ANTICLINES IN CENTRAL WYOMING.

By C. J. Hares.

INTRODUCTION.

The area herein designated central Wyoming, as shown in figure 16, covers nearly 5,000 square miles in Natrona and Fremont counties west of Casper and southeast of Lander, and includes no proved oil

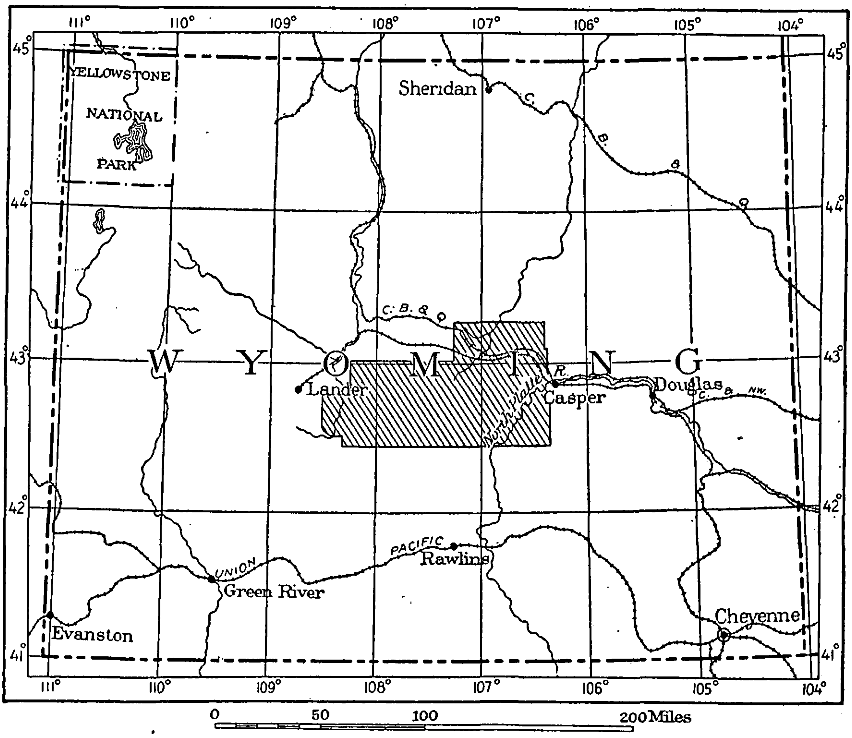

FIGURE 16.—Index map showing position of area designated central Wyoming.

fields. This area was investigated primarily to ascertain the possibilities of oil, and as a result it was found that the Carboniferous and Cretaceous formations which produce oil in other Rocky Mountain fields are well developed in central Wyoming and in places the oil seeps from them, but that in only a few places are these formations covered by impervious shale and within reach of the drill in folds favorable for the accumulation of oil and gas. The favorable folds are the Pine dome, the Oil Mountain anticline, the anticlines between Poison Spider and South Casper creeks, and the Emigrant Gap, Iron Creek, North Casper Creek, and Bates Hole anticlines, but even these most favorable folds may be barren of oil. The Cretaceous oil sands are below the surface in the Big Sand Draw anticline, in the anticline southwest of Powder River, and in the dome (?) on Wallace Creek, but each one has some disqualifying features. The oil-bearing formation may be too far below the surface to be easily reached by the drill, or the anticline may be incomplete—that is, the axis may pitch in one direction only, allowing any possible oil that the sand may have originally contained to migrate upward along the strata to the surface and to escape, either during the period of erosion prior to the deposition of the flat-lying variegated Tertiary beds that rest on the truncated edges of the folded Cretaceous and Carboniferous formations or during the present erosion period.

The area is in the Wyoming lowlands of the Rocky Mountain division of the United States, and is one of varied character, as it includes mountains, high escarpments, plateaus, badlands, and some large streams, but even though the area lies across the backbone of the Rocky Mountains and extends nearly to the Continental Divide, it is devoid of lofty snow-capped peaks. It is a natural pass over the mountains where the altitudes range from a little over 5,000 to 8,210 feet. This pass was chosen by the pioneers journeying overland to California and other parts of the far West. The Laramie Mountains border it on the southeast, the foothills of the Bighorn Mountains extend into the northeast part, and the Ferris, Pedro, Freezeout, and Seminoe mountains lie to the south. Sheep Mountain, on the western edge of the field, forms a part of the foothills of the Wind River Mountains. Crooks Mountain and Green Mountain are situated along the southern border and the Granite Mountains, in the middle-southern part of the area, are bare rugged granitic masses rising to an altitude of 8,040 feet in Hayden Peak, about 2,000 feet above the Sweetwater Valley. Sweetwater River unites with the North Platte in the Pathfinder reservoir, and the North Platte crosses the extreme southeastern part of the area and flows eastward into the Missouri. Twin Creek, which drains the northwest corner, flows into Little Popo Agie River, a tributary of Wind River. Beaver, Conant, Deer, and Muskrat creeks flow northward into Wind River and eventually into the Missouri by way of Bighorn and Yellowstone rivers. Wallace Creek, an upper tributary of Powder River, flows northeastward and eventually into the Yellowstone. The Rattlesnake Mountains, which rise 8,210 feet above sea level in the middle of the area, with the Sweetwater escarpment, form a part of the divides between these river systems.

The area may be reached from the east by the Chicago & Northwestern and Chicago, Burlington & Quincy railways, which cross the northern part of the area, or from the south by journeying 50 miles overland from Rawlins or other stations on the Union Pacific Railroad. The country is so sparsely settled and the land is so rough that many of the wagon roads are mere trails and usually follow of necessity the easiest route between towns or between some ranch and the nearest town on a railroad. Intricate badlands and other uneven features make travel difficult and haulage slow and unfit the land for agriculture.

Prospectors have been attracted by the indications of oil about the anticlines, but the rough land, the scarcity of permanent streams, and the remote location of good springs and fuel have controlled the location of drilled wells to the extent of preventing the prospecting of some of the more favorable parts of the anticlines for oil or gas. In addition to high freight rates there are excessive charges for teaming overland to the wells, most of which are from 10 to 30 miles from a railroad.

The subbituminous coal beds west of the Pine and Oil mountains, east of the Rattlesnake Mountains, north of the Dutton anticline, east of Alkali Butte, and on Big Sand Draw are available for fuel in these localities, but in the eastern part of the area coal beds are absent and other sources of fuel must be found. In the northeast corner of the area oil is available from the Salt Creek field by a day's haul, and in the eastern part by a similar haul from Casper. Timber is scarce, and most of the trees are scrub pine and cottonwood. The better timber is restricted to the higher mountains.

Prospecting for oil and gas in central Wyoming, because of the surface conditions outlined above, is expensive.

The geologic work upon which this report is based was begun in July, 1913, and completed in the autumn of 1914.

ACKNOWLEDGMENTS.

The writer appreciates the suggestions and criticisms of M. R. Campbell, who had general supervision of the work, and gratefully acknowledges the assistance of his associates in the field, M. W. Ball, Stuart St. Clair, J. B. Reeside, jr., K. C. Heald, and A. C. Collins. Many kindnesses were extended to the party during both field seasons by the ranchers and other persons living in the area, also by the oil companies engaged in prospecting the region

WATER SUPPLY.

Sweetwater River unites with the North Platte in the great Pathfinder reservoir, which stores water during the flood seasons for irrigation in eastern Wyoming and western Nebraska. These rivers and most of the creeks near their sources contain running water throughout the year, but the smaller creeks flow only early in the spring or after heavy showers. Even Powder River during the summer goes dry along most of its course, and though Beaver Creek supports trout above Hailey it runs dry farther down. As the precipitation averages only about 10 inches a year and usually falls in heavy showers the area is in the semiarid belt. Throughout the region there are many springs of good water, as well as many in which the water is exceedingly alkaline. The abundance of springs, together with the number of running streams, makes the country locally well watered and admirably adapted to stock raising. There is a large warm spring flowing good water at the head of Horse Creek, in sec. 35, T. 32 N., R. 86 W.; hot water rich in mineral salts issues from the gorge in the banks of North Platte River just above Alcova; and a big spring of excellent water in sec. 15, T. 32 N., R. 81 W., is used to irrigate about 1,000 acres of the Bessemer flats. The Big Sulphur Springs, in sec. 5, T. 38 N., R. 83 W., are locally well known. There is also warm water issuing from the sides of Beaver Gorge, about 4 miles above Hailey, in T. 30 N., R. 97 W. The Warm Springs, near the center of T. 29 N., R. 95 W., and Happy Springs, in the southeast corner of the same township, are valuable. Dams are built by ranchers in the dry valleys to pond the run-off of heavy showers and thus make it available for stock. This practice is followed also by oil companies to obtain water for drilling operations. At times, however, water for drilling must be hauled or piped from some distant creek or spring.

All the deep wells in this area have found artesian water in the sandstones. This fact and the presence of large springs indicate that artesian water may be obtained in many parts of the area where the structural and topographic conditions are favorable.

The Lower Cretaceous conglomerate is the principal water-bearing formation and usually furnishes a strong sulphur water. The sandstones in the other formations generally contain water in less quantity, because they are less continuous and less uniform in thickness and texture.

OBJECT OF THE SURVEY.

The examination of central Wyoming was undertaken to determine whether or not the region contains anticlines or other folds favorable for the accumulation of oil and gas and also the number and occurrence of oil sands. If favorable folds are present, the next important question is whether the oil-bearing sands are sealed below impervious rocks in those folds so as to hold the oil and gas or whether those sands have been exposed by erosion, allowing the oil and gas to escape.

The table facing page 238 illustrates the fact that in most of the Rocky Mountain oil fields the oil seeps and productive sands are confined chiefly to Cretaceous strata. The occurrences outside of the Cretaceous so far discovered have proved of minor economic importance.

The Wall Creek sandstone, the uppermost sandstone member of the Frontier formation, is the main productive sand at Salt Creek and the oil has a gravity of 0.82 to 0.85. Some oil having a specific gravity of 0.909 is obtained at Salt Creek in the Shannon sandstone lentil of the Steele shale, and some is also obtained in the Niobrara.[1] In the Grass Creek field the middle part of the Frontier formation bears oil, and along Shoshone River gas is obtained from the upper part of the Cloverly and some oil from sandstones in the Thermopolis and Mowry[2] shales but most of the oil (specific gravity 0.833) comes from a sandstone in the lower part of the Thermopolis shale.

At Greybull,[3] in the Peay anticline, gas and a light-gravity oil occur in the Kimball sand of the Mowry shale and in the top of the Cloverly. In the Torchlight dome at Basin a light oil of 0.7955 gravity occurs in the Peay sand of the Frontier formation, but in the Lamb anticline a heavy oil of 0.889 gravity occurs in the Kimball sand and the Peay sand, and gas occurs commercially in the Peay sand and in traces only in the Torchlight, Muddy, and Kimball sands.[4]

At Elk Basin gas and a light-gravity oil occur in sands (Frontier) of Benton age, and at Byron oil occurs in the Frontier and gas in the Cloverly.

At Spring Valley a light oil of 0.82 gravity occurs most abundantly in the Aspen shale, and to some extent a heavy oil occurs in the Bear River and Frontier formations. The Wasatch produces oil at both Spring Valley and Labarge, but according to Veatch[5] and Schultz[6] the Wasatch oil has migrated from the underlying Aspen shale. Sandstone in the Graneros shale at Moorcroft has produced the little oil obtained there,[7] which has a specific gravity of 0.919.

At Douglas the top of the "Cloverly" (Dakota?) produces some oil, and the sands (Frontier) of Benton age, both oil of gravity 0.843 to 0.93 and gas, but most of the commercial product comes from the

[1] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 37-83, 1911.

[2] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, pp. 89-113, 1914.

[3] Hintze, F. F., Basin and Greybull oil and gas fields: Wyoming State Geologist's Office Bull. 10, p. 45, 1914 [1915].

[4] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, pp. 157-190, 1916.

[5] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, p. 158, 1907.

[6] Schultz, A. R., The Labarge oil field, central Uinta County, Wyo.: U. S. Geol. Survey Bull. 340, p. 364, 1908.

[7] Barnett, V. H., The Moorcroft oil field and Big Muddy dome, Wyo.: U. S. Geol. Survey Bull. 581, pp. 83-117, 1914.

White River formation. According to Barnett,[1] however, the gas and oil obtained from the White River has probably been derived from the underlying beds of Benton age or from the "Cloverly" and is secondary in the White River.

At Lander, in the Big Popo Agie field, the oil at the Washakie oil spring and in the Plunkett well and other wells near by in the north end of the anticline is derived from the Mowry shale.[2] It has a gravity of 0.812. The heavy dark-brown oil (specific gravity 0.9+) comes from the Embar (Pennsylvanian to Lower Triassic) and Chugwater (Triassic) formations.

From this brief summary it is evident that the best oil (specific gravity 0.7955 to 0.856, or 45.98° to 33.5° Baumé) produced in paying quantities in the Wyoming fields is obtained from the Cretaceous rocks, and chiefly from beds of Colorado age, though much comes from beds of Montana age. A small quantity of oil of lower grade (specific gravity 0.9198 to 0.9091, 22.2° to 24° Baumé) comes from the Embar beds.

As the Lander field, in which the only notable quantity of oil comes from the Embar formation, joins on the west the area treated in this report, it seems reasonable to consider carefully any anticline or dome in this area in which that formation is sealed beneath impervious rocks and within reach of the drill. Any anticline or dome where the important oil-bearing formations of the Cretaceous are closed beneath thick beds of shale should be considered still more carefully.

The accumulation of oil and gas in all the productive fields of Wyoming, except Spring Valley and Douglas, is controlled by anticlinal folds. At Spring Valley the oil accumulates in a syncline—the reverse fold of an anticline—probably because the rocks are not saturated with water, a condition which allows the oil by force of gravity to seek the low places in the downfold or syncline.

In central Wyoming the wet porous sands occur between impervious shales. Where oil-bearing formations under such conditions have been folded the anticlines and domes have been found to be the favorable places for the retention of oil and gas, presumably because oil and gas, being lighter than water, are floated and forced to the crests of the anticlines and domes, or at least as far up as the water has any head. If, as is the case in many of the anticlines in central Wyoming, erosion has removed parts of the oil-bearing formations, the oil and gas have had ample chance to escape and there is little possibility of their retention. In such places indications of oil occur as seeps along the outcrop of the sandstone. Wells drilled down the

[1] Barnett, V. H., The Douglas oil and gas field, Converse County, Wyo.: U. S. Geol. Survey Bull. 541, pp. 49-88, 1914.

[2] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 7-36, 1911.

Sections showing occurrence of oil and gas in some of the Rocky Mountain fields.

[Correlations approximate and sections incomplete. o., Oil; g., gas; +, seeps or small production of oil or gas.]

System or series.	Group.	Spring Valley and Labarge.[a]	Grass Creek [b] and Oregon Basin.	Shoshone River.[b]	Greybull.[c]	Basin.[d]	Lander.[e]	Wyoming.[f]	Central Wyoming (this report).	Salt Creek and Powder River.[g]	Douglas.[h]	Moorcroft and Newcastle.[i]	Boulder, Colo.[j]	Florence, Colo.[k]
									White River. +		White River. o. g.			
Tertiary.		Wasatch. +o.	Wasatch.	Wasatch.			Wind River.	Wasatch. +	Wind River. +?					
		Evanston.	Fort Union.	Fort Union.	Fort Union.	Undifferentiated Fort Union and Lance.	Absent or concealed.	Laramie. Fort Union.	Fort Union.	Fort Union.	Fort Union.			
Tertiary(?).			Lance.	Ilo (Lance).	Ilo.				Lance.	Lance.	Lance.			Laramie (?).
		Adaville.	Meeteetse.	Meeteetse.	Montana, undifferentiated.			Fox Hills.	Lewis.	Fox Hills.	Fox Hills.	Fox Hills.	Fox Hills.	Trinidad. (?).
	Montana.		Mesaverde.	Gebo.	Eagle.	Mesaverde.	Mesaverde.		Mesaverde. Teapot. + Parkman.	Pierre. Parkman.	Pierre. Parkman (?).	Pierre.	Pierre. Hygiene. o. g.	Pierre. (o.)
		Hilliard.	Cody.	Colorado.	Pierre. Basin.	Cody.	Mancos.	Fort Pierre.	Steele. Shannon.	Shannon. o.	Shannon (?). +		(o.)	
								Niobrara.	Niobrara.	Niobrara. o.	Niobrara.	Niobrara.	Niobrara. o.	Niobrara.
									Carlile.	Benton.	Benton. +o. g.	Carlile.	Benton. o.?	Carlile.
Cretaceous.		Frontier. o.	Frontier. o.		Benton.	Frontier.		(+)	Frontier.	Wall Creek. o.	Wall Creek (?).			
	Colorado.			(+) (+)	Torchlight.	Torchlight. +			Wall Creek. +			Greenhorn.		Greenhorn.
					Peay. (o. g.)	(+) Peay. +g.			Peay. + +			Graneros.		Graneros.
		Aspen. o.	Mowry.	(o.)		Mowry. +o.	(+o.)	Fort Benton.	Mowry.	Mowry. +	Mowry.	Mowry. o.		
			Thermopolis. g.	(o.)		Thermopolis. +			Thermopolis.		(o?)			
		Bear River. o.	Cloverly.	"Cloverly." g.	Cloverly. o. g. Greybull.	Cloverly.	Dakota.	Dakota. +	Dakota. +		"Cloverly." o. +	Dakota. +	Dakota.	"Dakota." +
							Lower Cretaceous (?).	(+)	Lower Cretaceous. Shale.	Dakota(?). +		Fuson. +.		
		Beckwith.							Conglomerate. +			Lakota.		
Cretaceous(?).			Morrison.	Morrison. g.	Morrison.	Morrison.	Morrison.	Como.	Morrison. +	Morrison. +.	Morrison.	Morrison.	Morrison.	Morrison. +
Jurassic.		Twin Creek.		Sundance.			Sundance.	Shirley.	Sundance. +	Sundance. +.	Sundance.	Sundance.		
Triassic.							Chugwater. +o.	Triassic.	Chugwater. +		Chugwater.			
Permian.							Embar. o.	Permian.	Embar.				Lykins.	
Pennsylvanian.								Carboniferous.	Tensleep. +		Forelle (?). Satanka (?). + Casper.		Lyons.	
									Amsden.				Fountain.	

[a] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, pp. 157–158, 1907. Schultz, A. R., The Labarge oil field, central Uinta County, Wyo.: U. S. Geol. Survey Bull. 340, p. 364, 1908.
[b] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, pp. 89–113, 1914, and unpublished data.
[c] Hintze, F. F., Basin and Greybull oil and gas fields: Wyoming State Geologist's Office Bull. 10, p. 40, 1914 [1915].
[d] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, pp. 157–190, 1916.
[e] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, 1911.
[f] Knight, W. C., A preliminary report on the artesian basins of Wyoming: Wyoming Univ. Exper. Sta. Bull. 45, 1900. Knight, W. C., and Slosson, E. E., The Dutton, Rattlesnake, Arago, Oil Mountain, and Powder River oil fields: Wyoming Univ. School of Mines, Petroleum ser., Bull. 4, 1901.
[g] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 37–83, 1911; The Powder River oil field, Wyo.: U. S. Geol. Survey Bull. 471, pp. 56–75, 1912.
[h] Barnett, V. H., The Douglas oil and gas field, Converse County, Wyo.: U. S. Geol. Survey Bull. 541, pp. 49–88, 1914.
[i] Barnett, V. H., The Moorcroft oil field and Big Muddy dome, Wyo.: U. S. Geol. Survey Bull. 581, pp. 83–117, 1914. Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, pp. 334, 364, 379–388, 1905.
[j] Fenneman, N. M., Geology of the Boulder district, Colo.: U. S. Geol. Survey Bull. 265, pp. 76–98, 1905.
[k] Washburne, C. W., The Florence oil field, Colo.: U. S. Geol. Survey Bull. 381, pp. 517–544, 1910.

dip from such outcrops penetrate these beds and commonly obtain water with a few drops of oil. This was true of the Oil City, the Northwestern, the Dutton "Basin," and the Western States wells. Under these conditions it is clearly evident that anticlines having the oil-bearing sandstones completely sealed beneath impervious beds should be first chosen for prospecting.

The accompanying table summarizes the available information as to the geologic position of the oil and gas bearing beds in the Wyoming and some adjacent fields.

HISTORY OF PROSPECTING.

The presence of oil seeps in this region was first described by Aughey in 1886.[1] Some of these seeps, however, had been known since the days when the first emigrants passed through the region going to Oregon and California. It is reported that Cimineau,[2] a French trapper, and others sold lubricants to the caravans from the oil spring in sec. 28, T. 33 N., R. 82 W., 1 mile south of Poison Spider Creek, near Oil Mountain.

One of the first wells sunk in the area covered by this report was drilled in 1886 on Poison Spider Creek, in sec. 4, T. 32 N., R. 86 W., at Oil City, by the Colorado & Wyoming Land & Oil Co. Under the management of George L. Aggers, of Douglas, Wyo., this well was put down to a depth of 1,130 feet and at a depth of 500 feet struck 130 feet of sandstone, which carried a little oil and water.[3]

The two wells drilled by the Wyoming Central Association in the early eighties near the head of Powder River to depths of 700 and 900 feet were water wells with only a slight showing of oil.[4] It is thought that the first well drilled prior to 1886 near the SW. ¼ sec. 34, T. 34 N., R. 88 W., to a depth of nearly 1,000 feet, which obtained a slight amount of oil, gas, and much water, was one of the Wyoming Central Association wells.[5] The Northwestern Oil Co.'s well, which according to Knight[6] was drilled about the same time and a short distance northwest of the Wyoming Central Association wells to a depth of about 500 feet, struck no appreciable quantity of oil. When visited in 1915 a well near the west quarter corner of sec. 20, T. 33 N., R. 87 W., was giving off a small quantity of gas and a few drops of oil. There was only enough dark, thick, asphaltic oil on the water which rose to the top of the casing to furnish a small sample. No data seem to be available concerning the Moffat well, on Lovett Creek.

[1] Aughey, Samuel, Wyoming Territorial Geologist Ann. Rept., 1886, pp. 113-187.
[2] See U. S. Geol. Survey Bull. 612, p. 62, 1915.
[3] Ricketts, L. D., Wyoming Territorial Geologist Ann. Rept., 1888, pp. 22-36.
[4] Idem, p. 35.
[5] Aughey, Samuel, op. cit. Knight, W. C., Wyoming Univ. School of Mines, Petroleum series, Bull. 4, p. 28, map, 1901.
[6] Knight, W. C., idem, pp. 21-26.

Nearly contemporaneous with the sinking of the Northwestern well was the drilling of the Guthery well, in sec. 18, T. 33 N., R. 82 W., on Poison Spider Creek. This well was sunk to a depth of about 1,000 feet, and a flow of strong sulphur water was encountered, presumably in the Lower Cretaceous conglomerate. It is reported that some oil was found, but that the quantity was so insignificant that oil was hauled from the wells at Salt Creek and the place "salted." At the time of visit a small stream of water surcharged with hydrogen sulphide gas flowed from the casing, but there was no indication of oil.

It is said that a shallow well was drilled farther down Poison Spider Creek, just above the Goose Egg ranch, and that the tools were purposely lost in it.

The well near North Platte River, 2 miles above Alcova, struck water but no oil. Its location is in the syncline between the monoclinal fold to the west and the Alcova or Hot Springs arch to the east.

Scattered throughout the area are assessment pits of the oil-prospecting days of the eighties, and it is almost impossible to ride over the area for any considerable length of time without seeing some of them. It is reported that a small quantity of oil was collected in some of these pits near the Horse Creek dome, in secs. 26, 27, and 34, T. 32 N., R. 86 W. At the oil spring near the north end of Oil Mountain there are two pits. The western one of these, which was dug to a depth of 10 feet or so, has nearly filled up by caving and when visited contained about 3 feet of water covered with a thin scum of thick, dark oil. It is from this place that a small quantity of oil was supplied to the travelers who trailed through the region in the days of 1849.

After the era of assessment pits and shallow wells very little prospecting was done until the development of the Salt Creek and Bighorn Basin oil fields revived interest in oil through the area. The first operation was the sinking of a test well by the Midwest Oil Co. on the Castle Creek fold, near the east quarter corner of sec. 31, T. 38 N., R. 80 W., to a depth of about 2,000 feet. Some gas was found in the shale above the Wall Creek sand, and from the sand water rose nearly to the top of the casing. A little gas was escaping from the well when it was visited late in the fall of 1914.

A well completed in the summer of 1913 at the north end of the Dutton anticline was started near the contact of the Niobrara and Steele shales, in the NW. ¼ sec. 34, T. 34 N., R. 90 W. It was drilled to a depth of about 1,060 feet, and when visited it was giving off gas in small quantities, and thick, dark oil stood on the water about 20 feet below the top of the casing.

In the summer of 1913 the Ohio Oil Co. drilled two holes, one on Poison Spider Creek in the SE. ¼ SE. ¼ sec. 18, T. 33 N., R. 82 W., and the other in the NE. ¼ NE. ¼ sec. 2, T. 33 N., R. 95 W., near

Alkali Butte in the "Riverton oil field." In the well on Poison Spider Creek the Dakota sandstone at a depth of 641 feet contained some black oil. The Lower Cretaceous conglomerate at 785 feet carried water and a little oil, and the Morrison formation showed signs of oil. The well was sunk to a depth of 2,855 feet, and the last 15 feet was in the Tensleep sandstone, which contained artesian water. The other well, near Alkali Butte, encountered no water anywhere in the 2,945-foot hole, which was probably entirely in the Steele shale. A trace of gas and oil was obtained in a 7-foot bed of soft sand at a depth of 177 feet.

The Holmes well, in sec. 3, T. 36 N., R. 82 W., was the first one located on the North Casper Creek anticline. This well, which is about 500 feet west of the contact of the Niobrara and Steele shales, is 2 miles west of the axis of the anticline and was drilled to a depth of 1,170 feet. It penetrated 15 feet into the Wall Creek sand, from which water rose within 100 feet of the top of the casing.

The Fitzhugh well, 1½ miles north of the Holmes well, was started June 19 and finished August 24, 1913. It is near the west quarter corner of sec. 26, T. 37 N., R. 82 W., about 800 feet east of the upper contact of the Niobrara shale. The locator in the selection of this site seems not to have considered duly the record of the Holmes well and the form of the anticline, otherwise his location would not have been so near the contact of the Steele and Niobrara shales, a position on nearly the same structure contour as that of the Holmes well. The two logs are similar. In the Fitzhugh well water was struck in the Wall Creek sand at a depth of 1,000 feet, and the well was abandoned at 1,642 feet.

The Monongahela Oil Co. commenced operations in July, 1913, in the SE. ¼ sec. 9, T. 33 N., R. 81 W., just west of Twelvemile Spring, in the Emigrant Gap anticline. At a depth of 240 feet a flow of sulphur water was struck in the Lower Cretaceous conglomerate. This is the only well so far drilled near the axis of the anticline. The dry holes on Casper Creek, in Tps. 33 and 34 N., R. 80 W., are far down the east flank.

The Western States Oil Co.'s well, started in the summer of 1913 near the center of T. 33 N., R. 94 W., in the so-called Riverton oil field, is in the syncline between the Conant Creek and Alkali Butte anticlines. The location is on the Steele shale, and, according to reports, the Wall Creek sand, at a depth of 1,300 feet, showed some trace of oil. The well was not completed at the time of the field examination.

The Franco-American well, in the SE. ¼ SE. ¼ sec. 16, T. 34 N., R. 87 W., is on the Wallace Creek dome (?). This well was put down about 600 feet during the summer of 1913, but was idle when the area was mapped. Later it was sunk to a depth of more than 2,000 feet, probably entirely in the Fort Union and Lance formations, but encountered no oil.

The Toltec Oil Co. late in the fall of 1913 put down a well in sec. 11, T. 37 N., R. 85 W., on the Cottonwood Creek anticline, at the south end of the Bighorn Mountains. It was free from water down to a depth of 915 feet, except small quantities at 125 and 458 feet, but at 915 feet warm and highly charged sulphur water, presumably from the Lower Cretaceous conglomerate, flowed in large quantities over the top of the casing. The well was abandoned at a depth of 990 feet without obtaining oil.

In September and October, 1914, William M. Fitzhugh and his associates drilled a 1,975-foot dry hole in the NW. ¼ sec. 36, T. 37 N., R. 82 W., on the North Casper Creek anticline. They struck water in the Wall Creek sand at a depth of 440 feet and in the Peay sand at 1,045 feet, but the Dakota (?) sandstone at 1,675 feet was dry. The Lower Cretaceous conglomerate at a depth of 1,769 feet and also the Morrison formation carried water. Free carbon, bitumen, paraffin, and some carbonic gas were found in dark-blue shale at 1,560 and 1,679 feet. This well is located near the axis of the anticline about 2 miles north of its crest and with the other wells drilled near by has shown that the pool of oil or gas, if any exists in this anticline, is not greater than 1½ by 4½ miles in extent, which is almost the size of the Salt Creek field.

The Casper Oil Co. in the fall of 1915 started a well in sec. 28, T. 38 N., R. 81 W., about a mile below the 33 Mile ranch on Castle Creek. This well was dry for 1,900 feet.

Aside from these wells, drilled by standard outfits, numerous assessment holes have been put down with Star rigs, none of which have attained sufficient depth to be of value. The prospecting of this sort that has been done along the eastern flank of the Rattlesnake Mountains is a good example of waste of time and money.

OIL-BEARING FORMATIONS.

Many of the formations in this field, from the Cambrian to the Oligocene, contain sandstone members or strata, but only those which contain traces of oil or produce oil and gas in this or near-by fields will be described. The formations may be seen in the different anticlines of the field, and they will be taken up in stratigraphic order, the lowest one first, as shown in the columnar section on Plate XXIII. That some of the shales contain oil pools is not considered probable, although it is recognized that oil may be present in shale here, as it is in some other Rocky Mountain fields.

Cambrian and pre-Cambrian formations.—The Cambrian and pre-Cambrian beds, according to oral reports, are saturated with oil near Copper Mountain, on the south side of the Owl Creek Mountains, near T. 39 N., R. 92 W., about 40 miles northwest of the Rattlesnake

Mountains. The Wind River formation (Eocene), which overlies the Cambrian at this locality, is also said to snow traces of oil. The locality was not examined, but the information is considered reliable. No indications of oil, however, were observed in the Cambrian or pre-Cambrian in the area covered by this paper.[1]

Tensleep sandstone.—The Tensleep sandstone, of Pennsylvanian age, is the lowest formation which shows signs of oil in this field. It is approximately 200 feet thick in the Rattlesnake Mountains. An exposure of a few square rods in the SW. ¼ sec. 13, T. 33 N., R. 90 W., in the Dutton anticline, contains some oil, but so far as observed none escapes. At all other localities where the formation was examined it is barren. The rock is a medium-grained, highly cross-bedded, firmly cemented quartz sandstone, which is of sufficiently open texture to allow the free circulation of water, as shown by the Ohio well, on Poison Spider Creek.

Embar formation.—No indications of oil were seen in the Embar formation (Pennsylvanian, Permian, and Triassic), but in the Lander field,[2] which adjoins this area on the northwest, it is one of the main oil-producing formations. The Embar overlies the Tensleep sandstone and is composed of 225 feet or more of light-gray fossiliferous limestone, shale, chert, and beds of phosphate. It is typically developed in the western part of the area, where it is equivalent to the Park City and Dinwoody formations, but in the eastern part it is of an entirely different character, consisting mostly of red shale with some limestone, fossiliferous red and gray chert, and gypsum. The Embar in this field contains no thick beds of sandstone. It was reported that the well of the Pine Dome Oil Co. obtained its flow of gas from the Embar, but it is fully as probable that the gas came from the Tensleep sandstone.

Chugwater, Sundance, and Morrison formations.—Along the east flank of the Rattlesnake Mountains north of Garfield Peak there are places where the sandstones in the upper (Triassic) part of the Chugwater, the Sundance (Jurassic), and especially the Morrison (Cretaceous?) formations show signs of oil. Oil seeps from the Sundance and Morrison formations in the unproductive Powder River oil field,[3] which is adjacent to this field on the north. These formations contain thin and thick sandstones that in favorable folds would serve as reservoirs for oil. The formations present their usual characteristics. The Chugwater consists essentially of 1,000 feet of brick-red unfossiliferous sandy micaceous shale, thin-bedded sandstone,

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[1] Since this was written the indications of oil in this locality have been described as petroleum in granite by L. W. Trumbull (Wyoming State Geologist's Office, Sci. ser., Bull. 1, pp. 4–7, 1916).

[2] Woodruff, E. G., The Lander oil field: U. S. Geol. Survey Bull. 452, p. 27, 1911. Jamison, C. E., Geology and mineral resources of a portion of Fremont County, Wyo.: Wyoming Geol. Survey Bull. 2, pp. 33–34, 1911.

[3] Wegemann, C. H., The Powder River oil field, Wyo.: U. S. Geol. Survey Bull. 471, p. 71, 1912.

and gypsum. A thin limestone occurs near the top in the eastern part of the field, but in the western part this same limestone is near the middle of the formation. The Sundance consists of about 300 feet of marine olive-green shale and highly fossiliferous gray limestone. The Morrison consists essentially of 250 feet of fresh-water variegated shale and sandstone.

Lower Cretaceous conglomerate.—The next higher oil-bearing formation is the conglomerate assigned to the Lower Cretaceous. This is the lower part of the "Dakota" formation mentioned by Knight [1] as being the most promising oil-bearing formation of the field. It is the basal conglomeratic sandstone of the Cloverly formation of the Bighorn Mountains, the lower member of the Cloverly formation of the Basin and Greybull oil and gas fields,[2] and the Dakota (?) of the Salt Creek field.[3] It is identical with the conglomerate described as of Lower Cretaceous age (?) in the Lander field.[4] This formation contains dark-colored, well-rounded chert pebbles, commonly about the size of small marbles but reaching a maximum diameter of 1½ inches, firmly cemented. Usually the cement is silica, but in some places it is lime. The coarse basal conglomerate that constitutes the lower half of the formation grades upward into a slightly conglomeratic sandstone and the whole attains a thickness of about 60 feet. It varies little from this thickness throughout the eastern part of the area, though in the Conant Creek anticline it is only 8 feet thick. The formation where upturned forms small hogbacks, a feature which, with the lithologic character, makes its identification easy.

Though the conglomerate is mentioned by Knight [5] as showing traces of oil in the Dutton "anticline," none were noticed in it there or in the other exposures of the conglomerate, except along the Rattlesnake Mountains. It is probably the source of the oil at the seep in sec. 28, T. 33 N., R. 82 W., at the north end of Oil Mountain. Small quantities of dark, thick oil ooze from it near the Lew Smith Spring, at the head of Horse Creek, in sec. 26, T. 32 N., R. 86 W., on the southwest side of the Rattlesnake Mountains. A few sections of land have been patented as oil placer land about 2 miles south of Oil City because dark asphaltic oil seeps from the conglomerate beds in that locality. Northwest of Oil City and south of Garfield Peak the conglomerate contains little if any oil, but in places on Wallace Creek and on the small creeks near by it is saturated with dark asphaltic oil. The light volatile parts have evaporated from the oil

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[1] Knight, W. C., Wyoming Univ. School of Mines, Petroleum ser., Bull. 4, pp. 17–19, 1901.

[2] Hintze, F. F., jr., The Basin and Greybull oil and gas fields, Big Horn County, Wyo.: Wyoming State Geologist's Office Bull. 10, pp. 16–17, 1914.

[3] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, p. 44, 1911.

[4] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 18–19, 1911.

[5] Knight, W. C., op. cit., pp. 17–19.

that seeps here, and the heavy dark residue, mixed with soil and dead vegetation, has accumulated on the creek bottoms to a thickness of a foot or more and covers many square rods. This deposit is used locally for fuel, chiefly for engines drilling prospect holes. Strong sulphur water was found in the conglomerate in the Ohio well, on Poison Spider Creek, and in the Guthery, Monongahela, and Toltec wells, and similar water issues from the conglomerate in sec. 15, T. 33 N., R. 81 W. The Ohio and Guthery wells struck traces of oil in the conglomerate.

Dakota sandstone.—Directly below the Thermopolis shale and from 100 to 350 feet above the Lower Cretaceous conglomerate is a fine-grained brown to gray quartzitic sandstone, ranging in thickness from a few inches to a maximum of 60 feet, as observed at the south end of the Emigrant Gap anticline. This sandstone is considered the same as the Dakota of the Lander country.[1] It is the upper member of the Cloverly formation of some authors, but is here referred to the Dakota (Upper Cretaceous). It may correspond to the Greybull sand of the Bighorn Basin.[2] This sandstone contains no oil at the south end of the Rattlesnake Mountains or near Garfield Peak, but at numerous places on Wallace Creek and the creeks to the north it is saturated with dark asphaltic oil and, with the Lower Cretaceous conglomerate, furnishes the asphaltum found in that district. The Dakota shows no trace of oil throughout the rest of the field. This sandstone is so variable in thickness and so unfavorably situated in most of the anticlines that it is considered unimportant as a reservoir for oil unless it may be in the same anticlines as those mentioned in connection with the Lower Cretaceous conglomerate.

Mowry shale.—From 100 to 300 feet above the Dakota sandstone is the Mowry shale, of Upper Cretaceous age, a hard, fissile dark shale, weathering white, which contains abundant fish scales, vertebræ, and fins, but in which no complete skeletons have been found. The Mowry shale, which forms pronounced pine-bearing ridges in most of the anticlines, is normally about 300 feet thick and is an exceptionally good key rock. It is in most localities immediately overlain by a bed of bentonite. No traces of oil were seen oozing from this formation, but it produces oil in the Bighorn Basin,[2] at Lander,[3] and at Spring Valley [4] and is the probable source of the oil

[1] Woodruff, E. G., op. cit., pp. 18–19.

[2] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, pp. 157–190, 1916.

[3] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, p. 27 1911.

[4] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, p. 158, 1907.

in the Wasatch formation at Labarge.[1] Oil is reported to occur in the Mowry shale in the unproductive Powder River field.[2]

One of two samples of the Mowry shale tested by distillation yielded about 2 gallons of oil to the ton and the other a mere trace. The latter contained the greater quantity of fish remains. The tests were made in order to throw light on the possible origin of the Wyoming oil, but the results were unsatisfactory.

Frontier formation.—The Mowry shale is overlain by shale and sandstone that are referred to the Frontier formation, of Upper Cretaceous age. The sandstones, of which there are three distinct divisions corresponding in ascending order to the Peay, an intermediate sand, and the Wall Creek, are of medium to fine grain, gray, somewhat massively bedded, and from 20 to 200 feet thick. The formation attains a maximum thickness of 1,000 feet. The intervening shale, which makes up more than half of the formation, is dark and sandy. The lowest sandstone member, corresponding to the Peay, is persistent and characterized by large brown concretions, especially in the Emigrant Gap and Oil Mountain anticlines and the Pine dome. The middle sandstone is commonly characterized by small black chert pebbles about the size of peas, which usually distinguish it from the other two sandstones, though in a few places the Wall Creek contains similar pebbles. The upper or Wall Creek sand is the main productive oil sand in the Salt Creek field, 25 miles northeast of the North Casper Creek anticline,[3] but the Peay and Torchlight are important producing sands in the Bighorn Basin.[4] The Wall Creek sandstone may correspond to the Torchlight, as shown by Hintze, for it is stratigraphically at about the same position.

Thick, black oil oozes from the sandstones of the Frontier in the Alkali Butte anticline, and traces of oil were found in them along the Rattlesnake Mountains.

Teapot sandstone member of the Mesaverde formation.—The highest Cretaceous sand in which oil was observed is the Teapot sandstone member of the Mesaverde formation (Upper Cretaceous), a medium-textured white sandstone from 90 to 200 feet thick. This sandstone has a wide distribution in Wyoming and is the upper part of the Mesaverde. It is spoken of as the "sandstone forming Little Pine

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[1] Schultz, A. R., The Labarge oil field, central Uinta County, Wyo.: U. S. Geol. Survey Bull. 340, pp. 367–371, 1908. Trumbull, L. W., Prospective oil fields at Upton, Buck Creek, Rattlesnake Mountains, and Labarge: Wyoming State Geologist's Office Bull. 5, pp. 14–15, 1913.

[2] Wegemann, C. H., The Powder River oil field, Wyo.: U. S. Geol. Survey Bull. 471, p. 71, 1912.

[3] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 71–75, 1911.

[4] Washburne, C. W., Gas fields of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, pp. 348–363, 1908. Hintze, F. F., jr., The Basin and Greybull oil and gas fields, Big Horn County, Wyo.: Wyoming State Geologist's Office Bull. 10, pp. 41–47, 1914. Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 65, 1914.

Ridge" in the Salt Creek field and is the Teapot sandstone near Casper as described by Barnett.[1] It is the prominent sandstone that forms the striking white wall across Tps. 32 and 33 N., Rs. 82 and 83 W., southeast of the F L ranch. This sandstone, forming a low ridge locally known as Phayles Reef near the Marquis ranch, along the east flank of the Rattlesnake Mountains in secs. 4, 5, and 9, T. 33 N., R. 87 W., is highly saturated with oil. This sandstone at Phayles Reef is probably the one conditionally placed by Knight[2] in the Fox Hills and noted by him as saturated with oil. In prospecting for oil in the dome on Wallace Creek drilling should go at least deep enough to test this sand for oil.

Wind River formation.—The Wind River formation, of Eocene age, consists essentially of soft variegated shale, coarse brown sandstone, arkose, and both fine and coarse conglomerate. These beds are for the most part nearly flat-lying or tilted at very small angles and unconformably overlie all the older formations, including the Cambrian. No oil seeps were noted in the Wind River, but some are mentioned by Knight as occurring west of the Dutton anticline.[3] The Wind River is reported to show traces of oil south of the Owl Creek Mountains in T. 39 N., R. 92 W. Oil is obtained in small quantities from beds of nearly the same age at Spring Valley[4] and Labarge,[5] in southwestern Wyoming. It is probable that in all these places the oil has escaped from the underlying Cretaceous sands into the overlying beds. As the Wind River in places overlies the upturned Cretaceous oil-bearing sands, it is possible that in some of these places oil may be found in the Wind River, but this seems a remote possibility, and no commercial pools are to be expected.

White River formation.—The White River formation of Oligocene age, is composed essentially of loosely cemented light-colored fine and coarse sand, arkose, and conglomerate. Volcanic material, in the form of pebbles and single grains, is present throughout the formation. Red color is generally absent in the formation, but light green and buff are plentiful and even white rocks are not uncommon. The White River is nearly flat lying and rests unconformably on all formations from the pre-Cambrian granite of the Granite Mountains to the Steele shale and also the Wind River.

Small quantities of oil ooze from beds considered of White River age at the Lew Smith oil spring, in sec. 26, T. 32 N., R. 86 W., in the

[1] Barnett, V. H., Possibilities of oil in the Big Muddy dome, Converse and Natrona counties, Wyo.: U. S. Geol. Survey Bull. 581, pp. 113–114, 1915.

[2] Knight, W. C., Wyoming Univ. School of Mines, Petroleum ser., Bull. 4, pp. 28–29, 1901.

[3] Idem, p. 16.

[4] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, pp. 16, 139, 141, 143–144, 151, 1907.

[5] Schultz, A. R., Geology and geography of a portion of Lincoln County, Wyo.: U. S. Geol. Survey Bull. 543, p. 117, 1914.

Rattlesnake Mountains, but the oil probably comes from the underlying Lower Cretaceous conglomerate or the Dakota sandstone. A little asphaltic material occurs in rhyolitic bombs in the upper part of the White River formation on the Sweetwater escarpment in secs. 10 and 11, T. 32 N., R. 94 W.

It is possible that where this formation lies on the upturned Cretaceous oil sands, as in the area between Alcova and the Rattlesnake Mountains or at the south end of the Rattlesnake Mountains, it may contain small quantities of oil. Commercial pools, it is believed, are not to be expected in the White River in this field. Small pools, however, occur in beds of the same age at Douglas.[1]

ANTICLINES[2] AND OTHER FOLDS.

GENERAL FEATURES.

In comparatively recent geologic time, the outer crust of the earth in all parts of Wyoming, which once lay in great nearly level sheets or beds of shale, sandstone, and limestone, was bent and wrinkled into great and small anticlinal and synclinal folds. These folds or earth waves may be likened to the billows and waves on water or to the wrinkles on merino sheep. They are elongated, and some are much higher and larger than others. Some of the high rock folds in Wyoming are the giant anticlines of the Laramie, Granite, Wind River, Owl Creek, and Bighorn mountains. The Powder River, Green River, Wind River, and Bighorn basins are giant synclines. These great folds are not arranged in any definite order, as their axes trend in several directions.

The small anticlines described in this report are situated upon the sides of the giant folds or between them. They are elongated and compressed, their axes, which nearly parallel one another, trend in a northwesterly direction (see Pl. XXIII), and they are broken here and there by small faults. The axes of the small anticlines pitch either in one direction—for example, those of the anticlines that project as spurs from the giant folds—or in two directions—for example, those of the assemblage of more or less simple anticlines in the lowland area between the Laramie and Bighorn mountains.

[1] Barnett, V. H., The Douglas oil and gas field, Converse County, Wyo.: U. S. Geol. Survey Bull. 541, pp. 48-88, 1914.

[2] The term anticline is used here for brevity of description to include bowed-up folds that have two limbs—that is, sides in which the same strata dip in opposite directions from the axis. According to Willis (U. S. Geol. Survey Thirteenth Ann. Rept., pt. 2, p. 200, 1893), "the line or area of meeting of the sides is the axial region, the crest or crown of an anticline, the base or bottom of a syncline," and it is commonly called simply the axis. Generally the anticline is developed in nearly flat-lying rocks, and its axis pitches toward its two extremities, but in places the anticline or syncline is developed on the upturned rocks that form the rim of some large structural basin, and in that case the axis may pitch in only one direction. For convenience of description, anticlines and synclines developed on tilted beds will be called slope anticlines and slope synclines. Willis says: "When the limbs of an anticline are wide open downward further shortening of the zone of strata is possible by lessening of this angle; such may be called an open fold."

While the great, nearly level sheets of shale, sandstone (in part oil bearing), and limestone were being bent into anticlines, they were also being worn away from the crests of the anticlines, mostly by water and wind, and the detrital material so derived was in the main deposited as layers of mud and sand in the troughs of the giant synclines. These flat-lying layers filled the synclines and reached far up on the sides of the giant anticlines, nearly covering the small anticlines, some of which even now are largely hidden by the flat-lying beds. All the giant anticlines and many of the small ones have been truncated or worn down so deeply that in many places the oil-bearing sands have been exposed, allowing the oil to escape.

SWEETWATER ANTICLINE.[1]

The Granite Mountains, viewed broadly, are in the middle of a great upfold, which will be referred to as the Sweetwater anticline. Although dominantly anticlinal, it is by no means a single fold but is in reality an assemblage of folds that make up one giant, deeply eroded compound anticline. The nucleus of granite in the Sweetwater Valley and Granite Mountains is surrounded by strata which dip steeply in some places and slightly in others and which now represent the outcropping, worn edges of formations that probably once extended over the anticline. The Sweetwater anticline is approximately 50 miles wide by 120 miles long, and the granite nucleus is about 25 by 100 miles. The south limb and east end of the anticline are not represented on Plate XXIII. At the west end there is an apparent continuation of the great upfold in the anticline of Sheep Mountain in Tps. 30 and 31 N., Rs. 96, 97, and 98 W. The trend of the Sweetwater anticline is almost due east, and in this respect it is like the giant anticlines of the Uinta Mountains, in the northeastern part of Utah, and the Owl Creek Mountains, in the north-central part of Wyoming, but its trend is not in harmony with the dominant northwesterly anticlines in the remainder of Wyoming.

The widely separated limbs are represented now by such folded rocks as those in the Rattlesnake Mountains and at Alkali Butte, on the north side, and those at Happy Springs and Green Mountain, on the south. Large faults occur along the south limb of the anticline, and in places, especially at Green Mountain, the formations are overturned. These folds and faults about the sides of the Sweetwater anticline and much of the granite nucleus are now covered by flat-lying strata, either light-colored or variegated, that hide for the most part the detail of the anticline.

[1] Hayden, F. V., Exploration of the Yellowstone and Missouri rivers, pp. 77-78, U. S. War Dept., 1869: U. S. Geol. Survey Terr. Fourth Ann. Rept., pp. 24-35, 1872. Endlich, F. M., Report on geology of the Sweetwater district: U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., pp. 3-157, 1879.

The sedimentary formations from the Cambrian up to but not including the Wind River (see stratigraphic section on Pl. XXIII) probably once extended in great level beds across the area now occupied by the Granite Mountains and the Sweetwater Valley, as identical formations occur on both sides of the anticline, but with and after the upheaval that produced the anticline these beds were gradually eroded and for the most part if not entirely removed by streams from the crown of the anticline. The pre-Cambrian granite has been carved at least 2,000 feet deep, as the Granite Mountains rise that much above Sweetwater River, and this amount of dissection added to the total thickness of the sedimentary strata removed and the present altitude above sea level indicates an upward movement of at least 20,000 feet.

As the oil-bearing formations were removed during the upheaval of the anticline and before the deposition of the flat-lying light-colored rocks, there was and is now no opportunity for oil to migrate from them into the flat-lying rocks, as it is thought to have migrated at Douglas,[1] where oil and gas are found in flat-lying beds of the same age. Oil and gas, so far as known, have not been obtained commercially in granite. Because of these conditions the middle of the Sweetwater anticline offers no possibilities of oil and gas.

SHEEP MOUNTAIN ANTICLINE.

The Sheep Mountain anticline, which is crossed by Beaver Creek, lies in the vicinity of Hailey, a roadhouse station some 30 miles southeast of Lander. This open faulted anticline is short, lying mostly between the Big Bend of Twin Creek and Beaver Hill, a distance of 13 miles, and is almost as wide as long, but in no respect can it be called a dome. The rock strata on the northeast limb dip from 10° to 90°, with an average of about 15°, and those on the southwest limb 20° to 30°, as shown in figure 17. The outcrop of the inclined beds on the northeast side is much broader than that of the beds on the southwest, because of the lower dips and the presence of younger rocks that are not represented on the southwest side. Though the axis trends in general about N. 30° W., it is curved, with the convex side toward the southwest, as is shown by the strike of the formations involved in the fold. As the axis of the Sheep Mountain anticline passes slightly east of the axis of the Little Popo Agie anticline in T. 31 N., R. 98 W., but dies out near the Big Bend of Twin Creek, in the southeast corner of T. 32 N., R. 98 W., the anticline may be considered the generalized southward extension of the folds in the Lander oil field.[2] The axis is inclined and pitches northward, and

[1] Barnett, V. H., The Douglas oil and gas field, Converse County, Wyo.: U. S. Geol. Survey Bull. 541, pp. 49-88, 1914.

[2] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 22-27, 1911.

as the limbs of the anticline which open toward the granite on the Beaver divide are eroded the outcrops of none of the formations encircle it. Thrust faults at the south end of the anticline and near Sheep Mountain have disturbed the normal sequence of the rocks, as shown in figure 17. Flat-lying variegated rocks to the east and north and light-colored rocks to the east and south closely limit the visible parts of the anticline, which is separated from the folds of the Wind River Mountains by a narrow downwarp or syncline. Though the Sheep Mountain anticline is only from 9 to 18 miles southeast of the Little Popo Agie district of the Lander oil field, it probably does not contain important oil pools, because it is truncated down to the granite, all the oil-bearing formations being exposed. These conditions, in the absence of structural terraces or minor anticlines about the main upwarp to trap the oil in wet rocks, would allow any oil that was ever present in them to escape. No oil seeps were observed on the anticline.

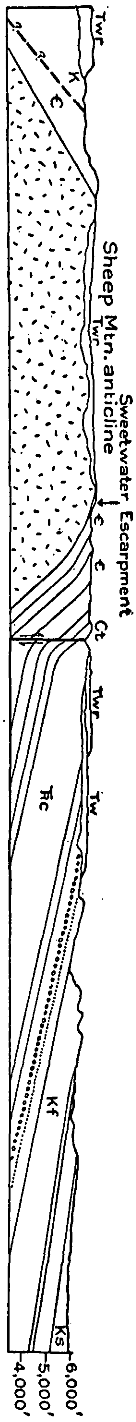

FIGURE 17.—Section through the Sheep Mountain anticline, Wyo.

BIG SAND DRAW ANTICLINE.

An apparently small anticline 12 miles northeast of Hailey is crossed by Big Sand Draw, a tributary of Beaver Creek, but no permanent water occurs near by. The folded rocks, which outcrop in a strip of land 6 miles long by 1 to 2 miles wide in Tps. 32 and 33 N., R. 95 W., are surrounded by flat-lying younger varicolored strata. The rock strata, as shown in figure 18, dip about 30° on each side of the axis, which trends a little west of north. The anticline as expressed by the sandstone north of Big Sand Draw is apparent, but to the south it is indistinct in the soft folded shale that is partly covered with grass. It seems from the small part of the anticline exposed that its axis pitches to the north and that none of the formations involved in the fold at present encircle the anticline.

So far as can be determined from the outcrops, the highest oil-bearing formation of Colorado age in this anticline is within reach of the drill, though at least 2,500 feet in depth. Whether or not oil pools are present in the anticline is, however, uncertain. Opportunity occurred before the deposition of the flat-lying beds for the oil, if then present, to migrate to the surface and escape. Likewise, since the deposition of the flat-lying

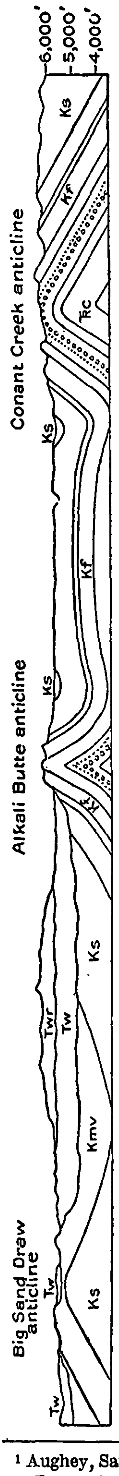

FIGURE 18.—Section through the Big Sand Draw, Alkali Butte, and Conant Creek anticlines, Wyo.

beds oil may have migrated upward and accumulated in inclined beds abutting against the overlying horizontal beds or in the base of the horizontal beds. This could have taken place only in the area south of the exposed part of the anticline. If it is assumed that the axis pitches in both directions and that the dark adobe shale exposed south of Big Sand Draw occupies the middle of the anticline, thereby tightly closing over the oil-bearing sandstone below, this anticline would be perhaps the most promising in the entire field, as oil pools might be present in the sandstone thus protected.

ALKALI BUTTE ANTICLINE.

A northward-pitching, closely folded anticline north of the Sweetwater escarpment in the vicinity of Alkali Butte and Mount Rogers forms a part of the complex folds of the so-called Riverton oil field and is reached with least difficulty by a trip of about 15 miles southeast from Riverton, a station on the Chicago & Northwestern Railway. The area about Mount Rogers was described by Aughey[1] as the Beaver oil basin. The oil, according to him, is of high grade, of 0.968 specific gravity, and of a mahogany color. Mount Rogers is sometimes spoken of as being on Oil Mountain Ridge, but that name leads to confusion with Oil Mountain, in the eastern part of the field, so the name Mount Rogers is preferable.

That part of the northwestward-trending anticline which can be seen is narrow and about 15 miles long. Its visible part south of Mount Rogers is shown by the closely folded shale and sandstone that pass beneath the flat-lying light-colored strata forming the Sweetwater escarpment. These sandstones, tilted at angles from 30° to 90°, form sharp ridges about 2 miles long in a lowland of shale. (See fig. 18.) The sandstones dip rather abruptly in the northwest corner of T. 33 N., R. 94 W., at an oil seep, and to the north the arch is low but is continued in shale to the vicinity of Alkali Butte, where less closely folded overlying sandstones form the north end of the anticline. The folded strata disappear beneath the nearly level varicolored beds 3 miles north of the butte, some distance north of the position shown by Woodruff and Winchester.[2] In passing

[1] Aughey, Samuel, Wyoming Territorial Geologist Ann. Rept., 1886, pp. 124–129.

[2] Woodruff, E. G., and Winchester, D. E., Coal fields of the Wind River region, Fremont and Natrona counties, Wyo.: U. S. Geol. Survey Bull. 471, pls. 49, 53, 1912.

along the crest or crown of the anticline it will be seen that the fold is sinuous but that both ends trend almost due north. The bend in the middle offsets the two straight ends about 2 miles, though there is no large fault. The axis rises to the south, as is shown by the absence of any visible southward-dipping strata. Erosion has left the anticline incomplete in the sense that it is not encircled by the formations involved in the fold. The anticline was developed on the north slope of the giant Sweetwater anticline and so is called a slope anticline.

In the northwest corner of T. 33 N., R. 94 W. (undivided township), small oil seeps occur in Frontier sands north of Mount Rogers and just south of the place where they dip below the shale. From one of the seeps a little west of the axis a film of oil accumulates on a pool of stagnant water. On the axis oil escapes from the next lower sandstone and remains in little depressions or on warm days trickles down the slope of the sandstone. Some black residue indicates the drying of the oil as it escapes. The largest seeps are about half a mile to the south of the seeps above described and north of Mount Rogers, a high, flat-topped hill, on the axis of the anticline, where oil oozes from a still lower sandstone (Peay) and accumulates in cow tracks and other small depressions. Pieces of old rusty machinery lying about are signs of a former intention to prospect, possibly that of the Omaha Oil & Transportation Co., mentioned by Aughey. The record of the well in the position of the unsurveyed SW. ¼ sec. 29, T. 33 N., R. 94 W., on Conant Creek, was not obtained, but seemingly it was a dry hole.

A temporarily abandoned well of the Western States Oil Co., begun in the summer of 1913, is 2 miles southeast of the oil seeps, in the syncline between the Alkali Butte and the Conant Creek anticlines. It is reported that at a depth of 1,300 feet a showing of oil was found in sandstone which is certainly the same as that at the oil seeps in the sharp ridge at Mount Rogers.

The Ohio well, drilled in the fall of 1913 a short distance west of the axis of the anticline, in the NE. ¼ sec. 2, T. 33 N., R. 94 W., was a dry hole, drilled in dark shale to a depth of 2,930 feet. At a depth of 177 feet, in a thin, soft sandstone, a little gas and oil were struck. No sand was encountered below 1,070 feet, and no water at any depth.

The Alkali Butte anticline is not regarded as a favorable structure for the accumulation of oil and gas, because the upper oil-bearing sandstones have been eroded from its crown and because the axis rises to the south, so that there is no domed area in which the lower oil-bearing sandstones and conglomerates are closed tightly below shale. In such an anticline, where the sandstones are saturated with water, any oil or gas once contained in them has presumably had an opportunity to escape. The oil seeps described above indicate that this process is still in operation. There is, however, a chance that an oil pool may be found even in spite of these unfavorable conditions.

CONANT CREEK ANTICLINE.

Southwest of Delfelder's ranch, on the heads of Long and Conant creeks, is an open complex anticline crossed by the Sweetwater escarpment. Small springs of good water are present along its east side and south end, and large sulphur springs issue in the southeast corner of T. 33 N., R. 94 W., from beds near its axis. The visible part of the anticline covers less than two townships and is limited on the north and east by flat-lying variegated beds and on the south by nearly level light-colored strata. In plan the Conant Creek anticline is short, owing in part to overlapping horizontal beds but more to the character of the fold; its axis is sinuous and pitches only in one direction. It has, as shown in figure 18 (p. 252), a wide northeast limb and a narrow west limb. Its complexity is due to three minor folds on the main anticline and to faults. One of the minor folds, which has dips of 18° to 29° and pitches away from the main anticline, is on the east side in the northwest corner of T. 32 N., R. 93 W.; another occurs at Sulphur Springs, and still another to the south, which is crossed near the middle by the Sweetwater escarpment. The last two, whose axes are slightly offset, are separated by a branch of Conant Creek and really make a large part of the main anticline. The dips on the east flank of the south fold range from 12° to 85° and those on the west flank from 8° to 20°. Small faults occur at the north end of the south fold, and a large strike fault on the west limb of the northernmost fold possibly furnishes opportunity for the escape of the water at Sulphur Springs. The offsetting of the formations in the north-central part of T. 32 N., R. 93 W., is more probably due to a fault than to an acute fold, though this is not evident from the manner of grouping formations on the map (Pl. XXIII).

In the general syncline between the Conant Creek and Alkali Butte anticlines there is a small, slightly arched anticline that pitches northward like those on each side. This fold, the Big Sand Draw and Alkali Butte anticlines, and the minor folds of the Conant Creek anticline resemble in shape and position the fingers of a hand.

A cross section through the anticline near Sulphur Springs (see fig. 18) displays dips of 32° to 65° on the narrow west limb, which is less than a mile wide, and dips of 30° to 47° in the same strata on the northeast limb. The outcrop of these beds on the west limb is about 2½ miles wide, but that on the east limb is about 8 miles wide, the greater width being due in part to low dips, but more to the presence of a great thickness of beds that are not found on the west limb or in the syncline between the Alkali Butte and Conant Creek anticlines. Viewed lengthwise the anticline shows a great thickness of beds dipping northward but no corresponding beds dipping southward. The absence of southward dips indicates the deep erosion which the anticline has suffered, also that it is a slope anticline. The anticline seems to end about 3 miles north of Sulphur Springs, as the massive sandstones along the north side of T. 33 N., R. 94 W., are not noticeably affected by the fold.

The Conant Creek anticline is not a favorable fold for the accumulation of oil and gas, because all the oil-bearing formations are stripped from its crest and even though minor folds are present they involve mostly the older formations, which generally are not oil bearing. Thus in no part of the anticline are the Cretaceous oil-bearing sandstones tightly sealed beneath shale in such a manner as to lead to the retention of oil and gas in the presence of water.

BUCK SPRINGS ANTICLINE.

An anticline is indicated by a small area of tilted sandstone beds surrounded by flat-lying variegated strata at Buck Springs, in T. 34 N., Rs. 92 and 93 W., 4 miles east of Delfelder's ranch. In plan the

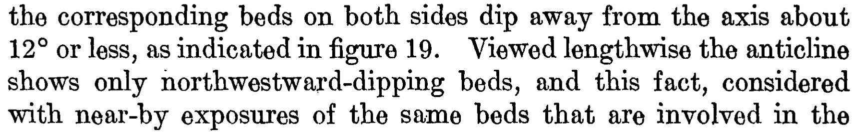

FIGURE 19.—Section through the Buck Springs anticline, Wyo.

visible part of the anticline is arrow-shaped, pointing northwest, and the corresponding beds on both sides dip away from the axis about 12° or less, as indicated in figure 19. Viewed lengthwise the anticline shows only northwestward-dipping beds, and this fact, considered with near-by exposures of the same beds that are involved in the arch, indicates an inclined axis or a slope anticline.

The relation of the Buck Springs anticline to other anticlines in its vicinity is purely speculative, because of the surrounding flat-lying beds. However, it is reasonably certain that there is a fault trending northeast from a point near the sharp bend of Long Creek possibly to the southwest corner of T. 34 N., R. 92 W. No definite fault plane is visible, its presence being inferred by the offset in position of the outcrop of some of the older formations in the Conant Creek anticline. The map, on which the many formations involved in the folds are combined into only three groups, does not adequately indicate the amount of the offset.

The Buck Springs anticline is not attractive as oil territory, because the oil-bearing Frontier formation is beyond easy reach of the drill, lying at a depth of more than 4,000 feet, and because of the pitch of the axis as outlined above.

DUTTON ANTICLINE.

An open northward-pitching slope anticline is situated in what is known as Dutton Basin, north of the Sweetwater escarpment, 6 miles west of the north end of the Rattlesnake Mountains and from 12 to 25 miles south of Moneta, a station on the Chicago & Northwestern Railway. This locality has been referred to in short notes by Aughey[1] and Ricketts[2] as the Dutton oil basin, and later described by Knight[3] and by Woodruff and Winchester[4] as the termination of an anticlinal fold. The part of the anticline not covered by flat-lying variegated beds is short and about one-third as wide as long. The southern part is marked by northward-converging sandstone ridges, so that in plan the formations or contour lines drawn on a particular bed resemble a series of nesting V's opening to the southeast. None of the beds involved in the fold at present entirely encircle the anticline, and viewed from the side it shows a series of northwestward-dipping beds and an inclined axis.

The west limb is narrow, with the beds dipping 20° to 45°; on the broad east limb the same beds dip 12° to 33°. (See fig. 20.) The

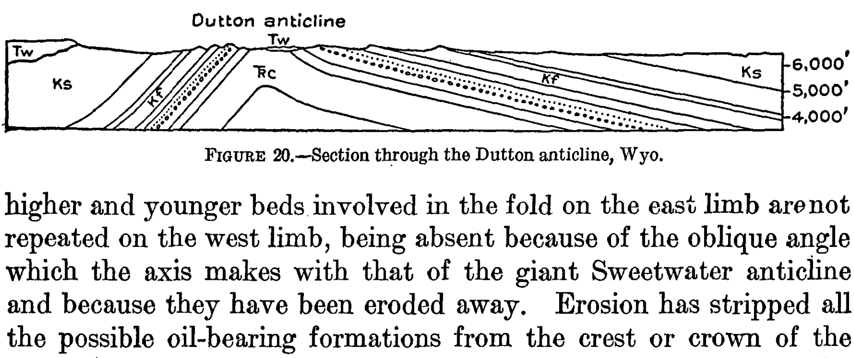

FIGURE 20.—Section through the Dutton anticline, Wyo.

higher and younger beds involved in the fold on the east limb are not repeated on the west limb, being absent because of the oblique angle which the axis makes with that of the giant Sweetwater anticline and because they have been eroded away. Erosion has stripped all the possible oil-bearing formations from the crest or crown of the anticline, and it is probable that truncation cut down even to the granite prior to the deposition of the flat-lying beds.

The formations on the west limb of the anticline probably join with the same formations exposed near the head of Muskrat Creek and farther west with those on Conant Creek, as indicated on the map (Pl. XXIII) by the dashed line under the stippled pattern. The northward-dipping beds in Tps. 32 and 33 N., R. 91 W., on Muskrat

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1 Aughey, Samuel, Wyoming Territorial Geologist Ann. Rept., 1886, p. 129.

2 Ricketts, L. D., Wyoming Territorial Geologist Ann. Rept., 1888, p. 35.

3 Knight, W. C., Wyoming Univ. School of Mines, Petroleum ser., Bull. 4, pp. 14-19, 1901.

4 Woodruff, E. G., and Winchester, D. E., Coal fields of the Wind River region, Fremont and Natrona Counties, Wyo.: U. S. Geol. Survey Bull. 471, p. 551, pl. 49, 1912.

Creek, are a part of the north limb of the giant Sweetwater anticline. Likewise, those on the east limb of the Dutton anticline probably join the same formations at the north end of the Rattlesnake Mountains. The Dutton anticline is separated from the Rattlesnake anticline by a shallow syncline occupied by Deer Creek and extending south past Black Mountain to the head of Dry Creek. (See fig. 21.)

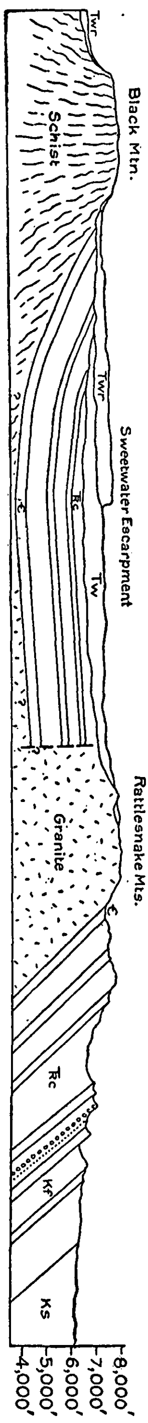

FIGURE 21.—Section through the north end of the Rattlesnake anticline, Wyo.

The Dutton anticline is commonly spoken of as the Dutton Basin oil field, but like the "Riverton oil field" it does not deserve the name. Oil seeps are rare and there are (June, 1916) no producing oil wells. The small outcrop of Tensleep sandstone in sec. 13, T. 33 N., R. 90 W., is saturated with oil, but the seeps mentioned by Knight[1] as occurring in the Dakota sandstone, "Niobrara sandstone" [probably Frontier], and Tertiary beds were not found. Near the apex of the converging sandstone ridges there are some bog holes from which a small quantity of bad water issues, but no oil was seen. About small vents in these places an occasional gas bubble escapes, and there is a distinct odor of hydrogen sulphide. The field has been prospected recently by numerous assessment wells and in the early days by pits. A well drilled on the axis, about a mile north of the apex of the united hogback ridges of the two flanks of the fold, obtained a showing of oil and gas. The casing was still in the hole at the time of the writer's examination, and water stood only a few feet below its top. A small amount of gas was being given off, and a sample of heavy dark-brown oil was obtained from the top of the water. The oil probably came from the Wall Creek sand, as the well is reported to have been drilled to a depth of about 1,060 feet. It was not analyzed.

Because any oil or gas which may have been contained in the formations has had ample chance to escape from their truncated edges during the erosion periods preceding and following the deposition of the flat-lying beds, and also because of the meager showing of oil seeps, it seems improbable that any considerable amount of oil has been conserved in this much eroded anticline. Small quantities may be entrapped where the oil-bearing formations abut

[1] Knight, W. C., op. cit., pp. 14-18.

against the flat-lying beds, but even this possibility seems remote.

RATTLESNAKE ANTICLINE (?).

The fold of the isolated Rattlesnake Mountains is about 50 miles west of Casper and 15 miles southwest of Waltman. The northwest end is anticlinal and faulted, as shown in figure 21, whereas from Wallace Creek southeast to Horse Creek the strata dip for the most part in one direction (northeast) and are disturbed by large intrusive masses, as shown in figure 22. The range has a length of about 25 miles, trends about N. 45° W., and parallels most of the anticlines in the area. Viewed broadly, it is a deeply eroded anticline resting on the granitic rocks of the Sweetwater Valley and formed on the northern limb of the giant Sweetwater anticline. Knight[1] considered the range as due to a great overthrust fault and shows the fold as a large monocline—that is, a fold in which the strata all dip one way—and Trumbull,[2] apparently following Knight, also considered it a monocline, but a map by Darton [3] shows a vestige of a southwest limb at the north end. Along the northeast side of the mountains are the Bighorn, Rattlesnake, and Arago oil basins of some writers.

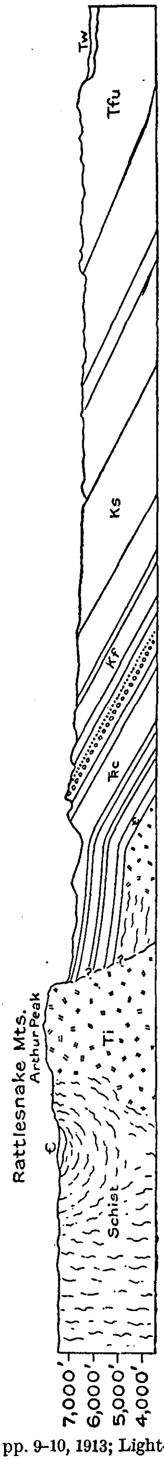

FIGURE 22.—Section through the Rattlesnake anticline at Arthur Peak, Wyo.

In plan the visible part of the fold is about one-third as wide as long and is encroached upon on all sides by the overlapping horizontal white and variegated beds deposited during and after the principal period of deformation. These level beds conceal the true relation of the Alcova and Dutton anticlines to the folds in the Rattlesnake Mountains. The outcrops of the formations involved in the folds of the Rattlesnake Mountains occur, in plan, in parallel bands with a southwestward-bending hook at the north end. At both ends they pass under younger flat beds. The normal dip and strike of the strata have been disturbed by late intrusive rocks, as shown in figure 22.

1 Knight, W. C., op. cit., p. 21.

2 Trumbull, L. W., Prospective oil fields: Wyoming Geol. Survey Bull. 5, pp. 9-10, 1913; Light-oil fields of Wyoming: Wyoming Geol. Survey Bull. 12, p. 125, 1916.

3 Darton, N. H., Paleozoic and Mesozoic of central Wyoming: Geol. Soc. America Bull., vol. 19, pl. 22, 1908.

This probably explains a small shallow syncline between Arthur Peak and Devils Saddle, in T. 32 N., Rs. 86 and 87 W. Large masses of intrusive porphyritic andesite form Garfield Peak, Arthur Peak, Devils Saddle, and Goat Mountain. The large white mineral in the porphyry is oligoclase-albite and the large black ones alkali pyroxenes. Smaller masses of the same rock are found also at many other places, shown on Plate XXIII. The sedimentary rocks surrounding these igneous rocks usually dip away from the intruded mass, but not uncommonly they are overturned and dip toward it.

A transverse section through the range south of the J E ranch and from Black Mountain to Wallace Creek (fig. 21) shows only a few beds dipping at low angles into the Deer Creek syncline, but east of the granite core these beds, as well as those which are shown by cross hatching on the map, dip about 45° E., and many others, mostly those not indicated by a pattern on the map, dip east at angles of 25° or more for a distance of over 6 miles. North of this section the beds on the west limb of the fold dip 37° or more, and in secs. 14, 24, and 25, T. 34 N., R. 89 W., a minor short syncline is developed on the main fold, as is shown on the map by the indentation of the cross-hatched area. A similar section through Arthur Peak (fig. 22) shows only eastward-dipping strata, tilted at angles of 16° to 40°, which gradually flatten and pass under the nearly level variegated beds and into the F L syncline on the east. The higher dips in general occur along the hogbacks forming the foothills of the mountains (the outer part of the area indicated by cross-hatching on the map).

The range viewed lengthwise along the summit displays from the southeast for 15 miles a granite and schist base, partly veneered with flat strata, which are here and there distorted by late intrusions. The folded sedimentary formations at the northwest end of the mountains dip on an average about 24° N. for a distance of 8 miles and then pass beneath the horizontal variegated beds.

It is possible that near the head of Horse Creek there is along the southwest side of the mountains a northwestward-trending fault. A large fault here, which was assumed by Knight [1] to connect with the alleged large fault at Alcova, is highly problematic, but credence is lent to this assumption by the fact that a large warm spring in sec. 35, T. 32 N., R. 86 W., issues from the supposed fault plane. Probably there is no fault of great magnitude at this place, for there is no marked offset of the formations near Deer Creek, in T. 34 N., R. 89 W., and the south end of the supposed fault near Alcova is not evident. There is, however, in T. 33 N., R. 88 W., at the north end of the Rattlesnake Mountains, a fault a few miles in length, but no further positive evidence was seen of such a large fault as would be necessary to account

[1] Knight, W. C., op. cit., p. 21.

for the absence in the Sweetwater Valley, southwest of the Rattlesnake Mountains, of the older as well as the younger folded formations that are present on the northeast side of the mountains. The formations probably once extended across Sweetwater Valley and have been eroded, because all of them having similar characteristics are found at Whiskey Peak and Green Mountain in Tps. 27 and 28 N., Rs. 89 and 90 W.

The indications of oil found at many places in the Rattlesnake Mountains are confined chiefly to the conglomerate (see section on Pl. XXIII) in the lower part of the Cretaceous and to the Dakota. These have been described by Aughey, Ricketts, Knight, and Trumbull in the papers already cited. At the Lew Smith spring, in sec. 26, T. 32 N., R. 86 W., a very small quantity of dark asphaltum issues from the bottom of a ravine in the flat-lying beds. It originates in either the conglomerate or the sandstone (Dakota), which are only a few feet below the surface. Southwest of Oil City, where the same conglomerate is more extensively saturated, a dark asphaltum oozes from its outcrop. A small outcrop of a higher sandstone (Frontier) in this vicinity, in the SE. ¼ SE. ¼ sec. 8, T. 32 N., R. 86 W., shows traces of oil. Between this locality and Garfield Peak no oil was found, but north of the peak, on Wallace Creek and on small draws cutting the upturned rocks in the hogback ridges from sec. 28, T. 33 N., R. 87 W., to sec. 34, T. 34 N., R. 88 W., the same conglomerate and sandstones as are found farther south are saturated with oil, and from seeps along the creek valleys dark asphaltum accumulates to considerable depth over many square rods. In this district there are traces of oil in all the formations from the Chugwater to the Dakota, also in the Frontier, and even the Teapot sandstone at Phayles Reef, in secs. 4, 5, and 9, T. 33 N., R. 87 W., is saturated with oil. The indications of oil are less and less pronounced toward the north end of the mountains, where there are no showings whatever.

The exact location of the two wells of the Central Association of Wyoming, drilled 700 and 900 feet deep, which passed through the "Fox Hills" [Frontier] and obtained some light oil, and of the one sunk by the Northwestern Oil Co. in September, 1887, which also obtained some light oil and water at 480 feet in the "Fox Hills" [Frontier], is not recorded [1] unless, as seems probable, they are the ones shown by Knight in sec. 34 and in sec. 28 or 29, T. 34 N., R. 88 W.

Two other shallow wells have been drilled along the mountains, one 1,130 feet deep at Oil City, which struck only a slight showing of oil at a depth of 500 feet, and one near the west quarter corner of sec. 20, T. 33 N., R. 87 W., which obtained a showing of oil and gas.

[1] Aughey, Samuel, op. cit., p. 134. Ricketts, L. W., op. cit., p. 35. Knight, W. C., op. cit., p. 28, map.

During the summer of 1913 some prospecting was done with Star rigs along the east side of the mountains, but no oil was obtained.

The Rattlesnake anticline is not considered favorable for the conservation of oil and gas, because none of the oil-bearing formations are closed tightly below thick shale beds in anticlinal folds. The fact that oil escapes from the outcrops of the formations along the east flank of the mountains seems to signify that most of the oil has been forced by water pressure to the outcropping edges of the formations, so that little remains in them at present, and wells drilled down the dip from the outcrop may be expected to strike plenty of water. It is not considered that the outcrops of these more or less saturated sandstones and conglomerate are so clogged with oxidized oil and asphalt as to make them reservoirs for oil down the dip, as occurs in some of the California fields.[1] This unfavorable view of the significance of such seeps is supported by the fact that the beds dip rather uniformly along the whole front of the mountains except in the area affected by the Wallace Creek dome (?), so that no structural terraces or minor anticlines occur.

WALLACE CREEK DOME (?).

A fold somewhat resembling a dome occurs in T. 34 N., R. 87 W., far out on the northeastward-sloping beds involved in the upturned limb of the Rattlesnake anticline or along the west limb of the F L syncline, according to the viewpoint of the individual. The syncline has been referred to as the Powder River syncline.[2] Wallace Creek, a tributary of Powder River, has eroded the flat-lying variegated beds from most of the township and displayed older folded rocks, which show dips of 3° to 10° or in some places 17°. In a section taken in a N. 45° E. direction across the northwestern part of the township there are strata dipping southwest as well as northeast, but in one taken in a similar direction through the dome and along the creek only eastward-dipping beds occur. A low arch is present in a section taken in a northwesterly direction. The folding seemingly did not progress sufficiently to form a complete dome, as there are no southwest dips along the south side of T. 34 N., R. 87 W.

The Wallace Creek dome (?) is less attractive than some other areas as a possible oil reservoir, because the proved oil-bearing formations are too deep to be reached easily by the drill. The highest sandstone showing oil in the region is the one saturated with oil at Phayles Reef, in secs. 4, 5, and 9, T. 33 N., R. 87 W. It is at least 4,000

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[1] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga district, Cal.: U. S. Geol. Survey Bull. 398, pp. 187-189, 1910.

[2] Woodruff, E. G., and Winchester, D. E., Coal fields of the Wind River region, Fremont and Natrona counties, Wyo.: U. S. Geol. Survey Bull. 471, p. 553, pls. 49, 56, 1912.

feet and perhaps much more below the surface. Before the Wallace Creek dome (?) is finally condemned as oil territory, a well should be drilled deep enough to test this sandstone. If a test well is to be drilled, preparations should be made to go 6,000 feet or more if necessary.[1]

The Franco-American well, in sec. 16, T. 34 N., R. 87 W., though not completed when the area was examined, struck no oil. The well was sunk more than 2,000 feet and may have reached well into the Lance formation.

It is interesting to note that the largest showings of oil in the upturned beds along the Rattlesnake Mountains are almost directly opposite the dome on Wallace Creek and that the heavily saturated Phayles Reef lies in the intervening area, but it is impossible to say whether or not this intervening area contains a body of oil.

ALCOVA ANTICLINE.

The town of Alcova is about 30 miles up North Platte River from Casper, in the midst of an area of folded rocks that have been exposed by the erosion of the river. The fold at Alcova may be considered as the southward-pitching end of an anticline that is paralleled on the east by the F L syncline and on the west by a narrow syncline and farther west by a monocline resting on the granitic nucleus of the giant Sweetwater anticline. The Alcova anticline is believed to be a part of the limb of the large Sweetwater fold.

The geology at Alcova has been briefly described by Knight,[2] who shows the tilted beds as a faulted monocline.[1] In a later paper[3] he refers to the fault as the Fremont thrust fault. The stratigraphy of this locality has been described briefly by Darton,[4] who shows the folds as a faulted anticline and monocline.

The visible part of the unsymmetrical anticline is about 16 miles long by about 7 miles wide, and it trends about N. 60° W. In passing along the southeastward-pitching axis from the northwest corner of T. 30 N., R. 83 W., through the Hot Springs gorge to the vicinity of the southeast corner of T. 30 N., R. 82 W., successively higher or younger rocks are encountered. The strata on the broad northeast limb dip on an average 10°, whereas those on the narrow southwest limb dip as much as 60°, as shown in figure 23.

The formations involved in the fold at first sight seem to be repeated by faulting, because the broad band of red rocks (Chugwater formation) on which Alcova is located is apparently repeated farther

[1] Trumbull, L. W., Prospective oil field at Upton, Buck Creek, Rattlesnake Mountains, and Labarge: Wyoming Geol. Survey Bull. 5, p. 10, 1913.

[2] Knight, W. C., Artesian basins of Wyoming: Wyoming Univ. Bull. 45, p. 236, 1900.

[3] Knight, W. C., Wyoming Univ. School of Mines, Petroleum ser., Bull. 4, p. 21, 1901.

[4] Darton, N. H., Paleozoic and Mesozoic of central Wyoming: Geol. Soc. America Bull., vol. 19, pp. 405-488, pl. 21, 1908.

up the North Platte by the alleged Fremont thrust fault, as shown by Knight and Darton, but on closer inspection it is found that the formations from the Chugwater up to the Niobrara may be traced continuously from the east limb of the anticline around the point of the fold and along the west limb, except where they are covered by flat-lying beds, as just west of the river, and connected with the same formations in the monocline below the Pathfinder dam. The traces of these formation boundaries are of the form of very much depressed Z's. The formations have been somewhat compressed on the west limb of the Alcova anticline, for even though the beds are on edge west of Hot Springs and along the Devils Gardens, there is scarcely sufficient width of outcrop to accommodate the normal thickness of the formations. It is possible that there are some small strike faults along the crushed zone that represent the southeastward dying out of the large fault on the southwest side of the Rattlesnake Mountains assumed by Knight. A small normal fault trending southwest about 4 miles northwest of Alcova and 3 miles east of the Childress ranch, offsets the formations about 200 feet.

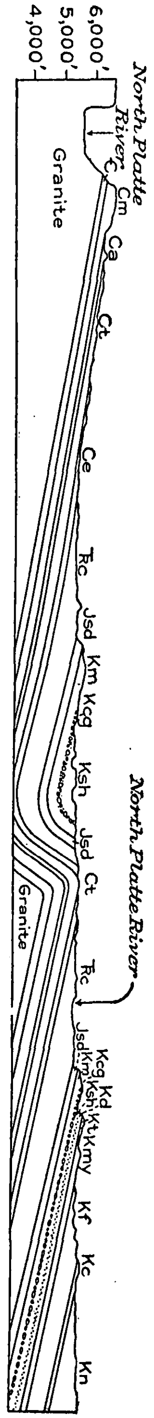


Figure 23.—Section through the Alcova anticline, Wyo.

The exact relation of the folds at Alcova to those in the Rattlesnake Mountains, on the northwest, or those in the Freezeout Hills, on the south, is obscured by the unconformable flat-lying beds. The strike of the beds in the Rattlesnake Mountains is in harmony with the strike of the beds at Alcova, and as the formations are the same in each area, they probably join beneath the flat-lying beds. The broken line beneath the stippled pattern on the map indicates such a connection. The intervening distance is about 12 miles, and it is assumed that truncated edges of the formations from Cambrian to Fort Union abut against the flat-lying beds. It is possible that where the formations that show large seeps of oil along the front of the Rattlesnake Mountains abut against the level beds these overlying beds may act as a trap, and oil pools may have formed either in the sands below or in the level beds themselves, but it is believed that no large pools may be expected here.

The area immediately about Alcova apparently has no future as oil territory, because the anticline is eroded below all the oil-bearing formations, allowing easy escape of oil and gas from the outcrop and leaving no favorable places for pools to be formed. No oil seeps were seen about Alcova, and the well drilled several years ago in sec. 25, T. 30 N., R. 83 W., 2 miles above the village, was a dry hole. Its location is in the syncline between the Alcova anticline and the monocline to the west and is in as unfavorable a site for a test well as could have been selected.

BATES HOLE ANTICLINE.

The anticline in Tps. 30 and 31 N., R. 81 W., in the middle of the Bates Hole country, is a small upwarp trending approximately N. 45° W. It lies a short distance northeast of the folded rocks at Alcova, south of the Goose Egg anticline, and immediately west of the highly folded and faulted rocks of the Laramie Mountains. It is in line with the axis of the F L syncline, which lies west of the Pine dome and Oil Mountain anticline. The axis of the Bates Hole anticline pitches at both ends at low angles and has a sag a short distance north of the south township line of T. 31 N., R. 81 W., making two unequal parts, of which the larger is the broad southern portion of the anticline, in the northeast corner of T. 30 N., R. 81 W., and the smaller the narrow northern portion of the anticline, in the southwest corner of T. 31 N., R. 81 W. A small strike fault, not shown on Plate XXIII, occurs south of the middle of the anticline. The anticline has a narrow west limb in which the beds dip from 70° to 90° and a broad east limb in which the same beds dip less than 40°.

West of the small north end of the Bates Hole anticline and separated from it by a narrow syncline is a small dome or short simple anticline covering less than a square mile. The dips in the encircling sandstone ridges that indicate its presence are about 50° on all sides.

In this small dome and also in the north end of the main anticline the Dakota sandstone is from 500 to 800 feet below the surface. The Tensleep sandstone is less than 1,500 feet below the surface in the middle of the southern part of the anticline. Because of the presence of this and other sands which yield oil or show indications of it in other localities, there is a possibility that the Bates Hole anticline may contain oil or gas. No indications of oil, however, were found on it at the surface.

GOOSE EGG ANTICLINE.

The faulted anticlinal fold of the Casper Range, a part of the giant fold of the Laramie Mountains, enters the southeast corner of this field in T. 32 N., R. 81 W., and structurally terminates in the anticline forming Goose Egg Mountain, a small outlier separated from the main range by North Platte River.[1] The mountain rises about 1,000 feet above the river.

The Goose Egg anticline as expressed in plan consists of a series of nesting V-shaped lines representing structure contours or even contacts of formations that open toward the Laramie Mountains and point westward. Its axis, sloping down from the giant anticline of the Laramie Mountains, pitches at a fairly high angle and trends a little south of west, at a considerable angle to the axes of the surrounding anticlines. (See Pl. XXIII.) The Casper fault,[2] which brings the granite to the surface in the Laramie Mountains, and the Emigrant Gap anticline limit the Goose Egg anticline on the northeast. As viewed in a north-south cross section near the highest part of the mountain the strata on the south flank of the anticline dip from 16° or possibly less to 21°, as shown in figure 24, but north of the axis in a narrow crushed zone they dip at very much higher angles and are even overturned. North of the highly tilted beds the dips decrease rapidly and the strata flatten, forming the large

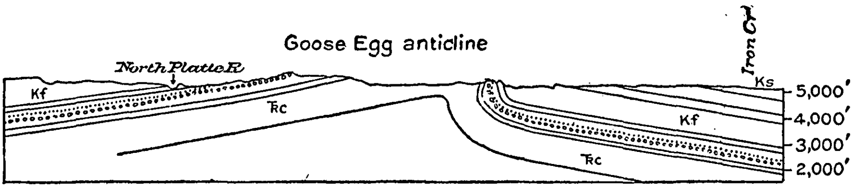


FIGURE 24.—Section through the Goose Egg anticline, Wyo.

bulge or arc on the north side of the anticline, as indicated in Plate XXIII.

The Goose Egg anticline is not considered favorable for the accumulation of oil and gas, because all the oil-bearing formations are exposed at the surface except the Tensleep sandstone, which is only a few feet below the river. This probably is water-logged even on the crown of the anticline, for a large spring that is used to irrigate about 1,000 acres of Bessemer Flats issues from the base of the Chugwater formation in the crest of the anticline.

IRON CREEK ANTICLINE.

The Iron Creek anticline occupies a small area in the northwest corner of T. 32 N., R. 82 W., where its crest is shown by inclined sandstone beds that form encircling ridges about an inner shale basin, and each sandstone is in turn surrounded by a shale valley.[3]

[1] Hayden, F. V., U. S. Geol. Survey Terr. Fourth Ann. Rept., pp. 26-28, 1872.

[2] Hayden, F. V., idem. Darton, N. H., Paleozoic and Mesozoic of central Wyoming: Geol. Soc. America Bull., vol. 19, pl. 21, 1908; Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, pp. 53-55, 1905. Barnett, V. H., Possibilities of oil in the Big Muddy dome, Converse and Natrona counties, Wyo.: U. S. Geol. Survey Bull. 581, pp. 105-117, 1915. Spencer, A. C., The Atlantic gold district and North Laramie Mountains, Wyo.: U. S. Geol. Survey Bull. 626, pl. 4, 1916.

[3] Hayden, F. V., op. cit., p. 28.

It is the fold connecting the Oil Mountain and Goose Egg anticlines. Like the Oil Mountain anticline, it trends northwest, but it is nearly at right angles with the Goose Egg anticline. The strata on the north end of the Iron Creek anticline dip 42°; those on the south end only 11°. The strata on the east side dip from 20° to 60° and the same beds on the west side from 31° to 62°, as shown in figure 25.

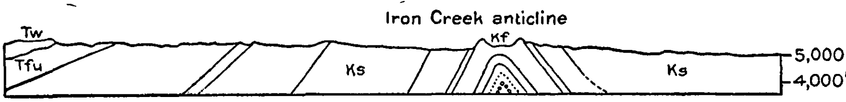


FIGURE 25.—Section through the Iron Creek anticline, Wyo.

The fold is ideal for the accumulation of oil and gas in wet rocks, but only the drill will show whether or not oil, gas, or water occurs in the Cretaceous sands below the Frontier sandstones, or in the conglomerate, sealed below impervious shale.

OIL MOUNTAIN ANTICLINE.

The Oil Mountain anticline, in Tps. 32 and 33 N., R. 82 W., a little over 15 miles west of Casper, is a small unsymmetrical fold, whose middle portion is indicated by concentric shale valleys and sandstone and conglomerate ridges that rise considerably above the surrounding country. The lower and outer portions of the flanks of the anticline, formed of soft shale, are less conspicuous than the inner portion, where the sandstones are exposed. The strata of the west limb dip rather uniformly at angles of 29° to 46° close to the mountain, but farther west the dips are as great as 80°; those on the east limb dip only 7° out on the flanks, but are vertical or even overturned close to the axis. The axis pitches abruptly southward and gently northward. (See fig. 26.) A strike fault with a throw of over 1,000 feet repeats the outcrop of some of the formations northwest of Oil Mountain, and the oil spring in sec. 28, T. 33 N., R. 82 W., is on the fault plane. East of the fault the rocks dip at low angles (3° to 9°) and show a marked flattening of the anticline in secs. 15, 16, 17, 19, 20, and 21, T. 33 N., R. 82 W., as indicated in figure 27. This flattening lies mostly south of Poison Spider Creek and presumably is the "peculiar U-shaped fault" of Knight.[1]

At the oil spring in sec. 28 heavy dark oil accumulates on water in an old prospect pit. The ground about the spring is slightly saturated and pieces of asphaltum lie on the surface. The oil possibly comes from the Lower Cretaceous conglomerate, which is only a few feet below the surface on the west side of the fault plane.

The Tensleep sandstone lies about 1,500 feet below the surface on the crest of the Oil Mountain anticline, and the Lower Cretaceous

[1] Knight, W. C., Wyoming Univ. School of Mines, Petroleum ser., Bull. 4, pp. 33-35, 1901.

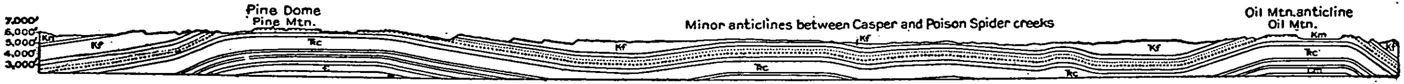


FIGURE 26.—Section along the axis of the Oil Mountain anticline, the minor anticlines between Poison Spider and Casper creeks, and the Pine dome, Wyo.

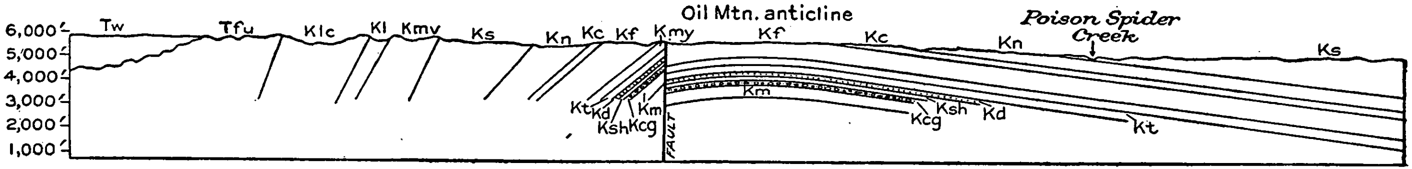


FIGURE 27.—Section through the Oil Mountain anticline, Wyo.

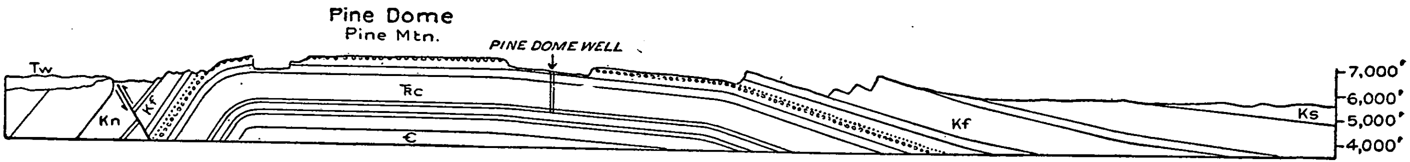


FIGURE 28.—Section through the Pine dome, Wyo.

conglomerate is only a short distance below the surface just west of the fault plane in sec. 28. These two localities, which are the most favorable for the retention of oil because of their position in the anticline and because some of the oil-bearing sands are sealed in the beds underlying them, should be tested before the Oil Mountain anticline is condemned as nonoil land.

MINOR ANTICLINES BETWEEN POISON SPIDER CREEK AND THE SOUTH FORK OF CASPER CREEK.

Between Poison Spider Creek and the south fork of Casper Creek there are three minor anticlines on the general anticline which extends from the Pine dome to Oil Mountain. These folds when compared with the Pine dome and the Oil Mountain anticline are small in area as well as in degree of deformation and topographic effect. They are separated from one another by transverse sags developed on the main anticline, as shown in figure 26. The northernmost of the three minor anticlines is about 4 miles long, and the same strata on both sides of it dip about equally at angles ranging from 15° to 30°. The middle one is about 3 miles long; the strata on the west side dip from 7° to 60°, but those on the east side only from 3° to 24°. The southernmost of the three is very small, being less than a mile long. The strata on the east side dip from 6° to 49° and those on the west 10°. The dip of 49° on the east side is exceptionally steep.

These minor anticlines doubtless have afforded opportunities for the accumulation of oil and gas, but whether they still contain oil and gas can not be determined with certainty prior to actual drilling. The two wells already drilled are near the axis of the general fold extending from the Pine dome to the Oil Mountain anticline, but in the cross sag between the Oil Mountain anticline and the minor anticlines. One of these, the Guthery well, 960 feet deep, in the SE. ¼ SE. ¼ sec. 18, T. 33 N., R. 82 W., is reported to have obtained a showing of oil. The Ohio well, in the NW. ¼ SE. ¼ sec. 18, T. 33 N., R. 82 W., obtained showings of oil in the Dakota sandstone, the Lower Cretaceous conglomerate, and the Morrison formation, but found the Tensleep sandstone, at a depth of 2,715 feet, water-logged. These sands, which are all sealed below impervious shales in the crowns of the anticlines, should be properly tested by the drill before the anticlines are finally condemned as of no value for oil. The dry holes do not necessarily prove that the anticlines do not contain oil, for many dry holes are drilled in and about any proved oil field.

PINE DOME.

The Pine dome, a large faulted dome forming Pine Mountain, 25 miles northwest of Casper, lies just south of the railroads and covers most of Tps. 34 and 35 N., Rs. 83 and 84 W. The dome is moderately arched and shows fairly steep dips about the sides, but in a large area on the crest or top the strata lie almost flat. (See figs. 27 and 28.) The dome is limited on the east by the syncline between it and the Emigrant Gap anticline. On the northwest a wide cross sag south of Powder River station separates it from the Cottonwood Creek anticline, and a cross sag at South Casper Creek limits it on the south side from the minor anticlines north of Poison Spider Creek. The flat-lying variegated beds reach up on its west side.

This moderately arched dome forms the north end of a compound anticline that extends from Pine Mountain to Oil Mountain, trends N. 45° W., and parallels the Rattlesnake and Emigrant Gap anticlines. The general fold on which the Pine dome and Oil Mountain anticline are developed is one of the connecting folds between the giant anticlines of the Laramie and Bighorn Mountains, the other connecting fold being the Emigrant Gap anticline. The distance between the most northerly beds of the Pine dome and the most southerly beds of the Cottonwood Creek anticline, a fold situated upon the south limb of the Bighorn Mountain uplift, is but 3 miles. The relations of the dome to the Laramie uplift on the south are even closer.

The dips on the north, east, and south sides of the dome are low, ranging from 6° to 24°, but those on the southwest, west, and northwest are from 11° to 90° and some of the strata on the west side are even overturned as much as 22°. Because of these high dips the resistant sandstone and hard shale beds form about the dome encircling hogback ridges that are in places impassable, and the beds of soft shale between the sandstone give rise to narrow valleys that with the sandstone ridges are continuous around the dome except where all are faulted out on the west side, as shown in figure 28, or are cut by small dry canyons heading in the mountain. An overthrust fault on the west side has a throw of about 2,000 feet, and a similar fault on the northwest side has a throw of about 800 feet.

No oil seeps were seen in the Pine dome, though it is reported that oil has been gathered from a tunnel in sec. 27, T. 35 N., R. 84 W. When this tunnel was visited some dirty black water was flowing from it, but no traces of oil were seen. The Pine Dome Oil Co. is reported to have brought in during the summer of 1914 a 2,000,000-foot gas well on the east side of the mountain in sec. 36, T. 35 N., R. 84 W., close to the crest of the dome, and just below the gas water was obtained, presumably in the Tensleep sandstone, which is entirely sealed in this dome. The Cretaceous sandstones are all eroded from the crest, and consequently if oil in commercial quantities exists here it must be sought in older rocks, such as the Carboniferous. This question can be determined only by drilling.

ANTICLINE SOUTHWEST OF POWDER RIVER STATION.

About 2½ miles southwest of Powder River station is a small open anticline involving at the surface the coal-bearing rocks that form prominent curved ridges of sandstone. Like other anticlines in this area it trends northwest. The axis presumably pitches at low angles at both ends, even though no formation completely encircles the anticline. The arch is limited on the east by a shallow syncline[1] that occurs between it and the Pine dome. The beds on the southwest side of the anticline dip from 25° to 72°, but the same beds on the east side dip 32° or less.

The Wall Creek sand, which is the principal oil-bearing sand at Salt Creek, is at least 3,000 feet and perhaps more than 4,000 feet below the surface on the crest of the arch. Because of the great depth of this sandstone, if for no other reason, the fold is not an attractive place to prospect for oil, although the facts that the Cretaceous oil-bearing sands are not exposed and that the anticline has a fairly large gathering ground in the great F L syncline suggest the possibility that it may contain oil.

COTTONWOOD CREEK ANTICLINE.

The compound anticline crossed by Cottonwood Creek, in Tps. 36, 37, and 38 N., Rs. 84, 85, and 86 W., is a minor upwarp on the south end of the great uplift of the Bighorn Mountains. It may be considered as a small southward-pitching anticline branching off from the margin of the greater anticline. The Cottonwood Creek anticline is in line with and probably was developed at the same time as the Pine dome and Oil Mountain anticline, which form a part of the fold that unites the Laramie and Bighorn uplifts. It is separated into two parts by a low cross sag which is followed by the perennial Cottonwood Creek in its eastward course just below the Desert ranch. To the north the limbs of the anticline gradually diverge and pass into the northward-rising beds of the Bighorn anticline. The axis of the northern part of the Cottonwood Creek anticline rises and is lost on the south end of the giant anticline of the Bighorn Mountains near the north side of T. 38 N., R. 86 W. The crown of the southern part of the anticline, in secs. 3 and 10, T. 37 N., R. 85 W., is shown by the tilted sandstone beds forming escarpments that dip away from this area. The part of the anticline south of Cottonwood Creek is short, as the area of sandstones in the middle is only about twice as long as wide, but, as shown in figure 29, the slightly dipping west limb continues across the flats to a point within a short distance of the railroad, where the dips increase rapidly, giving in

[1] Woodruff, E. G., and Winchester, D. E., Coal fields of the Wind River region, Fremont and Natrona Counties, Wyo.: U. S. Geol. Survey Bull. 471, p. 557, pl. 56, 1912.

effect a broad, low arch. Its axis trends in general northwest, but just west of Powder River, in the southwest corner of T. 37 N., R. 84 W., its direction is assumed with question to be east of north. The river crosses the extreme south end of the fold.

The strata on the east side of the Cottonwood Creek anticline dip 25° to 30°, much more steeply than those near the crown on the west side (6° to 10°), but not so steeply as those on the extreme west side (60° or more). In this respect the anticline is like those on the south and west sides of the field.

The Toltec well, in sec. 11, T. 37 N., R. 85 W., near the crown of the anticline, struck much warm sulphur water under considerable pressure at a depth of 915 feet, in the conglomerate which is shown on the stratigraphic section on Plate XXIII. The Cottonwood Creek anticline is likely to be barren of oil and gas because the upper oil-bearing sandstones are exposed at the surface, allowing opportunity for the oil to escape, and the lower sandstones and conglomerate are water laden.

BIG SULPHUR SPRINGS ANTICLINE.

The Big Sulphur Springs anticline, in Tps. 37 and 38 N., Rs. 83 and 84 W., is crossed by South Fork of Powder River and is one of the minor folds branching off from the Bighorn anticline. A cross sag followed by the river separates the anticline into two parts, one south of the river and the other on the slope of the Bighorn Mountains. The axis of the anticline is sinuous but in general trends northwest. South of Big Sulphur Springs the dips on the east flank are about 30° and those on the west flank about 5°; south of the river those on the east limb are about 10° or less and those on the west from 1° to 4°, as shown in figure 30. This anticline differs from many of the other anticlines in this region in having low dips on the west limb and steep dips on the east. South of the river a small fault at right angles to the axis has a throw of some 300 feet, and the beds on the north side have moved up relative to those on the south side. The folding here is similar to that in the

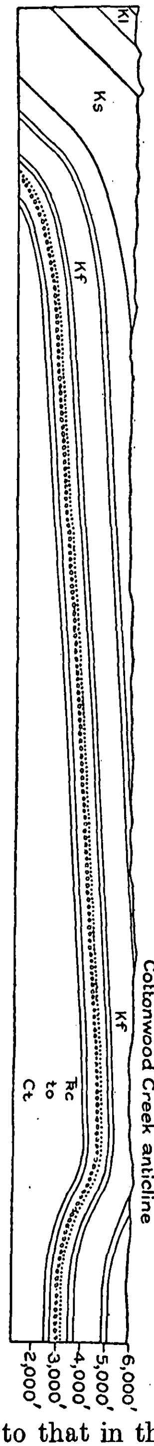


FIGURE 29.—Section through the Cottonwood Creek anticline, Wyo.

Cottonwood Creek anticline in trend and in that a small anticline is separated by a cross sag from the main uplift of the Bighorn Mountains.

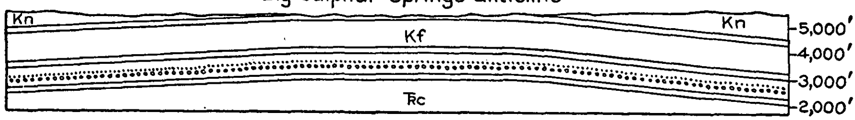


FIGURE 30.—Section through the Big Sulphur Springs anticline, Wyo.

The Big Sulphur Springs anticline is not considered favorable for the accumulation of oil and gas, because the conditions are similar to those in the Cottonwood Creek anticline, where the sandstones even near its crown contain water under pressure.

EMIGRANT GAP ANTICLINE.

The Emigrant Gap anticline is just west of Casper and trends about N. 45° W. from the Casper fault,[1] at the north side of the Laramie Mountains, to the Chicago & Northwestern Railway, a distance of about 20 miles. It is parallel to and about 10 miles east of the general anticline on which the Pine dome and Oil Mountain anticline are developed and with those uplifts forms a uniting fold between the giant anticlines of the Bighorn and Laramie mountains.[2] The anticline is much broader at the south end than it is at the north, as is indicated by the tapering outcrop of the formations involved in the sharp fold. (See Pl. XXIII.) Between this and the Big Sulphur Springs anticline there is a cross synclinal area which is the eastward continuation of the one at Powder River station, between the Pine dome and the Cottonwood Creek anticline. The axis of the Emigrant Gap fold is nearly in line with that of the Big Sulphur Springs anticline.

The dips of the beds on the narrow west limb of the Emigrant Gap anticline range from 40° to 70° and those on the east side near the axis from 8° to 30°, but farther east terrace-like structure is shown by the semicircular outcrop of the sandstones and shales in the southern part of the anticline (see Pl. XXIII), where the dips are as low as 1° to 7°, as shown in figure 31. The anticline is crossed near the middle by a cross sag that divides it into two parts. The southern part is the more pronounced because it is folded more, is eroded deeper, and is marked by prominent sandstone ridges, but it is the less attractive economically because nearly all the oil-bearing formations in it are exposed. The northern part has neither been folded so much nor eroded so deeply as the southern part and offers

[1] Hayden, F. V., U. S. Geol. Survey Terr. Fourth Ann. Rept., pp. 26-28, 1872.
[2] Idem, p. 28.

more inducement to prospecting, for some of the oil-bearing formations in it are sealed below shale. (See figs. 31 and 32.)

North of the cross sag which divides the anticline into two parts there are two minor upfolds on the main fold. They are indicated in the field by inclined beds of Frontier sandstone that form encircling ridges and escarpments. The southern one is dome-shaped and lies in secs. 19, 20, 29, and 30, T. 34 N., R. 81 W. The dips on the west side are about 70°, but those on the other sides are only 6° to 9°, as indicated in figure 32. On the crest of the dome the beds of sandstone are flat. A slight cross trough on the main

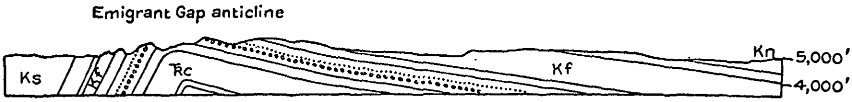


FIGURE 31.—Section through the south end of the Emigrant Gap anticline, Wyo.

anticline, on which is located the United States Geological Survey primary-control station in the SE. ¼ SE. ¼ sec. 24, T. 34 N., R. 82 W., separates the dome from the northern one of the two minor upfolds. This cross trough, instead of being a topographic depression like most of such features, is an eminence rising 5,955 feet above sea level.

The northern one of the minor upfolds, an ideal fold for the accumulation of oil and gas in wet rocks, is in secs. 15, 22, 23, 24, 25, and 26, T. 34 N., R. 82 W. The dips on the southwest side average about 70°; those on the northeast are about 8°. Because of this

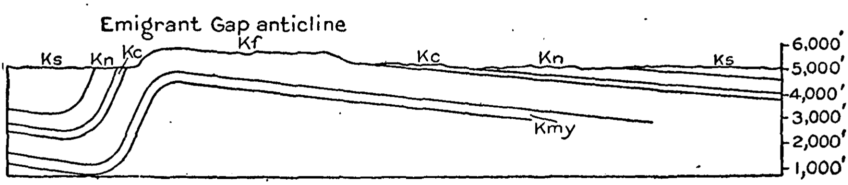


FIGURE 32.—Section near the middle of the Emigrant Gap anticline, Wyo.

great difference in the tilting of the beds the sandstones on the northeast side form a prominent, impassable southwestward-facing escarpment, but in contrast the same rocks on the southwest form only low hogback ridges. The crown of the anticline, in the SW. ¼ sec. 23, is shown by the outcrop of a hard shale, forming a slight hill in a large shale basin. This minor upfold is separated from the north end of the main fold by a slight cross trough near the corner of secs. 9, 10, 15, and 16, where the sandstones close over the principal arch. The crown of the north end of the main anticline is mostly confined to secs. 4 and 9, T. 34 N., R. 82 W., and sec. 33, T. 35 N., R. 82 W. The dips on the west side of the north end of the Emigrant Gap anticline range from 30° to 50°, and those on the east side are 20° or less.

The Emigrant Gap anticline shows no oil seeps and has not been prospected except by two wells far down on its east limb, on Casper Creek, and by a shallow well in the SE. ¼ sec. 9, T. 33 N., R. 81 W., drilled in the summer of 1914 by the Monongahela Oil Co. The well last mentioned, which is near the axis of the anticline and near the cross sag that divides the fold into two parts, obtained a flow of strong sulphur water at a depth of 240 feet. The anticline merits consideration as a favorable fold for the accumulation of oil and should be prospected farther south, in the south-central part of of sec. 25, T. 33 N., R. 81 W., to test the Tensleep sandstone, which is about 1,000 feet below the surface; also farther north in secs. 9 and 23, T. 34 N., R. 82 W., and in the northeast corner of sec. 30, T. 34 N., R. 81 W., to test the Mowry shale, the Dakota sandstone, the Lower Cretaceous conglomerate, and possibly the Morrison formation, which are from 500 feet or less to 1,000 feet below the surface. The first wells should be drilled near the center of sec. 23, T. 34 N., R. 82 W., and if the formations named are found to be water-logged there it would probably be of little use to drill in the other localities in the northern part of the anticline.

NORTH CASPER CREEK ANTICLINE.

The North Casper Creek anticline, a simple fold in Tps. 36 and 37 N., Rs. 81 and 82 W., is about 22 miles northwest of Casper, between

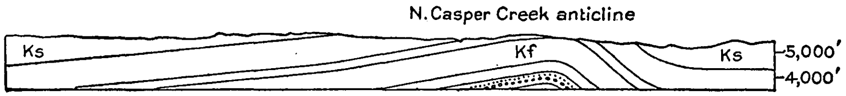


FIGURE 33.—Section through the North Casper Creek anticline, Wyo.

the old Hemmingway and Roseberry ranches. It is sometimes referred to as the Hemmingway dome. The anticline lies northeast of the Emigrant Gap anticline, and its trend is parallel to that of the other anticlines in this general region. Unlike most of these folds, it produces little effect on the topography because of the slight magnitude of the fold and because erosion has barely exposed one of the oil-bearing sands (the Wall Creek) on the very crown of the arch in the midst of Cretaceous shale.

In plan the formations crop out in elliptical bands about the anticline, the crest of which lies near the southeast corner of sec. 1, T. 36 N., R. 82 W., where the Wall Creek sand is exposed. As shown in figure 33, in transverse section the strata on the west side dip at angles of 8° or less, but east of the axis the dips are somewhat higher and in one place reach 45°. In a lengthwise section the axis is gently arched and pitches both northward and southward at angles of about 6°.

The steep dips on the east side are in harmony with similar dips on the east side of the Big Sulphur Springs and Castle Creek anticlines, but in contrast to the dips on the east side of the other anticlines in this area and those in the near-by Powder River [1] and Salt Creek [2] anticlines.

There are no oil seeps in the North Casper Creek anticline, and the three wells drilled about it struck considerable water in all the sandstones they encountered. However, an area about 4½ miles long by 1½ miles wide, or about two-thirds as large as the proved Salt Creek field, yet remains on the crown of the anticline, and it must be drilled before the presence or absence of oil can be fully determined. All the sands that show indications of oil in this field or adjacent fields, except the Teapot and the Wall Creek, are beneath the surface in this anticline. One or two deep wells drilled in sec. 1, T. 36 N., R. 82 W., would perhaps show whether this anticline contains oil, which the three wells drilled to the northwest of its crest have not conclusively done. These wells have shown that the sands in the lower parts of the anticlines are full of water, but other test wells higher up on the arch might strike oil or gas or both.

CASTLE CREEK ANTICLINE.

The Castle Creek anticline, an open fold in Tps. 37 and 38 N., Rs. 80 and 81 W., near the head of Castle Creek, is indicated on the ground by a westward-facing escarpment of Shannon sandstone, trending northwest across the west side of T. 38 N., R. 80 W., and a low northward-facing rim of the same sandstone on the north side of T. 37 N., Rs. 80 and 81 W. South of the 33 Mile ranch, in sec. 5, T. 37 N., R. 81 W., the escarpment fades away, owing to the greater softness of the sandstone and perhaps to its thinning. The axis of the fold, which trends northwest, may possibly represent the southward extension of the axis of the Powder River anticline,[1] and if so considered the axis as a whole is sinuous, like that of the Big Sulphur Springs anticline, with a sharp bend along the east side of T. 39 N., R. 81 W., to conform to the outcrop of the sandstones.

The strata on the east limb of the Castle Creek fold dip about 15°, and those on the southwest limb about 7°, as shown in figure 24. So far as observed there are no northward or northwestward dipping rocks in the Castle Creek fold, and thus the axis pitches gently southeast. For this reason none of the formations encircle the fold, and in this sense the anticline is at present incomplete.

The drill hole of the Midwest Oil Co., near the east quarter corner of sec. 31, T. 38 N., R. 80 W., is in a well-chosen locality near the

[1] Wegemann, C. H., The Powder River oil field, Wyo.: U. S. Geol. Survey Bull. 471, pp. 56-75, 1912.

[2] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 37-83, 1911.

middle of the fold. It was sunk to a depth of about 2,000 feet and a little gas was obtained in the shale above the Wall Creek sand, but as this was the objective sand of the test well and as it was found to contain water drilling was stopped. Two wells have been started in sec. 28, T. 38 N., R. 81 W., but the first was abandoned before being finished and operations on the other, owned by the Casper Oil Co., which started in October, 1914, ceased in January, 1915, at a depth of 1,900 feet. This well is entirely in shale and has struck no oil or gas. No oil seeps were seen during the field examination, and none are reported as occurring here. The anticline may not contain oil or gas in commercial quantities, though it is situated only a few miles southwest of the Salt Creek oil field, the most productive field in Wyoming.

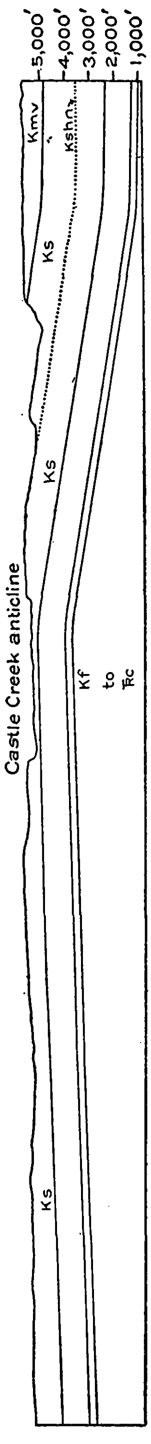


FIGURE 34.—Section through the Castle Creek anticline, Wyo.

POSSIBILITIES OF OBTAINING OIL.

From the results obtained by the wells already drilled in this field, which have cost at a moderate estimate over $200,000, it would seem at first thought that the country should be condemned as oil territory and that further expenditure of large sums of money would be fruitless. But if oil and gas in Wyoming have accumulated according to the anticlinal theory, which demands, in water-saturated rocks, that they are forced to or toward the crowns of the anticlines, and as this theory applies to the productive Salt Creek and Bighorn Basin fields, then the anticlines in central Wyoming have not been thoroughly and properly prospected. Nearly all the wells have struck large flows of water in the several sands from the Wall Creek down to the Tensleep, and as these sands outcrop either in the mountains of this area or in those adjacent to it, it is highly probable that the sands in all localities, except possibly in the structurally higher parts of some of the anticlines, contain water.

The attention of those who may in the future prospect in this area should be directed toward the most promising places in the most favorable anticlines and away from those which on account of pitching only in one direction or on account of having been eroded too deeply are not favorable for the accumulation of oil or gas. There are a few anticlines in the area in which possible oil-bearing sands are not exposed at the surface. As the rocks are charged with water under pressure, these places should be tested if further prospecting is attempted. The anticlines in which one or more of the oil-bearing formations—the Frontier sandstones, Mowry shale, Dakota sandstone, Lower Cretaceous conglomerate, Morrison and Embar formations, and Tensleep sandstone—lie within reach of the drill beneath thick shale beds are the North Casper Creek, Iron Creek, Emigrant Gap, and Oil Mountain anticlines, the minor anticlines north of Poison Spider Creek, and the anticline southwest of Powder River station. The most promising of these are the Emigrant Gap anticline (northern part), the minor anticlines between Poison Spider Creek and Casper Creek, the North Casper Creek anticline, and possibly the anticline southwest of Powder River station; and should these prove after thorough prospecting to be barren of oil, then the chances are against finding oil in the other anticlines of the area. The proximity of the North Casper Creek anticline to the proved Salt Creek dome suggests the possibility of there being an oil pool at this locality. The first two wells drilled in the summer of 1913 did not test the North Casper Creek anticline sufficiently to prove its character. As has already been pointed out, the wells are not located on the crown of the anticline, and two of them were drilled either only into the Wall Creek sand, which is exposed on the crown of the anticline, or only through the Frontier formation. There are no oil seeps from this sandstone where it is exposed on the crown of the anticline, and the negative results of drilling, taken in conjunction with the absence of oil seeps, prove conclusively that this sand, which is the chief oil-bearing sand of the Salt Creek field,[1] does not carry oil in the North Casper Creek anticline. The well drilled in the fall of 1915 by Mr. Fitzhugh and associates was farther up on the anticline and was sunk as deep as the Lower Cretaceous conglomerate and obtained water; therefore it has, with the other two wells, proved that a large part of the North Casper Creek anticline is barren of oil, and there remains only a few square miles of the highest part of the crown yet unprospected. Oil in this anticline may possibly be found in some lower sand, such as those in the lower part of the Frontier, the Lower Cretaceous conglomerate, or the Morrison formation, which lie 100 to 1,500 feet below the Wall Creek, or possibly the Tensleep, which is about 3,400 feet below the Wall Creek, or in some of the numerous intermediate sands. One or two wells drilled near the southeast corner of sec. 1, T. 36 N., R. 82 W., to a depth of

[1] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 37-83, 1911.

about 3,500 feet, would possibly demonstrate whether this anticline contains oil.

Some of the same formations as those noted above are sealed below thick shale beds in the minor anticlines on the northern part of the Emigrant Gap anticline. The Mowry shale is the lowest formation exposed in them, and it is possible that the underlying sands, at depths less than 2,500 feet, may be oil bearing, especially as this part of the Emigrant Gap anticline is one of the nearest anticlines in the entire area to the great Powder River basin and hence has a large gathering ground for the accumulation of oil and gas. However, whether or not it contains oil can not be foretold prior to a test by the drill. Test wells should be located in secs. 9 and 23, T. 34 N., R. 82 W., and the first one should be drilled in sec. 23, which is the most promising part of the anticline.

Conditions similar to those in the northern part of the Emigrant Gap anticline exist in the minor anticlines north of Poison Spider Creek, and these anticlines should be tested near the SE. ¼ NE. ¼ sec. 3 and the center of sec. 12, T. 33 N., R. 83 W., and possibly near the east quarter corner of sec. 18, T. 33 N., R. 82 W.

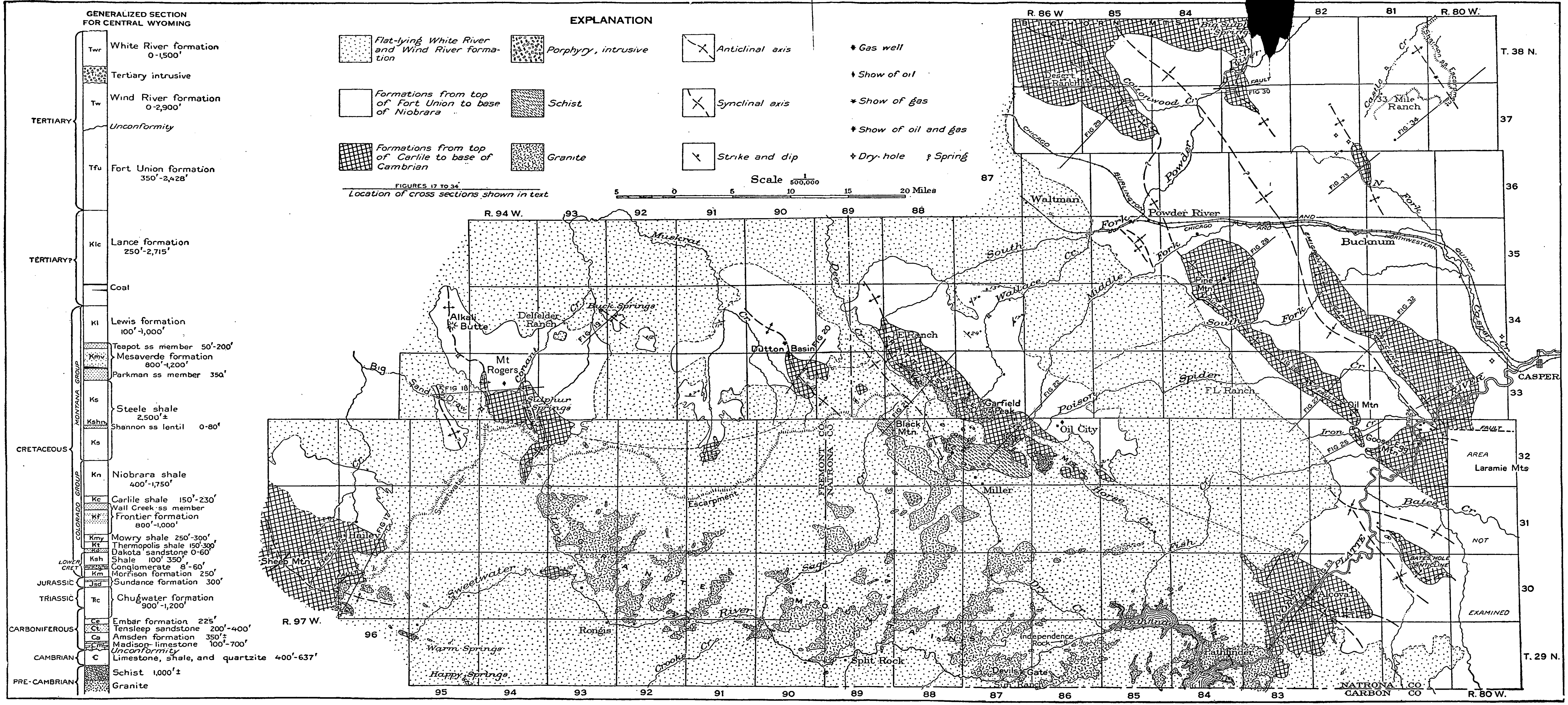
The formations from the Frontier to the Tensleep are below the surface of the Iron Creek anticline, and it is possible that the Mowry shale or some of the underlying sandstones or the conglomerate might contain oil or gas. A test well on Iron Creek within the inner sandstone rim would probably determine, if drilled to a depth of approximately 3,000 feet, whether or not oil is to be obtained in this anticline. The Mowry shale is about 500 feet below the surface, and the Lower Cretaceous conglomerate and Morrison formation would be reached at a depth of about 1,500 feet.

Likewise, the crest of the Oil Mountain anticline itself should be tested. Perhaps in this fold oil may be found in some sand like the Tensleep. A 1,500-foot well, properly located, would test the Tensleep sandstone in this anticline.

Attention should be paid also to the area southwest of the fault northwest of Oil Mountain, for this area is opposite the oil seep at the fault, and there is west of the fault an area of arched beds involving at the surface rocks as low as the Dakota. A well about 1,800 feet deep would possibly demonstrate whether or not the Lower Cretaceous conglomerate, the Morrison formation, and the Tensleep sandstone will yield oil in this place.

The Wall Creek sand is from 3,000 to 4,000 feet below the crest of the small anticline southwest of Powder River station, otherwise this fold might be considered favorably as a place to sink a test well.

Conditions similar to those in the Oil Mountain anticline exist in the south half of the Emigrant Gap anticline, where the Sundance formation occupies the crown of the anticline and the Tensleep sandstone



MAP SHOWING ANTICLINES IN NATRONA AND FREMONT COUNTIES IN CENTRAL WYOMING.

is about 1,000 feet below the level of North Platte River. The Bates Hole anticline falls in the same class.

The Pine dome has been shown by the well of the Pine Dome Oil Co. to contain gas, and as the Tensleep sandstone is wholly sealed here, the dome looks hopeful.

The large quantities of asphaltum on Wallace Creek and its tributaries along the east front of the Rattlesnake Mountains naturally suggest that there is an oil pool somewhere to supply the asphaltum, unless, as is possibly the case, the rocks are so eroded as to have allowed all the oil to escape. It should be noted that these exceptional showings of oil along the mountains are almost directly opposite the Wallace Creek fold and that a line drawn from the middle of that fold to the exceptional seeps along the mountain would pass close to Phayles Reef, which is highly saturated with oil. These seeps may be in some way related to the Wallace Creek fold, where perhaps the oil is caught, but in this fold all the formations below the Teapot sand of the Mesaverde formation, which outcrops at Phayles Reef, are beyond the reach of the drill.

The United States Geological Survey can not state positively that oil or gas in commercial quantities exists in any of these anticlines, but it does suggest that some of them appear, after field examination, to offer favorable conditions for the accumulation of oil and gas. Drilling is the only method of ascertaining whether or not oil or gas can be found in these folds.