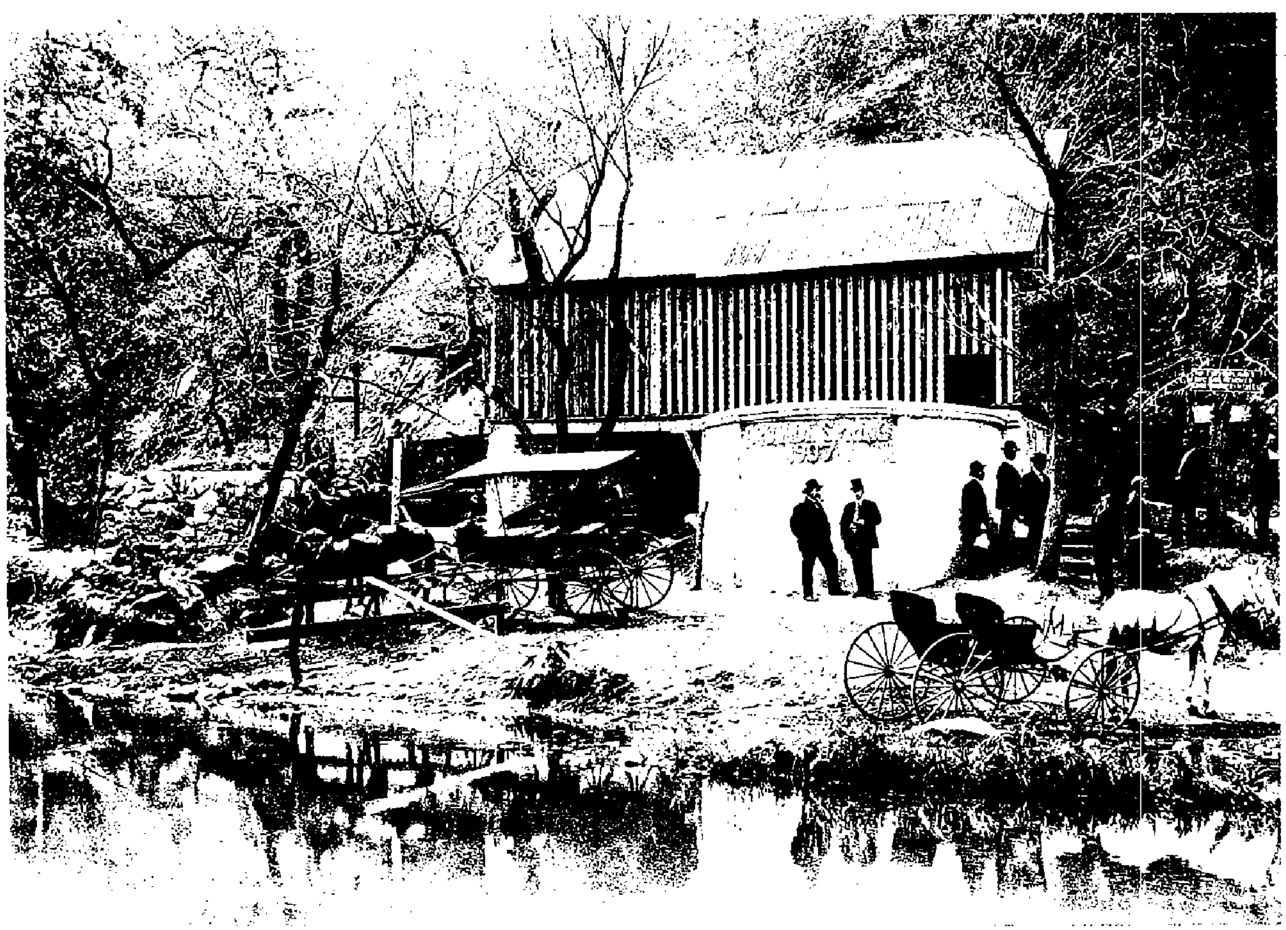
Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY / VOL. 44, NO. 1 — FEBRUARY 1984



On the cover—

Photo from Oklahoma's Early Days
Pictures Bromide Springs, near Sulphur

Gentlemen gather at Bromide Springs to fill water jugs in this early-day photo of the spring house at PlattNational Park (now Chickasaw National Recreation Area) near Sulphur, Oklahoma. Health seekers came from near and far to partake of the "benefits" of these sulfurous waters from the many springs in the area.

The picture, used with permission of the Western History Collections of The University of Oklahoma, appeared recently on the cover of *A History of the Oklahoma Geological Survey, 1908 - 1983.* This comprehensive and entertaining rendition of the Survey's story was written by OGS associate editor Elizabeth A. Ham and was published to commemorate the 75th anniversary of the agency. The 60-page book describes both the events and the personalities that have shaped the Oklahoma Geological Survey and its role in the State from its inception and early years up to its 1983 year under the direction of Charles J. Mankin.

"The author of this history, Elizabeth Awbrey Ham, is uniquely qualified to write about the Oklahoma Geological Survey. Moreover, she is probably the only person who could have done justice to such an account," Mankin said in his foreword to the book.

Copies of Special Publication 83-2 can be ordered from the Oklahoma Geological Survey at the address given below. The price is $4.

Oklahoma Geology Notes

Editor: Connie Smith
Editorial Staff: Elizabeth A. Ham, William D. Rose

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

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

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Contents

This publication, printed by The University of Oklahoma Printing Services, Norman, Oklahoma, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes, 1981, Section 3310, and Title 74, Oklahoma Statutes, 1981, Sections 231–238. 1,800 copies have been prepared for distribution at a cost to the taxpayers of the State of Oklahoma of $2,222.

SPRINGS IN THE ARBUCKLE MOUNTAIN AREA SOUTH-CENTRAL OKLAHOMA

Roy W. Fairchild[1]

Introduction

Numerous springs discharge water from rocks that make up the Arbuckle-Simpson aquifer in the Arbuckle Mountain area. The aquifer consists of limestone, dolomite, and sandstone of the Arbuckle and Simpson Groups of Late Cambrian to Middle Ordovician age. Information has been obtained for more than 100 springs issuing from the aquifer in its outcrop area (fig. 1). The springs were inventoried during a study of the hydrology of the Arbuckle Mountain area (Fairchild and others, 1983). Most of the springs are gravity springs, occurring where the potentiometric surface intersects the land surface. The springs are the areas of natural discharge from the aquifer.

Water Quantity

Of the springs whose discharge was measured, 50 percent discharged less than 100 gallons per minute (gpm), 30 percent discharged between 100 and 500 gpm, 11 percent discharged between 500 and 1,000 gpm, and 9 percent discharged more than 1,000 gpm.

Most springs are near faults or other fractures that in many places have been enlarged by solution. In some places, springs occur on the up-gradient sides of faults. Discharge water flows a short distance down a stream channel where it may enter an opening, such as a fracture, or seep into sand in the stream-channel bottom. Many springs are "wet weather" seeps, that is, springs that discharge during, and for a short time after, the rainy season. Such springs, which probably occur where the water table is perched, cease flowing when the perched water recedes below the spring outlet.

In several places faulting has brought less permeable rocks into contact with rocks that have a greater permeability. Because of the difference in permeability across the fault, water moves to the surface through fractures and

[1]Water Resources Division, U.S. Geological Survey, Oklahoma City, Oklahoma.

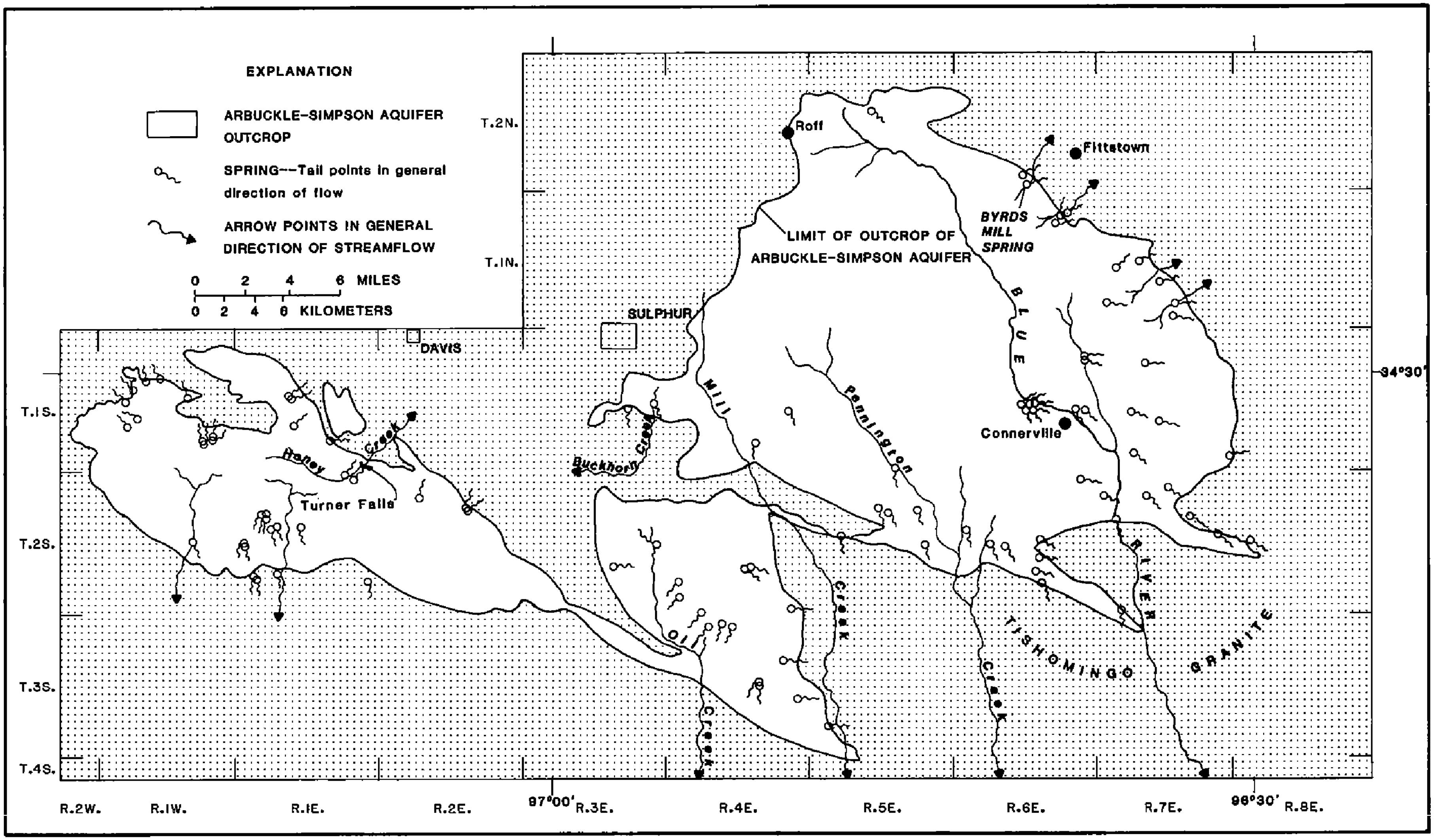

Figure 1. Map of Arbuckle Mountains area showing locations of springs.

discharges from springs and seeps along the fault. An example of this occurs in the southeastern part of the area where faulting has brought the Tishomingo Granite of Precambrian age in contact with rocks of the Arbuckle-Simpson aquifer (fig. 1). The granite, having almost no permeability, is a subterranean barrier to flow, and a ground-water mound exists on the north side of the barrier. Water is released from the ground-water mound through springs.

Several large springs contribute sufficient discharge to sustain perennial flow in the receiving streams. Byrds Mill Spring near Fittstown in the northeastern part of the area is such a spring. Data from a continuous-record gaging station established at this spring in 1959 show that the spring discharges as much as 40 cubic feet per second (ft^3/s) (18,000 gpm) and has a minimum sustained flow of about 8 ft^3/s (3,600 gpm).

Hydrographs of discharge from Byrds Mill Spring and the water level in two nearby wells that are completed in the Arbuckle–Simpson aquifer are shown in figure 2. As indicated by the hydrographs in figure 2, spring discharge varies with the water level in the aquifer. The hydrograph of discharge from Byrds Mill Spring does not include an unmeasured continuous diversion of approximately 6 to 10 ft^3/s (2,700 to 4,500 gpm).

Streams draining the outcrop area of the Arbuckle–Simpson aquifer are sustained by numerous springs and seeps that discharge from the aquifer. The part of streamflow that results from ground-water discharge is termed base flow and fluctuates directly in response to fluctuations in ground-water levels. Base flow of streams that drain the aquifer accounts for approximately 60 percent of the total annual runoff from the Arbuckle–Simpson outcrop area.

Water Quality

Most of the dissolved solids in ground water originate from solution of the rocks through which the water has moved. The concentration of dissolved solids in the water depends on the physical and chemical characteristics of the original water, the solubility of the rocks, and the length of time water is in contact with the rocks.

Samples of water were collected from 12 perennial springs in the Arbuckle Mountain area and analyzed for various chemical constituents. Maximum, average, and minimum concentrations of common dissolved chemical constituents in water from the springs are shown in table 1. The spring waters are chemically similar to water in the Arbuckle–Simpson aquifer. The temperature of springs varies slightly with the season, but averages about 16.5°C. Streams sustained by springs seldom freeze completely during the winter, although a thin ice sheet may form on the surface of the ponded water.

The proportions of cations and anions in water from springs are shown in figure 3. The concentration of data points on the left side of the diagrams in-

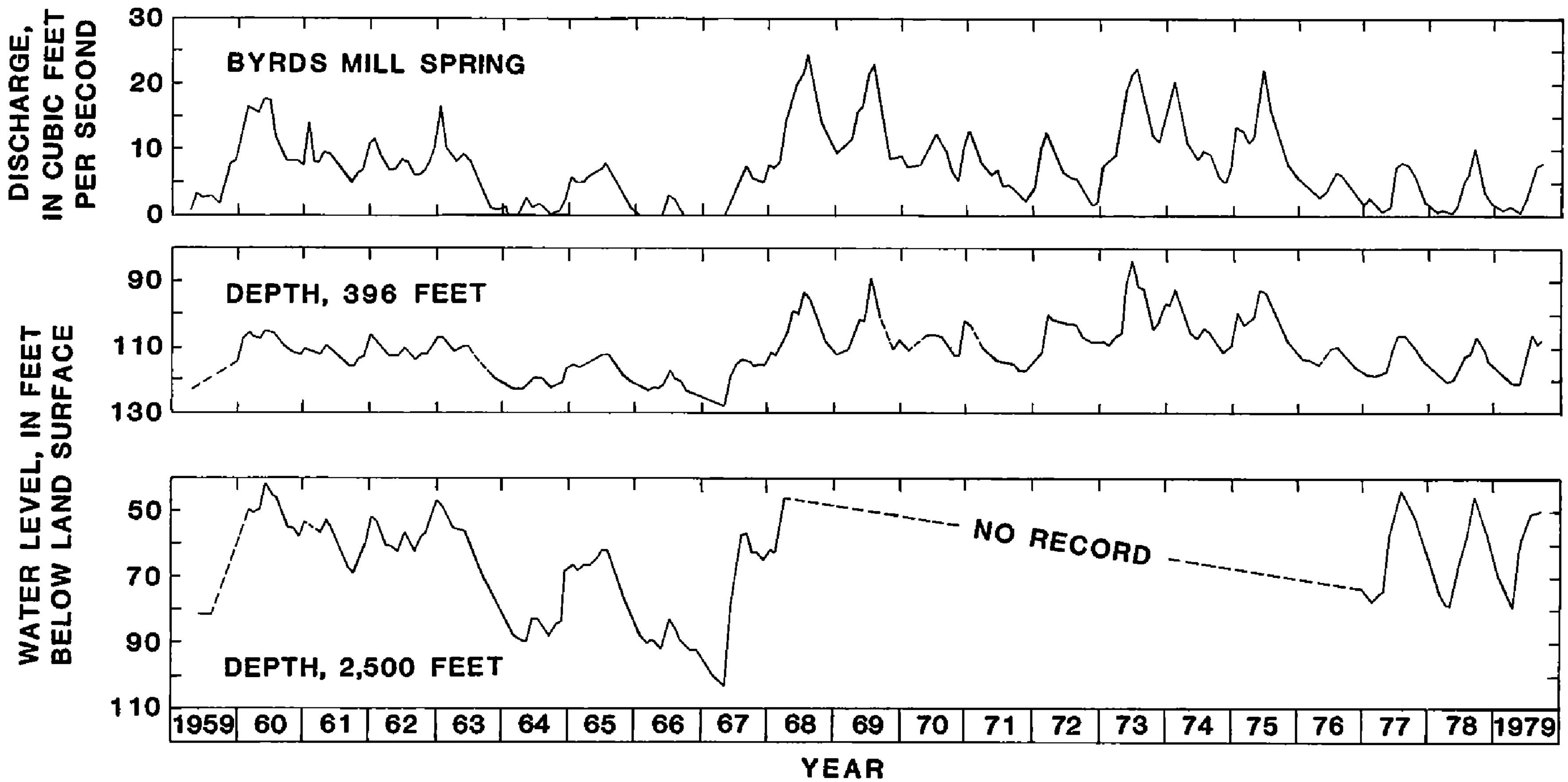

Figure 2. Hydrographs of water levels in two wells that tap Arbuckle-Simpson aquifer and discharge from Byrds Mill Spring (January 1959–June 1979).

TABLE 1.—MAXIMUM, AVERAGE, AND MINIMUM CONCENTRATIONS OF COMMON DISSOLVED CHEMICAL CONSTITUENTS IN WATER FROM 12 PERENNIAL SPRINGS IN ARBUCKLE MOUNTAIN AREA

(Constituents in Milligrams per Liter Except Where Otherwise Indicated)

Constituent	Maximum	Average	Minimum
Calcium	110	83	72
Magnesium	41	32	11
Hardness[1]	380	336	300
Dissolved solids	441	328	276
Carbon dioxide	77	34	16
Bicarbonate	440	379	280
Sodium	31	5.6	1.9
Chloride	62	9.0	2.3
Fluoride	0.2	0.1	0.1
Specific conductance[2]	790	632	580
Temperature[3]	22.0	16.5	7.0
pH[4]	7.5	—	6.9

[1]As $CaCO_3$.
[2]In micromhos per centimeter at 25°C.
[3]In degrees Celsius.
[4]Standard pH units.

dicates that water from the springs is a calcium magnesium bicarbonate type. The samples were collected when the water table was low and flow in streams was primarily base flow. Magnesium shows the greatest variation in the water. The variation in magnesium probably is related to the rock type with which the water had been in contact. Dolomite, $CaMg(CO_3)_2$, could be the source of the magnesium. According to Ham (1955, p. 1), the rocks of the Arbuckle Group are mostly limestone, $CaCO_3$, in the western part of the area, but are mostly dolomite in the eastern and northeastern parts of the area.

Travertine (calcium carbonate, $CaCO_3$) deposits occur in most stream beds, especially downstream from springs. Precipitation of the travertine in-

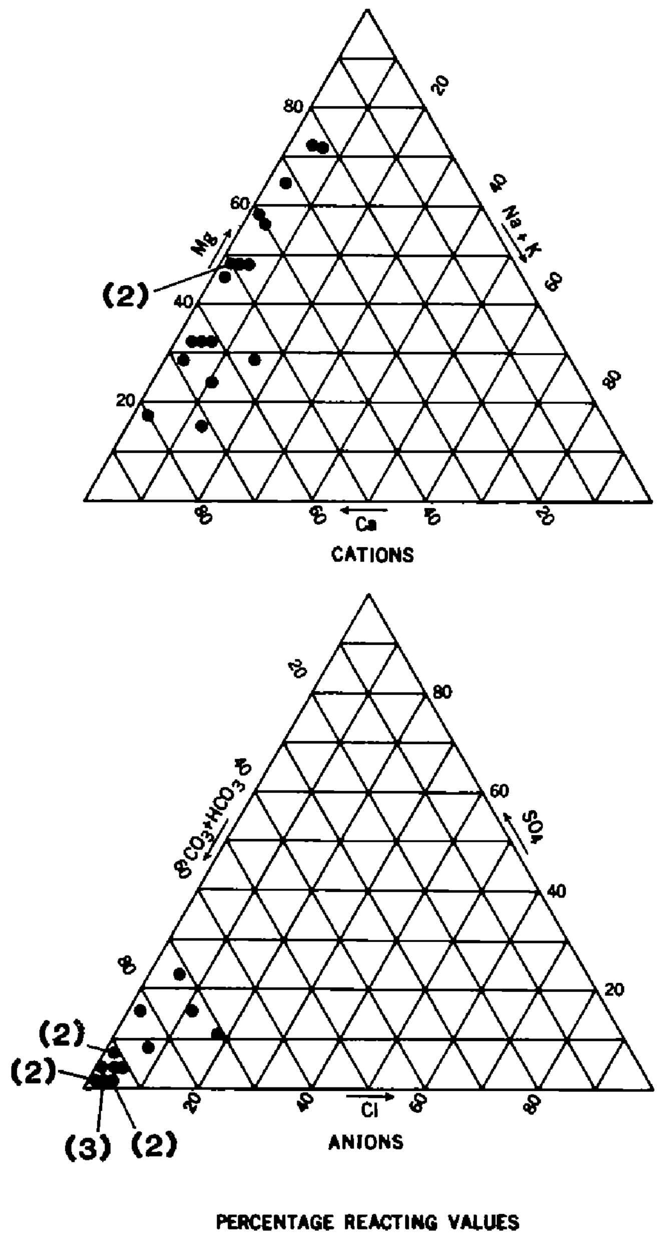

Figure 3. Proportions of cations and anions in water from springs in the study area (number in parenthesis is the number of samples represented by the point indicated).

dicates that the water is saturated with calcium and that, as the water discharges from springs, carbon dioxide (CO_2) is released and travertine is precipitated on the stream bed.

A prime example of travertine precipitation from stream water is a large deposit in Honey Creek at Turner Falls (fig. 4). Johnson and McCasland

Figure 4. T urner Falls flowing through the travertine deposits south of Davis.

(1971) described the deposit and indicated that blue-green algae assist in precipitating the calcium carbonate.

Another large deposit of travertine occurs in Honey Creek about 1 mi upstream from Turner Falls. The creek flows through a chasm in the upstream deposit, which probably has a depositional history similar to the deposit at Turner Falls. Several springs are upstream from Turner Falls. Upstream from these springs, the stream-bed material is coated with travertine, although no flow occurs in this reach of the stream during the summer dry season. Probably wet-weather springs occur intermittently upstream from the springs.

References

Fairchild, R. W., Hanson, R. L., and Davis, R. E., 1983, Hydrology of the Arbuckle Mountain area, south-central Oklahoma: U.S. Geological Survey Open-File Report 82-775, 153 p.

Ham, W. E., 1955, Field conference on geology of Arbuckle Mountain region: Oklahoma Geological Survey Guidebook 3, 61 p.

Johnson, Kenneth S., and McCasland, Willard, 1971, Highway geology in the Arbuckle Mountains and Ardmore area, southern Oklahoma: Oklahoma Department of Highways 22nd Annual Highway Geology Symposium Field-Trip Guidebook, 31 p.

ANCIENT PROCESS REMOVES SULFUR FROM COAL

An ancient process used to extract copper from low-grade copper ores is being studied as a process to eliminate some of the sulfur found in coal. First used on a large scale in Spain in 1750, bacterial leaching is a technique still used by most mining companies today.

Stan Yunker, a graduate student in OU's chemical engineering department, now is growing the same bacteria, *Thiobacillus ferrooxidans,* used in copper leaching. Yunker, working under the direction of Dr. John Radovich, of OU's chemical engineering department, is using the bacteria to remove inorganic sulfur from coal, thereby providing a cleaner burning fuel with less pollutants.

Yunker became interested in the copper-leaching process while completing a master's degree in microbiology at OU. "*Thiobacillus ferrooxidans* occurs naturally in copper-ore tailing piles left over from mining operations," Yunker said.

"The bacteria 'feed' on electrons from the iron portion of pyrite, a compound of iron and sulfur found in copper ores. Once stripped of an electron, the iron in the pyrite is released from the sulfur, leaving the sulfur free to react with other atoms.

"If water or air is present, the iron will take an electron from the oxygen in the water or the air to become a stable compound again. The iron and oxygen combine to form what we know as rust.

"The sulfur, once freed from the pyrite, can combine with the oxygen and hydrogen from water to form sulfuric acid. Both the rust and the acid can then be physically removed, resulting in an improved quality of copper ore," Yunker explained.

"In coal, the inorganic sulfur is also found mixed with iron in the form of pyrite. The chemical process works the same for removing sulfur from coal as it does from copper ores," Yunker said.

"The purpose of my work is to produce mass quantities of *Thiobacillus ferrooxidans* so that the release of sulfur from coal occurs at a higher rate," Yunker said.

Yunker has built a special reactor vessel to speed up the growth of the bacteria. In addition, he can control the acidity of the solution in the reactor, the temperature, and the concentrations of oxygen and nutrients in the solution.

"Rather than allowing rust to form after the bacteria strip an electron from the iron, electrons from the electric current in the reactor vessel are used to convert the rust back to a usable energy source for the organism. The availability of electrons from the electric current increases the bacteria's energy supply, which increases the growth rate. You don't have to keep introducing iron into the system to supply electrons, and no rust remains in the reactor during the growth of the organism, which results in a much cleaner process," Yunker explained.

"The harvested bacteria can then be transported to a coal desulfurization site and added to the existing bacteria to increase the rate of sulfur removal. The project has great commercial feasibility for mining companies that mine high-sulfur coal," Yunker said.

Yunker's work has been supported by the Oklahoma Mining and Minerals Resources Research Institute, a division of OU's Energy Resources Institute. Yunker received from the institute a fellowship to support his research. He also received funds for materials to build the reactor vessel.

OGS ISSUES REPORT ON PETROLEUM POTENTIAL OF OUACHITA MOUNTAINS

A new publication issued by the Oklahoma Geological Survey contains valuable data on petroleum resources of the Ouachita Mountains area of Oklahoma. The report, *Petroleum Occurrences and Source-Rock Potential of the Ouachita Mountains, Southeastern Oklahoma,* was prepared by Joseph A. Curiale, former OGS research assistant, now with Union Oil Co. of California. It is available as OGS Bulletin 135.

The Ouachita Mountains of southeastern Oklahoma and western Arkansas constitute the surface expression of the Ouachita Thrust Belt, a major geological structural feature that extends from southwestern Texas through Oklahoma and Arkansas and eastward through Mississippi. Petroleum occurs in this belt as natural gas, liquid crude oil, and solid bitumens, such as grahamite and impsonite.

Curiale's study is limited to the liquid oils and solid bitumens in the frontal and central Ouachita Mountains in Atoka, Latimer, Le Flore, Pittsburg, and Pushmataha Counties. Stratigraphically, the study covers the sandstones, shales, and cherts of the Paleozoic Ouachita facies, ranging from the Mississippian Stanley Group down to the Ordovician Womble Formation.

Detailed analyses of the oils sampled at the localities investigated indicate them to be thermally mature and unaltered high-quality oils and suggest also that they have a common source, probably the underlying Ordovician strata. The author states, however, that "several stratigraphic intervals in the Ouachita Mountains possess adequate source potential for petroleum generation" and that, with such a good source sequence, the area investigated, much of which has not been tested by drilling, "should definitely be considered a potential oil province."

Curiale has correlated oils with oils and bitumens with bitumens to determine their relationships and source. He includes results of both whole-rock and kerogen studies undertaken to establish petroleum potentials of several formations.

The 65-page bulletin contains 55 figures and 15 tables, including graphs, chromatograms, histograms, and distribution charts, that display results from physical, chemical, and elemental analyses of liquid crude oils, bitumens, and rock samples.

Bulletin 135 can be obtained from the Oklahoma Geological Survey at the address given inside the front cover. The price is $12 for hardback and $8 for paperback copies.

OKLAHOMA PLACE NAMES APPROVED

The U.S. Board on Geographic Names recently approved seven Oklahoma place names that were published in the January through March 1983 issue of *Decisions on Geographic Names in the United States* (Decision List 8301).

Cavalry Creek: stream, 27 km (17 mi) long, heads at 35°17'58" N, 99°03'40" W, flows E to the Washita River 13.7 km (8.5 mi) ESE of Cordell; Washita Co., OK; sec. 1, T9N, R16W, Indian Mer.; 35°16'45" N, 98°50'20" W.

Middle Carter Creek: stream, 8.9 km (5.5 mi) long, heads on the NE slope of Carter Mountain at 34°15'43" N, 94°45'35" W, flows WSW to Carter Creek 12.9 km (8 mi) SSW of Bethel; McCurtain Co., OK; sec. 35, T3S, R23E, Indian Mer.; 34°14'55" N, 94°51'35" W. Not: Mud Creek.

Mud Creek: stream, 4.3 km (2.7 mi) long, heads on the W slope of Holly Mountain at 34°16'43" N, 94°48'10" W, flows W 3.2 km (2 mi) then SSE to Middle Carter Creek 8 km (5 mi) S of Bethel; McCurtain Co., OK; sec. 30, T3S, R24E, Indian Mer.; 34°15'38" N, 94°50'00" W.

North Cavalry Creek: stream, 13.5 km (8.4 mi) long, heads at 35°19'55" N, 99°02'43" W, flows SE to Cavalry Creek 4.8 km (3 mi) SE of Cordell; Washita Co., OK; sec 13, T9N, R17W, Indian Mer.; 35°15'30" N, 98°56'58" W. Not: Cavalry Creek.

North Holly Creek: stream, 7 km (4.4 mi) long, heads on the NW slope of Holly Mountain at 34°17'55" N, 94°46'20" W, flows ESE to Broken Bow Lake 14.5 km (9 mi) SE of Bethel; McCurtain Co., OK; sec. 20, T3S, R25E, Indian Mer.; 34°17'00" N, 94°42'32" W.

Rocky Creek: stream, 7.5 km (4.7 mi) long, heads in an unnamed reservoir at 35°12'10" N, 99°00'33" W, flows NE to Cavalry Creek 4.3 km (2.7 mi) SSE of Cordell; Washita Co., OK; sec. 14, T9N, R17W, Indian Mer.; 35°15'15" N, 98°58'10" W. Not: Cavalry Creek.

South Holly Creek: stream, 6.4 km (4 mi) long, heads on the W slope of Holly Mountain at 34°16'45" N, 94°47'02" W, flows E to Broken Bow Lake 14.5 km (9 mi) SE of Bethel; McCurtain Co., OK; sec. 20, T3S, R25E, Indian Mer.; 34°16'38" N, 94°42'50" W. Not: North Holly Creek, Surprise Creek.

NOTES ON NEW PUBLICATIONS

Drilling: A Source Book on Oil and Gas Well Drilling from Exploration to Completion

Jim Short's latest book explains each aspect of the drilling operation, from finding the location to completing the well. Also in this 600-page text, he briefly discusses the history of drilling. The hunt for possible oil and gas locations and the methods for obtaining the rights to drill and produce a well are also covered.

A step-by-step summary of the basic drilling operation is included: planning the drilling program; obtaining the necessary equipment; moving in, rigging up, and spudding in; casing the hole; tripping the bit; fishing; logging; plugging a dry hole; and completing a producer. He describes why each procedure is needed and how each operation is performed.

The book includes over 200 photographs and illustrations, an expanded index, and an appendix.

Order from: PennWell Books, P.O. Box 21288, Tulsa, OK. The price is $60 U.S. and Canada, $80 export.

Mexico's Petroleum Sector: Performance and Prospects

Mexico's state-dominated oil industry, its philosophy and political/organizational actions, and their influence on U.S. energy policies and institutions are discussed in George Baker's new book.

Baker discusses Mexico both as a unique country and as a classic lesser developed nation. He analyzes Pemex, the state-owned petroleum giant, plus various facets of the Mexican government during the 1976–82 Lopez Portillo government and its continuing influence on Mexico.

The book examines the economy of Mexico, including the energy and foreign exchange subsidies and their impact on the oil sector. In addition, the author presents a new approach for calculating production costs that takes into account the value of imports as they relate to the exchange rate for Mexico.

The 312-page book is available from: PennWell Books, P.O. Box 21288, Tulsa, OK 74121. The price is $45 U.S.and Canada, $55 export.

Petroleum Exploration Worldwide

Author John C. McCaslin, exploration editor of the *Oil and Gas Journal,* reviews the growth and progress of petroleum exploration. By examining the past, McCaslin attempts to see what opportunities lie ahead for oil hunters working in the industry.

He chronicles findings since 1950 and looks at promising areas for future projects. The book reviews the history of oil exploration and production and tabulates the giant oil and gas fields around the world. McCaslin also examines the complex and varied geological features of the world, such as basins, sedimentary traps, reefs, arches, anticlines, and synclines. Also covered are the major advances made by explorationists searching for suitable production areas offshore. The book contains 192 pages.

Order from: PennWell Books, P.O. Box 21288, Tulsa, OK 74121. The price is $53 U.S. and Canada, $65 export.

Fundamentals of Formation Evaluation

Primary wireline logging measurements, their response relations, applications, and limitations are covered by author Donald P. Helander. His new 344-page book includes coring practices and mud logging and how to integrate these data with wireline log measurements for determining rock type and evaluating the strata drilled.

Also included are chapters on spontaneous potential, resistivity, acoustic and radioactivity logs, and discussions of well-log interpretation, interpretation methods, and the economics of evaluation work.

Order from: PennWell Books, P.O. Box 21288, Tulsa, OK 74121. The price is $56 U.S. and Canada, $77 export.

Essentials of Modern Open-Hole Log Interpretation

John Dewan's new 360-page book presents modern log interpretation for the geologist or engineer who is familiar with rock properties but has little experience with logs. Readers will become familiar with computer-processed logs generated by the service companies at the wellsite and office.

Order from: PennWell Books, P.O. Box 21288, Tulsa, OK 74121. The price is $39.95 U.S. and Canada, $53.50 export.

Altitude and Configuration of the Predevelopment Water Table in the High Plains Regional Aquifer, Northwestern Oklahoma

Open-File Report OF 82-0275, by J. S. Havens, consists of two oversized sheets.

Order from: U.S. Geological Survey, Water Resources Division, Room 621, 215 Dean A. McGee St., Oklahoma City, OK 73102.

Practical Sedimentology

Beginning with a brief review of environments in which sedimentation occurs, Douglas W. Lewis' text goes on to provide selected examples of vertical facies "models" used as guidelines for interpreting paleoenvironments, and outlines physical and chemical processes that are important in sedimentation. The book contains 288 pages as well as a number of illustrations and tables.

Order from: Van Nostrand Reinhold, Customer Service, 7625 Empire Dr., Florence, KY 41042. The price is $22.95

Recommended Procedures and Methodology of Coal Description

E. C. T. Chao, J. A. Minkin, and C. L. Thompson's report presents recommended procedures and methodology of coal descripton for use by coal geologists. Coal is examined in the laboratory under a binocular microscope; the description can be written quickly in semiquantitative and quantitative terms. The coal-bed profile so described highlights the coal characteristics in great detail and yet is easy to comprehend.

Order from: Eastern Distribution Branch, Text Products Section, U.S. Geological Survey, 604 South Pickett St., Alexandria, VA 22304.

Ground Water—Issues and Answers

This new AIPG booklet, *Ground Water—Issues and Answers,* explains what ground water is and its quality, sources, and consumption nationwide. It includes color-photo illustrations plus 32 charts, graphs, and drawings. The 24-page booklet was written by an Institute committee of ground-water specialists under the chairmanship of George H. Davis.

Order from: AIPG, 7828 Vance Drive, Suite 103, Arvada, CO 80003. One to 99 copies are $3 each, postpaid. One hundred or more are $2.25 each, postpaid. Orders of under $50 must be accompanied by a check.

Federal Coal Resource Occurrence and Federal Coal Development Potential Maps of the Wilburton 7.5-Minute Quadrangle, Latimer County, Oklahoma

Open-File Report OF 79-0303, by Geological Services of Tulsa, Inc., and B. T. Brady of USGS, consists of 33 pages and 25 oversized sheets.

Order from: Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225. Price: $49.25 paper copy, $16 microfiche.

Geothermal Energy: Second Edition

This 357-page reference work provides coverage of geothermal energy as an alternative source for electrical power generation. Author H. C. H. Armstead discusses the world's immense geothermal reserves, the proved commercial uses, and the economic and technological barriers that hinder utilization of this energy resource.

Order from: Methuen, Inc., 733 Third Ave., New York, NY 10164. The price is $49.95.

Maps in Earth Science Publications

This location guide to maps in the earth-science literature identifies more than 900 maps and their sources published in 1980. Titles of maps are arranged under geographic headings. Maps published during 1981–82 will be cited in a forthcoming volume.

Order from: I. D. Weeks Library, University of South Dakota, Vermillion, SD 57069. The price is $7; prepayment is required for orders under $20.

OKLAHOMA ABSTRACTS

GSA Annual Meeting
Indianapolis, Indiana, October 31–November 3, 1983

The following abstracts are reprinted from *Abstracts with Programs* of the Geological Society of America, v. 15, no. 6. Page numbers are given in brackets below the abstracts. Permission of the authors and of the GSA to reproduce the abstracts is gratefully acknowledged.

Structural Geometry and Deformational History of Benton Uplift, Arkansas

ABDOLALI BABAEI, Geology Department, University of Missouri–Columbia, Columbia, MO 65211

The Ouachita Mountains probably formed as a result of a Carboniferous collision between North America, and a southern plate. A thick succession of early to middle Paleozoic strata was deformed in the zone of suturing. On the western plunge of the Benton uplift the deformation resulted in two directions of fold vergence. Folds in the pre-Carboniferous rocks verge southward; folds in Carboniferous verge northward. Illite crystalinity, weakly-developed foliations, and the lack of penetrative fabrics indicate low metamorphic temperatures and pressures.

Three phases of deformation, essentially parallel or co-axial were found independent of the style of the folds. F-1 folds are isoclinal and have an axial-planar slaty cleavage. F-2 folds, which constitute most of the folds in the area include chevron, and conjugate types, and others of monoclinic symmetry. Associated with these folds are three orthogonal joint sets, and a set of conjugate shear. F-3 folds are large folds exhibiting a weakly-developed crenulation cleavage. COCORP seismic lines indicate that the primary direction of tec-

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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.

tonic transport was northward along south-dipping, low-angle faults. Slip-vector analyses based on conjugate and intersecting folds show that the maximum axis had a north–south bearing of varying degree of plunge.

Two models are proposed for the [existence] of double-verging folds. In the first, they are attributed to conjugate folding and shearing. In the second, the [reversal] of vergence, is attributed to re-folding of F-2 folds about the F-3 fold axes. [518]

Relationship of Paragenesis and Porosity Reduction to the Burial History of the Bromide Sandstone, Simpson Group, Oklahoma

CAROLINE J. BAJSAROWICZ and DAVID W. HOUSEKNECHT, University of Missouri–Columbia, Columbia, MO 65211

Comparison of diagenetic features in carbonate and noncarbonate-cemented sandstones of the Bromide Formation allows correlation of paragenesis and porosity reduction to burial history. Diagenesis and porosity reduction were similar for all Bromide sandstones during pre-Pennsylvanian shallow burial. Mechanical compaction significantly reduced porosity during this interval of burial. Precipitation of silica coats on quartz grains, illite, and isolated incipient overgrowths reduced porosity by several percent. Little intergranular pressure solution occurred and cannot account for all the quartz cement that precipitated during this shallow burial, indicating an external source for the silica.

Prior to deep burial in the Pennsylvanian, carbonate cement precipitated locally, preserving a mean minus cement porosity of 30% and inhibiting further diagenesis. High primary porosity is thought to have been present in noncarbonate-cemented sandstones at that time. However, this porosity was significantly reduced by intergranular pressure solution during deep and rapid burial in the Pennsylvanian. Samples that are finer grained and/or that contain between 3 and 9% authigenic illite experienced more intergranular pressure solution than others. Most silica liberated by pressure solution must have been exported from the Bromide, because little quartz cement precipitated. Hydrocarbon migration during the latter portion of this deep burial inhibited further diagenesis.

Carbonate-cemented sandstones with their high minus cement porosities have potential for generating secondary porosity whereas pressolved noncarbonate-cemented sandstones do not. [519]

Recurrent Intraplate Deformation on the Ancestral Rocky Mountain Orogenic Belt[1,2]

ROY T. BUDNIK, Bureau of Economic Geology, University of Texas at Austin, Austin, TX 78712

A three-pronged system of faults extending from Oklahoma and New Mexico into Colorado formed in the Precambrian and was reactivated during the

Ouachita, Laramide, and Basin and Range orogenies. This system includes (1) the Amarillo-Wichita Uplift of Texas and Oklahoma; (2) the Pedernal and Sangre de Cristo Uplifts in New Mexico ; and (3) the Uncompahgre and associated uplifts of Colorado. The Apishapa Uplift of southeast Colorado is continuous with the Amarillo Uplift via a series of previously unrecognized faults in northeast New Mexico and adjacent states.

All three segments formed before 1000 mya and exhibit offsets of basement terranes across them. The southern Oklahoma Aulacogen opened along the Amarillo-Wichita segment about 550 mya. The Ancestral Rocky Mountains developed in the Pennsylvanian, when tremendous volumes of arkoses were derived from uplifts within the fault system. Episodic uplift continued throughout the Permian. Maximum Laramide deformation occurred in the western and southern parts of the system, but Mesozoic strata were faulted and broadly folded along the Amarillo Uplift and its western extension. All segments were involved in Basin and Range deformation. Neogene deposits, formed at the time of maximum rate of extension, are 2 to 3 km thick along the axis of the Rio Grande Rift in Colorado and New Mexico and up to 300 m thick in rhomb (?) grabens along the Amarillo Uplift. At the present time the system divides the region into three provinces with internally homogeneous stress orientations. Low-level seismicity continues throughout the system.

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[2]Study funded by the U.S. Department of Energy under contract no. DE-AC97-83WM46651. [535]

Sedimentary Geology of the Reagan Formation in Southwestern Oklahoma

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The Upper Cambrian Reagan Formation, as exposed in the Slick Hills of southwestern Oklahoma, records a slow marine transgression across an irregular topography formed by the Middle Cambrian Carlton Rhyolite Group. The transgression buried hills up to 100 meters (300 ft) in height with slopes of up to 10°.

Initial deposits were small alluvial fans of local origin. Subsequently fluvial systems transported large amounts of mineralogically mature quartz sand from the north (probably the Canadian Shield). These sands were incorporated into an overall marine transgressive sequence which shows tidal influence (with dominant ebb tide effects). Fauna present include the *Skolithos* association and abundant phosphatic inarticulate brachiopods. Topmost Reagan sediments were deposited at a slow rate; they are highly glauconitic and evidence of phosphatic hardgrounds and periodic regressions is preserved.

Diagenesis of the Reagan is a complex siliciclastic perigenesis hallmarked by an abundance of iron. All the elements involved could have been derived from weathering and devitrification of the underlying basement. Basal sediments are heavily cemented by hematite. Quartzose sandstones are comprehensively cemented by syntaxial quartz, hematite, and ferric illite. Glauconite is present as peloids, altered rhyolite particles, and authigenic pore-filling cement. Topmost Reagan shows replacement of glauconite and quartz by calcite and siderite derived from ground-water circulation related to the overlying Honey Creek Limestone. [560]

Deformational Sequence of Frontal Zone Thrust Sheets, Ouachita Mountains, Oklahoma

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The Frontal Zone of the Ouachita Mountains is characterized as a trailing imbricate fan. The five principal thrust sheets include the Choctaw, Pine Mountain, Ti Valley, Briery, and Windingstair. Minimum shortening is 90 km in Oklahoma (Hendricks, 1959) and appears to decrease eastward in Arkansas. Major offset is along the Ti Valley and Windingstair faults. Detailed analysis within the Ti Valley thrust sheet reveals a complex fold history in which early orthorhombic folds record a northwesterly directed stress. Fold axis data suggest that these early folds were buckled about an east-west axis and then sheared by the overriding westerly directed Windingstair fault. Gravity data [indicate] that the Ti Valley fault was deformed by these later movements. The imbricate fan extends as much as 40 km into the Arkoma basin, cutting synorogenic sediments. Near McAlester, folds associated with these blind thrusts reveal a distinctive "hooked" outcrop pattern. Northeast-trending folds appear to deform a set of east-west folds, suggesting a shift in the shortening direction. This pattern is not apparent to the east in Arkansas. These data indicate a general rotation of the shortening direction during the evolution of the thrust belt in Oklahoma. Earliest faults, Choctaw and Pine Mountain moved northward, subsequent motion on the Ti Valley and Windingstair faults was directed to the northwest, and final adjustments on the Windingstair fault [were] towards the west. Similar rotation of the principal shortening direction has been observed in the Broken Bow Uplift. [653]

Cathodoluminescence Applied to Provenance Study of a Quartz Arenite: the Jackfork Sandstone, Ouachita Mountains, Arkansas

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Diagenesis and surficial weathering have simplified the mineralogy of the Jackfork Sandstone (Morrowan) such that it is now a quartz arenite. Standard petrographic techniques have been unsuccessful in determining its source area because few diagnostic components are preserved. Little feldspar is present, identifiable lithic fragments are rare, and the heavy mineral suite has very low diversity. Coeval sandstone units from the Black Warrior Basin, the Illinois Basin, and from the Marathon Uplift are similarly restricted in mineralogy.

Cathodoluminescence (CL) has been employed to determine petrologic affinities between the Jackfork of the southern Ouachita Mountains and sandstones from adjacent basins. Calibration of the technique by a survey of igneous and metamorphic rocks revealed that brown-CL quartz is associated with metamorphic rocks through garnet grade, whereas blue-CL quartz is derived from higher rank metamorphics and from both intrusive and extrusive igneous rocks. In sandstone, the quartz fraction is composed of an assortment of brown and blue-CL grains. The ratio of brown to blue quartz was determined by point counting under CL for each sandstone unit of this study.

The values of "percent brown CL quartz" are high and statistically similar for the Jackfork and the Parkwood Formation of the Black Warrior Basin, whose source area was to the south, whereas the Jackfork is not similar to any other of the formations studied. These results indicate that uplift of sedimentary and low rank metamorphic rocks accompanied the collision of South America and the Alabama promontory during the Middle Carboniferous, and that arc-related volcanism was not volumetrically significant at that time. [657]

Structural Style of Ancestral Rocky Deformation (Pennsylvanian-Permian), Mid-Continent Region, USA

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Pennsylvanian/Permian collisional orogeny in the Ouachita-Marathon belt fragmented the craton in the mid-continent region into a large number of blocks. Lateral movement of up to tens of km and vertical movement of up to several km occurred along faults between these blocks. Deformation was most intense within Late Precambrian/Early Paleozoic aulacogens—the West Texas and Southern Oklahoma Aulacogens and the Reelfoot Rift-Rome Trough system. Here rift-stage normal faults were probably reactivated as wrench and reverse faults.

Within deformed aulacogens, common structures include scissors and [propeller] faults, yoked basins, horst/grabens, and sigmoid anticlines (Tomlinson, 1952), as well as basement overthrusts and drape folds. Many of these unusual structures can be shown to be parts of wrench-caused "flower structures". Basement overthrusts are probably largely transpressional, some forming at bends in strike-slip faults.

On the platform, the typical structure is the basement-cored anticline, faulted on one side, commonly with multiple axial culminations and depressions. Chains of these anticlines extend for hundreds of km: the Nemaha

Ridge, Lasalle Anticline, and possibly the Irvine–Paint Creek Uplift are examples. Basement faults flanking these uplifts are probably continuous through areas of little vertical offset. Some basement faults (Nemaha Ridge) reverse throw direction along strike; some (Keokuk and Wilzetta Faults) can be mapped in the subsurface directly into belts of surface en-echelon folds and normal faults. These features strongly suggest strike-slip faulting.

Thus the fundamental structural style of the Ancestral Rocky deformation is basement wrench faulting, commonly with substantial vertical movement, with accessory drape folding, fold-faulting, and en-echelon folding of the sedimentary cover. [661]

Deep Burial Diagenesis and Dolomitization of Hunton Group Carbonate Rocks (Late Ordovician to Early Devonian) in the Deep Anadarko Basin

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The Hunton Group (late Ordovician to early Devonian), which originated as shallow shelf carbonates, shows progressive burial diagenesis with increasing burial to 25,000 feet in the deep Anadarko Basin of Oklahoma and the Texas Panhandle. Petrographic and geochemical study of cores and cuttings at 5,000 foot intervals from 5,000 to 25,000 feet show that shale-associated ferroan dolomite diagenetically replaced the original carbonate only at depths below 10,000 feet.

Burial diagenetic ferroan dolomite occurs as finely disseminated, 10-micron rhombic crystals and is most abundant near the base of the Hunton Group, particularly where an oolite unit overlies the thick marine Sylvan Shale which provides the necessary iron and magnesium ions. Ferroan dolomite also occurs within argillaceous zones and in clean carbonates overlying argillaceous zones in the Middle Hunton Group.

The restriction of this shale-associated ferroan dolomite to strata that have been buried below 10,000 feet implies that where these conditions are met, previously deeply buried strata can be recognized even if they have been subsequently uplifted. Our having demonstrated that these features have in fact formed at depth substantiates the conclusions of previous workers who infer deep burial for Mid-Continent outcrops showing postcompactional clay-derived shale-associated ferroan dolomite. [697]

Collision Effects on the Craton Caused by the Ouachita Orogeny

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To describe the effects upon the craton of the Ouachita orogeny, older structural boundaries within the basement rocks must first be defined. Newly published magnetic and filtered gravity maps, used with the model for basin formation of McKensie (1978), provide a powerful, albeit imperfect tool for predicting the position of pre-Late Paleozoic basins and structural highs, formed under general conditions of extension. Excepting basins having a strong tectonic imprint: the frontal Ouachitas and the Anadarko, positive gravity anomalies generally mark the basins, and negative anomalies mark the highs. This mosaic of basement blocks, many of which were fault bounded, was jostled in the Late Pennsylvanian by the Ouachita collision with widespread effects.

For example, in the region of the Mississippi embayment, the northeastern end of a horst was uplifted to form the Pascola arch. Older faults: the [Ste.] Genevieve and Rough Creek, were re-activated as thrusts up on their southwestern sides. In the region of the Great Plains, numerous sinistral, transcurrent faults were generated, that moved blocks of crust away from the main points of the Ouachita collision. Many plains type folds in the overlying strata show good correlation with predicted σ_1 trajectories. Many faults lie along the trends of the predicted Riedel shears. In the Anadarko and Amarillo basins, major, left lateral shears formed large flower structures. The faults may have offsets of hundreds of kilometers, extending as far as the [Ancestral] Rocky Mountains. In West Texas, right lateral shears associated with the Marathon uplift may explain structural patterns in the region of the Central Basin Platform. An actualistic model for the Pennsylvanian tectonics of the Midcontinent may well be the tectonic collision patterns of China and the Himalayas. [712]

Sedimentary Response to Basinal Subsidence Arkoma Basin, Arkansas

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The Arkoma Basin of western Arkansas and eastern Oklahoma is a peripheral foreland basin that developed as a structural feature during early Pennsylvanian time on the northern margin of the Ouachita geosyncline. The basin is filled with strata ranging from Cambrian to Pennsylvanian in age. The succession thickens southward from approximately 4500 feet at the northern margin of the basin to over 20,000 feet at the southern margin adjacent to the Ouachitas. Early and middle Paleozoic units in the basin are dominated by carbonate strata and display only slight thickening from north to south. The carbonate shelf setting was supplanted in early Pennsylvanian time by terrigenous depositional systems. Stable shelf conditions continued to dominate during Morrowan and early Atokan time and the Morrowan–early Atokan interval maintains a relatively constant thickness of 1500 to 2000 feet from the northern margin of the basin southward.

The early Atokan succession is characterized by thin, extensive units of sandstone separated by shale. The sandstone accumulated in deltaic environ-

ments during periods of coastal progradation from north to south across a stable shelf. Periodic transgressions produced open shelf conditions and the intervening shale units. The early Atokan shelf was broken in middle Atoka time by large east-trending normal faults. Down to the south movement on individual faults displaced lower Atoka sands by as much as 6000 feet in the southern part of the basin. Deltation continued in the northern part of the basin delivering middle Atoka sediments to the fault scarps where density currents transported them into deep water settings on the downthrown sides. Middle Atoka successions exceeding 9000 feet developed in the southern part of the basin in contrast to thicknesses of less than 1200 feet north of the active faults. [725]

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Depositional History and Diagenesis of the Viola Limestone (Ordovician), Southeastern Arbuckle Mountains, Oklahoma

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Deposition of the Viola Limestone (Middle and Upper Ordovician) in the southeastern Arbuckle Mountains took place on a carbonate ramp within and peripheral to the Southern Oklahoma Aulacogen. On the basis of sedimentologic and paleontologic characteristics, the Viola has been divided into 4 microfacies with corresponding depositional environments. These microfacies and depositional environments are, from oldest to youngest: Microfacies A (laminated biopelmicrosparite)—anaerobic deep ramp environment, Microfacies B (bioturbated biopelmicrosparite)—dysaerobic deep ramp environment, Microfacies C (bioturbated [pelmatozoan] biopelmicrosparite)—aerobic mid-ramp environment, and Microfacies D (bioturbated [pelmatozoan] biosparite)—aerobic shallow ramp environment.

The Viola Limestone has been subjected to a complex sequence of diagenetic events which have extensively altered the sediments and occluded virtually all primary porosity. The type of diagenetic alteration appears to be dependent upon rock type, environment of deposition, porosity, clay content, and the chemistry of the pore fluids. The major diagenetic events are, in their approximate order of occurrence: 1) microborings and the formation of micrite envelopes, 2) pyritization, 3) phosphatization, 4) cementation, 5) neomorphism, 6) dolomitization, 7) silicification, and 8) pressure solution and stylolitization.