THE GEOLOGICAL SURVEY OF WYOMING
HORACE D. THOMAS, State Geologist

REPORT OF INVESTIGATIONS NO. 3

STRATIGRAPHY OF THE SUSSEX SANDSTONE, POWDER RIVER BASIN, WYOMING

BY

Jaqueline Belden Wilson

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LARAMIE, WYOMING
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

STRATIGRAPHY OF THE SUSSEX SANDSTONE, POWDER RIVER BASIN, WYOMING

BY

JACQUELINE BELDEN WILSON [1]

ABSTRACT

The Sussex sandstone, now an important oil-producing unit in the Upper Cretaceous section of the southwestern part of the Powder River Basin, Wyoming, came into prominence in December, 1949, when the Delhi Corporation's No. 1 Govt. well first produced oil from this sand in the North Meadow Creek oil field. In January, 1951, there were 58 wells producing from the sand in the Sussex and North Meadow Creek fields.

The Sussex sandstone is known primarily in the subsurface. The study, therefore, was based on many electric logs and one generalized surface section. These sections were correlated and a study was made of the stratigraphy and regional relations.

The Sussex sandstone was named by A. E. Brainerd, of the Continental Oil Company, in 1949, and it is here treated as a member of the Cody shale. It is a light-gray fine-grained glauconitic marine sandstone and is about 40 feet thick where it is best developed in the Sussex and North Meadow Creek oil fields. It grades into shale within ten miles north and south of the fields, but its stratigraphic level can be discriminated on electric logs for about 75 miles along the west and south margins of the Powder River Basin. The Sussex sandstone is either Eagle, or post-Eagle and pre-Parkman in age, but no fossils have been found which would serve to definitely date it.

INTRODUCTION

The Sussex sandstone, now an important oil-producing unit in the Upper Cretaceous section of the southwest part of the Powder River Basin, Wyoming, came into prominence in December, 1949, when the Delhi Corporation's No. 1 Govt. well produced oil from this sand in the North Meadow Creek oil field. As more wells were drilled and the regional significance of this sandstone became better known, it was correlated with the "Water sand" (Thom and Spieker, 1931, p. 13) of the Salt Creek area ten miles to the south (Olson, W. G., personal communication). Later, the name, Sussex sandstone, was applied and has found general acceptance.

The investigation of the Sussex sandstone was undertaken at the suggestion of Dr. H. D. Thomas, State Geologist of Wyoming. The study, which was carried on during the summer of 1950, involved no field work but was confined to a detailed analysis of all dependable elec-

[1] A thesis submitted to the Department of Geology and the Graduate School of the University of Wyoming in partial fulfillment of requirements for the degree of Master of Arts.

tric logs, and of some subsurface sample logs, from the western and southern parts of the Powder River Basin. Electric logs and subsurface data used were those available to January 1, 1951.

The writer is indebted to Dr. H. D. Thomas, who directed the thesis and furnished the electric logs used in this study. Dr. J. D. Love, of the U. S. Geological Survey, also supplied subsurface information and offered many helpful suggestions in the drafting of illustrations and the writing of this report. W. G. Olson, of the Continental Oil Company, kindly furnished information concerning the economic development, the naming, and the lithology of the Sussex sandstone.

PURPOSE AND SCOPE OF INVESTIGATION

It is the purpose of this report to recount the history of the economic development and the naming of the Sussex sandstone, to present data which demonstrate the thickness and areal extent of this sand, to show the regional relationships of the Upper Cretaceous rock units and the correlation of the Sussex sandstone in this regional picture, to present hypotheses regarding the age of the sandstone, and to summarize its known economic significance and future potentialities.

NOMENCLATURE OF UPPER CRETACEOUS ROCKS OF SOUTHWESTERN POWDER RIVER BASIN

The Cretaceous rocks of the southwestern margin of the Powder River Basin total more than 7,000 feet in thickness and are predominantly shales, although numerous sandstones are interbedded (Thom and Spieker, 1931). This report is primarily concerned with the upper middle part of this sequence (Table 1).

The term, Steele shale, is used by many oil companies for the shale sequence below the Parkman sandstone member, at the base of the Mesaverde formation, and above the Frontier formation. This usage stems from the terminology applied by Thom and Spieker, as shown in Table 1. By definition, the name, Steele shale, should be used in areas where the Niobrara formation is distinguishable above the Frontier formation (Darton, Blackwelder and Siebenthal, 1910, p. 10; Bowen, 1918, p. 229). The term, Cody shale, is applicable to units made up of rocks of Niobrara age as well as much younger rocks. In the area covered in this report, the Niobrara formation, which includes the so-called Carlile, can not be recognized as a mappable unit. The term, Cody shale, therefore, is here applied to the shale sequence above the top of the Frontier formation (top of the First Wall Creek sand of drillers), and below the arbitrarily picked base of the Parkman sandstone. The contact between the Parkman sandstone and the Cody shale is gradational and its position is a matter of personal interpretation.

For the reasons stated above, the Sussex and Shannon sandstones are here considered members of the Cody shale, although Thom and Spieker (1931, p. 13) designated the Shannon sandstone as a member of the Steele shale (Table 1).

TABLE 1. Nomenclature of a part of the Upper Cretaceous rocks in the southwestern part of the Powder River Basin.

Thom and Spieker		This paper	
MESAVERDE FORMATION	Teapot sandstone member	MESAVERDE FORMATION	Teapot sandstone member
	Parkman sandstone member		Parkman sandstone member
STEELE SHALE		CODY SHALE	
	"Water sand"		Sussex sandstone member
	Shannon sandstone member		Shannon sandstone member
NIOBRARA FORMATION			
CARLILE FORMATION			
FRONTIER FORMATION	First Wall Creek sandstone	FRONTIER FORMATION	First Wall Creek sandstone

AREA STUDIED AND METHOD OF INVESTIGATION

The area included in this study is shown on Figure 1. This illustration also indicates the position of the area with respect to adjacent mountains and sedimentary basins in Wyoming.

The Sussex sandstone is known primarily in the subsurface; therefore, the study was based almost entirely on electric logs. A very generalized surface section on the east flank of the Salt Creek anticline provided the only available surface information (Thom and Spieker, 1931, pl. 6).

The Sussex and Shannon sandstone members of the Cody shale were differentiated by their definite and characteristic "kicks" on both the self-potential and resistivity curves of the Schlumberger logs of wells in the Sussex and Meadow Creek oil fields. Both sandstone "kicks" are easily distinguished in the thick sequence of Cody shale (see

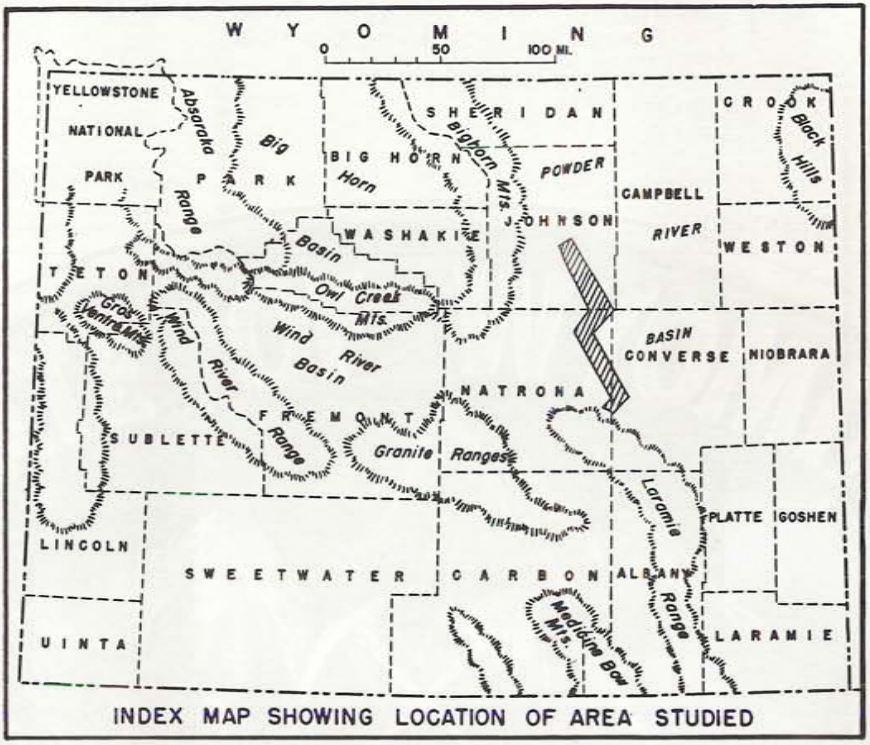

FIGURE 1.

wells 3 to 11, Plate 2). These "kicks" were traced north and south, with intervals between control points of not more than ten miles, until they were no longer recognizable. The line of stratigraphic sections, shown on Plate 1, is roughly a north-south line. West of this line of sections, except in the Salt Creek area, there are no known outcrops of the Sussex sandstone. To the east, the Sussex sandstone extends into the deeper part of the Powder River Basin where no drilling has been done.

Starting at the north end of the line of sections, selected logs were plotted using a correlatable "kick" somewhere near the base of the Parkman sandstone as the upper limit, although this horizon does not retain its original relation to the lowest occurrence of sandstone in the Parkman. The top of the Sussex sandstone was used as the datum horizon, and the base of the Shannon sandstone as the lower limit of the sections (Plate 2).

The chart of correlated sections of Cretaceous rocks along the south and west margins of the Powder River Basin was constructed from electric logs (Plate 3), but includes the published surface section at Salt Creek (Thom and Spieker, 1931, pl. 6).

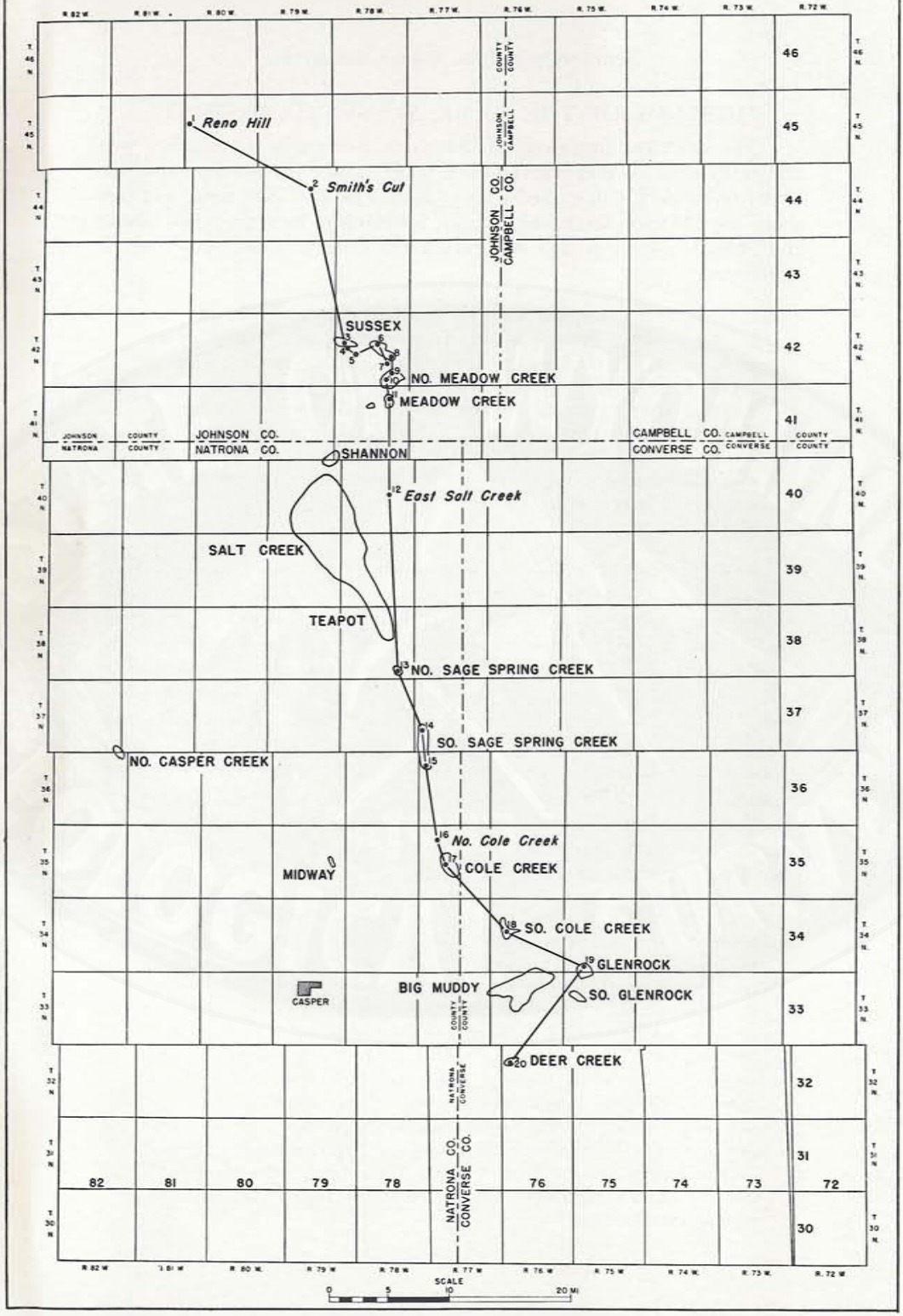

PLATE 1. Map showing locaation of oil and gas fields and line of logs shown on correlation chart of the Sussex and Shannon sandstones.

HISTORY OF THE NAME, SUSSEX SANDSTONE

The sandstone unit to which the name, Sussex, is now applied was first recognized by Wegemann (1911, p. 47) at the surface near the Salt Creek oil field. He described it as a 30-foot bed of sandstone, 225 feet above the Shannon sandstone. Later, referring to the same area, Thom and Spieker (1931, p. 13) recognized the sandstone and discussed it as follows:

> . . . 25 feet below the base of the lowest large bentonite bed [of the Steele], there is a bed of soft sandstone or sandy shale about 10 feet in thickness, within which is an almost continuous layer of sandstone nodules that affords the best key bed for mapping the structural details of the productive part of the Teapot dome. This sandstone, which is commonly known as the water sand, lies about 395 feet above the top of the Shannon sandstone, and because of its hardness it occurs extensively as a protective capping on hills and ridges near the crest of the Teapot uplift.

In the Sussex area, oil was first discovered in the Lakota sandstone in 1948 by the Continental Oil Company (Resume Rocky Mountain Oil and Gas Operations for 1948). The Shannon sandstone was recognized in the first well drilled. The Sussex sandstone is almost identical in lithology to the Shannon sandstone, but the two sandstones are normally separated by about 400 feet of bluish-gray shale in the Sussex field. The area is highly faulted and in the first well there were two sandstones about 50 feet apart which seemed practically identical. The operators at first thought a single sandstone, the Shannon, was repeated by faulting. Through subsequent drilling the normal relations of the two sandstones were determined and the "Stray sand" above the Shannon was eventually given the name, Sussex sand, as explained by Olson (personal communication):

> During the drilling of the first four wells at Sussex, the so-called "Stray sand" above the Shannon came into prominence as a producing horizon. At this time, 1949, this sand was recognized as the equivalent of the "Water sand" underlying the outer flanks of the old Salt Creek field. Perhaps this old drillers' term for this sand had set a precedent, yet the name "Water sand" seemed inappropriate. Mr. A. E. Brainerd then suggested the name, Sussex sand, be applied to the "Water sand" of the Salt Creek field and the "Stray sand" of the Sussex field. After having discussed the suggestion with me, and perhaps other members of the geological department, we agreed on the name, Sussex sand. It has since been recognized and used by other companies and apparently by the Wyoming Geological Association.

EXTENT OF THE SUSSEX SANDSTONE

The Sussex sandstone is best developed in the Sussex and Meadow Creek oil fields and, therefore, is most easily distinguished in that area, where it comprises about 40 feet of light greenish-gray fine-grained subangular glauconitic marine sandstone which contains shark teeth and black chert pebbles. The Sussex and Shannon sandstones appear identical in well samples, but no detailed petrographic work has been done on either of the sandstones.

Ten miles south of the Sussex field, the Sussex sandstone outcrops on the east flank of the Salt Creek anticline, the only locality where it has been identified with assurance in surface outcrops to date.

At Well No. 2 (Plate 2), 12 miles northwest of the Sussex field, the interval of the Sussex sandstone is occupied by a sandy shale which can, nevertheless, be correlated with certainty with the Sussex in the field. At Well No. 1, the Sussex sandstone is not distinguishable, but it is not known whether this is the result of faulting or of a complete change to shale. The next available log is of a well 64 miles to the northwest of Well No. 1 and it was found to be impossible to carry the correlation across that distance. In drilling status reports recently issued by Petroleum Information of wells drilled close to the Montana border in the northwestern Powder River Basin, the operators have designated a sandstone as the Sussex sand. The writer feels, however, that such a correlation is not justified on the basis of the present available data.

The Sussex sandstone grades into siltstone and shale south of the Meadow Creek field. At Well No. 12, there is still a prominent "kick" on the Schlumberger log, but at the north end of the Sage Spring Creek oil field the interval is represented by a much subdued, but still obvious "kick" which is here referred to as a "phantom." This "phantom" can be correlated south through the Cole Creek oil field, east to the Glenrock oil field, and south to the Deer Creek field. The last two wells show that even the "phantom" is difficult to recognize. It was found to be impossible to discriminate the horizon of the Sussex sand in wells drilled to the east, west and south of the Deer Creek well.

In summary, the Sussex sandstone and its shaly equivalent can be recognized on electric logs for a distance of 75 miles along the west and south margins of the Powder River Basin, but it is a well-developed sandstone for only about 15 miles in the area of the Sussex and Meadow Creek oil fields and along the east flank of the Salt Creek anticline.

REGIONAL RELATIONS OF ASSOCIATED ROCKS

The Parkman sandstone member of the Mesaverde formation, about 200 feet thick, is a medium-grained sandstone with bentonitic and kaolinitic cementing material and some coaly material, and is probably non-marine (Olson, personal communication). Regional study indicates that in general the base of the Parkman sandstone rises in the sec-

tion to the east and southeast, with reference to datum horizons on electric logs, and descends lower in the section to the west and northwest.

The Cody shale consists of about 1400 feet of soft bluish-gray shale containing layers of concretions, thin sandstones, and numerous beds of bentonite. About 400 feet of shale lies between the Parkman and Sussex sandstones. The shale interval between the Sussex and Shannon sandstone members remains fairly constant throughout the area and averages about 200 feet (Plate 3). The Shannon sandstone occupies a position about 800 feet above the top of the First Wall Creek sandstone.

The Shannon sandstone "kick" on the electric logs changes abruptly in thickness from Well No. 11 to Well No. 12 (Plate 2). A well drilled between these two locations since the chart was constructed indicates that an upper thin sandstone appears in sec. 25, T. 41 N., R. 78 W., about 20 feet above the top of the Shannon sandstone as differentiated to the north. This sandstone thickens southward and in Well No. 12 comprises an upper sandstone underlain by a shaly middle section, below which is another sandstone. From there south the distinctive Shannon sandstone "kick" represents a thicker interval, since it includes both sandstone units.

It is realized that there is much faulting in the Sussex and Meadow Creek fields, but faulted sections were easily distinguished because of the large number of electric logs available in which normal sections were encountered.

AGE AND CORRELATION OF THE SUSSEX SANDSTONE

The only fossils to have been reported from the Sussex sandstone in either the surface or subsurface are unidentifiable shark teeth from cored sections in the Sussex oil field. Fossils have not been reported from the shale interval between the Sussex and Shannon sandstones. The Shannon sandstone has been proved to be Eagle in age (Reeside, 1927). Plate 3 presents two possibilities as to the interpretation of the age and correlation of the Sussex sandstone with rock units to the north. The Shannon sandstone may correlate directly with the Eagle sandstone equivalent as differentiated in the Badger Creek area (dotted line), in which case the Sussex sandstone is of post-Eagle age and is replaced northward by the overlying shale unit. The other possibility is that both the Sussex sandstone and the Shannon are Eagle in age, and that the Sussex is a tongue of the Eagle sandstone (dashed line). Fossils collected from either the Sussex sandstone or the shale unit between it and the Shannon sandstone might prove which hypothesis is correct.

ECONOMIC SIGNIFICANCE AND POTENTIALITIES

In June, 1949, there were four wells in the Sussex field, none of which was producing oil from the Sussex sandstone. The potentialities of the Sussex were recognized but the wells were completed in deeper sands. On January 1, 1951, eighteen months later, there were about 115 producing wells in the Sussex-Meadow Creek area, 58 of which were

producing from the Sussex sandstone in the Sussex and North Meadow Creek fields, with a total cumulative production of 1,029,197 barrels of oil (Olson, personal communication). In Petroleum Information, February 10, 1951, it was reported that the Sussex sandstone is now producing gas in the Meadow Creek field where it had not previously been a producing horizon.

As has been demonstrated, the Sussex sandstone grades completely into shale to the north, south, southeast and southwest of the Sussex-Meadow Creek area. The sandstone has not been discriminated where the Cody shale crops out along the east flank of the Bighorn Mountains, west and northwest of the Sussex-Meadow Creek area. To the east and northeast of the area studied there are no data available. The Sussex may be present in that region, and may or may not prove to be of commercial value. Only future drilling in the Powder River Basin east and northeast of the Sussex and Salt Creek fields can determine the oil-producing possibilities of the Sussex sandstone in that region.

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