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Montana Oil Fields

Conrad F. Lundgren

M O N T A N A   O I L   F I E L D S

by

Conrad F. Lundgren

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

Montana School of Mines
Butte, Montana
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Introduction

Since the discovery of oil in Montana in 1916, the petroleum industry has advanced to a point where over 5,000,000 barrels of oil worth over $6,500,000 has been produced in each of the three past years (1936, 1937, and 1938).

The subject was chosen for thesis material because of the lack of a report on the Montana oil fields under one cover. There was no field work attempted, the problem being essentially one of compilation and condensation of much data and numerous reports.

The subject matter was gained from publications of the Montana State Bureau of Mines and Geology, Montana Oil & Gas Journal, U. S. Geological Survey, Am. Assoc. of Petroleum Geologists, Oil and Gas Journal, and various papers appearing in other publications as noted in the bibliography. Much of the detail of geological formations has been omitted but it may be found in numerous publications, some of which are listed in the bibliography.

Statistics on individual field production are those of the Montana State Oil Conservation Board; those of the state as a whole for the years 1916 to 1936 inclusive are taken from the Mineral Resources of the United States and for the years 1937 and 1938 from the Montana Oil Conservation Board. In the statistics on wells a blank space indicates lack of information as to the probable correct figure.

Acknowledgments

The writer is deeply indebted to Drs. E. S. Perry, G. F. Seager, and L. L. Sloss for the cooperation they have afforded, greatly alleviating the task of the preparation of the thesis.

Especially so, does the writer wish to thank Drs. E. S. Perry and L. L. Sloss for their critical reading and constructive criticism of the manuscript and the invaluable information and guidance they have given. The preparation of photographic prints was done under the guidance of Dr. L. L. Sloss.

Summary of Montana Oil Fields

In this thesis, thirteen areas, all lying east of the Rocky Mountain Front, are considered of sufficient importance to be recognized as an oil field and they are in order of discovery as follows: Elk Basin (1916), Devils Basin (1919), Cat Creek (1920), Soap Creek (1921), Kevin-Sunburst (1922), Big Lake (Lake Basin (1924), Pondera (1927, Bannatyne (1927), Sweet Grass Hills (1928), Cut Bank (1929), Border-Red Coulee (1929), Dry Creek (1930), and Baker-Glendive (1936). Of these, there is no commercial production from the Devils Basin, Soap Creek, or Bannatyne fields at present.

The above fields, excepting the Devils Basin, Cat Creek, Soap Creek, and Bannatyne, also yield gas in commercial quantities.

There are many anticlinal and domal structures throughout the state most of which have been tested for oil and gas. Since they do not yield oil or gas in commercial quantities they are not considered in this report.

Immediately following this page are statistics and graphs on oil production of the state and the individual fields, also maps and stratigraphic charts of the state. The fields are treated in order of their discovery.

PLATE I INDEX MAP OF MONTANA

TABLE I MONTANA OIL PRODUCTION

Year	Production (thousands of barrels)	Value (thousands of dollars)
1916[a]	45	46
1917	100	146
1918	69	126
1919	90	171
1920	340	1,045
1921	1,509	2,373
1922	2,449	4,084
1923	2,782	4,080
1924	2,815	3,754
1925	4,091	6,420
1926	7,727	10,170
1927	5,058	7,090
1928	4,015	6,400
1929	3,980	7,260
1930	3,349-	5,420
1931	2,830	2,730
1932	2,457	2,560
1933	2,273	2,220
1934	3,603	4,380
1935	4,603	6,150[c]
1936	5,868	7,700[c]
1937	5,839[b]	7,661[c]
1938	4,939[b]	6,486[c]
Total	70,831	98,470

[a] Production for years 1916-36 from Mineral Resources of U.S.
[b] Compiled from Montana Oil Conservation Board reports
[c] Calculated

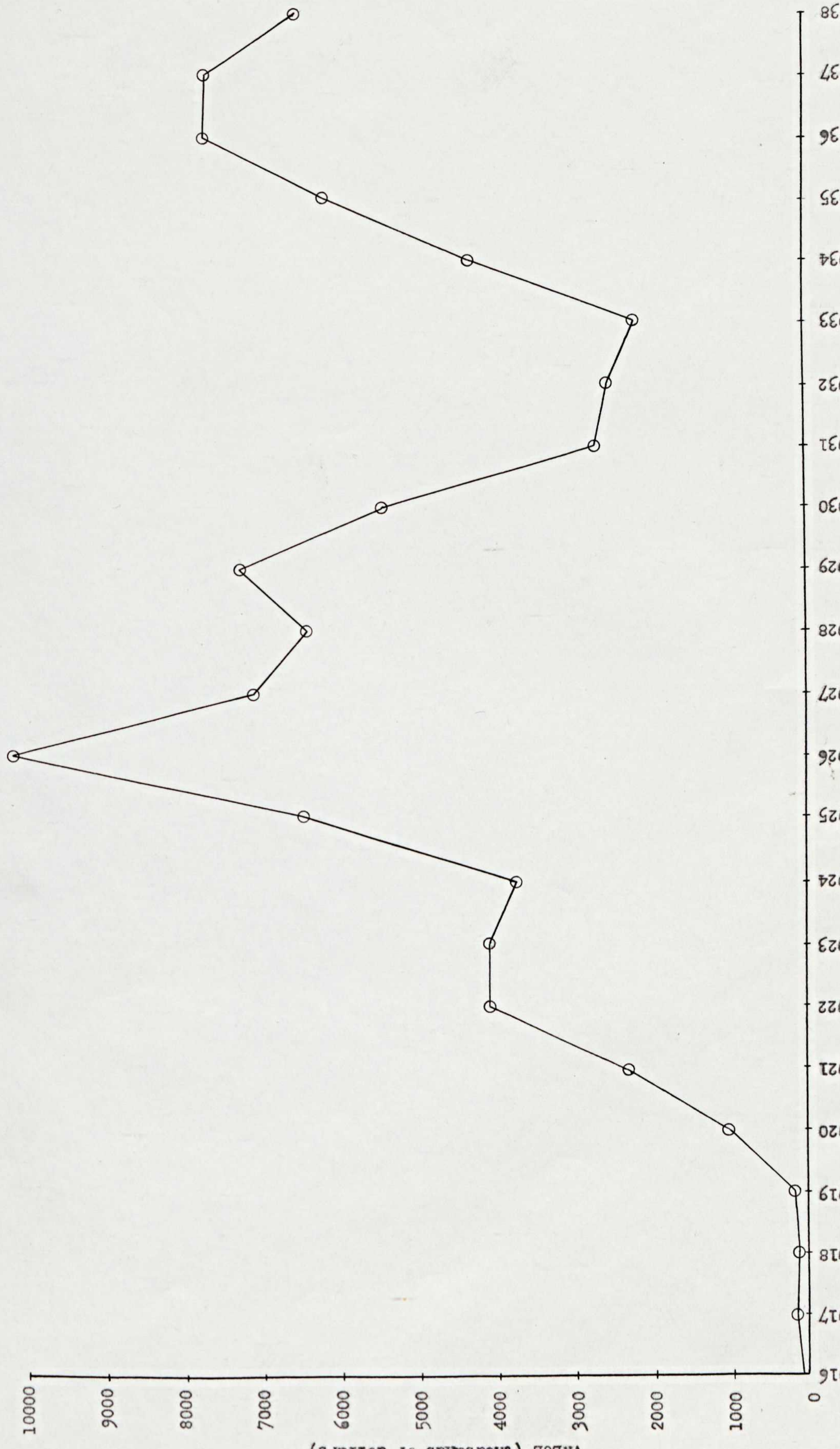


PLATE VI VALUE OF MONTANA OIL PRODUCTION FOR YEARS 1916-1938

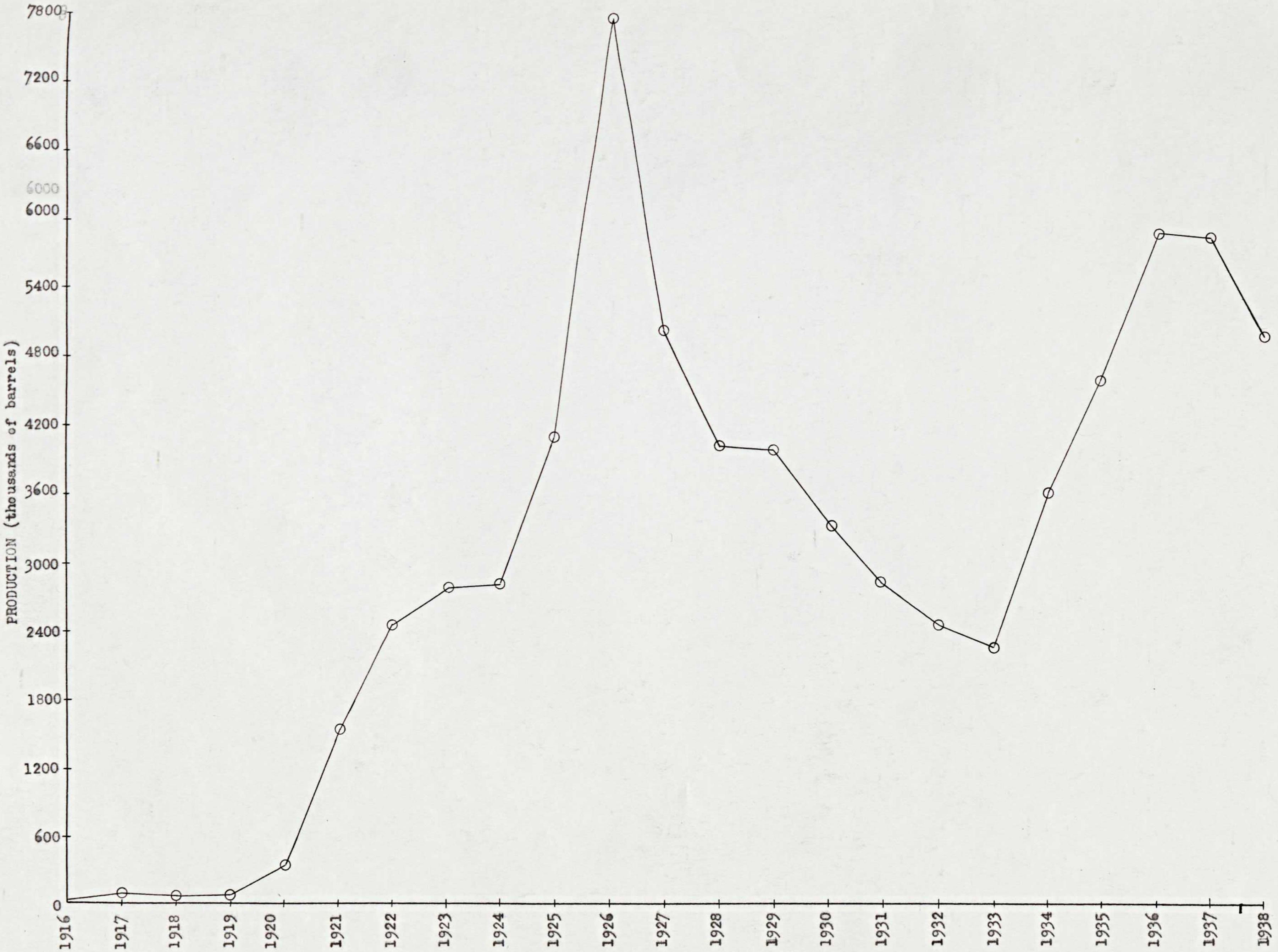


PLATE V MONTANA OIL PRODUCTION FOR YEARS 1916-1938

TABLE II MONTANA OIL PRODUCTION BY FIELDS

(thousands of barrels)

Year	Elk Basin	Devils Basin	Cat Creek	Kevin-Sunburst	Lake Basin (Big Lake)	Pondera	Sweet Grass Hills	Border*	Dry Creek	Cut Bank	Baker-Glendive
1916	45										
1917	100										
1918	69										
1919	90										
1920	97		243								
1921	46	3	1,350								
1922	47	1	2,202	29							
1923	28	1	2,081	442							
1924	24		1,529	1,187	24						
1925	21		1,234	2,705	24						
1926	18		1,003	6,457	50						
1927	17		776	4,035	48						
1928	18		611	3,149	33	158					
1929	19		488	2,388	23	977					
1930	16		415	1,911	23	748	1	120	15		
1931	16		357	1,577	23	573	1	178	164		
1932	13		312	1,329	14	432	7	113	188	21	
1933	17		262	1,186	18	351	11	51	128	275	
1934	16	4	236	1,566	16	361	15	70	12	1,198	
1935	8	3	292	1,359	18	429	14	40	60	2,321	
1936	12		254	1,538	15	421	12	43	213	3,332	
1937	9	1	224	1,624	18	414	10	63	99	3,364	14
1938			212	1,302	6**	217	2**	26	130	2,831	3**
Totals	776	14	13,695	32,899	328	5,081	73	704	1,009	11,435	17

(information from Montana State Oil Conservation Board)

*U. S. Geological Survey

**Figures for January-April

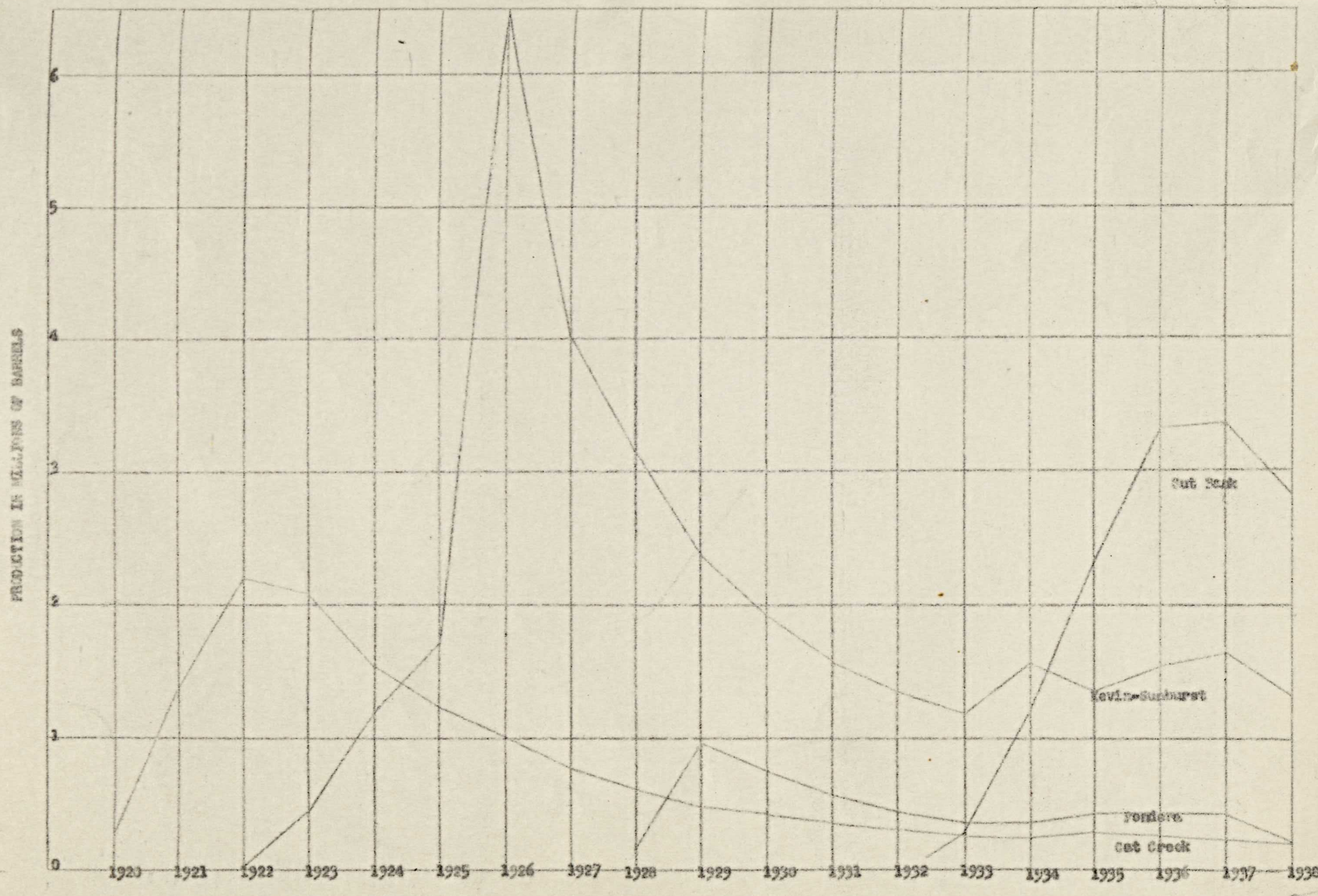


PLATE VII ANNUAL OIL PRODUCTION OF LEADING MONTANA OIL FIELDS
(other fields negible)

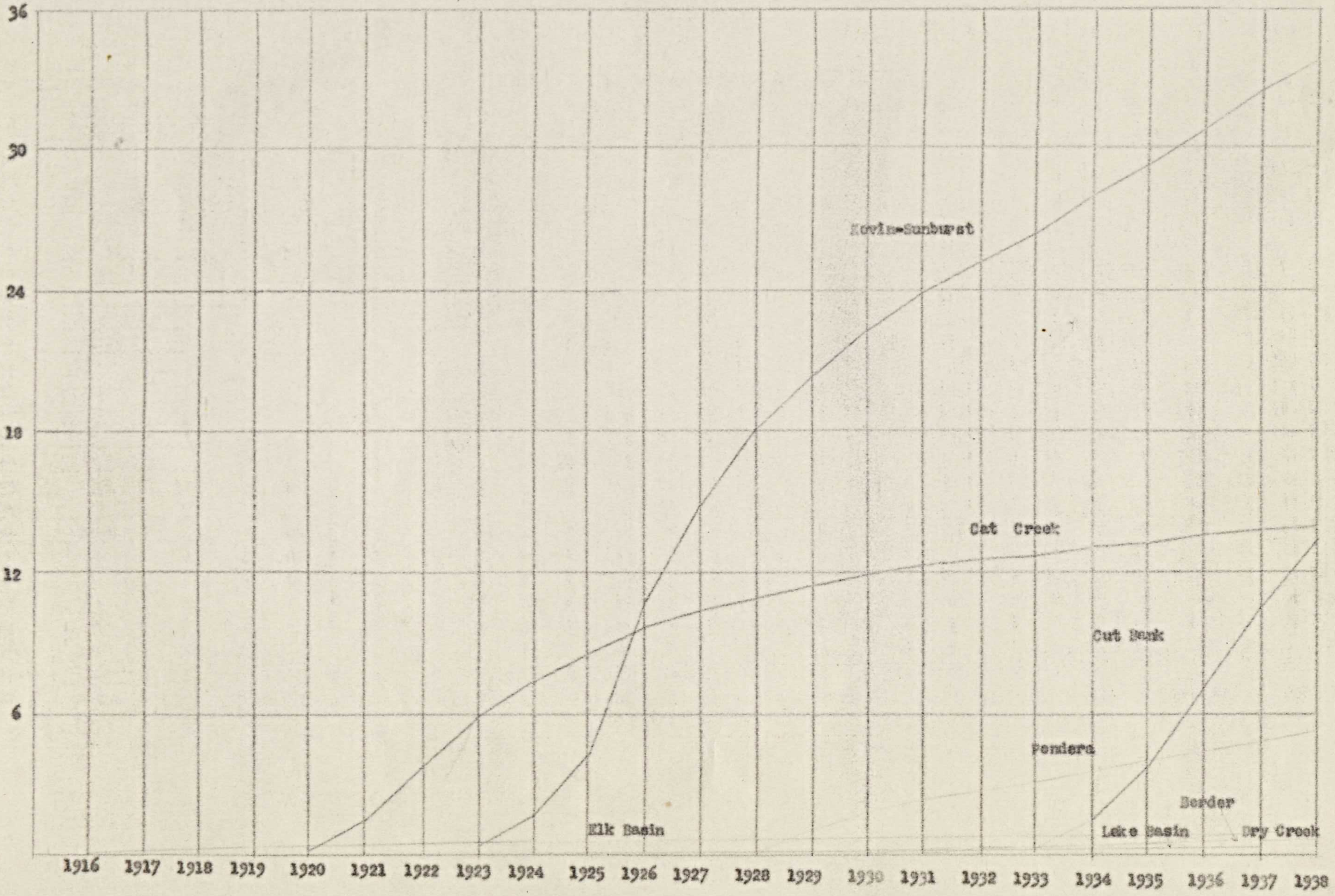


PLATE VIII TOTAL CUMULATIVE PRODUCTION BY FIELDS

TABLE III WELLS

Year	Elk Basin				Devils Basin				Cat Creek				Kevin-Sunburst				Lake Basin				Pondera				Bannatyne			
	oil	gas	dry	total	oil	gas	dry	total	oil	gas	dry	total	oil	gas	dry	total	oil	gas	dry	total	oil	gas	dry	total	oil	gas	dry	total
1916	6	0	1	7																								
1917	1	0	1	2																								
1918	2	0	6	8																								
1919					1	0	0	1																				
1920																												
1921					1	0	16	17	116	0	52	168					0	0	3	3								
1922									25	2	19	46	25	2	19	46	0	0	3	3								
1923									23	0	7	30	139	9	48	196	0	0	1	1								
1924									6	1	4	11	96	4	38	138												
1925									18	0	7	25	233	11	100	344	5	0	16	21								
1926					1	0	4	5	3	0	5	8	260	24	133	417												
1927									3	0	2	5	237	41	142	420					1	0	0	1	2	0	9	11
1928									3	0	3	6	101	45	77	223					0	1	8	9	10	0	2	12
1929									1	0	0	1	113	40	62	215	0	0	0	0	69	1	7	77	18	0	3	21
1930									2	0	1	3	44	12	30	86	0	0	0	0	81	0	3	84	4	0	1	5
1931									5	0	2	7	18	7	3	28	0	0	1	1	8	0	0	8	0	0	0	0
1932					1	0	0	1	0	0	0	0	6	1	0	7	0	0	0	0	1	0	0	1	1	0	0	1
1933					0	0	0	0	0	0	1	1	4	2	3	9	0	0	0	0	0	0	0	0	0	0	0	0
1934					0	0	0	0	0	0	0	0	21	0	2	23	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	41	2	5	48	0	0	0	0	3	0	0	3	0	0	0	0
1936	0	0	0	0	0	0	0	0	0	0	0	0	68	2	9	79	0	0	0	0	4	0	1	5	0	0	0	0
1937	2	0	0	2	0	0	0	0	0	0	0	0	69	4	26	99	0	0	0	0	0	0	0	0	0	0	0	0
1938	0	0	0	0	0	0	0	0	0	0	0	0	27	2	12	41	0	0	0	0	1	0	0	1	0	0	0	0

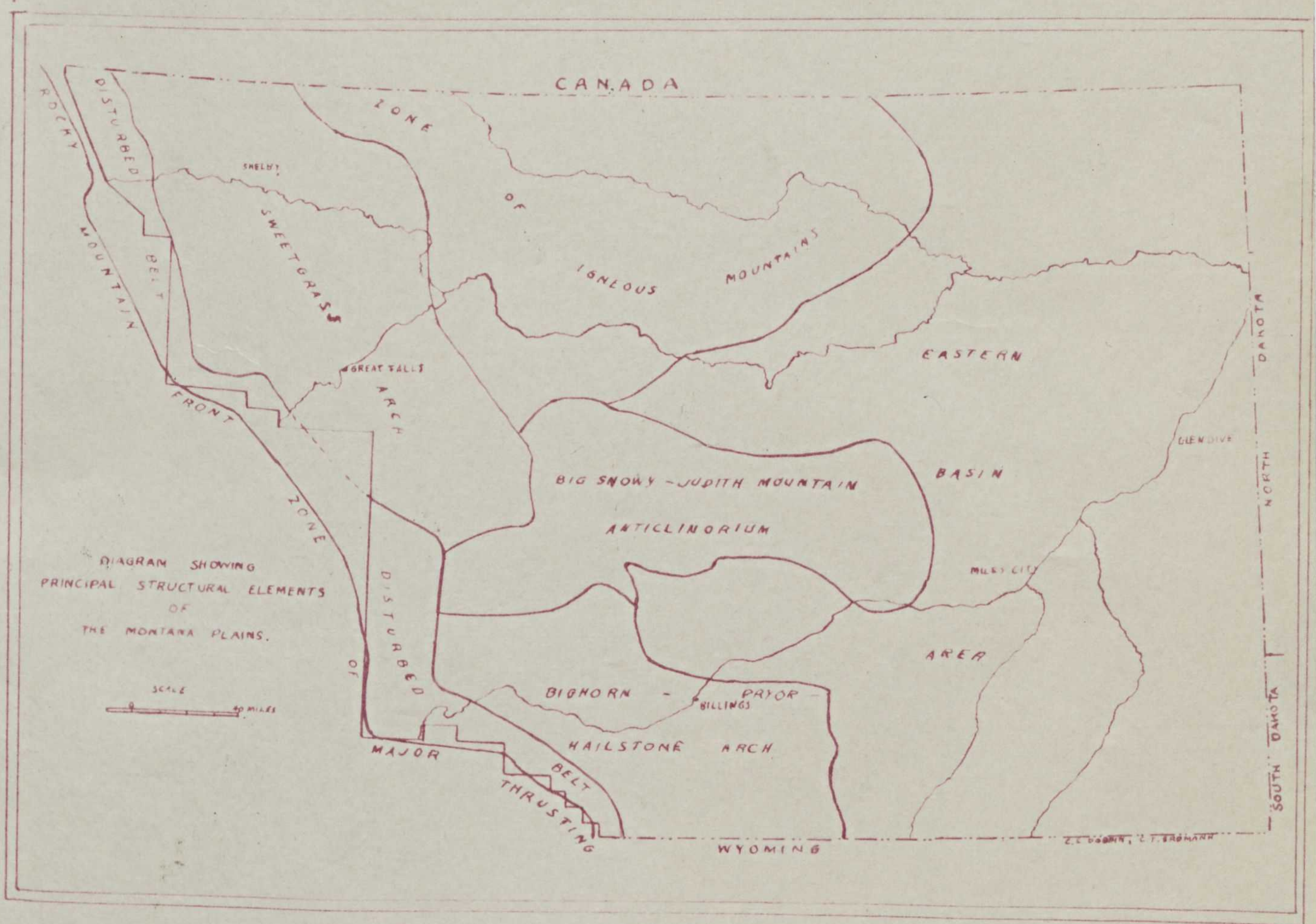
TABLE III (CONTINUED) W E L L S

Year	Border oil	Border gas	Border dry	Border total	Dry Creek oil	Dry Creek gas	Dry Creek dry	Dry Creek total	Sweet Grass Hills oil	Sweet Grass Hills gas	Sweet Grass Hills dry	Sweet Grass Hills total	Cut Bank oil	Cut Bank gas	Cut Bank dry	Cut Bank total	Baker-Glendive oil	Baker-Glendive gas	Baker-Glendive dry	Baker-Glendive total	Others oil	Others gas	Others dry	Others total	Total oil	Total gas	Total dry	Total total
1916																					0	0	0	0	6	0	1	7
1917																					0	0	0	0	1	0	1	2
1918																					0	0	0	0	2	0	6	8
1919																												
1920																												
1921																		1-10 per year							61	0	33	94
1922																					3	0	0	3	53	4	27	84
1923																					1	2	28	31	162	11	75	248
1924																					0	3	12	15	104	8	58	170
1925																					1	3	14	18	254	14	127	395
1926													0	1	0	1	0	13	0	19	3	4	17	24	266	29	155	450
1927													0	0	0	0	0	16	0	16	0	11	37	48	243	54	116	493
1928									0	0	3	3	0	0	0	0	0	22	0	22	0	10	28	38	183	56	120	359
1929					0	1	0	1	2	5	3	10	0	1	0	1	0	36	0	36	0	19	19	38	213	66	94	373
1930	16	1	7	24	1	0	0	1	2	2	1	5	0	2	3	5	0	24	0	24					74	40	68	182
1931	3	0	2	5	3	0	0	3	0	4	5	9	1	17	1	19	0	30	0	30	11	2	35	48	49	30	48	127
1932	6	0	0	6	6	0	0	6	3	0	0	3	6	20	3	29					1	0	23	24	30	21	26	77
1933	0	0	0	0	1	0	0	1	1	0	0	1	19	5	1	25					25	5	13	43	45	12	18	75
1934	0	0	2	2 2	1	0	0	1	1	0	0	1	102	3	8	113					2	18	24	44	127	21	36	184
1935	0	0	0	0	0	1	0	1	3	1	0	4	103	9	19	131					0	7	0	7	150	20	24	194
1936	0	0	0	0	0	0	0	0	0	0	1	1	97	7	13	117	1			1	1	3	13	17	168	14	45	237
1937	0	0	0	0	0	0	0	0	0	2	4	6	49	8	12	69	1	1	2	4	2	6	22	30	121	23	66	210
1938	0	0	0	0	0	0	1	1	0	0	0	0	30	6	4	40	0	1	0	1	1	1	4	6	59	10	21	90

PLATE II GEOLOGIC MAP OF CENTRAL AND EASTERN MONTANA

El
Kcc
Kbj
Etu
Kc
Roundup
Billings
Km
0
25
50 miles

PLATE III



—Diagram showing principal structural elements of Montana plains.

TABLE IV CORRELATION CHART OF MONTANA & WYOMING (modified after U.S.G.S.)

Era	Period	Elk Basin, Wyo.	Yellowstone, Stillwater, Big Horn, and Carbon Counties, Mont.		Crow Indian Reserve, Mont.	Central Mont.	Bearpaw Mts. Mont.	Sweetgrass Arch Mont.	Baker-Glendive, Mont.
CENOZOIC	Q	Quaternary	Quaternary		Quaternary	Quaternary	Quaternary	Quaternary	Quaternary
			Pliocene (?)				Late Tertiary		
							Oligocene (?)		
		Wasatch							
		Fort Union	Fort Union		Fort Union	Fort Union			Fort Union
MESOZOIC	K	Lance	Lance		Lance	Lance	Lance	Willow Creek	Lance
								St. Mary River	
			Lennep					Horsethief	Fox Hills
		Bearpaw	Bearpaw		Bearpaw	Bearpaw	Bearpaw	Bearpaw	Pierre
		Judith River	Judith River		Parkman	Judith River	Judith River		Judith River
				Parkman				Two Medicine	
		Claggett	Claggett		Claggett	Claggett	Claggett		Claggett
		Eagle	Eagle		Eagle	Eagle	Eagle	Virgelle	Eagle
			Telegraph Creek		Telegraph Cr.				
		Niobrara	Niobrara		Niobrara				
		Carlile	Carlile		Carlile				
				Torchlight					
		Frontier	Frantier		Frontier	Colorado	Colorado	Colorado	Colorado
				Peay					
		Mowry	Mowry		Mowry				
		Thermopolis	Thermopolis		Thermopolis				
		Cloverly: Greybull		Greybull					
			Cloverly		Cloverly	Kootenai	Kootenai	Kootenai	Dakota
	J	Morrison	Morrison		Morrison	Morrison	Morrison	Morrison	Morrison
		Sundance	Sundance		Sundance	Ellis	Ellis	Ellis	Sundance
	TR	Chugwater	Chugwater		Chugwater	Absent	Absent	Absent	Chugwater
PALEOZOIC	Pe	Embar	Embar (?)						
	P	Tensleep	Tensleep		Tensleep			Absent	Minnelusa
		Amsden	Amsden		Amsden				Amsden
	M	Absent	Absent		Absent	Big Snowy	Big Snowy	Absent	Absent
		Madison	Madison		Madison	Madison	Madison	Madison	Madison
	D	Absent	Probably absent		Absent (?)	(?)	Jefferson	Devonian	Devonian
	S	Absent	Absent		Absent	Absent	Absent	Absent	Absent
	O	Big Horn	Big Horn		Big Horn	(?)	Big Horn	Big Horn	Big Horn
	Є	Deadwood	Deadwood		Deadwood	(?)	Deadwood	Deadwood	Cambrian
		Absent	No evidense		Absent	M. Cambrian	(?)	M. Cambrian	

PRODUCING HORIZONS OF MONTANA OIL FIELDS

Field	Producing horizon		
	Formation	Sand	Age
Elk Basin	Frontier	First Wall Creek Second " " Third " "	U. Cretaceous
Devils Basin	Heath (Big Snowy)	Van Dusen	U. Mississippian
Soap Creek	Amsden		Pennsylvanian
Kevin-Sunburst	Kootenai Madison	Sunburst Ellis	L. Cretaceous
Lake Basin	Cloverly		L. Cretaceous
Pondera	Madison		Mississippian
Sweetgrass Hills	Colorado Kootenai	Blackleaf member Sunburst Baskoo	U. Cretaceous L. " L. "
Border	Kootenai	Sunburst Vanalta Cosmos	L. Cretaceous
Dry Creek	Cloverly		L. Cretaceous
Cut Bank	Kootenai	Moulton Sunburst Cut Bank	L. Cretaceous
Baker-Glendive	Madison		Mississippian

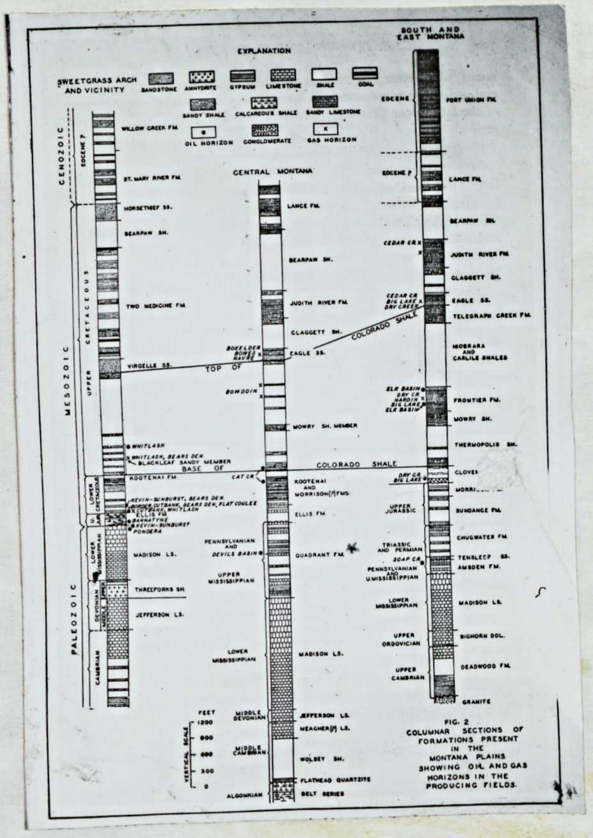


Fig. 1 Columnar sections of formations present in Montana plains, showing oil and gas horizons in proG ducing field. (Dobbin & Erdmann, Am. Assoc. Pet. Geol., Problems of Petroleum Geology, 1934)

Note: Quadrant formation of Central Montana section is how known to be the Heath formation of the Big Snowy group.

ELK BASIN FIELD

The Elk Basin field lies on the Montana-Wyoming state line, in the central extreme southern portion of Carbon County, Montana, and in the northeastern portion of Park County, Wyoming. That portion of the Elk Basin field in Montana was the first commercial oil field in this state. A pipe line runs to Frannie, 15 miles distant, a small town east of the field in Wyoming on the Chicago, Burlington, and Quincy railroad. A dirt road also leads to this town through which a hard-surfaced highway, No. 310, traverses north and south connecting Billings, Montana with Cody and Greybull, Wyoming.

History of development and production

In October 1915, the first well was completed in Elk Basin on the Wyoming side by James Hunt and others, who later organized the Elk Basin Petroleum Company which merged with the Mutual Oil Company and later with the Continental Oil Company. Production was from the First Wall Creek Sand, uppermost member of the Frontier formation (Colorado group), this being a local term applied to the initial producing horizon*.

Rapid development followed drilling of the discovery

*Bartram, J. G., Elk Basin Oil and Gas Field, Am. Assoc. Pet. Geol. "Structure of Typical American Oil Fields, vol. II, p. 578, 1929 well. However, in 1926 there were but two producing wells, this number being increased to seven in 1936. Since the peak production year of 1917, when 100,000 barrels of oil were produced, the yearly production has dwindled gradually to approximately 10,000 barrels in the past three years.

Gas was found in the Cloverly formation (Lower Cretaceous) at an average depth of 2,400 feet and beginning in 1928 was used in a "gas drive". This consisted of forcing the gas from the Cloverly into the Frontier oil sands through certain key wells intending to increase ground pressure in the oil horizon with a resultant increase in production which had been gradually waning. From the table on page it may be noted that this "gas drive" was a success, for it not only arrested the slump in the production but even increased it for two years and the decline thereafter was much less than it had been.

Stratigraphy

As the name denotes, the field lies in a natural basin. The central part is faily level but the south end and sides are rough due to the presence of resistant escarpments of sandstones of Eagle and Mesaverde (Judith River) formations, outcrops of which encircle the basin. Cody shale (Colorado) is exposed on the crest of the dome and it being much softer than the sandstone, it has eroded to form the basin. This shale is in general thinly laminated, and its color ranges from dull blue to dark gray. It has a variable thickness in the basin from 2,350 to 3,075 feet depending on the amount of erosion. Marine fossils are plentiful in this shale, well cuttings yielding Foraminifera and prisms from Inoceramus.

Below the Colorado shales lie the Cloverly (formerly known as Dakota) formation composed essentially of coarse sandstones approximately equivalent to the Kootenai farther north. The upper sandstone member of this group is a gas horizon. Beneath the Dakota or Cloverly are found the Morrison, Sundance, Chugwater, Embar, Tensleep, Amsden, and Madison in the order named. These formations have not been penetrated, but information from near-by Wyoming pools leads to the conclusion that they are present.

		Bearpaw
Montana	Mesaverde	Judith River
		Claggett
	Cody	Eagle
		Niobrara
		Carlile
	Frontier	Frontier
Colorado	Mowry	Mowry
	Thermopolis	Thermopolis
		Cloverly

The Morrison formation below the Cloverly consists of 375 feet of purple, reddish, and green-gray clay with interbedded sandstones. The Sundance formation, about 550 feet thick, consists of gray shales and sandstones with a little marine limestone. The following 900 feet of red beds are the Chugwater formation, which is underlain by the Ember limestone (Permian), Tensleep sandstone (Pennsylvanian), and Amsden limestone (Pennsylvanian) in the order named, these being 170, 210, and 300 feet thick respectively.

Structure

The Elk Basin anticline is on the north end of a large geosyncline, 150 miles long by 70 miles wide, known as the Big Horn basin. It is one of a series of similar folds lying between two large geanticlines which form the Big Horn mountains on the east, and the Absaroka and Beartooth mountains on the west, the latter being the eastward front of the main ranges of the Rockies in this area. The major uplifts are intensely folded. This general relationship of broad synclinal basins between mountain uplifts is common in the Rocky Mountain region. The Elk Basin anticline's long axis trends northwest and southeast and parallels the mountain folding, as do other numerous anticlines along the margins of the Big Horn basin. The dips of the strata on the northeast and southwest flanks of the symmetrical anticline ranges from 10° to 24° and the total closure is believed to be at least 800 feet enclosing more than four square miles.

Transverse to the long axis of the fold , the producing area is cut by numerous faults which are arranged into three sets. They were probably developed at the close of Cretaceous time after the development of the anticline.*

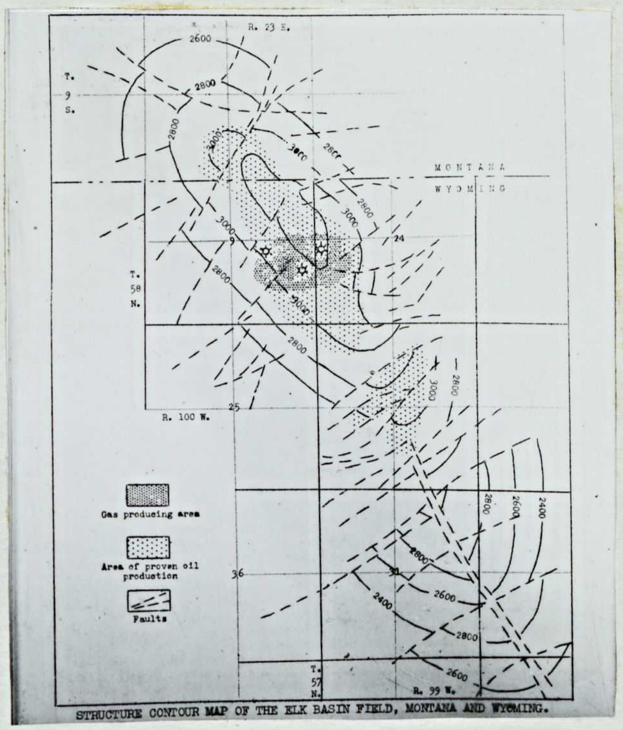


Fig. 2 Structure contour map of the Elk Basin Field
(Montana Bureau of Mines and Geology)

The oldest set runs northeast and southwest with downthrow on the south, and is followed by a second set that is parallel to the first but displace downward on the north; the youngest set trends parallel to the axis of the anticline with downthrow on the east. The dips of the transverse fault planes range from 40 to 75 degrees, and their verticl displacement from a little up to 700 feet. Those

*Estabrook, E. L., Faulting in Wyoming Oil Fields, Am. Assoc. Pet. Geol. Bull., vol. 7, pp. 95-102, 1923

Washburne, C. W., Epi-Anticlinal Faults of Elk Basin, Wyoming, Bull. Geol. Soc. Am., vol. 39, 1927 with throw to the north are on the northern part of the fold and those with throw down on the south are in the southern portion. The longitudinal faults (northwest-southeast) dip 65° E. and with vertical displacement up to 170 feet. Some of the faults persist downward to the Cloverly formation. If they disappear in formations below the Morrison formation, their cause is probably due to settling in the shaly formation, however, if they continue downward they are probably due to tension.

Oil occurrence

The oil producing sands are the First and Second Wall Creek Sands in the Frontier (Colorado) formation. It is probable that they should be correlated with the Dakota and Lakota sandstones of the Black Hills region. The First sand as it name signifies is the first sand encountered after drilling through 1,100 to 1,800 feet of Cody shale, so identification is positive. Its limits are indefinite for it is shaly in places, but it ranges from 75 to 100 feet in thickness. Due to clay and shale content it has a low porosity--up to 10 percent--which retards production. After continued drilling through approximately 135 feet of blue shale, the Second Wall Creek Sand is encountered which consists of 40 feet of clear sandstone, and which with a probable porosity of 18 to 20 percent is the best oil horizon in this field. Two hundred feet deeper is an irregular sandy shale known as the Third Wall Creek Sand, which gives showings of oil and gas. This sand is also in the Frontier formation.

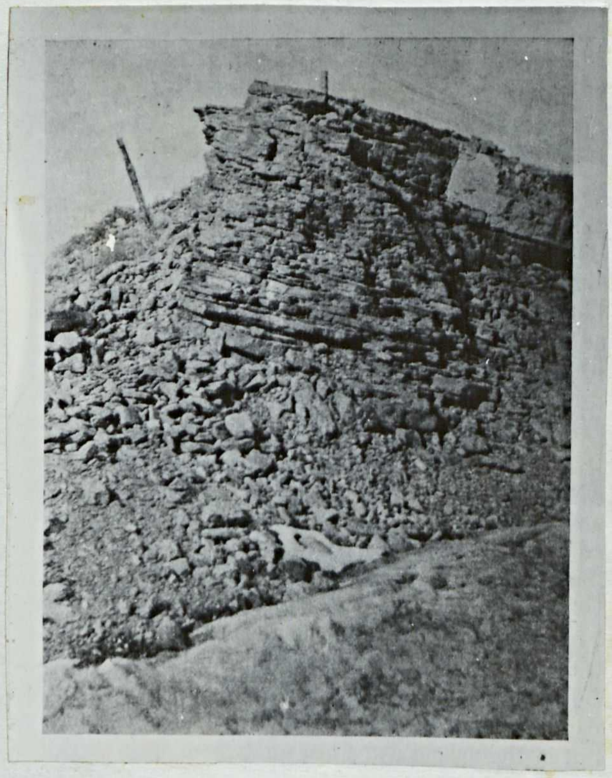


Fig. 3 Outcrop of First Wall Creek sandstone
(Bartram, A.A.P.G.Bull., vol. 16)

In the greater part of the field faulting does not appear to have affected the accumulation of oil in either the upthrown or down thrown blocks. In the south end it is important for oil is found only in upthrown blocks. Nearly normal rock pressures, amounting to 925 pounds for a depth of 2,400 feet, exist when the sands are drilled into indicating that the sands must have been sealed from the surface or from gas in the Cloverly formation. The oil fills the top of the fold in both upper sands and extends uniformly down all sides, 150 feet in the first sand and 350 feet in the second. There is no water in the first sand but water is found below the oil in the second.

The source of the oil is believed to be from the Cretaceous shales with which the sandstones have direct contact, for these shales are rich in organic material. The oil produces is green in color with a specific gravity of approximately 39° Baume and it is generally uniform in composition throughout the field except that in the south end where the gravity is higher but containing sulphur.

Future possibilities

Production from this field has gradually declined which would indicate that the future prospects of the area are not bright. However, as previously mentioned there is no water problem, thus doing away with the need for casing while drilling. Futhermore all drilling is through soft shale for an average of 1,500 feet, thus the costs of sinking a well to the present production horizons is cheap. These factors may warrant additional drilling, at least to the First Wall Creek Sand hoping for a spot of good porosity, for good wells are the rule in this field if the First sand is sufficiently porous. It appears that the Sundance sand of Jurassic age, the Embar of Permian age, and the Tensleep, Amsden, and Madison of Carboniferous age have possibilities but as yet they have not been properly tested.

DEVILS BASIN FIELD

The Devils Basin field is approximately 40 miles southwest of the Cat Creek field and 16 miles north of Roundup, the county seat of Musselshell County. The federal hard-surfaced highway No. 87 lies adjacent to the field and thus access to the field is easily gained.

History of development and production

Discovery of oil in this area was the first on structure entirely within Montana, earlier production being in the Elk Basin field which is chiefly in Wyoming. The Van Dusen Oil Company found oil December 1919, on the east end of the Devils Basin Dome, in sec. 24, T. 11 N., R. 24 E., at an approximate depth of 1,150 feet from a sand locally termed the Van Dusen in the Heath member of the Big Snowy group (Mississippian). This well started further oil prospecting in central Montana and later resulted in the discovery of the Cat Creek field. Production from the discovery well was first reported as 100 barrels per day but this production soon decreased to 10 barrels per day. In the following two years 17 more wells were drilled, only one being productive. Thus by July 1926, there were a total of 23 wells drilled, three of which were producing. All the producing wells are in the east end of the dome. Up to 1938 the field had produced 14,145 barrels, yielding 3,000 barrels in 1921 and 4,000 in 1934, the latter year being the best. Five small wells, three of which were shut in, was the 1934 status of the field. In 1936, there was was but one producer and at present there is no commercial production.

Stratigraphy

The lowest formation exposed in the basin is the Kootenai, it being exposed throughout the basin, and underlying the Colorado shale on the flanks, thus drilling in the Devils Basin begins in the Kootenai formation. In the Cat Creek field drilling begins in the Colorado shale. The Kootenai formation is about 500 feet thick underlain by 250 feet of variegated shales and lenticular sands of the Morrison formation (Jurassic). The Morrison rests upon 200 feet of marine limestone making up the Ellis formation (Jurassic). The Ellis formation lies unconformably upon the Amsden which is essentially a buff colored limestone with a few feet of red shale at its base. In the underlying Heath formation of the Big Snowy group occurs the oil-producing sand of this field, the formation consisting of 450 feet of black petroliferous shale and porous sandstones. At least two wells have penetrated the entire Big Snowy group (Heath, Otter, and Kibbey formations) totalling about 1,300 feet in the Devils Basin, bottoming a few feet in the underlying Madison limestone which like the Big Snowy formations is of Mississippian age.

Structure

The Devils Basin Dome has been eroded to form a topographical basin at its crest. The dome lies on the northeast side of a belt about one mile wide of steeply dipping strata. The strata dips gently away from other sides of the dome.

Oil occurrence

The only producing sand of the Devils Basin is the Van Dusen sand, 5 to 10 feet thick, encountered at depths varying from 1,120 to 1,175 feet. This sand is apparently lenticular for in some wells no sand was encountered at depths similar to adjacent producing well, this contention being supported by absence of faults and slight dip of strata on the crest of the dome where dry holes were encountered.

The oil is very dark and viscous. It has a specific gravity of 25^{o} Baume. The Heath formation of the Big Snowy group has been described as a black petroliferous shale and it is probably the source rock of the low-gravity oil as well as containing the sandstone reservoir rock.

Future possibilities

Out of 25 wells drilled on this structure only 4 have yielded commercial production which means that 84 percent of the wells drilled are unprofitable. The maximum initial production is about 100 barrels daily, which is a second point against any further prospecting. A third point against further development is the low grade of oil produced.

With the above factors in mind it is not surprising that the field has been dead for about five years, and it probably will see very little further activity.

CAT CREEK FIELD

The Cat Creek field lies in the central portion of the state, in the east central part of Petroleum County and the southwest part of Garfield County. Winnett, county seat of Petroleum County on a branch of the Chicago, Milwaukee, and St. Paul railroad, is the nearest railroad point, being about 15 miles west of the most productive structure.

The region has a rough topography due to numerous gullies of intermittent streams tributory to the Musselshell River that cuts through the field.

History of development and production

In February 1920, a well was drilled near the center of the Mosby Dome by the Frantz Oil Corporation in the southwest corner of the SE¼ NW¼ sec. 21, T. 15 N., R. 30 E. This well encountered a sandstone at 800 feet now known as the First Cat Creek Sand, which yielded a strong flow of fresh water. At a depth of 1,000 feet another sandstone, the Second Cat Creek Sand, was encountered and yielded 10 barrels of oil daily. Seven more wells were drilled on the Cat Creek anticline in the spring of 1920, three of which on the Mosby Dome found water in both sands, and four of which were drilled to the First Cat Creek Sand 1 to 2 miles further south without getting production and were shut down. The Frantz Oil Company in May of the same year struck oil in the First Cat Creek Sand on the West Dome in the northeast corner of the SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 14, T. 15 N., R. 29 E., which is about 3$\frac{1}{2}$ miles northwest of the Mosby Dome. The initial production of this well was rated at 200 barrels daily but in August its output increased to 2,500 barrels. The sucessful completion of this well stimulated drilling activity immensely with the result that at the completion of the field's second year (1921) , 168 wells had been drilled of which 116 produced oil and 52 were dry. Nearly all of this development took place on the West Dome, the wells ranging from 50 to 2,500 barrels in daily initial production, chiefly from the First Cat Creek Sand. A few wells found production in the Second Cat Creek Sand on the Mosby Dome during the same period. After discovery of oil in the Second sand on the West Dome in June 1922, by the Frantz-Harlan No. 3 in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 10, T. 15 N., R. 29 E., many of the wells producing from the First sand were deepened to the Second horizon.

Drilling activity has been on a decline since the years of 1920, 1921, and 1922, during which 214 wells were drilled, 141 being producers. There has not been a well completed since 1933 when one dry hole was drilled. A total of 2,833,000 barrèls of oil was produced in the field's best year which was 1922. Since that year production has decreased due to less well completions and falling production of existing producers. During 1938, 212,000 barrels of oil were marketed, which is a new low.

Stratigraphy

The uppermost formation exposed is the Bearpaw shale, which is 1,000 feet of gray to black gumbo-shale. That the formation is of marine origin is evidenced by the presence of marine fossils. The underlying Judith River formation is made up of 200 to 500 feet of lenticular gray to tan sandstone of terrestrial origin. The 500 to 600 feet of following Claggett shale is of marine origin and may be distinguished from the Bearpaw and Colorado shales by the presence of an upper portion of yellow calcareous concretionary beds. The Eagle is a grayish-white, chiefly non-marine sandstone which is thickest, most massive, and more non-marine in the western part of the area and more shaly to the east indicating presence of an ancient sea that lay to the east and advanced westward at various intervals to deposit the shaly members of the Montana group.

The underlying Colorado formation is the lowest exposed formation on the anticline and it has a thickness of 1,900 feet on the flanks where it is buried. On the domes in the field this formation is thinned by erosion to approximately 1000 feet. The First Cat Creek Sand lies at the base of this shale and may be equivalent to the Dakota sandstone of northern Wyoming.* Between the Colo-

Reeves, F., Geology of the Cat Creek and Devils Basin oil fields and adjacent areas in Montana, U.S.G.S. Bull. 786, 1927 rado and the marine calcareous sandstone of the Ellis formation of Jurassic age lies 560 feet of non-marine varicolored shale, sandstones, limestone, and some coal of the Kootenai formation and 200 feet of underlying non-marine sediments of the Morrison formation both of Jurassic age. The Ellis formation rests unconformably upon the Amsden formation (Pennsylvanian) and consists of 200 to 300 feet of marine sediments that are grayish-white fossiliferous sandstones and calcareous shales in the area of the field. The Amsden formation is essentially a limestone underlain by purple, red and buff-colored shale about 200 feet thick. Following the Amsden is the Big Snowy group of Mississippian age whose lower member, the Kibbey, is a red calcareous sandstone which may easily be mistaken for the Amsden. The Big Snowy is divided into three members, the upper 450 feet is a black petroliferous shale (Heath, the middle 700 feet is shale (Otter), and the basal 130 feet is the Kibbey. Underlying the Big Snowy formations is the Madison limestone (Mississippian) which is the lowest formation that has been penetrated by the drill. Its entire thickness has not been penetrated, however, so its thickness in the Cat Creek field is not known, but at its outcrop in the Big Snowy Mountains it has been measured by Hamblin as 1,145 feet thick.

*Hamblin, R. H., Stratigraphy and insoluble residues of the Upper Paleozoic formations of Montana, Master's Thesis In Geol. Eng., Montana School of Mines, 1939

Structure

The Cat Creek anticline lies on the northern side of the Big Snowy anticlinorium which extends from the Big Snowy and Judith Mountains to the Porcupine Dome, a distance of 100 miles. It is one of the long regional anticlines that characterizes this anticlinorium. The axis of the asymmetrical Cat Creek fold strikes N. 75° W. and upon it are imposed elliptical, asymmetric folded domes, six in number that are one-half to two miles in diamter. These domes form an en echelon series, their individual axes ranging from N. 35° to 55° W. The steeper dip of these domes is on the northeast flank.

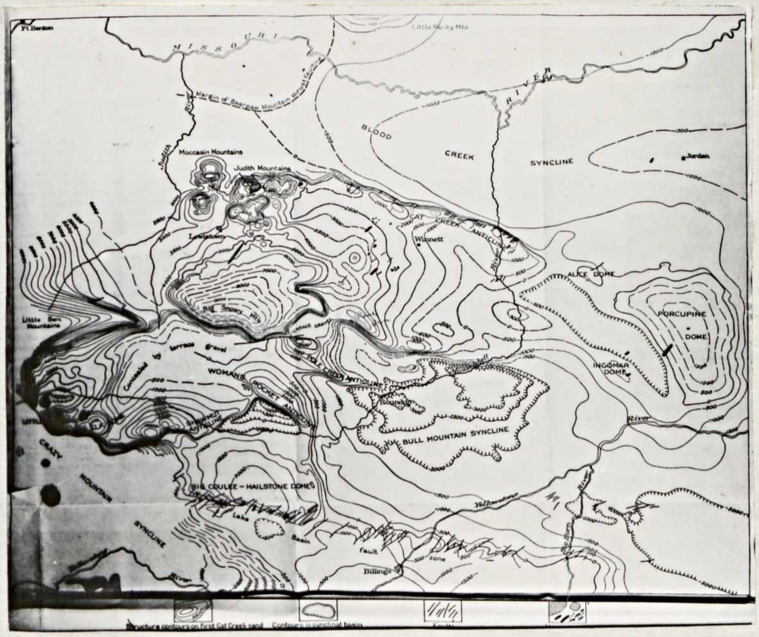


Fig. 4 Structural map of Central Montana (U.S.G.S.)

The central part of the Cat Creek anticline is considerably faulted, the trend of the faults being N. 50° to 60° E., rarely extended for more than 1 to 2 miles. The faults are chiefly normal and frequently extend across the crest of the domes, displacement ranging from a few feet to a possible 200 feet. Lupton and Lee* say the fault planes are vertical but Reeves** states the dip to be 60° to 70° with downthrow on the southeast as the character of ninety percent of the faults. Lupton and Lee believe the offsetting of the axes of the domes is due to lateral movement along the faults for most of the intensive faulting occurs where there is change in direction of strike of axis, in some cases represented by offset in the crest. Reeves disagrees with this explanation for forces producing lateral movement would be different from those producing the vertical movement that is found in all faults. Because of the similarity in strike, displacement, and short lengths of the faults, and the similar degree of folding on opposite sides of the axis, Reeves believes that faults are of the same origin and that there was no lateral movement and that faulting and folding were contemporaneous which could not be so if there were lateral movement.

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*Lupton, C. F., Lee, Wallace, Geology of the Cat Creek Oil Field, Montana, Am. Assoc. Pet. Geol. Bull., vol. 5, p. 271, March 4, 1921

**Reeves, Frank, op. cit. p.

Oil occurrence

Two of the producing sands have been previously mentioned, these being the First and Second Cat Creek Sands. There is another, called the Third Cat Creek Sand but it has produced very little oil. Most of the production is from the First sand; the oil from it has a specific gravity of 50° Baume. This sand is 25 to 60 feet thick and lies at the base of the Colorado shale, 800 feet below the surface in the first well drilled on the Mosby Dome. The Second sand is 160 to 235 feet below the top of the First sand and is likewise of Kootenai age. Its thickness is 10 to 60 feet, producing oil that has a specific gravity of 47° Baume. In both of these sands oil is found only in the crests of the domes; on the flanks water is found. A little heavy oil is found in the Third sand which is 100 to 150 feet below the top of the Second and also in the Kootenai formation.

It is Reeves' theory that some oil was derived from the overlying Colorado shales and gathered in the sands when sediments were being compacted and the water in the shales squeezed out and forced into sandstones from which the water later escaped. Later the oil collected in the crests of the domes and faulting allowed migration to lower sands. Lupton and Lee though conceding the Colorado shales as a possible source of some of the oil believe the great bulk of it has migrated from the underlying Ellis and Big Snowy (called Quadrant by Lee and Lupton) formations upward along fault planes assisted by artesian water circulation until trapped in the crests of the domes. The faults prevented complete flushing though a great amount of oil is believed to have been lost by that means. Futhermore they contend that lighter constituents of oil apparently migrate the farthest, hence the presence of the lightest oil in the higher horizons indicates the source of to be from below the producing sands.

To the presence of the faults must be credited the accumulation of oil in the domes for by the displacement of impervious shales to seal the pervious sands, reservoirs were created.

Future possibilities

The importance of the field is steadily decreasing for its production continues to fall from its maximum of 2,333,000 barrels in 1922 to 212,000 barrels in 1938. There has been but sporadic drilling in the field for many years due to the large percentage of dry holes, but outlying regions are being constantly tested with no noteworthy results as yet.

SOAP CREEK FIELD

This field which yields no commercial production of oil at present lies upon an asymmetrical dome at the fotthills of the Big Horn Mountains along their northeast side. Its location is in Big Horn County near the Montana-Wyoming state line. Of all the fields in Montana this one is probable the least accessible.

Wells drilled in February 1921, discovered a heavy black oil with a specific gravity of 20° Baume and high content of sulphur. The first well found some oil in the Tensleep sandstone (Pennsylvanian) at 1,534 feet and at 1,642 feet reported an initial production of 200 to 400 barrels daily from the Amsden formation(Pennsylvanian) directly underlying the Tensleep formation. A second well drilled to the lower horizon estimated initial production as 1,500 barrels daily. A third well got some oil at 1,710 feet from the lower part of the Amsden. This penetrated the Madison limestone (Mississippian) at 1,738 feet finding an oil horizon at 1,810 feet in the limestone with an initial production of 200 barrels daily. The production from these wells and later wells quickly fell off, discouraging further development of the field. The last well was drilled in 1935 yielding a small amount of oil. A total of 6 wells has been drilled of which but one was producing at the close of 1936. No commercial production is taken from the field at present.

Considerable erosion of the crest of the Soap Creek Dome has caused stripping of many formations leaving exposed at the surface the following formation of Cretaceous age. From the center of the dome outward are encountered the Cloverly formation, Thermopolis shale, Mowry shale, Frontier formation, Carlile shale, and Niobrara shale. (see the stratigraphic chart on page 13)

The structural trap accounting for accumulation of the oil is essentially an asymmetrical come with a closure of 800 feet. A factor affecting oil production is the large flow of water from the Amsden formation from wells on the flanks of the dome. The source rock is believed to be the limestone of the Madison formation (Mississippian. It is thought that the oil migrated up through small faults and fractures to its present horizon in the Pennsylvanian rocks.

Thus due to the difficulties and added precautions necessary for control of water, the low grade of oil yielded, and the remotemess of the region, the field has not fared well. The possibilities of its rejuvenation are meager and thus one of the state's first oil-producing structures may be considered as economically unimportant as far as oil production is concerned.

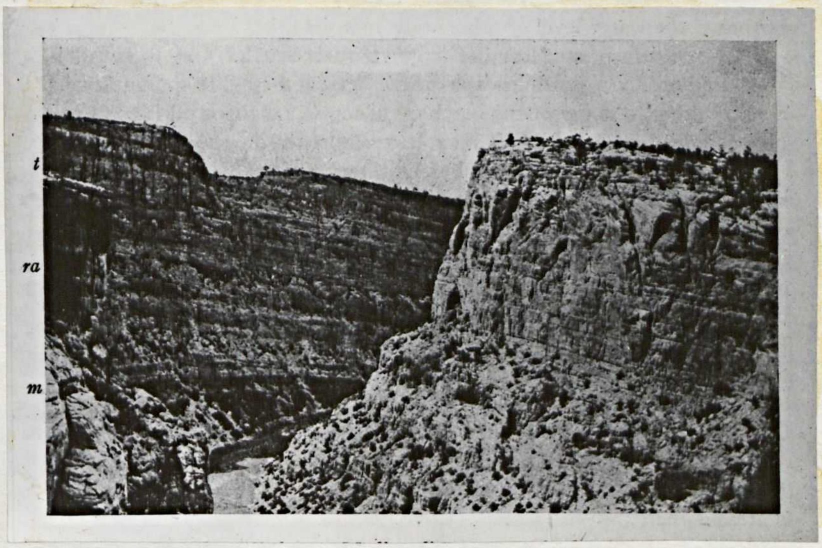


Fig. 5 Tensleep sandstone (t), Madison limestone (m), and other formations exposed in canyon. (A.A.P.G.Bull., vol. 16, Bartram)

KEVIN-SUNBURST FIELD

The Kevin-Sunburst field lies in the central part of Toole County, its central part is 15 miles south of the Alberta-Montana boundary line and 20 miles north of Shelby, the county seat. The field has been the state's most important field since its discovery in 1922 up to 1935 when the Cut Bank field became the state's largest producer.

History of development and production

The first well in this area was drilled in 1913 on the James Miller ranch in sec. 25, T. 34 N., R. 3 W., about 5 miles southwest of Kevin, to a depth of 1,755 feet, penetrating the Madison limestone (Mississippian) for 75 feet finding no oil but several small gas flows were found in the Colorado shale (Upper Cretaceous). The second well in the area which is termed the discovery well was completed in March 1922, in sec. 16, T. 35 N., R. 3 W., about 3 miles north of Kevin, 600 feet down structure on the northwest flank of the Kevin-Sunburst Dome, and 6 miles west of the later following main development. This well was drilled by the Gordon Campbell-Kevin Syndicate, striking oil at the Ellis-Madison contact (Campbell Pay) at a depth of 1,770 feet, yielding 5 to 10 barrels of oil per day with a specific gravity of 30° Baume. This well was deepened to 2,540 feet encountering water and then abandoned. The third well drilled, which proved to be the first commercial producer was put down by the Sunburst Oil and Gas Company in June 1922, in sec. 34, T. 36 N., R. 2 W., about 8 miles northeast of Kevin and on the north flank of the dome. This well yielded an initial production of 100 barrels daily of 36° Baume gravity oil from the Sunburst sand of the Kootenai (Lower Cretaceous) formation at a depth of 1,335 feet and proved to be 150 feet structurally higher than the discovery well.

By the end of the year (1922) 46 wells had been completed chiefly in the vicinity of the Sunburst well with subsequent development to the south and southeast. Of these 46 well, 25 were oil producers, 2 were gas producers, and 19 were dry holes, the total oil production for the year being 29,000 barrels. Development continued south in 1923 resulting in discovery of a few wells of larger initial production in what is now known as the Baker-Howling Pool. The Queen City Pool, 5 miles south of the Baker-Howling,was discovered in the following year, several wells yielding an initial production of 3,000 barrels daily. In 1925, development continued east of the Queen City area and resulted in finding of the East Side Pool which up to the present time has been the field's most important discovery. With development of this pool and the Lashbaugh Pool discovery in 1926, the production for that year was the field's best, being 6,457,000 barrels and incidentally the best year for the state. In 1927, drilling continued chiefly in proven areas although a few wells, yielding a large initial production, were drilled in the Wilcos and Baker-Barger Pools south of the East Pool.

Drilling activity in the field has been on the wane since 1927, and there were but seven completions in 1932, six of which yeilded mediocre production. In the following year, however, a new process of completing wells appeared and it was largely responsible for the continued life of this field. This was acid treatment of wells. Since 1933 completions have increased each year reaching 99 in 1937 of which 69 were oil producers and 4 were gas producers. At the end of 1936 the field boasted 850 producers. Production has likewise increased since the introduction of acid treatment of wells. Of the 1,785 wells that had been drilled before use of acid only 60 percent were commercial; in 1934, 91 percent were commercial although the average for the years 1934 to 1938 is not that high, being 78 per cent. The production during the past year (1938) was slightly less than half of the Cut Bank field's production being 1,302,000 barrels.

An important extension to the field was made in 1937, it being the so-called Rimrock or Rocky Ridge pool lying between the Kevin-Sunburst and Cut Bank fields approximately 6 miles north and west of Kevin. The discovery well of this pool was the Pfabe-Engleking in the northeast corner of SW¼ SW¼ sec. 26, T. 35 N., R. 4 W. Its initial production was 150 barrels of 38° Baume gravity oil (about 6° higher than the average) of paraffin base from the upper part of the Madison limestone which is the field's chief producing horizon. Before acidization it was rated as a 4-barrel well. Subsequent drilling has led to proving of an area of 12 to 15 square miles.

Stratigraphy

Nearly all the area is covered with glacial drift, the thickness ranging up to 200 feet. The Eagle sandstone, which is the lowest member of the Montana group (Upper Cretaceous) in the area, borders the field on the north, west and east sides, the Virgelle sand (basal Eagle) forming a prominent escarpment on the west side of the field. The underlying Colorado shale (Upper Cretaceous) is the first formation encountered by the drill bit in the area except for the glacial till. The lower lenticular sands of this formation yield water and small amounts of gas with showings of oil. One of these sands, very persistent in the north part of T. 35 N., R. 2 W., ordinarily carries water, therefore necessitating an extra casing string when drilling in that area. The shales total 1,750 feet, the amount penetrated by the drill varying from 700 feet on top of the structure to the full thickness on the west side of the field.

Following the Colorado formation the Kootenai formation of Lower Cretaceous age is met. It ranges in thickness from 350 to 400 feet, is composed of red and variegated shales and sands, and near its base is the Sunburst sand from 5 to 10 feet thick which is a relatively unimportant oil producing horizon in the field but the main gas horizon.

The Ellis formation of Jurassic age underlies the Kootenai, it being of marine origin and 200 to 250 feet thick. There is some evidence of a slight unconformity between the Ellis and the overlying Kooten ai and certainly the Ellis lies unconformably upon the Madison limestone (Mississippian). There was a great deal of erosion before deposition of the Ellis resulting in a "karst" topography, but the peneplanation of the pre-Ellis surface practically to base level and the existence of 100 to 150 feet of black limestone at the base of the Ellis causes the disconformity to be obscure. It is at the Ellis-Madison contact that the most prolific oil producing horizon of this field occurs, which has been called the "Ellis sand" but is actually the upper portion of the Madison lime. There are no true sandstones found in the 1,050 feet of Madison limestone. Water is found at varying horizons. The upper portion of the lime is dolomitic and silicified, and yields 95 percent of the field's oil. The lower 350 feet of this mass of limestone is shaly and sandy, and contains thin-bedded limestones.

Below the Madison was found 940 feet of anhydrite, gypsum, dolomite, shale, and limestone named by Perry* as the Potlatch anhydrite formation and correlated with the Jefferson of Devonian age. Underlying this formation is 300 feet of uncorrelated light gray to black limestone. This lies upon 700 feet of shale of probable Cambrian age. At the base of the Paleozoic series is about 75 feet of quartzite, which no doubt is to be correlated with the Flathead quartzite. The deepest well was drilled to 4,520 feet in sec. 21, T. 34 N., R. 1 W. and bottomed in quartzite.

Structure

The Kevin-Sunburst Dome is the most pronounced feature of the northern part of the Sweetgrass Arch. The total closure is about 850 feet. The major axis of the broad, gentle trends northwest and southeast. The dome contains approximately 22 townships within its lowest closing contour. The south end of the Kevin-Sunburst Dome is separated from the north end of the South Arch (southern part of the Sweetgrass Arch) by the Marias River syncline which trends east and west. The oil-producing area lies on the northwest side of the dome and covers about two townships.

*Perry, E. S., The Kevin-Sunburst and other oil and gas fields of the Sweetgrass Arch, Montana, Mont. State Bureau of Mines Memoir 1, 1928

The crest of the dome has been tested and proven barren of oil. South of the crest lies the gas-producing area covering approximately two townships. The dip of the strata away from the crest of the dome is relatively even on the east, south, and west sides ranging from 40 to 100 feet per mile, averaging 50 feet per mile. On the north side, with the dip being much flatter, is a terrace 150 feet structurally lower than the crest of the dome. A shallow syncline over 12 miles long , one mile wide, and 150 feet deep striking north-south divides the terrace into two domed areas, one on the east and one on the west each being three miles long (north-south), two miles wide, the closure of each being about 100 feet.

A map drawn on the Sunburst sand of the Kootenai formation as a datum structurally conformss closely with one drawn on the Ellis*Madison contact as a datum suggesting but a slight unconformity between the Kootenai and Ellis formations.

There are not surface evidences of faulting and well logs show no faults with appreciable throw. Two long areas in the central part of the dome showed steep dips of surface strate that were originally mapped as faults, but now believed the results of glaciation. Some so-called criteria for the belief of faults by some is given below with an explanation by Howell as to the true meaning of these criteria. They are as follows: "(1) offset wells producing from different levels, and in reality from different horizons but assumed to be the same horizon; (2) differences in production of offset well, the result of difference in sand porosity and lack of uniform saturation rather tan the result of faults; (3) large gas wells, situated very low structurally, mentioned elsewhere in this paper, caused probably by lenticularity and difference in porosity of the sand; (4) differences in color and character of the top of the Kootenai, the red shale streaks not being constant, thus resulting in confusion where markers in the Kootenai have been used as a datum; and (5) shale slumping or weathering of a peculiar type that has been mistaken for surface evidence of faulting."* Concluding the discussion of faults the same statements may be made now as stated above, that there is no apparent appreciable faulting in the field.

Oil occurrence

Some gas and showings of oil are found in the lower sands of the Colorado formation.

Near the base of the Kootenai formation is the Sunburst sand which is the chief gas-producing horizon of the field but yields very little oil. It is irregular in chara cter and thickness, the latter ranging from almost no-

*Howell, W. F., Kevin-Sunburst field, Toole County, Montana Am. Assoc. Pet. Geol. "Structure of typical American Oil fields, vol. II p. 264

thing to 75 feet. On the west side of the dome, north of Kevin, this sand is overlapped by a 50-foot sand which seems to be equivalent to the gas-producing sand (Upper Sunburst) of the Border field and to the Sunburst sand of the Cut Bank field.* On the northern limits of the field

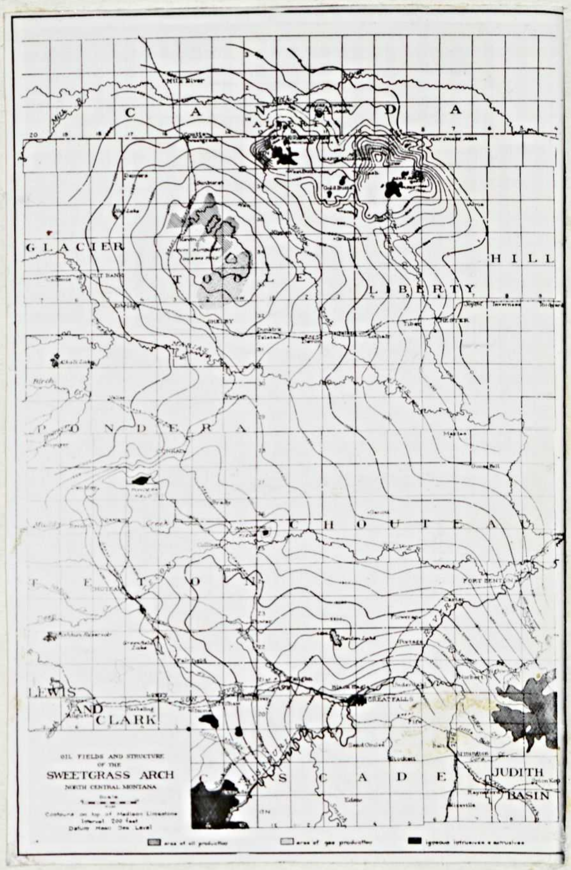


Fig. 6 Map of Sweetgrass Arch
(Romine, A.A.P.G.Bull., vol. 13)

some oil is found in the Sunburst sand but the initial production never exceeds 300 barrels and usually it is considerably less and the number of wells is few being

*Dobbin, C. E., Erdmann, E. C., Geologic Occurrence of Oil and Gas in Montana, Am. Assoc. Pet. Geol. Bull., vol. 18, p. 706, August 1934 about 50. The occurrence of gas south of the main high and structurally much lower, and also the fact that some of the more consistent producers lie structurally low, can be explained only by the lenticular nature of the Sunburst sands or its irregular porosity. Oil from this sand is of higher gravity than that from the "Ellis sand" of Madison age, being 36° Baume compared to 32° Baume but in the newly developed Rocky Ridge pool on the western side of the field the oil from the Madison lime is even lighter than that produced from the Sunburst horizons for its gravity ranges from 36° to 38° Baume. The Sunburst sand has a porosity ranging from 5 to 20 percent, its average 20-foot thickness being frequently interbedded with shales.

The stray lenticular sands in the Ellis formation are found 30 to 80 feet above the "Ellis sand" and there have been a few good wells producing from these stray horizons but offsets commonly fail to find production. Oil from these stray sands ranks with than from the Madison of the Rocky Ridge pool in quality and specific gravity.

The chief oil-producing horizon of the field is the upper 10 to 20 feet of the Madison limestone locally termed the "Ellis sand", but in reality the oil is trapped in complex porous zones of the limestone which have been developed primarily on the north flank of the dome. The Madison limestone is typically a massive, compact, crystalline limestone at any of its outcrops in the state but the buried producing horizon is very cherty in places and contains some sedondary silica and magnesia probably accounting for the porosity that is existent. In some places where wells are drilled through the black Ellis lime into the white Madison lime without striking oil or water, it appears that the reason therefore is the lack of porosity at the contact. In such areas the Madison lime surface may have not been greatly affected by weathering before deposition of the Ellis formation and also there was probably no subsequent water circulation as evidenced by the lack of any secondary material. The barren crest and south flanks of the Kevin-Sunburst Dome may be non-productive because of the lack of porosity. The high porosity of the Madison formation may be due to the following reasoning as cited by Perry*: "(1) simple solution may be responsible, wherein a part of the limestone has been carried away by ground water; (2) a porosity may have been developed by processes of replacement, wherein the calcium carbonate may have been replaced by magnesium carbonate or silica, either of which have a lesser molecular volume than calcium carbonate; (3) both solution and replacement may have been active, however, where molds of fossils exist, certainly some material has been carried away without new material being deposited." The stratigraphic position of the porous zone varies considerably, and may be from the Ellis-Madison contact to maybe 100 feet into the Madison formation to a depth ranging from 1,400 to 1,800 feet. Initial production from this horizon ranged from a few barrels to 5,000 daily.

The factors that have affected the accumulation of oil in the are the degree of erosion and weathering of the pre-Jurassic surface affecting the porosity, the occurrence of structural features as terraces and noses as a trap, and the presence of lenticular sands.

Opinion differs as to whether the oil migrated upward from the lower Madison and underlying Devonian shalesto its present level, or whether it migrated downward from the Ellis shales to the Ellis-Madison contact.

Future possibilities

Since its peak year in 1926, production has decreased in this field but in the past five years there has been a cessation in the gradual decline due to acid treatment of the wells. This acidization has been practiced on small producers including both old wells and those newly drilled. This practice has added new life to the field for it is certain that production would be much less and there would be also much less drilling activity if this means of increasing production was not available. Practically all the wells in the field including the newly developed Rocky Ridge pool six miles west of Kevin much be acidized to insure commercial production.

At present this field is the state's second best and it probably will be one of the state's foremost fields for many years. At the present time all the drilling activity is concentrated in the Rocky Ridge Pool but it is likely than other pools will be found and thus it appears that the field will have a long life.

LAKE BASIN FIELD

The producing district lies about 35 miles west of Billings, the chief production coming from the Big Lake Dome, a gentle flexure of the strata with a closure of about 120 feet. The names Big Lake and Lake Basin have both been used to designate the producing locality though the name Lake Basin as used by E. T. Hancock in U.S.G.S.Bull. 691, 1918, refers to a much greater area. The producing structure lies 15 miles north of hard-surfaced federal highway No. 10 and is accessible by dirt road.

History of development and production

In 1902 a well, which began in the Colorado formation, was drilled in the Hailstone Basin in Sec. 17, T. 3 N., R. 21 E. to 1,425 feet, and showings of oil and gas were encountered. This is 1 miles north of the Big Lake structure. Three more wells were drilled in 1921 in the Lake Basin district, one in sec. 21, T. 1 S., R. 21 E. starting in the Judith River formation and bottoming in the Colorado formation at a depth of 3,200 feet with but a showing of oil found in the Colorado formation; the second in sec. 34, T. 2 N., R. 21 E. on the Battle Butte structure, starting in the Bearpaw formation and bottoming in the Eagle formation at 1,150 feet, finding 500,000 cubic feet of gas in the latter formation; and the third well was drilled in s sec. 5, T. 3 N., R. 21 E., beginning in the Colorado formation and bottoming in the Ellis formation at 3,000 feet, no gas or oil being found. In 1922, another well was drilled on the Battle Butte structure bottoming in the Kootenai at a depth of 4,050 feet finding a showing of oil in the Eagle formation at 1,150 feet and in the Dakota (Kootenai) formation at 3,800 feet and also gas in the Colorado formation. Like the previous wells this one was also abandoned as were three following ones, their locations being in sec. 35, T. 1 N., R. 21 E., Sec. 30, T. 2 S., R. 21 E., and sec. 26, T. 2 N., R. 21 E. The discovery well known as the Hepp No. 1 was brought in during May 1924, by the Mid-Northern Oil Company on the Midwest Refining Company lease in the NE¼ of sec. 26, T. 1 N., R. 21 E. finding production in the Dakota formation at a depth of 3,824 feet with initial production of 120 barrels per day.

In the following three years 22 wells were drilled, 5 yielding oil in commercial quantities averaging 50 barrels per day each. The 1934 status of the field was 5 producers, this number being reduced to 3 in 1937.

Production from the field in 1924 was 24,000 barrels, which was increased to 50,000 barrels in 1926 marking the peak in production. The 1937 production was 18,000 barrels.

Until deepening of an old well in 1938, there had been no drilling in the field since 1931 during which year one dry hole was drilled.

Stratigraphy

In the producing region, namely, the Big Lake anticline the abundance of gumbo soil is attributed to the exposure of Bearpaw shale. Escarpment of sandstone are of the Lennep formation (Upper Montana group) and also there are exposures of Judith River Sandstones. The Judith River formation is 650 feet thick in the area, lying conformably upon Claggett shale. The marine sandstones and shales of the Claggett formation total 550 feet followed by 220 feet of Eagle sandstone. Below the Eagle and conformable with it is a series, 500 feet thick, of sandstones and sandy shales named by W. T. Thom, Jr. as the Telegraph Creek (see stratigraphic chart on page 13) formation and included in the Montana group of Upper Cretaceous age on the basis of the faunal evidence. In the Big Lake area the Colorado formation which underlies the Telegraph Creek formation is 2,100 feet thick. At a depth of about 3,200 feet the Dakota sandstones are encountered which may be correlated with the Kootenai formation.

One deep test well was completed in 1938, this test being the deepening of the Hepp No. 2 in the northwest corner of the NW¼ NW¼ sec. 25, T. 1 N., R. 21 E., originally drilled to a depth of about 3,800 feet to the Dakota sand in 1924. Drilling terminated at 6,006 feet in the upper few feet of the Madison formation with no important showings of oil or gas being encountered. In the Broadview dome, 15 miles northeast of the Big Lake deep test is another deep well drilling at present. It encountered the Madison limestone at 4,585 feet and is structurally higher than the Hepp No. 2 deep test.

Structure

The Lake Basin region is a rolling plain broken by buttes and basins and drained by the Yellowstone and Musselshell Rivers, the tributary streams offering a rough topography. The area is part of a broad arch, 40 miles wide and 130 miles long, lying between the Crazy Mountain syncline on the west and the Bull Mountain syncline on the east. No doubt the mountain making surrounding this area influenced the nature of the structural feature of it, these mountain making areas being the Big Snowy Mountains on the north, Little Belt Mountains on the northwest, Snowy Range on the southwest, and the Big Horn mountains on the southeast.

The Big Lake crescent-shaped dome (crescent-shaped due to curving of its axis) is about 6 miles long and 2 1/2 miles wide with a closure of 120 feet lying on the northeast flank of the Crazy Mountains. The dip is uniform and slight being 1 to 2 degrees in all directions. No faults are apparent, at least they do not appear at the surface. Another principal domal structure in the area is the Big Coulee-Hailstone Dome 11 miles north of the Big Lake structure. Its axis strikes southeast thus appearing to be an extension of the Big Horn uplift into which it appears to merge in the southern part of the region.

Another general feature of the region is an unusual series of faults that strike northeast and occur in an en echelon series that cross the field from the northwest corner southeastward and terminate about 8 miles north of Billings. The most intense shearing occurs along the steeply dipping south flank of the Big Coulee-Hailstone Dome. the faults range from one-half to nine miles in length and dip very steeply. The Big Lake field lies 10 miles south of the shear zone on the south flank of the Big Coulee-Hailstone Dome.

Oil occurrence

Oil having a specific gravity of 45° Baume occurs in the Cloverly formation at depths ranging from 3,795 to 3,860 feet. Nine hundred feet above the base of the Colorado formation lies a sandstone, 35 feet thick, that is known as the First Frontier sand and it is the largest gas producer in the Big Lake field. The Second Frontier sand is 100 beet below the First sand but it is not as thick and carries only a small amount of gas. The Dakota sand lies at the base of the Colorado at a depth of 3,820 feet in the discovery well and it is at least 50 feet thick carrying all the oil production of the field.

Future possibilities

The big Lake dome appears to be played out, this conclusion being based on its present meager production. Many dry holes have been drilled so renewed activity does not seem likely, coupled with the failure of a deep test, that was completed in 1938, to give any important showings.

PONDERA FIELD

The Pondera oil field enclosing about 3,000 acres lies about 10 miles southwest of Conrad, county seat of Pondera County. It is on the northwest flank of the southern portion of the Sweetgrass Arch. The field is accessible by graded road from highway No. 91 that extends north-south through Conrad.

History of development and production

The discovery well of this field was completed in June 1927, by the Montana Pacific Oil Company in the center of the SE¼ SE¼ sec. 17, T. 27 N., R. 4 W., to a depth of 2,060 feet, penetrating the Madison limestone (Mississippian) for 22 feet. The well was not a commercial oil well, yielding 3 barrels of oil and 3,500,000 cubic feet of gas daily from the upper part of the Madison formation. A second well one-half mile northeast of the discovery well was completed to a depth of 2,040 feet in March 1928, by the Fulton Petroleum Company. An initial production of 1,000,000 cubic feet of gas and 100 barrels of oil was found in the upper few feet of the Madison formation. Two wells to the east encountered commercial oil production and one to the west was rated non-commercial and this began an extensive drilling campaign eastward, resulting in 89 producing wells by February 1, 1929, their average production for January 1929, being 31 barrels per well per day or a total production for that month of approximately 80,000 barrels. For the year 1929 production was 977,000 barrels. Within the producing area dry holes are rare but many have such a small initial production as to be rated non-commercial. The year 1929 has proved to be the field's best and by 1938 annual production had dropped to 217,000 barrels. Acidization of wells began in this field in 1934 which not only checked the gradual decline in the production but served to boost production considerably as may be observed on Table II page 7. During 1934 there were no wells drilled, giving further importance to acidizing of the lime of the producing horizon. Since 1934 only 9 wells have been drilled in the area.

Stratigraphy

A discussion of the stratigraphy of this field, and also that of the Bannatyne field, would be a repetition of the stratigraphy discussed under the Kevin-Sunburst field; therefore, the reader is referred to page 41 for this discussion.

Structure

The Pondera structure is a terrace closed on the north, west, and east. No faults are apparent in the area, at least not of sufficient number and magnitude as to affect the accumulation of oil.

In this field oil is found adjacent to the steep northwest flank of the southern portion of the Sweetgrass Arch. Although the dip of strata on the Bannatyne structure, about 25 miles to the southeast, is not as great as that of the Pondera field it appears to be sufficient for the following observations by Romine*: "(1) that in regions of steeper folding greater jointing has occurred in the Madison limestone, thereby providing a better access to circulating water, which resulted in greater porosity, and (2) that the same jointing and fissuring have given freer channels through which oil could migrate from below."

Production in the Pondera field is gained in the area where the Madison limestone is at least 1,820 feet high structurally, (contours on top of Madison; datum mean sea level), producing only from its extreme top. (see map on page 46) South of the producing area the upper 15 to 25 feet of this limestone is tight and barren. It appears that the closure to the south of the terrace is due therefore to lack of porosity.

Oil occurrence

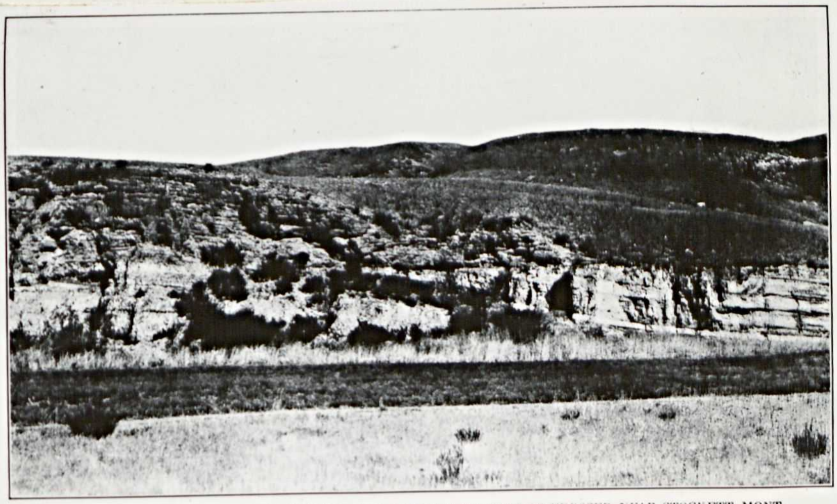
The oil, which has a specific gravity of 35° Baume, comes from the upper 40 feet of the Madison limestone at an average depth of approximately 2,000 feet. Water occurs

*Romine, T. B., Oil fields and structures of Sweetgrass Arch, Montana, Am. Assoc. Pet. Geol. Bull., vol. 13, no. 7, p. 797, July 1929.

100 feet below the Ellis-Madison contact and does not offer any difficulty in the field. Some gas is also encountered at the Ellis-Madison contact.

Production appears controlled to a great extent by the porosity which averages about 30 percent in the producing area, for the structural elevation of the wells varies but little, the barren wells to the south being somewhat higher but the porosity of the limestone is also much less.

A conjecture as to the possible source of the oil is the underlying shales of the Madison and Jefferson formations.



UNCONFORMITY BETWEEN THE MADISON AND ELLIS FORMATIONS AS EXPOSED NEAR STOCKETT, MONT.
Photograph by C. A. Fisher

Fig. 7 Madison-Ellis contact at Stockett, Mont.
(Collier, U.S.G.S.Bull. 812)

Future possibilities

There has been but one well completion in this field since 1936. The production is steadily falling but it has well due entirely to acidization of the wells. It is probable that the field would have been dead long ago except for the practice of acidizing the lime of the producing horizon.

There is probably not any chance for production below the present horizon, the Jefferson limestone of Devonian age having been tested by 4 deep test wells in the Kevin-Sunburst area and only some carbon dioxide gas found and a showing of oil.

BANNATYNE FIELD

The Bannatyne field is southeast of Conrad approximately 22 miles and about 25 miles southeast of the Pondera oil field. The nearest railroad point is at Collins about 9 miles distant. The field lies in gentle rolling country and is easily accessible by graded roads.

History of development and production

The discovery well of this field was drilled in July 1927, in sec. 8, T. 25 N., R. 1 E., by the Genou Oil Company. A black oil of 26^{o} Baume gravity was found at a depth of 1,445 feet in a "stray" sandstone, occurring at the base of the Ellis formation (Jurassic), and locally known as the Emrick or Bannatyne sand. After shooting, the initial production from this well was 30 barrels. Upon drilling of this well into the Madison limestone (Mississippian) sulphur water was encountered. Of the following 10 wells drilled nearby during the same year only an offwet to the discovery well found commercial production. In the following year, (1928), 12 wells were drilled; 10 being producers, their average initial production ranging from 10 to 40 barrels daily, and the other two being dry holes. In 1929 and 1930 there were 22 successful completions out of 26 wells drilled, but the initial production was small so that at the end of 1930 the field had but 5 producers totalling 75 barrels of oil per day. At present there is no commercial production coming from the field and furthermore there has been no well completion since 1930.

Stratigraphy

To give the stratigraphy of this field here would be repetition for it is generally the same as other fields of the Sweetgrass Arch, thus the reader is referred to page 41.

Structure

The Bannatyne structure is a small dome on the northeast side of the southern part of the Sweetgrass Arch with its longitudinal axis trending northeast-southwest and the steepest flank on the northwest side. The axis of the Sweetgrass Arch trends northwest-southeast. It is to be noted that the axis of the Bannatyne dome is approximately at right angles to the axis of the Sweetgrass Arch so the dome is sometimes referred to as a cross fold upon the major structure.

The closure of the dome is about 50 feet. The lowest closing contour includes about 1,600 acres but the field area is about 320 acres.

Oil occurrence

The only producing sand is the Emrick or Bannatyne which is 72 feet thick, however, only the upper 30 to 40 feet is saturated with oil. It is found at an approximate depth of 1,450 feet in the basal portion of the Ellis formation. The producing horizon, which is a true sandstone, requires shooting before any production ensues due to lack of porosity. This sand is at about the same stratigraphic position as the so-called "stray sand" in the Ellis formation which, locally, yields oil on the east side of the Kevin-Sunburst dome.

The oil has an asphaltic base, and its specific gravity is 26° Baume. It is probable that the oil had two possible sources: either it originated in the dark calcareous shales of the Ellis formation and migrated downward to the lower part of the formation to the Emrick sand, or else it originated in the Dark shales and limes of the lower Madison or Devonian and migrated upward to the producing horizon.

Future possibilities

As to the future outlook of this field it will suffice to say that no drilling has been done since 1930 and furthermore the field has had no commercial production since that year. It may also be pointed out that the oil is of lower quality than other Montana crudes commanding a small price, which coupled with the small initial production of wells that have produced makes the field less desirable. It would seem therefore that any further development is remote.

SWEETGRASS HILLS FIELDS

The Sweetgrass Hills cover a large area in the northeastern corner of Toole County and the northwestern corner of Liberty County. (see map on page65) The Hills of which there are five are the result of laccolithic intrusions and are not related in origin to the Sweetgrass Arch, the crest of which lies 15 miles west of the easternmost hill or mountain. The relief in the area, from the mountain tops to the surrounding plain, is about 2,000 feet. The igneous rocks that compose the core of the Hills are chiefly a syenite porphyry, and sedimentary formations of Paleozoic and Mesozoic age make up the flanks.

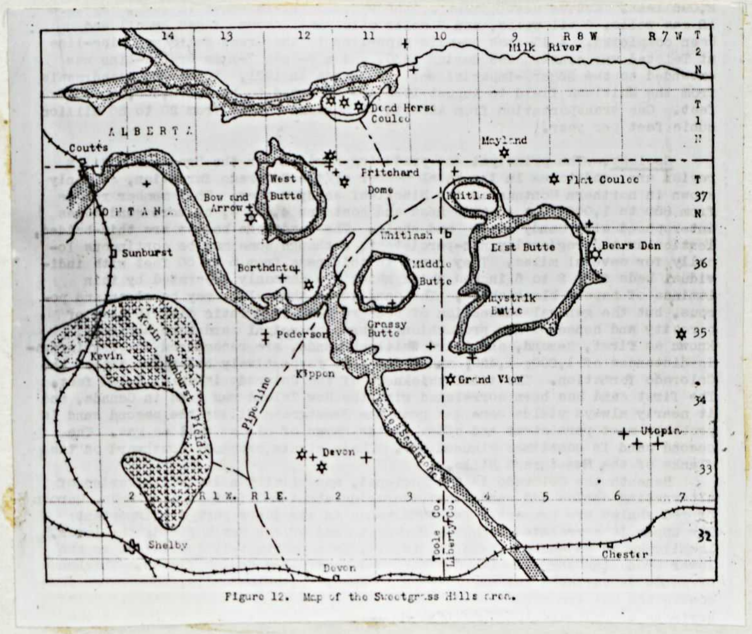


Figure 12. Map of the Sweetgrass Hills area.

Fig. 8 Map of the Sweetgrass Hills area
(Montana State Bureau of Mines and Geology)

History of development and production

The first two wells in the region, drilled in 1915, were gas producers, one in Alberta 4 miles from the International Boundary, called the Rogers-Imperial-Deadhorse Coulee well (largest gas well in Canada), and the other the Montana-Canadian Pritchard No. 1 on the Montana side of the boundary in sec. 4, T. 37 N., R. 2 E. Both of these wells lie on the Pritchard anticline which originates in the West Butte uplift and trends northeast. The Rogers-Imperial well had a total of 54,000,000 cubic feet per day initial flow of gas from several horizons, but from a sand in the lower part of the Kootenai (Sunburst sand of Kevin-Sunburst field) at a depth of 2,300 feet the initial flow is reported to have been 27,000,000 cubic feet. The 4,000,000 cubic feet daily initial flow of the Montana-Canadian well came from a sand near the base of the Colorado formation (Upper Cretaceous) at a depth of 1,780 feet. Three more well have been drilled on the Pritchard dome but all were dry.

The Whitlash field is the largest in the region and lies chiefly in the central part of T. 37 N., R. 4 E. In November 1918, the first well was put down on the Whitlash structure, about 4 miles west of the crest of the dome. This was the Montana-Canadian Oil Company-E. Brown No. 1 which encountered a large flow of gas but was abandoned.

In April 1924, the Gladys Belle-H. Brown No. 1 well, two and one-half miles west of the center of the dome had enormous gas flows in the lower sands of the Colorado formation at depths between 1,580 and 1,750 feet. This well was abandoned after completion to the Madison limestone (Mississippian) at a depth of 2,730 feet with oil showings at 1,840 and 2,095 feet. In 1932, a well drilled 4 miles north of the crest of the dome, termed the Mayland well, and located in Alberta encountered an initial gas production of 15,000,000 cubic feet of gas daily, chiefly from the Sunburst sand, at a depth of 3,100 feet. The Western Natural Gas Company-Hicks no. 1 drilling for gas in the center of the NW¼ NW¼ sec. 26, R. 37 N., R. 4 E. proved to be the oil discovery well of the Whitlash field for at a depth of 1,700 feet it found an

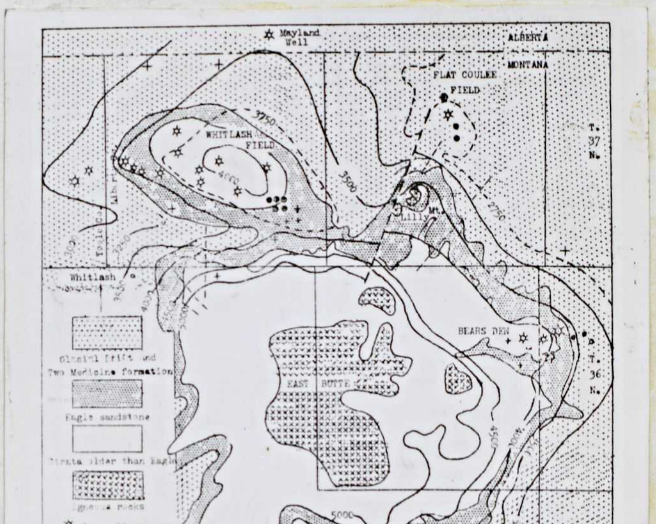


Fig. 9 Structure map of the Whitlash field. Contours on top of Colorado shale. (After U.S.G.S.) (Montana State Bureau of Mines and Geology)

initial flow of 100 barrels daily. The oil was 50° Baume gravity and came from a sand at the base of the Colorado formation. At the end of 1934, 12 gas wells, 4 oil wells, and 7 wells with showings of oil and gas had been completed. Activity in the field has been dormant since that time.

The Flat Coulee field lies 6 miles north of East Butte and approximately 4 miles east of the Whitlash field. A well completed in 1928 known as the Sunburst-Disotel No. 1 in sec. 10, T. 37 N., R. 5 E. near the crest of the dome had a reported initial production of 12 to 15 barrels daily of 31° Baume gravity oil from the basal Kootenai. The Ellis-Madison contact at a depth of approximately 3,000 feet yielded water and the hole was lost due to the terrific gas pressure from the basal Ellis formation at 2,880 feet which wrecked the casing. In June 1935, the J. H. Hamilton et al Co.-Northern Farms No. 1 well in the NE¼ SE¼ sec. 10, T. 37 N., R. 5 E. found a commercial production of 50 to 150 barrels daily. This production was from the basal Kootenai, locally termed the Baskoo sand (probably equivalent to Lower Cut Bank Sand of the Cut Bank field), at a depth ranging from 2,805 to 2,880 feet. In this well the 70-foot "sand" is 60 percent lime but acidization did not materially affect production.

Twelve wells have been drilled upon the Bears Den fold which lies about three miles east of East Butte and 8 miles southeast of the Flat Coulee field. The first commercial production was found in June 1929, in the Sunburst-Bears Den-Watford No. 1 well in the center of the NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 17, T. 36 N., R. 6 E. The initial production was reported to be 50 to 100 barrels daily from the Baskoo sand of the basal Kootenai at a depth of 2,470 feet. The oil is high grade, containing no sulphur, of 39° Baume gravity, and has a paraffin base. Previous to this commercial discovery, there were gas wells on the crest of the structure and one well was abandoned due to presence of black sulphur water. The 1936 status of the field was a total of 12 tests of which 2 yielded small amounts of high gravity oil, 4 were gas wells, 2 were shut in, and 3 were abandoned.

Taking the Sweetgrass Hills region as a whole, the first oil production was 1,415 barrels in 1930. The top year, was 1934 for the region yielded 14,990 barrels. In 1937, 10,407 barrels were produced. At present there are seven small producers in the combined fields of Whitlash, Flat Coulee, and Bears Den.

Stratigraphy

The map on page 67shows the surface focks and structure of the producing fields.

In general, the fields have a thick layer of glacial drift at the surface. The formations directly underlying the drift are chiefly of lower Montana age. However, the crests of the Whitlash and Bears Den structures have Colorado shale as the top formation, and beneath the drift of the Flat Coulee dome is the Judith River formation. The Colorado has a total thickness of 2,100 feet. Beneath the Colorado is the Kootenai formation of Lower Cretaceous age. It is about 500 feet thick and made up of shales and sandstones of probable terrestrial origin. Underlying the Kootenai is the marine Ellis (Jurassic) formation having a thickness of 325 feet with no productive oil or gas horizons. The Madison limestone is the lowest stratigraphic formation that has been penetrated in the Sweetgrass Hills and lies unconformably below the Ellis.

Structure

The sediments lying adjacent to the igneous plugs that make up the Sweetgrass Hills have been lifted locally forming several noses and terraces that radiate out from the Hills.

The Pritchard structure is a northeastward trending anticlinal nose originating on the northeast flank of the West Butte uplift.

The Whitlash Dome makes up the structure of the largest field in the Hills. It is an irregular, oval-shaped dome with a closure of about 500 feet enclosing 25 square miles. Some geologists believe there are faults present but due to the heavy cover of glacial till and lack of well data, this contention cannot be substantiated.

A small dome of apparent igneous origin makes up the Flat Coulee structure. It has a closure of about 100 feet, enclosing a probable productive area of one square mile.

The origin of the Bears Den fold forming a terrace is believed due to igneous intrusion of a plug. The dips vary from 10° to 20° and there is apparent faulting on the south side of the structure.

Oil occurrence

The chief gas-producing horizons of the region are the sandstones of the lower part of the Colorado formation which is known in norther Montana as the Blackleaf member. In the southeast corner of the Whitlash field these same sands yield a light oil with a specific gravity of 38° Baume, it being the first known occurrence of Blackleaf oil in the state. The average depth to this oil-producing sand is 1,700 feet.

, Two producing sands lie at the base of the Kootenai formation. The upper sand is correlated with the Sunburst sand (Stewart Sand) of the Kevin field. This sand is lenticular and may be split with shale members. It produces some gas but no commercial quantities of oil. Separated from the upper sand by variegated shales is the lower sand which is locally called the Baskoo sand and it is correlated with the Cut Bank sand of the Cut Bank field. This sand produces oil of 31° to 39° Baume gravity in the Whitlash, Flat Coulee, and Bears Den fields.

Future possibilities

The Sweetgrass Hills have been an area of drilling activity for over 25 years. During that span of years at least 50 wells have been drilled of which 12 produced oilc commercially, and 20 produced gas. At the close of 1936 there were seven producers and this status has not changed to date.

It appears the area has no great future although it is a proven source of gas. Sporadic drilling will probably continue in the future as it has in the past.

CUT BANK FIELD

The Cut Bank field extends south of the town of Cut-Bank about 8 miles and north about 12 miles. The width of the producing area ranges from 3 to 6 miles. Cut Bank is the county seat of Glacier County, the tOWn lying 43 miles east of Glacier Park. The Great Northern railroad, paralleled by federal highway No. 2, runs east-west through the town. A hard-surfaced highway extends 10 miles north into the field from Cut Bank. Two pipelines serve the

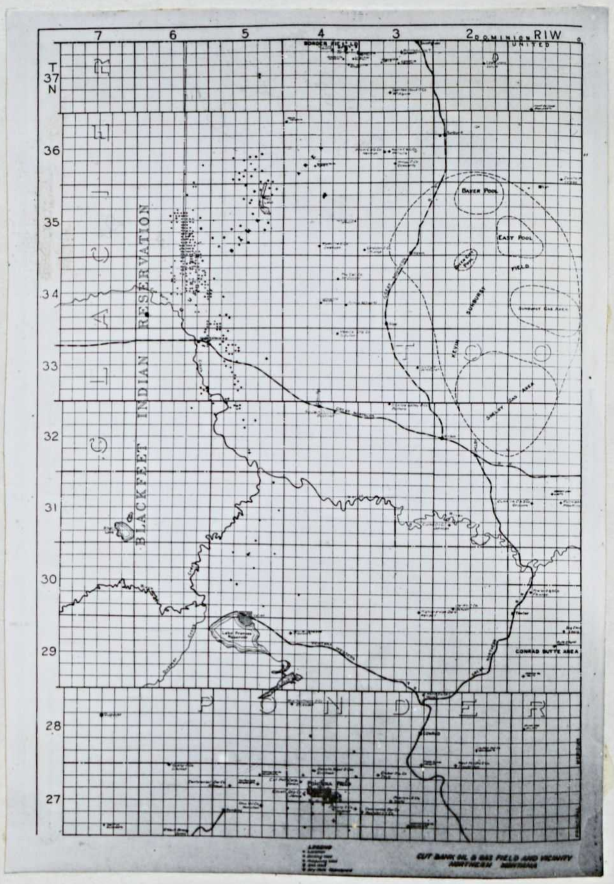


Fig.10 Cut-Bank Oil & Gas Field and Vicinity (Stewart)

field. One is owned by the International Pipe Line Company, a subsidiary of The Texas Company, and runs 28 miles to the International Refinery at Sunburst. The other serves the Northwest Refinery at Cut Bank and is owned by the Santa Rita Oil Company. Much of the field's oil is trucked on hard-surfaced highways to the Home Oil Refining Company at Great Falls, 120 miles distant.

History of development and production

The first well in the field was Sandpoint Oil Company's Berger No. 1 in sec. 1, T. 35 N., R. 5 W., drilled in September 1926. Gas was found in a lower Kootenai sandstone (Cut Bank sand), at a depth of 2,745 feet yielding 8,000,000 cubic feet per day but this was cased off for the well was intended as a test to the Madison limestone (Mississippian) and after drilling to this formation the well was plugged for no oil was found. The discovery well for the oil field, drilled in August 1929, was the Drumheller-Yunck No. 1, in sec. 1, T. 35 N., R. 6 W., nine miles southwest of the Sandpoint-Berger No. 1. This discovery well yielded an initial daily production of 7,000,000 cubic feet of gas and small quantities of oil from the same horizon as the Sandpoint well. After the Drumheller-Yunck well, the first commercial oil well was completed early in 1931, it being the only oil well drilled during the entire year. In 1932 however, the Santa Rita-Haglund No. 1 well was completed with an initial flow of 200 barrels of oil per day. This incited additional drilling activity by various operators and in the years of 1934, 1935, and 1936 about 100 producing wells per year were completed. Of a total of 40 wells drilled during 1938, 30 yielded oil, 6 yielded gas, and the remaining 4 were dry. During 1932, which marked the beginning of the field, 21,000 barrels of oil were produced. The peak of production was in 1937 when 3,364,000 barrels were yielded.

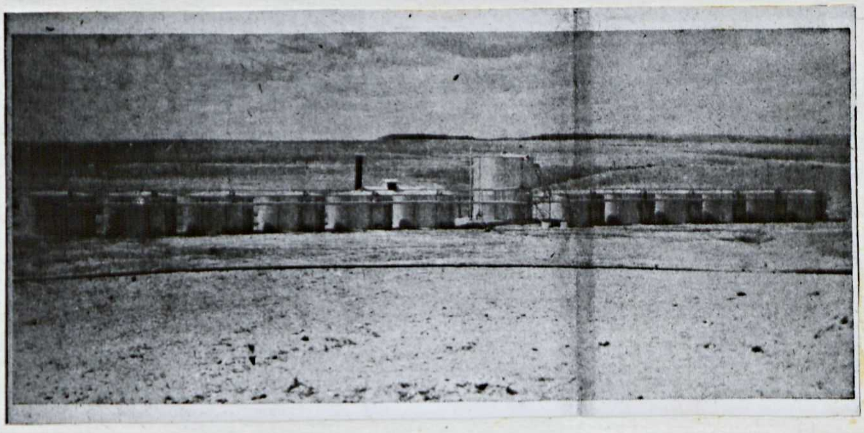


Fig.11 Storage tanks at largest well in Cut Bank field--
Santa Rita-Lander No. 1
(Montana Oil & Gas Journal)

There have been several highlights in the development of this field. One of these is the extension of the field south of the town of Cut Bank approximately 8 miles finding some of the best wells of the field with an initial production of 200 barrels daily. The largest gas wells in the state have been drilled in the North Cut Bank pool. The first well in the North Cut Bank area was the Yukon Oil-Jacobsen No. 1, completed in June 1933, in the center of the NW¼ NW¼ sec. 23, T. 23 N., R. 5 W., which is approximately 2 miles south of the International Boundary and 7 miles west of the Border field. Additional drilling in this area has resulted in three dry holes and one flowing well. Probably the most sensational well of the field is the Santa Rita-Lander No. 1, which lies on the northwest flank of the field near the Blackfeet Indian Reservation in the center of the $N\frac{1}{2}$ $SE\frac{1}{4}$ sec. 16, T. 35 N., R. 6 W. When "drilled in" during January 1936, it was considered a dry hole for no commercial production was obtained from the basal Kootenai sand (Cut Bank sand) but the upper sand (Moulton horizon) was shot with nitroglycerine and the well blew in as a gusher with an initial daily production of 1,000 barrels daily. This production has held up well for by the close of 1938 the well had produced $750,000 worth of oil. Offsets to this well have yielded but average production (75 barrels daily) from the Cut Bank horizon.

Stratigraphy

The surface of the field is for the most part gently rolling prairie, but this is broken by a rough area bordering Cut Bank River which cuts through the portion of the field south of the town of Cut Bank. Glacial debris ranging from 5 to 50 feet thick lies above bed-rock. Below the drift occurs about 300 feet of alternating sandstone and shale of the Two Medicine formation (see stratigraphic column, page 41) of Upper Cretaceous age. Next in order occurs the Virgelle sandstone (Eagle) which is about 250 feet thick. The Colorado shale from 1,710 to 1,790 feet thick underlies the Eagle, and is followed by the Kootenai of Lower Cretaceous age from 615 to 650 feet thick. The latter formation is easily recognized by the red shale cuttings in the drilling sludge.

The lithologic facies of the Kootenai formation are not uniform in northern Montana. Thus beds of shale and sandstone may not persist over large areas which may account for frequent dry holes within the proven area. There are two theories as to the origin of this formation. According to Perry* the Kootenai sediments are terrestrial having been derived from the west by east-flowing rivers over a coastal plain existent in the area, a condition accounting for the lenses of sandstone and shale. In a paper by Stewart** is mentioned the probability that the producing horizon (Cut Bank sand), which lies in the basal part of the Kootenai formation, is a shore line deposit of an ancient sea of late Jurassic or early Cretaceous time. In concordance with these two theories, the Moulton sand which lies in the Kootenai formation but is stratigraphically higher than the Cut Bank horizon, is believed

*Perry, E. S., Geological Report on Cut Bank Field, Montana, Oil & Gas Journal, vol. 32, p. 15, July 12, 1933

**Stewart, H. A., The Cut Bank Oil Field, Glacier County, Montana, Colo. Mines Magazine, vol. 26, no. 2, pp. 45-46, February 1936 to be a river channel or an off-shore bar type of sedimentation. Offsets to wells that have the Moulton horizon frequently do not have this sand indicating that this horizon is very narrow.

At the base of the Kootenai resting upon Ellis shale of Jurassic age lies the producing horizon known as the Cut Bank sand. The Ellis continues for 300 feet before the Madison limestone is encountered. Probably only two or three wells in the field have penetrated to the latter formation and in no instance has its entire thickness been penetrated.

Structure

The field differs from other Montana oil fields in that it is situated on a homocline which in this instance is the west flank of the Sweetgrass Arch. About 25 miles to the west begins the intense folding and faulting of the Rocky Mountains. About 7 miles north of Cut Bank occur two anticlinal noses, one trending northwestwestward on which oil is found and the other trending northeastward which constitutes the gas area. The general dip on the west flank of the oil producing nose is southwestward at the rate of 60 to 80 feet per mile. There is no faulting of any consequence known in the field, whereas in other Montana fields such as the Cat Creek, Dry Creek, and Elk Basin fields, the presence of normal faults is apparently essential for oil accumulation.

It is likely that the gas and oil trap in the field is a result either of decreasing porosity of the producing sandstone horizon eastward up the flank of the arch due to increasing shale content, or else, lensing of the sandstone in that direction. In the event of either situation there is not much information to be gleaned from surface work, thus the location of wells will depend chiefly on underground information gained from well logs.

Oil occurrence

The east line of the field seems to be defined by the gas area that exists there, and a series of dry holes along the western edge appears to have defined the western limit, though as yet there is no definite indication of an edge-water line in spite of the dip of the strata towards the west.

Showings of oil and gas have been found in the Blackleaf member of the Colorado formation. The only commercial production from this horizon in the state is from the Whitlash field of the Sweetgrass Hills area.

It is in the lower part of the Kootenai formation that the producing gas and oil horizons of the field are encountered. The uppermost sand in this formation, termed the Moulton sand, is found in the North Cut Bank area and it is about 30 feet thick. It yields flowing wells and it

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is from this horizon that the field's largest well produces. This sand is found at depths between 2,500 to 3,000 feet. The Upper Cut Bank horizon which produces some oil and gas is a sandstone, sometimes argillaceous, containing lenses of fine black chert particles. It is the Lower Cut Bank sand that is the most consistent producing horizon in the field. It is from 12 to 15 feet thick and consists of black chert and quartz grains. The average depth of the Cut Bank sands ranges from 2,700 in that portion of the field north of the town of Cut Bank to 3,100 feet in the producing area south of Cut Bank.

The oil from the Moulton horizon is a high gravity oil with a Baume rating of 39°. The Cut Bank sands yield a oil with a specific gravity of 34° Baume. Since higher gravity oils may be attributed to their longer migration, it is probable that the underlying Ellis shales may have been the source rock of the oil in these horizons.

Future possibilities

A statement by L. G. E. Bignell, petroleum engineer and staffwriter of the Oil & Gas Journal of Tulsa, may be accepted as an authoritative opinion of the possibilities of the Cut Bank field. This statement was taken from the Montana Oil & Gas Journal and it is as follows: "Cutbank oil and gas field in Northern Montana now exceeds the East Texas oil field in area, having more than 70,000 acres of productive oil land ... . The oil reserve is estimated at 280,000,000 barrels and the gas reserves in excess of 300,000,000,000 feet."

However promising the above statement sounds, it may be well to tell something of the field's progress. The production from this field is by far the largest in the state, producing double the amount of the next ranking field, the Kevin-Sunburst. Due to the loss of the Canadian market, because of the large production in Turner Valley in Alberta since 1934, it was necessary to prorate the field for about three years. Now however, due to a market created elsewhere the field is no longer under proration. This additional market was created by the building of a refinery two miles west of Cut Bank by the Santa Rita Oil Company in 1937 and by shipping of the oil to refineries in Great Falls, Kalispell, Spokane, and Pocatello. At present, construction of another refinery is under way at Cut Bank, it being built by the Glacier Production Company, a subsiduary of the Montana Power Company. These two refineries built near Cut Bank have greatly alleviated the market situation for now the average daily production of 7,700 barrels is assimilated.

The field is the most promising in the state with the possible exception of the Baker-Glendive, but the dry holes and small initial production of many wells due to varying sand conditions and also the necessity for pumping from the drilling-in stage of the wells may prevent the field from becoming one of major importance. It appears probable, however, that these same factors will prevent overproduction and insure a long life for the field.

BORDER--RED COULEE FIELD

This field lies in the northernmost part of Toole County, 40 miles north of Shelby and 6 miles west of Sweet grass. As part of the field extends into Canada it may aptly be called the most northern oil field in the United States. After a short period of development of about two year, dril ing ceased and declines in production were rapid. The topography is generally quite level, the area being farmed, but bordered on the east and west by large coulees.

History of development and production

The discovery well of this field was drilled in November 1929, and active development came in the following year with the limits of the field quickly determined. The discovery well lies in Alberta, 281 feet north of the International boundary. It yielded 3,500,000 cubic feet of gas and 60 barrels of oil daily when drilled in, which has decreased to 10 barrels at the present time. The oil from this well, which has a specific gravity of 31° Baume, comes from the lower part of the Kootenai formation from a sand locally termed the Vanalta after the name of the Vanalta Oil Company which drilled the well. The second well in the field was the first completed on the Montana side --McDonald-Farbo No. 1--it being a direct south offset to the discovery well lying in the southwest corner of $NE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 2, T. 37 N., R. 4 W. This well was completed in January 1930 as a 100-barrel producer. The third well in the field was the Cosmos-IowasCo. No. 1, one-half mile south of the discovery well and it proved to be the best well of the field. The last productive well was drilled in 1932, two wells drilled in 1934 proved to be dry, and there has been no drilling since.

The total producing area is about 1,000 acres including that portion in Alberta which is about one-fifth of the total area. That portion in Montana lies in sections 1 and 2, T. 37 N., R. 4 W.; the Alberta area borders these two sections and does not extend farther than one-quarter of a mile north. The year of peak production was 1931 when 178,000 barrels were marketed, but by 1938 annual production had decreased to 25,000 barrels, and there were but 10 producing wells each averaging 7 barrels daily.

Stratigraphy

The geological formations in this field are the same that occur in the Sweetgrass Arch in general and the Cut Bank field in particular. The Virgelle sandstone (basal Eagle) is exposed in the coulees on the east and west margins of the field; in the producing area it is covered by about 50 feet of glacial gravel. For further information about stratigraphy see that described under the Cut Bank field.

Structure

The Border field lies upon the easternmost of three north-plunging noses on the northwest side of the Sunburst dome. As is true of the Cut Bank field that also produces from sands of the Kootenai formation, the production of this field seems to be controlled essentially by porosity and lensing of sands. It is probable that the nose is closed on the south by decreasing porosity of sands for all wells south of the producing area were dry even though structurally higher. The nose is closed structurally on its west, north, and east sides.

Oil occurrence

The producing horizons are sands in the lower part of the Kootenai formation which is also the chief oil horizon of the Cut Bank field and chief gas horizon of the Kevin-Sunburst field. There are three producing sands present as set up by Dobbin and Erdmann* as follows: "the "gas sand," which occurs in the Sunburst zone of the Kevin-Sunburst oil field, and is probably somewhat higher stratigraphically than the type Sunburst; the Vanalta sand; and the Cosmos sand. The Cosmos sand is probably the basal sand of the Kootenai, and is 45-70 feet thick. Over the productive portion of the field it is split by a wedge

Dobbin, C. E., Erdmann, C. E., op. cit. p. 711

of gray-green pyritic siltstone which thickens toward the northeast. The upper sandstone is locally termed the Vanalta sand, and the lower the Cosmos sand . . . . The gas sand or upper Sunburst is 10-45 feet thick; the upper Cosmos(Vanalta) 5-15 feet, and the lower Cosmos sand 30-40 feet thick. The principal productive horizon is the lower Cosmos. It is a rather complex unit, exhibiting locally a laminated or ribbon structure in its upper part due to the intercalation of short, thin lenses of black shale with cross-bedded fluviatile sandstone. The lower part is cherty and locally conglomeratic. Cementation by white clay, which was probably carried into the unconsolidated sand before the overlying beds were deposited, has produced complex conditions. Lenses of porous sand are isolated in the tightly cemented sand, and the oil-gas-water system may vary in closely adjacent lenses. Some of the wells thus behave erratically; others show a very rapid decline."

The oil, which is of a mixed base,has a specific gravity of 30° Baume. It probably had its origin in the underlying Ellis shale.

Future possibilities

The fact that no location has been made in the Border-Red Coulee field since 1934 is ample evidence of its waning possibilities. Many dry holes have been drilled and have clearly defined the producing area. The only possible future prospect of the field is production from deeper horizons and it is probable that drilling of a deep test well will depend upon development of the North Cut Bank area and the development north and west of Kevin, both of which areas are being extended toward the Border field.

DRY CREEK FIELD

The Dry Creek field is about 8 miles east of Red Lodge and 12 miles northwest of the Elk Basin field. It is connected by a gravel road to state highway No. 32 that goes north-south through Red Lodge.

History of development and production

Two wells were drilled on the Dry Creek Dome in 1917 finding only showings of oil and gas. In 1929 the Ohio Oil Co.-Northern Pacific No. 1 in the southeast corner of the NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 11, T. 7 S., R. 21 E., found gas in the Eagle formation at a depth of 2,350 feet and in the Second Frontier sand at a depth of 4,460. A second well, the Ohio Oil Co.-Northern Pacific No. 2, in the northeast corner of the NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 11, T. 7 S., R. 21 E. 1320 feet west of the No. 1, struck oil in August 1930 in the first Dakota sand at 5,412 to 5,485 feet, thus becoming the oil discovery well for the field. Upon continued drilling of this well the second Dakota sand was met yielding a much heavier flow of oil than the first sand and it also was much thicker being about 300 feet. The hole bottomed at 5,518 feet and the initial production was estimated at 2,000 barrels daily from this discovery well. This production decreased considerably by the end of the year. This well also found a heavy flow of gas in the Frontier sand from which the No. 1 well produced gas. After losing seven strings of tools in the No. 1 well, the attempt to deepen it to the Dakota sand was abandoned.

In August 1931, two completions were made in the field at a depth exceeding 5,000 feet. One of these was a gas well and the other yielded an initial oil production of 400 barrels per day. In December 1931, one of the field's most sensational wells came into production, it being a gusher yielding an initial 2,400-barrel flow per day. This well is one mile east of the discovery well. Six oil wells were completed in 1932, one each in the two following years, one gas well in 1935, and but one completion since that date, it being a dry hole finished in 1938.

In 1930, the discovery year, the field yielded 14,500 barrels of oil; in 1936, the peak year, 212,000 barrels were produced, and during the first four months of 1938 the field yielded 129,000 barrels.

Stratigraphy

There is an inner scarp of Colgate (Upper Cretaceous) sandstone that partially surround the dome. Underlying formations of Lennup sandstone and Bearpaw shale are exposed at the surface of the crest of the dome. The Hell Creek member of the Lance formation surrounds the inner scarp of Colgate sandstone. South of the dome there is a scarp of Tullock and Hell Creek sediments, both Lance members. The outer scarp to the west and north is made up of the Tullock, the Tongue River, and the Lebo, the last two formations being members of the Fort Union of Tertiary age.

Below is a stratigraphic column of the dome.*

```
Tertiary system
  Paleocene series
    Fort Union formation
      Tongue River member
        lenticular sandstones with coal seams; gray
        sandy shale; brown carbonaceous shale; thick-
        ness in this area of greater than       3,000 feet
      Lebo member
        gray and brown shale and mudstones; buff
        limestone; and some sandstones
           thickness south of lineament         2,000 feet
               "      north  "     "              200   "
Cretaceous system
  Lance formation
    Tullock member
      persistent, irregular bedded sandstones
      with coal streaks; some shale
           thickness south of lineament           700 feet
               "      north  "     "              350   "
    Hell Creek member
      shale with sandstone lenses
           thickness south of lineament         3,500 feet
               "      north  "     "            1,000   "
  Colgate sandstone
    massively bedded, fairly persistent, light
    colored sandstone and gray shale
           thickness                              450 feet
  Lennep sandstone
    dark gray mudstone and brown sandstone
           thickness                              125 feet
  Bearpaw shale
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The thinning of sediments along a line called the lineament may be explained by supposing a sharp flexure

*Wilson, C. W. Jr., Geology of Nye-Bowler lineament, Stillwater and Carbon Counties, Mont., Am. Assoc. Pet. Geol. Bull., vol. 20, pp. 1161-1188, September 1936 or a fault scarp during deposition of the Hell Creek member of the Lance formation with downthrow on the south. Thus there would be a monoclinal fold draped over the buried fault with the high side on the north so deposition would be much thicker on the south until it reaches the level of the north side. This apparently resulted in much thicker formations on the south as evidenced by the Hell Creek and Tullock members of the Lance formation and the Lebo member of the Fort Union formation. It appears that a common level of the north and south sides was reached during the deposition of the Lebo member.

Structure

The Dry Creek Dome is the largest structure of a group of structures, chiefly domes, that extend in an east-southeastward direction across the northern end of the Bighorn Basin from Nye, close to the Beartooth Mountain front, to Bowler, 50 odd miles distant, at the west edge of the Pryor Mountains. There are twelve structures, two being half-domes, one an anticline, and the remainder are domes. This anticlinal trend and the superimposed structures thereon are asymmetricl folds with dips on the south from 10° to 45° and on the north from 5° to 20°.

The Dry Creek structure is essentially an elliptical dome, 4 miles wide and 6 1/2 miles long, with about 1,500 feet closure, broken by several northeast-southwest faults, some having a vertical displacement as great as 1,000 feet. Two parallel faults form a graben at the center so the part that would normally be the crest of the dome is dropped.

Oil occurrence

The producing horizons of the Dry Creek and Elk Basin fields are the same but the oil producing horizon in the former field is the gas producing strata of the latter and vice versa. Thus the Cloverly (Kootenai) formation in the Dry Creek field produces oil and in the Elk Basin field it yields gas, and the Frontier sand (Colorado) in the former field yields gas and in the latter field is yields oil.

It is supposed that the complex faulting present upon this structure prevented the flushing of the oil away from the domal trap by artesian water. This condition is much like that believed existent in the Cat Creek field wherein in both cases the oil is trapped by structure and subsequent faulting prevents the passage of water and oil through pervious strata to the surface.

Future possibilities

Due to the decided fall in production and the frequent dry holes the future progress of the Dry Creek field may be slight. Coupled with the above facts is the small area of the structure. As previously mentioned this field is one of a series of "highs". Several of the other "highs" have been tested but no commercial production of oil or gas has been found.

The Mosser Dome, which is south of Billings about 30 miles, has yielded small amounts of oil.

Fig. 12 Outcrop of Basal Conglomerate of Cloverly Formation (Knappen & Moulton, U.S.G.S. Bull. 822-A)

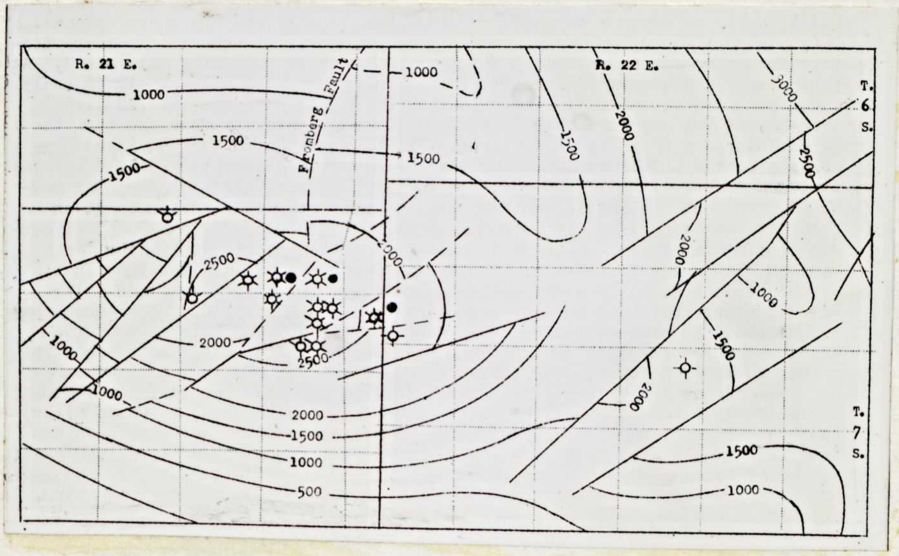

Fig. 13 Generalized structure contour map of the Dry Creek Field. (Mont. Bureau of Mines & Geology)

BAKER-GLENDIVE FIELD

This field lies in the extreme eastern portion of the state near the Montana-North Dakota state line. It is quite isolated from any other producing areas being at least 150 miles east of other Montana fields. It has been known as the Cedar Creek gas field, but the name Baker-Glendive has supplanted the former name in popular usage and in the literature. The Yellowstone River near Glendive cuts through the northern end of the anticline, the Baker-Glendive anticline, upon which many favorable oil structures lie. The Northern Pacific railroad passes through Glendive and the Chicago, Milwaukee, and St. Paul railroad passes through Baker, the latter town being about 80 miles southeast of Glendive. Roads throughout the area are chiefly of dirt surface.

History of development and production

There has been drilling upon the Baker-Glendive anticline since 1912 when gas was found but interest in the area did not quicken until 1936 when oil was discovered. Development of gas wells was sporadic in the years 1915 to 1926, in each of these years there 10 gas-well completions. The drilling activity increased in 1926 and continued through 1930 after which there was a decided lapse in the drilling of gas wells. In 1936, a deep test that had been spudded in the year before was sucessful in striking oil. Two deep tests that had been attempted before completion of the discovery well were unsuccessful, one ceased drilling before reaching the producing horizon in the Madison limestone when it proved to be a poor location structurally for it would have necessitated drilling about 1,000 feet deeper than present wells to reach the Madison limestone.

The sucessful deep test was the Montana-Dakota Utilities Company No. 1 in the NE¼ NW¼ sec. 17, T. 4 N., R. 62 E. on a local dome called the Little Beaver, being completed in September 1936, finding production from 6,645 to 6,698 feet. The initial production was unofficially rated as 400 barrels daily on the pump. The producing horizon is the upper part of the Madison limestone ("Ellis sand" of the Kevin-Sunburst field), upon which acidization is practiced in the Kevin-Sunburst field. Acidization was tried in this well resulting in an increased production, unofficially rated at 7,500 barrels daily but the third day following acid treatment the well turned to water. A possible cause of the change to water may be attributed to "coning". Subsequent meticulous work in an effort to shut off the water failed.

A second well was drilled 3,000 feet north of the discovery well in the center of the NE¼ SW¼ sec. 8, T. 4 N., R. 62 E., completed in 1937. This well is known as the Montana- Dakota Utilities No 2. and struck an unofficial production of 400 barrels daily at 6,750 feet from the Madison limestone. A well located 35 miles north of the discovery well which would be 5 miles north of Baker encountered water in the producing horizon of the Madison formation at a depth of 7,260 feet during the same year. It was plugged back to the Judith River formation and completed as a gas producer. Two additional wells drilled in the same year on the Little Beaver Dome did not find oil in commercial amounts. A gas well in 1938 has been the only recent completion in the field.

In 1937, the first year of oil production, the field yielded 14,197 barrels. From January to April of 1938 the production was 3,391 barrels.

Stratigraphy

The outcrop of the crest of the anticline is made up of Bearpaw shale(Montana group) of Upper Cretaceous age, it being one to eight miles wide following the trend of the anticline's axis in a northwest-southeast direction. Its length is about 100 miles, beginning a few miles southwest of Glendive and trending southeast through Baker and on a short distance into North Dakota. As in other parts of the state the Bearpaw shale is easily identified by the gumbo soil it forms at the surface. Enclosing the Bearpaw shale on the structure is the Fox Hills sandstone (Upper Cretaceous) and its outcrop is from one-half to two miles wide. The outcrop of the Lance formation (Upper Cretaceous) in turn enclosed the Fox Hills formation. On the southwest side of the structure from Glendive to Plevna, a distance of approximately 50 miles, the outcrop of the Lance formation is about one mile in width but its exposure elsewhere on the flanks of the anticline is up to fifteen milès wide.

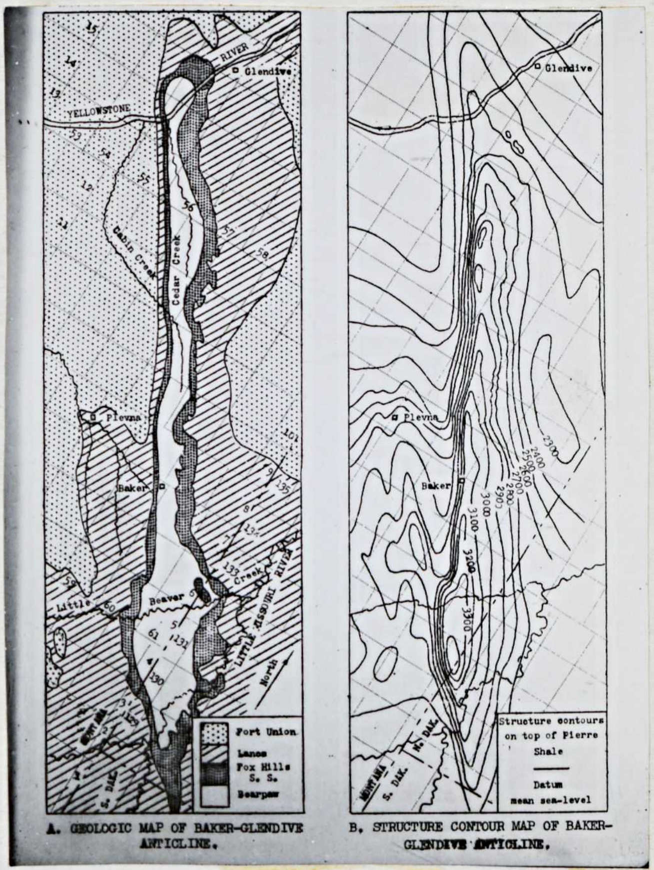

Fig.14 Geologic and structure maps of Baker-Glendive Anticline (Montana Bureau of Mines & Geol.)

The Fort Union formation (Tertiary) lies off the flanks of the anticline and extends for many miles on all sides of the structure.

Structure

The producing structure and about twelve other possible producing structures are all domes lying upon the same fold termed the Baker-Glendive anticline. It is upon the Little Beaver Dome that production is now gained. This dome lies very close to the Dakota line in the southern portion of the anticline. South of the producing dome are the Fox Hills and Gallup Creek Domes. North of the producing dome, in the order named, are the Hidden Water, Baker, Cabin Creek, and Thirteen Domes. Near Glendive which is 80 miles northwest of Baker is the Gas City Dome. All of these structures are possible oil producers, many produce gas but the possibilities of most of them as oil producers from deep horizons has not yet been tested.

The Baker-Glendive anticline is approximately 100 miles long beginning a few miles northwest of Glendive, its axis trending southeastward through Baker and extending about 25 miles into the southwestern corner of North Dakota. Its width varies from 6-12 miles. As indicated by the narrower outcrops of the formations as mentioned under stratigraphy of the area, the dip of the strata is steeper on the west flank than on the east, the values being from 5° to 30° on the west side and from 1° to 8° on the east flank. The varying dip of the west and east flanks as given above indicates that the anticline is slightly asymmetrical.

The closure of the anticline is a maximum near the Montana-Dakota state line being at least 600 feet. The closure of the producing structure, the Little Beaver Dome, is 300 feet.

Oil occurrence

The only oil producing horizon in the field is the upper 40 feet of the Madison limestone (Mississippian), the same horizon that is the chief oil producer in the Kevin-Sunburst and Pondera fields where it is called the "Ellis sand". This horizon is pierced at depths ranging from 6,645 to 6,698 feet and is thus the deepest horizon producing oil commercially in the state.

As previously mentioned there are many "highs" on the Baker-Glendive anticline, the closures of which range from 40 to 300 feet. These form important structural traps for the accumulation of oil in this field. Another factor that has affected the possible oil accumulation on the anticline is the proximity of the hydrostatic head of water in the Black Hills for the southern tip of the anticline lies in northwestern South Dakota not far from the Black Hills uplift.

The underlying Jefferson shales appear to have been the source rock of the oil that has later migrated to its present position in the upper part of the Madison limestone.

Future possibilities

Potentially speaking, this field has the possibilities of becoming the best field in the state and if that can be said it is also probable that it has the chances of outranking any field in the Rocky Mountain area.

As yet only six deep tests have been made of which the initial production of two was about 500 barrels daily which was increased after acidization. One of the two turned to water and the other to a small settled production. Therefore it seems that the field has hardly been touched as a possible oil source. The difficulty, however, is the depth to which wells must be drilled, involving a cost of about $200,000 per well, a price which will greatly curb development. Only large companies will prospect and then only after their resources decrease to such a point that they deem further drilling in the area to be necessary for the future development of their oil reserves.

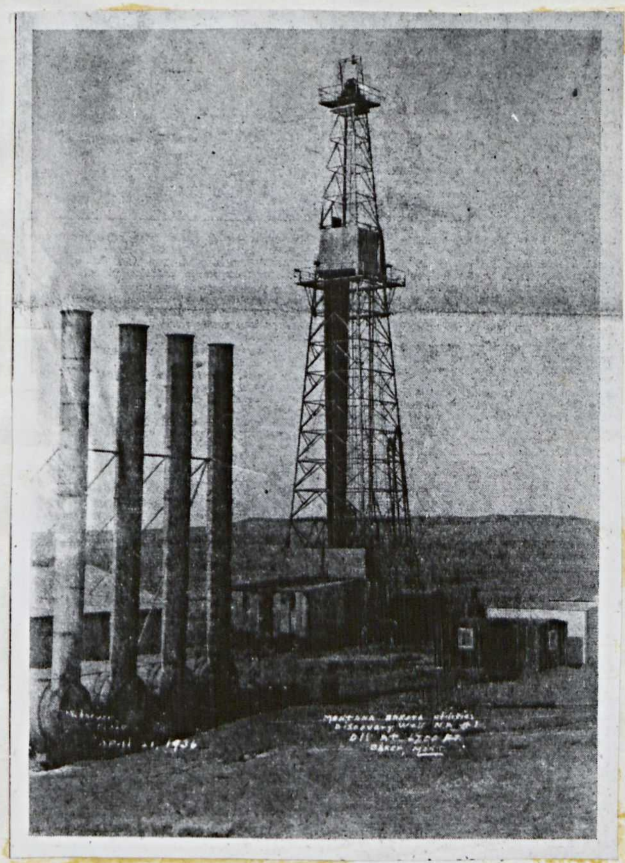

Fig.15 Rotary rig that brought in Baker discovery well
(Montana Oil & Gas Journal)

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