THE GEOLOGICAL SURVEY OF WYOMING

DANIEL N. MILLER, JR., State Geologist

PRELIMINARY REPORT NO. 11

Structural Geology of the Rex Lake Quadrangle Laramie Basin, Wyoming

BY

D. L. BLACKSTONE, JR.

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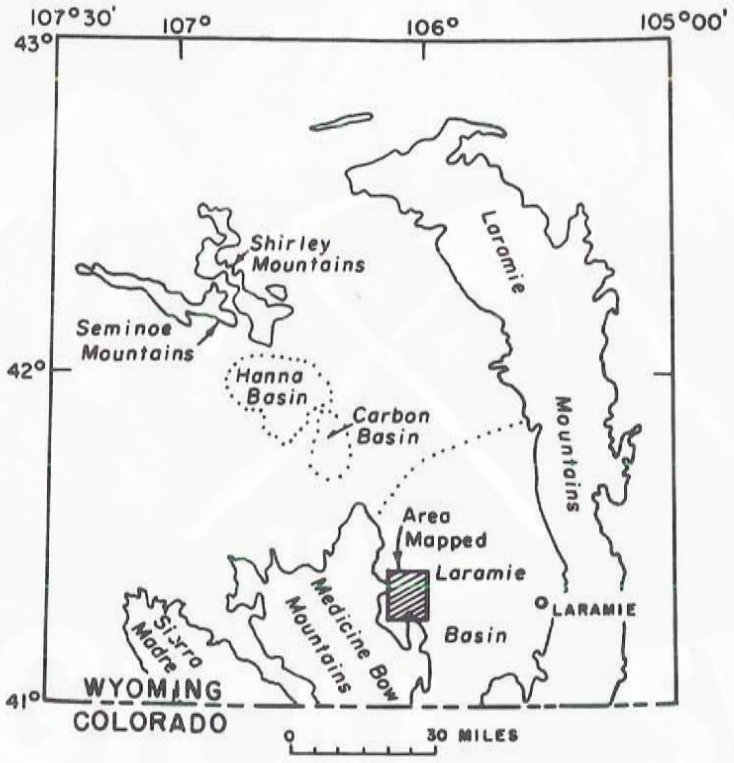

Fig. 1. Index map showing the location of Rex Lake Quadrangle.

STRUCTURAL GEOLOGY OF THE REX LAKE QUADRANGLE, LARAMIE BASIN, WYOMING.

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INTRODUCTION

The results of a geological investigation of the area covered by the U.S. Geological Survey Rex Lake 7 1/2 minute topographic quadrangle (106°00' - 106°07'30" - 41°15' - 41°22'30") are presented in this report. The map covers parts of Ts. 15 and 16 N., and Rs. 77 and 78 W., 6th P.M., all lying in Albany County, Wyoming. The area is located on the east flank of the Medicine Bow Mountains, and includes a part of Centennial Valley and Sheep Mountain. Access to the area is by way of Wyoming Highway No. 130, and the area is approximately 25 miles west of Laramie, Wyoming. (Fig. 1).

Published results of geologic investigations dealing specifically with the geology of the area include papers by Siebenthal and Darton (1909), Darton (1910), Beckwith (1933), Houston (1969), Knight (1953), de la Montagne (1953), and Mears (1953). Other pertinent published papers appear in the References.

Unpublished results of geologic investigations presented as graduate dissertations include those of Thomas (1928), de la Montagne (1953), McCallum (1964), and Cramer (1962).

Reconnaissance mapping of the Precambrian rocks was done by R.S. Houston while employed by the Geological Survey of Wyoming, and published as Memoir No. 1 by that agency.

The geologic mapping and investigation of this quadrangle and its peripheral areas has been carried out on a part time basis over a period of years beginning seriously in 1961. Mapping began on aerial photographs at a scale of 1:42,240 and was later supplemented by mapping on the topographic base, scale 1:24,000. The investigation was conducted to further the understanding of basement controlled folds in the region.

The writer wishes to acknowledge data received from R.S. Houston, S.H. Knight, and the late H.D. Thomas. Discussions with these individuals as well as with J.D. Love, M. McCallum, B. Mears, Jr., R.B. Parker, and W.H. Wilson, have contributed to the final result.

The interpretations are the writer's.

The writer wishes to acknowledge the many courtesies extended by ranchers in the area.

GEOLOGY

Stratigraphy

General

The exposed rocks range in age from Precambrian to Quaternary. Information concerning the rocks of Precambrian age is taken from Houston (1969) who presents a full discussion of the problems of the nomenclature of Precambrian rocks in the Medicine Bow Mountains. The Early Paleozoic is not represented since rocks of the Pennsylvanian Fountain Formation lie on the Precambrian basement.

The writer is familiar with the lithologic units involved, most of which have been described and discussed elsewhere. The writer has reviewed the published literature, consulted and checked many electric logs, and personally observed all map units on the outcrop though no detailed stratigraphic sections are presented. The thickness of units is based on well records and surface outcrop data.

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Essential stratigraphic information relative to this study is presented in Table 1.

Table 1. Stratigraphic units in the Rex Lake Quadrangle, Wyoming.

Age			General Lithology	Thickness
CENOZOIC	Quaternary	Recent	Alluvium, colluvium, landslide debris.	
		Pleistocene	Pediment gravels, glacial outwash, landslide debris(?). Outwash Qo from N. Fork; Qo_1 from Middle Fork, Little Laramie River.	0-100'
	Tertiary	Eocene	Wind River (?) Formation - Variegated claystone, sandstones.	200'+
		Paleocene	Hanna Formation - Basal conglomerate with quartzite boulders, arkosic sandstones, fossil wood.	1200'(?)
			Major Unconformity	
			Medicine Bow Formation - Sandstones, shales, carbonaceous shale, coals, ironstones. Pelecypod fauna. Only basal part present.	400'+
			Fox Hills Sandstone - Sandstone, gray, fine grained. Mapped with Lewis shale.	2200-2600'
			Lewis Shale - Shale, gray, marine, containing sandstone, fine grained, soft, local concretion zones.	
			Mesaverde Formation - Pine Ridge sandstone member at top (coal bearing). Sandstones brown, siltstones, and gray shales. Thick, yellow weathering sandstones near base.	1300-1500'
MESOZOIC	Cretaceous		Steele Shale - Shale, gray, marine. Persistent sandstone 1300' above base has been locally called "Shannon" sandstone.	2600-2900'
			Niobrara Formation - Calcareous shale with three well defined marlstone units.	500'
			Frontier Formation - Wall Creek Sandstone Member at top, "salt and pepper", sandstone, chert pebbles and shark teeth (at base).	10'
			Shale gray, changing to black at base. Septarian concretions in basal shale.	450'
			Mowry Shale - Shale, siliceous, weathers silver gray. Fish scales common. Numerous bentonite layers.	150'
			Muddy Sandstone - Sandstone, clean, medium grained.	20'
			Thermopolis Shale - Shale, black, marine containing thin lenticular olive green sandstone layers.	110'

Table 1 - continued

Age		General Lithology	Thickness
MESOZOIC	Cretaceous	Cloverly Formation - Tripartite unit. Limonitic yellow sand at top, pink siltstone in middle, and sandstone cross-bedded white, locally conglomeratic, at base.	150'
		Morrison Formation - Claystone, variegated, purple, green, maroon. Green chert and calcareous nodules.	300'
	Jurassic	Sundance Formation - Sandstone, yellow at top, green shale in lower part.	25-50'
	Permo-Triassic	Jelm Formation - Sandstones characterized by orange, pink, and lavender coloration. Lenses of clay pellet and limestone pellet conglomerate.	165'
		Chugwater Formation - Siltstones and sandstones, red, thinly bedded.	550'
	Permian	Forelle Limestone - Limestone, thinly laminated often "crinkled" or with algal bed structure. Lavender in color.	20'
		Satanka Shale - Shale or siltstone, red with local limestone layers.	120-160'
	Pennsylvanian-Permian	Casper Formation - Three units, upper yellowish sandstone, cross-bedded; middle hard red siltstone, lower sandstone, cross-bedded, white.	250'
	Pennsylvanian	Fountain Formation - Sandstone, arkosic, calcareous with interbeds of conglomerate. Pink to lavender maroon in color.	400'
	Precambrian	Granite, granite gneiss, and variable metamorphic rock types. See Wyoming Geological Survey Memoir No. 1 for complete discussion.	

The most serious stratigraphic problem is the age of the sedimentary strata lying above the sandstones heretofore mapped as the upper sandy units of the Cretaceous marine Lewis Shale. It appears that these upper sandstones are actually the Fox Hills Sandstone, and should be separated from the Lewis. The strata overlying this sandstone sequence have been described under several formational names, and the problems of correlating these units with the thick and complete sections of the Hanna Basin are not fully satisfactory.

Specific Stratigraphic Problems

The problems of correlation at this time are summarized in tabular form - Table 2, and are discussed below.

Cretaceous

Medicine Bow Formation

Within the Rex Lake quadrangle the youngest exposed rocks of Cretaceous age are assigned to the Medicine Bow Formation. The rocks are tan sandstones, carbonaceous shales, oyster bearing siltstones; concretionary ironstone beds, and a very local conglomerate containing pebbles of resistant sedimentary rock types. Pelecypods are locally abundant in the ironstone units.

The age of this unit on the basis of spores and pollen is late Upper Cretaceous. Age determinations were provided by Robert Tschudy, U.S. Geological Survey, Denver, Colorado, (Houston, p. 97, 1968).

In the Hanna Basin, about 35 miles to the northwest the same formation contains very similar beds in the basal part, but reaches a total thickness of about 4000 + feet.

Paleocene

Hanna Formation

The conformable sequence of strata of late Cretaceous age is unconformably overlain by strata correlated with the Hanna Formation of the Hanna Basin. The rocks mapped in the Rex Lake quadrangle as Hanna are characterized by bouldery conglomerates in the lower part, overlain by arkosic, pebbly sandstone containing large brown concretions, and siltstones. The conglomerates contain a large amount of quartzite, in fact the bulk of the material is quartzite. In addition there are significant amounts of chert (apparently Paleozoic in age), and quartz. Minor amounts of sandstone and materials derived from igneous and metamorphic rocks complete the suite. The unconformity between the Hanna Formation and the underlying Cretaceous is a strongly angular one and is clearly evident at two localities.

The first locality is in the NE$\frac{1}{4}$ sec. 29, T. 16 N., R. 77 W., at the site of an old coal prospect known locally as Citizen's coal mine. The well exposed contact between the marine Lewis Shale and the brackish water Medicine Bow Formation can be established on the basis of oyster bearing beds and coal seams, and changes strike from N. 50° E. to N. 70° W. around the nose of a fold. The Lewis Shale and Medicine Bow Formation in the southwest limb of the syncline are overturned, and pass directly beneath the overlying Hanna Formation which strikes E-W and dips approximately 5° N. The contact is sharp and can be traced for several hundred feet along the outcrop.

The second locality is at Bald Mountain and on the ridge to the west. The basal Hanna conglomerate can be traced around the southwestern and western faces of Bald Mountain, as shown on cross section B-B'. West of Bald Mountain on the ridge between Wards Gulch and the headwaters of South Fork Mill Creek there are conglomerates containing well rounded cobbles. It is the writer's belief that these conglomerates are the western extension of the Hanna Formation, and are overlapping older formations toward the mountains.

The age of the rocks herein mapped as Hanna Formation is believed to be Paleocene on the basis of palynologic collections made by R.S. Houston (1969). Samples from a fairly well exposed section of these rocks in sec. 6, T. 16 N., R. 77 W., about one-half mile north of the quadrangle boundary submitted to Mr. Robert Tschudy, U.S. Geological Survey, for identification, indicated that the Medicine Bow Formation is of Upper Cretaceous age, and that the overlying Hanna is of Paleocene age.

For the Bengough Hill quadrangle ten miles to the north the formational names Foote Creek (Late Cretaceous and Paleocene) and Dutton Creek (Paleocene) were used by Hyden (1966). The terms had previously been introduced by Hyden and others (1965) for rocks which herein are considered to be the correlatives of the Medicine Bow Formation and the Hanna Formation. Changes in this nomenclature are to be proposed by the U.S. Geological Survey.

Eocene

Wind River Formation (?)

Overlying the Hanna Formation in sec. 20, T. 16 N., R. 77 W., are about one hundred feet of varicolored (purple, green, maroon) claystones. The claystones are preserved on the downthrown side of a normal fault, occupy an area of approximately forty acres, and are well exposed in a deep gully resulting from overflow from the abandoned Douglas Willen irrigation ditch.

			Rex Lake Quadrangle This report 1969	Bengough Hill Quadrangle GQ 579 Hyden, 1966	W. G. A. Guidebook 8th Field Conference S. H. Knight, 1953	Rock Creek Field USGS Bull. 806-D Dobbin et al., 1929		Hanna Basin USGS Bull. 804 Dobbin et al., 1929
CENOZOIC	QUATERNARY	RECENT	Alluvium Colluvium				Pliocene(?) to Recent deposits	Terrace gravel
		PLEISTOCENE	Pinedale outwash Landslide material Pre-Wisconsin pediments	Gravel beds, several terrace levels				
	TERTIARY	PLIO.					Arlington terrace gravels	
		MIO.						N. Park Fm.
		OLIG.			Oligocene rocks			
		EOCENE	Wind River Formation(?) (Early Wasatchian)	Wind River Fm.	L. Eocene rocks	Tertiary rocks	Variegated beds equal to (?) Wasatch of other places. Hanna Fm. of Wasatch (Eocene age)	Hanna Fm.
		PALEOCENE	Hanna Fm. (Late Paleocene) Ang. Unconformity	Dutton Creek Formation Foote Creek Fm. Disconformity	Paleocene rocks			Ferris Fm.
MESOZOIC		CRETACEOUS	Basal part of Medicine Bow Fm. Fox Hills(?) Ss. Lewis Shale	Lewis Shale	Medicine Bow Formation Lewis Shale		Medicine Bow Fm. (not exposed)	Medicine Bow Fm. Lewis Shale containing Fox Hills fauna at top

Table 2. Stratigraphic nomenclature, and correlation.

The variegated claystones lie about 300' - 350' stratigraphically above the base of the Hanna Formation, but the contact relationships are not clear. The sediments have been tentatively correlated with the fossil bearing variegated claystones of the Cooper Basin a few miles to the north. Vertebrate fossils collected in badlands along Cooper Creek have been identified by Katherine Princhinello (1969) as a fauna characteristic of the Greybullian time interval (Early Wasatchian).

The lithologies are distinctive, and so similar to the dated Wind River Formation that the correlation is considered to be valid, despite lack of fossil evidence of age.

Quaternary

The Quaternary history of the region is evidenced in a variety of land forms, and associated deposits, but no attempt has been made by the writer to establish a critical chronology for this period of time. The geologic map reflects the writer's attempt to differentiate the major geomorphic features, but does not attempt to provide a complete treatment of the Quaternary. A good deal of the area is characterized by rather poor exposures of bedrock because of extensive colluvial type material. The reader is referred to de la Montagne (1953) for further detail.

One type of Quaternary deposit which warrants critical attention in this study is that resulting from mass gravity movement of material. One result of this type of activity has been to displace rather large masses of bedrock from their original structural position to lower topographic positions. Such occurrences are particularly evident on the east and north slope of Sheep Mountain. Misinterpretation of these features has complicated the structural interpretation offered previously (Beckwith, 1938). Details will be discussed under structural geology.

Structural Geology

General

In southeastern Wyoming three major mountain ranges dominate the structural pattern and from east to west are designated the Laramie Mountains, the northern Medicine Bow Mountains and the Sierra Madre. The Laramie Mountains and the Medicine Bow Mountains merge near the Wyoming-Colorado boundary and continue southward as the Colorado Front Range. The southern continuation of the Sierra Madre is the Park Range lying west of the North Park synclinal basin in Colorado. The uplifts are anticlinal in form and rocks of Precambrian age are widely exposed in the eroded cores. Compound synclinal basins lie between the major uplifts and are floored by Late Cretaceous and Cenozoic deposits. Peripheral to the major uplifts are a number of separate structural features including Ring Mountain, Jelm Mountain, and Sheep Mountain, in which rocks of Precambrian age are exposed. Associated with these discrete elements are synclinal depressions and complex fault relationships.

The structural features present in the Rex Lake quadrangle include a limited exposure of the southern part of the Arlington fault system that partially bounds the east flank of the northern Medicine Bow Mountains; the Centennial Valley-Mill Creek syncline; the Rex Lake anticline; the northern end of the Sheep Mountain block with associated faults and folds; a possible recumbent fold under the Arlington thrust; and normal faults.

A tectonic sketch map, Fig. 2, depicts the structural elements listed above.

Specific Structural Features

Arlington Fault System

The name Arlington fault was applied by Siebenthal and Darton (1909, p. 50) to a fault which they considered to extend along the east flank of Sheep Mountain and then northwestward along the Medicine Bow Mountains to the community of Arlington in Carbon County. Dobbin, and others, (1929, p. 144) further delineated the fault; King, (1964), Hyden, King and Houston (1967) and Houston (1969) provide additional details. The fault system is currently believed to be restricted to the Medicine Bow Mountain front.

The southern termination of the Arlington fault system is located in T. 15 N., R. 78 and 79 W., northwest of the community of Centennial, and appears to be a northeast trending shear zone in rocks of Precambrian age (Houston, 1969). At the north end of the Centennial valley the fault trace is well defined across the south slopes of Corner Mountain and then the trace approximates the stream course in Ward Gulch. The trace of the Arlington fault is believed to reappear in the SE$\frac{1}{4}$ sec. 14, T. 16 N., R. 78 W. at a considerably higher elevation along the ridge crest north of Ward Gulch.

The mass of Precambrian gneiss lying west of the elbow of the Ward Gulch drainage was originally emplaced as a part of the Arlington thrust plate. The dip of the original fault plane was approximately 15° west on

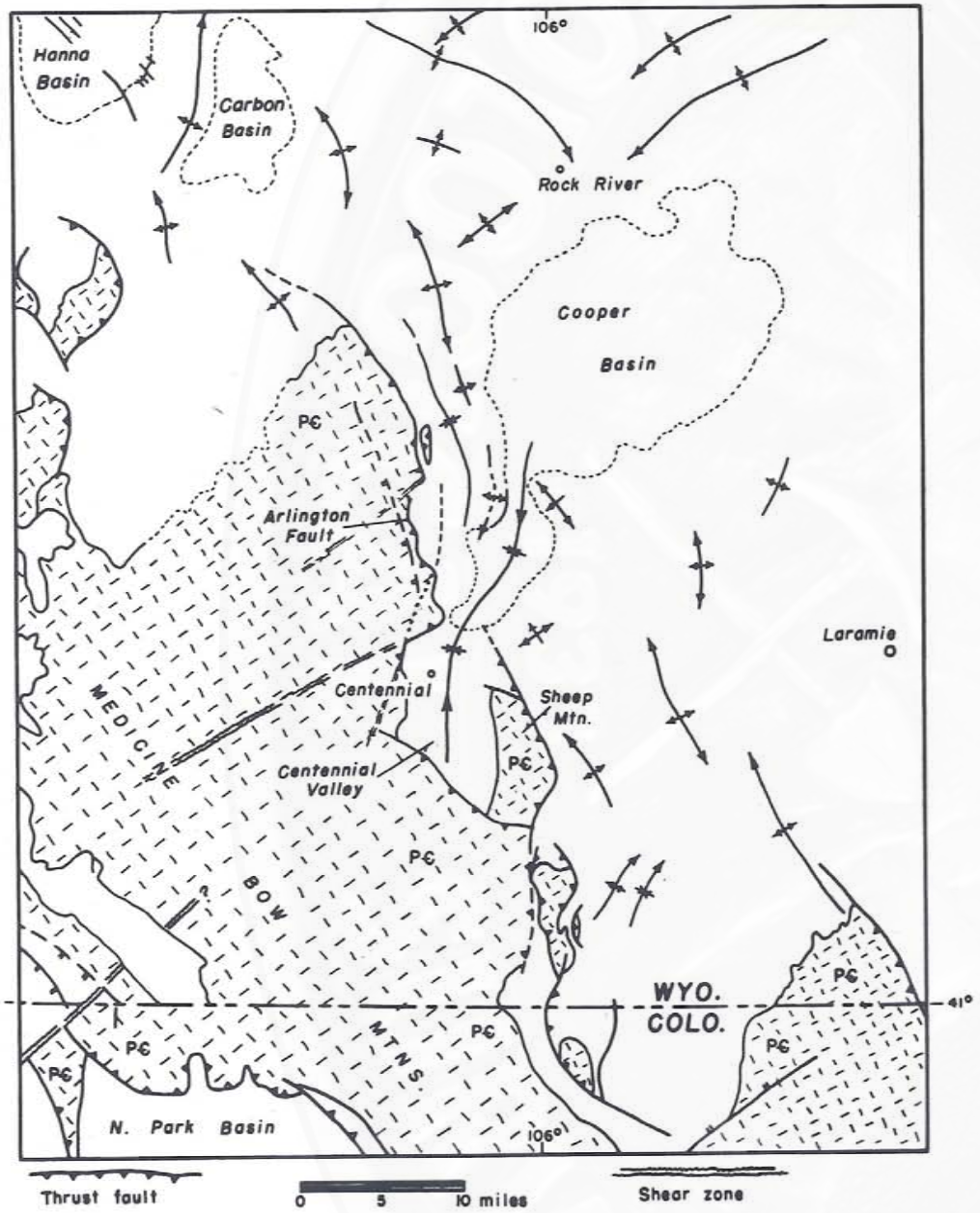

Fig. 2 Tectonic map showing the location of structural elements in the Medicine Bow Mountain area.

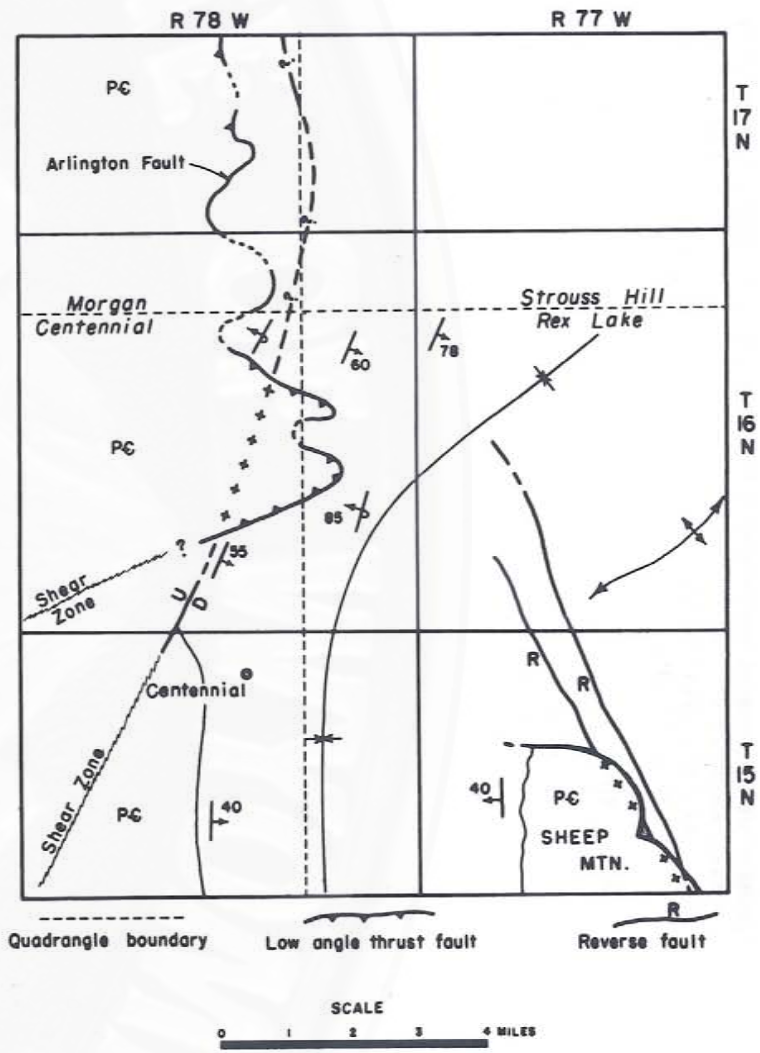

Fig. 3 Map showing boundaries of topographic quadrangles, and position of the Arlington thrust fault.

the basis of geological mapping in the Centennial quadrangle to the west. The Ward Gulch segment lies in fault contact with the Upper Cretaceous Niobrara Formation, Steele Shale, and Mesaverde Formation which dip at angles of 60° to 80° to the east, and strike approximately N. 25° W. Extensive landslides below the fault trace contain debris that can be identified as to formation, and which aid in the interpretation of the sub-thrust geology.

The base of the Ward Gulch segment of Precambrian rocks is at an elevation of 8800' at the southeast margin, and at about 9300' at the northwest edge. (See cross section B-B'). This discrepancy in elevation of the essentially west dipping Arlington fault plane is believed to be due to gravity movement of the segment. A segment of the Arlington thrust plate approximately two square miles in extent has rotated, and moved slightly southward, and downward. Separation took place upon a plane that trends N. 40° E., and dips steeply southeast.

The small area of Precambrian rocks lying above the trace of the Arlington fault plane north of Ward Gulch is believed to represent the toe of the thrust plate in original position. The exposures here are extremely poor and are located in dense lodgepole forest so that the interpretation depends upon photogeology. In view of additional mapping to the northwest the interpretation seems reasonable.

Associated with, and lying at a lower elevation than the trace of the Arlington fault an allocthonous mass of Chugwater, Forelle Limestone and Satanka (?) Shale is seen at the common corner of sections 13, 14, 23, 24, T. 16 N., R. 78 W. The mass has been derived from the rocks of the same age existing in the foot wall of the Arlington thrust, and will be discussed with the review of the cross sections.

Centennial Valley - Mill Creek Syncline

A broad shallow symmetrical syncline lying between the west flank of Sheep Mountain and the east flank of Centennial Ridge was described by Thomas (1928), and Beckwith(1938) and has been called the Centennial Valley syncline. Dips are approximately 40° to 45° on both limbs of the syncline, and in Centennial Valley proper the youngest strata involved are the upper units of the Steele Shale. The axial surface of the fold strikes essentially north-south in the southern end of the valley.

The west limb of the syncline steepens as the Arlington thrust fault is approached and is locally overturned in the vicinity of Bald Mountain. Likewise the axial surface of the fold changes in strike to N. 50° E. The fold continues beyond the quadrangle boundary to and across the valley of Mill Creek into the Strouss Hill quadrangle. The syncline is partially segmented by the faulted, compound, north plunging Sheep Mountain fold.

From Bald Mountain northeastward a conformable sequence of strata up to the lower Medicine Bow Formation, overlain unconformably by the Hanna Formation, lies in the trough of the syncline.

Rex Lake Anticline

Rex Lake lies in a breached anticline of the same name in which the sandy upper beds of the Steele Shale crop out in the topographic basin, and are in turn surrounded by a rim of concretionary sandstones of the lower Mesaverde Formation. The doubly plunging anticline is asymmetric to the northwest, the axial surface strikes approximately N. 55° E. and the steep limb is faulted at depth repeating the interval from the Permian Forelle Limestone to at least the Fountain Formation. (See cross section A-A'). The faults encountered in the lower section of three deep wells are believed to strike essentially parallel to the axial surface and dip to the southeast about 40°.

The trend of the anticline parallels that of the central segment of the Centennial Valley - Mill Creek syncline, and is one of several northeast-southwest trending structural features in the Laramie Basin.

Details concerning the discovery of the field, and production history are provided by Biggs and Espach (1960). Data concerning all wells drilled in the field are presented in Table 3.

Sheep Mountain Anticline and associated structure

The most prominent structural element in the Rex Lake quadrangle is the north end of the Sheep Mountain anticline, a north-south trending faulted structural feature in the core of which Precambrian Sherman type granite, and associated gneisses are exposed. The exposed area of Precambrian rocks is ten miles long, and six miles wide; is flanked on the west by strata overlying the basement in normal sedimentary contact; and is bounded on the east by faults.

The block is typical of many such structural elements in the Middle Rocky Mountain province. The "backside", or flank with the lesser dips is extremely regular, as the sedimentary sequence maintains a regular strike for several miles and the dip of the strata is uniformly about 40° west. The sediments have been stripped back from the core and crop out in a series of hogbacks and intervening strike valleys. The "front" or steep side of the ruptured fold is extremely precipitous, and the granitic core rises abruptly above the plains. Sedimentary

Table 3. WELL DATA-REX LAKE FIELD
T. 16 N., R. 77 W.
Albany County, Wyoming

OPERATOR	Location	Elevation	T. D.	Prod. Data	Depths to Formations: "Shannon" stray sands	Wall Creek Sandstone	Muddy Sandstone	Cloverly	Sundance	Chugwater	Forelle	Casper
Rex Dome Oil #1	300 F/S 300 F/E 14	7540(?)	1325	P. & A.								
Phillips Petroleum U. P. A. -#6-23	660 N/S 1977 W/E 23	7586	5700	D. & A.	1200	3262	3910	4025		4670	5400	5669
Ohio Oil Co. UP #1	330 FSL 1320 FEL 23	7561	3235	P. & A.	425-84							
Ohio Oil Co. UP #2	300 FSL 1420 FEL 23	7562	1800	P. & A.	1485							
Ohio Oil Co. UP #3	330 FSL 2040 FWL 23	7588	3942	Prod.			3760	3933				
Ohio Oil Co. UP #4	240 FSL 2540 FWL 23	7584	425	D. & A.	362-425							
Ropollo Oil Co. #1	330 FNL 330 FWL 25	7535	4295	P. & A.	1705	3630	4209					
Ohio Oil Co. #4 Coughlin	1670 FNL 885 FWL 26	7540(?)	448	P. & A.	423-48							
Ohio Oil Co. #1 Coughlin	1020 FNL 1620 FWL 26	7584	4436	Prod.	1175	3095	3723	3868		T.D. in Trc		
Ohio Oil Co. 1 #2 Coughlin	330 FNL 2310 FEL 26	7573	4053	P. & A.				4022				
Ohio Oil Co. #3 Coughlin	475 FNL 675 FEL 26	7550(?)	450	P. & A.	383-98							
Ohio Oil Co. #5 Coughlin	1320 FNL 1620 FWL 26	7570(?)	1618	P. & A.	1490-1580							
Wasatch #6 Coughlin	SW NW NW 26	7621	3968	Prod.	1260	3152	3835	3955				
Kingwood Rex Lake #1	2310 FNL 1650 FWL 26	7536	5900	D. & A.	1331	3360	4060	4228	4733	4975	5650	5790
Kingwood-Phillips Rex Lake #2	660 FNL 990 FWL 26	7619	5903	D. & A.	1254	3160	3770	3885	4338	4620	5490	5850
Phillips-Rex Lake #1 or Coughlin #7	NE SW NW 26	7551	6108	Prod.	1215	3090	3713	3824	4189	4460	5210 5590	5760
Ohio Oil Co. UP #1	2390 FNL 250 FEL 27	7536	3924	Prod.				3891				

rocks in the footwall beneath the bounding fault or faults are strongly overturned, locally sliced, and somewhat sheared adjacent to the fault.

In this particular case the eastern side of the mass is bounded by three faults, the principal of which is known as the Sheep Mountain fault. At ground surface the fault plane appears to dip approximately 40° to the west (cross section E-E'), but probably steepens at depth. Movement on this fault plane has placed Precambrian Sherman type granite in contact with overturned red beds, probably the Permo-Triassic Chugwater Formation. The thrust fault strikes N. 25° W. for several miles but within the quadrangle mapped the strike changes some 50° to a direction of N. 65° to 70° W. and is the northern boundary of the uplifted segment of Precambrian rock.

All strata on the east flank of Sheep Mountain involved in the fault relation are overturned and dip to the west. In the interpretation presented on cross section E-E' the combined slip on the three fault surfaces is approximately 6500 feet. Stratigraphic separation is approximately 4000 feet. Faults are shown as concave downward in attitude. Total differential structural elevation from the trough of the adjacent syncline, to the restored crest of the Sheep Mountain uplifted block is approximately 11, 000 feet.

South of Johns Creek near the common corner of sections 14, 15, 22, and 23, T. 15 N., R. 77 W., the surface trace of the three reverse faults can be established. The fault traces are then concealed until they reappear north of Wyoming Highway No. 130. In this area of extensive landslide debris Beckwith (1938, p. 1538) recognized the possibility that:

> ". . . some of the small patches of Niobrara and Steele shown on the map have probably been carried eastward by landslides."

However, he chose to separate the allochthonous masses of Niobrara Formation from the steeply dipping Steele Shale and Mesaverde Formation by a reverse fault. The present interpretation suggests that there is autochthonous Niobrara along the northeast flank of Sheep Mountain in the core of a fault-bounded anticline, and that the exotic masses in the landslide material were derived from the core of the anticline.

In the vicinity of U.S. Highway 130, five tests have been drilled for oil and gas. Records are available for four of these. By utilizing electric logs, dipmeter surveys, and core data in conjunction with surface mapping it is possible to delimit the three faults. The faults strike generally N. 30° W., and dip to the southwest. The displacement of strata on these faults decreases to the north, and one fault appears to pass beneath the unconformable Hanna Formation in sec. 20, T. 16 N., R. 77 W.

The group of faults, and related folds, extends the Sheep Mountain element northwestward and down plunge for some four miles from the northernmost outcrop of Precambrian rocks. The northwest trending structures cross the axis of the Rex Lake anticline which trends N. 60° E. and terminate that fold on the southwest.

The Sheep Mountain structural unit is paralleled on the northeast by a doubly plunging syncline that can be clearly defined in the Mesaverde Formation and that continued southwestward for several miles beyond this quadrangle.

Normal Faults

One distinct normal fault exists northwest of Citizens Coal mine in secs. 12, 20 and 21, T. 16 N., R. 77 W. The fault trace can be established from aerial photographs; a series of small springs that discharge along the trace; and by the fault contact between the Wind River Formation (?) and the Hanna Formation. The fault strikes N. 45° W., and is downthrown to the southwest. The amount of displacement cannot be accurately established, but on the basis of the thickness of Wind River (?) exposed may not exceed 300 feet.

At the northwest corner of the exposures of Precambrian rocks in the core of Sheep Mountain there are two normal faults of small displacement.

Development of Geologic Structure in the Rex Lake Quadrangle

General

No single 7 1/2 minute area of the earth's surface is a complete geologic entity in itself. The present case is no exception, and it is necessary to bring into the discussion evidence derived from adjacent areas to aid in the interpretation of the structural geology. Pertinent data has been discovered by mapping the sedimentary rocks exposed in the eastern third of the Centennial quadrangle immediately to the west; in the southeast corner and eastern part of the Morgan quadrangle to the northwest; and in the southern part of the Strouss Hill quadrangle lying directly to the north.

The major structural features are shown on a tectonic map, Fig. 2. The reader observes that the area in question lies east of the main body of the northern Medicine Bow Mountains, and includes some of the ancilliary structural elements that roughly parallel the east flank of the mountains. The principal direction of tectonic movement based on dip of fault planes, and asymmetry of folds is to the northeast throughout a rather large region. The exception to this sense of movement lies in structures such as Ring Mountain, Jelm Mountain, Quealy Dome, Seven Mile anticline, etc., which are asymmetric to the west.

The apparent direction of tectonic transport changes south of the Colorado-Wyoming boundary as demonstrated by the Independence Mountain thrust fault (Walters, 1957, Blackstone, 1953) which dips to the northeast, and exhibits movement to the southwest.

Arlington Thrust Fault

The Arlington thrust fault trace which is so well exposed as it crosses the south slope of Corner Mountain approximately two miles north of the community of Centennial is also well exposed in the northwest corner of the Rex Lake quadrangle. The fault can be mapped northwestward with varying degrees of accuracy to the community of Arlington (T. 19 N., R. 78 W.) in Carbon County. (Fig. 2). The sudden appearance of this fault in the vicinity of the North Fork of the Little Laramie River in sec. 28, T. 16 N., R. 78 W. has always been enigmatic. Topographically down slope from the fault trace along the south slope of Corner Mountain there are extensive areas of landslide material in which can be recognized lithologies of several sedimentary units that must lie beneath the Precambrian rocks of the thrust plate. In the Rex Lake quadrangle the Steele Shale, Mesaverde Formation and Lewis Shale strike N. 10° E., and dip eastward or are slightly overturned immediately east of or beneath the Arlington thrust plate. The Steele Shale and Niobrara Formation can be traced northward along strike, and they presumably pass beneath the thrust plate to reappear in the extreme northwest part of the quadrangle in the headwaters of South Fork Mill Creek. It is obvious that the thrust plate is overriding the near vertical sedimentary succession in the west limb of the Centennial Valley - Mill Creek syncline, and that the fault plane dips to the west at approximately 15°.

Less obvious is the relationship of the lower part of the sedimentary succession (Fountain through Cloverly) which strikes north-south and dips eastward into Centennial Valley from the flank of Centennial Ridge (Beckwith, 1938). As these units are traced northward from the latitude of Centennial the dip steepens to 55°, and the Fountain Formation is partially omitted and is in fault contact with Precambrian rocks in sec. 33, T. 16 N., R. 78 W. (McCallum, 1964, 1968). At about this point all units are concealed by the terminal moraine at the mouth of Libby Creek, and immediately beyond that to the north the rocks at the surface are of Precambrian age and lie above the Arlington thrust fault. The relationships are shown schematically on Fig. 3.

Along the headwaters of South Fork Mill Creek at elevations of 9,400' to 10,000' in the Morgan quadrangle there are extensive exposures of red beds, probably Permo-Triassic Chugwater Formation; fragments of Forelle Limestone in the float; and some exposures of sandstone which may be Casper Formation. Some of the red beds appear to have inverted dip and to be the extension along strike of the sedimentary succession which flanks Centennial Ridge. The situation is partially shown in Cross Section A-A'. At the extreme western end of section A-A' it is believed that at the surface Precambrian rocks probably are in fault contact with steeply dipping Niobrara Formation or Steele Shale. Exposures are very poor. The trace of the Arlington fault is deeply embayed westward at the head of South Fork Mill Creek (Fig. 3) and in the re-entrant overturned Chugwater (?) red beds are exposed.

To explain - (1) the recumbent attitude, and (2) the high topographic position of the red beds the writer believes that the fault mapped by McCallum (1968) at the north end of Centennial Ridge must be older than the Arlington thrust, must dip to the west, and movement on this fault has brought the Chugwater to a high structural position on its western and hanging wall side. Subsequently, the Arlington thrust developed, and moved eastward to overide the Centennial Ridge fault.

The eastward advance of the Arlington thrust plate overturned and disturbed the Chugwater and other units on the west dipping flank of the earlier fold. Evidence of such an earlier fold is provided by the scattered outcrops of Paleozoic and Mesozoic strata in the headwaters of Seven Mile Creek in the Morgan quadrangle (Houston, 1969).

The allocthonous mass of Satanka, Forelle, and Chugwater shown on Cross Section A-A' is anomalous, and difficult to explain. It is possible that the mass was initially transported eastward on the toe of the Arlington thrust plate, and moved downslope from that original position. It is equally probable that the mass moved by gravity from the flank of the fold now buried beneath the Arlington thrust plate, and therefore is older than the Arlington thrust.

As shown on Fig. 3, both the Centennial Ridge fault (older) and the Arlington thrust (younger) are related to, and apparently rooted in shear zones in the Precambrian terrane (McCallum, 1968, Houston, 1969). The Centennial Ridge fault appears to be the extension of a shear zone extending southward generally along the deep valley

of the Middle Fork Little Laramie River, on the west side of Centennial Ridge. The shear zone offsets Precambrian rock units, and the earliest movement must be of Precambrian date. Certainly there has been reactivation during Laramide time with resultant displacement of the sedimentary succession lying above the Precambrian.

The Arlington thrust fault is restricted to the rocks lying north of a shear zone that trends N. 55° E., that extends for a distance of some ten miles southwestward from Libby Creek, and that is a branch of the Nash Fork-Mullen Creek shear zone. The Arlington thrust fault in the vicinity of Corner Mountain strikes approximately N. 10° W., and dips about 15° SW., with a minimal eastward displacement at this locality of approximately 7,000 feet on the basis of the stratigraphic interval in the footwall. The thrust plane may steepen with depth, but no evidence is available on this point. The maximum lateral displacement on the thrust plane is in the vicinity of Corner Mountain and decreases northward.

Sheep Mountain Anticline

The Sheep Mountain structural element appears at first observation to be a classic example of germanic style deformation so common in the Wyoming section of the Rocky Mountain region. Perhaps it is such an example but certain unique features warrant discussion in order to clarify the nature of such deformation.

The exposed core of Precambrian rocks in Sheep Mountain consists almost entirely of pink, coarse grained granite similar in all gross aspects to the Sherman granite of the Laramie Mountains though at the north end of the block about two square miles of older granite and hornblende gneiss is exposed (Houston, 1969). The block therefore may be considered as essentially homogeneous in composition, but extensively jointed (Cramer, 1962).

The detailed mapping of the east flank of Sheep Mountain for several miles southward beyond the southern border of the Rex Lake quadrangle reveals that the block is bounded by two, and frequently by three faults.

The most conspicuous fault relationship is that which places the Precambrian granite in fault contact with Permian-Pennsylvanian rocks or with Permo-Triassic rocks. The fault plane was not directly observed at any point because the east face of Sheep Mountain has been over steepened by extensive landslides composed of great blocks of granite that conceal the bedrock. In a few deep valleys the red beds in the footwall can be found within two to four hundred feet laterally from granite in place in the hanging wall. The relationship of the overturned red beds suggests that the fault plane dips steeply to the west. Displacement on the fault plane must be in excess of 6,000 feet to allow for the projection of the sediments over the crest of Sheep Mountain.

The second major fault lies farthest to the east and at the surface transects Cretaceous rocks. In the southeastern corner of the quadrangle Steele Shale lies in the footwall of the fault situation, and is overturned 15° to 20°. As one traverses northward along the fault trace the Mesaverde, and Lewis in turn occupy the footwall position. The hanging wall consists from north to south of Mowry, Frontier(?), Niobrara, and Steele Shale. The fault plane must dip westward at a fairly steep angle to account for the overturned dips in the footwall.

A third major fault can be traced from the southern margin of the quadrangle in a N. 15° W. direction to the southwestern corner of sec. 20, T. 16 N., R. 77 W. where the fault trace is unconformably overlain by the Hanna Formation. The northern segment of the fault lies east of a well defined northwest plunging anticline. The Dyer & Rice No. 3 May, sec. 5, T. 15 N., R. 77 W. cut this fault plane in the well bore. The southern segment of the fault trace is poorly exposed, and appears to pass beneath the Precambrian rocks lying above the Sheep Mountain fault plane.

The segment of sedimentary rocks bounded by the second and third faults discussed above is folded into a sharp anticline. This anticline can be defined by surface mapping and is further delineated on the basis of data derived from wells drilled in sec. 5, T. 15 N., R. 77 W. The anticline trends approximately N. 15° W. and plunges in the same direction.

A striking aspect of the Sheep Mountain relationship is the northwest plunge. The narrow anticlines in the sedimentary succession plunge northward at rather low angles (10° to 15°), and the outline of the major structure as defined by the Steele Shale-Mesaverde Formation contact suggests a plunge of near 25° northward. In secs. 8 and 9, T. 15 N., R. 77 W., the fold as outlined by the Chugwater-Forelle contact would require that the plunge exceed 40° to the northwest. The relatively flat plunge of the narrow northwest trending anticlines suggests that these reflect the initial deformation. A fracture propagated upward from the basement rocks defined the northwest plunging structure, and as the basement segment on the hanging wall of the initial fracture or fractures was elevated and possibly rotated a cross fracture developed. The result was to allow that part of the basement now expressed as the topographic feature Sheep Mountain to rise and relieve the stress.

The exposed area of Precambrian gneiss and granite is terminated by the cross fault accentuating the block like appearance of Sheep Mountain so that the northeast corner of Sheep Mountain duplicates the "trap door" faulted blocks described elsewhere in Wyoming.

The difference between Sheep Mountain and several"trap door" type structures is that the initial movement on the basement fracture extended several miles farther north than the present area of exposed Precambrian. After initial displacement the block ruptured along a roughly east - west line allowing the southern segment to rise easily and to a much greater height. The northern segment was already deformed into sliced anticlines and remained relatively passive after the basement cross fracture developed.

The development of these faults may have been in the following order. The Sheep Mountain segment of Precambrian rocks was defined by fractures which bound the east and southeast margins. Movement upon these fractures may have produced a fold in the overlying sedimentary strata in the nature of a "drape fold". If major movement on this fracture plane had been the principal event, it appears that an early and primary fault would have been propagated upward through the sedimentary column and allowed the Precambrian rocks to override the footwall.

If such had occurred first, and been the dominant and controlling aspect there seems to be no reason for the development of the folds and faults which extend northwestward for five miles from Sheep Mountain.

An alternate explanation suggests that the early movement which generated the northwest plunging part of the Sheep Mountain block was upon a fracture plane represented at the surface by the easternmost fault trace. Some eastward crowding took place and was relieved by folds and faults. Elevation (and possible rotation) of the block of Precambrian granite continued so that the granite mass was raised rather precipitously upward upon a fault surface represented now by the most westerly (Sheep Mountain) fault trace.

The cross sections show the major fractures to be listric surfaces of fleur de lis shape, concave downward. Positive evidence for this is minimal, but current analysis suggests this to be a reasonable interpretation.

Age of Faulting

The date of the movement on the Arlington fault cannot be positively established, but the stratigraphic record suggests the following chronology.

The youngest exposed Cretaceous rock unit, the Medicine Bow Formation, along with all older strata, is folded to a near vertical position on the west flank of the Mill Creek syncline, but not all units are in fault contact with Precambrian rocks lying above the Arlington fault plane. The youngest unit actually in fault contact with Precambrian rocks is the Mesaverde Formation.

The deformed strata at Bald Mountain are overlapped with strong angular unconformity by the conglomeratic basal part of the Paleocene Hanna Formation. On the north side of Ward Gulch in sections 13, 14, 23 and 24, T.16 N., R.78 W. a small allochthonous mass of red beds including Forelle Limestone is overlain by a conglomerate including well rounded cobbles of quartzite. The cobble bearing strata are poorly exposed but cap the ridge, extend to the northwest and appear in turn to be over ridden by the Precambrian rocks in the toe of the Arlington fault. (see Cross Section A-A', Plate 1). The conglomerate is not continuous with that on Bald Mountain but is inferred to be the western extension of the Hanna Formation exposed there.

The interpretation offered above indicates that the Centennial Ridge fault developed first and is earlier than the deposition of the basal conglomerate of the Hanna Formation. Following the folding and faulting in this episode of deformation, the rocks were beveled by erosion, and across this surface was spread the coarse debris now comprising the Hanna Formation. The eastward movement of the Arlington fault plate followed the deposition of at least the basal Hanna.

The Hanna Formation in the Mill Creek syncline is strongly folded, indicating that the episode of deformation during which the Arlington fault developed, also further folded the Paleocene Hanna Formation.

Within the Rex Lake quadrangle there is only one outcrop area of rocks tentatively assigned to the Early Eocene Wind River Formation. The Wind River Formation crops out over parts of several townships in the nearby Cooper Lake Basin, and in much of that area the Wind River overlies the Hanna with slight discordance, and the underlying Hanna in turn overlies Lewis Shale indicating an extensive overlap.

It is believed that in the map area the Wind River(?) unconformably overlies the Hanna and overlaps it toward the mountains. The Wind River Formation is tilted, indicating that the principal episode of faulting and folding was completed by Early Wasatchian time.

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