ROBINSON RANCH FIELD,
CROOK COUNTY, WYOMING

Thesis for the Degree of M. S.
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Robert F. Ohlhaber
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ROBINSON RANCH FIELD,

CROOK COUNTY, WYOMING

BY

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PREFACE

Exploration for commerical petroleum reserves in the Powder River Basin of Wyoming has continued in various stages of activity since oil seeps were first noted on the flanks of the Black Hills in the mid 1800's. Activity reached a peak during the early 1900's, which included the discovery and development of three of the largest fields in the basin; Salt Creek (1908), Big Muddy (1916) and Lance Creek (1918). Changing market conditions forced a standstill of exploration and production from the mid 1920's until World War II. Exploration and development since this time has continued at a fairly constant rate to the present day, with emphasis on particular pay-horizons prevelent during certain periods. This paper is concerned with one such horizon, the Permo-Pennsylvanian Minnelusa formation, which is currently undergoing active investigation in the northeast portion of the basin, and one field in the area from which it produces, the Robinson Ranch Field. By studying the characteristics of this known producing field, the writer hopes to bring to light certain criteria which might aid in future exploration for similar oil accumulations in the Powder River Basin of Wyoming.

ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to Dr. J. H. Fisher, of the Department of Geology, Michigan State University, for his guidance and efforts in seeing that this paper was completed, and that the facts herein presented are essentially correct. Sincere thanks also to Dr. C. E. Prouty, Head, Department of Geology, who made it possible to complete the study in absentia from Michigan State University, to Dr. B. T. Sandefur, a very encouraging member of my committee, and to Tennessee Gas and Oil Company, for the time, facilities and help, particularly from Jack Bogrett. Finally, my sincere appreciation to my wife, Joanne, for her constant encouragement and invaluable assistance in editing this paper, and to Cecelia Hutchcraft, for her secretarial efforts in getting the manuscript in final form.

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INTRODUCTION

The Robinson Ranch Area, as covered in this paper, comprises some twenty square miles in the northeastern portion of the Powder River Basin, in the vicinity of, and including the town of, Moorcroft. The field is a recent discovery, and at the present time is still in the early stages of development.

Robinson Ranch field can be considered one of the more significant oil field discoveries in Wyoming in recent years. The importance of the field is not necessarily related to its' size, but rather to the zone from which production is obtained and the tools and methods employed in its discovery.

Production is from the Permian-Pennsylvanian Minnelusa formation. Until October, 1958, the discovery date of the Robinson Ranch Field, the only other significant Minnelusa production in this portion of the Powder River Basin was from the Donkey Creek Area, some five to six miles to the west. The Adon Field, which lies some thirty miles northwest of Robinson Ranch, did have some minor Minnelusa production when first developed in 1948, but is now abandoned.

Pan American Petroleum Corporation is responsible for the discovery and operation of the field. At the present time, there are ten Minnelusa producing wells and six dry tests in the area. Two of the dry holes were drilled by P. M. Oil Enterprizes, two by Davis Oil Company, and the other two by Pan American. In addition, there are four dry Dakota formation tests, and one dry shallow test which did not penetrate below the Pierre shale. These five dry holes were drilled before any serious thought was given to the possibility of Minnelusa oil in the Robinson Ranch Area.

This paper will attempt to explain the occurrence of Minnelusa oil at Robinson Ranch, and in so doing, point out various geologic features anomalous to the region which may be used in future petroleum exploration in the area. Subsurface methods are employed almost exclusively, since surface work is of little value in the area. Data used in the subsurface interpretations was derived from available electric logs, sample logs, samples, and various reports of the wells drilled in the area. The sources of all other information contained in this paper came from direct contact with the oil companies concerned, petroleum reporting services, and numerous references cited at the end of this paper.

LOCATION

Robinson Ranch Area is located in Crook County, Wyoming, in the northeastern corner of the state (Figures 1 & 2), some fifty miles from the Montana and South Dakota borders. The area includes Sections 19-22, 27-34 in Township 50 North, Range 67 West, and Sections 3-10 in Township 49 North, Range 67 West. The field proper lies northeast of the town of Moorcroft, which is included in the Robinson Ranch Area as covered in this paper. Accessibility to this area is good, with U. S. Highway 16 running through Moorcroft and county roads leading out of town directly through the field.

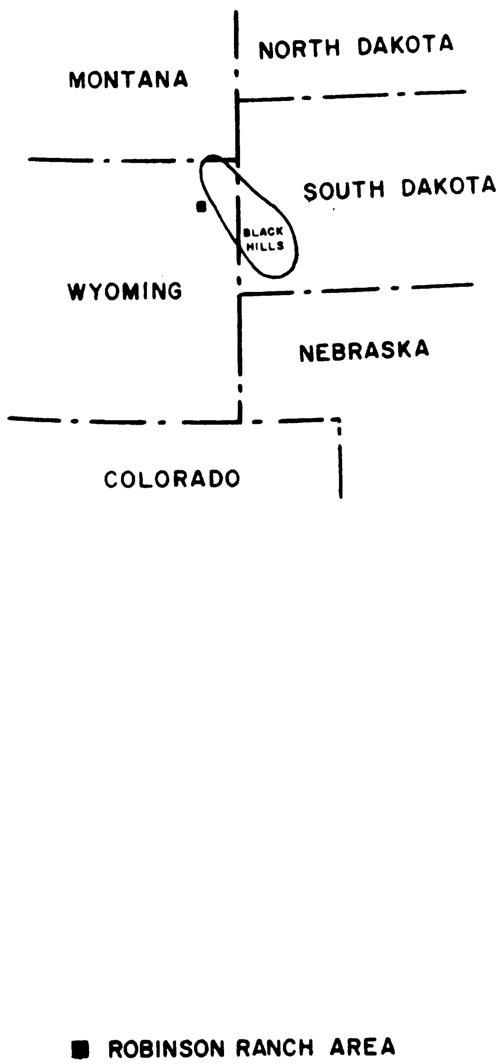


FIGURE 1
REGIONAL INDEX MAP

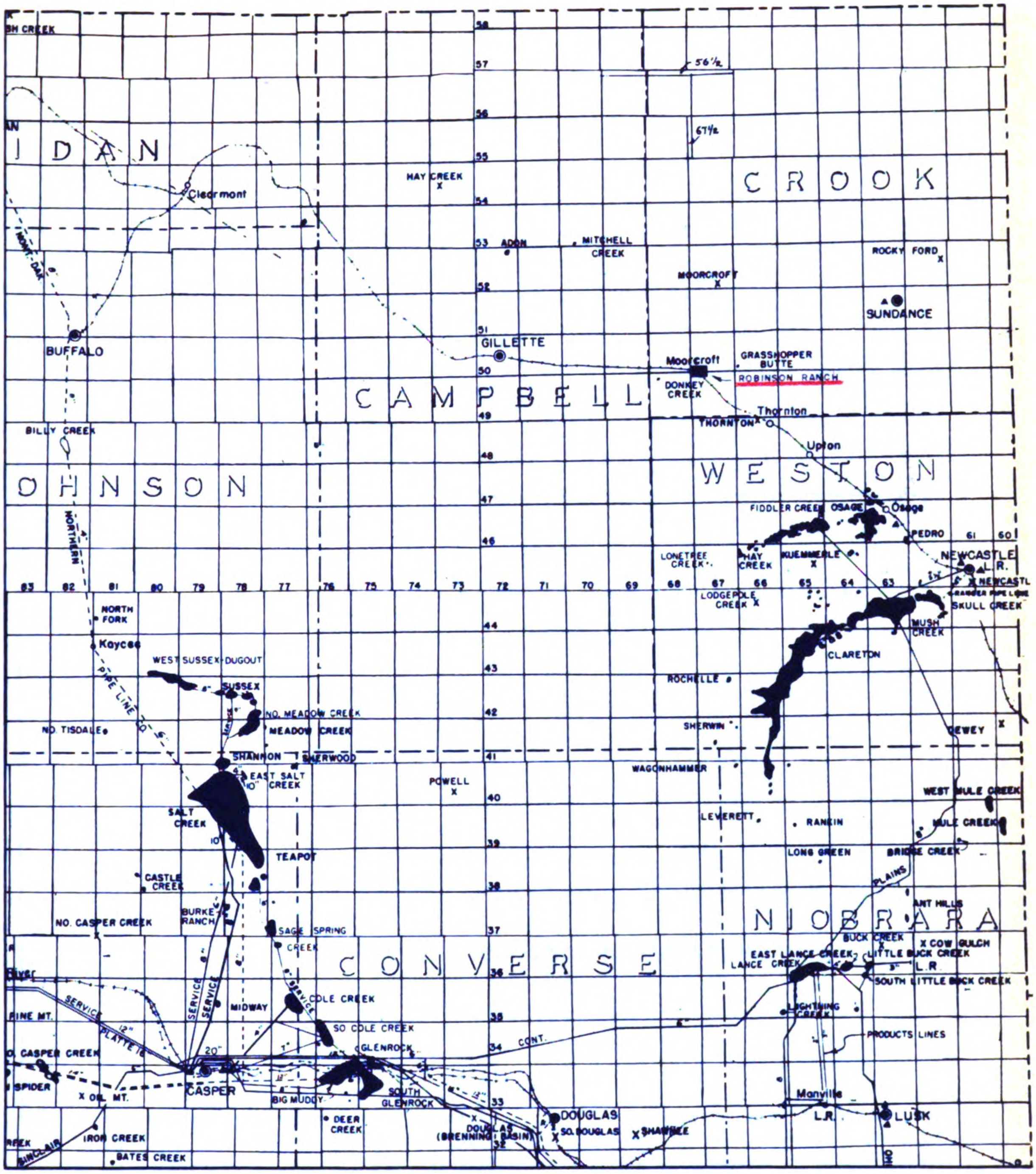
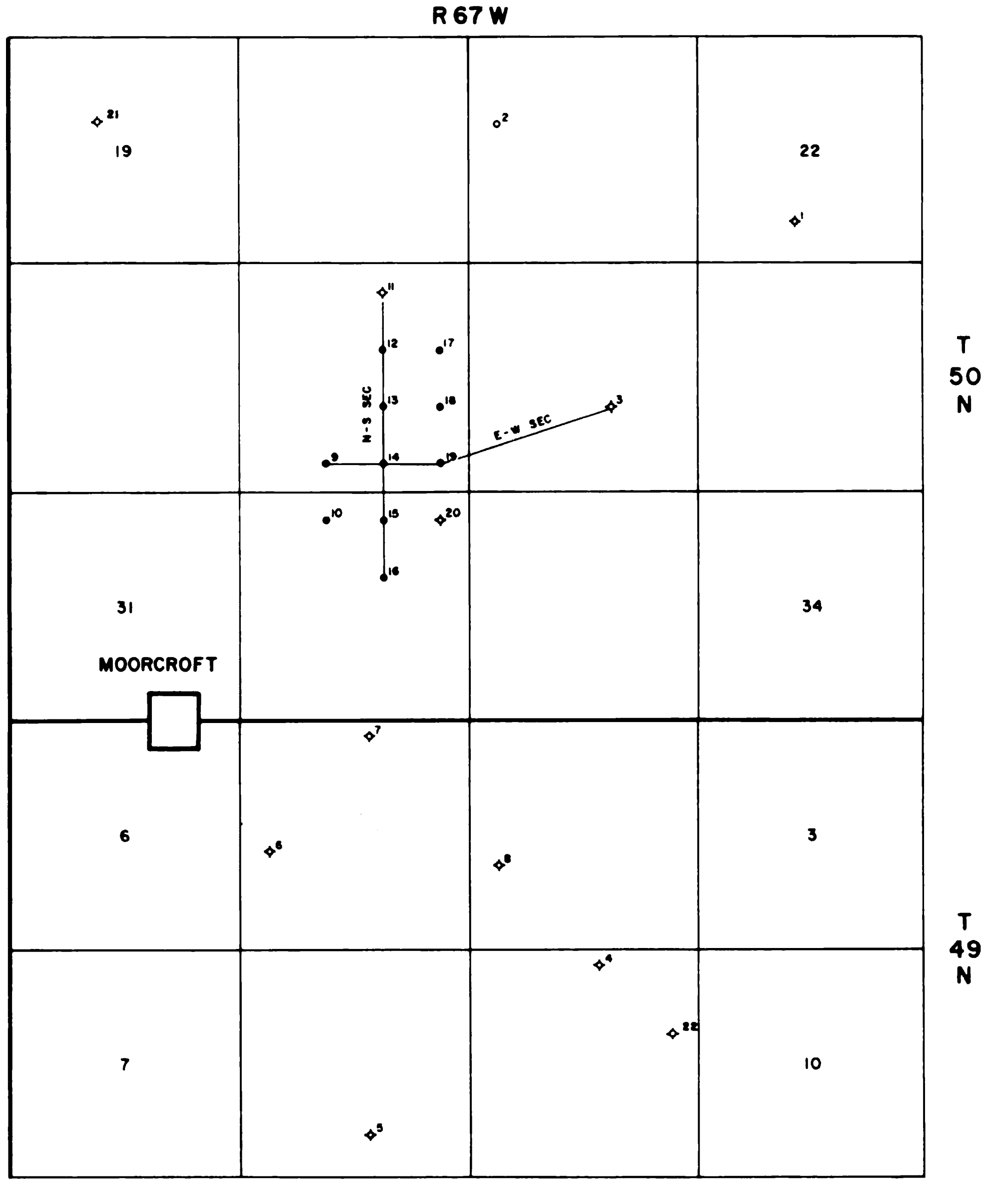


FIGURE 2

INDEX MAP

NORTHEASTERN WYOMING



INDEX MAP OF ROBINSON RANCH AREA, WYOMING

LIST OF WELLS

WELL & LOCATION

NO.		NO.	
1	PARRENT - BUCKMILLER NO. 1 NE SE SW SEC. 22 T50N R67W	11	GARIEPY - BRIGGS NO. 2 C NW NE SEC. 29 T50N R67W
2	P & M - BUCKMILLER NO. 2 SW NW SEC. 21 T50N R67W	12	PAN AM - ROBINSON NO. B-5 SW NE SEC. 29 T50N R67W
3	P & M - BUCKMILLER NO. 1 C NW SE SEC. 28 T50N R67W	13	PAN AM - STATE NO. C-1 C NW SE SEC. 29 T50N R67W
4	TEXACO - ROBINSON NO. 1 NW NW NE SEC. 9 T49N R67W	14	PAN AM - ROBINSON NO. B-1 SW SE SEC. 29 T50N R67W
5	TEXACO - ROBINSON NO. 2 NW NW SE SEC. 8 T49N R67W	15	PAN AM - ROBINSON NO. 1 C NW NE SEC. 32 T50N R67W
6	FERLEY - BUTTS NO. 1 N 1/2 NW SW SEC. 5 T49N R67W	16	PAN AM - ROBINSON NO. 2 C SW NE SEC. 32 T50N R67W
7	W & M - ROBINSON NO. 1 NW NW NE SEC. 5 T49N R67W	17	PAN AM - ROBINSON NO. B-4 SE NE SEC. 29 T50N R67W
8	PAN AM - ROBINSON NO. C-1 NW SW SEC. 4 T49N R67W	18	PAN AM - ROBINSON NO. B-2 NE SE SEC. 29 T50N R67W
9	PAN AM - STATE NO. C-2 SE SW SEC. 29 T50N R67W	19	PAN AM - ROBINSON NO. B-3 C SE SE SEC. 29 T50N R67W
10	PAN AM - HOFFINE GOV'T. NO. 1 NE NW SEC. 32 T50N R67W	20	PAN AM - ROBINSON NO. A-3 NE NE SEC. 32 T50N R67W
21	DAVIS - CORDELL NO. 1 SE NW SEC. 19 T50N R67W	22	DAVIS - ROBINSON NO. 1 SE NE SEC. 9 T49N R67W

SCALE: 1" = 4400'

R. F. OHLHABER

Fig. 3

NOVEMBER 20, 1959

GEOLOGIC SETTING AND REGIONAL HISTORY

Crook County, Wyoming, includes two geologic features within its boundaries - the Black Hills and the Powder River Basin. The Robinson Ranch Area lies on the northeastern margin of the basin, a short distance west of the fairly gentle (a few to 20 degrees) dips of the flanks of the Black Hills.

A detailed account of the regional history of the area is given in Darton (1901, 1909), Darton & Page (1925), and the Wyoming Geological Associations' 13th Annual Field Conference "Powder River Basin Guidebook (1958)".

The Black Hills are a broad domal uplift, some 120 miles long and 60 miles wide at the widest portion. A Pre-Cambrian core trends nearly north-south, flanked by upturned and truncated Paleozoic and Mesozoic sediments. The anticline extends beyond the crystalline core, trending northwest approximately 120 miles. The uplift is slightly asymmetrical; the east flank has dips of 45 degrees or greater, the top nearly flat, and the west flank fairly gentle with dips of 20 degrees or less.

Adjacent to the west flank of the Black Hills, and extending westward to the Big Horn Range, is the broad Powder River Basin. Cretaceous, Paleocene, and Eocene sediments make up the surface of the basin, with early Tertiary beds reaching a thickness up to 6,000 feet at the deepest portion, as evidenced by seismic work. With the exception of a few well established anticlinal structures found along the western and southern margins of the basin (Salt Creek, Billy Creek, Big Muddy and Lance Creek), almost no reversals of dip are to be found in the Powder River Basin.

Using Darton's (1925) estimate of 9,000 feet of uplift for the Black Hills, the structural relief between the bottom of the Powder River Basin and the top of the Black Hills, is approximately 20,000 feet.

Because the Paleocene and Eocene deposits of Laramide age are separated from the uplift by upturned and truncated Cretaceous outcrops, no overlap exists, and the age of deformation can only be approximated. The source of the Upper Cretaceous Lance and Fox Hills formations in the Powder River Basin may have been from the uplift, thus dating the doming as late Cretaceous. The distribution of the Eocene Wasatch formation seems to indicate that the uplift had occurred prior to that time, and was furnishing some of the sediments. On a geologic basis, it is doubtful that the major uplift of the Black Hills occurred prior to the uplift of the Bighorn Mountains, which can be dated as post Ft. Union (Paleocene) Pre-Wasatch.

Scattered outcrops of White River sediments in the Pumpkin Buttes Area, Township 44 North, Range 76 West, and abundant rocks of White River age in the Hartville, Lance Creek Area (southeastern margin), indicates the basin was receiving sediments as late as Oligocene time.

SURFACE GEOLOGY

The Upper Cretaceous Lance formation is the surface formation in the Robinson Ranch Area. The Fox Hills (Upper Cretaceous) sandstone crops out approximately one and one-half miles to the east of the field proper, and Fort Union Tertiary sediments lie some twenty miles to the west.

The Lance formation consists of a gray to yellowish gray sandstone and gray shale, with a few thin beds of carbonaceous shales.

Topography is generally rough, with a series of ridges and valleys striking approximately northwest by southeast, parallel to the trend of the Black Hills. Relief within the area averages 150 feet, with maximum relief approximately 300 feet. The field itself lies in a fairly flat valley bottom formed by an intermittant stream draining north.

Drainage of the area is by intermittant streams flowing north by northwest into the Belle Fourche River, making it part of the Missouri River watershed.

STRATIGRAPHY

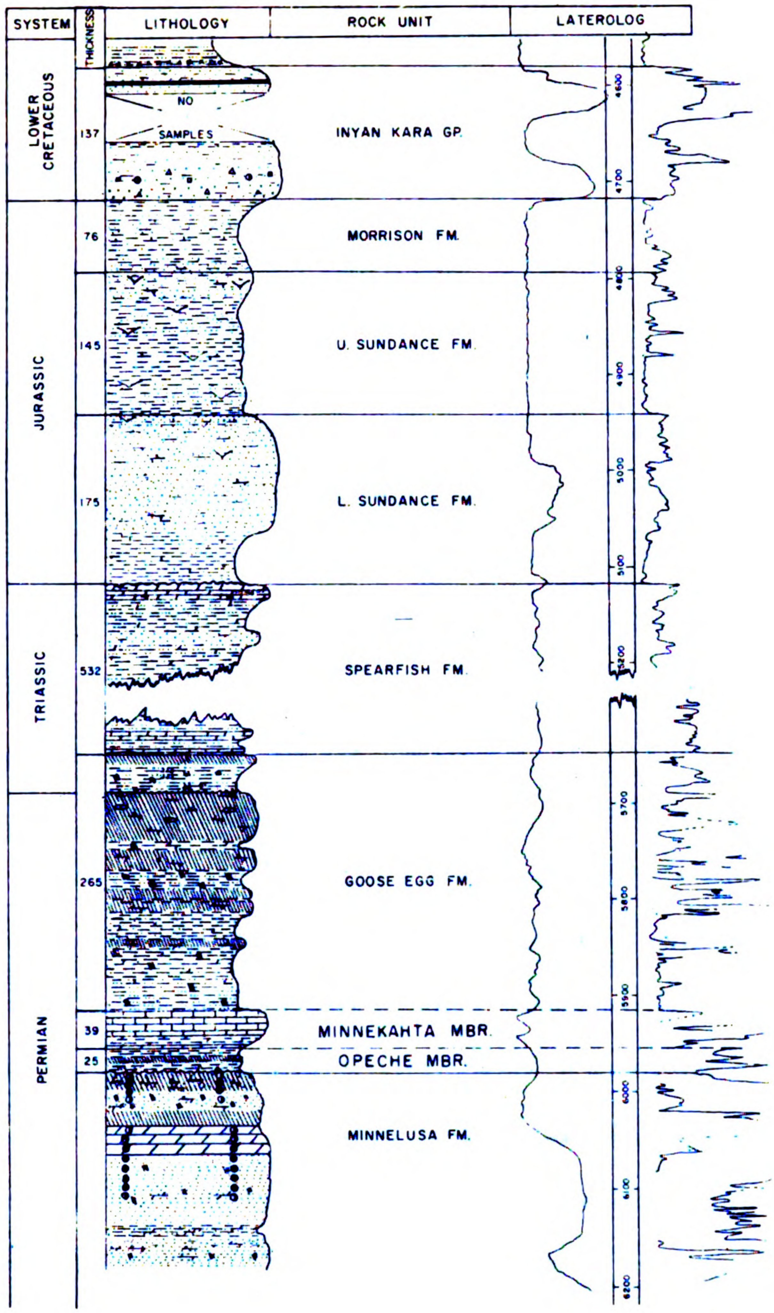
The stratigraphy of the Robinson Ranch Area is typical of the eastern margin of the Powder River Basin in Wyoming. Figure 4 represents surface and subsurface rock units present in this region. The thicknesses given from the surface Lance formation through the Skull Creek formation represent averages for that portion of the Powder River Basin; those given from the Fall River sandstone through the Minnelusa formation indicate the actual range of thicknesses found within the Robinson Ranch Field.

Only those members of particular interest to the petroleum industry are differentiated within formational units. Formations such as the Pierre and Lower Sundance contain mappable members not usually considered in subsurface exploration, and for that reason they are not

SYSTEM/SERIES	GROUP	FORMATION	MEMBER	THICKNESS IN FEET		GENERAL LITHOLOGY
Upper Cretaceous		Lance		600 - 750		Shale, gray, and sandstone gray to yellowish gray.
	Montana	Fox Hills		150 - 200		Sandy shale and siltstone; light gray sandstone.
		Pierre		1750 - 2170		Shale, dark gray to gray.
	Colorado	Niobrara		100		Chalk marl and calcareous shale numerous bentonite beds.
		Carlile	Sage Breaks	200	500	Shale, black to dark gray; abundant calcareous concretions.
			Turner Sand	200		Sandstone, thin bedded.
			Unnamed Shale	100		Shale, dark gray, numerous limestone and ironstone concretions.
		Greenhorn		300 - 350		Shale, light gray, calcareous, interbedded marl.
		Belle Fourche		450 - 600		Shale, black and gray, fissle, abundant bentonite and ferruginous concretions.
Lower Cretaceous		Mowry		150 - 190		Shale, black-brown black, siliceous, bentonite sandstone stringers, fish scales
		Newcastle		0 - 80		Sandstone, silty, medium grain and shale, sandy, some lignite and bentonite.
		Skull Creek		200		Shale, dark bluish gray, scattered lenticular clay - iron concretions.
	Inyan Kara	Fall River		55 - 65		Sandstone, brown, fine to coarse grained, massive cross bedded.
		Fuson		30 - 35		Shale, varigated, red, maroon, gray and buff-sandstone, gray to yellow.
		Lakota		45 - 65		Sandstone, gray, coarse grained, massive cross bedded, conglomerate.
Upper Jurassic		Morrison		70 - 140		Shale, green, gray-green, maroon, waxy, sandy.
		Upper Sundance		140 - 150		Shale, green-gray, silty, glauconite and interbedded glauconitic sandstone.
		Lower Sundance		160 - 210		Shale, gray to green-gray, sandstone, gray to tan, fine grained, thin limestone, sandy.
Triassic		Spearfish		475 - 590		Shale, siltstone and sandstone, soft, red, argillaceous.
Permian		Goose Egg		315 - 355		Shale, siltstone and sandstone, red to ocher, some gypsum and haylite.
			Minnekahta	40		Dolomite and limestone, tan
			Opeche	37		Shale, sandy, red and brown.
Pennsylvanian		Minnelusa	Upper	400	1150	Series of sandstones, carbonates, anhydrites, and red shales.
			Middle	200		
			Lower	350		

NOTE - Those thicknesses from the Fall River formation through the Minnelusa are representative of the Robinson Ranch Area. All other represent average thickness in the northeastern Powder River Basin.

PAN AMERICAN
ROBINSON NO. 1
C NW NE SEC. 32 T50N R67W
KB 4254



GRAPHIC COLUMNAR SECTION
CORRELATED WITH LATEROLOG
LOWER CRETACEOUS TO LOWER PERMIAN

R.F. OHLHABER NOVEMBER 16, 1959

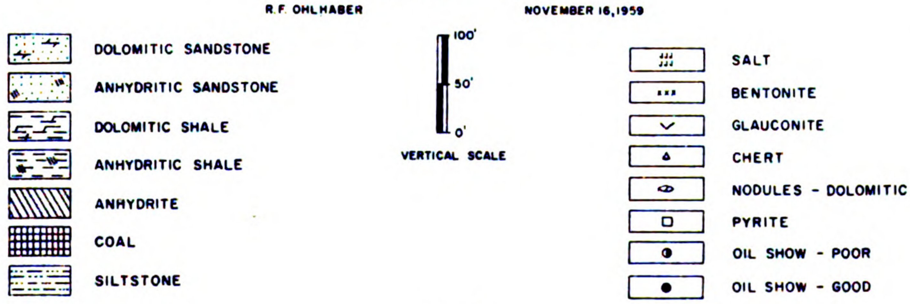


Fig. 5

mentioned here. Since this paper is not a stratigraphic study, only the productive Minnelusa formation will be discussed in detail. The remainder of the stratigraphic column is covered in general terms, with some emphasis on a few zones of interest.

CRETACEOUS

Marine gray to black shales dominate the stratigraphic section throughout Upper Cretaceous time, These shales are interbedded or interfinger with discontinuous sandstone further west in the basin. A few of the sands are continuous through this portion of the basin and produce oil. The Turner sand member of the Carlile formation has produced small quantities of oil, and can be correlated to the First Wall Creek sandstone found westward in the basin.

The Lower Cretaceous section represents a greater variety of depositional environments. In the Black Hills proper, marine sediments from the Mowry Shale through the Fall River sandstone are separated from the varied continental facies of the Fuson-Lakota sequence by a disconformity representing the advancing Cretaceous Sea. Within the Powder River Basin, however, the Fuson-Lakota sequence is at least in part marine, indicating a transgressive sea within the basin at this time.

The Mowry and Skull Creek formations are marine shale facies, separated by the marginal marine and deltaic deposits of Newcastle sandstone. The Newcastle sandstone is an excellent oil reservoir and produces at various fields near the Robinson Ranch Area.

The Fall River sandstone, which, along with the Newcastle sandstone, has accounted for virtually all the oil production in the northeastern portion of the basin prior to the discovery of Minnelusa oil, overlies the Fuson-Lakota sequence mentioned above. It is common practice, especially within the oil industry, to call the Fall River sandstone the Dakota sandstone. However, since Dakota is such a general term and applies to various parts of the entire Inyan Kara Group at different regional localities, this term seems undesirable.

JURASSIC AND TRIASSIC

The Jurassic rocks within the area include both continental and marine deposits. The Upper and Lower Sundance formations are marine sediments, overlain by the continental Morrison formation. The contact between the Morrison and Upper Sundance is a difficult one to pick both at the surface and in the subsurface, due to the re-worked nature of the Upper-Sundance sediments. The first occurrence of a glauconitic sand is generally conceded to indicate the Upper Sundance, and it is on this basis that the contact was determined for this paper.

A great regional unconformity exists between the Jurassic sequence and the Triassic Spearfish formation. The thickness of the Spearfish varies greatly because of the unconformity, even in the limited area covered in this paper. The Triassic rocks are easily identifiable in the region as a series of soft, red, sandy shales, siltstones, and argillaceous sandstones.

LOWER TRIASSIC AND PERMIAN

The 150 - 200 foot sequence of anhydritic red siltstones, anhydrites, red siltstones, and thin limestones above the Minnekahta limestone and

Opeche shale formerly were included in the Spearfish formation. Subsequent work by C. A. Burk and H. D. Thomas (1956) indicated that this interval is widespread, easily recognized, and can be correlated with the Upper Phosphoria and Dinwoody formations of western Wyoming. This unit and the underlying Minnekahta limestone and Opeche shale is now known as the Goose Egg formation. Thomas (1934) described the boundary between the Permian and Triassic systems as being marked by the top of the Ervay limestone member, from fossil evidence at the type locality in the northern Rattlesnake Hills of central Wyoming. Although the Ervay limestone is not present in the Robinson Ranch Area, there is a distinct lithologic break within the Upper Goose Egg formation, from a red shale to a bed of anhydrite. Correlating the anhydrite with the Ervay limestone, the Permian-Triassic boundary is placed 60 - 90 feet below the top of the Goose Egg formation. The lower portion of the formation is Middle Permian as determined by fossil studies (Burk, C. A., & Thomas, H. D., 1956) and unconformably overlies the Pennsylvanian and early Permian Minnelusa formations.

The Minnekahta limestone and Opeche shale members have been carried in geologic literature through the years as formational units. It is this writer's intention, however, to follow the Wyoming Geological Association's most recent terminology as stated in their 1956 publication "Wyoming Stratigraphy", and assign these units as members within the Goose Egg formation (Figure 4). These members, particularly the Minnekahta, which is dominantly a dolomite rather than a limestone, are easily recognized in the subsurface from electric and sample logs, and are used extensively as mapping horizons in subsurface exploration.

LOWER PERMIAN - PENNSYLVANIAN

Various names have been applied to the sequence of sandstones, carbonates, evaporites, and red shales that outcrop between the Permian red beds and the Mississippian Madison formation on the various uplifts surrounding the Powder River Basin. The Casper, Hartville, and Minnelusa formations may all be considered as rock equivalents, representing facies and thickness changes from one part of the basin to another. This paper will use only the name Minnelusa, and apply it to the above mentioned sequence in all regions of the basin. The Tensleep and Amsden formations of the Big Horn Mountains are not, however, rock equivalents. They are equivalent in time only to the lower and middle members of the Minnelusa formation, and must be treated as such.

The Minnelusa formation can be divided into three separate time rock units on the basis of regional unconformities; the Upper, Middle, and Lower members. The entire formation is marine, with the basal sandstone of the Lower member being a possible exception. By outlining the general regions of production within the Powder River Basin for each member, it becomes readily apparent the south-eastern portion of the basin accounted for almost all Minnelusa production prior to the discoveries of Donkey Creek and Robinson Ranch fields to the north.

UPPER MINNELUSA

The Upper Minnelusa member consists of sandstones, carbonates, (predominantly dolomite) and anhydrites, totaling approximately 400 feet in thickness. The percentage of sandstone to carbonates and evaporites averages 50 - 80 per cent sandstone as against 20 - 50 per cent carbonates and evaporites.

The Black Hills Area appears to have been a slight positive feature at the time of Upper Minnelusa deposition as evidenced by the high percentage of sandstone within the region. The source of the sandstone, however, was apparently from the west rather than the east. The nearly identical lithologic character of the Upper Minnelusa sandstones (Wolfcampian) to the Middle and Upper Pennsylvanian Tensleep sandstone in the Big Horn Basin, indicates the older sandstone (Tensleep) was deposited in western and central Wyoming, uplifted and eroded, then re-deposited as Upper Minnelusa to the east.

Paleontological evidence, as derived from various surface sections throughout the state, determines the age of the Upper Minnelusa as Wolfcamp (Agatston, R. S., 1954), or Lower Permian. It has been a somewhat false conception, particularly within petroleum circles, to consider the Minnelusa synonomous with Pennsylvanian, although recent discoveries such as the Robinson Ranch Field, are bringing to light what appears to be a more correct age interpretation.

As shown graphically on Figure 5, two sandstone beds, separated by an evaporite and carbonate section, occur near the top of the Upper Minnelusa. These sands apparently correlate with the Converse sandstone of the Lance Creek Field, located in the southeastern portion of the basin, and are named the First and Second Converse sands. The Converse sandstones are excellent reservoirs, and constitute the only productive zones within the Minnelusa in the northeastern region of the Powder River Basin, as evidenced at Donkey Creek and Robinson Ranch Fields.

MIDDLE MINNELUSA

The Middle Minnelusa is bounded, both top and bottom, by regional unconformities. The uppermost unconformity, separating the Upper and Middle Minnelusa members, is marked by a red shale marker bed. The basal unconformity separates Middle Pennsylvanian (Desmoinesian) from Lower Pennyslvanian (Atokan). The lower unconformity can readily be picked in the subsurface by characteristic kicks on both electric and radioactive logs, caused by a definite lithologic change at this point.

Sandstones and carbonates, with a few persistant thin beds of black shales, dominate the Middle Minnelusa section. Because they are continuous and have characteristic radioactive log kicks, the black shale beds are a valuable aid in long range correlation of the section. The greatest percentage of sandstones are found in the western portion of the basin, indicating a source in that direction. The oil producing sands of the Middle Minnelusa in the southeastern portion of the basin are called the "Leo" sandstones, and represent eastern extensions or tongues of the main sand bodies to the west.

The age of the Middle Minnelusa, as determined by fusulinid data from surface sections (Agatston, R. S. - 1954), is Virgillian, Missourian, and Desmoinesian (Upper and Middle Pennsylvanian). Not all the formations are present in various parts of the basin due to truncation.

Except for two pronounced variations, the section generally increases in thickness from northwest to southeast, with maximum deposition occurring adjacent to the Hartville Uplift. A marked thinning is apparent within this thick section at Lance Creek, indicating contemporaneous uplift with deposition. A second pronounced zone of thinning is found in the northeastern portion of the basin caused by Tertiary intrusives.

Oil production from the Middle Minnelusa Leo sandstones is presently confined to the southeastern portion of the Powder River Basin, primarily the Lance Creek Area.

LOWER MINNELUSA

The Lower Minnelusa member constitutes the remainder of the formation, from the regional unconformity at the base of the Middle Minnelusa to the erosional top of the Mississippian Madison formation. It correlates with the Amsden type section of the Big Horn Mountains, and is Atokanian and Morrowanian in age.

The top of the Lower Minnelusa is usually determined in surface sections or samples by the presence of an abundant pink or orange chert, and in subsurface by a marked decrease in magnitude in the curves of electric and radioactivity logs, indicating a thin bedded sequence of shales and carbonates.

The Lower Minnelusa is usually divisable into three units; upper cherty carbonates and red shales; cherty limestone; and basal sandstone. All the units are fairly constant in areal extent and thickness with the exception of the basal sand, or "Bell" sandstone as it is known. The discontinuity and variable thickness of this sandstone is probably due, at least in part, to the underlying, karst-type topography of the Madison formation upon which it was deposited.

The Reclamation limestone, a fairly clean carbonate directly above the basal sandstone, accounts for the only oil production to date from the Lower Minnelusa, this being restricted to the southeastern portion of the basin at Lance Creek and West Mule Creek fields.

STRUCTURE

SURFACE

There is not direct evidence of a structural feature at the surface in the Robinson Creek Area. The discontinuous gray shales and sandstone lenses of the Lance formation make surface measurements next to impossible, even in a restricted area such as is covered here.

The outcrop pattern of the Fox Hills sandstone, however, may indicate a northwest plunging nose and syncline as observed in Sections 9 and 10, Township 49 North, Range 67 West. The re-entrant of the Fox Hills into the basin could well be the surface expression of the subsurface structure responsible for production at Robinson Ranch Field. The general outcrop pattern of the Fox Hills sandstone, taken from U.S.G.S. Map OM-191, is outlined on the four subsurface structure maps, Plates I, II, III, and IV, and the probable relation to the structure demonstrated.

SUBSURFACE

The subsurface structure of the area is shown in Plates I, II, III, and IV.

Pan American Petroleum Corporation first discovered a subsurface structural anomaly in the Robinson Ranch Area in August, 1957, using seismic methods. Subsequent drilling has verified the high and the boundaries of the anticline have been more definitely defined. The structure is a slightly asymmetric anticline, having a generally north south axis.

The anticline apparently resolves into two separate highs, with depth, as seen on the contour maps of the Minnekahta and Minnelusa horizons, Plates III and IV. The amount of closure varies from the different horizons, but in general is somewhere around 40 to 50 feet, possibly more.

Formation tops and correlative points used in the construction of the structure contour maps were derived from available electric logs run on the wells. These logs are of three types; Schlumberger Electric (E) log, Induction-Electric (I-ES), and Laterolog (LL). The Laterologs were available only on those wells which penetrated to the Minnelusa. All well elevations were derived from a common source - The Power Surveying Company of Denver, Colorado.

Distant well spacing, and in some instances, no well control at all, necessitated a large amount of interpolation. For example, in the southern region of the area (Township 49 North), only one well out of five was drilled to the Minnelusa, that being Pan American's Robinson C-1, in Section 8. The fact that no wells have been drilled north of the field, makes it virtually impossible to determine the northern extent and configuration of the structure. P. M. Oil Enterprises Buckmiller No. 2 Unit, SW SW, Section 21, Township 50 North, Range 67 West, shown as a location, would help to solve this problem if completed. At last report (March, 1960) the well was spudded and surface casing set, but some sort of legal entanglement has prevented the drilling of the well to its proposed Minnelusa depth. Various petroleum industry reporting services still carry the well as a location, and until it is reported as an abandoned location, the possibility of it being completed still exists.

Although there is no direct evidence of a syncline between the P. M. Buckmiller No. 1 well in Section 28, Township 50 North, Range 67 West, and the field wells to the west, this writer believes that it does exist, and in the approximate location shown on the structure map. The attitude of the various horizons mapped at the above location indicate they are more compatible to the regional dip than to the structure; and, a surface expression of a syncline can be demonstrated in the outcrop pattern of the Fox Hills sandstone in Section 10, Township 49 North, Range 67 West. Further discussion of this problem follows, as each mapped horizon is reviewed separately.

PIERRE SHALE "A" HORIZON - PLATE I

Plate I represents the structure contour map of the Pierre"A" horizon. The "A" horizon is an arbitrarily chosen correlative point within the Pierre shale, easily recognizable on the logs of all the wells in the area. The purpose of mapping such a point is to determine if the structural feature present at depth is also reflected in the attitude of the younger rocks nearer the surface. The depth from surface to the "A" horizon averages from 2,700 to 3,000 feet within the area. Several factors prevented the choice of a horizon closer to the surface. They are as follows:

1. The varied lithology of the surface Lance formation results is uncertain correlations within that formation.
2. The absence of a horizon from one well to another due to topographic relief.

3. The various depths to which surface casing was set. Electric logs cannot be made through casing; therefore, a horizon seen in the log of one well may be masked by casing in another, even though it may be present at both locations.
4. Lack of a definite correlative point in the Upper Pierre shale.

The choice of the "A" horizon is further justified in that it has a characteristic log curve of a bentonitic zone or bed and represents a time-boundary marker.

The basic attitude of the structure at this horizon, as well as the other mapped horizons, was obtained by both well control and by following the general configuration of the Fox Hills sandstone outcrop. A reversal of the regional west dip is indicated between P. M. Buckmiller No. 1 and the Pan American field wells, Robinson A-3, B-2, B-3, and B-4. If the P. M. Buckmiller No. 1 well was placed so as to be on the flank of the structure, a marked broadening of the contours would result, causing a terracing of the east flank of the anticline. This would also involve using one point to determine a structural low, which should be avoided when possible in subsurface work.

The importance of this map is that it demonstrates that the structure is continuous through the Upper Cretaceous, even though it is not evident on the surface. This has important implications concerning future petroleum exploration in this portion of the Powder River Basin, where undisturbed Tertiary deposits and continental Cretaceous deposits at the surface make surface exploration unreliable, and many of the wells from which data must be used for subsurface exploration have penetrated only the shallower Cretaceous formations.

FALL RIVER SANDSTONE, PLATE II

The structural picture of the Fall River sandstone is essentially the same as discussed above for the Pierre "A" horizon. A reversal of dip amounting to more than 90 feet is indicated, with the exact amount of closure unknown.

The anticlinal axis has migrated slightly to the west and south with depth. The westward migration is to be expected, since the structure is located on regional west dipping strata of the eastern margin of the basin. The structural high, or crest, appears to be in the immediate vicinity of Pan American's Robinson B-1, while the discovery well, Pan American Robinson No. 1 is 14 feet lower at this horizon.

The Fall River tests, located in Township 49 North, Range 67 West, were drilled off structure, and offered no clue, before seismic work was initiated, that such a structure existed in the area. This illustrates that unless well control is unusually dense, possible structural features may be missed entirely by mapping on the Fall River sandstone or shallower horizons.

Although the Fall River sandstone is an important reservoir for oil in the Powder River Basin and produces at nearby Donkey Creek, it is apparently barren at Robinson Ranch. To this writer's knowledge, only three of the Minnelusa tests (discounting the four Fall River tests in Township 49 North) had any oil shows within the section and either tested or cored this interval. The wells and results are as follows:

1. Briggs-Gariepy No. 2, Center NW NE, Section 29, Township 50 North, Range 67 West. Cored - recovered 4½ feet of stained sand. No test.

2. Pan American Robinson No. 1, Center NW NE, Section 32, Township 50 North, Range 67 West. Drill Stem Test. Recovered 3,850 feet of fresh water.

3. Pan American Robinson C-1, NW SW, Section 4, Township 49 North, Range 67 West. Drill Stem Test. Recovered 4,107 feet of water.

One apparent anomalous feature of the structure at this horizon is the abrupt northwest swing of the contours indicated by the control afforded by Briggs-Gariepy No. 2, north of the field. Without additional drilling in this area, it is difficult to determine if the structure actually starts trending northwest at this point, or if this is simply a local feature of the Fall River sandstone, independent of the structural trend.

MINNEKAHTA LIMESTONE AND MINNELUSA FORMATION, PLATE III AND PLATE IV

The top of the Minnelusa formation represents an erosional surface which is sometimes difficult to correlate on electric logs. The Minnekahta limestone, on the other hand, has a characteristic log kick, and can be correlated accurately over large distances. The two horizons are discussed together, since they are separated only 60 or 70 feet stratigraphically and the structures mapped on both are essentially the same.

A major change in the subsurface structural pattern is evident when mapped on the Minnekahta and Minnelusa horizons. At this depth the anticline apparently resolves into two highs, separated by a saddle in the vicinity of Section 32, Township 50 North, Range 67 West. This interpretation is based on indirect evidence, as listed below.

1. There is a very slight difference in elevation of the Minnekahta limestone and Minnelusa formation from Pan American Robinson No. 2, Center SW NE, Section 30, Township 50 North, Range 67 West and Pan American Robinson C-1, Center NW SW, Section 4, Township 49 North, Range 67 West. The horizontal distance between the two wells is over 1,400 feet, yet the depth of the Minnekahta and Minnelusa varies only 25 feet. If a second high were not present as shown, an abrupt terracing of the south plunging nose of the anticline would exist.

2. It is believed that Pan American Petroleum Corporation drilled their Robinson C-1 well (location given above) to test a second structural high indicated by their seismic records. Since Pan American will not release any seismic data, this is just an assumption and cannot be confirmed. There are, however, few other valid geologic reasons for drilling this well, which is more than a mile from established production. The fact that the well was dry does not discount the presence of such a feature, as the well apparently missed the structure.

Another feature of the structure at this horizon shows the anticlinal axis swinging to the northeast near the crest of the main or larger high. Whereas the structure appeared to trend northwest when mapped on the Fall River sandstone, it now appears to trend slightly east of north. This is probably the basis for locating P. M. Buckmiller No. 2 in Section 21, Township 50 North, Range 67 West.

At least 30 feet of closure can be demonstrated, with another 20 to 40 feet probable. The crest of the anticline is approximately in the same location as it is at the Fall River sandstone horizon, except that it now extends farther south of include Pan American Robinson No. 1, Section 32 - the discovery well. It can be assumed Pan American located this well according to seismic data, to drill into the crest.

DEFORMATIONAL HISTORY

ORIGIN

The origin of the structure at Robinson Ranch is questionable, even upon the consideration and integration of the structural, sedimentary, and stratigraphic data available within the area. Little doubt exists that the structure was affected by the Laramide orogeny, but it may actually have originated much earlier in geologic time, during the Post Upper Minnelusa, Pre-Goose Egg period.

Discussion both for and against the concept of early Permian deformation is presented below. As an aid in determining the sequence of events, three isopach maps are included in this paper. Plate VII represents the thickness of the combined Minnekahta and Opeche members; Plate VI the thickness of the Goose Egg "shales" (undifferentiated) and exclusive of the Minnekahta and Opeche members; and Plate V, the thickness of the Spearfish formation.

EVIDENCE FOR EARLY-PERMIAN DEFORMATION

1. Plate VII, indicates that the thinning of the combined Minnekahta and Opeche members coincides with the crest of the anticline. Although the magnitude of thinning is not great (15 feet), it is sufficient to be mapped on 5 foot contours. Since no evidence of truncation of these units is apparent, this zone of thinning can be interpreted as

the result of deposition over a structural high, dating the structure as Post Upper Minnelusa - Pre-Opeche (Goose Egg).

2. The isopach map of the Spearfish formation, Plate V, also clearly shows a marked thinning over the structure. Disregarding the normal eastward regional thinning of the formation, the minimum thickness within the area occurs almost directly on the anticlinal crest. This feature is in direct accord with the attitude of the Opeche and Minnekahta members discussed above, and supports the theory of structural deformation within the area prior to Laramide movement.

3. A more positive approach to dating the structure as having originated at this time would be an isopach map of the Minnelusa, or at least of the Upper Minnelusa member within the Robinson Ranch Area, but lack of well data prevents this from being done. A regional study of the Upper Minnelusa, however, demonstrates that deformation within the basin possibly did occur during this time on a much larger scale (Foster, 1958). A marked thinning within the Upper Minnelusa may represent a buried, truncated, anticline, trending in a north-west direction along the eastern side of the Powder River Basin. If this interpretation is correct, it is probable that the smaller feature at Robinson Ranch originated at the same time.

4. The fairly rapid changes in thickness over relatively short distances of the Goose Egg formation within the basin indicates deposition on an erosion surface of moderate relief (Privrasky, Strecker, Grieshaber, and Byrne, 1958). This change in thickness of the Goose Egg is apparent in the Robinson Ranch Area, Plate VI, but its attitude is such that discussion is included in another section of this paper to demonstrate evidence against early Permian deformation.

5. A widespread breccia zone at the top of the Upper Minnelusa may represent erosion of that unit. A truncated unconformity can be observed on the surface between the Goose Egg (Opeche shale) and the Upper Minnelusa in the Sundance-Beulah Area of Crook County, Wyoming (Brady, 1958) NE¼, Section 8, Township 52 North, Range 61 West. Here, the horizontal Opeche shales overlie Minnelusa strata which dip approximately 8 degrees southwestward. In the basin, however, evidence of truncation depends entirely on individual interpretation and correlation of subsurface data (samples, electric logs, seismic), and thus is open to argument.

EVIDENCE AGAINST EARLY-PERMIAN DEFORMATION

1. The isopach map representing the thickness of the Goose Egg "shales" exclusive of the Minnekahta and Opeche members, Plate VII, can be interpreted as evidence of a depositional trough or low during Upper Permian time, and in the approximate position of the present structural high. An east-west section of the isopach shows the Goose Egg thickening towards the anticlinal crest. A north-south section generally parallel to the structural axis does, however, show some thinning at the crest.

Note Figure 6, a comparison of the Goose Egg section between two wells in the Robinson Ranch field. Pan American Robinson B-1 represents a location at or near the crest of the anticline - - Robinson B-2 a well on the eastern flank of the structure. The two wells are typical of the area, and reflect similar occurances in all the other well locations.

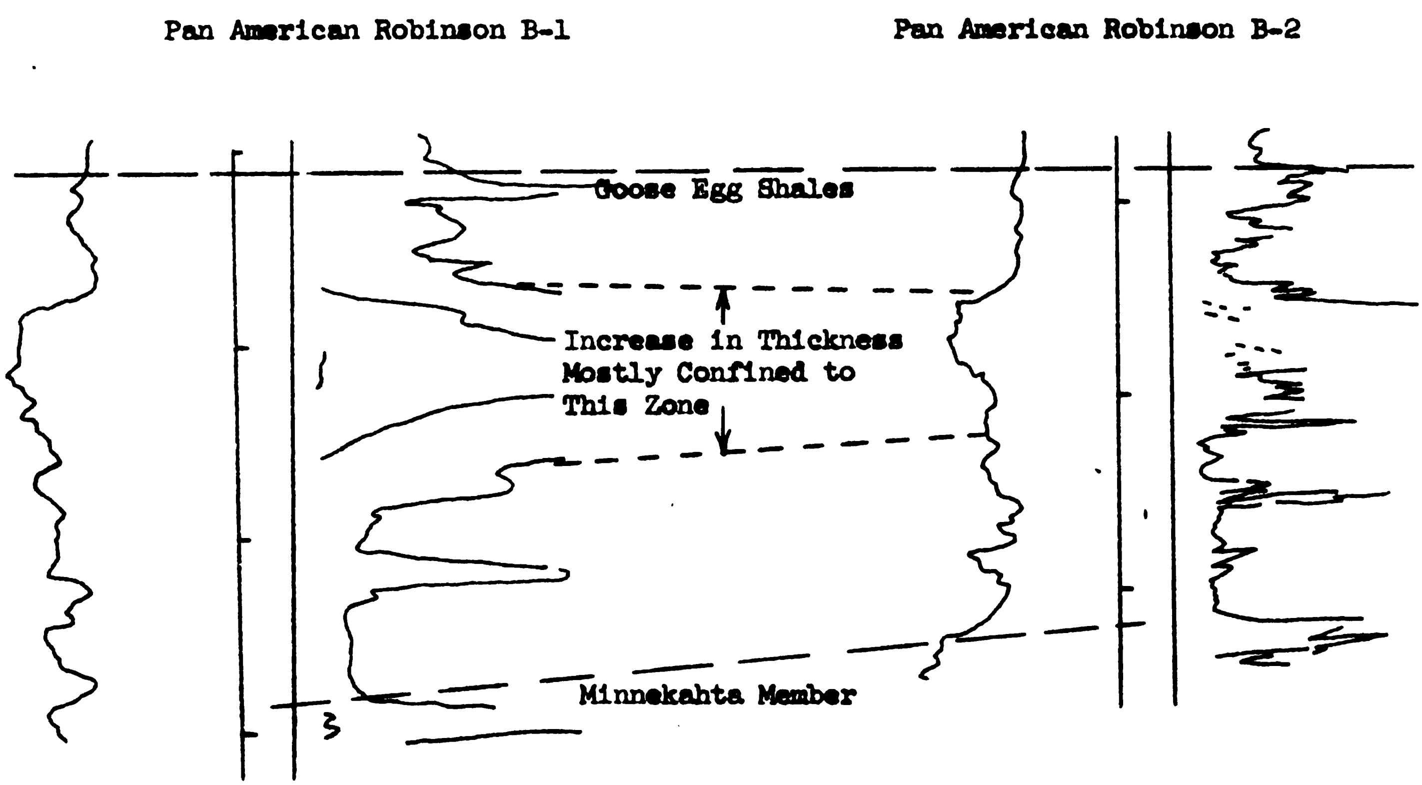


Figure 6. Comparison of the Goose Egg sections of two Robinson Ranch Field wells showing the zone of thickening.

The following facts can be observed from Figure 6:

(a) An increase in thickness of 40 feet from Robinson B-2 to B-1, or from the flank to the crest of the anticline.

(b) The change in thickness is mainly confined to one zone - an evaporite zone.

(c) The dominantly clastic zones are of a fairly constant thickness.

Since no samples or sample descriptions are available for the two wells cited above, it is assumed, by laterolog correlation, that the entire Goose Egg section is lithologically similar to the section at Pan American Robinson No. 1, which was described from samples and is shown graphically on Figure 5.

The lithologic character of the Goose Egg indicates deposition on a broad low land subject to alternate wetting and drying conditions in an arid, restricted, basin type of environment (Krumbein & Sloss, 1951).

The zone which accounts for most of the thickness change is dominantly a massive, dolomitic anhydrite, with a few thin stringers of red shale and siltstone. The question now arises as to what might account for the increased precipitation of anhydrite from one location to another at Robinson Ranch. The precipitation of salts from sea water is a complex process involving many factors, both physical and chemical. Under drying conditions during Goose Egg time, sea water may have concentrated in lows or depressions, accounting for the increased thickness of evaporites in restricted areas. This explanation is based on Clark's (1924) interpretation of the origin of anomalous thick salt deposits in areas having generally thinner, constant, evaporite section. If this is fact, and there was such a depression in the area during Goose Egg time, the origin of the Robinson Ranch anticline would probably have to be attributed to Laramide movement.

2. Deformation can be attributed to a zone of weakness in the basement complex. Such a weakness must have been in evidence during the Late Pennsylvanian or early Permian period if the Robinson Ranch structure originated at that time, and probably remains a zone of weakness to the present time. It is difficult to imagine why such a zone would not undergo greater deformation than what is apparent, due to the great forces that must have been active in that area during the Laramide orogeny.

EVIDENCE OF LARAMIDE MOVEMENT

The Powder River Basin had its origin in Late Cretaceous-Early Tertiary time, contemporaneous with the Laramide orogeny which elevated the mountain masses surrounding it (Eardley, 1951). Deformation was most intense along the western margin, near the steep west flank adjacent to the Big Horn mountains. Local deformations are also prevalent along the eastern margin, however, as evidenced by the structures associated with production at Donkey Creek and Robinson Ranch. These structures were apparently influenced to a major degree by the Black Hills uplift. (Strickland, 1958).

Upturned and truncated Late Cretaceous Lance sediments indicate deformation occurred some time after these continental sediments were deposited. Apparently undisturbed Wasatch (Eocene) sediments are distributed around the uplift (Black Hills) in such a manner to indicate the uplift had occurred prior to their deposition and was furnishing some of the sediments for these rocks (Eardley, 1951).

It is evident that local deformation within the basin, such as the structures at Robinson Ranch and Donkey Creek, either underwent additional movement or originated during this period of large scale deformation. These structures, especially along the eastern margin of the basin, exhibit similar stratigraphic and structural characteristics, and may be considered to have identical geologic histories.

PRODUCTION

HISTORY

Oil production in the northeastern Powder River Basin dates back to before the turn of the century. The years 1885 to 1900 saw many temporary oil booms around the town of Moorcroft. The presence of oil in the region had been known since the gold rush days in the Black Hills, as oil seeps were noted by prospectors on the western flanks of that large domal uplift.

The presence of shallow Cretaceous oil in commercial quantities satisfied most of the oil companies operating in this portion of the basin, although oil in the Minnelusa was known to exist for some time.

In 1923, the United States Geological Survey released a press statement, part of which reads:

> "Perhaps the most promising formation is the thick Minnelusa sandstone, and no test well reaching the deeper sands in the region should stop short of the formation . . . . some oil has been found in it, its great thickness and porous character fit it admirably for a reservoir, and the great mass of marine limestone below may well be a source of oil. All oil found in the Minnelusa so far is black and heavy."

Until very recently, however, the testing of the Minnelusa formation was confined to the flanks of the Black Hills, while wells in the Basin proper tested only the shallower Cretaceous pay sands. The Texas Company made the first important Minnelusa discovery in the northeastern Powder River Basin with its Adon No. 1 Unit in Section 2, Township 52 North, Range 72 West, in January, 1948. The well had an initial potential of 244 barrels per day at 31.5 A.P.I. gravity oil. Three subsequent wells were dry, and the one producer was abandoned in 1956 after a total cumulative production of 32,513 barrels of oil. The method of discovery was seismic, disclosing an anticlinal trap with approximately 100 feet of closure.

The discovery of Minnelusa oil at Donkey Creek was the next step toward proving the economical feasibility of producing oil from the deeper horizons within the basin. Donkey Creek was discovered in 1953 as a Dakota (Fall River) Lower Cretaceous producer. The presence of a possible oil pool was noted as early as 1950, when the Mule Creek Oil Company drilled a dry hole to evaluate geophysical anomalies, both gravity and seismic. Drill stem tests of the Dakota formation recovered substantial amounts of water and slight shows of oil.

The area remained inactive until True and Brown Producers (now True Oil Company) drilled the Dakota discovery well in April, 1953. Development of the Dakota horizon has continued to the present time. It was not until March, 1957, that True Oil Company drilled their Minnelusa discovery well. This well, the Burrows B-6, C NW NW, Section 8, Township 49 North, Range 68 West, flowed at the rate of 28 barrels of 31° A.P.I. gravity black oil per hour from a 20 foot section in the top of the Minnelusa. Development of Minnelusa production within the Donkey Creek area has proceeded continuously since that time, with 15 wells now producing.

Pan American Petroleum Corporation acquired their first of two productive Robinson Ranch leases in May, 1957, just two months after the Minnelusa discovery at Donkey Creek. Subsequent seismic work, started the following August, revealed a structural anomaly, which was drilled in October, 1958. The second productive lease, Robinson "B", was acquired in January, 1958. The delay in drilling is attributed to clearing up the minor mineral interests on the leases. The discovery well, Robinson No. 1, C NW NE, Section 32, Township 50 North, Range 67 West, had an initial production of 294 barrels of 26.4 A.P.I. gravity oil per day.

Altogether, Pan American acquired four leases, Robinson "A", USA Hoffine, Robinson "B", and State of Wyoming "C". All leases were acquired before the discovery well was drilled, and all have production.

Robinson Ranch differs from Donkey Creek in that the latter was primarily developed for Lower Cretaceous Dakota (Fall River) formation production, and only after development of this zone had continued for a period of four years was the possibility of Minnelusa oil production exploited. Robinson Ranch, however, was a Minnelusa play from the start, and is the only field in the northeastern Powder River Basin producing exclusively from the Permian-Pennsylvanian horizon.

PRODUCTION DATA

Pan American Petroleum Corporation has released only those production figures for the last two months of 1958 and the first eleven months of 1959. (The first full year of development of the Robinson Ranch field). Because the data is in terms of production by leases by months, it is necessary to integrate from Table I the completion dates of each well in various leases, and show which wells are included in the monthly production totals. Both oil and water production figures are shown in terms of barrels per month. Table I follows on the next two pages.

TABLE I

Company	Well No.	Spudded Completed	Bottomed In	IP
Pan American	Robinson B-1	1-24-59 2-19-59	Minneluse	544 BOPD
Pan American	Robinson B-2	3-1-59 3-31-59	Minneluse	376 BOPD
Pan American	Robinson B-3	3-20-59 4-12-59	Minneluse	390 BOPD
Pan American	Robinson B-4	4-12-59 5-10-59	Minneluse	580 BOPD
Pan American	Robinson B-5	5-13-59 6-27-59	Minneluse	63 BO 47 BWPD
Pan American	Robinson 1	10-12-58 11-28-58	Minneluse	294 BOPD
Pan American	Robinson 2	1-9-59 2-8-59	Minneluse	300 BOPD
Pan American	State C-1	12-4-58 1-12-59	Minneluse	228 BOPD
Pan American	State C-2	2-10-59 3-24-59	Minneluse	360 BO 102 BWPD
Pan American	Hoffine 1	3-7-59 4-19-59	Minneluse	104 BO 75 BWPD
Pan American	Robinson A-3	5-2-59 6-2-59	Minneluse	D & A
Pan American	Robinson C-1	5-29-59 6-18-59	Minneluse	D & A
P. M.	Buckmiller 1	5-5-59 8-8-59	Minneluse	D & A
P. M.	Buckmiller 2	Abandoned Location		

Parrent	Buckmiller 1	10-6-53 11-17-53	Pierre	D & A
Briggs-Garpiely	Robinson 1	11-9-56 5-27-57	Fall River	D & A
Lester Ferley	Butts 1	5-18-59 6-1-59	Fall River	D & A
Texaco	Robinson 1	4-24-48 5-31-48	Fall River	D & A
Texaco	Robinson 2	6-14-48 7-19-48	Fall River	D & A
W & M	Robinson 1	8-20-55 9-13-55	Fall River	D & A
Davis	Cordell 1	2-3-60 2-18-60	Minnelusa	D & A
Davis	Robinson 1	2-24-60 3-15-60	Minnelusa	D & A

See Index Map, Fig. 3, for locations

IP - Initial Production
BOPD - Barrels Oil Per Day
BWPD - Barrels Water Per Day
D & A - Dry and Abandoned

L. H. ROBINSON "A" LEASE

Year and Month		Oil	Water
1958	November	1,485	0
	December	7,966	16
	January	14,974	30
	February	18,263	1,073
	March	20,410	8,414
	April	17,219	10,034
	May	18,723	12,772
	June	18,591	17,010
	July	19,744	11,208
	August	23,989	18,279
	September	20,514	22,078
	October	16,443	24,876
	November	16,889	22,903
Total		215,120	148,693

Wells	Pan Am - Robinson No. 1	Nov., 1958 - Nov., 1959
	Pan Am - Robinson No. 2	Feb., 1959 - Nov., 1959

L. H. ROBINSON "B" LEASE

Year and Month		Oil	Water
1959	February	5,531	50
	March	17,416	235
	April	36,227	1,816
	May	48,316	29,186
	June	48,481	22,329
	July	49,198	30,963
	August	47,375	28,093
	September	42,305	29,310
	October	41,870	41,429
	November	33,923	38,354
Total		370,642	220,065

Wells	Pan Am - Robinson B-1	Feb., 1959 - Nov., 1959
	Pan Am - Robinson B-2	April, 1959 - Nov., 1959
	Pan Am - Robinson B-3	April, 1959 - Nov., 1959
	Pan Am - Robinson B-4	May, 1959 - Nov., 1959
	Pan Am - Robinson B-5	July, 1959 - Nov., 1959

STATE OF WYOMING "C" LEASE

Year and Month		Oil	Water
1959	January	7,665	93
	February	13,394	192
	March	18,513	3,983
	April	21,978	2,910
	May	21,589	21,266
	June	17,333	16,692
	July	18,772	18,035
	August	20,868	21,343
	September	16,522	11,390
	October	15,253	16,943
	November	16,089	24,516
Total		187,976	137,363

Wells Pan Am - State C-1 Jan., 1959 - Nov., 1959
Pan Am - State C-2 March, 1959 - Nov., 1959

E. M. HOFFINE LEASE

Year and Month		Oil	Water
1959	April	1,230	3,870
	May	1,534	5,301
	June	916	2,889
	July	1,055	2,805
	August	82	3,007
	September	832	2,910
	October	553	1,975
	November	651	1,470
Total		6,853	24,227

Wells Pan Am - Hoffine No. 1 April, 1959 - Nov., 1959

Total cumulative production for the Robinson Ranch field during this period amounted to 1,310,939 barrels of fluid -- 780,591 barrels of oil and 530,348 barrels of water. In terms of percentages, oil accounted for 59.5 per cent of the total fluid, and water 40.5 per cent. The average production of oil per well is 6,500 barrels per month or 215 barrels per day. This figure may be misleading, as many averages are. For example, the one producing well within the E. M. Hoffine Lease -- Hoffine No. 1, averages a little more than 20 barrels of oil per day, compared with 500 barrels of oil per day for Robinson No. 1 in the L. H. Robinson "A" Lease.

It is interesting to note the relationship between the amount of water recovered and the location of a well relative to the structure on the Minnelusa horizon (Plate IV). The discovery well, Robinson No. 1, is located on or near the crest of the anticline, within the L. H. Robinson "A" Lease. It produced nearly 24,500 barrels of oil and only 46 barrels of water for the first three months of production (see production figures). Robinson No. 2, on the same lease, was completed 2 months later in February, 1959, approximately 50 feet lower stratigraphically than Robinson No. 1. Observe, from the production data, how the amount of water recovered increased to over 1,000 barrels per month for this lease after Robinson No. 2 was completed.

Similar occurrences can be shown for each of the other leases. Hoffine No. 1, stratigraphically the lowest well in the field, has produced approximately four times as much water as oil. On the L. H. Robinson "B" Lease, water recovery was held to 50 barrels a month when Robinson B-1 was completed. This well is stratigraphically the highest in the field, located on the anticlinal crest (Minnelusa horizon). Upon the completion of the four other wells on the "B" lease -- Robinson B-2, B-3, B-4, and B-5, on the flanks of the structure, the total amount of water recovered per month is now above oil production.

OIL CHARACTERISTICS

The character of the oil produced at Robinson Ranch from the Minnelusa formation generally conforms in composition to oil indigenous to Permian rocks throughout the Powder River Basin. The general characteristics of Robinson Ranch oils are listed below:

API Gravity -------------------- 27 (Robinson Ranch - 26.4)

Sulphur Content % -------------- 2.0

Base --------------------------- Aromatic - Naphthene

Gasoline Content % ------------- 2.5

Carbon Residue % --------------- 5.8 (Strickland, J. W., 1958)

The sulphur content (2.0%) and carbon residue (5.8%) is high, compared to the low (2.5%) gasoline content.

Permian oils also have a high asphaltene content.

This oil is, on the average, of a better quality than oil of the same age found in the Big Horn Basin.

TRAP AND RESERVOIR CONTROL

Basically, Robinson Ranch Field produces from an anticlinal trap, approximately one mile long, having between 50 and 100 feet of closure. Pressures are supplied by a water drive, obviously effective as evidenced by the large amounts of water being produced with the oil.

Indirect evidence of a tilted water table may be domonstrated by the varying amounts of water produced at the different locations. Robinson A-3, Section 32, Township 50 North, Range 67 West, is a dry hole located only one quarter of a mile east of Robinson No. 1, the discovery well.

Hoffine No. 1, a producer, is located a quarter of a mile west of the discovery well. Structurally, Robinson A-3 is approximately 30 feet higher than Hoffine No. 1 and yet produced only water when the pay zone areas perforated and tested. Consequently, the pay zone at Robinson A-3 must be downdip from the oil-water contact. The ratio of oil-water - 1:4, produced at Hoffine No. 1 indicates it too is close to the oil-water contact. Thus, there is a difference in elevation of 30 feet in the oil-water contact from the east flank of the anticline to the west flank. That is, the contact is 30 feet higher to the east. Similar situations can be shown throughout the field.

On the basis of the above data, i.e., relative amount of water and oil produced from each well, an oil-water contact is shown on Plate IV, the structure mapped on top of the Minnelusa formation. This is only an approximate outline of the contact, but it clearly shows a definite tilt of the water-oil interface to the west. To map this contact more accurately, additional well data, such as micrologs or microlaterologs are required. Pan American Petroleum Corporation, however, will not release this data at the present time.

The apparent tilted water table at Robinson Ranch is not an anomalous feature of oil fields in the basins of Wyoming. Similar occurrences are numerous, particularly in the Big Horn Basin. One notable example is the Frannie Field in Park County, which exhibits a tilt of over 600 feet in the water-oil interface from the east flank to the west flank of the anticlinal trap responsible for production.

The theory of tilted water tables, as described by M. K. Hubbert (1953) results from water entering a formation at the outcrop and moving down the regional dips basinward. This water flow may displace oil trapped in anticlinal structures, and "push" it basinward until it is off center on the structural high. This is probably what happened at Robinson Ranch. The Minnelusa formation outcrops some 35 miles east of the Robinson Ranch area in the Black Hills. Water entering the formation at this point flows down the regional west dip into the Powder River Basin. This water flow displaced the oil trapped in the anticline, and moved it off-center to the west, thus accounting for the tilted contact.

ESTIMATED RECOVERABLE RESERVES

Until additional data is released by Pan American Petroleum Corporation, an accurate figure of the recoverable reserves within the Robinson Ranch Field cannot be given. The January 25, 1960, issue of "The Oil and Gas Journal" estimated the primary recoverable reserves at 9,225,000 barrels of oil. As of January 1, 1960, 843,000 barrels of oil had been produced from the field. Assuming "The Oil and Gas Journal" estimate to be correct, more than 8 million barrels of oil remain to be recovered.

FUTURE DEVELOPMENT AND EXPLOITATION

Future development within the area will probably be confined to exploration of unproven acreage outside the field itself. Drilling on 40-acre spacing, which is the required spacing of wells in the area, would necessitate locating tests fairly well off structure and downdip from the oil-water interface, as shown on Plate IV.

The best play appears to be the indicated second high south of the field in Sections 4 and 5, Township 49 North, Range 67 West (See Plates III and IV). Pan American attempted to drill this structure with their Robinson C-1 Minnelusa test in Section 4, but apparently missed, since the well was reported dry with no shows. Based on this writer's interpretation of the structure, a Minnelusa test should be drilled somewhere in the vicinity of C NE NE Section 5, Township 49 North, Range 67 West.

The latest wells drilled in the area were two Minnelusa tests by Davis Oil Company, both dry holes. Davis-Cordell No. 1, C SE NW Section 19, Township 50 North, Range 67 West, did not encounter any oil or gas shows and was not tested. This well was drilled some distance off structure, probably to evaluate the possibility of a stratigraphic trap within the Minnelusa formation. The second well, Davis-Robinson No. 1, C SE NE Section 9, Township 49 North, Range 67 West, was drilled to test a possible nosing of the Minnelusa, indicated on the surface by the outcrop pattern of the Fox Hills sandstone.

SIGNIFICANCE OF THE ROBINSON RANCH FIELD

Prior to 1958, exploration for oil along the eastern margin of the Powder River Basin was mostly confined to the relatively shallow, Cretaceous sandstones, namely the Frontier (Wall Creek), Newcastle, and Fall River. Discovery and production of Minnelusa oil at Adon and Donkey Creek fields heightened interest in the search for petroleum from this deeper horizon, which was climaxed by Pan American's discovery in late 1958 of the Robinson Ranch Field. In 1959, intensified deep drilling into the

Permo-Pennsylvanian Minnelusa formation resulted in the apparent discovery of at least one new Minnelusa field. Champlin Oil and Refining completed a Minnelusa well in Section 36, Township 51 North, Range 68 West, known as Prong Creek, with initial production of 500 barrels of oil per day. Lack of control in the area prevents this writer from determining if accumulation is controlled by structure or stratigraphy, although subsurface regional control suggests structure.

MINNELUSA OIL ACCUMULATION

Oil accumulation within the Minnelusa formation at Robinson Ranch is related directly to an anticlinal trap. Similar anticlinal structures along the eastern portion of the Powder River Basin produce, or have produced, Minnelusa oil, including Adon (abandoned), Donkey Creek, and Lance Creek Fields. Thus far, no Minnelusa production has been obtained by a purely stratigraphic type of trap. This is understandable, as the Converse pay sand (upper member of the Minnelusa formation) is a continuous, blanket type of sand and apparently does not pinch out within the basin.

The anticlinal structure responsible for the entrapment of Minnelusa oil at Robinson Ranch originated either during Post Minnelusa - Pre Goose Egg time or during the Laramide orogeny - with movement during Laramide time well established. The Minnelusa oil at Robinson Ranch is probably indigenous to the carbonate-evaporite facies of the upper member from which it is produced. Movement of the oil into the anticlinal trap occurred contemporaneously with deformation - either during early Permian or late Cretaceous time. Curtis, Strickland, and Busby (1958) mention an apparent relationship between oil distribution and marked "thins" represent Pre-Goose Egg vertical movements along which oil migrated and was trapped during Goose Egg deposition. According to Figure 2 of Foster's Minnelusa paper (1958), Robinson Ranch is located within a Minnelusa "thick", and is a direct contradiction of this theory.

ROBINSON RANCH - AS A KEY TO FUTURE OIL EXPLORATION

Future exploration in the eastern portion of the Powder River Basin will probably disclose many anticlinal structures similar to the one found at Robinson Ranch. The varied geologic phenomena which occurred in the Robinson Ranch Area down through geologic time were active throughout the region, as evidenced by regional studies of the Powder River Basin and the Black Hills. Further study of some of the geologic conditions found at Robinson Ranch and discussed in this paper may warrant their use in the continuing search for Minnelusa oil in the Powder River Basin.

The discovery of the Robinson Ranch Field must be attributed to seismic work, with no assistance from photogeology or surface mapping. A photogeologic map of the area does not show any strong evidence of structures, nor is the drainage pattern anomalous to the region. The importance of surface or photogeology should not be minimized, however, as it was probably the slight hint of structure offered by the outcrop pattern of the Fox Hills sandstone that initiated the seismic program.

Areas which show rapid variations in the thickness of the Spearfish formation should be studied carefully. The thinning of this unit over the structure at Robinson Ranch may be indicative of similar structures throughout the region.

Delineation of structure by the usual subsurface methods (i.e. electric logs and sample logs) is very improbable because of the sparse well control in the region. Anticlinal structure was not evident at Robinson Ranch prior to seismic work, although four Fall River formation tests had been drilled in the immediate vicinity years before.

Exploration should not be confined to areas where regional studies disclose "thinning" of the Minnelusa formation. The concept that the "thins" represent Post-Minnelusa, Pre-Goose Egg vertical movements, and that oil accumulated in the highs may be valid, but the very fact that Robinson Ranch is located in a regional Minnelusa "thick" indicates oil accumulation is not confined to these areas.

Finally, allowances for the migration of the structural axis with depth must be considered on anticlinal structures discovered at the shallower horizons. Careful study of the possible effects that hydrodynamic conditions may have on the accumulation of oil within the structure should be made, as evidenced by the tilted water table at the Robinson Ranch Field.

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