OKLAHOMA GEOLOGY NOTES

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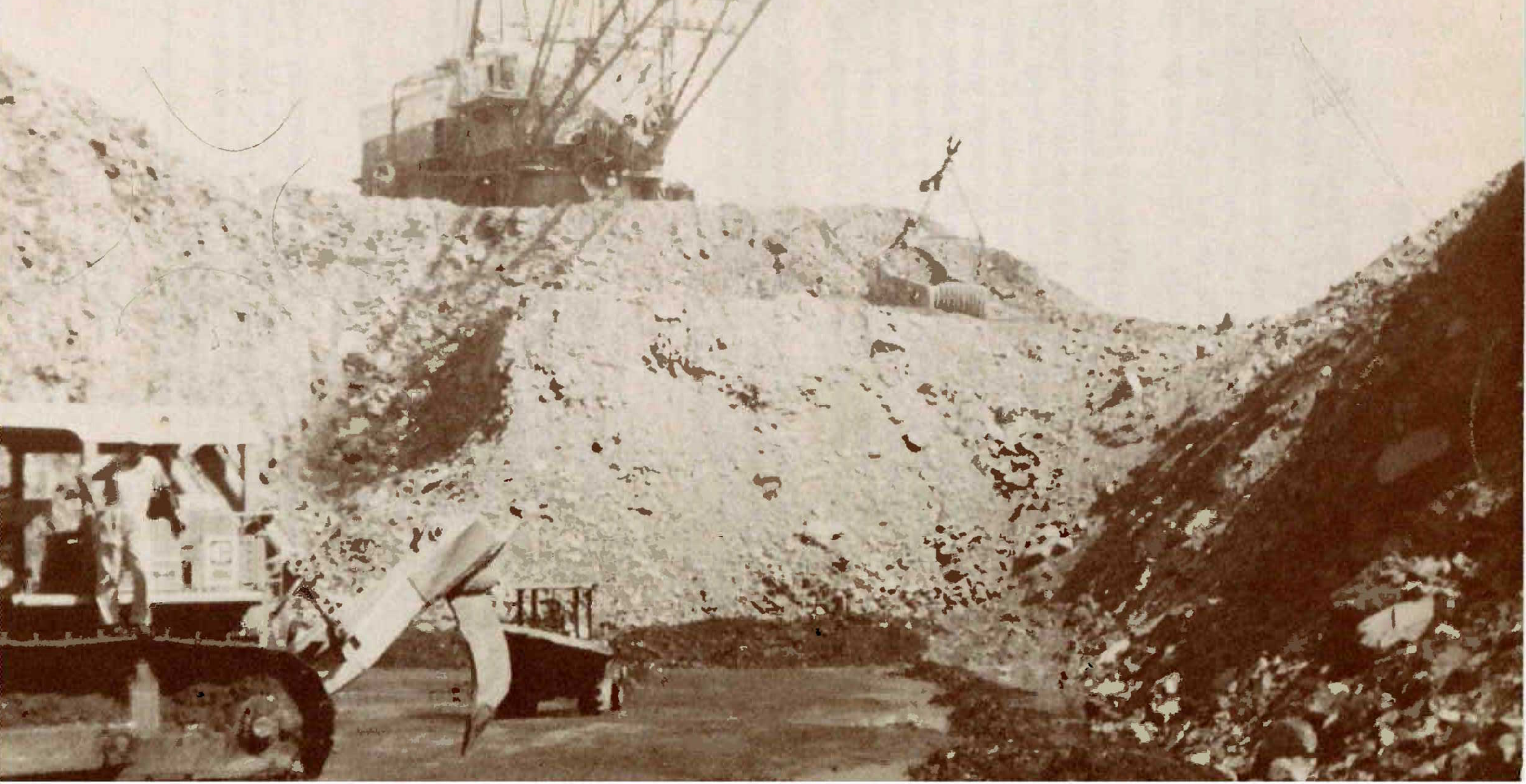

Cover Picture

SURFACE MINE IN STIGLER COAL HASKELL COUNTY, OKLAHOMA

This 1974 photograph shows the Stigler No. 9 Mine of Garland Coal and Mining Co. (of Fort Smith, Arkansas), 1 mile north of Stigler, Haskell County, Oklahoma, sec. 5, T. 9 N., R. 21 E. The coal bed mined in this 24-hour-a-day operation is the Stigler. Garland leased the coal many years ago from the U.S. Bureau of Land Management.

A dragline with a boom 200 feet long and a bucket whose capacity is 30 cubic yards (visible in background) has removed 70 feet of overburden, exposing the Stigler coal bed, 13–18 inches thick and of medium-volatile bituminous rank. The overburden consists of mudstone, siltstone, the thin Stigler rider coal, and underclay. All units are part of the McAlester Formation of Middle Pennsylvanian (Desmoinesian) age. Prior to stripping, the operator removes two zones of soil, which is set aside for later replacement following mining and grading.

The foreground of this photo shows a bulldozer equipped with a ripper, which is used to break the coal into blocks; these blocks are scooped up by a front-end loader (not shown). A machine with a rotating brush (visible behind the ripper) has cleaned the surface of the coal bed by removing clay, dust, and other contaminants.

Trucks haul the coal directly to Port Carl Albert, about 10 miles east of Stigler, for barge transport down the McClellan-Kerr Arkansas River Navigation System and the Mississippi River to New Orleans, where the coal is transferred to ships bound for Japan by way of the Panama Canal.

—*S. A. Friedman*

Editorial staff: William D. Rose and Elizabeth A. Ham

Oklahoma Geology Notes is published bimonthly by the Oklahoma Geological Survey. It contains short technical articles, mineral-industry and petroleum news and statistics, an annual bibliography of Oklahoma geology, reviews, and announcements of general pertinence to Oklahoma geology. Single copies, $1.00; yearly subscription, $4.00. All subscription orders should be sent to the address on the front cover.

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

This publication, printed by The University of Oklahoma Printing Services, Norman, Oklahoma, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes 1971, Section 3310, and Title 74, Oklahoma Statutes 1971, Sections 231-238. 1,800 copies have been prepared for distribution at a cost to the taxpayers of the State of Oklahoma of $2,336.

STATISTICS IN OKLAHOMA'S PETROLEUM INDUSTRY, 1978

Donald A. Preston[1]

Drilling Activity

Drilling activity in 1978 continued its upward trend in Oklahoma (table 1, fig. 1). Exploratory-test completions numbered 502 (up 6 percent), and development-well completions, 5,320 (up 19 percent). The completion success ratio for both drilling categories remained the same as last year, 30 percent for exploratory and 72 percent for development wells. The average footage drilled increased only slightly for development wells but showed a significant jump of almost 600 feet for exploratory tests.

Roger Mills County (table 2), with nine gas and two oil discoveries, and Canadian County, with six oil and four gas discoveries, posted the best exploration records for the State. Canadian County had a remarkable 91-percent exploratory success ratio; the county also substantially exceeded all other counties in footage drilled (all categories), closing the year with a total of 2,379,835 feet. Garfield County was second at 1,568,226 feet, with six other counties attaining

TABLE 1.—DRILLING ACTIVITY IN OKLAHOMA, 1978

(Source: American Petroleum Institute; Petroleum Information Corp. from *World Oil*, v. 188, no. 3, Feb. 15, 1979)

	1978				1977
	Oil	Gas	Dry	Total	Total
All wells					
Number of Wells	2,499	1,507	1,816	5,822	4,939
Total footage				29,860,456	24,277,757
Average footage				5,129	4,915
Exploratory wells					
Number of completions	64	89	349	502	473
Percentage of completions				30	30
Total footage				3,453,125	2,980,545
Average footage				6,879	6,301
Development wells					
Number of completions	2,435	1,418	1,467	5,320	4,466
Percentage of completions				72	72
Total footage				26,407,331	21,297,212
Average footage				4,964	4,769

[1] Geologist, Oklahoma Geological Survey.

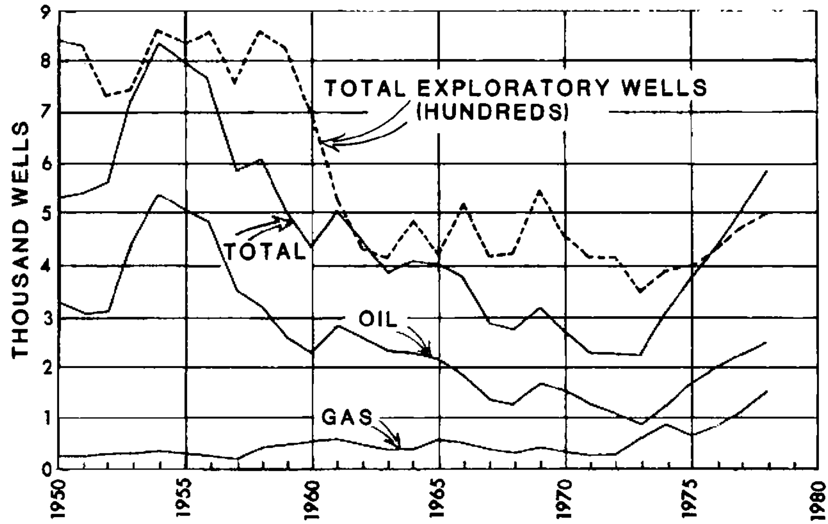

Figure 1. Graph showing total wells drilled, oil wells completed, and gas wells completed in Oklahoma, 1950–78. (Source: **Oil and Gas Journal.**)

totals greater than 1 million feet. Five tests were drilled deeper than 20,000 feet; more than half the tests (54 percent) penetrated less than 5,000 feet, and 89 percent of the tests were drilled to less than 10,000 feet.

Figure 2 depicts the maximum 1978 drilling depths by county for either development or exploratory tests in Oklahoma. The deepest drilling was generally concentrated in west-central Oklahoma (the Anadarko Basin); the shallowest was in the northeastern part of the State.

World Oil (v. 188, no. 3) attributes 93 percent of Oklahoma's 1978 wells to independent operators, as compared to 84 percent nationwide. In states averaging more than 2,000 wells in 1978, Oklahoma was third highest in independent-operator activity.

Figure 3 graphically illustrates the historical behavior of exploratory activities and hydrocarbon wellhead prices in Oklahoma from 1955 through 1978. The drilling and discovery data are expressed as 5-year moving averages to emphasize trends. Wellhead prices have been converted to constant 1967 dollars.

A substantial downturn of drilling and oil discoveries in Oklahoma began in 1959–61. This trend bottomed out in 1975. Oil discoveries and exploratory-drilling trends have been closely related from 1955 to 1979. Gas discoveries, on the other hand, have shown a greater independence from drilling activity. The price histories of oil and gas exhibit a similar disparity. The price-history graph (fig. 3) shows a gradual but consistent increase in gas prices between 1955 and 1970, whereas oil prices in that period underwent steady erosion. Prices sharply increased in 1974, and since then the trends of exploratory drilling, discoveries, and prices have all been upward.

TABLE 2.—COMPLETION DATA AND DEPTH INFORMATION FOR WELLS DRILLED IN OKLAHOMA DURING 1978

(Source: American Petroleum Institute)

County	Total number of wells drilled	Completions		Percent completions	Number of wells drilled in following total-depth ranges (in feet):[1]				
		Oil	Gas	(Oil and gas)	0-5,000	5,000-10,000	10,000-15,000	15,000-20,000	>20,000
Alfalfa	55	24	15	65	3	52	-	-	-
Atoka	3	0	0	0	1	-	2	-	-
Beaver	165	18	90	65	21	133	-	-	-
Beckham	38	0	24	63	14	2	1	18	3
Blaine	143	14	83	68	2	51	90	-	-
Bryan	6	0	4	67	3	3	-	-	-
Caddo	67	17	26	64	10	2	53	2	-
Canadian	242	101	113	88	-	154	84	-	-
Carter	97	72	1	75	49	37	2	3	-
Cimarron	39	2	11	33	29	10	-	-	-
Cleveland	45	17	3	44	-	44	1	-	-
Coal	25	1	14	60	7	14	3	-	-
Comanche	22	9	1	45	18	1	2	-	1
Cotton	28	17	0	61	28	-	-	-	-
Craig	38	0	25	66	38	-	-	-	-
Creek	183	125	14	76	178	-	-	-	-
Custer	65	13	23	55	-	2	55	7	-
Dewey	101	33	31	63	2	62	30	4	-
Ellis	73	13	29	58	1	40	30	1	-
Garfield	239	180	30	88	16	220	-	-	-
Garvin	85	22	5	32	39	42	1	-	-
Grady	91	21	41	68	7	8	62	9	1
Grant	45	10	6	36	18	27	-	-	-
Greer	67	2	45	70	66	1	-	-	-
Harmon	2	0	0	0	2	-	-	-	-
Harper	98	10	39	50	1	97	-	-	-
Haskell	37	0	19	51	7	29	1	-	-
Hughes	135	24	56	59	131	4	-	-	-
Jackson	13	0	1	8	9	4	-	-	-
Jefferson	10	2	0	20	7	3	-	-	-
Johnston	7	0	0	0	6	1	-	-	-
Kay	131	26	80	81	130	-	-	-	-
Kingfisher	121	94	18	93	-	119	1	-	-
Kiowa	37	6	6	16	36	1	-	-	-
Latimer	11	0	7	64	-	9	2	-	-
Le Flore	45	0	18	40	3	32	9	1	-
Lincoln	114	41	27	60	98	13	-	-	-

[1] List does not include re-entry wells that have been drilled deeper.

TABLE 2.—*Continued*

County	Total number of wells drilled	Completions Oil	Completions Gas	Percent completions (Oil and gas)	Number of wells drilled in following total-depth ranges (in feet):[1] 0-5,000	5,000-10,000	10,000-15,000	15,000-20,000	>20,000
Logan	246	170	19	77	34	200	-	-	-
Love	26	13	1	54	11	9	2	1	-
McClain	43	19	3	51	6	24	13	-	-
McCurtain	1	0	0	0	1	-	-	-	-
McIntosh	56	1	43	79	54	1	-	-	-
Major	175	91	69	91	2	157	11	-	-
Marshall	30	9	10	63	18	9	-	1	-
Mayes	3	2	0	67	3	-	-	-	-
Murray	13	3	0	23	9	3	-	-	-
Muskogee	63	25	15	63	63	-	-	-	-
Noble	91	42	9	56	63	26	-	-	-
Nowata	146	113	19	90	144	-	-	-	-
Okfuskee	82	31	25	68	82	-	-	-	-
Oklahoma	23	9	4	57	3	20	-	-	-
Okmulgee	226	90	67	69	226	-	-	-	-
Osage	597	401	30	72	595	-	-	-	-
Pawnee	62	35	5	65	62	-	-	-	-
Payne	85	41	2	51	74	10	-	-	-
Pittsburg	65	0	50	77	43	16	5	-	-
Pontotoc	92	64	7	77	91	1	-	-	-
Pottawatomie	117	70	4	63	79	36	-	-	-
Pushmataha	4	0	3	75	2	1	-	1	-
Roger Mills	62	3	37	65	1	10	16	34	-
Rogers	31	22	7	94	30	-	-	-	-
Seminole	89	52	5	64	85	3	-	-	-
Sequoyah	12	0	5	42	3	9	-	-	-
Stevens	155	108	20	83	125	20	3	2	-
Texas	112	13	57	63	45	67	-	-	-
Tillman	8	4	0	50	2	6	-	-	-
Tulsa	53	34	7	77	52	-	-	-	-
Wagoner	24	13	1	58	24	-	-	-	-
Washington	101	83	2	84	101	-	-	-	-
Washita	9	0	3	33	-	-	4	5	-
Woods	105	15	43	55	3	101	-	-	-
Woodward	92	9	30	42	1	82	8	-	-
Totals	5,822	2,499	1,507	69 (avg.)	3,117 (54%)	2,028 (35%)	491 (9%)	89 (2%)	5 (<0.1%)

[1] List does not include re-entry wells that have been drilled deeper.

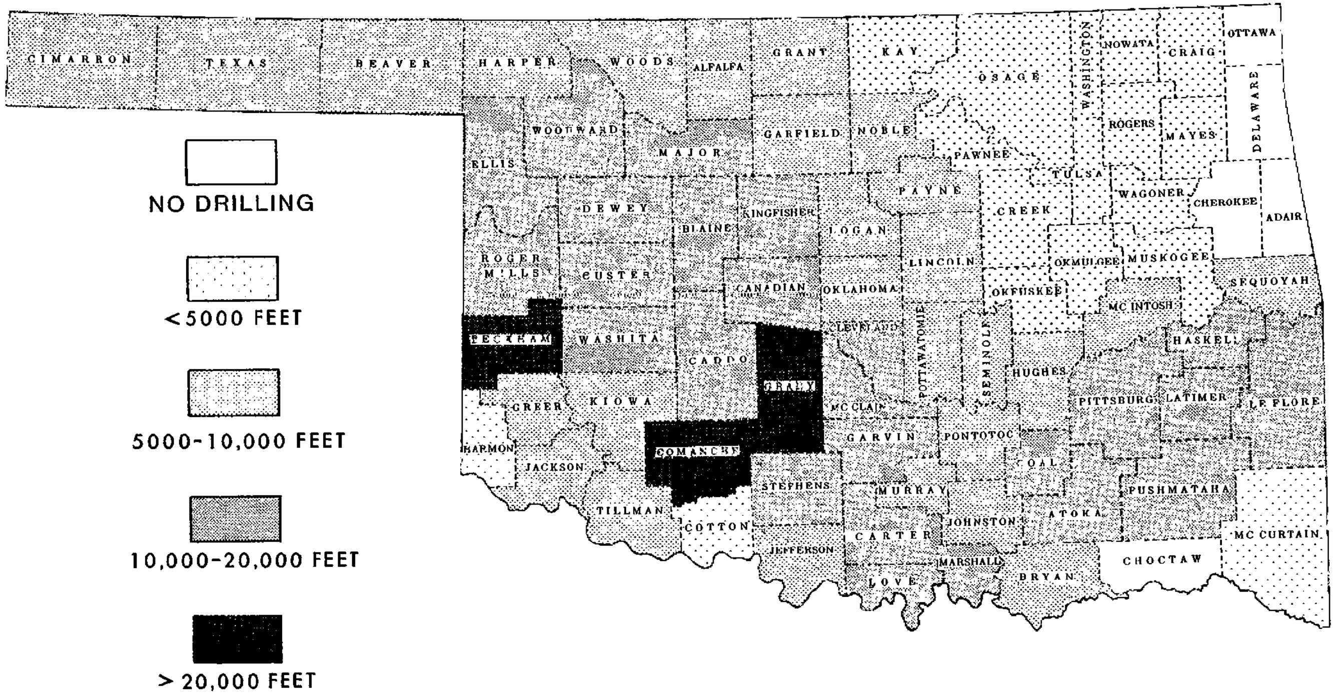

Figure 2. Map of Oklahoma counties Indicating maximum depth range of 1978 development or exploratory drilling.

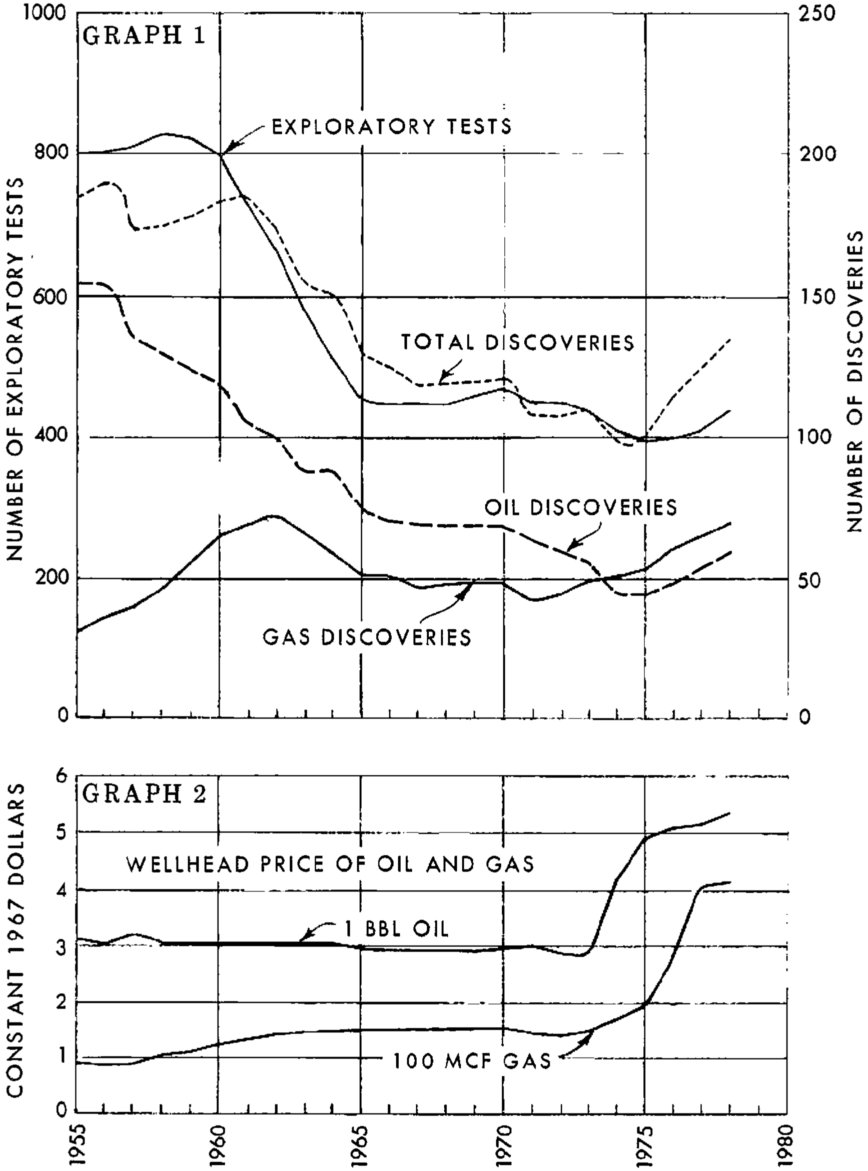

Figure 3. Graphs of exploratory activities and hydrocarbon prices in Oklahoma, 1955–78. Curves on graph 1 are 5-year moving-average trend lines; exploration-test curve related to scale on left; discovery curves related to scale on right.

Production and Reserves

Figures 4 and 5 reflect the continuing decrease in reserves for all categories of hydrocarbons produced in Oklahoma. Production has generally outstripped the addition of new reserves for the last several years: more than 20 for crude oil and more than 10 for gas.

Figure 4 shows a net reserves loss for the year of 0.2 trillion cubic feet of gas. The production-to-reserves ratio decreased from 7.04 in 1977 to 6.97 in 1978.

Figure 5 exhibits an extension of the downtrend of produced total liquid hydrocarbons in Oklahoma. Yearly output declined from 188 to 177 million barrels. Additions to reserves were up slightly, but net reserves had declined from 1,293 to 1,168 million barrels by year's end, yielding a production-to-reserves ratio of 6.60 as compared to 6.95 in 1977.

Table 3 is an historical listing of Oklahoma's annual production and mar-

Table 3.—Cumulative (through 1955) and Yearly (1956–78) Marketed Production and Value of Petroleum, Natural Gas, and Liquefied Natural Gas in Oklahoma[1]

Year	Petroleum		Natural gas		Natural-gas liquids[2]	
	Volume (1,000 bbls)	Value ($1,000)	Volume (MMcf)	Value ($1,000)	Volume (1,000 bbls)	Value ($1,000)
Through 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	80,096
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	N.A.
Totals	11,799,818	30,212,419	43,644,242	9,350,270	1,270,154	3,377,047[3]

[1]Preliminary figures for 1978.

[2]This format is restated from previous years to conform with the data supplied by the U.S. Department of Energy. These data were formerly supplied by the U.S. Bureau of Mines.

[3]Total does not include value for 1978.

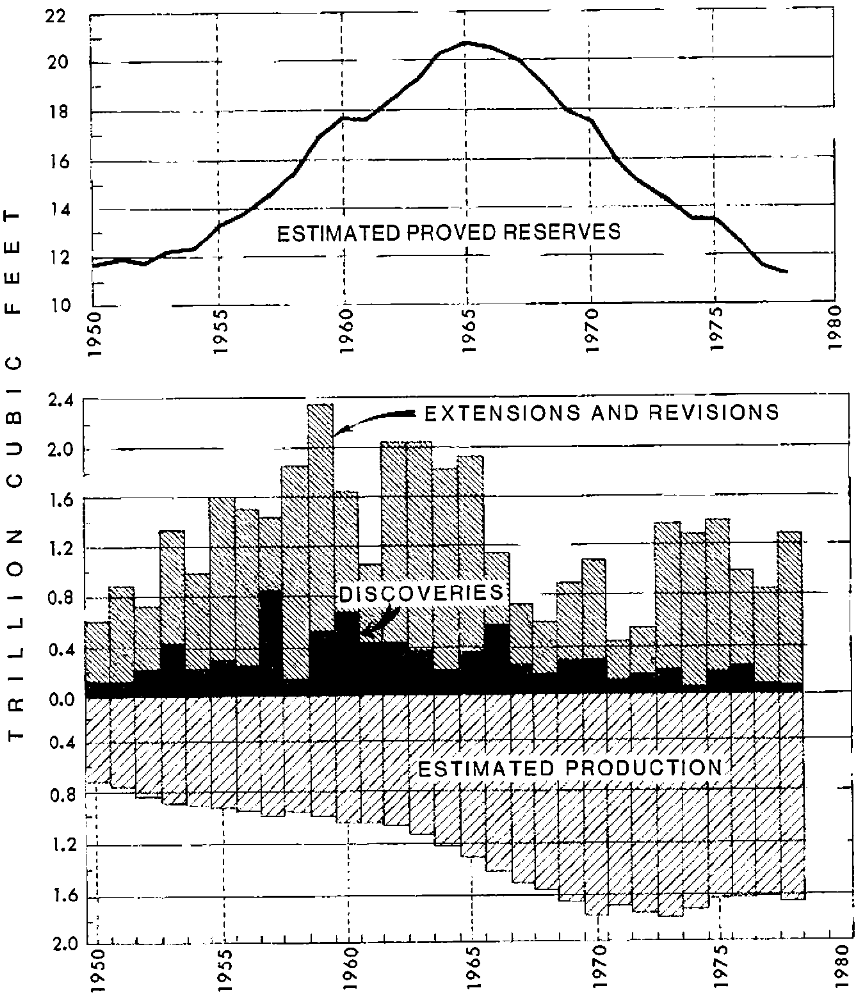

Figure 4. Graph showing statistics for estimated proved natural-gas reserves in Oklahoma, 1950–78. (Source: American Gas Association, annual reports.)

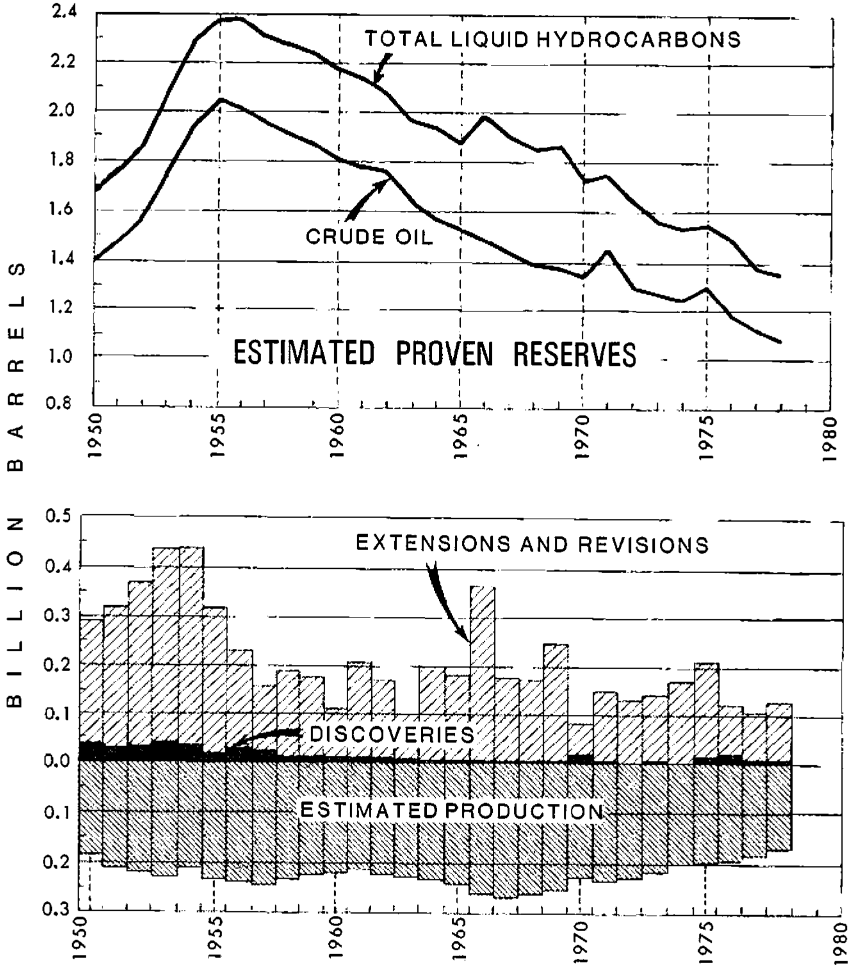

Figure 5. Graph showing statistics for estimated proved total liquid-hydrocarbon reserves in Oklahoma, 1950–78. (Source: American Petroleum Institute, annual reports.)

keted value of hydrocarbons from 1955 to 1979. The format of this listing has been revised from prior years to conform to the data categories as now provided by the U.S. Department of Energy, a service previously the responsibility of the U.S. Bureau of Mines.

Table 4 is a more detailed explanation of the State's production and marketing activities for the past year. The total hydrocarbons produced declined only slightly from 1977, whereas the marketed value of products showed a dollar gain. Crude-oil prices for the year averaged $10.90 per barrel. In all, 1,217 producing wells were added in 1978, although the average daily production per well dropped from 6.0 to 5.5 barrels.

Table 5 lists the 10 giant fields in Oklahoma (a giant oil field is defined as having more than 100 million barrels of estimated recoverable oil). Total 1978 oil production from Oklahoma's giant fields was 58,891,000 barrels versus 64,699,000 barrels for 1977, a drop of 9 percent. Approximately 89 percent of the reserves of these fields has been produced.

Once again, Oklahoma ranks third in natural-gas and fifth in crude-oil production.

TABLE 4.—HYDROCARBON PRODUCTION IN OKLAHOMA

	1977	1978
Crude oil and lease condensate		
Total annual production (1,000 bbls)[1]	151,390	150,456
Value ($1,000)[1]	1,504,817	1,640,595
Cumulative production 1891-1978 (1,000 bbls)	11,649,362	11,799,818
Daily production (bbls)	442,164	412,208
Total number of producing wells[2]	73,653	74,870
Daily average per well (bbls)	6.0	5.5
Oil wells on artificial lift (estimated)[2]	69,450	70,623
Natural gas		
Total annual marketed production (MMcf)[1]	1,824,978	1,773,582
Value ($1,000)[1]	1,452,683	1,599,771
Total number of gas and gas-condensate wells[2]	11,512	12,525
Natural-gas liquids		
Total annual marketed production (1,000 bbls)[1]	42,350	44,369
Value ($1,000)[1]	317,625	298,425

[1] 1978 data are U.S. Department of Energy preliminary figures.
[2] *World Oil*, v. 188, no. 3, February 15, 1979.

TABLE 5.—GIANT OIL FIELDS OF OKLAHOMA, 1978
(Source: *Oil and Gas Journal*, v. 77, no. 5, Jan. 29, 1979)

Field	1978 production (1,000 bbls)	Cumulative production (1,000 bbls)	Estimated reserves[1] (1,000 bbls)	Number of wells
Burbank	2,666	514,281	26,796	1,027
Eola-Robberson	2,147	119,228	20,870	512
Fitts	3,321	161,030	27,309	623
Golden Trend	4,632	416,036	39,552	1,030
Healdton	3,307	328,734	30,282	1,407
Hewitt	3,943	245,019	41,424	1,238
Oklahoma City	1,274	736,869	12,978	218
Postle	3,361	87,703	32,400	329
Sho-Vel-Tum	26,528	1,121,870	208,130	8,379
Sooner Trend	7,712	224,749	55,098	3,502
Total	58,891	3,955,519	494,839	18,265

[1]Percent of remaining reserves (est.): 11.12%.

Computerized Coal Data Now Ready for Use

Quantity and quality assessments of national coal resources can now be as close as the nearest computer terminal. The National Coal Resources Data System (NCRDS) recently announced its new national computer system, a user-oriented computerized storage, retrieval, and display system that has been developed by the Branch of Coal Resources of the U.S. Geological Survey.

NCRDS is an open-ended system containing geographic and geologic information that will be constantly updated and expanded into different areas as need arises. Data are collected not only from within the USGS but also from federal and state agencies, educational institutions, and the private sector of the coal industry. Operational files are now available, and data files are being tested.

For more information concerning NCRDS, write to Branch of Coal Resources, U.S. Geological Survey, 956 National Center, Reston, Virginia 22092. Ask for NCRDS Newsletter, v. 1, no. 1, July 1979.

Oklahoma's Geo ogical Societies Announce New Officers

New Officers and executive committees for the 1979–80 year .ave been announced by the following geological and geophysical societi s in Oklahoma:

Ardmore Geol ical Society

Pr sident, **Jim R. Hallett,** Q inton Little Co.
Vice-President, **J. . Garrison** Westheimer-Neustadt Corp.
Secretary- re su er, **Robert W. Allen,** independent-consultan
Past President **B. W. Bronc) James,** independent

Geophys al Sc iety of O lahoma City

President **B. B. (Bo) Ferrell,** Dat F nders
First Vice-Pre ident, **Clin utter,** Texas Pa ific Oil Co.
Second Vice P esident, **Bill Haselwood,** Forest Oil Corp.
Secretary, **Marc Pottorf,** Terra Resources Inc.
Treasurer, **Peter Silkworth,** Union Texas Pe roleum
P st President **Har Goeb ,** Nova Energy Corp.

Geophysical Society of Tulsa

Presi ent, **S W. (Si) Fruehling,** c nsultant
First Vice-Pre ident, **W. G. (Bill) Clemen ,** Cities S rvice Co.
Secc d Vice-Presi ent, **D. E. (Don) Wagner,** Amoco Pro luction Co.
Secretary, **. . (Chuck) Warnaca,** Conoco, Inc.

Geophysical Society of Tulsa ex cutiv committee for 1979–80. Seated, left to right: Janet L. Borgerding, e itor; C. . W rnaca, secretary; . W. Fruehli g, president; G. W. Finn, treasurer; W. G. Clement, fi st vice-president. Standing, eft to right: M. E. Arnold, past president (978–79); M. R. Hewitt, past president (1977–78); S. J. Laster, editor-elect. Not present: . E. Wagner, second v ce-p esi ent.

Oklahoma City Geological Society executive committee for 1979–80. Seated, left to right: J. W. McHugh, library director; Jerry E. Upp, second vice-president; Gary W. Hart, president; W. P. Anderson, Jr., first vice-president; G. Phil Spurlin, treasurer. Standing, left to right: David W. Kirtley, **Shale Shaker** editor; Paul B. Pipes, social chairman; W. T. Gans, public relations chairman; Don F. Weber, past president; Landon W. Holman III, professional affairs chairman; John G. Borger II, secretary. Not present: Douglas J. Seyler, representative-at-large to AAPG Mid-Continent Section; Warren L. Morris, chairman of representatives to AAPG House of Delegates.

Treasurer, **G. W. (Greg) Finn,** Seismograph Service Corp.
Editor, **Janet L. Borgerding,** Cities Service Co.
Editor-Elect, **S. J. (Stan) Laster,** The University of Tulsa
Past President (1978–79), **M. E. (Mo) Arnold,** Amoco Production Co.
Past President (1977–78), **M. R. (Marv) Hewitt,** Amoco Production Co.
District Representatives: **S. W. Fruehling, M. E. Arnold, and M. R. Hewitt**

Oklahoma City Geological Society

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Library Director, **J. W. (Jim) McHugh,** consultant
Social Chairman, **Paul B. Pipes,** consultant
Public Relations Chairman, **William T. (Tom) Gans,** Conoco, Inc.
Past President, **Don F. Weber,** independent
Representative-at-Large, Mid-Continent Section, AAPG, **Douglas J. Seyler,** Union Oil Co. of California; Chairman of Representatives to AAPG

House of Delegates, **Warren L. Morris,** consultant; Chairman of Professional Affairs Committee, **Landon W. Holman III, Donald C. Slawson**

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USBM Issues New Publications

Providing New Sources of Mineral Supply, by John Paul Gries, issued by the U.S. Bureau of Mines as Information Circular 8789, summarizes the history of 11 major metalliferous ore deposits or districts that are relatively new discoveries. The oldest operation described is the White Pine mine, where major exploration began in 1929; other discovery dates range from 1948 to 1976. To order, request GPO Stock No. 024–004–01941–7 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The price of the 42-page volume is $1.80 plus $1.00 for each mail order.

Minerals in the U.S. Economy: Ten-year Supply-Demand Profiles for Nonfuel Mineral Commodities (1968–77), USBM Special Publication 5–79, contains tabular and diagrammatic data essential to government, industry, and others in formulating policies and programs to help assure adequate supplies of mineral raw materials. Single copies of the 97-page report are free on request to Publications Distribution Branch, Bureau of Mines, U.S. Department of the Interior, 4800 Forbes Avenue, Pittsburgh, Pennsylvania 15213. Please include a self-addressed label.

Abandoned Coal-Mined Lands, Nature, Extent, and Cost of Reclamation, USBM Special Publication 6–79, by Wilton Johnson and George C. Miller, is also free on request, as above. The report indicates that during the past 10 years adherence to regulations has reduced the adverse effects of mining activities but that continued attempts should be made to assure restoration of areas affected by present and future mining and mineral processing. It focuses on the extent of abandoned coal-mined lands and the problems connected with the rehabilitation of such lands. Reclamation-cost data are current as of 1978.

ORIGIN OF RADIUM-RICH OIL-FIELD BRINES —A HYPOTHESIS

Salman Bloch[1]

Abstract—Some oil-field brines in Oklahoma and other areas are characterized by a lack of equilibrium between uranium-238 and one of its daughter products, radium-226. In addition, the radium content of these brines is anomalously high. Both of these characteristics are a function of the chemical properties of radium and the geochemical environment of petroleum reservoirs.

The high radium content of the brines is not necessarily caused by anomalously high uranium concentrations in the subsurface rocks, and, therefore, radium concentration must be used with caution as an exploration guide for concealed uranium deposits.

Introduction

It has long been known that many oil-field waters, including some from Oklahoma, contain unusually high concentrations of radium (Ra). All isotopes of radium are radioactive. Ra-226, the longest-lived Ra isotope (half-life of 1,622 years), is formed in the natural-decay series of U (uranium)-238. Ra-228 (half-life of 6.7 years) and Ra-224 (half-life of 3.64 days) belong to the Th (thorium)-232 chain of decay.

Geologic samples are often analyzed both chemically and radiometrically to determine their U contents. If the chemical content of uranium (cU) does not equal the radiometric one, the sample is considered to be in disequilibrium. Equivalent uranium (eU) is a measure of the radioactivity of a sample, reported as the concentration of U, in equilibrium, that would produce the measured radioactivity. An equivalent concentration of a radioisotope, such as ΣRa-226, is expressed, in percentage, as the amount of U in radioactive equilibrium required to sustain the measured amount of the daughter product. Thus, ΣRa-226 = 0.1 indicates that the sample contains the amount of Ra-226 that would be in equilibrium with 0.1 percent U.

The proportionality factor between the atomic concentration of uranium and radium is 2.84×10^6. This means that at equilibrium a sample contains 0.35 part of Ra for each million parts by weight of U. For example, 0.35 ppb (parts per billion) of Ra would translate into 0.1 percent of U, assuming equilibrium.

Theoretically, anomalously high amounts of Ra-226 in oil-field waters could be caused by anomalously high U concentrations in subsurface rocks through which the waters pass, or are in contact. Similarly, anomalously high concentrations of Ra-228 and Ra-224 suggest the presence of thorium-rich rocks in the subsurface.

A straightforward Ra-U correlation would be a useful tool in exploration for hidden U deposits.

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The purpose of this note is to show that such a simple correlation does not exist and that Ra-rich brines may form in contact with oil-field rocks of only average (non-anomalous) concentrations of U.

Discussion

General

Gott and Hill (1953) studied radioactivity in some oil fields of southeastern Kansas. They found that precipitates in separator tanks and discarded oil-well tubular goods on the surface contained up to 10.85 percent equivalent U_3O_8. These precipitates were derived from oil-well fluids. The radioactivity was almost entirely caused by Ra-226, with the equivalent amount of U-238 being absent. The authors concluded that these abnormally high concentrations of radium indicated "greater-than-normal" concentrations of uranium in the subsurface rocks.

Armbrust and Kuroda (1956) determined the amounts of Ra-224, Ra-226, and Ra-228 in a number of petroleum-brine samples from Oklahoma and northwestern Arkansas. The highest concentration was 1.62 millimicrocurie/liter of brine of Ra-226 ($= 1.62 \times 10^{-9}$ g Ra/liter of brine). This is approximately equal to 4.5 ppm (4,500 ppb) eU. For comparison, typical values for fresh surface and ground waters are in the range of 0.05 to 10 ppb cU (Jones, 1978).

Armbrust and Kuroda (1956) also found that while some brines contained only Ra-226 (characteristic of the U-238 series), others contained mainly radium isotopes characteristic of the thorium series, and still others had radium from both the thorium and uranium series. In solution, the radium isotopes were in excess of their U and Th parents.

Any explanation of the geochemistry of U and Ra in oil-field waters must account for two characteristic features of these waters: (1) the disequilibrium in solution between Ra-226 and U-238 and (2) the source of the anomalously high Ra concentrations in the brines.

The disequilibrium between U-238 and Ra-226 is simply a function of the geochemical environment of oil pools. The redox potential (Eh) around a petroleum pool will be strongly reducing, and under reducing conditions the U^{4+} ion is extremely stable. It follows that oil-field brines that are characterized by negative Eh values (Collins, 1975, p. 169) cannot be effective U carriers. In contrast, the mobility of Ra^{2+} will be increased at low Eh owing to reduction of SO_4^{2-}. This indicates that radium can be released into the brine by petroleum-reservoir rocks, which would account for the Ra-U disequilibrium.

The determination of the sources of the high Ra content in the brines not only is of scientific significance but also has economic application.

Are the anomalously high Ra concentrations in oil-field waters due to abnormally high U concentrations in subsurface rocks? I do not believe this is true in most cases, since the high Ra content in most brines can be explained by a combination of factors, the most important of which are the chemical properties of Ra and the geochemical environment of oil-reservoir areas.

Radium is a member of the Group II elements of the periodic table. Together with Ca, Sr, and Ba it forms a closely allied series. It is well known that the most important process in eliminating solute barium (the element most similar to Ra in its chemical properties) from circulation in sedimentary environments is the precipitation of the highly insoluble mineral barite ($BaSO_4$). One of the trends in the series Ca-Sr-Ba-Ra is a decrease of solubilities of sulfates with increasing ionic-radius size. It follows that radium sulfate ($RaSO_4$) must be even less soluble than barite.

Radium-bearing precipitates from southeastern Kansas, Oklahoma, and northwestern Arkansas oil fields are intimately associated with celestite ($SrSO_4$) and barite ($BaSO_4$) (Gott and Hill, 1953; Armbrust and Kuroda, 1956). It is not clear whether radium occurs in the precipitates in a phase of its own ($RaSO_4$) or in the crystal lattice of barite and celestite (the ionic radius of Ra^{2+} is 1.57Å, Ba^{2+}, 1.49Å, and Sr^{2+}, 1.32Å). Data presented by Stumm and Morgan (1970) strongly suggest that solid solution of $RaSO_4$ in $BaSO_4$ is more likely than the formation of an independent $RaSO_4$ phase. The basis for this conclusion is that, although the solubility of a salt making up the major component of a solid phase ($BaSO_4$ in our case) is not affected by the formation of the solid solution to an appreciable extent, the solubility of the minor component ($RaSO_4$) is significantly lowered.

As appreciable amounts of both radium and sulfate cannot be carried by the same solution, the radium-rich precipitates must have formed by intermingling of Ra-rich brines with comparatively high-sulfate ground waters or brines.

Komlev (1933, cited in Armbrust and Kuroda, 1956) and Nikitin (1933, cited in Armbrust and Kuroda, 1956) showed that radium-bearing waters contain practically no sulfates. The near absence of the SO_4^{2-} ion might be expected in some oil-field waters. Sulfate present in these waters will be reduced to sulfide in the presence of organic matter (hydrocarbons) and bacteria. Krauskopf (1967, p. 276) summarized the reaction, using methane as the organic reactant, as:

$$2H^+ + SO_4^{2-} + CH_4 \rightarrow H_2S + CO_2 + H_2O$$

Experiments indicate that the reaction is too slow to be significant without the help of the *Desulfovibrio* bacteria. The bacteria have been found to reduce sulfate in the laboratory and in nature, using a wide variety of organic sources including hydrocarbons, fatty acids, carbohydrates, and amino acids (Thimann, 1963). The bacteria are also easily adapted to a wide range of P-T conditions (Berner, 1971, p. 132).

Thus, Ra-226 released into a sulfate-deficient oil-field brine can stay in solution because of the lack of a precipitant. Some confirmation for this process is provided in the work of Vilonov (1962, cited in Collins, 1975), who studied oil-water contacts in some Soviet oil fields and found a distinctive pattern in the distribution of radioactive elements. In the contact zone, radium and its isotopes were concentrated in the water, and there was a relative decrease in uranium content, sometimes to zero.

Simple Model for Formation of Radium-Rich Brines

It remains to be seen whether the release of radium from reservoir rocks into pore solutions (brines) is effective enough to produce a significant enrichment of this element in the solutions. To assess this process, I will attempt to make reasonable assumptions about some parameters used in the simple calculation that follows.

An "average" sandstone contains 1.2 ppm U, an "average" graywacke, 2.6 ppm U, an "average" shale, 3.7 ppm U, and an "average" marine black shale, 20 ppm U (Granger, 1978). Let us assume that a reservoir sandstone has a porosity of 20 percent. Sandstone reservoirs with intergranular porosity range from a minimum for economic production of about 5 percent to totally unconsolidated sand with porosities exceeding 40 percent (Pittman, 1979).

The pore fluid has a density about 40 percent as great as the density of the surrounding rock (assuming $d_{(rock)} = 2.65$ gcm^{-3} and $d_{(fluid)} = 1.05$ gcm^{-3}). Hence, the weight of the pore fluid within a given volume of rock is only about 10 percent as great as the weight of the rock with a 20-percent porosity. If all radium produced by the decay of U present in the rock were released to the sulfate-free pore solution, the Ra-226 content in the solution, by weight, would be 10 times higher than the concentration of Ra that would be in equilibrium with the U in the rock. Complete release of Ra to the pore solution requires a total dissolution of the rock.

In a real rock-fluid system this "apparent enrichment factor" will be less than 10, because in this case some partitioning between the solid and liquid will take place and because the rock will not dissolve entirely. Not all radium will be removed from the solid phase, particularly inside the grains.

The "apparent enrichment factor" will be increased by a decrease in porosity. A decrease in porosity will, however, result in a decrease of the grain-boundary–fluid contacts, with a resulting decrease of the "apparent enrichment factor."

The transfer of radium from inside the rock grains (away from grain boundaries) to the pore solution can take place as a result of either solid diffusion through the grains or partial or complete dissolution of the grains.

Diffusion rates in silicates, particularly at low temperatures, are exceedingly low. Bailey (1971) estimated the diffusion coefficient of sodium in albite to be 10^{-29} cm^2/sec at 25° C. A convenient rough measure of the characteristic transport distance in diffusion is the expression $(Dt)^{1/2}$, where D is the diffusion coefficient and t is the time. Use of this expression for diffusion of sodium in albite yields a transport distance of 1.8×10^{-8} cm for a duration of 1 million years! The transport distance for Ra^{2+} can be expected to be even lower because of its much larger ionic size ($r_{Na^+} = 1.12$Å, $r_{Ra^{2+}} = 1.57$Å).

Because of the inefficiency of solid diffusion, let us focus our attention on the other mechanism, grain dissolution. There is very little doubt that this process takes place in subsurface rocks. According to Hayes (1979, p. 129), "a very large percentage" of porosity in sandstones "is not original intergranular porosity which escaped destruction, but rather is secondary or solution porosity, created by the dissolution of detrital grains and authigenic cements and replacements."

Chemically active oil-field brines and brine-oil mixtures are particularly effective in dissolving sandstone constituents. Zubov (1960) observed corrosion of quartz and fluorite by such fluids. Other constituents will obviously be corroded and dissolved in preference to quartz and fluorite.

Even if only some constituents are corroded or dissolved, and 20 percent of the produced radium is released into the fluid, there will still be a twofold "apparent enrichment factor." A sulfate-free pore solution in a sandstone with a 1.2 ppm U concentration may contain 2.4 ppm eU, owing to Ra-226.

As has been mentioned previously, the highest concentration of Ra-226 in a brine sample, as determined by Armbrust and Kuroda (1956), was equivalent to 4.5 ppm U. Such a concentration could easily be attained by a pore solution in a graywacke or shale or even a sandstone with a slightly above-average U abundance.

An alternative explanation of the origin of radium-rich brines has been offered by Dr. D. D. Runnells (personal communication). Stated briefly, radium sulfate could be precipitated on grain surfaces early in diagenesis when SO_4^{2-} is abundant. Radium would then be mobilized at a later stage by some complexing agent(s) present in oil-field brines.

The two hypotheses presented in this paper are not mutually exclusive. It is likely that the two processes discussed complement each other.

Conclusions

Our knowledge of the processes responsible for the formation of radium-rich brines is rudimentary. It appears, at least on the basis of theoretical considerations, that high radium concentrations in oil-field brines are not necessarily indicative of uranium occurrences in subsurface rocks. The geochemical milieu of reservoir rocks is such that it is possible to produce radium-rich brines in rocks with a normal (nonanomalous) uranium content. This conclusion implies that radium-rich oil-field brines may not be a reliable tool in exploration for hidden uranium deposits.

Acknowledgments

Discussion with Dr. Kenneth S. Johnson aided me significantly in preparation of this article.

I am also indebted to Dr. Donald D. Runnells for his very useful suggestions and comments.

Constructive criticism of the manuscript by Drs. James L. Bischoff, Robert Craig, M. Charles Gilbert, and William E. Harrison is greatly appreciated.

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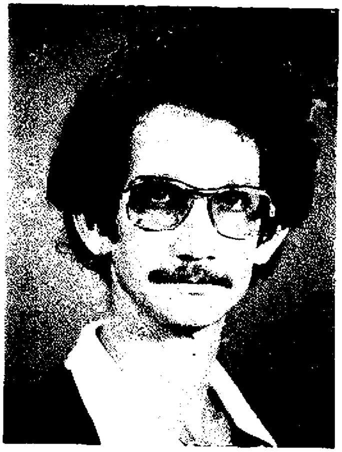
Atlas on Mineral Deposits Published

A recently published *Atlas of Economic Mineral Deposits*, by Colin J. Dixon, should be a useful reference for geologists and students of geology and mining. Illustrations and descriptions of the geologic features of 48 of the world's most important ore deposits are contained in this atlas. The material presented deals with deposits representing the main geological types, which consist of bauxite, copper, iron, lead, uranium, and manganese.

Each deposit is accompanied by a plate including maps, sections, and diagrams. In addition, each illustration is concomitant with a text of background material on geographic setting, history, and mining as well as geology. While seeking to provide a key to the understanding of the world's mineral wealth, this atlas also summarizes the basic factual information on deposits.

There are 53 maps on 15- by 10-inch sheets in this 143-page publication. The cost is $75.00 and can be purchased from the Cornell University Press, P.O. Box 250, Ithaca, New York 14850.

Wayne Furr Joins Staff as Cartographic Chief



Charles J. Mankin, director of the Oklahoma Geological Survey, has announced the appointment of T. Wayne Furr to the OGS staff as manager of cartography.

Wayne came to the Survey from a 13-year stint with the Branch of Cartography of the Publications Division of the U.S. Geological Survey in Denver, Colorado, where he worked in all phases of map-making. His training was obtained on the job and also through 229 quarter hours of credit earned at the Community College of Denver, where he was awarded an associate degree in drafting. He is nine hours away from another associate degree in surveying.

Recent duties with the USGS included compiling base maps of all kinds, developing a map-file system and designing a computer inventory system, maintaining records, determining photo-lab and cartographic operations from start to completion of map processing, designing illustrations, and supervising and training other workers. He has received special commendations for his supervision of studies in space-utilization and modernization.

All this background is being put to good use at the OGS, where he is working with fellow cartographers Roy D. Davis, Marion E. Clark, Mary Ellen Kanak, and Joseph M. Zovak. He has been reviewing the USGS technical standards on cartography and rewriting them to fit the OGS program, developing procedures that will be updated regularly to fit current needs.

A native of Oklahoma, specifically Mountain Park, Wayne has returned to his home State in accepting employment in Norman. He had his early primary-school training in Tipton, graduated from high school in Liberal, Kansas, and entered the U.S. Air Force immediately thereafter, serving for a period of almost 4 years. He and his wife, the former Phyllis Goorman of Englewood, Colorado, met while Wayne was stationed at Lowry Air Force Base; they were married in California, while he was stationed at Edwards Air Force Base; their daughter, Trudy, now 15, was born while Wayne was serving in the Far East. They also have a son, Shawn, who is 9. In Colorado, Phyllis held down a responsible position as head teller and savings counselor for a savings and loan company.

Wayne is an artist with a camera and has won awards for pictures entered in the annual USGS photo exhibitions. Other hobbies include skiing, both on snow and water, swimming (he worked with handicapped children in a swimming program in Colorado), fishing, and horses. The Furrs have brought two horses with them to Oklahoma, and Wayne, Phyllis, Trudy, Shawn, horses, and four dogs live on a 5-acre plot northeast of Norman.

We welcome them all to Norman. Including the inherited cats that came with their acreage.

Coal Monthly to Be Published

Coal-mining news associated with Oklahoma and Arkansas coal fields is soon to be published in a monthly newspaper entitled *Regional Coal News*. Information on mining activities, state and federal mining laws, market conditions, innovative ideas, and products and services will be presented in the newsletter. Plans call for copies of the publication to be sent to key personnel at each coal mine in Arkansas and Oklahoma and to government officials whose decisions could affect area coal production.

For more information, write to Regional Coal News, P.O. Box A, Poteau, Oklahoma 74953.

Oklahoma's 1979 Mineral Report Released by USBM

The value of raw mineral material to the State of Oklahoma was $3.5 billion, 16 percent of the gross State product for 1978, according to information in *Minerals in the Economy of Oklahoma*, a publication recently released by the U.S. Bureau of Mines as a part of its series State Mineral Profiles (SMP). The report is the result of a cooperative effort with the Oklahoma Geological Survey.

This second annual report concerning mineral production and the mining industry was written by Robert H. Arndt, State liaison officer with the Bureau of Mines, and Charles J. Mankin, OGS director. The publication discusses all nonfuel minerals produced in Oklahoma.

Recent data on energy fuels are now issued by the U.S. Department of Energy (DOE) and are no longer published in the Oklahoma mineral report, although a few estimates compiled by the Oklahoma Corporation Commission, Division of Oil and Gas Conservation, and by the Oklahoma Department of Mines concerning mineral fuels are included in the SMP.

This 33-page report relates information concerning manufacturing and production of Oklahoma minerals. Environmental issues, federal and State programs, legislation, employment, and transportation are also discussed in relation to Oklahoma's mineral economy.

SMP 1979 can be obtained on request from Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pennsylvania 15213. A limited number of single copies are available from the Oklahoma Geological Survey at the address on the front cover; there is no charge.

GSA to Convene in San Diego

The Geological Society of America will hold its 92d annual meeting in San Diego, California, November 5–8. Annual meetings of seven associated societies will be held concurrently with GSA, including the Cushman Foundation, Geochemical Society, Geoscience Information Society, Mineralogical Society of America, National Association of Geology Teachers, Paleontological Society, and Society of Economic Geologists. General chairman for the 1979 meeting is Richard L. Threet, of the Department of Geological Sciences at San Diego State University.

San Diego, referred to by some as "America's finest city," offers many attractions to the geologist as well as to the more casual sightseer, and 27 pre- and post-meeting field trips into surrounding areas (including Mexico, the sea, and Arizona) are scheduled, covering geological formations ranging from modern ocean and terrace deposits to Cenozoic and Mesozoic sedimentary rocks to igneous pegmatites and the San Diego batholith. During the regular meeting period, GSA and other societies will offer 22 symposia in addition to technical sessions and poster presentations.

The Oklahoma Geological Survey will have an exhibit at the meeting to display some current OGS programs, and five Survey geologists will attend technical sessions. Representing OGS will be Charles J. Mankin, director, S. A. Friedman and LeRoy Hemish, coal geologists, Salman Bloch, uranium geologist, and Donald A. Preston, petroleum geologist. Friedman is past-chairman of the GSA Coal Geology Division and was instrumental in establishing the division's committee on coal resources and reserves, which will offer a symposium at the San Diego meeting on "Evaluation of North American Coal Resources." Friedman also helped plan and is one of the leaders of a pre-meeting field trip on the geology and coal deposits of the Black Mesa region in Arizona. Hemish will also participate in this field excursion. Bloch plans to accompany another pre-meeting field trip over the geology and geothermics of the Salton Trough.

Sigma Gamma Epsilon, national honorary geological fraternity, of which Mankin is national secretary-treasurer, will have an exhibit at the meeting; Joseph A. Curiale, a University of Oklahoma geology graduate student, who is serving as part-time research assistant with the Survey, will attend the meeting as a delegate for OU's Gamma Chapter.

Claren Kidd, geology librarian, will also attend the annual meeting.

RENOVATED GEOLOGY LIBRARY HOLDS UNIVERSITY'S MAP COLLECTION

The Geology and Geophysics Library at The University of Oklahoma has an enhanced appearance and arrangement after a 9-week transformation by the University's physical plant. The main floor is now a lighter, brighter, quieter area in which to study or to consult the literature.

Five years ago the concept of a central map collection for The University of Oklahoma was conceived and presented to the Oklahoma Geological Survey, the School of Geology and Geophysics, and numerous University schools and departments. With these groups' approval of the concept, a floor plan was developed to centralize the University Libraries' map collection into one facility, to improve the appearance and work efficiency, and to open the stacks to all users.

Last year, the Oklahoma Geological Survey provided funds that the University matched with Section 13 and New College funds, and the University's physical plant began work October 23.

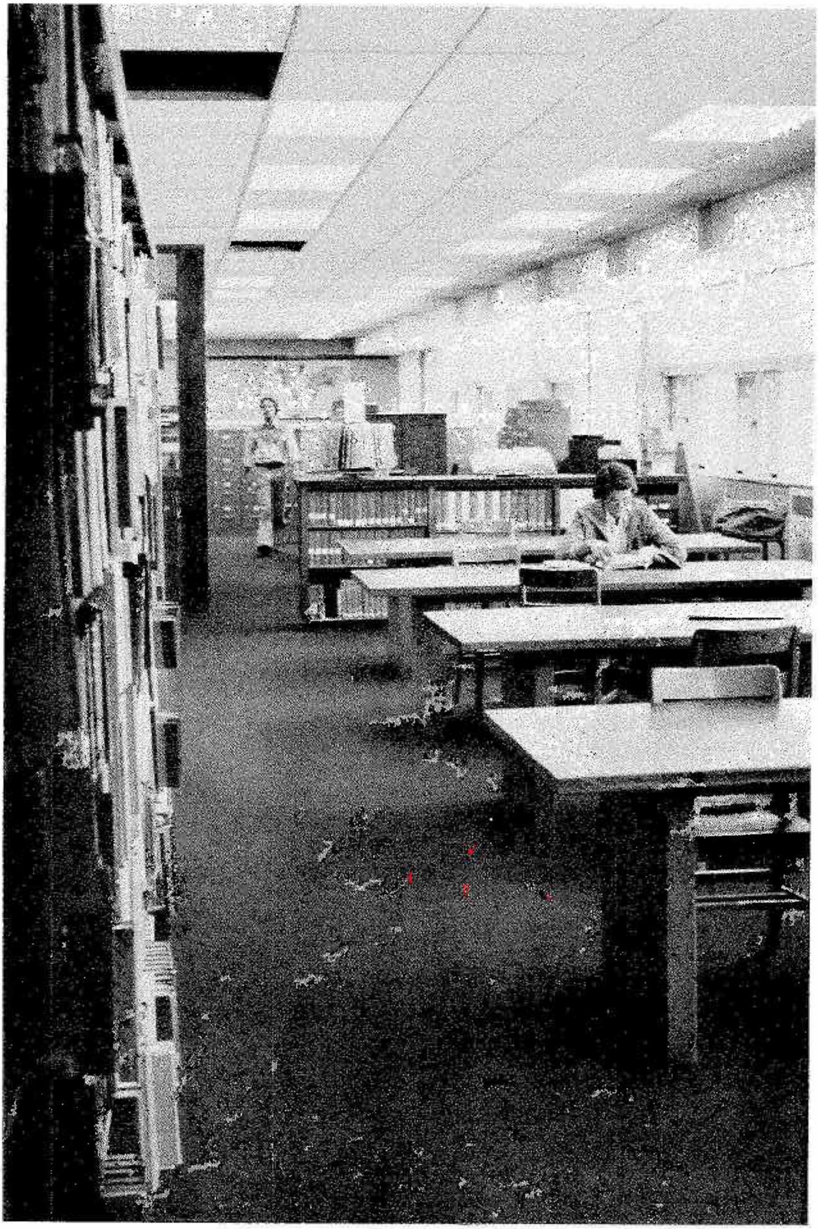
Map cases at the west end were consolidated or moved; vertical letter files, atlas cases, shelves, study tables, and chairs were removed and stored in other parts of Gould Hall; and a room on the second floor was designated as the "reading room." While two walls were being removed, new fluorescent fixtures were hung; an acoustical ceiling was suspended; rough-cut cedar panels were applied to the south wall; other walls were painted; and the restricted library area continued to offer normal library services.

After Thanksgiving, the western two-thirds of the library was almost completed, and work shifted to the east end. All the books were removed from the stacks and put on book trucks. The steel book stacks were then pushed into the renovated area, and the books returned to their shelves. The east end then underwent a transformation; an enclosed office was removed, the air-conditioning vent was shifted, carpeting was laid, and all library functions were shifted to the west end.

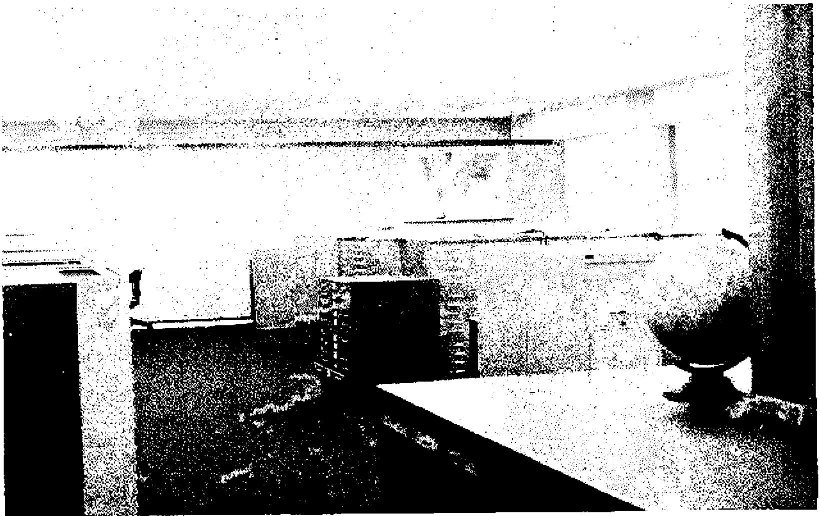
By December 22, the book stacks and their books were returned to their former position, but now they sat atop an orange-red carpet. With the aid of student assistants from Bizzell Memorial Library, the hauling section of the physical plant, our own library staff, and several other people, most pieces of equipment and furniture were in their permanent positions by the beginning of this year's spring semester.

The result of the work is an attractive, open area of 5,000 square feet to accommodate the stacks and map files. Two adjoining, glass-enclosed offices provide an efficient area for processing books and maps. Study tables and carrels are scattered throughout the carpeted, well-lighted space. Lined, off-white draperies absorb much of the cold air that had penetrated the north windows each winter.

The western one-third of the library contains horizontal map cases that hold thematic sheets and our depository collections of U.S. Geological Survey topographic quadrangles and series maps, U.S. Defense Mapping Agency maps of the



View of main floor of renovated Geology and Geophysics Library, looking toward new west room at far end.



New west room of Geology and Geophysics Library on ground floor of Gould Hall, housing University's map collection.

world, U.S. Central Intelligence Agency maps, and National Oceanographic and Atmospheric Administration topographic and bathymetric sheets.

Thus, most maps on The University of Oklahoma campus are housed in one central location, and the Geology and Geophysics Library is an aesthetically pleasing area in which to conduct research.

—*Claren M. Kidd*

Annual Review Volumes Issued

Two publications of general interest to geologists were issued recently by Annual Reviews, Inc., as a part of a series of annual reviews in various scientific fields.

Annual Review of Energy, edited by Jack M. Hollander, Melvin K. Simmons, and David O. Wood, volume 3, 544 pages, covers related topics on energy resources and use.

Annual Review of Earth & Planetary Sciences, edited by Fred A. Donath, Francis G. Stehli, and George W. Wetherill, volume 7, 517 pages, contains articles ranging from geochemical and cosmochemical applications to Paleozoic paleogeography.

These two books can be ordered from Annual Reviews, Inc., 4139 El Camino Way, Palo Alto, California 94306. The cost for each is $17.00, $17.50 if purchased outside the United States.

SOIL MAP REFLECTS A CLASSIC STRATIGRAPHIC DICHOTOMY IN THE ENID QUADRANGLE, OKLAHOMA

Robert L. Eutsler[1]

Field mapping of surface rocks in the Enid 1° $\times$ 2° Quadrangle, in north-central Oklahoma, has been carried out as part of the Oklahoma Geological Survey's project to assess the potential for uranium mineralization in north-central and west-central Oklahoma. This work is being done under a grant administered by Bendix Field Engineering Corp. for the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program (see *Oklahoma Geology Notes*, v. 38, April 1978, p. 65–66).

A preliminary version of a geologic map that will be included in Oklahoma Geological Survey Hydrologic Atlas 7, covering the water resources of the Enid Quadrangle, was used in field investigations of the quadrangle (Bergman and Bingham, in press). Figure 1 shows a simplified, reduced geologic map of the Enid Quadrangle that was redrafted from Bergman and Bingham's map. Marker beds and most of the outliers have been omitted for ease of reading.

Any geologic map shows the position and extent of rock units bounded by time-correlative boundaries. In this framework it is difficult to display gradual lithologic changes within formations. This is the situation in the Enid Quadrangle, where there is a grain-size increase from north to south, which affects several formations.

Units exposed in the Enid Quadrangle are Middle and Upper Pennsylvanian (Missourian-Gearyan) and Lower Permian (Cimarronian). Some of these units, such as the Wellington Formation, are defined from type sections in Kansas; some, such as the Garber Formation, follow designations from Oklahoma type sections. Descriptions of Upper Pennsylvanian and Lower Permian rocks in north-central Oklahoma make note of the gradual change in lithologies from marine shales and limestones in the northern part of the quadrangle to deltaic sandstones and shales in the southern part (Fay, 1971, 1972); this situation has been known for many years, but it is difficult to show on a geologic map.

The rocks of the Enid Quadrangle show a classic dichotomy in stratigraphy. The biostratigraphic boundaries and formational contacts trend north-south, but the boundaries between lithofacies trend east-west. The nonparallelism of facies and time boundaries tends to make geologic maps hard to use, simply because of changes in facies and the consequent difficulty of recognizing units in the field. A fairly simple solution to this problem is described herein.

Figure 2 is a soils map of the Enid Quadrangle presented at the same scale as the geologic map (fig. 1). It represents a modified version compiled from soils maps of the area that were prepared for the Oklahoma Water Resources Board

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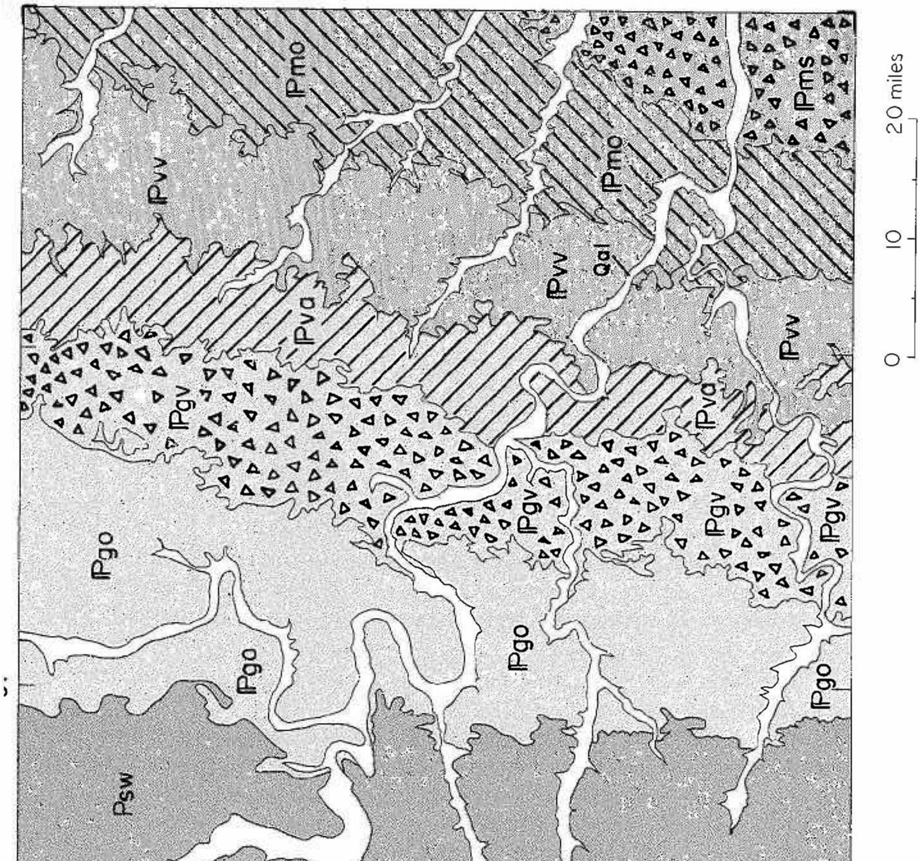
[1] Geologist, Oklahoma Geological Survey.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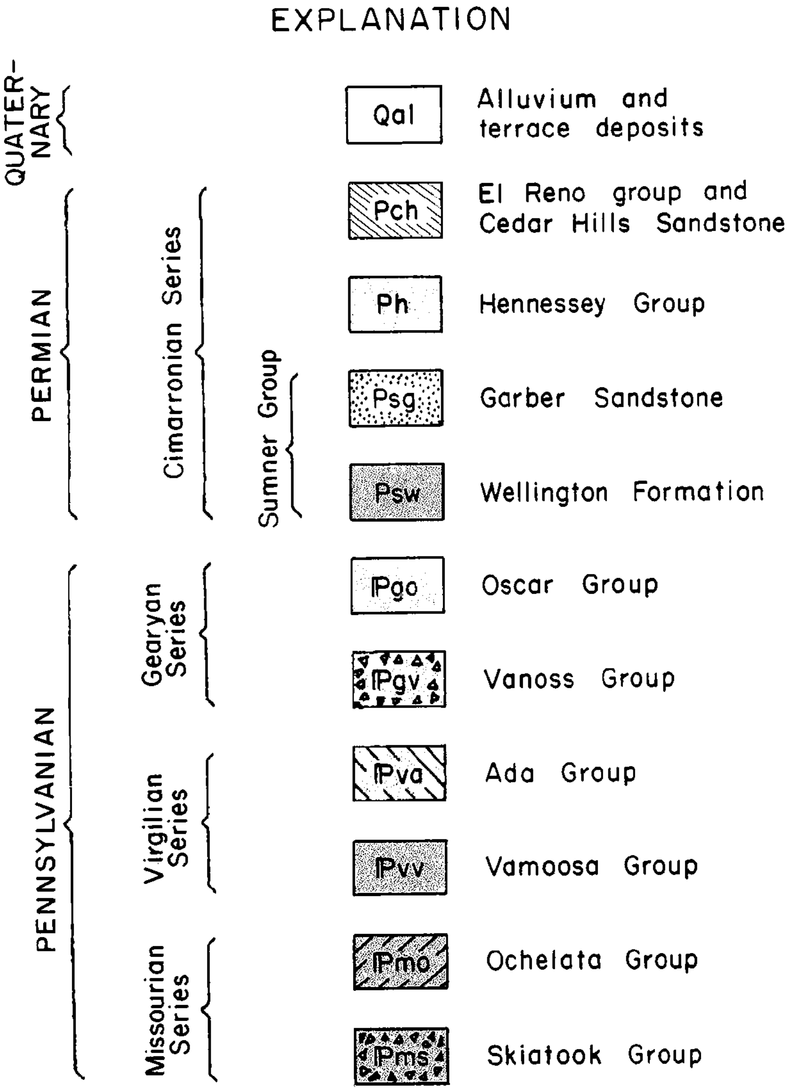
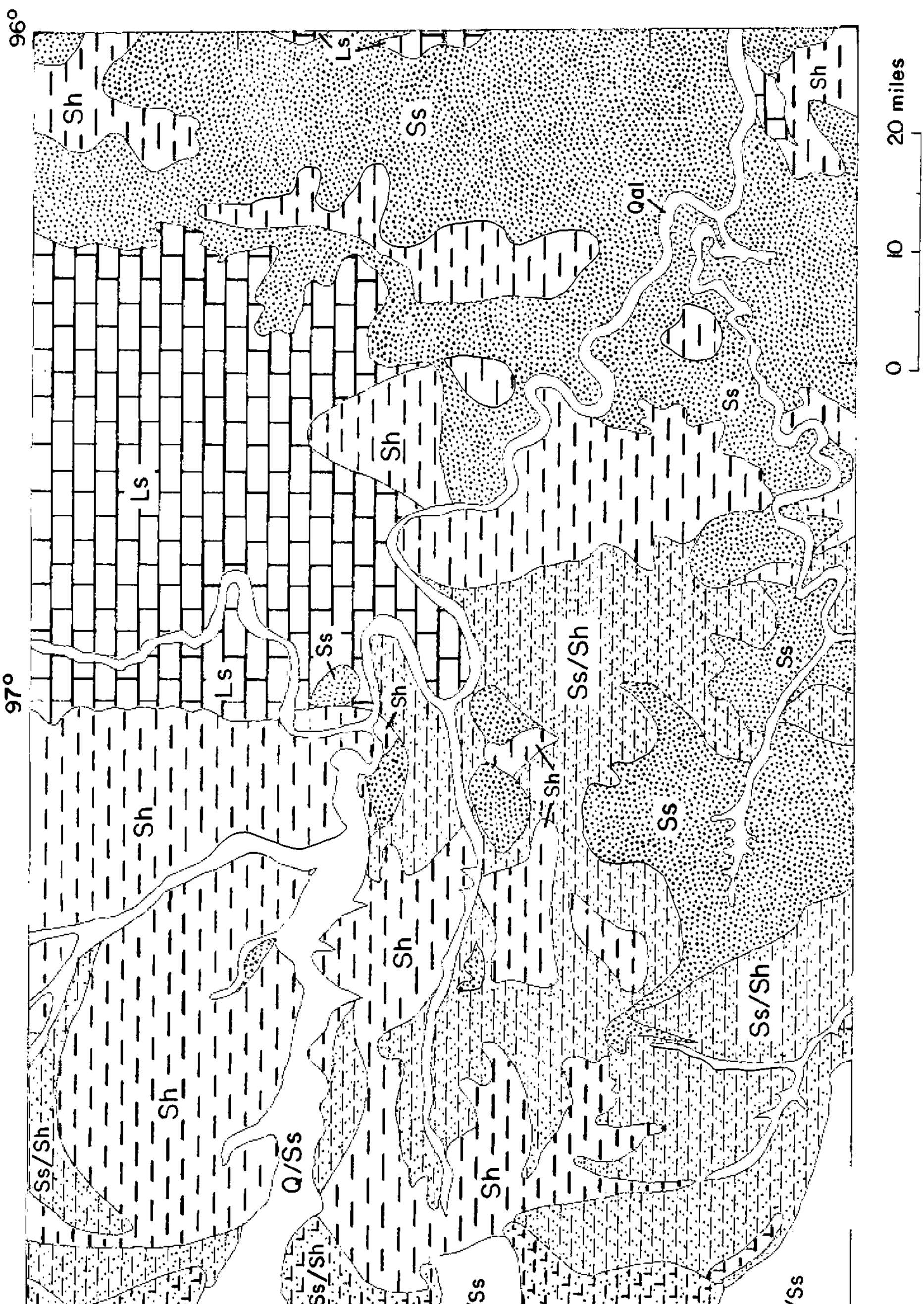


Figure 1. Generalized geologic map of Enid Quadrangle. After Bergman and Bingham (in press).

EXPLANATION

Ls	Soil groups derived from limestone and calcitic shales
Sh	Soil groups derived from shale
Ss/Sh	Soil groups derived from interbedded sandstones and shales
Ss	Soil groups derived from sandstones including alluvium and terrace deposits
C/SS/Sh	Soil groups derived from calcareous Permian sandstones and shales

Figure 2. Generalized soils map of Enid Quadrangle. After Hill and Prevett (1971) and Hill and others (1972).


96°
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20 miles

(Hill and Prevett, 1971; Hill and others, 1972). The maps have been combined and have been simplified by grouping together soils formed from similar parent materials, showing residual soils derived from sandstone, shale, interbedded sandstone and shale, limestone, and alluvium.

A comparison of the geologic map and the soils map demonstrates persistent facies changes that affected both Upper Pennsylvanian and Lower Permian deposition. The northern part of the soils map shows shale-derived soils in the western half and a large area of limestone-derived soils in the east. In contrast, the southern part of the soils map shows a complex interfingering of sandstone-derived soils with soils derived from shale and interbedded shale and sandstone. The shape of the smaller sandstone-derived soil areas suggests that the underlying parent material is in the form of a lenticular sand body, which conforms to the interpretations of numerous geologists who have studied the surface rocks in the southern part of the quadrangle (Nakayama, 1955; Fenoglio, 1957; Greig, 1959; Garden, 1971; Fay, 1971, 1972).

The soils map shows that the Garber Sandstone (Psg) is, in fact, quite shaly in the northern part of the quadrangle and becomes more sandy to the south. The Garber equivalent in Kansas is the Ninnescah Shale. A similar situation is apparent in the Upper Pennsylvanian Oscar, Vanoss, and Ada Groups. In the north, these formations are composed of thin limestone and dolomite beds which are interbedded with thick shales (Fay, 1971). The soils map (fig. 2) indicates that these formations become increasingly sandy to the south. The geologic map of the Oklahoma City Quadrangle (Bingham and Fay, 1975) shows that these formations become thinner and more conglomeratic from north to south.

The intent of this note is to make available a preliminary soils map for the Enid Quadrangle and at the same time to show the effect of a lithologic facies change that cuts across both formational and systemic boundaries. It is suggested that future work in this region should retain the lithostratigraphic framework and the formational names that have been applied to these units. Reference should be made to the particular facies within each formation under discussion in descriptions of the formations.

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USGS Publications Released

Maps for America

Maps for America, subtitled *Cartographic Products of the U.S. Geological Survey and Others*, by Morris M. Thompson, provides pertinent information on the understanding of map content. The publication covers the meaning and symbolization of maps, the possible errors and anomalies affecting the reliability and interpretation of maps, the diversity of maps and map data, and the different sources of maps and related information.

Prepared in conjunction with the USGS's centennial celebration as the nation's largest earth-science and civilian mapping agency, the 256-page publication contains 200 illustrations in full color.

The 9- by 12-inch book has been designed for use by the layman as well as the cartographer. Thompson feels that it should also appeal to practitioners in industry, science, and government, because it shows how cartographic products can serve their various needs.

Maps for America can be purchased for $11.00 each from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202. Orders must include check or money order payable to the U.S. Geological Survey.

Ogallala Aquifer

Digital-Model Projection of Saturated Thickness and Recoverable Water in the Ogallala Aquifer, Texas County, Oklahoma, by R. B. Morton, has been issued as U.S. Geological Survey Open-File Report 79–565. For information on obtaining the report, contact USGS, Water Resources Division, Room 621, 201 NW Third Street, Oklahoma City, Oklahoma 73102, or the Oklahoma Water Resources Board, 1000 NE 10th Street, 12th Floor, Oklahoma City, Oklahoma 73105.

Journals on Marine Technology Available

Marine Mining, edited by J. Robert Moore, is a new journal that provides scientists and engineers with information on current research on sea-floor minerals with respect to exploration, assessment, extraction, and ore processing. The publication contains full-length research papers, technical notes, brief summaries of recent developments in this field, and book reviews.

Four quarterly issues constitute volume 1, totaling approximately 400 pages. The subscription rate for volume 1 is $40.00 for institutional subscribers and $20.00 for personal subscribers. The subscription rate for volume 2 will be $48.00 for institutional subscribers and $24.00 for personal subscribers.

Volume 3 of *Marine Geotechnology*, edited by Adrian F. Richards, has been recently released. Solving marine problems in civil engineering and the earth sciences is of major concern in this journal. In addition, *Marine Geotechnology* publishes research devoted to all scientific and engineering aspects of sea-floor sediments and rocks. The material published pertains to the study of acoustical, biological, chemical, mechanical, and physical properties affecting the electrolyte-gas-solid sedimentary system of the sea floor.

Each volume consists of four quarterly issues totaling approximately 400 pages. The subscription rate for volume 3 is $40.00 for institutional subscribers and $20.00 for personal subscribers.

Correspondence relating to subscription matters should be sent to the publisher, Crane, Russak & Co., 3 East 44th Street, New York, New York 10017.

AAPG Publications of Note

Geological and Geophysical Investigations of Continental Margins, edited by Joel S. Watkins, Lucien Montadert, and Patricia Wood Dickerson, has been issued by The American Association of Petroleum Geologists as Memoir 29. This publication, an excellent reference volume for seismic studies and continental-margin case histories, is a compilation of 32 papers arranged into four sections. Some of the topics covered are rifted margins, convergent margins, and small-basin margins as well as resources, comparative structure, and eustatic changes of sea level. Price: members (AAPG-SEPM), $19.50; nonmembers, $24.00. Order from The American Association of Petroleum Geologists, P.O. Box 979, Tulsa, Oklahoma 74101.

Organic Geochemistry in Petroleum Exploration, Colin Barker, compiler, was prepared as AAPG Continuing Education Course Note 10. The material covered in this 159-page volume was developed from lecture notes for AAPG short courses. Fundamentals of geochemistry, organic matter in recent sediments, petroleum generation, migration of petroleum from source rock to reservoir, maturation and alteration of petroleum source rocks, and geochemical correlation of units are some of the topics discussed. Price: single copy, $8.00; 10 or more copies, $7.00 each; catalog no. 884.

Geology of Carbonate Porosity, by Don Bebout, Graham Davies, Clyde H. Moore, Peter A. Scholle, and Norman C. Wardlaw, was issued by AAPG as Continuing Education Course Note 11. This publication is the result of a short course on carbonate porosity offered at the Houston annual meeting held in April 1979. The 248-page reference publication covers topics such as porosity in carbonate-rock sequences, secondary carbonate porosity, dolomite reservoir rocks, porosity in shallow- versus deep-water limestone, and pore systems in carbonate rocks. Price: single copy, $10.00; 10 or more copies, $9.00 each; catalog no. 885.

Secondary Reservoir Porosity in the Course of Sandstone Diagenesis, by Volkmar Schmidt and David A. McDonald, Continuing Education Course Note 12, is available not only as a publication but also in a slide/audiotape series. The course set contains more than 150 color slides, three 60-minute audiocassettes with audible pulses for slide/tape synchronization, and a booklet containing lecture notes. This publication deals primarily with secondary porosity in sandstones that can be classified according to origin and pore texture. Price of the course notes: single copy, $7.00; 10 or more copies, $6.00 each; catalog no. 886. The complete set with slides and audiotape costs $120.00 plus $6.00 for shipping and handling; orders must be placed with Science-Thru-Media Co., 295 Fifth Avenue, Room 819, New York, New York 10016.

GSA Issues Publication on Paleoenvironments

Paleoenvironmental Maps of Pennsylvanian Rocks, Illinois Basin and Northern Midcontinent Region, by Harold R. Wanless and Cynthia R. Wright, presents in detail the environments of deposition of Pennsylvanian rocks in these two regions. This publication has been issued by The Geological Society of America as no. 23 in the society's Map and Chart series. The areal extent of selected stratigraphic sequences, the lithologic units within these sequences, and the environments of deposition of the lithologic units are important geologic data that should be of interest to students of Pennsylvanian stratigraphy, coal geologists, and mining engineers.

A 32-page text is accompanied by 160 black and white patterned maps, which are printed on one side of loose 8½- by 11-inch sheets. MC-23 costs $26.00 and can be purchased from The Geological Society of America, Publication Sales Department, 3300 Penrose Place, Boulder, Colorado 80301.

DOE's NURE Issues Hydrogeochemical Survey Report

The Clinton 1° × 2° Quadrangle in Oklahoma was studied in the report *Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Clinton NTMS Quadrangle, Oklahoma.* The 147-page report was one of five released as a part of the U.S. Department of Energy's (DOE) National Uranium Resource Evaluation (NURE) program and placed on open file by DOE.

Data from stream sediments and ground water tested from 667 and 699 sites, respectively, show that uranium concentrations range from less than 0.02 to 152.30 ppb in water samples and from 0.40 to 18.10 ppm in sediment samples.

A copy of the report can be inspected at the Oklahoma Geological Survey; it is also available on microfiche from the Grand Junction Office of DOE for $5.00. Prepaid orders should be sent to Bendix Field Engineering Corp., Technical Library, P.O. Box 1569, Grand Junction, Colorado 81501. Checks should be made payable to Bendix Field Engineering Corp., the operating contractor. For further information, write DOE's office in Grand Junction.

OKLAHOMA ABSTRACTS

Association of American Geographers Annual Meeting Philadelphia, Pennsylvania, April 22–25, 1979

The following abstract is reprinted from *Program Abstracts, 75th Anniversary Meeting* of the Association of American Geographers. The page number is given in brackets below the abstract. Permission of the author and of John R. Mather, editor, to reproduce this abstract is gratefully acknowledged.

Bulk Density, Particle Shape, and the Differential Erosion of Mine Dump Spoil Constituents

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Two contiguous strip-mine spoil bank complexes at Henryetta, eastern Oklahoma, were examined. These dumps were created by similar techniques and from

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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.

similar materials but at different times. One complex is 50, the other 20 years old. Pyncometer tests of surface materials indicate mean bulk densities of 2.1–2.2 (older site) and 1.9–2.0 (younger site). Comparisons of the stone fractions reveal significantly fewer coals, and more sandstones, in samples from the older site. Shales and ironstones occur in similar proportions on both sites. Results are explained in terms of differences in particle bulk density, particle shape, and resistance to comminution. [15]

AAPG-SEPM-EMD 28th Annual Meeting Rocky Mountain Section Casper, Wyoming, June 3–6, 1979

The following abstract is reprinted from the May 1979 issue, v. 63, of the *Bulletin* of The American Association of Petroleum Geologists. The page number is given in brackets below the abstract. Permission of the author and of John W. Shelton, editor, to reproduce the abstract is gratefully acknowledged.

Depositional Facies and Uranium Occurrence, Triassic (Dockum Group), Texas Panhandle

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Late Triassic (Dockum Group) rocks accumulated in relict Paleozoic basins bound by the Amarillo uplift on the north and the Glass Mountains on the south. Basins were reactivated by late Paleozoic or early Mesozoic tectonic activity that created the Gulf of Mexico.

More than 2,000 ft (600 m) of terrigenous clastics, derived mostly from older sedimentary rocks, accumulated within the basin. Source areas were in Texas, Oklahoma, and New Mexico. The Dockum Group accumulated in a variety of depositional systems including (1) braided and meandering streams, (2) alluvial fans and fan deltas, (3) highly constructive lobate deltas, (4) lacustrine systems including ephemeral and relatively long-lived lakes, and (5) mud flats.

Dockum sedimentation was cyclic, a reflection of alternately humid and arid climatic conditions. During humid climatic conditions lake level was relatively stable. Meandering streams supplied sediment to high-constructive lobate deltas in the central basin area; braided streams and fan deltas were dominant depositional elements within southern and northern basin areas. During arid climatic conditions base level was lowered, stream valleys evolved, and small fan deltas developed along ephemeral lake margins; evaporites, calcretes, silcretes, and soils developed on floors of ephemeral lakes and on delta platforms.

Uranium occurs within about 25 depositional facies. Highest uranium values are in lacustrine facies which developed under arid climatic conditions. Channel-lag facies of meander-belt systems generally exhibit consistently higher uranium values than other depositional facies. Crevasse-channel and crevasse-splay deposits locally contain mineralized carbonized wood. Delta-front sandstones of high-constructive lobate deltas contain uranium. Radioactive minerals are present within conglomeratic parts of the valley-fill sequence. Although a relation exists between uranium occurrence and depositional facies, prediction of uranium occurrence is difficult because of a complex groundwater history. [835]

OKLAHOMA GEOLOGY NOTES

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