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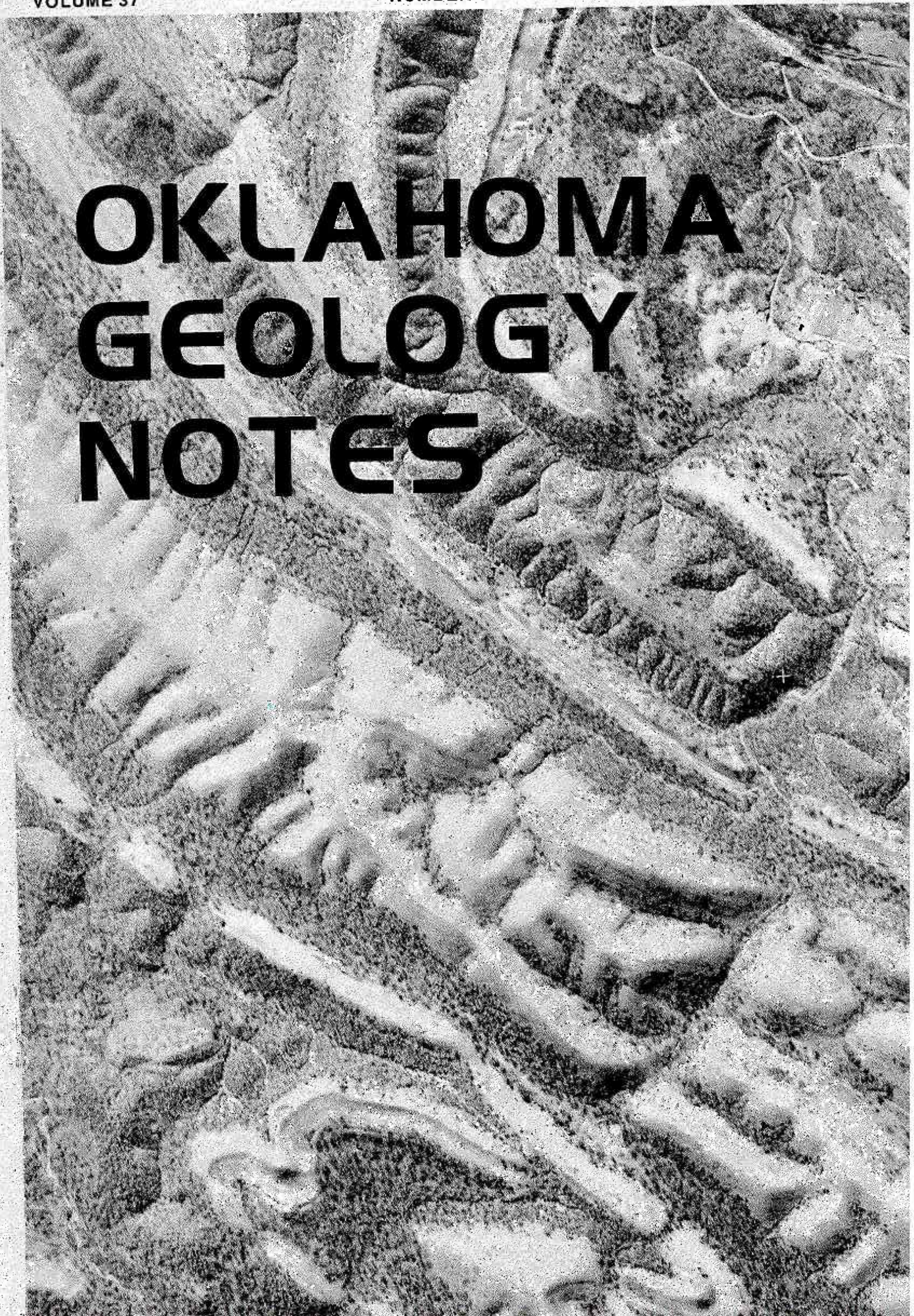
OKLAHOMA GEOLOGY NOTES



Cover Picture

FOLDED PALEOZOIC ROCKS IN THE DOUGHERTY ANTICLINE AREA OF THE ARBUCKLE MOUNTAINS

Volume 37 of *Oklahoma Geology Notes* will feature a series of aerial photographs of the Arbuckle Mountains in south-central Oklahoma as cover photographs. Of major interest in the Arbuckles is the thick sequence (5,000 metres) of early Paleozoic carbonates and late Paleozoic clastics that were folded and faulted during several orogenic episodes of the Pennsylvanian Period.

The cover of this issue displays tightly folded strata ranging from the Ordovician Simpson Group through the Mississippian Caney Shale. Bare ridges are outcrops of limestones such as the Bromide, Viola, Hunton, and Sycamore, whereas the wooded lowlands are shales such as the Sylvan, Woodford, and Caney. The axis of the southeast-plunging Dougherty anticline is just north of the center of the photo, and the northeast flank of Vine's dome is in the southwest quadrant. The photo covers parts of secs. 26, 27, 34, and 35, T. 1 S., R. 2 E., in Murray County.

The photograph was taken by the U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service.

—Kenneth S. Johnson

Editorial staff: William D. Rose, Rosemary L. Croy, Elizabeth A. Ham

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

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

This publication, printed by the Transcript Press, Norman, Oklahoma, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes 1971, Section 3310, and Title 74, Oklahoma Statutes 1971, Sections 231-238. 1,500 copies have been prepared for distribution at a cost to the taxpayers of the State of Oklahoma of $2,141.20.

THE MINERAL INDUSTRY OF OKLAHOMA IN 1976[1] (Preliminary)

Robert H. Arndt[2]

Oklahoma's raw mineral output attained a record high preliminary value of almost $2.7 billion in 1976, according to the Bureau of Mines, U.S. Department of the Interior (table 1). This is 17.8 percent above the 1975 value. Values of fuels reported as $2.6 billion and nonmetals as $113 million increased by 18.2 percent and 9.6 percent, respectively, over those of 1975. Only produced helium, sand and gravel, and stone decreased in value. Reported production of all commodities except crude oil, sand and gravel, and stone increased.

Drilling for oil and gas far exceeded that in 1975, with a reported maximum of 227 active drilling rigs during one week in November. Correspondingly, output of natural gas increased by 6.6 percent over that in 1975, but State output of crude petroleum continued to decline. Completion of Texoma and Seaway pipelines from the Texas Gulf Coast made additional crude petroleum available to Oklahoma refineries from terminals near Cushing and branch lines. The estimated value of products of Oklahoma petroleum refineries was $4 billion in 1976. Record barge shipments of 667,000 tons of petroleum products were made on the Arkansas River in Oklahoma. Coal production continued to expand from 26 regularly producing mines and several intermittent producers. A million-dollar coal washing plant was erected by Cenergy, Inc., near Welch. Coal producers nominated 44,148 acres of federal coal lands in southeastern counties for future lease sale by the Bureau of Land Management. The Oklahoma Geological Survey pursued cooperative studies with the U.S. Geological Survey and the U.S. Bureau of Mines to quantitatively define quality, physical character, and accessibility of individual coal beds in several counties.

Despite an upturn in housing construction, production of sand and gravel and gypsum continued to decline. Cement producers in Tulsa, Pryor, and Ada completed or undertook conversion of kilns to use coal as fuel instead of natural gas. St. Clair Lime Co. installed a dust-collecting system on a noncomplying kiln at its Marble City plant. Amoco Production Co. and Houston Chemical Co. finished constructing a plant near Woodward to extract iodine from formation brines.

A bill backed by the coal industry to establish a program for reclaiming abandoned surface-mined coal lands was passed by the State Legislature but was vetoed by the governor with a request that it be modified and reintroduced in 1977.

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[1]Prepared January 11, 1976, in the State Liaison Program Office-Oklahoma, U.S. Bureau of Mines, through a cooperative agreement between the USBM and the Oklahoma Geological Survey that calls for collecting information on all minerals except fuels.

[2]Liaison Officer-Oklahoma, U.S. Bureau of Mines, Oklahoma City.

TABLE 1.—MINERAL PRODUCTION IN OKLAHOMA[1]

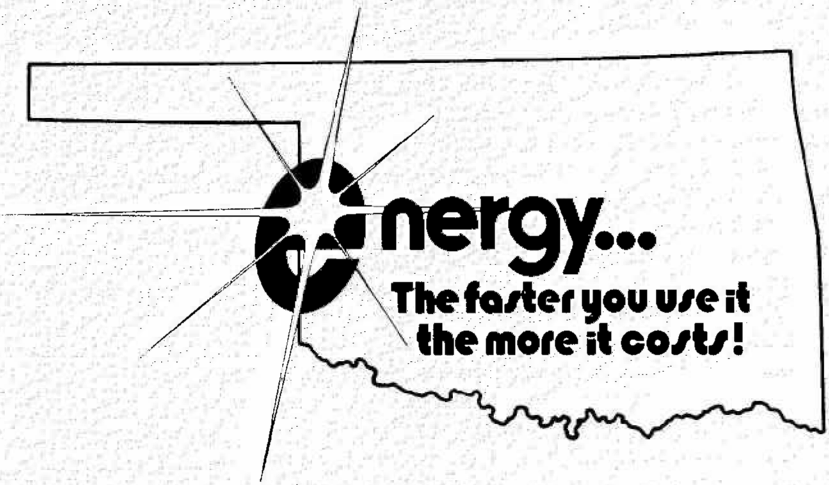
MINERAL	1975 QUANTITY	1975 VALUE (THOUSANDS)	1976 (PRELIMINARY) QUANTITY	1976 (PRELIMINARY) VALUE (THOUSANDS)
Clays (thousand short tons)	995	$ 1,701	1,032	$ 1,801
Coal (bituminous) (thousand short tons)	2,872	47,946	2,900	49,300
Gypsum (thousand short tons)	1,028	4,835	1,134	4,950
Helium:				
High-purity (million cubic feet)	224	7,411	227	7,334
Crude (million cubic feet)	143	1,776	150	1,800
Natural gas (million cubic feet)	1,605,410	513,731	1,710,586	858,714
Natural-gas liquids:				
LP gases (thousand 42-gallon barrels)	29,640	140,197	30,442	144,600
Natural gasoline and cycle products (thousand 42-gallon barrels)	10,835	63,383	11,276	63,287
Petroleum (crude) (thousand 42-gallon barrels)	163,123	1,389,164	150,627	1,432,463
Pumice (volcanic ash) (thousand short tons)	1	W	W	W
Sand and gravel (thousand short tons)	9,591	16,749	9,303	16,243
Stone (thousand short tons)	20,111	36,840	19,749	36,446
Value of items that cannot be disclosed: cement, copper (1975), lime, salt, silver (1975), tripoli, and values indicatd by symbol W	XX	43,362	XX	53,385
Total	XX	$2,267,095	XX	$2,670,323

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed." XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Value as estimated from 1975 unit value.

State Observes Energy Awareness and Conservation Month



In an attempt to heighten the awareness of critical energy needs and decisions facing the citizens of Oklahoma and the nation, Governor David L. Boren proclaimed the period November 15–December 15, 1976, as Energy Awareness and Conservation Month. The month-long observance was directed and coordinated by the Oklahoma Department of Energy and drew on the talents and efforts of hundreds of volunteers throughout the State. Serving as chairman of the statewide coordinating committee for the program was Wayne E. Swearingen, a well-known Tulsa petroleum-management consultant.

The program was kicked off November 12 in Oklahoma City by a symposium sponsored by Governor Boren and by U.S. Senators Henry Bellmon and Dewey Bartlett. The symposium drew an audience of about 3,500 persons of all ages, many of them from high schools, colleges, and universities throughout the State. The program, educational in nature, was geared largely to the students in the audience.

Speakers included Samuel J. Tuthill of the Federal Energy Administration, Washington, D.C., former state geologist of Iowa, and Glen E. Brandvold of Sandia Laboratories, Albuquerque, New Mexico, who has been active in nuclear-energy research and in alternate-energy experiments. These and other speakers told the audience that individual citizens would have to change their attitude toward energy use, conservation, and development in order to overcome the present period of tight supplies of conventional energy sources such as oil, gas, and coal.

William W. Talley II of Resource Analysis & Management Group, Oklahoma City, who is co-chairman (with William B. Cleary) of Governor Boren's energy advisory council, joined with other speakers in pointing out that economic incentives are directly related to increasing traditional supplies of crude oil and natural gas, because they add reserves to deposits already discovered and they encourage exploration for new deposits.

In the forefront of the many questions from the audience were those relating to the development and use of alternate energy sources such as solar energy and wind power. Generally, the speakers held that as conventional energy supplies continue to dwindle, and as their price continues to rise, the development of many of these alternative sources will be economically feasible; but they tended to dampen hopes that any of these sources could be developed sufficiently to make a significant impact on our total energy needs much before the end of the century.

The Oklahoma Geological Survey's involvement in the month-long energy program consisted principally in helping to prepare, in cooperation with the Department of Energy, a series of "white papers" and a brochure summarizing our main energy sources (oil, gas, and coal), nuclear-energy sources, and capital requirements for future energy development. These materials were developed by a committee on energy resources, one of the operating committees for the project. William B. Cleary, an Oklahoma City energy consultant, served as committee chairman. Co-chairmen were Charles J. Mankin, OGS director, and William L. Hughes, director of the Electrical Energy Laboratory at Oklahoma State University, Stillwater. Contributing a paper and a summary on coal-energy sources was Robert P. Luke of Kerr-McGee Resources Corp.

On balance, Energy Awareness and Conservation Month was probably successful in bringing energy problems and pending energy choices to the public's attention. Such an effort was obviously called for when a survey released by the Governor's office indicated that less than half of the State's population thought there was a real energy shortage.

Data Released on Rush Springs Aquifer

Basic Data Report on Ground Water Levels in the Rush Springs Sandstone Area of Southwestern Oklahoma, 1956-1976, is available free of charge from the Oklahoma Water Resources Board. Issued as Publication 74, the report supplements information contained in Hydrologic Investigations Publication 72, *Ground Water Resources of the Rush Springs Sandstone of Southwestern Oklahoma*, which was announced in the October 1976 issue of *Oklahoma Geology Notes* (v. 36, p. 195).

The basic-data report contains a map showing the location of selected wells and a map showing the generalized water-level changes from 1956 to 1976, in addition to a series of tables that show the rise or decline of water levels from the date a well was first measured to the 1976 measurement.

The report can be obtained on request from the Oklahoma Water Resources Board, Jim Thorpe Building, Oklahoma City, Oklahoma 73105.

Monument Honors Oil Pioneers

The 12th in a series of oil historical markers cosponsored by the Oklahoma Historical Society and the Oklahoma Petroleum Council was dedicated December 2, 1976, as part of the State's observance of Oklahoma Energy Awareness and Conservation Month (see related article, page 5). Governor David Boren, representatives of the sponsoring organizations, and a number of State officials participated in ceremonies for the unveiling of the monument, which recognizes the importance of early-day oil men in the growth of the petroleum industry and the Oklahoma economy.

Erected on the Historical Society grounds, southeast of the State Capitol and near a display of historical oil equipment, the 8-foot-high granite marker (pictured below) was constructed by Willis-Pellow Brothers Granite and Monument Works, under the direction of Bill Willis of Granite, Oklahoma. The art work was prepared by Jim McKinney of Cities Service Oil Co., Tulsa.

The monument program is designed to acquaint citizens as well as tourists to the State with the role of the petroleum industry in Oklahoma's history and development.

Participating in ceremonies marking the unveiling of the 12th oil historical marker were (left to right). Governor David Boren; D. W. Calvert, president of the Oklahoma Petroleum Council and executive vice-president of The Williams Companies, Tulsa; John Steiger, chairman of the Council's historical committee and manager of civic affairs for Cities Service Co., Tulsa; and Jack Wettengel, executive director of the Oklahoma Historical Society, Oklahoma City.

New OGS Publication Features Copper Deposits

A 99-page illustrated book, *Stratiform Copper Deposits of the Mid-continent Region, A Symposium,* has just been released by the Oklahoma Geological Survey. Issued as Circular 77, the volume represents the published results of 12 papers presented at a symposium conducted March 8, 1974, in Stillwater, Oklahoma, during the annual meeting of the South-Central Section of The Geological Society of America. The discussions cover copper deposits in Oklahoma, Kansas, Texas, and New Mexico.

Edited by Kenneth S. Johnson, economic geologist with the Oklahoma Geological Survey, and Rosemary L. Croy, OGS associate editor, the volume is prefaced by an introduction by Dr. Johnson and includes the following papers: "Permian Copper Shales of Southwestern Oklahoma," by Kenneth S. Johnson; "Geology and Mining Operations at the Creta Copper Deposit of Eagle-Picher Industries, Inc.," by Paul R. Dingess; "Sabkha and Tidal-Flat Facies Control of Stratiform Copper Deposits in North Texas," by Gary E. Smith; "Microscopy of Copper Ore at the Creta Mine, Southwestern Oklahoma," by Richard D. Hagni and Delbert E. Gann; "Mineralogy and Microtextures of Sulfides in the Flowerpot Shale of Oklahoma and Texas," by Albert L. Kidwell and Richard R. Bower; "Geochemistry and Petrology of Some Oklahoma Red-Bed Copper Occurrences," by Richard P. Lockwood; "Geochemical Exploration for Red-Bed Copper Deposits in North-Central Oklahoma," by Zuhair Al-Shaieb and Richard R. Heine; "Copper Occurrences Associated with Permian Rocks in South-Central Kansas," by Truman C. Waugh and Lawrence L. Brady; and "A Comparison of Selected Sandstone Copper Deposits in New Mexico," by Dennis J. LaPoint.

In addition, the following three abstracts are presented: "Red-Beds and Copper Deposits—Why the Association?," by James D. Vine and E. B. Tourtelot; "Central European Versus South-Central U.S.A. Geologic Settings of the Permian Basins and Associated Copper Mineralization," by Jan Krason; and "The Geology, Exploration, and Development of the Stratiform Copper Deposit Located Northwest of Crowell, Texas," by Howard G. Schoenike and Raul A. Zeballos.

The new circular reflects a growing interest in these layered deposits of copper. Only a few have been mined commercially, but according to Dr. Johnson, "Inasmuch as stratiform copper deposits contain about 30 percent of the world's copper resources, they represent an important class of ore deposits."

Oklahoma's only commercial production of copper—from the Eagle-Picher operation at Creta, in Jackson County—ceased in 1975 when the price of copper fell as the result of an unexpected surplus brought on by a decline in construction. Another deposit near Mangum, in Greer County, has been explored and shows potential for exploitation. Some New Mexico deposits have been productive. Texas and Kansas deposits have been explored extensively for possible future production.

All the deposits, whether commercial or not, are of scientific interest to sedimentologists, petrologists, petrographers, mineralogists, and geochemists.

Stratiform Copper Deposits of the Midcontinent Region, A Symposium can be obtained from the Oklahoma Geological Survey, 830 Van Vleet Oval, Norman, Oklahoma 73019. The price is $3.00 apiece for paperback copies, and $5.00 for hardback.

New U.S. Geological Survey Publications

A number of publications released recently by the U.S. Geological Survey may be of interest to Oklahoma geologists.

Demand and Supply of Nonfuel Minerals and Materials for the United States Energy Industry, 1975-90–A Preliminary Report supersedes Open-File Report 75-583. Part A, prepared by J. P. Albers, W. J. Bawiec, and L. F. Rooney, presents minimum estimates of nonfuel, mineral, raw-material requirements for major types of energy to meet the goals of the Project Independence Blueprint. Concrete and iron are needed in the largest tonnages, but substantial quantities of materials such as aluminum, barite, bentonite, manganese, and nickel are also needed. Part B, by G. H. Goudarzi, L. F. Rooney, and G. L. Shaffer, studies the availability of these materials and finds that the United States has no reserves of chromite, cobalt, manganese, or niobium and is totally dependent on imports for them; imports also provide a significant part of the supply of aluminum (bauxite), fluorite, nickel, and tungsten. Reserves of only a few commodities—barite, bentonite, copper, iron ore, lead, molybdenum, and zinc—are adequate to meet the national demand through 1990. The report, issued as Professional Paper 1006-A, B, can be ordered for $1.70 from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202.

Professional Paper 840, *Descriptions and Analyses of Eight New USGS Rock Standards,* compiled and edited by F. J. Flanagan, can be ordered from the address above for a price of $3.10. It contains preliminary analytical data, norms, petrography, and the geologic setting for eight new whole-rock sample powders. Included in 26 separately authored papers are analytical data by various methods on these new and the older USGS rock standards, another compilation of data on the 8 older samples, and the final compilation of data on muscovite P-207.

Uranium Resource Terminology in the United States [Opening remarks for the panel discussion on Uranium Resource Assessment Methodology, December 10, 1975], by W. I. Finch, is the title of Open-File Report 76-694. The 6-page report is available for public inspection at various federal depositories throughout the country, including the library at the Denver

Federal Center, 1526 Cole Blvd., Golden, Colorado, and the Energy Research and Development Administration, Grand Junction, Colorado.

Open-File Report 76-664, *Ground-Water Levels in Observation Wells in Oklahoma, 1971-74*, by R. L. Goemaat, is on display at 2 places in Oklahoma City—the USGS offices, Room 621, 201 Northwest 3d Street, and the Oklahoma Water Resources Board headquarters, the 5th floor of the Jim Thorpe Building.

The Geologic Map of Arkansas, by B. R. Haley and E. E. Glick of the U.S. Geological Survey and W. V. Bush, B. F. Clardy, C. G. Stone, M. B. Woodward, and D. L. Zachry of the Arkansas Geological Commission, has been published at the scale 1:500,000 (1 inch = about 8 miles). The map sheet is 34 by 53 inches and sells for $3.50. *Geothermal Gradient Map of North America*, prepared by the Geothermal Survey of North America Subcommittee of The American Association of Petroleum Geologists' Research Committee, has been printed at the scale of 1:5,000,000 (1 inch = 80 miles), and it sells for $4.00 per set. It consists of 2 sheets, each 40 by 63 inches, and it shows geothermal gradients of sedimentary basins by contours at intervals of 0.2°F per hundred feet of depth and equivalent thermal gradient values by color tints. Bottom-hole temperatures from more than 30,000 bore holes for oil and gas, and temperatures of water at land surface for water wells, were used for the map. *Subsurface Temperature Map of North America*, by the Geothermal Survey of North America Subcommitee of The American Association of Petroleum Geologists' Research Committee, is available at the same scale, same price, and also consists of two sheets, 40 by 63 inches. Contours show depth in thousands of feet below surface at 3 selected temperatures—158°F (70°C), 212°F (100°C), and 302°F (150°C); ranges of bottom-hole temperatures from more than 30,000 bore holes are shown by color symbols. All three maps can be ordered from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202.

1977 Oil-Industry Directory on Sale

The 1977 edition of the *USA Oil Industry Directory* is now available. Over 13,000 changes and additions have been incorporated, and the publishers promise complete listings for every integrated oil company in the United States, plus listings for major independents, pipeline companies, drilling companies, and major marketing firms. Individuals can inspect the directory for 10 days, and if they are not satisfied, they can return it for a full credit or refund.

Orders for the publication should be sent to The Petroleum Publishing Company, P.O. Box 1260, Tulsa, Oklahoma 74101. The directory sells for $45 per copy, plus postage, but if payment accompanies the order, the publisher will pay surface postage.

STRATIGRAPHY OF THE BOKCHITO FORMATION (CRETACEOUS) IN SOUTHERN OKLAHOMA

George G. Huffman[1]

Abstract—The Bokchito Formation in southern Oklahoma is a natural stratigraphic sequence consisting of shales, friable sandstones, and fossiliferous limestone beds overlying the upper part of the Caddo Formation (equivalent to the Fort Worth Formation of Texas) and underlying the Bennington Limestone. The Bokchito Formation is divided into five members; in ascending order they are the Denton Clay Member, Soper Limestone Member, Weno Clay Member, McNutt Limestone Member, and Pawpaw Sandstone Member. These subdivisions have been recognized and traced across Love, Marshall, Bryan, and Choctaw Counties, Oklahoma. They disappear beneath extensive terrace deposits in central Choctaw County and are thin or missing in eastern Choctaw and McCurtain Counties, where the Woodbine Formation (Late Cretaceous) rests unconformably on the Caddo Formation and older units.

Introduction

The Bokchito Formation was named by Taff (1902, p. 6) for exposures along Bokchito Creek near the town of Bokchito in Bryan County, Oklahoma. The sequence of units described by Taff consists of approximately 140 feet of clay shale, sandy clay, clay-ironstone concretions, friable sandstones, arenaceous limestones, and fossiliferous, ferruginous limestone. As defined by Taff, the Bokchito Formation included all beds between the underlying Caddo Limestone and the overlying Bennington Limestone. The strata in southern Oklahoma are for the most part shallow-water, nearshore, littoral deposits. They are known to continue southward into Texas, where they are represented by marlstones and limestones.

Hill (1901), working in the Denison area in North Texas, assigned equivalent beds to the Denison Group, which he divided into three subgroups: (1) a lower Denton subgroup containing the beds below the *Ostrea carinata* horizon; (2) a medial or Weno subgroup, including the beds between the *O. carinata* bed and the Main Street Limestone or the Weno and Pawpaw formations; and (3) the Pottsboro subgroup, consisting of the Main Street Limestone and the Grayson Marlstone.

Stephenson (1918) simplified Hill's classification by discarding the subgroup designations and recognizing the Denison as a formation consisting (in ascending order) of the Denton Clay Member, Weno Clay Member, Pawpaw Sandstone Member, Main Street Limestone Member, and Grayson Marl Member. Bullard (1926, p. 36) adopted Taff's original concept concerning the Bokchito Formation and subdivided it into three members using the terms already established in Texas, thus dividing the Bokchito Formation into the Denton, Weno, and Pawpaw Members. He gave the Bennington Limestone formational rank and correlated it with the Main Street Limestone of Texas. The Grayson marlstone was also given formational rank and

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described as consisting of 25 feet of fossiliferous clays or marls and beds of nodular limestones.

At the top of the Denton Clay Member is a persistent limestone marker bed commonly referred to as the *Ostrea carinata* bed. At the top of the Weno Clay Member, an arenaceous limestone commonly known as "Quarry Limestone" serves as a marker bed separating the Weno from the overlying Pawpaw Sandstone Member. Huffman and others (1975, p. 16) proposed the name Soper Limestone Member for the *Ostrea carinata* bed and applied the term McNutt Limestone Member to the "Quarry Limestone" of previous reports. Figure 1 shows the stratigraphic sequence in southern Oklahoma of units in the Bokchito and adjoining formations. Descriptions of the units are taken partly from Oklahoma Geological Survey Bulletin 120, *Geology and Mineral Resources of Choctaw County, Oklahoma* (Huffman and others, 1975), but in this paper the formation has been traced throughout southern Oklahoma.

CLASSIFICATION					ROCK	THICKNESS (FEET)	DESCRIPTION OF UNITS
CRETACEOUS SYSTEM	COMANCHEAN SERIES	WASHITA GROUP	Grayson Formation			0-27	Olive-gray to light-greenish-gray marlstone with interbeds of white, nodular limestone; fossiliferous, with abundant *Ilymatogyra arietina* (Roemer) and *Texigryphaea romeri* (Marcou)
			Bennington Limestone			7-13	Blue-gray, heavy-bedded to massive, fine- to medium-crystalline limestone; weathers yellow-brown, pitted and honey combed, fossiliferous, with abundant *Ilymatogyra arietina* (Roemer).
			BOKCHITO FORMATION	Pawpaw Sandstone Member		40-45	Yellow to brownish-red, ferruginous sandstone interbedded with gray to brown, sandy shale; grades laterally into shale. Abundant molds of *Protocardia*.
				McNutt Limestone Member		1-20	Gray-brown, sandy, fossiliferous limestone with abundant *Ostrea quadriplicata* Shumard ("Quarry Limestone" of older reports).
				Weno Clay Member		80-100	Yellow to reddish-brown, ferruginous, sandy shales with abundant molds of *Protocardia* and *Turritella*, selenite crystals on weathered surface.
				Soper Limestone Member		0-2	Gray, fossiliferous limestone with abundant *Texigryphaea washitaensis* (Hill), *Ostrea quadriplicata* Shumard, and *Rastellum (Arctostrea) carinatum* (Lamarck).
				Denton Clay Member		54-60	Blue-gray shale grading upward into beds of fossiliferous marlstone with abundant *Texigryphaea washitaensis* (Hill).
			Caddo Formation			150-160	Blue-gray to cream-colored limestone and interbedded shale. Includes equivalents of Duck Creek and Fort Worth Formations of Texas. Marked at base by abundance of large cephalopods.

Figure 1. Columnar section showing sequence of units in Bokchito and adjacent formations, southern Oklahoma.

Members of the Bokchito Formation

Denton Clay Member.—The Denton Clay was named by Taff and Leverett (1893, p. 272) for exposures along Denton Creek, Denton County, Texas. The Denton was originally assigned to the upper part of the Fort Worth Formation but was later reassigned by Hill (1901, p. 115), who considered it a separate unit lying between the Fort Worth and the Weno Clay. At the type locality, the Denton consists of 40 feet of bluish shales and the marls capped by a thin, fossiliferous limestone (*Ostrea carinata* bed).

The Denton Clay Member is well developed in Southern Oklahoma, having been mapped across Love, Marshall, Bryan, and Choctaw Counties. It extends beneath terrace deposits in eastern Choctaw County and is absent because of overlap of the Woodbine Formation in McCurtain County.

The Denton Clay Member has been described in Love County by Bullard (1925), Redfield (1929), and Frederickson, Redman, and Westheimer (1965). According to Frederickson, Redman, and Westheimer (1965, p. 27-28), the Denton comprises 70 feet of calcareous shales, marly clays, interbedded sandstones, and fossiliferous limestones. The basal beds consist of 2.5 feet of gray, calcareous shale. Overlying beds are interbedded shale and thin sandstones with a 2-foot bed of buff, ferruginous sandstone near the middle. The top of the formation is marked by 4 feet of fossiliferous marlstone capped by a thin, dense, fossiliferous limestone called the "*Ostrea carinata*" bed. *Texigryphaea washitaensis* (Hill) occurs in abundance in the upper beds. A similar sequence was described by Redfield (1929, p. 20) in a measured section along Red River, sec. 13, T. 8 S., R. 2 E.

In Marshall County (according to Bullard, 1926, p. 37-38), the Denton consists of 45 to 56 feet of brownish-yellow clay, with numerous sandstone beds and lenses, terminating at the top with a hard, brownish, arenaceous limestone. The lower 5 to 10 feet is described as a calcareous clay. A ripple-marked sandstone lies 30-35 feet above the base, and the top is marked by impure, fossiliferous limestones characterized by *Texigryphaea washitaensis* (Hill), *Ostrea quadriplicata* Shumard, *Leiocidaris hemigranosus* (Shumard), and *Rastellum (Arctostrea) carinatum* (Lamarck). A similar sequence was noted by Ganser (1968, p. 24-26). One of the best sections is exposed at the west end of the bridge across Lake Texoma, south roadside, sec. 35, T. 6 S., R. 6 E.

In Bryan County, Huffman and others (written communication) have described the Denton as a blue-gray to brownish-gray clay shale with thin interbeds of siltstone. The Denton becomes increasingly calcareous upward, and thin beds of fossiliferous marlstone occur immediately below the *Ostrea carinata* bed. The lower shaly portion of the Denton is almost devoid of fossils, whereas the upper calcareous beds have yielded *Texigryphaea washitaensis* (Hill), *Ostrea quadriplicata* Shumard, *Pecten (Neithea) texanus* Roemer, and *Rastellum (Arctostrea) carinatum* (Lamarck). Thicknesses range from 54 to 60 feet in Bryan County.

The Denton Clay Member is poorly exposed in Choctaw County; the best known exposure is in a railroad cut and ditch half a mile southeast of Soper, Oklahoma (sec. 13, T. 6 S., R. 15 E.). Elsewhere, the non-resistant clays and shales form an undulating surface covered with prairie hay and grasses. The unit consists of blue-gray to brownish-gray shales that grade upward into gray shale and marly limestones characterized by the association of *Texigryphaea washitaensis* (Hill), *Pecten (Neithea) texanus* Roemer, *Ostrea quadriplicata* Shumard, *Trigonia clavigera* Cragin, and *Rastellum (Arctostrea) carinatum* (Lamarck). Thicknesses range from 45 to 65 feet in Choctaw County where it forms a nearly continuous outcrop belt from the Bryan-Choctaw County line eastward through Soper and Hugo to the vicinity of Sawyer where it disappears beneath extensive terrace cover.

Soper Limestone Member.—The term Soper Limestone Member was applied by Huffman and others (1975, p. 16-17) to a bed of gray-brown to reddish-brown, hard, compact, fossiliferous limestone previously referred to as the "*Ostrea carinata*" bed. Actually, *Ostrea carinata*—now known as *Rastellum (Arctostrea) carinatum* (Lamarck)—occurs sparingly in the Soper Limestone and has been found in abundance in some layers of the upper part of the Caddo Limestone.

The Soper Limestone Member is named for an excellent exposure in a railroad cut 0.5 mile southeast of Soper, Choctaw County, Oklahoma (NE¼SW¼ sec. 13, T. 6 S., R. 15 E.), where it is 1.5 feet thick. It is a hard, resistant limestone that forms a prominent ledge capping the underlying Denton Clay Member. Because of its resistance to weathering and erosion, the Soper forms a conspicuous ledge where it crosses a highway or stream. Several south-flowing streams are floored by this unit.

The Soper Member serves as an excellent marker bed, separating the Denton Clay Member and the Weno Clay Member. Its contact with the underlying Denton is conformable and transitional; contact with the overlying Weno is abrupt and nongradational. Characteristic fossils include *Texigryphaea washitaensis* (Hill), *Ostrea quadriplicata* Shumard, and *Rastellum (Arctostrea) carinatum* (Lamarck).

Weno Clay Member.—The Weno Clay Member was named by Hill (1901, p. 121) for exposures near the village of Weno (now abandoned), northeast of Denison, Grayson County, Texas. The type Weno was described as comprising 92 feet of ferruginous, brownish-clay shales and marly clays. The "Quarry Limestone," now known as the McNutt Limestone Member, a blue-gray, massive, arenaceous limestone that oxidizes yellow, was included in the Weno by Hill but was later placed in the lower part of the Pawpaw Sandstone Member by Stephenson (1918, p. 142). Huffman and others (1975, p. 18) renamed the Quarry Limestone the McNutt Member on the basis of its excellent development and lateral persistence throughout Bryan and Choctaw Counties.

The Weno Member was described by Frederickson, Redman, and Westheimer (1965, p. 28-30) in Love County, Oklahoma, where it consists of interbedded, gray, marly shales and red, ferruginous, fossiliferous, concretionary sandstones. A marked feature of the Weno is slabby, ferruginous concretions that cover eroded slopes of the outcrop. A few of the sandstones are well cemented with iron oxide and contain an abundance of *Turritella*. Slabs of this indurated, fossiliferous sandstone commonly occur with the concretions on weathered surfaces. Some of the sandstones are locally cross-bedded. About 20 feet above the base of the Weno are several thin beds of selenite gypsum that are laterally continuous in some exposures. The outcrop is approximately 43 feet thick in Love County.

In Marshall County, Bullard (1926, p. 38) described the Weno Member as consisting of up to 135 feet of dark-gray to yellow clay. Ganser (1968, p. 28) recognized a maximum thickness of 90 feet in eastern Marshall County. Beds of soft yellow sand similar to that found in the Pawpaw Member were reported in the upper part of the Weno. The Weno is easily recognized by the large number of clay-ironstone concretions, whose weathered fragments cover the surface of the exposures. The Weno weathers easily, forming a rolling upland surface covered with grass, thus making good exposures difficult to find.

In Bryan County, the Weno Clay Member reaches a thickness of 80 to 90 feet in the northern part of the county (Hart, 1970, p. 81) and thickens southward to 109 feet in western Bryan County (Currier, 1968, p. 22). There the lower part consists of 45 to 50 feet of olive-gray shale with thin interbeds of brown, ferruginous sandstone and siltstone. Selenite crystals, limonite, marcasite concretions, and clay-ironstone concretions are present. Weathered slopes are littered with pieces of broken fragments of the ferruginous concretions.

The upper Weno (30 to 40 feet) contains a lower zone of medium- to thick-bedded, ripple-marked, ferruginous sandstone and interbedded clays. The uppermost 20 feet consists of massive-bedded, yellow to orange, fine-grained, friable, fossiliferous, and micaceous sandstones. The Weno conformably succeeds the Soper Limestone Member. Fossils are exceedingly sparse in both the shale and sandstone facies of the Weno. Molds and casts of *Turritella, Protocardia, Nucula,* and *Corbula* are present in some of the sandstone layers.

In Choctaw County, the Weno forms a wide outcrop belt from the county line west of Boswell to the Kiamichi River south of Sawyer, where it passes beneath the terrace cover. The thickness ranges from 30 to 53 feet and averages 50. The Weno Member consists of brownish shales and thin beds of red, ferruginous sandstone. The lower part is predominantly shale, with scattered thin seams of gypsum. Selenite crystals occur on weathered surfaces. The upper part becomes increasingly sandy, and at places the upper beds consist of soft, massive, yellow, fine-grained, poorly consolidated sandstone. Ferruginous sandstones in the Weno Member contain molds and casts of *Protocardia* and *Turritella*.

McNutt Limestone Member.—The term McNutt Limestone Member was proposed by Huffman and others (1975, p. 18) for a 2- to 3-foot bed of sandy, locally platy, fossiliferous limestone previously referred to as "Quarry Limestone." The name Quarry seems inappropriate, because the limestone is too arenaceous for quarrying in Southern Oklahoma and because Quarry is not a geographic term and therefore can be used only in an informal way. The name McNutt is taken from the McNutt Ranch, about 4 miles southeast of Soper, Choctaw County, Oklahoma, NE¼SE¼ sec. 36, T.

6 S., R. 15 E., where the unit is well exposed and forms the caprock around the hills of this upland area.

The McNutt Limestone Member varies from an arenaceous limestone to a highly calcareous sandstone, with the carbonate facies predominant. A sample taken from exposures east of U.S. Highway 271, north of Grant, on the south bank of Horse Creek, contained 77 percent carbonate and 23 percent insoluble material consisting of fine quartz sand and traces of magnetite (Alfonsi, 1968, p. 3).

The McNutt has been traced along a discontinuous exposure from west of Boswell to the vicinity of Grant (sec. 9, T. 7 S., R. 17 E.), and from there eastward to the vicinity of Sawyer, where it passes beneath the terrace. Fossils are rare in the McNutt Limestone except at places where an abundance of *Ostrea quadriplicata* Shumard occurs. *Texigryphaea washitaensis* (Hill), *Lopho subovata* (Shumard), *Pecten subalpinus* Bose, *Lima wacoensis* Stanton, *Nucula nokonis* Adkins, and *Protocardia* sp. have been identified.

In Bryan County, the McNutt Limestone Member varies from an arenaceous limestone to a calcareous sandstone. At places, only a single bed is present; elsewhere 2, 3, or even 4 beds (separated by calcareous silt, clay, and yellow sand) are present; the thickness ranges from a few inches to 20 feet. Insoluble-residue data indicate a composition of 76- to 82-percent calcium carbonate and 18- to 24-percent silt, sand, and clay. The limestones are thick-bedded, well indurated, fine- to medium-grained, bioclastic calcarenites. The most conspicuous fossil is *Ostrea quadriplicata* Shumard, whose outlines are abundantly preserved on weathered surfaces. Forms collected by Hart (1970, p. 88-89) include *Texigryphaea* sp., *Ostrea quadriplicata* Shumard, *Ostrea (Lopho) subovata* Shumard, and *Pecten (Neithea) subalpinus* (Bose).

Currier (1968, p. 24) reported 13 feet of Quarry Limestone in southwestern Bryan County, and Ganser (1968, p. 28) observed 15 to 20 feet in eastern Marshall County. In Love County, Redman (1964, p. 44) described the Quarry Limestone as a 2-foot bed of brown, fossiliferous, sandy limestone.

Pawpaw Sandstone Member.—The Pawpaw Sandstone (or Sand) was named by Hill (1894, p. 330) for exposures along Pawpaw Creek near Denison, Grayson County, Texas, where the unit was described as light-drab, fossiliferous, thinly laminated clay lying between the Weno Clay and the Main Street Limestone. It was described as becoming increasingly sandy northward.

In Choctaw County, Oklahoma, the Pawpaw consists of red and yellow sandstones interbedded with gray and reddish-purple sandy clay. The sandstones are poorly indurated, friable, and ferruginous. Weathered slopes are covered with clay-ironstone fragments and sandy rubble. The upper part is predominantly a fine-grained, ferruginous sand cemented with yellow, silty clay. Sieve analysis of a sample from the eastern part of the County (Duarte-Vivas, 1968, p. 37) indicates that the bulk of the grains are in the 3.0 ϕ to 4.0 ϕ range on the phi scale. The member is fairly uniform in thickness, averaging 35 feet. The ferruginous sandstones have yielded abundant molds and casts of small bivalves, including numerous specimens of *Protocardia* sp. *Engonoceras serpentinum* (Cragin) was collected immediately above the McNutt Limestone Member in the basal Pawpaw in sec. 36, T. 6 S., R. 15 E., on the McNutt Ranch.

In Bryan County, the Pawpaw Member is a complex sequence of clay shales, sandstones, and local lenses of very sandy, massive, calcarenite. The clay shales are gray to olive-gray, platy, and interbedded with thin sandstone and siltstone beds and clay-ironstone concretions. The sandstones are gray to brown where fresh but are weathered to varying shades of yellow, orange, and reddish-brown. The sandstones are fine-grained, well-sorted, subangular, ferruginous, friable, and quartzose with some cross-bedding and ripple-marked layers. Mica flakes, chert nodules, glauconite, clay-ironstone concretions, and macerated pelecypod remains have been observed. Lateral facies changes and eastward thinning characterize the Pawpaw along the present outcrop in Bryan County. In western Bryan County, sandstone predominates over subordinate amounts of sandy clay in a 42- to 45-foot-thick unit. The sandstone facies changes into shale eastward as indicated by the excellent exposure along Highway 70 east of Blue River in SW¼SE¼ sec. 27, T. 6 S., R. 10 E. In this exposure (south roadside only), a 16-foot lense of cross-bedded calcarenite occurs in the upper part of the Pawpaw (NE¼ sec. 34, T. 6 S., R. 10 E.).

In extreme eastern Bryan County, the Pawpaw consists of 45 feet of beds consisting predominantly of red to yellow, cross-bedded, friable sandstone. The sandstone is poorly sorted and silty, the grains are subangular to subrounded and are coated with iron oxide. Fragments of clay-ironstone litter eroded surfaces. The Pawpaw rests conformably on the McNutt Limestone Member and is succeeded conformably by the Bennington Limestone except in a small area in eastern Bryan County where the Woodbine Formation rests unconformably on the Weno Member of the Bokchito Formation.

Few fossils were observed in the Bryan County exposures. Hart (1970, p. 100) reported the presence of a few turritellids in the Pawpaw. Other fossils noted are *Protocardia* sp., *Nucula* sp., *Cyprimeria washitaensis* Adkins, and *Ostrea quadriplicata* Shumard.

In Marshall County, Bullard (1926, p. 43-44), described the Pawpaw Member as consisting of 60 feet of irregularly bedded sandy clays and sands lying between the "Quarry Limestone" and the Bennington Limestone. A section measured on the west bluff of the Washita River east of Woodville described the Pawpaw as consisting of a 22-foot section of blue to yellow clay containing clay-ironstone concretions and thin beds of yellow sandstone like those in the underlying Weno and a 38-foot section of soft yellowish to brown sandstone. Ganser (1968, p. 30) noted that the Pawpaw had thinned to 45 feet in eastern Marshall and western Bryan County in the Cumberland Area.

Frederickson, Redman, and Westheimer (1965, p. 30) divided the Pawpaw into a basal shale unit (16 feet) and an overlying buff to red sandstone sequence (36 feet) separated by a thin bed of calcarenite (1 foot) for a total of 53 feet in Love County.

Summary and Conclusions

In southern Oklahoma, the Bokchito Formation is a natural stratigraphic sequence of shales, friable sandstones, and fossiliferous limestones that lie between the upper part of the Caddo Formation (equivalent to the Fort Worth Formation of Texas) and the Bennington Limestone. The Bokchito Formation can be divided into five members. In ascending order, they are (1) Denton Clay Member, (2) Soper Limestone Member, (3) Weno Shale Member, (4) McNutt Limestone Member, and (5) Pawpaw Sandstone Member. Separation and delineation of the Bokchito members can be accomplished only where the marker beds, the Soper Limestone and the McNutt Limestone Members, can be recognized. These two marker beds have been mapped in Bryan and Choctaw Counties.

References Cited

Alfonsi, P. P., 1968, Lithostratigraphy and areal geology of east-central Choctaw County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 57 p.

Bullard, F. M., 1925, Geology of Love County, Oklahoma: Oklahoma Geological Survey Bulletin 33, 77 p.

———1926, Geology of Marshall County, Oklahoma: Oklahoma Geological Survey Bulletin 39, 101 p.

Currier, J. D., Jr., 1968, Stratigraphy and areal geology of southwestern Bryan County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 76 p.

Duarte-Vivas, Andrew, 1968, Geology of eastern Choctaw County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 70 p.

Frederickson, E. A., Redman, R. H., and **Westheimer, J. M.,** 1965, Geology and petroleum of Love County, Oklahoma: Oklahoma Geological Survey Circular 63, 91 p.

Ganser, R. W., 1968, Geology of the Cumberland area, Bryan, Johnston, and Marshall Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 60 p.

Hart, T. A., 1970, Areal geology and Cretaceous stratigraphy of northwestern Bryan County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 215 p.

Hill, R. T., 1894, Geology of parts of Texas, Indian Territory, and Arkansas adjacent to Red River: Geological Society of America Bulletin, v. 5, p. 297-338.

———1901, Geography and geology of the Black and Grand Prairies, Texas: U.S. Geological Survey 21st Annual Report, pt. 7, 666 p.

Huffman, G. G., Alfonsi, P. P., Dalton, R. C., Duarte-Vivas, Andres, and **Jeffries, E. L.,** 1975, Geology and mineral resources of Choctaw County, Oklahoma: Oklahoma Geological Survey Bulletin 120, 39 p.

Redfield, J. S., 1929, Differentiation of the Bokchito Formation, Love County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 36 p.

Redman, R. H., 1964, Post-Mississippian geology of Love County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 72 p. [incorporated in Oklahoma Geological Survey Circular 63; *see under* Frederickson, E. A., Redman, R. H., and Westheimer, J.M.].

Stephenson, L. W., 1918, A contribution to the geology of northeastern Texas and southern Oklahoma: U.S. Geological Survey Professional Paper 120-H, p. 129-163.

Taff, J. A., 1902, Description of the Atoka quadrangle [Indian Territory]: U.S. Geological Survey Geologic Atlas Folio 79, 8 p.

Taff, J. A., and **Leverett, S.,** 1893, Report on the Cretaceous area north of the Colorado River, *in* Fourth Annual Report of the Geological Survey of Texas, 1892, pt. 1, p. 241-354.

Ruth Sheldon Knowles Speaks at OU

Ruth Sheldon Knowles
(Photo courtesy of The Oklahoma Daily)

Ruth Sheldon Knowles, in a special lecture at The University of Oklahoma on January 19, outlined the events that she felt had led to our nation's current energy crisis and some of the steps needed to alleviate the crisis. Her lecture on the OU campus was sponsored jointly by the School of Geology and Geophysics, the Oklahoma Geological Survey, and the University's program in petroleum-land management.

Mrs. Knowles spoke from a wealth of knowledge and experience as an international petroleum specialist. A native of Tulsa, her assignments have taken her to many parts of the world as consultant, lecturer, and correspondent, and she has set forth her views most recently in her book *America's Oil Famine–How It Happened and When It Will End* (Coward, McCann & Geoghegan, Inc., 1975).

In speaking of our present energy bind, Mrs. Knowles remarked that much of our trouble could be traced to a 1954 Supreme Court decision that caused natural-gas prices to be placed under the jurisdiction of the Federal Power Commission for regulation on the interstate market. The result was an inordinate demand for cheap natural gas as a clean source of power for electricity generation, industrial use, and domestic heating. Therefore, the coal industry, already depressed, sank further into the doldrums. At about the same time, the refining of fuel oil became less profitable, Mrs. Knowles explained, because the Northeast, for instance, started importing "cheap" foreign fuel oil. This region now imports 90 percent of its fuel oil, and it is anything but cheap.

Mrs. Knowles believes that by 1970 the imminent approach of the energy crunch should have been apparent even to the casual observer. At that point, she said, she felt impelled to carry this message to the public —and did so with missionary zeal (she explained that she comes from a long line of Baptist circuit riders on her mother's side)—but her warnings were practically ignored.

She went on to recount that the public's environmental conscience, which had been awakened by Rachel Carson's *Silent Spring* back in the early 1960's, had grown steadily up to 1970. In that year this growth culminated in the nation's celebration of Earth Day and Congress' passage of the National Environmental Policy Act, which provided for the now omnipresent environmental-impact statement.

Other significant environmental events during this period were the oil spill in the Santa Barbara Channel, which halted further offshore drilling in California, and the shutting down of the Alaska pipeline project by an environmentalists' suit.

Mrs. Knowles pointed out that these things all worked to hamper further energy development at a time when the nation was just passing its peak in domestic oil production and when it needed desperately to increase its petroleum reserves and refining capacity. Inevitably, blackouts and gasoline shortages began cropping up.

But the event that really brought the energy-environment collision home to the public, Mrs. Knowles said, was the oil embargo by the Arab producing nations following the Yom Kippur War in the Middle East (October of 1973). The Arabs and other members of the Organization of Petroleum Exporting Countries (OPEC) proved that they had economic clout when they quadrupled the price of oil in early 1974. Mrs. Knowles feels that if these new world-market prices for oil had been allowed to stand in the United States for domestic production, our producers would have had the economic means to generate additional capital for exploratory drilling; but what actually happened—the federal government's two-tier pricing system for old oil and new oil, and then a further rollback of prices for new oil—was in reality an economic disincentive for exploration and further encouragement for wasteful consumption.

Mrs. Knowles went on to say that there is no way our country can avoid importing 50 percent of our oil needs by 1980 [we are presently importing 43 percent] because of the lead time of several years required to bring new fields into production. She emphasized the need for the government to act quickly on phasing out price controls on crude oil and gasoline and on deregulating natural gas on the interstate market. She said that if these actions are not taken, the United States will be at least 70-percent dependent on imports by 1990. She pointed out that crude oil and natural gas together account for 75 percent of our present energy needs and that by the end of this century they will still be supplying most of our needs. She stressed that if a free market is allowed to exist for energy, alternate energy sources—like solar, wind, tidal, and geothermal power—would be more economically viable.

On the subject of oil-company profits, Mrs. Knowles said that the petroleum industry makes an average of 11½ percent—about the same as most manufacturing companies. This comes out to only 2 cents a gallon, roughly, on petroleum products. She stressed that this return is not enough to provide capital needs for future energy exploration and development.

And on the subject of divestiture, she stated flatly that the concept is "the most idiotic thing I have heard of." She pointed out that divestiture would eliminate the cost-cutting efficiencies of integrated companies and that the consumer would end up paying a bigger bill. She emphasized that no monopolies exist—that no single company owns more than 8 percent of any operation.

Mrs. Knowles said that the consensus of specialists leads to the conclusion that we have in this country about as much oil still left to find as we have found in the past, but most of it will be more difficult to find and more expensive to produce. She also pointed out that at the present time small companies and independents are making 75 percent of our discoveries.

And she feels strongly that our country needs to continue the "freedom to disagree" as to where oil might or might not be found.

—*William D. Rose*

El Paso Hosts GSA South-Central Section

The South-Central Section of The Geological Society of America will hold its 11th annual meeting March 17-18 in El Paso, Texas. The Department of Geological Sciences of The University of Texas at El Paso and the El Paso Geological Society, co-sponsors for the meeting, have arranged premeeting field trips (March 16) to study the volcanics of the El Paso border region and the Ordovician stratigraphy of the Franklin Mountains, plus post-meeting trips (March 19) to cover the structure and geomorphology of the El Paso area and regional stratigraphy.

In addition to technical sessions on general geology, paleontology, petrology, tectonics, and sedimentology, 9 symposia will be held during the 2-day meeting. Subjects to be covered include tectonics and geophysics of the Mexican highlands, the southern Rio Grande rift, and the south-central United States; Ordovician and Permian deposits of the Southwest; and geology of the Sierra Madre and of the west Mexican coastal plain. Timely topics concern the geothermal resources of west Texas and southern New Mexico and the thermo-maturation of organic residues. A symposium on

"Women in Geology" may also be considered timely in view of the current interest in that resource.

Of special interest to Oklahomans is a symposium on "Coal Deposits of the Southern Western U.S.," to be held March 17. Two papers authored by Oklahoma Geological Survey staff members will be presented: "Investigations of the Pennsylvanian Coal Deposits in Eastern Oklahoma (1971-1976)," by OGS coal geologist S. A. Friedman; and "Preliminary Investigation of Pennsylvanian Underclays of Oklahoma," by F. H. Manley (Department of Geology, Georgia State University), S. A. Friedman, and OGS director C. J. Mankin. Papers on Oklahoma coal resources in Le Flore, Haskell, and Rogers Counties will also be presented at this symposium.

From the standpoint of its historical and cultural background, its geologic and geomorphic setting, and its immediate proximity to Mexico, El Paso is a fascinating community; it will provide a memorable setting for the outstanding scientific program that has been arranged for the 1977 GSA South-Central Section Meeting.

Short-Course Format Devised for Micropaleontology

The University of Nebraska will offer a short course in micropaleontology June 27-July 7. The 10-day course is designed to update industrial and academic micropaleontologists, plus management personnel, and to provide intensive course training to upper-level undergraduate and graduate geology students. Most of the biostratigraphically important microfossil groups will be reviewed, up-to-date information on their ecology and taxonomy will be provided, and their use in petroleum exploration will be evaluated.

The lecture staff for the micropaleontology course will consist of 10 specialists, including Dr. L. R. Wilson, George Lynn Cross Research Professor in the School of Geology and Geophysics at The University of Oklahoma and geologist with the Oklahoma Geological Survey. Lectures will be presented twice a day by each specialist, followed by a 2-hour laboratory session using compound and binocular microscopes. Each lecturer will provide materials for examination and study, and essential literature will be available in the laboratory. Notes on salient portions of each specialist's presentation will be incorporated in the bound course volume.

Basic tuition for the course is $600.00 and includes all required course material. Graduate or advanced undergraduate students can receive 2-3 semester hours credit at the in-state rate of $24.50 per semester hour ($49.00 or $73.50 in addition to the basic registration fee). Housing is available at the Lincoln Hilton or on campus in dormitories. Additional information will be mailed on request to Dr. Paul R. Krutak, course administrator, at the Department of Geology, 418 Morrill Hall, University of Nebraska, Lincoln, Nebraska 68508 (phone: 402-472-2645).

APHELECRINUS (CRINOIDEA: INADUNATA) FROM CHESTERIAN ROCKS OF OKLAHOMA

Harrell L. Strimple[1]

The purpose of the present study is to record the presence of *Aphelecrinus planus* Strimple, 1951, in the Pitkin Limestone of northeastern Oklahoma and to note atypical branching in the *A* ray of one specimen and a regenerated arm in another specimen of the species.

Aphelecrinus elegans Kirk, the type species of the genus *Aphelecrinus* Kirk, 1944, is from the St. Genevieve Limestone of Alabama.

A. planus is typically from the upper Fayetteville Shale, Chesterian, of Craig County, Oklahoma. This horizon has been correlated by Horowitz and Strimple (1974, fig. 2) with the Pendleian (E_1) of England, Namurian of Europe, and Serpukhov (C_1^3) of Russia. The Pitkin Limestone has been correlated (Horowitz and Strimple, 1974) with the Arnsbergian (E_2), Namurian of Europe and Protva (C_1^4(D)) of Russia.

A. exoticus Strimple, 1951, also occurs in the Fayetteville Shale but differs from *A. planus* in having a shallower, more flared cup with deep, broadly impressed radial adsutural areas and pronounced surface ornamentation. Both species, *A. planus* and *A. exoticus*, have lower cups and more pronounced notches between radial articular facets than those found in other species of *Aphelecrinus*. The genus is conservative in the retention of a cone-shaped cup with infrabasals visible in the side view of the cup and uniserial arms.

The ability to regenerate arms and other skeletal elements is well documented for modern as well as fossil echinoderms, but fossil evidence is uncommon enough to be considered an oddity. In one specimen (USNM 184648), the left arm of *C* ray has been lost above secundibrach *1* and the regenerated arm is only slightly larger than the pinnule, which apparently remained undamaged. The pinnules are quite large in *A. planus*, particularly those in the proximal region, which are the first formed. A larger, more mature specimen of the species (USNM 184646) demonstrates the second bifurcation of the arms, which may take place above secundibrachs *12-15*, and the buttressed effect often demonstrated on the pinnule-bearing side of the brachials. This is best shown by fig. 1b, which shows that some of the large (older) pinnulars bear a node near their distal end. An oblique view of the upper surface of a pinnular that could not be removed from the matrix (fig. 1c) does not adequately show the depth of the lateral sides but does illustrate the rounded exterior and the relative width of the ambulacral groove.

The presence of nonaxillary primibrach *1* and axillary primibrach *2* in the *A* ray of the larger specimens of *A. planus* (USNM 184646) is atypical of

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both the species and the genus, but several nonaxillary primibrachs are found in the *A* ray of the geologically older *Paracosmetocrinus* Strimple, 1967. Both *Aphelecrinus* and *Paracosmetocrinus* belong to the family Aphelecrinidae Strimple, 1967, and the specimen herein reported is thought thought to have reverted to an earlier stage in this regard. No specimens of the lineage have previously been reported with 2 primibrachs in the *A* ray; most have 1, 3, or more primibrachs. A species of the lineage will probably be found, eventually, with two primibrachs in each ray.

Material used in this study was collected in 1950-51 from a shale parting of the Pitkin Limestone in bluffs overlooking the Arkansas River, SE¼ sec. 27, T. 13 N., R. 20 E., Muskogee County, Oklahoma. The exposure was discovered by Claude Bronaugh (then a resident of Afton, Oklahoma) who followed up on a conversation about fossil "acorns" [*Pentremites*] found on the bluffs. The locality has yielded the most prolific accumulation of crinoids of Pitkin age to be found in Oklahoma.

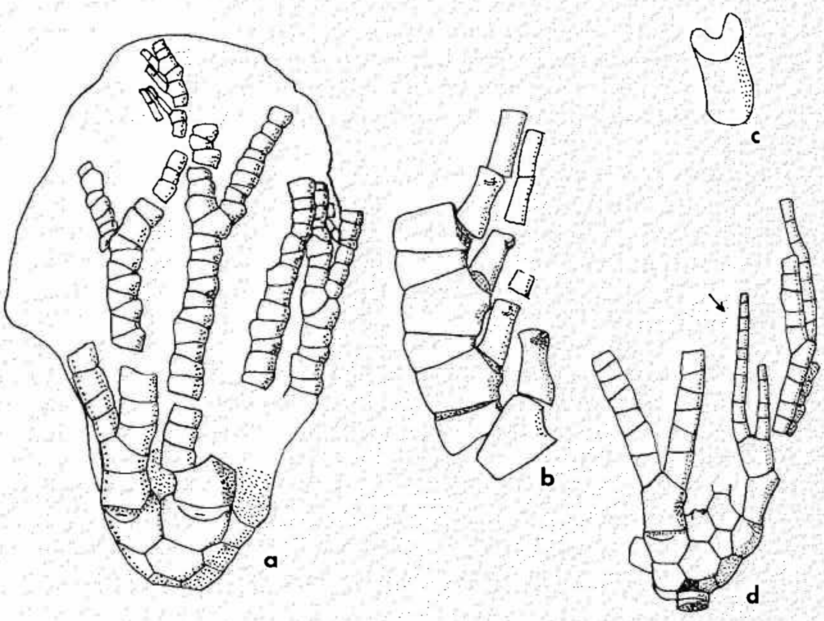

Figure 1. Camera-lucida drawings of *Aphelecrinus planus* Strimple, 1951, from the Pitkin Limestone, Muskogee County, Oklahoma: (*a*)—hypotype crown (USNM 184646), *A* ray at left with atypical axillary primibrach 2, ×3; (*b*)—brachials and pinnules from lower part of *D* ray arm, ×6; (*c*)—oblique view of pinnular, ×12.5; (*d*)—young hypotype crown (USNM 184648), posterior view shows regenerated arm (arrow) is not appreciably wider than pinnule to its right, ×3.

The two specimens reported here are designated hypotypes of *Aphelecrinus planus* and are housed in the National Museum of Natural History, Washington, D.C., catalogue numbers USNM 184646 and USNM 184648.

References Cited

Horowitz, A. S., and **Strimple, H. L.,** 974, Chesterian echinoderm zonation in eastern United States: Septiéme Congrès International de Stratigraphie et de Géologie du Carbonifere, Compte Rendu, Bd. III, p. 207-219, 2 figs.

Strimple, H. L., 1951, Notes on *Phanocrinus cylindricus* and description of new species of Chester crinoids. Journal of the Washington Academy of Sciences, v. 41, p. 291-294, figs. 1-12.

——1967, Aphelecrinidae, a new family of Inadunate crinoids: Oklahoma Geology Notes, v. 27, p. 81-85, 1 pl.

OKLAHOMA ABSTRACTS

AAPG Distinguished Lecture Series

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Aulacogens and Megashears: Natural Habitat for Oil and Mineral Deposits

JOHN M. BROWNING, J. M. Browning Consultants, Ltd., Calgary, Alberta, Canada

Sedimentary basins associated with linear structural features such as megashears, deflections, and geofractures striking at high angles to cratonic interiors have been prospected for oil since early in the history of petroleum exploration. Although long conceived as regional features, these linear structures only recently have been recognized to have a common origin as aulacogens or "failed arms" of plume-generated triple junctions formed during the process of continental breakup.

These features, trending at high angles from the rifted continental margin, mark ancient plate margins and establish the time of crustal rift-

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

ing. Some, formed at an early stage in the evolution of the earth's crust, have remained active or become reactivated as major sites of crustal dislocation during subsequent episodes of continental breakup and collision. Others, governing the course of major rivers, become the site of deltas that have augmented the sedimentary fill. These long structural and varied depositional histories and the critical timing of the ongoing tectonic processes, often of a transcurrent nature, together with the accompanying sedimentation have given rise to major hydrocarbon accumulations. In addition to the formation of favorable source beds, and structural and stratigraphic traps, the high heat-flow characteristic of these features often enhances the generation of oil and gas.

Some aulacogens are marked only by a line of alkaline intrusions, others have complex igneous histories and commonly become the site of base-metal mineralization of a syngenetic type.

Three of these features—the Athapuscow aulacogen of northern Canada, the Wichita aulacogen of southern Oklahoma, and the Huancabamba deflection of central South America—illustrate the problems related to time of formation and the sedimentary and tectonic evolution and illustrate the formation of local structures and depositional basins and their relation to the evolution of the major tectonic feature.

Several other regional features having oil and gas potential, e.g., the Delaware basin of West Texas, the Bathurst Inlet of northern Canada, and the Mississippi embayment of the Gulf Coast, that now are termed aulacogens offer comparisons. [p. 2067]

AAPG Regional Meeting, Southwest Section
Abilene, Texas, March 6-8, 1977

The following abstract is reprinted from the February 1977 issue, v. 61, no. 2, of the *Bulletin* of The American Association of Petroleum Geologists. The page number is given in brackets below the abstract. Permission of the author and of Gary Howell, AAPG managing editor, to reproduce the abstract is gratefully acknowledged.

Statistical Summary of Wells Drilled Below 18,000 ft (5,486 m) in West Texas and Anadarko Basin

RICHARD STEINMETZ, Amoco Production Co., Tulsa, Oklahoma

In West Texas and southeastern New Mexico, 402 wells have been drilled below 18,000 ft (5,486 m). Of this number, 230 (57%) are producing below 18,000 ft, nearly all of them from the Ellenburger, and 81 (20%) are producing above 18,000 ft. Of the total wells, 134 (33%) were wildcats, of which 72 (54%) were successful at any depth.

In the Texas Panhandle and Oklahoma, 141 wells have been drilled below 18,000 ft. Of this number, 41 (29%) are producing below 18,000 ft, most of them from the Hunton, and 44 (31%) are producing above 18,000 ft.

Of the total wells, 73 (52%) were wildcats, of which 30 (41%) were successful at any depth.

In the entire United States a total of 39,097 wells was drilled in 1975. Of this number 23,988 (61%) found oil or gas. Of the total wells, 9,214 (24%) were wildcats, of which 2,143 (23%) were discoveries. Comparison of the percentages of success for deep wells versus all wells in the United States indicates that deep-well prospects are evaluated more thoroughly and scientifically than shallower wells.

Crossplots of initial potentials (MCFD) versus depths of completion intervals exhibit no trend or correlation in either region. This suggests that there is no significant change in porosity or permeability with increasing depth in either the Ellenburger or Hunton carbonate rocks.

Data from *Petroleum Engineer* show that an average 22,000-ft (6,706 m) Pecos County well cost $72.75 per foot ($240.08 per meter) in 1970. The cost increased to $106.80 (47%) in 1975. An average 20,000-ft (6,096 m) Anadarko basin well cost $82.50 per foot ($272.25 per meter) in 1970 and $122.50 per foot ($404.25 per meter) in 1975 for an increase of 48%. By comparison, the average cost for all wells drilled in the United States increased 112% between 1970 and 1975. It is obvious that carefully monitored drilling practices and experience successfully held down inflationary costs of deep wells in both regions. [297]

AAPG-SEPM-SEG Pacific Sections Meeting San Francisco, California, April 21-24, 1976

The following abstract is reprinted from the December 1976 issue, v. 60, no. 12, of the *Bulletin* of The American Association of Petroleum Geologists. The page number is given in brackets below the abstract. Permission of the authors and of Gary Howell, AAPG managing editor, to reproduce the abstract is gratefully acknowledged.

Geologic Estimates of Undiscovered Oil and Gas Resources in the United States

BETTY M. MILLER, U.S. Geological Survey, and Harry L. Thomsen, Consultant, Denver, Colorado

The latest estimates of the nation's conventional oil and natural gas resources have been published in a detailed report as *Circular 725* by the U.S. Geological Survey, June 1975. This report was prepared at the request of the Federal Energy Administration by the Resource Appraisal Group in the Branch of Oil and Gas Resources, Denver, Colorado.

The report summarizes the estimates of undiscovered recoverable resources of oil, natural gas, and natural-gas liquids of the United States as assessed by the Resources Appraisal Group based on a comprehensive evaluation by more than 70 U.S. Geological Survey geologists of a large quantity of fundamental geologic and geophysical data gathered on more

than 100 potential petroleum provinces for onshore Alaska and the lower 48 states, and all offshore United States continental shelves to water depths of 200 m.

The Resource Appraisal Group's estimates (based on a 95.5 percent probability range) for the undiscovered recoverable resources amount to 50 to 127 billion bbl of crude oil with a mean of 82 billion bbl (current national economic recovery factor of 32 percent); 322 to 655 Tcf of natural gas with a mean of 484 Tcf (current national economic recovery factor of 80 percent); and 11 to 22 billion bbl of natural-gas liquids with a mean of 16 billion bbl.

The subeconomic part of the remaining resources for oil is estimated to be an additional 28 percent recoverable, for a total of 60-percent recovery. This could amount to an additional 120 to 140 billion bbl presently identified but currently subeconomic and another 44 to 111 billion bbl currently undiscovered and subeconomic. The subeconomic part of the natural gas resources is estimated to be an additional 10-percent recoverable, for a total of approximately 90-percent recovery. This could amount to an additional 90 to 115 Tcf presently identified but currently subeconomic and another 40 to 82 Tcf currently undiscovered and subeconomic.

A "best estimate" including both the total remaining identified reserves and the undiscovered recoverable resources reported from this study are: 144 billion bbl of oil, 923 Tcf of gas, and 28 billion bbl of natural-gas liquids. Total production through 1974 is 106 billion bbl of oil, 481 Tcf of gas, and 16 billion bbl of NGL.

The Resource Appraisal Group is continuing the development of and improvement on a comprehensive resource appraisal system within the U.S. Geological Survey. As new data, new interpretations, and new procedures are incorporated into the system the current estimates will be subject to revision. However, on the basis of the estimating procedures used involving the concepts of total-resource base, these changes are not expected to be of any significant magnitude for the United States as a whole within the foreseeable future. [2186]

GSA Annual Meeting, South-Central Section
El Paso, Texas, March 17-18, 1977

The following abstracts are reprinted from the *Abstracts with Programs* of The Geological Society of America, v. 9, no. 1. Page numbers are given in brackets below the abstracts. Permission of the authors and of Jo Fogelberg, managing editor of GSA, to reproduce the abstracts is gratefully acknowledged.

Paleozoic Tectonics of the Northwestern Gulf of Mexico

JOSEPH F. FISCHER, Department of Geology, The University of Texas at Arlington, Arlington, Texas

Paleozoic foreland facies rocks are distributed from Arkansas to New Mexico and south into old Mexico and are bordered on the south by deep water starved basin facies rocks of the Ouachita-Marathon thrust belt. This couplet is generally interpreted as a Paleozoic continental margin, crudely parallel to the present Gulf margin. The proto-Gulf was produced prior to the upper Cambrian by rifts connecting plumes near Florida, the SE corner of Oklahoma, and the Big Bend region. A failed arm from the Dallas plume formed the southern Oklahoma aulacogen; the Tobosa basin developed without rifting on the thermal bulge of the Big Bend plume.

The margins remained stable shelves until the end of the Devonian. The Stanley and Tesnus Formations mark the beginning of collisional orogeny. Northward and westward migration of foredeep basins ended in the Pennsylvanian in the east (Atoka Fm.) and the Permian in west Texas (Wolfcamp). A flysch sequence containing Carboniferous spores in the Sierra de Catorce of San Luis Potosí suggests original continuity of the foredeeps into Mexico, although oddly offset to the east at the present time. Re-entrant angles in the craton developed rifts during the collision, revitalizing the southern Oklahoma aulacogen and forming the Delaware basin. The existence of this basin and the continuous foredeeps suggests that Mexico was a part of the northern craton during the Paleozoic. Grabens filled with Triassic-Jurassic Huizachal redbeds fix the initiation of opening of the modern Gulf of Mexico. [18]

Investigations of the Pennsylvanian Coal Deposits in Eastern Oklahoma (1971-76)

S. A. FRIEDMAN, Oklahoma Geological Survey, 830 Van Vleet Oval, Norman, Oklahoma

A coal-investigations program, begun in 1971 at the Oklahoma Geological Survey (OGS), has resulted in a published (1974) report with extensive tables on the State's bituminous coal resources. This report includes information on reserves suitable for gasification. In 1976 a map was published showing the locations of the State's active coal mines. These studies show that of the 7,200 million short tons of the identified remaining coal resources in Oklahoma, only 30% is net recoverable.

In addition, work maps on 7.5 minute quadrangles, a Master's thesis, and an OGS-U.S. Bureau of Mines (USBM) cooperative project on the Hartshorne coals have resulted in detailed maps of (1) the structure and recoverable reserves on the Rowe coal, (2) the structure of the Hartshorne coals, and (3) the mined areas of these coals. Information on the Hartshorne coals permitted a USBM estimate of the gas content of the Lower Hartshorne coal.

Ten newly identified Desmoinesian coal beds have proved useful in stratigraphic correlation: two are key beds in the middle and lower parts of the Hartshorne Formation in Le Flore County; four are in the middle part of the McAlester Formation in Haskell and Le Flore Counties; and the others are in the Savanna, Boggy, and Senora Formations in Rogers County.

The detailed mapping of the structure, resources, and mined areas of the State's coals since July 1971 has provided a much-needed service for the coal industry, coal explorationists, and coal scientists. This basic program will continue and is expanding to include chemical and petrographic characterization of these coals. [19-20]

The Environmental Significance of Conodonts from the Hindsville Formation (Mississippian) of Northwest Arkansas

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The Hindsville Formation in northwest Arkansas is a predominantly carbonate unit that consists of several distinct lithofacies based on modal analysis. Lithofacies distribution, petrographic character, and stratigraphic relationships suggest the Hindsville was deposited in environments ranging from subtidal lagoon through shallow nearshore to open marine, offshore conditions. Low turbulence, possibly partially restricted, lagoonal environments of carbonate mud accumulation characteristically contain conodont elements in low diversities and abundance. Nearshore carbonate environments of moderate to high turbulence based on low mud/spar ratios, fragmented skeletal grains, and ooliths typically contain abundant and, relatively, the most diverse faunas. The deepest water Hindsville deposits, thought to have accumulated below effective wave base, of mixed carbonate and black terrigenous mud produce conodont faunas of low abundance and intermediate diversity.

Lithofacies boundaries do not coincide with conodont form-species distributions, which seemingly indicates that conodont organisms were not greatly affected by bottom conditions. However, conodont diversities and abundance, based on disjunct elements, exhibit systematic variations with regard to inferred water turbulence and to a lesser extent to water depth and distance from shore which suggests a nektonic mode of life for conodonts. The distribution of conodont form-species in the Hindsville is thought to be ecologically controlled because the unit represents a transgressive carbonate sequence that was deposited during a brief interval of geologic time, broadly corresponding to the *Gnathodus bilineatus-Kladognathus mehli* Zone of the standard Mississippian section. [22]

Coal Stratigraphy and Reserves in Southeastern Rogers County, Oklahoma

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Eight stratigraphically persistent coals were found during detailed geologic mapping of the surface and shallow subsurface of southeastern Rogers County, Oklahoma. The Bluejacket, Drywood, Rowe, Neutral(?) and four unnamed coals are contained in Desmoinesian rocks of the Boggy, Savanna, and McAlester Formations. One unnamed coal underlies the sporadic Spaniard limestone of the Savanna Formation. The base of this limestone defines the contact of the Savanna Formation and the underlying McAlester Formation. In places where the Spaniard limestone is absent, however, this contact is placed at the top of the second unnamed coal below the Rowe coal.

Anomalous eastward thinning of Desmoinesian strata may be explained by a topographic high that exists on basement terrain in the northeastern portion of the area combined with movement, contemporaneous

with deposition, along the Seneca Fault system, which trends northeastward through southeastern Rogers County.

Of the eight coals, only the Drywood and Rowe are economically important. Remaining resources are 10,930,000 short tons of Drywood coal and 22,500,000 short tons of Rowe coal. Some 3,920,000 short tons of Drywood and 9,230,000 short tons of Rowe coal are considered to be recoverable by strip mining. These coals are high in sulfur and are ranked as high-volatile B and C bituminous. They are suitable for electric power generation and industrial uses.

Twice as many bituminous coals were mapped than had previously been identified in the area, but only the Rowe and Drywood contain recoverable reserves. A persistent unnamed coal is useful in many places in determining the Savanna-McAlester contact. [22-23]

A Process-Response Model for a Lacustrine Delta Orifice

NORMAN J. HYNE and CECIL R. GLASS, Earth Sciences Discipline, The University of Tulsa, Tulsa, Oklahoma

Observations at the Arkansas River Delta orifice in the Great Salt Plains, Oklahoma, show that channel discharge, ambient water level and wave action control the geomorphology and sedimentation at the orifice. The channel orifice is delineated by the divergence of the levees at about 15-20° and the occurrence of a secondary bar in the channel. The distributary mouth bar occurs 2-2.5 channel widths out from the orifice, significantly closer than predicted by frictionless hydrodynamic models. The water depth over the bar is characteristically adjusted to the channel discharge by vertical accretion and erosion of sediments on the bar. During flood stage the channel environments show vertical accretion, whereas vertical erosion and massive progradation occurs during the transition from flood to normal stage. During low flow, wave action deforms the orifice environments. Sediment textures and structures correlate with flow hydrodynamics in the channel and orifice and are relatively constant in position with respect to each other during all flow stages. [28]

Seismic Belts in Arkansas and Neighboring States

KERN C. JACKSON, Department of Geology, University of Arkansas, Fayetteville, Arkansas

A plot of 250 epicenters based on macro- and microseismic data between the years 1845 and 1975 defines six seismic belts in Arkansas and contiguous states. The Mississippi-Wabash belt (including New Madrid) follows the river lineation. Major earthquakes are probably related to a deep crustal suture. Minor earthquakes are on an eschelon shallow to N-S faults (Street, Herrmann and Nuttli; *Science,* 1974, p. 1285). The East Ozark margin belt shows E-W and NW-SE faults (Street, *et al.*). John R. Gibbons (Syracuse Ph.D. dissertation, 1972) found up-thrust faults in this region with these trends. The Fall Line trend extends from Pine Bluff, Arkansas, into SE Oklahoma. Only one epicenter is as far south as the

Arkansas Graben System; therefore, they are probably related to flexure at the north margin of the Mesozoic basin rather than to salt flow of the Louann. The Frontal Ouachita belt extends from central Mississippi into Oklahoma and expands northward to the Arkansas River. One epicenter in Arkansas gives E-W trend with compressional sense (Street, *et al.*). The fault-bound Wichita-Amarillo block is the site of earthquakes near Ardmore, Oklahoma, and in the Texas Panhandle. The Nemaha Ridge belt includes events from El Reno, Oklahoma, to Manhattan, Kansas. Approximately 85% of the events plotted could be related to one of these six belts; the remainder were widely scattered. [28]

Calcareous Algae and Their Role in the Deposition of Some Morrowan Carbonates of Northeast Oklahoma

DAVID A. KOTILA, Department of Geology, The University of Texas at Arlington, Arlington, Texas

The middle and upper part of the Morrowan Series of Northeast Oklahoma contains abundant carbonates, many algal in nature. Calcareous algae contributed to the formation of these carbonates in many different ways.

The calcareous red algae *Cuneiphycus texanus*, *Archaeolithophyllum missouriense* and *A. lamellosum* contribute abundantly as biochemically precipitated skeletal elements in the sediment, act as sediment baffles and binders, and are important as frame-builders in algal mounds. Dasycladacean green algae, yet unnamed, contribute in a minor way to the carbonates as a highly abundant skeletal element and provide a baffle for fine sediment. Algal-foraminifer colonies of several growth habits also serve to trap and bind carbonate sediment, forming concentric nodules, thin digitate crusts up to 5 cm thick, or thicker regular crusts parallel to bedding and commonly over 15 cm thick.

Where the algal limestones are thick and well developed, a distinctive invertebrate fauna is commonly present, which includes the corals *Lithostrotionella, Michelinia, Chaetetes* and several solitary forms, and brachiopods, molluscs, bryozoans, echinoderms, and foraminifers in great abundance and diversity. [31-32]

Depositional Environments and Paleoecology of the Oil Creek Formation (Middle Ordovician), Arbuckle Mountains, Oklahoma

RONALD D. LEWIS, Department of Geological Sciences, The University of Texas at Austin, Austin, Texas

The early Middle Ordovician Oil Creek Formation of southern Oklahoma is composed of 3 major units: a basal sandstone of variable thickness, a thick, mixed carbonate-clastic unit, and a relatively thin, fine-grained carbonate unit. The basal sandstone is a well-sorted, well-rounded quartz arenite lacking sedimentary structures. The middle unit consists of thin-bedded, fossiliferous, arenaceous packstones alternating with essentially barren, greenish-gray shale. The uppermost unit is composed of algal wackestone and algal-"birdseye" mudstone.

This vertical sequence represents a transgressive-regressive cycle with a range of depositional environments and associated benthic communities. Estimates of biovolume percentage were used to rank the faunal elements in each facies. The transgressive phase has 3 major facies in an onshore-offshore sequence. The lower shoreface has thin sandstone beds, sandy packstones, and sandy shale. The fauna is dominated by horizontal burrows, ostracodes, pliomerid trilobites, and brachiopods. This grades through a transitional facies to an offshore facies with mega-rippled packstone and shale. The very diverse, echinoderm-dominated fauna here includes a new eocrinoid, crinoid holdfasts, ramose and massive bryozoans, brachiopods, trilobites, and ostracodes. Three major facies also occur in the upper, regressive phase. The inner shelf consists of thin to thick sandy packstones and sandy shale, and contains abundant small ramose bryozoans, echinoderms, and locally abundant bivalves. Packstones of the shaly nearshore facies are dominated by echinoderms and small ramose bryozoans. The algal wackestone of the intertidal-supratidal facies has abundant gastropods and ostracodes. [59]

Preliminary Investigation of Pennsylvanian Underclays of Oklahoma

FREDERICK H. MANLEY, Department of Geology, Georgia State University, Atlanta, Georgia, S. A. FRIEDMAN and CHARLES J. MANKIN, Oklahoma Geological Survey, 830 Van Vleet Oval, Norman, Oklahoma

During the past 100 years of commercial coal development in Oklahoma, 24 bituminous coal beds covering 1.5 million acres in 19 counties in eastern Oklahoma have yielded approximately 500 million tons, leaving 7,200 million tons of remaining resources. These resources are associated with underclays of potential economic significance. Early studies, based upon limited data, suggested that associated underclays were either poorly developed, absent, or potentially non-commercial. Recent surface-mining operations, increasing from 8 to more than 20 in the past 15 months, have revealed moderately well developed underclays.

Initial stratigraphic, mineralogic, and chemical studies of the underclays of the Hartshorne, Stigler, Cavanal, Rowe, Drywood, Secor, and Croweburg coals of Desmoinesian age from 6 counties have revealed that (1) the underclays possess overall characteristics important to successful industrial uses in other States, (2) kaolin minerals and variable amounts of poorly crystalline illite are present in some samples and are suitable for refractories, (3) mixed-layer illite and chlorite are present in other samples and are suitable for red-burning clay products, and (4) uniform mineral types exhibit extensive lateral continuity. Developmental testing of selected Oklahoma underclays is presently in progress by some companies, and at least one plant-development plan is under way. The clay-mineral content and the wide areal extent of the underclays should prove to have great economic impact on the State of Oklahoma. [62]

Coal and Gas Resources of the Lower Hartshorne Coalbed in Le Flore and Haskell Counties, Oklahoma

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The Lower Hartshorne coalbed in a 600 sq mi area in Le Flore and Haskell Counties contains at least 1 trillion cu ft of methane. Based on 900 coal data points, it is estimated that approximately 2.0 billion tons of the original coal resources remain. Resources calculated were within 2 miles of any datum point and were contained in beds more than 12 inches thick at depths of 2,000 ft or less. This new evaluation of coal resources was required to obtain an accurate data base for calculating the methane content of the Lower Hartshorne coalbed.

The Hartshorne is a very gassy, steeply dipping coalbed that is friable and quickly released its gas during extraction. Its gas content increases with depth and rank. Samples collected at approximately 1,500 ft contained about 545 cu ft of gas per ton; samples at 175 feet contained 80 cu ft/ton. More than 90 pct of the 1 trillion cu ft of gas contained in this coal is at depths of more than 500 ft. Methane drainage in advance of mining has been easy in this coalbed. Due to its high gas content, degasification will probably be required for mine operating at depths of more than 1,000 feet. The Lower Hartshorne coalbed ranges from outcrop to an estimated maximum of 7,000 feet in Le Flore County, so its gas potential is enormous. [65-66]

OKLAHOMA STATE UNIVERSITY

Depositional Environment and Trend of the Uppermost Part of the Vamoosa Formation and Lecompton Limestone in the Eastern Part of North-Central Oklahoma

DANIEL MORGANELLI, Oklahoma State University, M.S. thesis, 1976

Scope and Method of Study: Genesis and trend of sandstone bodies in the study interval were determined through a study of their geometries and internal features. These data were derived from surface measurements, correlation sections, and thickness maps. Determination of sandstone trends also involved interpretation of paleocurrent features. Gross depositional trends in the Lecompton Limestone were determined from variations in thickness and sedimentary structures.

Findings and Conclusions: The uppermost part of the Vamoosa Formation, informally designated as the Shaw Ranch Sandstone, was deposited during a regression following a minor transgression. Sediments were derived largely from the Ouachita uplift, with possible contribution from the Arbuckle uplift. Multistoried and multilateral lenticular sandstones in the study interval are alluvial and deltaic deposits. Genetic units range from 5 to 25 feet in thickness and 100 to 300 feet in width. Quartz-rich lenticular units are characterized by medium-scale crossbedding, cut-out, high-angle initial dip, fine to medium sand, and a paleocurrent direction of N25°W. Thin-bedded units are delta-fringe deposits, which are very fine-grained and well sorted. They contain ripple marks, parting lineation, interstratification, a primary paleocurrent trend of N60°E, and a secondary direction of N35°W. Depositional trends in the Lecompton Limestone may be related to thickness variations in the underlying sandstone and possibly to paleostructure. The Lecompton is characterized by medium- and large-scale crossbedding, wavy bedding, and interstratification. It was deposited in intertidal to subtidal environments.

Industrial Minerals Forum Slated for Norman May 12-14, 1977

The 13th Forum on the Geology of Industrial Minerals will be held May 12-14 in Norman, Oklahoma, on the campus of The University of Oklahoma. The forum is held each year as a means of letting representatives from industry, government, and academic institutions discuss the geology, exploration, evaluation, and production of important industrial minerals such as stone, sand, clay, gypsum, salt, and other nonmetallic rocks and minerals.

The meeting is held in a different state each year, so that participants can get a first-hand view of a variety of mineral deposits. Hosts for this year are the Oklahoma Geological Survey and The University of Oklahoma. In addition to the technical sessions, plans call for a trip to the Arbuckle Mountains of southern Oklahoma to see high-purity silica sand and high-purity dolomite and to study the general geologic framework of the Arbuckle Mountains.

Principal topics for this year's forum include silica-rich sediments (silica sand, novaculite, and tripoli), gypsum (resources, evaluation, and land reclamation), natural brines (bromine, iodine, and lithium), and energy in the industrial-minerals industry (energy uses, energy alternatives, and conservation). Proceedings of the forum will be published by the Survey. An attendance of 150 to 200 persons is expected at The Oklahoma Center for Continuing Education on the university campus.

The preliminary program is as follows:

Registration:	Thursday morning (May 12)
Technical Sessions:	Thursday afternoon
	Friday morning and afternoon
Business Meeting:	Thursday evening
Banquet and Social:	Friday evening
Field Trip:	Saturday, May 14

Additional information about the program, registration, and housing is available by contacting: Kenneth S. Johnson, Oklahoma Geological Survey, The University of Oklahoma, Norman, OK 73019.

New Theses Added to OU Geology Library

The following M.S. theses have been added to The University of Oklahoma Geology and Geophysics Library:

Investigation of Surficial, Structural Geology of Portions of Beckham, Custer, Roger Mills, and Washita Counties, Oklahoma, by Pamela Jean Zabawa.

A Paleomagnetic Investigation of Three Intrusions in Big Bend National Park, Brewster County, Texas, by Charles Downing Lewis, Jr.

Paleontology of the Garber Formation (Lower Permian), Tillman County, Oklahoma, by Larry Clark Simpson.

Subsurface Stratigraphic and Structural Analysis, Cherokee Group, Pottawatomie County, Oklahoma, by David Michael Pulling.

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