SOUTH DAKOTA

STATE GEOLOGICAL SURVEY

E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 27

LITHOLOGIC STRATIGRAPHY OF THE PIERRE FORMATION OF THE MISSOURI VALLEY IN SOUTH DAKOTA

By

W. V. Searight

University of South Dakota
Vermillion, S. Dak.

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PREFACE

The Pierre formation has long been a stumbling block to geologic progress in South Dakota. Its thickness, known definitely in but few places, is so great that it has been a serious handicap in determining the depth of artesian sands and other formations which might be of value. Outcropping over a third of the western half of the state and immediately underlying the glacial drift in at least two-thirds of the eastern half, it has proven a great drawback to prospecting by making impossible the detection of structural and stratigraphic features in this great area. The tendency to describe it as a uniform black gumbo shale of great thickness and lateral extent has had an adverse effect on geological prospecting where this formation was involved.

Believing that the Pierre contained recognizable subdivisions, the State Geological Survey requested Dr. W. V. Searight to investigate its outcrops along the Missouri valley for the purpose of making a section of the formation which could be used in correlating outcrops east and west of the valley. Such a section would not only be a much needed contribution to the stratigraphy of the state, but would furnish a tool for further work on its mineral resources. The results of his painstaking work are set forth in the following pages and represent a distinct forward step in the study of South Dakota stratigraphy in that they present for the first time a description of the lithologic members of this puzzling formation. It is expected that his work will lay the foundation for a much better understanding of geological conditions in South Dakota.

E. P. Rothrock
State Geologist

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LITHOLOGIC STRATIGRAPHY OF THE PIERRE FORMATION OF THE MISSOURI VALLEY IN SOUTH DAKOTA

INTRODUCTION

General Statement

The Pierre shale is a thick shale formation of Upper Cretaceous age which occurs widespread at and below the surface in South Dakota. Exclusive of glacial deposits, which conceal it east of the Missouri river over wide areas, it is the surface formation over a greater area in South Dakota than any other single formation. In many places in the state the formation is very thick, forming a blanket of shale over many square miles which reaches a maximum thickness of nearly 2,000 feet. The character of the topography, the arrangement of drainage, the relief, and the degree of surface slope of western South Dakota is determined in large measure by the rock material of this formation. The character of the soils of entire counties west of the Missouri is mostly determined by the character of the underlying Pierre. Surface water supplies are dependent, not only on rainfall, but also on the type of rock underlying the surface and therefore many of the problems concerned with surface water supplies in South Dakota are directly related to the Pierre shale. In connection with all deep water supplies and oil and gas accumulation, the Pierre is of very great importance since it outcrops so widely at the surface and extends under younger rocks over so wide a region in South Dakota. Drillings over much of South Dakota must penetrate all or part of the formation, the thickness passed through by the drill depending on the part of the formation exposed at the surface and the thickness developed in the locality. In addition, the study of the formation is of interest from a purely scientific standpoint for the information to be gained regarding the geological history of the region. Thus, for economic and scientific reasons, a study of the Pierre formation is of fundamental importance.

Geologists have long known that, although the Pierre formation appears remarkably similar from place to place, the character of the rocks of which it is composed are not identical and that variations occur in the formation. The investigations on which this report is based were made to determine the nature and character of these variations and to ascertain their geographic extent.

As a result of field and laboratory studies it develops that the Pierre formation is divisible into five main subdivisions. The subdivisions are sufficiently different from one another to permit

tracing along the Missouri River and its tributaries over the area investigated. Furthermore, some of these subdivisions are themselves divisible and the subordinate zones are readily traceable. In addition, the thickness of each of the subdivisions varies from place to place, in some cases to surprising extent. The Pierre formation, as a whole, likewise varies greatly in thickness over the area of outcrop, and doubtless elsewhere, due to variations in the thickness of its members.

Thus it becomes possible to determine the part of the Pierre exposed in any particular locality in the area investigated and to estimate the thickness of the formation below the surface. The information should also be valuable in determining the cause of variations in character of soils of which the Pierre is the parent material and in determining the sources of various salts and other impurities which occur in the surface waters of the region.

This report has been prepared to indicate the differences and similarities of the subdivisions of the Pierre, and to give as nearly as is now possible, the distribution of each of the members in the area investigated. In addition a summary of the important fossils is given and some suggestions are made as to the correlation of these beds with those of other areas.

Field Work

Field work was done on this project during the field seasons of 1934 and 1935. Three weeks were spent in the field during 1934 and two months in 1935. Travel was by car. Sections were made by hand level wherever possible. An aneroid barometer was used, however, where bases and tops of sections were at considerable distances apart. These were checked wherever possible on bench marks. Laboratory work, mainly micropaleontological, has been done on well cuttings and surface samples from these beds at odd intervals over a period of several years. Most of the results of these investigations will be given in another paper, however.

Acknowledgments

The writer wishes to express his appreciation for the hospitable assistance given by residents of the region investigated. Much of the area is difficult of access by car and many such places were reached with facility because of information kindly given by residents familiar with the localities visited and the progress of the work was thus very materially aided. Two conferences in the field, one in 1934 and one in 1935, were made with Dr. E. P. Rothrock, State Geologist, during which critical outcrops

were visited and discussed. Miss M. Grace Wilmarth of the United States Geological Survey has kindly made suggestions regarding the nomenclature of the subdivisions and M. K. Elias of the State Geological Survey of Kansas has given information by correspondence and has sent specimens from Kansas and Colorado which have been of material value. Reports and maps of previous writers have been freely consulted and credit is given to these in the proper place.

THE PIERRE FORMATION

Definition

The Pierre formation was originally defined as Formation No. 4 (1856) of the Cretaceous on the upper Missouri.[1] It was defined as a formation of plastic clays containing calcareous concretions, the principal fossiliferous beds of the Upper Missouri Cretaceous lying above calcareous marl containing Ostrea congesta and below sandy clays and calcareous sandstones. Since the calcareous marl below was later named the Niobrara and the sandstones above were later called the Fox Hills, the current definition remains essentially the same as the original. The Pierre formation of the Missouri Valley in South Dakota is the thick body of shale and clay interposed between the chalk rock of the underlying Niobrara and the sandstone of the overlying Fox Hills formations. Locally, where what appears to be a true Fox Hills fauna occurs in shale, over the Pierre, the upper limit is placed at the base of the beds containing the Fox Hills fauna.

Stratigraphic Relations

The stratigraphic relations of the Pierre and the underlying and overlying formations, the Niobrara and Fox Hills respectively, are believed to be those of conformity. Wherever it has been observed, the contact between the Pierre and Niobrara is sharp, although some intercalation between chalky and shale beds at the contact through an interval of a few inches up to a few feet has been observed. No evidence of channelling at the base of the Pierre, such as seems to be inferred by Meek and Hayden[2], has been noted. On the contrary, the succession of

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1. Meek, F. B., and Hayden, F. V., U. S. Geol. Survey of the Territories, Vol. IX, p. 23, 1876.

2. Meek, F. B., and Hayden, F. V., op. cit., p. 24, 1876.

Niobrara chalk to dark bituminous shale containing many fish remains appears to persist, not only over this area but far beyond it. The change in fossil content is notable but probably no greater than should be expected from the change in facies represented by chalk deposition followed by mud deposition. The faunal change possibly is not so great as is commonly supposed, as fish remains are fairly common in Niobrara as well as in basal Pierre. Even Ostrea congesta, the guide fossil of the Niobrara recurs in the Pierre. Further, bentonite beds, which are characteristic of the basal member of the Pierre, continue downward into the Niobrara for more than 70 feet. In the railway cut southwest of Chamberlain for example, nine bentonite beds were observed in the upper 70 feet of Niobrara. Since bentonite is now believed to be due to alteration of volcanic ash it appears to be possible that the series of ash falls responsible for the bentonite beds of early Pierre began in Niobrara time. In spite of the sharp contact between Pierre and Niobrara, it thus appears that the change is due to a change in conditions of sedimentation rather than erosion in an intervening interval.

The contact between Pierre and Fox Hills is one of transition from shale through sandy shale to fine sandstone of the Fox Hills. A faunal transition exists also, numerous forms such as members of the Discoscaphites group of cephalopods, which are characteristic of Fox Hills, having been introduced well down in the Pierre.

Distribution

The Pierre formation is widely distributed at and below the surface of South Dakota (Plate II). Except where it has been removed by erosion over the Black Hills and elsewhere over very restricted areas in the lower Missouri valley, it underlies all of South Dakota west of the Missouri river. East of Missouri river the distribution is uncertain, owing to the thick cover of glacial drift which conceals it. Even here, the formation is widespread under the drift as indicated by the fact that it has been uncovered in many places as far east as Turkey Ridge and near Yankton.

HISTORY OF SUBDIVISION OF THE PIERRE FORMATION

The rocks and fossils of the beds now called the Pierre have been known since the early exploration of the upper Missouri region. The discovery of remains of marine reptiles and other fossils is reported to have been made as early as 1832 by the Prince of Neuwied at the Great Bend, below Fort Pierre and fossils from these beds were also collected seven years later by Nicollet.[1] Fossils were also collected in 1849 from the Pierre by Dr. John Evans from Sage Creek, a tributary to Cheyenne River, in what is now eastern Pennington County.[2]

Probably the earliest section in which the Pierre is described in relation to the overlying and underlying rocks was published in 1855 by Hall and Meek.[3] In this section the Cretaceous is divided into five numbered formations of which No. 4, overlying

"calcareous marl containing Ostrea congesta" and underlying "arenaceous clays passing into argillo-calcareous sandstones" occupies the position of the Pierre. This formation is described as

"Plastic clays with calcareous concretions, containing numerous fossils. This is the principal fossiliferous bed of the Cretaceous formation on the Upper Missouri". The thickness is given as 250 feet.

The formation was named the Fort Pierre by Meek and Hayden in 1861 and four subdivisions, based in part on lithology and in part on fossils, were made.[4] This early description and classification is quoted as follows:

"Fort Pierre Group
Formation No. 4

Subdivisions	Localities
Dark-gray and blue plastic clays containing, near the upper part, Nautilus Dekayi, Placinticeras placenta, Baculites ovatus, B. compressus, Scaphites nodosus, Dentalium	Sage Creek, Cheyenne River, and on White River above the Mauvais Teres.

1. Meek, F. B., and Hayden, F. V., U.S. Geol. Survey of the Territories, Vol. IX, p. 21, 1876.
2. Owen, D. D., Report of the Geol. Survey of Wisconsin, Iowa, and Minnesota and incidentally a portion of Nebraska Territory, pp. 573-587, tables I-VIII, 1852.
3. Meek, F. B. and Hayden, F. V., op. cit., p. 23.
4. Meek, F. B. and Hayden, F. V., op. cit., p. 24.

Subdivisions	Localities
gracile, Crassatela Evansi, Cucullaea Nebrascensis, Inoceramus Sagensis, I. Nebrascensis, I. Vanuxemi, bones of Mosasaurus Missouriensis, etc.	Sage Creek, Cheyenne River, and on White River above the Mauvais Terres.
Middle zone, nearly barren of fossils	Fort Pierre and out to Bad Lands; also down the Missouri on the high country to Great Bend.
Lower fossiliferous zone, containing Ammonites Complexus, Baculites ovatus B. compressus, Heteroceras Mortori, H. tortum, H. umbilicatum, H. cochleatum, Ptychoceras Mortori, Odontabasis vinculum, Anisomyon borealis, Amauropsis paludiniformis, Inoceramus sublaevis, I. tenuilineatus, bones of Mosasaurus Missouriensis, etc.	Great Bend of the Missouri below Fort Pierre.
Dark bed of very fine unctuous clay containing much carbonaceous matter, with veins and seams of gypsum, masses of sulphuret of iron, and numerous small scales of fishes. Local; filling depressions in the bed below."	Near Bijou Hill on the Missouri.

The thickness of the Pierre was given as 700 feet. The special reference to the basal beds is of interest and indicated the early tendency to separate the lower Gregory of this report from the overlying Pierre.

The general distribution of the Pierre, then called the Fort Pierre in the area which is now South Dakota was outlined with remarkable accuracy by Meek and Hayden in 1876.[1]

The name of the formation was shortened to Pierre as early as 1896 by some writers.[2]

The Pierre about the Black Hills has been described in several publications by Darton. At the base he describes 150 feet of shale which is black and splintery and which contains three horizons of concretions, the upper one of which is associated with well developed cone-in-cone.[3] This basal succession is clearly the lower

1. Meek, F. B., and Hayden, F. V., op. cit., p. 34.
2. Darton, N. H., Preliminary report on artesian waters of a portion of the Dakotas: U.S. Geol. Survey 16th Ann. Rept. Part II, p. 8, 1896.
3. Darton, N. H., Oelrichs Folio, U.S. Geol. Survey, Atlas, No. 85, p. 4, 1902.

Gregory of this report. Darton also notes the occurrence of several other beds, and a zone of teepee buttes which he estimates is approximately 1,000 feet above the base.

In his classic work on the Great Plains, Darton[1] again describes the Pierre and its distribution, lithology, fossil content[2] and gives cross sections in the region surrounding the Black Hills, in eastern South Dakota,[3] and in eastern Nebraska.[4] Previous descriptions are repeated and amplified and the distribution nearly to Yankton and under Turkey Ridge is noted. At this time (1905) the occurrence of "some local chalky deposits to the south" (Mobridge member of the report) are noted in South Dakota and he observed also in northern Nebraska along Missouri and Niobrara valleys the occurrence of "very dark clays varying in thickness from 10 to 30 feet or more, to which Hayden has called attention (lower Gregory of this report). This is overlain by lighter-colored clays with thin seams of iron oxide averaging about 100 feet thick. (Upper Gregory, Sully member and Virgin Creek). Next above is an unusual feature in Pierre stratigraphy--a series of light-colored clays containing impure chalky beds weathering to buffish and reddish tints, about 100 feet thick, and in many outcrops somewhat resembling Niobrara formation" (Mobridge member).

A subdivision of the Pierre was made by Condra,[5] not primarily in South Dakota, but in that portion of Nebraska immediately south of the area investigated for this report. Some of the beds described are noted by him in South Dakota. The beds which are called lower Gregory in this report are described and the distribution as far north as Chamberlain is observed. In a description of the topography of Bazile Creek the following section is given.[6]

...."gradual clay slopes extend from altitude 1,560 to about 1,500 feet; steeper, chalky slopes with a narrower valley extend from altitude 1,500 to 1,400 feet; while the clays below give more gentle slopes and a wider valley down to about 1,280 feet, at which altitude the Niobrara chalk begins and bluffs prevail."

The interval between 1,500 and 1,560 feet is the Elk Butte member of this report, the "steeper chalky slopes" between 1,400 and 1,500 represent the Mobridge member and the interval between 1,280 and 1,400 lying above the Niobrara includes the combined Gregory, Sully, and Virgin Creek members of this report. A detailed section made three miles west of Fort Randall[7] describes accurately beds referred to the lower and upper Gregory and the

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1. Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U.S. Geol. Survey, House Doc. No. 780, 1905.
2. Darton, N. H., op. cit., pp. 40-41.
3. Darton, N. H., op. cit., pp. 135-137.
4. Darton, N. H., op. cit., pp. 148.
5. Condra, G. E. Geology and water resources of a portion of the Missouri river valley in northeastern Nebraska; U.S. Geol. Survey Water Supply Paper No. 215, pp. 15-17, 1908.
6. Condra, G. E., loc. cit., p. 16.
7. Condra, G. E., loc. cit., P. 17.

Oacoma zone of the Sully member of this report. The general subdivisions made by Condra are most closely in agreement with those of this report of any in the literature.

In a description of the Pierre of northern Haakon county by Ward[1] a section of 48 feet of "'chalky' shale" over "typical Pierre shale" is apparently that of the Mobridge member overlying the upper Virgin Creek.

The most important division of the Pierre in South Dakota was made by Russell, a former Survey member, in connection with oil and gas studies made in western Potter County.[2] A succession consisting of 475-500 feet of beds is described. The Agency shale is named and accurately described at the base of the succession of the area. Overlying the Agency, banded beds 30 feet in thickness and overlying shales with dark brown or purplish black ferruginous concretions 110 feet thick completes the Sully member of the present report, and accurately describes the Agency, Oacoma, and Verendrye beds as they are named in this report. The uppermost 215-240 feet includes both the lower and upper Virgin Creek and possibly 75-100 feet of the Mobridge member. The bentonites of the lower Virgin Creek were not observed although the beds of the upper Virgin Creek containing finely perforated concretions, crabs, belemnites and cylindrical concretions is distinctively described as "bed WE".

A detailed section of the lower basal Pierre as it lies on the Niobrara south of the Black Hills has been described by Rothrock.[3] The lower 98.8 feet with many bentonite beds certainly belong to the lower Gregory of this report and it is likely that the entire thickness of beds described, a total of 203.8 feet is part of the Gregory member.

In addition a great number of local descriptions by several writers describe the Pierre here and there without, however, deserving special comment in this place.

Outside of South Dakota, particularly west of the State where sandstone, coals, and terrestrial beds occur in the succession, much work on subdivision of beds equivalent to the Pierre has been done. A large number of more or less local or regional names exist in a voluminous literature, which, however, aid the subdivision along the Missouri River but little since the beds here are marine from base to top without important intercalated sands and continental facies.

An important contribution to the subdivison of the wholly marine facies of the Pierre has been made in western Kansas and

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1. Ward, Freeman, Structures of northern Haakon County: South Dakota Geol. and Natural Hist. Survey Circ. 22, pp, 5-10, 1925.
2. Russell, W. S., The possibilities of oil and gas in western Potter County. South Dakota Geol. and Nat. History Survey, Report of Investigations No. 7, pp. 3-5, 1930.
3. Rothrock, E. P., The Cascade Anticline; South Dakota Geol. and Nat. Hist. Survey, Report of Investigations No. 8, p. 4, 1931.

eastern Colorado by Elias.[1] By careful study in that region five members are differentiated lithologically and by fossils. Unfortunately complete correlation, probably because of gradual regional changes in lithology, are not yet possible between the Kansas-Colorado region and the Missouri valley region of South Dakota.

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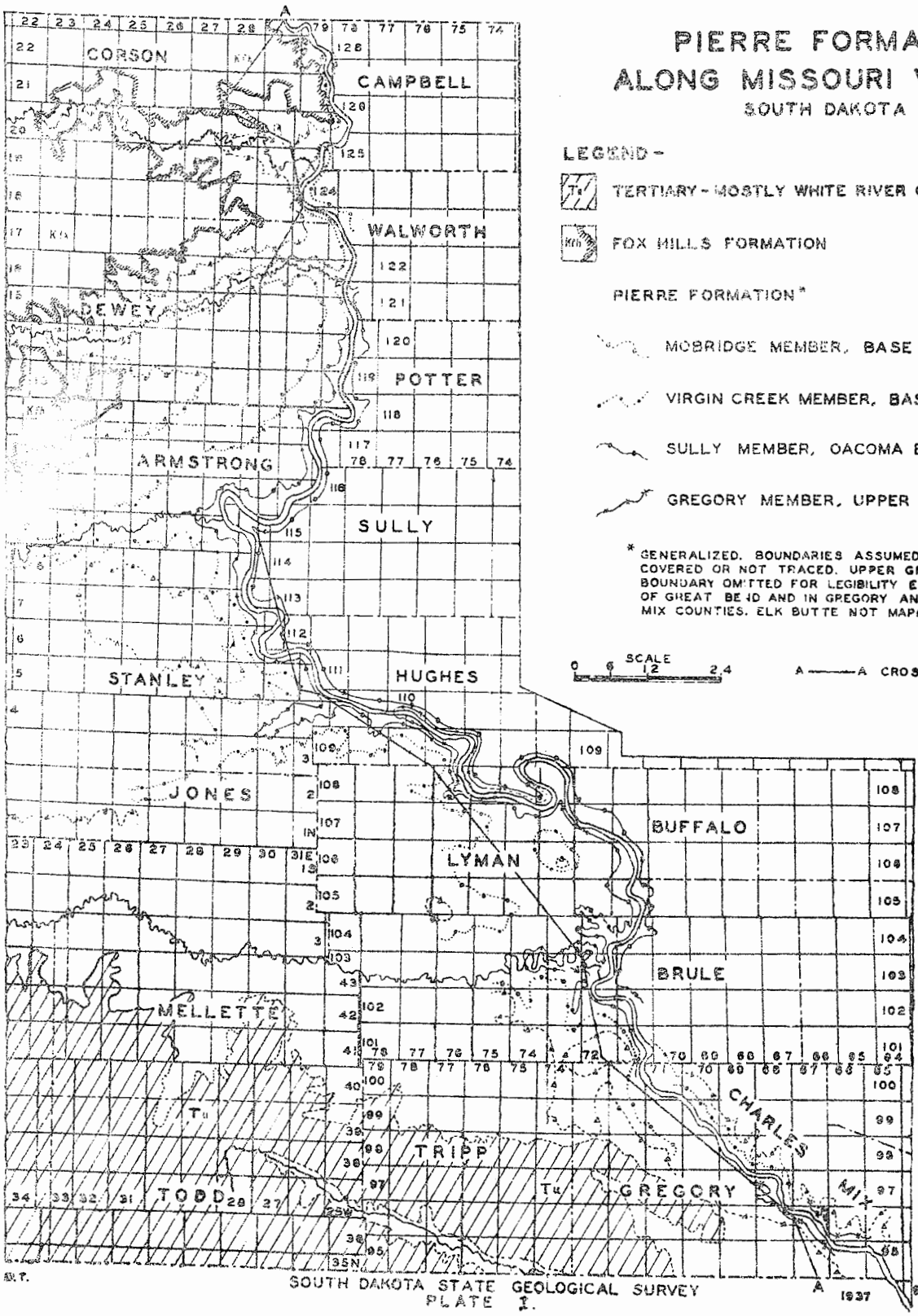
1. Elias, M. K., The Geology of Wallace County, Kansas: State Geological Survey Bulletin No. 18, pp. 43-131, 1931.



PIERRE FORMATION ALONG MISSOURI VALLEY

SOUTH DAKOTA

LEGEND -

Tu — TERTIARY - MOSTLY WHITE RIVER OLIGOCENE

Kfh — FOX HILLS FORMATION

PIERRE FORMATION*

MOBRIDGE MEMBER, BASE

VIRGIN CREEK MEMBER, BASE

SULLY MEMBER, OACOMA BEDS

GREGORY MEMBER, UPPER GREGORY

* GENERALIZED. BOUNDARIES ASSUMED WHERE COVERED OR NOT TRACED. UPPER GREGORY BOUNDARY OMITTED FOR LEGIBILITY EXCEPT WEST OF GREAT BEND AND IN GREGORY AND CHARLES MIX COUNTIES. ELK BUTTE NOT MAPPED.

SCALE 0 6 12 24

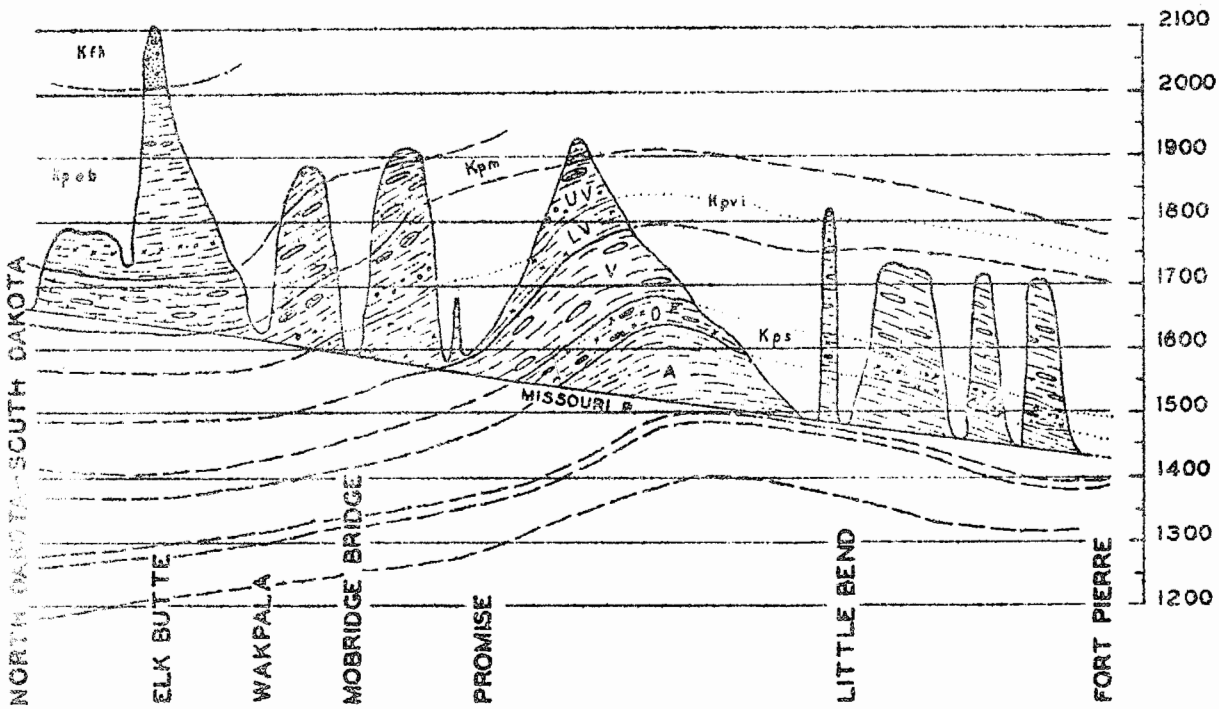
A ——— A CROSS SECTION PLATE II.

SOUTH DAKOTA STATE GEOLOGICAL SURVEY

PLATE I.

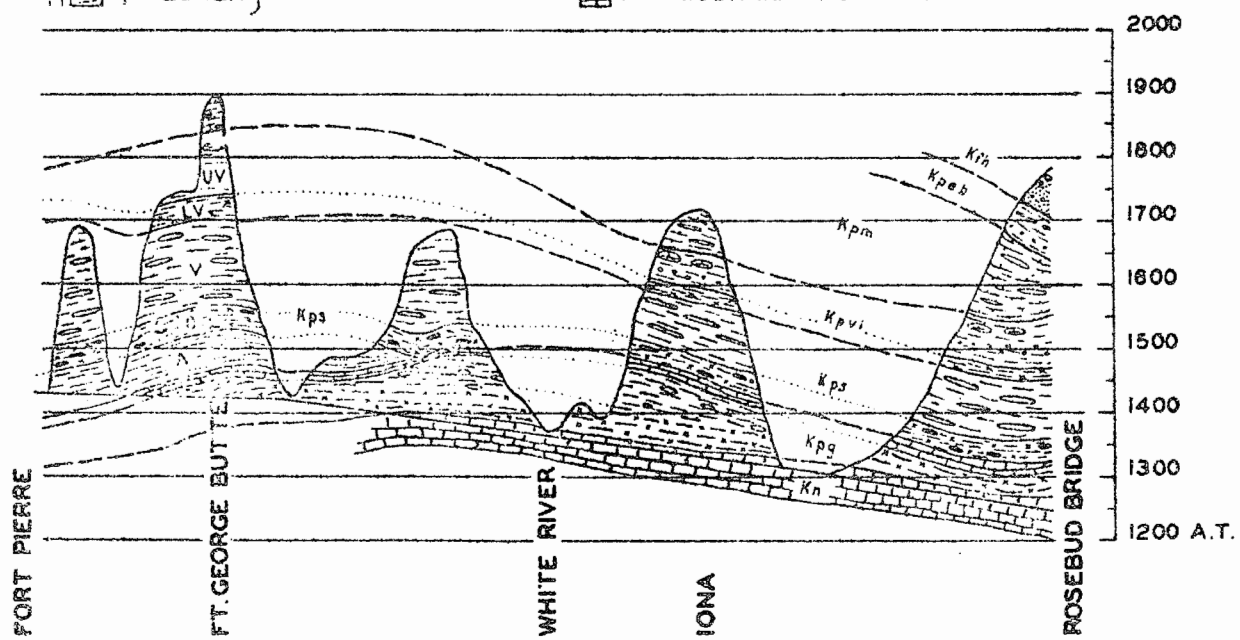
1937

CROSS SECTION OF PIERRE FORMATION
ALONG MISSOURI RIVER



LEGEND

- Kfh FOX HILLS FORMATION
- FORMATION
  - Kpeb ELK BUTTE MEMBER
  - Kpm MOBRIDGE MEMBER
  - Kpvi UPPER, Kpvi LOWER — VIRGIN CREEK MEMBER
- PIERRE — SULLY M.
  - Kps VERENDRYE BEDS, Kps OACOMA ZONE, Kps AGENCY SHALE — SULLY MEMBER
  - Kpg GREGORY MEMBER
- Kn NIOBRARA FORMATION



HORIZONTAL SCALE
MILES
0 5 25

PLATE II.

VERTICAL SCALE
1 INCH=200 FEET

R.T.

GENERALIZED COLUMNAR SECTION OF THE PIERRE FORMATION

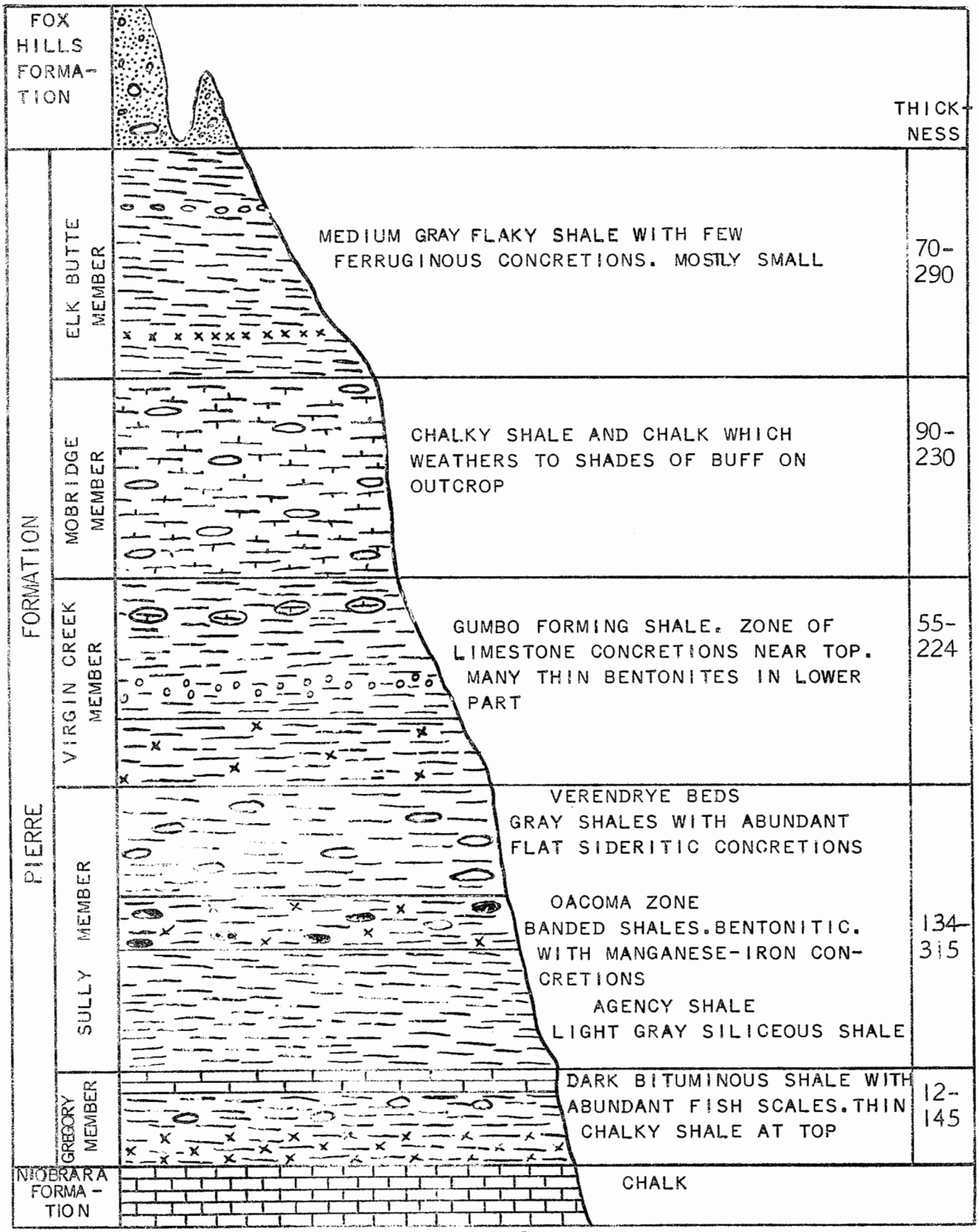
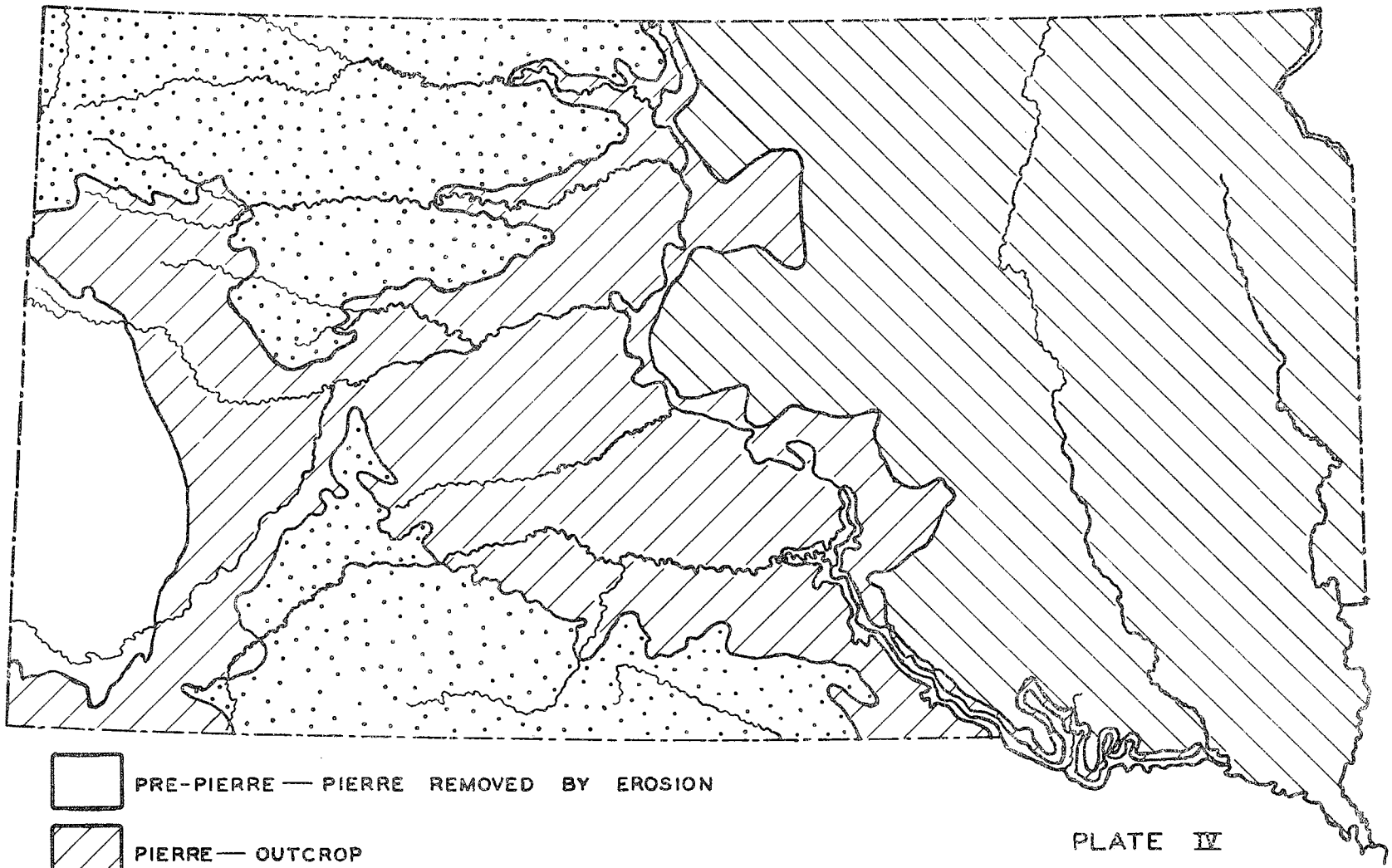


PLATE III.

DISTRIBUTION OF THE PIERRE FORMATION IN SOUTH DAKOTA



PRE-PIERRE — PIERRE REMOVED BY EROSION

PIERRE — OUTCROP

PIERRE — COVERED BY CRETACEOUS AND TERTIARY

IN PART UNDERLAIN BY PIERRE — MOSTLY DRIFT COVERED

PLATE IV

SUBDIVISIONS OF THE PIERRE FORMATION IN MISSOURI VALLEY

General Statement

In the region along the Missouri river in South Dakota, the Pierre is divisible on the basis of differences in lithology into five members (Plate III). From the base up these are the Gregory, Sully, Virgin Creek, Mobridge, and Elk Butte members, each named from a locality of typical development. Each member has been traced throughout the area of outcrop in the region studied (Plates I and IV). In the pages which follow the character, subdivison, and distribution of the various members are discussed in detail.

The Gregory Member

Name and Type Locality:

The Gregory member, the basal member of the Pierre formation, is here named from outcrops along the Missouri River in eastern Gregory county, South Dakota. This member is particularly well displayed in the cut bank at the south end of Rosebud bridge, south of Wheeler. Other outcrops almost equally typical lie to the east of the river, those south of U. S. Highway 18 in Charles Mix county being particularly well exposed. The Gregory county outcrop is chosen as typical because of the completeness of the succession exposed.

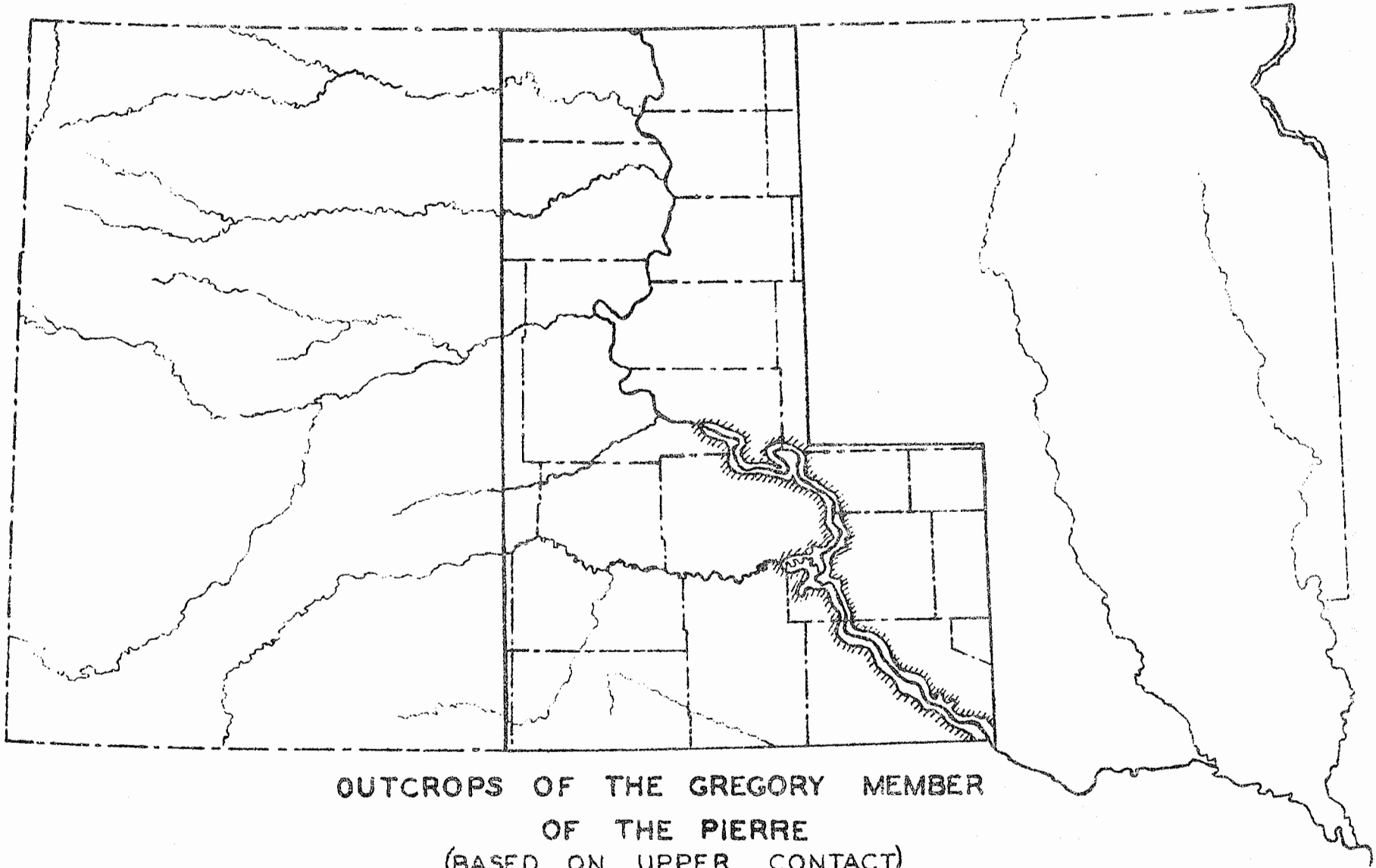
Definition:

The Gregory member of the Pierre includes all beds from the top of the Niobrara to the top of the chalky shale or argillaceous chalk zone exposed at the floor level of the south end of the Rosebud bridge in Gregory county, and to the upper contact of similar beds equivalent to this chalky zone elsewhere in the region investigated. As thus defined it includes all Pierre beds lying below the manganiferous (Oacoma) beds south of the Great Bend, and northward from this locality, all the beds lying below the Agency shale zone, which intervenes between the uppermost bed of the Gregory member and the manganese bearing zone of the overlying Sully member.

Distribution:

The Gregory member of the Pierre has wide distribution (Plates I and V) at and below the surface in and beyond the region investigated. It has been identified at the surface as far east as the old cement plant near Yankton, Yankton county. The member

PLATE V



OUTCROPS OF THE GREGORY MEMBER
OF THE PIERRE
(BASED ON UPPER CONTACT)

crops out along the valley of the Missouri from this point, except where it is covered by drift and slope mantle northward beyond the Great Bend. The uppermost bed disappears under the river and younger beds of the Pierre in Hughes county about 12 or 13 miles east of the State House in Pierre. The member extends westward below younger beds and is probably continuous with the outcrop of basal Pierre about the Black Hills which include beds which are, in part at least, lithologically very similar to those of the type locality.[1] These beds also extend southward under Nebraska toward Kansas where they possibly reappear at the surface as lithologically similar beds in the Smoky Hill member of the Niobrara. Presumably, however, they come to the surface in western Kansas as the lower part of the Sharon Springs member of the Pierre.[2]

Subdivisions and general characters:

At and near the type locality, the Gregory member of the Pierre is divisible into two lithologically and faunally distinct subdivisions which may be identified, with variations in lithology and thickness, throughout the area of outcrop. The lower Gregory consists of dark, bentonite bearing, bituminous shales which contain numerous fish scales. These beds vary considerably in lithology and greatly in thickness as indicated in later sections of this report. The upper Gregory is a thin but characteristic zone of chalk, chalky shale, argillaceous chalk, or marl. From the vicinity of the mouth of White River in Lyman county to the northernmost exposures of the member near DeGray in Hughes county, the lower and upper Gregory are separated by a very thin but persistent bed of sandstone.

Lithologic Details:

Lower Gregory: The lower part of the Gregory member consists of a succession of beds typically composed of thin bedded, flaky, dark, nearly black bituminous shale, which becomes dark chocolate brown on exposure, interbedded with thin beds of bentonite. The lower Gregory is characteristically exposed in buttress-like promontories which are notable in the smaller as well as the larger exposures.

Bentonite beds are characteristic of the lower part of the lower Gregory, in the area surrounding the type locality and elsewhere in the area investigated. Bentonite occurs only sparingly in the upper part, however. The bentonite, when fresh, is a fairly compact, soapy feeling clay of creamy white color. Exposure to water causes it to swell to many times the original volume. At a distance, in the outcrop, the contrast in color between the thin

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1. Darton, N. H., U.S. Geol. Survey, Folios Nos. 85, 107, 108, 128.
2. Elias, M. K., The Geology of Wallace County, Kansas; State Geol. Survey of Kansas, Bulletin 18, pp. 58-77.

bentonite beds and the dark shales of the lower Gregory give the impression of horizontal white chalk marks on the outcrop.

The bentonite beds range from paper thin laminae up to five and one-half inches in thickness. In the exposure at the south end of Rosebud bridge, Gregory county, 19 bentonite beds were counted. Eight of these are one inch or more in thickness and five are one-fourth inch or less in thickness. Seventeen of the nineteen beds observed occur in the lower fourteen feet of the lower Gregory. At this place the total aggregate thickness of bentonite observed was 25 inches. North of Chamberlain, to the north of Crow Creek, in a road cut on State Highway 47, fifteen beds of bentonite were observed whose aggregate thickness was 25 3/8 inches. These also occur in the lower 17 feet of the member. At the old cement plant three miles west of Yankton, where the lower Gregory is very thin, only two bentonite beds were observed in exposures which apparently include all of the beds of the lower Gregory at that place. These bentonite beds are each two to three inches thick. It is notable, however, that possibly as many as 17 bentonites are absent at Yankton and these in aggregate contain only approximately one-fifth of the bentonite commonly present in the lower Gregory.

The upper part of the lower Gregory is composed of beds which are, for the most part, similar to the bentonite bearing basal beds. They are less fissile in character, however, and tend to weather gray and somewhat silty in the outcrop. This difference in character is particularly notable in the vicinity of the mouth of White River and Chamberlain, where the upper part of the lower Gregory is of unusual thickness.

Concretions occur sparingly in the lower Gregory in a few localities, although they are apparently absent in the type locality. A few up to six inches in diameter occur between bentonite beds at the old cement plant at Yankton. Along Cedar Creek, to the west of the Great Bend, large septarian concretions associated with cone-in-cone occur in the creek bottom below eight bentonite beds. The concretions here reach a size of nine inches in thickness and seven and one half feet in diameter, the largest observed in the Pierre in the region investigated. Most of the concretions here consist of very compact hard, dark gray limestone about a pyritic central mass. Many, however, lack the pyritic core. Septarian cracks, in some cases up to one inch across, are entirely or partly filled with one or more generations of brown botryoidal calcite and pale yellow drusy calcite. Some cracks show in addition to the brown and yellow calcite a third generation represented by white rhombic calcite plates. Some of these concretions are fossiliferous.

Two rows of concretions of gray limestone occur 26 and 24 feet below the top of the lower Gregory, just above a bentonite bed four and one half inches thick, in the exposures along Cedar Creek. These occasionally reach a maximum diameter of three feet. These two concretion beds are possibly the same as two

similar beds observed in the same stratigraphic position in exposures 12 miles north of Reliance along the road to Lower Brule, five miles north of Chamberlain, and at the westward bend in the Missouri River near the mouth of Bull Creek in Brule County, where limestone concretions occur well up in the upper part of the lower Gregory.

Upper Gregory: The upper Gregory is a thin succession of chalky shale or marl. The succession is so characteristic and readily identified that were it not for the thinness of this group of beds and the unnecessary increase of named subdivisions of the Pierre it might well be named as a member of the Pierre. The upper Gregory has been previously noted by other authors, Condra having noted it south of the Missouri River and three miles west of old Fort Randall.[1] The beds were also differentiated from other beds of the lower Pierre in a section made near Chamberlain by D. F. Hewitt.[2]

At the base of the upper Gregory is a thin bed of fine grained, thin bedded, slabby sandstone which is light gray when fresh but is reddish brown or brown as commonly seen. It has been included with the upper Gregory rather than the lower because in one place at least, 12 miles east of Pierre along the Lewis and Clark trail, it appears to grade upward into the overlying beds whereas in every exposure observed the lower contact is sharp. Where observed it ranges between nine inches and two feet in thickness. The sandstone pinches out and has not been observed more than a short distance south of the mouth of Bull Creek in Brule county but elsewhere to the north it is persistent.

In and near the type locality of the Gregory member of the Pierre the chalky beds which constitute the uppermost stratigraphic element of the succession are well developed. Here the beds are composed ofmedium gray chalky shale and chalk, when fresh. These beds are readily distinguished from overlying beds in the weathered outcrop by the buff or yellow buff color developed by weathering. In the vicinity of the mouth of White River the beds appear to become less chalky in texture and are chiefly dense, bentonitic, calcareous shale or clay to near the Great Bend. Beyond this place they are again chalky in appearance.

In many places, particularly in the area surrounding the type locality, but also in the northernmost and easternmost exposures, the upper Gregory contains many small flattish word pebbles of dense gray shale, which rarely exceed one fourth inch in diameter. Quartz sand grains, some worn, others angular, are unevenly distributed through the upper Gregory. In the outcrop west of DeGray School the chalky beds are notably sandy in the lower part, thus suggesting intergradation with the underlying bed of sandstone.

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1. Condra, G. E., U. S. Geol. Survey Water Supply Paper No. 215, p. 17, 1908.
2. Dept. of the Interior, Memorandum for the press, Release for Feb. 5, 1930.

Detailed sections of the Gregory Member:

Detailed sections of the Gregory member have been made in many places. In the pages which follow, tables of succession are given which show the lithologic character and thickness of these beds. The sections have been chosen to indicate, in so far as possible, characteristic features of the beds as well as variations in character and thickness in various parts of the area of outcrop. The first (Table 1) describes the succession at the type locality, the second (Table 2) near Yankton, the third (Table 3) at Crow Creek in Buffalo county, the fourth (Table 4) along Cedar Creek west of the Great Bend in northern Lyman county, and the fifth (Table 5) the northernmost exposure of the member. These tables also show the character of the beds associated with the Gregory member.

Table 1

Succession of beds of the Gregory member of the Pierre, together with associated beds, at the type locality.

Type section of the Gregory member of the Pierre and associated beds at the south end of Rosebud bridge across Missouri River on United States Highway 18, Gregory county, South Dakota.

Pierre Formation			Feet
Sully member			
Oacoma zone			
44.	Shale, bentonitic, gray; contains many concretions of olive drab and gray manganese-iron carbonate which are strewed over the outcrop. A bed of brown bituminous shale one and one-half feet thick containing numerous bones and teeth of reptiles lies at the base.....		46
Gregory member			
Upper Gregory		Ft. In.	
43.	Shale, gray, chalky; weathers to buff along the outcrop....	5	
42.	Shale, gray, calcareous, flaky	5	
41.	Shale, gray, chalky.....	1	11
Lower Gregory			
40.	Shale, dark, poorly exposed	5	

		Feet	Inches
39.	Bentonite, creamy		1/4
38.	Shale, dark		6
37.	Bentonite, creamy		2
36.	Shale, dark	23	
35.	Bentonite, hard		1
34.	Shale, dark		9
33.	Bentonite, hard		2
32.	Shale, dark	2	
31.	Bentonite		3
30.	Shale, dark		2
29.	Bentonite		3 1/2
28.	Shale, dark		1 1/2
27.	Bentonite		1/2
26.	Shale, dark		2
25.	Bentonite		1 1/2
24.	Shale, dark		4
23.	Bentonite		1/2
22.	Shale, dark		1
21.	Bentonite		1
20.	Shale		4
19.	Bentonite		3
18.	Shale	3	6
17.	Bentonite		1/2
16.	Shale	10	
15.	Bentonite		1/2
14.	Shale		6
13.	Bentonite		1
12.	Shale, with bentonite streaks		3
11.	Bentonite		1/8
10.	Shale		3
9.	Bentonite		1/4
8.	Shale, dark		4
7.	Bentonite		1/4
6.	Shale, dark		4
5.	Bentonite		1
4.	Shale, dark	1	3
3.	Bentonite		1/4
2.	Shale, dark.bituminous, flaky	1	
		51'	8 5/8"

Niobrara formation

1. Limestone, chalk, gray of shaly appearance. Spalls off toward river at angle of about 45 degrees with the vertical. Becomes darker and more nearly vertical in upper five feet. Apparently contains more clay in upper part. Bentonite streak one inch thick four and one-half feet below the top. Weathers buff or orange buff on the outcrop..... 20

Table 2

Succession of beds exposed at the old cement plant near Yankton, South Dakota

Section of Gregory member of the Pierre and underlying Niobrara and overlying Sully beds exposed at the old cement plant three miles west of Yankton, South Dakota.

Pierre formation

Sully member

Oacoma zone — Feet

4. Shale, dark gray when dry, almost black. Shows tendency to break down to gumbo, especially in basal part. Weathers to dark, somewhat mottled ashy gray, especially in upper part. Contains 16 beds of bentonite varying between one-eighth inch and two or three inches in thickness. Bentonites separated by shale beds ranging between three inches and two and one-half feet in thickness. Contains fragments of large pelecypod shells and Ostrea of O. congesta. Discontinuous bed of soft buff vertically jointed concretions five feet above base..... 26

Gregory member

Upper Gregory

3. Chalk, impure, light gray, weathers buff or yellow-buff. Contains small, somewhat flat but well worn pebbles of gray shale, considerably darker than matrix, rather sparingly..... 5

Lower Gregory

2. Shale, brown, bituminous odor when heated with a match. Contains two beds of bentonite two to three inches thick. Gypsum crystals to two inches fairly common. Also contains scales of fish and numerous other fragmental fish remains..... 7

Niobrara formation

1. Limestone, chalk, medium to very dark gray when fresh, weathers nearly white to orange buff..... 85

Table 3

Succession of beds of the lower Gregory north of Crow Creek.

Section of the lower Gregory and underlying beds in a road cut along and north of Crow Creek along South Dakota Highway 47, 13.2 miles north of Chamberlain.

		Feet	Inches	Feet
Recent				
35.	Soil			1
Pierre formation				
Gregory member				
Lower Gregory zone				
34.	Shale, dark, brownish hue, bituminous	3		
33.	Bentonite		½	
32.	Shale, dark		6	
31.	Bentonite		1/8	
30.	Shale, dark		2	
29.	Bentonite		½	
28.	Shale, dark		4	
27.	Bentonite		2½	
26.	Shale, dark	1		
25.	Bentonite		4	
24.	Shale, dark	1		
23.	Bentonite, white buff tinge.		3	
22.	Shale, dark	1		
21.	Bentonite		3	
20.	Shale, dark	1		
19.	Bentonite		2	
18.	Shale		4	
17.	Bentonite		1	
16.	Shale		2	
15.	Bentonite		3	
14.	Shale, dark brownish cast, bituminous	3		
13.	Rock, siliceous, white to yellow, fine textured		6	
12.	Shale, dark		6	
11.	Bentonite		1	
10.	Shale, dark		6	
9.	Bentonite		3	
8.	Shale, gray		6	
7.	Bentonite		3/4	
6.	Shale, gray		8	
5.	Bentonite		½	

		Feet	Inches	Feet
4.	Shale, gray, bluish cast, weathers into chips. Yellow on cracks and joints...	3	6	
3.	Bentonite.....		½	
2.	Shale, gray, gypsiferous	1		20 3/4

Niobrara formation

1.	Limestone, chalk, buff poorly exposed.....	5

Table 4

Succession of Gregory member of the Pierre exposed along Cedar Creek west of the Great Bend, Lyman county, South Dakota.

Section of the Gregory member exposed along bluffs north steeply cut banks north of Cedar Creek, which drains eastward into west side of the Great Bend, northern Lyman county, South Dakota, showing beds of the Gregory member and overlying beds.

Pierre formation		Feet
Sully member		
Agency shale		
5.	Shale, light gray, weathers rusty brown on surface, especially in lower 15 feet. Contains gray limestone concretions to over one foot in diameter. Large Inoceramus here and there along bedding planes. Two or more thin bentonite beds in upper 20 feet.....	40±
4.	Covered interval, probably underlain by hard gray shale like that above..	30
Gregory member		
Upper Gregory		
3.	Shale, chalky, or marl, weathers first into thin, hard gray chips, then into gray-buff chalky band along the outcrop	5
2.	Sandstone, brown, thin-bedded, slabby-	3/4

Feet

Lower Gregory

1. Shale, medium gray, weathers to thin flakes and gumbo. Contains many tiny masses of bright pyrite. Sulphur yellow effloresent horizontal bands on outcrop mark the position of eight thin bentonite beds which are mostly one-half inch or less in thickness. One nearest top is four and one-half inches thick. Also thick bentonite bed 15 feet above the base. Two beds of concretions which reach size of 15 inches by three feet in maximum diameter 16 and 18 feet above base of exposure. Bed of large dark gray septarian concretions at bottom of creek reach thickness of 9 inches by 5½ feet by 7½ feet. Concretions at base so numerous as to make an almost continuous bed..... 43

Table 5

Succession of Gregory member exposed 12 miles east of Pierre.

Section of upper Gregory and associated beds exposed 12.3 miles east of State House in Pierre along the Lewis and Clark trail west of De Grey.

Pliestocene — Feet

Drift..... 10+

Pierre formation

Sully member

Agency shale

Shale, medium gray, flaky. Contains limonite concretions one foot above base. Bentonite streak one-half inch thick one foot above base..... 10

Gregory member

Upper Gregory

Shale, light to medium gray. Weathers buff and chalky. Sandy in lower part. Contains

	Feet
abundant small gray shale pebbles in lower part. Becomes hard, dense, buff and flaky in upper.....	9
Sandstone, brown, slabby; thin-bedded fine textured. Tightly cemented with iron in lower part.....	3/4-1
Lower Gregory	
Shale, medium gray to drab; breaks up into somewhat conchoidally fractured blocks. Contains small, yellowish, porous concretions to two inches in diameter perforated by small tubes similar to worm burrows. Deeply stained with purplish stain in upper part.....	3

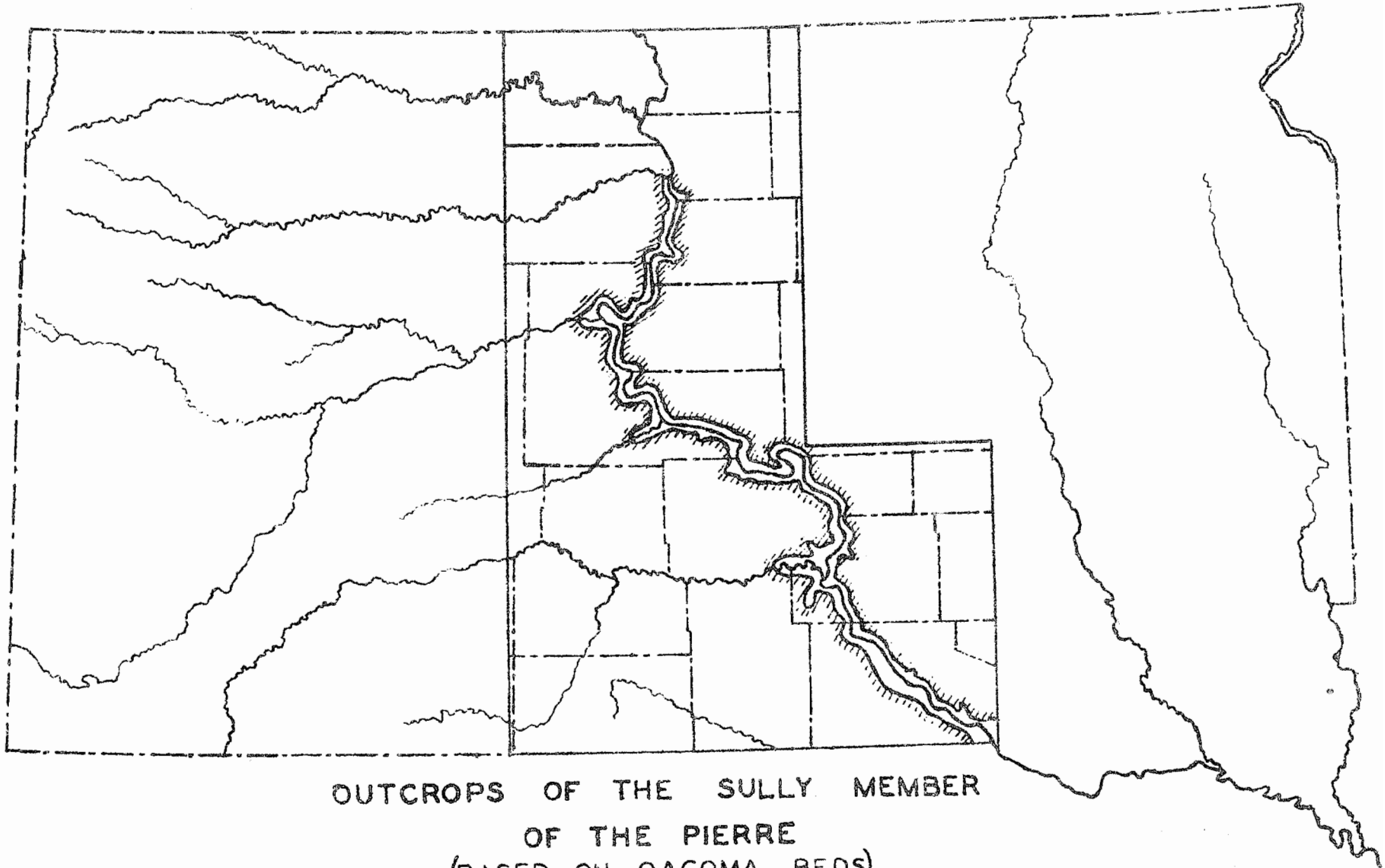
Thickness of the Gregory member:

The lower Gregory is 42 feet thick at the type locality at the south end of Rosebud bridge, Gregory County. At the outcrop above the Niobrara in the old cement plant three miles west of Yankton, Yankton County, the lower Gregory is very thin, being only seven feet in thickness. Along White River, south of Reliance, the thickness is greatly increased to 145 feet. Most of the thickening here occurs above the bentonites. At Chamberlain and north, the thickness is somewhat decreased to between 100 and 120 feet. South of Crow Creek, along South Dakota Highway 47, the thickness is decreased to 60 feet. Although the complete succession of lower Gregory is not exposed along Cedar Creek, west of the Great Bend, it is not likely that the thickness is greater there than at Crow Creek, as indicated by the fact that only 27 feet of lower Gregory occurs above the bentonite bearing lower beds.

The upper Gregory varies in thickness between 4 or 5 feet in the vicinity of the mouth of White River and 21 feet in NE $\frac{1}{4}$ Sec. 10, T. 96 N., R. 67 W. It is 9 feet thick at the northernmost exposure.

The total thickness of the Gregory member thus varies between a minimum of 12 feet at Yankton to 145 feet or more south of Reliance, along White River. The increase in thickness is apparently confined chiefly to the upper part of the lower Gregory in the beds above the bentonite bearing beds and below the upper Gregory west and north of the type location. The greatest thickness, which is approximately twelve times the minimum, is in the vicinity of Chamberlain and the mouth of White River. It is possible, however, that the thickness westward continues to be equal

PLATE VI



OUTCROPS OF THE SULLY MEMBER
OF THE PIERRE
(BASED ON OACOMA BEDS)

to the maximum. It may be suggested that the great differences in thickness in the Gregory member are due to non-deposition. In the exposure at Yankton, however, only two beds of bentonite were observed, with an aggregate thickness of only five or six inches. There is thus the possibility that part of the lower Gregory is missing due to post-depositional removal. This supposition also explains the occurrence of additional beds in the thicker exposures near the mouth of White River.

The Sully Member

Name and type locality:

The Sully member of the Pierre is named for characteristic exposures along both sides of the Missouri River in and opposite western Sully county, South Dakota. Typical exposures occur at the Little Bend opposite the site of old Fort Bennett and only a few miles north of one of the sites of Fort Sully. Characteristic exposures are not confined to this immediate vicinity, but may be seen at Cheyenne Agency, Dewey County, Fort Pierre in Stanley County, west and south of the Great Bend in Stanley and Lyman counties, and at and near Chamberlain and Oacoma in Brule and Lyman counties. In the Chamberlain-Oacoma vicinity, however, the lowermost zone is not developed.

Definition:

The Sully member of the Pierre consists of the body of shales lying between the chalky beds of the upper Gregory and the base of the highly bentonitic beds which lie at the base of the Virgin Creek member. It thus includes the basal beds of the Agency shale of Russell[1] and the top of the concretionary shales lying between the manganiferous Oacoma beds and the overlying highly bentonitic beds exposed at Fort Pierre, Oacoma, Cheyenne Agency and elsewhere in the Missouri valley of South Dakota.

Distribution:

The Sully member occurs as far east as the old cement plant at Yankton, Yankton County and has been traced north and west along the Missouri River and its tributaries to a short distance above the site of LeBeau where the base of the succession passes below the river. The uppermost beds pass below the river at or only a short distance below the highway bridge across the Missouri River at Mobridge (Plates I and VI). The Sully member has distribution at the surface southward into Nebraska for an unknown dis-

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1. Russell, W. L., The Possibilities of oil and gas in Western Potter county; South Dakota Geological and Natural History Survey, Report of Investigations No. 7, p. 5, 1930.

tance and doubtless occurs in western Kansas, where, however, its position in the succession is uncertain at this time. The member has been identified in well cuttings by its characteristic microfauna at considerable distance from the outcrop. The member occurs in cuttings in the Rosebud well in central Todd county, Hunter No. 1, drilled for the Gypsy Oil Company in 1931 in eastern Pennington county, and in the State School Lands No. 1 drilled in eastern Meade county by the Cosden Oil Company in 1927. Fossils characteristic of this member are listed also from the Ole Tanberg No. 1 well[1] in Ziebach county by Mrs. Applin. The Sully member thus has a known distribution, surface and subsurface, from Yankton to eastern Pennington and Meade counties and as far north as Dewey and Walworth counties. The maximum distance between known occurrences, namely the old cement plant at Yankton, and State School Lands No. 1 well is approximately 270 miles.

Subdivisions and general character:

The Sully member of the Pierre consists of a succession of beds divisible into three subdivisions which are readily recognizable over the area of outcrop. These have proven so useful in stratigraphic differentiations of the Pierre and are so characteristic in lithologic expression that names are applied to them here, with local significance only, however, unless further work indicates that use outside of the South Dakota region is merited.

The Sully member of the Pierre includes the following subdivisions, named from the base upward: the Agency shale, the Oacoma manganiferous zone, and the Verendrye shale zone. The Agency shale, a zone composed for the most part, where typically developed, of hard, light gray, siliceous shale, lies at the base of the Sully member. The Oacoma zone, a zone of highly bentonitic shales and clays containing manganiferous iron concretions over a considerable area, is the intermediate zone. The uppermost zone, the Verendrye shale, consists of clays and shales containing flattish concretions of clay ironstone which also contain some manganese, at least in places.

Lithologic Details:

Agency shale; distribution and lithologic character: The Agency shale (Plate III), which was first recognized and named by Russell[2], outcrops at Cheyenne Agency in southeastern Dewey county and continues to outcrop northward to the vicinity of the mouth of the Moreau river. The shale zone crops out in nearly, if not quite continuous exposures along the Missouri river, up

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1. Applin, E. R., A micro-fossiliferous upper Cretaceous section from South Dakota; Jour. Paleontology, Vol. 7, p. 219, 1933.
2. Russell, W. L., The possibilities of oil and gas in western Potter County, South Dakota Geol. and Nat. Hist. Survey, Report of Investigations No. 7, p. 5, 1930.

the Cheyenne river valley a short distance from the mouth, at Fort Pierre, and along Antelope Creek between Fort Pierre and the Great Bend, and to the west of the Great Bend, along lower Cedar Creek. South of Crow Creek, Buffalo county, the Agency shale is absent.

The Agency shale zone of the Sully member, where typically developed, is composed of light gray, siliceous shale which weathers to a gray of even lighter shade so that the weathered outcrop is silvery in appearance. The zone breaks down into conchoidally fractured, brittle, flattish chips and flakes. After exposure to weather, the pieces clink like slate and are harsh to the touch. Unlike most beds of the Pierre this shale does not weather to a gumbo. In many places a dark rusty brown stain so dark as to be almost purplish brown, occurs on the exposed surfaces. This dark stain is most conspicuous on relatively recently exposed joint faces and on freshly eroded surfaces in creek bottoms, and appears to be most characteristic of the lower part of the Agency shale.

The lower part of the Agency shale contains two or more thin bentonite streaks less than one inch thick. Several thin bentonites possibly occur in the upper part, as suggested by the manner of weathering, especially near the mouth of the Cheyenne river.

Concretions are not commonly observed in the Agency shale. Light medium gray concretions occur, however, just above the river level below the bridge west of Whitlocks Crossing. These reach a diameter of more than two feet. Along Antelope Creek, between Fort Pierre and La Roche, concretions of light gray limestone occur in a bed 52 feet above the creek bottom, only 13 feet below the top of the Agency. They are large, reaching a thickness of eight to ten inches and a maximum diameter of six feet. Small concretions, having a thickness of an inch and a diameter of six inches, which weather yellow and reddish yellow, occur rarely and sporadically elsewhere.

Oacoma zone; distribution and lithologic character: The Oacoma zone (Plate III), which is the medial subdivision of the Sully member of the Pierre, is one of the most conspicuous stratigraphic units exposed along Missouri River below the Great Bend. The barren, rounded clay knobs draped over with dark, black and purplish black, manganiferous concretions, and the dark zone between lighter colored gray shale zones have been traced along the Missouri River valley and tributaries from Charles Mix county northward to a point beyond the Great Bend. Although the manganiferous concretions are much less abundant north of the Great Bend, the zone has been traced, by stratigraphic position and lithologic character north as far as southwestern Walworth county, beyond which place the zone disappears beneath younger beds. The Oacoma zone has also been identified as far east as the old cement plant at Yankton. Furthermore, it is the microfossil content of the zone, in large measure, which permits the identification of the Sully mem-

ber in well cuttings from Todd and Pennington counties.

The Oacoma zone consists of beds of gray shale varying from a few inches to a few feet in thickness, alternating with very thin beds of bentonite and bentonitic clay. Near Oacoma and northward to the Great Bend and southward into Charles Mix county, it may be that bentonite is more or less disseminated through the shale as well as being concentrated into thin beds of relatively pure bentonite because the outcrops in this area weather down to bentonitic gumbo. This gumbo is very sticky and plastic when wet but dries to exceptionally hard clods of very uneven and irregular shape. North of the Great Bend the Oacoma zone is composed of beds of light gray, flaky shale with thin dark clays interbedded as elsewhere. Here, however, the flaky, light gray shales are notably more resistent than the thin, bentonitic, darker beds and the zone accordingly is conspicuously banded in the outcrop. Weathering and erosion of these beds produces a stair-step effect in the outcrop, the position of the treads being determined by the position of the thin bentonitic clays and that of the lifts apparently by the distance into the outcrop to which the bentonitic clay has been weathered.

Concretions, which occur on the outcrop in great abundance south of the Great Bend as black irregular masses, commonly of scoria-like appearance, have been well described from investigations made by D. F. Hewitt. Mr. Hewitt of the United State Geological Survey investigated the concretion beds in 1929 when shafts dug to determine the manganese content of the member were open. A description of the concretions, based on these investigations is quoted here.[1]

> "The manganiferous iron nodules commonly range from 2 to 3 inches in thickness and 3 to 8 inches in diameter and form persistent layers in the shale; where the quantity is low the nodules are separated, but where the quantity is high many nodules have coalesced to form continuous layers 3, 4 or even 5 feet long. The color of the fresh nodules ranges from pale gray to olive-green; under the influence of weathering the carbonates change to oxides and become black. Oxidation is complete to a depth of only a foot or two, but films of oxides are found to a depth of 6 or 8 feet. Even the unweathered nodules separate readily from the shale; with exposure to air the shale dries, cracks, and falls away from the nodules."

The manganese-iron concretions, together with the fossils associated with them, occur in greatest profusion in the vicinity of Chamberlain and Oacoma but they occur also in outcrops of the Oacoma zone as far south as Charles Mix county, twelve miles up Bad River from Fort Pierre, and about the mouth of the

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1. Dept. of the Interior, Memorandum for the press, Release for Feb. 5, 1930. Manganese iron carbonate near Chamberlain, South Dakota.

Cheyenne River in Armstrong and Sully Counties. North of this locality they occur in lesser quantity, but at the northernmost outcrop in southwestern Walworth county, three miles north of the mouth of Swan Creek, some manganese-iron carbonate concretions occur, together with their characteristic fossils.

As indicated, bentonite occurs in thin beds interbedded with the shales of the Oacoma zone and probably is disseminated through the shales themselves, particularly south of Great Bend. Thin streaks of bentonite have been observed in the Oacoma zone in many places but the weathering properties of bentonite and the rapid weathering of the bentonitic shales prevents observation of the bentonite beds in most places. Ten bentonite beds one inch thick were tabulated by Hewitt from a shaft excavated near Oacoma,[1] which apparently penetrated most of the zone. These bentonite beds were spaced at vertical intervals varying between three inches and several feet.

Masses of barite composed of crystals radiating from a common center to form rosettes, mostly one-half inch or less in diameter, are scattered sparsely over the outcrop in the exposures in Charles Mix and Gregory counties. They have not been observed near Chamberlain but they occur 2.7 miles north of Fort Thompson in Buffalo county.

Verendrye zone, distribution and lithologic character: The beds of the Sully member of the Pierre lying above the manganiferous Oacoma beds and below the bentonitic basal beds of the Virgin Creek member are here called the Verendrye beds (Plate III), with local significance only, however, from the exposure under and above the Verendrye monument, at Fort Pierre, in Stanley county.

The Verendrye beds are readily identifiable by stratigraphic position and lithology throughout the outcrop area which extends from southeastern Gregory county and southwest of Lake Andes in Charles Mix county to within a few miles of Mobridge, where the top of the Sully member passes beneath younger beds. The northernmost exposure noted was exposed in Sec. 33, T.17 N., R. 31 E., although the Verendrye zone extends under cover near the surface somewhat north of this exposure, perhaps nearly to Mobridge.

The Verendrye beds consist of light to medium gray shale which weathers first to gray chips of shale and later to bands of brown and gray gumbo. The lower part, in the area surrounding Fort Pierre appears somewhat banded in fresh exposures. Weathered exposures in many places show pronounced bands of gray and brown five to ten feet in width, with flattish concretions along the brown bands. The concretions are of light gray to olive green when fresh and become dark brown, rarely nearly black on exposure.

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1. Dept. of the Interior, Memorandum for the press, Release for Feb. 5, 1930. Manganese iron carbonate near Chamberlain, South Dakota.

They probably contain considerable iron carbonate as do those of the underlying Oacoma beds but they contain much less manganese, at least in most places. They differ also from the concretions of the Oacoma zone in their shape. The greater number are thin and notably flat, the upper and lower surfaces being nearly parallel in many cases. At Fort Pierre there are more concretions in the beds beginning 35 feet above the base to the top than elsewhere in the zone. Those high in the zone are larger than those below. At Wendte, up Bad River from Fort Pierre, where the Verendrye is exceptionally well developed, a bed of gray silty shale 20 feet thick occurs about 80 feet above the river. This gray bed does not weather to gumbo like the rest of the zone. It contains concretions, ovoid in cross section, of gray septarian limestone which reach a diameter of more than a foot. Thus in shape, color, and composition they differ from those characteristic of the Verendrye. A one-inch crust of cone-in-cone occurs in places about these concretions. Fossils occur rarely in it.

A few thin bentonite beds, two or more, less than an inch thick have been observed in the Verendrye at many places. Bentonite beds, however, are not commonly seen and do not occur in numbers in this zone. The zone possibly contains considerable disseminated bentonite, however, as suggested by the pronounced tendency of the beds to weather to gumbo.

Detailed sections of the Sully member:

Excellent exposures of the Sully member occur in many places. In the pages which follow representative sections are described in tables of succession. These sections have been chosen to show the stratigraphic succession of zones of the member, the relation of the Sully member to overlying and underlying beds, as well as to show lithologic details within the zones of the member. The tables of succession describe the beds exposed at the type locality in western Sully county, (Table 6) the succession opposite Whitlocks Crossing between the bridge across the Missouri River and the Cheyenne Agency in southeastern Dewey county (Table 7). The exposure at this place is the type section of the Agency shale.[1] The beds of the Sully member, as they are exposed at Oacoma, are described in the third table (Table 8) and the detailed lithology of the Oacoma zone as described by Hewitt near Oacoma from test shafts is copied in the succeeding table (Table 9). In the next table (Table 10) the succession at Fort Pierre is tabulated. It is here that the Verendrye zone at the top of the Sully member is typically exposed. A variation in lithology, including a gray bed containing large limestone concretions in the Verendrye beds is described in a section at Wendte, southern Stanley county (Table 11) and the northernmost satisfactory exposure of the Oacoma zone is described from above LeBeau, southwestern Walworth county (Table 12).

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1. Russell, W. L., The possibilities of oil and gas in western Potter county, S. Dak. Geol. and Nat. History Survey, Report of Investigations No. 7, p. 5, 1930.

Table 6

Succession of beds in the Sully member of the Pierre at the type locality opposite Fort Bennett

Section of beds of the Sully member together with overlying rocks exposed south of the Little Bend, just west of where the Missouri river can be seen both northeast and southwest of the road in western Sully county, opposite the site of old Fort Bennett.

Pierre formation	Feet
Virgin Creek member	
6. Shale, weathers to gumbo. Contains concretions of medium gray limestone.....	25 - 30
5. Shale, gray, flaky, contains bentonites in lower part, all poorly exposed.....	70
Sully member	
Verendrye zone	
4. Shale, weathers brown, contains several thin beds of flat, ferruginous concretions	110
Oacoma zone	
3. Shale, light gray, weathers to thin, drab gray, brittle flakes in beds one to three feet thick alternating with beds two to six or more inches in thickness of darker gray shale, probably bentonitic, which weathers brown. Alternation of colors produces a banded effect in the outcrop and differences in resistence of alternating beds produces stair step type of outcrop. Manganiferous iron carbonate concretions occur sparsely. Bed of very light gray concretions which weather into thin sheets eight feet below top. Baculites and Inoceramus 5-10 feet below the top in a manganiferous band.....	45
Agency shale	
2. Shale, light gray, weathers to thin, drab gray, brittle flakes; some tendency to banding in upper part; possibly a few thin bentonite beds in upper part.....	48
1. Covered, probably light gray shale like bed 2.....	30

Table 7

Succession of beds of the Sully member exposed at, below and above the bridge at Whitlocks Crossing, including the type section of the Agency shale.

Section of Sully member and overlying beds, beginning at river level, exposed at, below, and above the highway bridge across the Missouri river below Whitlocks Crossing and Cheyenne Agency, southeastern Dewey County, South Dakota.

Pierre formation	Feet
Virgin Creek member	
4. Shale, includes one or more bentonite beds, not well exposed.....	20
Sully member	
Verendrye zone	
3. Shale, gray; weathers brown. Contains flattish olive green concretions which weather dark brown, almost black. Two bentonite streaks in upper 20 feet....	130
Oacoma zone	
2. Shale, banded, mostly covered by gumbo from above.....	30
Agency zone	
1. Shale, light gray, siliceous. On weathering, breaks into flat, harsh feeling pieces which are very light in weight and which clink together like slate. Does not weather to gumbo. In lower part contains medium gray concretions to a diameter greater than two feet. Smaller concretions which reach a thickness of one inch and a diameter up to six inches, weather yellow and reddish yellow 20 feet below the top. Inoceramus occurs very sparingly.....	121

Table 8

Succession exposed along U. S. Highway 16 on hill west of Oacoma

Section of Sully member and underlying beds exposed on the hill along U. S. Highway 16 beginning 1.3 miles west of Oacoma, Lyman county, and extending one and one-half miles from the base of the section.

Pierre formation	Feet
Sully member	
Verendrye zone	
6. Shale, breaks down to brown gumbo in lower 50-60 feet, to gray gumbo above; contains flat olive green concretions which weather brown or black, especially at 50-60 feet above the base.....	160
Oacoma zone	
5. Shale, bentonitic. Weathers to gray and brown gumbo, mostly gray. Contains abundant olive green manganese-iron concretions which weather dark brown to purplish black.....	40
Gregory member	
Upper Gregory	
4. Shale, chalky, light gray; weathers to chalky buff.....	6 - 7
3. Sandstone, brown, thin bedded, slabby...	2
Lower Gregory	
2. Shale, light gray; few limestone concretions.....	60±
1. Covered slope.....	40

Table 9

Succession of beds in the Oacoma zone near Chamberlain as described by D. F. Hewitt[1] from a shaft penetrating these beds.

Section of Oacoma zone of Sully member from shaft 2, sec. 14, T. 104 N., R. 72 W. made by D. F. Hewitt.

	Feet	Inches
Shale, gray		6
Bentonite		1
Shale, gray	1	10
Bentonite		1
Shale, gray	1	8
Bentonite		1
Shale, gray	1	6
Bentonite		4
Shale, gray	1	2
Bentonite		2
Shale, gray	2	9
Concretion layer		4
Shale, gray	1	8
Concretion layer		4
Shale, gray	2	6
Bentonite		1
Shale, gray with concretions		6
Bentonite		1
Shale, gray		3
Bentonite		1
Shale, gray		5
Bentonite		1
Shale, gray	2	6
Shale, gray with 9 concretion layers	5	
Bentonite		1
Shale, gray with sporadic concretions	3	
Shale, gray with 11 concretion layers	3	3
Shale, gray	2	
	32	4

1. Dept. of the Interior, Manganese-iron carbonate near Chamberlain, South Dakota, Memorandum for the press, Release for Feb. 5, 1930.

Table 10

Succession of beds at Fort Pierre

Section of Sully member and overlying beds exposed in the railroad cut, under Verendrye monument and in cut along U. S. Highway 14 below, beside, and above the monument.

Pierre formation	Feet
Virgin Creek member	
4. Shale, flaky, sub-metallic sheen; contains one or more fairly thick bentonite beds indicated by bentonite "blossom".....	20
Sully member	
Verendrye beds	
3. Shale, light to medium gray, which weathers to brown and gray gumbo bands. Flattish concretions of olive green, which weather brown to nearly black along the brown bands at vertical intervals of from five to ten feet. Become abundant 35 feet above base. Scattered abundantly below Verendrye monument. Larger concretions in upper part. One or two thin beds of bentonite 125 feet above base.....	170-180
Oacoma zone	
2. Shale, of alternating light and dark layers. Light beds 1-3 feet thick. Dark layers thin. Light colored beds most resistant, the dark weathering to dark gray gumbo. Alternation produces banding and stair steps. Very few manganese-iron concretions. Bed of whitish gray concretions to 2-3 feet in diameter which weather into thin, mostly vertical slices. Difficult to measure because it dips rapidly in various directions and is much slumped....	30
Agency shale	
1. Shale, exposed in railway cut, light gray, fairly hard, breaks down to flattish conchoidal chips. On vertical	

Feet

joint faces a film of dark, rusty brown, almost purplish brown occurs. Contains one or more thin bentonite beds. At various intervals contains thin light colored bands of light weight harsh-feeling siliceous rock. Occasional small fragments and larger pieces of Inoceramus..... 28

Table 11

Succession at Wendt both north and south of Bad River.

Section of the Verendrye zone of the Sully member, and overlying beds exposed on roads leading both north and south of Wendte up valley wall of Bad River, southern Stanley county, South Dakota.

Pierre formation — Feet

Virgin Creek member

Upper Virgin Creek

5. Shale, drab, buff-gray, to brown. Chalky white gray concretionary material at base. Cone-in-cone 1/2-3/4 inches thick twenty feet above base. Contains numerous finely perforated concretions, Belemnitella, Serpula (?) wallacensis Elias and reptile bones.. 47

Lower Virgin Creek

4. Shale, purplish gray, metallic sheen; contains 17 or more bentonite beds, mostly thin but some 1-1½ inches. Many large gypsum crystals in lower 25-30 feet. Weathers to dark gumbo in upper 4-5 feet; contains a few small calcareous concretions 30 feet above the base. 74

Sully member

Verendrye beds

3. Shale, gray with flattish concretions. Concretions weather rusty brown, two feet in diameter in upper part, three inches thick..... 140

		Feet
2.	Shale, light to medium gray with medium gray limestone concretions to a size of eight inches thick and two feet in diameter. Cone-in-cone one-half inch thick with parallel "cones". Shale and gray shale make a band and terrace which may be observed for several miles below Wendte on Bad River.....	10±
1.	Shale, light gray, few concretions	50

Table 12

Succession of beds above Le Beau

Section of beds of the Sully member exposed in cut bank three miles north of the mouth of Swan Creek.

Pierre formation

Sully member

Verendrye beds

2.	Shale, somewhat banded, weathers brown. Concretionary band of limy white concretions at base.....	10

Oacoma zone

1.	Shale, banded. Light gray flaky shale form resistent bands about two feet thick with dark, less resistent gumbo bands 5-6 inches thick between.....	18

Thickness of the Sully member and its subdivisions:

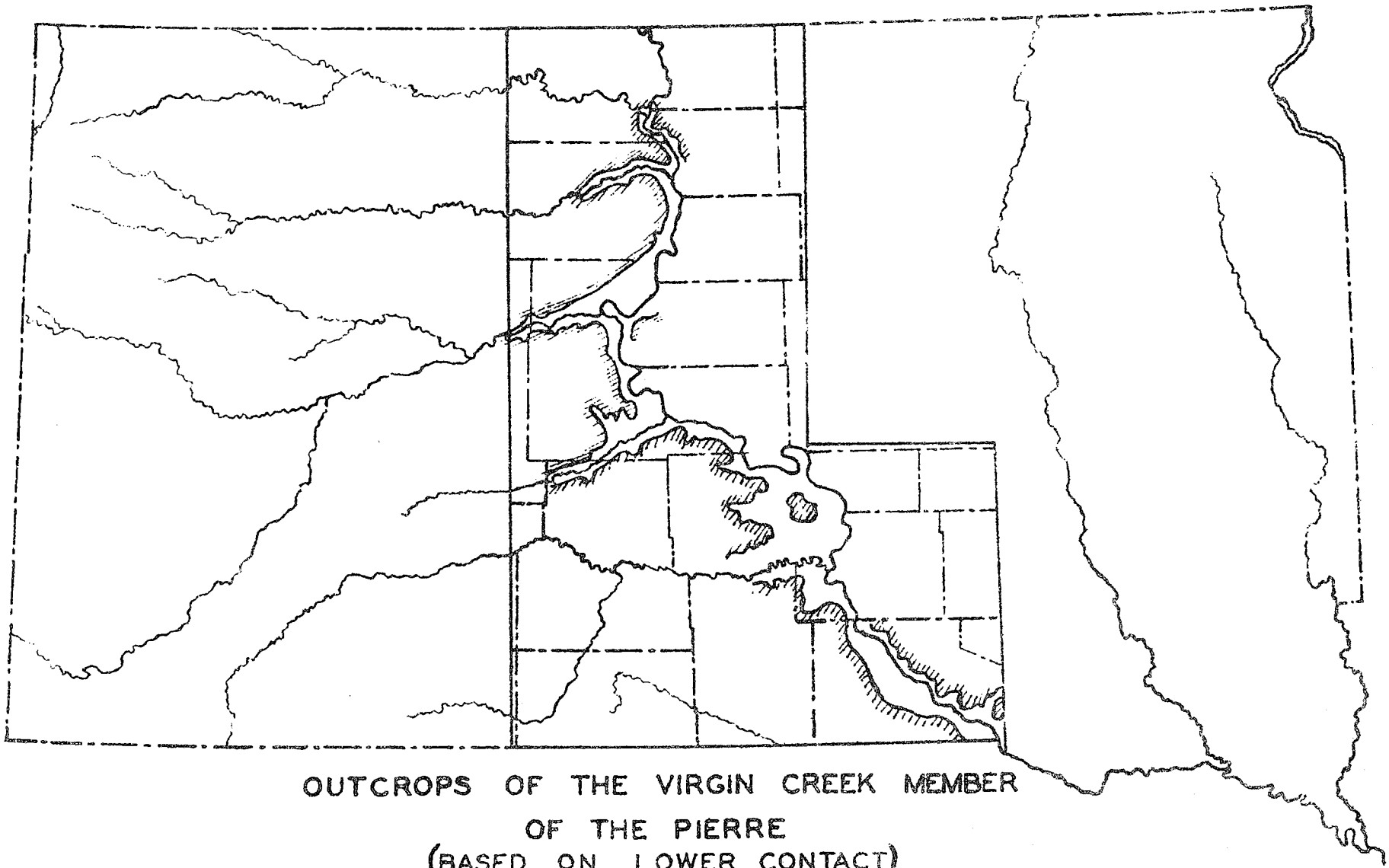
The Sully member of the Pierre varies considerably in thickness from place to place in the area of outcrop (Plate IV). Variation is due to variations in thickness of the subdivisions of which the member is composed. In the tables of succession which have been cited in preceeding pages, differences in thickness may be observed in the Agency shale. The Agency appears to be entirely absent south of Crow Creek in Buffalo county. At Cedar and Antelope creeks to the west of the Great Bend in Stanley county, a thickness of more than 65 feet of Agency occurs. Opposite Fort Bennett in Sully county the Agency is greater than 80 feet in thickness. Below Cheyenne Agency 121 feet of the Agency shale were measured and an unknown thickness occurs below the level of the Missouri River. The Agency thus is a wedge of shale of possibly 125 feet in thickness which thins out completely in approximately 80 miles.

Variations in thickness of the Oacoma zone are not great. Those which have been measured are possibly due in part to slumping, to minor faulting, to interpretation of the position of contacts, and to actual variations in thickness of beds of stratigraphic identity. Measurements of the zone vary between 20 feet on Antelope Creek to 46 feet near Wheeler in Charles Mix county. The Oacoma zone is thus fairly uniform in thickness within the area of outcrop.

The Verendrye beds, on the other hand, vary greatly in thickness from 88 feet near Wheeler in Charles Mix county up to more than 200 feet at Wendte on Bad River. Opposite Fort Bennett the zone is 120 feet thick, at Oacoma and at Cheyenne Agency approximately 130 feet, and at Crow Creek and Fort Pierre about 170 feet. The Verendrye zone thus thickens toward the west, possibly toward the Black Hills.

The total thickness of the Sully member varies between 134 feet in Charles Mix county and a probable 315 feet at Wendte. The lack of thickness in Charles Mix county is due to the absence of the Agency and the relative thinness of the Verendrye beds. Although there is some increase in thickness at Chamberlain the Agency is absent also in that locality. At Cheyenne Agency the thickness is at least 285 feet because of the great thickness of the Agency shale and at Fort Pierre the thickness is estimated to be 270 feet. The thickness at Wendte, southern Stanley county, is estimated on the thickness of the Verendrye which is more than 200 feet, the Oacoma 40 feet and on the presumption that the Agency is 75 feet thick there.

PLATE XII



OUTCROPS OF THE VIRGIN CREEK MEMBER
OF THE PIERRE
(BASED ON LOWER CONTACT)

The Virgin Creek Member

Name and type locality:

The Virgin Creek member of the Pierre is here named from an exposure in the valley wall of Virgin Creek and in the bare flats and hills above it one and one-half miles south of Promise, northeastern Dewey county, South Dakota. Here both the lower and upper parts of the succession are well exposed. The upper Virgin Creek, which is commonly badly slumped or outcrops under long gentle slopes and under wide flat areas, is well exposed here.

Definition:

The Virgin Creek includes all beds between the Sully member and the highly calcareous, chalky beds of the Mobridge member. It thus includes the bentonite bearing shales which lie above the Verendrye zone, with its characteristic iron carbonate concretions, and all characteristically non-calcareous beds to the base of the Mobridge. It includes, near the top, the zone of limestone concretions which contains the Sage Creek fauna of the Big Badlands and elsewhere, and which here contains the rather meager representation of that fauna.

Distribution:

The Virgin Creek member has wide distribution at the surface along the Missouri river and its tributaries. The outcrop is narrow and lies near the river in the southernmost outcrops in southeastern Gregory county and on the opposite side of the river in Charles Mix county. The outcrop widens northward, however, and forms a band, dendritically patterned, which is probably more than 20 miles wide in some localities. The base of the member passes below the level of Missouri River a short distance south of Mobridge, Walworth county and the top disappears under the river and younger beds about six miles south of the state boundary. From these outcrops in the Missouri valley, the member passes northward, under cover, under North Dakota, westward under the Great Plains, eastward under drift cover, and southward into Nebraska for an unknown distance. It covers wide areas north, south and east of the Black Hills and has been observed beyond these South Dakota outcrops in southwestern North Dakota and in eastern Montana along the crest of the Cedar Creek anticline. The member is also exposed, south of Springfield, Bon Homme county, and has been observed and identified five miles south of Crofton, Nebraska, 9 miles west and south of Yankton, Yankton county.

Subdivisions and general characters:

The Virgin Creek is readily divisible, on the basis of lithology, into two zones. The lower of these is composed of relatively resistent, light to medium gray shale which contains a number of thin but conspicuous bentonite beds. The upper part of the Virgin creek, especially the lower beds, breaks down to leaden gray gumbo, in many places tinged with rusty brown. The upper Virgin creek, in many places contains characteristic, small fossiliferous concretions in the lower part and a bed containing large limestone concretions, in some cases very fossiliferous, in the upper part.

Lithologic details:

Lower Virgin Creek: The lower Virgin creek consists of light to medium gray, hard shale which first erodes into buttress-like promontories similar to those of the lower Gregory. These buttresses are coated, in many places, with a reddish brown or rusty brown coating. Near Mobridge and on Virgin Creek the shale breaks down as it weathers into flattish pieces which produce a dull slaty "clink" when struck together. These are harsh to the touch like the typical Agency at the base of the Sully member. The pieces of shale later break up into thin flakes which have a faint purplish cast giving a sub-metallic sheen or luster to the beds, a character which has been noted in many places. North of Mobridge, near Ashley Island, 15 feet below the top, the shales are fissile and split into sheets which are like tar paper.

Thin bentonite beds are a characteristic feature of the lower Virgin creek. Indeed, it is on the basis of numerous thin white bentonite streaks across the outcrops that these beds are most readily distinguished. Eleven beds occur in the type section of the Virgin Creek above Promise on Virgin Creek and at Mobridge nine were noted, the thickest being one and one-half inches thick. Most of the bentonites are one-half inch or less in thickness. In Charles Mix county along U. S. Highway 28 in the SE$\frac{1}{4}$ sec. 25, T. 97 N., R. 68 W., eleven bentonite beds occur, the thickest of which is three inches thick. South of Wendte, above Bad River valley seventeen beds of bentonite were counted in the lower Virgin Creek. In an outcrop along U. S. Highway 14, in Willow Creek, west of Fort Pierre, the lowest exposed bentonite is four and one-half inches in thickness.

Concretions occur in the lower Virgin Creek, but rarely in abundance. In Virgin Creek one and one-half miles above Promise a zone occurs of light gray calcareous concretions so numerous and closely set that it produces a ledge which is over a foot thick in places. These concretions are deeply iron-stained both above and below. Sporadic gray concretions and

thin, hard, calcareous concretionary beds occur in these beds in many places. Cone-in-cone is associated with some of the larger concretions as a crust three quarters of an inch thick. Flattish gray septarian concretions to six inches or more in diameter, incrusted with glistening selenite and with the cracks filled with the same mineral were noted in these beds at several places. These gypsiferous concretions occur between beds of bentonite and also in overlying shale like that between the bentonites which are also included in the lower Virgin Creek because of lithologic similarity. Along Virgin Creek, the gypsiferous concretions occur 60 feet above the base of the exposure of lower Virgin Creek.

Upper Virgin Creek: Included in the upper Virgin creek are those beds of shale which lie above the bentonitic lower Virgin Creek and below the highly calcareous shale and chalk of the Mobridge member. These beds are rarely well exposed except at high elevations near drainage, because they break down readily to gumbo which obscures the outcrop and commonly that of underlying beds. The gumbo resulting from the weathering of the upper Virgin creek covers wide areas of sparsely grassed flats and gentle slopes west of the Missouri river.

In fairly recent exposures the upper Virgin creek, particularly the lower part, consists of gray shale which weathers rapidly to light gray, leaden gray and brownish gray gumbo which is arranged in horizontal bands of varying widths. The gumbo is extremely sticky when wet but it dries to irregular shaped, rough, hard clods and in drying also produces a system of irregular joints or "gumbo checks" on the surface. In many places the uppermost beds, those lying above a persistent bed of concretions, are somewhat silty in texture and show less tendency to gumbo formation.

Concretions have been observed in the upper Virgin creek at many places. Large, dark gray limestone concretions occur on Virgin Creek 30 feet above the base. A persistent bed of medium to dark gray concretions has been observed at many places over wide areas near the top of the Virgin creek. Many of these are septarian with sulphur colored calcite in the cracks. Locally, as in the vicinity of Midland and Capa, the concretions are highly fossiliferous but commonly fossils are of rare occurence. Near the Black Hills and in North Dakota and Montana they are abundantly fossiliferous and contain the Sage Creek fauna. The concretion bed varies between 20 and 70 feet below the top of the Virgin Creek.

The lower part of the upper Virgin Creek, in nearly every exposure, contains sporadic small concretions scattered through it. These differ from concretions at other horizons. They are

buff gray, and brown in color but are nearly white on the surface. They are characteristically perforated with many small holes, probably worm furrows. These concretions are formed about part of pelecypods, baculites, and crabs. Cylindrical concretions (Serpula (?) wallacensis Elias) with a longitudinal cylindrical axis which weathers out to leave an axial hollow are common at many places.

Detailed sections of the Virgin Creek member:

The characters and succession of beds of the Virgin Creek are indicated in tables of succession in pages which follow. A most complete exposure, the type section, on Virgin Creek is given in Table 13. This section shows not only the lower Virgin Creek, which is the part of the member most commonly seen, but also the upper Virgin Creek which is rarely exposed satisfactorily. Details of the bentonite bearing lower Virgin Creek are described in a section (Table 14) along Lance Creek 11.5 miles east of Hayes, Stanley county and one opposite Mulehead (Table 15) in Charles Mix county. The total thickness of the Virgin Creek member as it is exposed in SE$\frac{1}{4}$, sec. 3, T. 96 N., R. 67 W., Charles Mix county is described in Table 16. Descriptions of the Virgin Creek are included also with those of other beds in other sections of this report. (Table 6, p. 27; Table 7, p. 28; Table 10, p. 31; Table 11, p. 32; Table 17, p. 46; Table 19, p. 48; Table 20, p. 52; Table 22, p. 54.

Table 13

Succession of beds exposed along Virgin Creek above Promise.

Section of Virgin Creek beds exposed in cut bank and above, along Virgin Creek beginning 1.5 miles and extending to 1.8 miles south of Promise, northeastern Dewey county, South Dakota.

	Feet
Pierre formation	
Virgin Creek member	
Upper Virgin Creek	
3. Shale, medium gray; breaks down to somber leaden gray gumbo, very sticky when wet. Sporadic small perforated concretions and small concretions formed about crabs and Baculites and Serpula (?) wallacensis Elias scattered through lower part. Weathers to bands of light gray, lead gray and brownish gray.	

		Feet
	Bed of concretions of gray limestone to one foot or more in diameter 30 feet above base, also at 70 feet above base a bed of larger concretions, some septarian with sulphur colored calcite in cracks.....	100
	Lower Virgin Creek	
2.	Shale, breaks down to thin gray flakes with submetallic, bronzy appearance. Three bentonite streaks and a few concretions in upper part above top bentonite which is 25 feet above base. Contains gypsum filled and coated septaria 20 feet above the base.....	44
1.	Shale, light gray, erodes first to buttresses with red to rusty brown coating. Later breaks down to gentle slopes. Where recently undercut breaks into flattish pieces which produce dull slaty "clink" when struck. Later breaks down to flakes which have a faint purplish cast which produces a sub-metallic sheen. Contains 11 thin bentonite beds, closest together in upper part, ranging from three inches to five feet apart. Bed of light gray, calcareous concretions deeply iron-stained below and above; form a continuous ledge in the creek bottom.....	40

Table 14

Succession of lower Virgin Creek 11.5 miles east of Hayes.

Section of lower Virgin Creek exposed along Lance Creek in valley wall south of U. S. Highway 14, 11.5 miles east of Hayes, central Sully county, South Dakota.

Pierre formation	Feet	Inches
Virgin Creek member		
Lower Virgin Creek		
22. Shale, light medium gray, weathers to fine, thin flakes of sub-metallic luster. Three or		

		Feet	Inches
	more thin bentonite streaks in shale. Sparse ferruginous concretions to six inches thick by two feet in diameter about four or five feet above base	15	
21.	Bentonite		1/8
20.	Shale, gray	3	
19.	Bentonite		1/4
18.	Shale, gray	2	6
17.	Bentonite		1/2
16.	Shale, gray	2	6
15.	Bentonite		1/8
14.	Shale, gray	1	3
13.	Bentonite		1 1/4
12.	Shale		3
11.	Bentonite		1/8
10.	Shale, gray	2	6
9.	Bentonite		1/2
8.	Shale, gray	2	6
7.	Bentonite		1/2
6.	Shale, medium gray, weathers to chips	1	6
5.	Bentonite, very light gray		6
4.	Shale, gray	1	
3.	Bentonite, very light gray		3/4
2.	Shale, gray, sphaeroidally weathered, sphaeroids three inches long, two inches high	2	
1.	Shale, medium gray, black when wet, mostly covered	4	

Table 15

Succession of beds in the Virgin Creek member in northwestern Charles Mix County.

Section of lower Virgin Creek exposed in road cut along Federal Highway 281 in SE¼ sec. 25, T. 97 N., R. 68 W.

Pierre formation		Feet	Inches
Virgin Creek member			
Lower Virgin Creek			
23.	Shale, gray	7	
22.	Bentonite		1/4
21.	Shale, gray, hard		10

		Feet	Inches
20.	Bentonite, yellow.....		1/2
19.	Shale, gray.....	2	6
18.	Bentonite.....		1/2
17.	Shale, gray.....		11
16.	Bentonite.....		1/4
15.	Shale, gray.....	1	
14.	Bentonite.....		1/2
13.	Shale, gray.....		4
12.	Bentonite.....		1 1/4
11.	Shale, gray.....	1	
10.	Bentonite.....		1
9.	Shale, gray.....	1	6
8.	Bentonite.....		1/2
7.	Shale, gray.....	4	
6.	Bentonite.....		1
5.	Shale, gray.....		4
4.	Bentonite.....		3
3.	Shale, gray, contains flattish septarian concretions with septa filled with selenite and coated with selenite.....	5	
2.	Bentonite.....		1/2
1.	Shale, gray.....	7	

Table 16

Succession of Virgin Creek member exposed in SE $\frac{1}{4}$ sec. 3, T. 96 N., R. 67 W.

Section exposed in road cut and above to north along U. S. Highway 18, SE $\frac{1}{4}$ sec. 3, T. 96 N., R. 67 W., Charles Mix County, South Dakota, includes also underlying beds exposed in NE $\frac{1}{4}$ sec. 10, T. 96 N., R. 67 W., south of the highway.

Pierre formation	Feet	Inches	Feet
Mobridge member (exposed, see Table 19)			
Virgin Creek member			
Upper Virgin Creek			
17. Shale, breaks down to grass covered gumbo slope. Few finely perforated concretions, and Serpula (?) wallacensis Elias on slope....			34

		Feet	Inches	Feet
Lower Virgin Creek				
16.	Shale, gray, poorly exposed.	10		
15.	Bentonite		1	
14.	Shale, gray	1		
13.	Bentonite		1/2	
12.	Shale, gray		1 1/2	
11.	Bentonite		1	
10.	Shale, gray	1		
9.	Bentonite		1 1/2	
8.	Shale, dark gray		6	
7.	Bentonite		1/2	
6.	Shale, dark gray	3		
5.	Bentonite		1	
4.	Shale, very dark gray	2		
Sully member				
Verendrye beds				
3.	Shale, medium gray in lower 80 feet, dark gray above. Dark brownish black in lower part when damp. Breaks down to small conchoidally fractured chips and flakes which break down further to gumbo. Hard limy concretions to three inches thick by two feet in diameter 20 feet above the base. Few ferruginous concretions scattered through. Large selenite crystals in upper part			88
Oacoma zone				
2.	Shale, drab and gray when fresh; slightly calcareous. Contains more or less bentonite. First breaks down into drab flakes which are plastic when wet. Weathers down into gumbo with starchy fracture and gumbo checking on outcrop. Beds of manganese-iron nodules of olive green become dark brown to purplish black and accumulate on surface. Contains barite "roses" to 1.5 inches in diameter			46

Feet

Gregory member

Upper Gregory

1. Shale, chalky shale and chalk. Medium gray, thin bedded, blocky when fresh. Contains many worn gray shale pebbles to one-fourth inch in diameter. 21

Thickness of the Virgin Creek member and its subdivisions:

Owing to the tendency of the Virgin Creek member, the upper part in particular, to break down to a gumbo and to form topographic flats and slopes rather than more or less vertical outcrops, the thickness is commonly difficult to ascertain. The base is placed at or near the lower limit of the numerous bentonites of the lower Virgin Creek. The top may also be readily determined in many places because the overlying Mobridge member is relatively resistent and a pronounced color change from dark gray to yellow or buff occurs. The top and bottom, however, are commonly far apart, in many cases several miles, so that the interval contains any errors due to even small structural displacements.

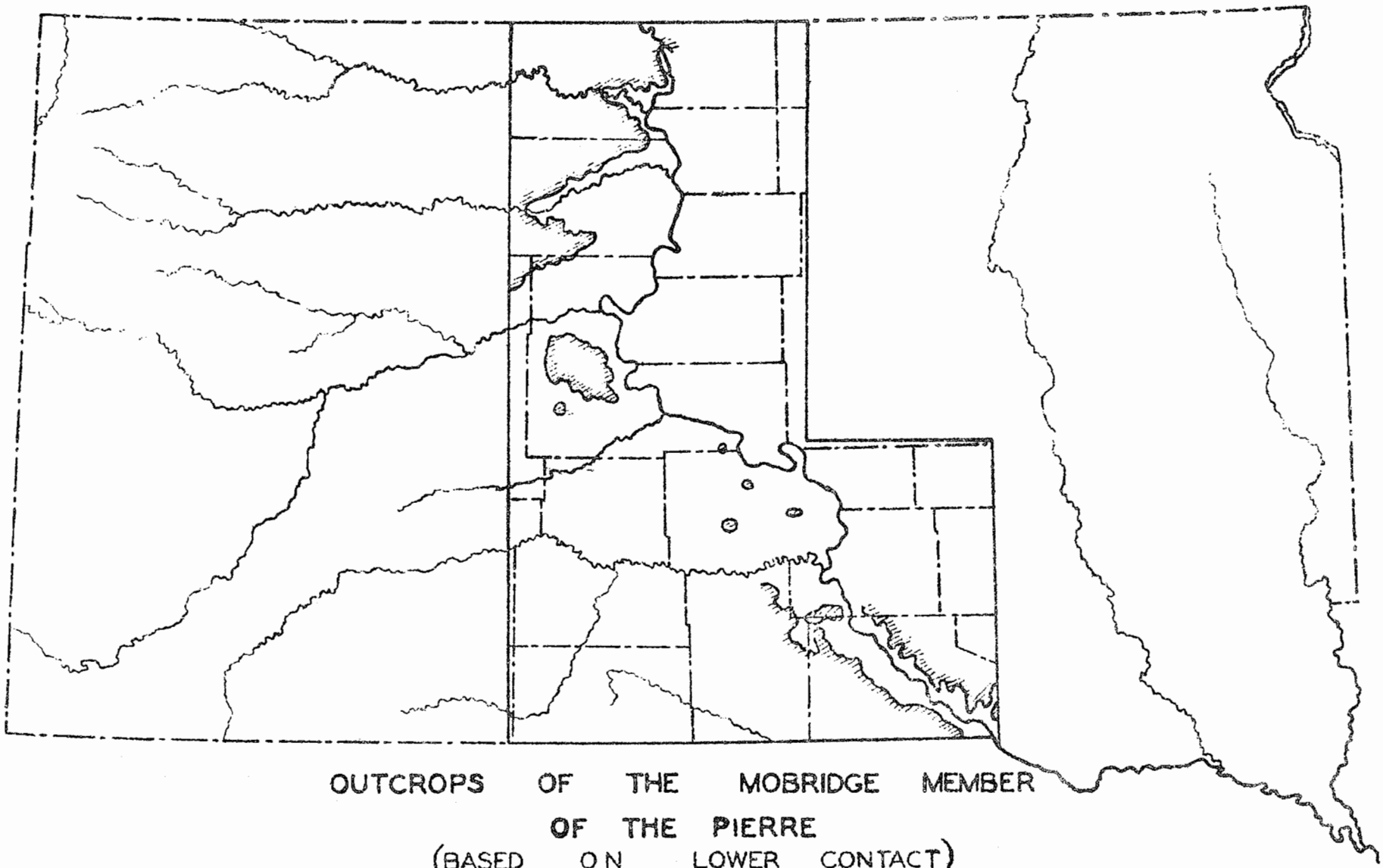
Nevertheless, a sufficient number of measurements have been made to indicate very considerable variations in thickness of the member and of its subdivisions. The member is thinnest in the southernmost exposures in Gregory and Charles Mix counties. The greatest thickness of beds occurs in the vicinity of the type locality in northeastern Dewey county. At Mobridge, however, the thickness appears to be considerably reduced.

The lower Virgin Creek is 26 feet thick in the SE $\frac{1}{4}$ sec. 25, T. 97 N., R. 68 W., Charles Mix county. This thickness includes at the top seven feet which lie above the uppermost bentonite exposed. South of Wendte above Bad River the lower Virgin Creek is 74 feet thick. On Virgin Creek, above Promise one and one-half miles, the thickness is somewhat more than 84 feet and opposite Mobridge somewhat more than 42 feet.

The upper Virgin creek is only 28 feet thick in sec. 10, T. 96 N., R. 67 W., in Charles Mix county. South of Wendte the beds below the persistent bed of concretions is 47 feet. On Virgin Creek the upper part, although not continuously exposed, is more than 100 feet thick and is probably 140 feet in thickness. Opposite Mobridge the thickness is 95 feet.

The total thickness of the Virgin Creek is thus about 55 feet in Charles Mix County, the thickness south of Wendte, Stanley County is more than 121 feet, probably approximating 170 feet. On Virgin Creek, northeastern Dewey County, the total thickness reaches a possible 224 feet and opposite Mobridge somewhat more than 137 feet. It is very probable that the member increases greatly in thickness near the Black Hills and in northwestern South Dakota.

PLATE VIII



OUTCROPS OF THE MOBRIDGE MEMBER
OF THE PIERRE
(BASED ON LOWER CONTACT)

Mobridge Member

Name and type locality:

The Mobridge member of the Pierre is named from a characteristic and typical exposure above the west end of the highway bridge across the Missouri River, at Mobridge. This exposure is thus in southeastern Corson county opposite the city of Mobridge, Walworth county, South Dakota, the city from which the member is named.

Definition:

The Mobridge member of the Pierre is a succession of highly calcareous shale, marl and chalk beds which lies above the gumbo forming shales of the Virgin Creek member and below the non-calcareous shale beds of the Elk Butte member. The member forms a wide buff band on the outcrop between the dark color of the underlying and overlying beds.

Distribution:

The Mobridge member extends from a position near the North Dakota boundary to the southern boundary of South Dakota (Plates I and VIII). The outcrop forms a relatively narrow band roughly parallel with the boundary of the Fox Hills across Corson, Dewey and Armstrong counties. In Stanley, Jones, and Lyman counties fairly wide, flattish areas are underlain by the member. In the Rosebud region, as indicated in outcrops in Tripp and Gregory counties, the Mobridge member underlies extensive areas where it is in large measure responsible for the buff and yellow subsoils of the region. Here and there, as in the Iona Hills in Brule county, Medicine Butte, north of Reliance in Lyman county, Fort George Butte in southeastern Stanley county, as well as the Bijou Hills in Brule county, are outliers of the member, overlain by younger rocks.

During this investigation the Mobridge member was not traced westward beyond South Dakota Highway 63 across southeastern Ziebach county and Manilla. Fossils in collections made by former members of the State Geological Survey indicate that it occurs near Plum Creek, central Haakon county, and near West Fork, northern Haakon county. The writer has observed beds of similar character containing characteristic fossils near Elm Springs, Boneita Springs, and Clough, Meade County and fossils, apparently from this member, were collected by Ward in the Big Badlands. Thus it apparently continues westward above the Virgin Creek over wide areas.

The member passes northward, under cover, under North Dakota, westward under the Great Plains, and southward into Nebraska where it extends considerably farther east than it is now known to do in South Dakota. This is indicated in a description of the Pierre along Bazile Creek by Condra[1] which indicates 100 feet of beds under chalky slopes which are underlain and overlain by clays. These outcrops are south and east of Running Water, Bon Homme county, South Dakota. The easternmost outcrops known at this time in South Dakota are south of Lake Andes, Charles Mix county, although the member doubtless persists, under drift into Bon Homme county.

Lithologic Character:

The Mobridge member consists of medium gray and medium bluish gray to dark gray shale and chalk. The beds are everywhere highly calcareous and more or less chalky, indeed, some of the basal beds in southern exposures are essentially chalk. In fresh exposures the rock is fairly massive but close observation indicates that massive beds five to fifteen feet thick are composed, at least in part, of thin obscure lamination only a fraction of an inch in thickness. Everywhere in the area of outcrop these beds weather to shades of buff ranging from light buff, almost white, to brownish buff, the lighter shades apparently predominating in the lower and upper parts.

Concretions and limestone lenses occur in the Mobridge member in many places. Near Mobridge flat concretions, mostly small, which are about one inch thick and reach a diameter of eight inches or more, are very common. These are composed of medium to dark gray limestone which weathers to brownish buff and deep chocolate brown. In many cases, near Mobridge, the concretionary limestones consist only of a limestone filling of the living chamber of Baculites. Rounded concretions measuring more than a foot in diameter occur in the member a mile and a half south of Nowlin on Bad River. At very many places, however, thin beds of limestone, discontinuous in outcrops where well exposed, occur at various positions in the member. These beds of limestone are probably gray when fresh but as commonly seen are weathered to buff, brownish buff and brown. They are commonly only a few inches thick, but here and there, reach thicknesses of more than a foot.

Across from Mobridge three such beds are present which reach a thickness of four inches at 41, 50, and 52 feet above the base of the member. Above Federal Highway in SE$\frac{1}{4}$ sec. 3, T. 96 N., R. 67 W., similar limestone occurs within 20 feet of the base and again 10 to 14 feet below the top. Well developed cone-in-cone which reaches a thickness of three inches is commonly associated with some of the higher limestone beds, particularly in outcrops south of Lake Andes in Charles Mix county. Fossils occur

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1. Condra, G. E., Geology and Water resources of a portion of the Missouri river valley in northeastern Nebraska, U. S. Geol. Survey Water-Supply Paper No. 215, p. 16, 1908.

in both the concretions and the limestone beds but are rare or essentially absent in many places.

Bentonite is not a conspicuous constituent of the Mobridge member although one bed an inch thick was observed 31 feet above the base in sec. 3, T. 96 N., R. 67 W. South and somewhat west of Platte in sec. 33, T. 98 N., R. 68 W., three one-inch bentonite beds occur in the lower 70 feet. Southeast of Kenel, 4.5 miles south of the North Dakota line, two thin beds occur at the top of the member and two other beds 50 feet below it.

Representative sections of the Mobridge member:

Exposures which show parts of the Mobridge member are common from near the North Dakota boundary southward along the outcrop into Nebraska. For the most part, however, the outcrop is covered by buff and yellowish buff chalky clay which indicates the position of the member. In the pages which follow, exposures are described which show the character of these beds where they are fairly fresh and where they are completely exposed. The first of the exposures described (Table 17) is the type section of the Mobridge member across the Missouri river from Mobridge. The second section (Table 18) described is near the northern boundary of South Dakota. The third table (Table 19) is a readily accessible exposure in Charles Mix county which permits detailed study of the succession.

Table 17

Succession of beds of the Mobridge member in the type section.

Section of the Mobridge member, together with underlying and overlying beds, exposed in road cuts along U. S. Highway 12 above west end of highway bridge across the Missouri river.

		Feet
Recent		
	5. Soil.....	2
Pierre formation		
Elk Butte member		
	4. Shale, poorly exposed. Apparently banded. Weathers gray with buff cast. Bentonite "blossom" at top.....	26
Mobridge member		
	3. Shale, calcareous, medium blue gray. Weathers light buff, light brownish	

Feet

buff in lower 50 feet. Concretions, medium to dark gray when fresh, weather to brownish buff; mostly small, less than eight inches in diameter and one inch in thickness. Concretions begin 10 feet above base and extend upward to 52 feet. In one cut upper three bands of concretions at 41, 50, and 52 feet above base become ledges of buff limestone four inches thick which apparently are not continuous. Fossils, chiefly Baculites occur both in concretions and loose in shale. Upper 50-60 feet weathers light buff on surface- 136

Virgin Creek member

Upper Virgin Creek

2. Shale, breaks down to gumbo. Beginning 10 feet above the base 45-55 feet of beds weather to somber dark leaden gray gumbo. Contains two beds of bentonite, the lower of which is 2.5-3.0 inches thick which are covered here but well exposed 5 miles north of Mobridge opposite Ashley Island. Contains small finely perforated concretions, Serpula (?) wallacensis Elias, and small crabs. Upper contact somewhat obscure, placed at top of non-calcareous beds in cut..... 95

Lower Virgin Creek

1. Shale, medium gray, hard, silicious; thin and evenly bedded. Fifteen feet below top separates into sheets like tar paper. A rusty brown film occurs on vertical joint faces. Breaks down to light and medium gray polygonal, Harsh feeling pices which produce a dull, slaty "clink" when struck. Nine thin beds of bentonite, mostly one-half inch or less in thickness, one bed one and one-half inches thick, occur in the upper part, bentonites six inches to two feet apart.

This shale erodes into buttresses along joints from Ashley Island to near the site of old Evarts..... 42

Table 18

Succession of Mobridge member and overlying beds exposed in northeastern Corson county, 4.5 miles southeast of Kenel.

Section of Mobridge member and overlying beds exposed in cut bank 1.5 miles north of ferry and 4.5 miles southeast of Kenel, exposure somewhat slumped but fresh.

Pierre formation	Feet
Elk Butte member	
2. Shale, flaky, light to medium gray. Contains small roundish ovoid concretions to three inches in diameter at or near the lower contact. Gradational contact about five feet.....	50
Mobridge member	
1. Shale, blue gray. Bed of brownish buff limestone to six inches in thickness with large concretions to a diameter of three feet and thickness of ten inches, with resin colored calcite in septarian cracks occur about 15 feet above the bottom. Some of the concretions are overlain by cone-in-cone 1/2-3/4 inches in thickness. Two bentonite streaks one to one and one-half feet apart occur 30 feet above the Missouri River. Two thin bentonites occur also near the upper contact.....	70-80

Table 19

Succession of beds in the Mobridge member north of U. S. Highway 18, Charles Mix county.

Section exposed in high bare hill north of U. S. Highway 18 in SE $\frac{1}{4}$ sec. 3, T. 96 N., R. 67 W.

Pierre formation	Feet
Elk Butte member	
11. Shale, hard, gray, non-calcareous, weathered rusty brown. Contains limonite concretions in several ledges 1-2 inches thick beginning 10 feet above base.....	18

Mobridge member		Feet	
10.	Shale, chalky; weathers buff on surface	10-14	
9.	Limestone, slabby gray, weathers buff	1/6-1/2	
8.	Shale, chalky, thin bedded, apparently medium gray when fresh, weathers buff	7	
7.	Shale, dark medium gray, calcareous, weathers into thin brown chips	5	
6.	Shale, chalky, thin bedded, weathers buff	5	
5.	Shale, dark medium gray, calcareous, weathers to thin brown chips	5	
4.	Shale, thin bedded, medium gray when fresh, weathers buff. Bentonite streak one inch thick nine feet above base	35	
3.	Shale, calcareous, gray. Buff limestone 2-4 inches thick at about the middle	7	
2.	Shale, chalky, thin bedded, apparently medium gray when fresh, weathers buff	15	89-93 Feet

Virgin Creek member

1. Shale, exposed below. (See Table 16)

Thickness of the Mobridge member:

The Mobridge member is fairly uniform in thickness, apparently more uniform than other members of the Pierre. Even here, however, considerable variation occurs. Opposite Mobridge in southeastern Dewey County the member measured 136 feet by hand level. A thickness of 230 feet was measured with an aneroid barometer north of Carlin Bridge across the Cheyenne River in southeastern Ziebach county. Here, however, the base was 12.2 miles north of the bridge and the top was 3.6 miles farther north. On the south road between Capa and Midland along southern Haakon county the thickness, obtained by barometer, is 190 feet. South of Platte in sec. 33, T. 98 N., R. 68 W. the barometric thickness is 200 feet. Opposite Mulehead on Federal Highway 281 two and three quarters miles north of the junction is 110 feet thick. In northern Nebraska, along Bazile Creek, Condra measured 100 feet of chalky beds at this position.[1] The member thus varies from 90 feet up to 230 feet in thickness.

1. Condra, G. E., Geology and water resources of a portion of the Missouri River valley in northeastern Nebraska, U. S. Geol. Survey Water Supply Paper No. 215, p. 16, 1908.

Elk Butte Member

Name and type locality:

The name Elk Butte member of the Pierre is given to those beds of shale which lie at the top of the Pierre beneath the cap of Fox Hills sandstone of Elk Butte, eastern Corson county, South Dakota. Along Federal Highway 12, as it rises toward Elk Butte, numerous road cuts west of Wakpala expose the beds of this member. The section beginning a little less than one and one-half miles west to five miles west of Wakpala along the highway is selected as the type section.

Definition:

The Elk Butte member includes all beds in South Dakota between the top of the Mobridge member and the base of the Fox Hills formation. It thus includes as its basal beds those non-calcareous shales which immediately overlie the calcareous, chalky, buff weathering shales of the Mobridge member. The upper limit, which is at the Pierre-Fox Hills contact cannot be placed with extreme exactness, even at the type locality, where the basal Fox Hills is a massive sandstone, because the contact is one of gradation. In the type locality it is set, however, where the dark gumbo forming shales give place to dominantly sandy buff beds which are included in the overlying Fox Hills formation. The zone of gradation is reduced to only a few feet in the type locality. In the southern exposures, the contact between Pierre and Fox Hills can not be readily determined by lithology owing to the occurrence of a Fox Hills fauna in beds which are lithologically similar to the Elk Butte. This Fox Hills fauna occurs very near the lower contact of the Elk Butte with the Mobridge member and includes Sphenodiscus lenticularis (Owen) which occurs elsewhere in South Dakota, so far as known, only in the Fox Hills, although Belemnitella bulbosa and Discoscaphites conradi, which occur with it here, occur in the Pierre at many places. Since no diagnostic Pierre forms have yet been found in this fauna it seems best, at this time, to consider that the shale beds below it in Gregory and Charles Mix counties represent the Elk Butte member of the Pierre and to assign the shale beds in which this fauna occurs, and the overlying shale to the Fox Hills. The upper limit of the Elk Butte thus defined on a lithologic basis in some localities and on faunal criteria in others is not entirely satisfactory. Until more satisfactory methods of defining the upper boundary are determined, however, it is suggested that the criteria used here be employed.

Distribution:

The Elk Butte member has been identified in outcrops extending between southeastern Gregory and southwestern Charles Mix counties on the south, to northeastern Corson county on the north.

The member apparently passes under the Fox Hills a short distance north of the northern boundary of the state. It underlies slopes and flats between the Mobridge member of the Pierre and the butte capping sandstone of the Fox Hills in Corson and Dewey counties. The member extends southward into Nebraska at least to Bazile Creek south and east of Bon Homme county, South Dakota as recorded by Condra's description[1] of clay slopes lying above "steeper, chalky slopes" which in turn lie above clays over the Niobrara chalk.

Lithologic character:

The Elk Butte member consists of very fine-textured, medium gray shale which is apparently very uniform throughout. Where it is cut into by rapid erosion or in road building it breaks down into fine, thin, flat polygonal chips which have a characteristic sub-metallic sheen or luster. This habit is most commonly observed in and about the type locality but it probably prevails throughout the area of outcrop since it has been noted south of the Iona hills in Gregory county.

No beds which differ strikingly from the usual character of the member have been observed. In the type section gumbo bands across the outcrop occur about 60 feet above the base and again at about 110 feet above the base. These may be due to a greater tendency of beds at these horizons to break down to gumbo since some bentonite occurs at about the position of the lower gumbo. Apparently all of the member eventually is reduced to gumbo on weathering. The uppermost 40 feet of beds in the type locality are brown and the uppermost 10 feet are sandy in texture.

Small, rather porous concretions occur 20 feet above the base and 40 feet below the top in the type locality. These are gray when fresh but become chocolate and rusty brown and yellow brown on weathering. Twenty miles south of Eagle Butte on State Highway 63 large limestone septarian concretions which weather to a very rusty brown with black iron oxide in the septarian cracks occur about 160 feet above the base of the member. Other large concretions occur in this section in sandy shale the base of which lies about 210 feet above the base of the Elk Butte member. Twenty feet below the base of typical buff Fox Hills sandstone south of Eagle Butte limestone concretions to three feet in diameter are enclosed and encrusted with well developed cone-in-cone. Concretions of limonite also occur in the Elk Butte member in Gregory and Charles Mix counties.

Bentonite is rarely observed in the Elk Butte member but at least one thin bed occurs about 25 feet above the base in

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1. Condra, G. E., loc. cit., p. 16

the section above the bridge opposite Mobridge.

Gypsum crystals of large size, to three inches in length occur in many places in the Elk Butte member. They are particularly abundant about 40 feet below the top in the type locality but they are common in many exposures.

Detailed sections of the Elk Butte member:

Because of its lithologic character continuous sections of the Elk Butte member are rarely exposed, the outcrop being commonly under gentle clay and gumbo covered slopes. In the tables of succession which follow representative and nearly continuous sections of the member are described. The first (Table 20) is the type section of the member below Elk Butte, eastern Corson county. The second table (Table 21) describes a succession south of Eagle Butte and the third (Table 22) a succession typical of the Elk Butte member as it occurs in Gregory and Charles Mix counties. Partial sections of the Elk Butte are described in connection with the Mobridge member (Tables 17, 18 and 19.)

Table 20

Succession of beds in the Elk Butte member between Wakpala and Elk Butte, eastern Corson County, South Dakota.

Section exposed along U. S. Highway 12 beginning three-fourths mile west of Wakpala and extending toward and up Elk Butte 4 1/4 miles, exposing Elk Butte member and overlying and underlying beds.

	Feet
Fox Hills formation	
6. Sandstone, fine, buff, (not measured).....	100
Pierre formation	
Elk Butte member	
5. Shale, sandy gray, weathers buff.....	10
4. Shale, medium gray, finely micaceous, breaks down to polygonal pieces. Buff to reddish brown on fracture fragments. Weathers gray.....	30
3. Shale, light medium gray, breaks to small polygonal pieces with sub-metallic sheen, exposed at intervals in cuts, interrupted by gumbo-producing beds at between 65-85 feet and at 130 feet above base. Large	

		Feet
	crystals of selenite abundant in upper 10 feet and 20 feet above base. Small light medium gray porous concretions which weather yellow brown at top and fragments of concretions were observed 20 feet above the base.....	270
Mobridge member		
2.	Shale, chalky, weathers buff, produces steeper slope.....	80
Virgin Creek (?)		
1.	Gumbo, poorly exposed.....	10

Table 21

Succession of beds of the Elk Butte member and the overlying and underlying beds exposed south of Eagle Butte, eastern Ziebach county.

Section of Elk Butte member together with overlying and underlying beds exposed along South Dakota Highway 13 beginning 15.8 miles north of Carlin bridge and extending to 19.2 miles north of the bridge. (Barometric).

Fox Hills formation		Feet
4.	Sandstone, fine, buff, unconsolidated. Contains large, dark gray concretions which weather brown and buff. Concretions reach a diameter of 15 feet and a thickness of 15 inches.....	60
3.	Shale, sandy, weathers drab, brown when wet. Flattish gray concretions in upper part in several rather closely spaced beds. Large concretions to three feet in diameter completely enclosed in well developed cone-in-cone 20 feet below the top	50
Pierre formation		
Elk Butte member		
2.	Shale, weathers to gumbo. Contains drab concretions which weather rusty at top and large limestone concretions which weather very rusty. Septarian concretions with black iron oxide in cracks occur 150 feet above the base.....	210

Mobridge member — Feet

1. Shale, mostly light gray with chalky lenses and several light buff limestone lenses and concretions of gray limestone at top... 230

Table 22

Succession of beds in the Elk Butte member south of Rosebud bridge, Gregory county

Section of the Elk Butte member and associated beds in road cuts along U. S. Highway 81 beginning at lower contact with Oacoma beds.[1]

Pleistocene — Feet

7. Silt, loesslike, pebbles at base..... 20

Fox Hills formation

6. Shale, brown when wet, brownish gray when dry, slabs of drab soft silty rock associated with cone-in-cone parallel with bedding in upper 30 feet. Breaks down first to sharply angular flakes and chips then to loose porous brown soil. In the 20 feet of beds above the base contains dark brownish gray limestone concretions to three feet in diameter and 18 inches in thickness. In upper 30 feet contains Belemnitella bulbosa, Discoscaphites conradi, Sphenodiscus lenticularis. Below at this place and in same beds above and opposite Mulehead Discoscaphites conradi occurs sparingly..... 80

Pierre formation

Elk Butte member

5. Shale, brownish, relatively few small concretions, becomes flaky gray below the middle..... 60

Mobridge member

4. Shale, very chalky, weathers to buff..... 90

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1. With the succession described in Table 1, the beds described in this table include a complete section of the Pierre.

	Feet
Virgin Creek member	
Upper Virgin Creek	
3. Covered gumbo slope, few perforated concretions observed.....	25-30
Lower Virgin Creek	
2. Shales with bentonites poorly exposed.....	15
Sully member	
Verendrye beds	
1. Shale, gray flaky, contains large manganese-iron concretions 15 feet above base.....	70
Oacoma zone (See Table 1)	

Thickness of the Elk Butte member:

The Elk Butte member, where it has been measured, is relatively thick. In the type section between Wakpala and Elk Butte in eastern Corson county the interval between the top of the Mobridge member and the base of typical Fox Hills sandstone is 310 feet (barometric). South of Eagle Butte twenty miles, the barometric thickness is 260 feet which includes fifty feet or more of shale in the upper part, which is sand and may prove to be Fox Hills. Although 140 feet of shale lies above the Mobridge member up the hill from the Rosebud bridge, in Gregory county and opposite Mulehead, only the lower 60 feet, which does not contain a Fox Hills fauna, is assigned to the Elk Butte member of the Pierre and the upper 80 feet of this shale is tentatively assigned to the Fox Hills. Thus limited, the Elk Butte varies between 60 and 310 feet in thickness.

THICKNESS OF THE PIERRE

The Pierre formation varies greatly in thickness from place to place both in the area investigated and apparently elsewhere in South Dakota. In the area of outcrop it is obvious that more or less of the formation has been removed by erosion. As indicated by the thickness of the various members as described, the original uneroded thickness was highly variable. Over wide areas (Plates I, II, and IV) the formation lacks much of the original thickness due to erosion. In other places much of the formation is covered by later deposits. Again, in many places the original thickness must be estimated because of both erosion and concealment.

Where the approximate thickness of the constituent members is known the approximate thickness of the formation can be readily determined. In many cases, however, the thickness of the various members cannot be ascertained close together and estimates of the total thickness of the formation therefore must contain errors due to variation in thickness of the members.

Logs of wells penetrating the formation are not of the desired value because not only the Pierre but also the underlying Niobrara are commonly logged as shale, making it difficult and even impossible to determine the contact with certainty. Adequate and carefully collected samples of beds through which the drill passes are of material aid but unfortunately too few such sets of samples are available over the area investigated and elsewhere in South Dakota.

The total uneroded thickness of the Pierre at various places has been determined as accurately as possible by measurements of the total section where it could be measured, by addition of the thickness of the members determined as close together as possible or assumed on the most valid information available.

The Pierre south of Rosebud bridge and in the immediate vicinity is thin, as determined from good exposures. Here the total thickness, as the formation is limited, is only about 400 feet. At Iona the minimum thickness is probably not less than 590 feet even when the thickness of the Elk Butte is estimated at only 60 feet, the Mobridge 150 feet, the Virgin Creek 55, the Sully 170 feet and the Gregory 155. At Wendte it appears that the thickness can not be less than 985 feet; assuming the thickness of the Elk Butte to be 160 feet, Mobridge 190 feet, the Virgin Creek 170 feet, the Sully 315 feet, and the Gregory member 150 feet. A conservative estimate of the thickness between Eagle Butte and Carlin bridge is 1075 feet, based on thickness of the members as follows: Elk Butte 260 feet, Mobridge 230 feet, Virgin Creek 200 feet, Sully 285 feet, and Gregory 100 feet. Under Elk Butte the thickness is believed to be about 995 feet based on the following thicknesses, known and estimated: Elk Butte 310, Mobridge 135, Virgin Creek 200, Sully 250, and Gregory 100 feet. The Pierre thus varies in outcrops between about 400 and nearly 1100 feet where the thickness is known or estimated as accurately as is now possible.

FOSSILS OF THE PIERRE FORMATION

The Pierre formation contains abundant fossils in many places, although over wide areas parts of the formation are essentially lacking in megascopic fossils. Along the Missouri valley, in many places parts of the formation which contain many fossils in other parts of South Dakota, are only sparsely supplied or are entirely barren. On the other hand, some forms which occur in the Pierre along the Missouri valley have not been noted elsewhere in South Dakota. Microscopic fossils occur in all the subdivisions of the Pierre. A complete discussion of the paleontology of the Pierre is not within the scope of this report but a brief summary of the forms identified will be made. The paleontology of the Pierre will be presented in future papers.

The megascopic fossils of the Pierre, those sufficiently large to be identified without the aid of a microscope, are chiefly those of shell fish or molluscs. Clamlike and nautilus like forms are the most abundant of these although the snail like forms are sparingly represented. Brachiopods, of a thin shelled type belonging to the genus Lingula occur sparingly and borings and tubes referred to the marine worms occur in parts of the formation. Vertebrates, animals with backbones, are represented by scales and bones of fishes, by bones of reptiles and by gastroliths, stones believed to have been used in the gizzards or stomachs of marine reptiles.

Foraminifera, the microscopic tests or hard parts of tiny single celled animals, occur in all parts of the Pierre and are present in abundance in certain strata.

Gregory Member: Scales and bones of fishes are abundant in the lower Gregory and these are the fossils most commonly found in it. Members of the clam tribe belonging to the genus Inoceramus occur near the mouth of Bull Creek and in the lower parts of Antelope and Cedar Creeks west of the Great Bend, southeast of Fort Pierre. Cephalopods, represented in the present seas by the chambered nautilus occur as straight shelled forms belonging to the genus Baculites and loosely coiled forms referred to Heteroceras(?).

No megascopic fossils have been collected from the chalky beds of the upper Gregory. The megascopic fossils of the Gregory are listed, as identified, in Table 23.

Foraminifera occur sparingly in the Lower Gregory and consist mostly of a very gibbous Ventilabrella and Gumbelina. The upper Gregory, however, contains an abundant and adequate microfauna. Many of the forms or their near relatives are represented also in the Taylor marl of Texas. Such species as Bolivinoides decorata (Jones), Bolivinita eleyi Cushman, Bolivina incrassata Reuss, Buliminella carseyae Plummer, Eouvigerina sp. of E. americana Cushman, Eponides micheliniana d'Orbigny, Gaudryina filiformis Berthelin, Marsonella oxycona (Reuss) and numerous other forms in this fauna

Table 23

FOSSILS OF THE PIERRE ALONG MISSOURI VALLEY

	GREGORY	SULLY	VIRGIN CREEK	MOBRIDGE	ELK BUTTE
Lingula sp.			X	X	
Serpula (?) wallacensis Elias			X		
Worm burrows (?)		X	X	X	
Anomia subtrigonalis		X			
Goniomya americana Meek and Hayden				X	
Inoceramus altus Meek		X			
I. convexus Hall and Meek	X	X			
I. proximus Tucmey		X			
I. sagensis Owen		X	X	X	
I. sublaevis Hall and Meek		X			
I. tenuilineatus Hall and Meek		X			
I. vanuxemi Meek and Hayden	X				
Inoceramus sp.	X				
Inoceramus sp. undet.		X			
Lucina occidentalis Morton				X	
L. subundata Hall and Meek				X	
Ostrea sp. cf. O. congesta Conrad		X	X		
Pholadomya hodgii		X			
Tardinacara (Pseudoptera) fibrosa (Meek and Hayden)				X	
T. (Pseudoptera) whitii (Toepelman)				X	
Anchura americana Evans and Shumard				X	
Fasciolaria (?) sp.		X			
Eutrephoceras sp.				X	
Baculites clinolobatus Elias				X	
B. compressus Say emend Meek		X			
B. compresus var. cf. B. compressus var. corrugatus Elias	x				
B. compressus var. reesidi Elias		X			
B. compressus Say var undet.		X			
B. grandis Hall and Meek			X	X	
B. Pseudovatus Elias		X			
Baculites sp. cr var. nov.		X			
Acanthoscaphites nodosus var brevis		X			
Acanthoscaphites nodosus var quadrangularis Hall and Meek		X	X		
Discoscaphites conradi (Morton)				X	
D. conradi var intermedius (Meek and Hayden)				X	
D. Nicolleti (Morton)				X	
Discoscaphites (?) sp. undet.		X			
Heteroceras (?) sp.	X				
Belemnitella bulbosa Meek and Hayden			X		
Dakoticancer overana Rathbun			X		
Campylostoma pierrenso Rathbun			X		
Hoploparia (?) gabbi Pilsbry*			X		
Fish remains	X	X		X	
Reptile bones, teeth	X	X	X		
Gastroliths			X		

* Iden. Mary J. Rathbun

occur in both the upper Gregory and in the Taylor of Texas. Most of these do not occur in other beds of the South Dakota Cretaceous, Gaudryina filiformis being an exception which occurs abundantly in the Niobrara.

Sully member: Part of the Sully member contains an adequate megascopic fauna although the member is essentially barren in many places.

The Agency shale has yielded both megascopic and microscopic fossils, but only locally. At the base of the exposure at the type locality of the Agency, below the bridge at Whitlocks Crossing, southeastern Dewey county, fossils occur in light gray limestone concretions. These have been identified as follows:

Fossils from the Agency shale at Whitlocks Crossing

Inoceramus convexus Hal and Meek
Inoceramus altus Meek
Baculites compressus Say emend Meek
B. convexus Say var. undet.
Acanthoscaphites nodous var quadrangularis Hall and Meek

Preliminary studies suggest that the meager microfauna of the Agency shale is related to that of the overlying Oacoma beds.

The Oacoma zone, whenever the characteristic manganese-iron concretions occur, contains abundant fossils, which unfortunately are commonly much broken. Those which occur most abundantly are Anomia subtrigonalis Meek and Hayden, and a Pteria-like shell which is not determined. Several species of the clamlike genus Inoceramus also occur. The occurrence of Ostrea sp., an oyster not distinguishable from Ostrea congesta Conrad, is of interest, since it is commonly supposed to be confined to the Niobrara in South Dakota. Cephalopods are represented by several species or varieties of Baculites and by Acanthoscaphites together with one specimen which appears to be an early introduction of the genus Discoscaphites. Mosasaurus (Clidastes) atrox Marsh and Tylosaurus proriger Cope, both marine reptiles, identified by M. R. Thorpe are recorded from Oacoma beds by Russell.[1] A bed only a foot thick at Rosebud bridge is worthy of note since it contains great numbers of fragmented bones and the teeth of reptiles and fishes.

The Oacoma beds also contain a characteristic microfauna which has been found to be represented in many places in outcrops and well cuttings. This fauna consists of a number of foraminifera among which agglutinate forms predominate. Some of the more important members of this microfauna are listed as follows:

1. Russell, W. L., The possibilities of oil and gas in western Potter county: S. Dak. Geol. and Nat. Hist. Survey, Report of Investigations No. 7, p. 4, 1930.

Ammodiscus glabratus Cushman and Jarvis
Epistomina caracalla (Roemer)
Globigerinella aspera (Ehrenberg)
Glomospira charoides var corona Cushman and Jarvis
Gyroidina depressa Alth
Haplophragmoides excavata Cushman and Waters
H. rugosa Cushman and Waters
Pelosina complanata Franke
Saccorhiza ramosa (H. B. Brady)
Spiroplectammina anceps (Reuss)
Radiolaria

The Verendrye beds are commonly not fossiliferous, at least not in the outcrop. A single specimen of Baculites pseudovatus Elias was collected from a bed of gray shale which contains limestone concretions along Bad River, one mile west of Wendte.

Virgin Creek member: Fossils occur very rarely in the lower Virgin Creek. An unidentifiable baculite was collected above Promise on Virgin Creek.

Both upper and lower zones of the upper Virgin Creek are fossiliferous, locally very fossiliferous. From Bad River northward characteristic forms including Serpula (?) wallacensis Elias, probably the burrow of a marine worm, Beleminitella bulbosa, related to the modern squid, and Dakoticancer overana Rathbun and Camplylostoma pierrense Rathbun, both of which are crabs.

Gray limestone concretions in the upper part of the upper Virgin Creek contain a megascopic fauna which appears to be the eastern representative of the Sage Creek fauna of the upper Pierre. This fauna, in the Missouri river area, is not so fully developed either in number of species or in abundance of specimens as it is near the Big Badlands or in northwestern South Dakota. The species which occur, however, are all members of the Sage Creek fauna and occur at the same stratigraphic position in the Pierre. The megascopic fossils identified from the Virgin Creek are listed in Table 23.

Preliminary work on collections of microfossils from the Virgin Creek indicate that it contains a characteristic and possibly diagnostic fauna of foraminifera among which agglutinated forms are important, Ammodiscus glabratus Cushman and Jarvis being a conspicuous member of the fauna.

Mobridge member: The Mobridge member contains a fauna which is apparently peculiar to it. More than any other fauna of the Pierre, the invertebrates appear to be transitional to those of the overlying Fox Hills. Some forms such as the pelecypods Tardinacara (Pseudoptera) fibrosa (Meek and Hayden) and Lucina occidentalis Morton appear to be restricted to the Mobridge member along Missouri River although the former occurs sparingly in the

Sage Creek fauna and the latter occurs at other positions in the Pierre in western South Dakota. Baculites clinolobatus Elias has not been found in beds other than those of the Mobridge member along the Missouri. These fossils and their Mobridge congeners are listed in Table 23.

A microfauna occurs in the Mobridge member which contains, among numerous other forms, Bulimina pupoides d'Orbigny, Bulimina obtusa d'Orbigny, Anomalina grosserugosa (Gumbel) and Loxostomum plaitum (Carsey). Several agglutinates of the Oacoma zone such as Saccorhiza ramosa (H. B. Brady) and Pelosina complanata Franke recur in the Mobridge beds.

Elk Butte member: Megascopic fossils have not been collected from the Elk Butte member of the Pierre. They may be entirely absent and are certainly rare in the outcrop.

A fauna of foraminifera has been collected, however, which preliminary studies indicate, is diagnostic.

CORRELATION

Comparison of lithology, together with fossil content, permits some statements regarding the correlation of the Pierre along Missouri Valley with beds of other areas. The Gregory, Virgin Creek, and Mobridge members have rather close correlatives elsewhere and at least part of the Sully member appears to be represented elsewhere.

The bituminous basal beds of the lower Gregory including bentonite undoubtedly extend to the region surrounding the Black Hills. They also correlate lithologically as well as by position with similar beds of Nebraska. The lithologic character is rather similar to that of the Sharon Springs of western Kansas[1] and is probably contemporaneous with it. The lower Gregory probably correlates also with the lower part of the Pierre of Colorado.

The upper Gregory has not been positively identified beyond the area described and in northern Nebraska. The microfauna, however, indicates rather close relationship with the Taylor marl of Texas and the correlatives of this formation.

The Oacoma beds of the Sully member correspond rather closely in character with the lower Weskan of Kansas, although the lower Weskan appears not to be manganiferous. The Oacoma beds, in many places, however, contain little if any manganese. Bentonite and ferruginous concretions are common both in the Oacoma beds and in the lower Weskan and both contain Anomia subtrigonalis as a most common fossil.

The upper Virgin Creek with the Sage Creek fauna is correlated with beds containing this fauna elsewhere in South Dakota in Sage Creek and about the Black Hills. The member is to be correlated with beds which occur in southwestern Harding county and in North Dakota and Montana along the crest of the Cedar Creek Anticline, a typical Sage Creek fauna having been described from that area.[2]

Mobridge member: The Mobridge member of the Missouri Valley is equivalent to similar beds which extend westward toward the Black Hills, northward into North Dakota and southward into Nebraska. The fauna corresponds closely with that of the Beecher Island shale of Colorado.[3] Both Mobridge and Beecher Island contain Tardinacara (Pseudoptera) fibrosa (Meek and Hayden), T. Pseudoptira whitii (Toepelman), Inoceramus sagensis Owen, Anchura americana Evans and Shumard, Lucina occidentalis Morton, Baculites

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1. Elias, M. K., The Geology of Wallace County, Kansas: State Geol. Survey of Kansas, Bulletin 18, pp. 58-77, 1931
2. Coryell, H. N. and Salmon, E. S., A Molluscan faunule from the Pierre formation in eastern Montana: Am. Mus. Novitates, No. 746, pp. 1-18, 1934.
3. Elias, M. K., Loc. cit., p. 130

grandis Hall and Meek, Baculites clinolabatus Elias, and Discoscaphites conradi Morton. This association does not occur in other parts of the Pierre as it is now known in South Dakota. It is true that a somewhat similar association occurs in the Sage Creek fauna of the upper Virgin Creek but the lower fauna contains in addition Acanthoscaphites nodosus var comprimus Owen, Inoceramus barabini Morton, Scaphites plenus Meek and lacks Descoscaphites conradi Morton.

Elk Butte member: The Elk Butte member is correlated with beds above the Mobridge member of the Pierre and below the Fox Hills formation in North Dakota to the north of the area described in this report. Beds to be correlated with it occur also in northern Nebraska south of the area. Equivalent beds elsewhere have not been identified.