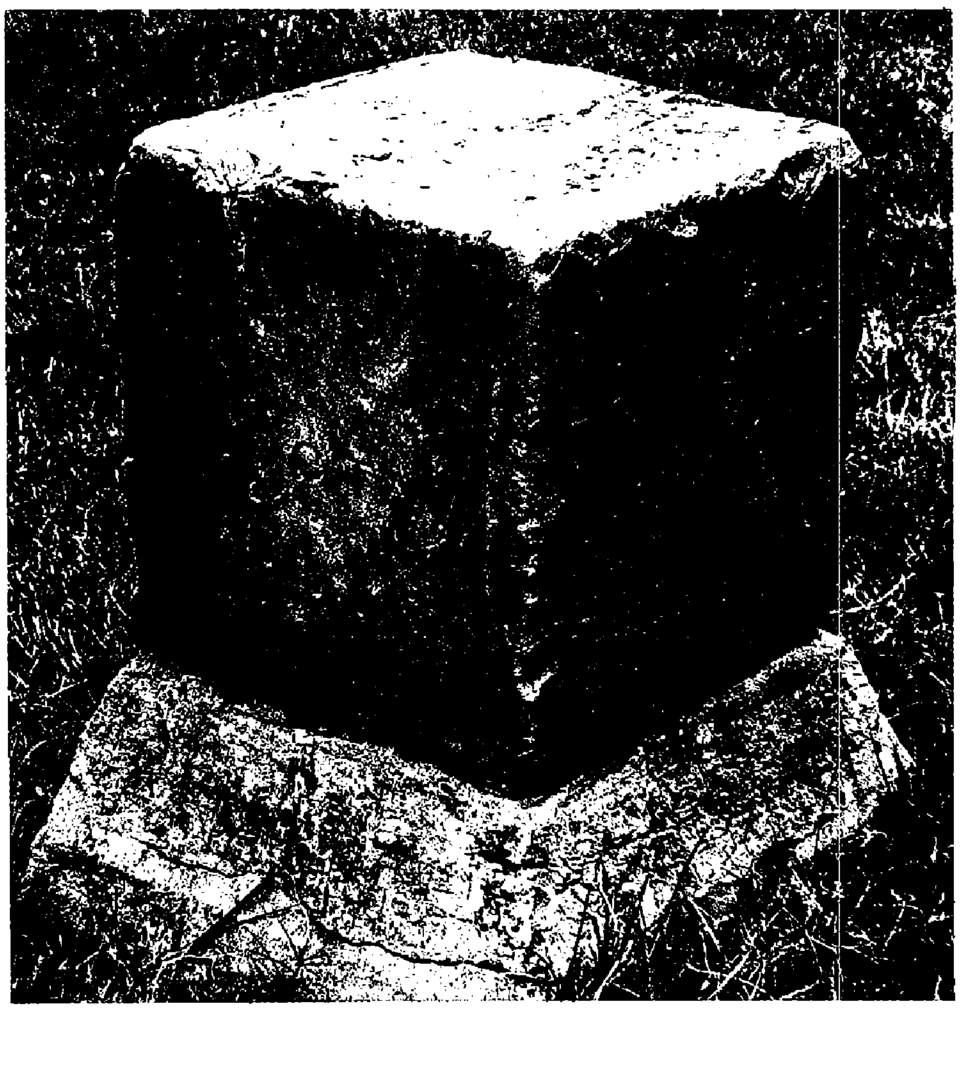
Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY / VOL. 43, NO. 6 - DECEMBER 1983



On the cover—

"Initial Point," Arkansas-Oklahoma Boundary

The photograph on the cover shows the "Choctaw" and "1858" sides of the small monument marking the "initial point" of Oklahoma's eastern boundary survey. The monument is of gray limestone and is surmounted by a capstone 17.5 in. square and 17 in. high. It is marked "Initial Point" on its north face, "Arkansas" on its east face, "Choctaw" on its west face, and "1858" on its south face. The marker is within the bounds of the Fort Smith National Historic Site, which is administered by the National Park Service, U.S. Department of the Interior.

Fort Smith itself was established on December 25, 1817, by Maj. William Bradford and a company of riflemen encamped on ground selected earlier that year by Maj. Stephen H. Long, a topographical engineer. Here, at the confluence of the Arkansas and Poteau Rivers, the fort was established to bring peace to the warring Osages and Cherokees, to prevent eager U.S. settlers from intruding on Indian land, and to protect legitimate settlers in the area.

For more information about Oklahoma's borders, see "History of the Boundaries of Oklahoma" on page 174 of this issue.

Oklahoma Geology Notes

Editor: Connie Smith
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Short articles on aspects of Oklahoma geology are welcome from contributors. A set of guidelines will be forwarded on request.

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STATISTICS IN OKLAHOMA'S PETROLEUM INDUSTRY, 1981

Robert H. Arndt[1]

Introduction

The value of Oklahoma's produced and marketed crude oil and natural gas reached an all-time high of $9.2 billion in 1981, an increase of 31.9 percent over that of 1980, according to the Oklahoma Tax Commission's Gross Production Division. This increase was brought about by an output of 152.3 million barrels of oil, approximately 1.4 percent more than in 1980, and 2.03 trillion cu ft of wet natural gas, up 6.7 percent from that in 1980 (table 1). Oklahoma ranked fifth in oil output among the nation's oil-producing states by providing 4.9 percent of the total national output, and third among the states in production of natural gas, with 10 percent of the nation's output.

Drilling

A burgeoning oil- and gas-drilling industry supported the increase in production of liquid hydrocarbons. Table 2, a statistical summary of oil- and gas-well drilling in Oklahoma, indicates that the number of wells drilled and footages involved increased by about 25 percent, as 11,300 oil and gas tests bored about 52.8 million ft of hole. Figure 1 summarizes the annual results in drilling since 1950, including the total number of tests drilled for oil and gas, the number of exploratory tests drilled, and the number of productive oil and gas wells completed.

Boreholes less than 10,000 ft in depth constituted 92.3 percent of all holes drilled in 1981 and 78.8 percent of the total drilling footage. A range of 10,000–15,000-ft depth was reached by 6 percent of the boreholes and involved 15.2 percent of footage. Between 15,000 and 20,000 ft in depth were 1.6 percent of the holes and 5.5 percent of the footage. Penetration deeper than 20,000 ft involved 0.1 percent of the tests and 0.6 percent of all drilling footage. The general distribution of maximum drilling depths attained in each

[1]Geologist, Oklahoma Geological Survey; director, Oklahoma Mining and Mineral Resources Research Institute.

TABLE 1.—HYDROCARBON PRODUCTION IN OKLAHOMA, 1981

	1980	1981 Okla. Tax Comm.
Crude Oil and Lease Condensate		
Total annual production (1000 bbls) [1]	150,140	152,252
Value ($1000) [1]	4,110,515	5,355,474
Cumulative production 1891-1981 (1000 bbls)[1]	12,093,599	12,245,851
Daily production (bbls)[2]	403,500	417,129
Total number of producing wells[2]	78,463	82,639
Daily average per well (bbls)[2]	5.1	5.1
Oil wells on artificial lift[2]	74,131	78,076(e)
Natural Gas		
Total annual marketed production (MMcf)[1]	1,902,157	2,030,225
Value ($1000)[1]	2,856,467	3,831,636
Total number of gas or gas-condensate wells[2]	15,245	16,994
Natural Gas Liquids		
Total annual marketed production (1000 bbls)[2]	70,000	74,000
Value ($1000)	1,917,000(e)	2,020,200(e)

[1]Oklahoma Tax Commission, tax-paid production.
[2]Published: *World Oil*, vol. 192, no. 3, Feb. 15, 1981; vol. 194, no. 3, Feb. 15, 1982. The Oil Producing Industry in Your State, 1981, 1982; IPAA, Petroleum Independent Publishers, Inc., 1981, 1982. DOE, various reports.
(e) = estimated.

TABLE 2.—DRILLING ACTIVITY IN OKLAHOMA, 1981

	1981 Oil	1981 Gas	1981 Dry	1981 Total	1980 Total
All Wells					
Number of wells	6,292	2,182	2,826	11,300[1]	9,041
Total footage				52,818,390	42,387,671
Average footage				4,674	4,688
Exploratory Wells					
Number of completions	134	113	404	651	508
Percentage productive				38	41
Total footage				4,685,481	4,006,094
Average footage				7,197	7,886
Development Wells					
Number of completions	6,158	2,069	2,422	10,649	8,533
Percentage productive				77	77
Total footage				48,132,909	38,381,577
Average footage				4,520	4,498

Source: American Petroleum Institute; The Oil Producing Industry in Your State 1982, IPAA, Petroleum Independent Publishers, Inc., 1982; World Oil, vol. 194, no. 3, Feb. 15, 1982.
[1]Excludes service, stratigraphic tests, and core test boreholes.

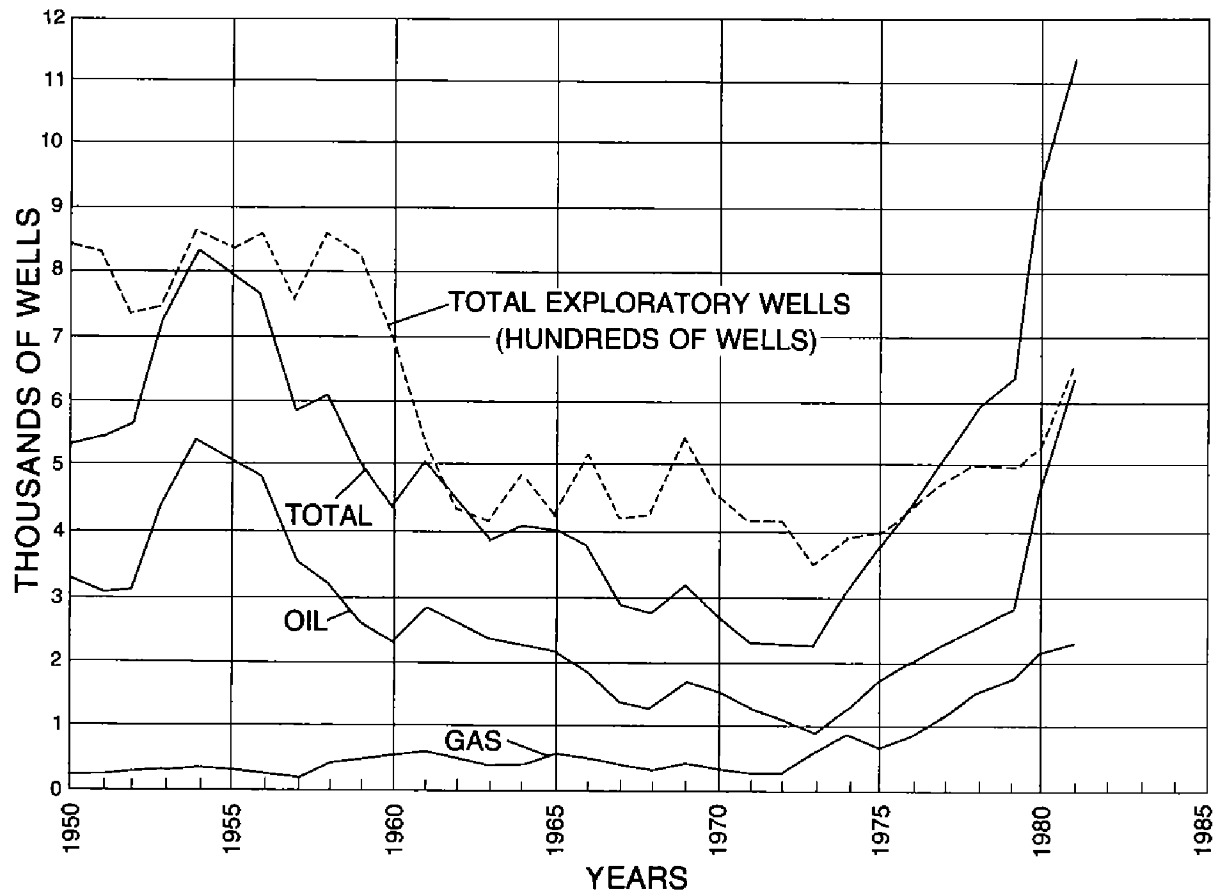


Figure 1. Graphs showing total wells drilled, oil wells completed, and gas wells completed in Oklahoma, 1950–81. (Source: OU Energy Resources Institute.)

county is depicted in figure 2. Counties leading in footage drilled were Kingfisher (3.9 million ft), Canadian (2.7 million ft), Major (2.5 million ft), and Garfield (2.2 million ft). Counties leading in the number of drilled holes were Osage (882), Okmulgee (555), Creek (511), and Nowata (489).

The massive increase in drilling projects and footage during 1981 required a large increase in the number of drilling rigs active in the State. Hughes Tool Co. reported 510 rigs active in the first week in January. The number of active rigs increased, with only minor reversals, to 689 in the first week in July and to the year's peak of 881 by December 21. Completions of exploratory oil wells and development oil wells rose by 45.7 percent and 33.9 percent respectively (table 2). Drilling for natural gas was less vigorous than drilling for oil, with fewer exploratory wells and only 6.2 percent more development wells completed than in 1980. The success ratio for all exploratory wells was reduced from the level of 1980 by 3 percentage points to 38 percent, while that of development wells remained at 77 percent. The average drilled depth of all exploratory wells decreased by 8.7 percent to 7,197 ft, whereas that of all development wells increased by 22 ft to 4,520 ft. The average drilled depth of all wells was 4,674 ft, 14 ft shallower than in 1980 (table 2).

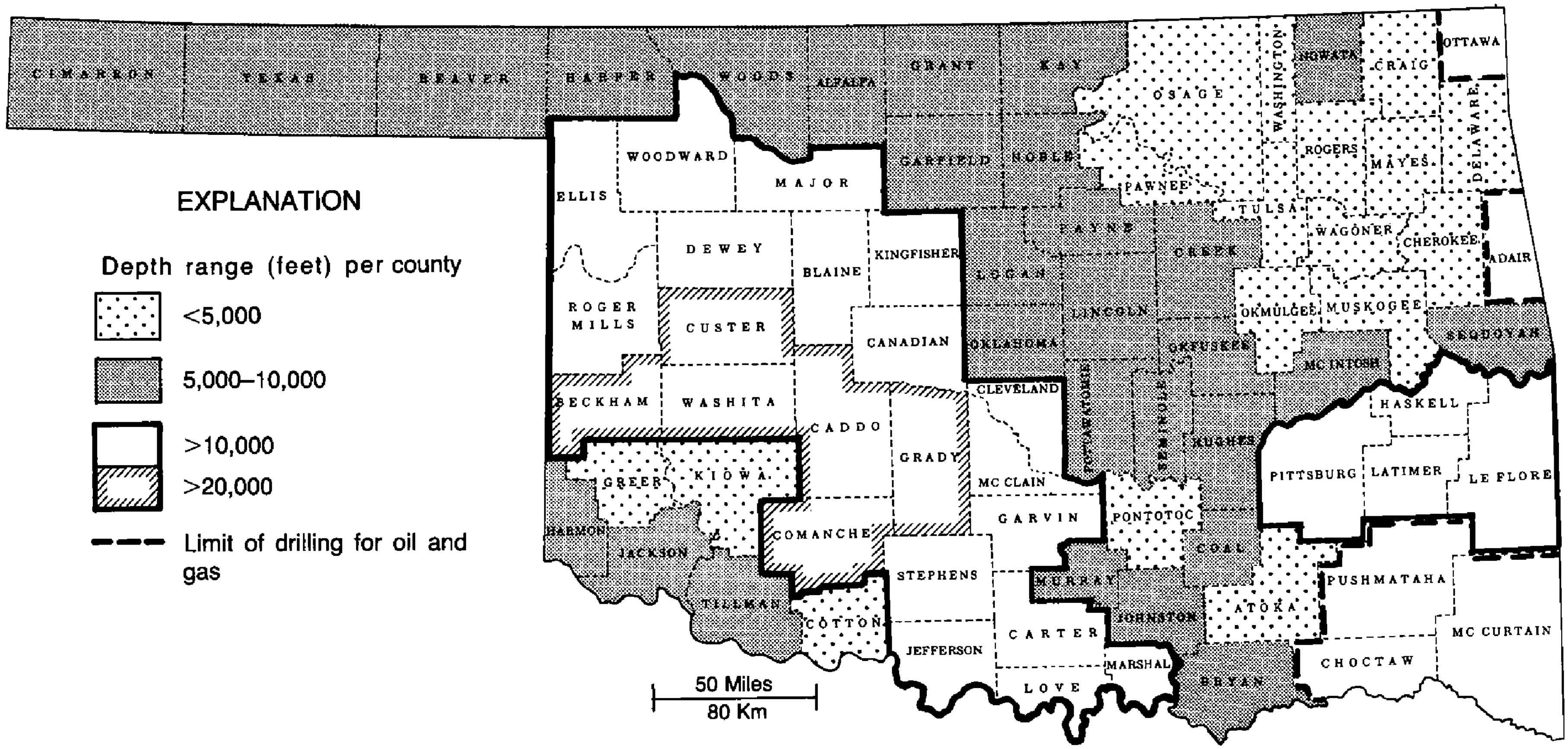


Figure 2. General distribution of maximum drilling depths attained in each county in Oklahoma in 1981.

Well Completions

Oil-well drilling was heavily concentrated in a roughly triangular sector of the State, extending from the Red River in Love County to Alfalfa and Nowata Counties on the Oklahoma–Kansas boundary (fig. 3). The counties in which more than 60 oil wells were completed lie wholly or partly within the sector, with the exception of Dewey and Muskogee Counties, which are immediately adjacent to the southwestern and southeastern sides of the sector. The 5,844 oil wells completed in these associated counties in 1981 made up 89.2 percent of the State's successful oil wells that year. Twelve counties within the sector, each having had 175 or more oil wells completed during the year, accounted for 57 percent of Oklahoma's completed oil wells, including 41 exploratory wells and 3,533 development wells. Osage County led in the number of development oil wells completed, having 593 completions, followed by Kingfisher (387), Nowata (343), Creek (340), Washington (316), and five other counties in the range of 200–300 wells. Completed exploratory oil wells were most numerous in Love County (12), Payne County (10), Logan County (9), and Osage County (8).

The number of oil wells completed in counties west of the central sector ranged from 1 to 58, with the exception of Jackson County, where no oil well was completed. East of the central sector, completions ranged from 1 to 32 oil wells per county. No oil wells were completed in the 12 counties along the eastern border of the State.

Gas wells were completed in 63 counties. Thirty-five or more gas wells were completed in each of 19 counties referred to in this article as the western gas sector of the State, an area that arbitrarily includes most of the Panhandle and central–western parts of Oklahoma plus Kay County (fig. 4). A total of 1,074 gas wells (49.2 percent of the State's successful gas wells in 1981) were completed in this area. Seventy-eight of the wells were exploratory; the remainder were development wells. Canadian County had the greatest number of gas-well completions, including 117 development wells and one exploratory well. Custer and Caddo Counties led in the number of completed exploratory wells, each having 15.

Each county in a block of 12 counties that are referred to as the eastern sector had 35 or more completed gas wells in 1981. The sector centers on Okmulgee County, extends north to Washington and Nowata Counties, south to Hughes and Pittsburg Counties, westward to Lincoln County, and eastward to Muskogee and Haskell Counties. Sixteen exploratory gas wells and 706 development gas wells completed in the sector made up 14.2 percent of all gas-well completions in Oklahoma in 1981. Haskell County led in exploratory completions (5), and Okmulgee County led in the total number of completions (129), all of which were development wells. Four counties had perfect records in completing all exploratory tests as producing wells. They were Atoka (1 oil), Canadian (6 oil and 1 gas), Kingfisher (2 oil), and Kiowa (1 oil). Detailed statistics of both oil-well and gas-well completions and drilling depths appear in table 3.

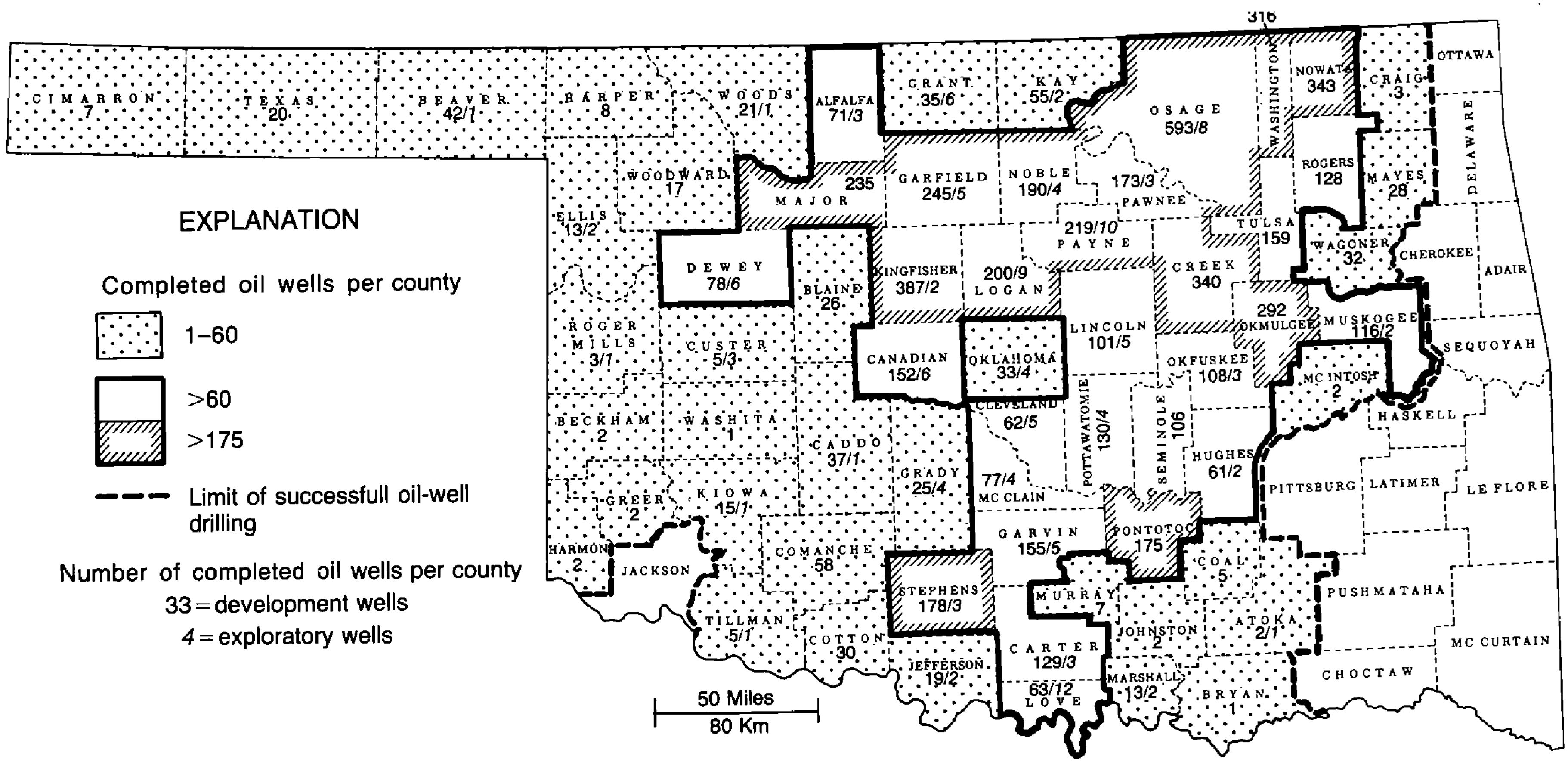


Figure 3. Number of oil wells completed in each county in Oklahoma in 1981.

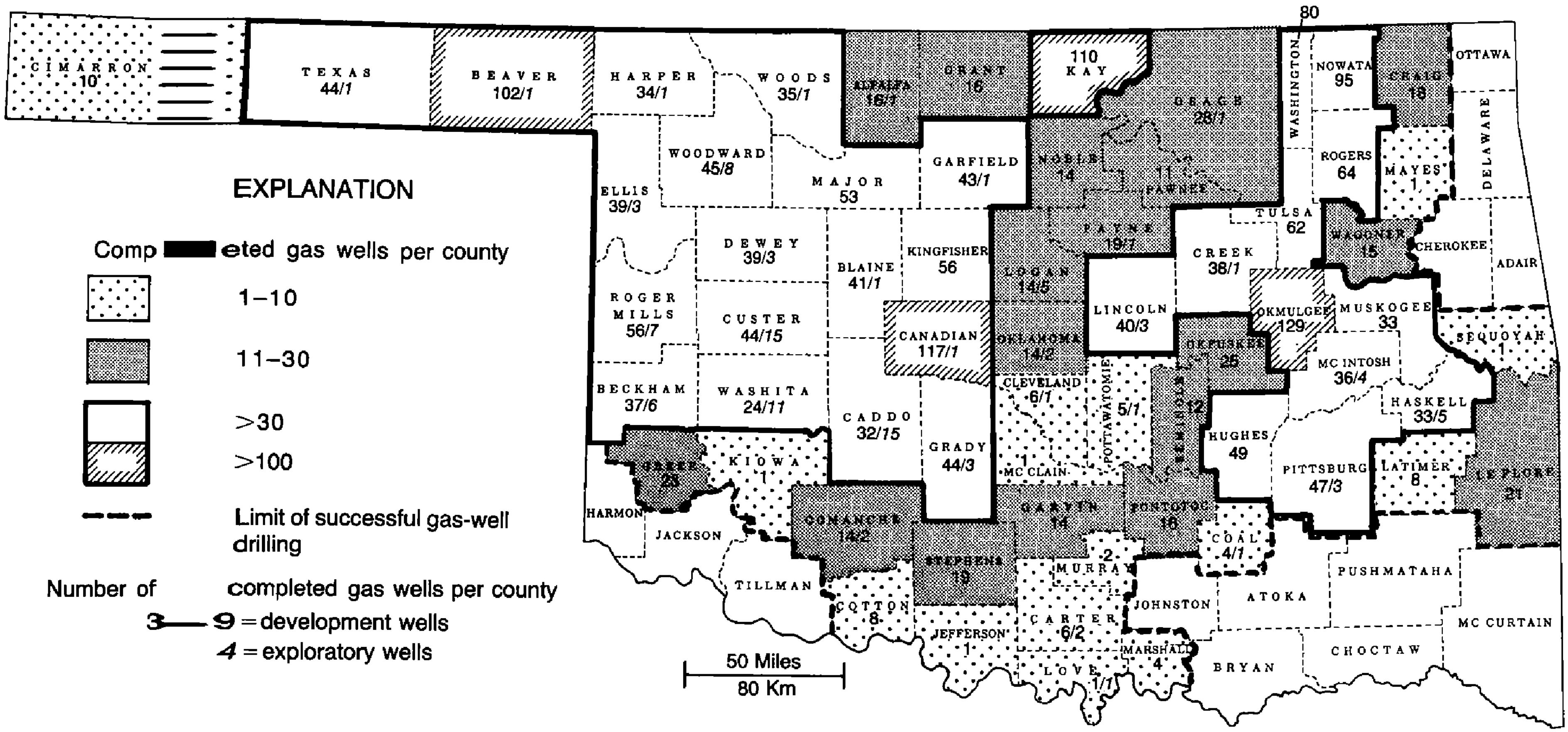


Figure 4. Number of gas wells completed in each county in Oklahoma in 1981.

TABLE 3.—COMPLETION DATA AND DEPTH INFORMATION FOR WELLS DRILLED IN OKLAHOMA DURING 1981
(SOURCE: OU ENERGY RESOURCES CENTER)

County	Total # of wells drilled	Completions Oil	Completions Gas	% Completions Oil & Gas	Number of wells drilled in following total-depth ranges (ft) 1-5,000	5,000-10,000	10,000-15,000	15,000-20,000	> 20,000
Altalta	113	74	17	80	9	103			
Atoka	3	3	0	100	3				
Beaver	212	43	103	69	14	196			
Beckham	59	2	43	76	14	4	7	30	3
Blain	98	26	42	69	3	57	36	1	
Bryan	6	1	0	17	5	1			
Caddo	118	38	47	72	36	1	52	25	1
Canadian	287	158	118	96	2	176	109		
Carter	163	132	8	86	82	66	11		
Cherokee	3	0	0	0	3				
Cimarron	44	7	10	39	28	16			
Cleveland	107	67	7	69		106	1		
Coal	17	5	5	59	8	9			
Comanche	94	58	16	79	89	3			2
Cotton	58	30	8	66	58				
Craig	54	3	18	39	54				
Creek	511	340	39	74	510	1			
Custer	103	8	59	65	2	1	77	20	1
Delaware	2	0	0	0	2				
Dewey	162	84	42	78		93	65	3	
Ellis	91	15	42	63		50	37	3	
Garfield	337	250	44	87	14	320			
Garvin	226	160	14	77	108	106	9	1	
Grady	98	27	47	76	12	18	48	19	1
Grant	111	41	16	51	45	66			
Greer	34	2	23	74	34				
Harmon	4	2	0	50	1	3			
Harper	84	8	35	51	3	80			
Haskell	61	0	38	62	30	25	5	1	
Hughes	168	63	49	67	163	5			
Jackson	3	0	0	0		3			
Jefferson	29	21	1	76	24	4	1		
Johnston	6	2	0	33	4	2			
Kay	234	57	110	71	232	1			
Kingfisher	453	389	56	98		415	35		
Kiowa	41	16	1	41	41				
Latimer	13	0	8	62	1	2	9	1	

TABLE 3.—CONTINUED

County	Total # of wells drilled	Completions Oil	Completions Gas	% Completions Oil & Gas	Number of wells drilled in following total-depth ranges (ft) 1-5,000	5,000-10,000	10,000-15,000	15,000-20,000	> 20,000
Le Flore	42	0	21	50		38	3		
Lincoln	240	106	43	62	183	54			
Logan	295	209	19	77	19	271			
Love	89	75	2	87	15	52	20		
McClain	111	81	1	74	4	69	37		
McIntosh	63	2	40	67	59	4			
Major	303	235	53	95	3	276	22		
Marshall	22	15	4	86	9	11		2	
Mayes	55	28	1	53	54				
Murray	29	7	2	31	25	4			
Muskogee	214	118	33	71	214				
Noble	264	194	14	79	106	156			
Nowata	489	343	95	90	488	1			
Okfuskee	207	111	25	66	206	1			
Oklahoma	87	37	16	61	3	83			
Okmulgee	555	292	129	76	555				
Osage	884	601	29	71	881				
Pawnee	269	176	11	70	268				
Payne	320	229	20	78	272	44			
Pittsburgh	93		50	54	57	25	10		
Pontotoc	248	175	16	77	248				
Pottawatomie	222	134	6	63	134	86			
Roger Mills	95	4	63	71	3	2	49	41	
Rogers	239	128	64	80	239				
Seminole	181	106	12	65	178	1			
Sequoyah	11		1	9	8	3			
Stephens	262	181	19	76	213	39	6		
Texas	126	20	45	52	16	109			
Tillman	19	6		32	8	11			
Tulsa	273	159	62	81	273				
Wagoner	67	32	15	70	67				
Washington	441	316	80	90	441				
Washita	54	1	35	67	4		19	30	1
Woods	107	22	37	55	4	102			
Woodward	117	17	53	60	3	105	8		
	11,300	6,292	2,182	64.1%	6894	3480	676	177	9
					61.3%	31%	6%	1.6%	0.1%

[1]List does not include reentry wells that have been drilled deeper

Production and Value

More than 80 percent of the 1981 output of crude oil was produced in 20 counties in the central part of the State and two counties in the Panhandle (fig. 5). Fifty-one percent of the oil was recovered in nine counties that had outputs of more than 5 million barrels of oil. Carter County yielded the largest quantity, 15.2 million barrels, and Stephens County ranked second with 14.3 million barrels. Only Le Flore and Choctaw Counties had no production. About 83.2 million barrels of oil, constituting 54.6 percent of the State's total output, was from stripper wells, according to the National Stripper Well Association. Stripper-well production in 1981 was reported to be about 4 percent greater than in 1980.

Natural gas was obtained primarily from the western gas sector. There, each of 18 counties yielded more than 25 billion cu ft of gas and collectively accounted for 77.8 percent of Oklahoma's total output in 1981 (fig. 6). The output in each of four counties in the eastern gas sector exceeded 25 billion cu ft for a total of 8.3 percent of Oklahoma's total output. In Texas, Canadian, Roger Mills, and Grady Counties (listed in order of decreasing output), production exceeded 100 billion cu ft of gas. No production was recorded in Ottawa, Delaware, Mayes, Choctaw, McCurtain, or Pushmataha County in the east or in Harmon County in the west.

Increments of petroleum, natural gas, and natural-gas liquids produced in 1981 raised Oklahoma's cumulative marketed production to 12.2 billion barrels of petroleum, 49.4 trillion cu ft of natural gas, and 1.5 billion barrels of natural-gas liquids. The presentation of historical data in table 4 conforms to data categories provided by the U.S. Department of Energy.

The average taxed value of produced crude oil at the wellhead was $35.18 per barrel, and that of marketed natural gas was $1.89 per thousand cu ft. Both values are extraordinarily high when contrasted with wellhead values of $3.78 per barrel of oil and $0.189 per thousand cu ft of gas in 1973, and somewhat higher than the $27.38 per barrel of oil and $1.50 per thousand cu ft of gas in 1980 (fig. 7). However, when reduced to terms of constant dollars based on 1967 conditions by application of the producer's price index, the average value of a barrel of oil was $3.00 in 1973, $4.98 in 1980, and $4.38 in 1981. Similarly, the average value of a thousand cu ft of natural gas in terms of constant dollars was $0.149 in 1973, $0.197 in 1980, and $0.201 in 1981. This signifies that relative to the inflation of the whole economy, the value of crude oil in 1981 was only 46 percent higher than in 1973, and the value of natural gas was only 35 percent above its value in 1973.

Reserves

The interplay between discoveries of new sources of oil and gas, withdrawals (production), and the extension and revision of estimated oil and gas re-

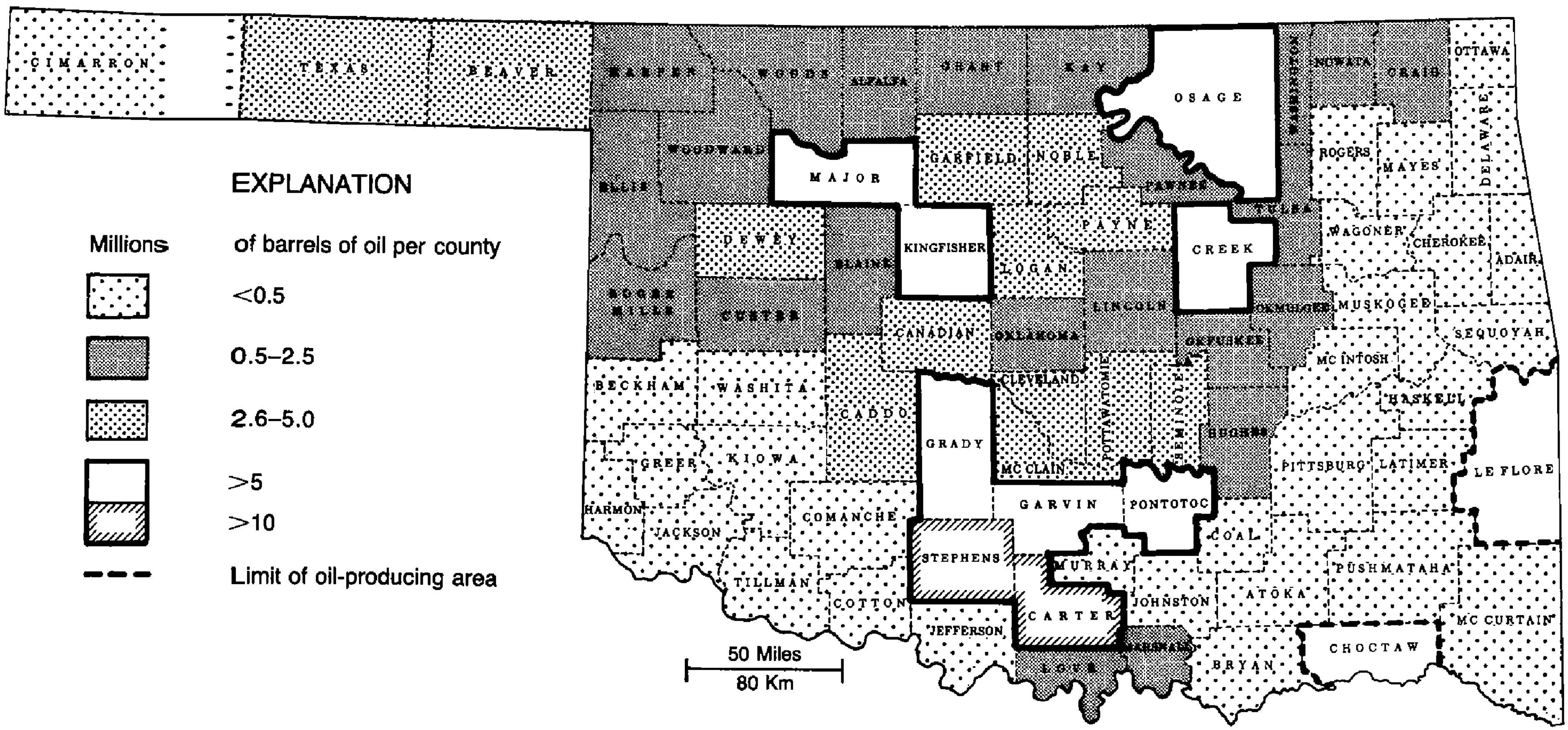


Figure 5. Outpu t of crude oil per county in Oklahoma in 1981

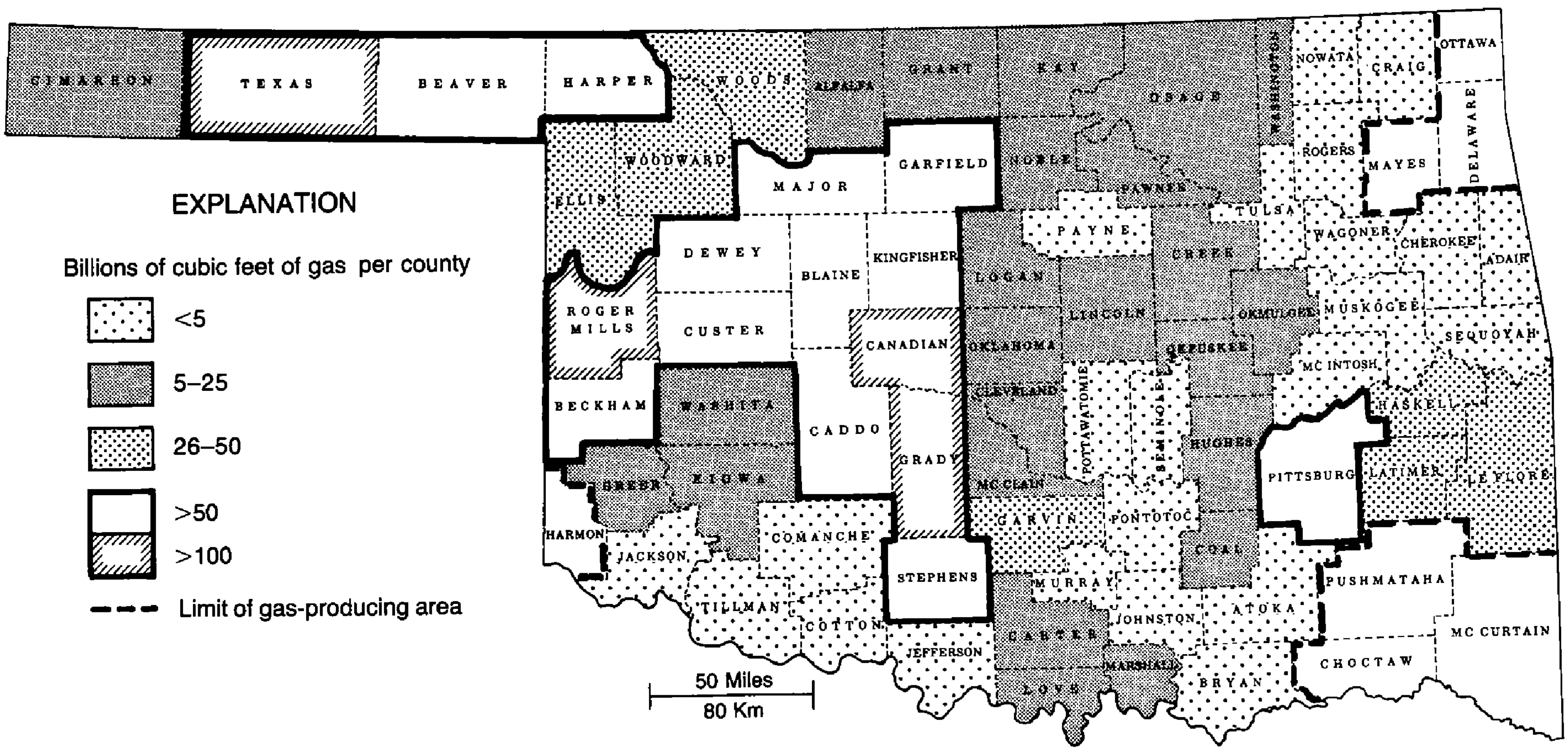


Figure 6. Output of natural gas per county in Oklahoma in 1981.

TABLE 4.—CUMULATIVE (THROUGH 1955) AND YEARLY (1956-80) MARKETED PRODUCTION AND VALUE OF PETROLEUM, NATURAL GAS, AND LIQUEFIED NATURAL GAS IN OKLAHOMA[1]

Year through	Petroleum Volume (1,000 bbls)	Petroleum Value ($1,000)	Natural Gas Volume (MMcf)	Natural Gas Value ($1,000)	Liquefied natural gas[2] Volume (1,000 bbls)	Liquefied natural gas[2] Value ($1,000)
1955	7,230,010	11,443,269	12,977,332	1,378,370	430,806	1,010,826
1956	215,862	600,096	678,603	54,288	25,454	49,970
1957	214,661	650,423	719,794	59,743	24,947	47,153
1958	200,699	594,069	696,504	70,347	26,141	51,851
1959	198,090	578,423	811,508	81,151	26,767	56,513
1960	192,913	563,306	824,266	98,088	30,816	65,483
1961	193,081	561,866	892,697	108,016	31,865	63,499
1962	202,732	591,977	1,060,717	135,772	33,136	60,987
1963	201,962	587,709	1,233,883	160,405	32,532	64,112
1964	202,524	587,320	1,323,390	166,747	34,163	62,066
1965	203,441	587,944	1,320,995	182,297	34,876	66,769
1966	224,839	654,281	1,351,225	189,172	36,771	80,046
1967	230,749	676,095	1,412,952	202,052	37,489	85,122
1968	223,623	668,202	1,390,884	197,506	39,402	78,349
1969	224,729	701,155	1,523,715	223,128	41,925	73,334
1970	223,574	712,419	1,594,943	248,811	42,842	92,908
1971	213,312	725,610	1,684,260	273,945	41,727	97,588
1972	207,633	709,033	1,806,887	294,523	41,707	99,810
1973	191,204	723,273	1,770,980	334,110	43,718	144,334
1974	177,785	1,277,076	1,638,492	458,904	43,812	251,099
1975	163,123	1,389,164	1,605,410	513,731	40,025	203,535
1976	161,426	1,484,297	1,726,513	866,710	42,514	254,018
1977	151,390	1,504,817	1,824,710	1,452,683	42,350	317,625
1978	150,456	1,640,595	1,773,582	1,599,771	44,369	488,059 (e)
1979	143,641	2,158,526	1,845,389	2,062,868	50,752	762,662 (e)
1980	150,140	4,110,515	1,902,157	2,856,457	70,000	1,917,000 (e)
1981	152,252	5,355,474	2,030,225	3,831,636	74,000	2,020,200 (e)
Totals	12,245,851	41,836,934	49,422,013	18,101,241	1,464,906	8,564,918

[1]Oklahoma Tax Commission

[2]Production for 1980 and 1981 from U.S. Department of Energy.

sources in existing fields is summarized in figures 8 and 9. Proved reserves of crude oil increased by about 20 million barrels to about 950 million barrels, total liquid hydrocarbons (crude oil plus natural-gas liquids) increased by about 50 million barrels to 1.58 billion barrels, and natural-gas reserves (dry) increased by about 1.56 trillion cu ft to about 14.7 trillion cu ft during 1981. The volume of discovered hydrocarbons was the highest since 1953, and that of natural gas was the highest since 1966.

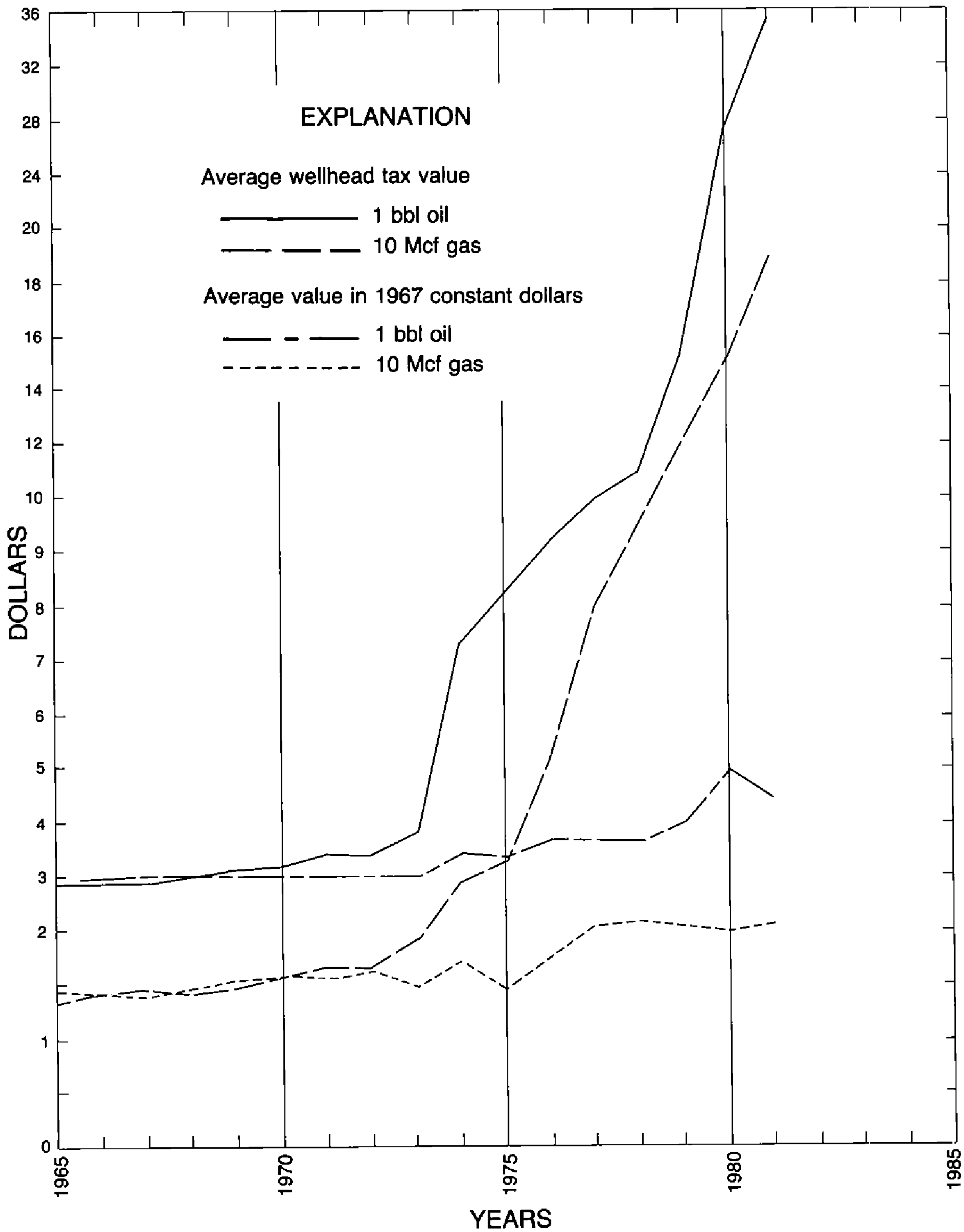


Figure 7. Average wellhead tax value for oil and natural gas in Oklahoma, 1965-81.

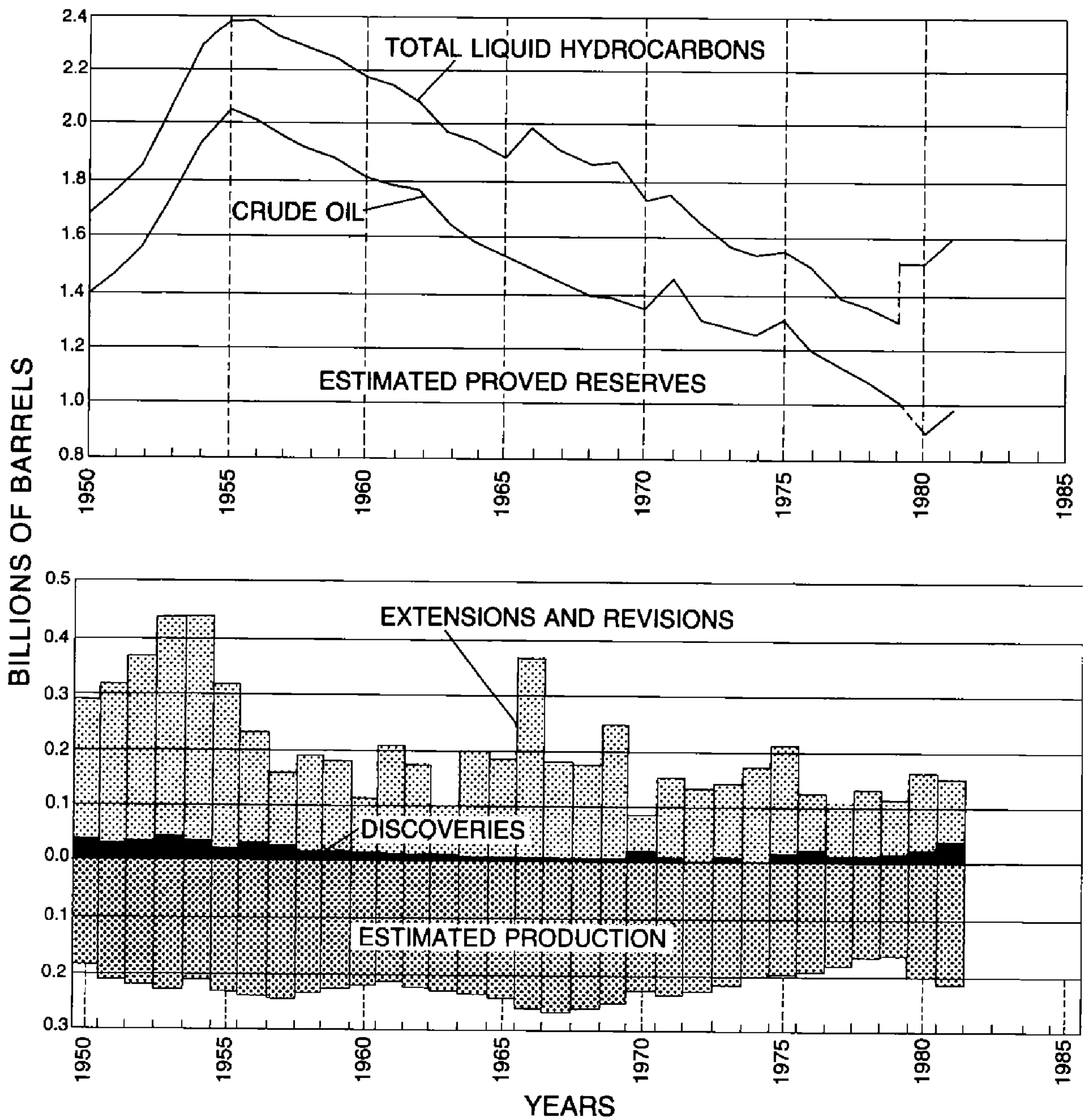


Figure 8. Graphs showing statistics for estimated proved total liquid-hydrocarbon reserves, extensions and revisions, discoveries, and estimated production in Oklahoma, 1950–81. (Source: U.S. Department of Energy, annual reports.)

Giant Oil Fields

The *Oil and Gas Journal's* annual list of giant fields in Oklahoma was increased to 11 by the return of Glennpool, which had been omitted for several years (table 5). If Glennpool production is omitted from the 1981 statistics of giant oil fields to provide comparability with 1980 statistics, oil production from the other 10 fields was 47.6 million barrels. Although this figure made up 32 percent of the State's total output, it was 7.8 percent less than the re-

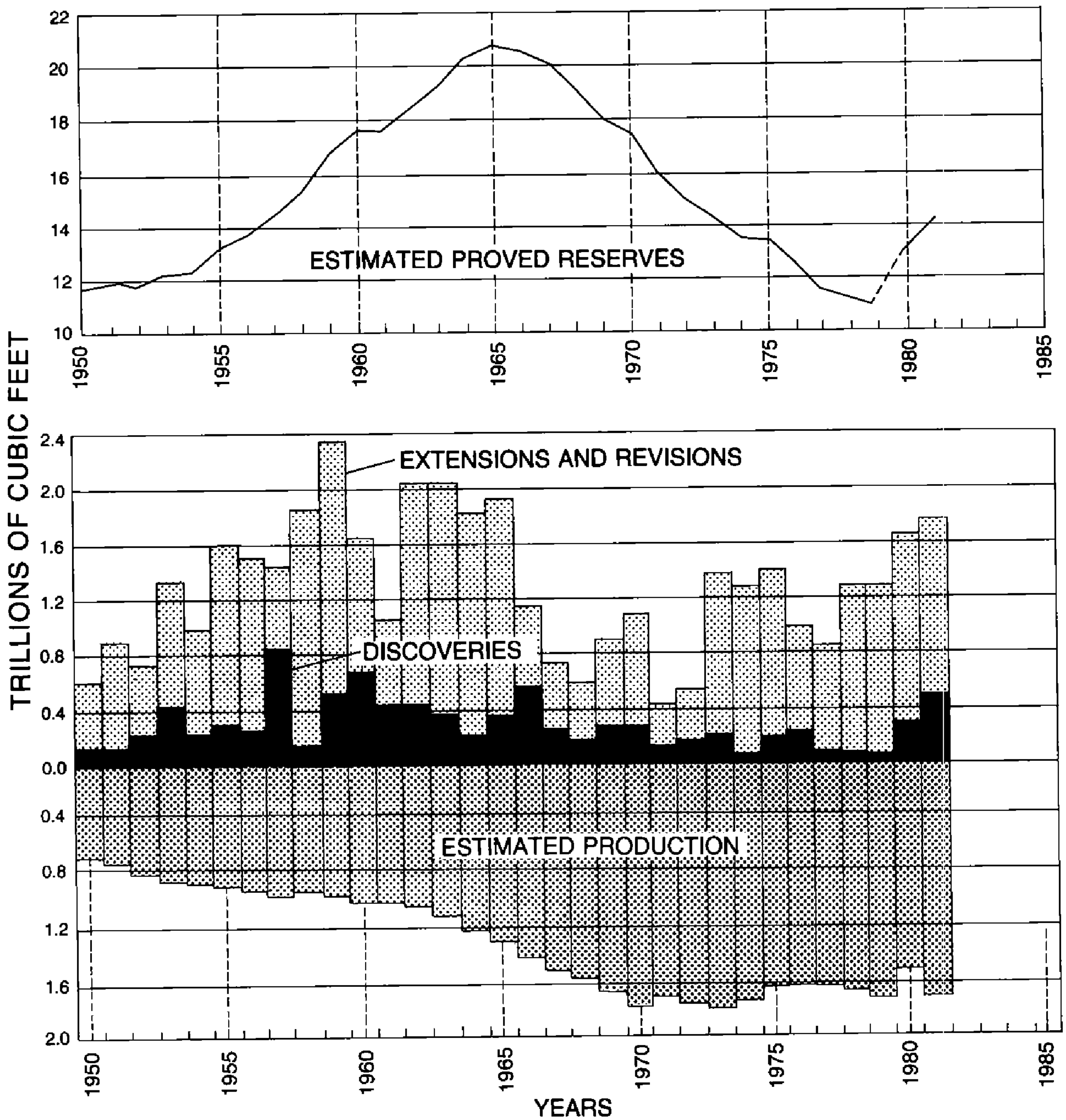


Figure 9. Graphs showing statistics for estimated proved natural-gas reserves, extensions and revisions, discoveries, and estimated production in Oklahoma, 1950–81. (Source: U.S. Department of Energy, annual reports.)

vised reported output of the same fields in 1980. Production was reduced in all fields except the Sooner Trend, where it increased by about 173,000 barrels. The Oklahoma City Field experienced the greatest reduction, about 1.3 million barrels of oil. Only Sho-Vel-Tum and the Sooner Trend gained an appreciable number of producing wells, 46 and 415, respectively. The remainder gained none to a few wells each, except for Oklahoma City and Postle,

TABLE 5.—GIANT OIL FIELDS OF OKLAHOMA, 1981
(Source Oil & Gas Journal, v. 80, no. 4, Jan. 25, 1982)

Field	1981 production (1,000 bbls)	Cumulative production 1/1/82 (1,000 bbls)	Estimated reserves (1,000 bbls)	Number of wells
Burbank	2,160	522,383	20,020	1,042
Eola-Roberson	1,653	124,259	15,716	563
Glenn Pool	1,114	320,198	9,802	1,090
Golden Trend	3,835	426,842	37,171	1,093
Healdton	2,380	329,932	22,956	1,400
Hewitt	2,922	254,068	32,152	1,251
Oklahoma City	889	738,816	9,952	204
Postle	1,865	94,654	25,179	322
Sho-Vel-Tum	20,533	1,185,134	144,866	8,545
Sooner Trend	7,643	243,731	51,357	4,420
Totals	48,720	4,408,664	385,755	20,562

both of which lost nine wells. Estimated reserves declined 8.9 percent below those of 1980.

MANKIN NEW VICE-PRESIDENT OF AIPG

Charles J. Mankin, director of the Oklahoma Geological Survey and of The University of Oklahoma Energy Resources Institute, has been elected national vice-president of the American Institute of Professional Geologists (AIPG). He will take office January 1, 1984.

Others elected to office include: W. Dean Grafton, of Cities Service Co. in Houston, president; Ernest K. Lehmann, of Ernest K. Lehmann and Associates of Minneapolis, president-elect; Richard J. Anderson, consulting geologist of Columbus, Ohio, secretary-treasurer; and Kenneth N. Weaver, director of the Maryland Geological Survey, editor.

AIPG, which now numbers 4,270 members, was founded in 1963 to provide an organization that would represent those geologists engaged in the business or professional practice of the science of geology. Members of the institute are required to be certified as to character, education, experience, and competence in the profession. Membership, which is drawn from across the United States and several foreign countries, represents industry, government, academia, and consulting geology.

OGS EDITOR PRESIDES AT AESE MEETING IN HOUSTON

President William D. Rose, geologist/editor of the Oklahoma Geological Survey, presided at the Association of Earth Science Editors' (AESE) annual meeting October 9–12 in Houston, Texas. The group met at the Nassau Bay Hilton near the National Aeronautics and Space Administration's Johnson Space Center. The nearby Lunar and Planetary Institute served as the official host group for the meeting.

Wendell Cochran, of the American Geological Institute (AGI), and a member of the AESE board of directors, told the gathering of progress that had been made toward cooperative publishing by AGI and AESE: a catalog of earth-science journals intended to help writers, and a comprehensive style guide for the earth sciences.

The secretary-treasurer of the association, Hal James, announced the newly elected members of the board of directors: Judy C. Holoviak, of the American Geophysical Union, vice-president and president-elect, and Elmer F. (Tres) Smith III, of the U.S. Geological Survey, member-at-large. James will begin his second term as secretary-treasurer when the new board takes office January 1.

Organizers of the meeting were Russell B. Merrill, in charge of the program, Rosanna Ridings, in charge of local arrangements, and Patricia and Ed Dickerson, who planned the annual dinner on board the *Elissa*, a restored 19th-century barque moored in the Galveston ship channel.

One of the main events of the meeting was the presentation of the AESE Award for Outstanding Editorial or Publishing Contributions to Walter Sullivan, science editor of The New York Times, for his singular achievements in communicating scientific information to the public principally through the newspaper medium. Sullivan received a similar honor from the American Association of Petroleum Geologists at its annual meeting in 1980.

Former recipients of the AESE award include Philip H. Abelson, of the American Institute of Physics, Brian J. Skinner, of Yale University, Robert L. Bates, of Ohio State University, and Wendell Cochran of AGI.

Members of the Oklahoma Geological Survey staff who took part in the meeting, in addition to Rose, were Connie G. Smith, who worked hard and long on the program committee, and Elizabeth A. Ham. Ham will be serving on next year's award committee.

Next year's annual meeting will be in Portland, Oregon, October 7–10, with the Oregon Department of Geology & Mineral Industries and the Washington Division of Geology & Earth Resources acting as hosts. Beverly Vogt will chair the local host committee.

HISTORY OF THE BOUNDARIES OF OKLAHOMA

Arthur J. Myers[1]

Introduction

The boundaries of the 13 original states were not defined in the Acts of Ratification, but in general the states maintained their claim to colonial boundaries established by royal decree or by agreement. Other states were admitted into the Union by acts of Congress, usually upon petition of the people residing in the territory, and their boundaries were defined in the enabling acts.

The entire basin of the Mississippi River and its tributaries and much of the coastal region of the Gulf of Mexico were subsequently known as the Territory of Louisiana, and were originally claimed for France by La Salle in 1682. In the early 1800's Napoleon Bonaparte feared a declaration of war by Great Britain and subsequent seizure of the mouth of the Mississippi and with it the Province of Louisiana, so he offered to sell the province to the United States. The offer was promptly accepted, and the consideration named was 60 million francs and the assumption by the United States of the "French spoilation claims," which were estimated to amount to $3,750,000. Article 3 of the treaty of cession, dated April 30, 1803, fixed the rate of exchange at 5.333 francs to the dollar. The total payment, including interest, made by the United States for this purchase was $23,213,567.73.

Oklahoma is one of the states formed from the Louisiana Purchase.

State Statistics

Of the 50 states, Oklahoma ranks 33d in size, with a total area of 69,956 sq mi. Of this, 68,924 sq mi is dry land or land temporarily or partially covered by water, such as swamps and river flood plains, streams, and ponds of less than 40 acres in area. The remaining 1,023 sq mi includes lakes, reservoirs, and ponds having an area of 40 acres or more.

The geographic center of Oklahoma is 8 mi north of Oklahoma City. The State's highest point is Black Mesa, in Cimarron County, at 4,973 ft, while

[1]Geologist, Oklahoma Geological Survey.

the lowest point is on the Red River in McCurtain County at 300 ft. The approximate mean elevation of the State is 1,300 ft. Oklahoma City has an elevation of 1,207 ft.

Figure 1 shows the latitude and longitude of the initial point of Oklahoma and the latitude and longitude of the "corners" of Oklahoma and surrounding states.

Figure 2 shows the distance in miles along the border of Oklahoma and its adjacent states. The total mileage along adjacent state boundaries is:

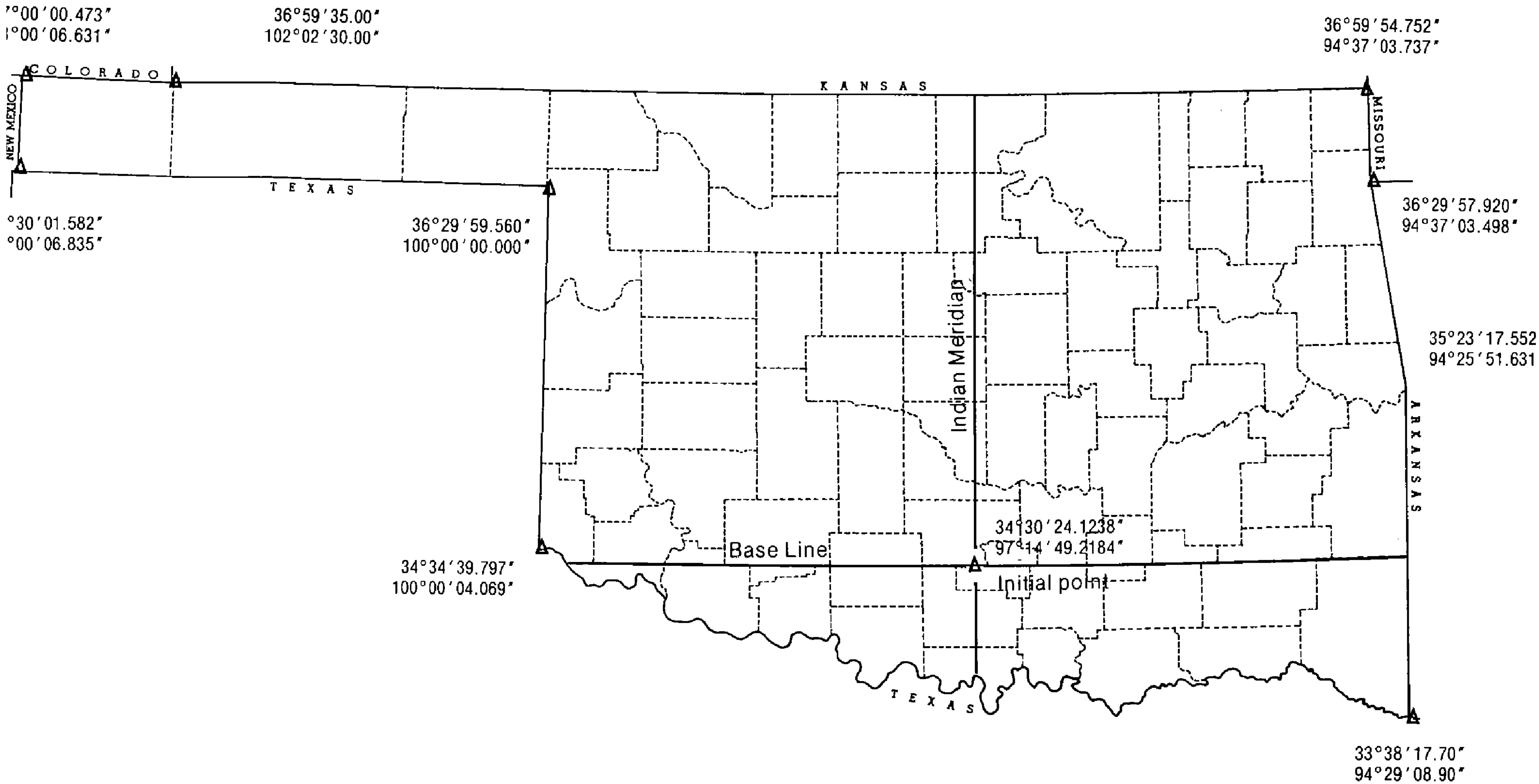
Missouri	34.42 mi
Arkansas	197.96 mi
Texas	903.34 mi
New Mexico	34.45 mi
Colorado	53.01 mi
Kansas	410.71 mi

Figure 3 shows internal distances within the State of Oklahoma. The maximum east–west distance is 466.76 mi from the southwest corner of Missouri to the southwest corner of the Oklahoma Panhandle. The State's initial point, at the Oklahoma–Arkansas border, is the most easterly part of Oklahoma, with Arkoma the most easterly town; the distance from that point to the Texas Panhandle is 314.39 mi.

The maximum north–south distance entirely within Oklahoma is 230.16 mi, which is from a point southeast of Mud Lake in McCurtain County (the crossing of the boundary loop immediately south of the Red River is disregarded) to the Kansas state line north of Ottawa County. The location of the south point is latitude 33°39′35.41″ N and longitude 94°39′18.30″ W. The north–south distance through central Oklahoma along longitude 97°07′30″ from the south side of the Red River to the Kansas state line is 226.24 mi.

Land Divisions

The division of Indian Territory (Oklahoma) into the section–township–range system was authorized by an act of Congress on April 8, 1864. It began in 1870 with the subdivision of the Chickasaw lands into quarter sections. The initial point was established on the north side of the Arbuckle Mountains and marked with a stone post, which is still standing (fig. 4A). The initials "IM" are on the west side of the post, and the date "1870" is on the north side. The point was probably chosen because it was in limestone bedrock, at an elevation above the surrounding land to the north and east, and because of its proximity to Fort Arbuckle. All of Oklahoma, except the Panhandle, has been surveyed as ranges east and west from this longitude, known as the Indi-



igure 1. Map of Oklahoma showing latitude and longitude of the initial point and ''corners.''

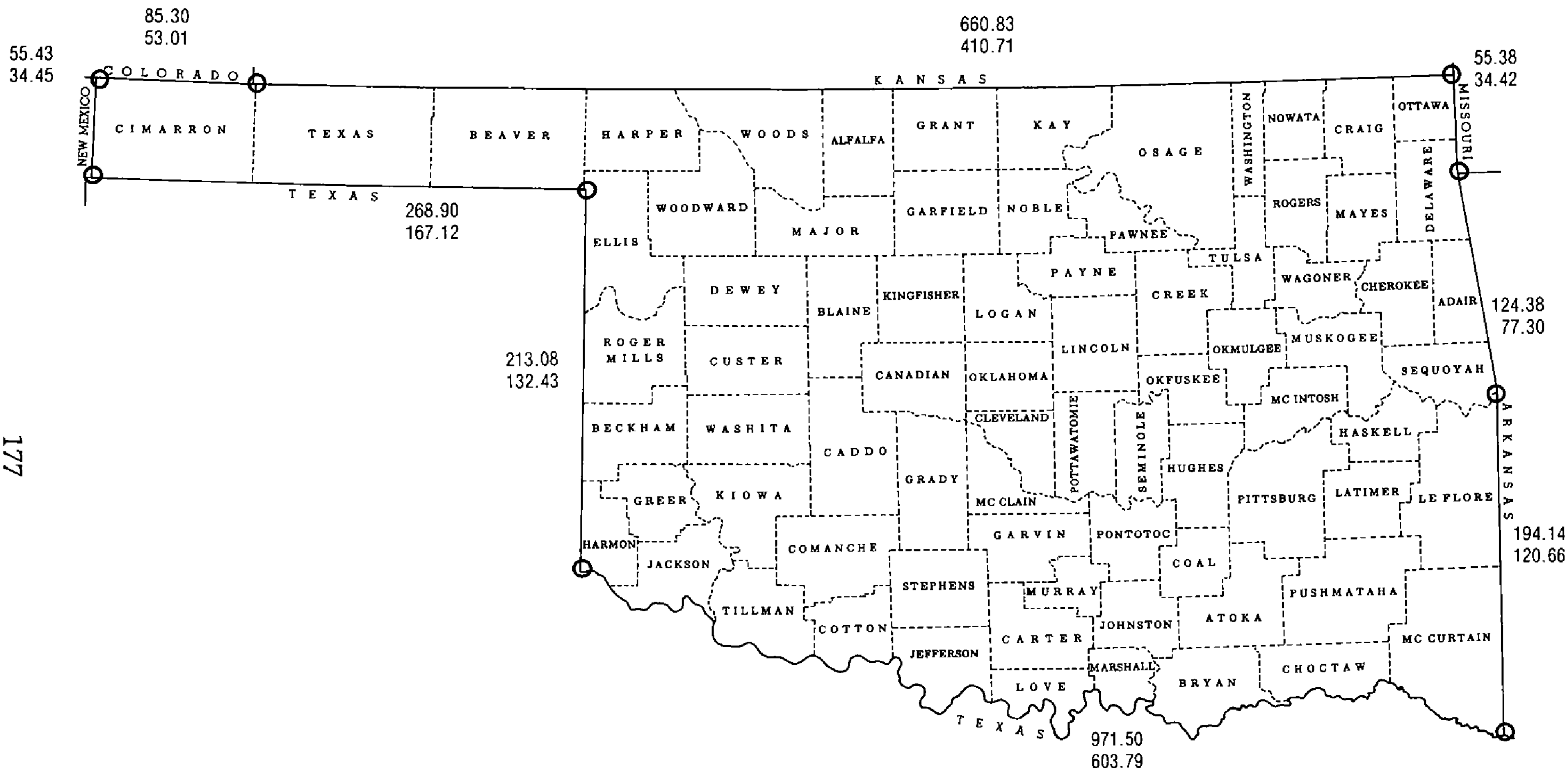


Figure 2. Map of Oklahoma showing distances along border with adjacent states. The bottom number is the distance in miles, the top number the distance in kilometers.

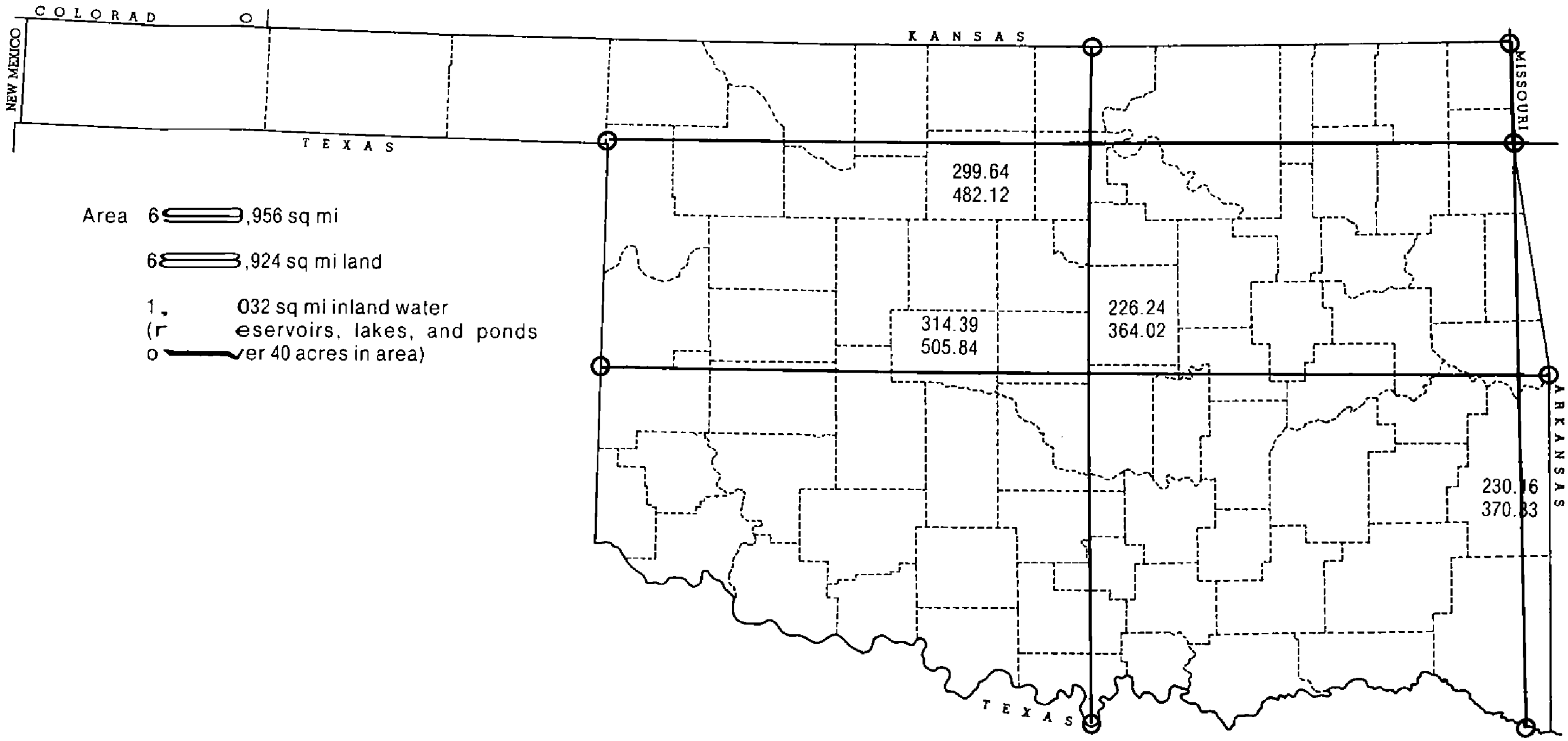


Figure 3. Map of Oklahoma showing internal distances. The top number is the distance in miles, the bottom number the distance in kilo meters.

A

B

Figure 4. Photographs of Oklahoma initial point. The stone post was sent in 1870 and marks the intersection of the Indian Meridian and base line. A, view from the southwest, with Indian 1954 triangulation station in the foreground. B, close-up view of Indian 1954 triangulation station.

an Meridian, and townships north and south are marked from the base line of latitude established by this marker.

During fiscal year 1870–71, 65 townships were surveyed and divided into 160-acre tracts with a total of approximately 1,350,107 acres. Except for the Panhandle, by 1879 most of Oklahoma west of the 96th meridian had been surveyed.

Beginning in 1927 the triangulation net west of the 98th meridian was adjusted. It involved 12,500 mi of arcs in 16 closed loops. Later the net east of the 98th meridian was adjusted, involving 13,000 mi of arcs in 26 loops. The North American datum for the adjustments is the Meades Ranch station in Kansas at latitude 39°13′26.686″ N and longitude 98°32′30.506″ W. First-order triangulation in Oklahoma includes seven first-order arcs (1927 datum) and was published in 1935 (Schmidl). Triangulation has continued, and in 1955 the Indian triangulation station was established. The marker is stamped "Indian 1954," and its position is latitude 34°30′24.1238″ N and longitude 97°14′49.2184″ W, which is 11.73 ft from the stone post set in 1870 by the original survey party. Figure 4B is a closeup of the Indian 1954 triangulation station.

Indian and Oklahoma Territories

Indian Territory was set apart by a Congressional act of June 30, 1834, and was described as follows:

> . . .all that part of the United States west of the Mississippi and not within the States of Missouri and Louisiana, or the Territory of Arkansas . . . shall be taken and deemed to be Indian Country.

The Territory of Oklahoma was organized from the western part of Indian Territory under the act of May 2, 1890. The act states, in part:

> That all that portion of the United States now known as the Indian Territory, except so much of the same as is actually occupied by the five civilized tribes, and the Indian tribes within the Quapaw Indian Agency, and except the unoccupied part of the Cherokee outlet, together with that portion of the United States known as the Public Land Strip [Donaldson, 1884, p. 462, 1187], is hereby erected into temporary government by the name of the Territory of Oklahoma.

A boundary between two states of the United States may be changed by agreement of the state legislatures, but the agreement must be approved by the U.S. Congress. Congress cannot change a state boundary without the consent of the states. A boundary between a state and a territory is fixed by joint action of Congress and the state. Boundaries between territories are fixed by Congressional action alone. Disputes between states regarding boundaries must be settled by the U.S. Supreme Court, whose decisions are final.

Bordering States

Of the six states that border Oklahoma, all but one, New Mexico, were admitted to the Union before Oklahoma:

Missouri	August 10, 1821	24th
Arkansas	June 15, 1836	25th
Texas	December 29, 1845	28th
Kansas	January 29, 1861	34th
Colorado	August 1, 1876	38th
Oklahoma	**November 16, 1907**	**46th**
New Mexico	January 6, 1912	47th

The boundaries of the states were set in the enabling acts for their admission; therefore, the State of Oklahoma is essentially what was left after the surrounding states had been formed.

Missouri

The southwest corner of Missouri was established at a point that sextant observations showed to be in latitude 36°30′ N and a large stone post was set to mark the point. In 1845 a mound of earth 5 ft tall, having a 10-ft base, was placed at a point 4.83 chains (318.78 ft; 1 chain = 66 ft) farther south.

A boundary monument, "Oklahoma-Missouri-Arkansas," was surveyed and erected in 1935. It is marked by a 2-ft-sq concrete monument 4 ft high resting upon a 3-ft-sq concrete base that projects 1 ft above ground. A stone set in the top of the monument is 5 x 12 in. and extends 12 in. above the concrete. The stone has "Misr" cut in the north side and "Ark" cut in the south side. The monument has "Missouri 1821" molded in the north side, "Oklahoma 1907" in the west side, "Arkansas 1836" in the south side, and "Erected by Ozark Culture Club 1915" in the east side (U.S. Coast and Geodetic Survey, 1959).

Arkansas

The west boundary of Arkansas was established by a treaty between the United States and the Cherokee Indians signed on May 6, 1828, and which contained the following description:

> The western boundary of Arkansas shall be, and the same is, hereby defined viz: A line shall be run, commencing on Red river, at the point where the Eastern Choctaw line strikes said river, and run due north with said line to the river Arkansas; thence in a direct line of the South West corner of Missouri.

The eastern Choctaw line was fixed by treaty with the Choctaw Nation on January 20, 1825, as beginning on the Arkansas River one hundred paces east of Fort Smith and running thence south to the Red River. When Arkansas was admitted as a state, the west boundary was the line described in the treaty with the Cherokee Indians.

The west boundary of Arkansas near Fort Smith was changed by an act of Congress approved February 10, 1905, to include in that state a part of Indian Territory (about one-fifth of a square mile), the boundaries of which were described as follows (Van Zandt, 1976, p. 118):

> Beginning at a point on the south bank of the Arkansas River one hundred paces east of old Fort Smith, where the western boundary line of the State of Arkansas crosses the said river, and running southwesterly along the south bank of the Arkansas River to the mouth of the Poteau; thence at right angles with the Poteau River to the center of the current of said river; thence southerly up the middle of the current of the Poteau River (except where the Arkansas State line intersects the Poteau River) to a point in the middle of the current of the Poteau River opposite the mouth of Mill Creek, and where it is intersected by the middle of the current of Mill Creek; thence

up the middle of Mill Creek to the Arkansas State line; thence northerly along the Arkansas State line to the point of beginning.

The west boundary of Arkansas south of the Arkansas River was surveyed and marked in 1825, while the line from old Fort Smith to the southwest corner of Missouri was marked in 1831.

A resurveying and re-marking of the entire west boundary of Arkansas was authorized in 1875 and completed in 1877. The lines from old Fort Smith, both north and south, diverged to the west and added to Arkansas more than 200 sq mi. The boundary mark on the Red River was found to be 4 mi 16 chains (22,176 ft) west of a line due south of old Fort Smith. The Cherokee and Choctaw Indians were paid for the land from which they had been wrongfully deprived (Van Zandt, 1976, p. 118–120).

The Oklahoma-Arkansas initial point was established in 1885 and resurveyed in 1915. The monument is of gray limestone, 4 ft high, 4 ft square at the base, and 17½ in. square at the top, which is surmounted by a capstone 17½ in. square and 17 in. high. It is marked "Initial Point" on its north face, "Arkansas" on its east face, "Choctaw" on its west face, and "1858" on its south face (Shmidl, 1935, p. 81). (See cover illustration and description on page 154.)

Texas

The south border of Oklahoma is now established as the position of the south bank of the Red River at the time when Texas was admitted to the Union. The boundary was in dispute for many years, with Texas claiming to the middle of the river. Briefs in a suit filed by Oklahoma against Texas were submitted to the U.S. Supreme Court at its October term in 1920. A decision was rendered April 11, 1921, reaffirming a former decision by the Supreme Court in 1896 making the south bank the boundary.

The Red River is a meandering stream, and since 1845 the course has changed many times. As a result, parts of Texas are now north of the present course of the Red River, and parts of Oklahoma are south.

The most southerly part of Oklahoma is along the south bank of Gunn Lake, an oxbow lake of the Billy Hall Bend of the Red River, south of its present course. This point is situated at latitude 33°36′56.46″ N and longitude 94°31′30.11″ W.

For more than 50 years the area known as "Greer County" (an area of more than 2,360 sq mi east of the 100th meridian and between the two main forks of the Red River) was in dispute between the State of Texas and the United States. Texas claimed that the North Fork was the main stream referred to in the description of the boundary in the Spanish treaty of 1819. The

United States claimed that the South Fork was the main channel and the proper location of the boundary.

Congress decided the matter on May 4, 1896, and awarded this area to Oklahoma.

In 1926, after a number of surveys, neither the U.S. Congress nor the State of Texas had approved any survey of the 100th meridian. That year the U.S. Supreme Court decreed that neither the boundary survey of 1859-60 nor the location of the 100th meridian in 1902-03 was acceptable in establishing the boundary and ordered that a new survey be made.

In order to locate the line exactly, the court-appointed commissioner placed it on the geodetic meridian determined from first-order triangulation by the U.S. Coast and Geodetic Survey. The marking of the boundary line began in 1928 at a point 340.28 ft east of a 1920 mark near the Red River and extended south to a point near the "cut-bank" on the south side of the river. At that point a large reinforced-concrete monument was built, and a reference mark on the meridian was placed at a point 351.2 ft farther south. From the cut-bank mark the line was run due north for a distance of 133.6 mi, checked in position at each of the 20 geodetic stations, and closed on the eastward extension of the 36°30′ parallel boundary line as determined by John H. Clark, the boundary commissioner, in 1860. Along the line there are now 160 concrete monuments, each having a lettered metal tablet set in its upper surface. The line as established was approved by the U.S. Supreme Court on March 17, 1930 (Van Zandt, 1959, p. 122-123).

The southwest corner of Oklahoma is marked by the Kidder monument, which was established in 1902 by the General Land Office. According to Shmidl (1935, p. 95), the station was marked by a stone post 10 x 14 x 45 in. projecting 18 in. above the surface of the ground, although both Douglas (1923, p. 153) and Van Zandt (1959, p. 123) stated that the post was 10 x 10 x 45 in. In 1923 a standard disk station mark was set in the center of the top of the stone and stamped "Kidder, 1902."

The northeast corner of Texas was established in 1928 and marked by a concrete monument with a base 30 in. square, set 24 in. into the ground. The base is surmounted by a galvanized iron form 24 in. in diameter at the base, 18 in. in diameter at the top, and 42 in. high. The monument is marked "The Supreme Court of the United States, Northeast corner of Texas, 1928" (Shmidl, 1935, p. 118).

The geodetic line between the Texas Panhandle and Oklahoma as now marked is 4,040 ft east of the 1859-60 line at the south end and 880 ft east of this line at the north end. The strip of land between the two lines has an area of about 44.6 sq mi, which the Supreme Court decision determined to be in Texas, not in Oklahoma.

The north line of the Texas Panhandle, which is the south boundary of the "public land strip," now the Oklahoma Panhandle, was fixed by statute at latitude 36°30′ N. The line was surveyed by Clark in 1860, and 17 monuments were erected.

Kansas

Kansas was admitted to the Union with its present boundaries. It was the first state to be admitted having meridional boundaries referenced to the Washington meridian, which passes through the dome of the old Naval Observatory in Washington, D.C.

The south boundary of Kansas was surveyed in 1857. The initial point on the 37th meridian at the west boundary of Missouri was determined from astronomic observations to be longitude 94°40′26.3″ W. The General Land Office resurveyed the line in 1872 from the 166th mile to the 266th mile, and in 1873 from the 207th mile to the 268th mile.

In 1902 two boundary stones on the Kansas-Oklahoma line were located by triangulation and marked with sandstone posts 5 x 12 x 20 in. projecting 9 in. above ground and marked "K" on the north side and "I T" on the south side (Van Zandt, 1976, p. 138–139). The 160th milepost is marked "160" on the top, and its location is latitude 36°59′54.030″ N and longitude 97°54′01.749″ W. The 163d milepost is marked "163" on the top, and its location is latitude 36°59′54.775″ N and longitude 97°57′16.233″ W (U.S. Geological Survey, oral communication, 1983).

Colorado

Colorado was organized as a Territory on February 28, 1861, with the same boundaries as the present state. Twice Congress voted to admit Colorado to statehood, but each time the bills were vetoed by the President; the principal reason given was the scanty population. However, a third enabling act, without a change in boundaries, was approved March 3, 1875. By proclamation, dated August 1, 1876, the President declared the admission complete.

In 1858–59 the south boundary of Colorado was surveyed by a Mr. Macomb from the southeast corner to the 103d meridian. The act of March 3, 1873, provided for the survey of the eastern part of the south boundary of Colorado from the southeast corner of the state to the 103d meridian and the east boundary of New Mexico, which lies between the northwest corner of Texas and the 37th parallel of north latitude. These surveys were made in 1873 and 1874 by U.S. deputy surveyor John G. Major and were approved by the Commissioner of the General Land Office on July 29, 1874.

The south boundary of Colorado west of the 103d meridian was surveyed by U.S. Surveyor E. N. Darling, presumably along the 37th parallel of latitude; however, subsequent investigation showed that gross errors in alignment and measurements existed. In 1902 Congress authorized the resurvey of the entire line between the State of Colorado and the Territories of New Mexico and Oklahoma. The survey was made by H. B. Carpenter in 1902–03, but the joint resolution passed by Congress for its acceptance as the legal boundary was vetoed by the President. The Carpenter line differs materially from the Darling line, being north of it in places and south of it in others. At the east end the Carpenter line is more than half a mile north of the boundary of the survey of 1858.

The U.S. Supreme Court, in an opinion dated January 26, 1925, held that the Darling line was the correct one because of its acceptance by Colorado and by the federal government, and a resurvey of the line was ordered. The court appointed Arthur D. Kidder of the U.S. Bureau of Land Management as commissioner to resurvey the Darling Line.

Computations

The distances between points in Oklahoma were computed by determining the differences in latitude or longitude and converting to statute miles accord ing to the values given in table 4 of U.S. Geological Survey Bulletin 640 (Douglas, 1916).

Computation of an East-West Distance

The maximum east-west distance across the State is from the southwest corner of Missouri to the southwest corner of the Oklahoma Panhandle at latitude 36°30′:

Longitude of the southwest corner of Oklahoma Panhandle: 103°00′06.835″
Longitude of the southwest corner of Missouri: 94°37′03.498″

$$\begin{array}{r} 103^\circ 00' 06.835'' \\ \underline{94^\circ 37' 03.498''} \\ 8^\circ 23' 3.337'' \end{array}$$

At latitude 36°30′, 1 second of arc equals 81.65 ft, hence:

30,183.337 x 81.65 = 2,464,489.46 ft = 446.76 mi

Computation of a North-South Distance

The maximum north-south distance lying wholly within Oklahoma is from a point on the south side of Mud Lake in McCurtain County, northward to a point near the northeast corner of Oklahoma.

Latitude of the northeast corner of Oklahoma: 36°59′54.752″
Latitude of the south side of Mud Lake: 33°39′35.41″

$$\begin{array}{r} 36^\circ 59' 54.752'' \\ \underline{33^\circ 39' 35.41''} \\ 3^\circ 20' 19.342'' \\ = 12{,}119.342'' \end{array}$$

The value of ft-per-second of arc along a meridian increases progressively northward from the equator; hence the total distance in seconds in converted into feet by increments:

Latitude	Distance (sec)		Value (ft/sec)	Distance (ft)
33	1,224.590	x	101.08	= 123,781.55720
34	3,600.000	x	101.09	= 363,924.00000
35	3,600.000	x	101.11	= 363,996.00000
36	3,594.752	x	101.13	= 363,537.26976
				1,215,238.82696
				= 230.16 mi

The distance along the Red River boundary between Oklahoma and Texas was determined from U.S. Geological Survey topographic maps. Using a map measurer, the boundary was measured a minimum of three times on each map; the average distance (in inches) was multiplied by 0.379 for 7.5-minute topographic maps (scale 1:24,000) and 0.986 for 15-minute topographic maps (scale 1:62,500). A total of 60 7.5-minute topographic maps and eight 15-minute topographic maps were used. The total distance was computed to be 603.79 mi.

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NEW WATER ATLAS PUBLISHED BY OGS

Oklahoma Geological Survey Hydrologic Atlas 9, *Reconnaissance of the Water Resources of the McAlester and Texarkana Quadrangles, Southeastern Oklahoma*, has been released by the Survey. The atlas is the ninth and final issue of a series produced under a cooperative agreement entered into in 1967 between OGS and the Water Resources Division of the U.S. Geological Survey to make a regional assessment of the availability and quality of Oklahoma's water resources.

The new atlas, compiled by USGS hydrologists Melvin V. Marcher and DeRoy Bergman, covers a large area of approximately 7,200 sq mi in the southeastern part of the State, including all or part of eight counties: McCurtain, Pushmataha, Choctaw, Le Flore, Latimer, Pittsburg, Atoka, and Bryan.

Each atlas in the series contains four large, colorful map sheets offering graphic information on the amount and quality of both ground water and surface water, including availability, chemical analyses, discharge, precipitation, runoff, streamflow records, and surface area and capacity of lakes. One sheet offers an updated areal geologic map at a scale of 1:250,000 (1 in. equals approximately 4 mi). The geologic map in HA-9 was compiled largely by OGS geologist Robert O. Fay.

Information on the geology is essential to a hydrologic study of the southeastern corner of the State, with the Pennsylvanian sandstones and shales of the Arkoma Basin in the north; the Cretaceous sands, shales, clays, limestones, and the extensive Quaternary terrace deposits of the Gulf Coastal Plain in the south; and the extremely complex geology of the Ouachita Mountains in the center of the quadrangle.

With the publication of HA-9, regional hydrologic information is now available for all of Oklahoma. Other atlases in this series include HA-1, on the Fort Smith Quadrangle in east-central Oklahoma; HA-2, on the Tulsa Quadrangle of northeastern Oklahoma; HA-3, on the Ardmore–Sherman Quadrangles of south-central Oklahoma; HA-4, on the Oklahoma City Quadrangle of central Oklahoma; HA-5, on the Clinton Quadrangle of west-central Oklahoma; HA-6, on the Lawton Quadrangle of southwestern Oklahoma; HA-7, on the Enid Quadrangle of north-central Oklahoma; and HA-8, on the Woodward Quadrangle of northwestern Oklahoma. Panhandle counties were covered earlier by the USGS.

These hydrologic atlases can be obtained from the Oklahoma Geological Survey at the address given inside the front cover. The price is $6 for HA-9, HA-3, and HA-4. The current price for HA-5, HA-6, HA-7, and HA-8 is $5, and for HA-1 and HA-2, $3.

HARRISON DISCUSSES AIPG AND ENERGY PROJECTS

William E. Harrison, OGS petroleum geologist and geochemist, recently attended the national meeting of the American Institute of Professional Geologists in Jackson, Wyoming, and visited federal offices in Denver and Salt Lake City about ongoing energy-research programs in Oklahoma.

As president of the Oklahoma Section of AIPG, Harrison represented the State on the Advisory Board Committee that proposes and recommends national AIPG policy and programs. Among the topics considered by the Advisory Board this year were state registration of geologists and AIPG evaluation of geology programs in American colleges and universities.

"State registration of geologists is a very sensitive issue nationwide, and I think the practicing earth scientists in Oklahoma will be among the last in the country to support registration," Harrison said. The Oklahoma Section is the third largest in the United States, with Texas and Colorado ranking first and second, respectively.

"AIPG is the only organization currently working to provide an evaluation of geology programs in this country, and we are looking carefully at other professions that monitor educational standards at the national level," Harrison added.

While enroute to the AIPG meeting, Harrison visited the Oil and Gas Branch of the U.S. Geological Survey to discuss an evaluation of petroleum-source rocks in northeastern Oklahoma. USGS workers recently came to Norman to discuss the results of their investigation and to get rock samples from the Oklahoma Geological Survey Core and Sample Library.

Harrison also gave a progress report to personnel at U.S. Department of Energy (DOE) offices in Salt Lake City on a project to evaluate the low-temperature geothermal resources in Oklahoma.

The DOE-funded effort is designed to identify regions in Oklahoma having potential for small-scale geothermal development, such as residential and light-industry areas. The project will be completed in 1984.

NEW BULLETIN CHARACTERIZES MC KENZIE HILL LIMESTONE IN WICHITA AND ARBUCKLE MOUNTAINS

Trilobites, Biostratigraphy, and Lithostratigraphy of the McKenzie Hill Limestone (Lower Ordovician), Wichita and Arbuckle Mountains, Oklahoma has been released by the Oklahoma Geological Survey as OGS Bulletin 134. The new bulletin represents a significant contribution to the knowledge of trilobite faunas in Oklahoma and to Lower Ordovician stratigraphy in the Wichita and Arbuckle Mountains.

The author of the 54-page volume is James H. Stitt, professor in the Department of Geology at the University of Missouri, Columbia. This work is a continuation of Stitt's earlier studies of Cambrian and Ordovician trilobites in Oklahoma, two of which have been issued previously as OGS bulletins.

Trilobites, three-segmented, ovoid arthropods, are found only in rocks of the Paleozoic Era. When recovered they are often rolled into a ball like large pill bugs and are one of the most fascinating types of fossils to amateur collectors. And they also are of value in dating the ages of rocks in which they occur and in worldwide correlations of rock strata.

Stitt states in the new bulletin that the rocks in the Wichita and Arbuckle regions of southern Oklahoma "provide the best opportunity in the midcontinental and eastern United States to collect and study the faunas and depositional environments of the Lower Ordovician."

For the purposes of this study, he collected and prepared more than 900 specimens, from which he has identified and described 17 species that are assigned to 10 genera. These include one new genus and four new species.

In addition to the paleontologic descriptions and zonations, the bulletin contains lithologic descriptions of member beds of the McKenzie Hill Limestone. With information gained from evaluating both the trilobite zones and lithologic zones, Stitt has been able to determine for the first time some relationships between the Lower Ordovician formations of the Arbuckles and the Wichitas. He states that the results of this study also will make possible better correlations between rocks of this age in southern Oklahoma and in other regions of the United States.

OGS Bulletin 134 can be obtained from the Oklahoma Geological Survey at the address given inside the front cover. The price is $12 for a hardback copy, $8 for paperback.

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Use of Drill Hole Information in the Search for Metallic Mineral Accumulations, Eastern Kansas

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Base metal mining in Kansas has been limited to shallow (less than 110 meter) zinc-lead mines in the Tri-State district of Missouri, Kansas and Oklahoma. Efforts to find substantial additional reserves nearby have failed. However, based upon host rock lithology and structure one concludes that other areas in the state offer good exploration targets. Existing drill hole information consisting of well cuttings and geophysical logs provides valuable data concerning the buried sedimentary units and the basement rocks which may be host to several kinds of mineral accumulations.

The west side of the Cherokee Basin is delineated by the NNE trending Humboldt Fault zone. The uplifted west block which constitutes the Nemaja Uplift shows a vertical displacement of about 250 meter[s] in the lower Paleozoic units. Major NW–SE trending fault zones extending into the Tri-State district affect the rocks in the Cherokee Basin. Mineralization in the district is controlled by structures showing the same NW and NNE trends. Examination of numerous drill holes penetrating the lower Paleozoic section has indicated

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OKLAHOMA ABSTRACTS is intended to present abstracts of recent unpublished papers relating to the geology of Oklahoma and adjacent areas of interest. The editors are therefore interested in obtaining abstracts of formally presented or approved documents, such as dissertations, theses, and papers presented at professional meetings, that have not yet been published.

the existence in places of abnormal quantities of metallic minerals. Pyrite (up to 50% over a 12 meter interval), Magnetite (up to 50% over a 5 meter interval), and sphalerite are the more common minerals encountered. A spatial relationship between mineralized units and the local structure is common. Crossplotting of data obtained from good quality geophysical logs offers a potential time saving avenue to identify anomalies, which can then be checked against existing samples. [1-2]

A Structural Analysis of the Cambrian-Ordovician Strata on the North Flank of the Wichita Mountains, Oklahoma

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The Limestone Hills of the Wichita Mountains, Oklahoma, are an integral part of the structural development of the mountains and the Wichita Fault System. The problem with this fault system is that the tectonic theories attributed to the creation of the Limestone Hills and the Wichita Mountains are contradictory. One theory is that the tetonic mechanism of this region was a block fault system. The other theory is that at least one of the major faults in the Wichita Fault System, the Meers Fault, is a part of a left lateral fault system. A structural analysis of the Limestone Hills; T 3-5 N, R 11-13 W; indicates that the latter theory is correct. Along all the faults trending N 60 W in this area, there are en-echelon folds trending northwest-southeast 10 to 30 degrees from each fault's trend. This indicates that these faults are synthetic left lateral strike-slip faults. The Blue Creek Canyon Fault; T 4 N, R 13 W; through Blue Creek Canyon is [an] antithetic right lateral strike-slip fault, which offsets two left lateral faults of the same name. And along the Stony Point Fault Zone in this region, there are a number of conjugate antithetic fractures, which have offset the Stony Point's faults. All of these faults, fractures, and folds are intimately related to the Meers Fault. The overall view of the Limestone Hills indicates various stages of development of a left lateral wrench fault system. [2]

Gravity and Magnetic Evidence for Keweenawan-Aged Diabase Intrusions in Northern Oklahoma

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Evidence for Keweenawan-aged diabase intrusions in the upper crust in northern Oklahoma is postulated on the basis of some 400 newly acquired

gravity and magnetic stations. The study area occupies parts of Kingfisher, Blaine, Major, Garfield, and Grant Counties, Oklahoma.

Interpretation of the data was accomplished using two modeling techniques—the Talwani–Ewing modeling algorithm for the magnetic data and a "vertical prism" styled modeling algorithm for the gravity data. Interpretation proceeded by using the constant-density prism method to iteratively predict a diabase intrusion pattern into an otherwise undeformed granitic basement. A final solution was obtained that showed agreement between observed and computed gravity anomalies of 1 mgal or less for most station locations. This geometrical configuration of diabase intrusions was then used to explain the observed magnetic anomalies. Good agreement between observed and calculated magnetic anomalies was reached for both purely induction-type computed anomalies considering a variable magnetic susceptibility, and anomalies computed using the concept of magnetic remanence as a major contributing factor.

Conclusions obtained from these modeling studies include the concept that the gravity and magnetic anomalies in this study area may be related to the larger Greenleaf anomaly of Kansas and the Mid-Continent Gravity High. Given the interpretation that the Mid-Continent Gravity High is indicative of a Precambrian (Keweenawan) rift system, then these intrusions envisaged could be evidence for an extension of this rift system into Oklahoma. [3]

Tectonics of the Oklahoma City Uplift

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The Oklahoma City Uplift consists of a number of small crustal blocks that were raised sharply along the axis of the Nemaha Ridge during the Late Mississippian and Early Pennsylvanian. Numerous earthquakes have occurred about 10 to 20 km west of the main axis of the Oklahoma City Uplift since 1908. A study was initiated to determine if there is a cause and effect relationship between the pre-1976 and recent earthquake activity to some of the faults associated with the Oklahoma City Uplift.

Structure-history cross sections of the Arbuckle–Simpson contact and isopach maps of selected lithologic intervals reveal a complex history of adjustments along faults in the vicinity of the Oklahoma City Uplift. Our interpretation of the data resulted in the delineation of eight fault zones that can be grouped into two distinct categories. Category (1), which includes the Oklahoma City and McClain County Fault zones, contains faults of constantly increasing displacements from early to late Paleozoic time. For example, the Oklahoma City Fault displacement was 536 m by the end of Oswego deposition; displacement continued to increase to 694 m by the end of Oread deposition and reached 726 m at the present. Category (2) faults, of which there are six, exhibit both increasing displacements from early to late Paleozoic time. Do the increasing displacements of category (1) faults suggest a deep propagation of these faults into the Central Oklahoma Granite basement complex, whereas the history of oscillating movements along category (2) faults suggest a much shallower propagation of these fault zones with depth? [5]

Distribution of Radium-226 in the Cambro-Ordovician Groundwater System, Tri-State Region, Kansas, Missouri, Oklahoma

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Radionuclides in drinking water pose a potential health hazard to consumers and water samples from all of the public water supplies in the Tri-State region of Kansas, Oklahoma, and Missouri either exceed the 5 pCi/1 permissible level for radium-226 set by US EPA or contin measurable quantities of this radionuclide. The purpose of this study was to determine the distribution, geochemical and hydrogeologic controls of radium-226 in the Tri-State region. All of the public water supplies obtain water from the Cambro-Ordovician aquifers in the Tri-State region. Dominant lithologies include dolomite and sandstone. The westward dip of these aquifers away from the center of the Ozark Dome is altered by tight folding and faulting. Semi-confined fresh water flow is from east to west except in areas of heavy pumpage. Radium-226 activities vary from one to 11 pCi/1 (1pCi/1 is equivalent to $1x10^{-12}$gms) and are highest along the eastern margin of the transition from fresh to salt water and at one location north of Baxter Springs, Kansas. Radium-226 activities show a significant correlation with Li, B, Sr, F, Cl and specific conductance and also seem to be higher in the presence of H_2S. Decreasing uranium concentrations along a traverse beginning in the fresh water area and ending in the transition zone [suggest] that uranium is precipitating where H_2S is present. Activity ratio values are all above one along the traverse. The most likely hypothesis explaining the distribution of radium-226 is that this isotope is a decay product of U-238 that is being precipitated by changes in redox conditions in the aquifer. This process may be modified by co-precipitation or ion exchange with other ions. [5-6]

Magnetic Intensity and Bouguer Gravity of the Central Arkoma Basin of Arkansas

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A total field magnetic intensity map and a Bouguer gravity map have been produced for an 828 sq. mi. area in the central portion of the Arkoma basin of

Arkansas. Stations are spaced at approximately one and two miles for the magnetic and gravity maps, respectively.

Both magnetic and gravity values tend to decrease in a southerly direction. This regional decrease in the potential field values may be associated with greater depth to the igneous basement.

Several closed contour magnetic anomalies occur in the area ranging from about 50-400 gammas in magnitude. The largest of these anomalies is characterized by a steep gradient and a sharply outlined extent, which is interpreted to imply an intrabasement source of rock having a high magnetic susceptibility. Some of the smaller anomalies may represent suprabasement sources.

The Bouguer gravity map is dominated by a large, circular anomaly which is 10 mgal in magnitude. This anomaly corresponds to the largest magnetic anomaly in map position. The steepness and shape of the Bouguer anomaly is considered to mean a significant horizontal change in the density of the basement. The gravity and magnetic data for this area are considered to be related to a mafic igneous intrusion in the basement.

Modelling of source bodies based on magnetic and gravity values provide a more quantitative view of intrabasement and suprabasement features, surface structural patterns, and large scale photolineaments in the Arkoma basin. [6]

Stratigraphic Relationship of Desmoinesian Coals in the Kiowa Syncline, Pittsburg County, Oklahoma

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Increased drilling for natural gas in the Arkoma Basin has provided detailed data on coalbeds within the Kiowa syncline, Pittsburg Co., Oklahoma. The Barringer No. 1-11, a type well, located in sec. 11, T. 5 N., R. 15 E., is a typical example of a recently air-drilled well in the syncline. The coalbed characterization activity was a result of the Methane-Recovery-from-Coalbeds Project which is a joint cooperative effort by DOE/Industry to delineate the coalbed methane resources in the U.S.

A logging suite consisting of gamma ray, gamma-ray spectral, electric, caliper and compensated density was used to develop a coal analysis log for the depth interval of 360 ft. (Boggy Formation) to 5070 ft. (Hartshorne Formation). A maximum of 18 coal bearing zones were penetrated having a total thickness of 33.3 feet. These coalbeds were identified and correlated with other recognized beds in off-set wells. This coring and logging activity provided the consistency necessary to extend this information to other parts of the syncline.

Synthesis of all available data indicates there is some lateral discontinuities in the coals. Coal properties are presented, such as thickness, proximate analysis, gas content, natural radioactivity, and rank. With an understanding of the depositional setting of the coals, the characteristics and variability of many of these properties can be predicted for the coals in the Kiowa syncline. Additional coring is needed to confirm the predicted correlations and to determine the coalbed gas content. [16]

Chemistry of Late Alkali Amphiboles from Wichita Granites

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Small pegmatitic veins, pods and seams are distinct, late associates of some of the younger granites of the Wichita Mountains igneous complex. These commonly contain black alkali amphiboles whose composition has been studied by electron microprobe methods. Samples were analyzed from veins from two granites: Quanah and Lugert. The amphiboles are all similar in being extremely Fe-rich (34-36 wt% expressed as FeO) and Mg-poor (<0.1 wt%). The amphiboles are distinctly different in certain crucial aspects, however:

Oxide/Element (wt%)	Quanah Veins	Lugert Veins
Na_2O	9.5–10.0	5–6
Al_2O_3	0.3–0.7	>1.0
CaO	0.2–0.9	3.5–4.0
TiO_2	<1.0	>1.0
MnO	0.7–1.0	>2.0
F	2–3	~1

These phases are some of the more Fe- and F-rich known among the sodic group. Those from the Quanah are much more sodic than standard riebeckite. Both the Quanah and the Lugert varieties are best termed arfvedsonite.

The higher F content in the Quanah-related ones inplies either a higher temperature of crystallization compared to the Lugert, and/or a much more F-rich source fluid. One explanation for their origins and differences starts with granites having the same original bulk chemistry but, due to emplacement position, having different histories of fluid expulsion. [16]

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