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The Geology of

EMMONS COUNTY

North Dakota

by

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THE GEOLOGY OF EMMONS COUNTY, NORTH DAKOTA

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ABSTRACT

The Pierre, Fox Hills and Hell Creek formations of the Cretaceous period, and the Cannonball formation of the Paleocene series of the Tertiary period are exposed at the surface in Emmons County. All the formations are of marine origin with the exception of the Hell Creek. Contacts between the formation are conformable, except for channel scours in the top of the Fox Hills.

Present maps of this area show the bedrock in almost all of Emmons and adjacent counties to the east as the "Lance" formation, the lowest unit of which is now known as the Hell Creek beds. Actually, the most extensive formation is the Fox Hills sandstone, the upper beds of which may be followed for a score or more miles eastward into Logan County. The lower Fox Hills, which is divided into two sandstone members, is found to pinch out eastward.

The Breien marine member of the continental Hell Creek beds was not observed in Emmons County. This fact, together with the pattern of known outcrops of this member in Morton and Sioux counties, indicates a brief readvance of the Cretaceous sea from the south.

Field evidence is in agreement with the view that the older glacial till sheet is considerably younger than was once supposed. Several large, partly abandoned valleys in Emmons County were studied in conjunction with known channels in neighboring areas. The regional drainage pattern and other evidence suggests that: (1) Badger and Apple Creek valleys are the abandoned continuations of the pre-glacial Cannonball and Heart Rivers: (2) the old northwest-southeast valleys represent temporary ice-marginal courses of the Missouri River: and (3) the present course of the river in south-central North Dakota may have been initiated during the retreat of an early ice sheet.

Elevations on various beds were obtained with a Paulin altimeter, and a surface structure contour map was constructed. The anticlines are small, and appear to be the result of successive periods of uplift and folding. Probably all increase in folding with depth. These folds are of interest as sites for oil test-drilling. In addition, a few anticlinal noses may have closure at depth in spite of the fact that the structures are adversely affected by the regional thickening of the section. Below a depth of about 2000 feet, the subsurface section contains a number of potential source beds and reservoir beds. Regional unconformities and the possibility of eastward pinch outs of beds are briefly mentioned.

The types of ground waters, the gravel and sand deposits, and the sandstone at the top of the Fox Hills are also discussed.

INTRODUCTION

Location and Geography

Emmons County is part of the Missouri Plateau and is bordered on the south by South Dakota and on the west by the Missouri River. It is 48 miles from north to south and has an average width of 32 miles.

Except for a dissected zone two to five miles wide along the river, the "breaks of the Missouri", and an area of buttes north and east of Linton, the topography is a rolling to hilly, mature plateau. The highest point in the county is 585 feet above the Missouri River, but the average relief is usually less than 200 to 300 feet.

All the drainage in the area eventually reaches the Missouri River. Beaver Creek, with headwaters in Burnstad Lake in Logan County, is the major stream and crosses the central part of the county. In the western half of the area all streams flow directly to the river and converge toward the west-central limits of the county. Streams in the northeastern and south-central parts of the county flow beyond the borders of the area before turning westward to the Missouri River. In the southeastern quarter of the county there are a number of sizeable lake basins with interior drainage.

Grain farming is the chief industry and is dependent upon an annual precipitation of about 15 inches, most of which falls during April, May, and June. The soil is generally sandy to loamy, but heavier clay soils have formed on glacial tills in the eastern half of the county. Along the "breaks" of the Missouri River there is a limited ranching industry. Blue gamma grass which withstands the droughts that occasionally plague this region covers the area. Trees are restricted to the water courses.

Dirt roads and prairie trails follow nearly every section line, and macadamed U. S. Route 83 bisects the county from north to south. There are also several graded and gravelled east-west county highways. The area is serviced by branch lines of two railroads; the Northern Pacific, and the Minneapolis, St. Paul and Ste. Sault Marie.

Field Work

During the summers of 1950 and 1951 the formations outcropping at the surface, glacial deposits as well as bedrock outcrops, were mapped; a surface map of the geologic structure was made; and an initial study of the ground waters and of the other known resources of the county was begun.

Contacts between the formations and other data were noted directly upon air photographs. This information was later transferred to a base map prepared by the State Highway Department. Where the glacial cover is thin the topography and textures of the soils, as interpreted from the air photos, was relied upon almost soley in locating the boundaries of the various deposits. In other localities, a soil auger and water well records were used in mapping the glacial and/or stream deposits.

Elevations for the structural map were obtained with a Paulin aneroid altimeter reading to two feet. Readings were frequently checked against known elevations, and one or two check readings were taken on each elevation point used in constructing the map. If two readings were within six feet of each other, the mean value was accepted, otherwise a third reading was made. Three lines of United States Coast and Geodetic Survey benchmarks were used as reference points in the western half of the county, and other benchmarks were found along the railroads. There are no benchmarks in the county east of the railroad and control points were run in by altimeter.

The ground water inventory is based upon 250 water well questionnaires which were sent to landowners throughout the county. Approximately 70 of the most informative well sites were examined in the field; data were obtained and the depth to the water level was measured wherever possible.

Acknowledgements

The field work for this paper was done under the auspices of the North Dakota Geological Survey. Most of the field equipment, the base maps, and the aerial photographs were provided by the Survey. The writer wishes to thank Dr. W. M. Laird, State Geologist, for his many helpful suggestions and for checking some of the field work. The writer is especially indebted to Professor C. M. Nevin of Cornell University, under whose direction this report has been prepared, for valuable criticism and guidance. Mr. G. W. Smith, consulting geologist of Bismarck, North Dakota kindly visited with the author in the field and discussed several field problems. Mr. Erwin Strecker ably served as field assistant during June, 1950.

PREVIOUS WORK

The earliest work done in this area is a reconnaissance sketch map of south-central North Dakota made by A. G. Leonard[1], former

[1] Leonard, A. G., (1912) Geology of south-central North Dakota: N. D. Geol. Survey 6th Biennial Report, pp. 21-101.

State Geologist. T. W. Stanton[2] briefly noted a few exposures of a white vocanic ash bed in the vicinity of Linton.

The older glacial drift in this part of the state was described by Leonard[3] and the younger Altamont moraines, which are found in the northeastern and southeastern corners of the county were mapped by J. E. Todd[4].

Considerable geologic investigation has been done in the areas immediately west of the county. W. R. Calvert, et. al.[5] mapped Sioux County, and W. M. Laird and R. H. Mitchell[6] mapped the southern part of Morton County. The Bismarck quadrangle, which includes a few square miles of northwestern Emmons County, was studied in some detail by Leonard[7]. Heavy mineral analyses of the Fox Hills, Hell Creek and Cannonball formations were made by Marie Lindberg[8] from outcrops in the Cannonball River valley.

GENERAL GEOLOGY

The three bedrock formations found in Emmons County are sediments of Late Cretaceous age. The Pierre shale and the Fox Hills sandstone are of the last stages of a marine environment in this area. The Hell Creek beds are the initial formation of a continental environment which has continued up to the present with but one exception.

The regional dip of these formations is less than a quarter of a degree (10-20 feet per mile) to the northwest. The eastern half of the county is covered by glacial deposits.

The Pierre shale, the oldest formation in the county, is a medium to dark gray marine shale that breaks down to small chips. The most extensive outcrops occur in the lower part of the bluffs of the Missouri River, and the best exposures are found in the creek bluffs around Linton. Examination of glacial tills and well records as well as test holes made by Laird and Akin[9] indicate that the Pierre shale underlies the glacial cover in approximately four townships in the southeastern part of the county. The approximate con-

[2] Stanton, T. W., (1917) A Cretaceous volcanic ash bed on the Great Plains of North Dakota: Wash. Acad. Sci. Journ., vol 7, pp. 80-81.
[3] Leonard, A. G., (1916) The pre-Wisconsin drift of North Dakota: Jour. Geol., vol. 24, pp. 521-532.
[4] Todd, J. E., (1896) The moraines of the Missouri Coteau and their attendant deposits; U. S. Geol. Survey Bull. 144, 71 pp.
[5] Calvert, W. R., et. al., (1914) Geology of the Standing Rock and Cheyenne River Indian Reservation, North and South Dakotas: U. S. Geol. Survey Bull. 575, 49 pp.
[6] Laird, W. M., and Mitchell, R. H., (1942) The geology of the southern part of Morton County, North Dakota: N. D. Geol. Survey Bull. 14, 42 pp.
[7] Leonard, A. G. (1912) U. S. Geol. Survey Geol. Atlas, Bismarck folio (no. 181), 8 pp.
[8] Lindberg, M. L., (1944) Heavy mineral correlation of the Fox Hills, Hell Creek, and Cannonball sediments, Morton and Sioux Counties, North Dakota: Jour. Sed. Pet., vol. 14, pp. 131-143.
[9] Laird, W. M., and Akin, P. D., (1948) Ground water in the Zeeland area, North Dakota: N. D. Ground-Water Studies No. 12, 38 pp.

tact with the Fox Hills formation is shown on the geologic map by long dashed lines.

Leonard[10] mapped the bedrock in the eastern three-quarters of the county as the "Lance" formation, the lowest unit of which is now known as the Hell Creek beds. Actually the most extensive formation is the Fox Hills sandstone which forms a 25 mile wide band diagonally across the county. The formation may readily be divided into a lower series of green-gray and brown sands and sandstones, and an upper sequence of thin, gray and brown sands and shales with some thicker sandstone strata. Most of the beds weather brown or gray. Several fossiliferous and indurated sandstone ledges in this formation form erosion levels.

The Hell Creek formation consists of sands, lignitic shales, lignites, clays, and bentonites. The colors range from white to dark gray and purple-brown. Fossils are limited to silicified plant fragments and a few reptilian bones. Unlike the Fox Hills sands which commonly form flat-topped buttes, the Hell Creek beds erode to crested hills with terraced slopes. The formation crops out chiefly in the northwestern corner of the area, but a few small channel fill remnants occur elsewhere. A zone of Hell Creek beds five miles in width is largely covered by the glacial deposits from the vicinity of Hazelton to Braddock. That the Hell Creek lies beneath this covered area is demonstrated by several small outcrops southwest of Braddock on Long Lake Creek; by records of the old Edick lignite mine about two miles south of Hazelton; by shallow cuts exposing lignitic strata along the Northern Pacific railroad; and by water well records. Long dashes on the geologic map mark the probable contacts with the underlying Fox Hills sandstone.

STRATIGRAPHY

The character of the deep lying rocks in the general area has been determined by six deep oil test holes, four of which went to the granite basement. The locations of these wells and the depths are given below. Detailed logs and samples are available for study at the North Dakota Geological Survey office in Grand Forks.

(1) Carter Oil Co. stratigraphic test NE¼/NW¼, Section 22, T. 136 N., R. 83 W. Morton County, Total depth 4930 feet.

(2) Phillips-Carter Cos., Dakota No. 1 NW¼/SE¼, Section 29, T. 136 N., R. 81 W. Morton County, Total depth 7790 feet.

[10] Leonard, A. G., (1912) Geology of south-central North Dakota: N. D. Geol. Survey 6th Biennial Report, pp. 21-101.

(3) Peak-Ohlhauser No. 1 NE¼/SE¼, Section 8, T. 132 N., R. 78 W. Emmons County. Total depth 5882 feet.

(4) Roeser and Pendleton, Weber No. 1 NE¼/SE¼, Section 35, T. 133 N., R. 76 W. Emmons County, Total depth 5556 feet.

(5) Northern Ordnance Corp., Franklin Investment No. 1 NW¼/SW¼, Section 35, T. 133 N., R. 75 W. Emmons County. Total depth 5359 feet.

(6) D. J. Carter and Co., Well No. 1 SE¼/SE¼, Section 26, T. 134 N., R. 72 W. Logan County. Total depth 2279 feet.

The subsurface section in this region includes representative of all the periods of the Paleozoic and Mesozoic eras except the Pennsylvanian and Permian. The entire section thickens toward the west.

The general classification of the exposed rocks in the area is as follows:

TABLE I

Quaternary system
- Recent series
  - Alluvium and dune deposits
- Pleistocene series
  - Wisconsin outwash deposits
  - Illinoian (?) till deposits

Tertiary system
- Paleocene series
  - Ludlow-Cannonball formations

Cretaceous system
- Upper Cretaceous series
  - Hell Creek formation
- Montana group
  - Fox Hills formation
- Upper sequence—Banded and Colgate members
  - Linton ash members
- Lower sequence—Timber Lake member
  - Trail City member

Pierre formation
- Elk Butte member

TABLE II Correlation Chart of the Upper Cretaceous and Paleocene

	North Dakota	South Dakota	East Montana	South Saskatchewan
PALEOCENE	Cannonball-Ludlow fms.	Cannonball-Ludlow fms.	Lebo Shale Tullock Sandstone	Lower Ravenscrag fm.
CRETACEOUS	Hell Creek fm.	Hell Creek fm.	Hell Creek fm.	Frenchman fm. Sandstone, clay, with rare coal
(Montana Group)	Fox Hills sandstone Upper sequence and Colgate sandstone	Fox Hills sandstone Banded beds mbr.	Fox Hills sandstone Colgate mbr.	Battle fm. (bent. clay) White mud fm. (sand, clay)
	Timber Lake mbr.	Timber Lake mbr.	Marine sandstone (Horse Thief sandstone of central northern area. Lennep sandstone of south central area.)	Eastend sandstone
	Trail City mbr.	Trail City mbr.		
	Pierre fm.	Pierre fm. Elk Butte mbr. Mobridge mbr.	Bearpaw shale	Bearpaw shale

CRETACEOUS SYSTEM

Pierre Formation

The Pierre formation was named by Meek and Hayden[11] from outcrops along the Missouri River in the vicinity of old Fort Pierre in central South Dakota. It is the lower unit of the Montana group and is the oldest formation of the Cretaceous system exposed in Emmons County.

Occurrence

Outcrops of the Pierre shale occur in the lower slopes of the Missouri River valley from the state boundary northward to within three miles of Beaver Creek. Small exposures are found for about seven miles up Beaver Creek and at the bridge three miles up Sand Creek. The best outcrops, several over 100 feet thick, form cliffs in the vicinity of Linton and in Section 30, T. 132 N., R. 75 W.

As indicated on the geologic map, the Pierre shale underlies the southeastern corner of the county. Also, it probably is the bedrock beneath a gravel basin in T. 132 N., R. 77 W. and beneath a considerable portion of an old stream channel which runs from the center of T. 133 N., R. 78 W. southeastward to the Strasburg area.

Lithology

The Pierre formation of the Northern Plains has usually been decribed as a rather massive, dark gray shale contining some thick chalk zones. Six members have been recognized in South Dakota[12]. The uppermost is the brownish-gray shale and is called the Elk Butte member. Below is the Mobridge chalk member. Although a few feet of the Mobridge may occur in the lowest levels along the Missouri River most of the Pierre shale in the county, and most certainly that around Linton, belongs to the Elk Butte member.

The Elk Butte member is a medium to dark gray shale which weathers to lighter colored flakes and erodes to rounded, grass-covered knolls. The upper part consists of clay-shale seams and thin streaks of brown silt.

Many thin layers of brown and olive-green, impure bentonites (weathered volcanic ash) occur in the top ten feet or so. This material has been called "Fullers earth" in some reports. It weathers to an unmistakbble yellow, probably from limonitic impurities, and colored pellets are found scattered over the slopes. The presence of yellow pebbles in the soil is a suggestion that the Pierre shale is nearby.

[11] Meek, F. B., and Hayden F. V., (1862) Phila. Acad. Nat. Sci. Proc., vol 13, pp. 419-420.

[12] Searight, W. V., (1937) Lithologic stratigraphy of the Pierre formation of the Missouri Valley in South Dakota: S. D. Geol. Survey Report of Investigations 27, 63 pp.

Gypsum crystals and calcareous concretions also mark the upper beds. White and golden gypsum stringers fill the joints and many fine "Fishtail twins" gypsum crystals are scattered on the slopes. The concretions are massive, fine-grained, gray limestone and are usually two or three feet in diameter. They are fossiliferous and seem to occur along definite levels or zones.

Occasionally, along the river, small hills or knolls topped by Fox Hills sand are found well down on lower slopes where Pierre shale should be. Usually the beds dip rather steeply, and slipping in the underlying shale appears to be the cause. A good example of a small landslide in which the Fox Hills beds dip 70° is located in the creek valley in Secion 28, T. 132 N., R. 78 W.

Relation to Overlying Formation

In many localities in the Dakotas, the Pierre contact is gradational with the overlying Fox Hills sandstone. This transition covers several tens of feet in which the silts of the upper Pierre become more numerous and frequently weather to the yellow-bluff color of the typical Fox Hills. Where concretions are present the contact was placed at the top of that zone. These concretions are about two feet below the highest bentonite.

Thickness

The thickest section of Pierre shale is at the park one mile southeast of Linton where 135 feet of the shale is exposed. Test holes in Emmons and adjacent counties show thicknesses of 900 to 1100 feet; the Pierre shale has a thickness of 1050 feet in the Northern Ordnace well near Linton. In Corson County, South Dakota the formation is reported to be over 1400 feet thick.

Fossils

The old report on the Cretaceous fossils of the Upper Missouri Country by Meek and Hayden[13] is still standard reference for identification of Pierre and Fox Hills fossils. This report was used for most of the determinations of fossils.

The Pierre fossils were collected within a 30 foot zone near the top and from the concretions at the top of the formation. The assemblage consists of forms that have been reported from both the upper Pierre and from the Fox Hills. To avoid repetition these fossils are listed in the discussion of the Fox Hills formation.

Three characteristic Pierre fossils occur in the concretions. They are: a small **Acanthoscaphites nodosus, Gervillia recta,** and an undetermined species of **Inoceramus.** On the other hand, **Sphenodiscus**

[13] Meek, F. B., and Hayden, F. V., (1876) Report of the United States Geol. Survey of the Territories, vol IX, Gov't. Printing Office, Washington.

lenticularis and **Sphaeriola cordata,** both commonly reported as Fox Hills fossils, are also present in the group.

Correlations

The Elk Butte member of the Pierre shale is correlative with the Bearpaw shale of eastern Montana[14] (See Table II, page 7). The formation may be equal to the basal portions of the Edmonton and St. Mary River beds of central and southwestern Alberta[15].

Fox Hills Formation

Meek and Hayden[16] named the Fox Hills formation after exposures at Fox Ridge in northwestern Armstrong and southwestern Dewey Counties, South Dakota. These rocks are the upper formation of the Montana group of the Cretaceous system.

Lithology and Occurrence

The Fox Hills formation is the most extensive of all formations outcrapping in Emmons County and forms a 25 mile band northeastward across the area. The beds also crop out on a structural high in T. 136 N., R. 76 W., and a narrow zone follows the Missouri River to within five miles of the northern boundary of the county.

Generally, the Fox Hills formation divided into a lower series of green-gray and brown sands and sandstone, and an upper sequence consisting chiefly of thin gray and brown shales and sands, with several thicker sandstone zones. However, in South Dakota, Morgan and Petsch[17] recognized two members within the lower part of the formation. In Emmons County, these two members, the Trail City (older) and the Timber Lake (younger), can be differentiated, and each is described on the following pages.

Trail City Member

This member includes the basal part of the Fox Hills, and crops out along the base of the Missouri River bluffs. Exposures are frequently obscured by slump debris and vegetation. Brown to gray sandy shales, which pass upward into brown and green-gray sands, make up this member. It is 50 to 75 feet thick in the outcrops, but the cross-section (Plate III, in pocket) shows that it thins eastward. The thinning is discussed in a separate section.

Oval "cannonball" concretions consisting of a dense, blue limestone core with sandy outer layers are typical of this member. These bodies are one to two feet in diameter, are fossiliferous, and weather

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[14] Hatcher, J. B., and Stanton, T. W., (1903) The stratigraphic position of the Judith River beds and their correlation with the Belly River beds: Science, new series, vol. 18, p. 212.

[15] Russell, L. S., (1950) Correlation of the Cretaceous-Tertiary transition in Saskatchewan and Alberta: Geol. Soc. Amer. Bull., vol. 61, pp. 36-37.

[16] Meek, F. B., and Hayden, F. V. (1862) Phila. Acad. Nat. Sci. Proc., vol. 13, pp. 419 and 427.

[17] Morgan, R. E., and Petsch, B. C., (1945) A geological survey of Dewey and Corson Counties, South Dakota: S. D. Geol. Survey Report of Investigations no. 49, 53 pp.

to tan or light gray. As in the Pierre concretions, the fractures may be filled with yellow calcite. Good examples of cannonball concretions are found on stream banks in Section 27, T 133 N., R. 77 W. Another type of concretions is a lenticular mass or ledge of coarse sand cemented by silica and/or limonite, which weathers to varying shades of brown. These ledges are usually less than a foot thick and may be locally persistent.

Timber Lake Member

The upper part of the lower Fox Hills, the Timber Lake member, is composed of uncemented, fine to medium grained, green-brown and gray sands. The average thickness along the river is about 60 feet, and like the Trail City, it also thins eastward. Although an overall greenish coloration is apparent in fresh exposures at several horizons throughout the Fox Hills formation, it is most characteristic of the Timber Lake and results from a high content of green amphibole (see the analyses of Lindberg, 1944).

Much cross-bedding, numerous claystone seams, and sometimes a vermicular or mottled pattern of small, light gray silt blebs are distinctive features of the Timber Lake. Limonite, and locally calcite, have cemented the coarser sands and form three to five concretionary zones, which weather out as ledges. These sandstones are one to three feet thick and usually are cross-bedded. A number of orange-brown, limonitic claystone seams up to four inches in thick-

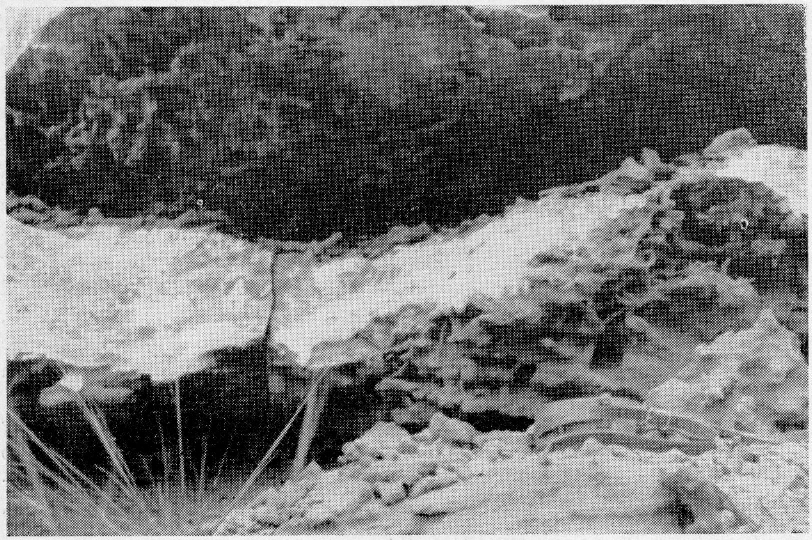

Figure 1. Halymenites sandstone ledge at the top of the Timber Lake member, Fox Hills formation.

ness occur in the sands between these zones. All the ledges contain the fossil **Halymenites** and the best and most numerous specimens are found in the upper sandstone (Figure 1). The sandstones are persistent and the intervals between beds are reasonably uniform.

The Timber Lake member is well exposed in the upper part of bluffs and canyons along the river from South Dakota almost to the Morton County line. The top ledge commonly forms a bench that extends four to eight miles from the Missouri trough.

Eastward Thinning of the Lower Fox Hills

The Trail City and Timber Lake members pinch out eastward and disappear between the southwestern corner and the center of the county (Plate III, in pocket). No recognizable beds of these members were found east of Range 78 West, but beds of the upper Fox Hills were followed as far east as central Logan County. Some eastward thinning is also evident in the upper part of the Fox Hills formation.

Thinning may be a normal change of nearshore into offshore sediments. If so, one would expect to find evidence of interfingering of the two lithologies, but none was observed. The contact of the Pierre shale with the overlying Fox Hills is gradational. However, Morgan and Petsch[18] state that, in Dewey County, South Dakota, this contact changes from gradational in the east to sharp in the west. This change gives some suggestion of interfingering.

In addition, if the surface upon which these sediments were deposited had been in the form of a broad rise or swell, a thinning of the section would occur. As indicated on the structural map, such high areas probably did exist in central and eastern Emmons County during the deposition of the Fox Hills.

Upper Fox Hills Sequence

The upper 160 to 230 feet of the Fox Hills formation is a series of gray to brown sands with thin gray shales. This rock series is generally covered along the butte slopes. It lies above the **Halymenites** bench of the Timber Lake member and is capped by a very resistant sandstone which is the topmost bed of the Fox Hills. Good outcrops of the upper sequence do occur near the river in T. 133 N., R. 78 W. Like the Pierre shales, the shaly zones in this part of the Fox Hills may slip and thus account for some butte tops which have erratic dips.

Generally, the sands and shales become more thinly bedded or banded toward the top. In some localities the rocks are green to gray, cross-bedded sands which contain either oyster banks, or exceptionally large **Halymenites** and discoidal, limonitic concretions, as in Section 13, T. 136 N., R. 77 W.

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18 Morgan, R. E., and Petsch, B. C., op. cit., p. 13.

Figure 2. Bedded, calcareous "Cannonball" concretion of the Fox Hills formation.

East of the Missouri River the banded sand and shale sequence of the upper Fox Hills is often succeeded by a white to light gray, calcareous sand. This sand is probably correlative with the Colgate sand of Montana and is considered part of the Fox Hills formation. In this area the gray sand or the banded sequence is usually overlain by the resistant Fox Hills datum sandstone which is described below. The datum sandstone can be traced westward to a point two miles beyond Solen in Sioux County where it is very thin.

In the valley of the lower Cannonball River the gray Colgate type sand shows characteristics of channel fill, and locally replaces the banded sequence. Here these beds are overlain with local disconformity by the basal lignitic shale of the Hell Creek formation. Small exposures of such contacts are located in Emmons County in the vicinity of Section 9, T. 135 N., R. 77 W.

Apparently the sandstone at the top of the Fox Hills was removed by erosion in the area west of the Missouri River. The true relationship between this sandstone and the basal Hell Creek lignitic shale is observed in Section 26, T. 136 N., R. 76 W., in Emmons County where the two beds are separated by two feet of brown sand and dark gray shale (see Measured Section 4).

The top of the Fox Hills is a resistant sandstone that caps the higher buttes in the southwestern and merges into and forms the land surface in the northwestern quarter of the county. The base of this bed was used as a datum plane for the structural map of the area. The stratum is a medium-grained, light to medium gray, bedded sandstone. It is usually four to seven feet thick although thickness up to twenty feet are known. Cross-bedding is common where the sandstone is thick. It weathers to varying shades of gray, or to a distinctive copper-brown with accompanying yellow stains. Pellets about one-eighth of an inch across are common in the sandstones as well as in the underlying light gray sands. **Halymenites** -type "tubes" are found, but these differ from the forms in other beds in that they are thinner and are predominantly vertical. Fossil wood ranging in size from purplish specks to white silicified fragments over a foot in length is common.

Along the eastern county line, a few miles north of Beaver Creek, the datum sandstone splits into two phases, which may alternate in position. One part retains the general characteristics of the datum bed but is darker gray and more quartzitic. The other is a coarse, lenticular, cross-bedded calcareous sandstone that weathers to buff color, often with some white, calcareous scale. Leaching of the cement gives it a spongy appearance. No fossils of any kind were found in this phase. Either bed may be as much as eight feet thick, and the zone within which alternation occurs is 10 to 14 feet.

Farther north, in T. 134 and 135 N., R. 74 W., only the calcareous sandstone phase is seen. The undersurface of the bed pinches and swells rapidly, and the bed apparently was deposited in depressions scoured into the poorly consolidated, fine sands below.

From Section 18, T. 135 N., R. 74 W. southwest of Section 18, T. 134 N., R. 75 W., the datum sandstone shows a marked northeastward lineation on the aerial photographs. These features are a series of straight, low swells, 150 to 200 feet wide, and they resemble giant ripples, Five sandstones interbedded with gray sands and totalling 30 to 38 feet in thickness are present at several points within this area. The top ledge is similar to the datum sandstone whereas the lower sandstones resemble the calcareous phase mentioned above. In general, the grains of these beds are coarser than those of the usual datum sandstone.

The linear features probably result from the building of a low sandbar or bank. Currents acting on such a "high" removed the finer, calcareous muds which were carried outward and accumulated, along with some sands, in hollows at slightly greater depths. This transported material formed the irregular and cross-bedded buff sandstone facies mentioned above.

Certain other beds in the upper Fox Hills are so prominent in the central and southwestern parts of the county that they merit some description. In the vicinity of Linton, Stanton[19] noted a white

[19] Stanton, T. W. (1917) A Cretaceous volcanic ash bed on the Great Plains of North Dakota: Wash. Acad. Sci. Jour., vol. 7, pp. 80-81.

volcanic ash bed which he describes as very fine-grained, mostly massive, and containing about 80 per cent volcanic glass. The writer traced this bed from points six miles north and east of the town, where its base is about 45 feet above the Pierre shale, to the extreme southwestern corner of the area where it lies 15 feet above the top of the lower Fox Hills. This bed is 25 feet thick.

Outcrops of two sea-green sandstones are found in the intermediate erosional levels around Linton and along Little Beaver and Cat Tail Creeks. The beds average about two feet in thickness and are often very hard or quartzitic. They are reported to contain "greenalite" and vocanic glass[20], and are frequently laminated with gray claystones. However, the mineral greenalite is rare in rocks younger than Pre-Cambrian. The green mineral that colors these beds occurs as well rounded microcrystalline aggregates. Most of the grains are anisotropic and are insoluble in concentrated HCl. These properties indicate that the mineral is not greenalite, but, is glauconite.

The sandstones are striking because weathering forms a black scale, and the ammonites and pelecypods stand out in relief. Gray shale galls are common and may give the rock a spotted appear-

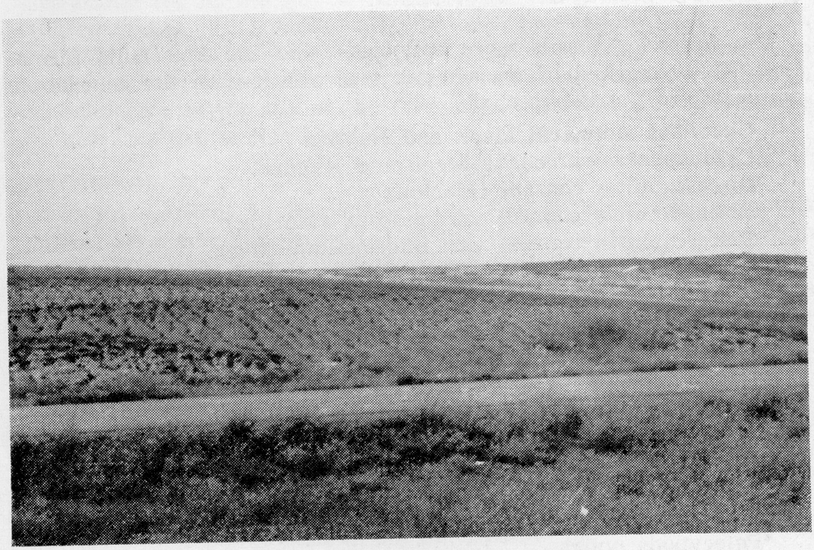

Figure 3. Small channel scour four miles north of Linton. Reptilian bone fragments were found in the dark Hell Creek beds at this locality.

[20] Stanton, T. W., op. cit.

ance. Differentiation of the two beds is difficult although the upper layer may be more platy and usually is greener. The lower bed is about 18 feet above the Linton ash bed, and the interval between the two green sandstones is 35 feet.

Relation to Overlying Formation

The basal lignitic shale of the overlying Hell Creek is conformable with the Fox Hills formation in this area. Two small channels have been scoured into the top of the Fox Hills, and a good exposure is located four miles north of Linton on U. S. 83 (Figure 3).

Thickness

Measured sections of the Fox Hills formation show a thickness of 325 feet in the southwestern corner of the county and 196 feet one mile east of Linton. It is estimated to have been about 280 feet thick near the mouth of Beaver Creek. Thus, the formation thins northeastward.

Leonard[21] gave a maximum thickness of 200 feet for the local Fox Hills. He stated that it was usually not much over 100 feet thick and mistakenly took the **Halymenites** sandstone at the mouth of Beaver Creek for the top of the Fox Hills.

Fossils

The following fossils were collected from the Fox Hills formation. Those marked by an asterisk also occurred in the concretions at the top of the Pierre shale.

Cucullaca shumardi Meek and Hayden
Cymbophera warrenana Meek and Hayden
*__Discoscaphites conradi__ (Morton)
*__Discoscaphites conradi__ var. gulosus (Morton)
*__Discoscaphites conradi__ var. intermedium Meek
*__Discoscaphites nicolleti__ (Morton)
Fasciolaria culbertsoni Meek and Hayden
Gastropods undet. (Fragments and casts of susiform, helicoid, and conical shells)
*__Gervillia subtortuosa__ (Meek and Hayden)
Halymenites major Lesquereux
*__Inoceramus__ sp.
Nucula cancellata Meek and Hayden
Nucula planimarginata Meek and Hayden
Ostrea glabra (?) Meek and Hayden
*Pelecypods undet.
*__Protocardia rara__ (?) (Evans and Shumard)
*__Protocardia subquadrata__ Evans and Shumard

[21] Leonard, A. G., (1912) Geology of south-central North Dakota: N. D. Geol. Survey 6th Biennial Report, pp. 43-44.

Pteria linguiformis (Evans and Shumard)
*__Pyropsis__ sp.
*__Sphenodiscus lenticularis__ (Owen)
*__Spironema tenuilineata__ Meek
Tancredia americana Meek and Hayden
*__Tellina scitula__ Meek and Hayden
Yoldia evansi (?) Meek and Hayden
Yoldia scitula Meek and Hayden
Bone fragments
Wood fragments

The so-called seaweed, **Halymenites,** occurs throughout the Fox Hills, particularly in the ledges of the lower part. The lower Fox Hills are further charcterized by **Cucullaea shumardi** and **Nucula cancellata.**

In the upper Fox Hills, the two green sandstones of the central and southwestern areas contain **Cymbophora warrenana** in abundance. All the **Discoscaphites** found in the Fox Hills occurred in these beds. **Protocardia rara (?)** were noted in a hard shale zone in the white volcanic ash bed. The valves are usually in juxtaposition but are spread.

Near the top of the Fox Hills formation are several oyster bands (**Ostrea glabra** (?)). These may be seen in Section 12, T. 132 N., R. 79 W. and for several miles north. Another bank is located in Section 31, T. 130 N., R. 78W. **Halymenites** are again notable in the sandstone at the top of the formation. Silicified wood fragments are also common to this horizon.

Correlations

Several workers have identified the Fox Hills formation in this general area and have traced it to the type locality. The formation is very extensive and is known in most of the neighboring states. The United States Geological Survey correlation chart for Montana tentatively correlates it with the Lennep sandstones of south central Montana.

Russell[22] correlates the Fox Hills with the Eastend, Whitemud, and Battle formations of Saskatchewan and southeastern Alberta. He further suggests that the Fox Hills is equivalent to part of the upper Edmonton of central Alberta and to part of the St. Mary River of southwestern Alberta.

Hell Creek Formation

Brown[23] gave the name Hell Creek beds to a group of continental

[22] Russell, L. S., (1950) Correlation of the Cretaceous-Tertiary transition in Saskatchewan and Alberta: Geol. Soc. Amer. Bull., vol. 61, pp. 30-31.
[23] Brown, Barnum, (1907) The Hell Creek beds of the Upper Cretaceous of Montana: Amer. Mus. Nat. Hist. Bull., vol. 23, art. 33, pp. 829-834.

strata cropping out along the stream of that name in Garfield County, Montana. About 100 feet of overlying lignitic beds were added to the original Hell Creek by Thom and Dobbin[24]. The formation was originally the basal member of the Lance but has since been separated from that formation. In North Dakota, the Cretaceous-Tertiary boundary is placed at the top of the Hell Creek Formation.

Occurrence

The Hell Creek formation is limited chiefly to the northwestern townships of the county. The beds are known to underlie the glacial cover between a few small exposures south and west of Braddock and outcrops in Section 20, T. 134 N., R. 77 W. In addition, erosional remnants occur four to five miles north of Linton and in the western part of T. 131 N., R. 78 W. Bare hillsides are common in this formation. Among the best outcrops are Coal Butte in Section 32, T. 135 N., R. 78 W. and the buttes around Section 33, T. 136 N., R. 78 W.

Lithology

Gray sands, brown to black lignitic shales, lignites, and gray bentonitic shales or clays make up the Hell Creek formation. The drab colors of these beds gave them the early name of "Somber Beds". All the Hell Creek sediments in Emmons County are of continental origin and are of limited extent.

Fine to medium-grained, calcareous, gray sands are dominant. Abundant dark minerals give the sands a "salt and pepper" appearance. The calcareous content in these sands aids rapid erosion, and cavities a few feet in diameter form in the sides of buttes. The sands often contain appreciable amounts of clay which, when of the bentonitic type, swell and form polygonal pattern of cracks. Cross-beds to three feet in height are very common. Thin partings of lignitic shale between the sand layers make the cross-bedding conspicuous.

The lignitic shales are usually brown and weather to a reddish-brown. They are thin-bedded and range in thickness from mere films to about three feet. Beds of black carbonaceous shales and lignites, less than a foot thick, sometimes occur.

Bentonitic clays are widespread in the Hell Creek formation. When freshly exposed, the clay is damp, sticky, and plastic. It has the property of absorbing moisture and thereby swelling considerably; and, upon drying, the outcrop is marked by an intricate pattern of polygonal cracks. This dried zone may form a rather strong crust over the wet clay beneath. Although the clays are seldom over six feet thick, they are fairly resistant to erosion and form rilled terraces

[24] Thom, W. T., and Dobbin, C. E., (1924) Stratigraphy of the Cretaceous-Eocene transition beds in eastern Montana and Dakota: Geol. Soc. Amer. Bull., vol. 35, pp. 481-506.

along the sides of buttes. These are easily identified in aerial photos and are an aid in mapping the formation. An unaltered volcanic ash bed three feet in thickness occurs in the basal part of the cliffs in Section 34, T. 135 N., R. 78 W.

Several types of small concretions are found in the Hell Creek sands. Most numerous are the ferruginous nodules which occur as lenses or irregular masses. Cores are either a gray, impure limestone or a siliceous shale. Weathering produces a yellow-brown, brown, or black shell which is probably exidation of iron impurities. Manganese also is present[25]. The surfaces of the concretions are somewhat varnished and show markings similar to septaria; i.e., resemble turtle shells. Other types of concretions are clusters of gypsum crystals and small spheres of sand cemented by calcite.

Cylindrical and branching concretions, which closely resemble the fossil seaweed **Halymenites,** are common in the formation. The fossil is composed of sand size materials and usually shows one color in cross-section whereas the concretions are often of finer materials and may show several color changes, each representing different weathering zones. If the rock is freshly broken, a carbonaceous film and small nodes may be detected on the surface of the fossil.

As pointed out by Laird and Mitchell[26], the Hell Creek formation characteristically erodes to steep sided buttes with a small flatland developed at the base. The poorly cemented sands and sandy clays in semi-arid climates are rapidly fluted to a maze of miniature gullies and spurs. In addition, leaching of calcareous cement creates small caverns. The caverns and gullies in and behind the face of the butte join together to isolate the columns and maintain erosion of the face at a relatively constant rate. Heavy rains coursing down the steep slopes tend to flush out and erode the embayment between the columns to the general level of the adjoining flatlands.

Relation to Overlying Formation

The Hell Creek formation is conformable with the overlying Cannonball in this part of North Dakota. The contact is placed at the top of the highest lignitic shale bed, and is accentuated by the buff color of the sands above. No good Hell Creek-Cannonball contact was found in Emmons County.

Thickness

A thickness of approximately 270 feet is obtained as the interval between the top of the Fox Hills (from the structure map) and the the highest elevation of the Hell Creek known in the county. The thickest measured section is 192 feet in Section 33, T. 136 N., R. 78 W.

[25] Laird, W. M., and Mitchell, R. H., (1942) The geology of the southern part of Morton County, North Dakota: N. D. Geol. Survey Bull. 14, pp. 10-11.
[26] Laird, W. M., and Mitchell, R. H., op. cit., p. 11.

Fossils

Numerous but poorly preserved plant remains are found in the lignitic shales. A few reptilian bones were found in the channel scour north of Linton.

Correlations

Several workers have identified the Hell Creek formation in this general area and have traced it to the type locality. The formation is known in the neighboring states.

Russell[27] correlates the Hell Creek with the following formations of the Canadian plains: the Frenchman of Saskatchewan, the uppermost of the St. Mary River in southewestern Alberta, and the top of the Edmonton of central Alberta.

TERTIARY SYSTEM

Ludlow-Cannonball Formation

The name Ludlow was given by Lloyd and Hares[28] to the continental beds which interfinger with the marine sediments named Cannonball by Lloyd[29] after outcrops along the Cannonball River. These two formations constitute the lower part of the Fort Union group, and are of Paleocene age[30].

The Ludlow formation is much like the underlying Hell Creek beds, but contains more lignites. The formation averages 20 feet in thickness west of the Missouri River in Morton County, and thins eastward. Consequently, it is unlikely that any of these beds persist into this area. None were recognized.

The Cannonball formation consists of fine, buff, marine sands and clay shales which resemble the Fox Hills sediments. The average thickness in Morton County is 300 feet, and they thicken eastward. However, the very limited presence of the Cannonball beds in Emmons County is due to the northwestward dip of the beds in this area and to the eastward slope of the land surface. Only two buttes (Sections 28 and 33, T. 136 N., R. 78 W.) are capped by at least 60 and perhaps as much as 110 feet of these beds. The upper parts of the buttes are poorly exposed, and the contact with the Hell Creek formation was not observed.

[27] Russell, L. S., (1950) Correlation of the Cretaceous-Tertiary transition in Saskatchewan and Alberta: Geol. Soc. Amer. Bull., vol. 61, p. 31.
[28] Lloyd, E. R., and Hares, C. J., (1915) The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Larmamie problem: Jour. Geol., vol. 23, pp. 523-547.
[29] Lloyd, E. R., (1914) The Cannonball River lignite field: U. S. Geol. Survey Bull. 541 G, 51 pp.
[30] Dorf, Erling, (1940) Relationship between floras of the type Lance and Fort Union formation: Geol Soc. Amer. Bull., vol. 51, pp. 223-233.
Fox, S. K., and Ross, R. J., (1940) Foraminiferal evidence for the Midway (Paleocene) age of the Cannonball formation in North Dakota: Jour. Paleontology, vol. 16, pp. 660-673.

QUATERNARY SYSTEM

Pleistocene Series

As shown on the geologic map (Plate I in pocket), much of eastern Emmons County is covered by glacial deposits, and bedrock outcrops are limited. The topography has been largely modified by continental ice sheets. Extensive outcrops are plentiful west of the areas designated as "glacial", and glacial debris, when present, is very thin and spotty. Bedrock controls the topography in that part of the county.

"Altamont" End Moraine

Young tills in the form of end moraines cross the extreme northeastern and southeastern corners of the county. In only a few square miles of the southeastern area do these tills show the typical knobby topography of end moraines, but Todd[31] traced them eastward into the main moraine in central Logan and McIntosh Counties. The tills are of late Wisconsin (Mankato) age and are part of the so-called "Altmont" moraine-complex. They are a blue gray, pebbly gumbo-clay which weathers to a buff or light gray.

Outlying Till Sheet

Large remnants of ground moraine, with a few areas of end morainic features, occur in the south-central and north-central part of the county. Scattered patches of till are found on the uplands along the Beaver Creek drainage system and along the Missouri River. Boulders occur on all the buttes in the county, including those adjacent to the river. The glacial debris continues across the river into northern Sioux and Morton Counties.

This till sheet differs from the "Altamont" end moraine in several respects other than position and topography. It is seldom more than 20 feet, and usually less than 8 feet thick. The till is a brown to grayish brown, sandy, yet somewhat plastic, clay with relatively fewer and smaller stones. Whether the slight lithologic differences between the two tills result from separate stages of deposition or from separate sources of bedrock supply is not certain at present. As shown on the geologic map (Plate I), the "Altamont" end moraine lies upon the Pierre shale and the clayey Hell Creek beds whereas the till to the west covers Fox Hills sandstones. Indeed, near Fox Hills outcrops, the western till is very sandy, and differentiation from later glacial outwash is rather difficult.

The age of this outlying till sheet has long been controversial. Leonard[32] believed that the many boulder beds found west of the

[31] Todd, J. E., (1896) The moraines of the Missouri Coteau and their attendant deposits: U. S. Geol. Survey Bull. 144, pp. 13-14.
[32] Leonard, A. G., (1916) The pre-Wisconsin drift of North Dakota: Jour. Geol., vol. 24, pp. 522.

Missouri River were the residuals after long erosion had removed the associated clays. He tentatively referred the till to the Kansan stage of glaciation[33]. Todd[34] speaks of "the Nebraskan or Kansan stage."

On the other hand, Wilder[35] stated that the older till just east of the river in central North Dakota is no more mature than the type Iowan drift. Evidence of slight erosion by running water in the areas away from the main streams in Morton County, plus the general paucity of stones in the till, suggested to Laird and Mitchell[36] that the boulder beds of that area had been deposited without much, if any, clay. In assigning this till to the Illinoian or Iowan stages, Leverett[37] pointed out the preservation of morainic features and of drift upon steep slopes. Alden[38] stressed a lack of weathering of the till and noted the presence of limestone pebbles, some of which retain glacial polish and markings, in the till. He reviewed the available data in the light of his work in this and other regions, and referred the till to the Illinoian and Iowan stages of glaciation.

As a result of reconnaissance in Emmons County and recent mapping elsewhere in the state by members of the United States Geological Survey, Benson[39] suggests that the "Altamont" complex and the outlying till sheet are of the same age; that is, of late Wisconsin (Mankato) age.

Late Wisconsin Outwash Deposits

Debris carried outward from the ice front is widespread over the county. Most of the debris in the northeastern area forms a 10 to 15 mile wide outwash sheet, whereas the materials were largely collected into distributary channels in the southern part of the county. (Only those portions of the channels which are clearly topographic are shown on the geologic map. The complete channels, including the inferred continuation of the Strasburg and Cat Tail Creek channels, are shown on the glacial sketch map.) Well records indicate that the sheet deposit is at least 60 feet thick near its source in the Kintyre area, and it thins rapidly westward. The deposits in the old channels are much thicker. A thickness of 185 feet is reported from a well at Strasburg. Present day streams have removed much of the glacial valley fill leaving remnants as terraces.

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[33] Idem., p. 532.
[34] Todd, J. E., (1914) The Pleistocene history of the Missouri River: Science, new series, vol. 39, p. 58.
[35] Wilder, F. A., (1904) The lignite on the Missouri, Heart, and Cannonball Rivers and its relation to irrigation; N. D. Geol. Survey, 3rd Biennial Report, p. 40.
[36] Laird, W. M. and Mitchell, R. H., (1942) The geology of the southern part of Morton County, North Dakota; N. D. Geol. Survey Bull. 14, p. 25.
[37] Leverett, Frank, (1917) Glacial formations in the western United States: (abstract), Geol. Soc. Amer. Bull., vol 28, p. 144.
[38] Alden, W. C., (1932) Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey. Prof. Paper 174, pp. 86-87.
[39] Benson, W. E., U. S. Geol. Survey, Personal communication.

A series of high terraces occur approximately 60 to 80 feet above the Missouri River. These levels are about a mile in width, and the inner boundary is often poorly defined. When the Missouri River cut into its bed at the end of the glacial age, the terraces remained as parts of the previous valley floor. Most of the levels are underlain by bedrock and the slope wash is not thick. Very thick cover, reportedly over 80 feet, occurs in T. 131 N., R. 79 W. and T. 129 N., R. 78 W., and it is so indicated on the geologic map. Elsewhere, the terraces more or less coincide with the Pierre pattern along the river and with the Fox Hills north of Section 35, T. 135 N., R. 79 W.

The terrace deposits are semi-sorted quartzose sands and gravels. A considerable amount of light and dark colored igneous pebbles and shale pebbles are also present. Limestone pebbles are sometimes found. The importance of these deposits as sources of sand, gravel and ground water is discussed under "Economic Geology.'

RECENT SERIES

Low River Terraces and Alluvium

The "bottom lands" or alluvial terraces of the Missouri River consist of clays, sands, and gravels deposited by flood waters. They are one to two miles wide and ten to fifteen feet above the river level. In Emmons County they lie within the 1580 and 1620 feet contour limes.

Sand Dunes

Areas of wind blown sands in the form of dunes 10 to 25 feet high are found in the old channels in T. 130 N., R. 79 W. and T. 133 N., R. 77 W. Smaller patches of drifting sands occur on T. 136 N., R. 77 W. The sands are apparently of some depth and are derived from the associated channel materials.

CRETACEOUS AND TERTIARY HISTORY

During late Jurassic and early Cretaceous times much of the continent, including the Northern Great Plains region, was slowly eroded to a gently sloping plain. At this time the sands, fine clays, and coal beds of the Morrison and Lakota formations were deposited. Slow subsidence of this lowland region resulted in a gradual flooding by shallow seas in the latter part of the Cretaceous period. Coarser sands were continuously deposited near the shores of the advancing sea to form the extensive Dakota sandstone. Finer silts and clays of the Benton formation were deposited some distance offshore, and, in the clearer waters, minute shells of lime-secreting organisms collected in vast numbers to make the chalky Niobrara beds.

Late in the Cretaceous period the region to the west of this shallow sea slowly rose, and mountains, with some accompanying vulcanism, began to form. The gradual uplift in the west caused the sea to retreat southeastward and to become increasingly shallow in the area now known as the Dakotas. It was at this time that the Pierre and Fox Hills formations were deposited.

The Pierre shales were deposited in open waters some distance from shore. Swimming organisms, such as the cephalopods, were common in these waters. The upper or Elk Butte shale member of the Pierre formation settled as a mud upon the Mobridge chalk member which had accumulated farther from shore. As shallowing progressed, the near-shore or sandy environment moved eastward and covered the muds. The sediments became more sandy and passed upward into the typical Fox Hills sandstones. An increase in the bottom-dwelling pelecypods is also noted in the upper few hundred feet of the Pierre formation. These animals lived in, or, more likely, their shells were washed into, depressions on the sea floor. There they became covered and cemented into concretions by the calcareous matter in the sediments. The change from the one formation to the other was very gradual, and the waters were relatively quiet for the thin shale and bentonite beds near the top of the Pierre are undisturbed.

During the deposition of the Fox Hills sandstones the sea had become so shallow that waves and currents left their marks, directly or indirectly, throughout the formation. Although some swimming cephalopods of the open sea persisted into these beds, the predominant fossils are the heavy, thick-shelled pelecypods and gastropods which lived with the zone of wave action. The seaweed, **Halymenites,** is characteristic of this formation. Currents sorted the materials causing cross-bedding and considerable variation in the lithology and thickness of the beds. Shells were battered and broken to be later accumulated and cemented to form fossiliferous "breccias."

Oyster banks, which are characteristic of brackish waters, are found near the top of the Fox Hills formation. The top or datum sandstone usually contains some silicified specks of wood. In places, however, many of the wood fragments are over a foot in length; elsewhere the chips are so numerous that they form mats or layers in the sandstone. This wood, along with considerable quantities of sand, was washed from the nearby land at certain times and was was rapidly buried.

The white volcanic ash bed and the two green sandstone ash beds above it prove that intensive volcanic activtity continued during Fox Hills time in the region to the west.

The succeeding Hell Creek beds were deposited as alluvial plain sediments by many streams which flowed from the old Rockies to the retreating sea. Alternating, cross-bedded lentils of sand and bentonitic clays were distributed over the low plain. The climate was warm and vegetation was abundant. Palms are found in these and in similar Tertiary beds higher in the section. The thickest lignitic shales were formed by the burial of plants which grew and/or were accumulated in the numerous lakes on the plain. Some of the trees were rapidly buried by floods of sands for the upright trunks can still be seen with the roots in the lignitic shales. Bones of large land reptiles or dinosaurs, such as **Triceratops,** are occasionally found in these beds.

Continental sediments were deposited until middle Tertiary (Oligocene) time for beds of this age are found in western North Dakota. The thickness of the lower Tertiary section indicates that these sediments once extended considerably east of the present limits. Volcanic ash beds were laid down at several horizons in this rock section.

The sea was not far removed from south central North Dakota during that time, and two limited readvances of the marine environment occurred. At a few places in Morton and Sioux Counties a thin, marine (probably brackish water) member lies about 20 feet above the base of the Hell Creek[40]. The member is called the Breien and consists of two gray sands separated by a gray bentonite. Its maximum thickness is 31 feet. The only known outcrops show a narrow north-south trend. The member was not recognized in Emmons County, but sections exposing the basal Hell Creek beds are few. These facts point to an invasion from the south by a small arm of the sea.

Recurrence of marine environment, represented by the Cannonball formation, was of sufficient duration to allow the accumulation of several hundred feet of sediments. The Cannonball sea advanced generally westward, but the distribution of the outcrops is such that a more certain direction cannot be determined.

North Dakota was eroded throughout late Tertiary and earliest Pleistocene time. Most of the rocks were weakly resistant, and intermittent uplifts caused rapid dissection. At least 1000 feet of lower Tertiary beds were stripped from this region[41]. Three, and perhaps four, benches were formed locally upon the resistant sandstones at the top of the lower and in the upper Fox Hills.

RECENT HISTORY

At first glance the drainage pattern of central and southern Emmons County appears to be peculiar, since the streams flow northwest against the flow of the Missouri River (see Figure 4). For

[40] Laird, W. M. and Mitchell, R. H., (1942) The geology of the southern part of Morton County, North Dakota: N. D. Geol. Survey Bull. 14, pp. 14-15.
[41] Fenneman, N. M. (1931) Physiography of western United States, McGraw-Hill Book Co., New York, p. 75.

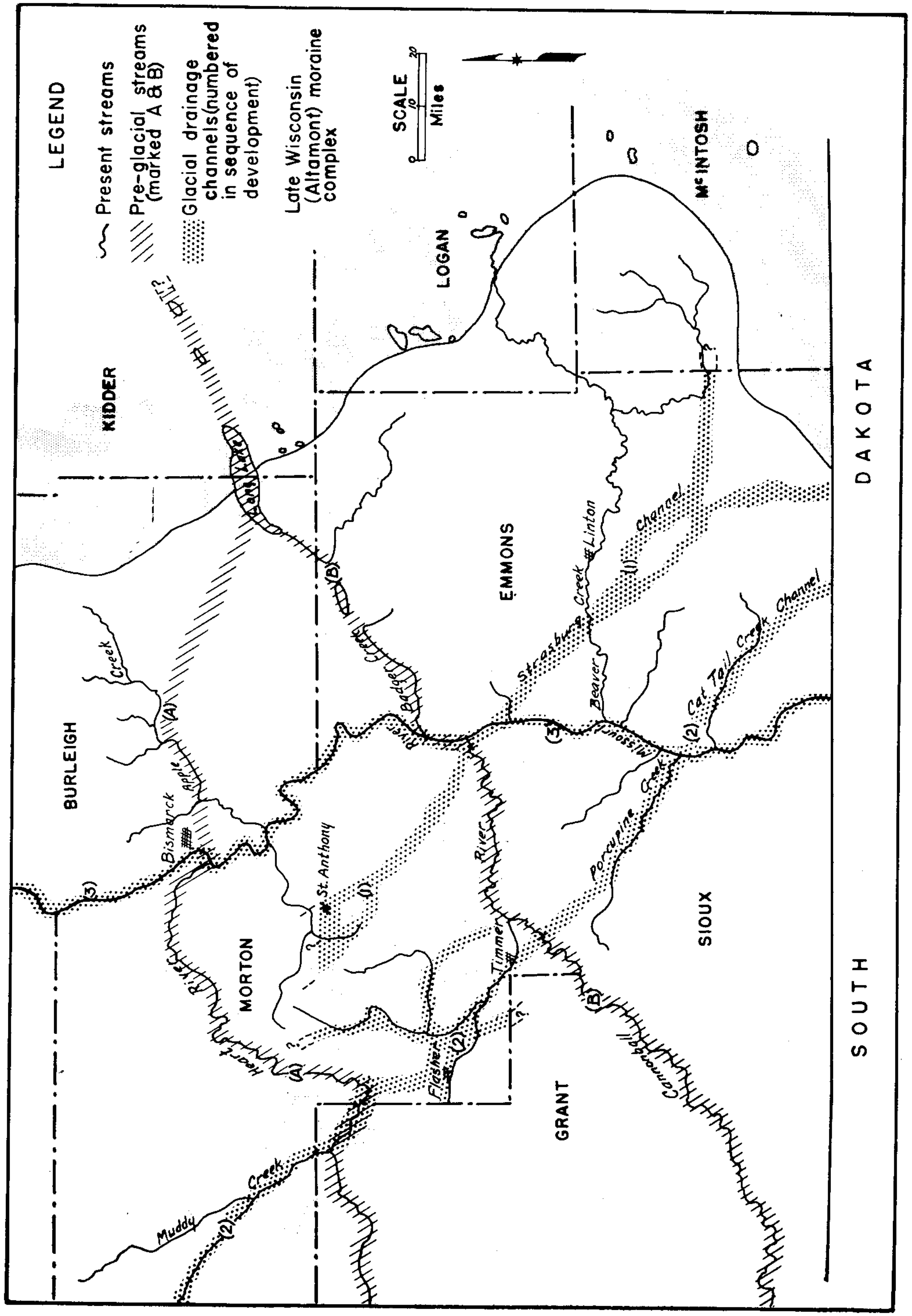


Figure 4. Regional sketch map of pre-glacial and glacial drainage in south central North Dakota.

example, Little Beaver and Cat Tail Creeks flow northwestward for many miles before making a sharp turn into the river. Also, the tributaries of Beaver Creek, with but one exception, enter from the north. This drainage pattern is probably the result of glaciation.

The Missouri Plateau slopes to the east, and it is probable that the pre-glacial Missouri River left its present course just east of Poplar, Montana, and continued northeastward to Hudson Bay. The present lower course of the river is thought to be the result of damming by an ice sheet which advanced from the northeast. The river was diverted, and cut the present channel while more or less following the ice margin southward. Todd and Alden discuss this theory.[42]

On the other hand, Leonard[43] cites thick glacial fill and an area of till in the valley of the Missouri River as evidence that the river pattern is of Tertiary age throughout North Dakota. In the writer's opinion, the difficulty of explaining a river that flows transversely to the slope of the plateau for hundreds of miles makes untenable a pre-Pleistocene origin for the present course of the lower Missouri River. Also, the old abandoned valleys in this area are best explained in conjunction with a Pleistocene age for this part of the river.

As shown on the regional glacial sketch map (Figure 4), the pre-glacial Heart and Cannonball Rivers flowed eastward to the James River (?) via the old valleys of Apple (A) and Badger (B) Creeks. These old channels, like others on the sketch map, are deep, usually about two miles wide, and contain little present day drainage.

In addition to a regional eastward slope of the land, the junction of the channels at Long Lake also suggests an eastward course. According to Leonard[44] test drilling along the Missouri River at Bismarck found up to 125 feet of glacial fill with bedrock at an elevation of 1545 feet. A well at the state penitentiary (which lies between the 1650 and 1700 contour lines) went through about 200 feet of glacial debris in Apple Creek and found bedrock between elevations of 1450 and 1500 feet. Thus, the bottom of Apple Creek valley appears to be below that of the Missouri River, and the old valley could hardly have been a tributary to the river.

The Strasburg (1) and the Cat Tail Creek (2) channels of Em-

[42] Todd, J. E., (1914) The Pleistocene history of the Missouri River: Science, new series, vol. 39, pp. 263-274.
Todd, J. E., (1923) Is the channel of the Missouri River through North Dakota of Tertiary origin?: Geol. Soc. Amer. Bull., vol. 34, pp. 469-493.
Alden, W. C., (1924) The physiographic development of the northern Great Plains: Geol. Soc Amer. Bull., vol. 35, pp. 385-424.
Alden, W. C., (1932) Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol Survey Prof. Paper 174, 130 pp.
[43] Leonard, A. G., (1916) Pleistocene drainage changes in western North Dakota: Geol. Soc. Amer. Bull., vol. 27, pp. 295-304.
[44] Leonard, A. G., (1912) Geology of south-central North Dakota: N. D. Geol. Survey 6th Biennial Report, p. 63.

mons County are continuous with abandoned valleys of Morton County which have been described by Leonard, and Laird and Mitchell[45]. (The position of Porcupine Creek valley in Sioux County is partly inferred. It makes a sharp break in the topography just west of the river, and was followed as far as aerial photographs were available.) These valleys have been described as pre-glacial, but they are more like intimately associated with glaciation of this region.

An early ice sheet is known to have advanced 40 to 60 miles west of the Missouri River. The ice blocked all pre-glacial streams flowing eastward and diverted them southeastward along the ice margin. Wherever the ice sheet remained stationary for a time, waters from the diverted streams, as well as from the melting ice, cut a deep channel system into the bedrock. Thus, the old Missouri River was turned from its course in west central North Dakota, and for a time flowed through these old valleys. If any moraine was deposited by the ice at these "stopping places", it was overridden and destroyed. There is some evidence that only small or moderate amounts of till were deposited by the earlier ice sheet. As the ice withdrew, melt waters scoured shallow, poorly defined discharge channels, some of which lead to the main valleys in southwestern Morton County.

The course of the present Missouri River in the area south of Bismarck was probably determined when the retreating ice front halted for a considerable period of time. Later, when the ice had moved farther eastward, glacial debris was carried through the Apple Creek, Badger Creek, and Strasburg channels into the Missouri River trough. The Beaver Creek distributary formed at this time.

As mentioned on page 21 the late Wisconsin ice sheet deposited a large end moraine-complex ("Altamont") which forms an arc through central Logan and McIntosh Counties and which touches the two eastern corners of Emmons County. Melt waters again poured glacial debris down the old valleys, including Beaver Creek, and into the Missouri River. The river and old channels thus gained additional filling. Perhaps a readvance of the ice, subsequent to the formation of the Missouri River trough in this area, would better explain the thick glacial fill. However, because only one ice advance is known west of the river, and because the fill is reported to consist of boulders and gravels, it seems that the above interpretation fits the data.

Much of the glacial material in the northwestern part of Emmons County forms an outwash sheet deposit, which almost buries the end moraine. A few small melt water distributaries crossed this area, and they are responsible for the more or less parallel northern

[45] Leonard, A. G., (1916) Pleistocene drainage changes in western North Dakota: Geol. Soc. Amer. Bull., vol. 27, p. 299.
Laird, W. M. and Mitchell, R. H., (1942), op. cit., pp. 40-41.

tributaries of Beaver Creek. Melt waters from the southern part of the county were intercepted by the old Strasburg channel with the result that Beaver Creek has only one sizeable southern tributary (T. 131 N., R. 74 W.). This tributary was probably part of the old Strasburg channel system and flowed due west to a point north of the village of Strasburg. The eastern part of the old channel was buried by glacial outwash from the late Wisconsin ice sheet. Small distributaries flowed northward across this area and entered Beaver Creek. One of these streams formed the present north flowing tributary.

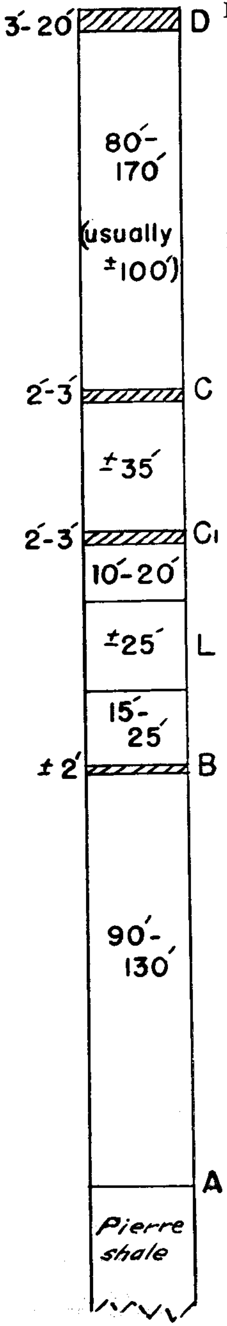
STRUCTURAL GEOLOGY

The datum for the structural contour map is the base of the sandstone at the top of the Fox Hills formation. A few points were taken on other horizons within the formation and were raised to datum (see Figure 5). For instance, the upper laminated, green sandstone in the upper part of the Fox Hills (marked "C" on the map) was used locally in the southwestern quarter of the county. Along the Missouri River it was ncessary to read on the uppermost **Halymenites** sandstone ("B"). in the south-central area an attempt was made to obtain elevations where the change from Fox Hills to Pierre lithology ("A") could be estimated from water well records.

Emmons County is located on the southeastern flank of the Williston Basin. The regional strike of the bed is northeast-southwest, and the northwestward regional dip averages 10 to 20 feet per mile, although dips up to 50 feet per mile are common. Regional structure contour maps[46] based upon scattered elevations on the Dakota sandstone indicate uniform dips for this area. The beds are seen to dip gently and, from the limited data available, rather uniformly northwestward. The general section (from the basement complex up through the Fox Hills) thins eastward from a thickness of 7200 feet or over in Morton County to about 5600 feet in central Emmons County.

Whether or not broad folds are present of this flank in North Dakota can be determined only after further detailed field work and test drilling has been done. Widespread and sometimes thick glacial deposits have hindered surface structural work in the areas east of Emmons County. A clearer picture of this portion of the Willis-

[46] Darton, N. H., (1909) Geology and underground water of South Dakota; U. S. Geol. Survey Water Supply Paper 227.
Ballard, Norval, (1942) Regional geology of the Dakota Basin: Amer. Assoc. Pet. Geol. Bull., vol. 26, pp. 1557-1584.
Laird, W. M., and Towse, D. F., (1951) Stratigraphy of North Dakota with reference to oil possibilities: N. D. Geol. Survey Report of Investigations no. 2 (revised 1951), Sheet 2.



D Light to medium gray sandstone containing plant fragments to 1' in length. Often weathers to copper-brown color. Weaker zones or local gray sand below weathers to pellets.

Brown sands with thin gray shales.

C Green and gray laminated sandstone. Weathers to sea-green and black. Fossilferous.

Brown sands.

C1 Banded green and gray sandstone. Poor sea-green weathering; locally weathers to rose-brown. Few fossils.

Brown sands.

L White, massive volcanic ash.

Brown sands with shale partings.

B Coarse, limonitized sandstone containing abundant **Halymenites.**

Gray to greenish-brown cross-bedded sands with rusty concretionary ledges every 6'-15'. Fewer **Halymenites.** Thin claystones and limonitic seams in upper part. Spheroidal sandy limestone concretions near base.

A Medium gray shale becoming sandy near top.

Figure 5. Columnar section of the Fox Hills formation. Horizons used in making the structure maps are noted by letters.

ton Basin has probably been obtained from geophysical surveys which have been carried on here from time to time, but this information is not available to the North Dakota Geological Survey.

Surface mapping in South Dakota indicates that dips on this flank of the basin are probably not so uniform as is generally supposed. A structural contour map by Ward[47] shows a 30 mile wide anticline plunging northwestward in Corson and Dewey counties. This fold was mapped as far east as the Missouri River, and a 20 mile continuation of folding having this trend would bring it to the south-central part of Emmons County. Morgan and Petsch[48] also mapped parts of Corson and Dewey Counties. They found that the regional northeastward strike of the beds, as shown on older maps, is modified by a sharp change to an approximately east-west strike. These workers also mention a structural terrace or flattening of the dip[49] that trends slightly east of north in the area just south of Emmons County.

The structural contour map of Emmons County (Plate II) shows several small anticlines which have surface closures between 30 and 80 feet. The two folds in T. 133 N., R. 75 W., and T. 133 N., R. 76 W. have been unsuccessfully tested (see list of test wells on page 5-6), but they are still of interest. Although structures in western North Dakota generally strike north-south or west of north, these two folds in the central part of the county strike considerably east of north. They are on the trend mentioned above and may be a continuation of the folding mapped in South Dakota.

Similarly, recent magnetic mapping in north-central North Dakota discovered anomalies which run in a general northeast-southwest direction[50]. Laird[51] has suggested that the basement beneath at least part of the Williston Basin may be a continuation of the northeast-southwest trending Pre-Cambrian structures of Minnesota.

On the other hand, it has been mentioned above that most other structures in western North Dakota strike north-south or west of north. The folds in southern Morton County[52] and the major portion of the Nesson anticline trend roughly north-south. The Baker-Glendive anticline in southeastern Montana, the diverging nose at the southern end of the Nesson anticline[53], and a subsurface Devonian

[47] Ward, Freeman. (1925) The structure of western South Dakota: S. D. Geol. and Nat. Hist. Survey, Circular 25.
[48] Morgan, R. E., and Petsch, B. C., (1945) A geological survey of Dewey and Corson Counties, South Dakota: S. D. Geol. Survey Report of Investigations No. 49.
[49] Idem. p. 43.
[50] Kohanowski, N. N., (1952) Magnetic map of Rolette and Towner counties and adjacent areas: N. D. Geol. Survey, Report of Investigation No. 6, Plate 1.
[51] Laird, W. M., (1952) The Williston Basin in North Dakota: Oil in Canada, March 17, p. 19.
[52] Laird, W. M., and Mitchell, R. H., (1942) The geology of the southern part of Morton County, North Dakota: N. D. Geol. Survey Bull. 14, Plate II.
[53] Nevin, C. M., (1946) The Keene Dome, northeast McKenzie County, North Dakota: N. D. Geol. Survey Bull. 21, Part 1, Plate I.

uplift in the Burleigh County area[54] all strike northwestward. Further, a probable fault with an approximately east-west strike is known in central Kidder County; the beds dipping steeply to the northeast against the regional dip.

Although the present evidence is inconclusive, it seems not unlikely that the trends just cited are controlled by the northeast southwest Pre-Cambrian structures and associated cross-faults[55]. Little is known of faults within the North Dakota portion of the basin. However, Lyons[56] gives geophysical evidence for a fault along the steep western flank of the Baker-Glendive anticline, and the split axis at the southern end of the Nesson anticline is suspect.

All the small folds in Emmons County are probably the result of differential and intermittent uplift, or, more logical for a basin area, of differential subsidence. During regional adjustments, some areas would rise faster than others, or, in the case of general downwarping, would lag behind. Undoubtedly these movements were accompanied over much of the region by faults in the basement and older Paleozoic rocks.

Successive periods of movement would cause an increase of folding and closure with depth. The more extensive uplifts in this region are marked by unconformities at the base of the Lakota, Ellis, and Spearfish formations. The most recent movements were associated with the last phases of Rocky Mountain deformation during the Tertiary.

As pointed out by Nevin[57], areas of low regional dip are often charcterized by supratenuous folds which are not associated with clearly defined structural depressions or synclines. This statement describes the structure of Emmons County and likely most of the Williston Basin as well. Such folds usually show a local thinning over the crest. An overall variation in thickness of about 100 feet is known in the Fox Hills formation, but a change of perhaps less than 50 feet is more common. Part of the surface structural irregularities may be attributed to this variation. If so, the beds would most likely be thinnest over the folds with the result that the surface closure would be minimized.

The several anticlinal noses in the southwestern part of Emmons County should be mentioned. At the surface, a later regional dip tends to change the symmetry of folds and to open them in a direction opposite to the regional dip. Thus, the noses, which plunge in

[54] Towse, Donald (1952) Preliminary report on the sedimentational history of North Dakota: Paper presented at February, 1952 meeting of Amer. Assoc. Pet. Geol., Salt Lake City, Utah, p. 6.

[55] Laird, W. M., (1952) The Williston Basin in North Dakota: Oil in Canada, March 17, 1952, p. 20.

[56] Lyons, P. F., (1950) A gravity map of the U. S.: Bull. Tulsa Geol. Soc., vol. 18, pp. 33-43.

[57] Nevin. C. M., (1949) Principles of structural geology: John Wiley & Sons, Inc., New York, pp. 50 and 65.

the same direction as the regional dip, are opened to the southeast. In addition, regional thickening to the northwest would tend to open these folds with depth to the southeast. This would further reduce the closure of these small anticlinal noses with depth.

Oil Possibilities

All petroleum producing areas have three things in common; source beds in which the oil originates, permeable rocks through which the oil migrates and in which it accumulates (reservoir rocks), and suitable traps which halt the migration and make commercial production possible.

Possible source beds in the region include the gray shales of the Colorado group, which have an overburden of about 1300 feet, and the black shales in the Ellis and Spearfish beds. Drilling depths to these black shales are from 2773 to 3100 feet. Oil may also have formed from marine beds of the deeper Paleozoic section, with the probable exception of the Cambrian. The most extensive source beds of the Paleozoic are limestones and dolomites, but the Heath and Englewood formations contain some bituminous shales.

Permeable sandstones, and limestones with interconnecting solution channels, are the usual reservoir rocks. Such beds may be folded to form an oil trap; or their permeability may end or pinch out; or they may be truncated by an unconformity and sealed by an overlying tight bed. In addition to the possibility of folds as oil traps, sedimentation and stratigraphic traps may be more important in Emmons County since it is on a flank of a large structural basin. In general, the magnitude of unconformities and the number of pinch outs of beds increase toward the outer flanks of large basins. Also, only moderate depths need be drilled to test the possible producing horizons on the flanks.

The shallowest possible reservoir strata are the Muddy (Newcastle) and Dakota sandstones, both of which are aquifers and are known to be lenticular. The water from the Dakota in the southeastern part of the state often carries some gas in it. Sands with good porosity and permeability are found in the Ellis formation.

The Kibbey sandstones are reported to be irregularly permeable, and solution breccias are known in the Charles formation. These reservoir conditions are likely to give a number of small, separate traps. A Shell Oil Company well at Richey, Montana has recently found oil in the Charles formation. The Madison limestone is oolitic to fragmental and often shows pronounced permeability in the upper part. These beds produce oil in Williams County and in southwestern Manitoba. Reef-like beds and good permeability occur in the Winnipegosan dolomite of the Devonian. The Stonewall limestone limestone is known to be porous and may have reef-structure. Finally, the Winnipeg sandstone is one of the most permeable zones in the section, and it is reported to pinch out on the eastern flank of the Williston Basin.

The larger unconformities known to occur in North Dakota are given on page 32. Whether or not all these unconformities underlie Emmons County the writer does not know. Well logs indicate that the Spearfish and Dakota formations are irregular in thickness, and that the uppermost Mississippian and Devonian sections thin rapidly eastward in the central part of the county. Both features may be the result of considerable erosion.

GROUND WATER AND ECONOMIC GEOLOGY

Ground Water

Simpson[58] compiled data on the ground waters of North Dakota. Although no figures are available for Emmons County, analyses of water from adjacent areas indicate that all producing units within the county generally contain moderately hard water. Many such waters are satisfactory for domestic use, and a number of localities in Emmons County do enjoy soft water. Water with a calcium-magnesium-iron content or 'hardness" up to 150 parts per million is suitable for most purposes, and those with less than 1000 to 1500 parts per million of dissolved solids, such as the sodium and potassium alkalis, are not objectionable for drinking.

By and large, Emmons County is fairly well endowed with ground water. Glacial gravels and sands contain the larger supplies of the area; and, along the Missouri River and in the southwestern quarter of the county where the supply from the bedrock is poor, the alluvial fill of the major valley may be tapped. The Dakota sandstone lies over 2500 feet below the surface and consequently is not utilized.

The most satisfactory and most easily obtained water in the county comes from the sands and gravels of the glacial channel and outwash deposits. It is generally low in dissolved minerals, but may be hard, especially where wells approach bedrock. Wells are dug or augered to an average depth of 25 to 30 feet, and the supply is usually adequate throughout the year.

Sandstones of the Fox Hills produce both soft and hard waters which contain an average mineral content of 1400 parts per million. Drilling depths range from 40 to 210 feet and the supply is usually abundant. This formation is most widely utilized in the central and northwestern parts of the county. Some outcrops of these beds have been badly dissected, and even isolated, by erosion and so do not

[58] Simpson, H. E., (1929) Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, 312 pp.

produce much water. One low pressure artesian flow is known to reach the surface.

The other rocks of the county are generally poor sources of water. The Hell Creek formation resembles the Fox Hills both in the quality of water and in the problem of isolation of areas too small to be self-sustaining sources of water. Also, the lenticular character of the beds makes the location of water difficult and the adequacy of supply uncertain. The few wells in the area of Hell Creek outcrops are 190 to 220 feet deep and may actually be tapping the Fox Hills beds.

The Pierre shale produces water only from sand lenses or from jointed horizons, and drilling into this formation is not generally satisfactory. Wells to 240 and 310 feet were drilled on one farm without the slightest success. A rather surprising number of wells, 35 to over 160 feet deep, have been drilled in the southern corners of the county, but most probably obtain their water from the basal Fox Hills or from gravels at the base of the glacial tills. Nevertheless, some wells are definitely known to penetrate the Pierre shale for some tens of feet. The water from this formation is hard and highly mineralized. It is often bluish or yellowish in color, and an oil film may form.

Water from the glacial clay-till is limited almost entirely to lenses of gravels within or to "quicksands" at the base of the till. Thus, the depths to water, and chances of success, and the adequacy of suuply are extremely variable. The water is commonly very hard and bitter.

Lignites

Old reports on the lignites of the state mention occurrences in Emmons County, but only a single bed near the base of the Hell Creek formation was observed. The bed is about two feet thick and is locally sandy. An abandoned mine tunnel is found in Section 32, T. 135 N., R. 78 W., and a pit is reported to have been operated two or three miles south of Hazelton.

Construction Materials

Most gravel pits of the county are located in terraces along the old glcial distributaries, but some are in the outwash sheet of the Kintyre area. The pits geenrally contain beds of fairly well sorted gravels in which pebbles less than an inch in diameter predominate. Sand layers up to 18 inches in thickness are infrequent and are of small extent. The most abundant sand deposits are found in the dunes area. Pebble-free sands as well as gravels should occur over 25 square miles of the old channel flat south and southeast of Linton.

The top sandstone of the Fox Hills is a source of cut or block stone in North Dakota, and it has been used for buildings at Linton and elsewhere within the county. Good sites for quarrying this stone are where the large slump blocks are observed for, at such places, the sandstone is apt to be thickest, well cemented, and relatively unjointed.

Miscellaneous

Some of the bentonitic clays of the Hell Creek were sampled, and most of these seemed to be of the nonswelling type. Further tests may prove them to be of use as a bleaching agent. However, these clays are not of sufficient quantity in this county to be of much interest.

The white volcanic ash bed, which outcrops in the southern half of the county, contains 80% volcanic glass and 15% quartz and feldspar and might have a use as an abrasive or scourer.

APPENDIX

Detailed Sections

The following measured sections illustrate the nature of the formations and members described in this report. Measurements are given to the nearest foot.

Section 1

NE¼, Sec. 12, T. 129N., R. 79W

(The top of the 15 to 20 feet thick datum sandstone is found east of and about 150 feet above the top of this section).

	Feet
Fox Hills formation	
1. Volcanic ash: light gray becoming darker and sitly near base	20
2. Covered slope	30
Timber Lake member	
3. Sand: brown, bedded	15
4. Sandstone: green-brown, cross-bedded, "salt and pepper", few large **Halymenites**	2
5. Sand: green-brown	6
6. Sandstone: brown, few poor **Halymenites**	1
7. Sand: brown	5
8. Sandstone: brown, few poor **Halymenites**	2
9. Sand: brown	4
10. Sand and shell zone: gray-green, coarse sand concretions; **Cucullaea, Sphenodiscus**	2
11. Sand: brown	19
Trail City member	
12. Sandstone: gray, concretionary	2
13. Sand: brown	4
14. Sandstone: gray, concretionary	1
15. Sand: brown	14
16. Sandstone; heavy cemented with limonite, very irregular	1
17. Sand: brown	7
18. Sandstone: gray	2
19. Sand: gray and brown, bedded "cannonball" concretions in middle of zone	24
20. Gentle slope; covered	20
Total thickness of exposed Fox Hills	181

Pierre formation

21. Gray shale; about 175 feet down to the Missouri River.

Section 2

SW¼, Sec. 9, T. 132N., R. 76W.

	Feet
Fox Hills formation	
1. Sandstone: light to medium gray, bedded, coarse-grained; plant stems up to three feet in length; local masses of stems and shale galls cemented by limonite; sandstone weathers to gray and copper-brown	8
2. Sand: brown and gray, medium-grained, bedded; thin olive shale seams and weak ledges	40
3. Covered slopes; probably brown sands	47
4. Sandstone: gray and green, banded; weathers to sea-green and black, locally to rose-brown. **Cymbophora** found in places	3
5. Sand, brown, bedded	36
6. Sandstone, gray, banded and platy; weathers gray with some slight greenish cast; few specks of woody matter	4
7. Sands and shales: olive, fine-grained sands with some shales	14
8. Volcanic ash: light gray, blocky to platy	22
9. Sand: brown: possible weak sandstone ledges	16
10. Covered valley slope	20
(Section continued at cliff south of Beaver Creek.)	
11. Sands and shales: banded sequence; weathers to buff	6
Total thickness of exposed Fox Hills	216
Pierre formation	
12. Shale; gray, some yellow "Fuller's earth" veinlets; weathers to buff chips	2
13. Shale: gray; thin olive bentonites in upper twenty feet; gypsum crystals and sulfur stringers noted on upper slopes; limestone concretions up to three feet thick in diameter and containing ammonites, pelecypods, and some gastropods mark the top of this zone	140
Total thickness of exposed Pierre	142

Section 3

NE¼, Sec. 35, T. 133N., R. 74W.

	Feet
Fox Hills formation	
1. Sandstone: buff, very calcareous, coarse-grained platy; upper part cross-bedded, sandstone locally split by a foot of loose brown sand, or it may be heavily cemented and stained a dark brown by limonite	6
2. Sand: brown, bedded	15
3. Sandstone; light gray, but slightly colored by red and yellow grains in places, quartzitic; locally banded; plant stems to two inches across	2
4. Sand: very light gray, coarse	4
5. Sandstone: poorly cemented, ferruginous layer	1
6. Sandstone: light gray, quartzitic, small cross-beds; gray, calcareous sands which weather to pellets found below	2
Total thickness of exposed Fox Hills	30

Section 4

NW¼, Sec. 26, T. 136N., R. 76W.

	Feet
Hell Creek formation	
1. Sands: dark green-brown, bedded	3
2. Sands: brown and olive sands with gray shale partings	3
3. Sands: dark gray, clayey, with limonite and black lignite blebs: weathers to medium gray and with polygonal cracks	2
4. Sands: light brown and gray; upper foot is a distinct green	4
5. Shale: chocolate, fissle, carbonaceous; weathers to red-brown	1
6. Shale: dark gray, carbonaceous partings and plant chips; weathers to light gray with some yellow stain and with polygonal cracks	1
7. Sand, brown	1
Total thickness of exposed Hell Creek	15
Fox Hills formation	
8. Sandstone: gray, medium-grained, locally calcareous; contains a number of plant stems; weathers to a marked orange-brown with some yellow stains and white calcareous scale	3
9. Sand: light gray, calcareous, with several thin carbonaceous seams; weathers to pellets	7
10. Sands: brown and gray, bedded	15
Total thickness of exposed Fox Hills	25

Section 5

Sec. 32, T. 135N., R. 78W.

Hell Creek formation	Feet
1. Shale: dark gray; channeled by dark till	20
2. Sand: brown, banded, with few gray sand seams, some carbonized plant blebs	5
3. Shale: dark brown, carbonaceous	2
4. Sand: gray, clayey, with carbonaceous partings; upper two feet weathers with polygonal cracks	9
5. Shale: brown, carbonaceous; several black lignitic partings in top foot; weathers light gray and flaky	9
6. Sands and shales: brown; with carbonaceous partings; weathers red-brown and flaky	6
7. Shale: olive-brown, flaky; with thin films of pulverized plant matter	5
8. Sand: gray, fine-grained, fluted; weathers white; some gypsum.	16
9. Sands: brown and gray, medium-grained; plant stems to three inches in length; thin limonitic sandstone layers and fluting in lower half	15
10. Clay: gray, bentonitic; forms narrow terrace	4
11. Clay: gray, spotted with limonite stains	3
12. Clays: gray bentonitic; few limonitic concretions at base	3
13. Sand: yellow-brown, banded, with carbonaceous sale partings	9
14. Shale: carbonaceous	1
15. Sand: yellow-brown, carbonaceous films	5
16. Slumped interval	28
17. Sand: brown, with cylindrical limonitic concretions; becoming cemented near base	6
18. Lignite: hard, black, some sulfur (?) staining (exposed in old mine tunnel on east side of the butte.)	2
Total thickness of exposed Hell Creek	148

Section 6

SE¼, Sec. 28, T. 136 N., R. 78W.

Cannonball formation	Feet
1. Sandstone: buff, platy, ferruginous	1
2. Sand: green-brown; weathers buff	7
3. Sand: gray, coarse-grained, massive; weathers buff; upper foot is cemented by limonite	11

4. Concretionary zone; ferruginous sandstone masses with undulating upper and lower surfaces; psuedo-spheroidal weathering	2
5. Sand: brown, moderately consolidated, some plant chips; base not exposed	38
Total thickness of exposed Cannonball	59
6. Covered interval ...about	65
(Section continued at NE¼, Sec. 33, T. 136N., R. 78W.)	
Cannonball beds (?)	
7. Sands: gray and brown, banded ...at least	20
Hell Creek formation	
8. Clay: dark gray, weathers light gray	1
9. Shale: carbonaceous	2
10. Sand: brown	5
11. Sandstone: brown, banded, with many carbonized wood specks; weathers cream	4
12. Sand: brown, with thin coarse ledge near middle	28
13. Shale: dark gray, carbonaceous, with thin black lignite and lignitics and at base	4
14. Clay: gray, sandy; weathers white	4
15. Sands: gray and brown, soft, cross-bedded fifteen feet above the base; much of this zone is badly slumped	50
16. Clay: bentonitic, plastic, gray; weathers to polygonal cracks; forms narrow bench	4
17. Gray sands, and gray and olive shales: single layers up to four or five feet thick; local benches; much slumping	72
18. Shale: carbonaceous, locally sandy, black iron nodules	2
19. Clay: gray, slightly bentonitic	6
20. Shale and sand: corbonaceous	4
21. Sand: gray, soft	6
Total thickness of exposed Hell Creek	192

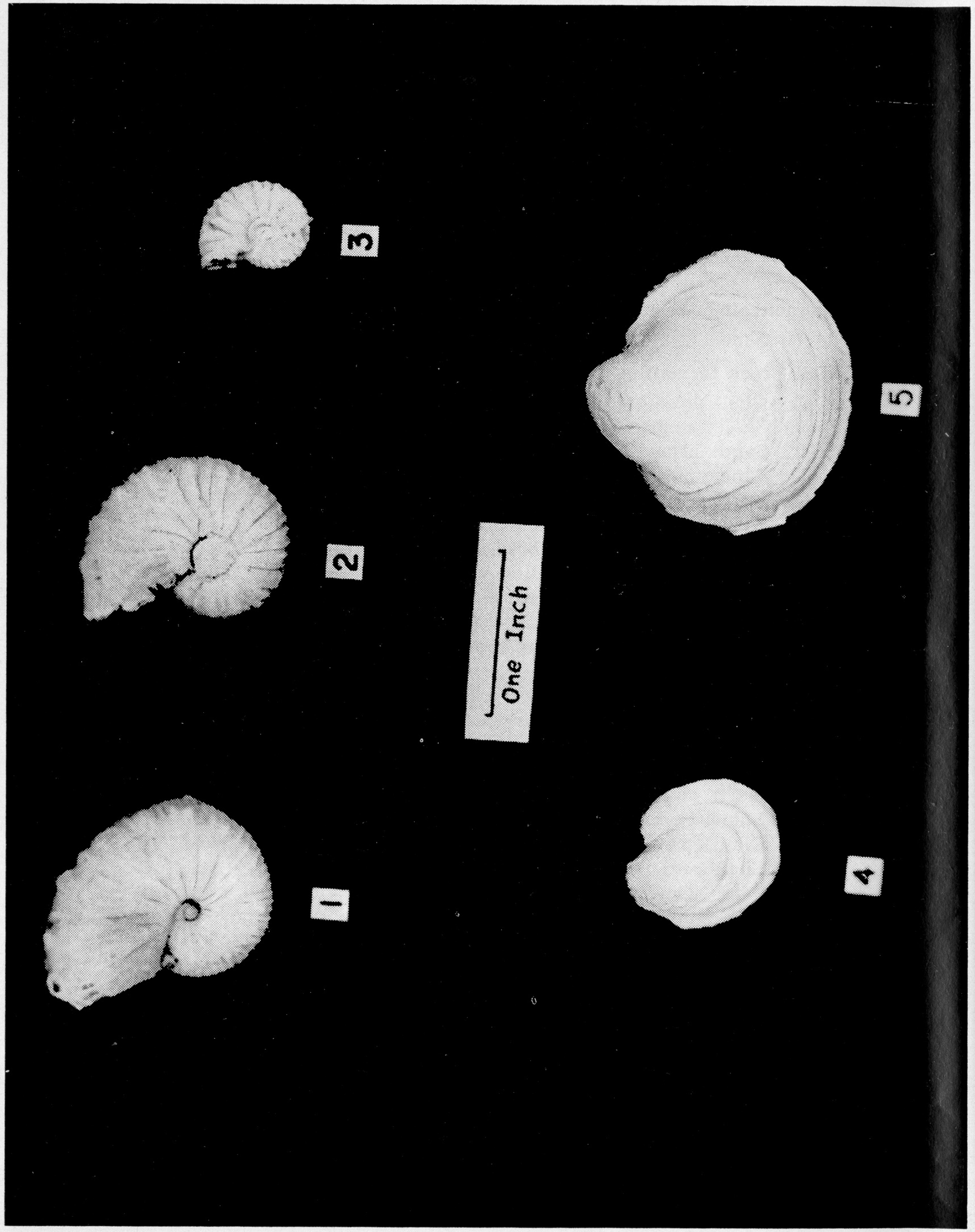


PLATE IV

Pierre Shale Fossils

FIGURES 1-3—*Acanthoscaphites nodosus* (Owen *non* Lopuski)
FIGURE 4—*Inoceramus* sp.
FIGURE 5—*Sphaeriola cordata*

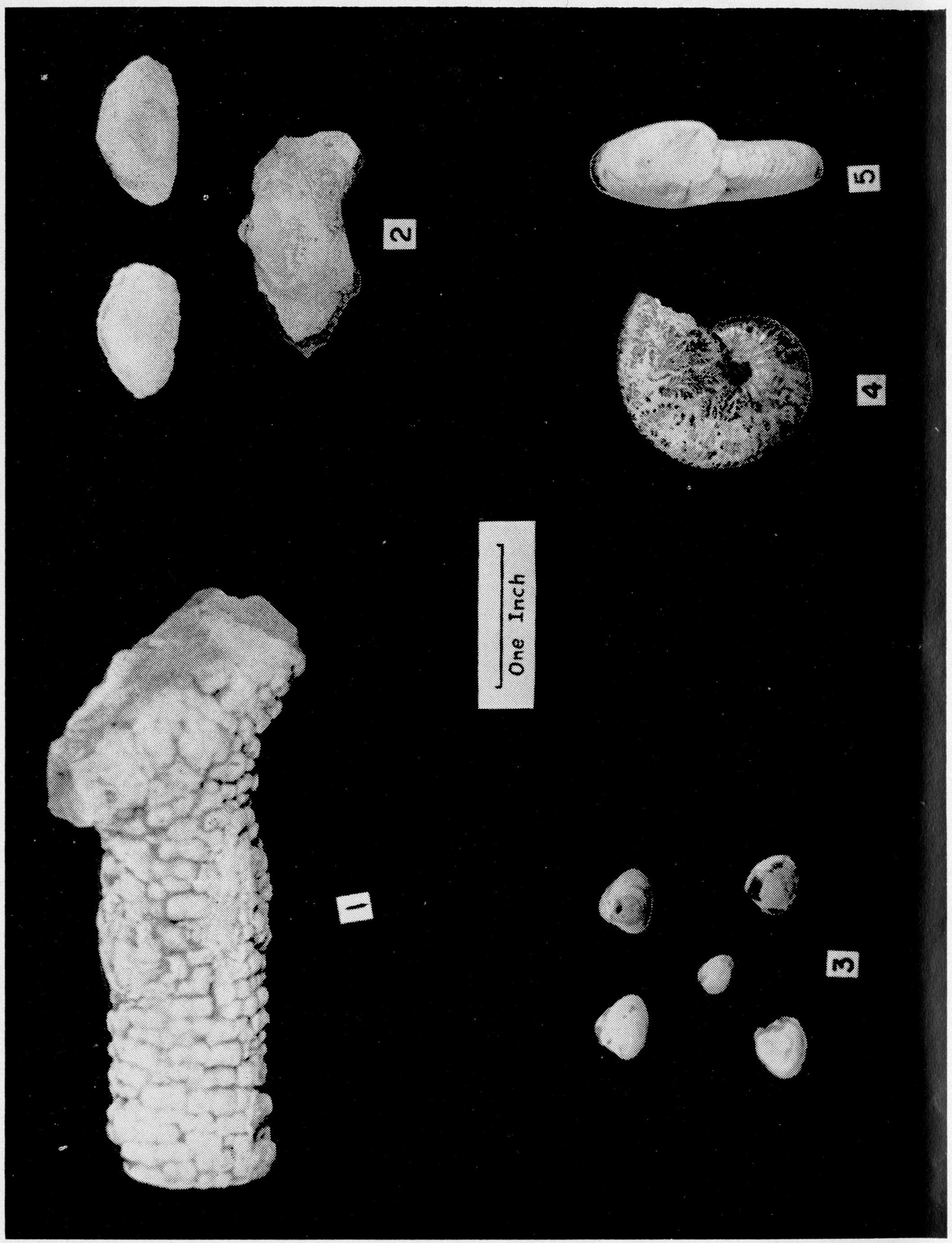


PLATE V

Fox Hills Fossils

FIGURE 1—*Halymenites sp.* Fossil seaweed? Characteristic of the Fox Hills sands

FIGURE 2—*Tellina scitula* Meek and Hayden

FIGURE 3—*Protocardia subquadrata* Evans and Shumard

FIGURES 4-5—*Discoscaphites nicolleti* (Morton) Found in the upper Pierre and lower Fox Hills formations

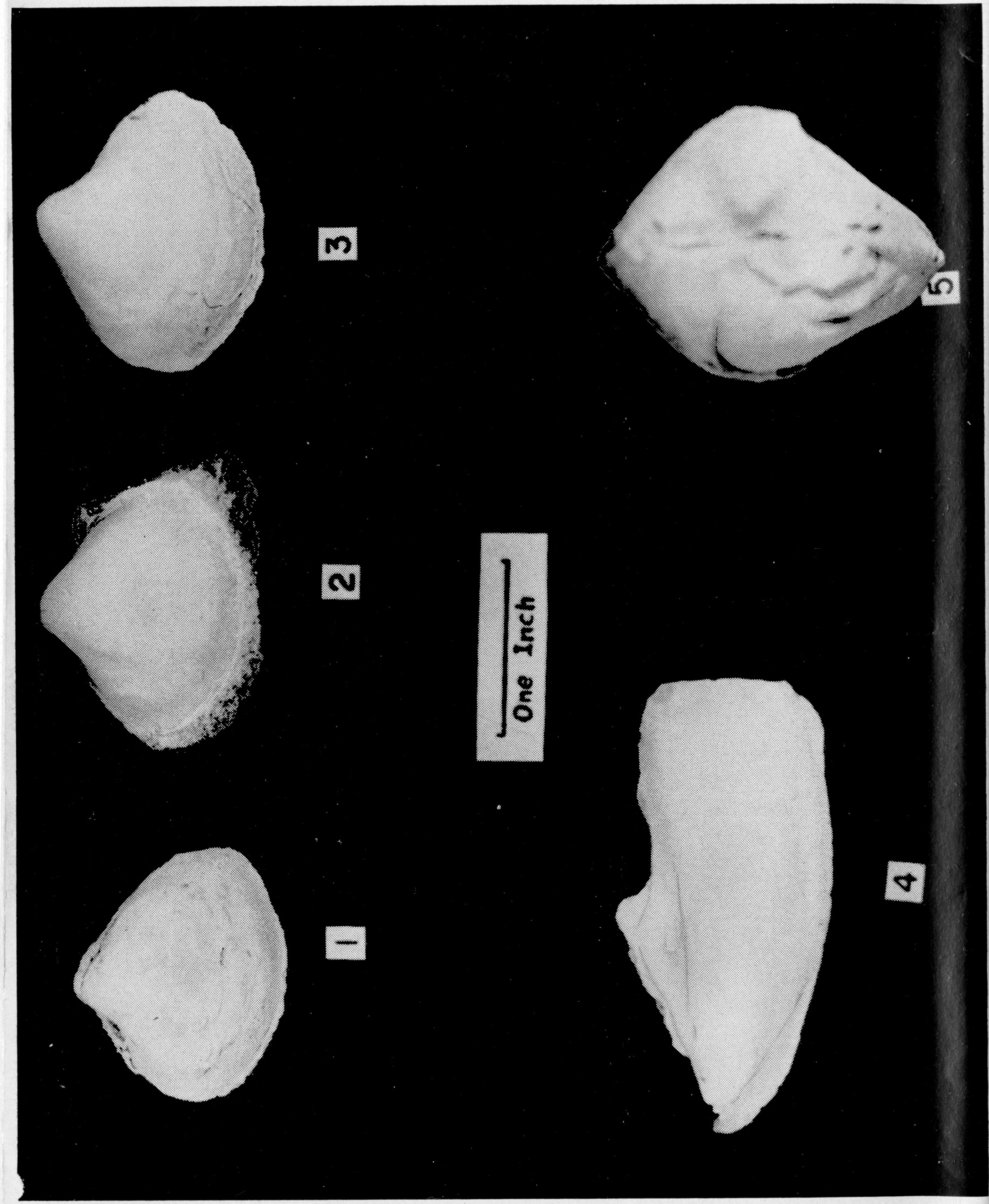


PLATE VI

Pierre Shales and Fox Hills Fossils

FIGURES 1-3—*Cymbophora warrenana* Meek and Hayden. Found chiefly in the green sandstones of the upper Fox Hills 1, 2 left exterior. 3 right exterior

FIGURE 4—*Gervillia subtortuosa* (Meek and Hayden). Found in the concretions at the top of the Pierre and in the lower Fox Hills formations

FIGURE 5—*Cucullaea shumardi*. Meek and Hayden. Found in the lower Fox Hills. Dorsal view.

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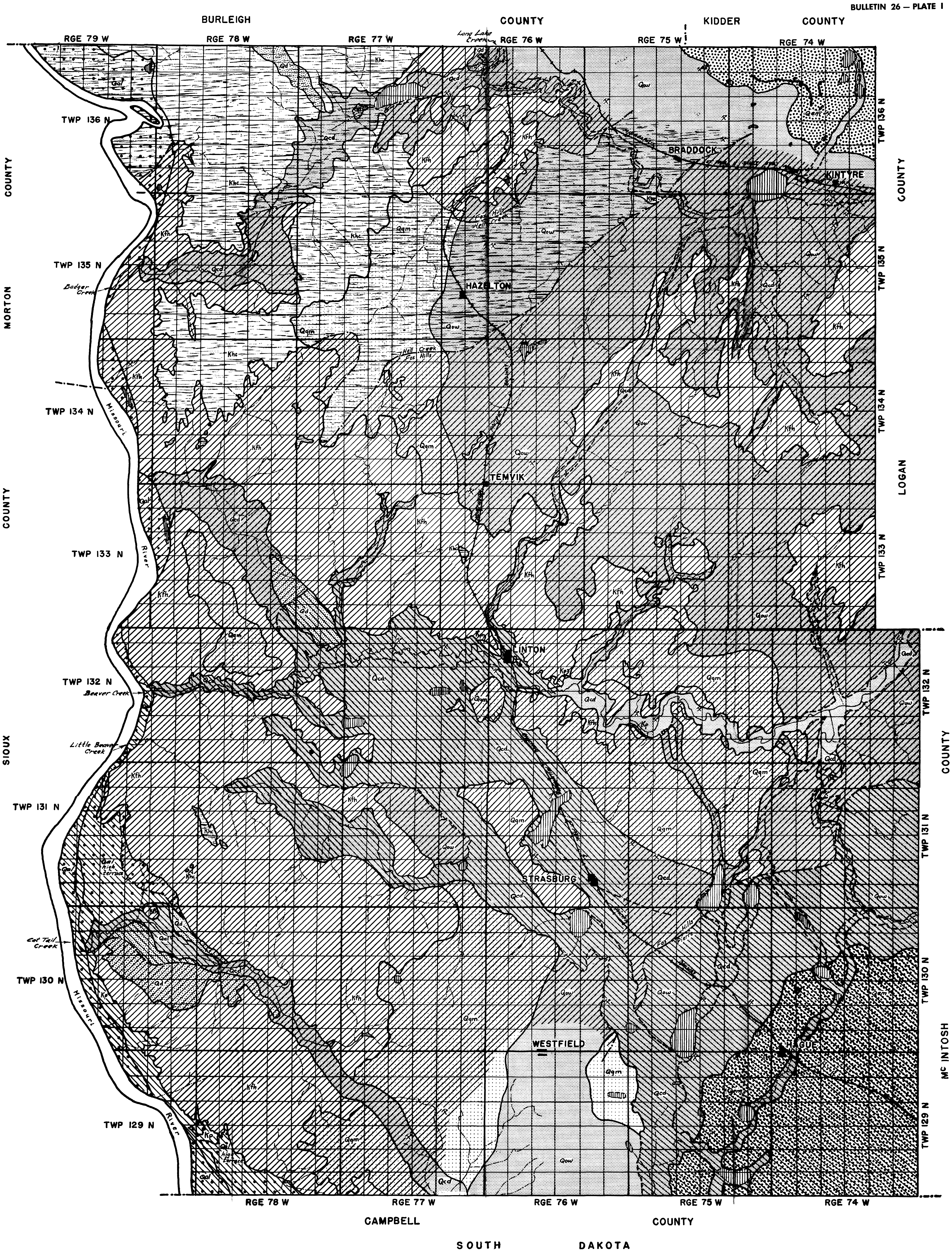
GEOLOGIC MAP *of* EMMONS COUNTY

by
STANLEY P. FISHER



LEGEND

Quaternary — Recent

- Qd — Dune sands
- Qal — River terraces

Quaternary — Pleistocene

- Qow, Qcd — Late Wisconsin outwash (Qow) and channel deposits (Qcd). (Covered by alluvium in the larger valleys).
- Qem — Late Wisconsin ("Altamont") end moraine
- Qgm — Late Wisconsin (Mankato?) till

Upper Cretaceous

- Khc — Hell Creek formation
- Kfh — Fox Hills formation
- Kp — Pierre formation

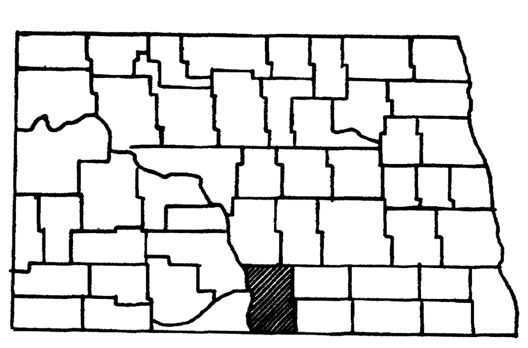
Other symbols

- Pleistocene drainage channels within outwash areas
- Esker
- Lake
- Gravel pit

Note: Bedrock patterns are shown beneath the surficial alluvium and glacial tills wherever the data warrant. Probable covered "contacts" of the bedrock formation are shown by this symbol:

SCALE
0 1 2 3 4 5
MILES

N

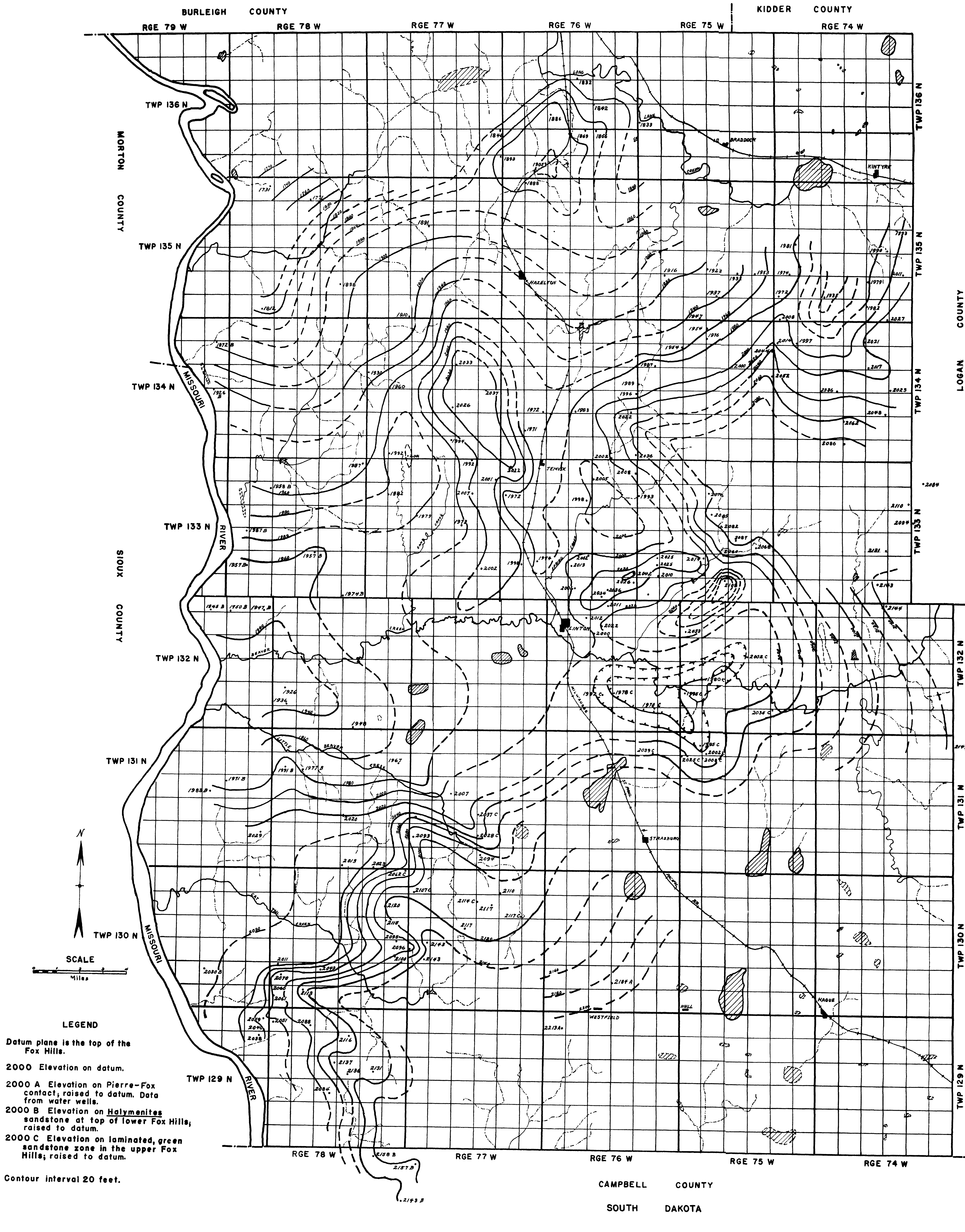


SURFACE STRUCTURE MAP

EMMONS COUNTY, NORTH DAKOTA

by

S. P. FISHER



STRATIGRAPHIC CROSS SECTION of the FOX HILLS FORMATION

by
STANLEY P. FISHER

Section 22 miles SSE of Emmons County

D bed.	Sandstone: hard, gray, crossbedded; caps buttes.	20'
	Sandstone: friable, gray; contains many plant stems.	6'
C bed zone	Sandstone: friable, brown to gray; with few hard bands.	30'
Poss. volcanic ash.	Shale: soft, bluish gray.	20'
Timber Lake mbr.	Shale: soft, with some rusty bands and two or three sandstones.	170'
Trail City mbr.	Sandstone: brown with few hard bands and calcareous concretions which contain Fox Hills fossils.	20'
	Sandstone: friable.	130'
Pierre fm.	Shale: dark, Pierre.	
	Total thickness Fox Hills fm.	396'

(From: W. R. Calvert, et. al, U.S.G.S. Bull. 575, p.13, 1914.)