Oil and Gas in Eastern Kansas

A 25-Year Update

By
MARGARET O. OROS

Kansas Geological Survey
The University of Kansas
Lawrence, Kansas 1979

Energy Resources
Series 13

Energy Resources Series 13

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By Margaret O. Oros

Printed by authority of the State of Kansas
Distributed from Lawrence

UNIVERSITY OF KANSAS PUBLICATIONS
January 1979

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John Mark Jewett (1896-1970)

Perhaps no one had a better grasp of the stratigraphy of eastern Kansas than did John Mark Jewett. He was a geologist who had observed and studied that section of his native state so well that, when leading a field trip through the area, he could point to almost any hill or valley or slope and give an accounting of its makeup: beginning with the surface soils and vegetation on down through the mineral-laden bedrock. Small wonder, then, that such publications as *Oil and Gas in Eastern Kansas* continue to be in demand.

Dr. Jewett of course was familiar with all Kansas stratigraphy and structural geology. His *The Geologic Making of Kansas,* delivered as a presidential address before the Kansas Academy of Science in 1961, and published in the fall issue of the *Academy Transactions* for that year, is a good summary of his contributions in those areas. Among his many publications, these are some of the most significant: three county studies—*Oil and Gas in Linn County* (1940), and *Geology of Riley and Geary Counties* (1941); *Geologic Structures in Kansas* (1951); *The Concept of Time in Stratigraphic Classification* (1962); *The Stratigraphic Succession in Kansas* (Jewett et al., 1968); his Kansas Academy of Science address on *The Kansas Academy of Science and One-Hundred Years of the Evolution of Geology* (1968); and three papers developed for the Interstate Oil Compact Commission—two in 1956 on disposal of oil-field brines and underground storage of liquid petroleum hydrocarbons, and the third paper dealing with underground storage of natural gas in Kansas (Jewett and Goebel, 1960). Dr. Jewett also supervised the preparation of map M-1, the *Geologic Map of Kansas,* which has a revision that was printed in 1964.

John Mark Jewett was born in DeSoto, not far from the University of Kansas. He received his education in geology up through the PhD degree at the University and for more than a quarter of a century was a member of the geology faculty and of the Kansas Geological Survey. Dr. Jewett had strong ties with the people of Kansas. To the extent that he could, he used his knowledge of Kansas geology and mineral resources to help his fellow Kansans, and others—through publications and such services as inspecting dams, consulting on groundwater supplies, and leading geologic field trips for laymen as well as geologists.

As a teacher he eagerly shared his experiences with his students who always found his "door open."

Dr. Jewett was a versatile scientist, and historian-philosopher too. Yet he was humble. And perhaps that is why he was a geologist who could serve his public so well.

MARGARET O. OROS*

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A 25-Year Update

INTRODUCTION

Kansas Geological Survey Bulletin 104, *Oil and Gas in Eastern Kansas,* by John Mark Jewett, has long been considered an indispensable report for geologists working in Kansas, particularly in the eastern third of the state. Published in 1954, it supplemented and updated two earlier reports with the same title (Jewett and Abernathy, 1945; Jewett, 1949). It is reprinted now so that it will be easily available to a new generation of oil and gas explorationists. The first 90 pages of "Oil and Gas in Eastern Kansas" are devoted to a discussion of the early history of the Kansas petroleum industry, a summary of developments since the publication of Bulletin 77 (in 1949), and a review of the geology of eastern Kansas. One of its most useful sections has been its "Index of Oil-Field Names for Producing Rocks" (pages 76-90); here one can find pay-zone terms used in the oil fields, and their correlations with formal geological-formation names. The major part of the text is devoted to a discussion of the geology, petroleum history, and oil and gas potential of each of the 43 eastern Kansas counties.

This update is intended only to provide statistical data that have accumulated since 1953, to mention briefly the discoveries in former nonproducing counties, to give a brief overview of Kansas petroleum developments, and to list recent exploration and development techniques. No attempt has been made to review all developments on a county-by-county basis in the East Range area.

* Ms. Oros worked in the Subsurface Geology Section of the Kansas Geological Survey from 1962 until her retirement in 1978.

HISTORICAL TRENDS

Western Kansas Developments

Prior to May 17, 1923, almost all commercial oil and gas production in Kansas had been from wells in the East Ranges. On that date, Valerius Oil and Gas Company (Lucky Seven), 1-Carrie Oswald, sec. 8, T.12S., R.15W., Russell County, discovered the Fairport field, on what was later called the Central Kansas uplift, and shifted exploration to the West Ranges. The No. 1-Carrie Oswald was still an oil producer in 1978, 55 years after its completion. Several other western Kansas wells were significant in exploration and development of that area. The earliest known producer in the state's West Ranges was a well drilled to a depth of 1,230 feet in 1887, in Lyons (sec. 34, T.19S., R.8W.), Rice County; that well supplied gas to Interstate Hotel and to some residences in Lyons for a number of years. The well's owners also drilled through a bed of salt, 275 feet thick, at 710 feet in this hole, and thus were primarily responsible for the development of the Kansas salt industry. Defenders and Traders Oil Company, 1-Boles, in sec. 3, T.35S., R.34W., Seward County, which was spudded in 1919, and completed seven months before the No. 1-Carrie Oswald, had an initial potential of five million cubic feet of gas per day. This well, which opened the Liberal gas field, later was called the discovery well of the Kansas portion of the Hugoton gas field. Several years passed, however, before other gas wells were drilled in southwestern Kansas. Amarillo Oil Company, 1-Masterson, drilled in 1918, in northern Potter County, Texas, is now considered the first gas well completed in the Hugoton-Panhandle field, which occupies a large area in southwestern Kansas and the panhandles of Oklahoma and Texas. The two gas wells were about 110 miles apart, and it was years before the area between these two discoveries was filled in with gas wells. The Hugoton-Panhandle field now stretches over 150 miles east-west in Texas and 190 miles from its southwestern extremity to the northern end of the field in Kansas.

Three Kansas counties (Harvey, Sedgwick, and Sumner) straddle the Third Principal Meridian, which separates the "East Ranges" from the "West Ranges" in Kansas. These counties have not been included in the "Oil and Gas in Eastern Kansas" reports. Reportedly, Harvey County's Walton field discovery well (sec. 4, T.23S., R.2E.) produced 2,100 bbl of oil in 1919, the year it was drilled, though

commercial production in the Walton field was delayed until 1923. Sedgwick County's first field was Valley Center, sec. 12, T.26S., R.1W., discovered in 1928. Sumner County production began in 1925, when the prolific Rainbow Bend field in sec. 14, T.33S., R.3E. (discovered in 1923) was extended westward from Cowley County into sec. 24, T.33S., R.2E. Gas was found in Sumner County in T.35S., R.2E., in 1915.

Eastern Kansas Drilling and Production, Compared with West Ranges Developments

With discovery of the Fairport field, drilling emphasis shifted westward. Production potentials of the new wells were much greater than for wells in the eastern part of the state, and, for several reasons, oil production in the East Ranges dropped dramatically in the next few years (Figures A & B; Table A). Soon the glut of oil produced by newly found fields in western Kansas and in other Midcontinent fields, along with the economic depression in the 1930s, caused the price paid for crude oil to drop—from $5.00 in the mid-1920s to 25¢ per barrel in the early 1930s (almost 50 years later the price again reached $5.00 per bbl). At times there was severe restriction, and some actual stoppage, of production in the fields. Stimulation of old wells by water or gas injection began slowly in the old eastern Kansas fields in the 1920s and was officially sanctioned by Kansas regulatory groups in 1935. Production of oil gradually increased in these fields, mainly as a result of the use of water flooding and pressure-maintenance methods. The high point was reached in 1955, when 30.7 million barrels of oil were produced in the East Ranges. Production then declined each year, reaching a low in 1975, when only 9.8 million barrels of oil were produced. Interestingly, the enhanced (secondary and tertiary) oil-recovery production figures indicate that oil recovered by these methods for the state as a whole peaked in 1968, when 32.4 million barrels were produced in the flooded fields; production by secondary recovery has declined each year since then. Figure A shows total oil production since it began in Kansas prior to 1900; total production (since 1923) compared with amounts produced each year by East Range wells; and production by secondary and tertiary methods of recovery. In addition, the graph shows natural gas production for the state, highlights of exploration, and several federal and international events or rulings that have affected the industry. Crude

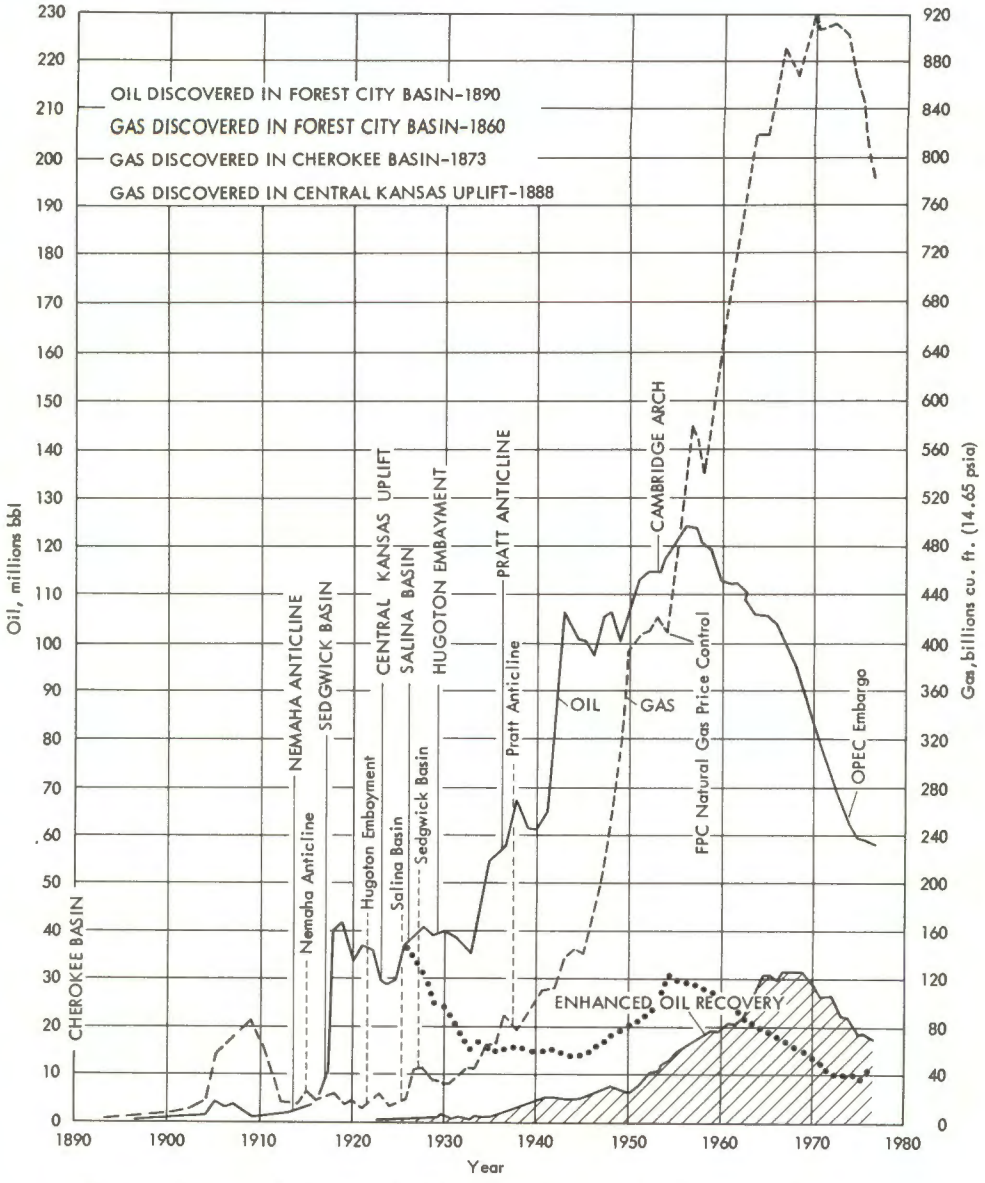


FIG. A.—History of Kansas oil and gas production. All Kansas crude oil up to 1923 was produced in East Ranges. Dots on graph show East Range production since 1923.

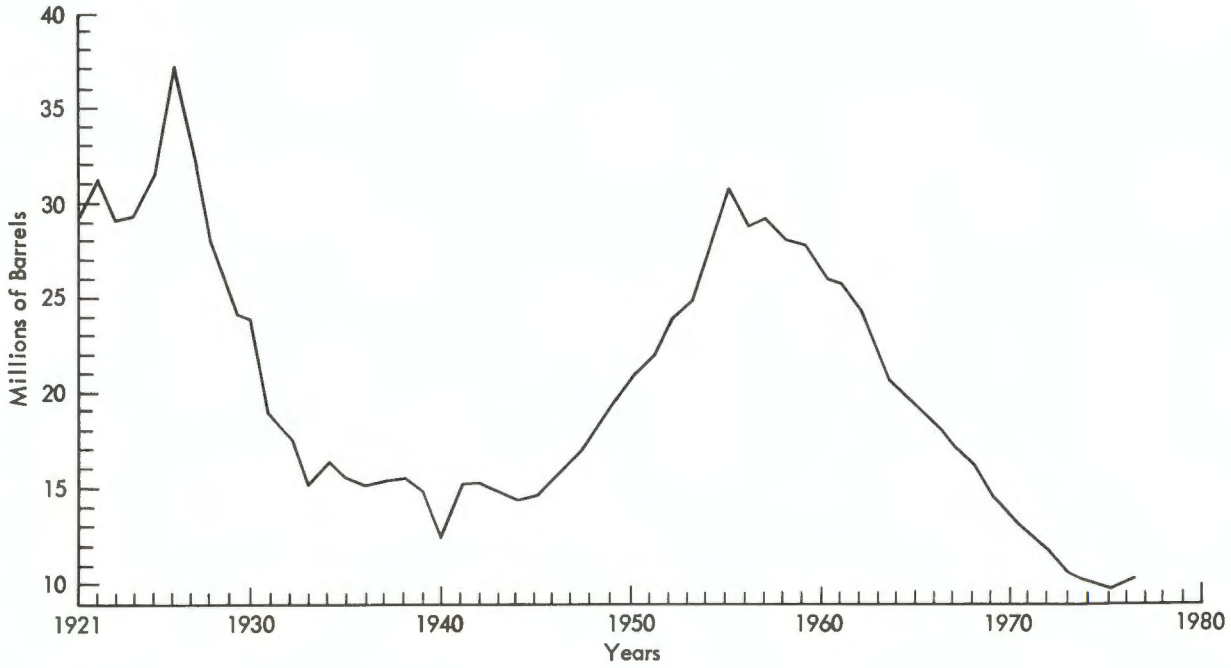


FIG. B.—Eastern Kansas oil production, 1921-1976.

oil production in Kansas has been declining since 1956, when it was 124.7 million barrels. In 1976, it was only 57.5 million barrels. Eastern Kansas oil production for the years 1921 through 1976 is shown in Figure B; Table A shows production by county for the years 1953 through 1976.

TABLE A. *Crude Oil Production in East Range Counties of Kansas, 1953-1976.*
(Figures are in thousands of barrels.)

COUNTY	Years: 1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Allen	613	828	807	845	969	964	979	1,012	967	948	858	845
Anderson	653	747	732	659	571	555	488	433	391	388	393	437
Atchison	—	—	—	—	—	—	—	—	—	—	—	—
Bourbon	38	62	35	35	33	30	29	28	58	99	72	57
Brown	—	—	—	—	—	—	—	—	—	—	—	2
Butler	8,616	8,758	8,649	8,138	8,059	7,715	7,929	7,800	7,573	7,148	6,539	5,978
Chase	31	33	33	32	52	87	113	104	100	87	72	76
Chautauqua	830	953	947	1,035	963	938	935	866	857	811	835	774
Cherokee	—	—	—	—	—	—	—	—	—	—	—	—
Clay	—	—	—	—	10	22	15	10	10	8	6	6
Coffey	106	214	190	162	140	124	111	101	93	97	99	109
Cowley	3,127	4,364	4,714	4,595	4,182	4,172	3,858	3,672	4,021	4,355	3,795	3,358
Crawford	55	58	54	49	46	40	38	41	34	40	63	72
Dickinson	102	106	143	128	103	99	76	62	59	46	49	43
Doniphan	—	—	—	—	—	—	—	—	—	—	—	—
Douglas	2	14	11	10	9	8	27	43	58	42	29	38
Elk	171	285	305	301	284	269	254	226	191	171	153	174
Franklin	481	454	377	348	306	281	294	334	380	335	262	230
Geary	—	—	—	—	—	—	—	—	2	1	1	1
Greenwood	5,638	6,141	8,485	6,789	6,978	6,467	5,845	4,759	4,116	3,647	3,282	3,188
Jackson	—	—	—	—	—	—	—	—	—	—	3	89
Jefferson	—	—	—	2	—	—	—	—	—	—	—	—
Johnson	—	6	4	8	6	4	3	5	5	24	30	47
Labette	49	81	98	100	127	98	120	110	108	101	85	110
Leavenworth	—	—	—	5	7	4	2	—	—	—	9	8
Linn	73	88	94	89	83	75	72	67	57	50	52	57
Lyon	263	383	416	349	269	227	182	157	126	102	93	88
Marion	680	725	910	1,398	2,170	2,595	3,110	3,297	3,378	2,594	1,817	1,376
Marshall	—	—	—	—	—	—	—	—	—	—	—	—
Miami	586	686	677	675	603	519	486	407	332	302	241	263
Montgomery	724	922	1,098	748	599	537	530	494	458	458	415	441
Morris	39	38	70	269	437	363	380	425	449	433	404	383
Nemaha	48	38	27	25	18	14	12	10	7	7	6	8
Neosho	612	618	635	638	606	555	521	488	477	477	469	495
Osage	—	—	—	—	—	—	—	—	—	—	—	—
Pottawatomie	—	—	—	—	—	—	—	—	—	—	—	—
Riley	—	—	—	—	—	—	57	212	245	221	211	195
Shawnee	—	—	—	—	—	—	—	—	—	—	—	—
Wabaunsee	566	182	153	324	297	266	256	280	270	257	250	244
Washington	—	—	—	—	—	—	—	—	—	—	—	—
Wilson	70	187	187	173	189	194	207	197	303	365	368	378
Woodson	688	755	862	999	921	831	815	803	782	834	824	915
Wyandotte	—	—	—	—	—	—	—	—	—	—	—	—
	24,861	27,726	30,713	28,928	29,037	28,053	27,744	26,443	25,907	24,448	21,785	20,485

TABLE A. *Continued.*

1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Cumulative production
815	846	912	833	620	579	538	506	434	415	392	438	33,378
381	347	304	296	273	260	255	249	221	212	233	235	24,605
—	1	—	—	—	—	—	—	—	—	—	—	1
51	97	122	111	108	97	98	84	59	50	47	70	2,263
4	6	6	6	5	4	3	1	2	1	1	2	145
5,583	5,083	4,860	4,347	3,938	3,776	3,565	3,221	2,824	2,428	2,375	2,446	516,798
67	50	52	64	55	52	44	42	40	33	34	35	1,560
885	763	715	672	699	540	559	523	471	464	459	573	61,185
—	—	—	—	—	—	—	—	—	—	—	—	—
4	2	2	2	—	—	—	—	—	1	1	—	96
121	120	112	105	111	130	166	198	230	414	438	411	5,375
3,000	2,795	2,553	2,597	2,266	2,235	1,906	1,770	1,922	1,809	1,843	2,005	146,255
86	78	75	66	59	52	44	38	31	31	29	28	1,758
50	92	99	87	35	37	34	38	29	24	22	22	2,299
—	—	—	—	—	—	—	—	—	—	—	—	—
40	44	44	35	30	28	23	21	19	20	30	22	696
161	158	170	157	164	165	241	251	200	182	184	194	18,902
214	209	174	167	153	123	107	91	74	79	80	87	14,215
2	2	2	1	2	2	2	4	2	1	1	1	29
3,300	3,192	2,834	2,674	2,309	2,143	1,926	1,722	1,475	1,323	1,275	1,268	273,322
83	77	33	20	10	15	24	16	7	7	9	12	404
—	—	—	—	—	—	—	—	—	—	—	—	875
49	39	30	24	22	22	21	20	15	14	14	15	421
94	73	74	45	40	25	22	18	10	13	13	17	1,996
6	2	2	1	1	1	1	2	2	2	1	1	138
55	64	51	52	46	35	33	28	18	18	21	24	1,983
92	154	160	207	160	170	187	157	137	128	102	200	10,643
1,158	1,017	803	763	729	650	566	484	390	364	342	343	63,566
—	—	—	—	—	—	—	—	—	—	—	—	—
186	159	147	136	216	120	106	86	67	72	82	105	21,198
410	373	339	351	283	293	278	283	214	229	271	362	52,174
356	339	324	303	277	277	274	273	265	288	238	235	7,206
22	18	14	12	6	7	5	1	3	4	5	4	415
531	515	467	379	300	265	251	220	194	196	152	197	32,011
—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	20	28	17	16	11	21	112
169	144	129	121	104	102	94	89	74	89	88	76	2,421
—	—	—	—	—	—	—	—	—	—	—	—	—
251	304	298	287	306	312	466	455	407	353	289	244	8,447
—	—	—	—	—	—	—	—	—	—	—	—	—
306	282	276	232	201	169	156	145	103	103	106	106	10,345
936	916	877	1,045	1,088	870	784	733	669	668	644	659	25,137
—	—	—	—	—	—	—	—	—	—	—	—	—
19,468	18,361	17,060	16,198	14,616	13,556	12,799	11,797	10,625	10,051	9,832	10,458	1,342,334

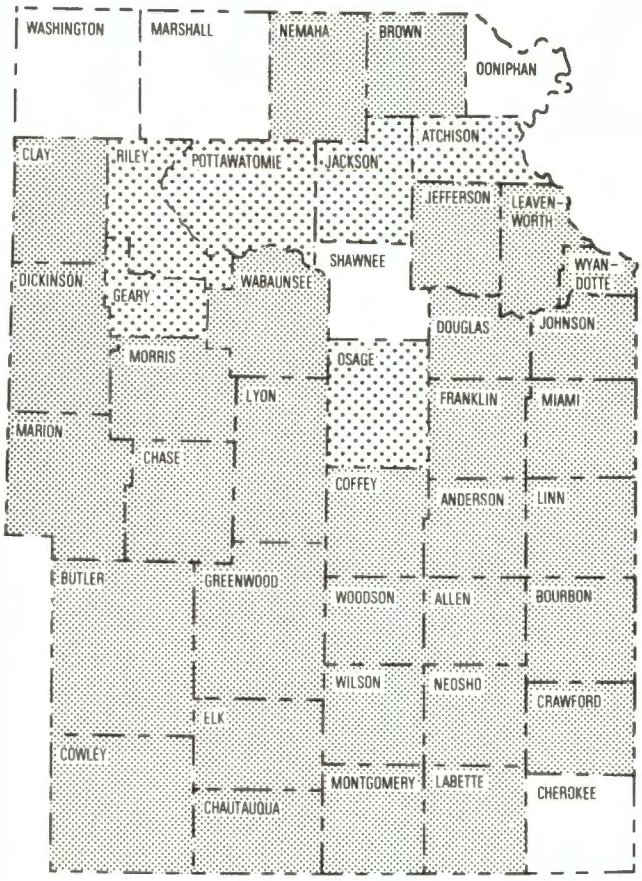
RECENT TRENDS IN THE EAST RANGES

New Producing Counties and Other Recent Developments

Since 1952, six eastern Kansas counties—Atchison, Geary, Jackson, Osage, Pottawatomie, and Riley (Figure C; Table B)—have been added to the state's oil-producing counties. The combined production of these six counties through 1976 is 3.1 million barrels of oil. The Atchison County field discovery (Worner) only produced 916 barrels of oil (from the Hunton zone) before it was plugged. Three fields (Ge-See, Aye, and Winfield) have been discovered in Geary County. Jackson County has had two discoveries (Leach and Soldier); oil production is from Hunton and Viola. Although a field was named in Osage County (Vassar), there is no record of oil being sold from it. Pottawatomie County's only field (Casey) produces from Viola rocks. Riley County has three fields (Yaege, Yaege NW, and Ge-See); production has been from Cherokee, Pennsylvanian conglomerate, Mississippian, and Hunton rocks. With 2,421,000 barrels of oil produced through 1976, Riley County has produced the most oil of any of the counties whose first production began after 1952.

Cherokee County had minor amounts of natural gas production in the early 1960s, and a gas well completion in 1976. No fields have been named in the county, and commercial oil and gas prospects there are still not thought to be very tangible. Pennsylvanian sediments are absent in the southeastern portion of Cherokee County and are not very thick in the northwestern and western areas (Bulletin 104). Fresh groundwater for municipal use is obtained from much older, Roubidoux (Upper Cambrian), rocks beneath Cherokee County.

Oil is now being produced in the Noell field, about eight miles north of the El Dorado field, Butler County, from Precambrian "Granite Wash"—the first known production from these rocks in Kansas east of the Central Kansas uplift. Noell oil wells are on the Burns dome, one of the largest well-defined structures on the lengthy Nemaha anticline. Prior to the discovery, the dome had been the subject of several papers explaining its lack of oil and gas production. Found in 1975, the Noell field produces from the Lansing-Kansas City as well as the Granite Wash rocks.



EXPLANATION

No commercial production to date

Oil production discovered since 1952

County had oil or gas production prior to 1953

FIG. C.—East Range counties of Kansas.

Thirty-six of the 43 counties lying entirely within the East Ranges of Kansas have had oil and gas production to date (Figure C). Cumulative production from these counties is now 1.3 billion barrels. Of that amount, 480.9 million barrels of oil were produced in the 24 years between 1953 (when Bulletin 104 statistics were assembled) and 1976. About 18,000 oil wells produced 10.5 million barrels of oil in 1976 (Fig. B). Crude oil production in all of Kansas to date is approximately 4.5 billion barrels, and about 29 percent has come from the East Range counties.

Ten Counties with Major Cumulative Production

Three East Range counties have been among the top 10 in oil production in Kansas: Butler, which ranks first with 516.8 million barrels; Greenwood, sixth with 273.3; and Cowley, tenth with 146.3 million barrels of produced crude. The western Kansas counties that rank in the top 10 are Barton (second), with 445.5; Russell (third), with 427.4; Ellis (fourth), with 360.3; Rice (fifth), with 299.2; Stafford (seventh), with 209.3; McPherson (eighth), with 183.2; and Rooks (ninth), with 160.7 million barrels of produced crude through 1976. These 10 counties have produced more than three billion of the approximately 4.5 billion barrels of oil produced in Kansas to date.

TABLE B. *Discovery Wells of New Producing Counties in Eastern Kansas* (Since 1953).*

County and Location	Operator Well No. & Lease	Comp. Date m-d-y	Total Depth (Ft.)	Name of Formation at TD	Prod. Depth (Ft.)	Prod. Form. or Zone	Initial Daily Prod.	Field Name	Cumulative Production Through 1976 (thou. bbl.)
Atchison C NE SE 19-7S-17E	Fred B. & Phillip F. Anschutz 1 Worner	9/11/64	2,966	Arbuckle	2,375–2,377	Hunton	52 BOPD + 82% Water	Worner	1
Geary SE SE SE 27-11S-8E	Adair Oil Company 1 Green	10/30/59	1,827	Mississippian	1,749–1,761	Cherokee	20 BOPD	Ge-See	29
Jackson C SE SW 15-7S-13E	Fred B. Anschutz 1 Leach	8/20/63	3,427	Arbuckle	3,230–3,240	Viola	20 BOPD + 60% Water	Leach	404
Osage NW NE NW 23-16S-16E	Messman & Rinehart 1 Woodward	6/06/61	1,617	Mississippian	1,546–1,564	Mississippian	25 BOPD	Vassar	No record of com'l production
Pottawatomie SE SE SE 9-7S-12E	McCulloch, Venus, & McCoy 1 Casey	4/07/71	3,600	Precambrian	3,306–3,310	Viola	64 BOPD + 65% Water	Casey	111
Riley NE SW SE 25-11S-8E	Cities Service 1 Yaege	6/12/59	1,696	Hunton	1,683–1,691	Hunton	36 BOPD	Yaege	421

* Natural gas production figures show 1,904 Mcfg produced in Cherokee County during 1960, and 1,696 Mcfg produced in 1961. A gas-well completion was listed for the County during 1976. No official field name has been given to date to any field in Cherokee County.

NATURAL GAS

East Range Production

At least 170 billion cubic feet of natural gas were produced in at least 25 of the eastern Kansas counties from 1953 through 1976. Gas production in all of Kansas during that period was about 17.6 trillion cubic feet, or roughly 100 times the amount produced in eastern Kansas. Gas production in eastern Kansas has not been significant in recent years, compared with that produced in southern and southwestern Kansas, or compared with crude oil produced in the East Ranges. During the early part of this century, however, natural gas was a major resource and fueled many industries. Many plants, including those for zinc smelting and glass manufacturing, were attracted to southeastern Kansas, where low-priced gas was available.

Low-volume gas wells are in use on farms and in homes, in quarries, and in other operations where only small quantities of gas are needed in the eastern part of the East Ranges. With the increase in price asked for natural gas in recent years, ownership of one's own gas well has become a valuable asset. Gas prices were artificially held down following a Federal Power Commission ruling in 1954. Some relaxation in mandated prices recently has resulted in more equitable returns to producers, but, concurrently, fuel bills are higher for purchasers.

Natural Gas Storage

A recent undertaking in Kansas has been the development of underground natural-gas storage areas. Three companies now have 14 storage fields in the East Ranges (Table C). These projects, with a working capacity of 42,708.7 million cubic feet, and a total reservoir capacity of 86,816.5 million cubic feet, make gas readily available to customers during cold weather when fuel use is at its peak. All gas storage is in Pennsylvanian sandstones in former gas fields, at depths ranging from less than 1,000 to about 3,100 feet.

Most gas placed in the eastern Kansas storage fields is produced in Oklahoma. Excess gas that is available during days of low usage is injected into the sandstones, where it is held until the critical "peak" days arrive.

TABLE C. *Eastern Kansas Underground Natural Gas Storage Areas, 1977.**

Company and Field or Area	Township and Range	County	Capacity, MMcu ft @ 14.65 psia @ 60°F			Storage Zone
			Cushion-Gas	Working-Gas	Total Reservoir	
Arkansas Louisiana Gas Co.						
Collinson	34S-3E	Cowley	1,266.9	1,075.7	2,405.5	"Severy"
Cities Service Gas Co.						
Boyer	26S-5E	Butler	721	299	1,020	Wabaunsee
Colony	22, 23S-19E	Anderson	3,805	5,399	9,204	"Colony"
Craig	13S-23E	Johnson	4,246	1,830	6,076	"Bush City"
Elk City	31, 32S-13, 14E	Montgomery & Elk	8,800	13,200	22,000	"Burgess"
McLouth	9, 10S-19, 20 & 21E	Jefferson & Leavenworth	6,064	7,801	13,865	"Bartlesville"
Piqua	24, 25S-17E	Allen & Woodson	2,203	1,027	3,230	"Colony"
Welda North	21S-19E	Anderson	6,385	3,637	10,022	"Colony"
Welda South	22S-19E	Anderson	6,574	5,215	11,789	"Colony"
Union Gas System, Inc.						
Buffalo	27S-16E	Wilson				"Squirrel"
Fredonia	29S-19E	Wilson				"Squirrel"
Liberty North	33S-17E	Montgomery	3,334	3,225	8,205	"Squirrel"
Liberty South	34S-17E	Montgomery				"Squirrel"
Longton	32S-12E	Chautauqua				"Layton"
		Totals	43,398.9	42,708.7	87,816.5	

* Kansas West-Range Counties have several underground natural gas and LPG storage areas. Data furnished by the companies listed above modified to show all capacities @ 14.65 psia and at 60°F.

Dr. Jewett mentioned the gas-storage projects in his three eastern Kansas reports, but he did not tabulate project data. The earliest reported experiments in storing natural gas underground date back to 1915, in Ontario, Canada. Kansas's earliest project was in Leavenworth County, in T.12S., R.20E. Jewett mentioned this project (Bulletin 104, p. 256):

> As early as 1927, gas was stored in the Six Corners field which formerly produced from the "Squirrel sand" at a depth of about 250 feet. The reservoir has a thickness of about 20 feet and the average wells produced about half a million cubic feet of gas daily when the field was opened. The practicability of natural gas storage in rock formations demonstrated in the Six Corners field is said to have been inducive to the common practice of storing gas in porous rocks in suitable structures.

The Six Corners field was developed by Cities Service Gas Company which now has the largest storage capability in the East Ranges.

WELL DRILLING AND PRODUCTION SINCE 1953

It is not possible to obtain accurate figures on the number of wells drilled over the years in eastern Kansas, as logs and completion data for many of the holes were never received by state agencies. Table D lists the number of wells estimated to have been drilled in 1953, 1954, 1955, and 1956. The data were based on a tally of drillers' logs that were delivered to state agencies, records of holes that were plugged, and information provided by companies operating waterflood and other secondary recovery projects.

During the mid-1950s, the Oil and Gas Conservation Division of the Kansas Corporation Commission issued a ruling requiring the filing of an "Intent to Drill" prior to start of drilling for oil, gas, core tests, etc. This information is compiled in Table E. As shown there, total intents filed in the East Ranges dropped from a high of 2,993 in 1959 to a low of 865 in 1973. Following the Arab embargo on oil exports in late 1973, requests for permission to drill

TABLE D. *Holes Drilled in Eastern Kansas Counties—From 1953-1956.**

County	Years: 1953	1954	1955	1956	County	Years: 1953	1954	1955	1956
Allen	125	341	230	333	Johnson	—	‡	9	8
Anderson	60	241	110	116	Labette	20	178	61	57
Atchison	—	—	—	—	Leavenworth	1	—	11	2
Bourbon	2	82	32	32	Linn	10	70	43	73
Brown	—	—	1	—	Lyon	38	30	51	24
Butler	362	256	140	269	Marion	73	63	120	270
Chase	3	1	15	17	Marshall	2	1	—	1
Chautauqua	50	1149	449	268	Miami	125	522	255	285
Cherokee	—	—	—	—	Montgomery	125	666	497	320
Clay	1	—	1	2	Morris	8	9	19	49
Coffey	29	204	61	28	Nemaha	8	—	—	—
Cowley	381	337	331	367	Neosho	93	319	83	335
Crawford	50	81	41	50	Osage	—	—	—	—
Dickinson	8	21	42	23	Pottawatomie	—	—	1	—
Doniphan	—	—	1	—	Riley	2	—	—	—
Douglas	1**	—	2	5	Shawnee	—	1	—	1
Elk	25	160	121	91	Wabaunsee	2	4	2	5
Franklin	100	109	130	153	Washington	—	—	—	—
Geary	1	—	—	1	Wilson	12	290	182	126
Greenwood	248	372	372	246	Woodson	100	212	36	238
Jackson	1	1	—	—	Wyandotte	—	—	—	2
Jefferson	†	—	—	1					

* Estimated in part; records used include drillers' logs, plugging records, waterflood project information, etc. Data are from Kansas Geological Survey annual oil and gas development reports.

**-or more

† Drilling confined to underground gas storage sites.

‡-a few tests

TABLE E. *Number of Intents to Drill Issued in Kansas East Ranges, 1957-1976.*[*]

County	Years: 1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Allen	443	380	391	314	266	203	173	196	294	220
Anderson	59	123	56	20	45	33	74	109	62	91
Atchison	—	—	—	—	—	—	2	5	1	1
Bourbon	14	7	16	14	93	11	18	29	37	92
Brown	1	—	—	1	—	1	1	10	3	2
Butler	363	357	368	288	259	180	217	160	159	154
Chase	13	20	27	16	15	12	6	6	8	6
Chautauqua	117	131	104	88	88	101	78	66	88	68
Cherokee	—	2	—	—	—	—	—	3	—	—
Clay	17	3	6	1	2	2	1	1	—	—
Coffey	18	9	3	8	17	2	14	23	24	13
Cowley	288	311	251	175	134	134	144	83	94	103
Crawford	35	64	156	25	43	77	71	192	75	23
Dickinson	12	12	10	10	5	2	5	7	7	6
Doniphan	—	—	—	—	1	—	—	—	—	—
Douglas	—	11	49	26	32	23	39	11	3	11
Elk	53	37	44	9	24	34	25	14	15	25
Franklin	49	79	177	64	42	61	55	40	45	23
Geary	1	1	8	3	4	2	—	—	5	—
Greenwood	247	228	319	203	178	124	145	164	220	152
Jackson	1	—	2	5	1	1	5	26	8	—
Jefferson	—	—	—	2	—	2	—	6	1	1
Johnson	7	4	28	63	45	26	27	29	29	11
Labette	65	39	35	33	45	30	57	89	55	46
Leavenworth	1	1	—	3	4	4	38	16	7	10
Linn	35	19	14	5	27	14	19	68	106	53
Lyon	18	3	13	6	9	8	8	2	10	9
Marion	19	277	268	274	224	113	51	42	34	30
Marshall	1	—	3	7	3	—	2	3	—	—
Miami	113	103	60	71	123	91	84	84	92	103
Montgomery	149	69	88	93	84	63	70	108	132	91
Morris	12	8	34	28	9	4	6	8	9	6
Nemaha	—	3	—	—	1	1	—	2	5	1
Neosho	214	192	162	272	129	151	281	280	208	102
Osage	—	—	—	—	9	—	1	—	—	—
Pottawatomie	—	1	17	11	3	—	2	3	2	—
Riley	1	2	37	17	6	7	4	3	7	2
Shawnee	—	1	—	—	—	—	—	—	2	—
Wabaunsee	5	9	24	12	3	2	8	8	9	5
Washington	—	—	5	1	—	—	—	—	—	—
Wilson	85	102	126	44	158	197	195	161	161	71
Woodson	104	98	91	86	114	148	116	127	133	121
Wyandotte	—	1	1	—	1	—	—	—	—	1
Yearly Totals:	2,560	2,707	2,993	2,298	2,246	1,864	2,042	2,184	2,150	1,653

[*] Unofficial totals. Data were tabulated from daily lists of "Intents" issued by the Conservation Division, Kansas Corporation Commission.
Figures may vary from year to year, depending on whether or not 'old well workover' permits were included in the totals.

TABLE E. *Continued.*

Years: 1967	1968	1969	1970	1971	1972	1973	1974	1975	1976		County totals
172	120	95	90	59	65	57	127	160	217	=	4,042
38	24	30	31	40	43	51	88	104	83	=	1,204
1	—	3	—	—	5	5	—	1	—	=	24
90	28	6	10	—	14	10	30	25	80	=	624
2	—	—	—	—	—	—	3	—	—	=	24
122	119	81	88	89	63	33	116	116	120	=	3,452
1	4	2	4	4	9	6	8	4	23	=	194
73	63	50	48	55	59	59	83	115	139	=	1,673
—	—	—	—	—	1	11	52	36	72	=	177
—	1	1	—	1	—	—	4	1	3	=	44
19	42	13	55	40	64	58	121	114	96	=	753
103	74	94	98	73	100	133	148	152	181	=	2,873
43	12	26	18	9	2	4	56	42	41	=	1,014
16	8	2	1	1	—	1	1	3	3	=	112
1	—	1	—	1	—	7	6	1	—	=	18
2	4	7	2	5	7	1	2	1	21	=	257
39	13	44	21	57	48	39	49	66	41	=	697
20	55	27	22	17	14	27	22	32	64	=	935
1	2	1	2	1	—	1	—	—	—	=	32
205	200	127	123	88	45	54	80	128	137	=	3,167
4	2	—	—	—	4	1	—	1	2	=	63
5	1	1	1	—	—	—	—	2	1	=	23
15	11	1	4	3	10	15	13	6	14	=	361
22	22	11	14	7	15	34	124	165	89	=	997
6	3	—	—	—	8	—	2	5	5	=	113
37	22	132	99	212	9	6	12	39	33	=	961
17	34	16	20	11	17	20	16	38	51	=	326
36	40	40	37	24	11	6	15	43	75	=	1,659
—	—	3	14	—	—	—	—	—	—	=	36
41	33	34	17	50	15	21	56	85	102	=	1,378
95	67	77	90	74	70	56	112	202	327	=	2,117
3	6	9	7	1	4	16	16	7	51	=	244
—	1	2	2	—	1	—	1	—	1	=	21
72	67	74	22	40	74	51	102	67	108	=	2,668
1	1	1	3	—	—	3	3	3	2	=	27
1	1	—	12	1	13	1	1	2	4	=	75
2	3	1	4	—	6	2	10	6	2	=	122
—	1	—	—	—	—	—	—	—	—	=	4
4	8	19	10	—	6	2	6	4	6	=	150
—	—	—	—	—	—	—	—	—	—	=	6
33	26	32	21	17	16	18	32	41	38	=	1,574
71	224	127	59	87	77	56	106	90	166	=	2,201
—	—	—	—	—	—	—	2	—	—	=	6
1,413	1,342	1,190	1,049	1,067	895	865	1,625	1,907	2,398	=	36,448

wells began to increase: 1,625 were filed in 1974, 1,907 in 1975, and 2,398 in 1976.

In the 20 years from 1957 through 1976, a total of 36,448 "Intents" were filed for drilling wells in the East Ranges. There is no way to estimate how many of the proposed holes were drilled; records indicate that many permits were cancelled before drilling started. Some were issued for reworking or drilling deeper in former holes (OWWO's and OWDD's). Many intents were for service wells of various types—such as water input wells. Some were for developing gas-storage projects; others, stratigraphic or core tests for example, were to seek information in wildcat territory prior to the drilling of deeper, more expensive tests.

Drilling Records

A unique well-numbering system was developed for use in Kansas and other states in 1966. Sponsored by the American Petroleum Institute, this system requires new holes to be identified by a number code that shows its location by state and county and, sequentially, by well. This numbering system, useful in identifying well records, is being applied more and more to all records for an individual hole. It also provides an easy way to check on the number of permits issued in each county.

State regulations regarding preservation of well samples and logs were revised in the early 1970s. As a result, there has been an increase in the percentage of well completions being filed with state agencies. A standardized well-reporting form is used to request data on the rock units that were penetrated, presence of oil, gas, or water, and other information needed for evaluating field environments. Many wells were drilled in Kansas before state regulations were formulated to require the filing of logs. It is remarkable how many well records were collected during those years. These early records and samples were used for subsurface studies that helped geologists discover additional petroleum deposits. In addition, the logs—which include data on coal beds, limestone descriptions, fresh and salty water, and other materials—were invaluable in the development of these other minerals. Sharing of confidential data in open-file libraries seems to have been unique with the petroleum industry. Drilling and leasing contracts worth thousands of dollars were often unwritten, and sealed with a handshake, in the early days of the industry.

FUTURE PROSPECTS FOR EASTERN KANSAS

Crude Oil—Pricing Policies and Changes

Prices paid for crude oil in Kansas have varied greatly over the years because of economic conditions, availability of crude oil, and other reasons. Producers also have had to contend with price variations paid by different refineries and crude oil gravity price differentials. Maximum prices have generally been paid for crude oil with a gravity of 40 to 44.9° API. Crude with gravities ranging above or below that range were purchased for 2¢ to 4¢ less per degree of gravity differential per 42-gallon barrel. A purchaser with available supplies of crude that ranged from the heavy to the light crudes could buy oil at the lower prices, and then blend the heavy and light crudes, resulting in a better price at the refineries.

In a report on price structures in the United States (Wattendorf and Mushovic, 1971, p. 75), it is stated that gravity differentials should not be used as the sole criterion for determining the value of crude oil.

> The lower prices refiners pay for crude oil below 40° API do not always correlate with the respective yields, and hence with profitability analysis. The situation stems from the fact that crudes with identical gravities may have widely differing chemical properties. It is these chemical properties that determine the relative value of a crude.

The 4¢ differential in price essentially has been dropped since Wattendorf and Mushovic's study was made. Prices have also been boosted, and oil from "stripper wells" (those that can produce only less than 10 bbl/day) has now, in early 1978, reached $15 for a 42-gallon barrel.

In recent years price increases for crude oil, natural gasoline, and liquid petroleum gas have influenced management thinking on drilling of wells and converting fields to secondary or tertiary production. Political decisions also contribute to the other uncertainties faced by members of the petroleum industry. Market prices currently are set by Congress and the White House, rather than in the market place. That has resulted in a curious price structure for both crude oil and natural gas, as well as a multiplicity of prices that change from month to month and then may be retroactively changed. Crude oil prices in 1977 in eastern Kansas ranged from slightly less than $5 per barrel to more than $15 for a 42-gallon

barrel of oil. Labor and equipment costs have increased greatly since 1973. The free enterprise system, in which prices vary because of changes in supply and demand, no longer applies to the U.S. petroleum industry marketing system.

Exploration and Production Developments

Several new developments are assisting present wildcatters and developers in Kansas. In the past, lack of elevation and accurate location data for many of the thousands of old drillers' logs made it difficult to use them to map subsurface structures. Currently, use of 7-1/2 min. topographic maps, which are available for virtually all East Ranges, helps immensely in overcoming the lack of those data on the logs.

There is increasing use of electric logs for evaluating production potentials and for correlating formations. Logs are more commonly run on deep holes, but less often on wells in the southeastern area of the state. Because some types of logs can be recorded in cased holes, they are an effective tool for studying wells prior to abandonment, especially if the wells had not been logged at the time they were drilled, or for assessing their value for an enhanced oil-recovery project.

Many geologists now use aerial photos and core hole data for mapping structure, satellite photos for detecting evidence of subsurface structure, and aeromagnetic maps for finding deep-seated anomalies. Seismic surveys are also used, especially in less-drilled areas.

Production of oil after wells have been depleted by pumping can in many cases be increased and the wells' producing life lengthened by injecting water or gas—commonly known as secondary recovery—or by using more sophisticated, and usually more expensive, additions of chemicals, detergents, steam, or heat—often referred to as tertiary recovery methods. Cost of the additives and labor has in most projects exceeded the return cost of the oil produced from the wells; to date, many companies have refrained from attempting the use of the more costly methods of production.

Fracturing wells to stimulate production, a technique started in the late 1940s, has been a common practice from the early 1950s up to the present time. Hydraulic fracturing is now commonly used in conjunction with other techniques in many well completions. Many limestone wells are acidized. Nitroglycerin, a common well stimulant for many years, is now rarely used.

Pre-Pennsylvanian Rocks

To date, thousands of holes have been drilled in the eastern two tiers of counties in Kansas, south of the Kansas River, where well drilling and the production of oil and gas started years before the turn of the century. With few exceptions, oil and gas are produced from Pennsylvanian rocks, though oil has now been found in Arbuckle rocks in the Indian Creek field in Anderson County. Neosho Falls-LeRoy field, just west of the common corners of Allen, Anderson, Coffey, and Woodson counties, has production from older rocks. Labette County, on the Oklahoma border, also has had wells that produce from Mississippian and Arbuckle rocks. All other production in the eastern part of the East Ranges is believed to have been from Pennsylvanian rocks. A search of well records indicates, also, that most of the drilling has not gone below the base of the Pennsylvanian, but, commonly, good shows of oil are noted in the top of the Mississippian in shallow wells, and oil seeps into mine shafts which penetrate these limestone formations.

Wallace Lee (1939) reported on the relationship between the thickness of Mississippian rocks and geologic structural features. The following excerpts are from his abstract:

> The Mississippian limestones include representatives of the Kinderhook, Osage, Meramec, and Chester series. They were deposited on a nearly flat surface on the Chattanooga shale. After their deposition they were gently folded and elevated and the subsequent erosion reduced the surface in pre-Pennsylvanian time to a nearly flat horizontal peneplain. Rocks lowered below the plain of base leveling were preserved; those that had been raised above it were worn away. There is, therefore, a close relation between the thickness of the Mississippian limestones and the folding that occurred during the time interval between the final deposition of the Chattanooga shale and the close of base leveling.
>
> As the structural features are closely related to the thinning of the Mississippian rocks, there is a close relation between thinning and the occurrence of oil and gas on the anticlines in the central and eastern parts of the state. Nearly all fields that produce from anticlines are underlain by thin sections of Mississippian rocks. It is concluded, therefore, that the presence of a thin section of the Mississippian in areas thus far unproductive may in some cases indicate the proximity of incompletely explored structural highs and warrant further investigation of the local conditions. Some prominent anticlines, however, are not productive of oil or gas.

> The producing zones in Mississippian rocks appear to be independent of stratigraphic formations. Production is dependent on the porosity of the limestone. The base leveling of the rocks brought the various formations of the Mississippian to the surface at different places and subjected them to weathering and leaching. In some places where the groundwater level had been lowered, porous zones are present to a depth of over 100 feet below the surface of the Mississippian.

Moore (1976) presented another hypothesis on oil and gas accumulations. Her theory on "Oriented Hydrocarbon Migration" is that crude oil may accumulate in the lower side of an anticline or dome as the valley fills with sediments. An example of this structural condition is found in southeastern Kansas, where Mississippian rocks were folded and subjected to erosion for a long time prior to and during deposition of Pennsylvanian Desmoinesian shales. During their long exposure, porous and permeable areas could have been formed and preserved on the lower slopes of the Mississippian rocks. The older rocks could have become more dense updip in some cases, trapping oil that migrated from the shale. The usual search for oil or gas in Mississippian rocks in southeastern Kansas has been confined to the higher structural areas.

Other formations that are prospective for oil accumulation beneath an unconformity are the Devonian "Hunton" dolomites and the Ordovician Viola Limestone and Simpson Sandstone in southeastern Kansas. Recent studies indicate that the "Hunton" may extend farther southeast than previously thought, and the Chattanooga Shale overlap of this and the deeper Ordovician rocks should provide the conditions for stratigraphic trapping of oil.

Theses that report results of studies of individual oil fields (McQuillan, 1968; Van Dyke, 1975; DuBois, 1977; Hulse, 1978), and a review of data from a core-test program in search of tar sands (Ebanks and James, 1974; Ebanks et al., 1977) provide new help in interpreting the geology of eastern Kansas. New maps (Oros, 1975; Cole, 1976; Watney, 1978; Yarger, 1978) also give new insight.

The need for protection of the environment from oil field pollution is being increasingly stressed. The State of Kansas has for many years had regulations and employees charged with policing the drilling and plugging of wells, and subsequent production of oil and gas and of salt water. The cost of their work is paid for by the producers, through assessments on oil and gas production.

The selected list of references that follows includes those referred to in this text, and reports by Jewett and others, published since 1954, that are pertinent to the geology and oil and gas production of the East Ranges of Kansas.

SELECTED REFERENCES

Adkison, W. L., 1963, Subsurface geologic cross-section of paleozoic rocks from Butler County to Stafford County, Kansas, Kansas Geological Survey, Oil and Gas Investigation 28, 90 p.

Ball, S. M., M. M. Ball, and D. J. Laughlin, 1963, Geology of Franklin County, Kansas: Kansas Geological Survey, Bulletin 1963, 57 p.

Bayne, C. K., 1962, Geology and ground-water resources of Cowley County, Kansas: Kansas Geological Survey, Bulletin 158, 219 p.

———, 1973, Geohydrology of Doniphan County, Northeastern Kansas: U.S. Geological Survey Atlas HA-462.

———, H. G. O'Connor, S. N. Davis, and W. B. Howe, 1971, Pleistocene stratigraphy of Missouri River Valley along the Kansas-Missouri border: Kansas Geological Survey, Special Distribution Publication 53, 32 p.

———, and W. H. Schoewe, 1967, Geology and ground-water resources of Brown County, Kansas: Kansas Geological Survey, Bulletin 186, 68 p.

Beck, H. V., 1959, Geology and ground-water resources of Kansas River Valley between Wamego and Topeka vicinity: Kansas Geological Survey, Bulletin 135, 88 p.

Beene, D. L., 1969, Oil and gas production in Kansas, 1967: Kansas Geological Survey, Special Distribution Publication 41, 144 p.

———, 1970, Oil and gas production in Kansas during 1968: Kansas Geological Survey, Special Distribution Publication 50, 144 p.

———, 1971, Oil and gas production in Kansas during 1969: Kansas Geological Survey, Special Distribution Publication 54, 143 p.

———, 1971, Oil and gas production in Kansas during 1970: Kansas Geological Survey, Special Distribution Publication 59, 142 p.

———, 1973, Oil and gas production in Kansas during 1971: Kansas Geological Survey, Special Distribution Publication 64, 144 p.

———, 1974, 1972 oil and gas production in Kansas: Kansas Geological Survey, Energy Resources Series 2, 149 p.

———, 1975, 1973 oil and gas production in Kansas: Kansas Geological Survey, Energy Resources Series 4, 156 p.

———, 1976, 1974 oil and gas production in Kansas: Kansas Geological Survey, Energy Resources Series 6, 160 p.

———, 1977, 1975 oil and gas production in Kansas: Kansas Geological Survey, Energy Resources Series 8, 164 p.

———, 1978, 1976 oil and gas production in Kansas: Kansas Geological Survey, Energy Resources Series 10, 169 p.

———, and M. O. Oros, 1965, Oil and gas developments in Kansas during 1964: Kansas Geological Survey, Bulletin 179, 52 p.

———, and M. O. Oros, 1967, Oil and gas developments in Kansas during 1965: Kansas Geological Survey, Bulletin 185, 177 p.

Berendsen, P., 1975, Kansas mineral industries report, 1974: Kansas Geological Survey, Mineral Resources Series 3, 88 p.

Brooking, D. G., 1970, Rb-Sr geochronologic investigation of basic and ultrabasic zenoliths from the Stockdale Kimberlite, Riley County, Kansas: Kansas Geological Survey, Bulletin 199, Part 2, 12 p.

———, 1970, High pressure mineral reactions in a pyroxenite granulite nodule from the Stockdale Kimberlite, Riley County, Kansas: Kansas Geological Survey, Bulletin 199, Part 3, 6 p.

———, 1970, Factors governing emplacement of Riley County, Kansas kimberlites: Kansas Geological Survey, Bulletin 199, Part 4, 17 p.

———, 1970, The Kimberlites of Riley County, Kansas: Kansas Geological Survey, Bulletin 200, 32 p.

CHELIKOWSKY, J. R., 1972, Structural geology of the Manhattan, Kansas area: Kansas Geological Survey, Bulletin 204, 13 p.

———, 1976, Pleistocene drainage reversal in the upper Tuttle Creek Reservoir area of Kansas: Kansas Geological Survey, Bulletin 211, Part 1, 10 p.

COLE, V., 1976, Precambrian structure of Kansas: Kansas Geological Survey, Map M-7.

———, and W. J. EBANKS, JR., 1974, List of wells drilled into Precambrian rocks: Kansas Geological Survey, Subsurface Geology Series 1, 101 p.

CROWLEY, D. J., 1969, Algal bank complex in Wyandotte Limestone (Late Pennsylvanian) in eastern Kansas: Kansas Geological Survey, Bulletin 198, 52 p.

DILTS, R. L., 1966, Secondary recovery and pressure maintenance operations in Kansas 1965: Kansas Geological Survey, Special Distribution Publication 30, 64 p.

———, 1967, Secondary recovery and pressure maintenance operations in Kansas 1966: Kansas Geological Survey, Special Distribution Publication 32, 68 p.

———, 1968, Secondary recovery and pressure maintenance operations in Kansas 1967: Kansas Geological Survey, Special Distribution Publication 36, 71 p.

———, 1969, Secondary recovery and pressure maintenance operations in Kansas 1968: Kansas Geological Survey, Special Distribution Publication 46, 74 p.

———, 1970, Secondary recovery and pressure maintenance operations in Kansas 1969: Kansas Geological Survey, Special Distribution Publication 49, 80 p.

———, 1972, Secondary recovery and pressure maintenance operations in Kansas 1971: Kansas Geological Survey, Special Distribution Publication 62, 84 p.

———, 1973, Secondary recovery and pressure maintenance operations in Kansas 1972: Kansas Geological Survey, Energy Resources Series 1, 74 p.

DUBOIS, S., 1978, The origin of surface lineaments in Nemaha County, Kansas: Unpublished master's thesis, University of Kansas, 37 p.

DUFFORD, A. E., 1958, Quaternary geology and ground-water resources of Kansas River Valley between Bonner Springs, and Lawrence, Kansas: Kansas Geological Survey, Bulletin 130, Part 1, 96 p.

EBANKS, W. J. JR., and G. W. JAMES, 1974, Heavy-crude oil bearing sandstones of the Cherokee Group (Desmoinesian) in southeastern Kansas: *in* L. V. Hills, Ed., Oil sands, fuel of the future, Canadian Society of Petroleum Geologists, Memoir 3, p. 19-34.

———, G. W. JAMES, and N. D. LIVINGSTON, 1977, Evaluation of heavy oil and tar sands in Bourbon, Crawford, and Cherokee counties, Kansas—Final report: U.S. Department of Energy, BERC/R.I. 77/20, 110 p.

EVERETT, J. P., and C. F. WEINAUGH, 1955, Physical properties of eastern crude oils: Kansas Geological Survey, Bulletin 114, 26 p.

FADER, S. T., 1974, Ground water in the Kansas River Valley, Junction City to Kansas City: Kansas Geological Survey, Bulletin 206, Part 2, 12 p.

FARQUHAR, O. C., 1958, The Precambrian rocks of Kansas: Kansas Geological Survey, Bulletin 127, 73 p.

GOEBEL, E. D., A. L. HORNBAKER, W. R. ATKINSON, and J. M. JEWETT, 1956, Oil and gas developments in Kansas during 1955: Kansas Geological Survey, Bulletin 122, 238 p.

———, A. L. HORNBAKER, P. L. HILPMAN, and D. L. BEENE, 1957, Oil and gas developments in Kansas during 1956: Kansas Geological Survey, Bulletin 128, 250 p.

———, P. L. HILPMAN, A. L. HORNBAKER, and D. L. BEENE, 1958, Oil and gas developments in Kansas during 1957: Kansas Geological Survey, Bulletin 133, 264 p.

———, P. L. HILPMAN, and D. L. BEENE, 1959, Oil and gas developments in Kansas during 1958: Kansas Geological Survey, Bulletin 138, 228 p.

———, P. L. HILPMAN, D. L. BEENE, and R. J. NOEVER, 1960, Oil and gas developments in Kansas during 1959: Kansas Geological Survey, Bulletin 147, 254 p.

———, P. L. HILPMAN, D. L. BEENE, and R. J. NOEVER, 1960, Data on secondary recovery projects in Kansas, 1959: Kansas Geological Survey, Oil and Gas Investigations 20.

———, P. L. HILPMAN, D. L. BEENE, and R. J. NOEVER, 1960, Data on secondary recovery projects in Kansas, 1960: Kansas Geological Survey, Oil and Gas Investigations 24.

———, P. L. HILPMAN, D. L. BEENE, and R. J. NOEVER, 1961, Oil and gas developments in Kansas during 1960: Kansas Geological Survey, Bulletin 155, 229 p.

———, P. L. HILPMAN, D. L. BEENE, and R. J. NOEVER, 1962, Oil and gas developments in Kansas during 1961: Kansas Geological Survey, Bulletin 160, 231 p.

———, P. L. HILPMAN, M. O. OROS, and D. L. BEENE, 1963, Oil and gas developments in Kansas during 1962: Kansas Geological Survey, Bulletin 166, 165 p.

———, and J. M. JEWETT, 1962, Possibilities for underground storage of natural gas near the Kansas River Valley: Kansas Geological Survey, Oil and Gas Investigations 27, 10 p.

GRISAFE, D. A., 1974, Kansas mineral industry report, 1973, with directory of Kansas mineral producers: Kansas Geological Survey, Mineral Resources Series 2, 100 p.

HAMBLETON, W. W., Ed., 1959, Symposium on geophysics in Kansas: Kansas Geological Survey, Bulletin 137, 375 p.

———, and D. F. MERRIAM, 1955, Magnetic anomalies in Wilson and Woodson Counties, Kansas: Kansas Geological Survey, Bulletin 114, 16 p.

HAMBLIN, K., 1969, Marine paleocurrent directions in limestones of the Kansas City Group (Upper Pennsylvanian) in eastern Kansas: Kansas Geological Survey, Bulletin 194, 25 p.

HARBAUGH, J. W., 1954, Marine bank development in Plattsburg Limestone (Pennsylvanian), Neodesha-Fredonia area, Kansas: Kansas Geological Survey, Bulletin 134, Part 8, 43 p.

———, 1960, Petrology of marine bank limestones of Lansing Group (Pennsylvanian), southeast Kansas: Kansas Geological Survey, Bulletin 142, 46 p.

HECKEL, P. H., 1975, Stratigraphic and depositional framework of the Stanton Formation in southeastern Kansas: Kansas Geological Survey, Bulletin 210, 45 p.

HILPMAN, P. L., 1958, Producing zones of Kansas oil and gas fields: Kansas Geological Survey, Oil and Gas Investigations 16.

HULSE, W. J., 1978, A geologic study of the Sallyards Field area, Greenwood County, Kansas: Unpublished master's thesis, University of Kansas, 152 p., appendices.

JAMHINDIKAR, S., 1967, Sedimentary characteristics of Pleistocene deposits, Neosho River Valley, southeastern Kansas: Kansas Geological Survey, Bulletin 187, Part 5, 13 p.

JEWETT, J. M., 1940, Oil and gas in Linn County, Kansas: Kansas Geological Survey, Bulletin 30, 29 p.

———, 1941, The geology of Riley and Geary Counties, Kansas: Kansas Geological Survey, Bulletin 39, 164 p.

———, 1949, Oil and gas in eastern Kansas, with special reference to developments from 1944 to 1948: Kansas Geological Survey, Bulletin 77, 397 p.

———, 1951, Geologic structures in Kansas: Kansas Geological Survey, Bulletin 90, Part 6, p. 105-172.

———, 1955, Liquefied petroleum gas storage in Kansas salt beds: Kansas Geological Society Annual Field Conference, No. 18, p. 91-94.

———, 1956, Underground storage of liquid petroleum hydrocarbons in Kansas: *in* Underground Storage of Liquid Petroleum Hydrocarbons in the United States: Interstate Oil Compact Commission, p. 26-34.

———, 1958, Subsurface geology of Kansas and its relation to accumulation and production of oil and gas: Oil and Gas Compact Bulletin, Volume 17, No. 2, p. 35-42.

———, 1960, How major geologic features developed in Kansas: World Oil, Volume 150, No. 1, p. 119-124, 149.

———, 1961, The geologic making of Kansas: Kansas Academy of Sciences Transactions, Volume 64, No. 3, p. 175-197.

———, 1962, The concept of time in stratigraphic classification: Kansas Academy of Science Transactions, Volume 65, No. 2, p. 97-109.

———, 1963, Pleistocene geology in Kansas: Kansas Academy of Science Transactions, Volume 66, No. 3, p. 347-358.

———, 1968, The Kansas Academy of Science and one-hundred years of the evolution of geology: Kansas Academy of Science Transactions, Volume 71, No. 3, p. 315-326.

——— et al., 1964, Geologic map of Kansas: Kansas Geological Survey, Map M-1, Scale 1:500,000.

———, and G. E. ABERNATHY, 1945, Oil and gas in eastern Kansas: Kansas Geological Survey, Bulletin 57, 244 p.

———, and S. M. BALL, 1965, Origin of some Late Pennsylvanian coals in eastern Kansas (Abstract): Geological Society of America Special Paper No. 82, p. 101-102.

———, C. K. BAYNE, E. D. GOEBEL et al., 1968, The stratigraphic succession in Kansas: Kansas Geological Survey, Bulletin 189, 81 p.

———, P. A. EMERY, and D. A. HATCHER, 1965, The Pleasanton Group (Upper Pennsylvanian) in Kansas: Kansas Geological Survey, Bulletin 175, Part 4, 11 p.

———, and E. D. GOEBEL, 1960, Underground storage of natural gas in Kansas, Kansas Geological Survey, Oil and Gas Investigations No. 21, 18 p. (Also published by the Interstate Oil Compact Commission, *in* Underground Storage of Natural Gas in the United States, May 1962, p. 59-74.)

———, and D. F. MERRIAM, 1959, Geologic framework of Kansas; A review for geophysicists: *in* Symposium on Geophysics in Kansas: Kansas Geological Survey, Bulletin 137, p. 9-52.

———, and G. Muilenburg, 1957, Guidebook 21st field conference in eastern Kansas, September 19-21, 1957: Kansas Geological Society Annual Field Conference No. 21, 126 p.

Jungman, W. L., 1966, Geology and ground-water resources of Neosho County: Kansas Geological Survey, Bulletin 183, 46 p.

———, 1968, Geology and ground water in Labette County, Kansas: U.S. Geological Survey, Map HA-279.

Kansas Secondary Recovery Committee, 1964, Secondary recovery operations in Kansas during 1962: Kansas Geological Survey, Special Distribution Publication 6, 8 p.

———, 1964, Secondary recovery operations in Kansas, 1963: Kansas Geological Survey, Special Distribution Publication 16, 7 p.

———, 1965, Secondary recovery and pressure maintenance operations in Kansas 1964: Kansas Geological Survey, Special Distribution Publication 20, 61 p.

Lee, W., 1956, Stratigraphy and structural development of the Salina basin area: Kansas Geological Survey, Bulletin 121, 167 p.

McQuillan, M. W., 1968, Geology of the Davis-Bronson pool, Allen and Bourbon Counties, Kansas: Unpublished master's thesis, Kansas State University, 127 p.

Merriam, D. F., 1963, The geologic history of Kansas: Kansas Geological Survey, Bulletin 162, 317 p.

Miller, D. E., 1969, Geology and ground-water resources of Allen County, Kansas: Kansas Geological Survey, Bulletin 195, 50 p.

Moore, G. A., 1976, Oriented hydrocarbon migration-result of geologic event timing (Abstract): American Association of Petroleum Geologists Bulletin, Volume 60, p. 699-700.

Mossler, J. H., 1973, Carbonate facies of the Swope Limestone Formation (Upper Pennsylvanian), southeast Kansas: Kansas Geological Survey, Bulletin 206, Part 1, 17 p.

O'Connor, H. G., 1955, Geology, mineral resources, and ground-water resources of Osage County, Kansas: Kansas Geological Survey Volume XIII, 50 p.

———, 1971, Geology and ground-water geology of Johnson County, northeastern Kansas: Kansas Geological Survey, Bulletin 203, 68 p.

———, 1974, Geology and ground-water resources of Montgomery County, southeastern Kansas: Kansas Geological Survey, Groundwater Series 1, 12 p.

Oros, M. O., 1975, Oil and gas fields in Kansas: Kansas Geological Survey, Map M-3A.

———, and D. L. Beene, 1968, Oil and gas developments in Kansas during 1966: Kansas Geological Survey, Bulletin 190, 191 p.

———, and D. K. Saile, 1974, Enhanced oil-recovery operations in Kansas, 1973: Kansas Geological Survey, Energy Resources Series 3, 113 p.

———, and D. K. Saile, 1975, Enhanced oil-recovery operations in Kansas in 1974: Kansas Geological Survey, Energy Resources Series 5, 100 p.

Risser, H. E., 1960, Kansas building stone: Kansas Geological Survey, Bulletin 142, Part 2, 70 p.

Saile, D. K., and M. O. Oros, 1976, Enhanced oil-recovery operations in Kansas, 1975: Kansas Geological Survey, Energy Resources Series 7, 112 p.

Sanders, D. T., 1959, Sandstones of the Douglas and Pedee Groups in northeastern Kansas: Kansas Geological Survey, Bulletin 134, Part 3, 33 p.

Schoewe, W. H., 1955, Coal resources of the Marmaton Group in eastern Kansas: Kansas Geological Survey, Bulletin 114, Part 2, 64 p.

Seevers, W. J., 1969, Geology and ground-water resources of Linn County: Kansas Geological Survey, Bulletin 193, 62 p.

———, 1975, Description of the surficial rocks in Cherokee County, southeastern Kansas: Kansas Geological Survey, Geology Series 1, 7 p.

TROELL, A. R., 1969, Depositional facies of Toronto Limestone Member (Oread Limestone, Pennsylvanian), subsurface marker unit in Kansas: Kansas Geological Survey, Bulletin 197, 29 p.

VAN DYKE, R. J., 1975, Geology and depositional environments of the reservoir sandstone, Kincaid oil field, Anderson County, Kansas: Unpublished master's thesis, University of Kansas, 81 p.

VERVILLE, G. J., J. M. JEWETT, R. O. KULSTAD, N. PLUMMER, W. H. SCHOEWE, E. D. GOEBEL, and C. K. BAYNE, 1958, Geology, mineral resources, and ground-water resources of Elk County, Kansas: Kansas Geological Survey, Volume XIV, 56 p.

VER WIEBE, W. A., E. D. GOEBEL, J. M. JEWETT, and A. L. HORNBAKER, 1954, Oil and gas developments in Kansas during 1953: Kansas Geological Survey, Bulletin 107, 204 p.

———, E. D. GOEBEL, J. M. JEWETT, and A. L. HORNBAKER, 1955, Oil and gas developments in Kansas during 1954: Kansas Geological Survey, Bulletin 112, 215 p.

WAGNER, H. C., 1953, Stratigraphy of the outcropping Pennsylvanian rocks in the Fredonia quadrangle, Kansas: U.S. Geological Survey, Chart 54 × 40".

———, 1954, Geology of the Fredonia quadrangle, Kansas: U.S. Geological Survey, Map GQ-49.

———, 1961, Geology of the Altoona quadrangle, Kansas: U.S. Geological Survey, Map GQ-149.

WALTERS, K. L., 1954, Geology and ground-water resources of Marshall County: Kansas Geological Survey, Bulletin 106, 116 p.

———, and C. K. BAYNE, 1959, Geology and ground-water resources of Clay County, Kansas: Kansas Geological Survey, Bulletin 136, 106 p.

WARD, J. R., 1973, Geohydrology of Atchison County, northeastern Kansas: U.S. Geological Survey, Atlas HA-467.

———, 1974, Geohydrology of Nemaha County, northeastern Kansas: Kansas Geological Survey, Groundwater Series 2, 19 p.

WATNEY, W. L., 1978, Structural contour map: Base of Kansas City Group (Upper Pennsylvanian), eastern Kansas: Kansas Geological Survey, Map M-10.

WINCHELL, R. L., 1957, Relationship of the Lansing Group and the Tonganoxie ("Stalnaker") Sandstone in south-central Kansas: Kansas Geological Survey, Bulletin 127, 29 p.

WINSLOW, JOHN D., 1972, Geohydrology of Jefferson County, Northeastern Kansas: Kansas Geological Survey, Bulletin 202, Part 4, 20 p.

YARGER, H., and S. Z. JARJUR, 1972, Gravity and magnetic survey of an abandoned lead and zinc mine in Linn County, Kansas: Kansas Geological Survey, Bulletin 204, Part 2, 13 p.

———, R. R. ROBERTSON, and R. L. WENTLAND, 1978, Aeromagnetic map of eastern Kansas, Kansas Geological Survey, open file map.