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

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INTRODUCTION

Petroleum exploration in Wyoming has been stimulated by the elimination of certain ideas which dominated geological thinking for many years. The belief that accumulation was strictly anticlinal has been precluded by the discovery of pools trapped in other ways. The idea that anticlinal closure must be in the magnitude of several hundred feet or more before an anticline can serve as a trap has been proved false. The theory that rocks at depths greater than 7,000 or 8,000 feet would be too tight and impermeable to serve as resevoir rocks has not been sustained by fact. The tenet that the Cretaceous sandstones were essentially blanket sands, without pinch-outs or changes in facies or permeability, has been expunged. Fault traps, long looked upon with disfavor, seem to have possibilities.

Oil is produced in Wyoming from rocks as old as pre-Cambrian and as young as Eocene. Within the thick sedimentary succession, many stratigraphic changes and sedimentary conditions may have served to trap oil. From time to time, stratigraphic units hitherto not known as oil producers have yielded oil, and new ones may join the list of producing units.

Surface exploration will continue significantly in the search for anticlines, for possible fault traps, or for structural anomalies at the surface indicating possible traps at depth. Geophysical exploration has proved effective in the search for structural traps in regions covered by unconformable Tertiary rocks and large areas are still amenable to such exploration. Stratigraphy and sedimentation will perhaps become the most important exploratory method in the search for new pools. A glance at the dry hole map of Wyoming (4) will serve to indicate the sparseness of subsurface stratigraphic control. Because many of the wells shown were drilled in early days, their logs are essentially useless. It has been in recent years only that adequate lithologic logs have been compiled and electric logs have been run. Today it is possible to assemble reliable subsurface data, and each new well adds to the picture.

It is apparent that the diverse ways in which oil and gas are now known to be trapped in Wyoming have greatly enhanced the petroleum possibilities, and that simple anticlinal accumulation is by no means the only potential. Obviously, for many years the lion's share of the production will continue to be from anticlinal fields, but it is good to know that the search for oil in Wyoming may well continue profitably beyond the time of the drilling of the last possible anticline.

EARLY EXPLORATION AND DEVELOPMENTS

The first producing oil well drilled in Wyoming was completed in 1884 in the Dallas field, Fremont County. The well was drilled near an oil seep which was shown to Captain Bonneville by Indian guides in 1833 (3). It happened that the Dallas oil seep

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TABLE 1

CRETACEOUS FORMATIONS IN THE SOUTHWESTERN PART OF THE POWDER RIVER BASIN

SYSTEM	SERIES	FORMATION		OIL SANDS
TERTIARY	EOCENE	Wasatch formation		
	PALEOCENE	Fort Union formation		
CRETACEOUS	UPPER CRETACEOUS	Lance formation		
		Fox Hills sandstone		
		Mesaverde formation		
		Cody shale	Steele	
				Sussex sand
				Shannon sand
			Niobrara	
		Frontier formation		Wall Creek sands
		Mowry shale		
		Muddy sandstone		Muddy sand
	LOWER CRETACEOUS	Thermopolis shale		
		Cloverly formation		Dakota sand
				Lakota sand
JURASSIC		Morrison formation		

was located along the crest of the Dallas anticline, and thus the first oil produced from a well in Wyoming was from an anticlinal trap. Interestingly enough, this old field produced nearly 200,000 barrels of oil in 1950.

Oil seeps were known in the vicinity of the Salt Creek field before 1880, and in 1889 a well drilled down-dip from a saturated-sand outcrop around the Salt Creek anticline discovered the Shannon pool. The second field, then, could be classed as a stratigraphic type trap, but when the first big producer was drilled on the crest of the anticline, resulting in the discovery of the Wall Creek sand production in the famous Salt Creek field, the Shannon pool faded into oblivion. Other anticlines early proved productive and by 1916, Big Muddy, Elk Basin, Garland, Grass Creek, Lost Soldier and other fields, all anticlinal in nature, had been discovered.

Thus began the search for anticlines, and for many years geologists, armed with plane tables and alidades, mapped the basin margins seeking "closed contours." Wyoming fields became known as excellent examples of the anticlinal accumulation of petroleum and natural gas.

Wells, drilled on closed anticlines to depths which were then economical, occasionally resulted in the discovery of oil and gas fields; others proved to be dry holes. Eventually most of the anticlines had been mapped, but new ones came to light in regions of cover or of poor exposures, or through pitting or core drilling to prove closure. Obviously, as an exploratory tool, the search for anticlines through surface mapping was governed by the law of diminishing returns. To expand reserves there were two recourses; first, to drill deeper on anticlines which produced from shallow sands, or which had proved dry in shallow sands; second, to search by geophysical means for anticlines buried by unconformable Tertiary rocks. Both methods were successful. Some anticlines, like Elk Basin, which had been moderate producers from shallow sands were prolific producers from deeper sands. Some which produced gas from shallower sands yielded oil from deeper sands, and some which had been dry in shallow sands produced oil from deeper sands. Even today, it appears that the total potentialities of any anticline can not be evaluated until drilling has been carried to the pre-Cambrian basement.

When surface geology had lost much of its effectiveness in locating untested anticlines, the seismograph came into importance, again seeking closed structures, but basinward ones obscured by an unconformable mantle of Tertiary rocks. This technique paid dividends in the discovery of such important deep fields as Worland, Church Buttes, and others. Because of the great size of the relatively unexplored basins, more fields of this sort will surely be found.

But during this period certain early developments, although not of great commercial importance, were heralds of things to come. Brigham Young and the Mormons, enroute to Utah in 1847, had used oil from seeps in Uinta County, in the southwest corner of the State, for lubricant and for medicine (3). In 1900 oil encountered in a well that was being drilled for water led to the discovery of the Spring Valley field. Approximately 70 wells drilled in succeeding years resulted in about 30 producers. The cumulative production has been only about 200,000 barrels, but Spring Valley was unique in that the oil occurred in sands in a homocline—there were no closed contours!

Oil seeps had also been long known in the region along the east flank of the Powder River Basin. Seeps in the Moorcroft area were exploited before 1888 (3), when oil was collected from a dozen springs and was pumped from one well 300 feet deep. Of interest to present operators is the fact that the oil was transported to mining towns in the Black Hills, where it was readily sold as lubricating oil for $28 per barrel. In 1912, a well which resulted in the discovery of the Osage field was drilled. In spite of the fact that there is no closed contour within the producing area—the structure being a simple homocline (2)—this field has produced over 6,000,000 barrels of oil.

Naturally, during the course of anticlinal exploration, many wells were drilled "off structure" and resulted in dry holes. It appears now that they were not drilled far enough "off structure." It is the intent of this paper to point out that important new discoveries are being made through wildcat wells in locations which the early-day Wyoming geologist would have thought ridiculous. Fields are being discovered in regions tramped over by generations of geologists and condemned as being "off structure." Oil is being found in areas where no anticline can be mapped at the surface. New discoveries are being made under structural conditions which would have been classed as most unorthodox in earlier days. And this fact is important, for it opens up a vast area which had once been thought to have no promise as the site for discovery of new oil fields.

As an example of the new exploratory trend—and discovery trend—

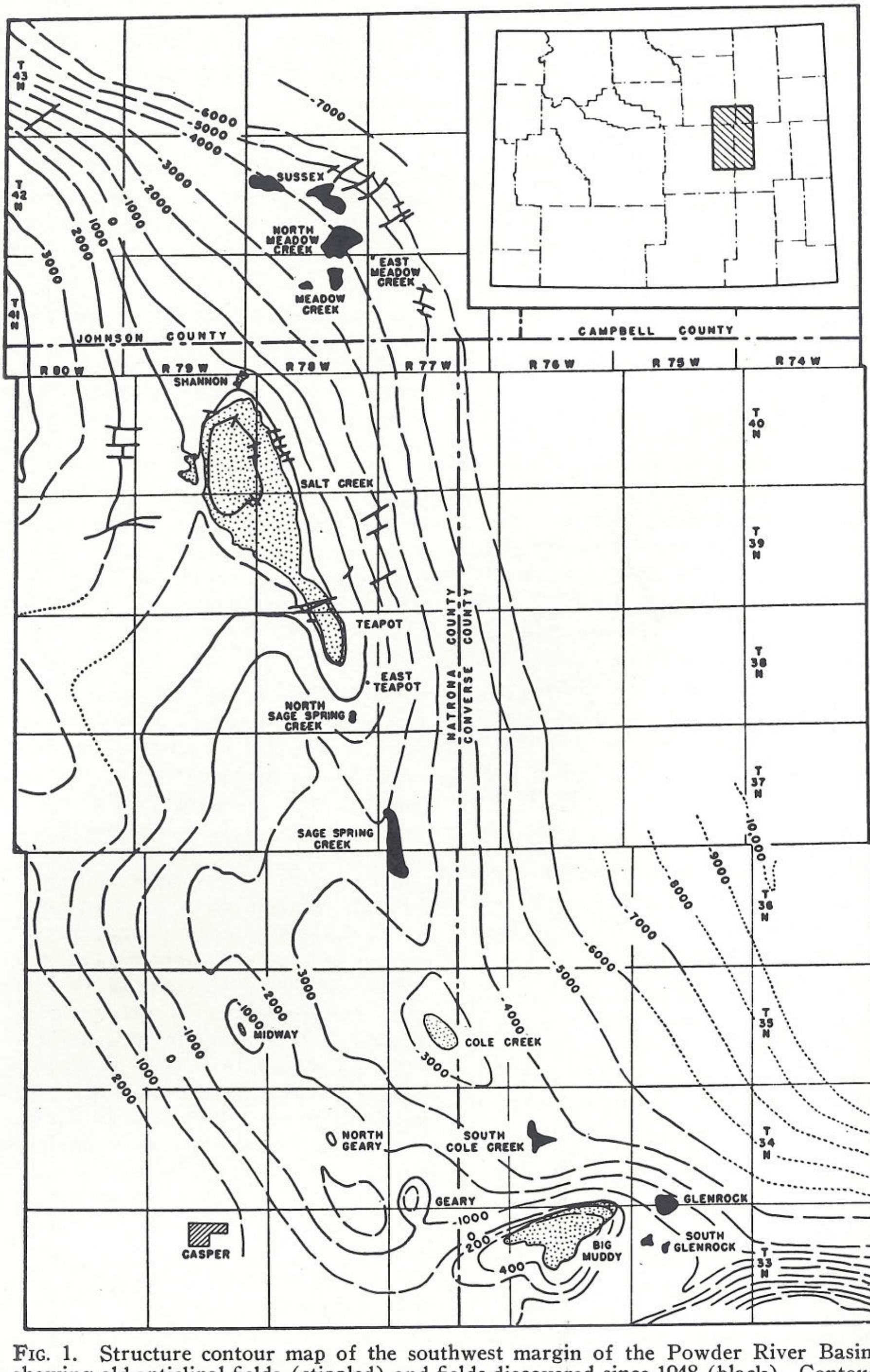

FIG. 1. Structure contour map of the southwest margin of the Powder River Basin, showing old anticlinal fields (stippled) and fields discovered since 1948 (black). Contour lines are on top of Cloverly. Small index map shows location of map area within Wyoming. (Modified from U.S.G.S. Preliminary Map 33, 1945.)

in Wyoming, the area about the old Salt Creek and Big Muddy fields has been selected. This region lies on the southwest margin of the Powder River Basin, as shown on the map (Fig. 1), and occupies parts of Johnson, Natrona and Converse counties. Fields shown on the map which are located on anticlines mappable at the surface are Salt Creek, Big Muddy and Midway. Salt Creek, discovered in 1906, has produced over 330 million barrels of oil; Big Muddy, discovered in 1916, has produced over 32 million barrels of oil; and Midway, discovered in 1931, has produced only about 200,000 barrels of oil from three wells. Other anticlines in the region, such as Geary and North Geary, were found barren in shallower sands or were then considered too deep for testing.

On the basis of seismic work, the Cole Creek field was discovered in 1938. The field is anticlinal in nature and up to the present time has produced about 5 million barrels of oil. In 1948 seismic exploration led to the discovery of anticlinal production at South Cole Creek. For over 40 years, therefore, the search had been for anticlinal production, either through surface observations or seismic surveys. Because it is commonly true in Wyoming that anticlines are not filled with oil down to the spill-points, but that production extends only part way down the flanks, a water well drilled down structure on an anticline was thought to condemn all structurally lower areas. Furthermore, it was believed that any wells drilled below the lowest closing contour were certain to be water wells. Until several years ago, then, it appeared that because all the major anticlines in the Salt Creek - Big Muddy area had been found, the petroleum-producing potentialities of the area were fairly well exhausted.

NEW DEVELOPMENTS

At the beginning of 1951, however, the situation is in marked contrast with that of previous years. During the past two years, seven producing fields have been discovered in this region which are not located on conspicuous surface anticlines and, according to earlier thinking, are "off structure."

Sussex-Meadow Creek area.—The Sussex-Meadow Creek area is located on the northeast flank of the Salt Creek anticline. Here the width of outcrop of the Lance formation is considerably greater than farther south, indicating a terracing or flattening of the dip. The outcrop of the Fort Union formation, where it swings to the west, is marked by a number of small faults and there are some obscure local reversals in dip in the underlying Lance formation. Other than this, there is no surface suggestion that one of the State's most important oil fields lies below. The discovery well at Sussex, completed in July, 1948, by the Continental Oil Company, was located on the basis of seismic exploration which suggested a possible trap at depth. North Meadow Creek was discovered in December, 1949; Meadow Creek in April, 1950; and East Meadow Creek in October, 1950. The fields are still being developed, and a great deal of additional subsurface information is needed to clarify exactly how accumulation is controlled. In the Sussex field accumulation in the Sussex sand and the Shannon sand (Table 1) is apparently controlled by faulting, as is Lakota accumulation in the eastern part. In the western part, however, Lakota production appears to be related to folded closure. Production in the North Meadow Creek field seems to be controlled by normal faulting. Meadow Creek is not faulted to as great a degree as Sussex and North Meadow Creek. The largest faults have about 100 feet of displacement and may have some effect on accumulation in the Shannon and Wall Creek sands. In February, 1951, the first suggestion of a reversal in dip toward the Salt Creek anticline was noted in a well which showed 25 to 30 feet of reverse dip on the Lakota sand in a quarter of a mile. Development has not progressed to the point, however, where it can be said that accumulation is controlled by faulting, by doming, by sand conditions, or by a combination of these factors. At any rate, Meadow Creek does not fit the concept of what used to be considered an orthodox Wyoming oil field.

Five sands have proved productive in these fields: the Sussex, the Shannon, the First and Second Wall Creek sands, and the Lakota. The Sussex sand had not been known as an oil-producer until the Sussex-Meadow Creek area was discovered. During 1950, these fields were the site of more developmental drilling than any other area in the State. From the time of discovery until the end of 1950, 114 wells had been drilled, with only 12 dry holes.

Sage Spring Creek.—In 1949 a well was completed by the Amerada Petroleum Corporation on the south plunge of the Salt Creek-Teapot anticline for a small producer in the Dakota sand. The fourth well, drilled two miles south of the discovery, ran several hundred feet lower structurally and showed different sand conditions. Up to the present time, nine producers and four dry holes have been drilled. The best well had an initial output of 184 barrels per day. Accumulation is controlled purely by sand conditions and production is not affected from a closed anticlinal structure.

In August, 1949, a discovery was made six miles north of the Sage Spring Creek discovery well, and at present there are three flowing wells in the field. This area is referred to as North Sage Spring Creek. Two dry holes have been drilled between North Sage Spring Creek and Sage Spring Creek proper.

These fields are located on the south plunge of the Salt Creek-Teapot anticline and there is apparently a regular southward dip. In North Sage Spring Creek the Dakota sand lies nearly 3,000 feet lower structurally than in the Salt Creek field and outside the lowest closing contour on the Salt Creek-Teapot anticline. The southernmost producer in Sage Spring Creek lies 1,600 feet lower structurally than the wells in North Sage Spring Creek. Dakota sand production has been almost negligible in the Salt Creek field, yet this sand is the producer on the south plunge—a fact supporting the belief that accumulation in the Sage Spring Creek fields is related to favorable sand conditions along the structurally low plunge of the Salt Creek-Teapot anticline. Sand thickness and permeability, which ranges from zero to 340 millidarcies, serve to control accumulation. These new productive areas would have been considered "off structure" and below the water table in earlier days.

Glenrock. — In December, 1949, just north of the town of Glenrock, the discovery well in the Glenrock field was brought in, producing from the Muddy sand at a structural position some 3,200 feet lower than the crest of the Big Muddy anticline and about six miles east of the highest part of the Big Muddy dome. The Muddy sand is not present in the Big Muddy field proper, and it appeared that accumulation was related to the wedge-edge of the sand on the east plunge of the anticline.

Several months later, production was also developed in the Dakota sand, which is a producer in the Big Muddy field. This latter well, only a short distance from the Muddy sand discovery well, penetrated no Muddy sand, and thus implied a pinch-out. In January, 1951, Muddy sand production was extended westward three miles, to the margin of the Big Muddy field. On the other hand, in 1946, Dakota production in the Big Muddy field proper had been extended eastward and to a position structurally lower than the lowest closed contour. It appears, then, that the region on the east plunge of the Big Muddy anticline, an area which earlier would have been considered "off structure," is characterized by sand conditions which have served to trap oil. Some geologists have felt that transverse faulting across the anticlinal plunge might account for the Dakota production at Glenrock, but as yet there is no definite evidence of such a structural condition.

South Glenrock.—The Big Muddy dome and the surrounding region were mapped by Barnett in 1915 (1). In his accompanying report, he remarked that the U. S. Geological Survey was constantly searching for domes as an aid to prospectors and said, "Although the Survey does not guarantee that oil will be found in any of these domes, its position is that domes are the most promising localities; and if the drill proves that they do not contain oil, *it is useless to search in other places.*" This tenet was followed for many years, and it was not until 35 years later, in July, 1950, that oil was discovered at South Glenrock in an area which had held no attraction because it was too low structurally. So far seven wells have been completed in the Muddy or the Dakota sands, the Muddy discovery well flowing 1,872 barrels per day. In late January, 1951, a dual completion well flowed over 1,500 barrels of green oil per day from both sands.

UNUSUAL FIELDS IN OTHER AREAS

Non-anticlinal oil fields are known elsewhere in Wyoming. Those which have received major attention lately are located on the west flank of the Black Hills and are represented by the old Osage field and the newer Mush Creek, Fiddler Creek, Skull Creek, Lodgepole, Clareton and other pools. Production is mainly from the Newcastle sand on a westward dipping homocline, and accumulation is controlled by permeability changes in that sand (2, 5).

Fields in which accumulation is related primarily to faulting have not been common in Wyoming, nor have such structures been attractive for exploration. It is true that in some of the old anticlinal fields cut by transverse faults, individual fault blocks may act as units, but such accumulation is essentially anticlinal in nature. Some fields have been discovered in recent years, however, in which there would have been no accumulation were it not for faulting, such as Silvertip, on the west flank of the Elk Basin anticline in Park County, and Lightning Creek, in the Lance Creek area, Niobrara County.

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REFERENCES

There are a number of publications and maps of a general nature which might prove of interest to the reader should he desire a more complete background regarding the geology and petroleum resources of Wyoming. It is impossible to give references to all the pertinent ones, yet a few are listed below. The geological history and structure of the State are given in condensed form in a bulletin issued by the Geological Survey of Wyoming (6). A recent map showing oil and gas fields, dry holes, anticlinal axes, unit areas, and pipelines has been issued by the U. S. Geological Survey (4). A compilation of the history and development of the oil and gas fields of the State, up to 1938, has been issued by the Bureau of Mines (3).

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