Oklahoma GEOLOGY Notes

OKLAHOMA GEOLOGICAL SURVEY VOL. 47, NO. 3 JUNE 1987

On the cover—

Wildhorse Mountain Formation in the Ouachita Mountains

Outcrop of sandstone and shale of the Wildhorse Mountain Formation of the Jackfork Group (Pennsylvanian) along U.S. Highway 259 south of Big Cedar in the Ouachita Mountains, southeastern Oklahoma. This outcrop is part of the longest continuous exposure of any formation in the Ouachita Mountains. It is one of many outcrops on the north flank of the Lynn Mountain syncline where the highway climbs to the top of Kiamichi Mountain. These strata, which strike approximately E–W and dip to the south, are interpreted as deep-water turbidites; the rocks exhibit many of the classic features of turbidites, including partial to complete Bouma sequences, sole marks, and convolute stratification. Fossils are rare, but impressions of large plants such as *Cordaites* and *Calamites* are abundant in some beds.

Neil Suneson

Photo by Jane Weber

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NAMES OF COAL BEDS IN THE NORTHEASTERN OKLAHOMA SHELF AREA

LeRoy A. Hemish[1]

The writer has carried out investigations of the coal-bearing strata in the northeastern Oklahoma shelf area of the eastern Oklahoma coal belt over the past nine years. A series of county reports on the coal geology of the region is to be published by the Oklahoma Geological Survey (Hemish, 1986, et seq.). The information presented here is a compendium of coal nomenclature currently recognized by the Survey as a result of these investigations.

Figure 1 shows the eastern Oklahoma commercial coal belt, and delineates its two general regions: (1) the northeastern Oklahoma shelf and (2) the Arkoma basin. Only coal beds of the shelf area are discussed in this report.

Since a list of coal-bed names recognized by the Oklahoma Geological Survey has not been published in more than 30 years, the need for an updated version is evident.

According to the North American Stratigraphic Code (1983, p. 851), "Most economic units, such as aquifers, oil sands, coal beds, quarry layers, and ore-bearing 'reefs' are informal, even though they may be named." Although informally named, coal beds are excellent markers, and coal-bed nomenclature is very useful in stratigraphic work.

No attempt was made to trace and record the many local, trade, and descriptive names which have been applied to these coals, and the problems of synonyms and homonyms are not dealt with here. Many of these names were given in the old report by the Oklahoma Geological Survey (1954, p. 121–131). Where synonyms have become well established, the second name is listed in this report (for example, "Croweburg" is synonymous with "Henryetta").

Figure 2 is a generalized geologic column showing the stratigraphic position of the coal beds discussed here. Like any other stratigraphic synthesis, this information is subject to revision.

Table 1 lists the names of the coal beds present in the shelf area, from youngest to oldest, along with information on the origin of the name (with the earliest known reference), and other important references and information. For economy of space, the references in the third column of Table 1 are given as numbers, corresponding to numbers assigned in the reference list. Some local, very thin, unnamed coal beds of little stratigraphic significance have not been included.

The Oklahoma Geological Survey will be grateful to geologists, landowners, drillers, and people in the coal industry for information about newly discovered coals or new discoveries in areas where named coals are not now known to exist.

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[1] Oklahoma Geological Survey.

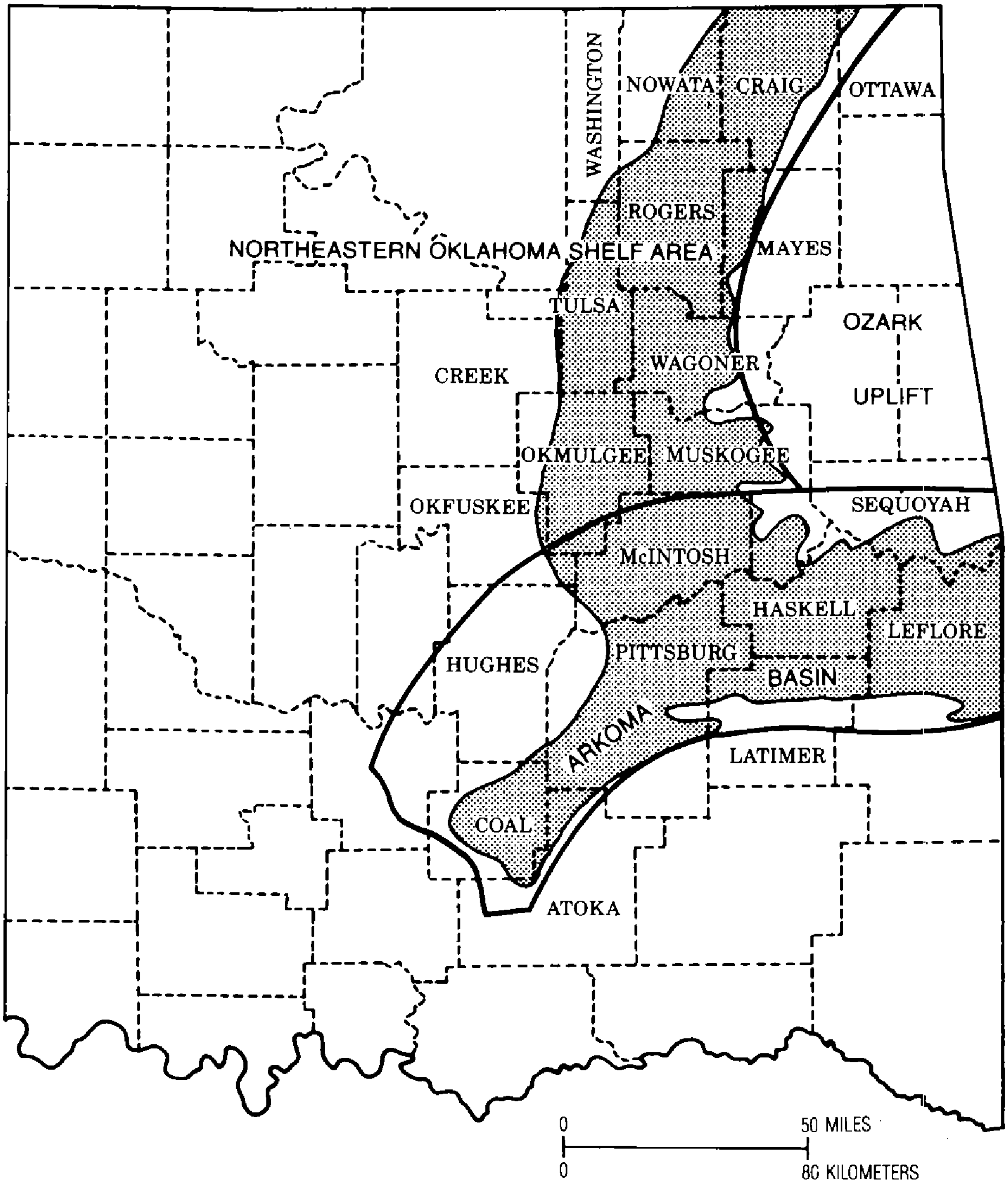
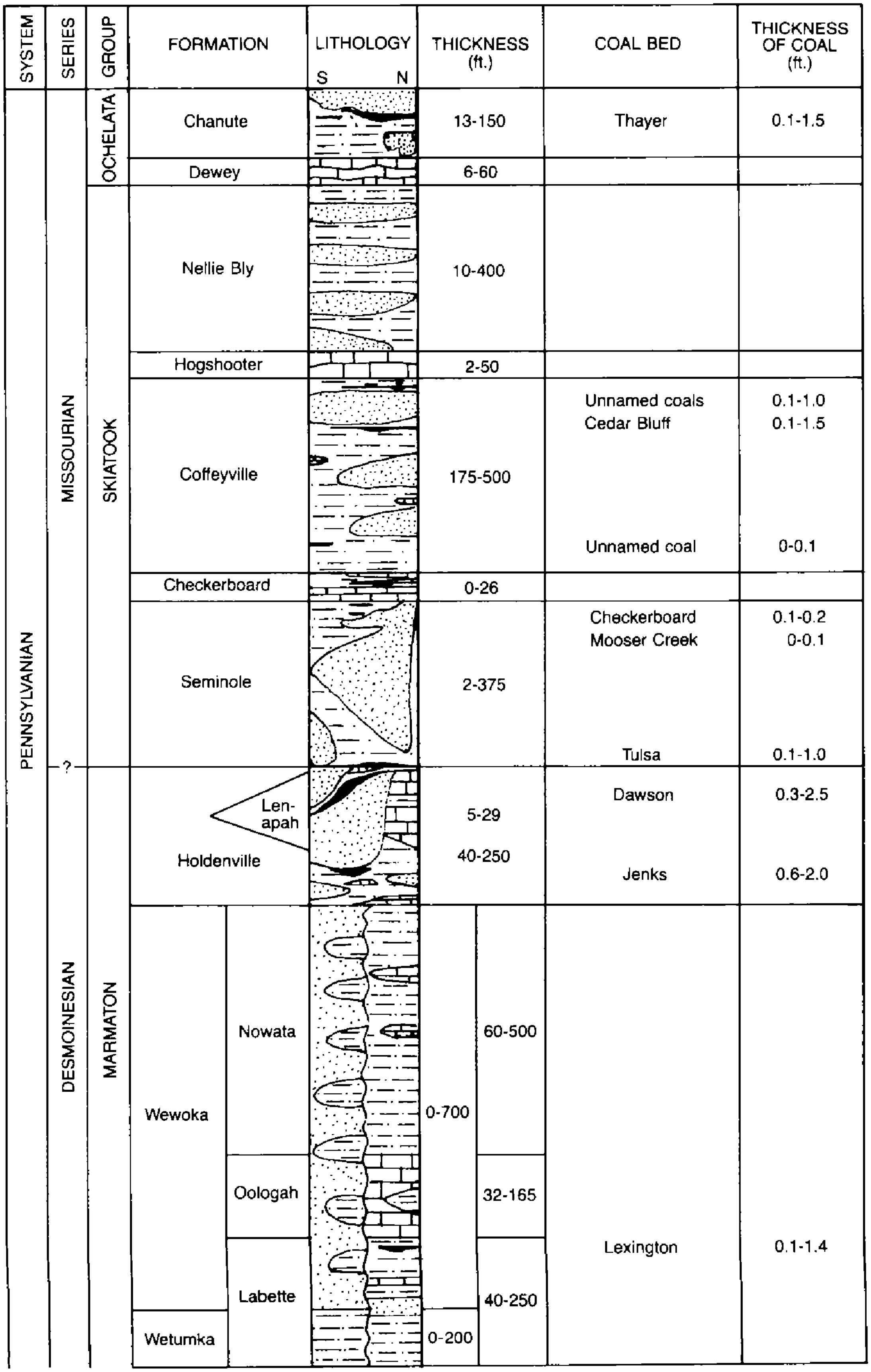
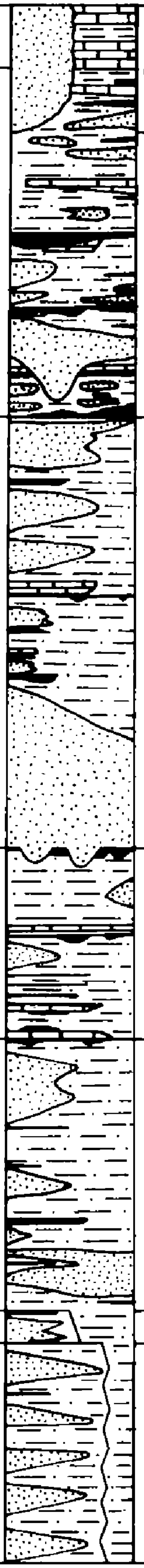


Figure 1. Map of eastern Oklahoma showing the commercial coal belt (stippled), the Arkoma basin, and the northeastern Oklahoma shelf.



SYSTEM	SERIES	GROUP	FORMATION		LITHOLOGY S N	THICKNESS (ft.)		COAL BED	THICKNESS OF COAL (ft.)
PENNSYLVANIAN	MISSOURIAN	OCHELATA	Chanute			13-150		Thayer	0.1-1.5
			Dewey			6-60			
		SKIATOOK	Nellie Bly			10-400			
			Hogshooter			2-50			
			Coffeyville			175-500		Unnamed coals Cedar Bluff Unnamed coal	0.1-1.0 0.1-1.5 0-0.1
			Checkerboard			0-26			
			Seminole			2-375		Checkerboard Mooser Creek Tulsa	0.1-0.2 0-0.1 0.1-1.0
	?								
	DESMOINESIAN	MARMATON	Lenapah			5-29		Dawson	0.3-2.5
			Holdenville			40-250		Jenks	0.6-2.0
			Wewoka	Nowata		0-700	60-500		
				Oologah			32-165		
				Labette			40-250	Lexington	0.1-1.4
			Wetumka			0-200			

Figure 2. Generalized geologic column of the coal-bearing strata, northeastern Oklahoma shelf area.



PENNSYLVANIAN	DESMOINESIAN	MARMATON	Calvin	Fort Scott	0-400	1-90		
		CABANISS	Senora		160-500		Mulky	0.5-0.8
							Iron Post	0.3-1.6
							Bevier	0.3-1.0
							Unnamed coal	0.1-0.2
							Croweburg	0.2-3.4
							Fleming	0.1-1.5
							Mineral (Morris)	0.1-2.7
							Scammon (?)	0.1-0.5
							Tebo	0.1-0.8
							RC	0.1-0.5
							Weir-Pittsburg	0-6.2
		KREBS	Boggy		35-700		Wainwright (Taft)	0.3-2.3
							Bluejacket	0.1-1.5
							Peters Chapel	0.1-2.0
							Secor rider	0-0.1
							Secor	0.1-1-8
			Savanna		150-200		Drywood	0.1-3.0
							Rowe	0.2-2.5
							Unnamed coal	0.1-0.3
							Unnamed coal	0.1-0.2
							Unnamed coal	0.1-0.6
							Sam Creek	0.1-0.2
							Tullahassee	0.1-0.9
			McAlester		100-400		Spaniard	0.1-1.1
							Keota	0.1-1.0
							Tamaha	0.1-0.3
							McAlester (Stigler)	0.1-1.1
							Keefton (Warner)	0.1-1.0
							Riverton	0.1-0.3
			Hartshorne		0-50		Hartshorne	0.1-0.4
			Atoka		0-975		Unnamed coal	0.1-0.6

TABLE 1. OKLAHOMA COAL BEDS (NORTHEASTERN OKLAHOMA SHELF)

Coal Bed	Origin of Name, with Earliest Known Reference	Other Important References and Notes Concerning Beds
Thayer	Name used by Haworth (1895, p. 276) for an economically important coal bed mined in the vicinity of Thayer, Neosho County, Kansas, in the late 1800s.	**51** (1940, p. 62–63,144); mined for local use only in Oklahoma; present in Nowata, Washington, and Osage Counties; underlies the Cottage Grove Sandstone Member of the Chanute Formation.
Unnamed coals		**51** (1940, p. 38,143–144); **53** (1952, p. 58–59); **54** (1959, p. 20,98); **36**; once mined for farm use in Nowata County; present from northernmost Creek County almost continuously to the Kansas–Oklahoma line; occurs in the upper part of the Coffeyville Formation in the shale interval immediately below the Hogshooter Formation.
Cedar Bluff	Named by Jewett (1932, p. 101) from a hill west of the Verdigris River a few miles north of Coffeyville, Montgomery County, Kansas.	**51** (1940, p. 38,143); **70** (1957, p. 339,359); **6** (1972c, p. 53); **36**; **38**; once surface-mined on a small scale in northern Tulsa County; occurs in the upper part of the Coffeyville Formation immediately below the Dodds Creek Sandstone Member in Tulsa, Washington, and Nowata Counties, Oklahoma.
Unnamed coal		**34** (Appendix 1, core-hole log 1; Appendix 2, measured section 5); **36**; observed in a core and on an outcrop in northern Okfuskee County; occurs in a shale interval in the lower part of the Coffeyville Formation.
Checkerboard	Named by Bennison and others (1979, p. vii,3–4) for its stratigraphic proximity to the Checkerboard Limestone in an exposure along Mooser Creek, NW¼NE¼ sec. 34, T. 19 N., R. 12 E., Tulsa County, Oklahoma; earlier referred to as the Upper Seminole coal.	**4** (1972a, p. 19); **5** (1972b, p. 46); **59** (1975); **7** (1984, p. 22); **76** (1984, p. 260–261); **38**; crops out in and around the city of Tulsa, Tulsa County, and sporadically in Nowata County; occurs in a shale interval from 2 in. to 9 ft below the Checkerboard Limestone; nowhere sufficiently thick to have economic importance.
Mooser Creek	Name used by A. P. Bennison and L. R. Wilson (1986, oral communication) for two thin local coal beds that crop out along Mooser Creek, in the NW¼NE¼ sec. 34, T. 19 N., R. 12 E., Tulsa County, Oklahoma.	**38**; occurs in a shale interval about 15 ft below the Checkerboard coal; of no economic value, but has stratigraphic significance.

Tulsa	Named from an exposure in the city of Tulsa, Oklahoma, by Bennison and others (1979, p. vii,4–5) near the Union Avenue bridge over Mooser Creek, one-quarter mile south of Skelly Drive, center of west line of NW¼ sec. 35, T. 19 N., R. 12 E., Tulsa County, Oklahoma; earlier referred to as the Seminole coal or the Middle Seminole coal.	**4** (1972a, p. 19); **59** (1975); **7** (1984, p. 44); **7** (1984, p. 258–260); **36**; **38**; **39**; occurs from northern Okfuskee County to the Kansas–Oklahoma line; mined in small surface pits in northwestern Okmulgee County in the past.
Dawson	Name used by Taff (1904, p. 396–397) for a commercially valuable coal bed mined in and around the town of Dawson, Tulsa County, Oklahoma. (Dawson is now a part of the city of Tulsa.)	**53** (1952, p. 125–128); **70** (1957, p. 325,336,339,358–359,363); **22** (1974, p. 9,34); **59** (1975); **8** (1979, p. 8–9); **24** (1982); **76** (1984, p. 257–258); **36**; **38**; **39**; occurs from northern Okfuskee County to the Kansas–Oklahoma line; of minable thickness in Okmulgee, Tulsa, and Rogers Counties; extensively strip mined in Rogers and Tulsa Counties, and mined underground in the city of Tulsa in the past.
Jenks	Name originally used in conversation by A. P. Bennison and L. R. Wilson for a coal exposed in a deep excavation about 1 mile south of Jenks, center of east line, SE¼SE¼ sec. 25, T. 18 N., R. 12 E., Tulsa County, Oklahoma; name "Jenks coal" duly proposed by Hemish, in prep., Coal geology of Creek, Tulsa, Wagoner, and Washington Counties, Oklahoma; earlier called "Lower Dawson coal."	**8** (1979, p. 7); **39**; crops out south of Jenks, Oklahoma, where it has been mined underground; also crops out sporadically in northwestern Okmulgee County. Possibly present northeast of Tulsa. Occurs in the Holdenville Formation at the base of the Lower Cleveland sand.
Lexington	Name used by Broadhead (1873, p. 46) for an economically important coal bed mined in the vicinity of Lexington, Lafayette County, Missouri, in the 1800s.	**13** (1953, p. 138); **58** (1954, p. 126); **70** (1957, p. 339, 358); **11** (1965, p. 44); **22** (1974, p. 9); **33** (1986b, p. 18); occurs near the top of the Labette Formation just below the Anna Shale Member in Craig, Nowata, and Rogers Counties; not believed to be of commercial importance, but unconfirmed past production from small surface mines reported in Nowata County.
Mulky	Name used by Broadhead (1873, p. 46) for a coal bed mined along Mulky Creek, Lafayette County, Missouri, in the 1800s.	**33** (1986b, p. 8,13,18–19); uppermost coal bed in the Senora Formation; occurs immediately above the Breezy Hill Limestone Member, and at the base of the Excello Shale Member; in Oklahoma, known only in the subsurface in T. 28 N., R. 19 E., Craig County; not of economic value.

TABLE 1. *CONTINUED*

Coal Bed	Origin of Name, with Earliest Known Reference	Other Important References and Notes Concerning Beds
Iron Post	Named by Howe (1951, p. 2092) for a rural school of that name in the southwest corner of sec. 31, T. 29 N., R. 20 W., in Craig County, Oklahoma.	**58** (1954, p. 125); **70** (1957, p. 322,357); **25** (1961); **11** (1965, p. 34,40–41,53,56); **22** (1974, p. 9,32,34); **24** (1982); **33** (1986b, p. 6,8,13,17,19–20); **37**; **38**; occurs in the upper part of the Senora Formation, about 2–3 ft below the Breezy Hill Limestone Member; one of Oklahoma's most important commercial coals; crops out from eastern Tulsa County to the Kansas–Oklahoma line; extensively mined by surface methods in Craig, Nowata, and Rogers Counties.
Bevier	The name "Bevier" was originally applied by McGee (1888, p. 328–336) to coal mined extensively at Bevier, Macon County, Missouri, after which town it takes its name.	**58** (1954, p. 122); **11** (1965, p. 34,40); **20** (1965); **33** (1986b, p. 6,8,13,17–19); **37**; occurs in the Senora Formation in the interval between the Verdigris Limestone Member and the Iron Post coal bed; not commercially important in Oklahoma; identified in Craig County, and tentatively identified at one place in Rogers County.
Unnamed coal		**33** (1986b, p. 17); occurs locally in Craig County, Oklahoma, in association with the black phosphatic shale that underlies the Verdigris Limestone Member of the Senora Formation; of no economic value.
Croweburg	Named from exposures in strip pits about 1 mile east of Croweburg, Crawford County, Kansas (Pierce and others, 1937, p. 74); also known in Oklahoma as the "Broken Arrow coal" and "Henryetta coal."	**52** (1944); **58** (1954, p. 123–125); **21** (1955, p. 194–196); **77** (1956); **70** (1957, p. 322,325,337,354,356–357); **47** (1959); **74** (1964); **48** (1967); **22** (1974, p. 9,32); **24** (1982); **33** (1986b, p. 1–2,6,8,10,13,16–17,20); **36**; **37**; **38**; **39**; **40**; occurs in the Senora Formation, from a few feet to as much as 50 feet or more below the Verdigris Limestone Member; one of Oklahoma's most valuable high quality commercial coals; extends almost continuously from Hughes County in the south where it is noneconomic, to the Kansas–Oklahoma line; mined extensively underground around Henryetta in the past, and strip mined almost continuously along the outcrop boundary northeast to the

Fleming	Named from exposures in strip pits north of the village of Fleming, Crawford County, Kansas (Pierce and others, 1937, p. 73).	**58** (1954, p. 124); **70** (1957, p. 356); **22** (1974, p. 9); **33** (1986b, p. 6,8,13,16–17,20); present only in northern Craig County, where it has been strip-mined in recent years; occurs in the interval between the Mineral coal below and the Croweburg coal above.
Mineral	Named by Pierce and others (1937, p. 69–70) from exposures near the town of Mineral, Cherokee County, Kansas; also known in Okmulgee County as the "Morris coal," and "Eram coal."	**58** (1954, p. 127); **21** (1955, p. 197); **70** (1957, p. 323,336,352,356); **71** (1962); **22** (1974, p. 9,32); **24** (1982); **33** (1986b, p. 6,8,13,15–17,20,23); **35**; **36**; **37**; **38**; **39**; occurs near the middle of the Senora Formation, generally just above the Chelsea Sandstone; in northern Craig County, directly overlain by the Russell Creek Limestone Member; crops out discontinuously from southern Okmulgee County to the Kansas–Oklahoma line; recently strip-mined in Okmulgee, northern Rogers, and Craig Counties.
Scammon(?)	Named for exposures along Cherry Creek, northwest of Scammon, Cherokee County, Kansas (Abernathy, 1936, p. 83–84; 1938, p. 195).	**33** (1986b, p. 15); present only in northern Craig County in Oklahoma, where it is known only from drilling data; occurs in the Senora Formation about 30 ft above the Tebo coal and 25–30 ft below the Mineral coal; too thin to have economic value.
Tebo	Named in Henry County, Missouri, by Marbut (1898, p. 123) for exposures along Tebo Creek.	**58** (1954, p. 130); **62** (1961); **22** (1974, p. 9); **11** (1965, p. 34); **24** (1982); **33** (1986b, p. 6,9,13–16); **35**; **36**; **37**; **38**; **39**; **40**; occurs in the lower part of the Senora Formation, underlying a black shale immediately under the Tiawah Limestone Member. Crops out discontinuously from east-central Okmulgee County to the Kansas–Oklahoma line; of minable thickness only in Wagoner County.
RC	Name used by Hemish, in prep., Coal geology of Rogers and western Mayes Counties, Oklahoma, for a coal bed of variable thickness found in central Rogers County; may be equivalent to a local coal bed in western Muskogee County arbitrarily referred to by Bennison and others (1979, p. 19–20) as the "Lower Tebo (Thurman?) coal."	**69** (1952, pl. 2); **29** (1954, p. 37, pl. 2); occurs in the lower part of the Senora Formation between the Weir-Pittsburg coal below, and the Tebo coal above; mined underground in the past in central Rogers County; reported by local residents in water wells; crops out in only two known places in Rogers County, Oklahoma.

TABLE 1. *CONTINUED*

Coal Bed	Origin of Name, with Earliest Known Reference	Other Important References and Notes Concerning Beds
Weir-Pittsburg	First discussed by Haworth and Crane (1898, p. 26), who stated that it was extensively mined near Weir City, Pittsburg, and other prominent mining towns in Cherokee and Crawford County, Kansas; Howe (1956, p. 46–48) further discussed the Weir-Pittsburg coal and explained how the term was modified to its present form. The Weir-Pittsburg coal has been known in the past as the "Pawpaw" coal in Rogers and Mayes Counties.	**58** (1954, p. 131); **70** (1957, p. 355,357–358); **9** (1963); **11** (1965, p. 34,53–54,67); **22** (1974, p. 9,31–32); **24** (1982); **33** (1986b, p. 1,5–6,9–10,13–14,16,20); **37**; **38**; **40**; marks the base of the Senora Formation in the northeastern Oklahoma shelf area; thickness extremely variable; crops out discontinuously from northwestern Muskogee County to the Kansas–Oklahoma line; surface-mined in the past in Craig, Mayes, Rogers, and Wagoner Counties; also mined underground in Craig and Rogers Counties; thickest coal bed in northeastern Oklahoma.
Wainwright	Name used for more than 50 years by miners and local residents for a coal produced around the town of Wainwright, Muskogee County, Oklahoma; name duly proposed by Hemish, in prep., Coal geology of McIntosh and Muskogee Counties, Oklahoma, for the same bed, and adopted by the Oklahoma Geological Survey; believed by the writer to be equivalent to the "Taft" coal, a name used by Bennison and others (1979, p. 23) for a thin, local coal present in northwestern Muskogee County.	**16** (1958, p. 68–69,88–89); **55** (1977, p. 46); **36**; occurs in the upper part of the Boggy Formation, stratigraphically, about 126 ft above the Inola Limestone Member; known to be present only in Muskogee County and extreme north-central McIntosh County; mined on a small scale in the distant past; also strip-mined southeast of Wainwright in the 1970s.
Bluejacket	Named by Searight and others (1953, p. 2748) at interstate conference, Nevada, Missouri, apparently because of its close proximity to the underlying Bluejacket Sandstone Member of the Boggy Formation in Kansas, Missouri, and northern Craig County, Oklahoma; according to Branson and others (1965, p. 31,33) to the south, in Mayes County, where the Inola Limestone Member of the Boggy Formation is present about 20 ft above the top of the Bluejacket Sandstone, the coal below the Inola Limestone is the Bluejacket coal. No other coal beds are present in this interval in Mayes County. Owing to onlap on the shelf, rock units in the Desmoinesian Ser-	**58** (1954, p. 122); **26** (1959, p. 75); **72** (1965); **32** (1986a, p. 178); **33** (1986b, p. 9, 13–15); **36**; **37**; **38**; **40**; occurs in the lower part of the Boggy Formation, almost immediately below the Inola Limestone Member; known to be present from McIntosh County northward to the Kansas–Oklahoma line; generally too thin to have economic value, except in western Mayes County and locally in Wagoner County. The bed is up to 18 inches thick and has been mined underground in the past in Mayes County.

	ies generally thicken markedly to the south toward the Arkoma basin and several stratigraphically lower (older) coal beds are present in the interval between the top of the Bluejacket Sandstone, below, and the Bluejacket coal, above. In the southern part of the shelf area the Bluejacket coal is identified by its association with the Inola Limestone.	
Peters Chapel	Named by Hemish (1986a, p. 177) from an exposure ~0.25 mi southeast of Peters Chapel, in the NW¼ SE¼NW¼NE¼ sec. 14, T. 15 N., R. 17 E., Muskogee County, Oklahoma (the coal has been mined extensively under the sandstone bluffs just south of Peters Chapel in the N½ sec. 14, T. 15 N., R. 17 E.); equivalent to the Upper Secor coal.	**8** (1979, p. 24–26); **36**; **40**; occurs in the lower part of the Boggy Formation, a few feet below the Crekola Sandstone Member; not known to be present north of southwestern Wagoner County; has limited economic value in parts of Muskogee County.
Secor rider	First recognition of the coal bed was by Dane and others (1938, p. 162,197,200–201; pl. 14–16), but the bed was not named. The coal was described as being 10–13 in. thick and occurring 20–30 ft stratigraphically above the Secor coal in T. 6 N., R. 15 E.; T. 7 N., R. 15 E.; T. 7 N., R. 16 E.; T. 7 N., R. 18 E.; and T. 8 N., R. 18 E., Pittsburg County, Oklahoma. Although the term "Secor rider" has been used verbally by miners and geologists for an unknown number of years, Friedman (1974, p. 28) was the first author to refer to the coal bed as a "rider" of the Secor in a printed document. Friedman (1978, p. 28) first used the name "Secor rider" in a published document; equivalent to the Middle Secor coal.	**8** (1979, p. 25); **32** (1986a, p. 171–173,175–177,181); **36**; **40**; occurs in the lower part of the Boggy Formation from a few feet to as much as 30 feet above the Secor coal bed. Present in Pittsburg, McIntosh, and Muskogee Counties, Oklahoma. Has economic value in Pittsburg County, where it has been mined and marketed in recent years. Commonly overlain by a thin, fossiliferous marine limestone bed.
Secor	Name first used by Chance (1890, p. 658,660, pl. 1), but origin of the name could not be determined. The coal bed was possibly named for a "Secor" family that lived in the area where the coal was first mined in Pittsburg County, Oklahoma (Oklahoma Geological Survey, 1954, p. 129); equivalent to the Lower Secor coal.	**73** (1937, p. 85–99); **70** (1957, p. 335,350–351); **15** (1961); **41** (1961); **56** (1967, p. 6,22,26,41–43,45,47); **22** (1974, p. 9,31); **8** (1979, p. 25–26); **24** (1982); **32** (1986a, p. 171—173,175–177); **36**; **38**; **40**; occurs in the lower part of the Boggy Formation almost immediately above the Bluejacket Sandstone Member in the northeastern Oklahoma shelf area. Known to be present only in Muskogee and Wagoner Counties of the shelf area. A valuable, high quality, commercial coal, mined extensively around Taft, Muskogee, and Porter, Oklahoma, as well as in counties to the south in the Arkoma basin.

TABLE 1. *CONTINUED*

Coal Bed	Origin of Name, with Earliest Known Reference	Other Important References and Notes Concerning Beds
Drywood	Named by Searight and others (1953, p. 2748) at interstate conference, Nevada, Missouri, from Dry Wood Creek, sec. 4, T. 32 N., R. 33 W., Vernon County, Missouri. Although spelled as two words by the original authors, the convention in Oklahoma has been to spell the name as a single word (Oklahoma Geological Survey, 1954, p. 124).	**61** (1955, p. 68); **70** (1957, p. 355); **10** (1964); **11** (1965, p. 26,29,31,53); **72** (1965); **22** (1974, p. 9); **27** (1976); **24** (1982); **33** (1986b, p. 6,9,11–13,15,20); **36**; **37**; **38**; **40**; occurs in the upper part of the Savanna Formation generally immediately below the Bluejacket Sandstone Member of the Boggy Formation; discontinuous but persistent, extending from Muskogee County on the south to the Kansas–Oklahoma line on the north; mined in the past by underground methods in Craig and Wagoner Counties; strip-mined in more recent times; of economic importance only in Craig, Mayes, Rogers, and Wagoner Counties in Oklahoma.
Rowe	Named by Pierce and others (1937, p. 65) for the Rowe School in sec. 34, T. 30 S., R. 25 E., Cherokee County, Kansas.	**58** (1954, p. 129); **49** (1955, p. 43,73); **70** (1957, p. 50,55); **18** (1961); **11** (1965, p. 26–27,53); **22** (1974, p. 9,31); **27** (1976); **55** (1977, p. 22,24–26,45); **8** (1979, p. 27); **24** (1982); **33** (1986b, p. 9,11–13,20); **37**; **38**; **40**; occurs in the middle part of the Savanna Formation, closely underlying the Doneley Limestone Member; a persistent bed, extending almost continuously across the shelf area and on into the Arkoma basin; generally thin, but of minable thickness locally in Craig, Rogers, Mayes, Wagoner, and Muskogee Counties where it has been surface mined at various times.
Unnamed coals		**33** (1986b, pl. 6,7); **37**; three unnamed coal beds are present in the lower part of the Savanna Formation between the Sam Creek Limestone Member below and the Rowe coal bed above. These coals, which are too thin to have economic value, are known from drilling records only, and have been found in Craig and Rogers Counties.

Sam Creek	Earliest known recognition of the coal bed was by Wilson and Newell (1937, p. 48–49). They stated, "In T. 13 N., and to the southward, coal and underclay occur sporadically beneath the upper [Sam Creek] limestone of the original definition." First published use of the name "Sam Creek coal" was by Bennison and others (1979, p. vi).	**45** (1952, p. 13–14, pl. II); **26** (1959, p. 57,156–158, pl. 8); **64** (1959, p. 26, pl. II); **27** (1976, p. 17); **37**; **38**; **40**; occurs in the lower part of the Savanna Formation, below the Sam Creek Limestone Member; known to be present in Rogers, Mayes, Muskogee, and Wagoner Counties; thin, and of no commercial value.
Tullahassee	Named by Hemish, in prep., Coal geology of Creek, Tulsa, Wagoner, and Washington Counties, Oklahoma, from the town of Tullahassee, which lies about 1½ miles north from the best exposure of the coal and associated strata in NE¼NE¼NE¼ sec. 1, T. 15 N., R. 17 E., Wagoner County, Oklahoma.	**3** (1959, p. 39); **8** (1979, p. 31); **40**; occurs 0–3 ft above the Spaniard Limestone Member in the lower part of the Savanna Formation; known only in northern Muskogee County and southern Wagoner County (where it is of minable thickness, and has been mined in the past).
Spaniard	Earliest known mention of the coal bed in published literature was by Wilson and Newell (1937, p. 45), but it was not named; first published use of the name "Spaniard coal" was by Bennison and others (1979, p. vi–vii,31–32).	**29** (1954, p. 57, pl. II); **49** (1955, p. 43); **16** (1958, p. 24); **28** (1958, p. 46); **3** (1959, p. 35,39); **26** (1959, p. 49); **64** (1959, p. 21,23); **27** (1976, p. 17); **55** (1977, p. 22); **37**; **38**; **40**; occurs in the upper part of the McAlester Formation, in a shale unit above the Keota Sandstone Member and below the Spaniard Limestone Member of the overlying Savanna Formation; known to be present from southern Muskogee County north into Craig County; generally thin, but of minable thickness locally in northern Muskogee County, where the coal was strip-mined in the 1930s.
Keota	Initially referred to by Wilson and Newell (1937, p. 44–45) as one of six separate "Keota beds" of varying lithology that comprise the Keota Sandstone Member of the McAlester Formation in sec. 10, T. 12 N., R. 18 E., Muskogee County, Oklahoma. The Keota Sandstone was named by Thom (1935) from outcrops in the vicinity of the town of Keota, Haskell County, Oklahoma. The term "Keota coal bed" was adopted by Hemish, in prep., Coal geology of McIntosh and Muskogee Counties, Oklahoma.	**3** (1959, p. 32–33); **55** (1977, p. 21); occurs in the upper part of the McAlester Formation, generally directly below a thin persistent, marine limestone within the Keota Sandstone Member—both the limestone and the coal bed are below the upper Keota Sandstone; known to be present in Muskogee County and to the south; probably present discontinuously north into Craig County, where one of several thin unnamed beds in the McAlester Formation may be correlative. Not considered of economic importance owing to thinness, but a locally occurring, one-foot-thick outcrop of the coal bed has been photographically documented by Bell (1959, p. 32) and again noted by Oakes (1977, p. 21) in Muskogee County.

TABLE 1. *CONTINUED*

Coal Bed	Origin of Name, with Earliest Known Reference	Other Important References and Notes Concerning Beds
Tamaha	Earliest known notation of the coal bed was by Wilson and Newell (1937, p. 44), but it was not named. The coal bed occurs in a shale bed a few feet above the Tamaha Sandstone Member of the McAlester Formation. The Tamaha Sandstone was named by Thom (1935, p. 509) from the town of Tamaha in northern Haskell County, Oklahoma. First published use of the name "Tamaha coal" was by Bennison and others (1979, p. vi–vii).	**36**; **40**; occurs in an unnamed shale unit in the middle part of the McAlester Formation, stratigraphically about 80–85 ft above the Stigler coal; known in the Arkoma basin, but identified only in Muskogee County in the shelf area; too thin to be of economic value.
McAlester (Stigler)	Named by Chance (1890, p. 656,658) from the city of McAlester, Pittsburg County, Oklahoma, where the coal was extensively mined in the late 1800s. The name "Stigler" was first used by Taff (1904, p. 8) for a coal mined around the town of Stigler, Haskell County, Oklahoma. Friedman (1974, p. 29) stated that the McAlester coal and the Stigler coal are correlative; therefore the earliest published name should be given preferential status. However, the usage of the name "Stigler" for the coal bed mined in large areas north and east of the town of Stigler has been so widespread verbally and in published literature, that it cannot be totally abandoned.	**73** (1937, p. 85–99); **58** (1954, p. 126,131); **49** (1955, p. 42,71); **70** (1957, p. 347–349); **3** (1959, p. 27,30); **19** (1964); **55** (1977, p. 16,19–20,45); **24** (1982); **40**; occurs in the McAlester Formation in the interval between the Cameron-Lequire Sandstone Member, below, and the Tamaha Sandstone Member, above; in the shelf area identified only in Mayes, McIntosh, and Muskogee Counties; of minable thickness south of the Arkansas River; thickens to the south in the Arkoma basin where the coal has been extensively mined in the past.
Keefton	Named by Hemish, in prep., Coal geology of McIntosh and Muskogee Counties, Oklahoma, from outcrops in the hills about 1–2 miles southwest of the village of Keefton, Muskogee County, Oklahoma, where numerous small abandoned wagon pits provide evidence of past mining. A section describing the coal and associated strata was measured in the NE¼NE¼SE¼SE¼ sec. 28, T. 13 N., R. 18 E., where the Keefton coal is well-exposed. The Keefton coal is equivalent to a coal bed for which the name "Warner coal" was proposed by Bennison and others (1979, p. vi–vii,35) for its associa-	**73** (1937, p. 86,95–96,98–99); **3** (1959, p. 27,75); **55** (1977, p. 17–18); **36**; generally occurs in a thin shale interval underlying a sandstone bed near the top of the Warner Sandstone Member of the McAlester Formation; known to be present only in Muskogee County in the shelf area; surface-mined on a small scale in the past, and strip-mined by modern methods in recent times; economical because of its low sulfur content and high heat value.

	tion with the Warner Sandstone Member of the McAlester Formation. In order to conform with usage adopted by the Oklahoma Geological Survey, however, it will here be called the Keefton coal, from the village of that name.	
Riverton	Named by Pierce and others (1937, p. 62) from exposures near the village of Riverton, Cherokee County, Kansas. Reed and others (1955, p. 65) suggested that the Riverton coal of Craig and Ottawa Counties, Oklahoma, and adjacent parts of Kansas may be equivalent to the Upper Hartshorne coal of the Arkoma basin, in Oklahoma. Wilson (1976, p. 20) concluded from palynological studies that the Riverton-Hartshorne beds are equivalent. However, Robert O. Fay (personal communication, 1979) stated that paleontological evidence indicates that the McCurtain Shale Member of the McAlester Formation is the lowermost unit recognizable in the Pennsylvanian System in Craig County. On that basis the Riverton coal would seem to be stratigraphically higher than the Hartshorne coal. For purposes of this report, the Riverton and Hartshorne coal beds are treated as two separate units.	**58** (1954, p. 129); **49** (1955, p. 43,45,68–69,73,75); **64** (1959, p. 13); **33** (1986b, p. 9,11); occurs near the base of the McAlester Formation just below the Warner Sandstone Member. Known to be present discontinuously from Ottawa County on the north to southwestern Mayes County on the south; very thin, and noneconomic in Oklahoma.
Hartshorne	The Hartshorne coal was named by Taff (1899, p. 435–437,448–451). Taff and Adams (1900) named the Upper and Lower Hartshorne coal when they stated (p. 274), "There are two coal beds associated with the Hartshorne Sandstone, known as the upper and lower Hartshorne coals." They further stated (p. 287), "These coals are so named because of their early and most successful mining at the town of Hartshorne,. . . and because of their association with the Hartshorne Sandstone." According to Wilson and Newell (1937, p. 86), the Hartshorne coal in Muskogee County is equivalent to the Upper Hartshorne coal.	**58** (1954, p. 130); **3** (1959, p. 23–24); **22** (1974, p. 9,28–29); **55** (1977, p. 45); **40**; occurs at the top of the Hartshorne Formation; present in only Muskogee County of the shelf area; not believed to have economic importance north of T. 12 N., but Wilson and Newell (1937, p. 86) reported an old small mine in the Hartshorne coal in sec. 20, T. 15 N., R. 19 E.
Unnamed coal		**73** (1937, p. 34–35, pl. 1); **40**; occurs in a relatively thick shale unit at the top of the Atoka Formation in T. 13 and 14 N., R. 19 E., Muskogee County; too thin to have economic value.

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CURRENT OKLAHOMA-RELATED USGS PROJECTS

The U.S. Geological Survey has been involved in a number of geologic and hydrologic studies that focus totally or in part on Oklahoma. The following lists of current projects were provided by the USGS Geologic Division and Water Resources Division.

Many of the projects are being carried out on a cooperative basis with the Oklahoma Geological Survey. The cooperative programs entail either joint funding for some aspect of the study, or a contribution of OGS personnel time to the study. Such joint efforts enable utilization of well-qualified scientists from the USGS and the OGS to work on projects important to Oklahoma.

Further information on the various projects can be obtained from project chiefs or district offices in the USGS, or from the OGS office in Norman. To contact USGS Geologic Division personnel, call the office of Harry A. Tourtelot, Assistant Chief Geologist, Central Region, Denver, Colorado, (303) 236-5438. USGS Water Resources Division projects can be pursued through the office of Charles R. Burchett, District Chief, Oklahoma City, Oklahoma, (405) 231-4256. Further information on OGS cooperative activities can be obtained from Kenneth S. Johnson, Associate Director, Norman, Oklahoma, (405) 325-3031.

Geologic Division

Hydrologic Modeling and Ore Deposits

Project Chief: L. H. Filipek

Project involves testing of various assumptions regarding the source of saturated brines in the Midcontinent (Arkansas, Kansas, Missouri, and Oklahoma), specifically, one-time flushing of brines from a deep part of basin, a local evaporite cap above or near site of deposition, and an evaporite source at some intermediate depth (e.g., Ordovician strata). The effects of through-to-basement thrust faulting on flow and temperature distribution will be tested also.

The Role of Niobium- and Selenium-Bearing Organic Complexes as Applied to Midcontinent Pb-Zn Mineralization

Project Chief: J. G. Viets

Previous research suggests that the Mississippi Valley-type deposits of northern Arkansas, Tri-State, Viburnum Trend, and Central Missouri are probably all related and the product of hot saline brines expelled from the Arkoma basin. The lead-rich deposits of the Viburnum Trend were formed by at least two chemically and isotopically distinct fluids that probably had a common origin but evolved differently as they traveled to the site of deposition through basal sandstone and carbonate aquifers, respectively. The fluids that formed the other districts, which are zinc-dominated, were all channeled through carbonate aquifers, as indicated by their chemical and isotopic character. The enrichment of lead, as well as copper, cobalt, and nickel, in the Viburnum Trend relative to other districts may be due to fluids containing these metals derived from the basal Lamotte sandstone. Focus is now on improving ICP–mass-spectrometry techniques for fluid-inclusion analysis and on improving gas- and ion-chromatography techniques and applying them to the regional sample set.

Cobalt in Mississippi Valley-Type Environments

Project Chief: D. L. Leach

Gas and hydrocarbon content of fluid inclusions from samples throughout the Mississippi Valley region will be determined and used to map the migration of hydrothermal fluids and to develop a model of ore transport and deposition. A regional fluid-inclusion study will be completed, and a thermal map of the Midcontinent region will be compiled.

Microbiogeochemistry of Tar Creek, Oklahoma Area

Project Chief: L. H. Filipek

Analysis of water and sediment samples collected along Tar Creek and a mine-discharge tributary and analyses of water samples collected from several mine shafts indicate that microbes are able to remove significant amounts of 1-ppm Cd, Fe, Pb, Zn, and Cu from solution, and that microorganisms may be involved in the crystallization of iron phases. Examination of iron precipitates by epifluorescence microscopy indicates that microorganisms were associated with these precipitates.

Plant and soil atomic-absorption analyses revealed apparent trends in the vegetation samples, both along and away from Tar Creek. Increases in the Co, Fe, Ni, and Zn concentrations of grass can be seen downstream. High concentrations for Cd, Fe, Pb, Ni, and Zn in grass occurred within 150 ft of Tar Creek along a traverse.

Samples of grass, sumac, and soil were collected according to a one-way, nested, analysis-of-variance variability in the concentration values of an element among distance increments (natural variance) and analytical procedures (error variance). All samples have been processed and submitted for analysis. All microbial enumerations and assays will be completed and compared with the chemical data in order to determine trends. Microbial metal-retention studies will continue, along with sequential extractions on sediments and examination of the association of microorganisms and iron phases. Statistical analysis of the grass analysis will be performed to determine whether the indicated increases in concentration downstream and away from Tar Creek are real. Examination and statistical processing of completed sumac, wheat, and soil analyses will continue. Grass and soil will be sampled along two more traverses away from Tar Creek and farther downstream from the earlier traverse.

Sources of Ore Constituents and Ore-Forming Mechanisms of Carbonate-Hosted Pb-Zn-Cu Deposits in Midcontinent Region of the United States

Project Chief: M. B. Goldhaber

Research has been directed at evolution of sulfur in the Midcontinent region. These data show that isotopically heavy sulfur is regional in extent in the Bonneterre dolomite but is absent in stratigraphically higher formations. There is a crude parallelism between regional values for sulfur isotopes and isotopic data for stratigraphically equivalent ores. Studies were conducted on the filled-sink deposits of Missouri, which provided links between these deposits and ore-forming processes in the Midcontinent. These results have implications for defining the extent of ore-forming processes in the Midcontinent. Research on the alteration of the Lamotte sandstone indicates that regional alteration patterns involve bleaching of the Lamotte and systematic sulfur-isotopic distribution patterns. More-detailed petrographic work will be carried out to document the timing of alteration events. Drill core has been obtained from a clay-filled sink, and mineralogic and isotopic analyses of these samples will be carried out. Additional isotopic studies will be undertaken to define the alteration of the carbonate section in the Midcontinent.

Silver Resources of the United States

Project Chief: A. V. Heyl

Field examinations of probable or known sandstone silver deposits in southeastern Oklahoma, westernmost Colorado, easternmost Utah near Moab, and possibly Montana are planned.

Reduction of Aeromagnetic Data to Basement

Project Chief: Lindrith Cordell

Major strike-slip and overthrust faulting has been identified in New Mexico. Geomagnetic data have been compiled for a large area centered on the Ouachita Mountains in Arkansas and Oklahoma. Major initiatives to improve magnetic-gradiometer and image analysis and interpolation techniques will be under way.

Geophysical Studies of Injection Wells

Project Chief: F. C. Frischknecht

Reports on the study of brine contamination in Oklahoma have been completed; there is an unexplained discrepency between resistivities interpreted from surface measurements and those determined from well logs. A final report on the use of airborne magnetics for the location of abandoned wells has been completed also. The project will assist the EPA with a revision of their version of a USGS report on the characterization of brine contamination by TDEM measurements.

Geophysical Mapping of the Precambrian Basement in the Central United States

Project Chief: T. G. Hildenbrand

Final versions of maps showing Bouguer gravity anomalies and residual total magnetic intensity of the study area will be compiled and submitted for review and publication. A report on the geologic significance of major geophysical features within the study area will also be prepared.

Remote-Sensing Studies of the Anadarko Basin, Oklahoma

Project Chief: D. H. Knepper

A digital Landsat multispectral-scanner mosaic using five Landsat scenes covering much of the Anadarko basin in southern Oklahoma has been prepared. A false-color infrared composite of the mosaic shows several long lineaments that appear to transect the structural grain in the region. Lineaments and linear features will be mapped from the Landsat mosaic of southern Oklahoma and analyzed for regional patterns. Side-looking-radar images of the Anadarko basin will be acquired to supplement the Landsat images in the structural study. Landsat Thematic Mapper data covering known oil fields in southern Oklahoma will be processed and analyzed to evaluate the potential of TM data for detecting evidence of hydrocarbon microseepage.

Anadarko Basin Studies

Project Chief: J. W. Schmoker

Petrographic and stratigraphic analysis of 20 Pennsylvanian cores from the Anadarko basin, Oklahoma, and X-ray-diffraction analyses of whole-rock and clay-mineral fraction for sandstones and shales from the Sunray DX Mazur core will be completed. Seismic sections of COCORP multichannel seismic data will be reprocessed, and Bouguer, isostatic, and residual-gravity maps of the Anadarko basin and surrounding areas will be compiled. The depositional environment of the Simpson Group in Kiowa, Comanche, Pratt, and Barber Counties, Kansas, will be interpreted. A model for Hunton deposition, based on porosity decrease (compaction) of underlying sediments as a function of thermal maturation, will be developed, along with an improved biostratigraphy for the Hunton Group in the deep Anadarko basin, using data obtained during the flurry of deep-drilling activity in the late 1970s and early 1980s. A sedimentological study related to the lower Paleozoic carbonates in the Anadarko basin, including preliminary core descriptions and field work, will be initiated. A computerized reconstruction of basin subsidence, with emphasis on the Woodford Shale as key horizon, and large-scale cross sections and fence diagrams in the Oklahoma area of the basin will be generated. Analytical data on fluid inclusions from Anadarko-basin core samples will be evaluated, and the geochemical characterization of oil types from many oil samples recovered from a wide area of the basin and from various formations will be identified and related to source rocks of origin. Natural gases obtained from a wide area of the basin will be characterized according to composition and isotopic properties. A vitrinite-reflectance isorank map of Paleozoic rocks of the central Anadarko basin will be compiled at 25- to 50-mi spacing.

Thermal History and Fluid Migration in Sedimentary Basins

Project Chief: R. C. Burruss

Samples for fission-track analysis from the Powder River, San Juan, Green River, North Slope, Anadarko, and Los Angeles basins will be collected.

Source of Magnetic Anomalies Over Hydrocarbon Deposits

Project Chief: R. L. Reynolds

Research will focus on determining the distribution and origins of magnetic iron-sulfide minerals at the Cement and Simpson oil fields in Oklahoma and Alaska, respectively. Magnetic properties of well cuttings and unoriented core segments will be measured and used to estimate total magnetization of rocks overlying oil and gas deposits. Magnetic models constructed from these magnetization values will be compared to observed magnetic anomalies.

Upper Cenozoic Tephrochronology

Project Chief: G. A. Izett

Plans are to continue collecting and processing volcanic-ash samples from the Central Region, and to prepare a report summarizing the state of tephrochronology for the United States. A report summarizing the results of the study on the tonsteins at the K/T boundary will also be prepared.

Gaseous-Emanation Detection

Project Chief: G. M. Reimer

Utilization of helium gas to characterize the paleohydrology of sedimentary basins will continue. Field work will be conducted in the Anadarko basin to evaluate the usefulness of revealing paleohydrologic patterns from the distribution of helium gas. A previous study in the Powder River basin provided evidence that this approach may be successful. A preliminary study indicated fault control on the location of high helium concentrations in areas of known natural-gas occurrences. That observation will be studied in greater detail to evaluate the control that local geology and hydrology have on the distribution of helium anomalies and their relationship to present-day ground-water flow.

Anadarko Basin Biostratigraphy/Paleoecology

Project Chief: J. E. Repetski

Plans are to continue to accumulate the necessary surface and subsurface data and samples from the Anadarko basin and related areas. The Oklahoma and Kansas state surveys will allow access to their core holdings. Preliminary compilation has begun to interpret these data in the context of project objectives, i.e., biostratigraphic zonation of the Arbuckle Group and related rocks will be made, and patterns generated by the distribution of conodont-alteration-index values at several stratigraphic horizons will be evaluated.

Estimation of High-Frequency Ground Motion in the Central and Eastern United States

Project Chief: D. M. Boore

Improved radiation-pattern corrections and allowances for the increase in duration due to wave-propagation effects, included in the basic program for the calculation of expected ground motions in the eastern United States, have been developed. A detailed look into the evidence for a source scaling in which moment times corner frequency to the fourth power is constant found no support for this scaling. Instead, the constant stress parameter scaling was found to give a reasonable fit to the sparse data within several hundred kilometers of eastern U.S. earthquakes. With this source scaling, a number of predicted-response spectral amplitudes were calculated for 5% damping and a range of distances and magnitudes. Regression analysis of this data set resulted in equations that can be used to specify the peak response on hard-rock sites for magnitudes and distances of concern in the design of structures. Effort will focus on completing a report discussing prediction of eastern ground motions; investigating schemes for including soil response in predictions; and investigating improvements in the basic random-process theory.

Geophysical and Tectonic Investigations of the Intermountain Seismic Belt

Project Chief: M. L. Zoback

This project has been expanded to include analysis of breakout data from the Mississippi Embayment and from the Anadarko basin, in an attempt to constrain stress orientations in the vicinity of the 1811–12 New Madrid earthquakes and the recently identified young faulting along the Meers fault zone in Oklahoma.

Investigation of Intraplate Seismic Source Zones

Project Chief: W. H. Diment

Two trenches across the Meers fault in Oklahoma indicate that the scarp was formed by a reverse fault that dips to the northeast in the shallow subsurface. Nearly all of the deformation in the alluvium is caused by warping and flexing, with only a small component of brittle deformation. Stratigraphic units in the trenches have a net vertical throw >3 m. Preliminary interpretation of trench data indicates one surface-faulting event since late Pleistocene time; however, this surface faulting is probably mid-Holocene or younger. There is no evidence in the trenches that supports a large component of lateral slip. A short, high-resolution seismic-reflection line conducted across the Meers fault shows a fault at ~270 m depth that can be connected to the surface faulting. This fault has a displacement of ~30 m. Additional geological and geophysical reconnaissance in the vicinity of the Meers fault will be under way.

Determining Landslide Ages and Recurrence Intervals

Project Chief: R. F. Madole

The Meers fault in Oklahoma was studied, and the investigation of the geometry of fault-generated fan deposits, representative soil profiles, and the magnitude of strike-slip movement will be completed. The regional stratigraphic framework, including a reconnaissance study of East Cache Creek from the Meers area to its confluence with the Red River, will be established. A study to determine the extent to which an early and middle Pleistocene stratigraphic record exists in the area, including a study of nearby sites containing the Lava Creek B volcanic ash, will be initiated to lay the foundation for studies of fault recurrence intervals.

Water Resources Division, Oklahoma District

Surface-Water Stations

Surface-water data will be collected to satisfy needs such as (1) assessment of water resources, (2) operation of reservoirs or industries, (3) forecasting, (4) disposal of wastes and pollution controls, (5) compiling discharge data to accompany water-quality measurements, (6) fulfilling compact and legal requirements, and (7) research or special studies. Data necessary for analytical studies will be collected to define for any location the statistical properties of, and trends in, the occurrence of water in streams and lakes, for use in planning and design. Standard methods of data collection will be used, as described in the series "Techniques of Water Resources Investigations of the United States Geological Survey." Partial-record gaging will be used instead of complete-record gaging, where it serves the required purpose.

Ground-Water Stations

Water-level data will be collected to provide a minimum long-term data base, so that the general response of the hydrologic system to natural climatic variations and induced stresses is known, and potential problems can be defined early enough to allow proper planning and management. A data base will be provided against which the short-term records acquired in areal studies can by analyzed. This analysis must (1) provide an assessment of the ground-water resource, (2) allow prediction of future conditions, (3) detect and define pollution and supply problems, and (4) provide the data base necessary for management of the resource.

Quality-Water Stations

Project will contribute to a national bank of water-quality data for definition and monitoring of chemical and physical qualities of streams. Operation of a network of water-quality stations will provide average chemical concentrations, loads, and time trends.

Sediment Stations

Water-resource planning and water-quality assessment require a nationwide base level of relatively standardized information. Project will contribute a national bank of sediment data for definition and monitoring of sediment concentrations and discharges in streams. A network of sediment stations will be established to provide spatial and temporal averages and trends of stream sediment concentration, sediment discharge, and sediment particle size.

National Trends Network (NTN) for Monitoring

Project is to determine variations in atmospheric depositions that occur on a week-to-week basis, and to collect wet and dry deposition products for analysis of elements and compounds that can contribute to chemical composition of surface waters.

A monitoring station will be set up and maintained in Oklahoma, as part of the National Trends Network (NTN), to make on-site measurements, process samples, and submit samples to an analytical laboratory.

Flood-Insurance Studies by Limited-Detail Methodologies

The 100-yr-recurrence-interval flood potential is to be determined for certain populated areas for the purposes of the National Flood Insurance Program. Inundation maps and flood profiles for the communities of Dover, Pocola, and Tishomingo, and Bryan County, will be published. Flood Insurance Studies for these areas will be prepared utilizing limited-detail methodologies to determine the 100-yr-flood-plain delineation. Stream profiles and elevation reference marks will be provided where applicable.

Oklahoma Water-Use Data

Water-use data that have been collected for the State of Oklahoma are in different formats and contain different bits of information that may make the data from one agency unusable by another agency. In addition, future data collection is presently based on different agency needs that can render the data to be collected by one agency incompatible with another agency's needs. Project will develop a comprehensive water-use data-collection and -management system for the State of Oklahoma to reconcile and assimilate data presently distributed throughout many federal, state, and local agencies. A planning meeting, under the lead of the Oklahoma Water Resources Board, will be held among all interested federal, state, and local agencies. The result of this meeting will be the development of a comprehensive water-use data system. Items to be considered will include types of data, format, and types of reports needed.

Coal Creek Basin

The study, in cooperation with the Bureau of Land Management, is to collect and interpret sufficient hydrologic data to predict and assess the effects of surface mining for coal and subsequent reclamation efforts on hydrologic characteristics in Coal Creek basin, Coal County, eastern Oklahoma. A secondary objective is collection of sufficient hydrologic data so that baseline hydrologic conditions can be defined and possible changes after mining can be documented. Development, calibration, and verification of a watershed model will aid in prediction of future effects of surface mining for coal.

Geohydrology of Alluvium and Terrace Deposits of the Cimarron River from near the Kansas State Line to Guthrie, Oklahoma

Quantitative knowledge of the hydrologic system is necessary for formulation of effective management plans and domestic water supplies. The area of study extends about 115 mi from Freedom, Oklahoma, in T. 26 N., R. 17 W., downstream to Gurthrie, Oklahoma, in T. 17 N., R. 3 W. This area includes the Cimarron terrace and associated aquifers.

Project is (1) to describe the geologic setting of the alluvial and terrace deposits along the Cimarron River from Freedom, Oklahoma, to Guthrie, Oklahoma; (2) to estimate the approximate quantity of water in storage, the approximate annual recharge, and the approximate annual discharge from the alluvium and terrace deposits and associated aquifers; (3) to provide estimates of the effects of future withdrawals from the aquifer by means of a digital model of the aquifer–river system; and (4) to document sources of existing and potential natural saline pollution.

All existing hydrologic data will be compiled; some existing wells may be inventoried to provide data in areas of sparse coverage. Collected data will be used to prepare maps of areal variations in aquifer properties, base of the aquifer, and water-level changes. The area will be modeled using the USGS modular three-dimensional finite-difference ground-water flow model to gain a quantitative knowledge of the system and to predict changes in ground-water storage at various levels of pumping stress. The three-dimensional model will be modified as necessary.

Limnology of Selected Coal-Mine Ponds in the Coal-Mining Region of Eastern Oklahoma

Limnological information is needed to manage this water resource created by strip-mining, and to further understand the limnological processes occurring in mine ponds.

Project is (1) to describe the limnological characteristics of the strip-mine ponds and other ponds in the area not associated with coal mining; (2) to determine if the limnological characteristics of strip-mine ponds are significantly different from those of other ponds; (3) to determine if the limnological characteristics of strip-mine ponds are significantly different among (a) those associated with different coal seams, (b) those associated with different mining and reclamation practices, and (c) those of different ages; (4) to intensively study selected strip-mine ponds and non-strip-mine ponds to develop an understanding of hydrologic, chemical, and biological processes occurring within the ponds, as well as the interrelationships among these processes.

Phase I involves statistical evaluation of historic data from 52 mine ponds, including Fe, Mn, SO_4, pH, temperature, and conductivity. Ponds will be classified for design of the next phase. Phase II involves sampling of ponds for major ions, Mn, Fe, Al, phytoplankton, zooplankton, benthic organisms, macrophytes, and chlorophyll. Phase III involves intensive study of selected ponds using the aforementioned parameters and any others deemed necessary.

Hydrogeologic Characteristics of Selected Shaly Formations in Oklahoma, with Particular Emphasis on their Suitability for Containment of Hazardous Wastes

In Oklahoma, industrial wastes are disposed of by near-surface burial and subsurface injection. In a recent reconnaissance study of the geology of rocks in Oklahoma that may be suitable for the disposal of hazardous waste, it was concluded that thick shales would be most favorable for near-surface burial of wastes. However, few data are available on the hydraulic properties of shales, and little is known of the role of shales in ground-water flow systems.

Project is (1) to conduct a literature search on the hydrology of shales; (2) to determine which physical properties of shale may be used as a relative index of permeability and fracture tendency; (3) to select four representative shales for study, map the outcrop areas, and describe the detailed geology of rocks at the test sites; (4) to evaluate the hydraulic and selected physical properties of the shales; (5) to evaluate the fracture tendency of shales and the resulting effect on ground-water flow; (6) using digital models, to estimate rates of ground-water flow through shales under realistic boundary conditions; and (7) to suggest hydrogeologic and physical criteria or guidelines for use in evaluating the suitability of shales for waste disposal.

A literature search will be conducted to assess the current state of knowledge of shale hydrology. Soil- and rock-mechanics theory will be consulted to determine if mechanical-properties tests may be used as a reliable index of shale permeability. The mineralogy, lithology, and stratigraphy of the shales at each of the four sites will be evaluated and mapped. Hydraulic and mechanical properties will be evaluated by lab analyses, aquifer and slug tests, geophysical logging, and model simulations. Fracture intensity will be determined from cores and borehole logs, and the relative importance of fracture flow will be considered. Estimates of shale hydraulic properties will be used in models to determine probable containment times for selected burial-site designs. Geologic and hydrologic factors will be suggested that should be considered in the evaluation of all candidate disposal sites.

Hydrogeology of the Blaine Aquifer and Associated Units in Southwestern Oklahoma

The Blaine aquifer consists of cavernous gypsum and dolomite beds interlayered with shales in the Permian Blaine Formation in Harmon, Jackson, and Greer Counties in southwestern Oklahoma. Ground water from the Blaine supports a local agriculture based mainly on irrigated cotton, corn, and wheat.

Declining water levels in parts of the Blaine aquifer are evidence that water is being withdrawn faster than it is being replenished. The Blaine aquifer has been artificially recharged since about 1961, although much of the effort was abandoned after 1975. The aquifer was recharged at more than 60 different locations by diverting streamflow and storm runoff into sinkholes and wells. Water in the Blaine aquifer is not used for human consumption, because of the large dissolved-solids concentrations, but the calcium sulfate water in the Blaine is acceptable for irrigation of salt-tolerant crops.

Project is (1) to evaluate and map the stratigraphy and structure of all geologic units in the study area adjacent to the Blaine Formation; (2) to evaluate the hydrology of the Blaine Formation and adjacent units; (3) to determine the distribution of major and selected trace and organic (agriculturally applied) chemical constituents in the aquifers; (4) to analyze the effects that extensive irrigation development and the artificial recharge program have had on the Blaine and associated aquifers, to project what effect they have had on the quantity and quality of water in the aquifer; and (5) to determine if opportunities exist for additional artificial recharge.

Investigators will (1) conduct a literature search on methods used to analyze ground-water flow in karstic aquifers; (2) assimilate all available geologic data; (3) perform test drilling, if existing data are inadequate; and (4) map joints and faults and areas of extensive sinkhole development, to facilitate an understanding of the ground-water flow system. The hydrologic work will include (1) establishment of a water-level network; (2) inventory of irrigation wells; (3) sampling and analysis of surface and ground water to describe the organic and inorganic water quality of the Blaine aquifer; (4) seepage runs and low-flow measurements; (5) inventory and estimation of water use from the Blaine; (6) estimation of transmissivity, using flow-net analysis and specific-capacity data; and (7) formulation of a conceptual model of the aquifer and adjacent units, to simulate the ground-water flow system.

Hydrogeology and Water Quality of the Garber–Wellington and Associated Aquifers, Central Oklahoma

The Garber–Wellington aquifer underlies ~3,000 mi^2 in central Oklahoma and is used for municipal, industrial, and domestic water supplies for most of the metropolitan area outside Oklahoma City proper. Although pumpage from the aquifer has increased dramatically in recent years, and water levels have declined, the principal threat to the continued viability of the Garber–Wellington aquifer is water-quality degradation. Salt water upconing in heavily pumped areas, natural occurrences of radioactive elements, and scattered occurrences of arsenic, chromium, and selenium in excess of the primary standards are not uncommon. Urban development over much of the aquifer, particularly on the unconfined recharge area, has had a major impact. Infiltration of polluted urban runoff, leakage from underground storage tanks (containing hydrocarbons and industrial chemicals), percolation from poorly designed and closely spaced septic systems, and disposal of industrial waste are among the urbanization problems. Other problems are related to the petroleum industry: seepage from waste pits, leakage through defective well casing, improper brine disposal, and cross-contamination in improperly plugged or unplugged abandoned wells. Also, there is potential for contamination of the Garber–Wellington aquifer by the Air Force's dumping of organic solvents and other industrial chemicals at Tinker Air Force Base in southeast Oklahoma City.

The Garber–Wellington National Water Quality Assessment (NAWQA) has two related objectives. The first objective is to study water-quality problems which affect the beneficial uses of ground water within the study area. The second objective is to develop, test, and improve methods for performing regional assessments of ground-water quality, with an emphasis on nationwide transfer value of the methods. Special importance will be placed on (1) the design of the sampling strategy, and (2) the method used to estimate the likelihood and probable extent of water-quality problems.

Investigators will sample and analyze ground water to (1) determine the distribution of trace elements, organic compounds, and other chemical substances that affect the beneficial uses of ground water and are widespread within the study unit; (2) identify zones within the study unit that are known to have or likely have water-quality problems at the present time; (3) identify zones within the study unit that, in relation to land-use and geologic and hydrologic conditions, have either a high susceptibility to future degradation or a low susceptibility to future degradation; (4) explore relationships between degraded ground water and land use and hydrogeologic and other pertinent factors; (5) identify specific ground-water-quality problems in the study unit which should be intensively investigated; and (6) provide a base of information which could be used to assess long-term trends in ground-water quality within the study unit. A sampling strategy will be designed on the basis of land use, hydrology, and other pertinent factors, which allows a regional assessment. Methods will be developed to use the information collected in each study to estimate the extent of water-quality problems, and, if possible, to estimate the spatial probability of the existence of problems.

Altus Air Force Base Hydrology: Reconnaissance and Pre-Survey Phase

Altus Air Force Base is among the priority sites scheduled for hazardous-waste cleanup as part of the Installation Restoration Program of the U.S. Air Force. Three sites on the base were identified during the IRP Phase I study as having potentially hazardous waste. Two sites are fire-training areas that may have been repositories for virtually any kind of combustible waste, liquid or solid, since the base was established during WWII. The other site is a fuel depot that has been subject to an unknown volume of jet-fuel spillage and leakage. The base does not overlie a major aquifer. The Permian shales of the Hennessey Group underlie all but the extreme northern part of the base. A few feet of Quaternary terrace deposits overlie the Hennessey in that area. The Air Force must assure that whatever contaminants have entered the ground do not migrate from the immediate vicinity of the disposal sites.

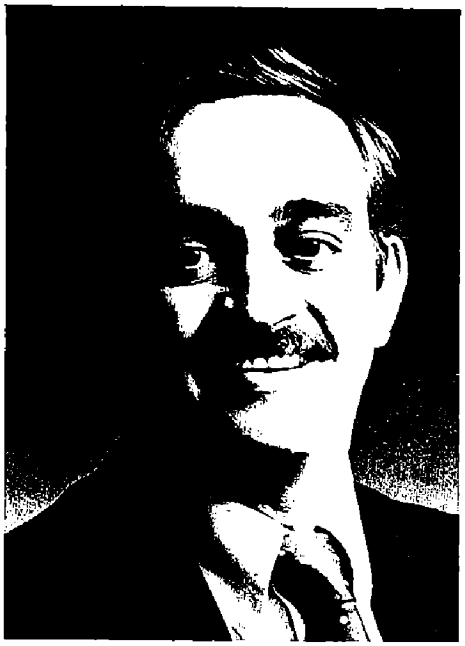
This study will be a preliminary investigation to determine the scope of work and the associated costs required to conduct a comprehensive assessment of the contamination at the sites, the areal extent of contamination, the ultimate fate of the contaminants in the hydrosphere, and the probable health risks associated with their existence. The final product of this study will be a report that details an investigative approach and the anticipated costs to conduct such as assessment. A base visit will be conducted to discuss the study requirements with base personnel, to inspect the disposal sites, and to gather all available data pertaining to the sites, including any previously developed geophysical and chemical information and disposal histories for the sites. These data and other pertinent information will then be used to develop the report detailing the investigative approach required for a subsequent comprehensive assessment of the contamination problem.

Preliminary Investigation of the Hydrogeology of the Chickasaw National Recreation Area

The Chickasaw National Recreational Area in south-central Oklahoma is experiencing significant reduction in spring and stream discharges. In 1906, the park benefited from 33 flowing springs, but now only five have sustained flow. Reduced discharge from these springs and periodic cessation of flow in the two streams flowing through the park have been attributed to increased pumping from the Arbuckle–Simpson aquifer, which underlies the park. Recorded ground-water-level declines in the area suggest that two major springs are expected to dry up within 10 yr, and that all remaining springs in the park will cease to flow within 40 yr. Increased stresses on the system are anticipated when eight new wells up-gradient from the park become operational.

Project is to collate the available hydrogeologic data for the Arbuckle–Simpson aquifer and overlying surface waters in the park and to evaluate the adequacy of these data for fully describing the surface-water/ground-water system associated with the area. If this evaluation shows that a more-comprehensive study is warranted, a detailed study plan will be prepared, describing the approach necessary to obtain a complete understanding of the system and the projected impacts of changes on the system as a result of potential imposed hydrologic stresses.

A comprehensive literature search and evaluation of more than 50 published reports on the area will be made. Existing information that describes the climate, geology, and hydrology of the park will be summarized. This information will be collated with recent unpublished climatic and hydrologic data and stored in a computer data base. All available data will be evaluated as to their adequacy in describing the ground-water/surface-water system in the park. If these data show that a more-comprehensive study is warranted, a detailed study plan will be prepared, describing methods to be used in characterizing the surface-water/ground-water system and the impacts on this system when stressed by increased water withdrawals.



James F. Kimpel

KIMPEL APPOINTED OU GEOSCIENCES DEAN

James F. Kimpel, a faculty member of the University of Oklahoma's School of Meteorology for 14 years and its director since 1981, has been appointed dean of OU's College of Geosciences.

OU President Frank E. Horton said that Kimpel "has proven his effectiveness in building a nationally recognized academic program and in working with alumni, professionals, and government officials in gaining the type of support needed to move the College of Geosciences to national prominence."

The College of Geosciences, established in 1981, brings together OU's School of Meteorology, School of Geology and Geophysics, and Department of Geography.

Kimpel serves as first vice president of Applied Systems Institute, Inc., the non-profit corporation of federal, private, and university agencies that together comprise OU's high-tech Weather Center. He is also a newly elected trustee of the University Corporation for Atmospheric Research, an organization that plays a leading role in the nation's university-based atmospheric research.

Kimpel received a Bronze Star for meritorious service in Vietnam, the College of Engineering Outstanding Faculty Achievement in Teaching Award in 1979, the OU Student Association Outstanding Faculty Award in 1984, and an Associates Distinguished Lectureship for 1984–86. He is also a recent recipient of a Regents' Award for Superior Professional and University Service.

A native of Cincinnati, Ohio, Kimpel earned a bachelor of science degree in mathematics from Denison University, and his master's and doctoral degrees in meteorology from the University of Wisconsin, Madison.

SEPM ANNUAL MIDYEAR MEETING
Austin, Texas, August 20–23, 1987

Hosted by the University of Texas at Austin, the Society of Economic Paleontologists and Mineralogists Fourth Annual Midyear Meeting will feature the following meetings and field trips.

Symposia and Technical Sessions

August 21

Seismic Facies of Ancient Submarine Fans
Classification of Large-Scale Flow-Transverse Bedforms
Petrology, Diagenesis, and Porosity History of Mineralogically Immature Sandstones
Carbonate Diagenesis
Fluid–Rock Interactions in the Salt Dome Environment
Carbonate Depositional Environments

August 22

Siliciclastic Depositional Environments
Paleontology
Reservoir Diagenesis and the Evolution of Micro- and Macro-Pore Networks in Carbonate Rocks
Late Paleozoic Evaporite Basins
MVT Sulfide Diagenesis and Its Relation to Carbonate Paragenesis and Basin Hydrologic Systems
Integrated Approaches to Paleobathymetric Reconstruction

SEPM Short Course

Origin and Migration of Subsurface Sedimentary Brines, *August 20*

Bureau of Economic Geology Core Workshops

Modern and Ancient Coal-Forming Environments, *August 20*
Late Paleozoic Evaporite Basins, *August 23*

Field Trips

Mega-Collapse Breccias and Associated Late-Stage Dolomitization of Ordovician Carbonates, Franklin Mountains, West Texas, *August 18–20*
Clastic and Carbonate Depositional Models in a Cratonic Basin Setting—Pennsylvanian of North-Central Texas, *August 19–20*
Paleozoic Buildups and Associated Facies, Llano Area, Central Texas, *August 20*
Lower Cretaceous Shelf Carbonates, Central Texas Hill Country, *August 23–25*

For further information about the meeting, contact SEPM, Meetings and Educational Programs, P.O. Box 4756, Tulsa, OK 74159-0756; (918) 743-9765.

SUBSURFACE NOMENCLATURE AGAIN IN PRINT

The widely used OGS Guidebook 6, *Subsurface Stratigraphic Names of Oklahoma,* by Louise Jordan, which has been out of print, is now available as a facsimile reprint. First printed in 1957, the 220-page book contains more than 600 names of Oklahoma subsurface units. For each name, the first printed reference, the type well, the depth, and a discussion are presented. A typical electric log is illustrated for many units.

Guidebook 6 is available over the counter or postpaid from the Oklahoma Geological Survey at the address given inside the front cover of this issue. The price is $7.

Christie L. Cooper

COOPER NEW *NOTES* EDITOR

Christie L. Cooper has recently been promoted to assistant editor at the Oklahoma Geological Survey and is the new editor of *Oklahoma Geology Notes*. She assumed the new position effective with the April issue, which had a new design to signal the change.

Working closely with geologist/editor Larry N. Stout, Christie is responsible for gathering and refining the wide variety of geologic papers, abstracts, news items, and pictures that go into the *Notes*.

In her new capacity, Christie also serves as production manager for Survey bulletins, circulars, guidebooks, and other publications—overseeing word-processing, typesetting, and proofreading, and attending to the numerous details that intervene before printing. She has for the past year produced the OGS special publications.

A graduate of Oklahoma State University, Christie has been with the Survey for two years. She previously worked for the Office of Research Administration and has been an employee of the University of Oklahoma since 1981.

OIL COMPANIES GIVE SUPPORT TO OU

- A $472,000 gift from the Exxon Education Foundation has launched a five-year plan to modernize engineering teaching laboratories at the University of Oklahoma. Payments of $118,000 during each of the next four years will provide support for faculty and teaching assistants who will introduce a digital data acquisition and processing system into the curriculum.

- For the 20th consecutive year, the Phillips Petroleum Foundation of Phillips Petroleum Co. has provided a professional-development-fund grant to the University of Oklahoma to "stimulate interest among students and faculty in the area of professional development." The grant was presented in the fall along with gifts to other OU programs, including $100,000 to the OU Energy Center, making the Phillips Foundation's total of gifts to 10 OU academic departments more than $139,000.

  This year's grant provides $6,400 to the College of Engineering, $3,000 to the College of Business Administration, $1,200 to the School of Geology and Geophysics, $1,200 to the College of Law, $1,000 to the College of Arts and Sciences, and $1,000 to Career Planning and Placement Services.

  Additional support provided by the foundation included $6,000 to the accounting enrichment program, $4,000 to fund scholarships in petroleum and chemical engineering, $2,500 for undergraduate scholarships in petroleum land management, $2,250 for three W. W. Keller scholarships for minority students in the College of Business Administration, $1,500 for the undergraduate chemistry scholarship program, and $1,500 for scholarships in geology.

- Sun Exploration and Production Co. has made a $20,000 grant to OU to help develop and retain faculty members in key scientific positions. The grant is the second installment of a five-year $100,000 commitment. Sun also has given OU $2,000 for scholarships in petroleum engineering. The $20,000 grant must be used for salary supplements, awards or assistance to professors, endowment of a chair in the school, or to aid graduate students who want to become petroleum and geological educators in the United States.

- The University of Oklahoma's petroleum engineering program has received grants totaling $4,000 from Conoco, Inc. Financial-Aid-to-Education grants of $2,500 for scholarships and $1,500 for unrestricted use were delivered to the OU School of Petroleum and Geological Engineering.

- Chevron has contributed $4,000 to the University of Oklahoma toward research in ground-water hydrology.

CONNIE SMITH AND PAULA HEWITT RECEIVE DISTINGUISHED SERVICE AWARDS

On Friday, April 24, 13 staff merit awards were presented by member groups of the Employee Executive Council in a ceremony held in the Forum at the Oklahoma Center for Continuing Education on the OU campus. Recognized by the Professional Staff Association for distinguished service and dedication to the University was Connie G. Smith, associate editor for the Oklahoma Geological Survey.

Connie has brought numerous improvements and innovations to her position, including computerizing the editorial process of the Survey. She was one of the first in this area to transmit type from office computer directly to the printer, eliminating the retyping of manuscripts and saving a tremendous amount of time and money. Her invaluable work has recently earned her the added title of public information officer.

Connie has served as president of the Professional Staff Association and as a representative to the Employee Executive Council. She is a member of the President's Partners and a strong supporter of the arts in the Norman/Oklahoma City area. Her hobbies include Oriental brushwork and photography. Connie has exhibited her work in Oklahoma City, Norman, and Fort Smith, Arkansas.

—Karen Weddle
PSA President

Connie G. Smith accepting her award from OU President Frank E. Horton.

Paula A. Hewitt accepting her award from OU President Frank E. Horton.

Each year, the Hourly Employees Council presents Distinguished Service Awards to six individuals from our membership of over 2,000 employees. To be selected for one of these awards indicates superior performance and contribution to the University of Oklahoma and the community. Paula (Polly) A. Hewitt, who is the supervisor of the copy center in the Oklahoma Geological Survey, is one of these very special people. On April 24, it was my pleasure as president of the Hourly Employees Council to present Polly with this award.

Polly is one of those individuals who is always willing to help others. She has often volunteered her own time to see that rush projects are finished on time. She can be counted on to make an extra effort when faculty, staff, or students are facing a deadline. Coming to work early and staying late are nothing new when someone needs her. Besides her work in the copy center, she takes a personal interest in the students. On weekends, Polly spends time with and does odd jobs for senior citizens in their homes and visits the elderly in nursing homes. It is not unusual to see her outside Gould Hall, feeding the birds and animals.

In recognition of her contributions to the Oklahoma Geological Survey and the University of Oklahoma, the Hourly Employees Council was proud to award Polly the Distinguished Service Award.

—Breck Turkington
HEC President

OGS STAFF ACTIVITIES

- OGS Director Charles J. Mankin has been appointed to a five-year term as a trustee of the Geological Society of America Foundation, GSA's fund-raising and financial-management arm.

- The American Institute of Professional Geologists executive committee met on the University of Oklahoma campus in January; OGS Director Charles J. Mankin is the current president of AIPG.

- At the annual meeting of the Midcontinent Section of the Society of Economic Paleontologists and Mineralogists, held last fall in Ponca City, Oklahoma, OGS staff presented these papers: "Hydrocarbon Production from Permian-Age Rocks in the Midcontinent," by Charles J. Mankin, Jock A. Campbell, Michelle J. Summers, Mary L. Fleming, and Al Schwartzkopf; "Nonpetroleum Mineral Resources of Permian Rocks in Oklahoma and the Texas Panhandle," by Kenneth S. Johnson; "Principal Aquifers in Permian Strata of Central and Western Oklahoma," by William F. Horak and Kenneth S. Johnson; "A Reappraisal of the Lithostratigraphy of the Council Grove and Chase Groups (Permian) in North-Central Oklahoma and Partial Equivalent Rock Units in Kansas and Nebraska," by James R. Chaplin.

- OGS Associate Director Kenneth S. Johnson presented a paper on "The Development of Sinkholes Resulting from Salt Dissolution and Collapse" at the Second Multidisciplinary Conference on Sinkholes and the Environmental Impact of Karst, held in February in Orlando, Florida. Johnson also addressed the Ardmore Geological Society in February, speaking on the geology of the Grand Canyon; Johnson has several times led geologic field trips through the Grand Canyon for the University of Oklahoma.

- OGS Director Charles J. Mankin chaired a panel discussion on "The Public's View of the Professional Geologist" at a joint meeting of the Oklahoma and Kansas sections of the American Institute of Professional Geologists, held in April at Ponca City, Oklahoma. At the same meeting, James R. Chaplin of the OGS staff presented a paper on "A Reappraisal of the Lithostratigraphy of the Council Grove and Chase Groups (Permian) in North-Central Oklahoma and Partial Equivalent Rock Units in Kansas and Nebraska." Connie Smith of the OGS staff spoke on the public's view of geologists serving in a state agency.

- OGS Senior Coal Geologist Samuel A. Friedman judged earth- and space-science projects submitted by high-school students at the 38th Oklahoma City Regional Science and Engineering Fair. At the 11th Annual Forum of Coal Geologists of the Western Interior Coal Basin, held in Columbia, Missouri, Friedman presented a review of the coal-mining activities and coal production in Oklahoma in 1986 and spoke about his research on the occurrence and distribution of trace elements in Oklahoma's coal resources and reserves.

OKLAHOMA ABSTRACTS

The Oklahoma Geological Survey thanks the Geological Society of America, *Tectonophysics*, and the authors for permission to reprint the following abstracts of interest to Oklahoma geologists.

Oil, Reptiles and a Permian Cave System on Bally Mountain, Oklahoma

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The Bally Mountain Range in eastern Kiowa County, southwestern Oklahoma (R14W, T6N) is an exhumed Permian landsurface built of homoclinal Lower Paleozoic carbonates unconformably atop Carlton Rhyolite. Dip is to the northeast at 22–41°. The carbonates are cut by numerous subvertical fractures, most of which trend between 060–110 or 160–020. Karst solution has opened up caves along these fractures. Caverns are small, mostly less than a meter in diameter. They are lined by a variety of calcite speleothems, some of which contain abundant hydrocarbon inclusions. In addition sticky bitumen lines some cavities. The stratigraphy of the caves comprises (i) initial cavern solution; (ii) vadose dripstone precipitation with crystal growth perpendicular to cavern walls; (iii) phreatic crystal precipitation in small ponds (crystal growth is subvertical); (iv) infill of the cave by siliciclastic detritus. The latter consists of local Arbuckle Group pebbles, reworked speleothem, clay and abundant Permian vertebrate fragments. In one cave laminated (?varved) clays have been subjected to considerable penecontemporaneous deformation, suggesting contemporary seismicity. The caves are of lower Permian age at the latest. They may have terminated during the Permian as the climate became more arid. Significantly, some in-place calcrete occurs in the siliciclastic infill of a few caves. The local Arbuckle Group rocks are an unlikely hydrocarbon source. Given the Pennsylvanian tectonic emplacement of the Bally Mt. area above the Anadarko basin, it is probable that hydrocarbon migration was upward from Paleozoic source rocks in the basin.

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Pressure Solution Arrays in the Slick Hills of Southwestern Oklahoma

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The Slick Hills of southwestern Oklahoma are the exposed part of the WNW trending Frontal fault zone (Ffz) between the Wichita uplift and the Anadarko basin. Upper Paleozoic deformation in this area resulted in up to 40,000 ft of apparent vertical displacement across the Ffz chiefly as a result of movements on a series of southerly dipping reverse faults. Fault-bounded blocks within the Ffz exhibit varying degrees of internally consistent deformation. One such

block is partly exposed in the southern Slick Hills between the Meers fault and the Blue Creek Canyon fault (a generally northeastward dipping "antithetic" reverse fault). This block exhibits greatly folded and faulted Arbuckle Group carbonates. Faults are mostly reverse structures dipping southwestward, folds generally face northeastward and are aligned in en echelon arrays. Fold trends are from 0–25° more northerly than the trend of the Meers fault. Our previous displacement vector studies suggest that the block has been subject to left-lateral transpression.

In addition to folds and faults the block is cut by numerous shear zones containing sigmoidal en echelon arrays of subvertical pressure solution surfaces. Such zones are from 6" to 6 ft wide. Individual solution surfaces show a wavy geometry; petrographic studies indicate that considerable amounts of rock have been dissolved at these surfaces. Displacement vector calculations for arrays which are subparallel with the Meers fault offer supporting evidence for left-lateral transpression. In addition some arrays are cut by fractures whose orientation suggests that they are left-lateral Riedel shears.

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Determination of Offset Across the Frontal Fault Zone, Wichita Uplift, S.W. Oklahoma

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The uplift of the Wichita Mountains represented the final event in the development of the southern Oklahoma aulacogen. Contrasting tectonic models have linked this intraplate deformation directly with coeval interplate collisions which formed the Alleghenian and Ouachita orogens. These models require either left-lateral strike-slip separation or a combination of right-lateral strike-slip and reverse dip-slip offset across the Frontal Fault Zone (FFZ), the northern boundary of the Wichita Uplift. These opposing models are evaluated using data from a subsurface mapping study of the FFZ.

The magnitude and sense of offset across the Mountain View Fault (MVF), the most basinward of the FFZ faults, can be constrained by the palinspastic restoration of isopach patterns for the Late Ord.–Dev. Hunton Gp. The offset of patterns between the Anadarko Basin and the FFZ can be explained solely by dip-slip displacement along the MVF. Structure contour maps constructed on the MVF show consistent southwest dips of 35–55°.

Separation across the northwest trending Meers Fault (MF), the southern boundary of the FFZ, is more poorly constrained as there are no lower Paleozoic sedimentary rocks adjacent to the fault in the hanging wall. However, northeast trending sections of the MF show little evidence for the additional shortening or extension which would be expected if these represented restraining or releasing bends along a strike-slip fault. These northeast trends are apparent elsewhere within the FFZ and appear to represent tear faults which segment the first-order, northwest oriented structures.

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Surface Structural Study of the "Courtney Hill" Area, Wichita Mountains, Southwestern Oklahoma

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The "Courtney Hill" area is located on the north flank of the Wichita Mountains. Ordovician rocks of the Arbuckle Group crop out in the Blue Creek Mountains–Slick Hills area of Kiowa County. Tombstone-like topography highlights the structural folds of the area.

The forces responsible for the formation of the northern Wichita Mountains have long been a source of controversy. Some workers have interpreted strike-slip movement on regional faults, while others have interpreted compressional thrust movement on the same faults.

Structural interpretations and analysis of the study area utilized detailed surface mapping, cross sections, and stereonets. The surface mapping shows that the folds are arranged in a left-stepping en echelon pattern. If only the map pattern is considered, one might conclude the cause of the formation of the folds to be a nearby left-lateral strike-slip fault. However, up-plunge exposure of the folds reveals that the anticlines die out down the axial surface, and detach on bedding plane thrusts. These folds are therefore compressional crenulations caused by volumetric constriction of the regional subsurface syncline, and do not represent "drag" folds related to basement-involved wrench or strike-slip faults.

There is a need for additional structural studies of the north flank of the Wichita Mountains in order to resolve the present controversy. These studies should include detailed surface structural mapping and construction of true scale cross sections.

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A Structural Analysis of the Slick Hills Using Landsat TM and Side Looking Radar Data

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Landsat Thematic Mapper (TM) and Side Looking Radar (SLR) data were used to map structural lineaments in the highly deformed Slick Hills area of southwestern Oklahoma. These low-lying hills represent a sequence of Cambro–Ordovician rocks that were intensely folded and faulted during the Pennsylvanian and early Permian.

From our analysis of the merged remote sensing data, we found two major lineament orientations from our rose diagram plots. One set of lineaments trends N30°–60°W and is associated with left-lateral thrust and high angle reverse faults. The second major lineament set is perpendicular to the first and trends N40°–50°E. This second set of lineaments, although not well-documented in the literature, are now confirmed to be right-lateral faults with minor displacements. The abundance of these northeast lineaments, integrated with proposed models of structural deformation, reinforces the theory of long-acting, left-lateral transpressive shear in the Slick Hills area.

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Structural Development of the Southeastern Margin of the Anadarko Basin

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Field investigations in the western Arbuckle Mountains, on the southeastern margin of the Anadarko basin, show that transpressional (chiefly compressive) deformation of Late Mississippian to Pennsylvanian age dominated the structural development of this area, followed in Late Pennsylvanian (Virgilian) time by a modest amount of strike-slip.

Mesoscopic south-dipping contraction faults and north-vergent concentric folds with associated uplimb thrusts, exposed on the crest and southwestern limb of the Arbuckle anticline south of Turner Falls are cut by strike-slip faults associated with the left-lateral Washita Valley fault system. Along the main strand of the Washita Valley fault in this area, a pull-apart graben indicates that strike-slip motion was transtensional and hence not responsible for the Arbuckle anticline. Offset second-order folds constrain the magnitude of strike-slip motion along the Washita Valley fault zone to less than 3 miles. Surface features of left-slip faults of the Washita Valley system and associated antithetic right-slip faults formed subsequent to the growth and erosion of the Arbuckle anticline to near-present erosional levels, consistent with the observed cross-cutting relationships.

Early contraction faults and associated minor folds on the north limb of the Arbuckle anticline, Lake Classen area, have been passively rotated with the north limb and are not evidence of gravity sliding. Locally this limb is overturned and early deformational features rotated more than 90°. Mesoscopic features observed in the second-order Russell anticline on the north limb indicate transpressional deformation in the hanging wall of the Arbuckle thrust, probably subsequent to thrusting.

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Left-Lateral Intraplate Deformation Along the Ancestral Rocky Mountains: Implications for Late Paleozoic Plate Motions

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North America underwent synchronous orogenic events during the late Paleozoic along its eastern margin (Alleghenian orogeny), southern margin (Ouachita orogeny), and within the southwestern part of the continent (Ancestral Rocky Mountain orogeny). All three orogenies were initiated in the late Mississippian to early Pennsylvanian, reached the greatest intensity in the middle Pennsylvanian, and ended in the early Permian. The Alleghenian and

Ouachita orogenies have been related to the closing of the proto-Atlantic and the collision between North America and South America–Africa: it is here proposed that the Ancestral Rocky Mountains were produced by a collision between eastern North America and Africa.

The Ancestral Rockies were formed as the result of reactivation of the Wichita megashear, a preexisting zone of weakness that extends from southern Oklahoma to eastern Utah. Previous plate tectonic models have implied that the megashear was a zone of right-lateral strike-slip faulting and north–northwest-directed compression. However, structural and stratigraphic data from Oklahoma and Texas suggest that the Wichita megashear was a major left-lateral fault zone formed under east–northeast-oriented compression. Palinspastic reconstruction of pre-mid-Devonian strata across the megashear in Texas indicates that 120 to 150 km of left slip occurred during the Desmoinesian (middle Pennsylvanian).

The proposed plate tectonic model for the ancestral Rocky Mountain orogeny includes: (1) movement of the North American plate eastward from a spreading center in the proto-Pacific; (2) closing of the proto-Atlantic Ocean; (3) collision of North America–Europe (Laurussia) and South America–Africa (Gondwana) resulting in the Hercynian, Alleghenian, and Ouachita orogenies; (4) differential movement across the Wichita megashear and formation of a left-lateral strike-slip fault zone (Ancestral Rocky Mountain orogeny) as the result of east–west compression within the North American plate; (5) relative northward movement of Gondwana against Laurussia producing the Marathon and Arbuckle orogenies; (6) development of a subduction zone to the west of the North American continent.

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Geomorphology of the Eastern Wichita Mountains, Southwestern Oklahoma

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The Wichita Mountains are Permian landforms now being exhumed and modified. The topographic forms are thus combinations of processes of two widely differing time periods. Stream superposition is locally dramatic. There are 5 principal physiographic provinces constituting the eastern Wichita Mountains: 2 valley-like lowland features and 3 prominent ridges. These features trend WNW, and are from NE to SW: Slick Hills, Meers Valley, Central Wichita Ridge, Central Lowland–Eastern Lowland, and Southern Wichita Ridge. These features are controlled by lithology and structure.

The Slick Hills are underlain chiefly by Arbuckle Group carbonates with distinct paleokarst features. Summit elevations typically reach 1900–2100′ along the main ridge. The Meers Valley is underlain by Permian Hennessey shale and Cambrian Raggedy Mountain Gabbro Group (RMGG). Elevations range from 1700′ in the NW to 1200′ in the SE. The Central Wichita Ridge is underlain entirely by Cambrian Mount Scott Granite and has approximately concordant upper elevations of about 2400′. The Central Lowland–Eastern Lowland is underlain by RMGG and Cambrian Carlton Rhyolite with elevations of 1800′ in the NW to 1400′ in the SE. The southern Wichita ridge is underlain mostly by Cambrian Quanah Granite with elevations of about 2200′ at each end with a district medial saddle.

To develop the Permian aspects of these features requires a tectonic sequence involving initial quiescence followed by local faulting and uplift, then final quiescence. Late Tertiary(?)–Quaternary aspects reflect regional control and progressive stripping away of pre-existant surfaces.

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Petrographic and Structural Evidence from the Igneous Suite in the Wichita Mountains Bearing on the Cambrian Tectonic Style of the Southern Oklahoma Aulacogen

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Field evidence suggests that the bimodal igneous suite making up the Wichita Mountains was emplaced in a rift environment at surface to shallow crustal levels, accompanied by seismicity. It is possible to detail some of the events which together make up a consistent story. Faulting (probably normal) occurred throughout development of the rock units. Concomitant erosion indicates the rift remained essentially a positive feature through most of the igneous stage. Shapes of rock units were determined by emplacement in an active tensional (extending) setting.

Petrologic data supporting this interpretation are based on: (1) truncated nature of both the Glen Mountains Layered Complex and the Roosevelt Gabbros of the Raggedy Mountain Gabbro Group; (2) strong plagioclase lamination in the GMLC; (3) hydrid rocks positioned at the RMGG–Wichita Granite Group contact; (4) granophyric and granophyric-spherulitic textures; (5) rhyolite dikes in granite; (6) diabase dikes and plugs.

Structural data supporting this are: (1) attitude discordances between successive age units; (2) attitude of the RMGG–WGG contact; (3) shapes of granite bodies and of rhyolite piles.

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Cyclic Units, Stratigraphy and Platinum-Group Element Mineralization of the Glen Mountains Layered Complex, Southwest Oklahoma

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Detailed mapping of part of the Glen Mountains Layered Complex (GMLC) indicates that the GMLC consists of a number of cyclic units composed of rhythmically layered plagioclase-olivine (POc), plagioclase-olivine-augite

(POAc), plagioclase-augite (PAc) and plagioclase cumulate (Pc). Individual cycles are characterized by upward increase in the amount of augite, oxide, and sulfide and an upward decrease in the amount of olivine. In addition the amount and extent of peritectic orthopyroxene + magnetite replacing olivine increases upward through each cycle as well as in the rhythmic layers. Successive cycles in the map area exhibit an upward increase in the amount of POc, POAc, and PAc. The cycles probably represent compositionally similar pulses of magma that underwent similar but slightly different evolutionary trends. The inferred crystallization sequence is plagioclase, olivine, clinopyroxene, and orthopyroxene. As presently defined more than 700 m of stratigraphic section is exposed compared with previous estimates of approximately 240 m for the entire GMLC.

Platinum-group element (PGE) mineralization occurs in the lower exposed cyclic units. Pt/(Pt+Pd) ratios range from 0.25 to 0.99 and indicate a magmatic origin. Geochemically anomalous values for Pt range from 50 to 3325 ppb and 45 to 1400 ppb for Pd. Anomalous samples are widely distributed over the southern exposed part of the GMLC indicating potential for a PGE zone or reef.

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Surface to Subsurface Structural Interpretation of the Pittsburg Quadrangle, Pittsburg County, Oklahoma

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A recent deep gas exploration play in the Frontal Ouachita Mountains of Oklahoma, along with an increase in roadcuts, well site clearings, and deforestation has augmented subsurface and outcrop data to the degree that new interpretations can be made regarding the complex structure of this thrust faulted terrain. This study examines the nature, origin, and sequence of emplacement of numerous structural features of the Pittsburg quadrangle, a sixty-square-mile area located on the boundary between the Ouachita Mountains and the Arkoma basin, near McAlester, Oklahoma, in southern Pittsburg County.

As an active continental margin during the latter part of the Paleozoic, the Ouachita Mountains experienced compressive forces of sufficient magnitude to cause overthrusting. Since then, erosion has revealed northeast trending, parallel bands of rocks.

The major thrust faults, from north to south are the (1) Choctaw, (2) Buck Creek, (3) Katy Club, (4) Pine Mountain, and (5) Ti Valley thrusts. Numerous imbrications occur between these, either linking major thrusts or dying out in bedding plane. The structural transition from the Ouachita Mountains into the Arkoma basin has been interpreted as an incipient triangle zone. A more mature and deeply eroded triangle zone exists farther south, within the Frontal Ouachitas. An area previously interpreted as a "Klippe" has, in this study, been reinterpreted as a gravity slide. Cross sections show minimum cumulative shortening in excess of 15 miles. With minor exceptions, fault propagation occurred in the direction of tectonic transport (northwestward).

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Potential for Landsliding in the South-Central United States from a New Madrid-Type Earthquake

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The largest series of earthquakes to strike the United States in historic times occurred in the New Madrid, MO, area in 1811–1812. These shocks preceeded much development in the south-central United States and the actual extent of damaging effects is not known because of the low population density at the time. A substantial part of the south-central United States region is designated Seismic Zone 0 (no damage) or Seismic Zone 1 (minor damage) in the Uniform Building Code.

Relationships between areal extent of landsliding and earthquake magnitude were developed by Keefer (1984). Rigid body displacement values were estimated by Wilson and Keefer (1985) for landslides based on a critical acceleration failure criterion and several accleration time histories from California earthquakes. They also incorporated a parameter known as Arias Intensity to define thresholds of landslide damage based on displacement. Arias Intensity (**Ia**) is defined as the integral of the square of the acceleration time history of an earthquake and has units of m/s. This is a particularly useful parameter because it incorporates peak acceleration, duration, and site conditions in a single number. Wilson and Keefer (1985) calculated **Ia** from acceleration time histories for California earthquakes in which moment magnitude (**M**) and source distance were available. A threshold **Ia** value of 0.5 m/s corresponding to a failure criterion of 10 cm of displacement was estimated for coherent slides, lateral spreads, and flows. Disrupted slides were considered possible for **Ia** $\geqslant$ 0.15 m/s which corresponds to a displacement of 2 cm.

Algermissen et al. (1982) used Ms 8.5 for the maximum magnitude in the New Madrid seismic source zone for the probabilistic acceleration model of the conterminous United States. A recently developed regression relates seismic moment (Mo) and Ms as $\log \mathrm{Mo} = \mathrm{Ms} + 18.85$ (Anderson, 1986). Thus, Ms 8.5 would correspond to an Mo of 2.2E+27 dn-cm and **M** 7.5. Nuttli (1973) suggests that the 1811–1812 New Madrid earthquakes could have had a maximum Ms of 8.7 which would correspond to **M** 7.7. Scaling **Ia** to this magnitude is based on an assumed log-linear relation in the manner used by Wilson and Keefer (1985) and yields $\log \mathbf{Ia}^* = -3.23 + \mathbf{M} - 2 \log r^*$ (n=30, r-squared = 0.73) where **Ia*** is the Arias Intensity corrected for **M** 7.7 and r* is the hypocentral distance with a focal depth of 20 km.

This relation suggests that, for earthquakes of **M** 7.7, **Ia*** values of 0.5 m/s probably will be experienced at distances (mean values) of 240 km and could be experienced at distances (mean plus one standard deviation) of 400 km.

Similarly, Ia* values of 0.15 m/s probably will be experienced at distances (mean values) of 440 km and could be experienced at distances (mean plus one standard deviation) of 735 km. Houston, located about 700 km from the New Madrid source zone, is within Seismic Zone 0, but may be exposed to earthquake ground motion sufficient to cause disrupted landsliding at susceptible sites. Other significant cities in the south-central U.S. that could be in areas where seismic shaking may be underestimated are Little Rock (150 km), Tulsa (450 km), Topeka (550 km), Oklahoma City (600 km), and Dallas (600 km).

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OGS CORE AND SAMPLE LIBRARY SUBJECT OF JULY MEETING IN NORMAN

The Core and Sample Library of the Oklahoma Geological Survey is the subject of a one-day meeting to be held July 28 in Norman, Oklahoma. The meeting is open to all who use the library or are interested in discovering more about it. Users can learn more about the facility and have input into future plans, and the OGS staff can learn more about the needs of the users.

The tentative agenda for the meeting includes morning sessions on the study of cores and samples and their usefulness in petroleum exploration and development, as well as a review of the library's present operating procedures. After a luncheon, the group will have an opportunity to tour the library and the OGS offices.

The meeting will be held at the Oklahoma Center for Continuing Education (OCCE), on the University of Oklahoma campus. There is no charge to attend the meeting, but reservations for the luncheon are needed by July 23 and can be made by contacting the Survey at 830 Van Vleet Oval, Room 163, Norman, OK 73019. The telephone number is (405) 325-3031.