
STATE OF SOUTH DAKOTA
George T. Mickelson, Governor

STATE GEOLOGICAL SURVEY
E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 58

GEOLOGY OF THE MISSOURI VALLEY AND VICINITY
NEAR MOBRIDGE

by

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July, 1947

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GEOLOGY OF THE MISSOURI VALLEY AND VICINITY

NEAR MOBRIDGE, SOUTH DAKOTA

I N T R O D U C T I O N

Purpose of the Report

The present survey was undertaken as a continuation of a project which has been underway for a number of years by the State Geological Survey. The project is aimed at obtaining a complete geologic description of the Missouri Valley. It was started in the vicinity of Pierre because of the use of the gas made in that region, carried north to the Moreau River in a search for possible oil structures, and south to the Rosebud bridge in an appraisal of the huge manganese deposits occurring there.

During the course of these investigations, it was found that the Pierre formation, which has been a stumbling block to oil prospecting for many years, could be separated into members and contained key horizons on which it was possible to map geologic structures. The earlier surveys had succeeded in giving an excellent picture of the lower part of this formation. The upper members, which are well exposed in the vicinity of Mobridge, had never been carefully subdivided. This survey, therefore, was undertaken in order to attempt to make such subdivisions and to find possible key beds that could be used in mapping. The stratigraphy involved here, therefore, includes the beds between the Agency shale zone of the Sully member of the Pierre formation and the base of the Fox Hills formation.

The second purpose of the survey was to investigate a wedge of siliceous shales which lies just above the river level near Mobridge. It was thought that the shales might offer certain possibilities as fire clays. These shales were, therefore, mapped and sampled and will be reported upon in a subsequent publication.

Location and Area

The survey covered parts of 24 townships lying along the Missouri River and extending about 30 airline miles up the Mis-

marks had recently been established from Mobridge south in connection with the proposed Missouri Valley Development project and these were used in the survey of the Missouri Valley south of Mobridge and in the Moreau Valley. These benchmarks were closely spaced and allowed normal accuracy in the traverses run between them. Further accuracy was obtained on some traverses by running two traverses simultaneously by the so-called double-rod method.

Acknowledgments

The author wishes here to recognize the painstaking work of his co-workers in the field. The accuracy of the survey is due entirely to their careful unraveling of the difficult geological problems. The rapidity with which the work was carried on is due, in a large measure, to the helpfulness of the citizens of Mobridge and the vicinity. These persons gave information on trails and outcrops which saved many hours of tedious searching. Though there were many who contributed in this manner, the author wishes to acknowledge especially the help of Mr. F. M. Goodman, a long time resident of the country, whose intimate knowledge of the region was especially useful.

Summary of Results

The field work shows that the upper part of the Pierre formation can be broken into mappable units and certain key horizons are sufficiently persistent to allow the mapping of structure. These key horizons, however, are not easily recognizable and require careful work by trained geologists if they are to be followed successfully. The main divisions of the Pierre formation are readily identified though there will always be considerable question as to the contact of the various members. These contacts are gradational and any contact chosen has to be more or less arbitrary.

The region lies on the west flank of the Dakota basin and, therefore all the strata dip toward the northwest. A notable deviation from this regional structure is a prominent anticline or shoulder projecting nearly at right angles to the regional dip. Though it was not possible to map complete closure on this structure, it offers some interesting possibilities for wildcat oil prospecting in this area.

The region offers three possible mineral resources which might be developed under proper market conditions. These will include the marls found in the Pierre formation, the refractory clays found in the same formation and the possibility of oil or at least small supplies of gas.

G E O L O G Y

EXPOSED FORMATIONS

Only two formations are exposed in the area. The uppermost of these is the sandy Fox Hills formation which overlies the clays and marls of the thick Pierre formation. Both of these belong to the upper part of the Cretaceous system.

Since the top of the Fox Hills is nowhere exposed, mapping had to be done on the contact of the Fox Hills with the Pierre formation and on various members and key horizons found in the upper part of the Pierre. The exposed formations are shown graphically in the accompanying columnar section.

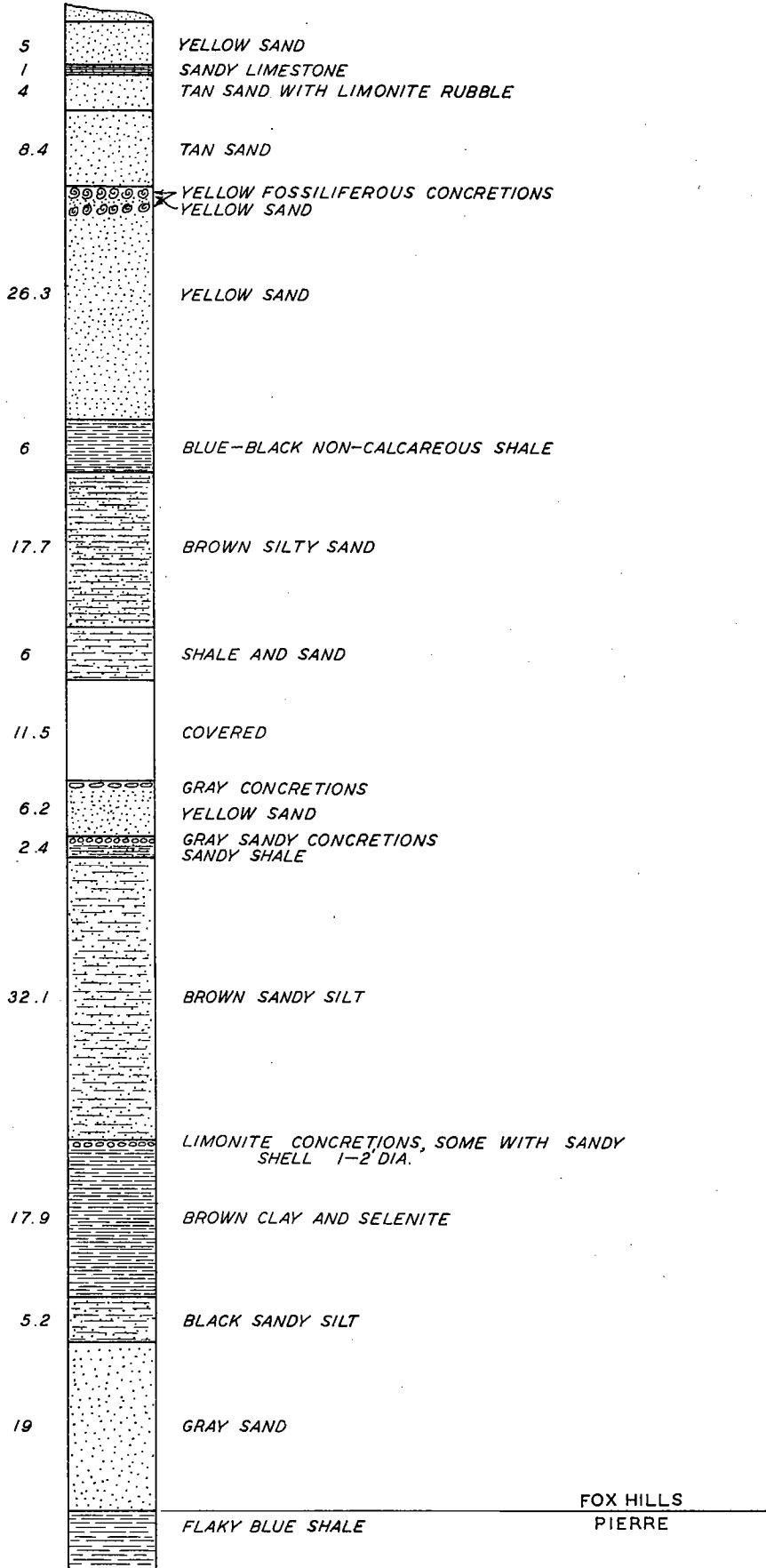
Fox Hills Formation

A considerable thickness of the Fox Hills is exposed north of the Grand River in the Rattlesnake Buttes which lie immediately west of Wakpala in Corson County. It also occurs on the highlands at the extreme western edge of the area where it caps the stream divide.

In general, the formation is composed of a clean, medium-grained, uniformly-sized, light buff sand which is cemented in most exposures to a poorly indurated sandstone. Near its base are certain layers of iron concretions and clay ironstone concretions which carry the famous Fox Hills invertebrate fauna. The lower fifty feet or so is usually covered with talus but where it has been exposed in stream or road cuts it shows alternation of sandy layers, some of them fine enough to be termed siltstone, and blue black clays similar to those found in the Pierre formation below. In other words the contact is gradational. In the section exposed along U.S. Highway No. 12, on the north bluff of the Grand River, the base of the formation seems to be fairly well marked by a ten foot layer of ash-gray sand. Below this sand is a line of quarter-inch limonite pellets, apparently the weathered product of a bentonite bed. This corresponds with the situation near Trail City where a similar bentonite was used as the base of the formation.

The lower part of the Fox Hills was carefully studied along this highway and showed the following section:

SECTION OF FOX HILLS
ON
HIGHWAY 12 NEAR RATTLESNAKE BUTTE



The 154 feet measured on the highway represents less than half of the thickness of the formation. On the opposite side of Elk Butte, Gries² measured 310 feet of Fox Hills from the top of the Butte to the Pierre contact. This thickness was obtained apparently by measuring to the top of Rattlesnake Butte. This is probably not the entire thickness of the formation though it may be most of it. Where wells have been drilled through it from the contact of the overlying Hell Creek, thicknesses of about 200 feet have been recorded. These thicknesses were obtained from 30 or 40 miles west and it is known that the formation thins in that direction.

Pierre Formation

The Pierre formation has often been called the Pierre Shale and though in general this is correct, in particular, it is far from the truth. The Pierre formation is made of a variety of fine grained sediments. Clays and siltstones are common. Chalks, marls, and even limestone beds are to be found. Clay ironstone and calcite concretions are common features of the formation. Some of them, having split and become drused with yellow calcite veins, are really large septarian concretions. In the area under discussion it has been divided into four members each with its own characteristic lithology:

Elk Butte Member	Blue, black, noncalcareous shale
Mobridge Member	Chalk and marls
Virgin Creek Member	Noncalcareous dark clays in the upper part, siliceous shale in the lower part
Sully Member	<u>Verendrye zone</u> , brown, noncalcareous clays, <u>Oacoma-Agency zone</u> , brittle siliceous shale

Most of the mapping was done on horizons in the Mobridge member and on the top of the siliceous beds in the lower Virgin Creek and Sully Members. A further description of these members, therefore, is included in this report.

Elk Butte Member

The Elk Butte member is exposed in the cuts along U.S. Highway 12 in the eastern half of Twp. 20 N Range 28 E on the north bluff of the Grand River west of Rattlesnake Butte. One hundred twenty feet of blue noncalcareous shale is exposed in scattered road cuts. This shale slumps rather badly and most of the slopes are grassed over so that it is impossible to get a continuous section. However, the prevailing character of this shale, besides its color, seems to be the flaky weathering. Small outcrops give the appearance of having poured shale flakes through a funnel at their base. In this respect it resembles the lower Virgin Creek outcrops in the vicinity of Pierre south of the region where it becomes silicious. Gries² describes this region as, "fine textured, medium gray shale, which breaks into thin polygomal chips, and ultimately weathers to gumbo."

While the Elk Butte is a fairly distinct and easily recognized member, it offers no key horizons on which structural mapping can be done. The base and top are usually covered and no distinctive beds were found anywhere in the exposed sections.

Mobridge Member

This is the most varied and interesting member of the Pierre formation of this part of the state. It was originally defined as the portion of the formation which included beds of chalk, chalky shale, sandy shale and perhaps some sandstone beds, lying between the Virgin Creek and Elk Butte members.³ The chalk and marl are undoubtedly characteristic of this member though it is not entirely composed of them. Noncalcareous zones are common in the exposures along U.S. Highway 12 at the bridge at Mobridge and along the same highway to the west.

The Mobridge member shows four distinct zones. At the bottom is a ten to fifteen foot zone of bentonite beds which weather into steps, the bentonite making the treads and calcareous and noncalcareous beds the risers. This commonly carries an abundance of small crabs and was designated in the field as the crab zone. Above it lies 75 feet of very calcareous dark blue shale or marl carrying a great number of clay ironstone

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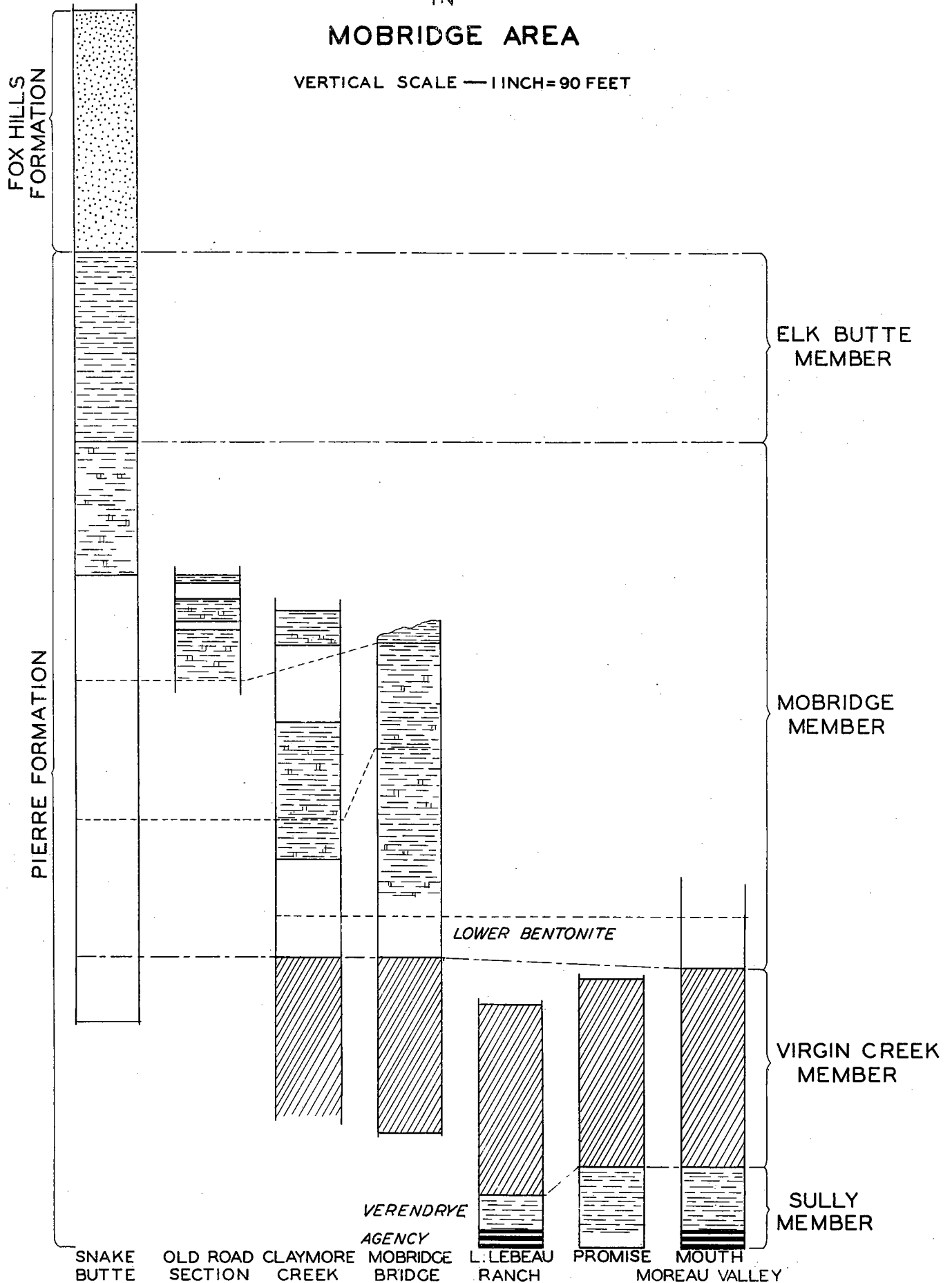
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FORMATIONS EXPOSED

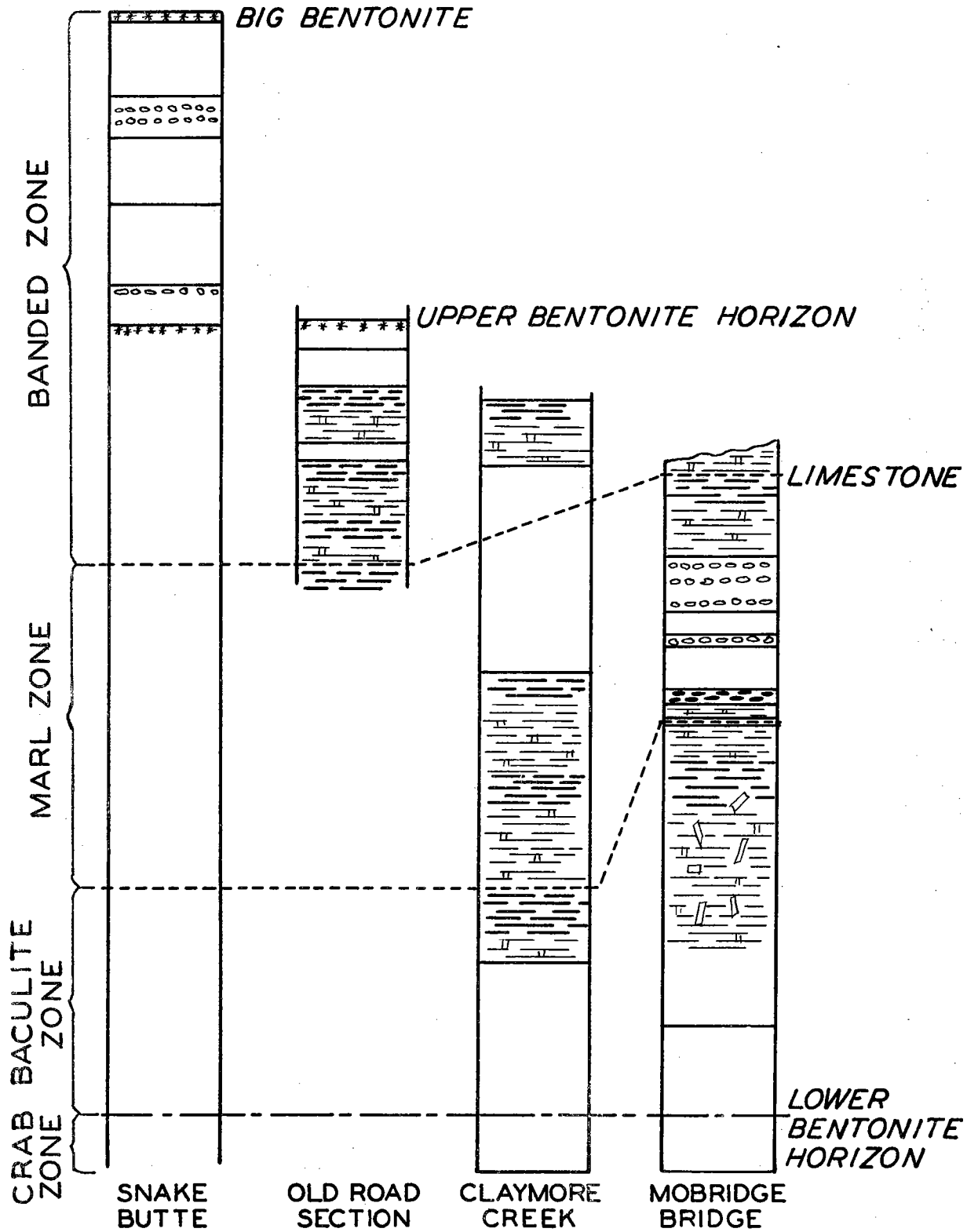
IN

MOBRIDGE AREA

VERTICAL SCALE — 1 INCH = 90 FEET



DIVISION OF MOBRIDGE MEMBER
 OF THE
 PIERRE FORMATION
 VERTICAL SCALE — 1 INCH = 40 FEET



concretions which enclose an abundant fauna of baculites. This was indicated as the baculite zone. Above the baculite zone is a thick zone of marls with some noncalcareous beds and some very large, septarian, limestone concretions with golden calcite druses in the cracks. The topmost division is a zone of alternating blue shales and chalky marls or chalk stone, in beds varying from a couple feet to ten or fifteen feet in thickness.

According to the original description of the Mobridge member the bottom should be placed at base of the lowest calcareous shale or marl and the top at the top of the highest. Unfortunately it is not easy to find these lowest and highest calcareous beds, partly because of the slumping and covering of the contacts and partly because it is impossible to follow these thin calcareous members from one outcrop to the next. The contacts with the overlying Elk Butte and underlying Virgin Creek are conformable and these gradations make it necessary to arbitrarily choose the contacts. For this reason there has been considerable difference in the descriptions which have been given of the Mobridge member. The top indicated in the type section at the west end of the Mobridge bridge by Searight and Gries is not the top of the banded section. There has also been some discrepancy in choosing the lower boundary, largely because of the fossils which were supposed to be confined to the Mobridge (particularly a plant fossil known as the Indian Bead and given the name of *Serpula wallacensis*).

In the Grand River section the alternating noncalcareous shale and marl bands were followed to a large bentonite bed with a profusion of barite roses in every outcrop seen. This bentonite could be followed southward well up on the divide between the Grand and Moreau Rivers. It was well exposed in small road cuts, and outcrops above and below left no doubt as to its position. However, it was impossible to determine whether the last band of calcareous shale was above or below this bentonite. The persistence and ease of distinction of this bentonite made it a convenient horizon to designate the top of the Mobridge member. Barite roses are not confined to this bentonite but its thickness, grey color, and the roses are characters which distinguish it from lower bentonites where barite was observed.

The base of the Mobridge was arbitrarily placed at the zone of bentonites which in this vicinity carries a fauna distinguished by an abundance of small round crabs about the size of a five cent piece. From three to five bentonites occur in a twelve foot zone with thin bands of more or less calcareous shale between. Where the slopes are weathered bare the benton-

ites form stair treads. A similar zone occurs not far from the top of the Mobridge member but the stratigraphic distance between the two make them easy to separate. Crabs are found sparingly in this upper zone, and barite roses sometimes are present.

These bentonite zones, the "lower crab zone," "upper crab zone" and the big bentonite, are all mappable horizons. To them should be added a thin limestone which occurs at the top of the baculite zone.

The Mobridge is very fossiliferous in places and former descriptions have tended to lump the fossils indiscriminately through the member. This is probably due to the fact that the divisions named here were not recognized in other regions of the Missouri Valley. The conspicuous fossils in the Mobridge are baculites, the crabs mentioned above, the plant fossil *Serpula*, and certain worm-like borings or root marks in some of the small concretions.

In the area around Mobridge, crabs were found in the basal bentonite zone in great abundance. They occurred sparingly in the upper bentonite 85 feet below the top of the member. Baculites were confined to the baculite zone in the lower part of the member and were found there in such abundance on new road cuts that the zone could not be mistaken. Where weathering had taken place, the baculites had been largely destroyed but small pieces of weathered clay ironstone from the concretions formed a rubble through the grass which easily identified the zone. It was not possible to localize the worm borings in the concretions though they were very abundant in the lower bentonite. Some were also found at intervals through the marly zones higher up.

The Indian Beads, *Serpula wallacensis*, are not confined to the Mobridge. One, eight inches long was found in the upper Virgin Creek and they seem to be rather indiscriminately scattered through the Mobridge member.

The concretions are somewhat diagnostic of the zones of the Mobridge. The clay ironstone concretions of the baculite zone have been described. These are dark brown weathering to a black rubble and rarely exceed eight inches or a foot in diameter. In

the marls overlying the baculite zone are the large, light, limestone concretions, most of them cracked in the center and the cracks drused with yellow calcite. In some of these the druses have formed veins but in most of them they are open, and crystal lined, making geodes. These concretions vary all the way from five or six inches to three feet across and are usually quite round in shape. The drused cracks seldom come to the surface and are exposed only when the concretions are broken open. An attempt was made to map on these concretions but was not successful. They seem to be scattered rather indiscriminately through the marls and even in places in the banded zone at the top of the member. Golden calcite concretions can sometimes be followed short distances in certain layers but it is impossible to transfer the interval from one outcrop to the next. In some cases the concretions were fused into limestone lenses four or five inches in thickness. The only one of these which was persistent, however, was the thin limestone at the top of the baculite zone.

Some limonite concretions were found locally in the marls above the baculite zone but it was not possible to trace them away from the outcrop at the west end of the Mobridge bridge.

Virgin Creek Member

The Virgin Creek member was separated by Searight³ from the overlying Mobridge by its lack of calcareous shales, and from the Sully member which underlies it by the fact that its lower part made conspicuous flaky shales and contained a great many conspicuous thin bentonite beds. Thus the Virgin Creek was divided into two divisions which Searight designated as upper and lower. The type section for this member is south of the railroad station at Promise in Dewey County, Virgin Creek being a tributary of the Moreau River entering it from the South.

The upper Virgin Creek has no distinguishing features in the type section. It is a dark clayey shale. For the purposes of this survey it included the noncalcareous shale below the lower bentonite zone of the Mobridge containing the abundant crabs. Gries² includes these fossils in his Virgin Creek but, since the shales in this crab zone are partly calcareous, it is here considered as the base of the Mobridge. It is also of interest to note that there are no crabs below this zone in the

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2. Page 22.

section at the west end of the Mobridge bridge. In the type section at Promise crabs were found considerably below the lower bentonite zone but from their position and their similarity to the crabs in the crab zone they were apparently float from the base of the Mobridge. Fifty-two feet of upper Mobridge was measured south of the Moreau in Section 33, Township 16 North, Range 31 East, near the mouth of the Moreau and 57 feet at the west end of the Mobridge bridge. Scattered dark clay ironstone concretions up to two or three feet through are found in this zone. However, they are not sufficiently abundant nor sufficiently well alined to be used as horizons or even as indicators of the zone.

The lower Virgin Creek zone is easily identified in this area. As was shown in a former publication⁴ the lower Virgin Creek in the south was characterized by a flaky shale which weathers to a gumbo and by very numerous bentonite beds, most of them but an inch or less in thickness. A short distance south of the Moreau this zone becomes siliceous and north of the Moreau as far as it could be traced it was entirely siliceous. Pieces immersed in water for days refused to make mud and its outcrops stand up as steep buttresses at the base of the cliffs along the Missouri.

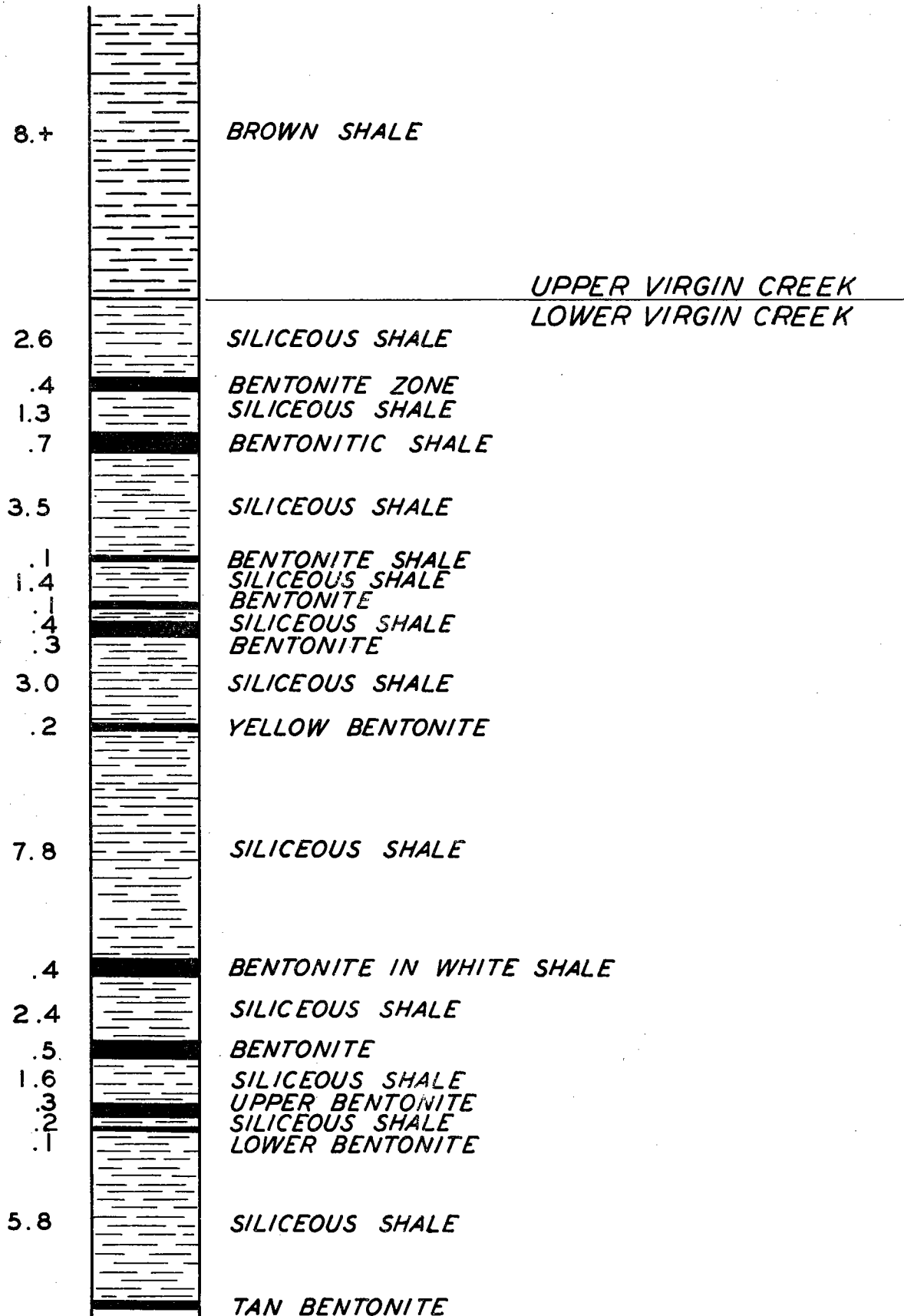
It outcrops well up above the valley bottoms in the Moreau and adjacent Missouri. By the time it reaches Mobridge only a third of it protrudes above the water. From the bridge it can be traced twelve to fifteen miles up the Missouri Valley before the regional structure carries it underground. On the Lloyd LeBeau ranch 97 feet of strata are assigned to the lower Virgin Creek. At the bridge at Mobridge only 33 feet project above the water and the bottom of the zone is not exposed.

The lower Virgin Creek in this region runs true to form in the number of bentonites it contains. In the 33 feet exposed at the Mobridge bridge ten bentonite beds were measured. These were more or less grouped in pairs or triplets with 3 to 8 feet of shale between the groups. Most of the bentonites are very thin, varying in width from less than a quarter to a half an inch in thickness.

This zone is one of the three such zones known in the State. It has the same physical characters and seems to have much the

4. Page 26.

SECTION OF VIRGIN CREEK
AT
WEST END OF MOBRIDGE BRIDGE



same makeup as the underlying Agency shale and as the Mowry shale which is found in the Graneros formation of western South Dakota. On grass slopes it breaks down into little polygonal chips a quarter inch or less in diameter which do not weather to a gumbo but break down into finer and finer pieces because of their brittleness. Bars of this shale below the cliffs at the water's edge in the Missouri do not form a mud and always offer a solid footing. Some clay-ironstone concretions are scattered through this zone and also some white lime concretions. However, they were not sufficiently continuous nor extensive to be used as horizon markers.

Sully Member

The Sully member is exposed only in the southern part of the area. Its outcrops are found in the Missouri bluffs and near the mouth of the Moreau. The regional dip carries it below the surface a few miles above the mouth of the Moreau in both valleys.

Two zones of the Sully member are exposed in the area. The upper one made of medium dark clayey shale which on large weathered surfaces has a brownish cast. It was named the Verendrye zone by Searight³ from exposures about the Verendrye monument in Fort Pierre, Stanley County, South Dakota. A characteristic of the Verendrye is the large flat iron concretions which weather to a very black rubble. Some concretions are several feet across and up to a foot in thickness. Others are kidney shaped. The long direction is always parallel to the bedding of the shale. The rubble from these concretions has been described as cinder-like and this makes a fair indicator of the zone. No such dark concretions occur in the overlying lower Virgin Creek.

Below the Verendrye lies the Agency-Oacoma zone. In the lower Missouri Valley this clay is a very sticky gumbo with a high concentration of iron carbonate nodules carrying manganese. North of Pierre, however, it changes its character and becomes a siliceous shale which was first described from the Cheyenne Agency in southern Dewey County by Russell.⁵ Like the overlying lower Virgin Creek, the Agency shale does not make mud when it is wet. In fact it is used some places as a road metal because of its water repellent property. It breaks down into small polygonal chips which are a light silvery color when dry. These

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chips enable it to be followed beneath grassy slopes as they do not immediately break down into unrecognizable pieces. The shale is very thin and very brittle. Gries² gives 124 feet as the thickness of the Agency shale at the Cheyenne Agency. In the area here described, however, the thickest outcrop showed only ten feet of the zone exposed above the river level.

The total thickness of the Pierre formation exposed in this area is 610 feet. This however, comprises a large part of the formation as the Agency shale is near the base of the Sully member. Below the Sully, farther downstream, lies some 35 to 40 feet of the Gregory member made largely of grey to brown shale with intercalated beds of marl and chalky shale, and below that another 35 feet of the Sharon Springs member which is a bituminous shale and forms the bottom member of the formation.

Key Beds

In this area, the most useful horizons for mapping structure in the Pierre formation were:

1. The top of the Elk Butte member
2. The bentonite at the top of the Mobridge member
3. The "upper bentonite" horizon in the Mobridge member
4. The limestone on top of the baculite zone of the Mobridge
5. The bentonite zone at the base of the Mobridge member
6. The top of the Lower Virgin Creek member
7. The top of the Agency shale zone of the Sully member

The top of the Elk Butte member or base of the Fox Hills formation can be used if the bentonite mentioned above is taken as the horizon. The lower sands are not reliable as there is considerable slumping and sliding of blocks and as the gradational contact often makes it difficult to ascertain which is the lower sand bed. In previous mapping the fossil horizons in the lower Fox Hills were used as guides to the bentonite which was chosen as the base of the formation. Though these layers of concretions can not be used for mapping because of the variation in their position in different outcrops, they can be used as

reference horizons since the basal bentonite lies about 130 to 140 feet below these concretions.

The big bentonite bed (4 inch more or less) with the abundant barite roses was followed fairly easily on the divide between Claymore and Snake Creeks and in the Grand Valley.

The "upper Bentonite" zone lies just above the bottom of the Grand River flats and makes a fair horizon which can be followed in that part of the valley. It may be found higher topographically farther south though it soon disappears in the uplands where it can not be easily recognized.

The four inch limestone exposed at the top of the baculite zone above the Mobridge bridge is fairly persistent. Some other concretionary layers in the Mobridge appear to fuse into thin limestones. It is necessary therefore to determine an outcrop's position with respect to the baculite zone to be sure it is this horizon.

The lower bentonite zone at the base of the Mobridge member is an especially useful horizon as it can be traced over most of the area. The number and thickness of the bentonites and the abundance of crabs and "worm eaten" tan concretions make it fairly easy to recognize. Its position at the base of the baculite member is also an advantage in identifying it since the rubble from the iron concretions of the baculite zone can easily be recognized even though the slopes on which it occurs are grassed over.

The top of the lower Virgin Creek is a better horizon for mapping in the Mobridge area that further south since it can be easily recognized by the siliceous shale chips in the grass or on the outcrop and the light silvery grey color of the lower Virgin Creek which contrasts sharply with the dark color of the overlying upper Virgin Creek. The contact is very sharp and therefore leaves little chance of becoming confused as to its exact position.

The top of the Agency shale has the same advantages as a mappable horizon as does the lower Virgin Creek. The two look so much alike that they could easily be confused were it not for the vertical distance between them. It was not very useful in

the area mapped because its outcrops were limited to the extreme southeastern corner. It could be useful, however, as a horizon indicator in core drilling operations anywhere in the area.

The present survey had to confine its activities to the outcrops in the stream valleys. However, core drilling and possibly some geophysical prospecting can be done on the large areas of grassed over uplands by determining the depths to the siliceous zones particularly the lower Virgin Creek. It is doubtful whether it would be possible to identify the other horizons in the Pierre with sufficient accuracy from drill records.

SUBSURFACE STRATIGRAPHY

The formations which would be encountered in drilling this area can only be inferred since no deep well has ever been drilled in the region. Several wells have been drilled to the artesian sand but none have penetrated the formations below them. The best information, therefore, will have to come from wells drilled some distance away and from a general knowledge of the geology of the state.

The best record available in the immediate vicinity is a water well which was drilled in Lincoln Park at the east end of the Mobridge bridge in 1928. This was to supply water for a swimming pool but also produced sufficient gas to use in the resort. A careful record was not kept from this well but from the driller's log the following formation log is deduced:

Log of Lincoln Park Well, Mobridge, South Dakota
Location SE $\frac{1}{4}$, Sec. 26, T 124 N, R 80 W, Walworth
County, South Dakota

0-1275	River fill, lower Pierre, Niobrara and Carlile formations.
1275-1330	Greenhorn limestone, "Cap rock".
1330-1750	Graneros and Dakota formations.

Twenty foot of perforated casing at the bottom used as a screen indicates that at least that much of the Dakota formation was penetrated. Since the top of the formation is usually tight it is probable that there is more Dakota than the screen was set for.

At least four other wells producing a little gas and artesian water have been drilled in the area mapped. The salty character of the water indicates that it is from the Dakota formation. No information on the depths or logs of these wells is available, however.

The most light on the underground formations of this area is derived from a core drill hole that was sunk as a stratigraphic test by the Carter Oil Company near Whitlock's Crossing in Potter County. This well is about 30 miles south of the southern boundary of the area under discussion and, therefore,

the same sequence of strata cannot be guaranteed. However, it is sufficiently close to give a reasonable expectation that the same formations, with perhaps some changes in thickness, could be expected in this area.

The Carter Test was drilled with a core drill and cuttings were also saved so that a double record was kept. It was drilled through the entire sedimentary section and into the underlying pre-Cambrian thus giving a complete record of the sedimentary strata in its vicinity.

This well penetrated a total depth of 3580 feet of sedimentary rock. Since it started near the base of the Agency shale, which outcrops in the southern part of the area here under discussion, it is reasonable to suppose that approximately the same thickness of sediments will be found about Mobridge. Since the top of the Agency outcrops in the southeastern corner of the area mapped, wells drilled to the north and west would have progressively more of the Pierre shale to penetrate. A detailed log of the well made from cuttings in the State Geological Survey Laboratory by Mr. C. L. Baker is published elsewhere.⁶ The following log made by geologists of the Carter Company will give the character of the sediments.

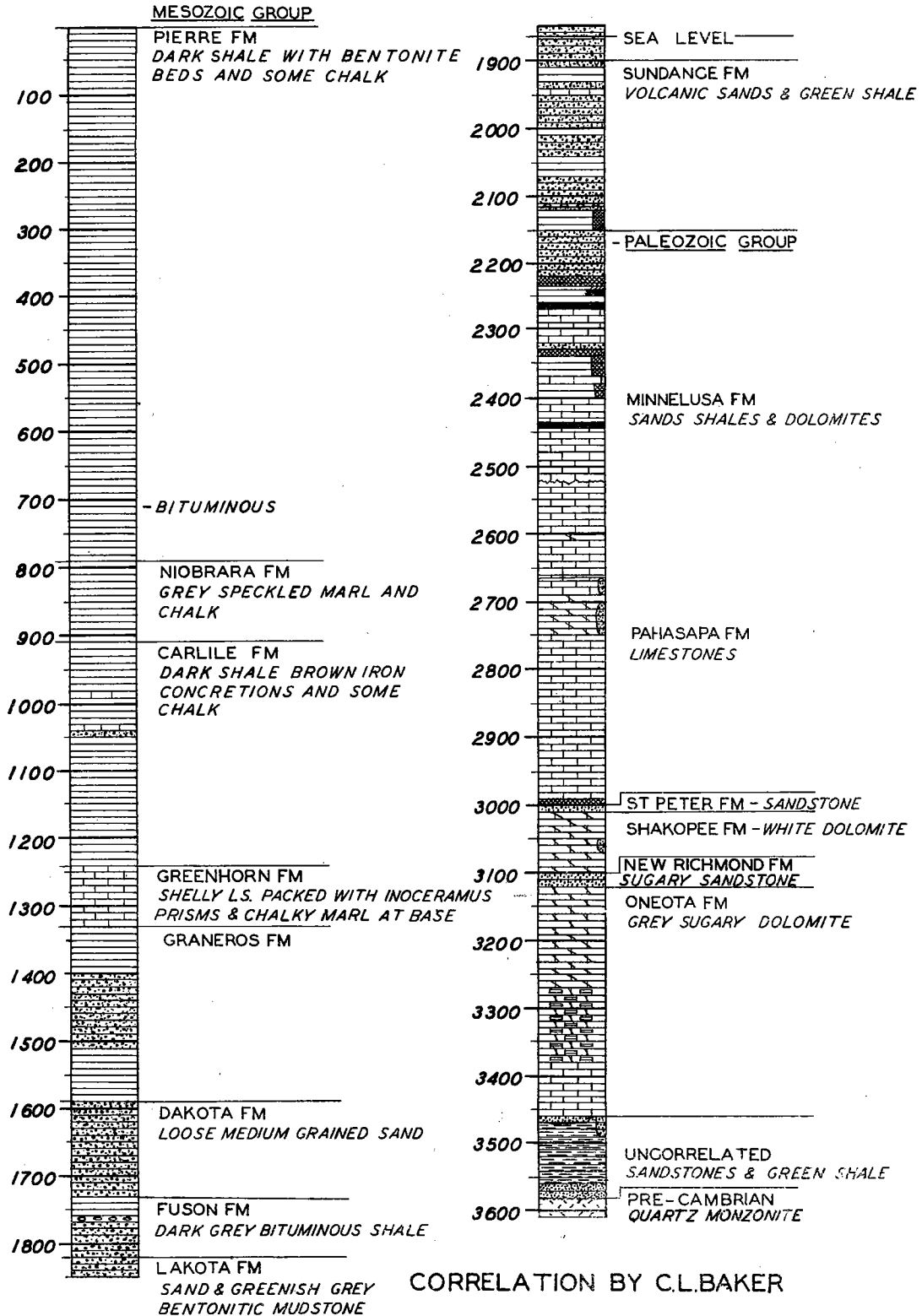
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LOG OF CARTER STRATIGRAPHIC TEST NO I

POTTER COUNTY

STATE OF SOUTH DAKOTA

LOCATION T118N R78W S34



A correlation of the cuttings by Mr. C. L. Baker indicates the following formation log:

Mesozoic Group	0- 790	Pierre
	790- 910	Niobrara
	910-1240	Carlile
	1240-1590	Greenhorn and Graneros
	1590-1730	Dakota Sandstone
	1730-1760	Fuson
	1760-1900	Lakota
	1900-2150	Sundance
	Paleozoic Group	2150-2270
2270-3000		Limestone, position undetermined
3000-3460		Ordovician limestones and dolomites
3460-3570		Undetermined green shale and sandstones
Pre-Cambrian Group	3570-3610	Quartz Monzonite

The 1200 feet of limestone is extremely interesting because it does not follow the Black Hills section which has usually been assigned to all rocks west of the Missouri. The Ordovician limestones are very much thicker than anything in the Black Hills and make the lower 400 feet of the limestone section. The upper 730 feet may correspond to the Pahasapa (Madison) formation and may possibly include limes of the Minnelusa formation.

STRUCTURE

The Mobridge area lies on the eastern flank of a large pitching trough or geosyncline whose axis runs northwest-southwest, roughly through the cities of Lemmon and Philip. This large structure extends northward through Montana and into Saskatchewan, Canada, and is known by various names. In Canada the center of the basin is called the Moose Jaw Synclinorium, while farther south, in North Dakota, it is sometimes known as the Williston Basin. In South Dakota it has been called the Lemmon Geosyncline. Perhaps a better name for the entire structure would be the Dakota Basin because so much of it lies in North and South Dakota.

While the general trend of the axis is northwest-southeast, its plunge gives strikes which, on the eastern flank, trend toward the northeast. In the vicinity of Mobridge and the lower Grand and Moreau Rivers the strata strike approximately north 70° east and dip north 20° west at an average rate of about 30 feet to the mile.

The large area between outcrops prohibit the mapping of small details of structure. And since the Survey was interested only in discovering larger structural features, no attempt was made to outline the small folds which must exist in any such region.

One departure from the regional structure exists, however, which might be of interest to oil prospectors. This is a shoulder projecting northwestward from about the location of the Mobridge Highway Bridge. Its axis trends northwest almost parallel to the axis of the Dakota Basin and lies a mile to a mile and a half east of Highway 12 between Claymore and Snake Creeks. A flat top, approximately six miles long and two miles wide breaks out of the northern slope of the regional structure about opposite Mobridge. From the north edge of the flat the beds dip sharply toward the Grand River at a slope of about 50 or 60 feet to the mile. From the elevations of the key beds no reverse slope was detected. This may be due, in part, to the lack of data in places which would show this reverse dip.

The structure is suggested by the course of the Grand River, Snake and Claymore Creeks which have apparently been deflected

by it. A sharp bend in the Grand River convex to the north may represent the lower northern end of the fold. Snake Creek also curves northward around the front edge of the terrace. Claymore Creek has a similar bend convex to the south. While "creekology" is not always reliable as a basis for structure, in this case it follows so closely the structure which is indicated by bedrock outcrops that there is little doubt but that the structure is the factor controlling their courses.

For want of a better name this structure has been called the Snake Creek Anticline.

A fold which may have closure is indicated about 6 miles southwest of Mobridge and 8 miles east of Trail City. Lack of outcrops, however, made it impossible to contour this structure. If a closure exists on the western end, the structure would have a reversal dip to the southeast of approximately 30 feet and an axis trending northeast-southwest, parallel to the regional strike.

A much smaller shoulder is indicated in the Moreau Valley at the junction of the highway to Promise and Cheyenne Agency. Its top is in Section 4, T 16 N, R 30 E. The top of this small shoulder is about 2 miles long but there is a long even slope north of it for about four miles. Similar curves in the contour lines are indicated in the northeastern corner of the map and two gas wells are located on the high part of these curves. However, the outcrops in this region are not sufficiently widespread to be of assistance in plotting the details of the structure.

The significant structural picture in the area covered appears to be the northward regional slope of the strata broken by one prominent anticline or shoulder, the Snake Creek anticline.

E C O N O M I C P O S S I B I L I T I E S

Though this survey was made primarily to determine the structural conditions in the Mobridge area it may be in order to point out certain economic products which may be of value to this community. At present none of them are exploited though they seem to offer some possibilities in the present economy of the region. No appraisal has been made of any of them with the exception of oil and gas and their mention here is simply to draw attention to their presence.

Sand and Gravel

Some enormous terraces of sand and gravel occur in the area. These lie fifty to 100 feet above the bottoms of the present valley. The largest appear to be along the Grand River especially near its mouth. The city of Mobridge is situated on another large terrace and a big spillway of sand and gravel occupies the bottom of Blue Blanket Creek Valley, passing through Glenham. Most of these deposits cover a number of square miles and seem to have considerable thicknesses of sand and gravel. Such deposits always run into the millions of cubic yards and are, therefore, of interest not only for local projects but for large construction jobs and commercial gravel pits.

Clays

The Pierre formation offers a limitless source of materials for brick and tile clays. The noncalcareous beds are worth investigating for this purpose. Such horizons as the upper Virgin Creek and the thick blue noncalcareous shales in the banded zone of the Mobridge member offer especially interesting prospects.

The presence of lime in clays tends to make brick and tile soft on burning but in proper proportion imparts a yellow color which is very pleasing to the trade. By mixing controlled amounts of marl with the noncalcareous shales or by selecting marl beds which are only slightly calcareous, yellow brick and tile materials could be obtained. Bentonitic zones are not desirable as

the bentonite causes undue air and fire shrinkage. Clays from such zones as the basal bentonite zone of the Mobridge, therefore, should be carefully tested before any attempt is made to use them.

Bentonite layers, while very numerous in the formations exposed in the Mobridge area, are usually too thin for commercial exploitation. The only one that might offer any possibilities is the four inch bed found on the Claymore-Snake Creek Divide and in the Grand River Valley. Because of the cost of stripping and excavating, however, a four inch bed offers very little competition to the four foot beds which are obtainable in the Black Hills area. However, if there is a demand for bentonite in the Mobridge vicinity, this possibility might be worth investigation. It is not certain whether the barite roses so common on the outcrops would offer a supplementary mineral product. No investigation was made to find out whether this barite occurred in the buried portions of the zone or whether it was a phenomena developed on weathering, where the bed is at the surface. There is a market for barite in the paint and paper industry but enormous amounts of the bentonite would have to be excavated and screened to get sufficient barite for a commercial exploitation.

Refractory Clays

The siliceous shales of the Agency and lower Virgin Creek offer some interesting possibilities as refractory clays. A later report is planned dealing with the possibilities of this shale. If it could be easily worked, there is in the lower Virgin Creek an enormous supply of this material. Such clays are used in making fire brick, furnace lining and similar materials which have to withstand high temperatures.

Rock Wool

The ingredients of the ordinary rock wool which is used for insulation are clay and lime. The proportion of these must be such that they melt easily into a glass and can be spun through some type of spinnerette into glass fibers. No investigations have been made to determine whether the marls of the Mobridge member contain the right proportions for this purpose or whether it would be possible to mix them with other clays to make the

proportions needed. If such investigations should prove favorable, the Mobridge area would need only some form of heat to manufacture spun glass in any amount its trade would demand.

Oil and Gas

Like gold, oil is where you find it and the last word in prospecting for it is the drill. However, there are certain places where the chances of striking a pool are better than others because of geological conditions favorable for its origin and accumulation. The first requisite is the presence of formations in the sedimentary series which can carry oil in sufficient quantities to make a well.

It has been pointed out before that the upper artesian horizon has furnished gas in widely scattered parts of the area, these wells are all near the Missouri River. Gas, in each case, comes up with artesian water which is highly corrosive and few of the wells have been constructed so as to prevent this corrosion, therefore, there has been leakage and loss of gas as well as water.

The southernmost gas well is about 8 miles directly south of Mobridge on the west side of the Missouri Valley. It is in the NW $\frac{1}{4}$ of Sec. 23, T 17 N, R 30 E. The water is salty but furnishes a pond for stock watering and sufficient gas to use in the farmhouse.

The second well was drilled for a resort at the east end of the highway bridge at Mobridge. This is known as the Lincoln Park well. It gave salty water for the swimming pool and enough gas to supply the bathhouse and resort with light and heat. The well, however, was allowed to deteriorate and is not now in operation.

Three wells were drilled on what was known as the old Skinner ranch in the northeastern part of the area. The southernmost of the three is at the headquarters ranch house in the SE $\frac{1}{4}$ of Sec. 32, T 126 N, R 78 W, ten and one half miles north and one mile west of Glenham. Though this is an old well and the casing badly corroded, it furnishes plenty of salty stock water

and enough gas to heat and light the large ranch house. Two miles north and two miles east of this well is a second well drilled for stock water. This well is in the bottom of a valley and the casing is entirely gone leaving the well in a crater. It still furnishes considerable water and gas is bubbling through it and wasting into the air. Three and one half miles north and one quarter mile west of the ranch headquarters house is a third well, the most northern on the ranch. It was also drilled for stock water in a valley well back in the breaks of the Missouri. This well has also deteriorated and a large crater formed around it by stock and the erosion of the well water. Water and gas of the same general character and amount as in the other two wells issues from this well.

These five wells indicate that in the vicinity of Mobridge there is a supply of gas which, properly harnessed and used, can supply enough for at least domestic purposes on the farms and ranches in the vicinity. This gas can be reached at a depth of approximately 1800 to 2000 feet. With noncorrosive pipe and properly constructed wells there should be little or no leakage for many years and a very valuable fuel should be available to the residents of this area.

The rocks below the Dakota sandstone are also favorable as oil and gas carriers. Sandstones and limestones have proven good reservoirs in many regions and the latter are particularly good source rocks. The cuttings from the Carter test mentioned above show at least two bituminous horizons, which under the proper structural conditions, might allow the accumulation of pool oil. Since approximately the same rocks underlie the Mobridge area as were encountered in the Carter test a prospector has a reasonable chance of striking production in this area.

A second requisite for the accumulation of oil pools is a trap. There are many kinds of traps which cannot be seen from the surface, however, the most useful trap in prospecting new territory is a structural fold such as an anticline or terrace. The folds near Mobridge have been described above and any of them would offer possibilities as drilling sites. The largest and perhaps the most interesting, however, is the fold designated as the Snake Creek structure. This has sufficient length (6 miles), sufficient width (2 miles), and a sufficiently large collecting area about its base to allow an accumulation of oil or gas. This structure is large enough to extend vertically to the top of the "granite". Its shape underground, however, may

change somewhat due to a difference in the stiffness of the rocks. As was pointed out, the lower half of the section is made of very competent rocks, limestone and sandstone, while the upper half is made of plastic shales. It is possible, therefore, that these competent rocks would show a more pronounced anticline than appears on the surface. This, however, can only be determined by drilling. Such structures have caused oil accumulation in many fields in spite of the lack of closure.

Depth of Drilling

As was stated above considerable changes can take place in 25 or 30 miles; however, until better information is available on the local sedimentary column it is reasonable to suppose that approximately the same thickness of sediments underlies the Mobridge area as is found in the well at Whitlock's Crossing. Since any well on the Snake Creek structure would have to start only 100 or 200 feet higher stratigraphically than the well at Whitlock's Crossing it would appear that a depth of 3600 to 3800 feet should reach the granite in this area. Drilling deeper than the granite is not recommended. The pre-Cambrian rocks are difficult and expensive drilling and do not yield oil in commercial quantities.

Water for drilling is available in all the large streams and there are numerous dam sites which can be utilized on the smaller tributaries over the entire region. Access to the region is good and a good system of highways and side roads cover most of it. The topography is not so rough but that haul roads can be made from these to any point in the area. The main line of the Chicago, Milwaukee, and St. Paul Railroad passes through Glenham, Mobridge, and Wakpala and a side branch traverses the valley of Snake Creek to Trail City.

The Mobridge area is still very much wildcat territory but from the foregoing it would appear that an oil prospector would at least get a good run for his money in this region. Considerably more information on the structure is desirable in many parts of the area as the present map had to be very much generalized in regions where control was not available. Core drilling and some types of geophysics might be used to advantage to determine more accurately the structures that have been indicated. They could also be used in such areas as the northcentral part of the map and in carrying key beds between the outcrops along

the rivers and the base of the Fox Hills sandstone in the western part of the map. Such prospecting would also be necessary east of the Missouri River since that area is covered entirely by glacial drift which makes surface structural mapping impossible.

The present survey, it is hoped, will point the way to the better locations and save needless expensive prospecting and drilling. If it will do this it has served its purpose.

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