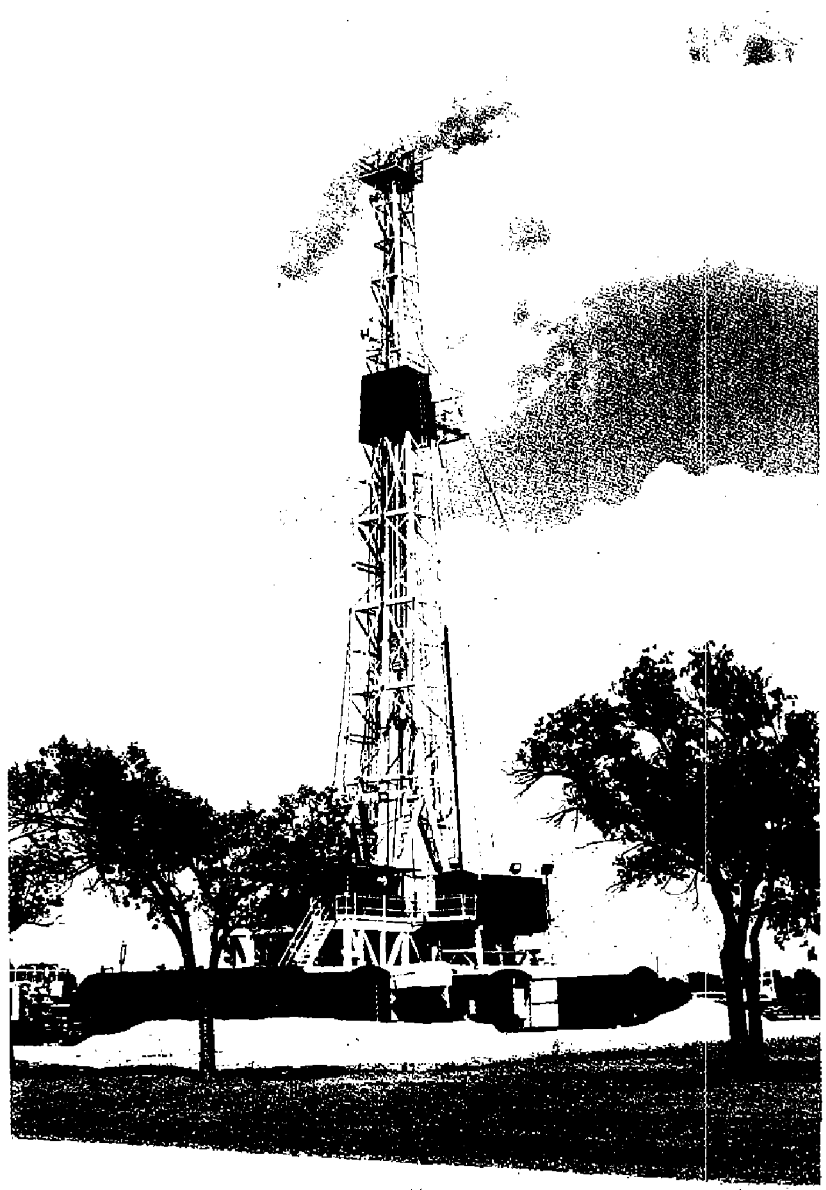
Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY/VOL. 45, NO. 3—JUNE 1985



On the cover—

Drilling Completed on Holden Energy Corp.'s 24–2 OU

Drilling was completed in mid-May at Holden Energy Corp.'s 24–2 OU, in sec. 24, 9N–3W, just north of Robinson Street on The University of Oklahoma's north campus in Norman. The well reached a total depth of 10,001 ft, where drilling was completed in rocks of the Arbuckle Group.

The company has run production casing and is currently testing several zones for hydrocarbon potential. Company representatives said they are "encouraged" but have no further information to release at this time.

Margaret R. Burchfield

Cover photo by Connie Smith

Oklahoma Geology Notes

Editor: Connie Smith
Contributing Editors: Elizabeth A. Ham, William D. Rose
Editorial Assistant: Christie Cooper

Oklahoma Geology Notes, ISSN 0030-1736, is published bimonthly by the Oklahoma Geological Survey. It contains short technical articles, mineral-industry and petroleum news and statistics, reviews, and announcements of general pertinence to Oklahoma geology. Single copies, $1.50; yearly subscription, $6. All subscription orders should be sent to the Survey at 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73019

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

Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY/VOL. 45, NO. 3—JUNE 1985

Contents

This publication, printed by The University of Oklahoma Printing Services, Norman, Oklahoma, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes, 1981, Section 3310, and Title 74, Oklahoma Statutes, 1981, Sections 231–238. 1,800 copies have been prepared for distribution at a cost of $2,378 to the taxpayers of the state of Oklahoma.

THE THATCHER CREEK MEMBER: BASAL UNIT OF THE COOL CREEK FORMATION IN SOUTHERN OKLAHOMA

Deborah A. Ragland[1] and R. Nowell Donovan[2]

Abstract

A distinctive lithologic unit (the Thatcher Creek Member) is described from the base of the Lower Ordovician Cool Creek Formation in the Slick Hills of southwestern Oklahoma. The unit is one of the few lithostratigraphic marker zones in the Arbuckle Group. It is an important key in unraveling the complex structural deformation in the area.

Introduction—A Field Mapping Problem

The Slick Hills of southwestern Oklahoma are composed of a sequence of greatly folded and faulted lower Paleozoic carbonates, most of which are assigned to the Arbuckle Group, here about 5,500 ft thick. These rocks contain few distinctive lithologies or stratigraphically significant fossils. As a result, formational subdivision of the group is on a gross scale, and boundaries are recognized with difficulty on the basis of either lithostratigraphic or biostratigraphic criteria (table 1).

Detailed field mapping (Babaei, 1980; Donovan, 1982; Beauchamp, 1983; Marcini, McConnell, 1983; Marcini, in progress; Stubbs, in progress) of complex structural terrain has been bedeviled by homotaxial problems. By far the most useful lithostratigraphic marker horizon is the boundary between the McKenzie Hill and Cool Creek Formations. This boundary is taken as the first significant influx of macroscopically visible quartz sand into the section. The unit concerned is distinctive both on the ground and from the air. It has been traced easily over 50 mi in well-exposed ground, even in areas complicated by imbricate thrusting and overturned folds. We propose to designate this unit as the Thatcher Creek Member and to recognize it formally as the basal unit of the Cool Creek Formation.

Historical Background and Formal Designation

In 1933, Ulrich established the Cool Creek Formation of Oklahoma as a formal unit. For many years the lower boundary was taken to be the

[1] Teaching assistant, T. Boone Pickens, Jr., School of Geology, Oklahoma State University, Stillwater, OK 74078.
[2] Professor, T. Boone Pickens, Jr., School of Geology, Oklahoma State University, Stillwater, OK 74078.

TABLE 1.—GENERAL STRATIGRAPHIC SECTION FOR SLICK HILLS, SOUTHWESTERN OKLAHOMA

SYSTEM	SERIES	GROUP	FORMATION	AVERAGE THICKNESS
PERMIAN	Leonardian	Hennessey	Wichita (Post Oak Member)	120m (400 ft)
LOWER ORDOVICIAN	Canadian	Upper Arbuckle	West Spring Creek	90+m (300+ft)
			Kindblade	425m (1400 ft)
			Cool Creek	425m (1400 ft)
			McKenzie Hill	300m (1000 ft)
		Lower Arbuckle	Signal Mountain	260m (850 ft)
CAMBRIAN	Croixan		Fort Sill	200m (650 ft)
		Timbered Hills	Honey Creek	90m (300 ft)
			Reagan Sandstone	0–45m (150 ft)
			Carlton Rhyolite	

change from the "heavier [sic] beds of limestone" at the top of the McKenzie Hill to the more easily eroded beds of the Cool Creek Formation (Decker, 1939). It was not until 1956 that the unit at the base of the Cool Creek Formation was recognized as a quartz-rich limestone (Ham, 1956). This unit has since been used by geologists to locate the base of the formation in petrologic field studies (Barthelman, 1968; Brookby, 1969; Donovan, 1982; Ragland, 1983).

Several distinct beds make up the unit; therefore, the rank of member in the rock-material category has been assigned. As all of the geographic names in the vicinity of the type section have been used for the identification of structural features and other stratigraphic units, it was necessary to derive an alternative name. Because the unit is distinguished in hand specimen by its "tough, gritty and limy nature," we suggest the name "Thatcher Creek"; in recent publications (e.g., Donovan, 1983; Gilbert and Donovan, 1984) the unit has been so termed.

Location and Description of the Type Section

The type section of the Thatcher Creek Member is in the valley of a heretofore unnamed tributary of Blue Creek, which is herein designated Thatcher Creek, in sec. 11, T4N, R13W, Comanche County, Oklahoma (fig. 1, a and b). The member ranges in thickness from 3.5 m (12 ft) to 5 m (16 ft), and has weathered to form a characteristic gully. It is a multistoried unit composed mainly of limestone and detrital quartz in variable amounts (fig. 2).

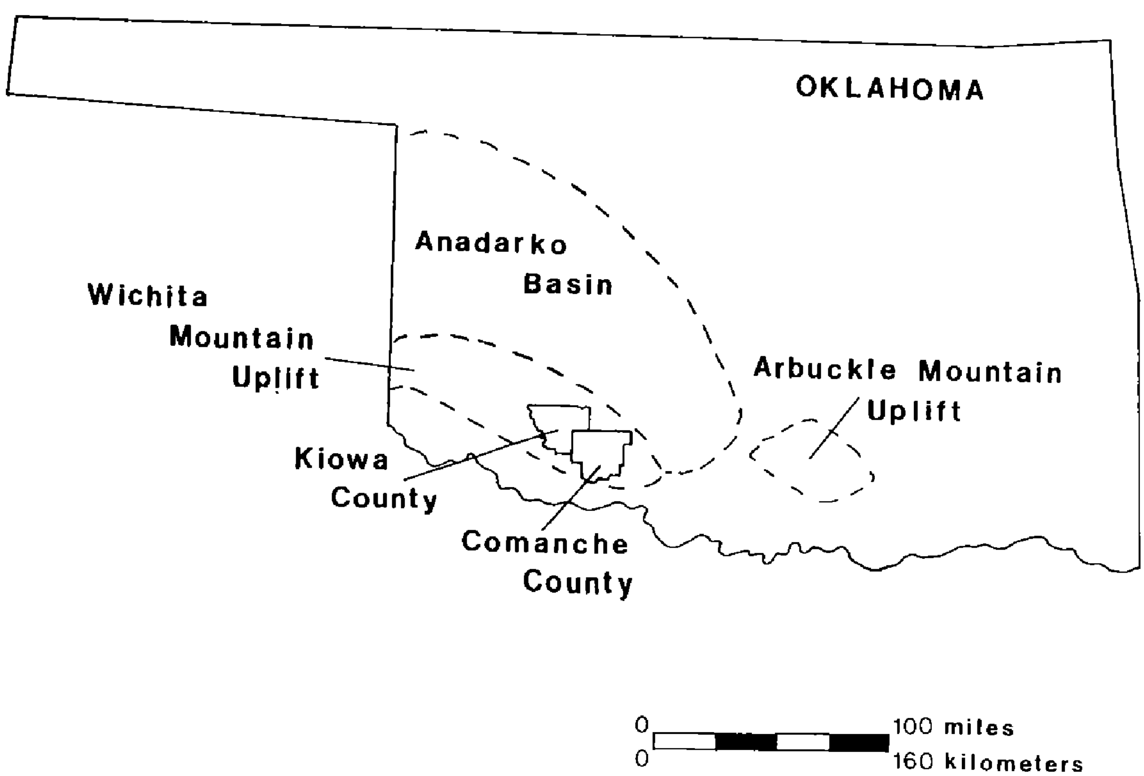


Figure 1a. Map of Oklahoma showing location of Comanche County.

Although fine-grained detrital quartz is found in the upper 18 m (60 ft) of the McKenzie Hill Formation, it is widely dispersed and not readily apparent in hand specimen. A notable increase in the percentage of quartz sand, which is complemented by an increase in grain size (to coarse), marks the boundary between the McKenzie Hill and Cool Creek Formations. The first 0.5 m (2 ft) of the Thatcher Creek Member contains 5 to 20% quartz sand in beds that exhibit parallel laminations, some small-scale trough crossbedding, and symmetrical ripple marks (average wavelength 18 cm or 7 in.).

Higher percentages of quartz sand (from 20 to 40%) occur in the overlying 1.2 m (4 ft) of section. Associated clastic grains include pellets, ooids, and various intraclasts, some of which are pebble sized. Most cements are drusy or equant spar; in some areas significant micrite matrix is present. The only bed in the Thatcher Creek Member that contains no apparent quartz sand is a thinly bedded micritic limestone approximately 1.8 m (6 ft) from the base. Overlying this bed is the most distinctive bed in the member, a 20-cm (8-in.) blocky-weathering limy sandstone containing as much as 80% quartz sand. Sand grains (quartz plus minor chert and microcline) range in size from fine to very coarse; most are coarse to very coarse. The bed contains medium-scale crossbedding and symmetrical ripple marks. Above this distinctive unit the quartz-sand content averages 40%. These uppermost beds are parallel laminated and crossbedded (both small and

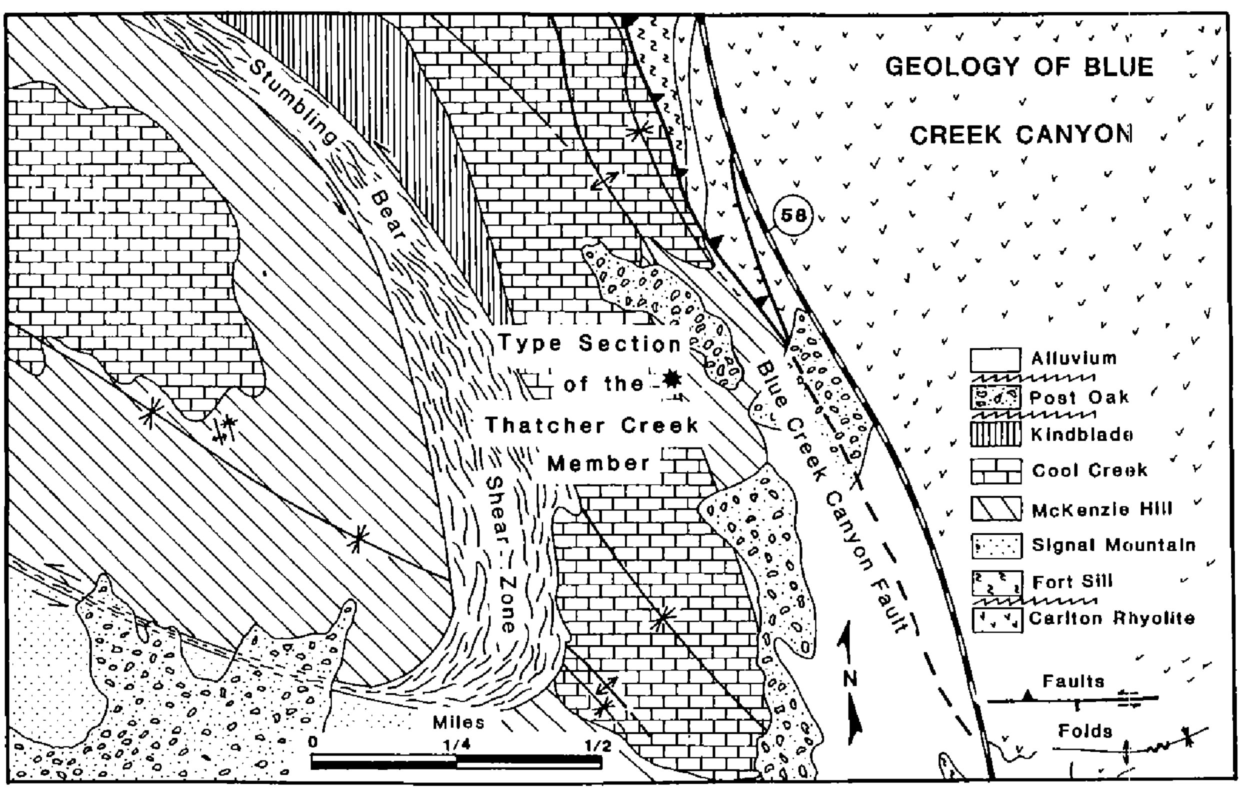


Figure 1b. Geologic map of Blue Creek Canyon, Comanche County, Oklahoma, showing location of type section of Thatcher Creek Member (after Donovan and others, 1983).

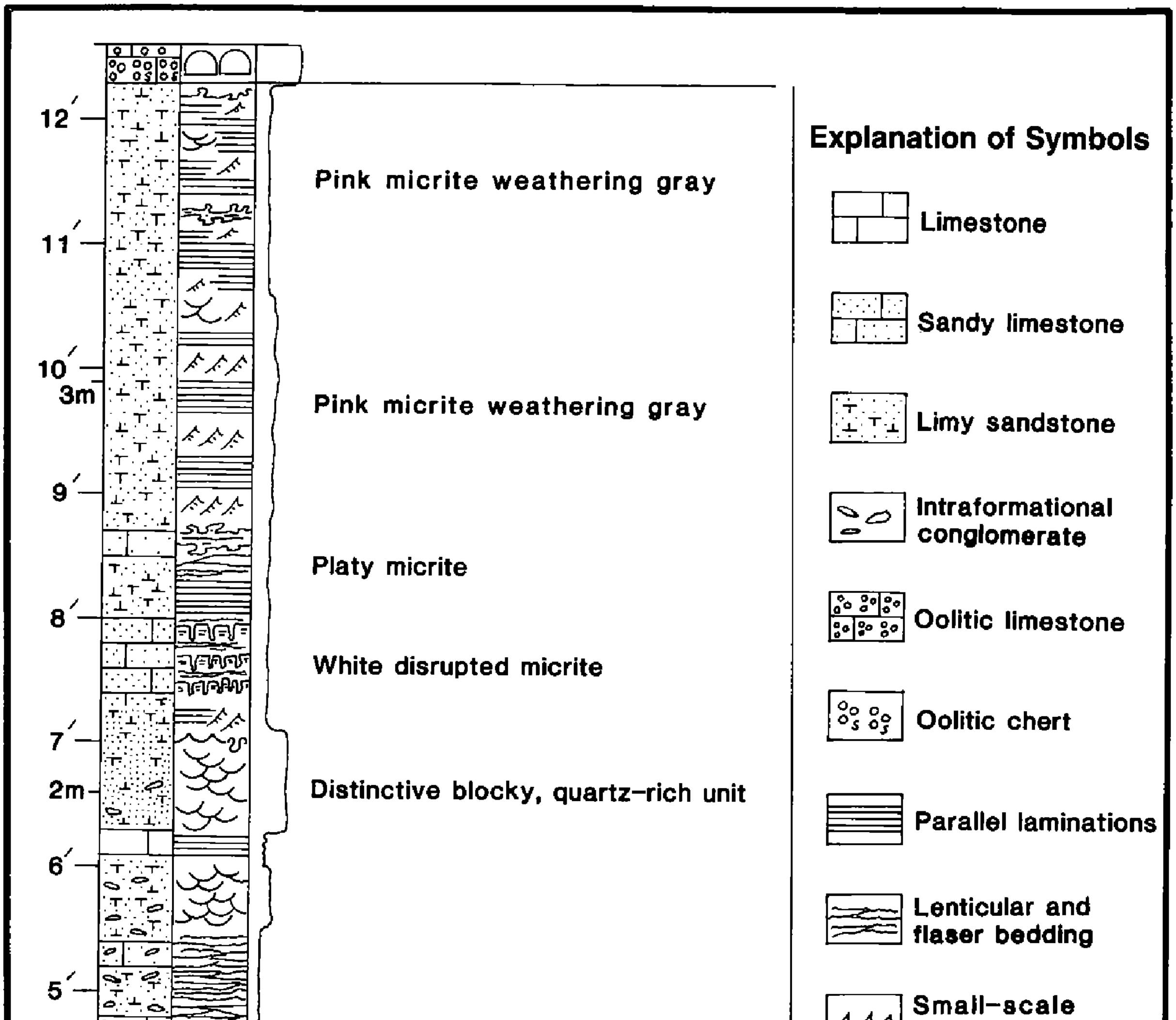


Figure 2. Type section of Thatcher Creek Member of the Cool Creek Formation as measured in Blue Creek Canyon, Comanche County, Oklahoma.

medium scale) with some bioturbation. Bioturbation is particularly apparent in thin (about 1 cm) interbeds of micrite.

Massive algal mounds form a resistant ledge above the Thatcher Creek Member. Although quartz sand is common throughout the Cool Creek Formation, no limy sandstone is as distinctive as the basal unit.

Regional Correlation

The Slick Hills can be divided into two structural blocks on either side of the Blue Creek Canyon Fault (Donovan, 1982). The type section is located in the southern block (the "Lawtonka graben" of Harlton, 1972). Throughout this block the character of the Thatcher Creek Member is remarkably consistent, although individual units of sandstone are rarely traceable for more than 200 m (600 ft). In some areas, subaerial mud cracks are present. In addition, several surfaces of subaqueous shrinkage cracks (Donovan and Foster, 1972) have been noted. In two or three small areas the member has been more or less completely dolomitized; this dolomite is late diagenetic and apparently related to high-angle reverse faulting.

In the northern structural block (the "Blue Creek horst" of Harlton, 1972) the member is somewhat thinner but otherwise similar to the type section. Toward the northwest, thin algal boundstones are intercalated among the clastic layers.

The type section of the Cool Creek Formation is along Route 77 in the Arbuckle Mountains (Ulrich, 1933). Unfortunately, the quality of exposure here is poor, and the contact between the McKenzie Hill and Cool Creek Formations is covered. The contact is well exposed, however, 100 yards (91 m) due south of the observation point at Turner Falls. The basal strata in the Cool Creek Formation are closely comparable to those in the Wichitas, and the Thatcher Creek Member can easily be recognized. The member is about 2 m (6 ft) thick and has weathered to form the characteristic gully. As at Blue Creek Canyon, the greatest concentration of quartz is found in the middle part of the member. All the sedimentary characteristics present in the Wichita area are represented here. The principal difference is that the amount of quartz present is greater than that found in the Wichita area. Indeed, the whole Cool Creek Formation in the Arbuckle Mountains area appears to be richer in quartz. This suggests that the source of siliciclastics lay generally to the east. Support for this suggestion is provided by the fact that the stratigraphically equivalent Roubidoux Formation of eastern Oklahoma, Missouri, and Arkansas is a dominantly siliciclastic unit.

Depositional Environment of the Thatcher Creek Member

The influx of coarse siliciclastic sands first recorded in the Thatcher Creek Member is an event of regional significance. The upper McKenzie Hill Formation is dominated by relatively thick-bedded algal boundstones that record an essentially static shallow-water-carbonate environment. At the beginning of Cool Creek time a major but distant uplift (north and east of the Slick Hills, on the evidence of crossbedding readings) led to the burial of the McKenzie Hill algal mounds by mobile mixed siliciclastic and carbonate sands. Initial transport of these sands was as small subaqueous sand waves, no taller than 15 cm (6 in.), in small, sluggish channels. Much of the sediment was reworked by wave action, as evidenced by symmetrical ripple marks with internal geometries characteristic of oscillating water. The relatively high energy of this environment coupled with the large clastic input inhibited the growth of algal colonies. Periodic desiccation is indicated by subaerial mud cracks. Subaqueous shrinkage cracks suggest fluctuating salinities and hint at the existence of brackish pools in which mud settled from suspension as salinity gradually increased. Though no body fossils have been found in the quartz sands, several layers have been bioturbated. Horizontal burrows of *Cruziana* type are found on the surfaces of ripple marks. Other disrupted layers in the member may have been due in part to vertical burrowing. In summary, the Thatcher Creek Member exhibits the hallmarks of a high intertidal or supratidal environment with substantial sediment input from the hinterland.

Thatcher Creek–type conditions terminated when the formation of algal boundstones resumed, probably in response to an overall increase in water depth. Similar units to the Thatcher Creek Member occur at several points throughout the upper Arbuckle Group. However, none of these units is as prominent or well developed as the Thatcher Creek Member.

Acknowledgments

It is a pleasure to acknowledge financial support from the Oklahoma Geological Survey and Sun Exploration and Production Co.

References Cited

Babaei, A., 1980, The structural geology of part of the limestone hills in the Wichita Mountains, Caddo and Comanche Counties, Oklahoma: Oklahoma State University unpublished M.S. thesis, 63 p.

Barthelman, W. B., 1969, Upper Arbuckle (Ordovician) outcrops in the Unap Mountain–Saddle Mountain area, northeastern Wichita Mountains, Oklahoma: University of Oklahoma unpublished M.S. thesis, 67 p.

Beauchamp, W. H., 1983, The structural geology of the southern Slick Hills, Oklahoma: Oklahoma State University unpublished M.S. thesis, 119 p.

Brookby, H. E., 1969, Upper Arbuckle (Ordovician) outcrops in the Richards Spur–Kindblade Ranch area, northeastern Wichita Mountains, Oklahoma: University of Oklahoma unpublished M.S. thesis, 73 p.

Chase, G. W., Frederickson, E. A., and Ham, W. E., 1956, Résumé of the geology of the Wichita Mountains, Oklahoma, *in* Hicks, I. C., Westheimer, Jerome, Tomlinson, C. W., Putman, D. M., and Selk, E. L., editors, Petroleum geology of southern Oklahoma: American Association of Petroleum Geologists, v. 1, p. 36–55.

Decker, C. E., 1939, Two lower Paleozoic groups, Arbuckle and Wichita Mountains, Oklahoma: Geological Society of America Bulletin, v. 50, p. 1311–1322.
Donovan, R. N., 1982, Geology of Blue Creek Canyon, Wichita Mountains area, *in* Gilbert, M. C., and Donovan, R. N., editors, Geology of the eastern Wichita Mountains, southwestern Oklahoma: Oklahoma Geological Survey Guidebook 21, p. 65–77.
Donovan, R. N., editor, 1983, The geology of the Blue Creek Canyon area in the Slick Hills of southwestern Oklahoma: Oklahoma State University, School of Geology, Special Publication, 79 p.
Donovan, R. N., and Foster, R. J., 1972, Subaqueous shrinkage cracks from the Caithness Flagstone Series (Middle Devonian) of northeast Scotland: Journal of Sedimentary Petrology, v. 42, p. 309–317.
Gilbert, M. C., and Donovan, R. N., 1984, Recent developments in the Wichita Mountains: Field Trip Guidebook for Geological Society of America, South-Central Section, 101 p.
Harlton, B. H., 1972, Faulted fold belts of southern Anadarko basin adjacent to frontal Wichitas: American Association of Petroleum Geologists Bulletin, v. 56, p. 1544–1551.
McConnell, D., 1983, The mapping and interpretation of the structure of the northern Slick Hills, southwestern Oklahoma: Oklahoma State University unpublished M.S. thesis, 131 p.
Ragland, D. A., 1983, Sedimentary geology of the Ordovician Cool Creek Formation as it is exposed in the Wichita Mountains of southwestern Oklahoma: Oklahoma State University unpublished M.S. thesis, 170 p.
Ulrich, E. O., 1933, Simpson group of Oklahoma: Geological Society of America Bulletin, v. 44, p. 105–106.

THE DUAL HISTORY OF FORT GIBSON, OKLAHOMA

Rick L. Darr[1] and Royal H. Mapes[1]

The Fort Gibson Military Park in northeastern Oklahoma exhibits an unusual dual history. Not only does it have a diverse military history—from construction, to abandonment, to reconstruction—but also another history within the stones used in the construction.

Fort Gibson, established in 1824, is located at the confluence of the Verdigris, Grand, and Arkansas Rivers. The fort was built by the United States Army (Colonel Matthew Arbuckle and five companies of the Seventh Infantry) after the Osage Indians, under the leadership of Mad Buffalo, massacred a party of fur trappers to the south on the Blue River, in November of 1823. After the Indian Removal Act of 1830 and the relocation of southeastern United States Indians into present-day Oklahoma, the fort became the headquarters of the Army's Department of the Southwestern Frontier. Upon completion of relocation of the tribes, the fort was turned over to the Cherokees in 1857. Fort Gibson was retaken from the Cherokees by Union troops in 1863 and held throughout the Civil War. The fort was abandoned in August 1890.

Reconstruction of the fort (an exact duplicate of the original fort) was controlled by the Work Projects Administration (W.P.A.) and the State of Oklahoma in 1935–36. The original fort construction used sandstone obtained from a quarry 2.4 km (1.5 mi) northeast of the fort. The sandstone used in the reconstruction came from the original quarry and from Braggs Mountain, located approximately 11.3 km (7.0 mi) south of the fort (Q. B. Boydstun, 1984 personal communication).

The quartz sandstone used in the construction is fine grained with ripple marks and crossbedding; fossils are only sparsely present with bioturbation (burrows, feeding traces, and trails) being the most common. Invertebrate fossil skeletons, including ammonoid cephalopods, crinoids, and bivalves, are preserved in isolated pockets as molds and casts with all original shell material having been destroyed by dissolution (fig. 1).

The ammonoids provide the best biostratigraphic key for determining the age of the sandstone used in the construction. Two genera, *Gastrioceras* and *Phaneroceras*, are present in the floor stones of the barracks, which were totally rebuilt during the reconstruction phase. The specimens are not sufficiently well preserved for species identification. These taxa occur in other places in Oklahoma and Arkansas. The presently known stratigraphic range for these taxa is from Lower Pennsylvanian (Saunders and others, 1977) to Middle Pennsylvanian (Plummer and Scott, 1938). Oakes (1977), in

[1]Department of Geological Sciences, Ohio University, Athens, OH 45701.

Figure 1. The internal molds of two ammonoids identified as *Phaneroceras* sp. in an isolated pocket exposed in a quartz sandstone in the floor of the barracks at the reconstructed fort at Fort Gibson, Oklahoma.

his mapping of Muskogee County, indicates that both of the quarries yielded their stones from Atokan age strata, the Atokan being between the Morrowan and Desmoinesian. Other Atokan ammonoids have also been reported in Oklahoma by Unklesbay (1962).

It is not precisely known which quarry yielded the ammonoids. Examination of all the exposed blocks of sandstone in still-standing buildings from the original fort yielded no evidence of fossils; these building stones presumably came from the original quarry. Therefore it is probable that the fossil-bearing sandstone in the barracks floor is from the quarry 11.3 km (7.0 mi) to the south on Braggs Mountain.

Even though Fort Gibson has an important military history, the fossils provide information on a much older aspect of Oklahoma that is often overlooked by the casual visitor to the fort. The fossils tell us that about 350 million years ago the area around the fort was a warm, shallow sea with marine life. The Atokan-age sandstone containing the fossils may have been a beach- or delta-related environment where the skeletons of the dead animals were deposited.

Acknowledgments

We would like to acknowledge Q. B. Boydstun, chair of the Old Fort Gibson Commission, Fort Gibson, Oklahoma, for his assistance in locating the quarries. Don Westfall, curator of the fort, was also extremely helpful with the general historical information. We would also like to thank Dr. W. B. Saunders, Bryn Mawr College, for bringing the fossils to our attention. Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for the support of this research (PRF No. 15821-AC2).

References Cited

Oakes, M. C., 1977, Geology and mineral resources (exclusive of petroleum) of Muskogee County, Oklahoma: Oklahoma Geological Survey Bulletin 122, 78 p., 2 pls.

Plummer, F. B., and Scott, Gayle, 1938, New Pennsylvanian ammonoid fauna from the Millsap Lake formation (Strawn group) of Texas [abstract]: Geological Society of America Bulletin, v. 49, p. 1919–1920.

Saunders, W. B., Manger, W. L., and Gordon, Mackenzie, Jr., 1977, Upper Mississippian and Lower and Middle Pennsylvanian ammonoid biostratigraphy of northern Arkansas, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian–Morrowan stratigraphy and the Mississippian–Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 117-137, 6 pls.

Unklesbay, A. G., 1962, Pennsylvanian cephalopods of Oklahoma: Oklahoma Geological Survey Bulletin 96, 150 p., 19 pls.

WESTERN INTERIOR COAL BASIN FORUM HELD IN LAWRENCE, KANSAS

Five geologists from the Oklahoma Geological Survey met at the ninth forum of coal geologists of the Western Interior Coal Basin with nine geologists from the Kansas, Missouri, and Iowa geological surveys and one U.S. Geological Survey hydrologist based in Kansas. The one-day meeting, which was held in Lawrence, Kansas, was followed by a field trip to two strip mines at Pittsburg, Kansas.

William W. Hambleton, director of the Kansas Geological Survey, welcomed the group to the new KGS wing on April 2. During the morning session a representative from each state presented data on the coal industry in his state. This information is summarized as follows.

Fourteen coal companies in Missouri produced 6.8 million tons of coal in 1984, for a new record high and a 23% increase over 1983. Twenty-three Oklahoma companies produced 4.3 million tons of coal from 37 mines in 1984; this represents a 14% increase over 1983. Six companies in Kansas produced 1.3 million tons of coal in 1984, the same quantity as in 1983. In Iowa an estimated 560,000 tons was produced in 1984 from four surface mines and one underground mine, representing a probable 35% increase in production over 1983. In 1985 more coal probably will be produced in each of these states than in 1984, even though the Kansas City Power & Light utility is changing to subbituminous coal shipped from Wyoming.

That afternoon the group discussed geologic coal research and funding, learning that funding from the USGS was drawing to a close in a year or so for states other than Oklahoma.

Joy Bostic and Larry Nuelle reported on research and mapping in Missouri, stating that coal data have been entered into the NCRDS (National Coal Resources Data System) of the USGS but that there were complaints related to using the system and that the system at the federal level often was inaccessible. They said that coal reserves were currently being mapped and determined in one Missouri county. They distributed a report presenting results of research sponsored by the Missouri Geological Survey on desulfurization of coal through beneficiation, combustion with lime, and geologic modeling. Field studies in Cedar, Dade, and Barton Counties delineated resources of low-sulfur coal in the Riverton Formation, Atokan Series.

Lawrence Brady and his student assistants reported progress on a major project in Osage County, Kansas, on the Nodaway coal bed. This bed is 10 to 18 in. thick, ranging up to 36 in. thick where it was mined, and it contains 6–8% sulfur, 10% ash, and about 11,000 Btu. Also, 408 underground and surface mines produced 12 million tons of coal from 1869 to 1890, making Osage County fifth in coal production in Kansas.

Work continues on deep-coal investigations east of the Nemaha Ridge. The eastern part of the Sedgwick Basin contains mainly nonmarine clastics, and west of this area the section is marine in origin. The Kansas Survey has its own computer system for entering and plotting coal data.

Mary Howes reported on coal research in Iowa. Old and new coal-company data were used in the NCRDS project. Two 1984 publications were distributed at the meeting: Iowa Geological Survey Technical Paper 5 by Hatch, Avcin, and Van Dorpe on *Element Geochemistry of Cherokee Group Coals,* and Iowa Geological Survey Technical Information Series 12 by Ravn, Swade, Howes, and others on *Revision of Pennsylvanian Stratigraphic Nomenclature.* The Black Oak and Cliffland coals, in the lower part of the Cherokee Group, contain the major part of Iowa's coal resources. The Laddsdale coal zone contains five coal beds, underlies the Seville Limestone, and is mined in all four active mines in Iowa. The Whitebreast coal (=Croweburg coal in Oklahoma) lies at the base of the Swede Hollow Formation and is overlain by the Ardmore Limestone (=Verdigris Limestone in Oklahoma). The Mulby coal is as much as 7 in. thick and is overlain by the Excello Shale; the contact between the two units represents the base of the Marmaton and the top of the Cherokee Groups.

Brian J. Cardott, Laurie A. Warren, LeRoy A. Hemish, and Samuel A. Friedman reported on coal research in Oklahoma. An introduction and summary were given by Friedman.

Cardott presented slides representing samples of coal from 19 localities on which 27 petrographic analyses were performed. Vitrinite was the dominant maceral in the samples, ranging from 67.5 to 85.1%, as shown by reflected white-light technique. Vitrinite reflectance ranges from 0.56 to 1.39%, as coal rank ranges from hvCb to mvb coal. These analyses were performed on 12 named coal beds.

Warren presented a brief report on the status of the Oklahoma Geological Survey–NCRDS coal-data computerization program. Data forms have been prepared for 770 measured stratigraphic sections in areas covered by seven topographic quadrangles in Craig County. These coal and lithologic data were derived from coal-company records and Oklahoma Survey records in the form of mine maps, logs, road cuts, and mine cuts.

Hemish reported on the structure and correlation of the Eram coal in Okmulgee County. Detailed cross sections and structure maps provided the basis for an interpretation which concludes that normal faults extend from the Seneca Fault zone southwestward from Rogers County into Wagoner and Okmulgee Counties, where these faults show as much as 300 ft of throw. This indicates that the Eram coal is equivalent to the Morris coal, which had already been correlated with the Mineral coal of Craig and Rogers Counties. Thus, the Eram coal is correlated with the Mineral coal.

Friedman described a project on the geology, coal resources, and mined areas in the Hartshorne–Gowen area, Latimer County. The Hartshorne Sandstone is 200 ft thick in this area; 60 ft of this sandstone overlies the

Lower Hartshorne coal at most places. The Upper Hartshorne coal is mostly absent because of nondeposition on the positive parts of an ancient deltaic–alluvial plain. The Lower Hartshorne coal is 2 to 4.5 ft thick and is hvBb in rank. One strip mine is currently operating, although most past mining was done by underground methods.

The following day Lawrence Brady led a field trip from Lawrence to Pittsburg, Kansas, where we visited and observed the geology at the Clemens Coal Co. Mine No. 22 and The Alternate Fuels Co.'s Croweburg Mine. At the Croweburg Mine we observed five coal beds in two pits—the Mulky, Bevier, Croweburg, Fleming, and Mineral, in descending order. The vertical stratigraphic sequence embracing the five coals is about 60–70 ft thick. Only the Croweburg and Mineral coals were regularly recovered; the others were or could be recovered in places where they were at least 8–10 in. thick.

We observed extensively reclaimed areas adjacent to the active mines, and Brady reported that state and federal inspectors were working smoothly with the mine operators. The sulfur content of these coals is more than 3%.

The 10th forum of coal geologists of the Western Interior Coal Basin is scheduled to meet in Norman, Oklahoma, next April. Samuel Friedman will coordinate the activities and logistics of the informal meeting.

Samuel A. Friedman

WATER WELL GROUP SCHEDULES SHORT COURSE ON GROUND WATER

The National Water Well Association has scheduled November 4–6 as the dates for a short course on ground water and water-well technology. The course is targeted to new members of the water-well industry to provide an orientation on ground water and well technology. Other groups considered in the development of this program were salesmen, upper echelon executives, and engineers who would like to better understand the newest technology and exchange ideas with the technical staff of the National Water Well Association.

Monday's schedule includes sessions on topics such as basic geology, hydrogeology, the driller as your customer, and ground-water source heatpumps. Tuesday sessions include water-well-drilling technology, well completions, unconsolidated well design, rock well design, and ground-water contamination and aquifer restoration. The final day of meetings will examine mathematical ground-water models, exploring for ground water, borehole geophysics, domestic water systems, rehabilitating water wells, map reading, and a final discussion and awarding of certificates.

The registration fee is $390, and must be received two weeks prior to the date of the course. For information about this or other programs, contact the National Water Well Association, 500 West Wilson Bridge Road, Worthington, OH 43085.

WELL COMPLETIONS RANK OKLAHOMA SECOND IN NATION AGAIN

For the 11th consecutive year, Oklahoma maintained its position in 1984 as the second most active drilling state in the nation, based upon reported well completions.

More wells were completed in Texas than in any other state, with Kansas in third place, according to figures from the American Petroleum Institute and Denver-based Petroleum Information Corp.

Meanwhile, rotary drilling rig activity in Oklahoma declined to a six-year low in March this year, and Oklahoma leaders are warning that federal tax law changes proposed by the Treasury Department would bring about a significant drop in drilling and petroleum production.

Statistics from Petroleum Information showed drilling completions up in Oklahoma last year by 1% over the previous year, making 1984 the third best year in Oklahoma's drilling history, with 10,053 wells completed as compared with 9,950 in 1983. API, using slightly different reporting procedures, showed 1984 as Oklahoma's fourth best year, with a 1.5% decline in completions, from 10,043 wells in 1983 to 9,887 last year.

The record year was 1982, when the API reported 12,008 wells completed in Oklahoma, surpassing the previous record year of 1981, in which 11,329 were completed.

Because of a time lag in reporting, completion totals do not accurately reflect the drilling rig activity during the same time period.

Less encouraging in 1984 were API figures showing 16.7% fewer exploratory wells completed than the year before, dropping from 647 to 539. The percentage of exploratory wells also declined, falling from 6.44% of all wells completed in 1983 to 5.45% of last year's total wells of all types.

There was also a 5.62% drop in total depth of all wells completed in Oklahoma last year, to 46 million ft from the previous year's 48.7 million ft. The footage of exploratory wells declined much more, amounting last year to nearly one-third less than in 1983.

The breakdown on 1984 total wells shows that oil wells accounted for 53.2% of all completions and gas wells 18.4%, with 27.8% of all wells proving to be dry holes. Other wells reported were service wells, stratigraphic and core tests, according to the API.

Petroleum Information estimated that the daily average production of crude oil in Oklahoma increased by 4.3% last year over that of the previous year, while natural gas production showed an even larger increase of 7.2%.

Oklahoma ranked third in total expenditures for drilling and completing wells last year, according to PI estimates, with a substantial decline from the 1983 total due to lower footage costs for drilling, as well as less deep drilling activity in the Anadarko Basin of western Oklahoma, brought about by the gas deliverability surplus.

The conclusion to be drawn from these reports is that although Oklahoma ranks near the top as a drilling state, with oil and gas production increasing, there is an imperative need for more exploratory drilling. It is important for the nation to provide incentives for domestic activity, rather than to adopt tax law changes that would discourage drilling and curtail petroleum production.

Victor E. Bartlett, Chairman of the Board
Oklahoma-Kansas Oil & Gas Association

SME–AIME MINING EXHIBIT PLANNED

A Technological Information Exchange Exhibition is scheduled in conjunction with the 1985 Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) Fall Meeting, October 16–18, at the Albuquerque Convention Center in Albuquerque, New Mexico.

More than 2,000 representatives from the mining and minerals industries are expected to attend the meeting. Programs, equipment, and services displayed by manufacturers, consulting firms, government bureaus, and educational institutions reflect many of the technical session subjects that will be discussed at the meeting.

In addition to the exhibit, a number of technical sessions, short courses, symposia, field trips, and social events also are scheduled.

For further information on either the exhibit or the meeting, contact the Meetings Dept., Society of Mining Engineers, Caller No. D, Littleton, CO 80127.

MINING HEALTH AND SAFETY TOPIC OF SME–AIME ANNUAL MEETING

The Engineering Health and Safety in Coal Mining Symposium will be held March 2–6, 1986, at the Hilton Hotel in New Orleans, Louisiana. The objective of the two-day symposium is to review health and safety applications in coal mining.

The symposium is part of the Annual Meeting scheduled for the Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers (SME–AIME).

About 20 papers are planned for presentation. Session topics include human factors, health effects and accident analysis, geomechanical aspects, and environmental facets. Human factors, health effects and accident analysis sessions will be held on the first day with the remaining two sessions presented on the second day.

Printed copies of the proceedings will be available at the meeting. Registration for the meeting includes admittance to the symposium.

For further information contact the Meetings Dept., Society of Mining Engineers, Caller No. D, Littleton, CO 80127.

OKLAHOMA'S WATER-INFORMATION NEEDS DISCUSSED AT RECENT OKC CONFERENCE

The collection and dissemination of more complete and accurate data regarding water use, abuse, availability, and quality were the primary concerns expressed by those attending a conference on water-information needs for Oklahoma, held March 13 in Oklahoma City. Approximately 100 representatives of various federal, State, and municipal agencies were present at the one-day conference, sponsored by the U.S. Geological Survey, Water Resources Division.

James H. Irwin, Oklahoma district chief of the USGS Water Resources Division, stated that the purpose of the conference was to consider specific water issues and to determine what kinds of information need to be collected and shared. Currently some of the major water problems in Oklahoma include distribution of water resources from areas with more water to those with less, the effect of urbanization on water quality, scenic-river pollution, hazardous-waste disposal, and the potential for ground-water pollution associated with coal mining and oil and gas production.

While many agencies nationwide are responsible for gathering information on water supply and quality, a centralized, computerized data bank is desirable. Irwin told the group about the National Water Data Exchange (NAWDEX), a USGS program that provides information on the location and types of water-resource data collected by these agencies. The service is available to anyone involved in water-resources management, regulation, or research.

Some of the federally funded projects under way in Oklahoma at present include research on the effects of coal mining on ground water in eastern Oklahoma, an investigation of the limnology in coal-mining areas, predictive models of ground-water supply, a study of the geochemistry of the Tar Creek lead–zinc mine waters because of the concern for polluting the underlying Roubidoux aquifer, and analyses of regional aquifers and flow systems, Irwin related. The USGS has just released a report entitled *Oklahoma—A Summary of Activities of the U.S. Geological Survey Water Resources Division for 1985*, which outlines all current projects. The 129-page book also includes a list of the Oklahoma reports published by the USGS. The book can be obtained free of charge from the U.S. Geological Survey, Water Resources Division, Room 621, Old Post Office Building, 215 Dean A. McGee Avenue, Oklahoma City, OK 73102; telephone (405) 231-4256.

James Schuelein, chief of the Oklahoma Water Resources Board's Administrative Division, said the National Water-Use Information Program of the USGS and OWRB is designed to collect, analyze, store, and disseminate water-use data both nationally and locally. Begun in 1978, the program has helped to standardize collection of water-use information from state to state.

Kenneth S. Johnson, associate director of the Oklahoma Geological Survey, said that immediate water-information needs for Oklahoma include a database on precipitation, runoff, evapotranspiration, and such surface-water data as stream-discharge rates and flood-stage projections. Since 95% of the State's usable water is underground, additional ground-water information is extremely important.

Johnson reported that more data are needed to deal with the natural contamination of water in Oklahoma (such as those pertaining to chloride-control measures on rivers and desalination) and the natural inequities of water in Oklahoma (such as the feasibility of transferring water from the eastern to the drier western part of the State). A cost/benefit analysis indicates that desalination and water transfer would be impractical at present; however, these projects may become feasible solutions in the future. Data are sorely needed on man-made contamination of the State's surface- and ground-water systems caused by waste disposal and petroleum, mining, and agricultural activities, as well as information regarding measures for cleanup programs, Johnson said. Johnson believes Oklahoma's future resource development will depend on (1) the availability of sufficient amounts of good-quality water, (2) the nature of the demand for water as determined by population and industrial and agricultural growth, and (3) the economics of water delivery. He said it is also important to look at the environmental cost related to our need for water.

During a panel discussion of surface-water-information needs, Judy Duncan, chief of the State Environmental Laboratory Service, Oklahoma Department of Health, explained how the laboratory monitors municipal waste-water systems. She said that the data resulting from these investigations, as well as laboratory services, are available to other agencies. Duncan said there is a continuing need for quality flow data, information on toxic and municipal discharges, and more monitoring of dissolved-oxygen-level data to protect the State's fish and wildlife population.

Kenneth Crawford, a representative from the National Weather Service, announced that Digital Radar Data (RADAP), which estimates rainfall on the Earth's surface, is now available at no cost. Another service being developed by the National Weather Service is Next Generation Weather Radar (NEXRAD), which will allow these data to be used nationwide to manage water supplies. NEXRAD will be available in the late 1980's.

During a panel discussion of ground-water-information needs, Oleta Rodgers, executive director of the Northern Oklahoma Development Association in Enid, said that there should be a statewide concern for the contamination of ground water, crop and range land, and drinking water from salt-water injection wells. She pointed out that while the oil industry has done good things for the State's economy, energy-related activities have also caused major ground-water problems. Rodgers said that at least seven State agencies are involved in the monitoring of water resources, and she thinks that the present system is too fragmented.

Many of those at the conference saw a need for the public to be made more aware of the seriousness of ground-water issues and a need for more legislation and research to protect these resources for the future of Oklahoma.

Christie Cooper

NOTES ON NEW PUBLICATIONS

Annual Review of Earth and Planetary Sciences, Volume 13

Contents of this 436-page volume, edited by George W. Wetherill, include revolutions in the earth sciences, patterns of alluvial rivers, the Appalachian–Ouachita connection, direct TEM imaging of complex structures and defects in silicates, amino-acid racemization dating of fossil bones, downhole geophysical logging, and the Midcontinent Rift System. The book also includes a subject index and cumulative indexes of contributing authors and chapter titles.

Order from: Annual Reviews, Inc., 4139 El Camino Way, Palo Alto, CA 94306. The price is $44 in the U.S.A., $47 elsewhere, postpaid.

Annual Review of Energy, Volume 9

Chapters on energy storage, environmental standards and national energy policies, an update on econometric studies of energy-demand behavior, the trend of structural change in the international oil industry in the 1980's, and oil-export policy and economic development in OPEC are among those included in this 577-page volume edited by Jack M. Hollander.

Order from: Annual Reviews, Inc., 4139 El Camino Way, Palo Alto, CA 94306. The price is $56 in the U.S.A., $59 elsewhere, postpaid.

Biogenic Structures: Their Use in Interpreting Depositional Environments

Edited by H. Allen Curran, this collection of 19 papers was developed from an SEPM symposium on biogenic structures held in 1980. Each paper presents a case-book example of the use of biogenic structures or trace fossils as an aid to the interpretation of the depositional environment of the surrounding sediments. The papers cover a wide range of environments from nonmarine to deep-sea settings with ages from Cambrian to Holocene. The illustrated, 364-page volume should be helpful to sedimentologists, paleontologists, and stratigraphers interested in and involved with the interpretation of depositional environments through the use of sedimentary structures.

Order from: SEPM, P.O. Box 4756, Tulsa, OK 74159. The price is $29 for SEPM/AAPG members, $36 for nonmembers. Oklahoma residents must add sales tax: 6% for those living in Tulsa, 3% elsewhere in Oklahoma.

Carbonate Cements

Edited by Nahum Schneidermann and Paul M. Harris, this illustrated, 408-page volume stresses recent developments in the study of modern marine and fresh-water cements, their ancient analogues, and proposed relationships to burial conditions.

In the first of four sections, authors review geochemical and geologic constraints on cement mineralogy, morphology, and distribution through geologic time. In the second section, early stable and metastable marine cements from a diverse group of environments and geologic ages are discussed. In the third part, examples of integrated geochemical and petrographic studies on regional distribution of burial cements are presented. Finally, examples of fresh-water cements, representing either the beginning or end of the carbonate diagenetic cycle, are shown. Several of the 21 papers explore the timing and sequence of cement precipitation as part of integrated regional and burial studies of producing carbonate reservoirs.

Order from: SEPM, P.O. Box 4756, Tulsa, OK 74159. The price is $29 for SEPM/AAPG members, $36 for nonmembers. Oklahoma residents must add sales tax: 6% for those living in Tulsa, 3% elsewhere in Oklahoma.

Atlas of Sedimentary Rocks Under the Microscope

This new atlas by A. E. Adams, W. S. MacKenzie, and C. Guilford is a laboratory tool for studying sedimentary rocks in thin sections. More than 210 color photographs illustrate thin sections of sedimentary rocks representative of those found worldwide. Requiring only a basic knowledge of mineralogy and paleontology, the 104-page book covers terrigenous clastic rocks, concentrating on sandstones, and shows carbonate rocks and the range of bioclast types. Also illustrated are ironstones, cherts, evaporites, phosphorites, and carbonaceous rocks in thin sections. Appendixes detail how to make a thin section, stain thin sections of limestones, and make acetate peels.

Order from: John Wiley & Sons, Inc., One Wiley Drive, Somerset, NJ 08873. The price is $24.95 plus local sales tax and postage and handling.

Petroleum Formation and Occurrence, Second Edition

The second edition of this work by B. P. Tissot and D. H. Welte has been expanded to include completely new chapters on gas, heavy oils and tar sands, distribution of world petroleum reserves, case histories on habitat of petroleum, and geological and geochemical modeling. Other chapters have been enlarged and updated, such as those on geochemical fossils, biological markers, primary migration, asphaltenes and resins, coal as a possible source rock, and oil–source-rock correlations. The 699-page book contains 327 illustrations and more than 270 new references.

Order from: Springer-Verlag New York, Inc., P.O. Box 2485, Secaucus, NJ 07094. The price is $44.50 plus $1.50 to cover shipping. New York and New Jersey residents must add sales tax.

Carbonate Petroleum Reservoirs

This 624-page book presents 35 detailed case studies involving 41 carbonate oil and gas reservoirs. The studies document the salient aspects of reservoir origin and character. The book contains 266 illustrations and covers a range of geologic histories, properties, and production characteristics. To help the reader gain quick access to this information, editors Perry O. Roehl and Philip W. Choquette have included an introductory overview, reservoir summaries, and a glossary of terms.

Order from: Springer-Verlag New York, Inc., P.O. Box 2485, Secaucus, NJ 07094. The price is $59 plus $1.50 to cover shipping. New York and New Jersey residents must add sales tax.

Man-Induced Land Subsidence

Land subsidence has been caused by man in at least 37 states of the U.S.A. It affects an aggregate area of more than 40,000 km^2 and may cost the nation as much as $100 million annually, according to editor Thomas L. Holzer. This 231-page GSA Review in Engineering Geology includes nine papers in three categories: (1) fluid withdrawal from porous media, (2) drainage of organic soil, and (3) collapse into man-made and natural cavities.

Order from: GSA Publication Sales, P.O. Box 9140, Boulder, CO 80301. The price is $28. Colorado residents must add sales tax.

Coalbed Methane Resources of the United States

Edited by Craig T. Rightmire, Greg E. Eddy, and James N. Kirr, this volume is a collection of 15 papers, 13 of which are detailed reports assessing the coal-bed methane resources of selected U.S. sedimentary basins. Contained are statistics of volumetric methane generation and Btu ratings of methane resources found as such across the United States.

Order from: AAPG Bookstore, P.O. Box 979, Tulsa, OK 74101. The price is $28 for AAPG members, $34 for nonmembers, plus $4.50 for fourth-class shipping to addresses in North America. Oklahoma residents must add 6% sales tax.

Geologic World Atlas

This large-format atlas, completed in 1984, is designed to cover the world's geology with 22 sheets. All sheets are complete and housed in a binder which can be opened to allow removal of selected sheets or addition of related sheets, if needed. Sheets include a general explanation with text, North America, South America, Africa, Europe, Asia, South-East Asia, Australia, Antarctica, Antarctic Ocean, Arctic Region, Pacific Ocean, Indian Ocean, and Atlantic Ocean. Continental sheets are drafted at a scale of 1:10 million; other sheets may vary. The introductory text and the explanatory text that accompanies each mapping region are printed in both English and French.

Order from: AAPG Bookstore, P.O. Box 979, Tulsa, OK 74101. The price is $245 plus $12 for fourth-class shipping to addresses in North America. Oklahoma residents must add 6% sales tax.

Depositional Models of Shelf and Shoreline Sandstones

Author Thomas F. Moslow discusses methods of developing depositional and exploration models for sandstone reservoirs associated with one or more of a variety of shelf and shoreline settings. He explains how the careful use of sedimentologic and stratigraphic criteria—well logs, cores, outcrops, seismic methods, and structure maps—can more accurately predict the subsurface distribution and trend of reservoir-quality sandstones.

Moslow also covers the three-dimensional framework of modern clastic sedimentary environments, and he explains its effect on proper interpretation of vertical sequences, lateral facies relationships, sand-body geometries, and inhomogeneities of sandstone reservoirs.

Order from: AAPG Bookstore, P.O. Box 979, Tulsa, OK 74101. The price is $8 plus $1.50 for fourth-class shipping to addresses in North America. Oklahoma residents must add 6% sales tax.

Analyzing Your Logs, Volumes I and II

Author Jim Brock presents a double format in Volume I, which allows beginners to master the concepts of analysis while giving the more advanced analyst an opportunity for accurate, in-depth study. Volume I contains 260 pages and more than 100 illustrations. Contents include reservoir parameters, resistivity concepts, water saturation, spontaneous potential, shale crossplots, resistivity logs, induction logs, sonic logs, neutron/density logs, and gamma-ray logs.

Volume II (*Advanced Open Hole Log Interpretation*) resumes where Volume I ends, providing techniques for accurately evaluating gas zones, porosity crossplots for exact porosity computations, methods of shaly-sand interpretation, mineral identification plots, and how to extract the most information out of a wildcat situation. This book also contains information on state-of-the-art technology.

Log-analysis video cassettes are also available. Part 1 of the cassettes discusses the basics of log interpretation, Part 2 covers the intermediate aspects, and Part 3 compares the various techniques available.

Order from: Petro-Media, Inc., 1729 Rose Road, Tyler, TX 75701. The price of Volumes I and II is $32 each, or $53 per set. Texas residents must add $1.58 tax per book or $2.67 per set. The price of the video-tape course is $375 and includes free copies of both volumes. Texas residents must add $19.18 tax per tape set.

Mineral Industries of Europe and the U.S.S.R.

This 143-page Mineral Perspective report by the U.S. Bureau of Mines presents a summary review of the mineral industries of 26 European countries and the U.S.S.R. Mineral production, international mineral trade, and the role of minerals within each country and in terms of world supply are reviewed. The principal mining companies are listed, along with their locations and capacities. Basic information is presented on labor, energy, and infrastructure relative to the mineral industries. Maps for each country show the generalized locations of major mineral deposits, petroleum sources, and processing or refining plants. The maps also show major roads, railways, pipelines, and ports that are important to mineral transportation and trade.

Order GPO Stock No. 024-004-02139-0 from: Superintendent of Documents, Government Printing Office, Washington, DC 20402. The price is $5 postpaid; add 25% to the price for foreign shipment.

Estimate of Self-Supplied Domestic Water Use in Oklahoma During 1980

A limited number of copies of this 20-page USGS Water-Resources Investigations report by J. D. Stoner are available for free distribution from the U.S. Geological Survey, Water Resources Division, Room 621, Old Post Office Building, 215 Dean A. McGee Avenue, Oklahoma City, OK 73102; phone (405) 231-4256.

WRI 83–4223 can also be ordered from: Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225. The price is $3.50 for microfiche and $3 for a paper copy, postpaid; add 25% to the price for shipment outside the U.S.A. (except Canada and Mexico).

Hydrologic and Climatologic Data for the Lehigh Area, Southeastern Oklahoma, May 1977 to January 1982

This 213-page USGS Open-File report by S. P. Blumer and J. C. Scott is available free in limited quantities from the U.S. Geological Survey, Water Resources Division, Room 621, Old Post Office Building, 215 Dean A. McGee Avenue, Oklahoma City, OK 73102; phone (405) 231-4256.

OF 84–0599 can also be ordered from: Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225. The price is $3.50 for microfiche and $28.25 for a paper copy, postpaid; add 25% to the price for shipment outside the U.S.A. (except Canada and Mexico).

Time, Rocks, and the Rockies: A Geologic Guide to the Roads and Trails of Rocky Mountain National Park

This illustrated guidebook by Halka Chronic focuses on the roads and trails of Rocky Mountain National Park, pointing to the evidence of processes that have shaped the Rocky Mountains in the past and continue today.

Order from: Mountain Press Publishing Co., P.O. Box 2399, Missoula, MT 59806. The price is $7.95 plus $1 for postage.

OKLAHOMA ABSTRACTS

AAPG, Southwest Section, Convention
Fort Worth, Texas, February 24–26, 1985

The following abstract is reprinted from the *Bulletin* of the American Association of Petroleum Geologists, v. 69, no. 1. The page number is given in brackets below the abstract. Permission of the author and of the AAPG to reproduce the abstract is gratefully acknowledged.

Petroleum Source Rock Potential of Arbuckle and Ellenburger Groups, Oklahoma and North Texas

LYNN CARDWELL, Cardwell Exploration Co., Midland, TX

Oil and gas have been produced from the Cambro-Ordovician Arbuckle and Ellenburger Groups in Oklahoma and Texas for more than 50 years, but as yet no studies have addressed the question of petroleum source beds within these units. The solution of this problem is important in determining whether significant petroleum accumulations can be expected to be found deep within this thick and relatively unexplored section of carbonate rocks.

Detailed studies of the composition of oils produced from Arbuckle fields compared with those from Pennsylvanian fields show no discernible differences. These studies, which include determination of the composition of gasoline-range and C_{15+} saturate hydrocarbons and also saturate/aromatic/asphaltic ratios, strongly suggest that very similar source beds generated all the oils. Similar analyses of the bitumen present in nonreservoir Arbuckle and Ellenburger rocks show that very distinct differences exist between the oils and the rock bitumens. Arbuckle and Ellenburger rocks apparently were not the source beds for any of the oils investigated in this study.

Further studies of thermal maturity and organic richness of Arbuckle and Ellenburger rocks by use of pyrolysis–gas chromatographic methods reveal that this part of the section is thermally mature, and has generated at least some hydrocarbons; however, hydrocarbon and organic carbon contents are very low, indicating that commercially significant amounts of petro-

---

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

leum have not been generated or expelled. The lack of adequate amounts of organic matter is interpreted to be the reason that these rocks have not acted as significant petroleum sources. Based on this geochemical evidence, other, younger, rocks have generated the oils found in the Arbuckle and Ellenburger Groups. [142]

GSA, Northeastern Section, Annual Meeting Lancaster, Pennsylvania, March 13–16, 1985

The following abstract is reprinted from *Abstracts with Programs, 1985* of the Geological Society of America, v. 17, no. 1. The page number is given in brackets below the abstract. Permission of the author and of the GSA to reproduce the abstract is gratefully acknowledged.

A Re-evaluation of the Upper Middle Ordovician Graptolite Zonation of North America

STANLEY C. FINNEY, School of Geology, Oklahoma State University, Stillwater, OK 74078

The part of the North American graptolite zonation from high in the *gracilis* Zone to the *spiniferus* Zone is much disputed. In large part this is due to the poor quality of available sections in terms of structural complexity, stratigraphic continuity and extent, faunal diversity and abundance, and lithologies suitable for fossil preservation. Recently obtained collections from Maryland, Virginia, Kentucky, and Oklahoma also show that different zonations established for the *gracilis–spiniferus* Zone interval in large part reflect different biofacies.

The recognition of biofacies is based on newly discovered co-occurrences of selected index species. In the Big Fork Chert in the Ouachita Mountains of Oklahoma, *Climacograptus bicornis* occurs with *Corynoides americanus*, and *C. americanus* occurs with *Climacograptus spiniferus* in the Viola Springs [Formation] in the Arbuckle Mountains of Oklahoma. The ranges of these species overlap in ascending order from *bicornis* to *americanus* to *spiniferus*. The ranges of additional species used by others to establish several zones between the *bicornis* and *spiniferus* Zones (*Orthograptus ruedemanni* and *Climacograptus mohawkensis*) overlap the ranges of *C. bicornis* and *C. spiniferus* in the Big Fork Chert and in Virginia in the [Martinsburg] Formation. The occurrence of [*Diplograptus*] *liptotheca* with *C. typicalis* and *C. spiniferus* in the Lexington Limestone of Kentucky also indicates that the *spiniferus* Zone

follows closely upon the *bicornis* Zone. In Britain, it is restricted to the *multidens* Zone, which is largely equivalent to the North American *bicornis* Zone. *D. leptotheca* also occurs in a part of the Martinsburg Formation in Maryland that is considered by others to be below the *americanus* Zone. [19]

GSA, Southeastern Section, Annual Meeting Knoxville, Tennessee, March 20–22, 1985

The following abstracts are reprinted from *Abstracts with Programs, 1985* of the Geological Society of America, v. 17, no. 2. Page numbers are given in brackets below the abstracts. Permission of the authors and of the GSA to reproduce the abstracts is gratefully acknowledged.

Paleoenvironmental Distribution of Wenlockian (Silurian) Conodonts and Inarticulate Brachiopods, South-Central United States

JAMES E. BARRICK, Department of Geosciences, Texas Tech University, Lubbock, TX 79409; and BARBARA BIGGERS, Department of Geology, University of Kansas, Lawrence, KS 66045

In the south-central United States, Wenlockian conodont biofacies are distributed relative to paleoceanographic conditions that prevailed across a broad carbonate shelf. The transition from the *Dapsilodus* Biofacies, through the Mixed Biofacies, to the *Panderodus* Biofacies parallels that of a spectrum of lithofacies ranging from quiet-water, offshore wackestones to high energy, shallow water grainstones. The occurrence of conodont biofacies shows no specific correlation with lithofacies or other biofacies associations, but the biofacies are distributed stratigraphically and geographically relative to regional patterns in water depth or circulation.

Small phosphatic inarticulate brachiopods, recovered from conodont residues, show a strong substrate preference for quiet-water offshore mudstones and wackestones. *Artiotreta parva* is restricted to the offshore, mud-dominated environment. Species of *Opsiconidion*, although less abundant, are more widely distributed in mud-dominated environments.

Conodont biofacies, inarticulate brachiopods, and carbonate lithofacies record an abrupt major increase in water depth at the beginning of the Wenlockian. Later in the Wenlockian, faunal and lithic associations changed in response to shallowing water depth and the influx of fine terrigenous detritus. [79]

Conodont Biostratigraphy and Correlation of the Tyner Formation (Middle Ordovician), Eastern Oklahoma

JEFFREY A. BAUER, Department of Geology and Mineralogy, Ohio State University, Columbus, OH 43210

The Tyner Formation is part of a thin sequence of Ordovician rocks exposed along the southern flank of the Ozark Uplift in eastern Oklahoma. Until now, correlation of the Tyner has been mostly speculative due to the apparent absence of fossils. Conodonts, however, are present in large numbers in portions of the shale/dolostone unit.

Preliminary results of the conodont study of the Tyner show that despite its thin development (maximum of 27 meters near Tahlequah, OK), it is representative of sediment accumulation over a substantial amount of geologic time. The formation contains *Neomultioistodus–Paraprioniodus*, *Phragmodus–Plectodina*, and *Aphelognathus* conodont associations successively from base to top.

The Whiterockian–Mohawkian conodont associations of the Tyner allow correlation of the unit with the well-known, thick Ordovician sequence in the Arbuckle Mountains of southern Oklahoma. As a result, the lower and middle Tyner are equated with a portion of the Oil Creek and possibly the lower McLish Formations. The uppermost Tyner is a correlative of the Pooleville Member of the Bromide Formation. [79]

AAPG Annual Convention
New Orleans, Louisiana, March 24–27, 1985

The following abstracts are reprinted from the *Bulletin* of the American Association of Petroleum Geologists, v. 69, no. 2. Page numbers are given in brackets below the abstracts. Permission of the authors and of the AAPG to reproduce the abstracts is gratefully acknowledged.

Hydrocarbon-Induced Diagenetic Aureole (HIDA)—Mineralogical and Isotopic Models

ZUHAIR AL-SHAIEB and JANET CAIRNS, Oklahoma State Univ., Stillwater, OK; and R. A. LILBURN, Union Oil of California, Oklahoma City, OK

The Permian red beds that overlie some giant oil fields in southwestern and south-central Oklahoma have undergone extensive mineralogical and

chemical diagenesis. The diagenetic minerals occur within a distinctly zoned aureole that delineates the position of the oil field. The geometries of the aureoles strongly reflect the major structural elements that controlled emplacement of hydrocarbons in the underlying rocks. Calcite, ferroan calcite, manganese-rich calcite, dolomite, ankerite, pyrite, marcasite, and native sulfur are the major diagenetic minerals. The innermost zone of each aureole is characterized by abundant carbonate cementation and generally coincides with a major fault system. Pyrite and marcasite cements are commonly associated with carbonate-cemented zones; these minerals occur also in the bleached sandstones.

δC^{13} values of carbonate cements indicate 3 major sources of carbon: (1) an organic source with δC^{13} values of approximately $-32‰$ vs. PDB, (2) a freshwater source with an average δC^{13} value of $-8.0 \pm 3‰$, and (3) a hybrid source (freshwater and organic). A mixing model was developed to calculate the proportion of organic carbon in carbonate cement.

δS^{34} values of pyrite and marcasite average 6.1‰ and range from -9 to $+16‰$. The isotopic composition of sulfides is similar to that of oil in the underlying reservoirs. Formation of diagenetic pyrite and marcasite is explained by reduction of iron oxides in red beds by hydrogen sulfide, and by other organic material associated with hydrocarbons.

The HIDA concept can be used in exploration for oil and gas, specifically in structurally controlled reservoirs. [319]

Wrenching and Oil Migration, Mervine Field, Kay County, Oklahoma

HAROLD G. DAVIS, Tenneco Oil, Oklahoma City, OK

Since 1913, Mervine field (T27N, R3E) has produced oil from 11 Mississippian and Pennsylvanian zones, and gas from 2 Permian zones. The field exhibits an impressive asymmetric surface anticline, with the steeper flank dipping 30°E maximum. A nearly vertical, basement-involved fault develops immediately beneath the steeper flank of the surface anticline. Three periods of left-lateral wrench faulting account for 93% of all structural growth: 24% in post-Mississippian–pre-Desmoinesian time, 21% in Virgilian time, and 48% in post-Wolfcampian time.

In Mesozoic through early Cenozoic times, the Devonian Woodford Shale (and possibly the Desmoinesian Cherokee shales) locally generated oil, which should have been structurally trapped in the Ordovician Bromide sandstone. This oil may have joined oil already trapped in the Bromide, which had migrated to the Mervine area in the Early Pennsylvanian from a distant source. Intense post-Wolfcampian movement(s) fractured the competent pre-Pennsylvanian rocks, allowing Bromide brine and entrained oil to migrate vertically up the master fault, finally accumulating in younger reservoirs.

Pressure, temperature, and salinity anomalies attest to vertical fluid migration continuing at the present time at Mervine field. Consequently, pressure, temperature, and salinity mapping should be considered as valuable supplements to structural and lithologic mapping when prospecting for structural hydrocarbon accumulations in epicratonic provinces. [248]

Diagenetic Destruction of Primary Reservoir Porosity in Viola Limestone, South-Central Oklahoma

G. MICHAEL GRAMMER, Texaco, Inc., Denver, CO

The Viola Limestone in south-central Oklahoma is a Middle and Upper Ordovician carbonate unit interpreted as being deposited on a carbonate ramp within and peripheral to the Southern Oklahoma aulacogen. Depositional environments within the study area ranged from anaerobic deep ramp through aerobic middle and shallow ramp. TOC analyses of the lower anaerobic deep-ramp facies suggest that, at least locally, the Viola is a potential hydrocarbon source rock. Detailed petrographic examination of the Viola indicates that primary porosity in the shallow-ramp skeletal packstones and grainstones was initially quite high. This combination of source potential and original porosity should make the Viola an attractive target for hydrocarbons in southern Oklahoma. The Viola, however, has been subjected to a complex sequence of diagenetic events that have extensively altered the sediments and occluded much of the primary porosity. A thorough understanding of the timing and nature of these events can be critical in evaluating the economic potential of the Viola.

Petrographic evidence combined with the use of cathodoluminescence indicates that several generations of calcite cementation occurred within the shallow-ramp packstones and grainstones. An initial phase of very early, possibly synsedimentary, marine cementation is evidenced by cloudy, inclusion-rich syntaxial cements on echinoderm fragments. This early phase of cementation was followed by several generations of clear syntaxial calcite, prismatic calcite, blocky mosaic calcite, and bladed mosaic calcite, all of which indicate changes in the pore-water chemistry after precipitation of the inclusion-rich cements. This phase of meteoric-phreatic cementation occurred soon after the marine cementation and occluded virtually all remaining primary porosity. [258–259]

Correlation of Illite Crystallinity and Thermal Maturity in Carboniferous Strata of Ouachita Mountains

JOHN M. GUTHRIE, W. D. JOHNS, and D. W. HOUSEKNECHT, Univ. Missouri, Columbia, MO

Carboniferous shales from the Ouachita Mountains have been studied to determine mineralogy and thermal maturities, the latter ascertained by means of vitrinite reflectance and bitumen/organic carbon ratios.

The less than 2 μm fractions of these shales indicate 2 major clay-mineral components, illite and chlorite, and 2 minor varieties, expandable clays and pyrophyllite. Expandable clays are found at low thermal maturities and pyrophyllite at high maturity. Scanning electron micrographs show differences in clay morphology and texture, which are influenced by the degree of thermal maturity.

Weaver's sharpness ratio for illite and Kubler's crystallinity index are both significantly related to mean vitrinite reflectance. The log of the sharpness ratio increases while the log of the crystallinity index decreases with increasing mean vitrinite reflectance. These relationships suggest that illite crystallinity is controlled by the same geologic agents that control vitrinite reflectance, namely temperature and time.

A plot of vitrinite reflectance and/or crystallinity index versus bitumen/organic carbon ratio shows a maximum analogous to a hydrocarbon window.

These statistically significant correlations provide a useful means of estimating the thermal maturity of these strata where they contain insufficient amounts of vitrinite for thermal maturity evaluation. [260]

Crystallographic Influences on Pressure Solution in a Quartzose Sandstone

BRIAN D. HICKS, DAVID W. HOUSEKNECHT, and KENNETH R. APPLIN, Univ. Missouri at Columbia, Columbia, MO

The solubility of quartz differs with crystallographic direction. A universal stage was used to measure the orientations of the optic axes and contact planes of 160 pairs of quartz grains in the Bromide Formation (Simpson Group) of Oklahoma. These quartz grains exhibit long, sutured, and concave–convex contacts. Results indicate that the geometry of a pressolved contact is independent of the crystallographic orientation of opposing grains. However, given a concave–convex contact, the optic axis of the concave grain tends to lie at a higher angle to the contact plane than the optic axis of the convex grain. We conclude that the extent and type of pressure-solution contacts in quartzose sandstones are not significantly influenced by crystallographic orientation. Other factors, such as grain size and clay content, are probably more important in controlling the pressure-solution features.

Geometric etch pits, which form at the point of emergence of crystal defects, were produced by hydrothermally etching quartz crystals, quartz sand, and quartzose sandstones. The abundance, nature, and distribution pattern of crystal defects inherited from source rocks might be more important factors in affecting pressure solution of quartz grains than differences in quartz solubilities arising solely from variations in Si–O bond strengths. The extent of etch-pit formation on quartz cement may also serve as a qualitative indicator of the dissolved silica saturation in pore fluids. [265]

Structural Relations Between Marfa, Marathon, Val Verde, and Delaware Basins of West Texas

G. R. KELLER and K. J. SMITH, Univ. Texas at El Paso, El Paso, TX

The Marfa, Marathon, Val Verde, and Delaware basins and related uplifts formed the major structural elements of the southwestern continental margin of North America during the Paleozoic. In contrast with the relatively simple relationships where the southern Oklahoma aulacogen intersects the Ouachita orogenic belt, structural relationships in the area of these basins are very complex. Various geologic evidence points to an allochthonous Marathon basin. However, a prominent gravity anomaly is associated with the Ouachita system as it extends from western Arkansas through Oklahoma and Texas into northern Mexico. If this anomaly is the signature of the early Paleozoic continental margin, then the location of the Marathon basin with respect to this anomaly suggests lateral displacements have been only on the scale of tens of kilometers. The Delaware basin seems clearly analogous to the Anadarko basin in that it formed as a result of reactivation of a major crustal flaw (not necessarily a rift). This reactivation was a result of the Ouachita orogeny. The Marfa basin is also flanked by a linear gravity high and basement uplift. The relationship of this anomaly to the gravity high associated with the Ouachita system suggests that the Marfa basin may be more analogous to the Delaware basin than foreland basins such as the Ft. Worth and Arkoma. A prominent gravity high that extends into northern Mexico is associated with the Devil's River uplift, and the relationships between this feature, the Val Verde basin, and adjacent structures suggest major deformation on a crustal scale. [272]

Petrology and Porosity of Devonian Misener Formation, West Kremlin Field, Garfield County, North-Central Oklahoma

CHARLES F. MANSFIELD and CURTIS E. BRECKON, Univ. Tulsa, Tulsa, OK

The Misener formation is a laterally discontinuous, mixed carbonate–[siliciclastic] unit, comprising dolomite-cemented, quartz-rich arenite and quartz-bearing dolomite. It reaches a thickness of 60 ft in the West Kremlin field, overlies an unconformity that truncates lower Paleozoic sedimentary strata, and is overlain by the Woodford (black) Shale. Based on petrographic and sedimentary features, it appears to have been deposited in a shallow, tide- and wave-influenced, marine environment.

The quartz-rich arenites are fine to very fine grained and well to very well sorted. They contain mostly monocrystalline quartz clasts, very fine grained, well-crystallized dolomite rhombs, and less than 2% K-feldspar. Lithic fragments, which are rare except for chert pebbles in the basal 1–2

cm, include silicified shale, phosphatic shale, and carbonate micrite. Accessory components include glauconite, phosphatic oolites, conodonts, fish scales, and authigenic pyrite. Devonian outcrops of the Ordovician Simpson Sandstone likely supplied most of the quartz detritus.

The best porosity is unevenly distributed in the mixed quartz–dolomite layers. Authigenic clay is rare, and quartz overgrowths are well developed but partly replaced by dolomite rhombs. Partial dissolution of the rhombs has formed a secondary porosity with good permeability due to pore-throat enlargement. Dolomite-poor, quartz-rich sandstones are well cemented by quartz overgrowths, and the pores contain abundant authigenic clay. The quartz-bearing dolomite is tight and, near the overlying Woodford Shale, is partly replaced by chert. [283]

Hydrodynamic Systems of Orthoconic Nautiloid Cephalopods: Independent Check on Phylogeny

VERONICA McFARLAND, Univ. Texas at Arlington, Arlington, TX

Seldom is it possible to use direct evidence of the physiology of extinct marine organisms as a means of investigating the phylogenetic relationships at any taxonomic level. Hydrodynamic mechanisms of orthoconic cephalopods are an exception because the form and structure of aragonite deposits used as hydrodynamic devices reflect the genetically controlled physiology of the animal. Data on cameral and siphuncular deposits (hydrodynamic devices) of Pennsylvanian (Desmoinesian/Westphalian C) orthocones from the Boggy Formation (=Buckhorn asphalt) of southern Oklahoma provide a test of existing phylogenetic relationships established by standard paleontological methods. The analysis reveals that early growth stages of many taxa considered to be related at the family level have similar to identical morphologies of cameral deposits, while some do not. In all cases, the form of the cameral deposits changes among taxa during later growth stages. In one case, congeneric taxa are shown to belong to different genera on the basis of gross differences in deposits designed to function hydrodynamically. [286]

Regional Paleogeography and Habitat of Hydrocarbons in Ouachita Foredeep Basins

LARRY MECKEL, L. D. Meckel & Co., Houston, TX; DAVE SMITH, Canadian Hunter Exploration Ltd., Calgary, Alberta, Canada; and LEON WELLS, L. D. Meckel & Co., Houston, TX

Eight present-day structural basins occur along the leading edge of the Ouachita thrust belt, a 1,400 mi (2,250 km) Paleozoic overthrust trend that

extends from the Appalachians to Mexico. These basins, now separated by either subtle arches or pronounced basement uplifts, are components of a widespread late Paleozoic foredeep that formed in front of the Ouachita orogenic belt as a result of tectonic loading. This elongate depression filled during Pennsylvanian and Permian times with up to 15,000 ft (4,590 m) of sediment varying in origin from alluvial to deep marine.

An estimated 10 TCF of commercially recoverable natural gas has been discovered to date in the clastics of this foredeep basin trend. Four basins contain the bulk of these known reserves.

The major conclusions of a study of late Paleozoic paleogeography, the structural style, and the habitat of hydrocarbons in this foredeep trend are:

1. The clastics were dominantly derived from cratonic or Appalachian sources, not from the rising Ouachita orogene. There appear to be at least three major entry points along the north margin of the foredeep and one known entry point from the Ouachitas.

2. The facies range from coal-bearing deposits to deep-water turbidites. Fluvial and shallow-marine facies are found in the more stable areas; several turbidite depocenters occur in the areas of rapid, early subsidence.

3. The vast majority of the discovered hydrocarbons (gas) occurs in gas-saturated deep-basin traps. These very large fields occur in turbidites (Val Verde and Arkoma basins) and fluvial to shallow-marine deposits (Fort Worth basin).

4. Large undeveloped reserves can be documented in several basins in low-permeability reservoirs. In addition, there has been only rank wildcat exploration in three of the basins—Desha, Kerr, and Marfa. [287]

Editor's Note: Abstract modified slightly at authors' request.

Controls on Pennsylvanian Algal-Mound Distribution in Mid-Continent North America

REX C. PRICE, Chevron Canada Resources Ltd., Calgary, Alberta, Canada; JOHN C. MITCHELL, Exxon Production Research Co., Houston, TX; and ROBERT L. RAVN, Sohio Petroleum Co., San Francisco, CA

Middle (Desmoinesian) and Upper (Missourian) Pennsylvanian phylloid algal-mound distribution in Missouri, Kansas, and Oklahoma is largely controlled by subtle sea-floor topography. Topographic highs served as loci favoring initiation and continued growth of complexes. Topographic highs controlling mound distribution are the "shelf-edge rise" in northeastern Oklahoma, the "Bourbon arch" in southeastern Kansas, and the "Mine Creek prodeltaic shale buildup" in west-central Missouri.

Outcrop studies document controls on development of these mounds and reveal the potential for development of stacked mounds. This will help exploration for these features in the subsurface to the west.

The shelf-edge rise and Mine Creek prodeltaic shale buildup control the location of the Oologah algal-mound complex and an isolated algal mound in the Pawnee Limestone, respectively. These apparently were positive features only during Middle Pennsylvanian time. In contrast, the Bourbon arch apparently was controlled by basement faulting and remained high for a more-extended period of time. Both Middle and Upper Pennsylvanian algal mounds coincide with the geographic position of the Bourbon arch and result in a stacked-mound complex. Evidence suggesting that the Bourbon arch was a positive feature [is] (1) thinning of clastics over the feature and (2) change from anoxic, black, fissile, and phosphatic basinal shales to oxygenated, diversely fossiliferous gray shales over the arch. [298]

Facies and Geochemical Characterization of Mississippian Rocks in Palo Duro and Hardeman Basins, Texas

STEPHEN C. RUPPEL, Bur. Econ. Geology, Austin, TX

Mississippian rocks in the southern Texas Panhandle constitute a complex sequence of carbonate deposits formed in a platform-to-basin setting. Following relatively rapid transgression and inundation of the area from the north and east, the Hardeman basin area was characterized by outer platform conditions in which isolated carbonate buildups developed surrounded by relatively deep water. The Palo Duro basin to the west was the site of shallow-water, inner platform deposition. In intermediate areas, limestone turbidites, perhaps derived from carbonate buildups to the east, accumulated in quiet water. After this initial transgression, an upward-shallowing trend resulted in the formation of ooid to skeletal shoals throughout the area.

Although current production in the area is coincident with the distribution of organic-rich Upper Mississippian shales in the eastern part of the Hardeman basin, TOC studies indicate that potential carbonate source rocks are present in the western Hardeman and eastern Palo Duro basins. Mississippian rocks in the Palo Duro basin proper have little source rock potential. Vitrinite reflectance studies indicate that Hardeman basin rocks are well within the oil window. However, correlative deposits at equivalent depths in most of the Palo Duro basin are only marginally mature.

Although thermal maturity seems to be mirrored by the present geothermal gradient, and source rock quality appears related to depositional setting (depth of water), successful exploration outside currently productive areas will require a detailed analysis of organic geochemistry and depositional facies. [303–304]

Reexamination of Bengal Fan Model for Turbidites of Frontal Ouachitas

MICHAEL B. UNDERWOOD, Univ. Missouri, Columbia, MO

The lower member of the Pennsylvanian Atoka Formation outcrops within the frontal Ouachitas of Arkansas. Strata are comprised of turbidites and related deep-marine deposits, which locally exceed 5.5 km (18,000 ft) in structural thickness. Several previous workers have drawn analogies between Ouachita turbidites (or flysch) and the present-day Bengal Fan, located in the eastern Indian Ocean. As a first-order approximation, this model is basically correct, especially in terms of overall tectonic setting. Yet, when examined in detail, there are striking dissimilarities between the frontal Ouachitas and the Bengal Fan.

The dimensions of the Bengal Fan are staggering, it measures roughly 1,000 km (620 mi) by 3,000 km (1,860 mi). The main feeder channel is 13 km (8 mi) across and 850 m (2,790 ft) deep. Channels within the mid-fan region are up to 2–3 km (1.2–1.9 mi) in width and 100 m (330 ft) in depth, and some channels maintain continuity for well over 2,000 km (1,240 mi). Rates of vertical sediment accumulation are no more than 75 m/m.y., with isopach data showing only 3.5 km (11,500 ft) of post-Eocene accumulation. Limited sampling also shows rather low sand–mud ratios over much of the fan.

Lithofacies data and depositional cycles within the lower Atoka Formation are suggestive of middle-fan, outer-fan, and basin-plain environments. If Atoka channels were as large as those of the Bengal Fan, they certainly remain unrecognized in the rock record. Instead, the entire length of the outcrop belt in Arkansas is less than 250 km (155 mi), and facies changes define a clear east-to-west transition from middle fan to basin plain. Significantly, Atoka sedimentation rates were approximately 10 times higher than Bengal rates. It is evident that the Atoka fan system was much more confined than the Bengal Fan; it probably formed within a narrow, rapidly filling, remnant ocean basin rather than on an unrestricted abyssal floor. [313]

Devonian Novaculites as Source of Oil in Marathon–Ouachita Thrust System

I. ZEMMELS, P. L. GRIZZLE, C. C. WALTERS, and F. R. HANEY, Sun Exploration and Production Co., Dallas, TX

The Arkansas Novaculite of southern Oklahoma and the Caballos Novaculite of west Texas (both Devonian) form fractured reservoirs in the Marathon–Ouachita thrust system. These formations were examined to ascertain their petroleum potential.

Findings include the following. (1) The thermal maturity of the thrust system conforms to the maturity of the sequence that it has overthrust, suggesting that this allochthonous facies is not anomalously mature. (2) Shale units within the novaculites contain oil-prone organic matter in sufficient concentrations to constitute source rocks. (3) The composition of oils from Isom Springs field in southern Oklahoma and from McKay Creek field in west Texas is virtually identical and generally resembles Devonian oils in Oklahoma and west Texas.

We conclude that the Devonian novaculites of the Marathon–Ouachita thrust system are self sourcing and do not require a fortuitous juxtaposition of source rocks of a different age to produce a commercial deposit. [318–319]

GSA, South-Central Section, Annual Meeting
Fayetteville, Arkansas, April 14–16, 1985

The following abstracts are reprinted from *Abstracts with Programs, 1985* of the Geological Society of America, v. 17, no. 3. Page numbers are given in brackets below the abstracts. Permission of the authors and of the GSA to reproduce the abstracts is gratefully acknowledged.

Correlation and Subsurface Distribution of Ordovician Rocks in the Arkoma Basin of Oklahoma

JEFFREY A. BAUER, Department of Geology and Mineralogy, Ohio State University, Columbus, OH 43210

Comparison of Ordovician rocks exposed in southern and northeastern Oklahoma shows striking variations in thickness and lithology. Middle Whiterockian–Mohawkian rocks are represented in the south (Arbuckle Mountains) by the upper Simpson Group and in the northeast (Illinois River Basin) by the Tyner and Fite Formations. The upper Simpson (McLish, Tulip Creek, and Bromide Formations) consists of over 300 meters of carbonates, shales, and sandstones. The Tyner consists mostly of shale and is overlain by birdseye limestone of the Fite. The Tyner–Fite section reaches a maximum development of only 30 meters. Conodonts (e.g., *Phragmodus, Plectodina,* and *Aphelognathus* among others) found in both the upper Simpson and the Tyner–Fite allow correlation of the two sections.

Recently examined core material from localities in the Arkoma Basin has yielded large numbers of conodonts of Whiterockian age. Those conodonts, which include *Neomultioistodus, Histiodella, Paraprioniodus,* and *Plectodina,* allow correlation with the previously mentioned surface exposures. Although the core collections come from only limited ranges in the subsurface, their correlation establishes a framework on which to base future facies interpretations of Ordovician rocks across the Arkoma Basin in Oklahoma. [150]

Thermal Maturation of the Woodford Shale (Devonian–Mississippian) in the Anadarko Basin, Oklahoma

BRIAN J. CARDOTT, Oklahoma Geological Survey, Norman, OK 73019; and MICHAEL W. LAMBERT, Kansas Geological Survey, Lawrence, KS 66044

The Woodford Shale (Upper Devonian–Lower Mississippian) has attained thermal maturity to post-maturity with respect to the generation of liquid hydrocarbons in most of the Anadarko Basin in western Oklahoma.

Untreated whole-rock well cuttings and core material from selected intervals of the Woodford Shale in 28 wells were examined under reflected white light. Thermal maturation was determined by measuring the reflectance in immersion oil (R_o) of first-generation vitrinite particles. A minimum of 45 reflectance measurements were recorded for each well. The Woodford Shale was sampled at depths from 5,060 ft (1,542 m) in the northeastern shelf to 25,115 ft (7,655 m) in the deepest part of the basin to the southwest.

An isoreflectance map of the Woodford Shale in the Oklahoma part of the basin shows a systematic increase in mean vitrinite reflectance from 0.48 to 2.61% from northeast to southwest across the basin. A thermal anomaly has raised the Woodford Shale to anthracite rank in two wells (4.29 and 4.89% R_o) in the deep Anadarko Basin. A modification of the isoreflectance map delineates those areas of the basin where the thermal history of the Woodford Shale is optimum for the generation of liquid hydrocarbons (mean R_o of 0.5 to 2.0%).

Exponential and linear regression equations derived from computer-generated plots of vitrinite reflectance versus depth predict: (1) the reflectance gradient (0.01 to 0.05% R_o/100 ft), (2) the vitrinite reflectance of the Woodford Shale at any depth in the Anadarko Basin, (3) the depths for oil generation (approximately 5,000 ft or 1,524 m) and liquid-hydrocarbon death zone (approximately 18,000 ft or 5,486 m), and (4) a range of erosion of from 1,500 ft (457 m) to 4,000 ft (1,219 m). [153]

Preliminary Study of Soil–Landscape Age Using Pleistocene Volcanic Ash Buried in High Terrace Deposits Across Oklahoma

BRIAN J. CARTER, Agronomy Dept., Okla. State Univ., Stillwater, OK 74078

Extensive alluvial, aeolian sand, and loess deposits mantle the landscape in West Central Oklahoma immediately east of the [escarpment] to the High Plains. These unconsolidated Pleistocene deposits bury an uneven Permian bedrock surface.

Most deposits are eroded into concave–convex hillslope forms. However, stable high terrace landforms do exist discontinuously between the major west to east trending rivers. The rivers are the Arkansas, Cimarron, North and South Canadian and Red in Oklahoma. These early Pleistocene deposits were probably once part of a continuous plain. Probable extent of these deposits and plain [is] from Abilene, Texas, north to Wichita, Kansas, and from the [escarpment] to the High Plains in the Texas and Oklahoma Panhandles east to Oklahoma City, OK.

Volcanic ash deposits found within these unconsolidated Pleistocene deposits correlate with early Pleistocene ash falls ranging in age from 0.4 to 2.3 m.y. as previously dated in Kansas and Nebraska. The stable landscape terrace positions are marked soils that are deeply weathered, with one or more lithologic discontinuities, and buried paleosols. [153]

Recognition of Pre-Desmoinesian (Pennsylvanian) Unconformity in Northern Ardmore Basin, Oklahoma

W. W. CLOPINE, R. H. BENTHIEN, D. L. BROWN, L. D. CRAWFORD, M. M. DENNEN, R. A. WARWICK, and P. K. SUTHERLAND, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019

Seismic profiles across the Ardmore Basin indicate the occurrence of a regional unconformity within the lower part of the Pennsylvanian in the Ardmore Basin. The magnitude increases to the northeast in the vicinity of Ardmore, Oklahoma. What may be the same unconformity was detected in a preliminary study of the fauna, recovered from washing 35 10 ft channel shale samples collected from a surface section on the Dutton Ranch (sec. 15, T. 3 S., R. 3 E.) in the northeastern Ardmore Basin, as published by Tennant, Sutherland and Grayson (1982, fig. 51). In this section, the 100 ft shale overlying the Otterville Ls (unit 5) contains Morrowan ostracodes, including *Amphissites marginiferous* Bradfield, *Amphissites alticostatus* Bradfield, *Cornigella pushmatahensis* Harlton, and *Paraparchites wapanuckaensis* Harlton. That shale is overlain by a 30 ft unfossiliferous interval consisting of a thin basal conglomerate, an unfossiliferous buff-colored shale, a 1 ft coal and a 5 ft siltstone. This sequence is in turn overlain by a highly fossiliferous marine shale (unit 9) that contains the Desmoinesian brachiopod *Mesolobus* and the Desmoinesian ostracode *Amphissites centronotus* (Ulrich and Bassler). Unidentified fusiform fusulinids were recovered 100 ft above the base of this shale and the Lester Ls lies 150 ft above the base. [154]

Application of Remote Sensing to a Structural Study of the Ouachita Thrust Belt in Southeast Oklahoma and Southwest Arkansas

ADERBAL C. CORREA, Conoco Inc., 555 Seventeenth St., Denver, CO 80202

Side-looking airborne radar images acquired by a synthetic aperture radar system (SAR) and Landsat images were used in this study along with geological and geophysical data. SAR images were the primary source of remote sensing information with complementary information provided by Landsat images. The application of remote sensing data provided the means to create regional displays of the area which minimized the effects [of] vegetation and soil cover and helped to enhance structural features.

Two major structural styles along the frontal zone of the thrust belt in the Ouachita Mountains are clearly shown by remote sensing displays. The eastern side of the thrust belt in Arkansas is characterized by small amplitude, tight folds, a highly complex faulting pattern, and a relatively narrow frontal thrust fault zone. The western side of the thrust belt in Oklahoma is characterized by large amplitude folds, a less complex fault pattern, and a much wider frontal thrust fault zone. The two parts of the frontal zone of

the thrust belt are separated by a strike-slip fault zone that allows for different amounts of movement of thrust plates on either side of the fault zone.

Other geological characteristics of the Ouachita thrust belt such as the change of strike of faults and folds along the frontal zone are explained within the structural framework defined on remote sensing data. [154]

Fluid Inclusions in Midcontinent Country Rocks

RAYMOND M. COVENEY, JR., and EDWIN D. GOEBEL, Dept. of Geosciences, Univ. of Missouri, Kansas City, MO 64110

Within and outside of Midcontinent mining districts, sphalerite, calcite and dolomite contain inclusions of aqueous brines (≥ 15 wt% equiv. NaCl) and hydrocarbon fluids. Most inclusions homogenize at 80–110°C, recording the presence of warm fluids in the U.S. Craton at some time in the past. Most likely, only a thin layer of sediments (≤ ½ km) ever covered most of the strata containing the inclusions. Hence the measured temperatures are too hot to be explained solely on the basis of burial depths—at least not with normal geothermal gradients.

There are indications that some inclusions may contain brines expelled from nearby basins such as the Arkoma–Ouachita Trough (Rowan, et al., 1984, GSA Abs.). However, because the ages of most inclusions are unknown, it may be premature to conclude that all stem from a single event. Other feasible explanations exist for the measured temperatures: for example, passage of the Midcontinent over a mantle hot spot during or subsequent to the L. Paleozoic. In addition, Hanor (1980, Econ. Geol.) suggests that generation of gases from organic matter trapped in fluid inclusions may lead to anomalously high filling temperatures and consequently to erroneous conclusions about thermal histories. From crushing stage runs we have found compressed gases in some inclusions. If these gases were generated after the entrapment of the fluids, estimated temperatures of formation may have to be adjusted downward in some cases. Regardless of these ambiguities, fluid inclusions are useful to petroleum geologists as well as the students of ore deposits, although clearly they provide no panacea and must be examined critically. [154–155]

Early Permian Thermal Alteration of Carboniferous Strata in the Ouachita Region and Arkansas River Valley, Arkansas

GEORGE A. DESBOROUGH, ROBERT A. ZIMMERMANN, MAYA ELRICK, U.S. Geological Survey, Denver Federal Center, Denver, CO 80225; and CHARLES STONE, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204

Vitrinite reflectance values and zircon fission-track ages on samples of Carboniferous strata from the Ouachita uplift record pervasive thermal alteration that occurred during Early Permian time. Pre-Mesozoic strata in the central Ouachita region were subjected to temperatures of 175°–200°C for prolonged periods greater than 1 m.y. based on vitrinite-reflectance measurements (1.5–3.0%) on humic materials in Carboniferous strata. Fission-track ages of zircon from the same beds document the thermal alteration at about 278 ± 25 m.y.b.p.

Our data show that a regional high heat-flow (175°–200°C) event occurred in Arkansas during late Paleozoic time and contrasts with localized thermal effects of Cretaceous plutons.

The source of heat that resulted in fluid migration and emplacement of base-metal deposits in southern Missouri and central and northern Arkansas may be related to the late Paleozoic heating event in the Ouachita region. Also the large natural-gas fields in Paleozoic strata in the western part of the Arkoma Basin in Oklahoma and northwestern Arkansas may be related to gas generation during maturation of humic-rich Carboniferous beds in Early Permian time. [155]

Sequential Deformation of Ordovician Slates in the Stephens Gap Area, Eastern Broken Bow Uplift, Oklahoma Ouachita Mountains

MICHAEL C. DIX, Dept. of Geosciences, Univ. of Houston, Houston, TX 77004

Detailed mapping in the Stephens Gap area at the SW corner of Broken Bow Lake has documented the following polyphase deformational history in slates and thin quartzose metasandstones mapped as Mazarn/Blakely Fms. undivided: D_1) Generally NNE–SSW trending recumbent isoclinal F_1 folds with pervasive axial planar S_1 cleavage that strongly parallels S_0 away from hinge areas. Boudinage and transposition of S_0 are locally associated with F_1. D_2) NNW–SSE trending open macroscopic and open to tight mesoscopic upright F_2 folds. Associated subvertical axial planar S_2 cleavage coarsely crenulates S_1 near the small mesoscopic folds; elsewhere the crenulation is common but more subtle. D_3) Early formed thin veneers of NW–SE trending quartz slickenfibers on crenulated S_1. Fiber orientations on these [discrete] slip surfaces are similar to those observed in the Glover fault zone and are assumed to be coeval. The Glover fault is an unusual young-over-old thrust that has transported the Bigfork Chert–Arkansas Novaculite sequence NW(?) over the slates. Later formed open upright F_3 folds with an ENE–WSW trend fold all previous structures and appear related to the late regional arching of the Broken Bow uplift. This arching gently tilts all structures in the study area SSE off the uplift flank.

F_1 and F_2 folds in the Mazarn/Blakely slates beneath the Glover fault trend at large angles to F_1 and F_2 folds previously documented in the younger Bigfork–Arkansas sequence above the Glover fault. Early D_3 thrusting juxtaposed these structurally discordant sequences. Later F_3 folds correlate well with similarly trending NNW vergent folds in the younger sequence (Nielson 1982), demonstrating post-thrusting autochthoneity. [156]

Tectonically Broken Formation in the Womble "Shale" of the Broken Bow Uplift and Its Association with the Glover Fault

MICHAEL C. DIX and JOHN F. CASEY, Dept. of Geosciences, Univ. of Houston, Houston, TX 77004

Exposures of the Womble Fm. (M. Ordovician) in the Broken Bow uplift comprise an uncertain thickness of turbiditic metagreywackes, locally calcareous, and interbedded slates. The black shales that typically dominate the Womble Fm. in other parts of the Ouachita Mtns. are strikingly subordinate here. [Reconnaissance] mapping has revealed a belt of broken formation of Womble lithologies closely associated with the previously mapped trace of the Glover fault, a controversial young-over-old folded thrust proposed by Miser (1929). The broken fm. is composed of greywacke clasts embedded in a slaty matrix characterized by pervasive [anastomosing] cleavage. Cleavage within clasts is usually well developed, crosscutting relict bedding laminations and paralleling matrix cleavage. Clasts commonly show a strong preferred orientation parallel to matrix cleavage. Sedimentary contacts are not observed to bound the broken fm. and available evidence indicates greywackes were well lithified when stratal disruption occurred. Greywacke disruption and cleavage formation are interpreted to be coeval expressions of large scale ductile shearing. A purely tectonic origin for the broken fm. is favored. Undisrupted Womble greywackes structurally below the broken fm. belt and/or the Glover fault trace display recumbent fold styles characteristic of the Collier–Blakely sequence coring the Broken Bow uplift. Greywackes above this structural boundary show the more upright fold styles typical of the Broken Bow flank sequence (Bigfork–Arkansas Fms.). It is tentatively suggested that the broken fm. formed along a major décollement, across which different fold styles and strain patterns developed. Subsequent motions along this zone were taken up by the Glover fault, which preserves appendages of the broken fm. as fault bounded slices along its trace. [156]

The Formation of the Meers Valley, Southwestern Oklahoma

R. NOWELL DONOVAN, STEVE BRIDGES, and KATHY BRIDGES, T. Boone Pickens, Jr. School of Geology, Oklahoma State University, Stillwater, OK 74078

The Meers valley in southwestern Oklahoma is an exhumed early Permian feature which trends southeast–northwest for approximately 20 mi. The south side of the valley is formed by the eroded scarp of the Wichita Mountains; the major topographic control is provided by the Mt. Scott granite sill which overlies both the Mt. Sheridan gabbro and part of the Carlton rhyolite. The north side of the valley is formed by the 140–310 trending Meers fault, to the north of which lie the Slick Hills (composed of the Cambro–Ordovician Arbuckle Group). The valley floor is filled by a variety of Permian conglomerates, sandstones, shales and calcretes which are collectively referred to as the Post Oak Formation.

Recent mapping has revealed a complex stratigraphy in the Post Oak infill. Conglomerates composed of granite clasts (derived from the south side of the valley) are overlain by three distinct conglomerate units composed of limestone clasts shed from the Slick Hills. The lower and upper of these units are pebble conglomerates whereas the middle unit consists of enormous angular boulders up to 30 m^2. We [interpret] this unit (which thins to the south) as a record of contemporary movement of the Meers fault with an implicit downthrow to the south. This movement, which is probably the final Paleozoic pulse on the fault, is a reversal of the earlier enormous downthrow to the north. The relationships are further complicated by the fact that the boulders found in the middle unit are formed of Arbuckle Group rock types not now found immediately to the north of the fault. The most appropriate reconstruction suggests that at least 2 mi of left lateral movement has taken place.

In summary the Meers Valley initiated by erosion along the line of Meers fault. Reactivation of the Meers fault (with an oblique movement) produced a half-graben structure. [156]

Conodonts from the Lower and Middle Ordovician Rocks of the Ouachita Mountains, West-Central Arkansas

R. L. ETHINGTON, Geology Dept., Univ. Missouri–Columbia, Columbia, MO 65211

Conodonts were found in the Lower Ordovician rocks of the Ouachita Mountains nearly 50 years ago, but they have been studied systematically for only a decade. These fossils occur in thin limestone beds, lenses, and clasts in these primarily shaly rocks in sufficient numbers and diversity to permit biostratigraphic evaluation of the sequence by comparison with zonal schemes that have been established for the geoclinal rocks of the southern Appalachian region and for shallow-water carbonate rocks of the Arbuckle and Ozark areas of Oklahoma and Missouri.

The conodonts recovered from the upper Collier Shale document the Early Ordovician age of the exposed part of that unit. Only a single specimen, which lacks biostratigraphic value, has been found in the Crystal Mountain Sandstone. Conodonts typical of the Ozark–Arbuckle facies occur in the Mazarn Shale together with species that represent deep- or cold-water, basinal conditions. They indicate that the formation spans much of middle and upper Lower Ordovician. Elements recovered from the upper Blakely Sandstone at several localities place the Blakely–Womble contact near the top of the Whiterockian Stage. Conodonts are abundant in many samples collected from the Womble Shale, in which representatives of three conodont zones have been found. Age of the Womble ranges from early Chazyan through early Blackriveran. [157]

GSA, North-Central Section, Annual Meeting
DeKalb, Illinois, April 25–26, 1985

The following abstracts are reprinted from *Abstracts with Programs, 1985* of the Geological Society of America, v. 17, no. 5. Page numbers are given in brackets below the abstracts. Permission of the authors and of the GSA to reproduce the abstracts is gratefully acknowledged.

An Evolutionary Gradient Among Late Ordovician Benthic Invertebrates Across an Onshore–Offshore Sequence of Faunal Provinces

ROBERT L. ANSTEY, Department of Geological Sciences, Michigan State University, East Lansing, MI 48824-1115

Onshore–offshore, or margin to craton transects across the Late Ordovician shelf sea reflect changes in provincial biotas rather than a smooth gradient in community composition. Many taxa used in defining communities are eurytopic with respect to provincial boundaries. Three substrate-limited, biomelike provinces can be recognized from the coincident stenotopy of bryozoans, solitary corals, and conodonts: the onshore North Atlantic Province (which lacks corals), the intermediate Richmond Province/Exterior Midcontinent Subprovince, and the offshore Red River–Stony Mountain Province/Interior Midcontinent Subprovince (Elias 1982, 1983; Sweet 1979). Benthic cephalopod distributions (austral and boreal "realms" of Flower 1946) suggest comparable stenotopy. Bivalve stenotopy is pronounced within the onshore province.

Brachiopods and trilobites were generally eurytopic; approximately half of the bryozoan genera were likewise eurytopic across all three provinces. Cosmopolitan bryozoan genera co-occurring in Baltoscandia and Siberia sharply delineate the margins of the intermediate (Richmond) province by their increased diversity within its two bounding provinces. Immigrant genera from Baltoscandia were most common within the Midcontinent Maquoketa Subprovince.

Bryozoan stenotopy and endemism are correlated within the intermediate (Richmond) province, where most generic originations took place. The production of higher level evolutionary novelties, however, was limited to the onshore province. The onshore and intermediate provinces were most affected by the terminal Ordovician extinction. Offshore province bryozoans survived differentially, and became predominant in Silurian faunas. [278]

Lenapah Formation (Upper Marmaton Group, Desmoinesian, Middle Pennsylvanian) in Northern Midcontinent

HELENE GREENBERG, Geology Dept., University of Iowa, Iowa City, IA 52242

The Lenapah Formation represents a minor marine cycle that lacks the offshore black phosphatic shale typical of other cyclic units. Its variable lithologies and poor exposure have historically resulted in its miscorrelation with the newly proposed Lost Branch Formation in western Missouri and southern Iowa. In its type area near the Kansas–Oklahoma border, the Lenapah comprises three members, in ascending order: 1) Norfleet Limestone, 2) Perry Farm Shale, 3) Idenbro Limestone. The Norfleet, a complex unit of shale and limestone facies, represents a transgression. The Perry Farm, consisting of shale with limestone nodules, represents a minor regression (Parkinson, 1982). The Idenbro, a calcilutite grading upward in places to calcarenite, represents a later, more minor transgressive–regressive cycle.

The lower Norfleet contains an abundant conodont fauna dominated by several species of *Neognathodus* and including *Adetognathus* and *Anchignathodus*. Species of *Neognathodus* include *N. dilatus, N. roundyi, N. medexultimus*, a new species and intermediate forms. Conodonts are sparse in the remainder of the Lenapah.

From its type area, the Lenapah thins northward, and the Idenbro Member pinches out in eastern Kansas. The Norfleet Member is traced as far north as Iowa, where *Adetognathus* replaces *Neognathodus* as the dominant conodont in sparser faunas. The conodont-rich facies from western Missouri southward were deposited in an offshore environment of slow sedimentation. In contrast, the abrupt lateral facies changes between marine shale, sandstone, skeletal calcilutite and calcarenite in the upper part of the formation indicate a fluctuating nearshore environment with several pulses of fine to coarse terrigenous detritus. [291]

Lost City Limestone Member of the Hogshooter Formation (Missourian, Upper Pennsylvanian) in Northeastern Oklahoma

WM. L. NIEMANN, Geology Dept., Univ. of Iowa, Iowa City, IA 52242

Type Hogshooter near the Kansas–Oklahoma border consists of three members, in ascending order: 1) Canville Limestone, 2) Stark Shale, 3) Winterset Limestone. The thin, dense, dark Canville records a transgression. The black Stark Shale represents slow sedimentation during maximum transgression, and the thick Winterset Member is regressive. Southward, in the Tulsa area, the Hogshooter consists of the thick, massive calcilutitic Lost City Member and, in places, an overlying calcarenite considered to be a facies of the Winterset. A few miles farther south, the Hogshooter thins to a thin lower limestone and an overlying phosphatic black shale. A thin phosphatic shale zone detected above the Lost City in the Tulsa area yields an abundant conodont fauna, including *Gondolella*, which is found only in the Stark Shale at other Hogshooter localities. This horizon thus represents a Stark equivalent, formed during maximum transgression in water too shallow for development of the black shale facies dominant to the north and south. This depositional high spot provided a favorable site during transgression for growth of the phylloid algal facies dominating the Lost City. At a maximum thickness of at least thirty feet, the Lost City is one of the thickest transgressive limestones in the Midcontinent Pennsylvanian. Widespread black shales in the Midcontinent typically seal the underlying transgressive limestone from meteoric waters accompanying subsequent regression. In the Lost City, abundant algal-blade-sheltered voids point to cementation before compaction of the sediment. Geochemical data will help to determine whether the cements are mainly marine or even meteoric in origin, in view of the extremely thin shale covering the Lost City. [320]

OKLAHOMA GEOLOGICAL SURVEY 1908