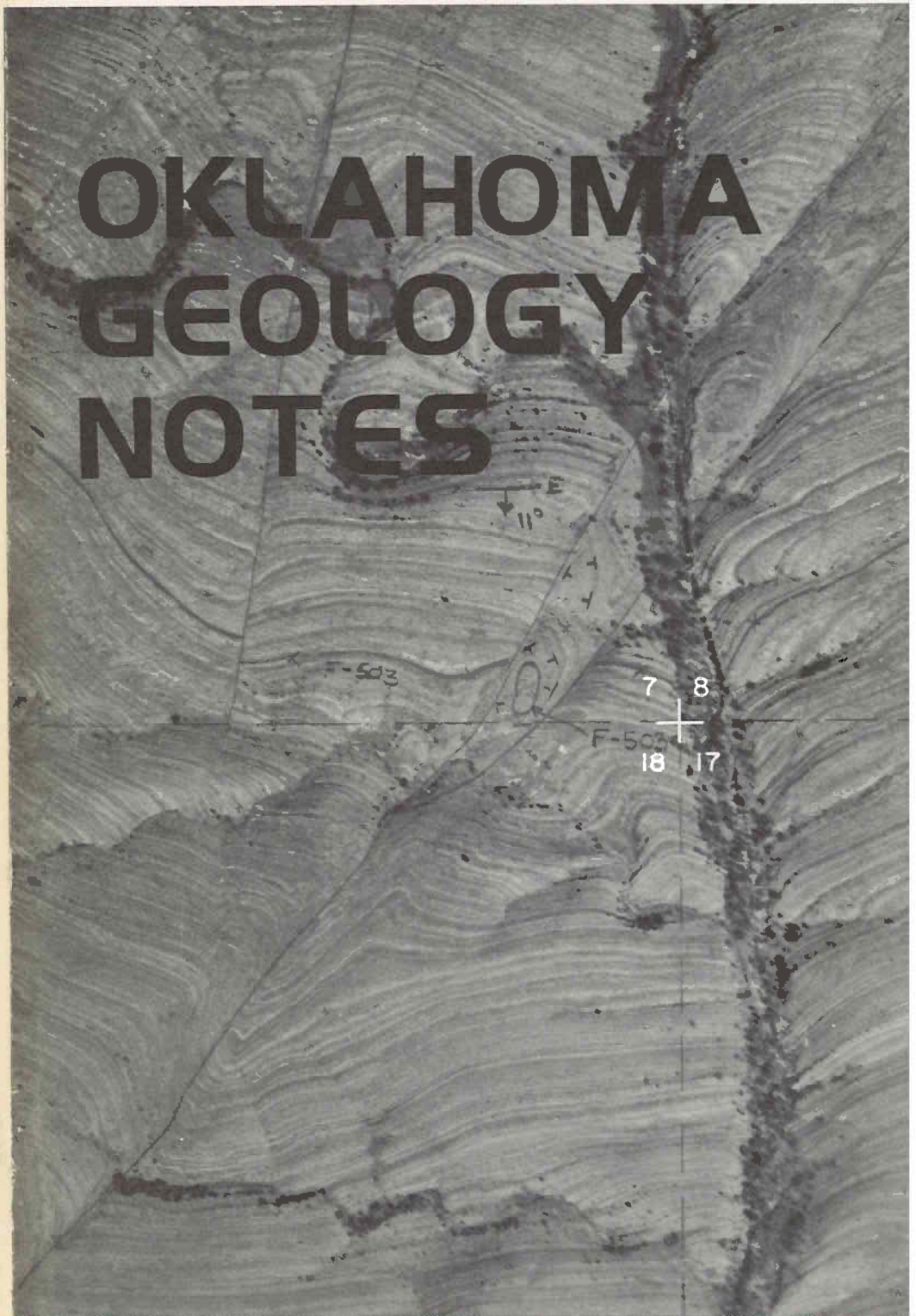
VOLUME 37 NUMBER 6 DECEMBER

OKLAHOMA GEOLOGY NOTES



Cover Picture

ORDOVICIAN LIMESTONES IN THE ARBUCKLE MOUNTAINS

Part of the thick Paleozoic carbonate sequence of southern Oklahoma is shown on the cover photograph for this issue. Strata are limestones of the West Spring Creek and Kindblade Formations of the Ordovician-age Arbuckle Group, exposed in a complex outcrop pattern on the south flank of the Arbuckle anticline. Small trees and shrubs are common only along streams where the water supply is sufficient and where a veneer of alluvium has been deposited.

Beds dip generally southward (lower part of the photograph), at an angle of 10 to 20 degrees, but are disrupted by several north-northeast-trending faults and are tightly folded in the southwest.

The area covered by the photograph is mainly in secs. 7 and 18, T. 2 S., R. 1 E., in Murray County, and the long axis of the picture is about 1 mile. 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. Hardage, 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 University of Oklahoma Printing Services, 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 $2,527.00.

OKLAHOMA GEOLOGICAL SURVEY
ANNUAL REPORT

July 1, 1976–June 30, 1977

Introduction

The production of mineral and energy resources continues to be the mainstay of Oklahoma's economy. For more than two decades, the value of mineral and energy commodities within the State has increased each year. The estimated value for 1976 was $2.67 billion, and it is apparent that that figure will be equaled or exceeded in 1977.

Approximately 95 percent of the 1976 production value was derived from crude oil and natural gas, a percentage that has been consistent for many years. Although the value of petroleum production has increased dramatically since 1973, actual production of crude oil and natural gas has declined. The increasing unit value of each commodity has been more than enough to offset the decline in production, thus providing for increases in value each year.

It is unlikely that coal production in Oklahoma will ever approach either the energy or the dollar value of current petroleum production, but coal is an important component of the State's minerals industry and will likely assume a more significant share in the immediate future. Coal is the nation's third most important energy resource, and in 1976 Oklahoma production amounted to 3.6 million tons, for an estimated value of $57.6 million. In all probability, a new production record will be established in 1977 that will break the old State mark of 4.8 million tons set in 1920.

Other mineral production had modest gains in 1976, with increases in some commodities offsetting declines in others. Carbonate rock continues to be the major industrial mineral, with production designed for aggregate, the cement industry, and specialty products. Sulfate rock (gypsum and minor anhydrite) remains important to the State's industrial-minerals economy, and the output as registered over the past few years has been relatively stable. The remaining mineral commodities continue to play minor but locally important roles in the State's economy.

Energy Programs

During the 1977 fiscal year, the Survey continued to emphasize energy programs initiated during the past few years. Surface mapping in the coal fields, regional subsurface investigations, and topical studies of heavy-oil occurrences were key programs conducted during the year.

With completion of an investigation of the Hartshorne coal beds in Haskell and Le Flore Counties, the Survey can provide specific information on the location, thickness, configuration, and chemistry of these strata. (The study was supported in part by a grant from the U.S. Bureau of Mines.)

A map was prepared depicting the location, ownership, and general magnitude of production for all active coal mines in Oklahoma. This is planned as an annual project with a revised map to be released each spring.

Following publication in June 1976 of a comprehensive study of Hunton strata in the Anadarko basin (OGS Bulletin 121), a companion study of Hunton strata in the Arkoma basin was initiated. The project should be completed next year, with publication expected in the fall of 1978. These investigations will provide explorationists with a comprehensive geological analysis of a key stratigraphic interval in two important gas-producing provinces.

A study of heavy-oil occurrences in northeastern Oklahoma, initiated in the 1976 fiscal year, was continued by means of a drilling program to obtain core and sample information at key localities within the study area. The project, funded in part by a grant from the U.S. Energy Research and Development Administration (ERDA), is part of a 3-state assessment of heavy-oil occurrences in Oklahoma, Kansas, and Missouri. The OGS is coordinating its investigation with those of the other two state surveys, and it is anticipated that the study will be completed during the next fiscal year. Although heavy-oil deposits are of limited economic importance at the present time, the assessment of Oklahoma's heavy-oil potential was considered to be a prudent investigation, because future petroleum demands—together with projected declining reserves of normal crude oils—will substantially enhance the economic potential of heavy-oil and tar-sand deposits. The project in northeastern Oklahoma is the first of several studies of this type that will be undertaken by the Survey in various parts of the State.

The Core and Sample Library continues to serve an important role in connection with a wide range of geological investigations. Increased usage of this facility as a repository for the petroleum industry is taxing the available physical facilities, and the shortage of storage space for cores and samples will have to be alleviated soon or the Survey will have to reduce its activities in this important service area. In a companion activity, the Survey now has the Oklahoma Corporation Commission drillers' logs on microfilm. The file, accessible to the public through a microfilm reader-printer, is available in the Survey offices.

Geologic Mapping and Minerals Investigations

A basic Survey responsibility is the preparation of a geologic map of the State at a scale adequate to provide data for both regional and local studies. Geologic mapping on a county-by-county basis is designed to fulfill that function. During the past fiscal year, field studies were conducted in Marshall and Washita Counties. Maps of Custer, Bryan, and Muskogee Counties are in manuscript preparation, and a bulletin with an accompanying areal geologic map of Muskogee County is scheduled for publication in early fall [Bulletin 122, *Geology and Mineral Resources (Exclusive of Petroleum) of Muskogee County, Oklahoma*, by former OGS geologist Malcolm Oakes, was published posthumously in September 1977]. The county-mapping program has been ac-

celerated in recent years, but the present rate is still not sufficient to keep pace with needs.

An assessment of surface-mining activities in the State (exclusive of coal) is progressing satisfactorily. This project, supported in part by a grant from the U.S. Geological Survey, was set up as a 3-year study to examine past and present mining activity. Data on the location of each surface mine, the commodity mined, the tonnage removed, and the extent of reclamation of the mined area are being compiled for each surface-mining operation in the State, including abandoned pits and quarries. The project is particularly important in view of the current Congressionally mandated study of the feasibility of extending federal controls on surface mining of coal to all other minerals. This study should provide Oklahoma with a rational basis on which to respond to any proposed federal legislation.

A new staff position in industrial minerals has been created for the Survey in the next fiscal year. This position will permit the staff to devote additional attention to several important commodity issues—including an analysis of the micromineralogy and microchemistry of rock products with particular emphasis on increasing concern with "asbestos-form" minerals. This position will also permit the Survey to give additional attention to interest in carbonate rocks and high-silica sand.

Water Programs

The Survey continues to discharge its responsibilities in water resources through the cooperative program with the Water Resources Division of the U.S. Geological Survey. Field work on the regional water-resources-assessment program has now been completed, and 5 of the 9 proposed hydrologic atlases that cover the State exclusive of the Panhandle have been published. (The Panhandle was covered by a previous study conducted by the U.S. Geological Survey.) The hydrologic atlases provide a regional analysis of the distribution, relative quantity, and quality of the State's ground-water resources.

A comprehensive program of aquifer assessment has now been initiated, and work is progressing satisfactorily on the Vamoosa, the Antlers (Trinity), and the Arbuckle aquifers. The Vamoosa and the Antlers studies should be completed in the next fiscal year, with publication by the Survey expected shortly thereafter.

A major hydrologic study of the eastern Oklahoma coal fields was initiated during the fiscal year. Initially, this study will provide a base-line assessment of the water distribution and quality in this region in advance of an anticipated major expansion of coal-mining operations. The continuing program will be designed to monitor the impact of mining operations on the area's water supply. The Survey will include information on the geology and coal resources as part of the study and will conduct analytical work on the water samples collected. The analytical work is expected to involve several hundred samples per year.

A project involving the analysis of the water in abandoned zinc mines in the Miami-Picher area of northeastern Oklahoma was completed during the 1977 fiscal year; preliminary results were released as U.S. Geological Survey

open-file report 77-163. The study showed that water contained in the mines is of marginal quality and may require treatment even for industrial cooling and other related activities. The study was funded by the U.S. Geological Survey, the Oklahoma Geological Survey, and the City of Miami through the Northeast Counties of Oklahoma Economic Development Association.

Environmental Geology

Complete analysis of the environmental effects of natural-resources development and of major construction projects commonly includes outlining significant geological factors. Providing a basis for understanding the impact of these factors is an important mission of the Survey.

The Survey is involved in a major project that is designed to assess the seismicity and tectonic analysis of the Nemaha uplift and related geological features. The study, funded in part by a grant from the U.S. Nuclear Regulatory Commission (NRC), is a 5-year effort to develop a Statewide network of seismograph stations and to compile the necessary geological and geophysical information in order to delineate the boundaries of the tectonic elements in north-central Oklahoma. The seismograph network will provide continual monitoring of local earthquakes in order to define areas of differing earthquake risk in the State. Companion studies (as a part of the overall program of seismicity and tectonic analysis of the Midcontinent region) are being conducted by the geological surveys of Kansas and Nebraska. One of several uses for the resulting information will be to aid the NRC in evaluating sites for nuclear power plants.

In addition to these special projects, the Survey continues to provide geological information used in the preparation of environmental-impact statements for highway and other major construction projects. Assistance is also provided to local communities to be used in evaluating geological factors related to development in their areas. Criteria for sanitary-landfill operations, information on local subsidence and other foundation problems, and identification of flood-prone areas are provided by the Survey. In many of these matters, the OGS serves primarily as a clearinghouse for gathering information obtained by other agencies and providing it to the public.

Public Service

The basis for all Survey responsibility is service to the public. All of the programs outlined in this report have been undertaken with that in mind. Other efforts to meet this obligation are vested in publishing various reports of investigations, responding to requests for information and assistance, making presentations to technical and civic organizations, and serving on committees for local, state, and national professional, governmental, and civic organizations. The publication efforts of the Survey have increased consistently over the past several years (see Appendixes B and C). This published material provides a wealth of documented information that can be used for many years in efforts to resolve future natural-resource and environmental problems.

An increasingly larger share of professional and technical staff time is devoted to responding to requests for information. Although no complete record is kept, it is estimated that the number of responses requiring measurable staff time would exceed 2,000 for the fiscal year. This does not include the large number of public-service requests that can be handled with prepared material (for instance, requests from school children for rock, mineral, and fossil samples).

The members of the professional staff are called upon for a wide range of public presentations (see Appendix D). This activity has also increased markedly during the past few years with the increasing public awareness of growing energy and other natural-resource problems. It is reasonable to assume that the equivalent of as much as one-half of a professional staff member's time may soon be involved in this activity. These functions are important in the professional development of individual staff members and in the further dissemination of information collected by the Survey.

Acknowledgment

The Survey has now completed its 69th year of service to the State. Throughout its history, the Survey has adhered to its basic mission of service to the people through research and dissemination of information on the State's natural resources. In discharging its responsibilities, the Survey is ever mindful that many of its important contributions would not have been possible without the close cooperation of numerous State and federal governmental agencies, many professional and civic organizations, and countless business and industrial units. The Survey expresses its sincere appreciation for the efforts of others and pledges its continued dedication to the mission of serving as the State's research agency for natural resources.

—CHARLES J. MANKIN, *Director*

APPENDIX A

Survey Staff, 1976-77 Fiscal Year

Professional

Thomas W. Amsden

Robert O. Fay

David A. Foster

S. A. Friedman

Rosemary (Croy) Hardage

William E. Harrison

Kenneth S. Johnson

Kenneth V. Luza

Charles J. Mankin

Reza Moussavi-Harami[1]

John A. E. Norden[2]

John F. Roberts

William D. Rose

Leonard R. Wilson

Part-Time Professional

George G. Huffman
(The University of Oklahoma)

Frederick H. Manley
(Georgia State University)

A. J. Myers
(The University of Oklahoma)

James H. Stitt
(University of Missouri, Columbia)

Patrick K. Sutherland
(The University of Oklahoma)

Technical

Cartographic

Marion E. Clark
Roy D. Davis
David M. Deering
Kelly D. Hilburn[3]
Joanne R. Ledet[4]
Wendy Oberlin[5]
Birnie Whitlow[6]

Core and Sample Library

Eldon R. Cox
Kenneth N. Miller[7]
Gary L. Wullich[8]

Editorial

Elizabeth A. Ham

Electron Microscope Technician

William F. Chissoe III

Geological Technician

Robert D. Wingate

Laboratory Technician

Robert M. Powell

Secretarial

Betty J. Bellis
Helen D. Brown
Margarett K. Civis
Laveda F. Hensley[9]
Paula A. Hewitt[10]
Patricia A. McMahan[11]
Cynthia Sarem-Aslani[12]
Gwen C. Williamson

---

[1] Appointed January 1977.
[2] Appointed September 1976; deceased April 1977.
[3] Appointed July 1976.
[4] Appointed July 1976; resigned August 1976.
[5] Appointed June 1977.
[6] Appointed September 1976; resigned May 1977.
[7] Terminated January 1977.
[8] Appointed January 1977.
[9] Appointed January 1977.
[10] Appointed July 1976.
[11] Appointed October 1976; terminated January 1977.
[12] Terminated November 1976.

APPENDIX B

List of Survey Publications Issued, 1976-77 Fiscal Year

New Publications

Bulletin 124.—*Late Cambrian and Earliest Ordovician Trilobites, Wichita Mountains Area, Oklahoma*, by James H. Stitt. 79 pages, 12 figures, 6 plates. Issued April 1977.

Circular 76.—*Shale and Carbonate-Rock Resources of Osage County, Oklahoma*, by William H. Bellis and T. L. Rowland. 50 pages, 18 figures, 1 color map panel, 4 tables. Issued November 1976.

Circular 77.—*Stratiform Copper Deposits of the Midcontinent Region, a Symposium* (Kenneth S. Johnson and Rosemary L. Croy, editors). Proceedings of a symposium held March 1974 at the South-Central Section meeting of The Geological Society of America, held at Oklahoma State University, Stillwater. 10 papers, 3 abstracts, 99 pages, 99 figures, 4 plates, 13 tables. Issued February 1977.

Coal-Mine Map.—*Map of Eastern Oklahoma Showing Active Coal Mines (January 1, 1976)*, compiled by S. A. Friedman. Scale 1:500,000. Issued July 1976.

Hydrologic Atlas 5.—*Reconnaissance of the Water Resources of the Clinton Quadrangle, West-Central Oklahoma*, by Jerry E. Carr and DeRoy L. Bergman. 4 color sheets including geologic map, scale 1:250,000. Issued September 1976.

Oklahoma Geology Notes.—Six bimonthly issues (August 1976–June 1977) containing 168 pages.

Publications Reprinted

Bulletin 67.—*Geology and Mineral Resources of Haskell County, Oklahoma*, by M. C. Oakes and M. M. Knechtel. 128 pages, 5 tables, 8 figures, 2 plates (geologic map and structure map without color; 4 plates omitted). Issued 1948; third printing, August 1976.

Geologic Map, GM-15.—*Mineral Map of Oklahoma (Exclusive of Oil and Gas Fields)*, by Kenneth S. Johnson. One color sheet, scale 1:750,000. Issued February 1970; reprinted November 1976.

Guidebook 14.—*The Composite Interpretive Method of Logging Drill Cuttings*, second edition, by John C. Maher. 48 pages, 14 figures, 1 plate. Issued 1964; third printing, March 1977.

Guidebook for 1973 GSA Annual Meeting.—*Igneous Geology of the Wichita Mountains and Economic Geology of Permian Rocks in Southwest Oklahoma*, by Kenneth S. Johnson and Rodger E. Denison, with contributions by Douglas C. Brockie, Hugh E. Hunter, and Nancy L. Scofield. Guidebook for Field Trip no. 6. 33 pages, 35 figures, 9 tables. Issued November 1973; fourth printing, March 1977.

Mineral Report 3.—*Glass Sands*, compiled by J. O. Beach. 21 pages, 4 tables, 1 map. Issued 1939; reprinted September 1976.

Mineral Report 5.—*Limestone Analyses*, compiled by S. G. English, Robert H. Dott, and J. O. Beach. 28 pages, 3 tables, 1 map. Issued 1940; reprinted May 1977.

Mineral Report 6.—*Dolomite and Magnesium Limestone*, compiled by J. O. Beach and S. G. English. 20 pages, 3 tables. Issued 1940; reprinted September 1976.

Mineral Report 8.—*Copper in the "Red Beds" of Oklahoma*, by C. A. Merritt. 20 pages. Issued 1940; reprinted September 1976.

Mineral Report 13.—*Mineral Production of Oklahoma 1885-1940*, compiled by J. O. Beach. 38 pages, 9 figures. Issued 1942; reprinted September 1976.

Mineral Report 14.—*The Possibility of Magnesia from Oklahoma Oil Field Brines*, by A. L. Burwell. 26 pages, 1 plate, 6 tables. Issued 1942; reprinted January 1977.

Mineral Report 27.—*Uranium in Oklahoma, 1955*, by Carl C. Branson, A. L. Burwell, and G. C. Chase. 22 pages, 2 maps. Issued 1955; reprinted August 1976.

Mineral Report 30.—*Asphaltite in the Ouachita Mountains of Southeastern Oklahoma*, by William E. Ham. 12 pages, 1 map. Issued 1956; third printing, July 1976.

Mineral Report 34.—*The Mineral Industries of Oklahoma in 1956 and 1957*, by Peter Grandone and William E. Ham. 24 pages. Issued 1958; reprinted May 1977.

APPENDIX C

Publications by Survey Staff, 1976-77 Fiscal Year

THOMAS W. AMSDEN

Early Late Silurian biofacies and lithofacies in central United States [abstract], *in* Precambrian geology, *section 1 of* 25th International Geological Congress Abstracts, v. 1, p. 299.

Middle Paleozoic history of Anadarko and Arkoma basins, Oklahoma [abstract]: American Association of Petroleum Geologists Bulletin, v. 61, p. 760-761.

ROBERT O. FAY

Gold in Oklahoma: Oklahoma Geology Notes, v. 36, p. 214 (cover-photo description).

Oil in the Ouachita Mountains of Oklahoma, *in* Decker, R. E., and Black, Bernard (editors), A study of Paleozoic rocks in Arbuckle and western

Ouachita Mountains of southern Oklahoma: Shreveport Geological Society, Guidebook for 1976 field trip of Gulf Coast Association of Geological Societies, p. 91-106.

S. A. Friedman

Coal deposits of the Senora Formation (Middle Pennsylvanian) in part of northeastern Oklahoma [abstract]: Geological Society of America Abstracts with Programs, v. 9, p. 596-597.

Coking-coal reserves of Oklahoma [abstract]: American Association of Petroleum Geologists Bulletin, v. 61, p. 787.

Effect on recoverable coal reserves by surface mining under adverse geological and engineering conditions [abstract]: Geological Society of America Abstracts with Programs, v. 8, p. 876.

Investigations of the Pennsylvanian coal deposits in eastern Oklahoma (1971-76) [abstract]: Geological Society of America Abstracts with Programs, v. 9, p. 19-20.

Map of eastern Oklahoma showing active coal mines (January 1, 1976): Oklahoma Geological Survey, scale 1:500,000.

Oklahoma, *in* 1976 Keystone coal industry manual: New York, McGraw-Hill Mining Publications, p. 617-621.

Preliminary investigation of Pennsylvanian underclays of Oklahoma [abstract]: Geological Society of America Abstracts with Programs, v. 9, p. 62 (with Frederick H. Manley and Charles J. Mankin).

Southwest regional energy council meets in Dallas: Oklahoma Geology Notes, v. 36, p. 208-209.

Elizabeth A. Ham

Oklahoma Geology Notes: Oklahoma Geological Survey, v. 36, nos. 4-6; v. 37, nos. 1-3, 224 p. (ed., with William D. Rose and Rosemary L. Hardage).

Rosemary L. Hardage

Oklahoma Geology Notes: Oklahoma Geological Survey, v. 36, nos. 4-6; v. 37, nos. 1-3, 224 p. (ed., with William D. Rose and Elizabeth A. Ham).

Stratiform copper deposits of the Midcontinent region, a symposium (ed., with Kenneth S. Johnson): Oklahoma Geological Survey Circular 77, 99 p.

A tribute to W. Dow Hamm, Sidney Powers Memorial medalist: The Sooner Geologist, 1976-77 Academic Year, v. 8, p. 3-5.

William E. Harrison

Cretaceous magnetic polarity stratigraphy of IPOD Leg 48 sediments [abstract]: American Geophysical Union Transactions, v. 58, no. 1, p. 45 (with Leg 48 shipboard scientists).

Exploration methods and concepts I, II—a review: Oklahoma Geology Notes, v. 36, p. 196-197.

Glomar Challenger, drill ship for DSDP's Leg 48: Oklahoma Geology Notes, v. 36, p. 134 (cover-photo description).

Glomar Challenger sails on Leg 48: Geotimes, v. 21, no. 12, p. 19-23 (with Leg 48 shipboard scientists).

Organic diagenesis—its relation to Gulf Coast oil [abstract]: American Association of Petroleum Geologists Bulletin, v. 60, p. 1610.

KENNETH S. JOHNSON

Folded Paleozoic rocks in the Dougherty anticline area of the Arbuckle Mountains: Oklahoma Geology Notes, v. 37, p. 2 (cover-photo description).

Homoclinal dip on south flank of Arbuckle Mountains: Oklahoma Geology Notes, v. 37, p. 38 (cover-photo description).

Introduction to the symposium, *in* Johnson, K. S., and Croy, R. L. (editors), Stratiform copper deposits of the Midcontinent region, a symposium: Oklahoma Geological Survey Circular 77, p. 1-2.

Limestones and shales on the southwestern edge of the Arbuckle anticline: Oklahoma Geology Notes, v. 37, p. 66 (cover-photo description).

Minerals, mineral industries and reclamation, *in* Morris, J. W. (editor), Geography of Oklahoma: Oklahoma Historical Society, p. 93-111.

Permian copper shales of southwestern Oklahoma, *in* Johnson, K. S., and Croy, R. L. (editors), Stratiform copper deposits of the Midcontinent region, a symposium: Oklahoma Geological Survey Circular 77, p. 3-14.

Sharp flexure in Permian rocks of southwestern Oklahoma: Oklahoma Geology Notes, v. 36, p. 174 (cover-photo description).

KENNETH V. LUZA

Energy and mineral resources map: Nevada Bureau of Mines and Geology Environmental Folio Series, Reno quadrangle, p. 34-35 (with H. F. Bonham).

Pauls Valley waste-treatment project dedicated: Oklahoma Geology Notes, v. 36, p. 168-169.

Physical properties map: Nevada Bureau of Mines and Geology Environmental Folio Series, Reno quadrangle, p. 37-41.

Seismicity and tectonic relationships of the Nemaha uplift in Oklahoma, Kansas, and Nebraska: American Nuclear Society Transactions, v. 26, p. 131-133.

Waste-treatment-management planning in Oklahoma: Oklahoma Geology Notes, v. 37, p. 75-80.

Water-quality study initiated in northeastern Oklahoma: Oklahoma Geology Notes, v. 36, p. 155-157.

CHARLES J. MANKIN

Oklahoma Geological Survey annual report, July 1, 1975–June 30, 1976: Oklahoma Geology Notes, v. 36, p. 215-228.

Oklahoma, *in* Summary of state activities: State Geologists Journal (Association of American State Geologists), v. 29, p. 46-47.

Preliminary investigation of Pennsylvanian underclays of Oklahoma [abstract]: Geological Society of America Abstracts with Programs, v. 9, p. 62 (with Frederick H. Manley and S. A. Friedman).

JOHN F. ROBERTS

Statistics of Oklahoma's petroleum industry, 1975: Oklahoma Geology Notes, v. 36, p. 233-241.

WILLIAM D. ROSE

AAPG News-Release Handbook: one approach to effective communication [abstract]: AESE Blueline, v. 9, no. 5, p. 3, 1976.

Oklahoma Geology Notes: Oklahoma Geological Survey, v. 36, nos. 4-6; v. 37, nos. 1-3, 224 p. (ed., with Rosemary L. Hardage and Elizabeth A. Ham).

Ruth Sheldon Knowles speaks at OU: Oklahoma Geology Notes, v. 37, p. 19-21.

APPENDIX D

Papers Presented by Survey Staff at Professional Meetings 1976-77 Fiscal Year

University of Oklahoma, Science Education Seminar
Norman, Oklahoma, July 6, 1976

CHARLES J. MANKIN
The nation's energy dilemma

General Accounting Office, Seminar
Washington, D.C., July 23, 1976

S. A. FRIEDMAN
Determination and evaluation of coal reserves

International Geological Congress
Sydney, N.S.W., Australia, August 18, 1976

THOMAS W. AMSDEN
Early Silurian biofacies and lithofacies in the central United States

American Society for Testing and Materials, Symposium on Field Description of Coals
Ottawa, Ontario, Canada, September 23, 1976
S. A. FRIEDMAN
Field description and characterization of coals sampled by the Oklahoma Geological Survey (1971-1976)

Oklahoma City Geological Society, Meeting
Oklahoma City, Oklahoma, September 23, 1976
KENNETH S. JOHNSON
Geology of the Permian Blaine Formation in southwest Oklahoma

Association of Earth Science Editors, Annual Meeting
Albuquerque, New Mexico, October 17-20, 1976
WILLIAM D. ROSE
AAPG News-Release Handbook: one approach to effective communication

Oklahoma Science Teachers Association, Meeting
Midwest City, Oklahoma, October 21, 1976
CHARLES J. MANKIN
Oklahoma's energy resources

Geological Society of America, Annual Meeting
Denver, Colorado, November 8-11, 1976
S. A. FRIEDMAN
Effect on recoverable reserves by surface mining under adverse geological and engineering conditions

National Waste Terminal Storage Program
Oak Ridge, Tennessee, December 8, 1976
KENNETH S. JOHNSON
Evaluation of Permian salt deposits in the Texas Panhandle and western Oklahoma

Oklahoma Association of Electric Cooperatives, Annual Meeting
Oklahoma City, Oklahoma, January 19, 1977
CHARLES J. MANKIN
Energy supply—an Oklahoma perspective

Gulf Universities Research Consortium, Workshop on Enhanced Oil Recovery
Houston, Texas, January 26-28, 1977
CHARLES J. MANKIN
Types of data needed for development of EOR techniques

Tulsa Geological Society, Monthly Meeting
Tulsa, Oklahoma, February 8, 1977
KENNETH S. JOHNSON
Coal mining and land reclamation in eastern Oklahoma

Sigma Gamma Epsilon, Monthly Meeting
Norman, Oklahoma, March 8, 1977
CHARLES J. MANKIN
The myth of alternate energy sources—a modern Aesop's fable

Geological Society of America, South-Central Section Annual Meeting
El Paso, Texas, March 17-19, 1977
S. A. FRIEDMAN
Investigations of the Pennsylvanian coal deposits in eastern Oklahoma (1971-76)
Preliminary investigation of Pennsylvanian underclays of Oklahoma (with Frederick H. Manley and Charles J. Mankin)
CHARLES J. MANKIN
Preliminary investigation of Pennsylvanian underclays of Oklahoma (with Frederick H. Manley and S. A. Friedman)

Oklahoma Heritage Foundation, Monthly Meeting
Oklahoma City, Oklahoma, March 21, 1977
KENNETH S. JOHNSON
Development of Oklahoma's mineral industries

Union Carbide Nuclear Division and U.S. Energy Research and Development Administration, Salt Dissolution Review Meeting
Austin, Texas, March 30, 1977
KENNETH S. JOHNSON
Dissolution of salt on the east side of the Permian basin in Texas and Oklahoma

Phillips University, Energy Awareness Conference
Enid, Oklahoma, March 31, 1977
KENNETH S. JOHNSON
Coal mining and land restoration

Tulsa Geological Society, Monthly Meeting
Tulsa, Oklahoma, April 12, 1977
THOMAS W. AMSDEN
Middle Paleozoic history of the Anadarko and Arkoma basins, Oklahoma

University of Oklahoma, College of Arts and Sciences, High School Day
Norman, Oklahoma, April 23, 1977

CHARLES J. MANKIN

Career opportunities in geology and geophysics

Geological Society of America, North-Central Section Annual Meeting
Carbondale, Illinois, April 27-30, 1977

S. A. FRIEDMAN

Coal deposits of the Senora Formation (Middle Pennsylvanian) in part of northeastern Oklahoma

New Mexico Geological Society, Permian Basin Section of Society of Economic Paleontologists and Mineralogists, and New Mexico Bureau of Mines and Mineral Resources, Symposium on Ochoan and Guadalupian Rocks of Southeastern New Mexico and West Texas
Carlsbad, New Mexico, May 4, 1977

KENNETH S. JOHNSON

Stratigraphy and mineral resources of Guadalupian and Ochoan rocks in the Texas Panhandle and western Oklahoma

Oklahoma City Geological Society, Discussion Group
Oklahoma City, Oklahoma, May 10, 1977

S. A. FRIEDMAN

Coal deposits, reserves, rank, and production trends in the United States and in Oklahoma

Forum on the Geology of Industrial Minerals, 13th Annual Meeting
Norman, Oklahoma, May 12-14, 1977

KENNETH S. JOHNSON

Major gypsum districts of western Oklahoma

CHARLES J. MANKIN

Overview of the geology and mineral resources of Oklahoma

U.S. Army Corps of Engineers, Chloride Control Review Meeting
Tulsa, Oklahoma, May 25, 1977

KENNETH S. JOHNSON

Geologic setting for emission of brine at Salt Plains in western Oklahoma

Norman Rotary Club, Weekly Meeting
Norman, Oklahoma, May 26, 1977

KENNETH S. JOHNSON

Coal mining and reclamation

Institute of Oklahoma Studies
Stillwater, Oklahoma, June 5-18, 1977
CHARLES J. MANKIN
Flush production: petroleum and natural gas in Oklahoma

American Association of Petroleum Geologists, Annual Meeting
Washington, D.C., June 12-16, 1977
THOMAS W. AMSDEN
Middle Paleozoic history of the Anadarko and Arkoma basins
S. A. FRIEDMAN
Coking coal reserves of Oklahoma

American Nuclear Society, Annual Meeting
New York City, June 12-17, 1977
KENNETH V. LUZA
Seismicity and tectonic relationships of the Nemaha uplift in Oklahoma, Kansas, and Nebraska

University of Oklahoma, Faculty Development Seminar on Conventional Energy Sources
Norman, Oklahoma, June 23, 1977
KENNETH V. LUZA
Role of the geologist in the nuclear fuel cycle

Devonian-Trilobite Bulletin Published by OGS

A new bulletin issued by the Oklahoma Geological Survey presents a major contribution to the knowledge of trilobite faunas in Oklahoma and to Early Devonian stratigraphy and paleogeography.

OGS Bulletin 123, *Trilobites of the Haragan, Bois d'Arc, and Frisco Formations (Early Devonian), Arbuckle Mountains Region, Oklahoma*, is the result of a long-term investigation by K. S. W. Campbell, chairman of the Department of Geology of The Australian National University at Canberra. It continues an earlier study done by Dr. Campbell on trilobites from the Silurian Henryhouse Formation in Oklahoma that was published in 1967 by the Oklahoma Geological Survey as Bulletin 115. Both of these studies were based on collections of the Survey and The University of Oklahoma, supplemented by smaller but important collections in the Smithsonian Institution and the Peabody Museum at Yale University.

Campbell's work represents the first systematic study of these trilobites, and it is of particular value in relating the Oklahoma forms and their habitat to species

of the same general time span in other parts of North America. Campbell considers the faunas to be a filtered Appalachian assemblage, with some elements from the Great Basin and possibly beyond. His study indicates that a barrier existed between New York and Oklahoma along the Devonian seaways and that this barrier filtered migration between the two areas and also affected salinity of the waters, thus affecting faunal diversity.

In all, 36 trilobite species were recovered from the Early Devonian formations, including 11 Campbell describes as new species. He also designates 2 new subspecies and names 2 new genera, 2 new subgenera, and a new subfamily. He presents a reassessment of the taxonomy of trilobites and discusses polymorphism in these forms, which he states has been used mistakenly in some instances to erect new species. The descriptions of trilobite morphology are detailed and informative, particularly in reference to the lens structure of the eyes. His specimens are well preserved and are shown to good advantage in the carefully reproduced plates.

The 227-page bulletin, containing 40 plates, 36 text-figures, and 5 tables, can be obtained from the address on the front cover. The price is $10.00 for clothbound and $8.00 for paperbound copies.

Ordovician Crinoids Described in OGS Circular

Circular 78, *Calceocrinids from the Bromide Formation (Middle Ordovician) of Southern Oklahoma*, by James C. Brower, was released in November by the Oklahoma Geological Survey. The brief report (27 pages, 4 plates) describes 3 new species of this family of crinoids, 1 of which is named the type species for a new genus. All specimens described and illustrated were recovered from the Criner Hills and Arbuckle Mountains region of Carter, Murray, and Johnston Counties, Oklahoma.

Dr. Brower is a professor at the Heroy Geological Laboratory of Syracuse University in New York. He explains that this study is part of an expanded work by several authors to be published at a later date as a monograph on all Bromide echinoderms.

In addition to the systematic descriptions and statistical data, a major contribution is made by the author in his discussion of the probable living habits, growth, and early ontogeny or evolution of Middle Ordovician crinoids. He states that although these species are among the four most primitive calceocrinid species, radiation of the family was well along during Bromide time.

Circular 78 can be obtained from the Oklahoma Geological Survey by writing to the address on the front cover. The price is $4.50 for clothbound and $2.50 for paperbound copies.

Hydrologic Atlas of Lawton Quadrangle Published

A set of four large map sheets, printed in color and released in October by the Oklahoma Geological Survey and the U.S. Geological Survey, offers graphic information on the ground-water and surface-water resources of southwestern Oklahoma. The area covered in the report embraces about 5,460 square miles (4,100 km^2) in Harmon, Greer, Jackson, Tillman, Kiowa, Caddo, Comanche, Cotton, Grady, Stephens, and Jefferson Counties.

Issued as Hydrologic Atlas 6, *Reconnaissance of the Water Resources of the Lawton Quadrangle, Southwestern Oklahoma*, by John S. Havens of the USGS, the publication represents another phase of a long-term cooperative project of the OGS and the USGS to provide information on water availability and water quality for all of Oklahoma exclusive of the Panhandle.

Sheet 1 of the set is at a scale of 1:250,000 and shows the areal geology, covering geologic provinces that include the Wichita Mountain uplift, the Hollis basin, and parts of the Anadarko basin, the Marietta basin, and the northern shelf. Rocks exposed range from the Cambrian igneous rocks of the Wichitas through Paleozoic sedimentary rocks to the much younger terrace deposits, dune sands, and alluvial deposits. It is the mineral content, porosity, and permeability of these rocks that determine in large part the quality and to some extent the amount of recoverable water in the area. Some water from the Permian evaporites contains calcium sulfate, calcium carbonate, and (or) sodium chloride. Water recovered from the Cambrian and Ordovician limestones and dolomites is commonly of the calcium carbonate type.

Recharge of both ground water and surface water is seasonal. Streamflow is controlled by precipitation (the average range within the quadrangle is 22 to 33 inches per year, most of which falls during the warm seasons), but ground-water recharge is most effective in the drier winter months, when evaporation and transpiration are lowest.

Data on ground-water availability are given on sheet 2 of the set, and information on surface sources is found on sheet 4. Sheet 3 contains detailed information on quality and chemical make-up of water in the various aquifers in the quadrangle.

The principal cartographic preparation for the report was done by OGS cartographer David M. Deering. OGS geologist Robert O. Fay contributed significantly to the geologic map.

The atlas can be obtained from the Oklahoma Geological Survey by writing to the address on the front cover. The price is $5.00. Other atlases in the series are available from the Survey as follows: HA-1, Fort Smith quadrangle, east-central Oklahoma, $3.00; HA-2, Tulsa quadrangle, northeastern Oklahoma, $3.00; HA-3, Ardmore-Sherman quadrangle, southern Oklahoma, $5.00; HA-4, Oklahoma City quadrangle, central Oklahoma, $5.00; and HA-5, Clinton quadrangle, west-central Oklahoma, $5.00.

OKLAHOMA MEMBERS OF APGS MEET IN OCTOBER

Suzanne Takken, incoming secretary-treasurer of national APGS (photo by Peggy J. Durham)

John S. Fryberger, incoming president of Oklahoma Section, APGS

The annual meeting of the Oklahoma Section of the Association of Professional Geological Scientists was held October 14 and 15 at the Sheraton-Century Center Hotel in Oklahoma City. An excellent program was highlighted by luncheon addresses by William B. Cleary, independent oil operator, Oklahoma City, and Charles J. Mankin, director of the Oklahoma Geological Survey. John S. Fryberger, incoming section president, presided at the meeting.

Mr. Cleary spoke on the future of the independent oil producer, whom he characterized as being caught by today's energy crisis in a squeeze between higher costs and more government control.

Dr. Mankin described his experiences as chairman of a special committee formed within the National Research Council of the National Academy of Sciences. His committee's task was to report to the Secretary of the U.S. Department of the Interior on opportunities to increase natural-gas production in six selected offshore fields in the Gulf of Mexico (see related news item on the following page).

Charles A. Jones, Cleary Petroleum Co., described his company's offshore drilling program here in landlocked Oklahoma. Faced with the problem of developing a field that extended under Lake Texoma, at the southern border of the State, he related some of the logistical and environmental problems involved in

transporting large offshore barges from the Gulf Coast region to carry out development drilling in the lake.

Melvin V. Marcher of the Water Resources Division of the U.S. Geological Survey discussed his agency's programs in evaluating water resources in Oklahoma.

Lt. Col. Richard Mattes of the U.S. Army Corps of Engineers in Tulsa described a program of salt control in the Arkansas and Red River basins. The plan, which was designed to circumvent natural brine pollution, includes building upstream dams on small tributaries, completely isolating salt springs at their sources, and building bypass canals around these sources.

At the section's annual business meeting, plaques for outstanding service were presented to past section presidents Suzanne Takken, Leroy Gatlin, and Edward L. Johnson. In addition, it was announced that Suzanne Takken had been elected national secretary-treasurer of the association to serve during the coming year.

John A. Taylor, national APGS president and a past president of the Oklahoma section, gave a thought-provoking talk about the energy crisis and politics in Washington.

Incoming section officers are as follows: president, John S. Fryberger, Engineering Enterprises, Inc.; first vice-president and president-elect, Wilgus B. Creath, consultant; second vice-president, Gary A. McDaniel, consultant; and secretary-treasurer, J. Philip Boyle, Jr., independent. New section district representatives are Robert F. Walker (Oklahoma City), consultant; Cleo E. Buck (Tulsa), Herndon Drilling Co.; and Gary F. Stewart, Oklahoma State University, Stillwater, representative-at-large.

—Robert L. Isaac
Texas Pacific Oil Co.

OCS-Gas Committee Completes First Report

The first of six reports examining opportunities to increase natural-gas production from selected fields in the Gulf of Mexico was delivered in October to the Secretary of the U.S. Department of the Interior by a special committee chaired by Charles J. Mankin, director of the Oklahoma Geological Survey (see an earlier article in the June 1977 issue of *Oklahoma Geology Notes*, v. 37, no. 3, p. 74). The Committee on Gas Production Opportunities, organized within the National Research Council of the National Academy of Sciences, examined Tiger Shoal field, which is leased to Texaco, Inc.

Gas Production at Tiger Shoal could be boosted, the committee found, by restoring higher production rates in six reservoirs (in 1976 the average gas production was 445 MMcf/day). The committee also concluded that production could be increased even more with additional wells and production facilities. For example, an economic model used by the committee predicts that at current price levels ($0.36 per thousand cubic feet) production could be increased so that the average daily delivery in the 4-year period 1978-81 could be 18 percent higher than in 1976. But the committee added a sobering qualifier: such an acceleration of known reserves would shorten the life of the field by about 50 percent.

The report estimates economically recoverable gas at Tiger Shoal to be 1,375 billion cubic feet, a figure lower than the estimate by the U.S. Geological Survey and lower than both estimates provided by Texaco. These differences, the committee noted, do not affect the results of its study.

The committee's assessment is based on a detailed engineering analysis prepared by the New Orleans consulting firm of Atwater, Carter, Miller, and Heffner. This analysis was submitted to Texaco for technical review, and the Atwater analysis and Texaco's critique of it are appended to the committee's report. The engineering analysis involved the examination of privileged, proprietary geological and engineering data held by the U.S. Geological Survey. At the request of the committee, Texaco and the other commercial producers whose fields are among the six to be examined waived confidentiality in order to allow both the data and the committee's analyses to be available to the public.

In its critique, Texaco indicated that it plans to maintain its 1976 production levels at Tiger Shoal through 1978. After that, additional wells are to be drilled and production subsequently increased to enable Texaco to honor its long-term sales commitments.

Other Gulf of Mexico fields to be examined by the committee include East Cameron Block 64, Eugene Island Block 266, Vermillion Bay Block 14, South Marsh Island Block 48, and East Cameron Block 271. The committee expects to deliver all remaining field reports to the Secretary of the Interior by the end of the year. The committee's final report, which will make general recommendations for increasing overall gas production, will follow.

In addition to chairman Mankin, other members of the Committee on Gas Production Opportunities are Claude R. Hocott, The University of Texas at Austin; Alfred E. Kahn, Civil Aeronautics Board, Washington, D.C.; Don E. Kash, The University of Oklahoma; Richard Maxwell, University of California at Los Angeles; H. William Menard, University of California at San Diego; Francis J. Pettijohn, Johns Hopkins University (emeritus); John J. Schanz, Jr., Resources for the Future, Washington, D.C.; Lois Sharpe (retired), League of Women Voters Education Fund, Falls Church, Virginia; and Robert L. Whiting, Texas A&M University.

Copies of the committee's report, *Opportunities for Increasing Natural Gas Production in the Near Term, Volume One: The Tiger Shoal Field*, are available from the office of Public Affairs, Department of the Interior, 18th and E Streets, NW, Room 7217, Washington, D.C. 20240.

STATISTICS OF OKLAHOMA'S PETROLEUM INDUSTRY, 1976

John F. Roberts[1]

Higher oil and gas prices, though shaky at times, resulted in the drilling of 4,393 wells in search of oil and gas in 1976, an increase of 597 wells (16 percent) over the number drilled the previous year (table 1, fig. 1). There were 434 exploratory (wildcat) wells drilled, 40 more (10 percent) than were drilled in 1975. Caddo County had 21 wildcats and a 48-percent success ratio. Most of the discoveries there, of which 3 were oil wells and 7 were gas wells, occurred in

TABLE 1.—DRILLING ACTIVITY IN OKLAHOMA, 1976[1]

	1976[2]				1975
All wells[2]	CRUDE	GAS	DRY	TOTAL	TOTAL
Number of completions	1,991	790	1,435	4,393	3,796
Footage				22,364,701	18,631,.93
Average footage				5,091	4,908
Exploration wells[3]					
Number of completions	70	65	299	434	394
Percentage of completions				31	28
Footage				2,763,891	2,608,013
Average footage				6,368	6,619
Development wells[3]					
Number of completions	1,921	725	1,136	3,782	3,252
Percentage of completions				70	70
Footage				19,282,232	15,642,120
Average footage				5,098	4,810

[1] Source: *Oil and Gas Journal*, v. 75, no. 21, May 23, 1977: API data.
[2] Footages and totals include 177 service wells, average of 1,801 feet per well.
[3] Excludes service wells.

Red Fork and Morrow-Springer sands. Adjacent Grady County had 15 wildcats, of which 3 were oil and 5 were gas wells, for a 53-percent success ratio. Logan County had 18 wildcats, 9 oil wells and 1 gas well, for a success ratio of 56 percent. This production was from Pennsylvanian sands and Mississippian limestones. Garvin County had 18 wildcats (8 oil wells and 1 gas well) for a 50-percent success ratio. Production there was from Pennsylvanian sands and from Hunton

[1] Geologist, Oklahoma Geological Survey.

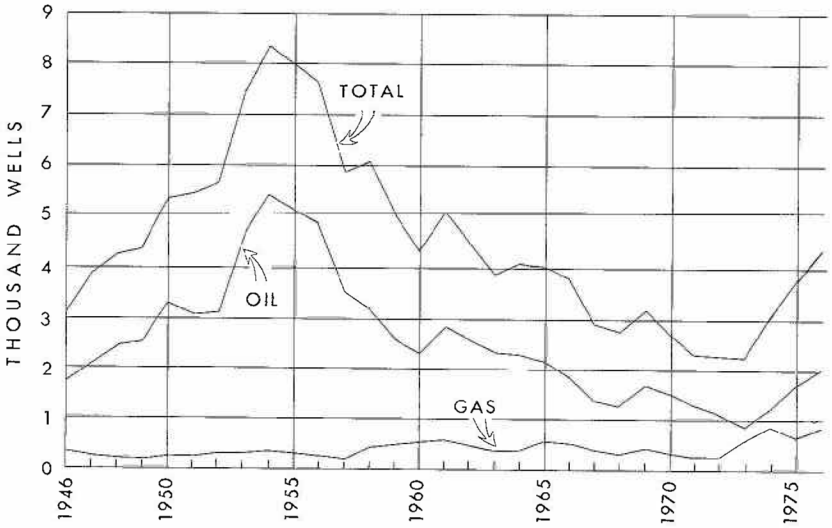


Figure 1. Graph showing total wells drilled, oil wells completed, and gas wells completed in Oklahoma, 1946–76. Source: **Oil and Gas Journal.**

and Bromide rocks. Other significant discoveries from Morrow, Springer, Hunton, and Arbuckle units were completed along the north rim of the Anadarko basin in western Oklahoma.

World Oil reports that independent producers drilled 82.7 percent of the total wells drilled in the United States. In Oklahoma, they drilled 93 percent of the total wells.

Table 1 summarizes drilling activity during 1976 and compares it with that of the previous year. The average total depth of all wells increased from 4,908 feet the previous year to 5,091 feet. This increase reflects accelerated drilling in the Anadarko basin in search of higher priced natural gas. The average total depth of wildcat wells decreased from 6,619 feet to 6,368 feet, mainly because no ultra-deep wells (below 25,000 feet) were completed during the year.

The 22 giant fields of Oklahoma are listed in table 2. (A giant field is one that has an estimated ultimate recovery of more than 100 million barrels of oil.) The giant fields produced 56 percent of the year's total liquid hydrocarbon production from 36 percent of the State's producing oil wells. These giant fields have produced 54 percent of the total cumulative production for the State.

Table 3 lists cumulative and yearly production and the value of all petroleum products to January 1, 1977. Table 4 compares petroleum production for the last 2 years. Crude-oil production declined again, as did daily average production per well. More wells were considered to be producers even though the total production

TABLE 2.—GIANT OIL FIELDS OF OKLAHOMA, 1976

FIELD	1976 PRODUCTION (1000 BBLS)	CUMULATIVE PRODUCTION (1000 BBLS)	ESTIMATED RESERVES (1000 BBLS)	NUMBER OF WELLS
Allen	2,475	131,641	10,359	1,545
Avant	345	107,302	1,698	655
Bowlegs	900	160,637	4,911	155
Burbank	3,090	510,509	30,491	1,070
Cement	2,250	144,976	10,024	1,420
Cushing	2,580	468,432	16,568	1,605
Earlsboro	495	217,409	2,591	205
Edmond, West	590	156,267	3,733	425
Eola-Robberson	2,730	113,857	26,143	485
Fitts	2,970	156,493	16,507	655
Glenn Pool	1,805	313,001	16,999	1,050
Golden Trend	5,485	413,686	86,314	1,080
Healdton	3,955	304,915	48,085	1,420
Hewitt	4,905	229,391	40,609	1,190
Little River	305	160,506	4,494	160
Oklahoma City	1,780	737,591	14,324	230
Postle	4,880	80,504	59,882	315
Seminole, Greater	910	201,246	8,754	255
Sho-Vel-Tum	31,465	1,066,521	233,479	8,005
Sooner Trend	9,550	218,104	45,896	3,175
St. Louis	995	218,110	6,890	600
Tonkawa	280	135,762	1,238	200
Totals	84,470	6,207,107	689,989	25,900

Source: *Oil and Gas Journal*, v. 75, no. 5, January 31, 1977.

was lower, which indicates a lower limit of economic production owing to higher prices for oil from stripper wells.

Figure 2 notes the total number of wells drilled and the number of successful completions in each county. A total of 4,216 wells were completed in 70 of the 77 counties in the State (this total does not include 177 service wells). Of the counties having a significant (more than 100) number of wells completed, Kingfisher had a 91-percent success ratio, but the single wildcat drilled in that county was a failure. Canadian and Major Counties had 87-percent success ratios. In addition, Canadian County had 7 successful wildcats out of 10 tries (70 percent), and Major County had 2 out of 3 attempts (67 percent). Osage County, as usual, had the most tries (436) for a 69-percent success ratio. Statewide, the success ratio was 66 percent.

TABLE 3.—CUMULATIVE (THROUGH 1955) AND YEARLY (1956–76) MARKETED PRODUCTION AND VALUE OF PETROLEUM, NATURAL GAS, NATURAL GASOLINE, AND LIQUEFIED PETROLEUM GAS IN OKLAHOMA[1]

YEAR	CRUDE PETROLEUM		NATURAL GAS		NATURAL GASOLINE AND CYCLE PRODUCTS		LIQUEFIED PETROLEUM GAS	
	VOLUME (1,000 BBLS)	VALUE ($1,000)	VOLUME (MMCF)	VALUE ($1,000)	VOLUME (1,000 GALS)	VALUE ($1,000)	VOLUME (1,000 GALS)	VALUE ($1,000)
Through 1955	7,230,010	11,443,269	12,977,332	1,378,370	14,420,482	890,729	3,673,364	120,097
1956	215,862	600,096	678,603	54,288	489,963	26,543	579,101	23,427
1957	214,661	650,423	719,794	59,743	460,644	25,329	587,140	21,824
1958	200,699	594,069	696,504	70,347	440,798	26,029	657,114	25,822
1959	198,090	578,423	811,508	81,151	448,353	29,443	675,869	27,070
1960	192,913	563,306	824,266	98,088	531,995	33,074	762,258	32,409
1961	193,081	561,866	892,697	108,016	521,237	33,358	817,082	30,141
1962	202,732	591,977	1,060,717	135,772	552,795	35,764	838,903	25,223
1963	201,962	587,709	1,233,883	160,405	555,467	35,131	810,894	28,981
1964	202,524	587,320	1,323,390	166,747	554,053	34,011	880,804	28,055
1965	203,441	587,944	1,320,995	182,297	570,129	34,561	894,665	32,208
1966	224,839	654,281	1,351,225	189,172	576,124	35,715	968,254	44,381
1967	230,749	676,095	1,412,952	202,052	568,905	35,846	1,005,633	49,276
1968	223,623	668,202	1,390,884	197,506	584,010	38,829	1,070,874	39,520
1969	224,729	701,155	1,523,715	223,128	614,082	38,931	1,146,768	34,403
1970	223,574	712,419	1,594,943	248,811	622,146	39,933	1,177,218	52,975
1971	213,312	725,610	1,684,260	273,945	595,854	40,856	1,156,680	56,732
1972	207,633	709,033	1,806,887	294,523	611,478	42,709	1,140,216	57,101
1973	191,204	723,273	1,770,980	334,110	616,308	49,070	1,219,848	95,264
1974	177,785	1,277,076	1,638,492	458,904	528,402	84,638	1,311,702	166,461
1975	163,123	1,389,164	1,605,410	513,731	436,170	63,338	1,244,880	140,197
1976	150,627	1,432,463	1,710,586	858,714	473,592	63,287	1,278,564	144,600
Totals	11,487,173	27,015,173	40,030,023	6,289,820	25,772,987	1,737,169	23,897,831	1,276,167

Figures from: *Minerals Yearbook* of the U.S. Bureau of Mines. Totals for crude petroleum differ from those compiled by the U.S. Bureau of Mines and the American Petroleum Institute principally because of the exclusion from USBM and API compilations of an estimated production of 26,355,000 barrels for the years 1905–1906.

[1] Preliminary figures for 1976.

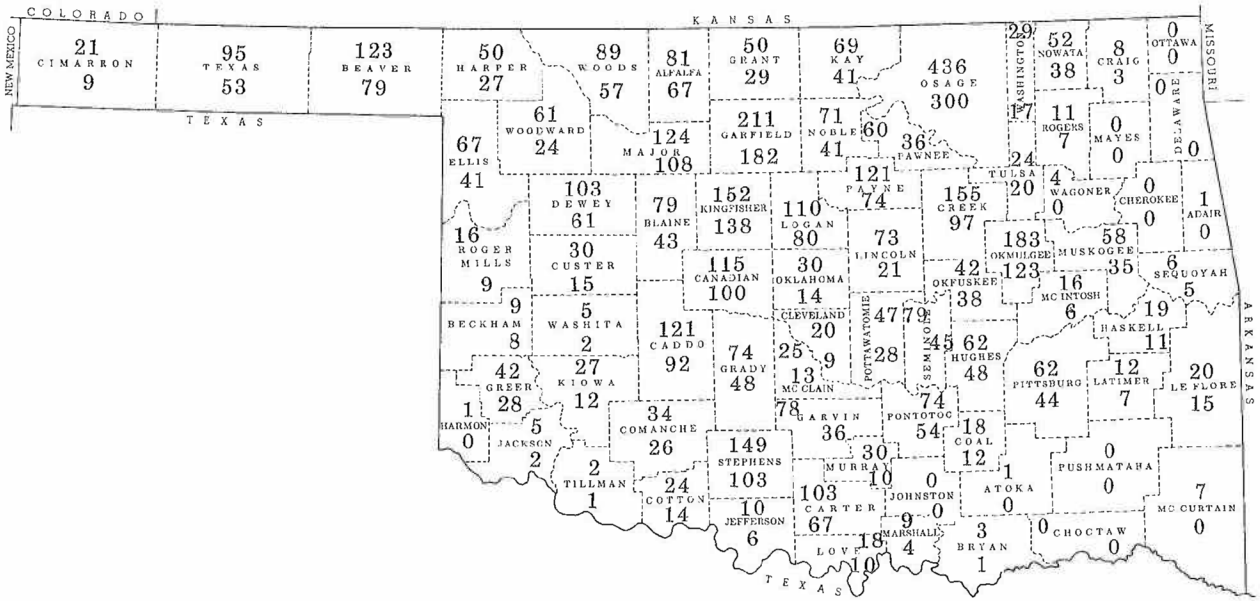


Figure 2. Total drilling by counties during 1976. Upper figures give total number of wells drilled; lower figures give number of successful completions. Source: American Petroleum Institute In cooperation with U.S. Bureau of Mines.

Figure 3 shows a decrease in natural-gas reserves from 13.1 trillion cubic feet to 12.5 trillion cubic feet—more gas was produced than was added by discoveries and revisions. The ratio of reserves to production was 7.5, down from 7.8 the previous year.

Figure 4 indicates a decrease in extensions and revisions and in production and a slight increase in discoveries of total liquid hydrocarbons from the previous year. Production declined from 195 million barrels to 192 million barrels during 1976. Net reserves at year's end had declined from 1,539 million barrels to 1,466 million barrels, a reserve-production ratio of 7.7.

National Stripper Well Survey, January 1, 1977, a joint project of the Interstate Oil Compact Commission and the National Stripper Well Association, indicates that at the close of 1976 Oklahoma had 53,357 stripper wells, 74 percent of the total number of producing oil wells. A stripper well, for the purpose of this survey, is a well producing 10 barrels of oil per day or less during the year under consideration. In Oklahoma, stripper wells produced 73,459,288 barrels of oil, 46 percent of the total crude-oil production. Only 881 stripper wells were abandoned, whereas 1,739 were abandoned the previous year. Remaining reserves of stripper crude oil total 631,383 thousand barrels of oil, 53 percent of the State

TABLE 4.—HYDROCARBON PRODUCTION IN OKLAHOMA

	1975	1976
Crude oil and lease condensate		
Total annual production (1,000 bbls)[1]	163,123	150,627
Value ($1,000)[1]	1,389,164	1,432,463
Cumulative production 1891-year (1,000 bbls)	11,336,546	11,487,173
Daily production (bbls)	446,912	412,677
Total number of producing wells[2]	71,657	72,388
Daily average per well (bbls)	6.2	5.7
Oil wells on artificial lift estimated)[2]	67,568	68,257
Natural gas		
Total annual marketed production (MMCF)[1]	1,605,410	1,710,586
Value ($1,000)[1]	513,731	858,714
Total number of gas and gas-condensate wells[2]	9,707	10,293
Natural-gas liquids		
Total annual marketed production (1,000 bbls)[1]	40,475	41,718
Value ($1,000)[1]	203,580	207,887

[1] Item for 1975 is U.S. Bureau of Mines final figure. Item for 1976 is U.S. Bureau of Mines preliminary figure.

[2] *World Oil*, annual forecast and review issue, vol. 184, no. 3, February 15, 1977.

total. The increasing importance of stripper wells and their increasing share of the total State production reflect the impact of increases in the price of oil. Higher prices permit wells to be produced to lower levels of daily production before the economic limit is reached. Lower production levels also produced

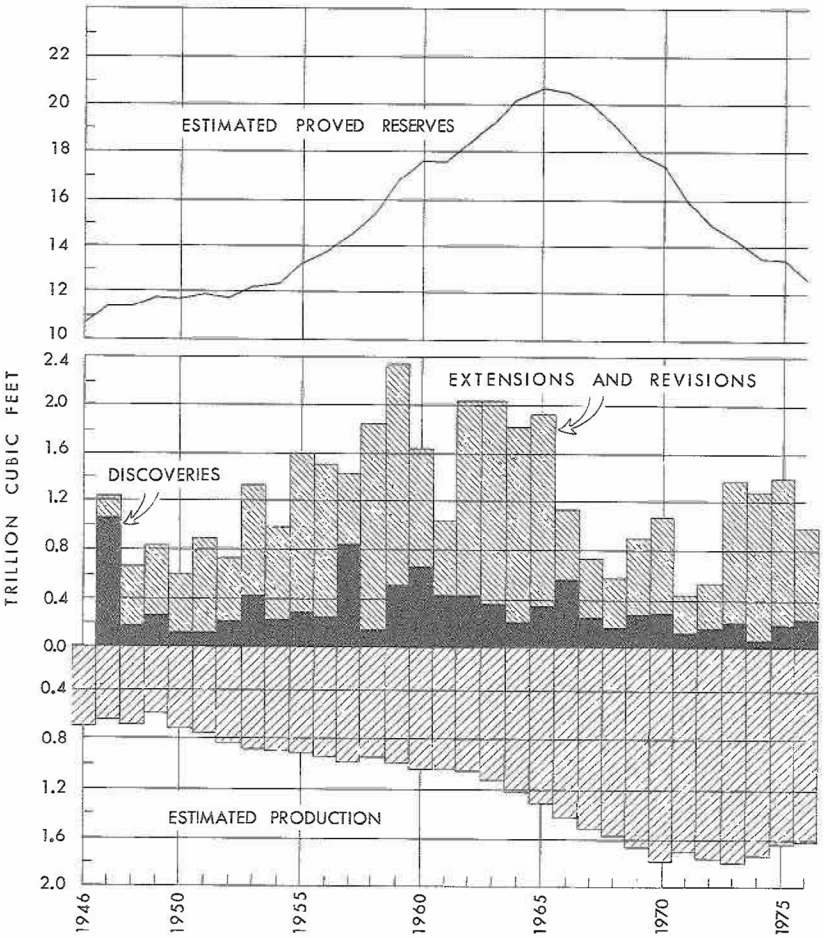


Figure 3. Graph showing statistics on estimated proved reserves of natural gas in Oklahoma, 1946–76. Source: American Gas Association, annual reports.

additional quantities of oil that otherwise would not have been recovered before abandonment.

Oklahoma continues to rank third in the nation in natural-gas production (with 8.5 percent of the total U.S. production) and fourth in liquid-hydrocarbon production (5.3 percent of the total). The State ranks fourth in the nation in natural-gas reserves and fifth in oil reserves.

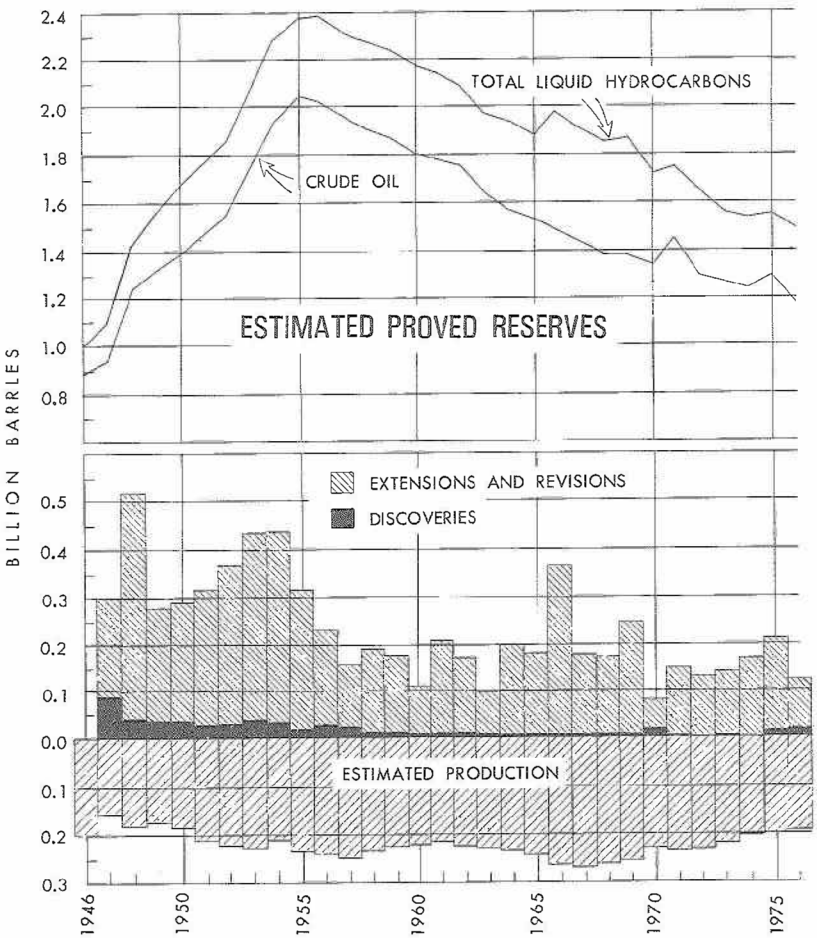


Figure 4. Graph showing statistics on estimated proved reserves of total liquid hydrocarbons in Oklahoma, 1946–76. Source: American Petroleum Institute, annual reports.

Tulsa to Host GSA South-Central Section in March

The South-Central Section of The Geological Society of America is an organization of particular interest to Oklahoma geologists, especially those of Norman. This branch of the GSA, proposed at the annual GSA meeting in 1965, was formed in 1966 and held its first meeting in April 1967 on The University of Oklahoma campus at the Center for Continuing Education, with the Oklahoma Geological Survey and the OU School of Geology and Geophysics serving as co-sponsors. OGS director Charles J. Mankin was vice-chairman of the section during its first year and assumed the presidency following the 1967 meeting.

The 12th annual meeting of the South-Central Section will be held next March 6-7 in Tulsa, with the Department of Earth Sciences of The University of Tulsa and the Tulsa Geological Society serving as co-sponsors. In addition to the regular technical sessions, symposia will be held on structural geology, Precambrian geology of the Midcontinent, land use, and seismic stratigraphy. Scheduled field trips will offer opportunities to examine the stratigraphy and structure of the Arbuckles and the stratigraphy, environment of deposition, and sedimentation of Pennsylvanian rocks. A field trip will also study land-use planning in the metropolitan Tulsa area.

The Norman campus will be well represented at the meeting by OGS personnel and by faculty and students of the OU School of Geology and Geophysics.

Kenneth S. Johnson, economic and environmental geologist, and Kenneth V. Luza, engineering and environmental geologist, of the Survey staff, will co-chair a symposium on land-use planning and geology and will present a joint paper on "Surface-Mined-Lands Inventory and Related Land-Use Practices in Oklahoma." Johnson will also present a paper co-authored with S. Thomas Gray, geologist with the U.S. Army Corps of Engineers, on "Major Sources of Chlorides in the Arkansas River in Oklahoma."

Thomas W. Amsden, OGS paleontologist and stratigrapher, will be co-chairman of a technical session on paleontology and palynology.

M. Charles Gilbert, visiting geologist with the Survey and chairman of the Department of Geology of Virginia Polytechnic Institute and State University, will be co-chairman of a special session on the Wichita Mountains and will lead a small group in an informal pre-convention field trip to the Wichitas. Gilbert will also talk on "Quanah Granite-Gabbro Relations, Wichita Mountains" and on the "Wichita Mountains Mapping Project."

Dr. Mankin will participate in the meeting as an incoming member of the management board of the organization.

John S. Wickham, acting director and professor of the School of Geology and Geophysics, will present a paper, "Effects of Initial and Boundary Conditions on Strain and Shape of Single-Layer Folds," written with J. M. Anthony, Roger Feenstra, and R. E. Manz. Wickham will also serve as co-chairman of a session on mechanical interpretation in structural geology: drape folds, strike-slip faults. He and Rodger E. Denison, independent petroleum geologist of Dallas, an OU alumnus, will lead a field trip to the Arbuckle Mountains.

Robert H. DuBois, Kerr-McGee professor of geophysics and director of the OU Earth Sciences Observatory, has prepared a paper for the meeting, together with James E. Lawson, geophysicist with the Observatory, and Paul H. Foster and Marc Tsufis, also of the Observatory. The paper, "Automated Selection of Radio Propagation Paths for V.H.F. Radio Telemetry of Geophysical Data," will be presented by Lawson, senior author.

David B. Kitts, David Ross Boyd professor of the history of science and geology, will talk on "Models in Geology."

Graduate students at OU presenting papers are: David R. Clupper, "The Lithostratigraphy and Depositional Environments of the Pitkin Formation (Mississippian) in Adair County, Northeastern Oklahoma"; Grant Zimbrick, "The Significance of Sandstones in the Trace Creek Shale Member of the Pennsylvanian Bloyd Formation in Adair County, Northeastern Oklahoma"; and Gayle Tapp, "Predictions of Fracture Density in Single-Layer Folds Using Finite-Element Computer Models." Tapp's paper was co-authored by John Wickham.

For additional information on the meeting, contact Norman J. Hyne, Department of Earth Sciences, The University of Tulsa, 600 South College, Tulsa, Oklahoma 74104 (phone, 918—939–6351, ext. 515).

Mankin Assumes AGI Presidency

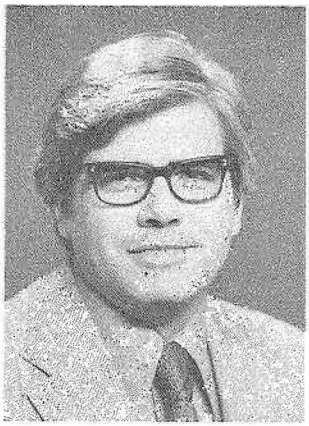
Charles J. Mankin, Oklahoma Geological Survey director, became the new president of the American Geological Institute during last month's annual meetings of The Geological Society of America held in Seattle. Installation was conducted at the AGI board of directors' meeting November 10.

AGI was founded in 1948, as an affiliate of the National Academy of Sciences under the National Research Council, with the purpose of unifying the various fields in the geological sciences. Its stated goals were to upgrade geological training and the quality and attainments of earth scientists, to disseminate earth-science information, and to promote research and its applications. A correlative goal is to develop closer relationships with other sciences.

In 1963 the institute became an independent organization. It has grown over the years from the original 11 cooperating organizations to become a federation of 18 major scientific and professional member societies. It has numerous corporate members (industries dependent on earth resources) and 26 academic associates, including The University of Oklahoma. A current goal is to expand this membership even further.

Operating under a nonprofit, self-sustaining concept, AGI offers its services to scientists, member societies, educators, and to the general public.

Cole Robison Named Visiting Geologist at OGS



Coleman R. Robison, paleobotanist from The Ohio State University, Columbus, Ohio, has joined the staff of the Oklahoma Geological Survey on a 7-month appointment as a visiting geologist. Cole is working under a $32,000 grant from the U.S. Bureau of Land Management (BLM) to survey the paleontological resources of the southeastern Oklahoma coal fields (Arkoma basin) on land containing federal coal reserves. Charles J. Mankin, OGS director, is project director.

This project was established in response to a national public law that requires scientific surveys of public lands that may be disrupted by mining. The purpose of these mandated surveys is determination of whether or not significant paleontological and (or) archeological material could be destroyed by mining the land. If such material is found, it must be retrieved and stored.

Interest in mining in the southeastern Oklahoma area has increased greatly on both local and national levels. The lands being investigated are in an area formerly known as Segregated Indian Lands, and the BLM is responsible for the submission of environmental-impact statements on these lands. Data obtained by Robison on invertebrate, vertebrate, and plant fossils are necessary to complete these statements.

Cole's work with the OGS entails extensive literature reviews, field surveys, and preparation of a final report including recommendations for protective measures and retrieval of the material. He is being assisted in his project, which began October 1, 1977, and is due to be completed May 1, 1978, by graduate students in paleontology from the OU School of Geology and Geophysics.

Coleman Robison is a native of Orofino, Idaho. He obtained his secondary education in Soap Lake, Washington. Following a tour of active duty with the U.S. Army Signal Corps, he earned an Associate in Science degree from Big Bend Community College in Moses Lake, Washington. He obtained a B.A. in botany

from Central Washington State College in Ellensburg in 1968, and in 1975 he received his Ph.D. from the University of Montana at Missoula.

Cole has an impressive record in paleobotany. While pursuing studies toward his doctorate at the University of Montana, he taught both upper- and lower-division courses in paleobotany, taxonomy, physiology, comparative morphology, and general botany. He was awarded a National Aeronautics and Space Administration traineeship and served as a research assistant, doing work on fossilized and living conifers. Following completion of his doctoral work, he became a research associate with the Department of Botany at the University of Montana, conducting paleobotanical investigations on conifer cones from Cretaceous deposits of North America. In 1976 he received a postdoctoral fellowship in the Department of Botany of The Ohio State University, where he did paleobotanical research on Mesozoic conifers and Paleozoic cordaiteans.

He is a member of 14 professional and honorary societies and has presented papers at several national meetings. He has numerous publications to his credit.

Cole is married to Nancy St. John of Altamont, New York, who received a B.A. degree in American literature from the State University of New York at Oneonta. Nancy has done editorial work for the Department of Social Work at the University of Montana. She was active in local politics in both Missoula and Columbus.

We welcome both Robisons to Norman!

ENERGY CONFERENCE HELD AT OU

There is a need for more effective leadership and more effective communication with the technical and general public on the serious nature of energy problems facing the United States. If we do not make sensible decisions about our energy future, we may find that our options will soon be extremely limited. Fortunately, we still have the opportunity to work out plans for an orderly transition to future energy supplies. These were the principal conclusions reached by participants at an energy conference sponsored by the International Alumni Association, who gathered at The University of Oklahoma October 27–30.

The meeting, dubbed "Energy in our Future—a Question of Choices," was an initial effort to focus attention on this vital issue. The conference began on the evening of October 27 with a presentation on the ethics of energy in our way of life by Tom Boyd, assistant professor of philosophy at OU.

On October 28, the first session focused on the present energy situation: dependence on fossil fuels in our society. Donald E. Menzie, professor of petroleum and geological engineering at OU, introduced the topic with remarks on future methods of enhanced crude-oil recovery. Next, Barth Walker, an Oklahoma City legal consultant, discussed present and future prospects of the oil and gas industry. Ruth Sheldon Knowles, an internationally known petroleum specialist,

writer, foreign correspondent, and lecturer, presented a talk on the future of relations between the oil and gas industry and governments. Following this, the role of coal in our energy future was assessed by Maj. Gen. William Randolph of Kerr-McGee Corp.

Energy and our basic life-support systems was the topic for discussion during the afternoon's session. Charles Wesner, president of the Norman chapter of the Sierra Club, assessed the apparent conflict between energy and the environment. Raymond Mill, OU College of Health, examined the subject energy and air quality. The energy crisis and our water systems was the topic presented by George Reid of the OU School of Civil Engineering and Environmental Science. Discussions of agriculture energy, by Sam Hammonds of the Oklahoma Department of Agriculture, and organic methods, by Joe Nichols of Atlanta, Texas, completed the program for October 28.

The next day, the question of energy conservation was discussed by Cedomir Sliepcevich of the OU School of Chemical Engineering and Material Science. A look at energy-efficient building techniques by Floyd Calvert and Raymond Yeh, both of the OU School of Architecture, was followed by a panel discussion on government energy policy.

Alternate energy sources were reviewed by a panel of experts on solar, geothermal, ocean-thermal, wind, and biochemical energy, followed by an examination of possible uses of nuclear power by Gary Hohmann of Westinghouse Electric Corp. Research in power-systems planning was discussed by John S. Ball of the U.S. Department of Energy's Bartlesville research center.

A banquet speech by Ralph Buultjens of Pace University, New York City, entitled "A New Global Design—Ethics, Power, and Poverty in Today's World," completed the conference program. The association's annual business meeting was held on the final day, October 30.

—Donald E. Menzie
OU School of Petroleum and Geological Engineering

Colorado Coal Map Published

Licensed Coal Mines in Colorado, compiled by David C. Jones, has been published by the Colorado Geological Survey as Map Series 8. The 2-color, 19- by 32-inch map shows the locations and status of all presently licensed coal mines in the state and includes data on coal beds, production, and number of employees for each mine. Coal-resources areas are overprinted in green on the map, with coal fields delineated for each area. According to the CGS, licensed coal mines increased from 45 in December 1975 to 61 in April 1977, and the map should be of interest to anyone following the development of this resource.

Map Series 8 can be obtained for $2.00 prepaid from the Colorado Geological Survey, Room 715, 1313 Sherman Street, Denver, Colorado 80203.

Rocky Mountain Publications Cover Shale Reservoirs and Colorado Subsurface

The Rocky Mountain Association of Geologists' Special Publication 1, *Oil and Gas from Fractured Shale Reservoirs in Colorado and Northwest New Mexico,* by William W. Mallory, is oriented toward hydrocarbon exploration. It contains a map plus a text describing such topics as regional setting, productive provinces, reservoirs, exploration practices, and oil sources. The cost is $10.00 to nonmembers and $8.00 to members of RMAG.

Special Publication 2, *Subsurface Cross-Sections of Colorado,* by the RMAG research committee, Dennis Irwin, chairman, includes 22 electric-log cross sections, with a text, index map, and nomenclature chart encompassing every sedimentary basin in Colorado. The publication is available to nonmembers for $20.00, while the price to members is $15.00.

These publications can be ordered from the Rocky Mountain Association of Geologists, 505 Colorado Building, 1615 California Street, Denver, Colorado 80202.

Two Energy Volumes Published

Energy Bibliography & Index, Volume 1, issued by Gulf Publishing Co., is a guide to 20,000 books, maps, government documents, and technical reports in the field of energy. Entries are indexed under 5 categories, with an average of 15 access points; abstracts of 50-100 words are included under main entries, and Library of Congress call numbers are given. The projected series of the bibliography will contain five volumes, and quarterly updates can be ordered.

The price is $295.00 for volume 1. Orders should be sent to Gulf Publishing Co., Book Division, P.O. Box 2608, Houston, Texas 77001.

The Energy Sourcebook, issued by the Center for Compliance Information of Aspen Systems Corp., is a 667-page compendium of almost everything anyone could want to know about energy. It covers 15 sources of energy from essentially every viewpoint that could be considered: resources and potential sources, consumption, outlook, legislation, technology, economics, conservation, and guidelines for industry.

The $39.50 volume can be ordered on a 30-day free-trial basis from Department E, Center for Compliance Information, 20010 Century Boulevard, Germantown, Maryland 20767.

GEOMORPHOLOGY OF CLEVELAND COUNTY OKLAHOMA

Martin J. Haigh[1]

Introduction

Historical physiography has become an unpopular field of geomorphology. Nevertheless, evidence for planation by marine transgression and deposition, or by lacustrine-subaerial aggradation, is common in the geological record. Furthermore, L. C. King (1962) and the geomorphologists of the Soviet Union (Gorelov and others, 1970) and of Eastern Europe (Mazur and Cinura, 1975; Badea, 1975; Gavrilovic, 1975) have presented overwhelming evidence for the existence of continent-wide planation surfaces and their correlation with particular geological events. In the American West, the creation of the Ogallala aggradational surface is correlated with the uplift of the Rocky Mountains.

In Western geomorphology, the subject of widespread subaerial planations has become hopelessly controversial as a result of its association with the outmoded Davisian paradigm (see Ruhe, 1975). Recent research has tended to neglect such topics in favor of process studies, although this trend seems to be changing (Melhorn and Flemal, 1976). Increased appreciation of the significance of results from the continental interiors of Eurasia and Africa (King, 1962) has reopened the debate concerning the reality of subaerial planation, notably pedi planation. This situation has been enhanced by the renewed appreciation that rivers neither exist in a steady state nor change progressively but that their history is a series of brief phases of erosional activity separated by longer phases of relative stability (Womack and Schumm, 1977; Schumm, 1976). It is unlikely that these phases ever result in the creation of a "plain," but the record of these events is still recorded in the differential beveling of the landscape.

Such bevelings may be stimulated by any one of a suite of circumstances. These include climatic change, tectonic uplift, a change in base level, or the fact of a river's incision into rock strata with varying capacities to resist erosion (Holland and Pickup, 1976; Cole, 1937). Episodic erosion instigates kinematic waves of accelerated erosion that are transmitted upstream from the affected portion of the drainage basin as knickpoints, upslope as traveling inflections (Marosi, 1972), and away from the river by hillslope retreat (King, 1962), identified as sequences of valley benches, spur platforms, or perhaps eventually concordant summit lines.

Study Area

Cleveland County, which occupies 547 square miles in central Oklahoma, lies on the northeastern flank of the Canadian River. It is an area of low relief. In

[1] Assistant Professor, Department of Geography, University of Chicago, Chicago, Illinois.

terms of absolute altitude, the county ranges from 1,360 feet above sea level in the northwest (on the divide between the North Canadian and the Canadian Rivers) to 960 feet at the point where the Little River (fig. 1) flows into Pottawatomie County en route to its junction with the Canadian River. Relative relief per section (square mile) is 100–150 feet in the east to less than 50 feet near the Canadian River in the west (fig. 2).

The substrata in Cleveland County are predominantly red beds that are Early Permian in age (Burton and Jacobsen, 1967). The eastern half of Cleveland

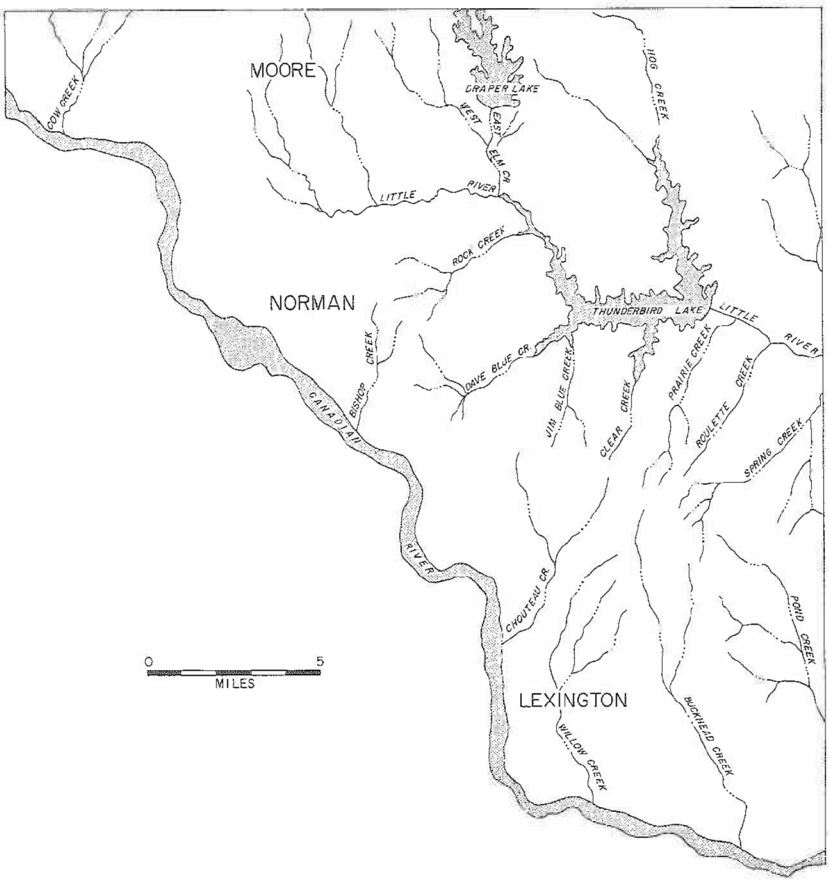


Figure 1. Map showing drainage of Cleveland County, central Oklahoma.

County is underlain by the Garber Sandstone and by the Wellington Formation. These two units comprise 800–1,000 feet of cross-bedded sandstone, irregularly interbedded with shale. The sandstone beds are friable, fine grained, and easily eroded. The western third of the county is underlain by the Hennessey Shale. This unit is composed of 100–200 feet of essentially homogeneous reddish-brown shale; individual beds range up to 10 feet in thickness. The clayey shales contain layers of siltstone and a fine-grained sandstone. The Chickasha Formation and the Duncan Sandstone crop out in the northwestern part of the county. These strata

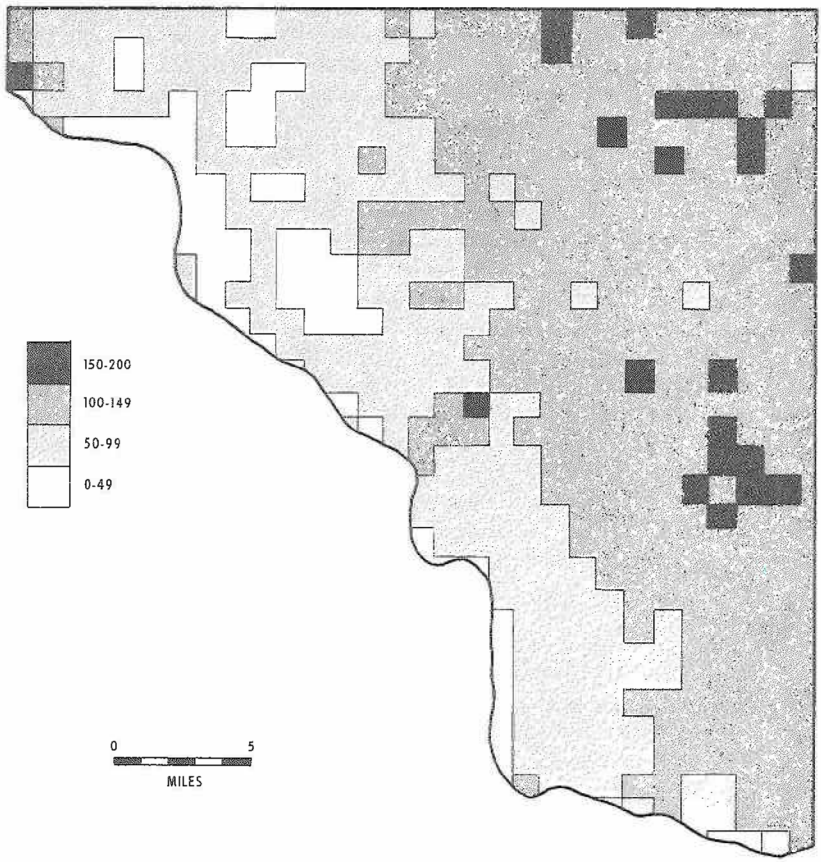


Figure 2. Map showing relative relief (in feet) for Cleveland County, Oklahoma.

conformably overlie the Hennessey Shale and consist of sandstone, siltstone, conglomerate, and shale beds. All these formations lie on the eastern side of the Anadarko basin and have a westward regional dip of 30–35 feet per mile (Wood and Burton, 1968).

Underlying lithology has considerable impact on surface physiography. Surface exposures of the Hennessey Shale are characterized by grass-covered prairie and a relative relief of less than 100 feet per section. The Garber Sandstone and the Chickasha and Duncan Formations give rise to rolling, wooded hill country and a relative relief of between 100 and 200 feet per section.

The second major control of surface physiography is the area's drainage network. The Canadian River forms the southern and western boundaries of the county. The active river channel consists of a number of braided channels choked with sediments derived from its upper reaches in the Sangre de Cristo Mountains of New Mexico and the Texas Panhandle. The river flows in a wide, alluvium-filled channel flanked by terrace deposits. Five terrace series have been recognized for both the Canadian and the North Canadian Rivers. In Blaine and Dewey Counties these occur 50, 150, 220, 270, and 300 feet above the present flood plain (Fay, 1959). In southeastern Oklahoma, Hughes County, 4 terraces have been discovered at 10–15, 30–40, 65–80, and 200 feet (Weaver, 1954). The highest of these is thought to correlate with the 270- and 300-foot terraces of Blaine and Dewey Counties and is thought to be Kansan in age. The lower terraces are probably Wisconsinan and Illinoian in age (Brown, 1967).

In addition to the terraces, channel-floor sediments elsewhere testify to at least eight cycles of alluviation (Kessler, 1970). Dune deposits presumably derived from these channel sediments are found locally along the Canadian River. They appear to be vegetated and stabilized. Along the north side of the river, adjacent to State Highway 9 in Norman, housing developments have been started on dune deposits. The discharge of the Canadian Riser is 94,000 acre-feet per year, and the average gradient is 4 feet per mile.

The Little River, which drains an area of about 297 square miles, is a completely different stream. This system has its headwaters inside Cleveland County. Consequently, it carries a much smaller sediment load and has fewer associated alluvial deposits. The stream has a smaller discharge, about 45,700 acre-feet per year, but a steeper slope, some 12 feet per mile east-southeast. Drainage density is about 0.77.

Method of Analysis

It may be argued that the highest parts of any landscape will be the last to lose the remnants of earlier beveling, since these are farthest from the river channel, the center of later dissection. Altimetric-frequency analysis consists simply of counting the number of summits or closed contours within a particular height range and interpreting summit clusters as relics of former planations. The technique has disadvantages. A large flat plateau, obviously a feature of considerable morphologic significance, may count only once, while a dissected upland may yield many data points. Further, results may become distorted if the technique is

applied to too large an area. Few surfaces are flat, most have a regional tilt, and some possess a considerable internal local relief. In this study, paleosurfaces were identified by the comparison of closed contour heights. Altimetric-frequency histograms were constructed for each topographic quadrangle in the research area, and summit height clusters cross-correlated across adjacent maps. These data were supplemented by analyses of the flattenings on river-valley spurs.

Results and Discussion

Five summit platforms were identified by examination of the altimetric-frequency histograms. Closed contour areas associated with each surface were then mapped (fig. 3). The highest of these was found between 1,360 and 1,370

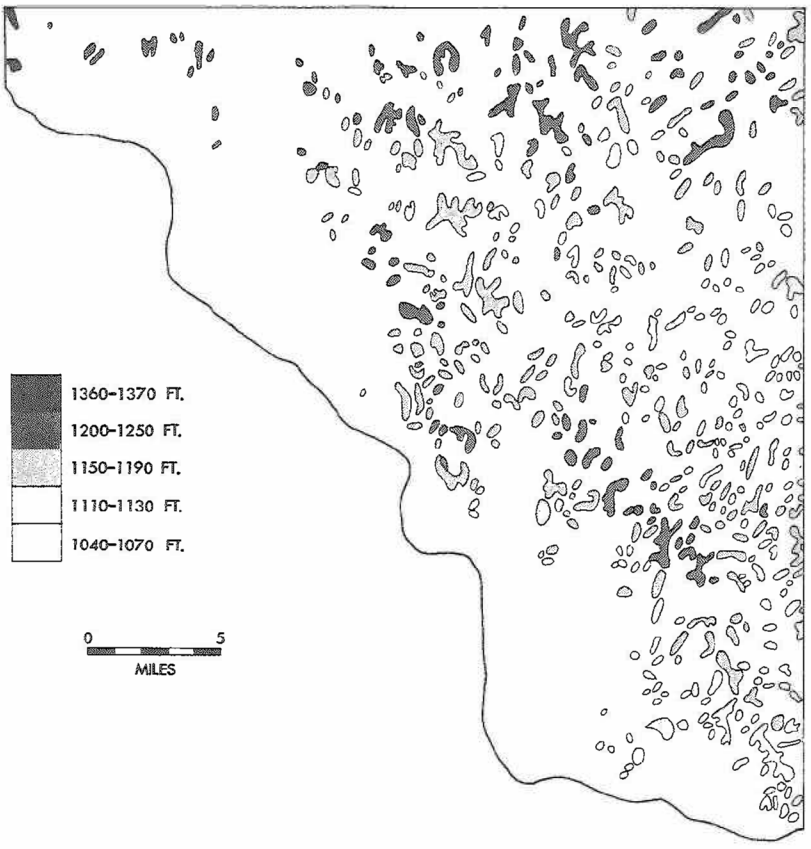


Figure 3. Paleosurface relics in Cleveland County, Oklahoma.

feet in the extreme northwestern part of the county. This surface is entirely associated with outcrops of the Duncan Sandstone and the Chickasha Formation, and the area is probably lithologically controlled. Two closely associated but probably distinct surfaces are discovered between 1,150 and 1,250 feet. The higher surface (1,200–1,250 feet) is closely associated with the Hennessey Shale outcrop but does not seem to be entirely lithologically controlled. The lower surface (1,150–1,190 feet), which is mainly found on its southern and valleyward fringe, is typically developed on Garber and Wellington sandstone units. The two lowest surfaces are quite distinct and are clearly associated with the incision of the entire river system. They are best developed in areas surrounding the Little River. The distribution of all these surfaces is generalized as figure 4.

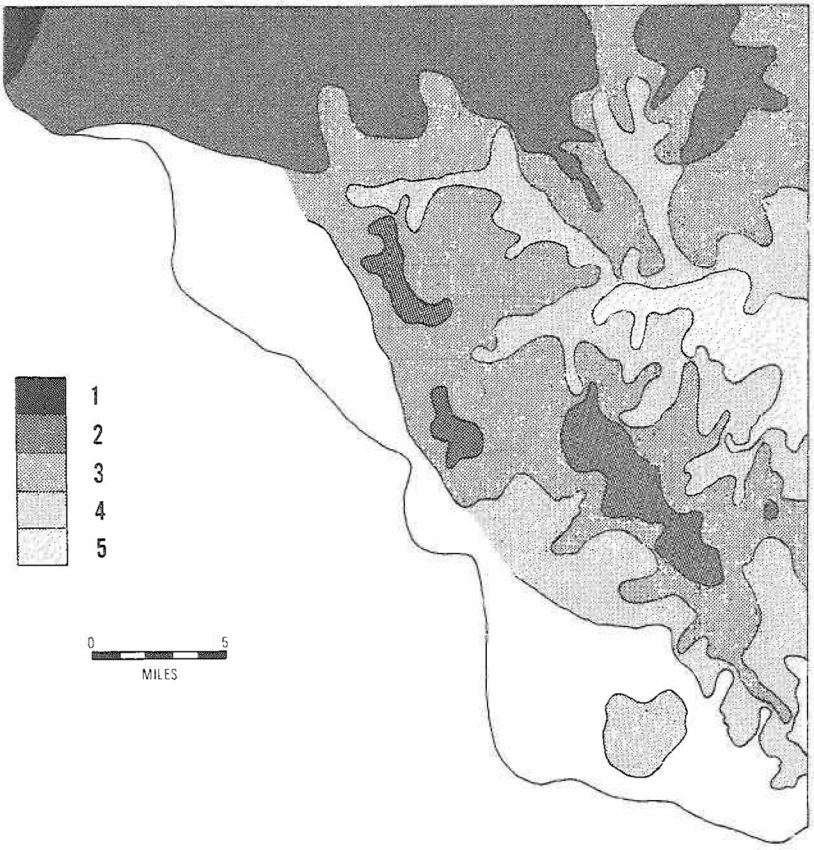


Figure 4. Generalized summary of distribution of paleosurface relics 1–5 (see fig. 3 for heights of paleosurfaces).

Denudation Chronology

The rivers of Oklahoma owe their present character to the uplift of the Rocky Mountains in late Tertiary and Early Cretaceous times. This uplift had three effects. First, it gave the entire State a southeastward tilt. Second, it caused a withdrawal of the sea beyond the margins of the State by the middle of the Tertiary Period. Third, it created a vast amount of sediment, which blanketed the central and western parts of the State in the late Tertiary (Johnson, 1971; Harris, 1970). Modern Oklahoma rivers, the Canadian included, formed on top of this aggradational Ogallala surface and carried its sediment. They were braided, bed-load streams liable to dramatic changes in course and, following the regional tilt, the adopted subparallel southeastward courses (Evans, 1955). It is suggested herein that the original drainage of Cleveland County was dendritic and southeastward draining, probably controlled by the grain of the Permian bedrock but certainly closely associated with drainage near the margins of the Ogallala aggradational surface. It is considered possible that Elm Creek, Hog Creek, Pond Creek, Buckhead Creek, and Willow Creek, together with the north forks of the Little River in Moore, may constitute relics of this original drainage pattern (Hendricks, 1937) that persisted into paleosurface 2 as shown in figure 4.

Subsequent evolution of Cleveland County's drainage has been conditioned by intrinsic differences between the character of the Canadian River and the autochthonous Little River. The Canadian River's channel is still a bed-load stream carrying a heavy sediment load derived from the Rocky Mountains. Its valley floor tells of multiple cycles of infilling associated with effects of Quaternary climatic fluctuation on the erosion of New Mexico. The stream carries too much sediment to be effective as an agency of incision. This situation, however, does not affect its tributaries; their small sediment loads are locally derived, and erosion is readily translated into incision. Kinematic waves of episodic incision, thus, are more readily transmitted upstream in local streams and much more readily translated into headward erosion. In figure 4, a far greater area of each paleosurface is associated with the Little River than with the Canadian, where an acceleration of erosion potential is more likely to be damped by sedimentation. This situation has several consequences. First, it gives a competitive advantage to the Canadian tributaries. Also, it gives a competitive advantage to downstream tributaries, which experience rejuvenation first and have a greater relief energy. The two processes have tended to cause the development of systems of parallel, trellis-like tributaries of which the Little River is a good example. They also tend to make the main channel vulnerable to capture by its own tributaries. In Cleveland County, it is inevitable that the Little River System will divert the Canadian in the same way that it has already diverted the Canadian's tributaries (fig. 5; also, see Hendricks, 1937). An ancient case of such a capture and main channel abandonment is illustrated by the disposition of the Gerty sands near Ada (Evans, 1955).

Acknowledgment

I would like to thank Mr. W. Shepherd, Mr. W. Shearer, and Mr. J. Hanner for their assistance in this project.

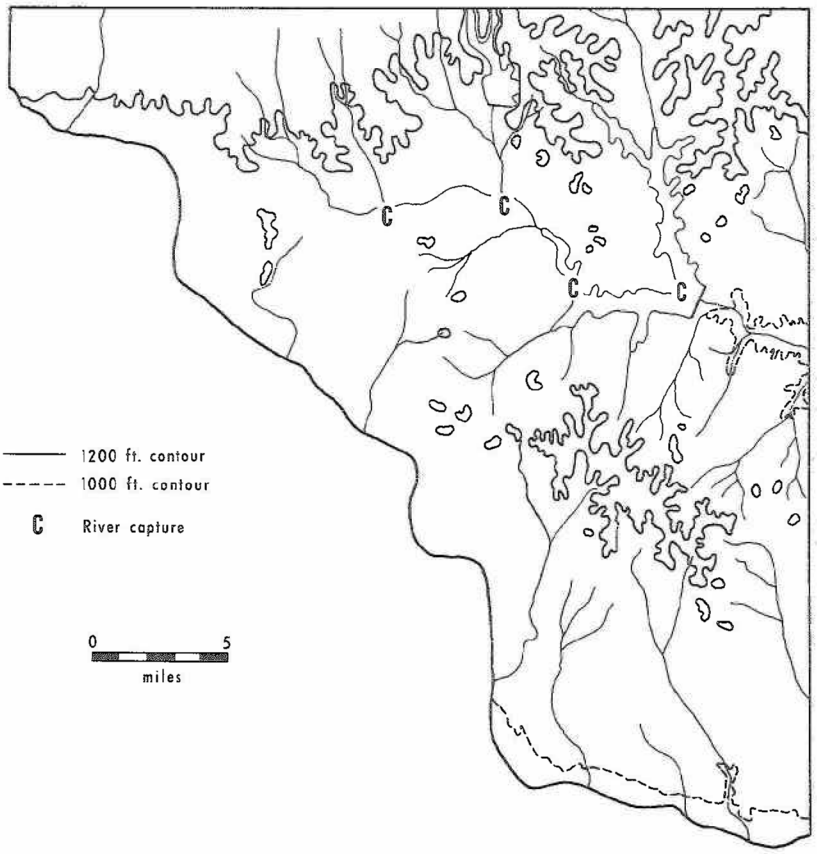


Figure 5. Map showing evolution of the Upper Little River basin, with contours.

References Cited

Badea, L., 1975, Apropos des surfaces d'aplanissement dans les Carpates roumaines: Studià Geomorphologica Carpatho-Balcanica 9, p. 17–26.

Brown, H. A., 1967, Structural control of Canadian River in western Oklahoma: Oklahoma Geology Notes, v. 27, p. 135–149.

Burton, L. C., and Jacobsen, C. L., 1967, Geologic map of Cleveland and Oklahoma Counties, Oklahoma: Oklahoma Geological Survey Circular 71, pl. 1, scale 1 inch = 1½ miles.

Cole, W. S., 1937, Development and structural control of erosion surfaces: Journal of Geology, v. 45, p. 141–157.

Evans, O. F., 1955, The rivers of Oklahoma, *in* Highway Geology of Oklahoma: Oklahoma City Geological Society, p. 8–10.

Fay, R. O., 1959, Pleistocene course of the South Canadian River in central western Oklahoma: Oklahoma Geology Notes, v. 19, p. 3–12.

GAVRILOVIC, D., 1975, State of research on the planation surfaces in the Carpatho-Balkan area of Yugoslavia: Studià Geomorphologica Carpatho-Balcanica, v. 9, p. 53–63.
GORELOV, S. K., DRENEV, N. V., MESCHCHERYAKOV, YU. A., TIKANOV, N. A., and FRIDLAND, V. M., 1970, Planation surfaces of the U.S.S.R. [In Russian]: Geomorfologiya, v. 1, p. 18–29.
HARRIS, S. A., 1970, Bends of the South Canadian: Shale Shaker, v. 20, p. 80–95.
HENDRICKS, T. A., 1937, History of the Canadian River of Oklahoma as indicated by Gerty sand: Geological Society of America Bulletin, v. 48, p. 365–372.
HOLLAND, W. N., and PICKUP, G., 1976, Flume study of knickpoint development in stratified sediment: Geological Society of America Bulletin, v. 87, p. 76–82.
JOHNSON, K. S., 1971, Introduction, guidelines, and geologic history of Oklahoma, *book 1 of* Guidebook for geologic field trips in Oklahoma: Oklahoma Geological Survey Educational Publication 2, 15 p.
KESSLER, L. G., 1970, Channel sequences and braided-stream development in South Canadian River, Hutchinson, Roberts, and Hemphill Counties, Texas [abstract]: American Association of Petroleum Geologists Bulletin, v. 54, p. 1786.
KING, C. A. M., 1966, Techniques in geomorphology: London, Arnold, p. 240–262.
KING, L. C., 1962, Morphology of the Earth: Edinburgh, Oliver and Boyd, 726 p.
——— 1976, Planation remnants upon high lands: Zeitschrift für Geomorphologie, v. 20, no. 2, p. 133–148.
MAROSI, S., 1972, Some questions of anthropogenic slope development: Acta Geographica Debrecina, v. 10, p. 133–143.
MAZUR, E., and CINURA, J., 1975, Planation surfaces in the western Carpathians [in Russian]: Studià Geomorphologica Carpatho-Balcanica, v. 9, p. 27–36.
MELHORN, W. N., and FLEMAL, R. C. (editors), 1976, Theories of landform development: New York State University at Binghamton Publications in Geomorphology, 300 p.
RUHE, R. V., 1975, Geomorphology: Boston, Houghton Mifflin, p. 125–149.
SCHUMM, S. A., 1976, Episodic erosion: a modification of the geomorphic cycle, *in* Flemal, R., and Melhorn, W. (editors), Theories of landform development: New York State University at Binghamton Publications in Geomorphology, p. 69–85.
WEAVER, O. D., JR., 1954, Geology and mineral resources of Hughes County, Oklahoma: Oklahoma Geological Survey Bulletin 70, 150 p.
WOMACK, W. R., and SCHUMM, S. A., 1977, Terraces of Douglas Creek, northwestern Colorado: an example of episodic erosion: Geology, v. 5, no. 2, p. 72–76.
WOOD, P. R., and BURTON, L. C., 1968, Ground-water resources in Cleveland and Oklahoma Counties, Oklahoma: Oklahoma Geological Survey Circular 71, 75 p.

New Thesis and Dissertation Added to OU Geology Library

The following Ph.D. dissertation has been added to The University of Oklahoma Geology and Geophysics Library:

The Magnetic Environment of Tektites, by Richard R. Donofrio.

The following M.S. thesis has also been added to the library:

Depositional History of the Basal Atoka Formation in Northeastern Oklahoma, as Interpreted from Primary Sedimentary Structures and Stratification Sequences, by Bradley Blake Jones.

Earth-Science Editors Meet in Ohio

Ohio State was invaded twice this fall by representatives of The University of Oklahoma. Still basking in the warmth of glowing reports about OU's football team, three Oklahoma Geological Survey staff members journeyed to Columbus to hear reports of a different sort. Bill Rose, OGS geologist-editor, and Rosemary Hardage and Betty Ham, OGS associate editors, attended the 10th anniversary meeting of the Association of Earth Science Editors.

Session topics ranged from basic typography and readability to the price of editorial excellence. Marty Edwards of Edwards Brothers, Inc. (a printing firm), presented advice on evaluating printing bids, and Jack Zanzig of Bergstrom Paper Co. presented the group with information, and admonitions, about paper availability and suitability. One session was devoted to a discussion of the Copyright Clearance Center, which has been established as a result of the new copyright law passed in 1976 and which goes into effect January 1, 1978.

Bill and Rosemary co-chaired a workshop for geological survey editors, along with Barbara Harris of the Missouri Geological Survey. Rosemary was elected to a 3-year term on the AESE Board of Directors and was named to serve on the association's program committee for the 1978 convention, which will be held in Butte, Montana, in September.

The Association of Earth Science Editors was founded in 1967 by 38 editors who gathered in Columbus at the American Chemical Society's Chemical Abstracts Service to discuss methods of improving publications that disseminate the results of geological investigations. In 10 years, the membership has grown to more than 200 persons from throughout the United States, Canada, and Mexico, plus several from overseas countries—but the goals of the group remain the same.

Persons interested in additional information about the association, which is a member society of the American Geological Institute, are welcome to contact the OGS editorial staff at the address on the front cover.

INDEX[1]
VOLUME 37, 1977

[1] Reference is to first page of article containing indexed item.

Mail Orders Accepted for USGS Open-File Reports

As of October 1, copies of most U.S. Geological Survey open-file reports can be purchased by mail from a centrally located facility at Denver, Colorado.

Previously, copies of USGS open-file reports were available for public inspection, or copies could be obtained at the purchaser's expense—not by mail—at designated survey libraries, public inquiries offices, or other facilities. Now they can be ordered from Open-File Services Section, Branch of Distribution, U.S. Geological Survey, Box 25425, Federal Center, Denver, Colorado 80225 (phone, 303—234-5888). Prepayment is required by checks or money orders payable to the USGS and in the exact amount. Orders should be placed by series and number (such as Open-File Report 77-123) and complete title.

The address given is for open-file reports only, not for other USGS publications.

OKLAHOMA GEOLOGY NOTES

Volume 37 December 1977 Number 6