlets and leaves. Highly lignitic in upper 1/2 foot	5 1/2
3.	Coal, impure. Contains considerable fusain and selenite	1/12
2.	Coal, black, hard, brittle, vertically jointed. About equally glance and dull	2
1.	Clay, gray	1/12
	Total exposed	26 1/4–29 1/4

The first and second are the typical sections of the area and indicate the similarity between the components of the zone in different outcrops. They also show that considerable variations in the member are to be expected in very short distances, since these sections are

only about two thirds of a mile apart. The section at the Hafner mine alone shows the rapid thinning and thickening of the clastic beds of the succession. The third section is one which appears on Winchester's geologic map[1] in the lower Lance, the Hell Creek of this report. The earlier survey did not, however, recognize the continuity of the Scotch Cap sandstone of the Ludlow-Cannonball, which extends well into the area mapped on Winchester's map as lower Lance. (Plate I) The greater part of this area is mapped as Ludlow-Cannonball by the present survey, and the coal of the third section cited is believed to correlate with one of those of the basal Ludlow zone. The fourth section, that at the Herzog mine, is typical of the basal coal zone near South Fork of Grand River. The lowermost clays in the first two sections are arbitrarily placed at the top of the Hell Creek, and that at this position in the Herzog mine probably belongs here also.

Plant fossils occur in the basal coal zone. Collections were made by the Winchester survey and identified by F. H. Knowlton. The fossils occur, as noted in the sections cited above, in the coal above the lowest coal bed in the mines in Sec. 29 and 17, T. 17 N., R. 13 E. These were listed as follows[2].

"Sec. 29, T. 17 N., R. 13 E. (from baked shale above lignite bed which occurs at base of Ludlow Member).

Carpites sp.
Sapindus affinis? Newberry.
Fern, fragmentary.
Corylus sp.
Celastrus sp.?
Cocculus haydenianus Ward.

Sec. 17, T. 17 N., R. 13 E. (from shale above lignite at Sexton mine).

Onoclea sensibilis Linne.
Cocculus haydenianus Ward.
Sapindus cf. S. affinis Newberry.
Sapindus grandifoliolus Ward.
Conifer, Taxodium? sp. "

The plants listed consist of ferns, a conifer or evergreen, the hazel, the soapberry, of which several species

1./ Winchester, D. E., et al, The lignite field of northwestern South Dakota: U. S. Geol. Survey Bull. No.627, Plate II, 1916.
2./ Winchester, D. E., et al, loc. cit. page 24, 1916.

grow in southern United States, a beechlike shrub, a berry producing vine, and a vine or shrub related to the false bittersweet.

Lower Sandstone and Silt Zone:

The lower sandstone and silt zone consists of sand and silty sand which immediately overlies the lower coal zone. It is well and typically exposed to the east of the road 2 miles south of the northwest corner of Sec. 31, T. 19 N., R. 14 E. The sandstone is also to be seen above the lower coal zone in strip mines which uncover the upper part of the upper coal zone. Sandstone forming low bluffs in Secs. 32 and 33 is correlated with it, since it appears to lie at this stratigraphic position.

The zone consists of micaceous sandstone and micaceous silt of buff, brown, yellow, and light gray color. Here and there as at the mine in SE.1/4, SW.1/4 Sec. 20, T. 19 N., R. 14 E., the base consists of buff or yellowish buff sand which grades upward into sandy silt. Near the uppermost coal in the lower 1 1/2 feet some glance coal occurs. Higher beds of the zone exposed 2 miles south of the northwest corner of Sec. 31, T. 19 N., R. 14 E., consist of sandy, buff, micaceous thinbedded silt grading upward into fine, silty, light gray, micaceous, massive sandstone.

In many places the lower part of the zone contains large and thick concretionary masses of cemented sandstone to 15 feet or more in diameter and 3 feet in thickness. In the Sundermeyer mine in the NW.1/2, Sec. 20, T. 17 N., R. 17 E., to the east of the area, masses such as these in the upper part of a sandstone, probably to be correlated with the lower sand of this area, reach 50 feet in length.[1]

The total thickness is not exposed at any place in the area and is difficult to estimate. The thickness of the beds exposed in the northwest corner of Sec. 31, T. 19 N., R. 14 E., is fifteen feet, to which at least eight or ten feet exposed in nearby mines should probably be added. At the Sundermeyer Mine the thickness totals 40 feet or more.[2] The total thickness in this area is 65 feet or more.

A typical section of these beds is exposed in NW.1/4, NW.1/4 Sec. 31, T. 19 N., R. 14 E. In it, however, the base is not exposed and a covered interval

1./ Searight, W. V., Preliminary report on the coal resources of South Dakota: South Dakota Geol. and Nat. Hist. Survey Report of Investigations, No.3, page 14, 1930.

2./ Searight, W. V., loc. cit. page 14.

of 37 feet between the highest exposed beds and the Hillen coal succession, exposed along the road 0.65 miles south, is included. The exposure is described in the table of succession which follows.

Section of the lower sandstone and silt zone exposed in the NW 1/4, Sec. 31, T. 19 N., R. 14 E., in a draw east of the north-south road.

		Feet
3.	Covered	37
2.	Silts, buff, micaceous, thin-beded, sandy; in places banded	8 1/2
1.	Sand, massive, fine, silty. Light gray, brown streaked in places. Grades from fine sandy silt at the base	7 1/2
	Total exposed	53.

Molds of large leaves of deciduous trees occur in the upper part of the sand (bed 1) of the section cited in the preceeding table.

Hillen Coal Zone:

The Hillen coal zone is a zone of clay, shale, sandstone, and coal lying above the lower sandstone and below the Scotch cap sandstone. This zone is especially well developed in the southern tier of sections across T. 19 N., R. 14 E., but outcrops also in the southern part of T. 19 N., R. 13 E. It is mostly covered along Thunder Butte Creek and south of the divide between Thunder Butte Creek and Rabbit Creek, but here and there thin coal beds associated with sands and clays, lying above a sandstone correlated with the lower sandstone and below the Scotch Cap sandstone, apparently belong here. The Hillen coal zone has not been traced outside the mapped area, except very near it, but is possibly a persistent zone like the basal coal zone.

The zone is so similar to the basal coal zone that it can be distinguished from it only by its stratigraphic position between the Scotch Cap sandstone and the lower sand.

Where best exposed, as in the mine in NE 1/4, Sec. 31, T. 19 N., R. 14 E., the lower part of the zone consists of four coal beds. The lower three beds are separated

by thin beds of clay. In a later section on coal they are treated as one bed. The third coal in the succession is underlain by sandstone in typical exposures and is in turn overlain by sandstone.

The upper part of the zone is poorly exposed. In the ravine draining northwest in the NW. 1/4 Sec. 35, T. 19 N., R. 14 E., however, a thin coal bed occurs, overlain by fine gray silts and sands. These beds are thinly laminated and crossbedded on a small scale. They contain fragments of leaves and plant debris. Only 5 1/2 feet of beds separate this coal bed from the base of the Scotch Cap sandstone.

Coal beds of the succession are thin, black, vertically jointed, and horizontally laminated. They vary in thickness individually, the thickest coal and the lowest bed exposed being the bed in the Hillen mine which is 4 1/2 to 4 5/6 feet thick, split, however, by shale which may thicken considerably elsewhere. Locally bone probably occupies the position of one or more of the coal beds of the succession. The coal beds appear to thin out pronouncedly to the south, and exposures are very rare along Thunder Butte Creek. They are believed to be represented, at least in part, by thin coals a few inches in thickness outcropping around low buttes in Secs. 17, 18, and in section 5, T. 17 N., R. 14 E. and in section 32 T. 18 N., R. 14 E. and elsewhere in this part of the area. A coal bed believed to belong to this zone is reported also along the south section line of Sec. 25, T. 18 N., R. 13 E.

Clays which separate the lower coals of the Hillen zone are of the underclay type. The clays are for the most part structureless, and lamination is absent or obscure. The second and third coal beds, or beds believed to represent these beds, are separated in some places at least, by gray and buff clay, buff shale, and buff, yellow, and gray sandstone. Beds predominantly of sandstone interbedded with thin beds of shale and silt intervene between the third and fourth coals in the succession. The clastics separating the coal beds appear to become thicker and coarser from the base upward. Thin clay beds separate the lower coals. Between the second and third beds most of the thickness, which reaches nine feet in the Hillen mine, is shale. The beds between the uppermost coals are dominantly sand, with some silt, aggregating 24-26 feet in thickness. Considerable variation from place to place occurs, however, in thickness and character of beds composing this succession.

The total thickness of the zone is probably approximately 90 feet. Greater thickness may occur locally,

but in some parts of the area the thickness is probably less.

Variations in lithologic details are suggested in the tables of succession which follow:

Section of the Hillen coal zone and overlying beds exposed in the Hillen mine in the NE 1/4, Sec. 31, T. 19 N., R. 14 E.

		Feet
11.	Soil - - - - - - - - - - - - - - - - - -	1/2
10.	Silt and wash - - - - - - - - - - - - - -	2 1/2
9.	Shale, lavender gray or pinkish gray; grading upward into drab gray. Obscurely, thinly laminated. Somewhat tough; jointed into small, polygoral pieces. Layer of concretions two inches thick one foot below the top - - - - - - - - - -	9
8.	Coal, black, horizontally bedded. Contains considerable glance coal. Split by a concretionary sandstone mass 5/6 of a foot thick and four feet in diameter - - - - - - - - - - - - - - - - - -	1/3
7.	Shale, silty, brown, drab, and gray. Thin bedded, thinly laminated. Contains fossil leaves about 3 1/2-4 feet above the base - - - - - - - - - - - - - - - - -	5 3/4-6 1/2
6.	Coal, thinly laminated, dirty, bony in places. Upper contact sharp - - - - -	1/3-1
5.	Clay shale, light to dark gray. Contains glance coal. Position mostly occupied by bony coal and lignitic shale in some places - - - - - - - - - - - - - - - -	1/24-1/2
4.	Coal, bright, black, red-stained. Gypsiferous on joints and bedding planes. Horizontally laminated. Contains considerable glance coal - - - - - - - - - -	2 5/6
3.	Clay shale, horizontally laminated, light to dark gray - - - - - - - - - - - - -	0-1
2.	Coal, black, bright, hard. Horizontally laminated. Contains much glance coal. Pyrite in crystalline masses up to two inches in diameter - - - - - - - -	1 1/2-2
1.	Clay, underclay, medium gray, siliceous, structureless. Contains coalified rootlets. Much slickensided, tough - - - - - - - - - - - - - - - -	1/2
	Total exposed - - -	23 11/12-27 1/6

Section of Hillen coal zone exposed in a small mine in the NW.1/4, SW.1/4 Sec.4, T. 18 N., R. 14 E.

		Feet	
12.	Soil	1	
11.	Sand, banded, light gray, silty	5	
10.	Coal bony, or black carbonaceous shale		1/3
9.	Clay, gray, poorly exposed	3	
8.	Silt, sandy, gray, thinly banded in upper part	5	
7.	Sand, light gray, fine. Ferruginous concentrate at the base. Bedding throughout at angles of 15-20° to beds below. Cemented to form concretions to 2 1/2 feet thick in a zone oriented at the same angle as cross bedding	10	
6.	Shale, silty, distinctly and thinly laminated in middle. Gray below; brownish in upper three inches	2	
5.	Sand, brown, ferruginous. Ferruginous concretions at base		1/2
4.	Shale, light gray; very thinly laminated. Upper part slightly silty	4	
3.	Shale, jet black, highly carbonaceous, thinly laminated, brittle. Bituminous odor on heating. Slacks readily on exposure		1/2
2.	Coal, black, hard, brittle. Pyritic in upper part. Pyrite in masses up to one inch in diameter, sparing	1	1/2
1.	Clay, medium gray		1/2
	Total exposed	33	1/2

Section of beds of Hillen coal zone of the Ludlow-Cannonball, exposed in a small mine in the SE.1/4, NE.1/4 Sec. 33, T. 19 N., R. 14 E., on the east side of the valley wall of small northwest draining valley.

		Feet	
12.	Soil	1	
11.	Silt, ashy gray	1	
10.	Sandstone, gray, thinbedded, fine textured, hard. Ripplemarked		5/6
9.	Covered interval	4	
8.	Silt, very thinbedded, gray, lignitic. Grades into brown, flaky shale above	10	
7.	Sand, banded, gray, buff and brown;		

		Feet
	mostly drab gray above. Cemented about five feet above base into masses up to eight feet across and one and one half feet thick - - - - - - - - - - - -	9
6.	Coal, black, considerable glance - - - - -	1 1/2
5.	Shale, lignitic, flaky. Contains abundant plant debris - - - - - - - - - - - -	1/2
4.	Sand, buff; gray above. Massively thinbedded. Contains plant debris. Contains marcasite concretions to nine inches in greatest diameter near base -	8
3.	Shale, light gray; somewhat silty - - - - - -	3
2.	Shale and coal. Shale carbonaceous in varying amounts from place to place - -	-1/2-1
1.	Coal, black, reported - - - - - - - - - - - -	.2
	Total Exposed - -	41 1/3-41 5/6

Section of beds of the Hillen coal zone exposed a small mine in SW.1/4, NE.1/4, Sec. 35, T. 19 N., R. 14 E. along the south wall of small draw tributary to the larger northward draining valley.

		Feet
12.	Sandstone and shale, poorly exposed in upper 15 feet. Buff, horizontally and evenly bedded, with thin shale and silt beds. Cemented into flattish concretions at intervals above base. Coal blossom exposed under silts 10 feet below top - - - - - - - - - - - - - - - -	32
11.	Sandstone and shale, buff and gray. Each texture like underlying two beds. Sandier above - - - - - - - - - - - -	1 1/6
10.	Sand, buff; thinly crossbedded or ripplemarked. Entirely cemented in places - - - - - - - - - - - - - - - - - -	1
9.	Shale, light gray; darker gray in lower half foot. Contains fragments of coalified plant debris. Very thin selenite band at top - - - - - - - - -	2
8.	Coal, black, brown stained. Vertically jointed. Horizontally laminated. But little glance. Middle two inches bony - - - - - - - - - - - - - - -	11/12
7.	Shale or clay shale, light gray; thin lignitic streaks one fourth foot above base. Contains abundant	

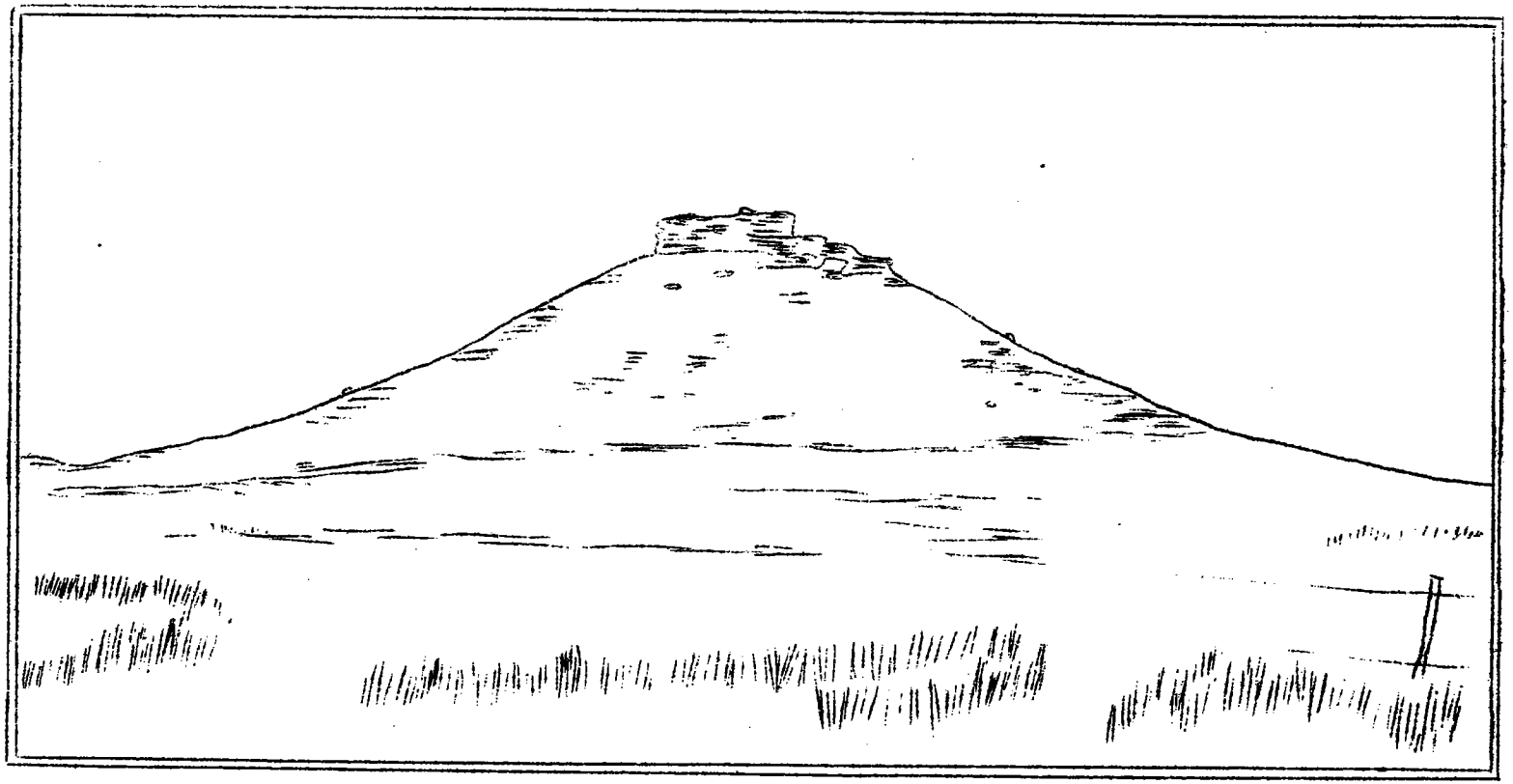

FIGURE V.

Scotch Cap Butte.

		Feet
	plant debris, two feet above the base. Sticks and branches preserved as coal; fossil leaves oriented flatwise - - - - - - - - - - - - - - - - -	3 1/2
6.	Coal, black, bony - - - - - - - - - - - -	1/12
5.	Coal, black, brittle, thinly banded horizontally. Contains considerable fusain and little glance - - - - - - - - -	2/3
4.	Fusain and bony coal. Contains clear selenite - - - - - - - - - - - - - - - - - - -	1/24-1/12
3.	Clay, underclay, light gray, structureless. Only slightly gritty. Slickensided from top to bottom. Contains rootlets and some glance coal - - - - - - - - - - - - - - - - - - -	1 1/4
2.	Coal, bony, flaky, "blackjack". Brown stained, some glance coal - - - - -	1/6
1.	Coal, hard, brittle, much glance - - - -	1 1/6
	Total Exposed - - - - -	44 11/12

Scotch Cap Sandstone:

The sandstone lying above the Hillen coal zone and below the position of the Bison coal and the Bison silts is perhaps the most conspicuous bed in the Ludlow-Cannonball succession of central Perkins county. For purposes of description it is here called the Scotch Cap sandstone, from the cap of a conspicuous butte of this name in NE.1/4, NW.1/4, Sec. 23, T. 18 N., R. 12 E., a mile and a half west of the area. Typical exposures occur in the area along a topographic feature known as Rocky Ridge lying diagonally across Sec. 14, T. 18 N., R. 13 E.

The bed is widely exposed within the mapped area from the eastern boundary to that at the west. It is poorly exposed south of the N. boundary of T. 17 N. within the mapped area, but many low buttes south of this line, particularly in the northwestern part of T. 17 N., R. 14 E. are capped with sandstone which is probably at this position. Many buttes and rock terraces in the southern two tiers of sections of T. 19 N., R.14 and the northern two tiers of sections of T. 18 N., R. 14 are capped with this sandstone. The most extensive exposures within the mapped area, however, are west, southwest, and south of Bison, where exposures along Thunder Butte Creek are practically continuous.

Outside the area a sandstone, apparently the same, occurs in conspicuous masses 0.8 miles north and 0.6 miles west of the bridge across South Grand River north

(fig.5)
of Bison. It forms the cap of Scotch Cap Butte from which the local name is derived, and numerous other buttes between this butte and Cash to the west of the mapped area. Typical exposures occur south of Cash.

The Scotch Cap sandstone is fairly uniform lithologically from place to place. The bed is massive and composed of fine, silty, micaceous sandstone of a light gray or light buff color. In many places, however, it is drab or brown. The sand commonly contains small, subspherical concretions up to an inch in diameter, composed of loose uncemented sand inclosed in a thin limonitic shell. Here and there, it also contains vertical limonite stained tubes 1/16 inch in diameter which suggest worm burrows. Ripplemark is fairly common. Cementation is essentially absent except in certain places where the surface of the sand is case hardened or where it is rather loosely cemented to form concretionary masses several feet in diameter elongated parallel with the major jointing. The most notable occurrence of these concretionary masses in the area is on Rocky Ridge where a wagon road crosses it along the south line of Sec. 22, T. 18 N., R. 13 E. In some outcrops ledges of loosely cemented sand two or more feet thick occur. In many places the uppermost foot or two is of peculiar mottled or spotted appearance resembling oolites. This uppermost bed is commonly medium gray or brown.

Limestone, possibly of marine origin, occurs within the sandstone in one exposure in NW.1/4 Sec. 25, T. 19N., R. 14 E., where it lies about midway between the top and bottom of the sandstone exposed. This rock is dense, very fine textured, dark medium gray. It is brecciated and septarian, the septarian cracks being partly filled with yellow calcite crystals. The limestone is composed of fragments of limestone ranging from a small fraction of an inch up to several inches in diameter. Some of the fragments are sharply angular, but most are more or less rounded. In the lower part these fragments are cemented with limestone similar in character, but in the upper part sandstone occurs in the interstices between the fragments. Bedding of the sandstone overlying the limestone bends over fragments of the limestone. The limestone is thin, varying between two inches and one foot in thickness. No fossils were observed.

The Scotch Cap sandstone is variable in thickness, although both upper and lower contacts are rarely exposed. The horizon varies from 5 up to 36 feet. The former thickness is well exposed in SE.1/4, NE.1/4, Sec. 11, T. 18 N., R. 13 E. and the latter in NW.1/4, Sec. 25, T. 19 N., R. 14 E.

Unconformable relations at the top of the Scotch Cap sandstone, probably only local, are suggested in an outcrop in NW. 1/4 Sec. 35, T. 19 N., R. 14 E., where a thickness of 8 feet of white sandstone overlain by shale exposed at the northwest is reduced at the southeast to 1 1/2 feet overlain by alternating sands and silts. The contact here is very sharp. The relations suggest the removal of a part of the Scotch Cap sandstone before deposition of the overlying beds.

Details in lithology and lithologic succession are illustrated in the tables of succession. The first is a section of Scotch Cap Butte (fig. 5) from which the local name for the sandstone has been taken because of its conspicuous position and because of numerous exposures in buttes to the north and west and to the east of this landmark. The second is also typical and shows not only the maximum thickness of these beds in the area but also included limestones of considerable interest.

Section of Scotch Cap sandstone in Scotch Cap butte in the NE. 1/4, NW. 1/4 Sec. 23, T. 18 N., R. 12 E.:

		Feet
5.	Sandstone, light gray to drab, fine-grained, cross-bedded, cross laminae, thin, fairly hard in places - - -	10
4.	Sandstone, fine, buff to yellow brown, cross-bedded, fairly hard, friable in places. Black specked; micaceous - - - - - - - - - - - - - - - - - - -	8
3.	Sandstone, fine, light gray, black specked, fairly hard; cross-bedded. Limonite streaked - - - - - - - - - - - - - -	3 3/4
2.	Silt, buff, and sandy, not cemented - - - -	2
1.	Covered - - - - - - - - - - - - - - - - - -	50-60
	Total Exposed - - - -	21 3/4

Section of beds composing the Scotch Cap sandstone at the top of a conspicuous small butte in the NW 1/4 Sec. 25, T. 19 N., R. 14 E.:

		Feet
8.	Sandstone, mottled, medium gray, volitic in appearance - - - - - - - - - - -	2/3
7.	Sandstone, gray, cemented ripple-marked - - - - - - - - - - - - - - - - - - -	2
6.	Sand, massive, gray, silty, fine. Yellow, ferrugainous zone one inch thick six feet below top. Cemented slightly in upper part, elsewhere loose and friable - - - - - - - - - - - - - - - - - - -	17
5.	Sandstone, gray and buff, firmly cemented. Ripplemarked. Encloses fragments of	

		Feet
	underlying limestone. Some partly rounded limestone fragments to top of bed. Bedding of sand bends over limestone inclusions - - - - - - - - - - - - - - - - - -	1 1/2
4.	Limestone, dark medium gray, dense, brecciated, septarian. Septarian cracks partly filled with yellow calcite crystals composed of fragments of limestone from a small fraction of an inch up to several inches in diameter. Some fragments angular; mostly more or less rounded. Interstices between fragments mostly filled with limestone in lower part but sandstone in upper. No fossils observed - - - -	1/6-1
3.	Sandstone, like underlying, but slightly cemented and noticeably ripplemarked - - - - - - - - - - - - - - - - - -	1 1/2
2.	Sand, light gray, massive, silty, fine thin bedded, not cemented. Ripplemarked in upper part - - - - - - - - - -	14
1.	Covered interval - - - - - - - - - - - - - - - -	30
	Total Exposed - -	36 5/6-37 2/3

Bison Coal and Associated Beds:

A thin succession of sandstone, shale, and a thin coal lies between the Scotch Cap sandstone and the Bison silt and sandstone zone. This group of beds is rarely well exposed, but has been identified from the vicinity of Bison. It has been identified as far northwest as the prominent butte in Sec. 31, T. 19 N, R. 13 E. A coal bed penetrated in numerous wells in Bison lies apparently at this horizon. Details representative of this succession and probably representative also of the usual thickness are included in the tables of succession which follow. They also include the overlying Bison beds, the White River, and the Scotch Cap sandstone below.

Section of Ludlow-Cannonball and associated beds, exposed in the SE.1/4, NW.1/4 Sec. 12, and the SE 1/4, NE 1/4 Sec. 11, T. 18 N., R. 13 E. in a steeply cut ravine and its tributaries. Uppermost beds on terrace-like flat and in small knoll west of the wagon road.

		Feet
Oligocene		
	White River	
	Chadron	
9.	Clay, gumbo, weathered surface light gray, porous, hard, gumbo jointing on surface. Sticky and	

		Feet
	siliceous; starchyfracture - - - -	9
	8. Covered interval, mostly clay? - - -	20
Upper Cretaceous		
Ludlow Cannonball		
Bison beds		
	8. Clay and silt, banded buff and gray, very hard and tough when dry. Clay gray, flaky; containing thin lenses of hard, fine grained, thinly crossbedded sandstone one to six inches thick. The interbedding of sand, clay, and sandstone continue upward in about equal textural proportions to the upper 15 feet where the clay and sandstone become colorfully bedded into buff, gray, and pink streaks. The sandstone becomes more notably crossbedded, and beds approach a foot in thickness. Sandstone changes from dark buff and brown to light buff and gray 10 to 12 feet below the top. Nodular kindschen-like limestone concretions arranged in layers occur in clay and sand in upper 10 feet. These range from a fraction of an inch up to 8 inches across - - - - - - - -	33
Bison coal zone		
	6. Shale, dark gray, flaky - - - - - -	1 1/3
	5. Silt, gray, ashy; weathers yellow or buff; contains thin, darker gray silt streaks in upper part - - - - - - - - - - - - - -	6 1/2
	4. Shale, silty, brown, thinly laminated, gypsiferous - - - - - - -	1/4
	3. Coal, Bison coal, weathered, flaky, probably bony coal or mostly "blackjack" - - - - - - - - -	1 1/6
	2. Sandstone and shale, consisting of thinbedded, fine gray, micaceous sand with thin brown laminae on bedding planes in lower foot and thinbedded sand with thinly bedded lignitic shale in upper part. Upper part contains sandy concretionary masses up to 10 inches in greatest diameter. Upper foot almost entirely flaky, lignitic shale - - - - - - - - - - - - - -	3

	Feet
Scotch Cap sandstone	
1. Sandstone, fine, gray, massive, though crossbedded. Micaceous, friable; contains small concretions up to one inch in diameter, consisting of limonitic shell enclosing loose sand. Contains vertical limonite tubes one sixteenth inch in diameter, possibly worm burrows ----------	5
Total ----------	79 1/4
Bison coal and associated beds ---	12 1/4

Section of Bison coal and associated beds exposed in the prominent butte rising high above its surroundings in the NW. ¼, NE. ¼ Sec. 31, T. 19 N., R. 13 E.

	Feet
Ludlow Cannonball	
Bison beds	
4. Silt, sandstone, and clay, poorly exposed. Sandstone most prominent in upper part, where beds reach a thickness of 1 1/2 feet. Sandstone weathers to thinbedded slabs. Exposure weathers yellow or buff. Abundant limy concretions in upper part ----------	27
Bison coal and associated beds	
3. Shale, dark brownish gray ------	1
2. Coal, flaky, dirty, bony -------	1/2
Scotch Cap sandstone	
1. Sand, massive, fine. Light ashy gray. Similar in appearance to old forest soil ----	5
Total ----------	33 1/2
Bison Coal and associated beds --	1 1/2

Bison Zone:

The Bison silt and sandstone zone is a conspicuous and readily identifiable succession of silty and sandy calcareaous beds which are the uppermost beds of the Ludlow-Cannonball member of the Lance in the central Perkins county area. In the weathered outcrop these beds are yellowish buff and buff. They are the bedrock of the divide between South Fork of Grand River and Thunder Butte Creek. They thus underlie the town

of Bison from which the local name here applied is given. The beds also underlie the White River deposits on the buttes rising above their surroundings at the north of the highway in Secs. 1, 2, 3, 4, and 11, T. 18 N., R. 14 E. and in Sec. 34, T. 19 N., R. 14 E. The Bison silt and sandstone zone also forms the cap of the prominent, isolated butte in Sec. 31, T. 19 N., R. 13 E. Distribution outside the area mapped in this report is not known, although the beds extend eastward toward Meadow for an unknown distance. Character, distribution, and thickness within the area suggest that they may be widely distributed outside the central Perkins county area.

The greater part of the succession is composed of alternating beds of buff and gray shale, silt, and fine sandstone. Gray clay and buff silt predominate in the lower part, whereas thinly crossbedded sandy beds become increasingly important in the upper part. In the lower part of the succession, beds of fine sandstone up to six inches in thickness occur, but in the upper part reach a foot or more in thickness. In the upper part the silty beds are cemented into the rather hard, tough rock, common in many exposures. On erosion these more resistent beds produce ledges of buff, silty, calcareous rock and outcrops of slabby siltstone and sandstone. In many places, among the more sandy beds in the upper part of the succession, sandstone concretions of thin crossbedded silty sand ranging from one inch in diameter up to a thickness of nearly five feet are of common occurrence. The concretionary masses are commonly buff and brown. They are very irregular in shape. When weathering occurs, they part along bedding planes into thin sheets. In the upper ten feet, below the sandstone, small, irregularly shaped limestone concretions occur in softer clay and shale beds. These are very similar to the kindschen which occur in loess in many places and have probably been formed in the same way, i.e., by deposition by ground water charged with lime carbonate.

The Bison beds are probably 100 feet or more thick.

Fossils have not been observed in these beds. The uniform character, general distribution in the area, lack of coal or other terrestrial material, presence of abundant calcium carbonate, and close proximity to marine beds north of South Fork of Grand River suggest that the Bison beds are marine in origin.

Two of the most typical successions of the Bison zone have been described in tables of succession at the close of the description of the underlying Bison coal

and associated beds on the preceeding pages(pp.32-33).

Thickness of the Ludlow-Cannonball:

The combined thickness of the zones of the Ludlow-Cannonball varies between 272 feet and 327 feet. The minimum figure is derived from the addition of the minimum thickness of the constituent parts of the succession, whereas the maximum is the sum of the maxima. The average of the two extremes probably most closely approximates the total thickness. The thickness in the area is thus approximately that of the Ludlow and Cannonball member of the Lance in their type of localities.[1]

Stratigraphic Relations:

The Ludlow-Cannonball lies conformably on the Hell Creek of early Lance age. Outside the area, to the north and northwest, the member lies conformably beneath the Fort Union. In the central Perkins county area the member underlies the Chadron of White River age in relations of marked unconformity.

Correlation of the Ludlow-Cannonball:

The Ludlow-Cannonball is the equivalent of beds lying east of the Rocky Mountain front between the Hell Creek and Fort Union, as delimited in South Dakota, and [illegible] equivalents. Apparently these beds are the equivalent of the Tullock[2] member of the Lance together with the Lebo[3] shale, of Montana, the latter being included in the Fort Union[4]. The Bison beds are thus, wholly or in part, probably the equivalent of the Lebo shale of Montana. The sandy beds of Fort Union of South Dakota, to the north and west of the area, appear to correlate with the Tongue River member of the Fort Union of Wyoming, Montana and North Dakota.

1./ Winchester, D. E., et al, The op. cit., pp. 20 and 22; 1916.

2, 3, 4./ Thom, W. T., Jr., and Dobbin, C. E., Stratigraphy of the Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: G. S. A. Bulletin, Vol. 35, pp. 481 to 506.

Fort Union

No deposits of Fort Union age occur in the central Perkins county area, although the formation lies between Ludlow and White River and between Cannonball and White River to the north, northeast, and northwest in Perkins county. The Fort Union probably was originally deposited over the whole of Perkins county. It is now absent because of erosion which occurred between the time of deposition of the Fort Union and the deposition of the White River. Belief that the Fort Union formerly was of wide extent is based on the distribution of residual boulders of quartzitic rock bearing impressions of roots and branches and residual boulders of chalcedonized wood like those which occur in the Fort Union. These occur far south and east of Perkins county. The quartzitic boulders occur also in basal White River deposits but there, so far as known, after many observations, only as residuum from the Fort Union. Where they occur *in situ* they are, in some cases at least, in the underclay of one or more beds of coal of Fort Union age.[1]

White River

Distribution:

Deposits of White River age occur in isolated patches on higher elevations within the central Perkins county area. The most conspicuous exposures are at the tops of the several buttes north of State Highway No. 18 in sections 1, 2, 3, and 4, T. 18 N., R. 14 E. and Sec. 34, T. 19 N., R. 14 E. and in several buttes in sections 23, 24, 25, and 26, T. 17 N., R. 14 E. The hill occupying Sec. 19, T. 18 N., R. 13 E. contains White River deposits, and two very small patches occur within a mile northeast of Bison in sections 11 and 14, T. 118 N., R. 13 E. White River deposits lie outside the central Perkins county area in Fox Ridge to the south, Slim Buttes and Short Pine Hills to the west, and White Butte to the north. In addition there are numerous other smaller occurrences.

Stratigraphic Position:

Beds of Chadron age are the only Oligocene deposits

1./ Winchester, D. E., *et al*, Op. cit., pp. 30-31; 1916. Searight, W. V., A preliminary report on the coal resources of South Dakota: So. Dak. Geol. and Nat. Hist. Survey, Rept. of Inv. No. 3, pp. 18-19; 1930

in the central Perkins county area, and these occupy the position of the lower part of the formation. In the Big Badlands of South Dakota along White River, where a classic section of Oligocene deposits is displayed, beds occur in the following succession:

Generalized section of the White River deposits of the White River Badlands.

		Feet
Lower Miocene, Arickaree formation		
Oligocene		
Brule formation - - - - - - - - - - - - - - - -		405-465
Protoceras beds - - - - -	150-175	
Oreodon beds - - - - - - -	255-290	
Chadron formation - - - - - - - - - - - - - - -		0-180
Titanotherium beds		
Cretaceous		

The central Perkins county deposits include only a part of the Chadron as it is developed in the Big Badlands. To the westward, however, in the Slim Buttes, a considerable part of the Oreodon beds of lower Brule age are developed.

Character and Lithologic Succession:

The Chadron of central Perkins county consists, from the base up, of gravel, here and there cemented to conglomerate, overlain by gray gumbo clays, which are in turn overlain by one or more thin beds of fresh water limestone.

Basal Gravel and Sand:

In many places the basal beds of the Chadron consist of coarse sand and gravel of fluviatile origin. These deposits are composed entirely of hard materials, mostly highly silicious. In many places where sorting is good the basal deposit consists mostly of coarse white quartz sand. Where the deposit is coarser, however, red "felsite" porphyry, chert and flint of several colors, petrified wood, quartzite, chalcedony, and other materials occur. Some of the material is well worn by water, but some is subangular. Percussion marks on pieces are abundant, particularly on chert and flint. In many places, much of the chert and flint is highly polished. The polish over the surface of pebbles is brilliant and remarkably uniform and extends not only over projecting parts of the surface but also into reentrants and crevices. A satisfactory theory for the genesis of this polish has not been developed. Wind suggests itself as an agent, but the uniformity of polish over the surface together with a lack of wind shaped or wind etched pieces seems to eliminate this possibility.

Materials range in size from grains of coarse sand up to boulders several inches in diameter. Large boulders of Fort Union quartzite scattered over the surface of the Ludlow in central Perkins county and in many places on older formations are believed to be derived from this part of the Chadron.

Kinds of material and their possible sources are indicated in the table made from a count of pebbles from an exposure on the south side of a butte in N 1/2, NE 1/4, Sec. 3, T. 18 N., R. 14 E. (Table 1) Pebbles and cobbles over the square yard of surface and more than one fourth inch in diameter were counted.

TABLE I

Pebble count of Chadron gravel in N 1/2, NE 1/4 Sec. 3, T. 18 N., R. 14 E.

	Source and Per Cent		
	Local	Black Hills(?)	Foreign
1. Chert, brown			37
2. Quartz, white		16	
3. Porphyry, red "felsite		2	
4. Quartzite, Fort Union	4		
5. Quartz, smoky		4	
6. Quartzite, brown			5
7. Quartzite, gray			10
8. Chert, gray			8
9. Flint, black			6
10. Chalcedony	1		
11. Chert, mottled			1
12. Quartz, milky		1	
13. Petrified wood	1		
14. Sandstone, conglomeratic			2
15. Unclassified			2
Totals	6	23	71

In this count 71 per cent are materials transported into this area from outside of South Dakota. The 23 per cent listed as Black Hills possibly have been derived from igneous rocks of the Black Hills.

The material listed as Fort Union quartzite is of particular interest. It consists of hard, drab, and brown, fine textured quartzitic rock. Todd has noted the occurence of this rock, which he described as "flint", at the top of Cave Hills.[1] Here, as in central Perkins county, however, the boulders appear to be residual in basal Oligocene and derived originally from the Fort Union. Casts and molds of roots and branches are commonly present. It occurs not only as a part of the gravels at the base of the Chadron, but also as scattered boulders over a large part of western South Dakota, underlain by rocks older than Fort Union. Some boulders west of the Missouri River but near it, are associated with glacial boulders and have probably, at least in part, been transparted from the east and north. One piece was collected in the extreme eastern part of South Dakota, where it occured in glacial deposits. A boulder of very similar, if not identical material, was found approximately 100 miles east of the Missouri River in Iowa. Boulders of arkose cemented with silica in western Kansas agree closely in description with those of South Dakota.[2] In Kansas, however, the boulders are contained in gravels of much later age.

In South Dakota the boulders occur in place in rocks of Fort Union age.[3] Where they occur on rocks older than Fort Union, or in lower Chadron, they are believed to be residual after erosion of the Fort Union. Their occurence in basal Chadron suggests the accumulation as residuum during the interval between Fort Union and early White River time.

Dark to light gray chalcedonized wood in basal Chadron appears also to have its source in the Fort Union. The petrified wood, like the arkosic quartzite, is believed to be residual in basal Chadron.

In the pebble count (Table 1) four kinds of pebbles (23 per cent) are listed with the Black Hills (?) as a source. All of these, of which white quartz (16 per cent), smoky quartz (4 per cent), milky quartz, (1 per cent), and red "felsite" porphyry (2 per cent), may have been transported from the Black Hills. They may, however, have been

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1./ Todd, J. E., Preliminary Report on the Geology of the Northwest-Central Portion of South Dakota: South Dakota Geological Survey Bulletin 4, pp. 37-38; 1908.

2./ Elias, M. T. Geology of Wallace County, State Geological Survey of Kansas, Bulletin 18, pp. 163-164; 1931.

3./ Winchester, et. al., loc. cit., p. 30; 1916.
Searight, W. V., loc. cit., pp. 18-19; 1930.

transported from the Rocky Mountain region.

The remaining ingredients of the gravels (71 per cent), consisting of various cherts, flints, quartzites, and sandstones are of foreign derivation, probably from the Rocky Mountain region.

The pebble count, which is probably a representative one, indicates that the basal Chadron gravels, for the most part, have been transported to the region from far off sources, undoubtedly to the west.

Distribution of Basal Gravels and Sands:

The basal gravels occur only in patches and occur wherever White River deposits are mapped in the central Perkins county area.(Plate 1) Where overlain by clays, however, they may not be co-extensive with these overlying beds. If not actually absent, thickness is reduced in many places to a sprinkling of pebbles above the contact between Lance and White River.

Thickness:

Basal Chadron gravels range in thickness from a sprinkling of pebbles above the basal contact up to ten feet or more.

Origin:

Lithology, bedding distribution, and variation in thickness suggest fluviatile deposition by streams of considerable transporting power, mostly from a high region to the west.

Chadron Clays and Limestone:

Chadron clays, the Titanotherum clays of many authors, overlie and in many places intergrade with the basal Chadron gravels and sands. Everywhere they consist dominantly of light gray clays which weather into gumbo clays with gumbo checking and starchy fracture. In some places in the central Perkins county area and in many places outside, as in Fox Ridge and Lemmon Buttes in northern Meade county, the Slim Buttes in eastern Harding county, and in the White River Badlands, small pebbles like those in the basal Chadron are very sparingly distributed through the lower few feet of clay. Here and there in the lower few feet, clays are of a distinct pink or reddish color. In many places gray to nearly white caliche-like limy material occurs in two or more thin zones.

At the top of the central Perkins county section a thin limestone about a foot in thickness, of white to grayish

white, thinly laminated brittle limestone occurs. This limestone contains small fresh water gasteropods.

Section:

The table of succession which follows is typical for the area, and all White River beds of the area are represented in it.

Section of the White River and associated deposits exposed in a prominent butte in N 1/2, NE 1/4 Sec. 3, T. 18 N., R. 14 E., and in section north; with the exception of the Ludlow-Cannonball, exposed on southwest of the butte, the former in a gully at the north.

		Feet
Recent		
5.	Soil- -	1
Oligocene		
White River		
Chadron		
4.	Limestone, slabby, light gray - - - - - - - -	1
3.	Clay, weathers to light gray gumbo, small quartz and chert pebbles to one inch occur sparingly in the lower 5 or 6 feet. Gumbo jointing on dried surface and starchy fracture within. Hard, limy caliche-like zone 1/4 foot thick 8 feet above the base. Float of another similar zone comes apparently from about 28 feet above base. Here and there at or near the base 5 feet of pink gumbo clay occurs - - - - - - - - - - - - - - - -	54
2.	Sand and gravel, poorly exposed. Consists of hard and siliceous gravels, cemented in places to form conglomerate, in some cases cement is calcium carbonate; in others cementing material is siliceous. Pieces range in size from granules up to cobbles more than 5 inches in greatest diameter. Some pieces well worn, others subangular. Cherts in many places highly polished, without, however, showing any indication of wind etching. Polish on exposed angles no greater than that on reentrants caused by conchoidal fracture. Brilliantly polished cherts show well developed deep, conchoidal fracture in many cases. Quartzites	

	Feet
and quartz show but little polish. Upper part composed principally of evenly sorted white quartz granule gravel or gravel and coarse sand -	24

Cretaceous
Ludlow-Cannonball
Bison beds

1. Silt, sand and shale - - - - - - - - - - - - - - -	20

Thickness:

The maximum thickness of White River exposed in the area is probably that of the beds exposed in the buttes cited, where the thickness is 57 feet.

Fossils:

The fragment of a large rib, probably of a titanothere and a piece of a large molar of a titanothere were observed in the clay. Winchester collected fragments of a pelvis probably of Caenopus or Aceratherium[1] from the butte in Sec. 3, T. 18 N., R. 14 E., the one at which the section cited is exposed.

Stratigraphic Relations:

White River beds of this area lie unconformably on older strata. In the buttes along the north boundary of T. 18 N., R. 14 E., they lie on the upper Ludlow-Cannonball, the Bison beds. On Rocky Ridge in Sec. 22, T. 18 N., R. 13 E., Chadron conglomerate and gravel lies on the Scotch Cap sandstone and in Secs. 23, 24, and 26 it lies on older beds of the Ludlow-Cannonball. Outside the area in many places, as in White Butte, the White River lies on Fort Union. In the Short Pine Hills it lies on Hell Creek. The erosion between Fort Union and Chadron represented in Harding and Perkins counties has been estimated at 750 feet of beds.[2] The amount in South Dakota is much greater than this, however. In the Stoneville area of western Meade county, basal Chadron rests on Fox Hills and in the Big Badlands south of Wall on the upper transition zone of the Pierre. Basal White River of the Black Hills area levels the upturned strata of older Cretaceous, Paleozoics and even the pre-Cambrian. The unconformable contact at the base of the White River is thus a most significant one. Indeed, it is the only known unconformity of major importance in the succession of South Dakota from the basal Dakota to the White River.

1./ Winchester, D. E., et. al., op. cit., p. 33 and 150, 1916.
2./ Winchester, D. E., et. al., op. cit., p. 33, 1916.

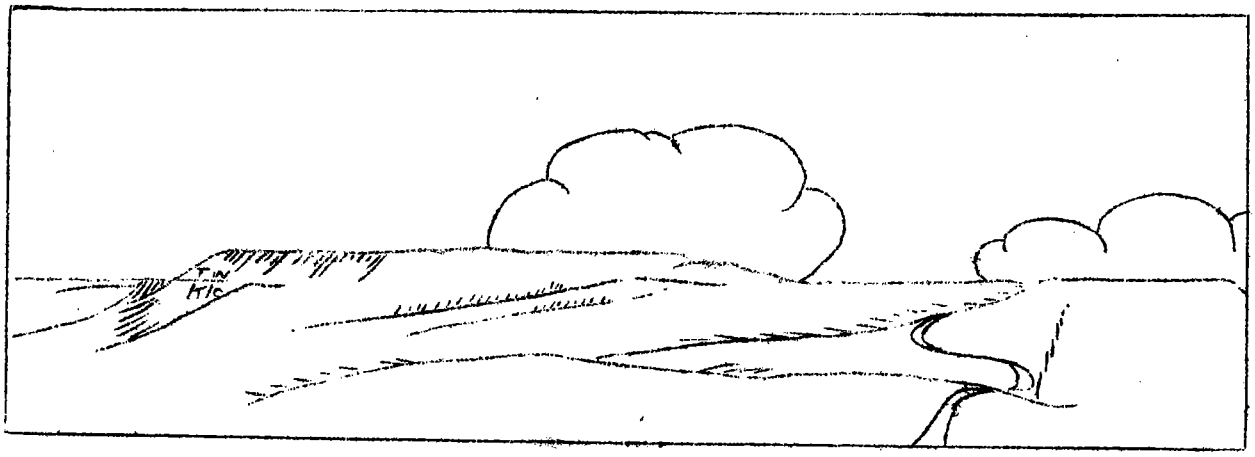


FIGURE VI

Butte along north line sec.3, T. 18 N.,R. 14 E.
to show pre-Chadron peneplain.
(TW--Chadron Klc--Ludlow-Cannonball.)

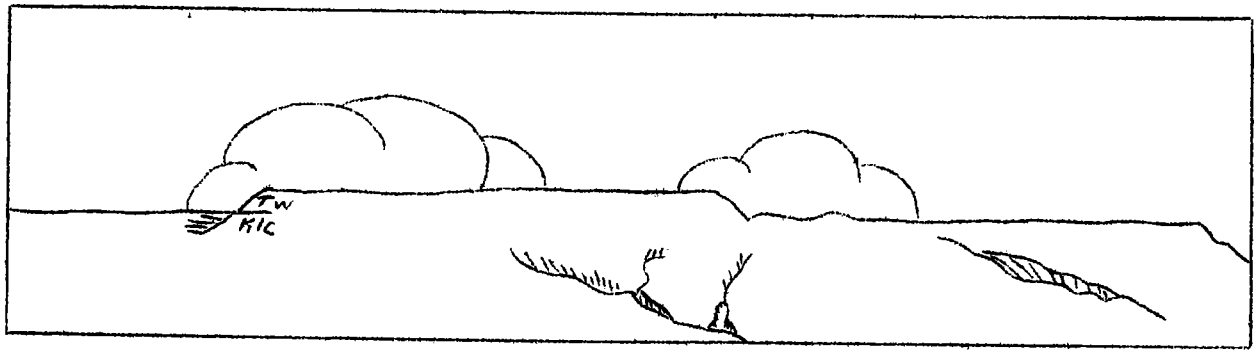


FIGURE VII

Butte between sections 3 and 4, T. 18 N., R.
14 E. to show pre-Chadron peneplain.
(TW--Chadron, Klc--Ludlow-Cannonball)

The erosion surface below the White River is widespread. Although probably never flat, flatness was probably closely approached so that the surface below these deposits may well be called a peneplain. This peneplain (Figs, 6-7) appears to be the same as that cutting the "Interior" beds of the Big Badlands,[1] to which the name Interior peneplain has been given.[2] This peneplain appears to represent the same unconformable contact and erosion surface as the Cypress Plain of Alden[3] which he extends from the Cypress Hills Plateau of southwestern Saskatchewan to eastern Montana.

Correlation:

The White River beds of central Perkins county are to be correlated with the lower part of the Chadron of the White River Badlands, The basal gravels are correlated with the channel sandstones of Wanless[4] at this position and apparently are to be correlated with gravels lying on the Cypress Plain of Alden.[5]

Pleistocene

Terrace Deposits:

Terrace deposits of gravel, sand, and silt lie along Thunder Butte Creek beneath low terraces whose tops are 20-25 feet above the valley bottom. The most important of these appear on the geologic map of the area. In one of these deposits fragments of bone, apparently part of a ball and socket joint of an elephant, were found by Mr. G. J. Blindert. These bones were not mineralized but nevertheless suggest the Pleistocene age of the deposit.

The general character and thickness of the deposits are indicated in the tables of succession which follows.

Section of Pleistocene Terrace deposits along Thunder Butte Creek in the N. 1/2, NW 1/4 Sec. 31, T. 17 N., R. 14 E.

1./Wanless, H. R., Stratigraphy of the White River Beds of South Dakota: Am. Phil Soc. Proc., Vol. LXII, pp. 194-208; 1923.
2./Wanless, H. R., loc. cit., p. 198; 1923.
3./Alden, W. C., Physiographic development of the northern great plains: G. S. A. Bull., Vol. 35, pp. 389; 1924. Alden, W. C., Physiography and Glacial Geology of Eastern Montana and Adjacent areas: United States Geological Prof. Paper 174, pp. 4-10; 1932.
4./Wanless, H. R., loc. cit., p. 200; 1923.
5./Alden, W. C., loc. cit., pp. 4-12; 1932.

		Feet
2.	Gravel, very coarse at base - - - - - -	3-5
1.	Silt and sand. Elephant bones collected from this bed by Mr. G. J. Blindert - - - - - - - - - - - - - -	3+

Section of Pleistocene Terrace deposits and underlying deposits on the south section line along North-South quarterline, Sec. 3, T. 17 N., R. 14 E. (Partially repeated for convenience from a preceeding page)

3.	Silt -	2
2.	Gravel and sand, fairly clean rubble and sand - - - - - - - - - - - - - -	2-3
	Total - - - - - - - -	4-5

Recent

Slope Mantle, Soil, and Alluvium:

Slope mantle, soil and alluvium are the Recent deposits of the area. Over much of the area older deposits are concealed by slope mantle and soil. Wash and alluvium occurs at the valley bottoms of all of the watercourses.

ECONOMIC GEOLOGY

Introductory Statement:

A complete survey of the economic geology of the central Perkins county area is not within the scope of this investigation. The sandy beds of the Ludlow-Cannonball furnishing, as they do, the sandy water absorbing soils of the Big Meadow, are of prime importance. It should be pointed out that the well known wheat region of Perkins county occupies a belt which is coextensive with the boundaries of the sandy beds of the upper Lance, except where relatively recent erosion has cut the surface into a topography too rough for agriculture. The Hell Creek member is so largely composed of clays and tight gumbo sands that they, and the soils formed from them, are impervious to waters which supply soil moisture and are thus mostly unfit for agriculture.

The coal of the area, next to the soils, is the most important geologic feature, considered economically. Discussion of the coal is made as complete as possible in the succeeding pages. Brief references to gravel and conglomerate are made also.

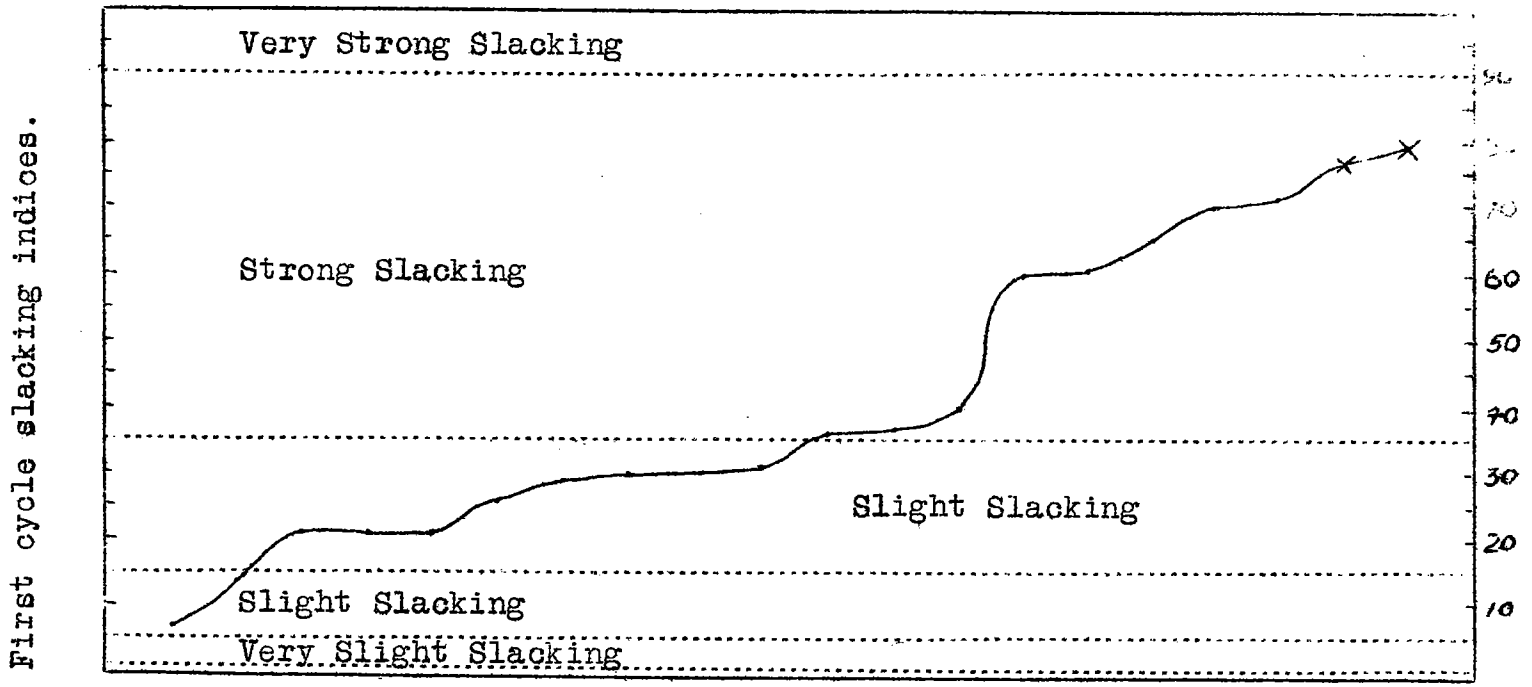


FIGURE VIII

First cycle slacking indices of South Dakota coals. Two samples indicated by (X) are from basal Ludlow-Cannonball of central Perkins county. Other samples shown by (.).

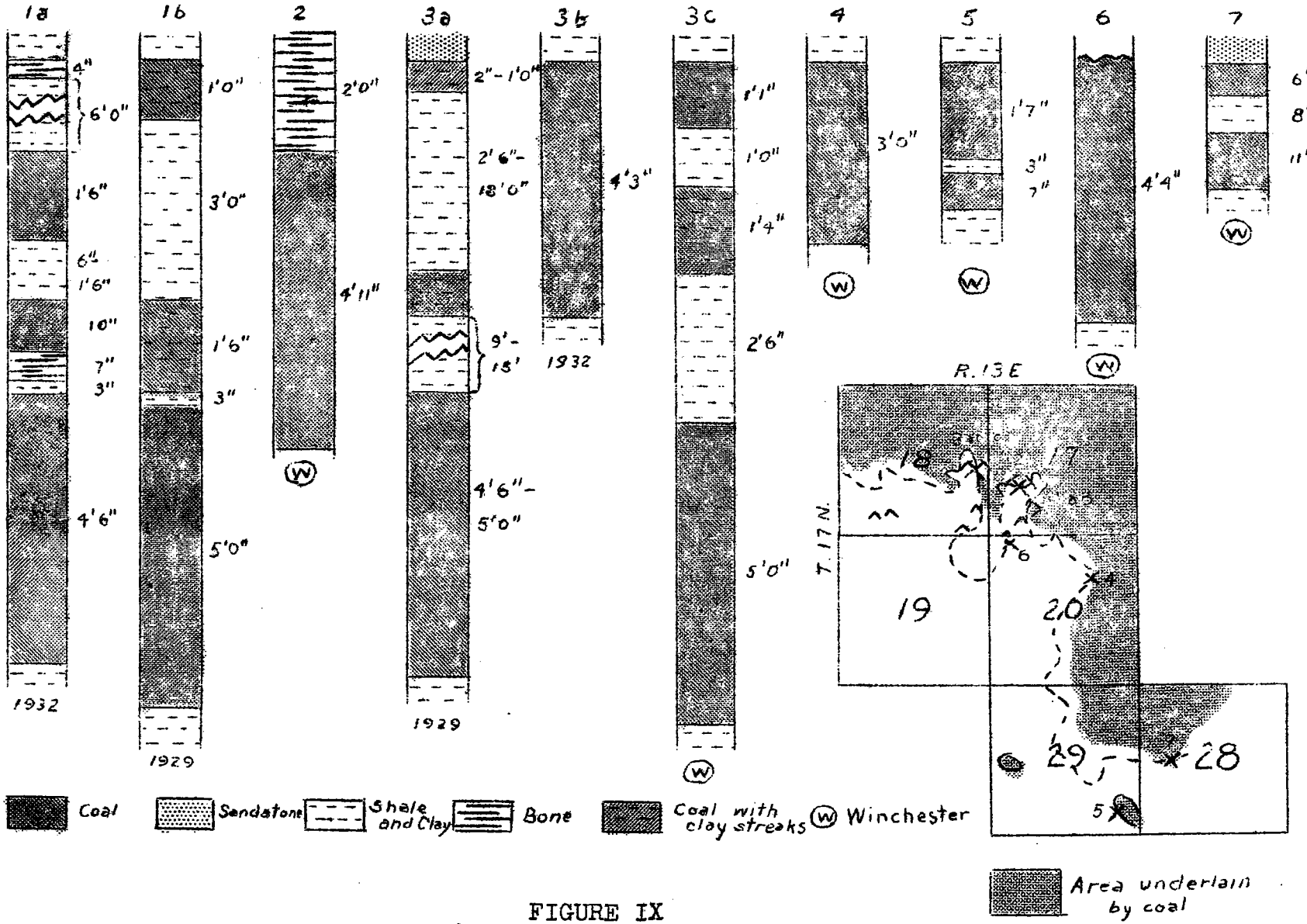
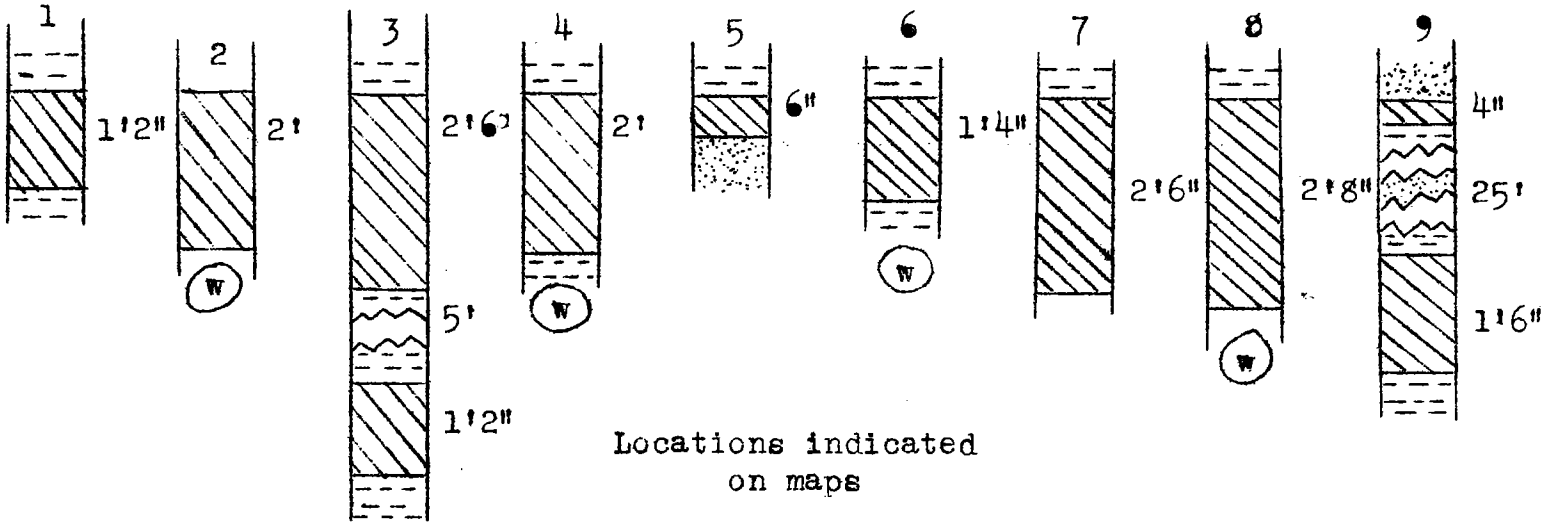
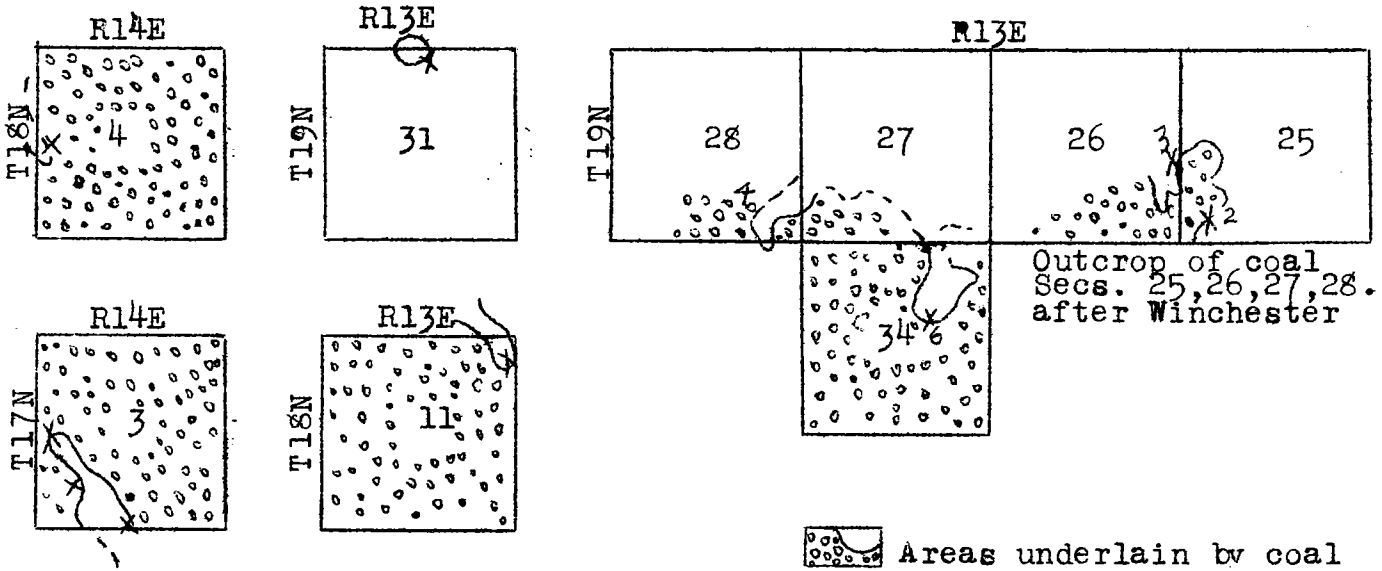


FIGURE IX
Coal sections in T. 17 N., R. 13 E. Locations indicated on map.



Locations indicated on maps



Coal sections in T.18N., R.13E.; T.19N., R. 13 E.; T.17N., R.14E; and T. 18 N., R.14

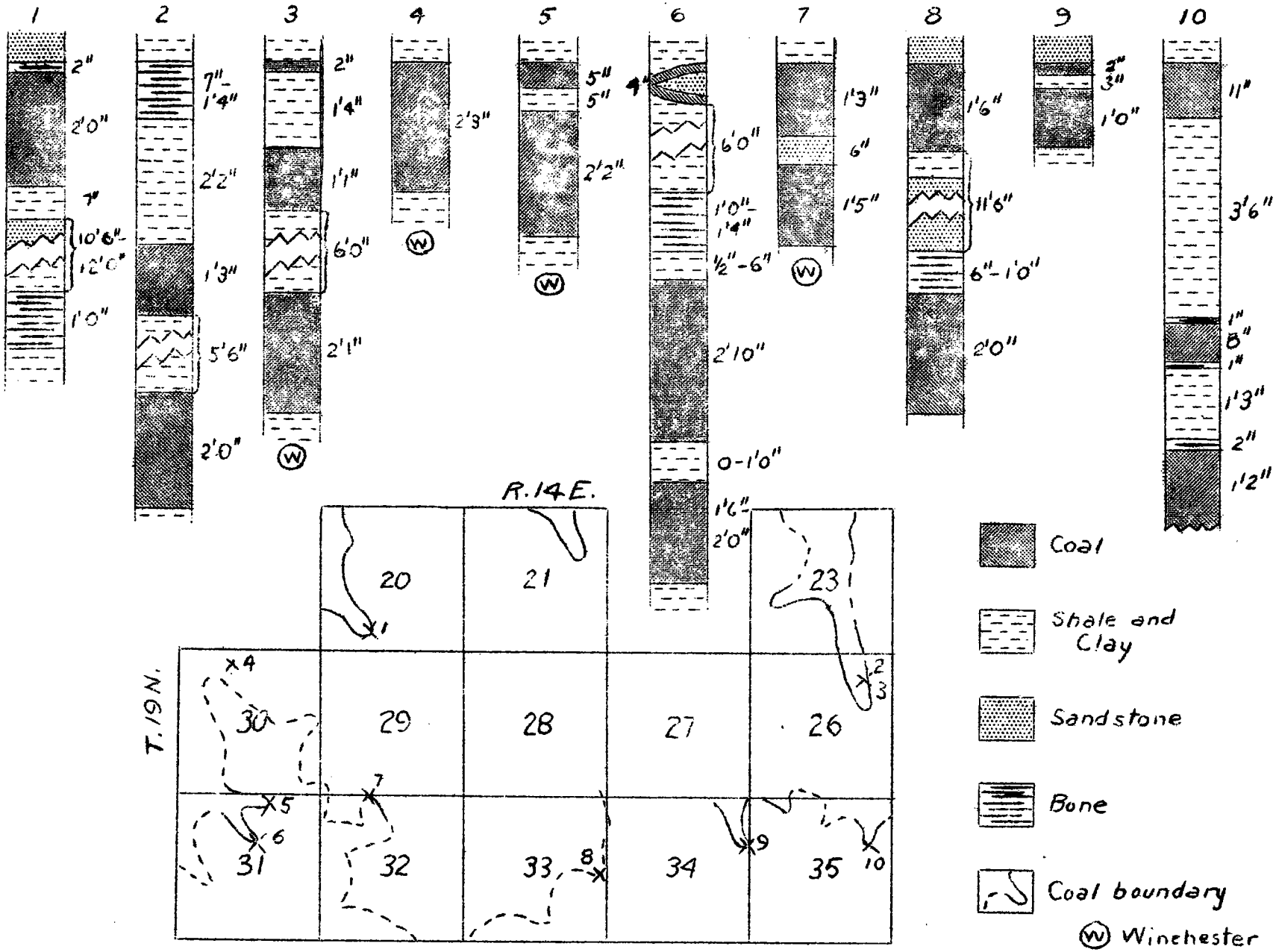


FIGURE XI

Coal sections in T. 19 N., R. 14 E. Locations indicated on map.

Coal

Introductory Statement:

Coal has been mined for local use in central Perkins county since the settlement of the area. Since 1910 or before, coal has been removed from the southwestern corner of the mapped area. One of the first occupations of the settlers was to go to the mines on "Rabbit Creek" for the winters supply of coal. Coal has since been discovered and mined elsewhere in the area. With the exception of coal trucked into the area from the Lodgepole area to the north, most of the fuel consumed in central Perkins county is even now mined within the area. Many thousands of tons of coal have been mined here since occupation. Practically no coal is shipped in on the railroad. The coal, while not suitably situated geographically for large scale production, has thus been of great local value, more particularly since other available fuels are essentially lacking within or near the area.

All of the coal of the area, in workable beds, occurs in the Ludlow-Cannonball beds of the Lance formation in the basal coal zone and in the Hillen coal zone. The Bison coal is too thin for mining in the area. Although several thin beds have been observed in the upper part of the Hell Creek near the area mapped, none of these appear to have requisite thickness here for even very small operations.

Distribution:

Coal occurs in the area in many places at or near the surface. Outcrops have been mapped and appear on the geological map. (Plate I) Many exposures, not of value however, have been plotted for stratigraphic purposes as prospect pits or small outcrops. Although some coal doubtless underlies all of the area overlain by the Ludlow-Cannonball, in most places the beds are thin or under cover of thickness too great for profitable mining.

Important Areas:

Most of the coal mined in the area has been recovered in the past from sections 17 and 18, T. 17 N., R. 13 E. from the coal zone at the base of the Ludlow-Cannonball. The deposits at this locality apparently will continue to be the most important. Except in Sec. 31, T. 19 N., where a coal bed in the Hillen succession thickens considerably, the coal is too thin and lies under too great a thickness of overburden for other than very small scale mining. (Figures 9,10,11)

Thickness:

The coal varies in thickness from a few inches up to nearly six feet. The thickest coal observed occurs in Sec. 31, T. 19 N., R. 14 E., where a coal bed in the Hillen succession of the Ludlow-Cannonball reaches a thickness of 5 2/3 to 5.5/6 feet. Here, however, the bed is split into three benches by thin beds of clay shale, or possibly clay shale beds between three of the coals of the succession, become so thin that the coal beds are separated by small intervals. In the small mine in NW. 1/4, SW. 1/4, Sec.4, T. 18 N., R. 14 E., the total coal exposed is only 1 1/2 feet in thickness. Another mine in SE. 1/4, NE. 1/4, Sec. 33, T. 19 N., R. 14 E. exposes a coal bed 1 1/2 feet thick. A bed 2 feet thick, however, is reported 12 feet below the one exposed.

The coal in Secs. 17 and 18, T. 17 N., R. 13 E., at the base of the Ludlow-Cannonball, reaches a maximum thickness of 5 feet, although it commonly varies at the mines between 4 1/2 and 5 feet. Two other thin coals above the thickest bed vary individually between less than one foot to one and one half feet in thickness. In the NE. 1/4, Sec. 25, T. 17 N., R. 13 E., the coal poorly exposed is very thin. There is the possibility, however, that a somewhat thicker coal lies below the exposed bed, since a bed correlated with the same zone northeast 5 1/2 miles is reported to be 2 1/2 feet thick.

Basal Ludlow-Cannonball coals north of the Grand River-Thunder Butte Creek divide are thin. The thickest coal bed observed is two feet thick in the Herzog mine in the NW. 1/4, NE. 1/4, Sec. 26, T. 19 N., R. 14 E.

Physical Character:

The coals of the area are black, fairly brittle, laminated horizontally, and jointed vertically into blocks. The color of the powdered coal, the streak, is brown. The coal is made up of alternating thin layers of dull, lusterless coal and shiny bright coal. The bright coal is in sufficient abundance to give the beds a relatively bright appearance in the clean mine outcrop. Here and there, interlaminated with the coal, are thin sheets of fusain, a material which has much the appearance of fragments of charcoal strewed about on bedding planes. In some cases fusain is highly impregnated with iron pyrite or iron sulphide. Thin lenses of highly carbonaceous shale, similar in appearance to coal, commonly known as "blackjack" is interbedded with coal in some places. Here and there small masses of iron pyrite also occur.

These coals are similar in physical character to coals

PROXIMATE ANALYSIS OF CENTRAL PERKINS COUNTY COAL[1]

TABLE II

Name and location[2]	Form of analysis[3]	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Heating values B. T. U.
1	A	33.57	26.26	30.97	9.20	0.35	7308
	C		39.53	46.62	13.85	0.53	11001
2	A	31.85	27.42	34.72	6.01	0.22	7582
	C		40.23	50.95	8.82	0.32	11125
3	A	27.49	29.46	31.76	11.29	1.68	7237
	C		40.63	43.80	15.57	2.32	9981
4	A	40.5	25.5	22.8	11.2	1.6	5160
	C		42.9	38.3	18.8	2.7	8680

1./ All analyses excepting No.4 analysed by Chas. Bently, South Dakota State School of Mines; No.4 by H. M. Cooper, U. S. Bureau of Mines.

2./ (1) Carlson Mine, SE 1/4, SW 1/4 sec. 17, T. 17 N., R. 13 E.
(2) Hafner Mine, NE 1/4, SE 1/4 sec. 18, T. 17 N., R. 13 E.
(3) Hillen Mine, SW 1/4, NE 1/4 sec. 3, T. 19 N., R. 14 E.
(4) Old Sexton Mine, NW 1/4, SW 1/4 sec. 17, T. 17 N., R. 13 E.

3./ Form of analysis -
A. as received
C. moisture free

in the lower Ludlow elsewhere[1] and similar to coal beds in the lower part of the Hell Creek where they occur in Corson, Dewey, and Ziebach counties.[2]

Slacking:

The coals of Perkins county, like other coals of South Dakota and North Dakota, most of those of Montana and many elsewhere in the coal fields east of the Rocky Mountains, slack considerably on exposure to air. The slacking property is due to the high water content, bed moisture, which is lost in drying after mining or after exposure. Alternate wetting and drying after mining contributes to the effectiveness of slacking.

A laboratory test, by means of which the slacking property of coals may be measured, has recently been developed by the United States Bureau of Mines.[3] The South Dakota Geological Survey has applied this test to a number of coals from the South Dakota coal field.[4] Two samples from the central Perkins county area were tested. As indicated by the graph (Figure 6) these coals have a pronounced tendency to slack as do most of the coals of Perkins county. The samples tested are to be classified as strong slacking coal.

Chemical Composition:

The chemical composition of coal furnishes perhaps the most reliable basis for estimation of the fuel value of the coal. Coal is composed of a number of elements which may be stated individually, (ultimate analysis), or grouped together, (proximate analysis), as moisture, volatile matter, fixed carbon, ash, and sulphur. Three samples of coal were collected from the area. The standard procedure for sampling of the United States Bureau of Mines was followed as closely as possible. The samples were analysed by the Mining Experiment Station of the South Dakota State School of Mines. The proximate analysis of these coals are tabulated (Table II) together with another analysis from the area.

1./ Searight, W. V., Preliminary report on the coal resources of South Dakota: So. Dak. Geol. Survey, Rept. of Inv. No. 3, pp. 36-43; 1930.

2./ Searight, W. V., loc. cit., pp. 32-36; 1930.
Searight, W. V., The Isabel-Firesteel coal area: So. Dak. Geol. and Nat. Hist. Survey, Rept. of Inv. No. 10, pp. 17-19; 1931.

3./ Fieldner, A. C., Selvig, W. A., and Frederick, W. H., Accelerated laboratory test for determination of slacking characteristics of coal: U.S.Bur. of mines, R.I. No. 3055; 1930.

4./ Searight, W. V., Slacking properties of So.Dak. coals: So.Dak. Geol. and Nat. Hist. Survey, Rept. of Inv. No. 12, p. 5, and Fig. 12 p. 12; 1932.

The analysis show that the moisture content is high, the range being between 27.49 and 39.8 per cent. The average is 33.18 per cent. That of the basal Ludlow-Cannonball coal is between 31.85 and 39.8 per cent and the average 35.07 per cent.

Volatile matter in the coals of the area as received ranges between 25.3 and 29.46 per cent, and dry coal ranges between 39.53 and 42.0 per cent. The coal as received averages 27.11 per cent of volatile matter, whereas the dry coal averages 40.6 per cent. The lowest percentage of volatile matter in the analysis of basal Ludlow-Cannonball coal is 31.85 and the highest 39.8 as received. The average as received is 35.07 per cent. In the dry analysis of basal Ludlow-Cannonball the range is between 39.53 and 42.0 per cent, and the average is 40.59 per cent.

Fixed carbon in all the coals of the area varies between 23.8 and 34.72 per cent as received and averages 30.41 per cent. The dry coal ranges from 43.8 up to 50.95 with an average of 45.24 per cent. The coal analysis of basal Ludlow-Cannonball as received also range between 23.8 and 34.72 per cent. The average as received percentage is 29.83. The percentages for fixed carbon in all the samples are: low, 43.8; high, 50.95; and average, 45.25. Those are for the dry analysis of basal Ludlow-Cannonball coal: low, 39.6; high, 50.95; and the average, 45.72 per cent.

Considerable variation in the ash content of the coals of the area is indicated by the analysis. The coal analyses as received for all, ranges between 6.01 and 11.29 per cent, and those for the basal Ludlow-Cannonball between 6.01 and 11.1 per cent. The coal as received averages are 9.4 and 8.77 per cent respectively. Dry analysis range between 8.82 and 18.4 per cent for all, and these extremes are from the analysis of basal Ludlow-Cannonball area coal. The averages are 14.16 and 13.69 per cent respectively.

Sulphur content of all the analyses ranges between 0.22 and 1.68 per cent as received. The average is 0.8 per cent. The dry coal shows a range from 0.32 up to 2.32 per cent. Figures for basal Ludlow-Cannonball coals as received are: low, 0.22 per cent; high, 0.96 per cent; average, 0.81 per cent. For the dry coal the percentages are: low, 0.32 per cent; high, 1.59 per cent; average, 0.81 per cent.

Heating Value:

Heating value is measured in either British thermal units(btu) or calories. The British thermal unit is most commonly used in describing the heating value of coal. A British thermal unit is the amount of heat required to raise

one pound of water one degree Fahrenheit.

The heating value of the coals of the area as determined (Table II) ranges between 5480 Btu and 7582 Btu with an average of 6902 Btu. The heating value of completely dry coal ranges between 9110 Btu and 11125 Btu, with an average of 10304 Btu. The lowest and highest heating values are from basal Ludlow-Cannonball coal, but the average is somewhat higher than all Ludlow-Cannonball. The average is 10412 Btu.

Comparison With Other Coals:

The data concerning chemical composition reviewed in the preceeding pages and tabulated (Table II) are a basis for comparison with other coals of South Dakota and elsewhere.

Moisture content is lower than that of the average Ludlow coals of South Dakota, that of the Hillen coal being much lower. Less moisture is indicated than that of the average in the Isabel-Firesteel bed in the lower part of the Hell Creek of Dewey and Ziebach counties.1 Variation from the moisture content of the Fort Union coals is slight, however.

Volatile matter as indicated by averages of dry analyses is somewhat higher than in the average of Ludlow coal in South Dakota. Average volatile matter is almost identical with that o f the Isabel-Firesteel bed of the lower part of the Hell Creek. It is somewhat lower than that of the Fort Union.

Fixed carbon as indicated by dry averages is somewhat higher than that of the average Ludlow and the Fort Union coals. The highest value in the dry analyses closely approximates the average of the Isabel-Firesteel bed, and the average is nearly 5 per cent below it.

Ash content in the dry analyses is low and in very similar in value to the Isabel-Firesteel bed, is much less than in the average Ludlow of South Dakota, and less than that of the Fort Union.

The sulphur content in dry samples averages below average Ludlow and Fort Union, but is more than that of the Isabel-Firesteel bed. The basal Ludlow-Cannonball coal, however, is only slightly more than the Isabel-Firesteel coal.

Heating value is only slightly below the Isabel- Firesteel

1./ Searight, W. V., The Isabel-Firesteel coal area: South Dakota Geol. and Nat. Hist. Survey, Rept. of Inv. No. 10, pp. 22-30; 1931.

bed and coals of Fort Union age and is well above that of the average Ludlow in South Dakota.

Compared with available analyses of other coals of the South Dakota field, the coals of the central Perkins county area are relatively low in moisture, relatively high in volatile matter and fixed carbon, low in ash, about average in sulphur and relatively high in heating value. It compares most favorably with other coals of South Dakota, North Dakota, and eastern Montana. Compared with bituminous coal, such as that of Franklin county, Illinois, water content is very high, being between three and four times as great. Volatile matter is higher and fixed carbon much lower than in bituminous coal. Ash is nearly the same in Franklin county, Illinois bituminous, and sulphur is less. Heating value as received central Perkins county coal is about half that of Franklin county bituminous, whereas the dry heating value is nearly 77 per cent that of the Illinois bituminous cited.

Roof, Floor and Overburden:

Beds overlying the coal beds of the area consist of shale, clay shale, silt and sandstone, and thin coals. Clays and shales are jointed into irregularly shaped, relatively small pieces. Shales are in many cases thinly laminated and sandy. Sands are for the most part poorly cemented. The rocks above the coal are thus not good roof material. In such a region without cheap timber, undermining is practically prohibited.

The floor of the coals of the area is chiefly hard, structureless, siliceous clay. This clay forms a satisfactory floor when fairly dry, but becomes plastic and sticky when watersoaked.

The overburden consists of the beds lying over the coals. It is mostly relatively soft. Some of the beds, particularly lignitic and carbonaceous shales, are tough and difficult to remove by the use of small scale machinery and tools. Large flat, tightly cemented concretions, several feet in diameter and a foot or more in thickness which occur in sands 10 to 15 feet above the coals, in many cases require blasting to break them up sufficiently for removal.

Overburden in the Carlson, Hafner, and Sexton mines in Secs. 17 and 18, T. 17 N., R. 13 E., ranges between 20 and 35 feet. Cover in the Hillen mine is about 20 feet, but the thickness increases rapidly to 35 feet and more behind the face. In the smaller mines very small areas only lie under less than 35 feet of cover.

Mining Methods:

Coal in the area is recovered entirely by open pit methods. Scrapers pulled by tractor or horses are used to uncover the coal. After uncovering, the coal is broken up by shooting with dynamite and black powder. In the larger mines the overburden is removed during the summer months. It is shot and hauled during the fall and winter months. In the smaller pits the owner or the owner and his neighbors uncover sufficient coal in the fall for the winter's supply.

Recommendations:

Much thin coal, two feet or less in thickness, occurs north of Grand-River-Thunder Butte divide. Although the outcrops are mostly covered by grass, soil, and slope mantle, the position of the outcrop has been plotted as closely as possible as inferred from outcrops and topography. Thin coals should also be found along the boundary between Hell Creek and Ludlow-Cannonball in T. 17 N., R. 14 E. The boundary here is concealed so that the location of the coal is indefinite. The thicker coal of the Hillen mine in SW. 1/4, NE. 1/4, Sec. 31, T. 19 N., R. 14 E., appears to beathickening and probably continues only a short distance eastward from the mine.

The coal mined in Sec. 17 and 18 continues westward from the Hafner mine in SE. 1/4, NE. 1/4, T. 17 N., R. 13 E. The outcrop, however, is concealed. Prospecting should discover minable coal west of the Hafner mine. South of the Hafner mine, the coal appears to be mostly burned, and prospecting here will probably prove unprofitable. Coal should be found along the Ludlow-Cannonball and Hell Creek contact south and east of the Carlson mine in SE. 1/4, SW. 1/4, Sec. 17, T. 17 N., R. 13 E., although the contact is entirely covered.

Gravel

Gravel occurs along Thunder Butte Creek in the area as mapped. (Plate I) The deposits are thin, mostly between two and three feet in thickness, but reaching five feet in N. 1/2, NW. 1/4, Sec. 31, T. 17 N., R. 14 E. The deposits consist of fairly clean sand, gravel, and rubble, commonly under two feet or more of silt. The deposits are small.

Conglomerate

Cemented gravel, or conglomerate, of White River age occurs in thickness up to ten feet at the top of Rocky Ridge in Sec. 22, T. 18 N., R. 13 E., and in the butte

caps in Secs. 23 and 26, T. 17 N., R. 14 E. These deposits have been used locally for coarse foundation stone. Crushed, they could possibly be used to a limited extent as gravel and for concrete aggregate.