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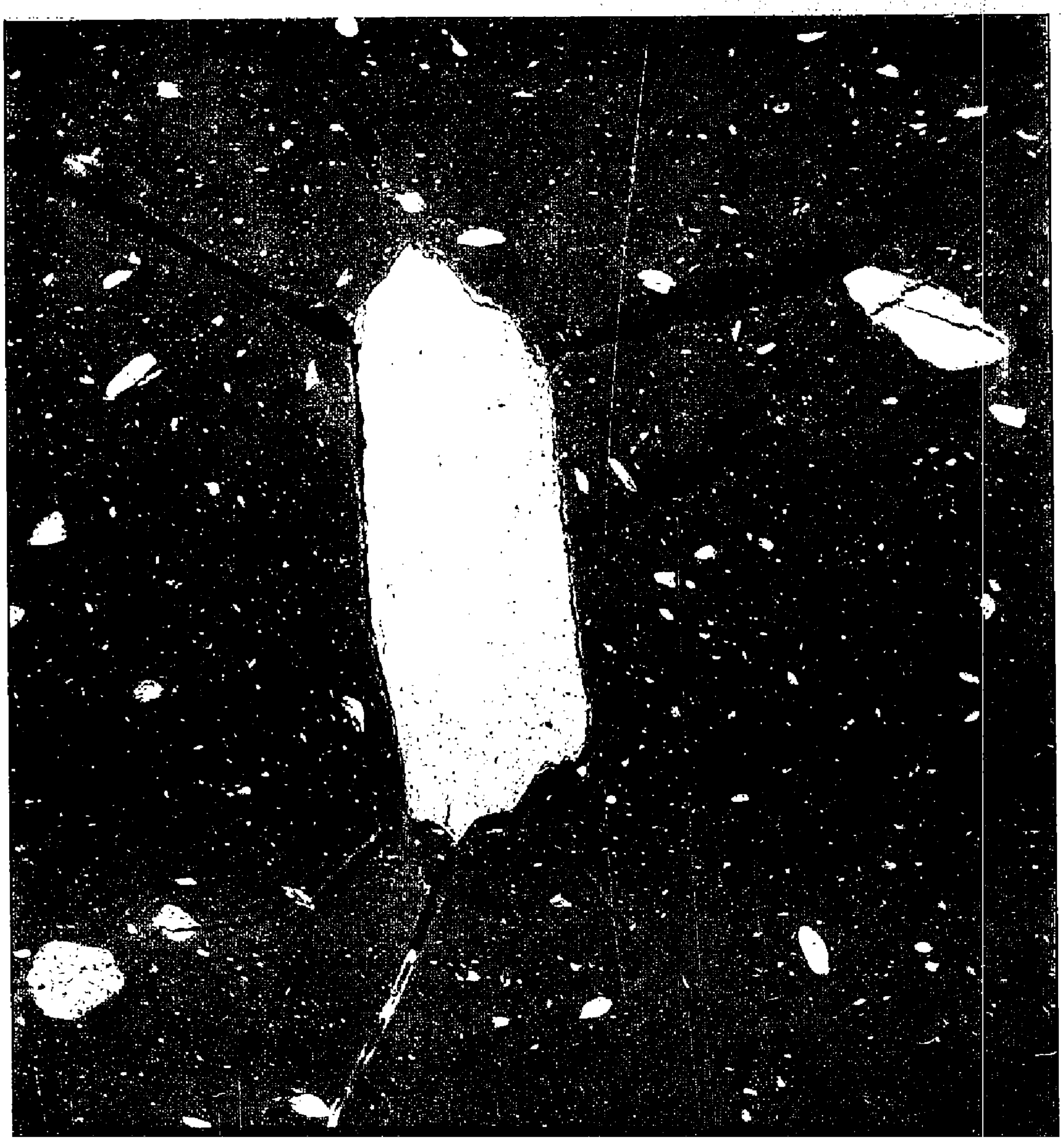

On the cover—

Minerals in the Whitesboro Impsonite

A scanning electron photomicrograph (back-scattered image, scale bar = 100 μm) depicting minerals (mostly clays) in a polished impsonite sample from the Whitesboro deposit in Le Flore County, Oklahoma (sec. 19, T. 3 N., R. 23 E.). Some of the clay grains and clay aggregates contain detectable amounts of vanadium, an element highly enriched in this sample.

Some solid-hydrocarbon samples from south-central Oklahoma and the Ouachita Mountains of southeastern Oklahoma are exceedingly pure, containing <1% ash yield. Other samples yield >20% ash. In the sample suite there is a very strong positive correlation between ash yield and the concentration of vanadium (an element commonly enriched in solid hydrocarbons). See article on p. 136–143.

Robert B. Finkelman
U.S. Geological Survey

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OKLAHOMA GEOLOGY NOTES

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TRACE-ELEMENT CONTENT OF SOLID HYDROCARBONS FROM OKLAHOMA

***Robert B. Finkelman*[1] *and Brian J. Cardott*[2]**

Solid hydrocarbons, which include asphaltites (such as gilsonite and grahamite) and asphaltic pyrobitumens (such as impsonite and albertite) have been used as energy sources and as chemical feedstocks. These solid hydrocarbons, also known as migrabitumen and solid bitumen, were mined in the Ouachita Mountains of southeastern Oklahoma in the late 19th and early 20th centuries. Long before that, Native Americans used asphaltites as adhesives to bind stone arrowheads to wooden shafts (Cardott and others, 1993).

Grab samples of grahamite and impsonite were collected from tailings piles at abandoned mines or prospects in the Ouachita Mountains of southeastern Oklahoma. Although much has been written about the geology and origin of these hydrocarbons (Cardott and others, 1993, and references cited therein), there is little information about their trace-element content, except that they are enriched in vanadium and nickel (Curiale and Harrison, 1981; Curiale, 1992). Trace-element information could be useful as an indicator of source material, by-product potential, and potential environmental impact. In this note we present data on the trace-element content of eight solid hydrocarbons (three impsonite samples and five grahamite samples) from south-central Oklahoma and the Ouachita Mountains of southeastern Oklahoma. These samples include the five reported on by Cardott and others (1993) and three additional grahamite samples from the Loco, Pumroy, and Jumbo deposits (Table 1).

Information on location, host rocks, and composition of the solid hydrocarbons is given in Table 1. Figure 1 shows the sample locations. Splits of each sample were analyzed by one or more of the following procedures: instrumental neutron activation analysis (INAA), atomic absorption (AA) spectroscopy, and optical emission spectroscopy (OES). INAA is a quantitative analytical procedure conducted on the raw material. Quantitative AA analysis and semiquantitative OES were performed on the 550°C ash. Descriptions of these procedures, as applied to coal, can be found in Golightly and Simon (1989).

Tables 2 and 3 give results of the chemical analyses reported on an as-received basis. The major oxides are grouped in Table 2. Oxide totals range from 78.8 to 111.8%. There was insufficient sample available for complete analysis of the samples from the Pumroy and Kiamichi deposits. Table 3 contains data on trace elements in parts per million (ppm), except for gold (Au), which is in parts per billion (ppb).

The nickel (Ni) content of the solid bitumen samples is very uniform and ranges from 305 to 430 ppm. However, the NiO content of the ash varies from 0.3 wt% (Whitesboro) to 7.4 wt% (Pumroy). Vanadium (V) content of the bitumen shows a

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TABLE 1. — LOCATION INFORMATION, ROCK ASSOCIATIONS, AND COMPOSITIONAL DATA

Deposit	Loco	Pumroy	Jumbo	Sardis	Kiamichi	Whitesboro	Windingstair	Page
Other names used	LeGrande LeGrand	McGee Creek McGee Valley	Impson Valley Choctaw mine Old Slope mine	Jackfork Valley Jackfork Creek Tuskahoma				Black Fork Mountain
Type	Grahamite	Grahamite	Grahamite	Grahamite	Grahamite	Epi-impsonite	Epi-impsonite	Epi-impsonite
Location	sec. 6 T. 2 S. R. 4 W.	sec. 30 T. 1 S. R. 14 E.	sec. 28 T. 1 S. R. 15 E.	sec. 9 T. 2 N. R. 18 E.	sec. 22 T. 2 N. R. 20 E.	sec. 19 T. 3 N. R. 23 E.	sec. 20 T. 3 N. R. 25 E.	sec. 24 T. 3 N. R. 26 E.
Thickness	max. 12′	max. 10′	max. 40′	max. 25′	max. 8″	max. 8″	max. 12′	max. 15′
Host rock	Purcell Sandstone (Hennessey Group)	Stanley Group	Stanley Group	Tenmile Creek Fm. (Stanley Group)	Tenmile Creek Fm. (Stanley Group)	Stanley Group	lower part of Jackfork Group	Wildhorse Mountain Fm. (Jackfork Group)
Age	Permian	Mississippian	Mississippian	Mississippian	Mississippian	Mississippian	Pennsylvanian (Morrowan)	Pennsylvanian (Morrrowan)
Sample no.	955	867	868	866	912	910	899	898
Composition[a]								
Moisture			0.25	0.54	2.88	2.09	2.16	0.60
Ash			1.45	0.27	23.35	23.73	1.82	0.77
Volatile matter			42.33	44.21	34.79	19.82	23.80	22.00
Fixed carbon			55.97	54.98	38.98	54.36	72.22	76.63
Sulfur			1.47	1.46	2.89	1.48	1.61	1.65
Reference			Taff (1899)	Cardott et al. (1993)	Cardott et al. (1993)	Cardott et al. (1993)	Cardott et al. (1993)	Cardott et al. (1993)

[a]Percent, as-received basis, as reported from the literature.

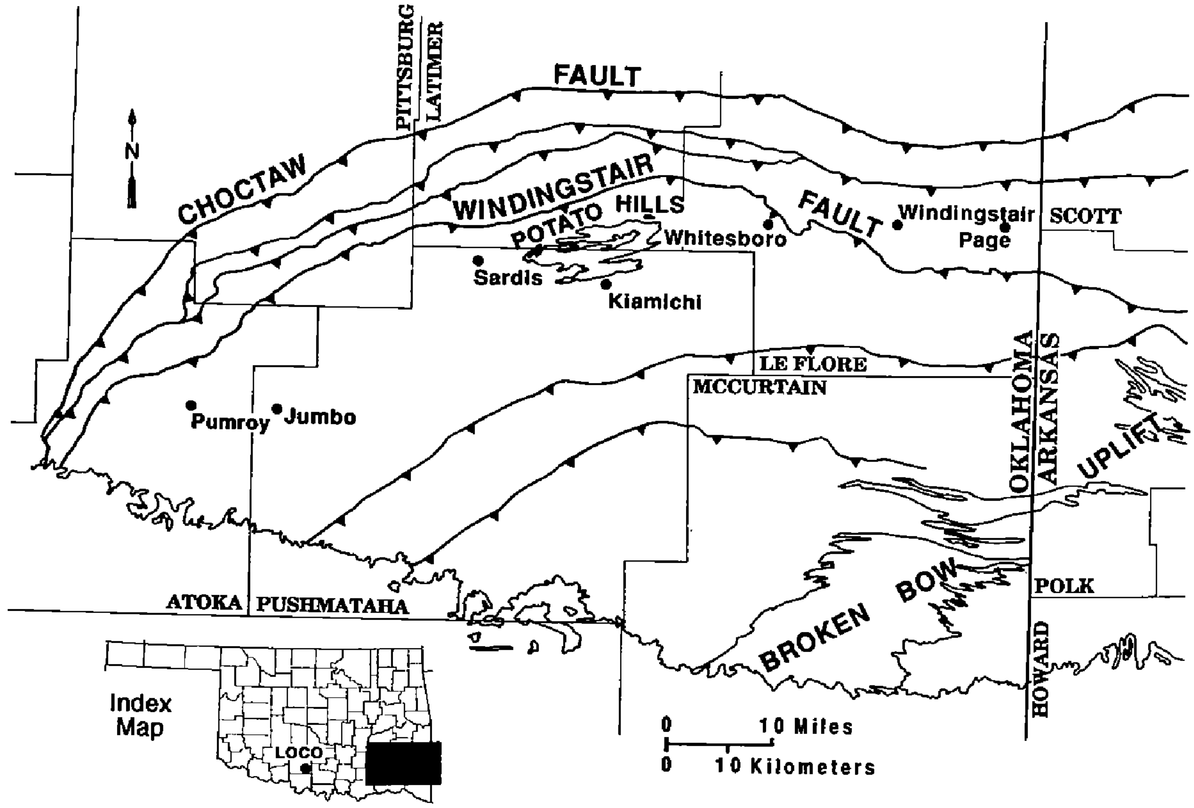

Figure 1. Location of solid-hydrocarbon samples. The Loco deposit is located on index map.

wide variation from 90 ppm (Pumroy) to 11,900 ppm (Whitesboro), with all but two samples (Pumroy and Kiamichi) having >800 ppm. The V_2O_5 contents of the ash range from 2.6 wt% (Pumroy) to 19 wt% (Page). It should be noted that the vanadium and nickel contents reported here differ from those reported by Curiale and Harrison (1981) and Curiale (1992). The differences (Table 4) probably reflect differences in the composition of individual samples collected from tailings piles and should serve as a caution against drawing firm conclusions based on the analyses of samples collected in this manner.

Other anomalous trace-element concentrations include the high gold (Au) content (53 ppb) of the Page impsonite sample (6.6 ppm on an ash basis [(53 ppb/0.8% ash) × 100 = 6,625 ppb or 6.6 ppm]), the high tungsten (W) in the Page sample (~1,000 ppm in the ash [(8.6 ppm/0.8% ash) ×100]), and the high thallium (Tl) in the Windingstair impsonite sample (320 ppm on an ash basis [(4.16 ppm/1.3% ash) × 100]).

The uranium (U) contents of these samples did not exceed 0.82 ppm on an as-received basis. Uraniferous asphaltites are known from several states (Hawley and others, 1965) and from Great Britain, where Parnell (1988) found bitumen specimens having as much as 20% uranium. The solid hydrocarbon samples from Oklahoma appear to have moderate molybdenum (Mo) contents, the highest being 3.1 ppm (Loco). Krejci-Graf (1972) cited a Peruvian albertite having 350 ppm molybdenum; Saltoglu and others (1978) reported on a Turkish asphaltite having 1,300 ppm molybdenum; and Parnell (1988) cited a Colombian bitumen having 1,000 ppm molybdenum.

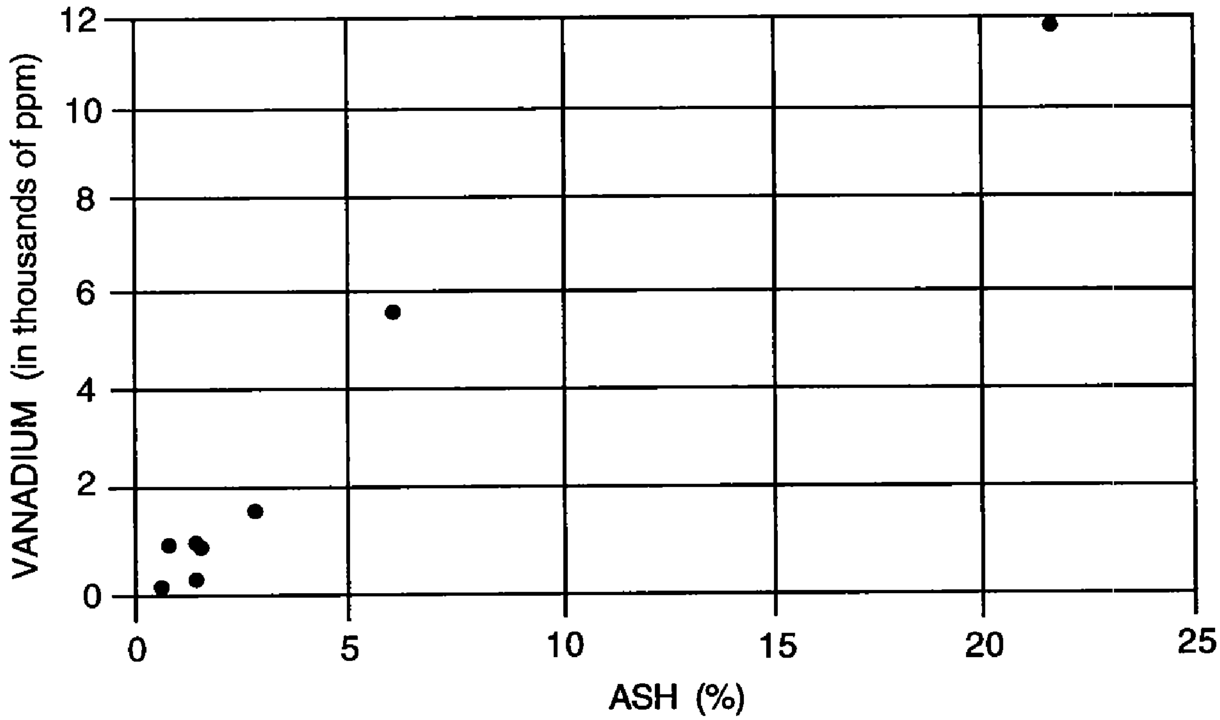

Figure 2. Plot of ash yield to vanadium.

A curious feature of our sample suite is the very strong positive correlation between vanadium and the ash yield ($r = 0.97$; Fig. 2). The ash of these samples contains 2.6–19 wt% V_2O_5; however, it is very unlikely that the original ash contained this much vanadium because few, if any, sediments contain this much vanadium.

One explanation for the relationship between vanadium and ash is that vanadium existed as an organometallic complex, such as a porphyrin, in the precursor of the solid hydrocarbon (Dunning, 1963). As the material began to mature and condense, vanadium may have been expelled from the organometallic complex. Hodgson (1954) suggested that vanadyl porphyrins are less stable than their nickel counterparts. The released vanadium could then react with the ash components to form various inorganic phases. The more ash components there are in the bitumen, the more ash there is for the vanadium to react with; thus, there is the strong correlation between vanadium and ash yield.

This suggestion is consistent with comments of Parnell (1988) who noted that very high metal enrichments necessitate the existence of minerals in the solid bitumen. He suggested several ways in which the mineral inclusions could form. Parnell (1988, p. 195) stated that, "When a metal is concentrated within a bitumen by continuous absorption of metal or loss of hydrocarbons, at some stage the metal can no longer be accommodated as an organometallic complex and will have to precipitate as an inorganic mineral." He offered as evidence the occurrence of the vanadium sulfide, patronite, in solid bitumens having exceptionally high vanadium contents. In addition, Finkelman (1981) reported micron-size crystals of montrosite (VO[OH]) in a Venezuelan asphaltite containing >1,000 ppm vanadium in the ash.

The wide range of vanadium contents that appear in Table 4 may reflect the relationship between vanadium and ash yield. Chemical analyses from the three different studies indicate that the nickel content of the solid hydrocarbons is uniform

TABLE 2. — CHEMICAL ANALYSES OF OKLAHOMA SOLID BITUMEN: MAJOR OXIDES IN THE ASH[a]

Analysis[b]	Oxide	Loco	Pumroy	Jumbo	Sardis	Kiamichi	Whitesboro	Windingstair	Page
AA	SiO_2	53.2	—[c]	61.7	57.4	—	61.7	36.2	38.3
AA	Al_2O_3	18.4	7.4	18.6	17.8	10.4	20.0	12.8	10.2
AA	Fe_2O_3	4.6	4.6	6.2	5.1	4.5	6.4	7.7	5.7
AA	MgO	0.7	0.8	1.6	0.7	0.9	1.8	0.8	3.5
AA	CaO	0.7	13.2	0.6	0.7	0.9	0.7	1.0	3.9
AA	Na_2O	0.3	0.4	1.4	0.3	1.0	1.2	0.5	0.5
AA	K_2O	1.2	1.1	3.2	1.2	2.7	3.1	1.6	2.4
AA	TiO_2	0.9	0.5	0.8	0.9	0.5	0.9	0.5	0.3
AA	P_2O_5	—	—	0.1	—	—	0.1	1.4	0.9
AA	MnO	—	—	0.1	—	—	—	0.0	0.3
AA	BaO	—	—	—	—	—	—	0.1	0.16
INAA	NiO	3.8	7.4	0.9	3.2	3.9	0.3	3.9	6.5
AA	V_2O_5	10.7	2.6	16.6	9.8	3.4	9.5	12.1	19.0
INAA	CoO	—	—	—	—	—	—	0.1	0.16
	Total	94.5		111.8	97.1		105.7	78.8	91.8
	Ash (%)	2.8	0.6	6.0	1.5	1.3	21.6	1.3	0.8

[a]All values are in weight percent.
[b]AA = atomic absorption spectroscopy; INAA = instrumental neutron activation analysis.
[c]— = no data.

within each of the three sites. Vanadium content, however, varies substantially at each site. We infer that the variation of vanadium is real and not an artifact of sampling or analysis. The wide range of vanadium contents is consistent with the range of ash yield we found for a grahamite sample not included in this study. The ash yield for nine particles from the Waldrop grahamite ranged from 0.03 to 0.36%. We also found a similar range of ash yield for the Kiamichi grahamite. Cardott and others (1993) reported the ash yield to be 23.35% (Table 1). In the split used for elemental analysis, we found an ash yield of 1.3% (Table 2).

Preliminary scanning electron microscopy and X-ray diffraction analysis of the Oklahoma samples indicate that the vanadium may be associated with clays. Qualitative energy-dispersive X-ray fluorescence analysis indicates the presence of vanadium in clay particles from several samples (Kiamichi, Windingstair, and Page). Roscoelite, a mica containing as much as 27% vanadium, has been shown to weather to mixed-layered mica-montmorillonite and chlorite (Hathaway, 1959). Further work is being conducted to ascertain the mineralogical associations of the vanadium in these samples.

Parnell (1988) noted that metals are particularly concentrated in the asphaltene fraction of the bitumen; thus, degraded bitumens, which are enriched in asphal-

TABLE 3. — CHEMICAL ANALYSES OF OKLAHOMA SOLID BITUMEN: TRACE ELEMENTS ON AN AS-RECEIVED BASIS[a]

Analysis[b]	Element	Loco	Pumroy	Jumbo	Sardis	Kiamichi	Whitesboro	Windingstair	Page
OES	Ag	—[c]	—	—	—	—	—	—	0.01
INAA	As	1.29	0.16	0.74	0.06	0.62	1.99	0.47	0.6
INAA	Au (ppb)	<0.5	0.43	<0.7	0.37	0.55	<2	5	53
OES	B	—	—	—	—	—	—	0.9	0.6
AA	Ba	19	1.86	34.8	10.2	5.59	147	5.07	3.12
INAA	Be	—	—	—	—	—	—	0.16	0.16
AA	Cd	—	—	—	—	—	—	0.03	0.06
INAA	Ce	2.99	0.36	5.4	0.58	0.96	24	1.13	0.88
INAA	Co	3.72	26.6	23.2	13	1.69	12	21.8	16.6
INAA	Cr	4.81	0.72	5.2	0.93	1.82	21.4	2.75	2.6
AA	Cu	5.9	0.54	1.74	3.3	0.23	38.9	1.95	1.68
INAA	Er	—	—	—	—	—	—	—	—
OES	Eu	0.05	<0.01	0.1	0.01	0.3	0.5	0.03	<0.03
OES	Ga	—	—	—	—	—	—	1.56	0.688
INAA	Hf	0.176	<0.02	0.273	0.035	0.037	1.09	0.073	0.083
INAA	La	2.04	0.192	3.31	0.359	0.444	13.9	0.7	0.508
AA	Li	1.9	0.186	3.96	1.05	0.754	19.66	0.468	0.336
INAA	Lu	0.018	<0.003	0.031	0.004	—	0.135	0.009	<0.009
AA	Mn	3.64	1.32	28.8	1.95	2.21	71.3	18.2	1.28
AA	Mo	3.08	—	0.582	1.5	—	2.16	2.47	0.752
OES	Nb	—	—	—	—	—	—	0.247	0.02
INAA	Nd	<3	<1	<3	<1	<2	<10	<1	<2
INAA	Ni	400	305	360	395	320	430	370	370
AA	Pb	—	—	—	—	—	—	0.4	0.96
INAA	Sb	0.084	0.098	0.07	0.02	0.855	0.205	0.096	0.098
INAA	Sc	0.458	0.072	0.984	0.083	0.108	4.28	0.16	0.132
INAA	Sm	0.29	0.038	0.563	0.048	0.075	2.63	0.1	0.08
OES	Sn	—	—	—	—	—	—	6.1	0.1
AA	Sr	9.24	1.68	9	5.1	1.22	36.7	4.81	1.12
INAA	Ta	0.042	<0.03	0.084	<0.02	<0.4	0.328	0.03	<0.03
INAA	Tb	0.025	<0.003	0.057	<0.007	<0.009	0.266	0.02	<0.01
INAA	Th	0.43	0.065	0.95	0.083	0.115	4.07	0.15	0.14
OES	Tl	—	—	—	—	—	—	4.16	1.68
INAA	U	0.139	0.04	0.244	<0.03	0.082	0.82	0.083	<0.07
AA	V	1740	90	5760	855	260	11900	910	880
INAA	W	0.087	<0.04	0.135	0.024	0.065	0.54	5	8.6
AA	Y	0.59	0.2	1.5	0.032	—	5.83	0.403	0.12
INAA	Yb	0.127	0.022	0.229	0.025	0.038	0.84	0.07	<0.03
INAA	Zn	6.3	<2	6.5	<2	2.9	23.6	5.9	8.1
AA	Zr	5.9	—	9	3	—	32.4	7.5	2.2
INAA	Se	0.77	0.47	0.5	0.27	0.49	0.8	0.29	<0.4
INAA	Br	7.54	0.8	2.4	1.52	2.68	2.86	7.15	6.63
INAA	Rb	4.6	<2	10.9	<2	<3	36	<2	<2
INAA	Cs	0.084	0.072	0.07	0.086	0.099	2.96	0.083	0.066

[a]All values are in ppm, except as noted.
[b]AA = atomic absorption spectroscopy; INAA = instrumental neutron activation analysis; OES = optical emission spectrographic analysis.
[c]— = no data.

TABLE 4. — V AND Ni CONTENTS (ppm) OF OKLAHOMA SOLID HYDROCARBONS

Site	Element	Source: Curiale & Harrison (1981)	Curiale (1992)	This paper
Jumbo	Ni	402	422	360
	V	399	544	5760
Sardis	Ni	725, 608	459	395
	V	183, 318	436	855
Pumroy	Ni	370	359	305
	V	583	1000	90

tenes, contain more metals (vanadium and nickel) than their nondegraded equivalents. He further stated that, with increasing time and/or temperature and consequent decrease of the H/C ratio of the solid bitumen, metals originally bound in organic form may precipitate. In other words, the bitumen becomes supersaturated with metals as organic matter is lost.

In studying the bitumen reflectance, volatile matter content, and solubility of five of these samples, Cardott and others (1993) found a trend that they attributed to thermal maturation. We found no detectable relationship of vanadium content to degree of thermal maturation, to geographic location, or to the sulfur content of the solid hydrocarbons. If such relationships exist, they have been overshadowed by the V/ash relationship.

These preliminary observations on solid hydrocarbons from Oklahoma indicate that their trace-element geochemistry contains information that may be useful in determining the organic/inorganic interactions that occurred during their genesis and as an indicator of by-product and environmental-impact potential.

The anomalously high concentrations of gold and tungsten (plus the presence of silver) in the Page impsonite may be indicative of nearby mineralization. Any use of the Windingstair impsonite should take into account the presence of thallium, a potentially phytotoxic element. The solid hydrocarbons also offer us an opportunity to study the complex interactions of vanadium and other elements with organic matter. However, comprehensive, systematic mineralogical and chemical analyses will be required to extract the potential value of the trace-element geochemistry of solid hydrocarbons.

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OKLAHOMA PETROLEUM INDUSTRY

Charles J. Mankin[1]

Introduction

The petroleum industry has been, and remains, Oklahoma's most important economic activity. Even today, with depressed crude-oil and natural-gas prices, the gross revenues from production were in excess of $5 billion for 1992. The gross-production taxes from that revenue exceeded $344 million. Employment in the industry was about 65,000, two-thirds of whom were in exploration and development.

Production of crude oil and natural gas is a significant component of Oklahoma's history and development as a State. From Statehood through 1992, Oklahoma produced >16 billion bbl of crude oil (Fig. 1). The peak production for crude oil was 278 million bbl in 1927.

Oklahoma also produced >76 trillion cubic feet (Tcf) of natural gas from 1947 through 1992 (Fig. 2). Data prior to 1947 are incomplete, but the volumes of marketed natural gas were small, mostly for local or regional use.

With the development of interstate gas-transmission systems, the production of natural gas has grown to >2 Tcf/year. The peak year in natural gas production was 1990, with 2.23 Tcf.

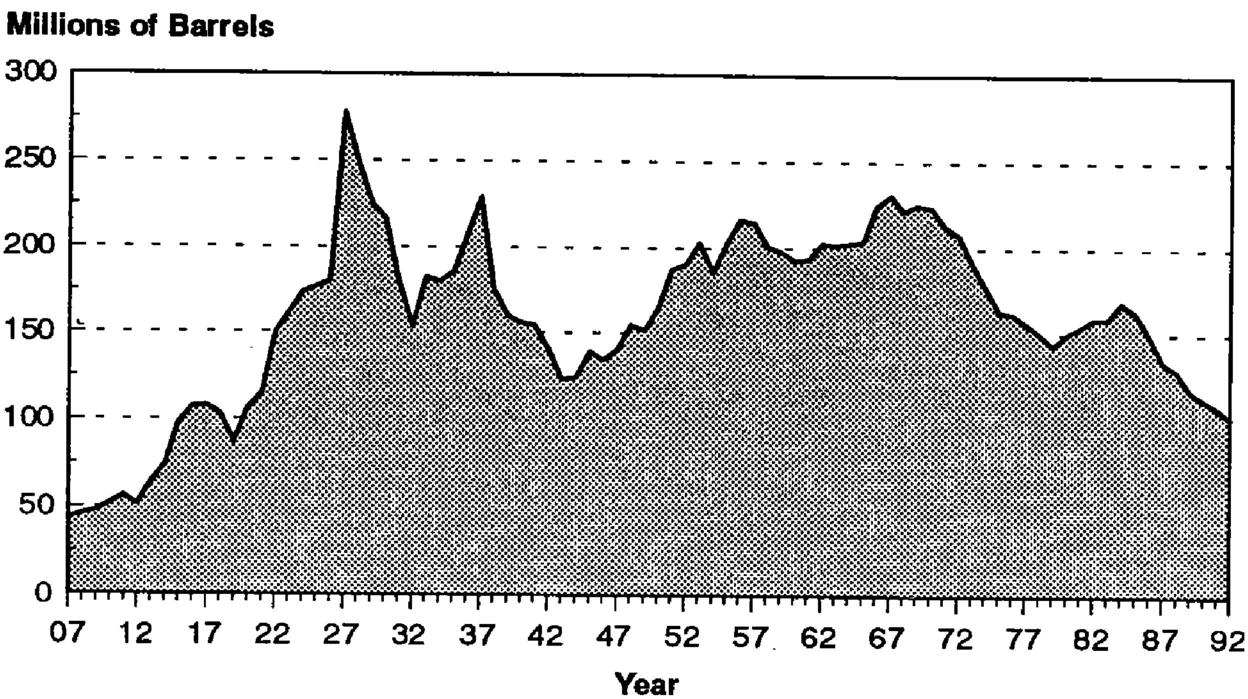


Figure 1. Petroleum production in Oklahoma, 1907–92.

[1]Oklahoma Geological Survey.

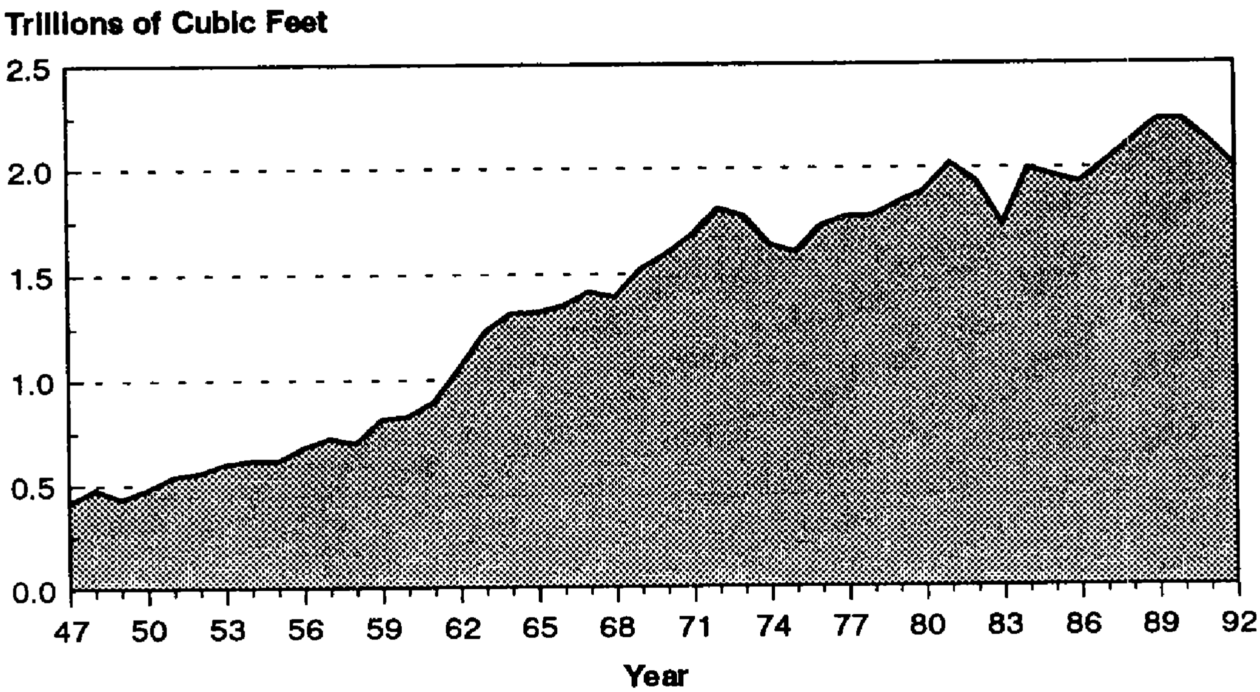


Figure 2. Natural-gas production in Oklahoma, 1947–92. Accurate data are not available for marketed natural-gas production prior to 1947.

Petroleum

With the decline in world oil prices, crude-oil production in Oklahoma began a steep decline (Fig. 3). That decline has averaged 8 million bbl/year, leaving Oklahoma's production in 1992 at 101 million bbl. In 1993, Oklahoma will produce <100 million bbl of crude oil. The last time that occurred in the State was in 1919.

Oklahoma's crude-oil production comes from 101,000 producing wells, 73,000 of which are classified as stripper wells (Fig. 4).

The average oil production per well in Oklahoma is now at 2.9 bbl/day. The average for stripper wells is <2 bbl/day. This low rate of production, and the fact that most oil wells are on artificial lift (pumping), lead to high operating costs. In 1991, 90,000 of the 101,000 wells operating in Oklahoma were on artificial lift. Thus, these wells are very sensitive to economics. Decreases in price, or increases in taxes or operating costs, lead to an increase in the rate of well abandonment. The current operating costs for oil production in Oklahoma range from $9.00 to $12.00 per barrel, depending upon the volume of produced water and other operating expenses.

Information is not available at present to determine the actual production for each well in the State because production is reported by lease or sub-lease and not by well. However, lease production is still a useful measure because each lease contains one or more wells. Therefore, lease production will be equal to, or more than, the actual well production. An examination of lease and sub-lease reported production for the first six months of 1992 indicates that two-thirds of the producing leases are in the range of 0–4 bbl/day (Fig. 5).

In the first half of 1992, there were 3,000 active leases that reported no production. More than 6,000 leases (20%) reported as much as 1 bbl/day of production. Another 6,000 reported 1–2 bbl/day of production. To the extent that these leases have more than one well, the actual per-well production would be less.

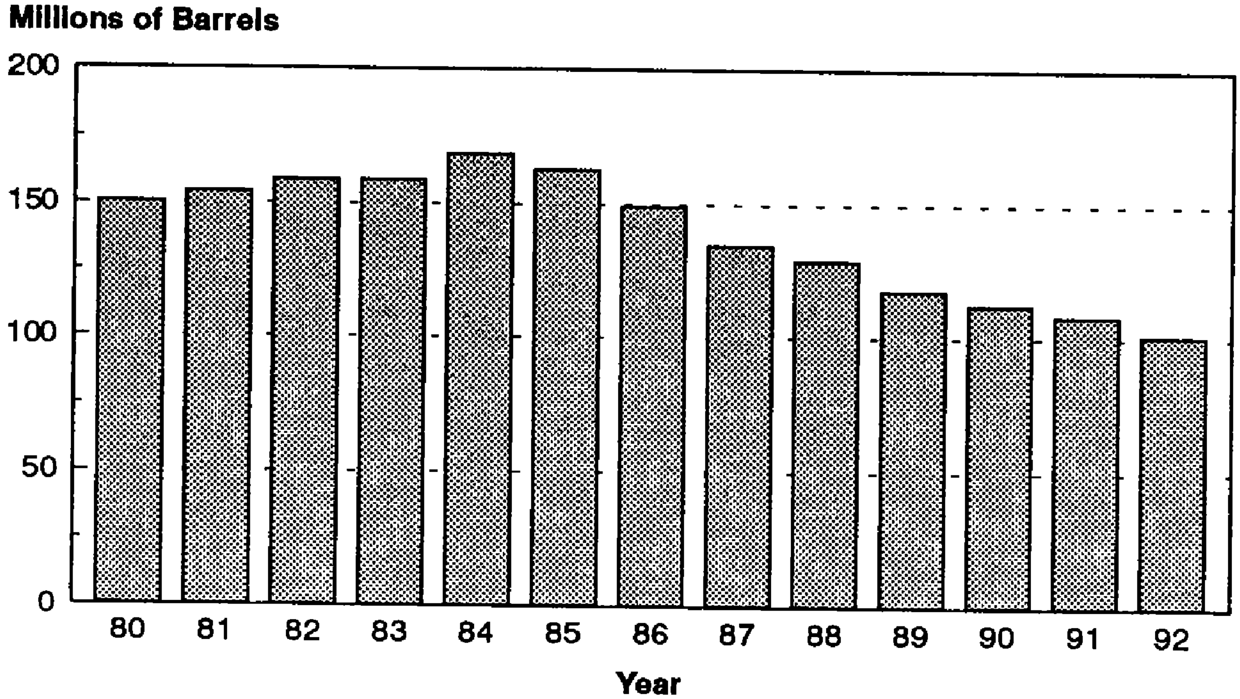


Figure 3. Production of crude oil in Oklahoma, 1980–92. The decline from 1984 through 1992 averages 8 million bbl/year.

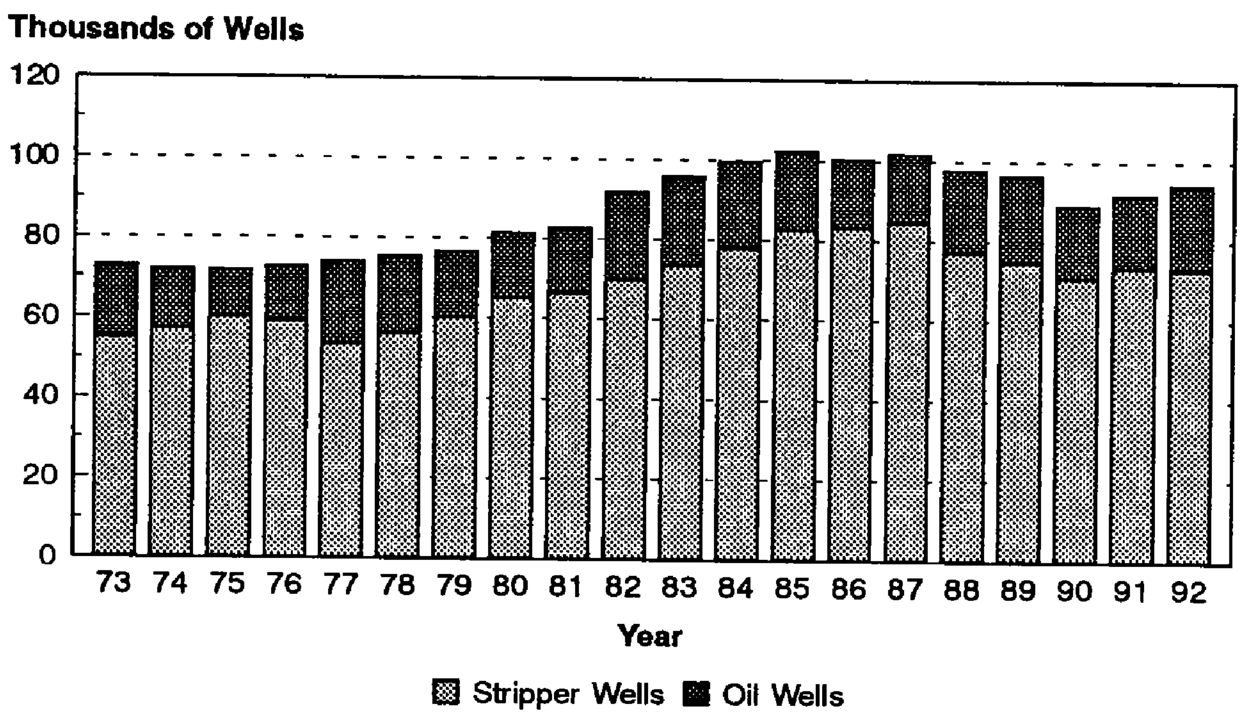


Figure 4. Producing oil wells in Oklahoma. Stripper wells account for about 75% of the total number of wells.

There are slightly more than 1,300 leases and sub-leases in Oklahoma that produce >30 bbl/day. These were not included in Figure 5 because the number of such leases in each increment of production is very small and could not be shown on the figure at its present scale. In total, these 1,300 leases contribute 7% of the State's crude-oil production.

The distribution of annual crude oil production is shown in Figure 6. More than 10% of the State's annual production of crude oil comes from leases that produce <4 bbl/day, 30% is from leases that produce <10 bbl/day, and 50% is from leases that produce <20 bbl/day. These leases are among those with the highest operating costs, and therefore they are very sensitive to decreases in prices and/or increases in taxes. It is from these leases that most of the wells are abandoned in the State.

With the decrease in price and increase in operating costs, the rate of abandonment of wells has been increasing rapidly (Fig. 7).

For the past four years, >2,000 wells per year have been plugged and abandoned. Increases in operating costs, without a corresponding increase in price, will result in an additional increase in the abandonment rate of wells. Because of the large number of wells that are in the marginal (stripper) category, increases in operating costs will produce a significant rise in the number of abandoned wells per year.

The premature abandonment of producing wells not only costs the State in production, but also affects the overall economy. Each well should be considered to be a small business because each well requires several people, spending at least part of their time, to support its operation. Thus, the abandonment of wells adds to the loss of jobs in the community where the abandonment takes place.

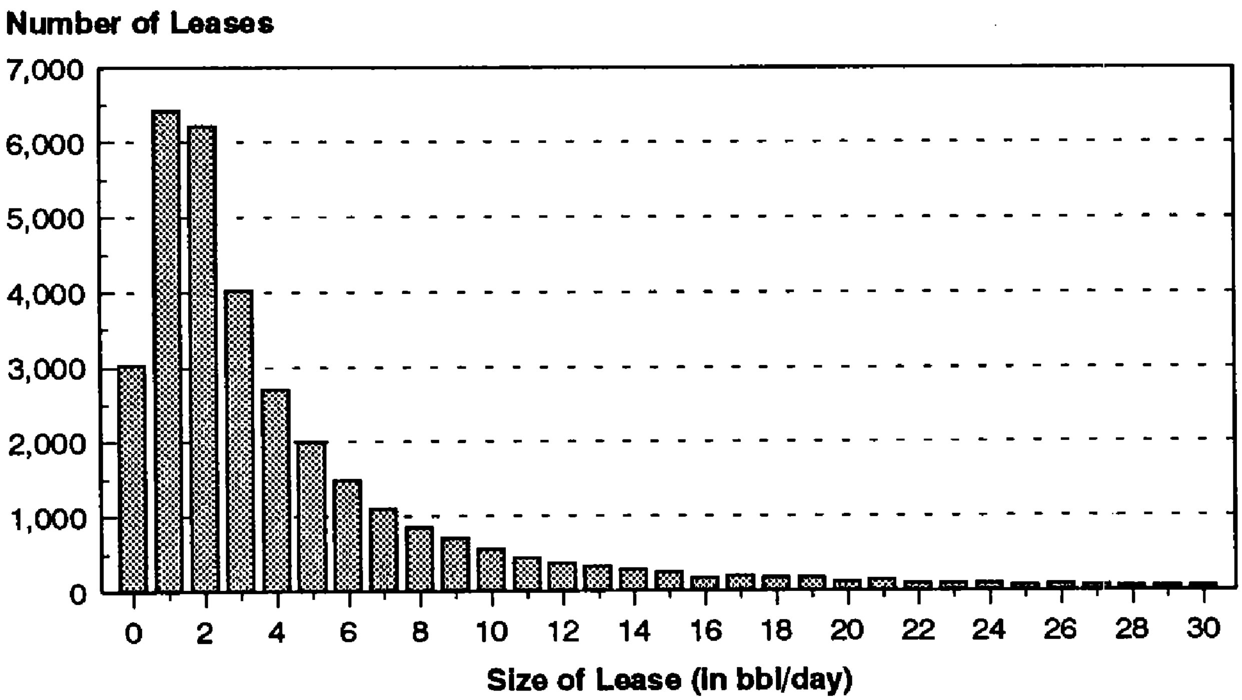


Figure 5. Number of leases versus size of lease production for 1992. The total number of leases represented in this figure is 32,459.

Because virtually all of the wells that are in the marginal category are on artificial lift, increases in operating costs from higher electrical prices will contribute substantially to increased abandonment of wells. In addition, for those wells that use natural gas or natural-gas liquids (e.g., butane or propane) as the energy supply for

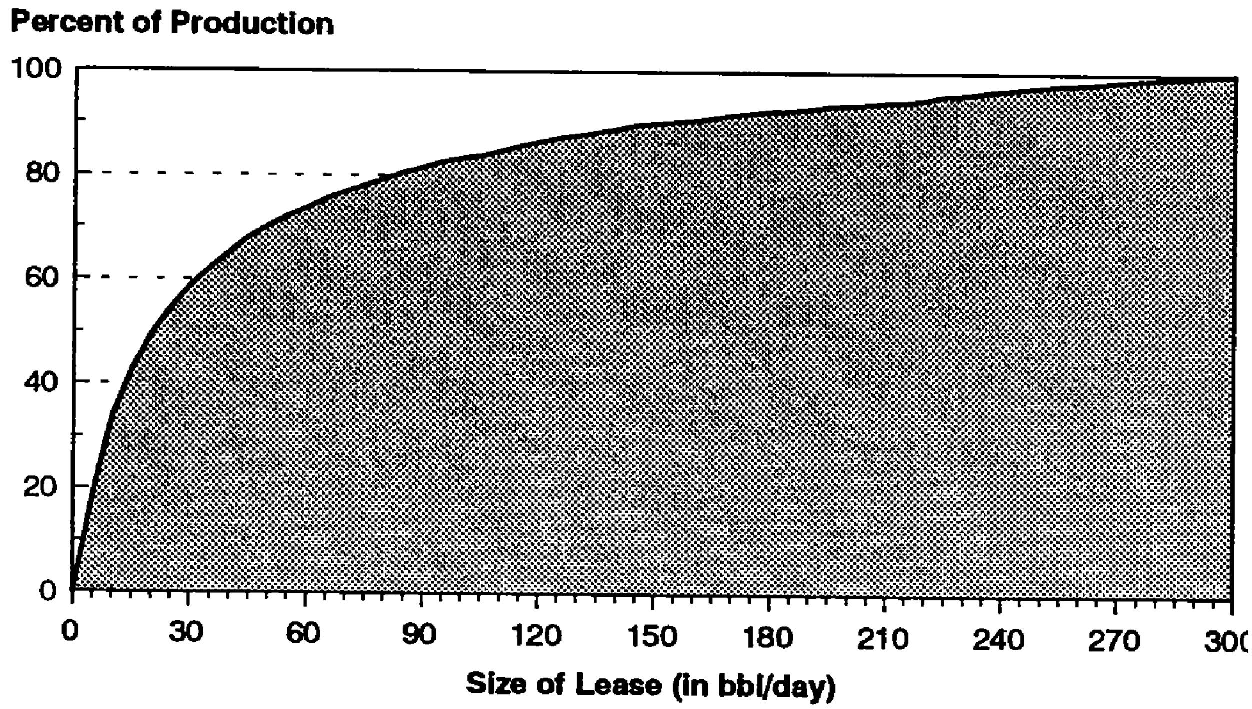


Figure 6. Annual production of crude oil, by size of lease, in cumulative percent.

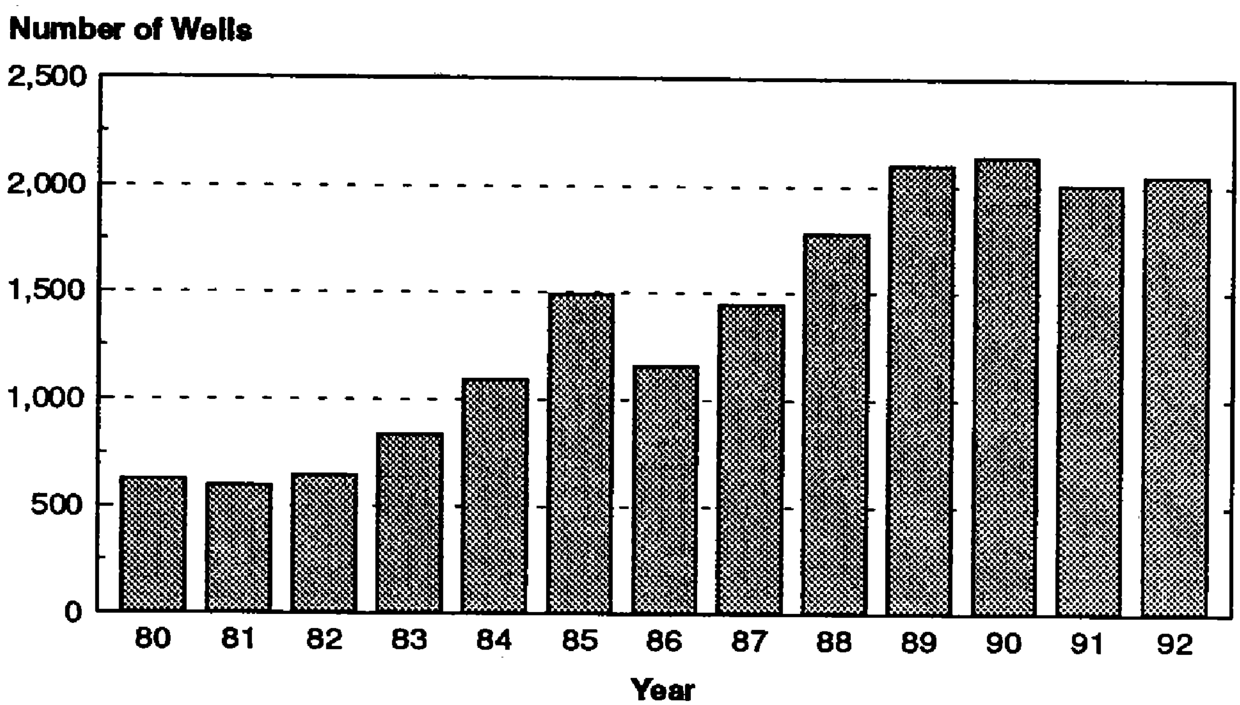


Figure 7. Abandonment of producing wells in Oklahoma, 1980–92. The 1992 figure is an estimate.

pumps, increased costs of these commodities also will contribute to the loss of producing wells.

Natural Gas

Natural-gas production consists of that portion that comes from gas wells (nonassociated natural gas) and that portion produced in association with the production of crude oil (associated natural gas). In 1992, <20% of the total natural-gas production was associated natural gas. This report describes the production of nonassociated natural gas.

The State has about 28,000 producing natural gas wells. They range in size from wells that produce as little as 50 thousand cubic feet (Mcf) to >50 million cubic feet (MMcf) of gas per day. As with crude oil, natural-gas production is reported by lease or sub-lease. Thus, production by well is not readily available. However, the reported production by lease is a reasonable measure of well production because, for most natural-gas leases, the well spacing is larger than for most oil-producing leases; thus, a natural-gas lease is more likely to reflect production from a single well. The number of leases and sub-leases that were reported as active in the first six months of 1992 was 21,510. These leases were divided into categories of 50 Mcf/day, and the number of leases in each category is shown in Figure 8.

In Figure 8, 1,000 active leases reported no production for the first six months of 1992. More than 8,300 leases produced an average of <50 Mcf/day. An additional 3,500 leases produced <100 Mcf/day. The illustration includes only those leases that have an average production of as much as 1,200 Mcf/day, representing >97% of the total distribution. The remaining distribution includes leases with productions

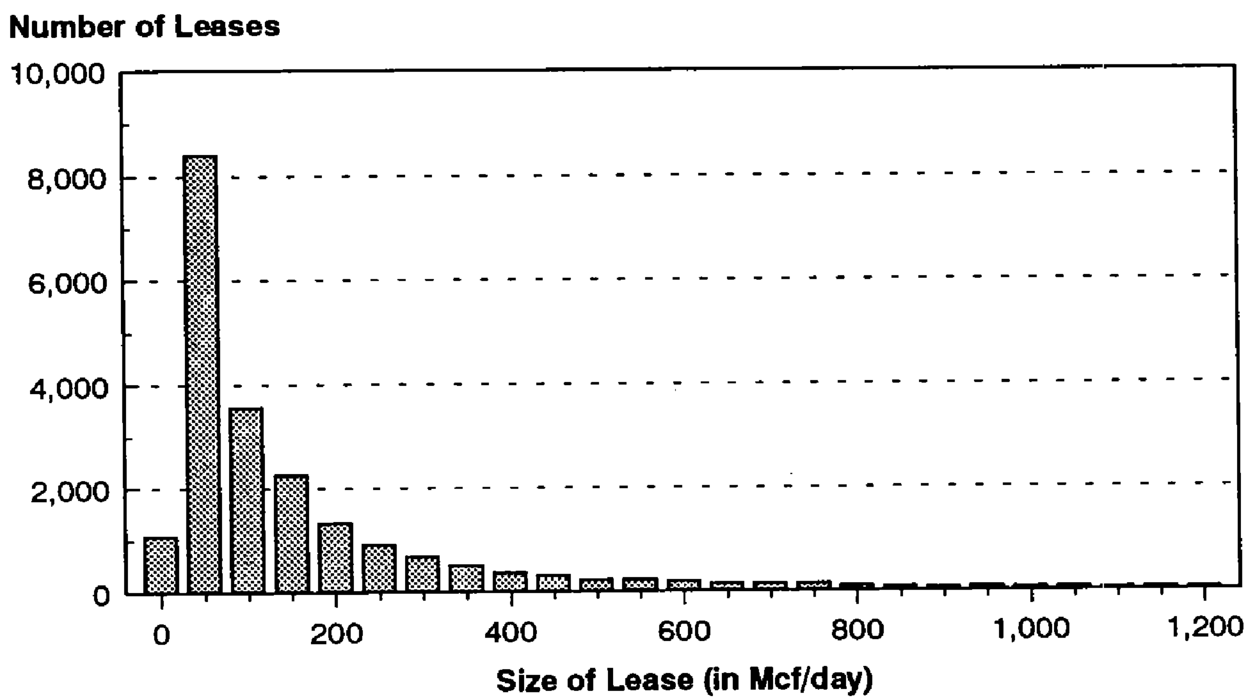


Figure 8. Distribution of number of natural-gas-producing leases by size of lease, in increments of 50 Mcf/day.

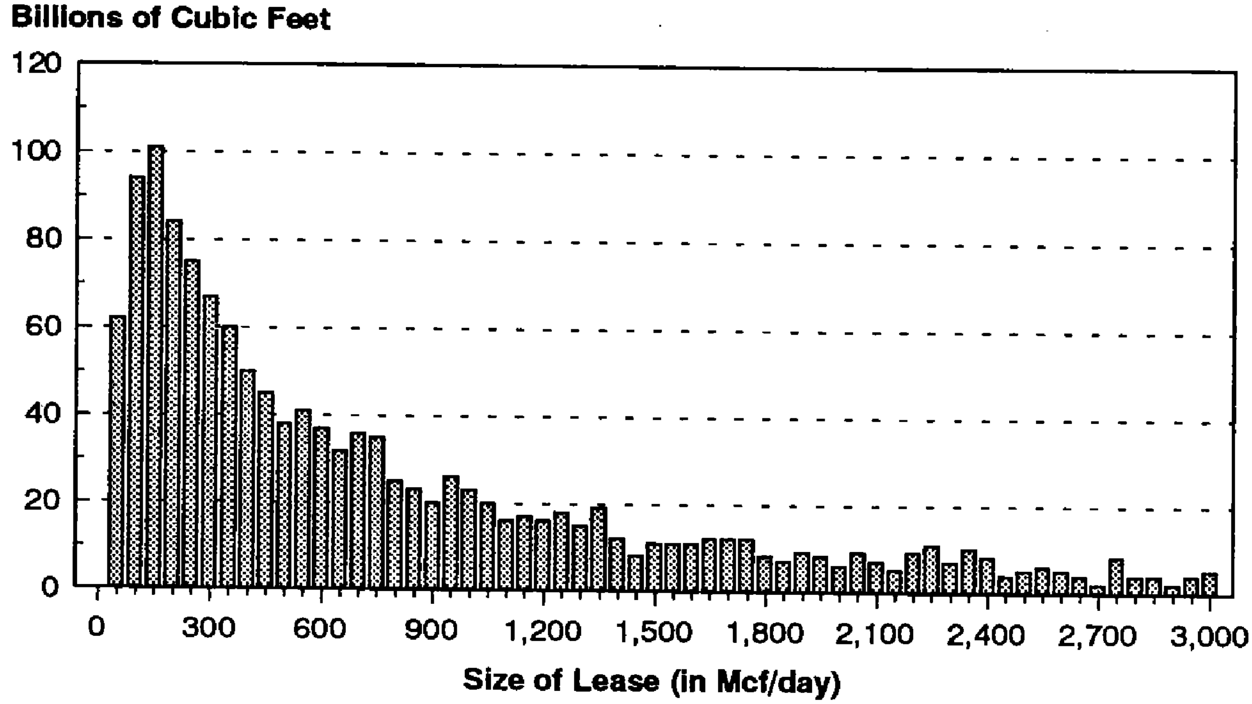


Figure 9. Annual production of natural gas, by size of lease. The entire distribution is shown, except for the 139 leases that exceed 3,000 Mcf/day in average production.

of as much as 3,000 Mcf/day, in increments of 50 Mcf/day, and a final category that includes all leases exceeding 3,000 Mcf/day. The final category contains 139 leases, representing 0.6% of the total distribution.

Annual non-associated natural-gas production, separated by size of lease, is shown in Figure 9. The same lease-size distribution was used as in Figure 8. The annual production, by size of lease, in cumulative percent is shown in Figure 10.

An examination of Figures 9 and 10 shows that 30%, or 500 billion cubic feet (Bcf), of annual production of non-associated natural gas is from leases that produce <300 Mcf/day. One-half (800 Bcf) of the State's annual non-associated natural gas production is from leases that produce <700 Mcf/day. Thus, even with natural gas, production from small wells is important to the total annual volume.

For the past several years, natural gas has been sold at a price well below replacement cost. Consequently, both drilling and reserves have declined. Unless prices improve and stabilize above $2.00 per Mcf, we can anticipate a shortage of supply in the near future.

Conclusions

The proposed Btu tax on crude oil and natural gas can have a significant negative effect on future production. If the tax is imposed at the wellhead on these commodities, the decline in production will be dramatic. More than 85% of Oklahoma's producing oil leases could be abandoned within three to five years, thus reducing the State's crude-oil production by >30 million bbl/year. The information on natural gas suggests a similar, but less dramatic, effect on the State's production.

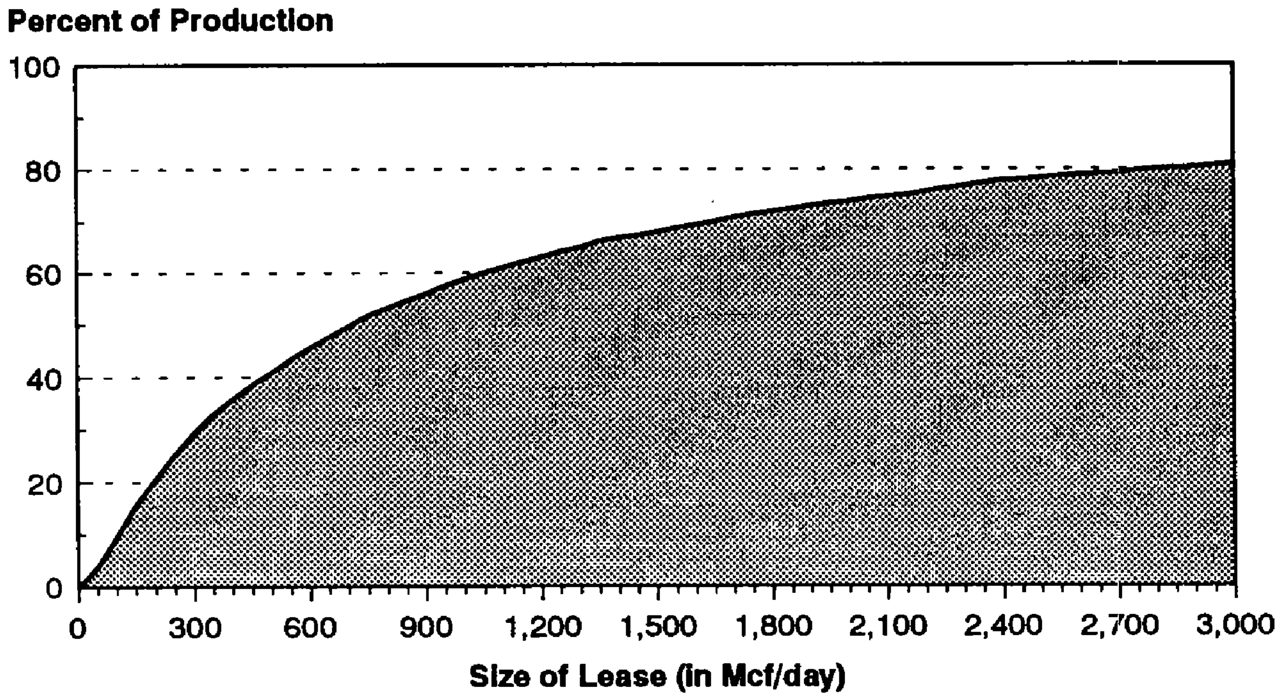


Figure 10. Annual production of natural gas, by size of lease, in cumulative percent. Those leases that exceed 3,000 Mcf/day, in average production, account for 19% of the total production.

If the Btu tax is imposed at the gasoline pump, then the primary effect will be the increased operating costs that the producer will have to pay for electricity, gasoline, diesel, and natural-gas liquids (butane and propane). While those cost increases will have a less dramatic effect on production, nevertheless, they will be negative. This will cause an increase in the rate of well abandonment, unless offset by a corresponding increase in oil and gas prices.

Thus, the effect of the Btu tax on the petroleum industry in Oklahoma will be negative. The only uncertainty is the severity of that effect.

Acknowledgments

This report was prepared with the assistance of Geological Information Systems (GIS), a research unit of the University of Oklahoma. GIS has worked with the Oklahoma Geological Survey in developing the Natural Resources Information Systems (NRIS), a set of computerized data bases that now contain information on petroleum production and well-history records in the State. In the future, NRIS will contain information on coal, non-fuel minerals, and water.

Special appreciation is extended to Ms. Anne Mycek-Memoli and Ms. Mary Banken for developing the information from NRIS for this report.

NEW OGS PUBLICATION

SPECIAL PUBLICATION 93-2. *Industrial-Minerals Development in Oklahoma—A Symposium,* edited by Kenneth S. Johnson. 88 pages. Price: $5.

From the editor's preface:

Industrial minerals are widely distributed in Oklahoma and they are being mined in 69 of the State's 77 counties. These industrial minerals, most of which are used in the construction industries, include limestone, granite, gypsum, salt, sand and gravel, clays, cement, silica sand, and iodine, among other minerals; they do not include metals, coal, or oil and gas. Industrial minerals are critical to the State's current and future development, for without ready access to these commodities, the costs of construction and manufacturing would increase sharply.

On December 1–2, 1992, a symposium was held in order to better understand the resource base, rules, regulations, and environmental issues related to wise development of Oklahoma's industrial minerals. The format established for the symposium was to have 17 speakers discuss the major factors involved in starting up and operating an industrial-mineral mine; these factors include exploration, leasing, permits, quality control, transportation, marketing, inspections, water quality, wetlands, air quality, reclamation, and future developments. The symposium was jointly organized and cosponsored by the Oklahoma Geological Survey, Oklahoma Department of Mines, Oklahoma Mining Commission, and U.S. Bureau of Mines. About 125 people attended the symposium, including representatives of industry, government (city, state, and federal), academia (faculty and students), environmental organizations, and the general public. This symposium-proceedings volume contains the written papers of all who presented talks at the symposium.

Special Publication 93-2 can be obtained over the counter or by mail from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031. Add 10% to the cost of publication(s) for mail orders, with a minimum of 50¢ per order.

OPEN HOUSE SET FOR OGS LOG LIBRARY

An open house is scheduled for Friday, September 10, from 2 to 6 p.m., at the new location of the Oklahoma Geological Survey's Well Log Library. Old movies of the boom days in the Oklahoma oil fields will play continuously, Joy Hampton, former OGS petroleum geologist and coordinator of the event, said. Hot dogs, popcorn, and other "movie" food will be served.

The library was moved from Gould Hall at the University of Oklahoma to a location at 1425 George Street in Norman. George Street runs south from Lindsey Street, and is east of the main campus of OU.

The Log Library is the repository for more than 200,000 logs and several sets of scout tickets.

For more information about the open house, contact the Library at (405) 447-3118.

NEW OKLAHOMA LAW DEFINES GEOLOGISTS

A new Oklahoma law signed into effect May 26 of this year defines the terms "geology" and "geologist." The legislation, which was House Bill No. 1167, was entered as Section 35 of Title 25, and defines geologists by either education or work experience. When work experience is used in lieu of education, it is "grandfathered" into the legislation and includes work experience for a period of five years prior to the law's effective date of May 26. Publication in a geologic publication or experience as an expert witness in legal proceedings also are considered as geological work experience.

The law reads as follows:

BE IT ENACTED BY THE PEOPLE OF THE STATE OF OKAHOMA:

SECTION 1. NEW LAW A new section of law to be codified in the Oklahoma Statues as Section 35 of Title 25, unless there is created a duplication in numbering, reads as follows:

As used in the Oklahoma Statutes:

1. "Geology" means the science which is:
   a. the study of the earth and its origin and history, in general,
   b. the investigation, including collection of specimens, of the earth's constituent rocks, minerals, fossils, solids, fluids including surface and underground waters, gases, and other materials, from the center of its core to the outer limits of its atmosphere, and
   c. the application and utilization of this knowledge of the earth for the benefit of mankind; provided, the knowledge and principles of geology may also be applied to extraterrestrial bodies; and
2. "Geologist" means a person who:
   a. has earned a baccalaureate or higher degree in a geological science from an institution of higher education which is accredited by a regional or national accrediting agency, with a minimum of thirty (30) semester hours or forty-five (45) quarter hours of undergraduate or graduate work in a field of geology, or
   b. has a specific and continuous record of related and verifiable geological work experience for five (5) years prior to the effective date of this act. Publication in a geologic publication or prior qualification as an expert witness in an administrative or judicial proceeding, hearing, or trial shall be prima facie verification of geological work experience.

SECTION 2. It being immediately necessary for the preservation of the public peace, health and safety, an emergency is hereby declared to exist, by reason whereof this act shall take effect and be in full force from and after its passage and approval.

HUNTON GROUP WORKSHOP AND FIELD TRIP
Norman, Oklahoma, November 2–3, 1993

The Oklahoma Geological Survey and the Bartlesville Project Office of the U.S. Department of Energy will co-sponsor a major core workshop and field trip focusing on the Late Ordovician–Silurian–Devonian Hunton Group in the southern Midcontinent. The workshop will be held at the University of Oklahoma, Norman, Tuesday, November 2, and the field trip will examine excellent outcrops in the Arbuckle Mountains on November 3. It will be possible to attend the workshop, the field trip, or both events.

The Hunton Group is a widespread sequence of shallow-marine carbonates in the southern Midcontinent. It consists mainly of limestone in the deep-basin area of the southern Oklahoma aulacogen, and it is partly dolomitized in the shelf area. The unit has been of major interest as a target for oil and gas exploration for many years, and this workshop is intended to help in the exchange of information about this important petroleum reservoir.

Below is a tentative program for the workshop presentations:

- **Overview of Hunton Facies and Reservoirs in the Anadarko Basin**, by Zuhair Al-Shaieb, Oklahoma State University, Stillwater, OK; Geoff Beardall; Kathy M. Lippert, Southwestern Energy Production Co., Oklahoma City, OK; Frederica Manni, Core Laboratories, Houston, TX; Felicia Matthews, Independent Geologist, Oslo, Norway; and Pat Medlock, MASERA Corp., Tulsa, OK
- **Sequence Stratigraphy of the Hunton Group as Defined by Core, Outcrop, and Log Data**, by Richard D. Fritz and Pat Medlock, MASERA Corp., Tulsa, OK
- **Outcrop and Subsurface Evidence for Karsted Reservoirs in the Fusselman Formation (Silurian), Permian Basin, Texas**, by S. J. Mazzullo, Wichita State University, Wichita, KS
- **Aspects of the Hunton at the Western End of the Anadarko Basin, Texas Panhandle**, by Bob Olsen, Arrington CJM, Inc., Canadian, TX
- **Reservoir Characteristics of an Upper Hunton Gas-Producing Zone, Southwest Ringwood Area, Major County, Oklahoma**, by Gene Mear, Independent Geologist, Austin, TX; and Keith Hutton, Cross Timbers Oil Co., Fort Worth, TX
- **Study of Selected Hunton Cores from the Anadarko Basin, Oklahoma**, by Gerald M. Friedman, Northeastern Science Foundation, Troy, NY
- **Depositional and Diagenetic Character of Hunton-Equivalent Rocks in the Permian Basin of West Texas**, by Stephen C. Ruppel, Bureau of Economic Geology, Austin, TX
- **Stratigraphy and Petroleum Potential of the Hunton Group (Silurian–Devonian) in the Forest City Basin Area of Nebraska and Kansas**, by Marvin P. Carlson, Nebraska Geological Survey, Lincoln, NE; and K. David Newell, Kansas Geological Survey, Lawrence, KS

- **Log-Derived SP Trends of the Hunton, with Possible Ramifications to Henryhouse–Chimney Hill Depositional Environments, Lincoln and Logan Counties, Oklahoma**, by Kurt Rottmann, Beard Oil Co., Oklahoma City, OK
- **A Regional Look at Hunton Production in the Anadarko Basin**, by Sherrill D. Howery, Consulting Geologist, Oklahoma City, OK
- **Penters Formation Paleokarst in the Arkoma Basin and the Black Warrior Basin**, by Pat Medlock, MASERA Corp., Tulsa, OK
- **Stratigraphy of the Cason Shale, Brassfield, St. Clair, and Lafferty Limestones, and Penters Chert (Late Ordovician–Early Devonian) in the Arkansas Ozarks**, by William W. Craig, University of New Orleans, New Orleans, LA

For further information about the program, contact Ken Johnson, Workshop Coordinator. Copies of the final program and registration form can be requested from Tammie Creel, Registration Co-Chair, or from the OGS receptionist at (405) 325-3031.

UPCOMING MEETINGS

American Association of Stratigraphic Palynologists Meeting, "Palynology, Climate, and Sequence Stratigraphy of the Pliocene," October 27–28, 1993, Baton Rouge, Louisiana. Information: John Wrenn, Amoco Production Co., Box 3092, Houston, TX 77253; (713) 556-2297, fax 713-584-7468.

Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration—A Conference and Exposition, November 9–11, 1993, Houston, Texas. Information: National Ground Water Association, 6375 Riverside Dr., Dublin, OH 43017; (614) 761-1711, fax 614-761-3446.

MIDCONTINENT GAS RESERVOIRS ATLAS NOW AVAILABLE

The recently released *Atlas of Major Midcontinent Gas Reservoirs* is a cooperative effort of the geological surveys of three Midcontinent states—Arkansas, Kansas, and Oklahoma.

Edited by D. G. Bebout, W. A. White, and T. F. Hentz (Bureau of Economic Geology, The University of Texas at Austin), and M. K. Grasmick (Oklahoma Geological Survey), the study summarizes information from 530 gas reservoirs in Oklahoma, Kansas, and Arkansas that have produced at least 10 Bcf of natural gas. For the first time, new extended boundaries of Oklahoma fields have been delineated to include most of the previously unassigned production in the State.

Contributing authors are Mac Woodward (Arkansas Geological Commission); K. D. Parham (Kansas Geological Survey); and T. L. Bingham, R. L. Brown, J. A. Campbell, and R. A. Northcutt (Oklahoma Geological Survey).

The 85-page atlas is presented in a 17″ × 22″ format with four color plates at a scale of 1:1,000,000. The subject matter of the plates is (1) producing stratigraphic unit and major structural elements, (2) plays and depositional environment of reservoir facies, (3) reservoir lithology, and (4) trapping mechanism.

Coordinated by the Bureau of Economic Geology, this atlas is the third in a series that began with the *Atlas of Major Texas Gas Reservoirs*, published in 1989, and continued with the *Atlas of Major Central and Eastern Gulf Coast Gas Reservoirs*, published in 1992. The objective of these atlases is to document principal geologic and engineering characteristics of natural gas reservoirs in the major gas-producing regions of the United States. The Gas Research Institute provided major funding to compile data and prepare and print the atlas.

Reservoirs are categorized into 28 plays on the basis of geologic attributes such as lithology, geologic age, trap type, and depositional environment. There are 32 data tables and 404 figures in support of the geologic plays (listed below).

PERMIAN PLAYS:

Wolfcampian Platform Dolostone—Amarillo–Wichita Uplift, Oklahoma
Wolfcampian Shallow-Shelf Carbonate—Hugoton Embayment, Kansas and Oklahoma
Lower Permian Sandstone—Southern Oklahoma Folded Belt

PENNSYLVANIAN PLAYS:

Pennsylvanian Alluvial-Fan and Fan-Delta Siliciclastics—Anadarko Basin, Oklahoma
Virgilian Deltaic Sandstone—Anadarko Basin, Oklahoma

Virgilian Fluvial-Deltaic Sandstone—Sedgwick Basin, Kansas
Virgilian Shallow-Shelf Limestone—Hugoton Embayment, Kansas and Oklahoma
Missourian Shallow-Marine Sandstone—Anadarko Basin, Oklahoma
Missourian Cyclic Shelf Limestone—Hugoton Embayment, Kansas
Desmoinesian Fluvial-Deltaic Sandstone and Shallow-Marine Limestone—Anadarko Basin, Oklahoma
Desmoinesian Fluvial-Deltaic Sandstone—Arkoma Basin, Oklahoma and Eastern Kansas
Atoka Marine Sandstone—Anadarko Basin, Oklahoma
Atoka Channel, Submarine-Fan, and Transgressive Sandstone—Arkoma Basin, Oklahoma and Arkansas
Morrow Sandstone—Anadarko Basin and Hugoton Embayment, Kansas and Oklahoma
Morrow Nearshore, Shallow-Marine Sandstone—Arkoma Basin, Oklahoma and Arkansas
Thrusted Spiro–Wapanucka Sandstone and Limestone—Arkoma Basin, Oklahoma
Morrow (Wapanucka) Shallow-Marine Carbonate—Arkoma Basin, Oklahoma
Springer Marine Sandstone—Anadarko Basin, Oklahoma

MISSISSIPPIAN PLAYS:

Mississippian Chert and Carbonate and Basal Pennsylvanian Sandstone—Central Kansas Uplift and Northern Oklahoma
Lower Chester Shallow-Marine Sandstone and Sandy Carbonate—Hugoton Embayment and Anadarko Basin, Kansas and Oklahoma
Upper Chester Shallow-Marine Carbonate—Anadarko Basin and Hugoton Embayment, Kansas and Oklahoma
Meramec–Osage Fractured Carbonate—Anadarko Basin, Oklahoma
Sycamore Fractured Carbonate and Siliciclastics—Southern Oklahoma Folded Belt

LOWER PALEOZOIC PLAYS:

Siluro–Devonian Shallow-Marine Carbonate—Anadarko Basin, Oklahoma
Cambro–Ordovician Structures—Anadarko and Ardmore Basins, Oklahoma
Lower Paleozoic Fault Blocks—Arkoma Basin, Oklahoma and Arkansas
Upper Cambrian Stratigraphic Traps—Central Kansas Uplift
Ordovician Structural Traps—Central Kansas Uplift

THE SOCIETY FOR ORGANIC PETROLOGY 10th ANNUAL MEETING Norman, Oklahoma, October 9–13, 1993

The 10th Annual Meeting of The Society for Organic Petrology (TSOP) will be held at the University of Oklahoma, Norman, October 9–13.

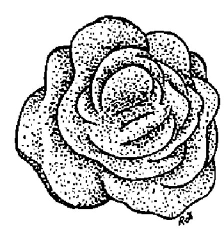
A two-day, pre-meeting short course on "Petroleum Geochemistry for Exploration Geologists and Geochemists," will be held Saturday and Sunday, October 9–10, in the Energy Center on the OU campus. Taught by Dr. R. P. Philp, professor of petroleum geochemistry, the course will review basic concepts of organic and petroleum geochemistry and applications to petroleum exploration and reservoir problems. The various aspects of organic and analytical chemistry necessary for completion of this course will be included.

Technical and poster sessions will be held in the OCCE Forum Building on Monday and Tuesday, October 11–12. Topics for the technical session are varied, covering coal (peat to bituminous; cannel to banded; gas; beneficiation); kerogen (petrology, chemistry and kinetics); petroleum geochemistry and migration; reservoir geochemistry; palynology; paleobotany; paleoclimate; and solid hydrocarbons. The invited speaker is Dr. M. D. Lewan of the U.S. Geological Survey, whose topic will be "Identifying and Understanding Suppressed Vitrinite through Hydrous Pyrolysis Experimentation."

A one-day, post-meeting field trip to the Arbuckle Mountains in southern Oklahoma will be held Wednesday, October 13. The trip will include stops at hydrocarbon source rock exposures, abandoned asphalt pits, fossil collecting sites, and scenic overlooks.

For further information about the meeting, contact Brian Cardott, Oklahoma Geological Survey, 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031, fax 405-325-7069.

NEW BOOK AVAILABLE ON OKLAHOMA'S ROSE ROCK



A new book, entitled "The Rose Rock of Oklahoma," has just been prepared and released by Joseph G. Stine and Nancy A. Stine of Noble, Oklahoma. The authors, who own and manage the Timberlake Rose Rock Museum in Noble, have devoted much of their lives collecting, studying, and exhibiting rose rocks, and preparing rose-rock sculptures.

The book describes the distribution, formation, and importance of rose rocks in Oklahoma, and relates the legends that have grown around this symbol of the State of Oklahoma (the rose rock became the official state rock in 1968). The 68-page book is well illustrated and informative; it is available for $6 from Timberlake Press, P.O. Box 663, Noble, Oklahoma 73068-0663; phone (405) 872-9838.

AAPG MID-CONTINENT SECTION MEETING
Amarillo, Texas, October 10–12, 1993

Howdy! Welcome to Amarillo, the "Yellow Rose of Texas." The Panhandle Geological Society and PGS Auxiliary are pleased to host the 1993 Mid-Continent Section Meeting of the American Association of Petroleum Geologists.

The theme of our convention is "Geologic Frontiers in the Mid-Continent." We chose this theme because we believe we are standing on the threshold of the door to a bright future. As geologists we are charged with the task of constantly rethinking old ideas, developing new techniques, and utilizing innovative technologies. Those who see the future as a new frontier will step through the door and be the trailblazers of our time. It is imperative that we have the foresight and commitment to take that step.

The technical session presents papers that offer a panoramic view of the "State of the Section" spanning from the development of new ideas to the re-evaluation of old interpretations. We have also included a section on environmental issues as they relate to exploration to keep pace with the growing need to address these issues.

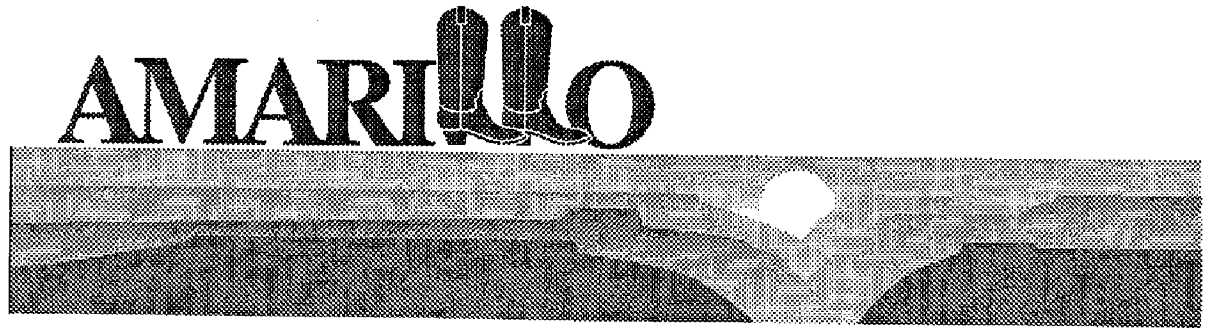
The field trips also span from the old to the new. Professors from West Texas A&M University will guide you through the rocks of the area. Stops will include the colorful walls of the Palo Duro Canyon State Park and Alibates Flint Quarries National Monument, where Paleo-Indians quarried flint over 10,000 years ago. A visit to the Panhandle Plains Museum will include the Petroleum Wing where an authentic cable-tool rig is exhibited. Finally, a tour of a contemporary petrochemical plant will be conducted.

Steve Crowell, our keynote speaker, will offer his views of the Mid-Continent as a viable area for continued exploration. At the All-Convention Luncheon, Thomas Barber will address the need for continued investment in exploration. Jim Pearson, DPA luncheon speaker, will discuss the problems of theft of geologic ideas and information. I am confident that each presentation will be enlightening.

I would like to extend my heart-felt thanks to everyone who contributed to the success of this meeting. I truly had exceptional support.

Welcome! Enjoy the finest in Texas hospitality.

—Jerry Anderson
General Chairman



AAPG Mid-Continent Section Meeting Agenda

Technical Sessions

October 11

1992 Estimate of Undiscovered Conventional Oil Resources in the Mid-Continent
Upstream Source Systems and Downstream Trap Systems
Sequence Stratigraphy—A Historical Perspective
What Happened to Science?
Relationship of Facies and Sequence Stratigraphy to Paleokarst and Fracture Overprints in the Carbonates of the Arbuckle Group in Evaluation of Exploration and Horizontal Drilling Potential
The Ames Astrobleme
The Geology of the Dakota Aquifer in Kansas
Factors Controlling Simpson Group Production in Central Oklahoma
Depositional Environment of the Cleveland Formation in the Ellis Ranch and Bradford, Cleveland Fields, Ochiltree and Lipscomb Counties, Texas
Reservoir Framework and Exploration Potential of the Cleveland Formation (Western Anadarko Basin) Using a Sequence-Stratigraphic Model
Depositional Environments of the Red Fork Sandstone in Custer and Roger Mills Counties, Southwestern Oklahoma
Submarine Fan Delta Depositional Environment of the Pennsylvanian Red Fork Sandstone

October 12

Environmental, Health, and Safety Issues for the Petroleum Geologist
The Use of Electromagnetic Methods to Locate Potential Sources of Highly Saline Water Entering the Canadian River Valley
Geochemical Characterization of Ground Water in the Vicinity of the Pantex Plant near Amarillo, Texas
Perched Aquifers—Their Potential Impact on Contaminant Transport in the Southern High Plains, Texas
Current and Emerging Fossil Energy Resources in Nebraska
3-D and the Penn Reef Play—Recent Experience
Morrow Channel Case Histories Using a New Exploration Approach
Lotus Template for Calculating Well Logs

Prediction of Upper Morrow Sandstone Thickness in Lipscomb County, Texas, through Analysis of Seismic Amplitudes
Seismic Exploration in the Dalhart Basin, Western Texas Panhandle
Log Analysis of a Pennsylvanian Strawn Sand Re-Entry in Central Texas
Recognition of Subaerial Exposure and Flooding Surfaces in Carbonate—Siliciclastic Eolianites and Marine Carbonate Sequences in Southwestern Kansas
Geologic Controls on the Occurrence of Methane in Coal Beds of the Pennsylvanian Hartshorne Formation, Arkoma Basin, Oklahoma
Quantitative Open-Hole Logging with Very Small Diameter Wireline Tools
Interpretation of the Reagan Fault, Garvin, Johnston, Murray, and Stephens Counties, Oklahoma
Outsourcing of Common Industry Data within a Major Oil and Gas Exploration Company

Short Course

Introduction to 3-D Seismic with Application to Stratigraphic Traps, *October 10*

Field Trips

Palo Duro Canyon and Panhandle–Plains Historical Museum (Harrington Petroleum Wing), *October 10*
Alibates Flint Quarries National Monument, Lake Meredith, and the Phillips Petroleum Refinery and Laboratories at Borger/Phillips, Texas, *October 10*

For further information about the Mid-Continent Section Meeting, contact AAPG, Convention Dept., P.O. Box 979, Tulsa, OK 74101; (918) 584-2555. The preregistration deadline is September 10.

THREE OGS STAFF MEMBERS RETIRE

Three employees have retired from the Oklahoma Geological Survey this year, taking with them a total of 40 years of experience. Eldon Cox, manager of the Core and Sample Library, left OGS after 21½ years; Louisa Joy Hampton was an OGS geologist for 10½ years; and Velma Cottrell was in the publication sales area for eight years. Pictures show retirees receiving plaque from OU President Van Horn.

Eldon Cox

Eldon came to the Geological Survey in 1971, and began work with the core and sample collection. He served in the Air Force in England during World War II, then came home to take engineering classes at Oklahoma Baptist University, in Shawnee, Oklahoma, and the University of Oklahoma, here in Norman. The class work was put to good use in the petroleum industry, providing Eldon a solid background for his work at the OGS.

After school, Eldon began work as a permit man and geophysical crew member with Standard Oil and Gas. He then moved into geological drafting, working for Sohio Petroleum, Pan American Petroleum Corp., and Humble Oil and Refining Co. before they closed their local office. This experience and his contacts in industry were very valuable to him at the Core and Sample Library.

"Eldon's dedication and diligent work at the OGS have helped us to expand and catalog our collection to its current status," Dr. Charles J. Mankin, OGS director, said.

"His industry experience, his organizational skills, and his ability to work with people enabled him to make a great contribution to this facility and its customers."

Louisa Joy Hampton

Louisa Joy Hampton became a Survey geologist in 1981, after working on campus at the Energy Resources Institute (ERI) since 1979. Before coming to ERI, she had been employed by the Oklahoma Corporation Commission since 1956. While with the Commission, Joy worked in virtually all areas of oil and gas regulatory activities.

Joy is active in the American Association of Petroleum Geologists, the American Institute of Professional Geologists, the Oklahoma City Geological Society, and the Interstate Oil and Gas Compact Commission.

She earned her degree in geology, with a minor in paleontology, in 1942, and was something of a pioneer in the field, since there were few female geologists working at that time. Her early experiences in the oil field included work with the seismic crews, when she sometimes sat on a case of dynamite on the way to the field.

"Joy truly was a pioneer in Oklahoma's petroleum industry," Dr. Mankin said. "As one of very few women geologists at that time, she set a standard for dedicated performance that others would do well to emulate."

"Because of her, we now have the most extensive collection of publicly available petroleum well-history information in the State," he added. "Her total commitment to her assigned responsibilities and to her profession set her apart from the crowd."

"She was, and continues to be an asset to the OGS and the State."

Her geologic background and working knowledge of Oklahoma fields proved to be invaluable for organizing the well logs at OGS. Her ties with industry also helped acquire more logs and more file cabinets in which to store the expanding collection.

Joy's efforts to catalog and file the well logs almost depleted the entire State of Oklahoma of file cabinets. She always knew just how many new ones she needed for each added group of logs or 1002-A's, and had colleagues scouring the area for certain colors and sizes of cabinets.

Staff members from OU's architectural and engineering services office came to old Gould Hall many times to look at the shifting walls and worry about the integrity of the building as Joy's collections continued to grow.

Velma Cottrell

Velma Cottrell began work at the OGS on January 14, 1985, but was soon sidelined for five months with a broken hip after a fall in icy weather on March 2 of that year.

Velma had worked on campus before as a cashier at the University Book Exchange from 1976 through 1978, then entered the world of medicine, working at a medical lab and doctor's office before coming to the Survey.

Many OGS customers came to know and rely on Velma from her work at the reception desk and publication sales area. Her willingness to take the extra time to find a specific map or book was a great help in tracking down needed, but often obscure, information.

"Velma had never worked with geologic maps when she came to the Survey," Dr. Mankin said. "But she made a great effort to learn about map scales, legal descriptions of property locations, and the other information found on our topographic sheets."

"Her efforts were greatly appreciated by our staff and customers, and her knowledge of our maps and publications will be missed very much."

The Oklahoma Geological Survey will miss these valued employees for their professionalism and their contributions to our work place, but we will miss them most of all for their sincere friendship. We all join in wishing them all of life's best for productive and enjoyable retirements.

—Connie Smith

OKLAHOMA ABSTRACTS

The Oklahoma Geological Survey thanks the American Association of Petroleum Geologists, Geological Society of America, U.S. Geological Survey, and the authors for permission to reprint the following abstracts of interest to Oklahoma geologists.

The Importance of Core-Drilling as a Research Instrument: The Oklahoma Geological Survey's Scientific Drilling Program

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The Oklahoma Geological Survey's drilling rig represents a unique scientific facility within the State with the capability to investigate geologic targets to a depth of 1,000 feet. The drilling rig serves as an ideal research tool for hypothesis testing, sample acquisition, and establishment of stratigraphic control points in regions of poorly exposed outcrops and in regions where access to outcrops is limited.

Core-hole data help: (1) to establish and correct sequence correlations from shelf to basin; (2) correct surface and subsurface mapping errors; (3) verify geologic structures; (4) propose depositional models; (5) gather data concerning the distribution, thickness, characteristics, and areal extent of coal deposits and associated strata; (6) designate reference wells near previously established surface type sections (localities) for outcrop to subsurface correlations; (7) document the geometry, thickness, and lateral extent of major and secondary laterally discontinuous Pennsylvanian–Permian sandstone-producing reservoirs; (8) identify physical surfaces (e.g., sequence boundaries, transgressive/regressive surfaces, maximum flooding surfaces, etc.) and stratal stacking patterns; and (9) provide cores for public use from stratigraphic intervals that are poorly known.

Some results from newly acquired core-hole data include (1) recognition of several previously unidentified coal beds in the shelf area and their correlation with coals in the basin, (2) documentation of the stratigraphic position and lateral continuity of locally reported sandstone-producing reservoirs, and (3) confirmation that many lithostratigraphic units of previously uncertain stratigraphic position and continuity in the subsurface can be stratigraphically correlated to surface sections.

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Complex Dolomitization History of the Arbuckle Group, Arbuckle Mountains, Oklahoma

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The Cambro–Ordovician Arbuckle Group in the Arbuckle Mountains, Oklahoma, has a complex history of dolomitization which resulted in two types of massive dolomite: stratal dolomite and discordant (fault-related?) dolomite bodies.

Stratal dolomite, commonly with medium to coarsely crystalline textures, is present in the lower Arbuckle Group. Most stratal dolomite samples have $^{87}Sr/^{86}Sr$ ratios similar to associated limestones and coeval seawater, suggesting an early marine origin. However, all stratal dolomite samples are characterized by low delta ^{18}O values (–7.2 to –11.9‰, PDB), indicating post-depositional meteoric modification during the development of unconformities at Ordovician time.

Discordant dolomite bodies are developed mainly in the middle and upper Arbuckle Group. This type of dolomite is commonly finely to medium crystalline and has a large range of delta ^{18}O values (+6.8 to –5.8‰, PDB). Strontium isotopic compositions suggest that this type of dolomite has originated from at least two different processes. In the Tishomingo Anticline area, dolomitization was probably related to post-early Ordovician seawater circulating through karst conduits because $^{87}Sr/^{86}Sr$ ratios (0.70772 to 0.70901) of most discordant dolomite samples are lower than Cambro–Ordovician seawater. In the Arbuckle Anticline area, discordant dolomite probably formed from basinal fluids at Permo–Pennsylvanian time because this dolomite is characterized by radiogenic $^{87}Sr/^{86}Sr$ ratios (0.70951 to 0.70974) as well as high Fe and Mn concentrations.

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Structural Style and Tectonic History of the Arbuckle Mountains, Southern Oklahoma

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Construction of U.S. Interstate Highway 35 across the Arbuckle Mountains of southern Oklahoma resulted in a series of roadcuts that provide a nearly continuous "cross section" of the regional structure and stratigraphy. Although these outcrops are frequently used as stops on numerous academic and industry field trips in the Arbuckle region, virtually no work involving the detailed analysis of small-scale structures exposed in these roadcuts has been published. We therefore systematically identified, described, and interpreted these exposed structures, applying additional surface and subsurface observations made elsewhere in the Arbuckle region, in order to determine the overall structural style and tectonic history of the Arbuckle uplift.

Structures exposed in the Arbuckle region record a dynamic deformational history, but are generally consistent with an overall structural style of concentric (or parallel) deformation in response to regional horizontal compression.

Willis (1992) previously classified five types of geologic structures which commonly develop in parallel-folded strata: fore-limb ("rabbit-ear"), back-limb, and cross-crestal structures, pop-out anticlines, and synclinal-hinge faulting. Examples of each of these structures, as well as other characteristics of concentric deformation, including geometric fold habit and multiple detachment levels, were identified in the Interstate 35 roadcuts and elsewhere within the Arbuckle region. These features and additional structures, including bedding-plane and tectonic stylolites, and fractures (both shear and tension gashes), were used to reconstruct the stress/strain history of the Arbuckle uplift.

During the late Precambrian to middle Cambrian, the Arbuckle Mountain region was affected by the initial development of the southern Oklahoma aulacogen. Crustal rifting was accompanied by the formation of major marginal normal faults and emplacement of rhyolites, basalts, and hypabyssal intrusions. Rapid sedimentation and subsidence within the aulacogen resulted in the accumulation of thick sedimentary Sequences. As sedimentation and burial continued, numerous bedding-plane stylolites and perpendicular calcite-filled tension gashes formed in response to the increasing vertical overburden stresses. Later plate-tectonic reorganization during the late Paleozoic, however, shifted the maximum principal stress from a vertical to near-horizontal orientation, thereby resulting in regional horizontal compression which culminated in the closure of the aulacogen system and formation of the Arbuckle–Wichita trend. In the Arbuckle region, uplift occurred primarily in response to basement-involved thrusting along the Washita Valley fault, the Blind Dog fault, the Chapman Ranch thrust, and additional blind faults. Early stages of thrust-related folding were dominated by layer-parallel compression, as indicated by conjugate shear fracture orientations, tectonic stylolites with "teeth" parallel to bedding, and small-scale thrust systems. Bedding-parallel slippage (or flexural slip) is indicated by numerous bedding-parallel slickenlines, and appears to have played an important role throughout all stages of fold development.

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Reservoir Characterization of Mississippian Sycamore Formation, Ardmore Basin, Oklahoma

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The Sycamore Formation is a regionally extensive, low permeability oil reservoir in the Ardmore basin of southern Oklahoma. The Sycamore consists of two distinct members. The lower, nonreservoir member (<=80 ft thick) consists of glauconitic shale, and minor argillaceous-siliceous limestone. The upper member (<=400 ft thick) comprises the Sycamore reservoir, consisting of thin–medium bedded, peloidal silty turbidites or liquefied sediment-gravity flows. Regionally, the Sycamore thins southeastward by downlap from 480 ft to <150 ft. To the northwest, proximal flow units within the upper member rarely exceed 3 ft in thickness, and typically exhibit Bouma A–C–E or A–C sequences. Southeastward, distal flow units thin considerably, consisting of A or D–E sequences only. Primary sedimentary structures indicate generally southeastward directed transport. Coincident with southeastward thinning is decreased siliciclastic content, and increased argillaceous and total carbonate content. Siliciclastic content in proximal facies reaches >60% rock volume. Porosity and permeability are best preserved in siliciclastic-rich facies and/or above subsea depths of –10,000 ft, below which porosity loss occurs due to compaction and cementation by calcite, microcrystalline silica and minor dolomite.

Primary interparticle matrix porosity is commonly <6% but ranges locally to 25%. Minor secondary moldic porosity is locally developed. Matrix permeability is typically <1 md due to small pore throat size and high-tortuosity flow pathways. However, the brittle and thin bedded nature of the upper Sycamore renders it fracture-prone. Where intensely fractured, permeability reaching several darcies significantly enhances reservoir producibility.

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Outcrop and Subsurface Examination of Mississippian Sycamore Formation, Ardmore Basin, Oklahoma

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Sycamore Formation samples from outcrop in the Arbuckle Mountains, Oklahoma, were compared with conventional core samples from the adjacent Ardmore basin to determine lateral and vertical facies variability, depositional environment, and reservoir potential. Petrographic examination of samples from six outcrop localities were compared to 20 Sycamore cores from throughout the Ardmore basin. Regionally, wireline logs demonstrate the Sycamore consists of a thin basal, low resistivity shale member gradational to a thicker, high resistivity, limy peloidal siltstone upper member. Stratigraphically, the Sycamore thins by downlap NW to SE from 480 ft in the Sho-Vel-Tum area, to <150 ft thick in the Madill–Aylesworth area. The formation becomes less silty, and more argillaceous and carbonate-rich in the downdip direction (southeast). The basal member (≤80 ft thick) consists of locally glauconitic shale, and minor argillaceous-siliceous limestone. The upper member (≤400 ft thick) largely consists of thin- to medium-bedded, upward fining depositional units. Upward fining sequences consist of a massive to slightly graded basal stratum gradational upward to plane parallel or ripple lamination, overlain by thin shale drape. Locally, proximal massive units are amalgamated exhibiting sharp low angle, discordant contacts. Vertical successions in distal flow units consist of thin interbedded, locally silty, peloidal limestone and calcareous shale. Cut-and-fill structures, rip-up clasts, sole marks, and other features in proximal localities indicate tractive flow was episodically active during deposition and directed southeastward.

Skeletal debris within the Sycamore Formation is rare. Where present, megascopic fossils are allochthonous and of shallow water origin. A *Zoophycus–Helmenthoida–Chondrites–Teichichnus* ichnofacies assemblage identified in core and outcrop suggests deposition at depths exceeding 600 ft. Depositional processes likely involved turbidity currents or liquified sediment-gravity flows in a basin slope environment.

Reservoir potential is locally variable but may be good where porosities can reach 18% as in the Sho-Vel-Tum area. Alternatively, economic production has

been established where intense fracturing enhances low matrix permeability. Typical reservoir properties are poor, porosity ranges from 4 to 6% with matrix permeability commonly <0.1 md.

Unpublished abstract for a poster presentation at the 1993 American Association of Petroleum Geologists Annual Convention.

Structural Analysis of the Northwest Plunge of the Arbuckle Anticline, Southern Oklahoma

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An understanding of structural style and geometry is extremely important to exploration, exploitation, and development of hydrocarbons. No consensus exists for the southern Oklahoma foreland despite extensive well and outcrop data. Within the Arbuckle Mountain front, little agreement exists as location, geometry, sense of movement, and relationships of major faults, as well as basic structural style. This paper attempts to integrate field, subsurface well control, and seismic data in a consistent manner in order to clarify these relationships analysis of a series of balanced cross sections across the Arbuckle Mountain front from the West Timbered Hills area westward through Eola, Roberson, and Royal Pool fields show that fault-bend folding, with slightly oblique slip motion on the Arbuckle thrust, best explains observed structural data. Thrust displacement decreases westward from its maximum of eight miles in the West Timbered Hills area of the exposed Arbuckle anticline. There is a corresponding change in geometry from that of a fault-bend fold to that of a fault-propagation fold. Footwall deformation in the Eola area has folded the overlying Arbuckle thrust. During a previously unaddressed period of post-compression extension, a larger normal fault reactivated the earlier basement ramp of the Arbuckle thrust, backing the hanging wall down the fault. Such structures have resulted in "beheaded" basement blocks similar to those found in the Wyoming foreland. These structures may be misinterpreted as "flower" structures and give rise to a philosophy of local wrenching.

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Structural Style and Timing of Late Paleozoic Basement Uplifts in Southern Oklahoma

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Proposed theories of deformation in southern Oklahoma presently involve large-scale basement thrusting or large magnitudes of strike slip. As more and better seismic data and well control have become available, a predominant interpretation of the structural style is emerging. This style is characterized by a large basement overhang along the mountain fronts, created by major reverse dip-slip (thrust) faults. Additionally, these reverse faults may have an antithetic back-thrust on the hanging

wall. In cross section, this style appears as a wedge-uplift that is often mistakenly interpreted to represent the upper portion of a "flower structure" created by wrench-faulting.

Structural uplifts in southern Oklahoma developed as a result of Late Paleozoic Wichita, Ouachita and Arbuckle orogenies. Emplacement of the thin skinned Ouachita thrust belt occurred during the Ouachita orogeny (Mississippian through Middle Pennsylvanian). Basement-involved compressional uplifts of the Wichita Mountains and Criner Hills were initially uplifted during the Wichita orogeny (Late Mississippian to Early Pennsylvanian), while the Arbuckle anticline and Tishomingo uplift reached their culmination during the Arbuckle orogeny (Middle to Late Pennsylvanian). Some early-formed structures (Wichita orogeny) never grew again, while others show continued growth during the later Arbuckle orogeny. Many late-formed structures (Arbuckle orogeny) show no prior history of uplift during the Wichita orogeny.

Evidence for the timing of these uplifts are the various conglomerates and unconformities preserved in the subsurface, and occasionally exposed at the surface. Age-dating of these unconformities strongly suggests a sequence of deformation in which the culmination of uplift progressed generally from south to north through time. This sequence is also suggested by deformation of the thin-skinned Ouachita thrust belt by basement-involved structures of the Arbuckle orogeny.

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Chloroﬂuorocarbons (CCl_3F and CCl_2F_2): Use as an Age-Dating Tool and Hydrologic Tracer in Shallow Ground-Water Systems

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Procedures have been developed for sampling ground water for trace levels of chlorofluorocarbons (CFC's, Freons). Samples are collected and stored in 50 milliliter borosilicate glass ampules that are sealed at the well site in an environment isolated from air and free from CFC's. CFC concentrations, which remain stable in the sealed glass ampules for many months, are determined using purge-and-trap gas chromatography with an electron-capture detector to less than 1 picogram per kilogram. The analytical procedures are relatively simple, inexpensive, and require about 10 minutes per sample.

The procedure was applied to water samples from shallow Quaternary alluvium and terrace deposits in central Oklahoma. Results of CFC age-dating of about 400 samples show that CFC's are generally consistent with tritium data and can be extremely useful tracers and age-dating tools in hydrologic studies. Preliminary CFC-model age dating indicates that, in the past 40 years, there may have been two major periods of significant ground-water recharge in central Oklahoma. The first significant period of recharge occurred in the years 1945–60, and the second in 1967–75. The results indicate that much less recharge may have occurred in the drought years 1960–67. Precipitation and tritium data are consistent with this conclusion derived from the CFC's, CCl_3F (F-11), and CCl_2F_2 (F-12) model age-dating. The precipitation record indicates that another wet period may have occurred in the mid-1980's that was not recognized. This water may reside in the unsaturated zone or may have not yet intercepted the well-screens of domestic and municipal wells completed in the alluvium and terrace deposits.

Several areas of ground water with F-11 and(or) F-12 concentrations in excess of that in equilibrium with modern air have been identified in the alluvial and terrace deposits of central Oklahoma. One area originates within the Oklahoma City limits and extends for several kilometers along the North Canadian River. Another major area originates southeast of the city of Norman and extends more than 20 kilometers along the Canadian River. There may be some correlation between these observed CFC anomalies, high population densities, the geographical location of sewage-disposal ponds, and sewage returns into rivers and streams. It is conceivable that some of the CFC contamination may result from the seepage of sewage effluent (with high concentrations of CFC's into the alluvial and terrace deposits.

The preliminary results from the shallow unconfined ground waters in Pleistocene sands of the Delmarva Peninsula indicate that there is very little contamination of the shallow aquifers with CFC's. Contamination levels in central Oklahoma are significantly greater than those observed on the Delmarva Peninsula. Model CFC ages for waters from Fairmount, Del., also appear to be consistent with tritium concentrations in the ground waters.

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The U.S. Geological Survey Side-Looking Airborne Radar (SLAR) Acquisition Program: Image Data of the South Central Region

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The U.S. Geological Survey (USGS) has had a program to systematically collect side-looking airborne radar (SLAR) image data since 1980. Image strips, with a swath width varying from 20 to 46 km, are acquired by commercial survey companies using X-band (3 cm) radar systems. The strips are collected with 60 percent sidelap for optimum image selection and for stereoscopic capability. To make the data more accessible, the image strips are assembled into 1° × 2° quadrangle mosaics using the national 1:250,000-scale topographic map series for control, format, and nomenclature.

SLAR image mosaics have been compiled for about 40 percent of the conterminous United States and Alaska. Twenty-seven of these mosaics are available for the states of the South Central Region. Starting in the west with the Big Bend area of Texas, the quadrangles are El Paso, Van Horn, Marfa, Presidio, Emory Peak, Ft. Stockton, and Pecos, and north into the Panhandle, Clovis (Texas only), Tucumcari (with New Mexico), Plainview, and Amarillo. The Perryton and Lawton mosaics are in Texas and Oklahoma. The Clinton, Oklahoma City, and Ardmore are Oklahoma quadrangles. Continuing east, Ft. Smith and McAlester share the border with Arkansas. Russellville and Little Rock are in that state and Memphis and Poplar Bluff share boundaries with adjoining Tennessee and Missouri. The Kansas mosaics are Great Bend, Pratt, Hutchinson, Wichita and Joplin. Most of the image strip data are available in digital form on nine-track tape. Poplar Bluff, Russellville and the Kansas quadrangle data (except Joplin), are also available on CD-ROM (compact disc-read only memory). All USGS SLAR data can be ordered from the USGS EROS Data Center, Sioux Falls, SD 57198.

It is planned to display these data in a poster session to show the potential of the SLAR mosaics for geoscience, GIS, and other environmental studies. The special oblique geometry of the SLAR image mosaics emphasize subtle geologic structural detail and present the terrain in a readily interpretable synoptic view.

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Possible Origin of Clastic Plugs in the Triassic System of Northeast New Mexico, Southeast Colorado, and Northwest Oklahoma Panhandle

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Over 138 clastic plugs occur in Triassic Dockum Group strata in the study area. Plugs are near vertical, roughly cylindrical, and up to 91 m across. A 107 m shaft was dug into one. Plugs are composed of relatively clean very fine quartz sandstone, brecciated country rock, or both. Small amounts of Cu and traces of Au, Ag, and U occur. Quartz sandstone dikes less than 1 m thick radiate from plugs or occur singly. Plugs and dikes are truncated by Jurassic strata. Upward intrusion of mobile sand and collapse modes of origin have been proposed; however, thorough studies are lacking.

Preliminary field work indicates that plugs and dikes occur only in pre-Jurassic structural (and paleotopographic?) lows. Well logs reveal thick Permian anhydrite beds at about 330 m depth. Possibly, prior to Jurassic deposition, buried gypsum dewatered and recrystallized to anhydrite, with a 38% reduction in rock volume. Saline waters of dehydration, under lithostatic pressure, rose to the surface along fractures. Strata above the anhydrite sagged regionally and collapsed locally. Sand plugs and dikes are water-escape features: rising water winnowed out fines, leaving sand-sized detritus. Country rock and pre-Jurrasic surficial deposits are probable sand sources. Breccia plugs are collapse features.

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Proboscideans and Age of Arnett Local Fauna, Northwestern Oklahoma

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The Arnett local fauna (lf) is from Adair Ranch, Ellis County, Oklahoma. Proboscideans comprise a mammalian order containing modern African and Asian elephants and their extinct relatives—African palaeomastodons; long-ranging and widely distributed "shovel-tuskers" or platybelodons and amebelodons; "oval-tusk-

ers" or gomphotheres; mastodons or mammutids; and their elephant-like descendants, the tropical, Old World stegodons.

Re-identification of proboscideans from Arnett indicates that its lf contains a new and large species of *Gomphotherium* or "oval-tusker"; a gigantic species of *Gomphotherium;* the primitive, late Clarendonian and middle Hemphillian mastodon *Zygolophodon serridens;* and the progressive, late Clarendonian to early Blancan mammutid *Pliomastodon matthewi.* This faunule is almost identical to that of the Snake Creek lf of northwestern Nebraska, and, therefore, is indicative of an earlier middle Hemphillian age (ca. 6.8 Ma.). The Snake Creek lf contains a large *Gomphotherium;* a gigantic *Gomphotherium; Z. serridens;* and *P. matthewi.* The new and large, Arnett *Gomphotherium* is sampled from skulls, several jaws, many tusks, and numerous cheekteeth. This species is allied to early Clarendonian to middle Hemphillian *G. cimarronis* because it has long, low skull. However, it differs from *cimarronis* in evolving wider skull and larger cheekteeth. The gigantic *Gomphotherium* is represented by a mandibular fragment with third molar in the Oklahoma Museum of Natural History (OMNH). Its molar has five ridges and is 254 mm long and 94 mm wide (vs. sympatric *Gomphotherium* with observed length range of 181–214 mm and width range of 74–92 mm). An upper tusk (OMNH 4362) is identifiable as *Z. serridens* because it is short, downcurved with high enamel band, and has a well-developed interval wear facet, all traits characteristic of that mammutid. OMNH 4437, an upper tusk, is identifiable as *P. matthewi*, for it is straight, narrow and high, without enamel band—like tusks in that mastodon.

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Origin, Distribution, and Movement of Brine in the Permian Basin (U.S.A.): A Model for Displacement of Connate Brine

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Na-Cl, halite Ca-Cl, and gypsum Ca-Cl brines with salinities from 45 to >300 g/L are identified and mapped in four hydrostratigraphic units in the Permian Basin area beneath western Texas and Oklahoma and eastern New Mexico, providing spatial and lithologic constraints on the interpretation of the origin and movement of brine. Na-Cl brine is derived from meteoric water as young as 5–10 Ma that dissolved anhydrite and halite, whereas Ca-Cl brine is interpreted to be ancient, modified-connate Permian brine that now is mixing with, and being displaced by, the Na-Cl brine. Displacement fronts appear as broad mixing zones with no significant salinity gradients.

Evolution of Ca-Cl brine composition from ideal evaporated sea water is attributed to dolomitization and syndepositional recycling of halite and bittern salts by intermittent influx of fresh water and sea water. Halite Ca-Cl brine in the evaporite section in the northern part of the basin differs from gypsum Ca-Cl brine in the south-central part in salinity and Na/Cl ratio and reflects segregation between halite and gypsum-precipitating lagoons during the Permian. Ca-Cl brine moved downward through the evaporite section into the underlying Lower Permian and Pennsylvanian marine section that is now the deep-basin brine aquifer, mixing there

with pre-existing sea water. Buoyancy-driven convection of brine dominated local flow for most of basin history, with regional advection governed by topographically related forces dominant only for the past 5 to 10 Ma.

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The Ames Crater: Origin and Reservoir Characteristics of a Buried, Ordovician Impact Structure, Major County, Oklahoma

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A meteor impact in the early Ordovician is interpreted to be the origin of the Ames Crater and its associated oil and gas reservoirs. Potential reserves of up to 50 MMBO and 40 MMCF of gas are present in and around the crater located in Major County, Oklahoma (T20–21N, R9–10W). The morphology of the crater is presently best defined by a structure map on the Sylvan shale which indicates a circular depression with steep walls about 8 miles in diameter. The circular feature is also obvious on gravity maps. The Sylvan structure map also indicates the rim of the circular feature is raised and the depressed floor of the feature contains small, raised and depressed features. The gross size, shape, and details of the floor suggest an impact origin for the crater. Analysis of conventional and sidewall core samples, cuttings, and logs show that the rim of the crater is Arbuckle dolomite and that he crater floor is dominated by a complex assemblage of giant blocks of Arbuckle dolomite; breccias of dolomite; breccias of granite; and mixed granite-dolomite breccias, pebble conglomerates, and litharenites. The crater filling material is allocthonous. Quartz grains with shock lamellae and highly altered, vesicular lithologies have been identified from arenites and conglomerates in the crater floor. These lithologies and textures strongly support the impact origin. The reservoirs are overlain by Simpson shale (Ordovician) and consist of many structural traps with intergranular porosity between clasts and dissolution porosity within dolomite and granite rock fragments.

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The Ames Meteor Impact Crater

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The origin of an unusual structural feature near the town of Ames, in the S.E. part of Major County, Oklahoma, has been subject to much speculation. Maps on subsurface horizons show an intriguing circular-shaped closure around a low some 20 square miles in area approximately centered around the town of Ames. Early drilling revealed an unusually thick and low Hunton section, so an initial characterization was "The Hunton Graben." Deeper drilling established Arbuckle dolomite production on a circular rim around this low.

Subsequent drilling and mapping indicate the structure is an impact crater. Initial Arbuckle dolomite wells were located on the rim of the impact crater. While significant discoveries, the prolific oil production from wells located on the crater floor established this structure as possibly the largest known productive astrobleme.

The first crater floor well, the D. & J. Gregory 1-20, T21N–R9W may be the largest oil well established from a single pay in Oklahoma. The pay zone is granite breccia formed as a characteristic central rebound feature. Conservatively estimated primary recoveries are over 4 million barrels of oil for this well. Later crater floor wells have established production from granite wash overlying brecciated dolomite and from solution enhanced porosity and fracture systems, all sealed by Oil Creek shale.

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Oklahoma Geology, The Challenge in a Changing Environment

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A diversity of geology and programs exists in Oklahoma which requires the SCS geologist to use a wide range of expertise in order to contribute to the many existing programs.

Our geologic work force consists of Bob L. Tillman, Sedimentation Geologist, Chickasha, and Glen B. Miller, Engineering Geologist, Stillwater, Oklahoma.

Our poster display illustrates channel erosion commonly encountered during planning investigations within Oklahoma. Channel erosion consists of the removal of soil and rock by a concentrated flow of water. It includes, but is not limited to, ephemeral gully erosion, streambank erosion, roadside erosion, and flood-plain scour. All contribute sediment to floodwater retarding structures and are important considerations in watershed planning. Each of these types of channel erosion is displayed and discussed on the poster display.

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Effects of Hydrocarbon Microseepage on Magnetic Susceptibility of Soils

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The hypothesis that hydrocarbon microseepage can cause anomalous increase in soil magnetic susceptibility was tested by sampling transects across oil and gas accumulations. Numerous sites with multiple samples per site were used to distinguish possible anomalies from background noise.

Transects over several fields indicate anomalies with statistically significant increases over off-field background levels. A thirteen mile transect in southern Oklahoma shows magnetic anomalies linked with underlying color changes in redbeds above hydrocarbon traps. Sampling of vertical soil profiles indicates that the uppermost horizons contain the anomalies. Mineral identification by Curie balance indicates magnetite and possibly pyhrrotite as the magnetic carriers. Sampling at a new field discovery in northeastern Oklahoma suggests a ring anomaly and accurately reflects the fields limits eventually delineated by drilling.

The results suggest that microseeping hydrocarbons can cause anomalies in soil magnetic susceptibility. The process is complex and identification of anomalies is controlled by a number of variables. Soil type and variations in parent material can mask the effect. The anomalies may be positive or negative and the dynamic nature of the anomalies is not well understood. Collection and analysis techniques (e.g., use of both mass and volume units) are critical to obtaining meaningful data. The formation of the magnetite is also open to question although it could involve inorganic processes and/or bacterial activity. Despite the complexities, measuring soil magnetic susceptibility is quick and inexpensive and may be an effective direct hydrocarbon indicator under certain conditions.

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