OKLAHOMA GEOLOGY

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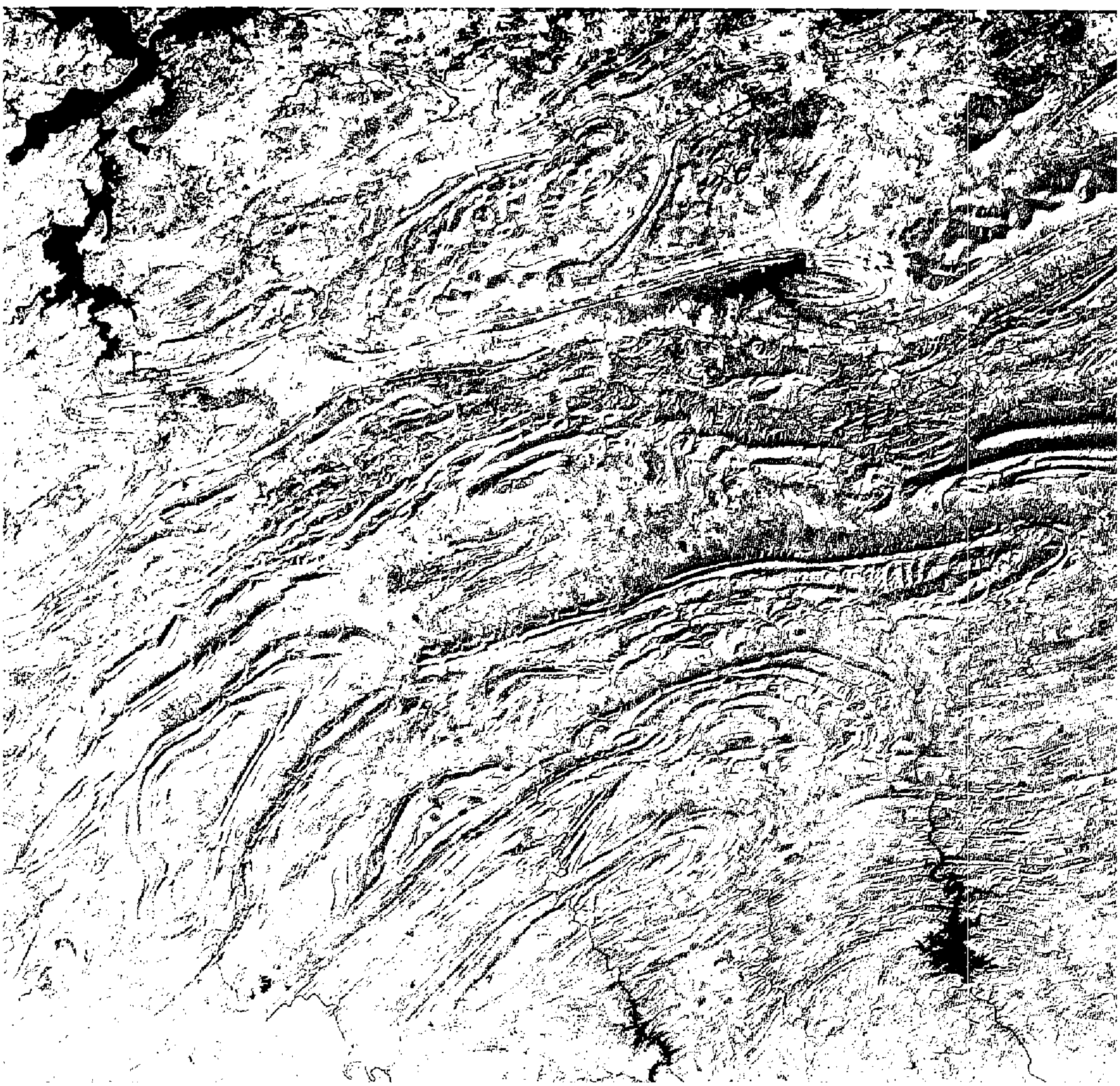

On the cover—

View from Space of the Oklahoma Ouachita Mountains

On the cover is a Landsat image of the Oklahoma part of the Ouachita Mountains. Taken from an altitude of ~570 mi, this image shows the beautiful yet complex structures that make up the geomorphology of southeastern Oklahoma.

Surface expressions of major folding and thrusting can be seen. Imbricated sandstone ridges can be traced for miles only to be abruptly faulted out. The image clearly shows the large synclines that are common in the central Ouachitas. Features representing the older rocks are also present; the tightly folded Broken Bow uplift is at lower right, while the Potato Hills are near center. Major lakes such as Eufaula Lake (upper left) and Broken Bow Lake (lower right) are easily visible. Wister Lake (upper right) lies across the axis of an anticline. The Ouachita Mountains extend well to the south but are covered by the onlap of coastal plain sediments, which can be seen across the bottom of the image.

The northern part of the Ouachita Mountains is currently being heavily explored for gas. Between late 1986 and April 1991, 127 wells have been drilled in the frontal belt between the Choctaw and Windingstair faults (see related article on page 84).

This Landsat image was provided by Timothy K. Cannon of Planetary Data, Tecumseh, Oklahoma.

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OKLAHOMA GEOLOGY NOTES

C O N T E N T S

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UPDATE ON OUACHITA MOUNTAINS FRONTAL BELT EXPLORATION AND DEVELOPMENT

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Introduction

Recently Suneson and Grasmick (1989) compiled a list of all reported oil and gas wells spudded before January 1, 1989, in the Ouachita Mountains of southeastern Oklahoma. Since that time the area has witnessed an exploration boom: in 1989, 27 wells were drilled in the frontal belt of the Ouachita Mountains; in 1990, 60 wells were spudded (Fig. 1). This paper updates the well list published by Suneson and Grasmick (1989), focusing on the frontal belt, which is bounded by the trace of the Choctaw fault on the north and the trace of the Windingstair fault on the south. Table 1 lists wells spudded between late 1986, when the current phase of frontal-belt exploration began, and the end of 1990. Completion results include those reported through March 31, 1991. Figure 2 shows the expansion of drilling activity.

Exploration in this area is continuing; between January 1 and March 31, 1991, 19 wells have been spudded in the frontal belt. In addition, exploration has extended south of the Windingstair fault to the north flank of the Potato Hills.

This list of wells and completion results was compiled primarily from the Oklahoma Geological Survey's Natural Resources Information System (NRIS) (based on the Oklahoma Corporation Commission Form 1002-A) and reports published by the Petroleum Information Corporation (Oklahoma City). The report by Tilford (1991) was particularly helpful in compiling some of the data listed in Table 1.

Source of Data

Initial funding for the development of a data file of oil and gas wells in and near the Ouachita Mountains was provided by the Oklahoma Geological Survey as part of the Cooperative Geological Mapping Program (COGEOMAP) with the Arkansas Geological Commission and the U.S. Geological Survey (USGS). COGEOMAP is a USGS program designed to fund new geologic mapping on a cost-sharing basis with state geological surveys. The primary goal of the Ouachita COGEOMAP Project is to produce new, detailed geologic maps of the Ouachita Mountains at a scale of 1:24,000 (7.5′-quadrangle base). To date, the Oklahoma Geological Survey has released nine geologic maps of the northern Ouachita Mountains and adjacent Arkoma basin.

[1]Oklahoma Geological Survey.
[2]Geological Information Systems, University of Oklahoma.

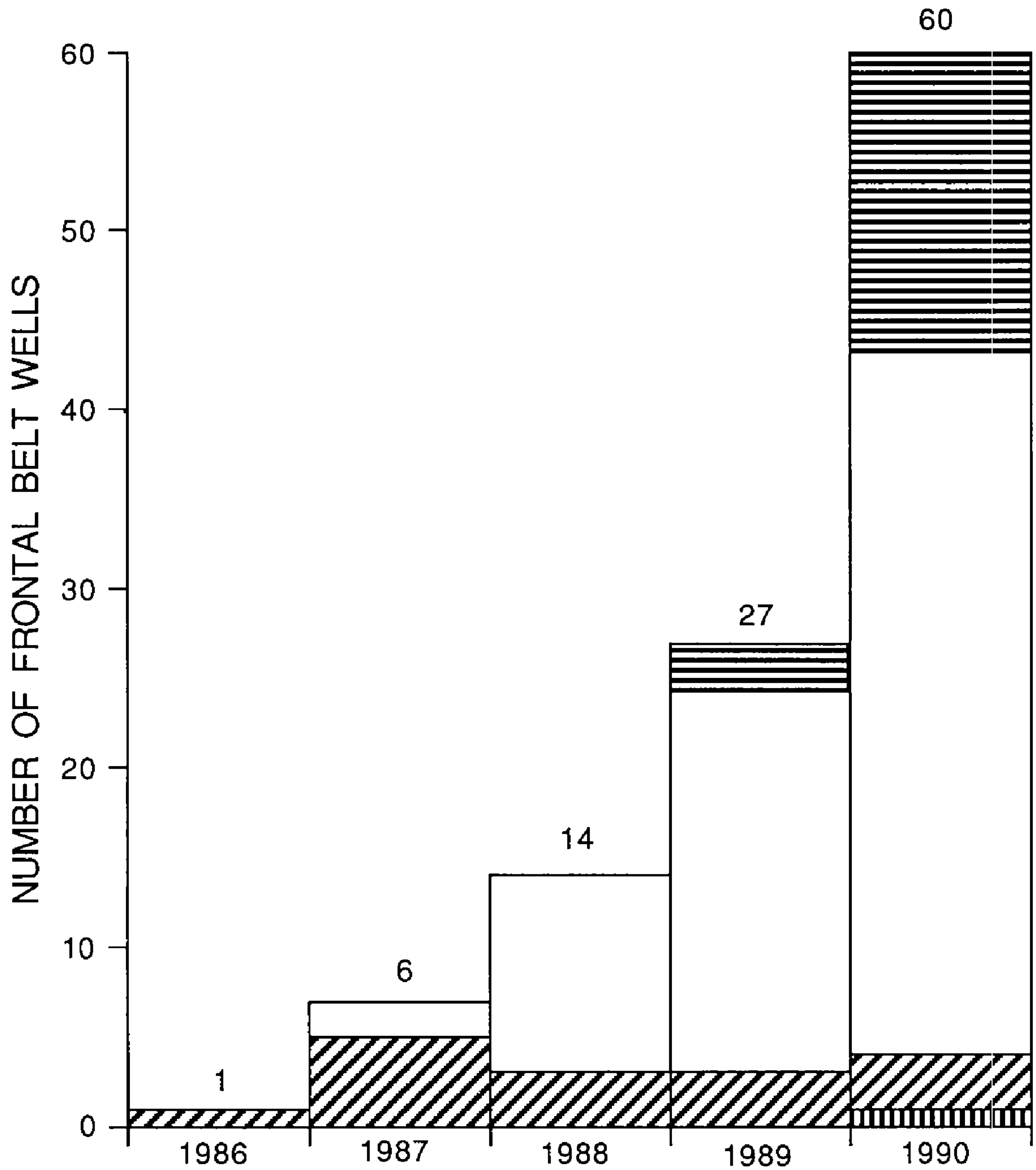


Figure 1. Histogram showing drilling activity in the Oklahoma Ouachita Mountains frontal belt. Only those wells whose surface locations are south of the trace of the Choctaw fault are included. Diagonal-hatched area includes wells near and in West Wesley and Northeast Wesley fields. Open area includes wells near and in Pittsburg, Southwest Haileyville, South Hartshorne, and South Wilburton fields. Horizontal-hatched area includes wells near and east of South Panola field. Vertical-hatched area includes single well near the town of Atoka.

TABLE 1. — OUACHITA

MAP NO.	SPUD DATE	OPERATOR	NO.	FARM	SEC-TSP-RNG	OBJECTIVE/DEPTH	TD	PBTD
FIG 2A								
1	1986 11 28	AMOCO	1	L R JENKINS	09 01N 13E	WAPANUCKA/12000	10376	
1-A	1987 05 13	AMOCO	1-A	L R JENKINS	09 01N 13E	WAPANUCKA/14800	13468	
2	1987 06 07	ARCO	1-19	INGERSOLL	19 01N 13E	ARBUCKLE/18000	15080	
3	1987 07 22	SAMSON	1	KAY	15 03N 15E	WAPANUCKA/6100	6700	567
4	1987 09 29	ARCO	1-18	MCENTIRE CLARK	18 01N 13E	WAPANUCKA/16000	682	
5	1987 12 10	AMOCO	2	L R JENKINS	09 01N 13E	WAPANUCKA/10928	11496	
6	1987 12 31	AMOCO	1	GARRETT UNIT A	02 03N 16E	ATOKA/16500	15047	
FIG 2B								
1	1988 01 08	EXXON	1	MABRY TRUST	12 04N 17E	SPIRO/13500	13200	1314
2	1988 03 04	AMOCO	1	ZIPPERER UNIT	32 04N 17E	SPIRO/12600	13497	
3	1988 05 18	TEXACO	1	LAFEVERS	10 01N 13E	WAPANUCKA/15000	12850	1273
4	1988 06 19	ARCO	1	HART	06 04N 19E	ARBUCKLE/18500	18085	
5	1988 06 22	AMOCO	1	ROSSO UNIT	05 03N 16E	WAPANUCKA/13700	14050	
6	1988 06 29	TEXACO	25-1	J J CHASTAIN	25 02N 13E	CROMWELL/12800	12320	1184
7	1988 08 04	TEXACO	2-1	CARL GODDARD	02 03N 15E	WAPANUCKA/13500	12132	
8	1988 09 27	D-PEX	1	CHURCH LAKE	29 05N 19E	SPIRO/13200	13985	
9	1988 09 29	ORYX	2	DIAMOND UNIT	30 05N 19E	CROMWELL/13800	12311	11435
10	1988 10 13	TEXACO	2-1	F A SMITH	02 01N 13E	CROMWELL/14000	13800	7145
11	1988 10 14	AMOCO	1	PATTERSON UNIT	27 04N 17E	CROMWELL/16500	14380	
12	1988 10 28	HAMLTN BROS	2-30	CHITTY SCOTT	30 03N 14E	CROMWELL/10500	10440	
13	1988 11 03	TEXACO	1-1	J A GODDARD	01 03N 15E	ATOKA/8400	7485	
14	1988 12 06	TEXACO	21-1	WAYNE WALLACE UNIT	21 04N 17E	CROMWELL/14000	13694	1336
FIG 2C								
1	1989 01 06	TEXACO	1-6	J A COLLINS	06 03N 16E	WAPANUCKA/12500	11670	5090
2	1989 01 07	EXXON	1	H & H CATTLE CO A	33 04N 17E	CROMWELL/14600	14518	8262
3	1989 01 13	TEXACO	11-1	F A SMITH B	11 01N 13E	CROMWELL/13500	13517	6640
4	1989 01 15	D-PEX	1	JENKINS	16 01N 13E	SYCAMORE/13500	12634	
5	1989 03 15	ARCO	1	DROMGOLD	04 03N 16E	CROMWELL/14500	14600	13625
6	1989 03 15	TXO	1	CHESTER 'A'	35 03N 14E	ATOKA/6500	6520	
7	1989 03 17	AMOCO	1-A	TSCHAPPAT UNIT	03 03N 16E	CROMWELL/14100	14497	
8	1989 04 30	EXXON	1	SZENASY UNIT	01 03N 16E	WAPANUCKA/14100	15000	14560
9	1989 05 03	EXXON	1	ELLIOT DAVIS	31 04N 17E	CROMWELL/14300	15080	14992
10	1989 07 01	AMOCO	1-A	RETHERFORD	25 04N 17E	CROMWELL/15000	12660	12618
11	1989 07 01	AMOCO	1-21	CINDY	21 05N 20E	REAGAN/16500	18730	
12	1989 07 11	AMOCO	1	SCOTT	36 04N 15E	BRAZIL/6800	6662	
13	1989 08 08	ANADARKO	1-15	ALFORD A	15 05N 21E	ARBUCKLE/17000	17470	10695
14	1989 08 11	EXXON	1	ROY RETHERFORD UNIT	31 04N 18E	CROMWELL/16500	14980	13642
15	1989 08 12	AMOCO	1	INGLE UNIT	21 05N 22E	CROMWELL/14500	13490	
16	1989 09 04	EXXON	1	ELLIS RUDY TRUSTEE	30 04N 17E	CROMWELL/14600	14600	
17	1989 09 30	ARCO	1	ULYSSES	35 04N 18E	ARBUCKLE/20250	17480	

FRONTAL-BELT WELLS

PRODUCING FM - A	GROSS PERFS	IPF	PRODUCING FM - B	GROSS PERFS	IPF	CLASS
						D
SPIRO OVERTHRUST	8758-8822	1134	WAPANUCKA OVERTHRUST	8926-9096	COMM	G
						D
WAPANUCKA 4TH THRSTD	5190-5466	400				G
						D
SPIRO	NR		WAPANUCKA	NR		G
ATOKA EIGHTH	13194-13266	6040	CROMWELL FOURTH	13882-13912	9154	G
ATOKA BASAL SPIRO	12406-12465	225				G
WAPANUCKA	12148-12286	15069	BASAL ATOKA	12012-12066	45170	G
WAPANUCKA	12258-12285	8077				G
						D
ATOKA OVERTHRUST	4872-4904,12486-12518	2200				G
WAPANUCKA	11062-11240	2800				G
						D
						D
SPIRO	11288-11336	4097				G
						D
ATOKA BASAL (SPIRO)	11840-11895	5300	WAPANUCKA	11944-12124	14500	G
CROMWELL	10273-10337	3200	WAPANUCKA	9337-9507	2500	G
RED OAK	4339-4440	1700	ATOKA 6	6080-6144	4500	G
ATOKA OVERTHRUST	13258-13308	10800				G
						D
ATOKA MIDDLE	5030-5201	320				G
ATOKA MIDDLE	6388-6688	253				G
WAPANUCKA	12231-12306	1430				G
ATOKA	10855-10895,12821-12826	200				G
						D
SPIRO	9616-9648	5200				G
ATOKA	14088-14154	4019				G
WAPANUCKA	11994-12116	6172	SPIRO	11864-11942	11166	G
BASAL ATOKA (SPIRO)	12142-12170	51900				G
THRUSTED SPIRO	13584-13616	12500				G
BRAZIL	6172-6546	7700				G
SHAY	10601-10636	335				G
SPIRO	13338-13365	13492				G
LOWER ATOKA	9480-9756	1100				G
						D
						D

MAP NO.	SPUD DATE	OPERATOR	NO.	FARM	SEC-TSP-RNG	OBJECTIVE/DEPTH	TD	PBTD
FIG 2C (cont.)								
18	1989 10 01	TEXACO	7-1	A J MABRY UNIT	07 04N 18E	CROMWELL/16000	13850	8386
19	1989 10 03	AMOCO	1	MCENTIRE	03 01N 13E	WAPANUCKA/8700	9208	
20	1989 10 03	TEXACO	29-1	BURNETT	29 02N 14E	ARBUCKLE/18000	17500	
21	1989 10 05	TEXACO	2-2	GODDARD	02 03N 15E	ATOKA/8500	7260	4000
22	1989 10 24	AMOCO	1	TOMLIN	29 04N 17E	CROMWELL/15250	14087	
23	1989 12 03	TEXACO	6-2	JAMES A COLLINS	06 03N 16E	ATOKA/7900	8690	8581
24	1989 12 26	TEXACO	28-1	MANUEL RUDY ESTATE	28 04N 17E	CROMWELL/13550	13591	12638
25	1989 12 30	KERR-MCGEE	3-31	LEE SCOTT	31 03N 14E	CROMWELL/10700	10600	
26	1989 12 30	EXXON	1	GARRETT & CO A	26 04N 18E	WOODFORD/15500	15289	
27	1989 12 30	SAMSON	2	VAN DYKE	35 04N 15E	ATOKA M/7600	7593	
FIG 2D								
1	1990 01 09	EXXON	1	GARRETT & CO C	33 04N 18E	WOODFORD/14550	14840	14691
2	1990 01 09	AMOCO	1	A J MABRY	31 05N 19E	WAPANUCKA/12200	13139	
3	1990 01 11	AMOCO	1	M C WATTS	06 03N 17E	WAPANUCKA/14000	13200	13042
4	1990 01 31	TEXACO	11-1	NORTON	11 03N 16E	WAPANUCKA/16500	18416	
5	1990 02 17	TIDE WEST	1	ATOKA WILDLIFE	23 01N 12E	CROMWELL/16000	16000	
6	1990 02 22	EXXON	1	GARRETT & CO B	34 04N 16E	CROMWELL/14020		12750
7	1990 03 11	B T A OIL	1	9001 JV-P MABRY	11 04N 18E	CROMWELL/14000	14100	10712
8	1990 03 20	EXXON	1	H & H CATTLE CO F	09 03N 17E	CROMWELL/14400	14495	
9	1990 03 28	MOBIL	1	GREEN BAY PKG.	08 04N 23E	ARBUCKLE/22500	22500	
10	1990 03 31	AN-SON	1-20	HARDCASTLE	20 05N 20E	ARBUCKLE/15500	14300	14254
11	1990 04 02	NEARBURG	1	WISTER LAKE	16 05N 23E	CROMWELL/14500	14254	
12	1990 04 06	B T A OIL	1	9001 JV-P AMASON	24 04N 18E	CROMWELL/14000	14090	13869
13	1990 04 11	TEXACO	23-1	JENNINGS	23 05N 19E	ARBUCKLE/14100	16125	
14	1990 04 14	B T A OIL	1	8904 JV-P HOLLAN	20 05N 23E	WAPANUCKA/16500	15117	
15	1990 04 15	TEXACO	29-1	MANUEL RUDY ESTATE	29 04N 17E	WAPANUCKA/12000	14335	13350
16	1990 04 16	AMOCO	1	R SMITH	26 05N 20E	WAPANUCKA/14370	14525	
17	1990 04 18	AN-SON	1-21	NEVIL	21 05N 23E	CROMWELL/14500	16675	
18	1990 05 11	TEXACO	32-1	DROMGOLD B	32 04N 16E	CROMWELL/13800	12430	
19	1990 05 15	AMOCO	1	BOBCAT RIDGE	30 05N 20E	SPIRO/14600	14983	14935
20	1990 05 20	AMOCO	1	STEVENS	26 04N 17E	WAPANUCKA/13200	11907	
21	1990 05 24	EXXON	1	WATTS BROS. A	30 04N 18E	CROMWELL/15000	14930	
22	1990 06 02	TEXACO	3-1	STAFFORD	03 03N 15E	ATOKA/6600	6438	
23	1990 06 07	EXXON	1	WATTS BROS. B	32 04N 18E	CROMWELL/13750	13750	
24	1990 06 17	TEXACO	33-1	DROMGOLD 'C'	33 04N 16E	RED OAK/7500	7083	
25	1990 06 18	ARCO	2	SCOTT 'M'	31 04N 16E	RED OAK/8000	8000	
26	1990 06 19	AMOCO	1	DEVILS BACKBONE	31 05N 24E	REAGAN/22500	21019	
27	1990 06 24	ORYX	1	HUNT	05 01N 14E	WAPANUCKA/12500	13000	
28	1990 06 27	TEXACO	36-1	SILVA	36 04N 16E	WAPANUCKA/15000	15300	
29	1990 07 07	AMOCO	1	WALKER	32 05N 19E	SPIRO/13100	13406	
30	1990 07 14	EXXON	1	GARRETT 'D'	34 04N 18E	WAPANUCKA/14950	14400	
31	1990 07 26	AMOCO	36-1	WATTS MOSE	36 04N 17E	WAPANUCKA/13350	13850	

Continued

PRODUCING FM - A	GROSS PERFS	IPF	PRODUCING FM - B	GROSS PERFS	IPF	CLASS
SPIRO WAPANUCKA U	5680-5803	483	ATOKA	8014-8136	35	G
SPIRO/WAPANUNUCKA	7940-8016	9500				G
SPIRO/WAPANUNUCKA	12279-12423	1159				G
ATOKA M	3394-3512	1087				G
ATOKA OVERTHRUST	13636-13674	7500				G
ATOKA SIXTH	7393-7539	6358				G
OVERTHRUST ATOKA	12448-12516	875				G
WAPANUCKA	9514-9710	3400				G
SPIRO	14814-14878	6000				G
ATOKA M	6834-7050	5500				G
ATOKA BASAL (SPIRO)	14435-14514	6223				G
LOWER ATOKA	9920-9930	250	LOWER ATOKA	10144-10170	1000	G
BASAL ATOKA (SPIRO)	12696-12734	2800				G
						D
NR						
SPIRO	12396-12425	6390				G
ATOKA	8580-8604	2522				G
						D
NR						
SPIRO	13988-14053	6000				G
						D
SPIRO	13649-13696	5111				G
						J
						D
						D
SPIRO-WAPANUCKA	13332-13374	28008				G
						D
						D
SHALLOW SPIRO	6244-6300	4000	SPIRO	14642-14666	5800	G
ATOKA LOWER	7520-7610	COMM	OVERTHRUST ATOKA	11812-11907	9738	G
						D
ATOKA MIDDLE	2172-4980	463				G
						D
ATOKA MIDDLE	5790-6106	730				G
RED OAK	6790-7075	8100				G
						D
NR						
SPIRO	14658-14708	2028				G
NR						
ATOKA MIDDLE	12702-12757	3174				G
ATOKA BASAL SBTHRST	13140-13440	16000				G

TABLE 1. —

MAP NO.	SPUD DATE	OPERATOR	NO.	FARM	SEC-TSP-RNG	OBJECTIVE/DEPTH	TD	PBTD
FIG 2D (cont.)								
32	1990 07 29	AMOCO	1	SMITH FRED	04 01N 13E	WAPANUCKA/9100	8874	
33	1990 08 08	AMOCO	1	O'DAY	12 03N 16E	CROMWELL/12000	13200	
34	1990 08 08	JMC	1	BLUE MTN	22 04N 17E	CROMWELL/15000	14000	
35	1990 08 17	ARKLA	1	SMITH-ENGLISH	25 05N 21E	ATOKA/12700	10702	4300
36	1990 08 17	TEXACO	24-1	SPANGLER	24 05N 19E	CROMWELL/15000	15000	
37	1990 08 18	AN-SON	1-10	GOLDEN	10 04N 20E	CROMWELL/16700	17650	
38	1990 08 23	ARROW	1-19	LAUBACH	19 03N 15E	WAPANUCKA/9300	9300	
39	1990 08 26	PACIFIC	1-16	SPEARS	21 04N 18E	WAPANUCKA/14000	14000	
40	1990 08 27	EXXON	1	MOORE	28 04N 18E	WAPANUCKA/14300	14300	
41	1990 08 31	HLMRCH&PAYNE	1	BURGER TRUST	06 04N 19E	CROMWELL/14500	14500	
42	1990 09 03	ARCO	1-23	NEWELL	23 04N 18E	CROMWELL/16000	15218	
43	1990 09 03	ARCO	1-34	TNT	34 04N 18E	WAPANUCKA/15250	15580	
44	1990 09 06	AN-SON	1-28	TURNEY	28 05N 20E	SPIRO/15500	15157	14490
45	1990 09 16	AMOCO	1	JAMES WALLACE	07 03N 16E	WAPANUCKA/11600	13950	
46	1990 09 19	TEXACO	35-1	DROMGOLD 'D'	35 04N 16E	SPIRO/13000	14729	
47	1990 09 25	GHK	1-9	POPE	09 03N 15E	BRAZIL/6500	6240	
48	1990 09 25	CHAPPARAL	1-29	VFW	32 05N 19E	SPIRO/12800	12533	
49	1990 10 05	BTA	1	9001 JV-P WORKMAN	22 04N 18E	WAPANUCKA/15000	14660	
50	1990 10 07	AMOCO	1	BAUMAN	27 05N 20E	WAPANUCKA/14600	14106	
51	1990 10 22	BTA	1	9001 JV-P MORELAND	12 04N 18E	ATOKA/10000	10000	
52	1990 10 26	ARCO	1-13	DOLLINS	13 04N 18E	WAPANUCKA/14500	14500	
53	1990 11 03	EXXON	1	ELLIS	04 04N 21E	WAPANUCKA/15500	15000	
54	1990 11 06	AMOCO	1	MINGS	16 05N 22E	SPIRO/11850	11850	
55	1990 11 27	HLMRCH&PAYNE	1-5	GARY	05 04N 19E	CROMWELL/14500	14500	
56	1990 12 07	TEXINIA	1-13	BRISCO	13 02S 11E	ARBUCKLE/14000	DRG	
57	1990 12 20	AMOCO	1-A	LAST CHANCE	11 03N 17E	SPIRO/15500	DRG	
58	1990 12 26	EXXON	1	YOURMAN	09 04N 19E	CROMWELL/16300	16300	
59	1990 12 28	AMOCO	30-1	RETHERFORD	30 04N 18E	ATOKA/14000	14000	
60	1990 12 28	AMOCO	9-1	H&H CATTLE CO.	09 03N 17E	WAPANUCKA/14500	14500	

Note: All depths are drilled depths (ft); all IPFs are MCFGPD; G—gas, D—dry, J—junked,

Prior to and in conjunction with the mapping, a preliminary computerized file was established containing geologic and engineering data on oil and gas wells in and immediately adjacent to the mountains. This initial effort was followed by the NRIS project, a broader effort undertaken to provide more accurate, detailed, and accessible information on the State's resources, with an initial emphasis on oil and gas production and well data.

NRIS presently consists of two major components: an Oil and Gas Production (OGP) subsystem and a Well History file. The OGP subsystem's lease file includes identification and location data, producing formation(s), DOE/EIA field codes, and monthly production totals since 1983. The field file includes the DOE/EIA field

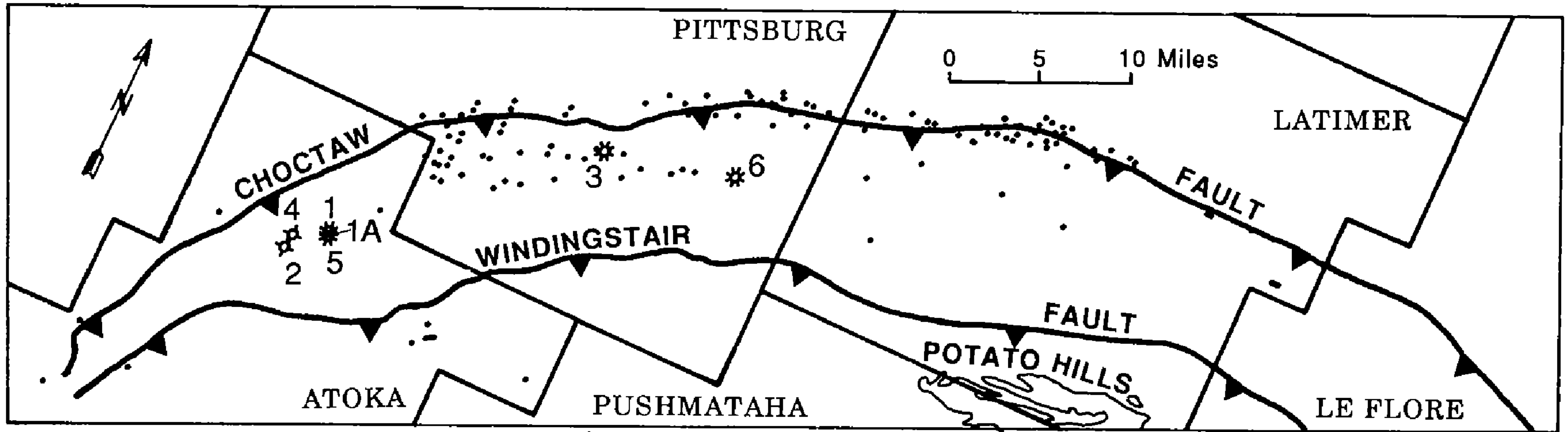
Continued

PRODUCING FM - A	GROSS PERFS	IPF	PRODUCING FM - B	GROSS PERFS	IPF	CLASS
						D
NR						
SPIRO	13660-13750	19000				G
ATOKA MIDDLE	3770-3792	300				G
NR						
SPIRO	15978-16060	25107				G
						D
NR						
NR						
NR						
NR						
NR						
SPIRO	14220-14250	36061				G
NR						
NR						
						D
OVERTH ATOKA BASAL	12372-12421	4216				G
NR						
NR						
NR						
NR						
NR						
NR						
NR						
NR						
NR						
NR						

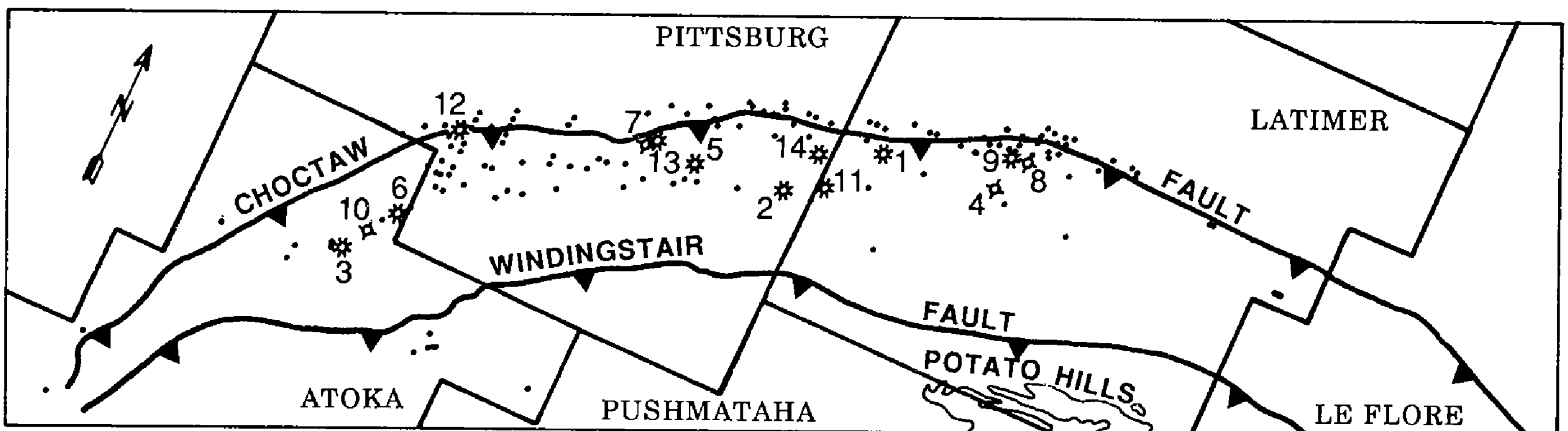
NR—no report.

codes, county codes, discovery date, cross-reference information for discontinued field names, location legal descriptions, cumulative production (where available), and monthly production totals since 1983.

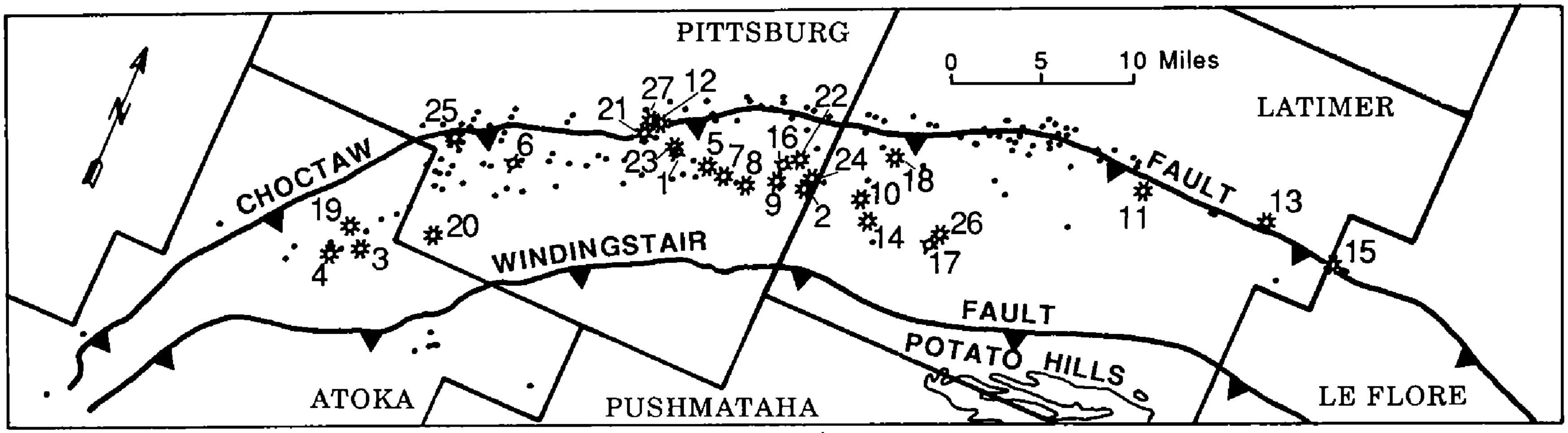
The second NRIS component, the Well History file, presently contains information on all oil and gas wells for which completion reports are available for the Arkoma basin area, the Ouachita Mountains area, most of the deep Anadarko basin area, and all of southern Oklahoma (i.e., areas south of T. 12 N.). The data base includes wells dating from the early 1900s to the present. Completion reports filed with the Oklahoma Corporation Commission on Form 1002-A are the primary source documents for this file, with some supplemental data gathered from well logs



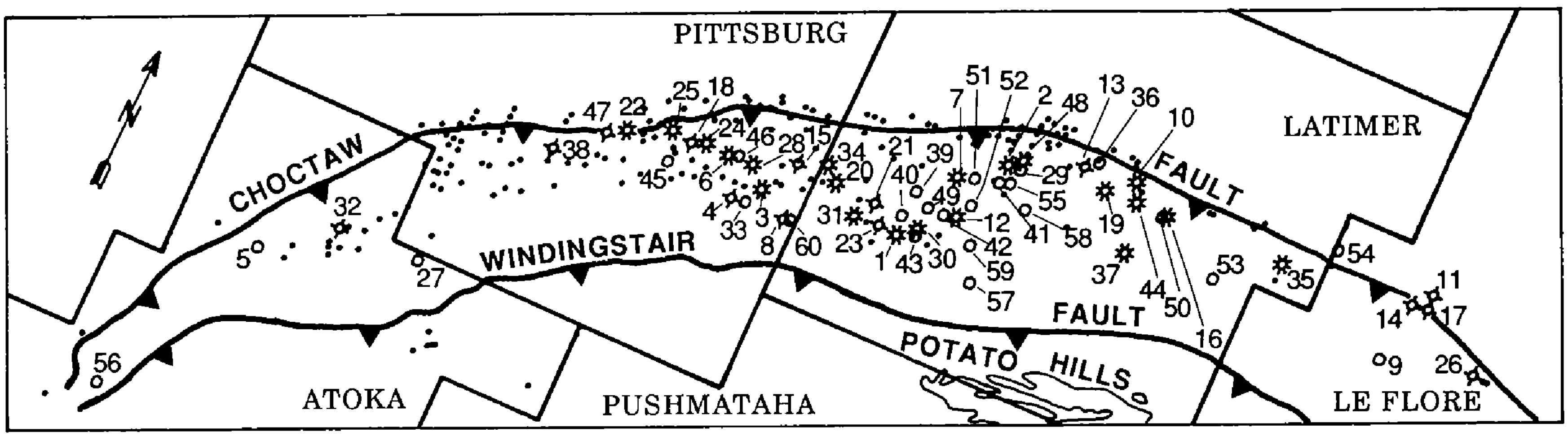
A. 1987 and pre-1987 wells ☼ Gas well ⌖ Dry well • Existing well



B. 1988 and pre-1988 wells



C. 1989 and pre-1989 wells Gas well Dry well • Existing well ○ No report



D. 1990 and pre-1990 wells

Figure 2. Maps showing surface locations of wells spudded in late 1986 and 1987, 1988, 1989, and 1990. Well numbers correspond to map numbers given in Table 1. Source: Oklahoma Geological Survey, NRIS data files. These data were mapped using a digital land grid data base, supplied by Phillips Petroleum Co.

and scout tickets. Data included in the file are: well identification data; well location (county, legal description, and latitude-longitude); drilling, completion, and plugging dates, and date of first production; elevations; well classification, casing, and cementing information; producing-formation completion and test data; and records of penetrated formations.

At the present time, nearly 160,000 records have been added to the Well History file. The current work phase is concentrated on computerizing data for the remainder of western Oklahoma (all wells west of the Indian meridian, including the Panhandle). State-wide coverage of about 300,000 records is expected by the summer of 1992.

Efforts are ongoing to enhance the basic data found in both the Well History and the OGP subsystems. A Phillips Petroleum Co. donation of an Oklahoma digital land grid to the Survey has made possible the calculation of latitude and longitude coordinates for all well, lease, and field locations. This enhancement has allowed the development of computerized mapping applications for the NRIS data. Funding for the NRIS activities has been received primarily from the U.S. Department of Energy, Bartlesville Project Office, with supplementary support from private sources.

Exploration Highlights, 1986–90

Exploration in the frontal belt of the Oklahoma Ouachita Mountains through the early part of 1991 can be summarized as one of alternating periods of drilling rank wildcats followed by periods of announcements of discoveries. November 1986 to November 1988 was a period of relatively widely spaced wildcat drilling throughout the central and western parts of the frontal belt; most of these wells discovered significant reserves in the Cromwell, Wapanucka, Spiro, and Atoka. In addition, the "Deep Wilburton" field in the Arkoma basin was discovered. December 1988 to June 1989 was a period of several announcements of discoveries, confirmations, and extensions, including the South Hartshorne, Southwest Haileyville, Wesley, and West Wesley fields. From July 1989 to June 1990, exploratory drilling expanded to the east and sparse Arbuckle tests south of the trace of the Choctaw fault continued. From July 1990 to February 1991, more discoveries were announced, including the South Panola, Northeast Wesley, and West Summerfield fields. A chronology of significant events is as follows:

1986

November. Amoco 1 Jenkins spudded near the one-well West Wesley oil field. Well blew out. Replaced by 1-A Jenkins spudded in May 1987.

1987

February. ARCO 2 Yourman spudded as 15,000′ Arbuckle test in Wilburton gas field.

May. Amoco 1-A Jenkins spudded. Replaces 1 Jenkins.

August. Amoco announces gas discovery in 1-A Jenkins from overthrusted Spiro and Wapanucka.

October. Oklahoma Nomenclature Committee of the Mid-Continent Oil and Gas Association (ONC) establishes West Wesley field in sec. 9, T. 1 N., R. 13 E. (Amoco 1-A Jenkins—discovery well).

November. ARCO 2 Yourman goes on-line. Official announcement of gas discovery in Arbuckle not made until January 1988.

December. Amoco 1 Garrett A spudded. First Pennsylvanian test in central part of frontal belt. Labeled as 16,500′ Atoka test.

1988

January. ARCO announces gas discovery in 2 Yourman from Arbuckle.

March. Amoco 1 Zipperer spudded as 12,600′ Spiro test.

June. ARCO 1 Hart spudded. First Arbuckle test south of trace of Choctaw fault. Was a dry hole.

June. Texaco 25-1 Chastain spudded. 12,800′ Cromwell test northeast of 1-A Jenkins discovery.

November. Texaco 1-1 J. A. Goddard spudded. 8,400′ Atoka test west of 1 Garrett A and 1 Zipperer activity.

December. Amoco announces significant gas discovery in 1 Zipperer from Spiro–Wapanucka.

1989

January. Amoco announces gas discovery in 1 Garrett A from Spiro and Cromwell.

April. Texaco announces gas discovery in 25-1 Chastain from Wapanucka. Confirms 1982 discovery of Wesley field.

June. Texaco announces gas discovery in 1-1 J. A. Goddard from Atoka (Red Oak and Smallwood sandstones).

July. An-Son 1-21 Cindy spudded. 16,500′ Reagan (Arbuckle) test south of Panola field, east of most drilling activity.

July. ONC expands Southwest Haileyville field to include sec. 1, T. 3 N., R. 15 E. (Texaco 1-1 J. A. Goddard).

August. Anadarko 1-15 Alford A spudded. 17,000′ Arbuckle test east of 1-21 Cindy well.

August. Amoco 1 Ingle spudded. 14,500′ Cromwell test east of 1-15 Alford A well.

September. ARCO 1 Ulysses spudded. 20,250′ Arbuckle test spudded within frontal belt, south of 1 Hart well. Encountered drilling problems and was abandoned.

October. Texaco 29-1 Burnett spudded. 18,000′ Arbuckle test spudded east of West Wesley and Wesley fields activity.

1990

February. Amoco 1 Short spudded. 16,100′ Hunton test far to east of 1 Ingle and north of trace of Choctaw fault. Was a dry hole.

March. BTA 1 9001 JV-P Mabry spudded. 14,000′ Cromwell test between activity in South Hartshorne and Panola fields.

TABLE 2. — OTHER

SPUD DATE	OPERATOR	NO.	FARM	SEC-TSP-RNG	OBJECTIVE/DEPTH	TD	PBTD
1987 11 10	WLHD COMP	2	SUMAR	28 05N 20E	WAPANUCKA/3200	3200	
1988 05 30	HOMESTATE	1-14	COPELAND	14 02S 11E	REAGAN/12000	9323	
1988 07 16	UNITED	1-24	WYRICK	24 01N 14E	STANLEY/5500	2128	
1988 09 16	ABIDE	1	LAMBERT	06 01N 14E	ARBUCKLE/3500	3400	
1988 12 16	A&I	1-8	J R	08 01N 15E	JACKFORK/2200	1525	
1990 01 15	BBR	1	TAYLOR	15 03S 11E	BIGFORK/3195	14540	5000
1990 05 04	BBR	1	FHA	15 03S 11E	BIGFORK/3000	2600	

Note: All depths are drilled depths (ft); all IPFs are MCFGPD (unless noted otherwise);

March. An-Son 1-20 Hardcastle spudded. 15,500′ Arbuckle test as follow-up to 1-21 Cindy spudded nine months previously.

April. Nearburg 1 Wister Lake spudded. 14,500′ Cromwell test between 1 Ingle and 1 Short wells. Within about two weeks, two additional wells spudded in adjacent sections. All were dry holes.

May. ONC establishes South Hartshorne field in secs. 16–17, 21, 25–27, 32–33, T. 4 N., R. 17 E. and sec. 31, T. 4 N., R. 18 E. (Amoco 1 Zipperer—discovery well).

August. Anadarko announces modest gas discovery in 1-15 Alford A from Atoka.

August. BTA announces gas discovery in 1 9001 JV-P Mabry from Atoka.

September. Amoco announces gas discovery in 1 Ingle from Atoka.

October. Since its discovery, the nine-well South Hartshorne field has produced 26.8 bcfg.

October. ONC establishes West Summerfield field in sec. 21, T. 5 N., R. 22 E. (Amoco 1 Ingle—discovery well). ONC establishes South Wilburton field in secs. 11, 14, and 24, T. 4 N., R. 18 E. (BTA 1 9001 JV-P Mabry—discovery well).

November. An-Son announces gas discovery in 1-20 Hardcastle from Spiro.

November. ONC establishes South Panola field in sec. 20, T. 5 N., R. 20 E. (An-Son 1 Hardcastle—discovery well). ONC expands South Hartshorne field to include secs. 32–33, T. 4 N., R. 18 E.

1991

January. Texaco announces gas discovery in 29-1 Burnett from Spiro.

January. AMOCO announces gas discovery in 1-21 Cindy from Spiro.

January. ONC establishes Northeast Wesley field in sec. 29, T. 2 N., R. 14 E. (Texaco 29-1 Burnett—discovery well).

OUACHITA WELLS

PRODUCING FM - A	GROSS PERFS	IPF	PRODUCING FM - B	GROSS PERFS	IPF	CLASS
						D
						D
						J
						D
STANLEY	718-748	7BOPD				O
						D
BIGFORK	2358-2476	40				G

G—gas, O—oil, D—dry, J—junked.

February. Since its discovery, the four-well South Haileyville field has produced 2.6 bcfg.

In addition to the significant ongoing exploration in the frontal belt, several other wells have been drilled in other parts of the Ouachita Mountains since late 1986. Table 2 lists those wells that are not considered in this report to have been part of the current frontal-belt exploratory effort. These include shallow gas and oil wells in the frontal belt, shallow gas wells in the McGee Valley area, and deep exploration wells in the central belt south of the trace of the Windingstair fault and on the Broken Bow uplift.

References Cited

Tilford, M. T., 1991, Arkoma basin thrust belt play—March 1991 update: Manuscript distributed to participants of Mid-Continent/AAPG Field Trip No. 1, The western Ouachita Mountains frontal belt, Oklahoma, April 10–12, 1991, Annual Meeting, American Association of Petroleum Geologists, Dallas, Texas, 29 p.

Suneson, N. H.; and Grasmick, M. K., 1989, Oil and gas wells, Ouachita Mountains, Oklahoma: Oklahoma Geology Notes, v. 49, p. 152–183.

MINERAL INDUSTRY OF OKLAHOMA, 1990

The value of nonfuel mineral production in Oklahoma was estimated at $237 million by the U.S. Bureau of Mines. This was an $18 million increase over the 1989 figure. Increased demand for and sales of cement, iodine, and crushed stone offset a decline in construction sand and gravel sales. Oklahoma continued to rank 35th nationally in total mineral value and was the only state with iodine production. The 1990 estimated mineral value reversed a four-year trend of decreasing value. Sales, however, remained several million dollars below the record $251.6 established in 1985.

Employment.—Mining employment for the first six months of 1990, including oil and gas extraction, averaged 44,400. This was a 4% increase over the same period in 1989. Total State employment for the same period rose only 2.1%.

Environment.—A task force appointed by the Governor reported that Oklahoma's environmental regulation agencies were fragmented and should be consolidated. However, legislation that would have consolidated a number of State agencies, including the Department of Mines, died in the 1990 Appropriations Subcommittee in the Oklahoma House of Representatives.

Personnel at the Sequoyah Fuels Corp., a uranium processing plant at Gore, discovered extremely high uranium concentrations in water samples when storage tanks were excavated. Contamination also was noted at other sites on the plant property, but there was no indication that off-site water had been affected.

Legislation and Government Programs.—The 1990 Oklahoma legislature passed and the Governor signed Senate Bill 263, which defined and regulated brine production.

The former U.S. Bureau of Mines helium plant in Boise City was deeded to the town of Keys, the city of Boise City, and Cimarron County. The plant terminated helium extraction from natural gas wells in the Keys field in 1981 and was completely closed in 1985.

Review by Nonfuel Mineral Commodity.—The three leading mineral commodities, in terms of value, were crushed stone, portland cement, and iodine. These three accounted for 69% of the total mineral value. This was a 3% increased over the 1989 value reported for the three commodities.

The community of Gore became the center of controversy surrounding State permits granted to two limestone mining firms, Allied Mining Corp. of Stilwell and Brazil Creek Minerals of Fort Smith. The public was concerned over possible noise, dust, and blasting issues, as well as the potential for increased truck traffic and road damage. A citizens group, The Save the Lower Illinois Inc., was formed to fight the limestone mines.

Creta Gypsum Inc., Olustee, applied for a surface mining permit in Jackson County. The firm sought the necessary permits to develop a surface mine to recover gypsum.

The internationally renowned Frankoma Pottery was seized by the Internal Revenue Service early in April because of a tax issue. The company reopened a few weeks later under federal bankruptcy court protection. A fire in 1983 closed the company for a year and resulted in the loss of key sales personnel and customers. The pottery company has struggled financially since the fire.

NONFUEL MINERAL PRODUCTION IN OKLAHOMA

	1989		1990[a]	
Mineral	**Quantity[b]**	**Value (thousands)**	**Quantity[b]**	**Value (thousands)**
Cement:				
Portland (thousand short tons)	1,236	$39,360	1,400	$44,800
Clays (metric tons)	565,956	1,619	596,686	1,796
Gem stones	—	—	—	—
Gypsum (thousand short tons)	2,523	14,369	2,578	15,120
Iodine (kilograms)	1,505,714	23,947	1,861,500	29,325
Sand and gravel:				
Construction (thousand short tons)	8,500[c]	20,000[c]	7,100	16,900
Industrial (thousand short tons)	1,216	18,310	1,195	19,070
Stone:				
Crushed[d] (thousand short tons)	23,598	81,969	22,600	89,500
Dimension (thousand short tons)	8,290	762	8,138	684
Combined value of cement (masonry), feldspar, lime, salt (1988), stone [crushed dolomite (1988), crushed granite (1989–90)], tripoli (1988–89)	—	18,695	—	20,006
Total	—	219,031	—	237,201

Source: USBM Denver Regional Office of State Activities in cooperation with the Oklahoma Geological Survey.
Dashes indicate data not available, withheld to avoid disclosing company proprietary data, or not applicable.
[a]Preliminary figures.
[b]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[c]Estimated.
[d]Excludes certain stones; kind and value included with "Combined value" data.

SEPM ELECTS NEW OFFICERS

Officers of the Society of Economic Paleontologists and Mineralogists for the 1991–92 term are:

President: Gail M. Ashley, Rutgers University
President-Elect: Harry E. Cook, U.S. Geological Survey, Menlo Park, California
Paleontology Councilor: Gregory H. Blake, UNOCAL
Sedimentology Councilor: Stephan A. Graham, Stanford University
Secretary-Treasurer: Michael E. Field, U.S. Geological Survey, Menlo Park, California
Councilor for Research Activities: Lisa M. Pratt, Indiana University
Editor, *Journal of Sedimentary Petrology:* Harvey Blatt, University of Oklahoma
Editor, *PALAIOS:* David J. Bottjer, University of Southern California
Editor, Special Publications: Barbara H. Lidz, U.S. Geological Survey

NOTES ON NEW PUBLICATIONS

Analyses of Subsurface Permian Rock Samples from the Central Oklahoma Aquifer

The geochemical analyses of subsurface Permian rocks from eight cored test wells in the Central Oklahoma aquifer have been completed by the USGS. This report is part of the National Water-Quality Assessment Program, which is intended to identify and explain major factors affecting water quality. The Central Oklahoma aquifer underlies ~3,000 mi^2 of central Oklahoma and is the major source of ground water for municipal, industrial, commercial, and domestic usage. Future development of the aquifer may be limited because concentrations of arsenic, chromium, selenium, and residual gross-alpha activity locally exceed government drinking-water standards. In addition, high concentrations of uranium are also locally present. This 65-page USGS open-file report was written by E. L. Mosier, P. H. Briggs, J. G. Crock, K. R. Kennedy, D. M. McKown, R. B. Vaughn, and E. P. Welsch.

Order OF 90-456 from: U.S. Geological Survey, Books and Open-File Reports, Federal Center, Box 25425, Denver, CO 80225. The price is $4 for microfiche and $10.25 for a paper copy; add 25% to the price for shipment outside North America.

UPCOMING MEETINGS

Environmental Site Assessments Case Studies and Strategies Conference, July 29–31, 1991, Columbus, Ohio. Information: National Water Well Association, 6375 Riverside Dr., Dublin, OH 43017; (614) 761-1711.

Society for Economic Paleontologists and Mineralogists, Annual Meeting, August 15–18, 1991, Portland, Oregon. Information: Susan Green, SEPM, P.O. Box 4756, Tulsa, OK 74159; (918) 743-9765.

American Association of Petroleum Geologists, International Conference and Exhibition, September 29–October 2, 1991, London, England. Information: AAPG International Conference, P.O. Box 979, Tulsa, OK 74101; (918) 584-2555.

Society for Organic Petrology, Annual Meeting, September 30–October 1, 1991, Lexington, Kentucky. Information: Jim Hower, Center for Applied Energy Research, 3572 Iron Works Pike, Lexington, KY 40511; (606) 257-0261.

Society of Petroleum Engineers, Annual Meeting, October 6–9, 1991, Dallas, Texas. Information: Sally Goldesberry, SPE, P.O. Box 833836, Richardson, TX 75083; (214) 669-3377.

American Institute of Professional Geologists, Annual Meeting, October 16–19, 1991, Gatlinburg, Tennessee. Information: Lawrence I. Benson, ERC/EDGE, P.O. Box 22879, Knoxville, TN 37933; (615) 966-9761.

Oklahoma Geological Survey, Arbuckle Group Core Workshop and Field Trip, October 29–31, 1991, Norman, Oklahoma. Information: Kenneth S. Johnson, OGS, 100 E. Boyd, Room N-131, Norman, OK 73019; (405) 325-3031.

OKLAHOMA ROCK CLUBS

Ada Hardrock and Fossil Club
P.O. Box 1202
Ada, Oklahoma 74820
Meets 2nd Thursday
Ada Public Library

Enid Gem and Mineral Society
2614 West Oklahoma
Enid, Oklahoma 73703
Meets 1st Thursday
Hoover Building
Garfield County Fairgrounds

McCurtain County Gem and Mineral Club
406 S.E. Avenue E
Idabel, Oklahoma 74745
Meets 3rd Tuesday

Mount Scott Gem and Mineral Society
P.O. Box 481
Apache, Oklahoma 73006
Meets 2nd Friday
Center for Creative Living

Northwest Arkansas Gem and Mineral Society
Route 1, Box 288A
Colcord, Oklahoma 74338
Meets 4th Tuesday
113½ North Broadway
Siloam Springs, Arkansas

Oklahoma Mineral and Gem Society
P.O. Box 25632
Oklahoma City, Oklahoma 73125
Meets 3rd Thursday
Will Rogers Garden Center
3400 N.W. 36th

Osage Hills Gem and Mineral Society
P.O. Box 561
Bartlesville, Oklahoma 74005
Meets 3rd Thursday
First Presbyterian Church

Shawnee Gem and Mineral Club
10 Donna Lane
Shawnee, Oklahoma 74801
Meets 1st Tuesday
Jefferson School
(except during vacations)

Stillwater Gem and Mineral Society
1116 South Gray
Stillwater, Oklahoma 74074
Meets 4th Thursday
United Methodist Church
7th and Duck

Tahlequah Rock and Mineral Society
501 Seminary
Tahlequah, Oklahoma 74465
Meets 3rd Tuesday
Tahlequah Public Library

Tri-State Rock Club
1207 North Canyon
Guymon, Oklahoma 73942
Meets 3rd Tuesday
Seniors Center

Tulsa Rock and Mineral Society
P.O. Box 2292
Tulsa, Oklahoma 74101
Meets 2nd Monday
Aaronson Auditorium,
Tulsa Main Library

Western Oklahoma Gem, Rock, and Mineral Society
112 South Main
Elk City, Oklahoma 73644
Meets 2nd Tuesday
Berlin Community Building

OKLAHOMA ABSTRACTS

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

Climatic Influence on Basin Sedimentation: Peru–Chile Trench as an Analogue for the Ouachita Basin

C. BLAINE CECIL and N. TERENCE EDGAR, U.S. Geological Survey, Reston, VA 22092

The Peru–Chile Trench, off the west coast of South America, is a modern example of climatic influence on sedimentation, and may represent a modern analogue for the sedimentary rocks of the Ouachita Mountains. The Peru–Chile Trench extends from the equatorial wet zone (lat. 8°N to 5°S) through the subtropical desert belt (lat. 5°S to 30°S). Adjacent to the desert, one of the driest in the world, the sediment-starved Peru–Chile Trench contains pelagic, deep-sea clay and is totally devoid of terrigenous clastic sediment. Although the subduction zone continues to the southern limit of South America, the trench is filled with sediment south of lat. 30°S (temperate wet zone).

If the desert conditions of the Peru–Chile coasts were replaced by conditions of seasonal rainfall, thick clastic sediments from the Andes Mountains (more than 7,000 m high) would probably be deposited on the pelagic clays at the bottom of the trench (more than 8,000 m deep), such as occurs south of lat. 30°S. Because the influence of climate on sedimentation is generally not recognized in interpretations of sedimentary sequences, such a sequence in the geologic record would probably be misinterpreted as representing slow deep-water deposition followed by an orogeny that resulted in a tectonostratigraphic wedge.

Sediments similar to those deposited in the Peru–Chile Trench are found in the Ouachita Mountains; thin shales, cherts, volcanic ash, and minor siltstones and sandstones (turbidites) were slowly deposited in a deep basin during Ordovician to Mississippian time while the basin was moving northward through the dry belt (from about lat. 30°S to about 10°S). Beginning in Mississippian time, there was a significant increase in coarse clastic sedimentation as the Ouachita basin began to move into the tropical wet belt (between lat. 10°S and 5°S), and in the mid-Pennsylvanian Atokan time, about 8,500 m of coarser clastic sediment was deposited. The clastic sediment deposition has been attributed solely to tectonic activity. However, movement of the deposystem into a wetter regime may also have caused the introduction of abundant terrigenous sediment, and thus paleoclimate may have played a significant role influencing the resulting stratigraphic sequence.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1991*, v. 23, no. 1, p. 15.

Eustatic and Tectonic Control of Sedimentation in the Pennsylvanian Strata of the Central Appalachian Basin

DONALD R. CHESNUT, JR., Kentucky Geological Survey,
University of Kentucky, Lexington, KY 40506

Analysis of Pennsylvanian rocks in the Central Appalachian Basin reveals eustatic and tectonic controls on sedimentation. Large-scale basinal features were controlled by tectonics. An Early Pennsylvanian unconformity represents erosion of mid-Carboniferous foreland basin deposits and marks uplift of the foreland basin. The tectonic cause of the uplift may have been relaxation or collisional braking. Distribution of post-unconformity Early Pennsylvanian strata shows that the Early Pennsylvanian foreland basin was underfilled, i.e., the forebulged had not been crested. Alluvial deposits derived from the Appalachian highlands were transported to the northwest toward the forebulge. The only outlet available to further sediment transport was toward the southwest, between the alluvial wedge and the forebulge. Crossbed measurements of the Lee sandstones support a southwestern trunk transport system. Sediments may ultimately have ended up in the Ouachita Trough via the Ouachita–Southern Appalachian forelands basin. This southwestern transport was periodically interrupted by northeastward transgression, represented by marine strata in the major marine transgression cycle.

The extensive nature of Middle Pennsylvanian Breathitt coal beds and marine strata may mark a period of overfilling of the foreland basin and cresting of the forebulge. Chronologic analysis of the Breathitt Formation supports a eustatic control for the coal-clastic (CC) cycle (= Appalachian cyclothem), modulated by the 0.43 ma orbital periodicity. Peats deposited at lowstand were preserved as coals. The major marine trangression (MMT) cycle (2.5 ma) (= 5 to 7 CC cycles) was controlled by an unknown eustatic cycle or periodic tectonic mechanisms. The Breathitt coarsening-upward trend (12–20 ma?) (5 to 8 MMT cycles) represents increasing intensity of the Allenghenian Orogeny.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1991,* v. 23, no. 1, p. 16.

Marine Transgressions in the Central Appalachian Basin During the Pennsylvanian Period

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University of Kentucky, Lexington, KY 40506

Compilation of paleontological data from Pennsylvanian rocks from the Central Appalachian Basin reveals that marine and brackish strata overlie the major coal beds. The extensive nature of marine strata and major coal beds, and the repetitive sequences of coal-bearing strata with a 0.43 ma periodicity support eustatic control for these marine transgressions.

Mapping of biofacies of the marine strata shows that during the Early Pennsylvanian, the marine source was to the south or southwest. Stratigraphic analysis of Early Pennsylvanian rocks indicates that these foreland basin deposits onlapped toward the forebulge, but did not crest it. Biofacies mapping of Middle Pennsylvanian strata shows a southern and western source for marine conditions. The forebulge was probably crested at times, especially along saddles such as the Cumberland Saddle. Hingelines at the southern end of the Rome Trough and at the Kentucky River Fault System, both of which subsided to the south, may have caused deeper marine conditions in the southeastern part of the basin. Geologic studies indicate marine sources to the north or northwest for late Middle and Late Pennsylvanian time.

During the Early Pennsylvanian, marine waters from the Ouachita Trough transgressed through the underfilled Ouachita and Appalachian forelands basins. Forebulges of these systems were not breached. During the Middle Pennsylvanian the basins were alternately filled and underfilled, and at times the forebulges were breached along saddles. Marine transgression proceeded through the subsiding part of the foreland basin and through saddles. During the late Middle and Late Pennsylvanian, the Ouachita Basin was deformed, closing off access for marine transgression through the southern foreland basins. Marine waters apparently transgressed through the Illinois Basin, through Ohio, north of the Jessamine Dome, to the Dunkard Basin.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1991,* v. 23, no. 1, p. 16.

The Appalachian–Ouachita Rifted Margin of Southeastern North America

WILLIAM A. THOMAS, Dept. of Geology, University of Alabama, Tuscaloosa, AL 35487

Promontories and embayments along the late Precambrian–early Paleozoic Appalachian–Ouachita continental margin of southeastern North American are framed by a northeast-striking transform faults. Inboard from the continental margin, basement fault systems have two sets of orientation; one is northeast parallel with rift segments, and the other is northwest parallel with transform faults.

Late Precambrian clastic and volcanic syn-rift rocks overlie Precambrian basement rocks along the Appalachian Blue Ridge. Lower Cambrian sandstone at the base of a transgressive passive-margin succession over-steps the rift-fill successions and basement rocks, defining the time of transition from an active rift to a passive margin along the Blue Ridge. Locally thick Early Late Cambrian and older sedimentary rocks fill downthrown blocks of the intracratonic Mississippi Valley–Rough Creek–Rome graben system and Birmingham basement fault system. These basement fault systems, which indicate northwest-southeast extension like the Blue Ridge rift, are overstepped by Upper Cambrian strata. The northwest-striking Southern Oklahoma fault system is interpreted to be a transform fault that propagated into the the continent from the Ouachita rift. Early and Middle Cambrian rift-related igneous rocks along the fault system and adjaceant Precambrian basement are overstepped by Upper Cambrian sandstone.

The differences in age of rift-related rocks suggest a spreading-center shift at the beginning of the Cambrian Period from the Blue Ridge rift to the Ouachita rift southwest of the Alabama–Oklahoma transform fault. From Early to Early Late Cambrian, a small component of extension propagated northeastward to form the intracratonic fault systems northeast of the transform fault, but most of the extension of the Ouachita rift was transformed along the Alabama–Oklahoma transform fault to the Mid-Iapetus Ridge outboard from the Blue Ridge passive margin.

Reprinted as published in the Geological Society of America *Bulletin*, v. 103, p. 415, March 1991.

Evidence for Glacial-Eustatic Control Over Pennsylvanian Cyclothems in Midcontinent North America and Tests for Tectonic Effects

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Pennsylvanian major marine cyclothems in Midcontinent North America consist of a thin transgressive limestone, thin offshore shale and thick regressive limestone, covering an area of perhaps 500,000 km^2 from southern Kansas to Iowa and Nebraska, and separated from one another by well developed paleosols across most of this region. Southward, the offshore shales extend into the basins of Oklahoma, and the regressive limestones and paleosols grade into deltaic/fluvial clastics derived from the Ouachita detrital source. Because the dark phosphatic offshore shales record deposition below a thermocline in at least 100 m of water, sea level rise and fall of at least that amount is required over the entire northern region to account for the widespread dark shale/paleosol cyclicity. Tracing of all major cyclothems across both the Forest City Basin and adjacent Nemaha Uplift rules out local differential tectonics on the northern self as a major control. Coincidence of all reasonable estimated periods of these marine cycles (20 ky to 400 ky) with the Milankovitch band of orbital parameters that control Pleistocene glacial fluctuation points to glacial eustasy as the major control over Midcontinent cyclicity. Although tectonic subsidence helped provide space for Midcontinent sediment accumulation, tectonic control over *cyclothem* deposition would require *both subsidence and uplift* of this (or a large nearby) region at Milankovitch frequencies, but all such tectonic mechanisms available so far act at periods at the very least 5 times greater (2 my+). Firm biostratigraphic correlation of major midcontinent cyclothems with similar depositional cycles in Texas and Illinois identifies a strong glacial eustatic signal in those regions, with little evidence of temporally differential tectonism among them. Preliminary observations that only certain major marine cycles extended into the Appalachian Basin suggest that the absence of others may reflect tectonic uplift there and that with better correlation, the longer-term tectonic signal can be identified in that area.

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Stratigraphic Cyclicity in Foreland Geologic Systems of Permo–Carboniferous Age

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Shallow marine and marginal marine depositional systems of foreland regions lying between cratons and orogens are potentially subject to all the principal influences thought to control stratigraphic cyclicity: autogenic, climatic, tectonic, glacioeustatic, and tectonoeustatic. In foreland settings, both clastic and carbonate depositional environments of shelf or epeiric seas and adjacent coastal plains are sensitive to shifts in strandline position caused by local or regional variations in sediment supply, and to fluctuations in accommodation space controlled by either global eustasy or tectonic flexure that changes relative sea level. For over fifty years, many have attributed development of prominent Permo–Carboniferous foreland cyclothems primarily to effects of Gondwanan glacioeustasy, but dominance of alternate controls has been difficult to exclude. Stratigraphic analysis of key sequences in the southern Cordilleran region supports a glacioeustatic origin for Permo–Carboniferous cyclothems through the following combined observations that are difficult to reconcile with dominance of other controls: (a) ubiquitous development of stacked cyclothems in both the Permo–Carboniferous Ouachita–Marathon foreland and in correlative non-foreland strata of Nevada and Utah, coupled with absence of comparable cyclicity in older Antler and younger Sevier foreland successions; (b) diachronous non-cyclothemic stratigraphic records of foreland tectonic flexure that produced migratory forebulges; (c) basinwide distribution of multiple correlative cyclothems in selected Ancestral Rockies basins; (d) provisional correlation of individual cyclothems from the midcontinent region through the Ouachita–Marathon foreland; and (e) apparent cyclothem duration within the Milankovitch time band.

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Late Paleozoic Deformation of the Texas Foreland: Styles and Phases

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The completed "Tectonic Map of Texas" displays the complex Late Paleozoic structure of the Ouachita foreland. Two major axes of deformation (Wichita–Amarillo, WA; and Central Basin, CB) and several linear deformation zones bound little-deformed basement blocks. Individual elements in CB are characteristically of 1–5 km width, and organized in "ridge" and "transverse zone" domains. The WA contains uplifts and basins of 10–50 km width, with internal structure. Most features

in the area are contractional or transpressional; the smaller widths of CB structures may be related to décollement on a mid-crustal LVZ. A major cratonal subsidence event (the West Texas Basin, WTB) is superposed on CB and points west; it began after the early phases of deformation and outlasted all deformation, suggesting that it is only indirectly related to deformation itself.

The late Paleozoic deformation occurred over a span of 50 Ma. Stress systems responsible and possible tectonic causes are noted italics:

I. Early Pennsylvanian (320–304 Ma) ("Wichita"): Major Ouachita thrusting; development of foredeeps and associated extension; major NW-compressive transpression in WA; minor compression with strike-slip faulting in the CB; minor strike-slip faulting elsewhere. *Northwest-directed stress from closure of the Ouachita Basin.*

II. Middle Pennsylvanian (304–292 Ma) ("Colorado"): Continuing north-south compression, uplift and subsidence on AW; major (extensional?) uplifts in New Mexico and Colorado; late Ouachita thrusting; formation of a successor basin behind the Ouachita thrust; quiescence(?) on CB. *Stress system unkown; possibly an extensional element?*

III. Late Pennsylvanian (292–286 Ma) ("Arbuckle"): Major north-south compression and sinistral strike-slip faulting on AW ("Arbuckle"); uplift of basement massifs; beginning of compression and strike-slip faulting on CB; beginning of strong subsidence of WTB. *North to northwest-directed stress from subduction south of Ouachita Basin.*

IV. Early Permian (286–270? Ma) ("Pecos"): End of deformation on AW; final emplacement of Marathon thrust sheets; major east-west compression and sinistral strike-slip faulting on CB; major subsidence of WTB. *West-directed compression transmitted from an eastern Alleghanian(?) event.*

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Petroleum Geochemistry of Texas and Oklahoma Oils from the Marathon/Ouachita Fold Belt

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The Marathon uplift of west Texas and the Ouachita Mountains of Oklahoma and Arkansas comprise the surface expressions of a Paleozoic orogenic belt extending across the south-central United States. A century of petroleum exploration in the Marathon and Ouachita exposures has yielded several oil discoveries. In this study, detailed molecular, elemental, and isotopic data are presented for nine Texas oils, five Oklahoma oils, and four Oklahoma solid bitumens, all associated with thrust belt rocks of the Marathons and Ouachitas. Oil-oil and oil-solid bitumen correlations are proposed, and the character of the organic matter in the source rock(s) is deduced from the chemistry of the oils and solid bitumens.

All 18 samples are sourced from the same (or very similar) organic matter. This indicates that they are probably cogenetic, despite geographic separations of hun-

dreds of miles. Chemical differences in these samples derive from secondary effects, including biodegradation (e.g., solid bitumens) and differing levels of thermal maturity. The occurrence of unusual chemical compounds (certain bisnor- and trisnorhopanes) in all samples probably indicates the presence of anaerobic bacteria in the depositional environment. Source deductions from oil chemistry suggest that an Ordovician unit is responsible for these oils and solid bitumens. This conclusion is consistent with previous literature suggesting an Upper Ordovician source for Oklahoma Ouachita oils and supports tectonic reconstructions of the region during Ordovician time.

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Structural Linkage: Ouachita and Ancestral Rocky Mountains

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Recent detailed studies provide a preliminary model to correlate Carboniferous deformation in Texas, Oklahoma, and New Mexico. Subsidence was initiated during the Mississippian in all of the basins across this region. Within the Ouachita Mountains of Oklahoma northerly directed shortening characterizes the initial deformation. While poorly constrained, this shortening included two folding events of Mississippian through Middle Pennsylvanian (Atokan) strata. Subsequently, the shortening direction rotated counterclockwise to the northwest, generating a third fold set and the basement-cored Broken Bow uplift. This deformation appears to reorient large thrusts of the central zone and is interpreted to reorient folds observed in the Ti Valley thrust sheet of the frontal zone. Timing of this deformation is constrained by late Desmoinesian synorogenic sediments in the Arkoma basin.

The earliest deformation within the Arbuckle Mountain area was initiated in the Early Pennsylvanian (Morrowan). In the Arbuckle Mountains proper the first movement began in Atokan time, intensifying during the Desmoinesian with continuing deformation involving conglomerates of mid-Virgilian age. There is little agreement on the principal deformational style; however, initial shortening normal to the structural grain followed by left lateral slip is consistent with detailed field observations.

Within the Marathon area deformation is characterized by several décollements and associated northerly directed thrusts. Timing of deformation is outlined in two stages: initial Desmoinesian and Missourian age followed by Virgilian to Wolfcampian deformation. No rotation in shortening direction is mentioned. In the Taos trough eastward thrusting along a major north-south trending fault occurred during Atokan to early Desmoinesian time. From late Desmoinesian to Wolfcampian time a northerly sediment source indicates uplift along an east-west trending fault. This change in source area suggests a change in shortening direction coincident with the strong north-south compression in the Marathon region.

A collisional model involving several continental blocks converging in a diachronous fashion can account for the above data.

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Tectonic Evolution of the Wichita Uplift, Oklahoma Implications for Linkage of Deformation Between the Ancestral Rocky Mountains and Ouachita–Marathon Orogen

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The Wichita uplift is a critical link in the chain of basement uplifts that define the Ancestral Rocky Mountains. The style of deformation along the northern margin of the uplift, and patterns of deposition in the adjacent Anadarko basin were used to analyze the late Paleozoic evolution of the uplift. Results of this analysis revealed: (a) the uplift was transported over the southern margin of the basin on oblique (left-reverse) slip basement faults; (b) the transition from uplift to basin is divisible into three segments that reflect the partitioning of deformation along the northern margin of the uplift; and (c) Pennsylvanian sedimentation patterns within the Anadarko basin reflect the southeastward migration of the basin depocenter.

Knowledge of the magnitude and sense of slip on the bounding faults of the Wichita uplift places constraints on interpretations of foreland deformation adjacent to the Ouachita–Marathon orogen. Some previous tectonic models have proposed up to 150 km of left-slip associated with the Wichita uplift. However, the above analysis indicates left-slip was an order of magnitude less, and was approximately equal to the magnitude of reverse-slip. A tectonic model is presented that accounts for deformation of the Wichita uplift as a consequence of diachronous, oblique convergence within the Ouachita–Marathon orogen. In this interpretation crustal shortening either occurred along the plate margin or was distributed within the foreland of the orogen.

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Sedimentologic Evidence for Uplift of the Ouachitas

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Facies patterns and petrographic characteristics of clastic units in the Arkoma and Ardmore basins in Oklahoma constrain the timing of major uplift in the Ouachita thrust belt. In the Arkoma Basin to the north of the Ouachitas, a change in paleocurrent directions, introduction of detrital chert, and evidence of deformation in the Boggy–Thurman (early–middle Desmoinesian) sequence record the uplift. The Boggy, composed of sandstone-shale sequences that record southerly progradation of fluvially dominated deltaic complexes, was folded at the time of uplift in the Ouachitas. Subsequently, the Thurman, which had a source to the southeast, was deposited in a resurgent basin over the Boggy. Detrital chert in the Thurman, derived from Ordovician and Devonian units, records the first arrival of sediments

from the uplifted Ouachitas. The facies sequences in the Thurman are similar to Appalachian-type cyclothems and their origin could be related to episodic thrust faulting. In the Ardmore Basin to the northwest of the buried Ouachita front, currently ongoing studies indicate that the Deese Group (Desmoinesian) records major uplift with the introduction of large volumes of chert. The Devils Kitchen Member, for example, coarsens upward from prodelta to alluvial fan deposits and records the progradation of delta/fan deltas into the basin. The facies progression is represented both vertically and laterally. The characteristics of the sequences in both the Arkoma and Ardmore basins indicate that major uplift in the Ouachitas occurred during early to middle Desmoinesian.

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Deep Exploration Possibilities along the Ouachita Trend

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The late Paleozoic Ouachita orogeny produced a sinuous deformed belt that extends from Alabama through Mississippi, Arkansas, Oklahoma, Texas, and finally southward into Mexico. Although this orogenic belt has been studied for many years, it is poorly understood because exposures are very limited and most drill holes stop once low grade metamorphic Ouachita facies rocks are encountered. However, recent geophysical studies have provided important new data that make it possible to reevaluate exploration possibilities along the Ouachita trend. A deep seismic study along a profile extending from the Ouachita Mountains in southwestern Arkansas into northwestern Louisiana has provided a surprisingly clear image of the early Paleozoic continental margin in the area. This margin is largely undeformed and suggests that the Ouachita orogeny involved little if any shortening of continental crust. Along with gravity data, this result implies that Ouachita thrusts are thin-skinned structures that include features such as the Benton and Broken Bow uplifts. Using these results as a base from which to build, we have been able to trace this margin southeastward into Mississippi and westward through Texas and into Mexico. Although some production has been established in Ouachita facies rocks, gravity anomalies and limited amounts of seismic data suggest that two subthrust plays have potential. The first is simply the extension of well-known foreland basins (Arkoma, Fort Worth, Val Verde, etc.) beneath the thrusts, and our point is that these basins probably extend further than previously believed. In addition, there are areas where completely new subthrust basins are possible. The second play is the early Paleozoic continental margin and rift basins that formed during the early stages of its development. Our results to data indicate that these features are not greatly deformed and are at economically drillable depths in many areas. However, the area south of the Paleozoic continental margin should be avoided because the thickness of Ouachita facies rocks exceeds 10 km.

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Origin of Porosity Development in a Mixed Terrigenous-Carbonate Reservoir Unit, Batson Field Area, Arkoma Basin, Arkansas

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Sandstone units in the Morrowan Hale Formation provide much of the natural gas in the northern part of the Arkoma basin in northwestern Arkansas at drilling depths ranging from 1,500 to 6,000 ft. The producing section crops out in the Boston Mountains north of the Cass fault system, and is especially productive immediately south of the fault system in the Batson field area of the Arkoma basin. The Hale Formation is unconformably underlain by the Mississippian Pitkin Limestone, and is composed of a lower Cane Hill Member, dominated by shale and discontinuous sandstone units, and an upper Prairie Grove Member. Bloyd strata overlie the Prairie Grove. The Prairie Grove Member, a major reservoir unit in the Morrowan section ranges from 100 to 150 ft in thickness and is composed of quartz sand with varying amounts of skeletal and oolitic material. Pervasive calcite cement is abundant in some areas.

The Prairie Grove Member accumulated on a tidally dominated shelf during early Morrowan time. Quartz sand was concentrated in broad, shallow channel systems by tidal currents forming moderately porous lobes and elongate trends. Interchannel areas were dominated by carbonate banks with abundant skeletal organisms. Porosity within these banks was occluded by calcite cement. Dissolution of calcite cement and enhancement of porosity occurred in channel systems that had moderate porosity as basinal fluids migrated northward prior to gas emplacement. Fluid movement through the interchannel carbonate banks was insignificant and porosity remained low.

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Tide-Generated Sand Bodies in a Mixed Terrigenous-Carbonate Sequence, Lower Pennsylvanian (Morrowan) of Northwest Arkansas

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The Prairie Grove Member of the Hale Formation in northwest Arkansas is composed of mixed terrigenous-carbonate sands that were deposited within a tide-dominated coastal zone and adjacent shelf during Early Pennsylvanian time. The unit is extensively exposed in the Boston Mountains north of the Arkoma basin and is continuous in the subsurface of the basin. Prairie Grove sediment accumulated on a stable depositional surface that was gently inclined to the southeast prior to the

structural development of the Arkoma basin later in Pennsylvanian time.

Sections composed of fine to medium-grained quartzarenite containing 5–40% fragmented and abraded skeletal grains pass laterally and abruptly into intervals composed of skeletal limestone that contain minor quantities of quartz sand. Skeletal grains in limestone sequences are not fragmented or abraded and are poorly sorted. Intervals dominated by quartzarenite display large scale sets of trough cross-strata. Alignment of axial troughs and dip directions of foresets indicates that north-south oriented, bi-directional current systems were active during accumulation. Quartzarenite successions are confined to bodies that range from 0.5 to 1 mi in width and are elongate north-south perpendicular to depositional strike. They are indicative of previously unrecognized shallow channel systems. Quartz sand from the eastern part of the basin and locally derived skeletal fragments were deposited in the channel systems by ebb and flood tidal currents. The channel systems were bounded by stable carbonate banks dominated by skeletal debris.

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Elevated Thermal Maturation in Pennsylvanian Rocks, Cherokee Basin, Southeastern Kansas: Importance of Regional Fluid Flow

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Thermal history of sedimentary basins is commonly assumed to be dominated by burial heating. Marked contrast between reconstructed burial temperatures and other temperature determinations would suggest alternative processes. In the Cherokee basin of southeastern Kansas, reconstruction of burial and thermal history indicates that basal Pennsylvanian strata were not buried more than 1.8 km, and should have reached only about 90°C. However, our study of Pennsylvanian rocks of the Cherokee basin indicates that higher temperatures were reached and that the pattern of thermal maturation is inconsistent with simple burial heating.

Regional pattern of vitrinite reflectance reveals several "warm spots" where thermal maturation is elevated above the regional background. R_m values in warm spots reach 0.9–1.5%; background values average 0.7%. These values correspond to temperatures of 110°C on a regional level to >150°C in warm spots. Rock-Eval pyrolysis confirms the vitrinite data; average T_{max} of 436°C is equivalent to R_m of 0.65%. Over a thickness of 600 m, vitrinite data show a very low vertical gradient. However, in individual wells, closely spaced values exhibit high spikes that may show an increase from 0.65 up to 1.36% R_m over only a 6 m interval.

Primary fluid inclusions in late Ca–Mg–Fe carbonate cements yield homogenization-temperature modes or petrographically consistent populations ranging from

100 to 150°C. These data suggest that the samples experienced at least those temperatures, hence fluid inclusions closely agree with vitrinite and Rock-Eval.

Elevated temperatures, warm spots, confined thermal spikes, and a low R_m gradient argue against simple burial heating. These observations are consistent with regional invasion of warm fluids, probably from the Ouachita–Arkoma system, and their subsequent upward migration into Pennsylvanian strata through faults and fractures. Petroleum exploration should consider the possibility of regionally elevated thermal maturation levels with even more elevated local maxima. Consequences may include local generation of hydrocarbons or local changes in diagenetic patterns.

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Red Oak Gas Field, Arkoma Basin, Oklahoma

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Red Oak gas field, with ultimate reserves of greater than 2 TCF methane, is the largest field in the Arkoma basin. As a result of dynamic tectonic evolution of the basin during the Atokan, sandstone reservoirs display significant contrasts in reservoir characteristics.

The basal Atokan Spiro sandstone is a quartz arenite deposited in southward prograding deltas on a tectonically stable shelf. Geologic events associated with evolution of the Ouachita–Arkoma tectonic system influenced the Spiro reservoir. Most important among these were (1) fracturing of the Spiro into normal fault blocks, (2) facies selective diagenesis, (3) liquid hydrocarbon accumulation, (4) thermal degradation of hydrocarbons to methane, and (5) hydrothermal quartz cementation below hydrocarbon-water contacts. Consequently, optimum Spiro reservoir quality occurs along linear, north-south channel trends at locations that were structurally high at the time of thermal overmaturation.

The middle Atokan Red Oak sandstone is a sublithic arenite deposited by westward flowing turbidites in slope channels localized above normal faults formed during tectonic breakdown of the precursor shelf. During burial, diagenesis destroyed porosity in some slope channel facies and enhanced porosity in others. During methane generation in encasing shales, the Red Oak was an amalgamation of porous and nonporous slope channel sandstones. Compression associated with late stages of Ouachita orogenesis deformed the reservoir horizon into a thrusted anticline, separated from the underlying Spiro by décollements in intervening shales. In contrast to the Spiro, optimum Red Oak reservoir quality occurs along linear, east-west channel trends at locations that were structurally low at the time of deposition and diagenesis.

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Diagenetic History of a Calcareous Quartzarenite: Implications for Porosity Distribution in a Natural Gas Reservoir, Northern Arkoma Basin, Arkansas

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The Prairie Grove Member of the Hale Formation (Morrowan) is composed of quartz sand with a significant component of carbonate skeletal debris. The unit is a major natural gas reservoir in the Arkoma basin of Arkansas. The reservoir exhibits dramatic variations in porosity. Pervasive calcite cement in many areas occludes pore spaces and reduces porosity to unacceptable levels for gas production. In other areas dissolution of cement and framework skeletal grains has created secondary porosity values as high as 20%. The pattern of carbonate grain and cement dissolution is broadly controlled by the distribution of original constituents and is directly related to the diagenetic history of the rock.

The Prairie Grove Member accumulated on a shallow tide-dominated shelf. Medium-grained quartz sand composes from 50 to 95% of the framework grains. The remaining framework grains are composed of crinozoan and bryozoan bioclasts. In sections with abundant skeletal grains (30–50%) solution packing and early dissolution of skeletal grains produced pervasive calcite cement that destroyed intergranular porosity. Subsequent fluid migration through these intervals was minimal. Sections in which skeletal grains formed less than 30% of the framework grains were not pervasively cemented and retained some primary porosity. Later movement of unsaturated fluids through these intervals dissolved skeletal grains and early cement thus enhancing porosity and reservoir quality.

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Balanced Cross-Section, Northern Ouachita Orogen, Oklahoma

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The north-vergent Ouachita fold-thrust belt structurally overlies an autocthonous carbonate platform and shelf margin. The deformed sequence consists of about 1 km of lower and middle Paleozoic deep-marine "starved basin" strata (contemporaneous with the platform) overlain by 15 km of Carboniferous flysch, most of which was deposited south of the shelf margin. In Early Pennsylvanian time the platform foundered due to accelerated tectonic subsidence, and was overlapped by the youngest flysch unit (Atoka Fm.).

A balanced cross-section of the northern Ouachitas was constructed assuming that dramatic thickening of the flysch sequence occurs just to the south of the buried platformal shelf margin, and that the entire platform was undeformed during thrusting. The Ti Valley thrust sheet, which contains evidence of the platform to basin

transition in the flysch strata it carries, was deflected upward at the shelf break and carried northward by younger in-sequence thrusts. Palinspastic restoration places this transition, and the undeformed shelf margin, about 25 km south of the frontal thrust. This is 70 km farther north than many other estimates. Total tectonic shortening is about 50%.

Recently acquired paleocurrent data in the northwestern Ouachitas show that Atoka Fm. flysch that overlay the drowned platform was deposited by east-directed currents. This is in contrast to the northerly and westerly paleoflow characteristic of all other Ouachita flysch sequences. A western source for the northwesternmost Atoka Fm. flysch is suggested, and the thick-skinned style uplifts of the Arbuckle and Wichita mountain belts are implicated as source areas.

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Geochemistry of Mississippian–Pennsylvanian Volcaniclastics in the Ouachita Mountains, Oklahoma and Arkansas: Implications for Tectonic Environment

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The Carboniferous flysch sequence of the Ouachita Mountains contains volcanic tuffs and tuffaceous sandstones interbedded with the dominant shales. Layers of rhyodacitic tuffs and tuffaceous sandstones are mainly concentrated in the lower portion of the Mississippian Stanley Group (where they are up to 40 m thick), but also occur intercalated with the shales of the Pennsylvanian Jackfork Group. The tuffs range from vitric-crystal and vitric tuffs to crystal-rich tuffs. These submarine pyroclastic flows thicken toward the south, and their source was either a continental island arc or an oceanic island arc. Previous petrographic studies of the tuffs show that they are comprised principally of quartz, plagioclase (An_{10-50}), relic glass shards and altered pumice fragments.

The trace element and isotopic geochemistry of these tuffs is of interest in constraining the tectonic evolution of the Ouachita orogenic belt, particularly in identifying the nature of the landmass (island arc or continent) which collided with the southern margin of the North American continent. Preliminary, reconnaissance trace element analyses of associated shales demonstrate higher Th/Sc ratios for Stanley Group shales compared to the overlying Jackfork Group, Atoka Formation and Caney shales. This would be indicative of a more siliceous provenance, and suggestive of the influence of sediment derived from a continental island arc.

We are currently undertaking a comprehensive geochemical study of the tuff units. Trace element (including REE) data and Sr and Nd isotopic data for the tuffs will be used to discriminate between an oceanic or continental arc origin. X-ray fluorescence and INAA data currently being collected will be presented at the meeting, and used to interpret the origin and petrogenesis of these Carboniferous tuffs.

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Thermal Origin of Impsonite Demonstrated in Sample Suite, Ouachita Mountains, Oklahoma, U.S.A.

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Two grahamite and three impsonite localities are within an 82-km-long segment (Sardis to Page) of the Ouachita Mountains of southeastern Oklahoma. The migrabitumens occur as fault- and fracture-filling vein deposits in turbidite sandstones and shales of the Carboniferous Stanley and Jackfork Groups. Based on vitrinite reflectance of the shales, the regional thermal maturation increases from west to east. Grab samples were collected from abandoned mine or prospect dumps to study the petrographic and geochemical characteristics of the bitumens at the grahamite to impsonite transition and the relation of the bitumens to the regional thermal maturity pattern.

The two grahamite samples, soluble in organic solvents (22% and 10% EOM), are classified at the grahamite/impsonite boundary with conflicting petrographic and bulk chemical maturity indicators (bitumen reflectance, volatile matter, solubility). Three epi-impsonite samples are insoluble in immersion oil and relatively insoluble in organic solvents (<6% EOM).

Maximum and average (nonpolarized light) bitumen reflectance values increased from 0.75% to 1.79% from west to east, consistent with the regional maturation trend. Mean apparent bireflectance increased from 0.04% to 0.38%, ranging from isotropic to anisotropic. Microtexture changed from nongranular to patchy granular to granular (mosaic texture).

The regional maturation trend, based on vitrinite and bitumen reflectance values, was confirmed by a detailed geochemical investigation of bitumen extracts. Although biomarker analyses were influenced by extensive biodegradation effects, molecular parameters based on the phenanthrenes, dibenzothiophenes, and others were identified as useful maturity indicators.

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