****

STATE OF SOUTH DAKOTA
George T. Mickelson, Governor

STATE GEOLOGICAL SURVEY
E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS
No. 65

NORTH PART

OF THE

WHITEWOOD ANTICLINE

----

by

Bruno C. Petsch

University of South Dakota
Vermillion, South Dakota
April, 1949

****

TABLE OF CONTENTS

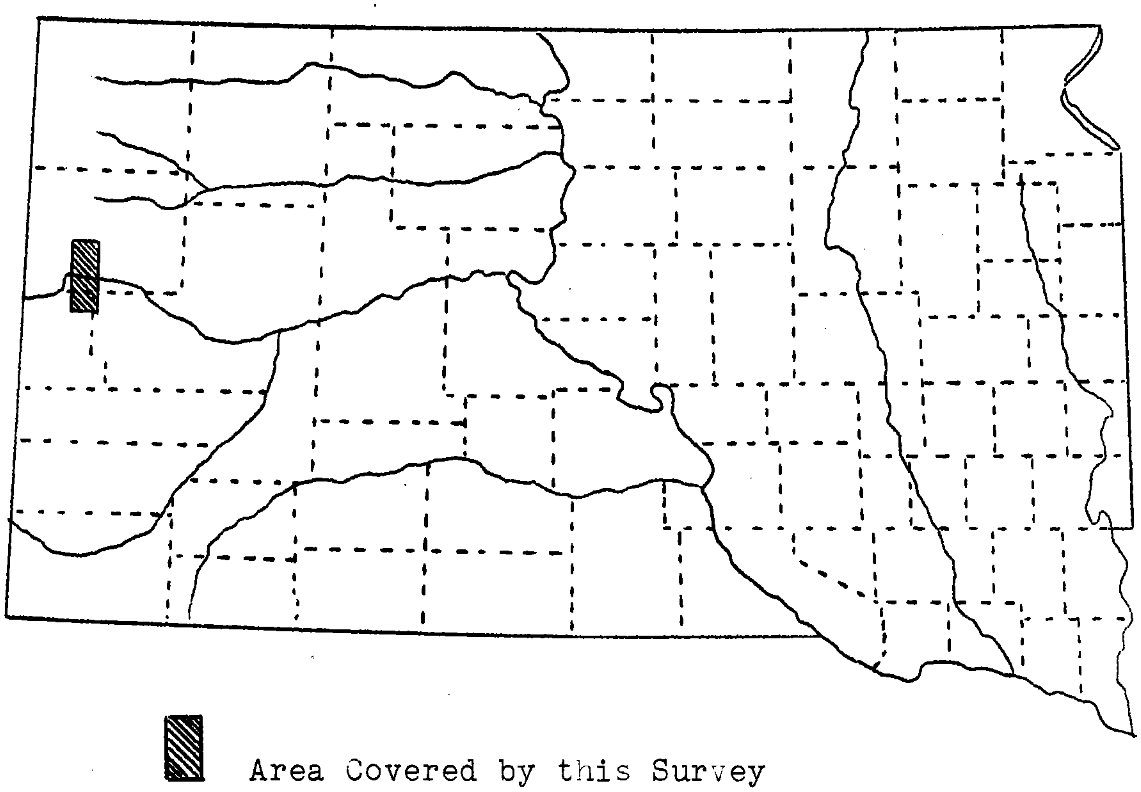
LIST OF ILLUSTRATIONS

NORTH PART
of the
WHITEWOOD ANTICLINE

by

Bruno C. Petsch

INDEX MAP



Area Covered by this Survey

FIGURE 1

INTRODUCTION

LOCATION OF THE AREA

The area described in this report is in the central western part of South Dakota. It is situated in the northeastern part of Lawrence County and the south central part of Butte County (Figure 1). It includes the vicinity around Orman Lake, sometimes known as the Belle Fourche Reclamation project, which is north of the Belle Fourche River, and extends south and east of the city of Saint Onge, which is south of the river. The city of Belle Fourche is about 6 miles west of the center of the area. The area is about 18 miles long and 10 miles wide, and covers about 180 square miles.

PURPOSE OF THE REPORT

This investigation is part of a series of studies undertaken by the South Dakota Geological Survey to determine the detailed structure of the northern Black Hills region. It is a continuation of the program for determining the oil and gas possibilities in South Dakota.

The Whitewood anticline is known from the work of N. H. Darton and C. C. O'Harra, and this investigation was made to determine more precisely its structure and other characteristics.

PREVIOUS INVESTIGATION

The investigation of the geology of the Dakota Territory began as early as 1804 and continued intermittently to the present time. It wasn't until 1874 that the investigations were carried on in the Black Hills proper by H. N. Winchell and Henry Newton.

The geology of the Belle Fourche Quadrangle was mapped in 1906 by N. H. Darton and Dr. C. C. O'Harra (3), at which time the main structures at the northern margin of the Black Hills were outlined.

METHODS OF WORK

This investigation of the Whitewood anticline was carried on by a plane table survey. Traverse lines were run throughout the area to determine the position of outcrops of rock formations. Sea level altitudes were taken from bench marks established by the United States Geological Survey. A topographic map of the region was made in 1903, hence bench marks are numerous. Prominent outcrops were measured to determine the sequence of key beds and the character of formations. Two plane table parties were used for the survey. The mapping was done on a scale of one inch to 2500 feet. Most traverses were double-rodded; they were closed on bench marks or within themselves, and horizontal control was checked by section corners whereever found.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the work of the members of this survey party: Mr. Loyd Carlson and Mr. Marion Glass, who alternated the duties of geologist and surveyor with one plane table party; and Mr. George Zink, who assisted the writer as surveyor with the other plane table, and who aided also with the geological work. The chapter on the Newcastle sandstone and dikes and sills was written by Mr. Loyd Carlson.

A word of appreciation is also due to the people of the area who in many ways assisted in the progress of the work by providing information and by numerous other courtesies.

Numbers in parentheses refer to publications listed in the bibliography at the back of this report.

COLUMNAR SECTION OF EXPOSED FORMATIONS

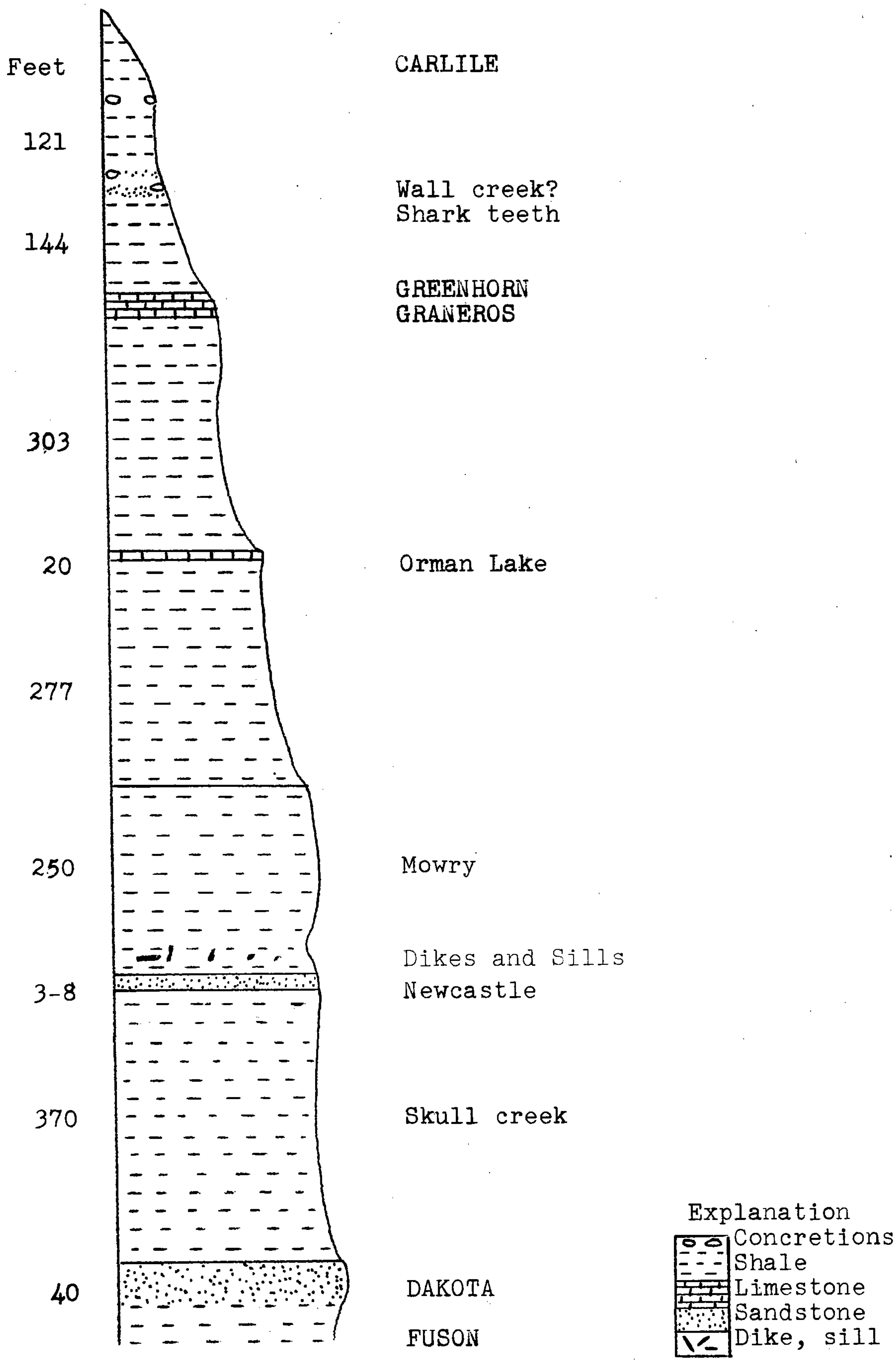


FIGURE 2

EXPOSED FORMATIONS

The rock formations on the surface of the area are of Cretaceous age, and range from the Dakota Sandstone up into the Carlile shale. Their sequence is as follows from the youngest at the top downwards:

CARLILE FORMATION

GREENHORN FORMATION

GRANEROS FORMATION

Belle Fourche shale

Orman Lake limestone

Mowry shale

Sandstone dikes and sills

Newcastle sandstone

Skull Creek shale

DAKOTA (FALL RIVER) FORMATION

These formations are made up of shales, limestones, and sandstones, and comprise about 1500 feet of section. (Figure 2.)

The surface formations are hidden or covered in part by the large lake, the wide valley alluvium of the Belle Fourche River, and older terrace deposits of gravels. The position of the surface formations are shown on the geologic map (Figure 3) and are described in the text that follows.

CARLILE FORMATION

The Carlile formation lies on the Greenhorn formation and is present on the east flank of the anticline on the east side of the lake, south of the Belle Fourche River; and on the west flank, west of the lake, west of Susie Peak.

The formation is a black to dark-gray shale with regular layers of ferruginous and sandy limestone concretions. Some are a yellow to bright buff and others are white.

The lower part of the Carlile commonly has "badland" topography; it supports a growth of sagebrush difficult to traverse by car.

A layer of sandstone about 144 feet above the base of the Carlile has been called the Wall Creek sand of Wyoming. This alternates with, or changes to, huge yellow-brown concretions (Figure 4 B) forming a continuous horizon used in mapping that portion of the structure. In the sandstone are groups of bentonitic calcareous sandstone or silt galls in places numerous enough to form a conglomerate. Below this concretion-sandstone horizon is usually about four feet of dark uncemented sand. The slopes of this portion of the Carlile section contain many well-cleaned fossils. Mollusks, sharks teeth (Lamna), and ship worm borings (Teredolites) are common. Twenty feet above the yellow-concretion sandstone is a second horizon, analogous to it (Figure 4 A). The two horizons usually form a double terrace in the topography which is well displayed west of Susie Peak. The sandstone is in thin layers and weathers out in slabs as much as two feet across and ¼ inch thick.

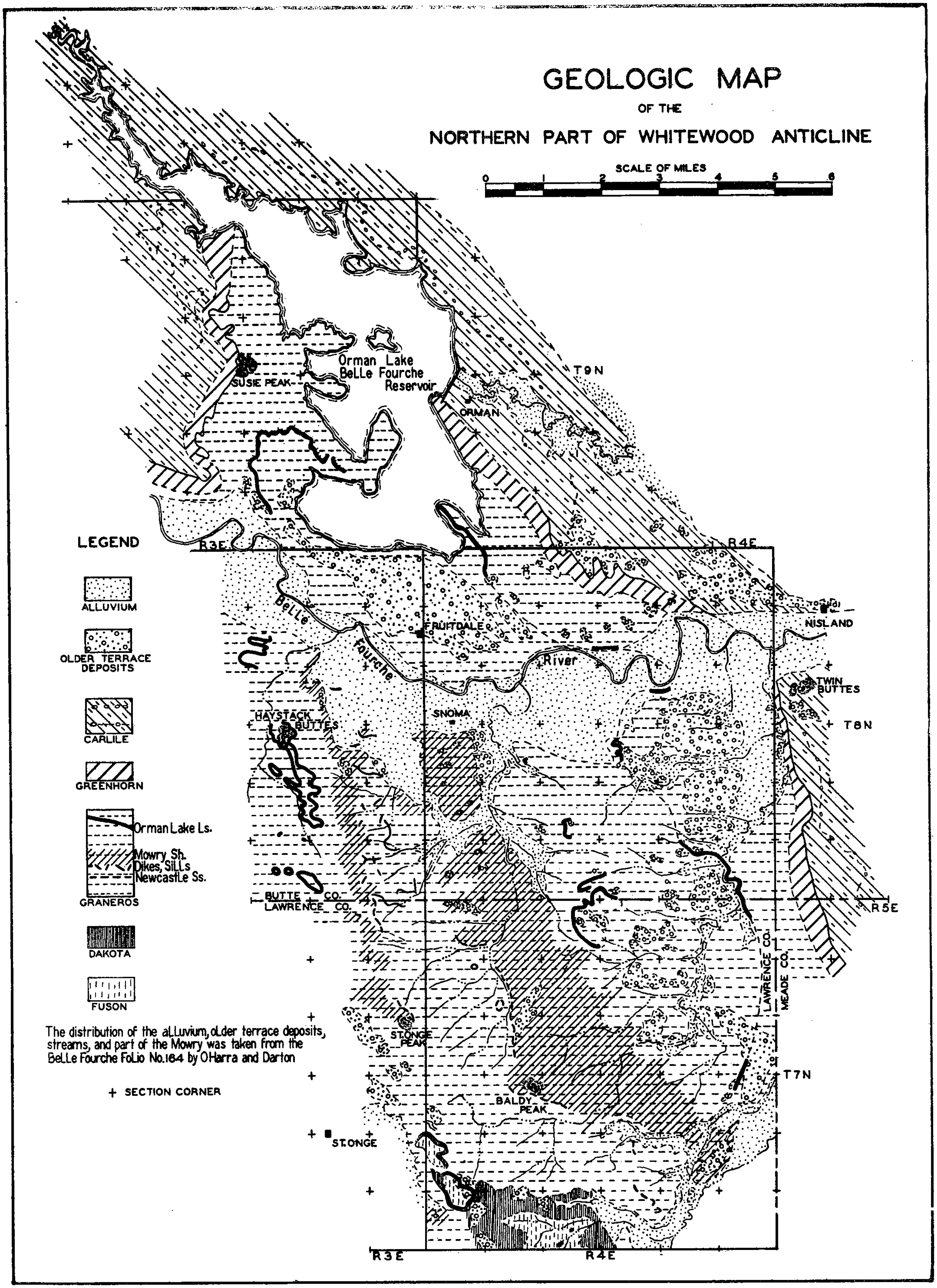

GEOLOGIC MAP
OF THE
NORTHERN PART OF WHITEWOOD ANTICLINE
SCALE OF MILES
0 1 2 3 4 5 6
LEGEND
ALLUVIUM
OLDER TERRACE DEPOSITS
CARLILE
GREENHORN
Orman Lake Ls.
Mowry Sh.
Dikes, Sills
Newcastle Ss.
GRANEROS
DAKOTA
FUSON
The distribution of the alluvium, older terrace deposits, streams, and part of the Mowry was taken from the Belle Fourche Folio No.164 by O'Harra and Darton
+ SECTION CORNER
Orman Lake
Belle Fourche
Reservoir
SUSIE PEAK
ORMAN
T9N
R3E
R4E
NISLAND
FRUITDALE
Belle Fourche River
TWIN BUTTES
T8N
HAYSTACK BUTTES
SNOMA
BUTTE CO.
LAWRENCE CO.
R5E
LAWRENCE CO.
MEADE CO.
ST. ONGE PEAK
T7N
BALDY PEAK
ST. ONGE
R3E
R4E

FIGURE 3

Carlile Section

Succession of beds of the Carlile formation northwest of Susie Peak, Sec. 8 and 9, T. 9 N., R. 3 E.

	Feet
Shale, dark gray, white limestone concretions at top	101
Sandstone and yellow concretions	1-3
Shale, dark gray	20
Sandstone with galls, and yellow concretions	1-3
Uncemented dark sand	4
Shale, dark gray, shark teeth	40
Concretions, brown to red ironstone	0-1
Shale, dark gray	104
Top Greenhorn limestone	

GREENHORN FORMATION

The Greenhorn formation is usually considered a limestone, but in the area of this report many of the Greenhorn characteristics are lacking. For example, in the southern part of the Black Hills at Edgemont, the formation is a prominent ledgemaker which it is not here.

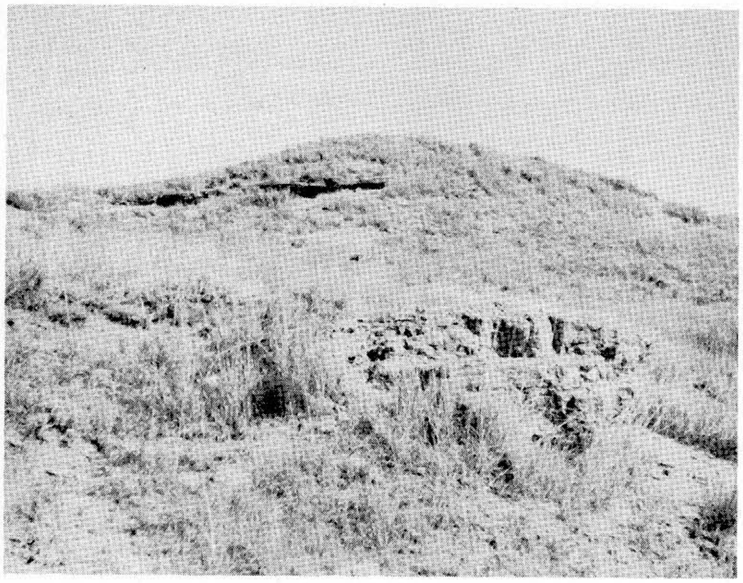
South of Nisland the Greenhorn is difficult to trace because ledges are absent, and it is well grassed over with no prominent topographic features. Small exposures are to be found in an occasional road cut or creek bank.

In the vicinity of Susie Peak and southwestward, the Greenhorn has a tendency to form ledges, and its base can be mapped to a certain extent. The formation is reported to be from 25 to 35 feet thick. An interval of 27 feet was observed from the base of the formation to the top of its dip slope west of Susie Peak.

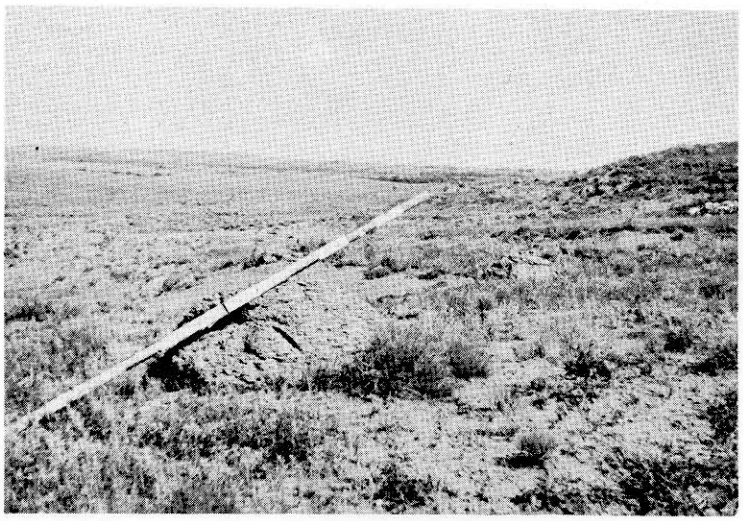
Greenhorn-Graneros Section

Succession of beds at the contact at Susie Peak,
Sec. 15, T. 9 N., R. 3 E.

	Feet	Inches
Shale, light brown calcareous..............	3	
Shale, gray-brown calcareous. Streaks of alkali........................	3	
Limestone, layer of impure, shelly.........		3
Shale, light and dark brown calcareous.....	1	6
Concretion layer, limey....................		8
Shale, brown calcareous....................	1	
Limestone, shelly impure, brown............		4
Shale, brown calcareous....................	1	2
Shale, black calcareous....................	1	8
Shale, alternate brown and black calcareous................................	3	6
Shale, black calcareous....................	2	2
Shale, alternate black and brown calcareous................................	4	
Shale, black calcareous....................	5	
Shale, black calcareous....................	2	8
Shale, black calcareous....................	3	1
Shale, alternate black and brown calcareous................................	2	6
Shale, alternate black and brown calcareous, mostly black.................	1	5
Bentonite, gray and brown..................	1	
Shale, black calcareous. Few brown streaks....................................	15	
Bentonite, yellow..........................		3
Shale, brown-gray calcareous. Some alkali....................................	9	6
Bentonite, yellow..........................		1
Shale, black to brown non-calcareous.......	4	8
Bentonite, chrome yellow...................		3
Shale, black tough non-calcareous..........	2	6
Shale, bentonitic, yellowish, layered......		6
Shale, black to brownish-gray..............	2	
Concretion layer, rusty brown iron oxide.....................................		2
Shale, brownish-gray non-calcareous. Occasional bentonite and alkali..........	5	6
Shale, band of rusty colored...............		1
Shale, gray non-calcareous.................	1	
Shale, rusty...............................		2
Shale, brownish with occasional rusty beds of iron.............................	30	



A: Sandstones in lower Carlile shale.
Sec. 11, T. 9N., R. 3E.



B: Concretions in lower Carlile shale.
Sec. 19, T. 8N., R. 5E.

Figure 4

Greenhorn Section

Succession of beds on U. S. Highway 212, west of Nisland; Sec. 3, T. 8 N., R. 4 E.

	Feet Depth
Shell Layer.	
Limestone, hard, with broken shells.	
Shell Layer.	
Clay or chalk, light gray, limey.	
Shell Layer....................................	2.2
Shale, light buff, limey, thin shell layers, broken shell fossils, limestone ½", oil smell.	
Shell Layer....................................	3.6
Shale, buff to gray, limey, conchoidal fracture.	
Shell Layer....................................	5.4
Limestone, shaly, hard, ochre to gray to buff, broken shells, beds of pure limestone ¼"-1".	
Shell Layer....................................	6.1
Shale, gray to buff, limey, conchoidal fracture, concretion horizon (limestone).	
Shell Layer.	
Limestone, rusty buff, shaly, broken shells, lenses of thin limestone.	
Shell Layer....................................	7.9
Clay, mottled black and gray, limey, conchoidal fracture; changes to buff.	
Shell Layer....................................	9.0
Limestone, buff to gray shaly, broken shell layers, limestone lenses.	
Shell Layer....................................	9.2
Shale, black to gray mottled, limey, conchoidal fracture; light rusty brown, thin bedded, almost orange in spots.	
Shell Layer....................................	12.3
Shale or clay, light buff, thin bedded, limey, broken shells, thin bedded limestone lenses.	
Shale, gray to buff, ochre streaks, conchoidal fracture.	
Shale, rusty brown, weathers to black, limestone lenses.	
Shell Layer....................................	14.5
Shale, base of black, weathered, light rusty buff limey shale layers.	
Shell Layer....................................	15.6
Shale, black layer 1"-2" thick, limey, conchoidal, light gray clay.	
Limey shell layer.	
Shell Layer....................................	16.1

	Feet Depth
Shell Layer..	17.2
Clay layer, conchoidal fracture, buff.	
Shell Layer.	
Clay, light gray, conchoidal fracture.	
Shell Layer..	20.0
Shells.	
Clay, gray to buff, limey.	
Concealed.	

The above section was measured down a 17° sloping bank of a road cut. A steel tape was stretched down the slope, and the section was described accordingly.

GRANEROS FORMATION

The Graneros formation forms the thickest and most extensive exposures on the anticline which covers an area about 16 miles long, north and south; four miles wide in the north and eight miles in the south. The formation is largely composed of shales. The thickness of the formation was determined to be 1200 feet by solving equations for intervals between key horizons.

The Graneros formation was named for Graneros Creek, in the Walsenburg Quadrangle, Pueblo County, Colorado. The name was suggested by R. C. Hills and applied by G. K. Gilbert, 1896, to the rocks lying between the overlying Greenhorn and to the underlying Dakota.

In the region of the Black Hills the Graneros formation is divided into members as follows in descending order:

	Feet
Belle Fourche shale member..........	580
Mowry shale member..................	250
Nefsy shale member..................	?
Newcastle sandstone member..........	3-8
Skull Creek shale member............	370

Apparently the Nefsy shale cannot be distinguished from the Mowry here. The thicknesses given are in the Whitewood anticline.

Belle Fourche Shale Member

The Belle Fourche shale member is the uppermost part of the Graneros. It is calculated to be 580 feet thick. On a color basis the member can be divided into two parts: the lower part is a dark gray shale with bentonite layers up to the Orman Lake limestone: the upper part, including the Orman Lake, is brown to buff shale with sandy layers (one lying about 28 feet below the base of the Greenhorn limestone) and smells of oil when struck with a hammer.

The upper part of the Belle Fourche member above the slabby limestone (Orman Lake) has been placed in the Greenhorn (2) on the west side of the Black Hills. This probably will not hold for localities on the Dakota Basin side of the Black Hills.

At the base of the Belle Fourche and the upper part of the Mowry are three bentonite layers.

Orman Lake Limestone

Near the middle of the Belle Fourche shale member of the Graneros is a horizon of flaggy limestone (Figure 5 A and B). The limestone forms an escarpment trending northwest from Belle Fourche along the northeast side of Middle Creek valley, and is prominent on both sides of the anticline. It was called the Middle Creek limestone by M. E. Wing (9). The name also is used locally by persons interested in geology. It is here proposed to abandon the name Middle Creek for this limestone because the name has prior usage in eastern Kansas, northwestern Missouri, southeastern Nebraska, and southwestern Iowa where it refers to a Pennsylvanian limestone that outcrops along Middle Creek in Linn County, Kansas. This bed, therefore, will be called the Orman Lake limestone in this report.

The name Orman Lake limestone can be applied to this horizon because very good exposures of it occur on the west and south sides of that lake and in the peninsula which extends into the lake from the southeast. On the peninsula the shore of the lake is covered by many of the limestone slabs (Figure 5 A).

A similar limestone has been observed at this horizon at several places around the outskirts of the Black Hills. It has been described (2) as a thin slabby or flaggy limestone containing fragments of fossils similar to those in the Greenhorn formation above it near Osage, Wyoming, and is described south of the Black Hills in Fall River County (7).

The Orman Lake limestone is a beach coquina. The material is composed entirely of broken shells reduced to all sizes. It contains also black grains and flakes of organic material and emits a strong petroleum odor when struck with a hammer. A distinguishing characteristic of the limestone is its abundance of shark teeth. The rock is gray-brown when fresh and light buff to yellow when weathered. It is hard and resistant enough to be a ledge-maker. At the outcrop it breaks out in large slabs which are generally used for riprapping stock dams. The limestone occurs in at least three layers.

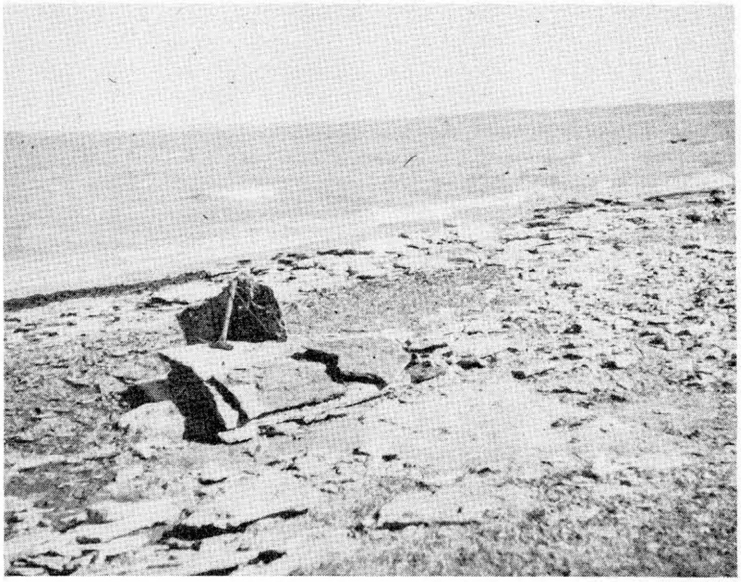
Orman Lake Section

Succession of beds north of Haystack Buttes in Sec. 10, T. 8 N., R. 3 E.

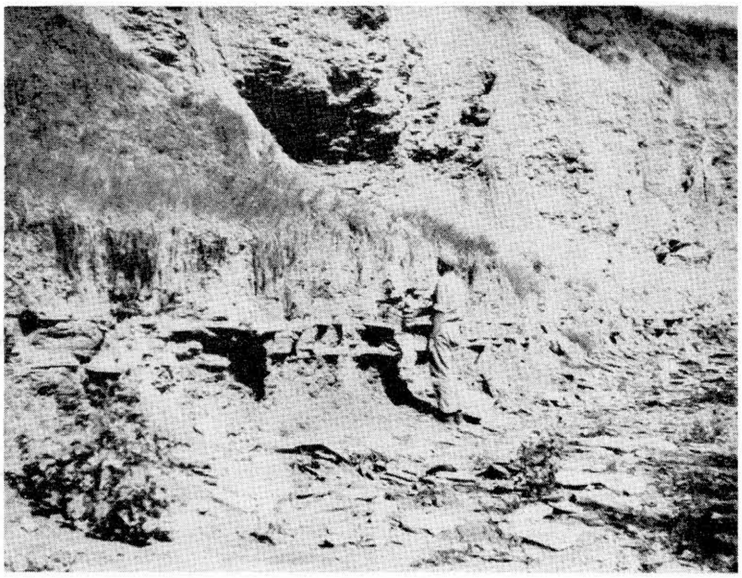
	Feet	Inches
Coquina limestone................		1-2
Shale, gray calcareous; weathers yellow................	8	
Coquina limestone................		1-2
Shale, gray calcareous; weathers yellow................	12	
Coquina limestone, slabby........		2-12
Bentonite, gray-blue.............		1
Coquina limestone................		2
Shale, black.....................	8	
Bentonite, impure brown..........		6
Shale, black.....................	5	
Bentonite, impure brown..........		4

On the crest of the anticline in Sec. 27, T. 9 N., R. 3 E., only the lower heavy 12-inch coquina limestone is present forming dip slopes to the north and west in the locality. In T. 8 N., R. 4 E., south of the Belle Fourche River, only the lower member is present and it is usually covered with older terrace deposits common in the area. There is an exposure of the lower member in the channel of the river in Sec. 14, in the above township.

The lower bed which lies on the black shale is an ideal mapping horizon for structure determination and was used as the datum horizon on the structure map.



A: Slabs of Orman Lake limestone on the southeast peninsula of the lake. Sec. 31, T. 9N., R. 4E.



B: Orman Lake limestone along Stinkingwater Creek. Sec. 36, T. 8N., R. 4E.

Figure 5

Mowry Shale Member

The Mowry shale member of the Graneros is separated from the Skull Creek member below by the Newcastle sandstone, and from the Belle Fourche member above by a group of three bentonite layers. The position of the Mowry shale on the anticline is generally outlined by forest or wooded areas of scrub oak and pine trees (Figure 6). It has very little soil, and on exposure it is white to silver gray. The weathered pieces snap or rattle when handled because it is a hard siliceous shale. Roads over the Mowry are not muddy when wet. The member contains many detached fish scales. Near the top are several large cone-in-cone concretions. All these characteristics make the Mowry conspicuous and easily identified. There are no traceable key beds in it. The Mowry shale is well exposed east of Baldy Peak (Figure 6 A).

Upper Mowry Section

Succession of beds at the contact northeast of Haystack Buttes in Sec. 15, T. 8 N., R. 3 E.

	Feet	Inches
Bentonite, light gray, contains much iron rust	2	
Shale, light gray	6	
Bentonite, grayish tan, nearly pure	1	2
Shale, gray Mowry	14	
Bentonite, grayish tan with 2" bluish sandy bentonite at base	1	
Shale, gray to silver gray Mowry	9	
Bentonite, buff and grainy	1	

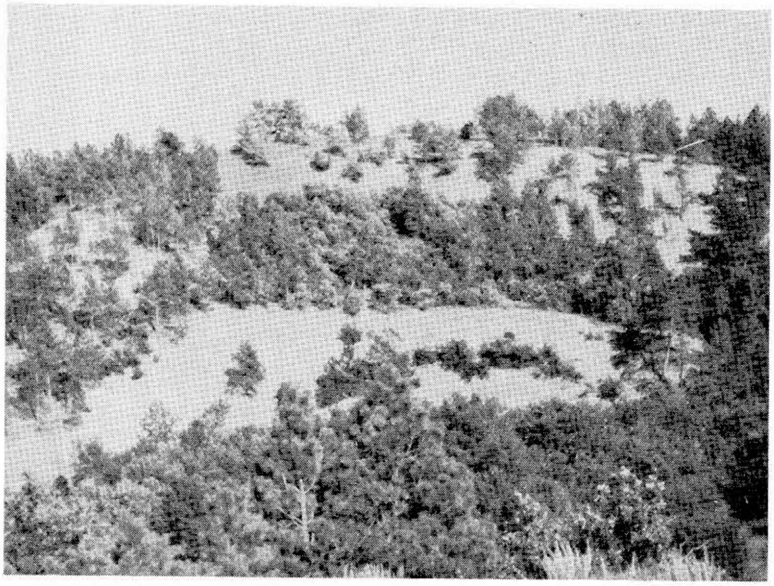
Mowry Section

Succession of beds on a steep outcrop on Stinkingwater Creek in Sec. 21, T. 7 N., R. 4 E.

	Feet	Inches
Shale, black hard; weathers silver gray, platy. Contains fish scales, grades up to soil	10	
Bentonite, very light grayish tan, has veins of iron oxide	1	
Shale, black hard (siliceous?) as above. Numerous fish scales	12	
Hard dark gray and brown slabby iron oxide		1

	Feet	Inches
Bentonite, gray, very rusty		1
Shale, bentonitic, rusty; iron oxide and bentonite disseminated throughout bedding planes and joints. Shale is light gray, slightly sticky where wet, does not weather to plates	1	3
Bentonite, light tannish gray, considerable iron oxide throughout	1	7
Shale, very bentonitic light gray, considerable iron oxide		8
Bentonite, gray-tan. Tan color due to considerable iron oxide	1	
Brown hard layer of iron oxide. Numerous small gypsum crystals		½ ±
Shale, hard dark gray; some iron oxide and bentonite disseminated. Numerous small gypsum crystals	8	6
Bentonite, gray, impure with shale. Contains some biotite flakes, crumbles		3
Shale, very dark gray; some bentonite and iron oxide. Weathers to plates	4	10
Bentonite, light tannish gray, rusty		6
Shale, dark gray bentonitic. Bentonite in joints and planes. Occasional small gypsum crystals. Slightly harder bed 4 feet down	8	6
Shale, hard platy. Considerable iron oxide		1
Shale, dark gray. Weathers platy	15	
Shale, dark gray bentonitic. Much yellow bentonite in joints and planes	1	3
Bentonite, lensy, gray		0-3
Shale, dark gray bentonitic; much yellow bentonite in joints and planes. Friable	4	9
Bentonite, dark brown		2
Shale, dark gray bentonitic. Yellow bentonite in joints and planes	2	10
Sandstone, dark gray, iron oxide stained. Three layers with grayish shale between	1	5
Shale, dark gray, considerable yellow bentonite	15	

Base of Section at creek level.



A: Mowry shale east of Baldy Peak.
Sec. 22, T. 7N., R. 4E.

B: Mowry shale south of Snoma.
Sec. 19, T. 8N., R. 4E.

Figure 6

Sandstone Dikes and Sills

A series of sandstone dikes and sills outcrop along the axis of the anticline in Sec. 1, T. 7 N., R. 3 E., and Secs. 14, 23, 24, 25, 26, 35, and 36, T. 8 N., R. 3 E. Stratigraphically they lie approximately in the position of the Newcastle (?) member of the Graneros. They are from five to fifteen feet thick and from 50 to 2500 feet long. Some of them form prominent ridges; others appear as a row of sandstone boulders and cobbles, often marked by a small silver leafed plant, Psoralea argophylla Pursh (10), which grows more thickly on the weathered and disintegrated dike material than on the enclosing shale. The dikes and sills lie at angles from horizontal to vertical and are in no particular system or pattern.

The dike material is gray to brownish gray tough sandstone. It is composed of medium sized angular and subangular quartz particles with some fine, rounded, light green bentonite particles, and minor biotite and hornblende. It is tightly cemented with calcite.

It is derived from the Newcastle (?) member (8). The material was squeezed upwards into overlying shales. Apparently the larger the dikes are, the less the thickness of the Newcastle sandstone would be. Hence, this would account for the thinning of the Newcastle sandstone.

Newcastle (?) Member

A member separating the Skull Creek and Mowry shale outcrops intermittently from Sec. 1, T. 7 N., R. 3 E., to St. Onge Peak, Sec. 13, T. 7 N., R. 3 E., on the west flank of the anticline, and from Sec. 1, T. 8 N., R. 4 E., to Sec. 3, T. 7 N., R. 4 E., on the east flank. It may be tentatively correlated with the Newcastle member (2) found west of the Black Hills since it occupies a similar position in the stratigraphic section.

Newcastle Section

A composite section showing the succession of beds in the vicinity of St. Onge Peak, Sec. 13, T. 7 N., R. 3 E.

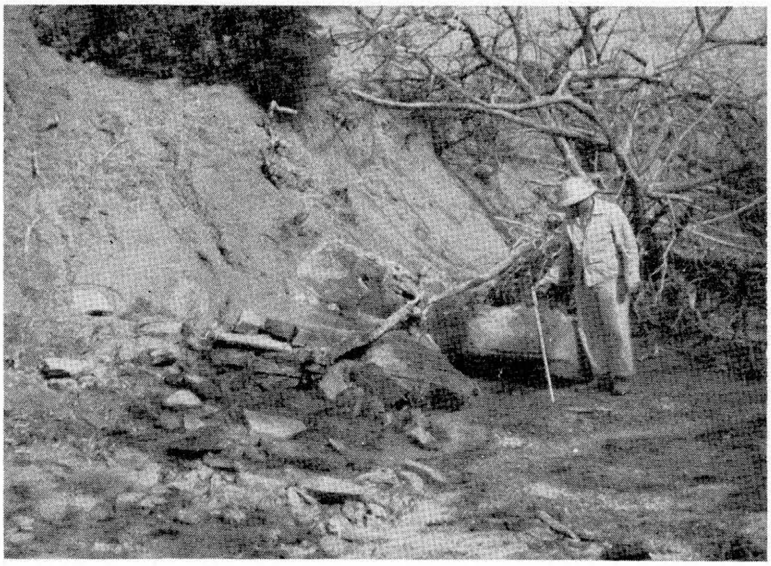
	Feet	Inches
Conglomerate, brown to gray, white streaked, flattened chert pebbles ¼ to 1 inch large in diameter, weakly cemented with subrounded, polished, grit sized quartz particles and hydrous iron oxide...........................		3-12
Sandstone, gray to buff, medium-grained, porous; largely angular to subangular quartz particles...........................		3-24
Shale, gray, weathers to a silver-gray color, usually grassed over..............	8	
Sandstone, brown to grayish brown, medium to fine-grained, massive..............	8±	

Outcrops are not prominent; they are well grassed over and difficult to follow. In most exposures the conglomerate has disintegrated on weathering, and the loose pebbles lie upon the thin sandstone.

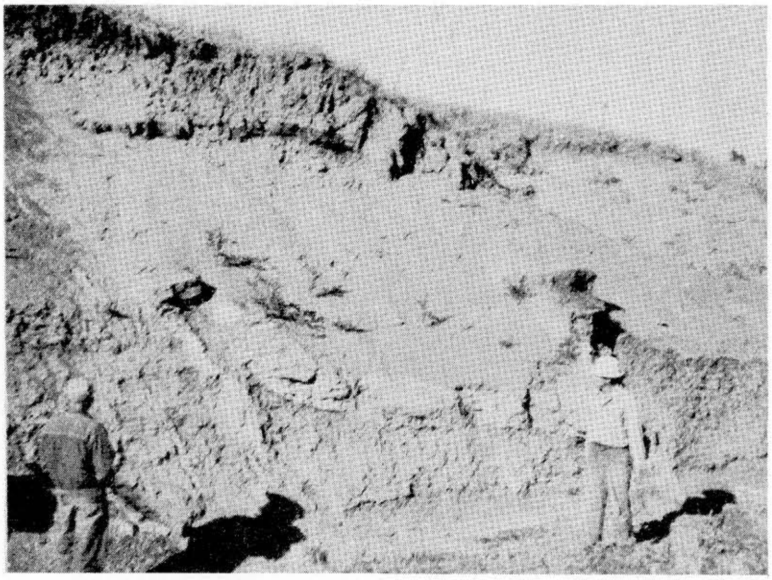
The conglomerate and thin sandstone are seldom over six inches thick. The maximum thicknesses were found in the south fork of Stinkingwater Creek, in Sec. 21, T. 7 N., R. 4 E. There, large blocks of conglomerate and sandstone lie in the creek bottom (Figure 7 A). The sandstone in these blocks is about 2 feet thick and the conglomerate from six to twelve inches. The blocks are probably not in place since the area has undergone much slumping, and the altitude of this exposure is much lower than the altitude and dip that other nearby outcrops would predict.

An interesting feature of the conglomerate is the uniform composition and shape of the pebbles. According to Baker (1), the probable source of these pebbles is the Phosphoria formation, (Permian), of western Wyoming. The flattened, shingle-like shape indicates beach or near shore deposition.

The heavy sandstone at the base of the member is concealed or absent in most outcrops. It is found on the west and southwest sides of St. Onge Peak and in several other places along the west flank of the anticline. It apparently furnished the material for several sandstone



A: Newcastle sandstone at the base of a landslide, along Stinkingwater Creek. Sec. 21, T. 7N., R. 4E.



B: Sandstone dikes and sills. Sec. 36, T. 8N., R. 3E.

Figure 7

dikes on the northwest and north sides of St. Onge Peak. It makes prominent dip slopes on the east flank in Sec. 27 and 34, T. 7 N., R. 4 E. Several clay ironstone concretionary beds lie below it in this area at intervals of 8 to 10 feet.

Skull Creek Member

The Skull Creek member is the lowest part of the Graneros formation and lies on the Dakota (Fall River) sandstone formation. It is 370 feet thick and is composed of black and dark gray shales. It contains scattered lens-shaped concretions. There are no markers in it which could be used for mapping.

SUBSURFACE FORMATIONS

The Whitewood anticline extends off the Black Hills uplift as a north-northwestward extension beginning somewhere at the Vanocker Creek laccolith which is about six miles south of the town of Sturgis. As a result, all the Paleozoic formations from the pre-Cambrian up to the Lakota sandstone are exposed in the Black Hills portion of the anticline and would be encountered in the subsurface of that part of the Whitewood anticline which was mapped (Figure 8).

Since the Graneros is the oldest formation which covers most of the area, the Dakota sandstone will show the first change in the formations encountered in drilling.

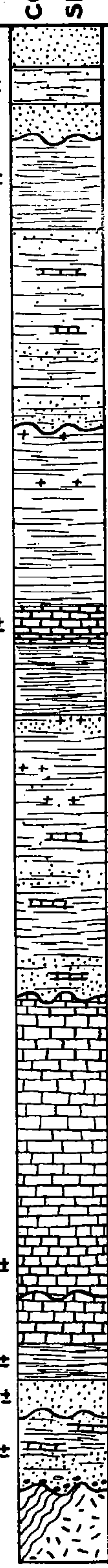
DAKOTA FORMATION

The Dakota formation is a water-bearing sandstone from 40 to 80 feet thick in the northern Black Hills. It usually forms a bold outcrop. The sandstone is from clear to rusty in color, flaggy to massive, and sometimes has quartzite layers. In the lower portion there are many iron and sand concretions.

FUSON FORMATION

The Fuson formation is generally varicolored clays--purple, white, yellow, and gray. Sometimes a layer of sandstone is present. The lower part is a light-colored fine clay. The clays contain many minute manganese pellets which are a horizon marker in drill cuttings. The formation is 60 feet thick more or less.

SUBSURFACE FORMATIONS



APPROXIMATE THICKNESSES	FORMATIONS	
40-80+	DAKOTA (FALL RIVER)	Sandstone, massive, flaggy
60±	FUSON	Sandy shales, gray, purple
40-90	LAKOTA	Sandstone, massive, flaggy
150 ±	MORRISON	Bentonitic clays, vari-colored
322-359*	SUNDANCE	Shales, Sandstones, Limestones, Green shales, Glauconite
280-700	SPEARFISH	Red Beds, Sandy shales, Gypsum
50±	MINNEKAHTA	Limestones, light lavender
120-130	OPECHE	Red shales and clays
470-675	MINNELUSA	Shales, Sandstones, Limestones, Anhydrite
460-500	MADISON	Limestones, caves,
50±	ENGLEWOOD	Limestones, lavender
20-80	WHITEWOOD	Dolomites, Limestones
40-100 ±	BLACK RIVER	Green shales
18-53±	ST PETER	Sandstones, scolithus
335±	DEADWOOD	Sandstones, Shales, green, Limestones, Conglomerate
	PRE-CAMBRIAN	Schists, Granites

*Ralph W. Imlay, Marine Jurassic of Black Hills A.A.P.G. Feb. 1947

FIGURE 8

LAKOTA FORMATION

The Lakota formation is a water-bearing sandstone from 40 to 90 feet thick. It is a white to rusty color, flaggy to massive, and occasionally irregularly bedded. It contains quartzite layers. Some sandstone layers contain clay galls. Petrified and carbonized wood is common; this defines it clearly from the Dakota. The lower portion of the Lakota is conglomeratic in some areas.

MORRISON FORMATION

The Morrison formation is generally a varicolored shale or clay. It is often referred to as the somber beds. Its thickness varies much more than other formations due to the unconformity at the top and ranges 150 feet more or less.

SUNDANCE FORMATION

The Sundance formation is more than 300 feet thick and contains thick sandstone horizons which are the first possible oil-bearing rocks to be encountered with the drill. A characteristic feature of the Sundance both in the outcrop and in drill cuttings is glauconite pellets. The formation is composed of gray and green bentonitic shales, sandstone, and limestones. It has been recently divided into five members (5), namely: Redwater shale, Lak, Hulett sandstone, Stockade-Beaver shale, and Canyon Springs at the base. Below the Canyon Springs member of the Sundance is the remainder of the Jurassic section, namely: the Gypsum Springs and the Nugget sandstone at the base.

SPEARFISH FORMATION

The Spearfish formation is generally known as the Red Beds and, of course, are an exceptionally good marker in well cuttings because they are red. Even a bystander will know for certain what formation is being drilled because the mud has a reddish tinge. The formation is from 280 to 700 feet thick. The latter figure is taken from the log of the Experiment Station well at Newell. It is composed of red shales and sandy red shales with an occasional bed of gypsum. The first gypsum will be encountered at the top of the Red Beds.

MINNEKAHTA FORMATION

The Minnekahta formation is a hard well-bedded limestone. Its color is gray to pink and lavender. On the outcrop it is somewhat pink to lavender and is 50 feet more or less thick. The rock is tough to trim into a hand specimen and has a petroleum odor when broken. It is easily distinguished in the outcrop because it forms a vertical wall in canyons; and, in rolling topography, it forms paving in pastures. The Minnekahta is always the first limestone encountered with the drill after drilling through the Red Beds.

OPECHE FORMATION

The Opeche formation is a series of red shales, clays, and some sandstones. It is usually more purplish than red. It is from 120 to 130 feet thick and has an occasional bed of anhydrite.

MINNELUSA FORMATION

The Minnelusa formation is an important formation because it is expected to yield oil on a closed anticline. It is made up of sandstones, limestones, a few red shales, and anhydrite. The anhydrite has been removed by solution in the outcrop and probably the upper half has collapsed making a thinner section on the outcrop than in the subsurface.

The following section in Bear Butte Canyon shows the Minnelusa formation in detail. Location is just west of the county line in Sec. 12, T. 5 N., R. 4 E.

Bed Number	Description	Feet
40	Sandstone, reddish to gray, covered with much slumped Opeche shale and slabs of Minnekahta limestone......................	40
39	Limestone, gray rather soft, porous, tufa-like on surface...........................	12
38	Sandstone, buff, red-stained................	15
37	Limestone, gray, hard, fine-grained........	3
36	Sandstone, grayish brown to buff, forming lower part of cliff........................	40
35	Sandstone, gray to brown, forming bold cliff face. Cross-bedded and weathering to rounded masses. Forms cliff face below upper massive sandstone.......	85
34	Talus-covered interval......................	18
33	Limestone, sandy, gray to reddish..........	5
32	Talus-covered interval......................	20
31	Sandstone, brownish, calcareous............	1
30	Shale, red, fine-grained...................	2
29	Limestone, brown, sandy, thin-bedded, reddish stained..........................	3
28	Sandstone, red, coarse-grained, stains rocks below and grades upward into overlying limestone. Not too well exposed...	16
27	Limestone, pinkish, hard, fine-grained, containing a large depauperate appearing fauna. Small trilobites (<u>Phillipsia</u>), <u>Aviculopecten</u>, <u>Nucula</u>(?) <u>Bellerophon</u>, etc., very plentiful.....................	3
26	Limestone, gray, brown, fine-grained, sandy....................................	2
25	Sandstone, brecciated, gray and red mottled. The breccia fragments are gray calcareous sandstone.....................	6

Bed Number	Description	Feet
24	Limestone, brown, sandy, fine-grained......	2
23	Sandstone, gray, partly talus-covered......	10
22	Limestone, gray externally, pinkish internally, fine-grained..................	3
21	Sandstone, pinkish, coarse, forming bold cliff face................................	33
20	Sandstone, brownish, coarse, brecciated in places................................	2
19	Limestone, sandy, cherty, fine-grained, gray..	5
18	Sandstone, gray, fine-grained, weathering pinkish to reddish. Surface covered with small round nodules. Forms bold cliff face...........................	22
17	Limestone, gray and brown, partly talus-covered, thin-bedded.....................	6
16	Sandstone, gray to reddish, fine-grained...	12
15	Limestone, gray to pink, sandy, fine-grained....................................	4
14	Sandstone, fine-grained, pinkish, weathering to hard outcrops.................	28
13	Talus-covered interval......................	5
12	Limestone, gray coarse-grained, sandy......	1
11	Limestone, gray, fine-grained, in places cherty..................................	2
10	Sandstone, pink with dark streaks, in places red, medium-grained...............	4
9	Limestone, gray to pinkish, fine-grained, contains calcite druses and iron crystals on exposed surfaces.................	2
8	Limestone, pinkish, weathering gray, forming bold founded exposure............	10
7	Limestone, gray, fine-grained, with very thin sandy layers.......................	2
6	Limestone, pinkish mottled, fine-grained, ledge-forming, partly talus-covered......	18
5	Limestone, pinkish to white, with alternating thick and thin layers, contains plates and spines of echinids and small compositas................................	12
4	Talus-covered interval.....................	6
3	Limestone, pinkish gray, fine-grained, pitted....................................	3
2	Sandstone, white to pinkish, medium-grained....................................	10
1	Shale, red, sandy, partly talus-covered, lying upon brecciated Pahasapa limestone....................................	20
	Total.....................	493

In the southern Black Hills and in Wyoming the Minnelusa formation is divided into members which have not been identified in the northern Hills, as, for instance, the Converse sand, the Red Marker, and the Leo sand group.

MADISON LIMESTONE (PAHASAPA) FORMATION

The Madison Limestone (Pahasapa) formation is a massive white, in places cherty, limestone from 460 to 500 feet thick. It is the cliff-forming limestone of the Black Hills and houses all the commercial caves in the region. The Madison can be cavernous in the Whitewood anticline because several borings encountered caves in the region south of the Black Hills.

In view of the fact that the Big Snowy group (6) comes into the state from the northwest, it is probable that the Charles formation will be present in the anticline above the Madison. However, recent studies in Harding County show that the Charles wedges out somewhere between the north line of Butte County and the city of Deadwood.

ENGLEWOOD FORMATION

The Englewood formation is a pinkish-purple limestone, thin-bedded to massive, and is about 50 feet more or less in thickness. It is present beneath the Madison formation and this contact is sharp and abrupt, especially in color.

ORDOVICIAN AND CAMBRIAN FORMATIONS

Any wildcat well drilled on a structure in South Dakota would not be a complete test until it had been drilled to the basement complex. In this respect the Ordovician and Cambrian formations should be tested. In the Ordovician system the formations likely to be encountered are the Whitewood dolomites and limestone, 20-80 feet thick: the Black River green shales, 40-100 feet thick; and the St. Peter sandstones, 18-53 feet.

The upper Ordovician (Bighorn) and the upper part of the Trenton of the middle Ordovician wedges out in the subsurface between the north line of Butte County and the city of Deadwood (1). The Cambrian formation has the Deadwood sandstones, green shales, limestone and a conglomerate at the base. The type section in the city of Deadwood is 335 feet thick. The Deadwood lies on pre-Cambrian rocks which will be schists or granites of the basement complex and is the limit to which a well should be drilled.

No deep wells have been drilled on the structure so no figures are available as to the depths of formations likely to be encountered.

A well drilled in Sec. 24, T. 9 N., R. 5 E., by the Department of Agriculture on the Experimental farm is the deepest boring in the county and is 14 miles due east of the axis of the anticline. The well is 4400 feet deep and the log shows the standard Black Hills section (Figure 9).

Log of Experimental Farm Well

Sec. 24, T. 9 N., R. 5 E.

Formation	Description	Feet Depth
CRETACEOUS		
Pierre	Shale, gray......................	0- 800
Niobrara	Shale, gray, calcareous..........	800- 990
Carlile	Shale, gray......................	990-1380
Greenhorn	Shale, gray, calcareous..........	1380-1410
Graneros	Shale, gray......................	1410-2400
Dakota	Sandstone, colorless to yellow..	2400-2440
Fuson	Shale, brick-red to green.......	2440-2535
Lakota	Sandstone, white to colorless...	2535-2570
	Sandstone, colorless to yellow..	2570-2580
	Sandstone, siltstone and clay...	2580-2640

SUBSURFACE CROSS SECTION

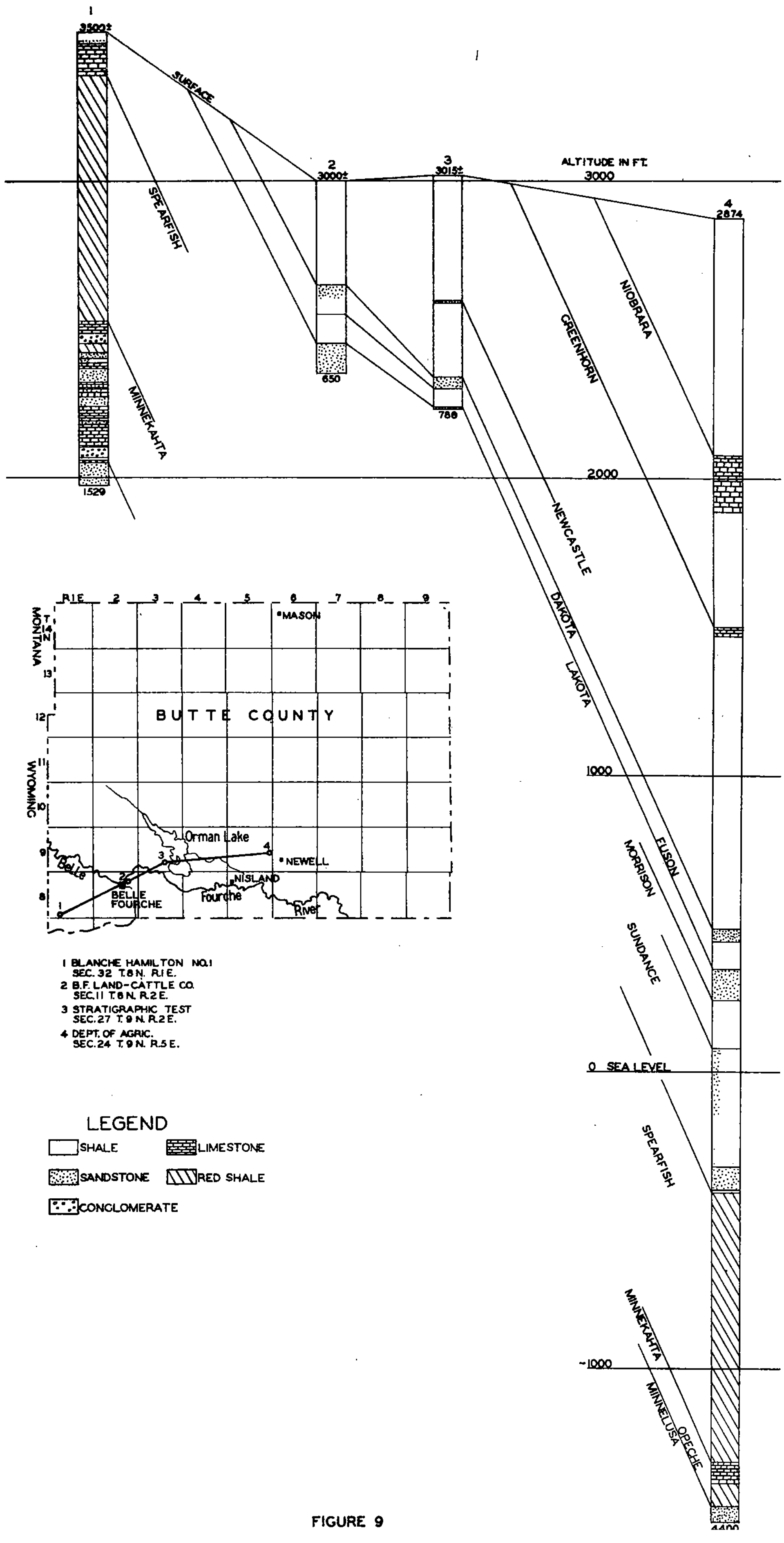


FIGURE 9

Formation	Description	Feet Depth
JURASSIC		
Morrison	Clay, green, some layers silty; many rounded sand grains......................	2640-2800
Sundance	Clay, silt and sand, gray to green......................	2800-3010
	Clay, silt and sand, light gray to green, glauconitic.	3010-3120
	Clay, silty, gray, brown and buff......................	3120-3200
	Sandstone, white to buff, glauconitic.................	3200-3280
	Clay, gray....................	3280-3290
TRIASSIC (?)		
Spearfish	Shale, grading from chocolate brown above to reddish brown below...........	3290-3500
	Anhydrite, gypsum, some limestone and sand, white to gray....................	3500-3520
	Sand, colorless to orange, sharp......................	3520-3530
	Shale, red-brown, some gypsum........................	3530-4160
	Shale, white to buff and pink, some calcareous......	4160-4200
	Clay, gray....................	4200-4210
PERMIAN		
Minnekahta	Limestone, pink to white, some red clay..............	4210-4270
Opeche	Shale, red, and limestone, red to white...:..........	4270-4350
PENNSYLVANIAN		
Minnelusa	Sandstone, colorless, to bottom of hole at 4400.....	4350-4400

A small boring drilled for stratigraphic information in the SE$\frac{1}{4}$, Sec. 27, T. 9 N., R. 3 E., by the Wm. Syeler Company is on the axis of the structure. The boring was 788 feet deep and the log shows the standard Cretaceous section (Figure 9).

Log of Stratigraphic Boring

Sec. 27, T. 9 N., R. 3 E.

Description	Feet Depth
Clay, weathered brown gray, with Inoceramus prisms from Greenhorn limestone, coarse sand grains, selenite, fragments of brown iron oxide concretions, chert fragments, mica flakes and some fragments of metamorphic rocks..................	0- 10
Belle Fourche shale, dark blue-gray, bentonitic, with fine white mica flakes....	10-420
Much brownish bentonite......................	10- 20
Shale with a little quartzose silt...........	80-100
1½ feet blue-white bentonite, clay has lighter gray silt interlaminae.............	100-108
Fragments of fish scales.....................	150
2 feet blue white bentonite..................	250-260
Particles of white bentonite clay............	300-310
Siltstone, with brown mica flakes and light gray bentonite, fish fragments.......	320-340
Shale, finely laminated, bentonitic, dark gray (370-380 feet some light gray silt with brown mica flakes)....................	340-420
Newcastle sandstone, fine-grained, angular, gray, with some small bentonite pellets....................................	420-430
Bentonite....................................	432-440
Skull Creek (Thermopolis) shale, with Inoceramus prisms at 550, a little gray siltstone at 570, and chalcopyrite at 590..	430-680
Micaceous siltstone and fine sandstone, light gray, glauconitic....................	600-610
Shale, dark blue-gray, finely laminated, bentonitic..................................	610-680
Dakota sandstone, gray, fine-grained, rounded and etched grains, finer grained with bentonitic matrix below 690.........	680-720
Fuson manganese pellets, light brown..........	720-730
Considerable blue-white bentonite............	730-740
Siltstone, muscovitic, light gray, carbonaceous, with light blue-green and drab bentonite.............................	740-750
Perhaps mostly cavings.......................	750-780
Sandstone, light, gray, fine-grained, angular, partly recrystallized, carbonaceous and muscovitic. Likely top of Lakota.................................	780-788

STRUCTURE

The Whitewood anticlinal structure is a north projection of the Black Hills uplift. Its axis begins several miles southeast of the city of Whitewood at the Vanocker Creek laccolith, which is centered about six miles south of Sturgis, and extends north between St. Onge and Baldy Peaks past the east side of Susie Peak and through the northern portion of Orman Lake. From here it plunges beneath the plains country to the north. It is at least 26 miles long and 8 miles wide.

Its surface expression is marked by the forest growth on the Mowry shale, which lies on both the east and west flanks of the structure south of the Belle Fourche River; and by the dip slopes of the Orman Lake limestone, west of the lake and about two miles north of U. S. Highway 212. The west dip of the Carlile shale, northwest of Susie Peak, shows quite plainly that portion of the west flank. The Belle Fourche River flows across it about the middle of the structure. Some of the structure is concealed by river alluvium, by the large lake, and by upland gravel deposits.

The magnitude of the structure is such as to bring to the surface on the axis a section from the middle Carlile to the Dakota sandstone. In the vicinity of St. Onge Peak at least 1500 feet of sediments have been uparched and eroded away on the anticline. The axis plunges about 90 feet per mile northward. The east flank of the structure slopes into the Dakota Basin to the east. From the Newcastle sandstone outcrop to Twin Buttes, on the east flank, it dips underground at the rate of over 100 feet to the mile northeastward for at least seven miles. This is also true in the vicinity of Orman Lake. The west flank of the structure is not as broad. Southeast of St. Onge it dips sharply (18°SW) into a pronounced synclinal valley. In the locality of Haystack Buttes, which are structurally low, the west flank is only a mile wide. The Haystack Buttes themselves are synclinal.

In the Susie Peak area the structure is a general northward plunging anticline, true for the whole Whitewood anticline. This tilt is interrupted by superimposed structures.

West of Orman Lake, south of Susie Peak, in Sec. 27, T. 9 N., R. 3 E., is a possible closed structure determined from elevations on the Orman Lake limestone. The outcrop makes a semi-circle, dipping northeast, north, and west. The west dip is as much as 12°. The elevation of the outcrop south of the semi-circle on the west side is 3040 feet, and on the east side is 3048 feet, as compared to 3118 feet over the axis of the anticline. However, this does not signify that the structure has south closure because the limestone has been eroded away from over the axis at these low points, and it is now uncertain as to how high or low it had been folded.

In the south bank of the Belle Fourche River in Sec. 14, T. 8 N., R. 4 E., is an outcrop of the Orman Lake limestone which has a 5° west dip or reversal, indicating a possible structure just to the east. This is possibly the reason why the Greenhorn limestone outcrop bulges to the northeast. A water well drilled by the Northwestern Railroad at Nisland in 1927 reported an oil show at 1400 feet. However, due to the position of the limestone outcrop in the river valley, the west dip could be due to slumping.

In the northeast part of T. 7 N., R. 4 E., and the southeast part of T. 6 N., R. 4 E., are two traces of outcrops of the Orman Lake limestone. The west trace is in the group of high prominent flat top buttes and the east trace is along Stinkingwater Creek. With respect to elevations on the limestone in both localities it would seem to be an ordinary east dip, but a butte on the south line of Sec. 27, T. 8 N., R. 4 E., which reaches 3208 feet in altitude, does not have the limestone. This suggests that the Orman Lake limestone was folded above it. The black shales of the butte and in gullies below indicate that it is not a down fold underneath the butte.

Elevations on the Orman Lake limestone in the Haystack Buttes area and southward show a low synclinal area on the west flank of the Whitewood anticline.

There is a closed anticlinal structure in the southwest corner of T. 7 N., R. 4 E. (Figure 10). This structure has a 50 foot closure and is about one mile long and about three-quarters of a mile wide. It is shown by two "windows" made by the Fuson formation. This structure seems to be on the axis of the Whitewood anticline.

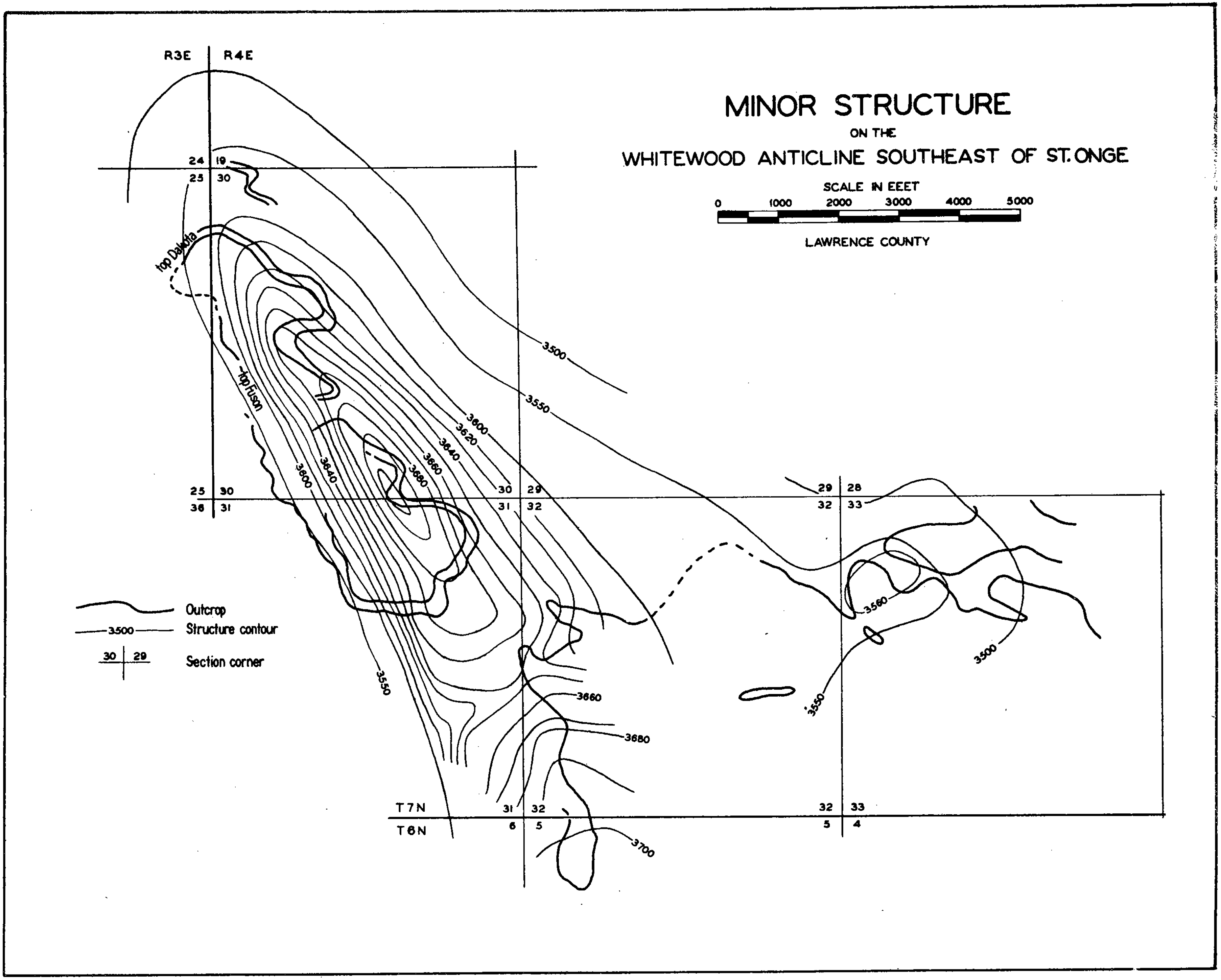

MINOR STRUCTURE
ON THE
WHITEWOOD ANTICLINE SOUTHEAST OF ST. ONGE
SCALE IN EEET
0
1000
2000
3000
4000
5000
LAWRENCE COUNTY
R3E
R4E
T7N
T6N
top Dakota
top Fuson
3500
3550
3600
3620
3640
3660
3680
3700
3560
24
19
25
30
36
31
29
32
28
33
6
5
4
Outcrop
3500
Structure contour
Section corner

FIGURE 10

DRILLING FACTORS

PREVIOUS DRILLING

Oil development has been attempted without success several times in Butte and Lawrence Counties, but several shows of oil and gas have been encountered in widely scattered localities north of the Black Hills. Most wells were not drilled on structure which accounts for their failures. Wells started on structure were abandoned before proper depths were reached.

The following is a list of drillings to date:

County	Well	Location Sec.	TN.	RE.	Company	Results
Meade	H. Milin #1	24	6	5	Denver	820 TD granite
Butte	B. Hamilton #1	32	8	1	Wy-Twx. Corp.	1529 TD show O&G
"	Strat. Test	27	9	3	Seyler	788
"	Two Top #1	30	10	6	Local	2860 show G
"	Voorhees #1	35	9	3	"	300
"	________ #1	7	7	4	"	?
"	________ #1	30	7	4	"	?
"	RR. Well #1	7	8	5	N. Western RR.	1400 water show O
"	Exper. Farm #1	24	9	5	Dept. of Agric.	4400 TD water
Lawrence	Thompson #1	21	6	4	Preston Oil	1020 TD show O

The Voorhees #1 was located on the axis of the Whitewood anticline. The well was drilled intermittently and finally reached a depth of about 300 feet where it was discontinued somewhere in the Graneros.

In Secs. 7 and 30, T. 7 N., R. 4 E., are the remains of two wells the records of which have long since been lost. It is assumed they penetrated the Dakota sandstone.

A few artesian wells in the Belle Fourche River valley serve domestic purposes; they are probably drilled to the Dakota. The Thompson #1 was drilled near the town of Whitewood. The well is located on the south end of the anticline near the Black Hills uplift where there seems to be no south closure or reverse dip.

From the history of the drilling activity one can conclude that the Whitewood anticline remains untested, hence it offers good possibilities for oil and gas prospecting where there is closed structure.

POSSIBLE OIL AND GAS HORIZONS

Formations which produce oil and gas in Montana and Wyoming are present in the Whitewood anticline. At reasonably shallow depths are the Dakota and Lakota sandstones which may justify testing although they are generally water sands here.

The first important horizon is the Sundance formation which contains thick sandstone members. The next horizon of equal importance is the Minnelusa formation. Like the Sundance it also is comprised of several thick sandstone members. (See section of Minnelusa by Dille in the chapter describing subsurface formations. Refer to bibliography.)

The lower horizon which offers equal possibilities for oil accumulation are the wedging out of the Big Snowy and the thinning of the Madison limestone formation (Pahasapa). The final horizons which should be tested before a location is condemned are the higher Ordovician wedge-outs and the St. Peter and Deadwood sandstones. Shows of oil in these formations have been found in deep tests in northwestern South Dakota.

ACCESS AND WATER

Most portions of the Whitewood anticline can be reached via gravel or dirt roads.

U. S. Highway 212 completely crosses the anticline north of the Belle Fourche River, and a county graveled road crosses the anticline south of the river. Ungraded dirt roads and numerous trails give access to each side of Orman Lake. A county graveled road crosses the anticline diagonally from St. Onge to Snoma. Aside from these roads there are some section line roads in the area.

Surface water is easily obtainable for drilling. In the north portion is Orman Lake which has a shore line of several miles. Directly across the lake, about the middle of the anticline, is the Belle Fourche River which is a permanent water course. Paralleling the river are numerous irrigation canals which meander across the structure.

The creeks are generally dry during the summer months. These contain many stock dams which generally have water throughout the year.

BIBLIOGRAPHY

1. Baker, C. L., Deep Borings in Western South Dakota, South Dakota State Geological Survey, R. I. 57, 1947.

2. Collier, A. J., The Osage Oil Field, Weston County, Wyoming, U. S. Geological Survey Bulletin, No. 736, 1922.

3. Darton, N. H. and O'Harra, C. C., Belle Fourche Folio, No. 164, U. S. Geological Survey, 1909.

4. Dille, Glenn S., Minnelusa of Black Hills of South Dakota, A. A. P. G., May 1930.

5. Imlay, Ralph W., Marine Jurassic of the Black Hills Area, South Dakota, and Wyoming, A. A. P. G. Bulletin, Feb. 1947.

6. Perry, E. S. and Sloss, L. L., Big Snowy Group: Lithology and Correlation in Northern Great Plains, A. A. P. G., Oct. 1943.

7. Rothrock, E. P., The Chilson Anticline, R. I. 9, South Dakota State Geological Survey, 1938.

8. Russell, W. L., The Origin of Sandstone Dikes of the Black Hills, American Journal of Science, fifth series, Vol. XIV, New Haven, Conn., pp. 402-408, 1927.

9. Wing, M. E., Bentonite of the Belle Fourche District, R. I. 35, South Dakota State Geological Survey, 1940.

10. Winter, J., Professor of Botany, University of South Dakota, Vermillion, S. D. (personal interview).