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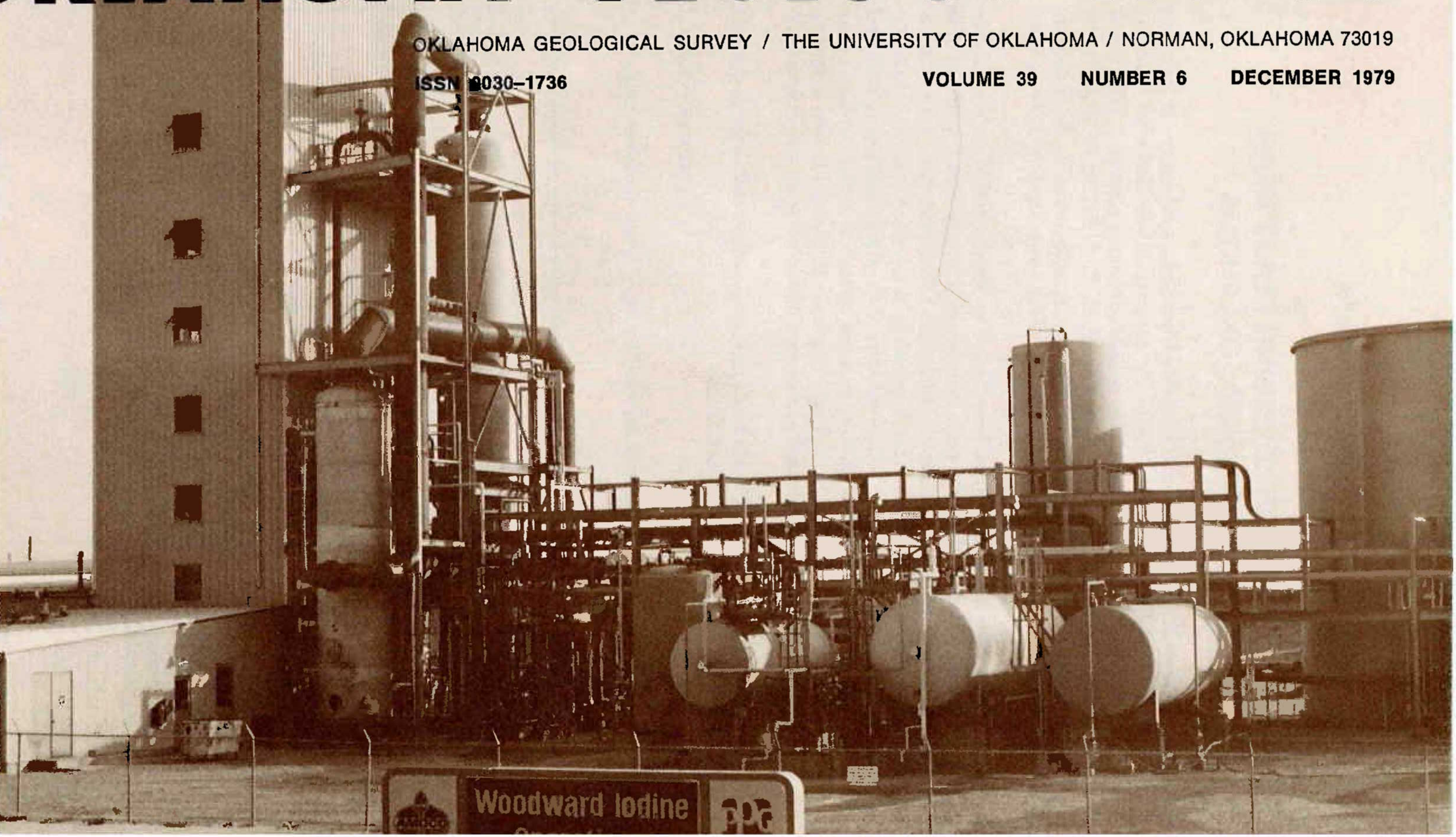

## *Cover Picture*

# IODINE PROCESSING PLANT NEAR WOODWARD, OKLAHOMA

Amoco Production Co. and Houston Chemicals, a subsidiary of Pittsburg Plate Glass (PPG) Industries, began the commercial production of iodine in northwestern Oklahoma in early 1977 at their processing plant near Woodward, Woodward County, Oklahoma (secs. 21 and 22, T. 24 N., R. 20 W.). Iodine-rich brines, with an average concentration of 300 ppm, occur in the Morrowan sandstones (basal Pennsylvanian) near Woodward at a depth of 7,200 to 7,400 feet.

Nine production wells have been drilled in Harper and Woodward Counties. Brine is pumped from the wells to a storage tank and then is pumped in to an oxidizing and stripping column, where the iodine-rich water is oxidized to create an iodine vapor. This vapor is passed in to a second column, where it is reduced and adsorbed in an iodine solution. This solution advances to a final recovery section, where it is oxidized to form crystalline iodine, which is purified and packaged for shipment. The spent brine is pumped to one of five injection wells, where it is returned to the same formation from which it is withdrawn.

This plant is capable of producing 2 million pounds of iodine per year, about one-fifth of the needs of the United States.

*—Kenneth V. Luza*

(Cover photograph courtesy of Howard M. Cotten, Amoco Production Co.)

Editorial staff: William D. Rose and 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, $1.00; 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.

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# OKLAHOMA GEOLOGICAL SURVEY ANNUAL REPORT

## July 1, 1978–June 30, 1979

### Introduction

Significant production of natural resources has been going on throughout Oklahoma's 72-year history of statehood and has contributed substantially to the State's economy, profoundly influencing the direction of growth. Actually, development of mineral resources began long before Oklahoma became a state.

Coal mining began in 1873 in the coal fields of what is now eastern Oklahoma, and by 1907, when Oklahoma Territory became the State of Oklahoma, almost 40 million tons of coal had been produced from more than 400 underground mines. With current annual production exceeding 5 million tons, this fuel resource continues to play a significant role.

Petroleum was first produced in 1897 with the completion of the Nellie Johnstone No. 1 on the banks of the Caney River in what is now northeastern Oklahoma. By 1907, a thriving petroleum industry existed in the State, with an estimated annual production of about 50 million barrels. Since the first discovery well, more than 300,000 wells have been drilled in Oklahoma, with a recovery of more than 13 billion barrels of petroleum and slightly more than 43.6 trillion cubic feet of marketed natural gas.

Production of lead and zinc also preceded statehood, through the opening of a mine in the Peoria district of Ottawa County in 1891, and Oklahoma became a major producer of these metals. Although no mining of lead and zinc is being done in the State at present, the possibility of future production cannot be discounted. The only other metallic mineral recovered in the State in any substantial quantity has been copper, which had a brief production history in southwestern Oklahoma in the late 1960's and early 1970's. This metal also has potential for the future.

Gypsum, clays, limestone, sand and gravel, and granite, which were also produced before statehood, have been important to the State's economy. These and other industrial minerals have an annual production value of almost $150 million.

The present annual value of all minerals produced in the State has reached a record of more than $3.5 billion. Petroleum and natural gas contribute more than $3.2 billion to this total, with values approximately equal for each fossil fuel.

It is obvious from this background that Oklahoma is a mineral- and energy-producing state with many natural resources contributing to various facets of its overall economy.

An important charge of the Survey has been to provide fundamental geological and mineral-resources information to assist in the further orderly development of the State's natural resources. Activities in support of this mission, as well as the other responsibilities of the Survey, are described in this annual report.

## Energy-Resources Studies

Studies conducted by Survey staff that are especially pertinent to petroleum include the completion of investigations of the Hunton strata in the Arkoma Basin by T. W. Amsden, completion of work on heavy-oil occurrences in northeastern Oklahoma by W. E. Harrison, continuation of source-rock and petroleum-maturation studies by W. E. Harrison and J. A. Curiale, and the annual compilation of petroleum statistical information on Oklahoma. The Hunton study is being processed for publication and will be issued in early 1980. The heavy-oil study has been released as U.S. Department of Energy (DOE) Open-File Report BETC/1812-1. The annual statistical data have been published in the December 1978 issue of *Oklahoma Geology Notes* (v. 38, p. 225–233).

The vacancy created by the death of J. F. Roberts will be filled in the fall of 1979 [this position has now been filled by D. A. Preston, formerly with Shell Development Co.], and another position in petroleum geology will be filled during the 1980 fiscal year. The increase in number of personnel devoted to petroleum-related studies, together with an expansion of research facilities in this area, will improve further the Survey's ability to meet its charter obligation.

Coal investigations continue to occupy the talents of S. A. Friedman and LeRoy Hemish. These investigations include field work in Craig, Nowata, Mayes, and Rogers Counties; preparing detailed maps for county coal reports; collecting information on all active mines during 1977–79 for an update of the active coal-mine map; and completion of a study of the Hartshorne coals in Haskell and Le Flore Counties. In addition, a significant amount of staff time is devoted to responding to the multitude of inquiries for information on the eastern Oklahoma coal fields. This is handled primarily by S. A. Friedman.

Uranium investigations in west-central and north-central Oklahoma are being conducted by Salman Bloch, with staff support from R. L. Eutsler and J. J. Myers. These investigations are funded by a contract with Bendix Field Engineering Corp. under the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program. K. S. Johnson is serving as project director for the effort, which includes an assessment of the uranium-resources potential of the Clinton and Enid $1^\circ \times 2^\circ$ quadrangles. The project will be completed in the spring of 1980.

## Mineral Investigations

An inventory of all past and present surface-mining activity, exclusive of coal, is continuing. This effort, funded in part by the U.S. Geological Survey, is being conducted by K. S. Johnson, with assistance on aerial-photo interpretation from A. J. Myers and field-data collection by P. A. Eidson and several part-time student assistants. The project will be completed in the spring of 1980.

A study of all active mines in the western half of the State has been initiated, with partial funding from the U.S. Bureau of Mines as a part of its Mine Inventory Locater System (MILS). The data collected will be incorporated in the USBM national data base and will be available in a machine-retrievable fashion. K. S. Johnson is supervising this project, with assistance from A. J. Myers.

A map compilation of information on the Southwest Davis Zinc Field in the Arbuckle Mountains has been completed by R. O. Fay. Compilation of information on copper anomalies in the State, also by R. O. Fay, is continuing.

Several specific investigations of various mineral deposits have been conducted during this past fiscal year in response to specific requests. These investigations have included examination of sand and gravel, clay and shale, limestone, gypsum, and glass-sand deposits. Numerous requests for information on metallic- and industrial-mineral production, occurrences, and potential were handled by several Survey staff members. The anticipated addition of another staff member in the industrial-minerals field in the 1980 fiscal year will provide some much-needed assistance in this area.

## Environmental and Engineering Studies

The Survey assumed responsibility for the operation of the Oklahoma Geophysical Observatory at Leonard, near Tulsa (formerly The University of Oklahoma Earth Sciences Observatory), in July 1978. Since that time a number of changes have been made in its facilities and operating procedures that have increased its scientific value to the State and its visibility to the nation. An array of seismometers has been located around the State to detect and locate seismic activity in the region. A map depicting the locations of all historical earthquakes in Oklahoma through 1978 has been published. It is anticipated that this map will be periodically updated with the locations of all recently recorded earthquakes. Plans are being formulated with the U.S. Geological Survey to establish a geomagnetic station at the Observatory. If approved, the USGS would provide the geomagnetic equipment, and the Observatory would provide the operational support.

We anticipate that plans will be completed and construction will begin on a 900-square-foot addition to the Observatory building in the coming fiscal year. This proposed expansion will provide needed space for record storage and examination, instrument maintenance and repair, and related research activities.

The Observatory is operated by a four-person staff, with J. E. Lawson, Jr., serving as chief geophysicist and P. H. Foster as laboratory supervisor. K. V. Luza serves as the Survey's liaison for the Observatory, and, in his capacity as project director of a 5-year study of the seismicity and tectonic framework of north-central Oklahoma, he is able to ensure proper coordination of Survey and project support for the facility. The project is funded in part by the U.S. Nuclear Regulatory Commission.

Studies of coal-mined lands and related reclamation activities are continuing under K. S. Johnson and S. A. Friedman. These efforts support important information needs of the U.S. Department of the Interior, Office of Surface Mining; the Oklahoma Department of Mines; and the Oklahoma Conservation Commission. Several new projects in this area will be undertaken next year.

## Stratigraphy and Geologic Mapping

Fundamental to any mineral- or energy-resource assessment, or to any environmental evaluation, is the availability of good geologic maps and an understanding of the stratigraphic relationships of rocks in the area under investigation. The Survey continues to support a large number of projects directed toward these objectives. During the past year, geologic maps and reports on Bryan County, prepared by G. G. Huffman and others, and on Custer County, by R. O. Fay and D. L. Hart, Jr., were published.

The preparation of geologic reports of Alfalfa County, by K. S. Johnson, Marshall County, by G. G. Huffman, and Washita County, by K. S. Johnson, is continuing. It is anticipated that work on Marshall County will be completed in the next fiscal year, with publication scheduled during 1981. The completion of these three will bring to 27 the number of such county reports.

The Survey is participating in the program sponsored by The American Association of Petroleum Geologists to put together stratigraphic-correlation charts for each sedimentary basin in the United States. This program, known as the Committee on Stratigraphic Units of North America (COSUNA), involves the Director, C. J. Mankin, as a regional coordinator, R. O. Fay as principal compiler, and several other Survey staff members and faculty of the OU School of Geology and Geophysics as advisors. Geologists with the Arkansas Geological Commission and the Texas Bureau of Economic Geology will also participate by covering parts of their states included in the region. Drafts of the correlation charts are anticipated for review early in 1980.

Comprehensive geologic investigations have been carried out on upper Paleozoic strata in northeastern Oklahoma over the past several years. Results of some of these efforts were published as OGS Guidebook 19 on the *Mississippian-Pennsylvanian Shelf-to-Basin Transition, Ozark and Ouachita Regions, Oklahoma and Arkansas*, P. K. Sutherland and W. L. Manger, editors. This guidebook was produced for one of the field trips held in conjunction with the Ninth International Congress of Carboniferous Stratigraphy and Geology, which convened in Urbana, Illinois, in May 1979.

A program of geologic mapping of the Wichita Mountains in southwestern Oklahoma is continuing under M. C. Gilbert. The results of this effort will be issued as a two-panel map covering the mountains, with a related explanatory text. Field work on the first of these panels will be completed in the summer of 1980. Related studies include the petrology and geochemistry of several of the igneous rock units. These studies are being conducted by several investigators from The University of Texas at Arlington, Rice University, and Virginia Polytechnic Institute and State University, with partial Survey support for several of these efforts.

The Survey is also continuing its program of support for field-mapping studies by graduate students at several universities. The theses and dissertations produced through this program are placed on open-file status in the Survey's office.

### Cooperative Water-Resources Investigations

A program of water-resources investigations in cooperation with the U.S. Geological Survey has been under way for many years. That program has focused on a regional assessment of the State's ground-water resources in terms of availability, quality, and general-use patterns. In addition, this regional assessment has identified several areas that warrant more detailed investigations: specific aquifers that are currently undergoing further investigations include the Antlers Sandstone, the Arbuckle Limestone in the Arbuckle Mountains, and the Vamoosa aquifer. The program is also examining baseline water quality in the coal fields of eastern Oklahoma.

These cooperative water studies will provide important basic information on the State's ground-water resources and will also enable the determination of any deterioration in water quality resulting from coal-mining activities.

### Public Information and Assistance

A charter responsibility of the Survey is to serve the public's needs in the area of information on mineral resources. This responsibility is fulfilled through a variety of activities designed to disseminate both technical and general information on the State's natural resources and to advise individuals, companies, organizations, and governmental officials on the wise use of these resources.

The Survey maintains a core and sample repository, where rock materials obtained during exploratory drilling for oil and gas are filed. These materials are important in developing a better understanding of the subsurface geology of our State. The facility, operated by E. R. Cox, assisted by G. L. Wullich, contains core samples from 1,851 wells plus a large quantity of well cuttings. Public use of the library is increasing as interest in exploratory drilling for oil and gas intensifies.

Examination of rock and mineral specimens at public request continues to be an important function of the analytical-chemistry section. S. J. Weber, R. M. Powell, and the staff are responsible for providing analytical information on samples submitted by the public from their property. Although this activity occupies only a small part of the time of the analytical-chemistry section, it is viewed as an important public service.

Response to public inquiries concerning mineral resources in the State seems to be ever increasing. Requests range from questions about interesting mineral, rock, and fossil localities for the amateur collector to questions on coal thickness and quality in a particular part of the eastern Oklahoma coal fields. Approximately one-fourth of the time available to the staff is devoted to responding to this array of natural-resources questions.

In an effort to respond more effectively to many of these and other public needs for earth-science information, the Survey has developed several publication series. These range from technical bulletins, circulars, geologic maps, hydrologic atlases, and geologic guidebooks to general and educational publications designed for public-school students and the general public. The preparation and publication of these materials are accomplished by the cartographic-drafting section and the editorial section. (The staff members of these two sections are listed in Appendix A of this report.)

Finally, dissemination of the Survey's publications and operation of the organization are the responsibility of a dedicated staff without which the organization would fail to function. These individuals are also identified in Appendix A.

## Related Professional Activities

The activities of the staff in a wide array of professional, technical, and civic activities provide a further dimension to the public-service function of the Survey. Unfortunately, space does not permit a detailed account of the many presentations made at local, regional, national, and international meetings. Nor is it possible to list the many committees on which different staff members serve. A few examples of these activities are listed in the following appendixes. It should be noted, however, that the mere fact that the staff are so involved is a clear indication of their professional stature and dedication. It is a record of accomplishment for which the State can be justifiably proud.

### Summary

The many activities of the staff of the Survey could not be pursued effectively without a sense of unity and a spirit of cooperation. Further, many of the programs resulting from these activities are successful because of a close relationship with other State agencies, federal counterpart organizations, and numerous scientific and professional societies. To the many organizations and individuals who have contributed much to the success of the Survey, we extend a heartfelt expression of appreciation.

—CHARLES J. MANKIN, *Director*

## APPENDIX A

### Survey Staff, 1978–79 Fiscal Year

**Professional**

Thomas W. Amsden
Salman Bloch[1]
Robert O. Fay
David A. Foster[2]
Paul H. Foster
S. A. Friedman
Elizabeth A. Ham
William E. Harrison
LeRoy A. Hemish
Kenneth S. Johnson
James E. Lawson, Jr.
Kenneth V. Luza
Charles J. Mankin
John F. Roberts[3]
William D. Rose
Judy A. Russell[4]
Stephen J. Weber[5]

**Part-Time Professional**

George G. Huffman
(The University of Oklahoma)
John D. Naff
(Oklahoma State University)
Patrick K. Sutherland
(The University of Oklahoma)

**Temporary Professional**

Robert L. Eutsler (Minerals Geologist) (May 79–Feb. 80)
James J. Myers (Minerals Geologist) (Jan. 79–Feb. 80)

**Technical**

*Cartographic*

Marion E. Clark
Roy D. Davis
Kelly D. Hilburn[6]
Mary Ellen Kanak
Joseph M. Zovak

*Core and Sample Library*

Eldon R. Cox
Gary L. Wullich

*Geological Technician*

Robert D. Wingate[7]
David O. Pennington[8]

*Senior Laboratory Technician*

Robert M. Powell

*Maintenance*

Ron E. Evans[9]

*Secretarial*

Betty D. Bellis
Helen D. Brown
Margarett K. Civis
Laveda F. Hensley
Paula A. Hewitt
Shirley Jackson
Mitzi G. Moore
I. Jean Smith
Gwen C. Williamson

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[1] Appointed October 78.
[2] Transferred to IPE Assignment, OU Grants and Contracts.
[3] Deceased November 78.
[4] Resigned May 79.
[5] Appointed September 78.
[6] Resigned June 79.
[7] Retired January 79.
[8] Changed to Geologic Technician January 79.
[9] Appointed February 79.

## APPENDIX B

### List of Survey Publications Issued, 1978–79 Fiscal Year

#### New Publications

Bulletin 114.—*Geology and Mineral Resources (Exclusive of Petroleum) of Custer County, Oklahoma*, by Robert O. Fay and D. L. Hart, Jr. 88 pages, 53 figures, 3 plates, 4 tables. Issued June 1979.

Bulletin 125.—*Articulate Brachiopods of the Quarry Mountain Formation (Silurian), Eastern Oklahoma*, by Thomas W. Amsden. 75 pages, 22 figures, 13 plates, 2 tables. Issued October 1978.

Bulletin 126.—*Geology and Mineral Resources of Bryan County, Oklahoma*, by George G. Huffman, Thomas A. Hart, Laurence J. Olson, John D. Currier, and Robert W. Ganser. 113 pages, 49 figures, 1 plate, 11 tables. Issued April 1979.

Circular 79.—*Proceedings of Thirteenth Annual Forum on Geology of Industrial Minerals*, Kenneth S. Johnson and Judy A. Russell, editors. 107 pages, 14 papers, 2 abstracts, 63 figures, 54 tables. Issued February 1979.

Guidebook 19.—*Mississippian-Pennsylvanian Shelf-to-Basin Transition, Ozark and Ouachita Regions, Oklahoma and Arkansas*, Patrick K. Sutherland and Walter L. Manger, editors. 72 pages, 116 figures. Issued April 1979.

Map GM-19.—*Earthquake Map of Oklahoma* (with accompanying text), by James E. Lawson, Jr., Kenneth V. Luza, Robert L. DuBois, and Paul H. Foster. 15 pages, 4 figures, 2 tables. Map scale 1:750,000. Issued June 1979.

*List of Available Publications*.—20 pages. Issued May 1979.

*List of Publications of Oklahoma Geological Survey, 1902–1978*, compiled by Elizabeth A. Ham and Claren M. Kidd.—75 pages. Issued June 1979.

*Oklahoma Geology Notes*.—Six bimonthly issues (August 1978–June 1979) containing 260 pages.

#### Publications Reprinted

Bulletin 67.—*Geology and Mineral Resources of Haskell County, Oklahoma*, by Malcolm C. Oakes and M. M. Knechtel. 136 pages, 8 figures, 5 tables. Issued 1948; fifth printing, February 1979.

Bulletin 68.—*Geology and Coal and Natural Gas Resources of Northern Le Flore County, Oklahoma*, by M. M. Knechtel. 76 pages, 1 figure, 3 tables. Issued 1949; fourth printing, January 1979.

Circular 24.—*Broken Arrow Coal and Associated Strata*, by Malcolm C. Oakes. 40 pages, 2 plates. Issued 1944; second printing, February 1979.

Guidebook 15.—*Guide to Alabaster Cavern and Woodward County, Oklahoma*, by Arthur J. Myers, Arrell M. Gibson, Bryan P. Glass, and Carol R. Patrick. 38 pages, 41 figures. Issued 1969; fourth printing, April 1979.

Guidebook for 1973 Annual GSA Meeting.—*Regional Geology of the Arbuckle Mountains, Oklahoma*, by William E. Ham, compiled by T. L. Rowland, with contributions by Thomas W. Amsden, Rodger E. Denison, James R. Derby, Robert O. Fay, A. Allen Graffham, T. L. Rowland, Richard L. Squires, James H. Stitt, and Elliott W. Wiltse. Prepared originally as a guidebook for

GSA field trip no. 5, reprinted for AAPG field trip no. 1, 1978 annual meeting. 61 pages, 54 figures, 1 map. Issued 1973; fourth printing, February 1979.

Mineral Report 3.—*Glass Sands*, compiled by Charles M. Gould and J. O. Beach. 21 pages, 1 map. Issued 1939; third printing, March 1979.

Mineral Report 13.—*Mineral Production of Oklahoma 1885–1940*, compiled by J. O. Beach. 38 pages, 9 figures. Issued 1942; third printing, January 1979.

Mineral Report 14.—*The Possibility of Magnesia from Oklahoma Oil Field Brines*, by A. L. Burwell. 26 pages, 1 plate, 6 tables. Issued 1942; third printing, March 1979.

Mineral Report 23.—*Oil Possibilities near Idabel, McCurtain County, Oklahoma*, by Leon V. Davis. 26 pages, 3 figures, 1 map, 2 tables. Issued 1953; third printing, March 1979.

Mineral Report 25.—*Mineral Industry of Oklahoma in 1952*, by F. F. Netzeband, W. E. Ham, and J. H. Warren. 26 pages, 7 tables. Issued 1954; third printing, March 1979.

## APPENDIX C

### Publications by Survey Staff, 1978–79 Fiscal Year

Thomas W. Amsden

Articulate brachiopods of the Quarry Mountain Formation (Silurian), eastern Oklahoma: Oklahoma Geological Survey Bulletin 125, 75 p. 1978.

Late Ordovician-Early Silurian strata in Mid-Continent area [abstract]: American Association of Petroleum Geologists Bulletin, v. 63, p. 410. (Reprinted in Oklahoma Geology Notes, v. 39, p. 103.) 1979.

Salman Bloch

The effect of low temperature alteration of basalt on the oceanic budget of potassium: Geology, v. 7, p. 193–196 (with J. L. Bischoff). 1979.

Metalliferous sediments on mid-ocean ridges: origin, classification and geochemical implications: Przeglad Geologiczny (Warsaw), v. 26, p. 465–470 (Polish with English abstract). 1978.

Phosphorus distribution in smectite-bearing basal metalliferous sediments: Chemical Geology, v. 22, p. 353–359. 1978.

Robert O. Fay

Geology and mineral resources (exclusive of petroleum) of Custer County, Oklahoma: Oklahoma Geological Survey Bulletin 114, 88 p. (with D. L. Hart). 1978.

Order Coronata Jaekel, 1918, *in* Moore, R. C., and Teichert, Curt, editors, Echinodermata 2, *pt. T of* Treatise on invertebrate paleontology: University of Kansas and Geological Society of America, v. 2, p. T574–T578, figs. 367–370. 1978.

PAUL H. FOSTER

Earthquake map of Oklahoma (with accompanying text): Oklahoma Geological Survey Map GM-19, with 15-p. text. Map scale 1:750,000. (With James E. Lawson, Jr., Robert L. DuBois, and Kenneth V. Luza.) 1979.

S. A. FRIEDMAN

Basic characteristics of coal reserves, *in* Campbell, J. M., and others, editors, Energy sources and systems, *v. 2 of* Mineral property economics: Campbell Petroleum Series, p. 32–61, 86–87. 1978.

Coal geology: The Coal Geologist (Geological Society of America, Coal Geology Division Newsletter), v. 5, no. 2, 2 p. 1978.

Coal geology: Geotimes, v. 24, p. 26–27. 1979.

Field description and characterization of coals sampled by the Oklahoma Geological Survey, 1971–1976, *in* Dutcher, R. R., editor, Field description of coal: American Society for Testing and Materials Special Technical Publication 661, p. 58–63. 1978.

ELIZABETH A. HAM

Bibliography and index of Oklahoma geology, 1977: Oklahoma Geology Notes, v. 38, p. 119–168. 1978.

John Fredrick Roberts (1911–1978): Oklahoma Geology Notes, v. 39, p. 28–30. 1979.

List of publications of Oklahoma Geological Survey, 1902–1978: Oklahoma Geological Survey, 75 p. (with Claren M. Kidd). 1979.

Oklahoma City Field passes half century mark: Oklahoma Geology Notes, v. 38, p. 234–236. 1978.

Oklahoma Geology Notes: Oklahoma Geological Survey, v. 38, nos. 4–6, v. 39, nos. 1–3, 257 p. (editor, with William D. Rose and Judy A. Russell). 1978–79.

USGS: the first hundred years: Oklahoma Geology Notes, v. 39, p. 63–67. 1979.

WILLIAM E. HARRISON

Evaluation of heavy-oil potential of northeastern Craig and northwestern Ottawa Counties, Oklahoma: prepared for U.S. Department of Energy, BETC/1812-1, 46 p. 1979.

Graphitization of kerogen as a potentially useful method of assessing temperatures, *in* Scholle, P. A., and Schluger, P. R., editors, Aspects of diagenesis: Society of Economic Paleontologists and Mineralogists Special Publication 26, p. 45–53. 1979.

Statistics of Oklahoma's petroleum industry, 1977: Oklahoma Geology Notes, v. 38, p. 225–233. 1978.

LeRoy A. Hemish

Geology and geohydrology of the Knife River Basin and adjacent areas of west-central North Dakota: North Dakota Geological Survey Report of Investigations 64, 402 p. (with Gerald H. Groenewold, John A. Cherry, Bernd W. Rehm, Gary N. Meyer, and Laramie M. Winczewski). 1979.

Oklahoma hosts coal forum: Oklahoma Geology Notes, v. 39, p. 61–62. 1979.

Kenneth S. Johnson

Gypsum resources of Permian Basin [abstract]: Mining Engineering, v. 31. 1979.

Major gypsum districts of western Oklahoma, *in* Johnson, K. S., and Russell, J. A., editors, Thirteenth annual forum on the geology of industrial minerals: Oklahoma Geological Survey Circular 79, p. 6–14. 1979.

Potential for subsurface disposal of industrial wastes in Oklahoma [abstract]: American Association of Petroleum Geologists Bulletin, v. 63, p. 475 (with John F. Roberts). (Reprinted in Oklahoma Geology Notes, v. 39, p. 104–105.) 1979.

Proceedings of Thirteenth Annual Forum on Geology of Industrial Minerals: Oklahoma Geological Survey Circular 79, 107 p. (editor, with Judy A. Russell). 1979.

Regional assessment of United States salt-bearing basins for disposal of radioactive wastes [abstract]: Geological Society of America Abstracts with Programs, v. 11, p. 15 (with Serge Gonzales).

Regional geologic characteristics important for storage of radioactive waste in salt deposits of United States [abstract]: Geological Society of America Abstracts with Programs, v. 10, p. 429 (with Serge Gonzales and T. F. Lomenick). 1978.

Regional studies for assessing favorability of rock units for disposal of industrial wastes [abstract]: Association of Engineering Geologists Annual Meeting Program and Abstracts, p. 26–27 (with Kenneth V. Luza). 1978.

Stratigraphy and mineral resources of Guadalupian and Ochoan rocks of the Texas Panhandle and western Oklahoma, *in* Austin, G. S., compiler, Geology and mineral deposits of Ochoan rocks in Delaware Basin and adjacent areas: New Mexico Bureau of Mines and Mineral Resources Circular 159, p. 57–62. 1978.

James E. Lawson, Jr.

Earthquake map of Oklahoma (with accompanying text): Oklahoma Geological Survey Map GM-19, with 15-p. text. Map scale 1:750,000. (With Robert L. DuBois, Paul H. Foster, and Kenneth V. Luza.) 1979.

Oklahoma earthquakes, 1978: Oklahoma Geology Notes, v. 39, p. 83–90 (with Kenneth V. Luza). 1979.

Operation of a statewide seismic network without telemetry costs: American Geophysical Union, 1978 Midwest Meeting Abstracts, p. 11. 1978.

Seismicity and tectonic relationships of the Nemaha Uplift in Oklahoma, Part II: prepared for U.S. Nuclear Regulatory Commission, NUREG/CR-0875, 82 p. )with Kenneth V. Luza). 1979.

Kenneth V. Luza

Earthquake map of Oklahoma (with accompanying text): Oklahoma Geological Survey Map GM-19, with 15-p. text. Map scale 1:750,000. (With James E. Lawson, Jr., Robert L. DuBois, and Paul H. Foster.) 1979.

Granite quarry, Johnston County, Oklahoma: Oklahoma Geology Notes, v. 39, p. 82 (cover-photo description). 1979.

Oklahoma earthquakes, 1978: Oklahoma Geology Notes, v. 39, p. 83–90 (with James E. Lawson, Jr.). 1979.

Regional studies for assessing general favorability of rock units for disposal of industrial wastes [abstract]: Association of Engineering Geologists Annual Meeting Program and Abstracts, p. 26–27 (with Kenneth S. Johnson). 1978.

Sand and gravel processing plant, Canadian River, near Noble: Oklahoma Geology Notes, v. 39, p. 2 (cover-photo description). 1979.

Seismicity and tectonic relationships of the Nemaha Uplift in Oklahoma, Part II: prepared for U.S. Nuclear Regulatory Commission, NUREG/CR-0875, 82 p. (with James E. Lawson, Jr.). 1979.

Water-quality-management planning in Oklahoma: Oklahoma Geology Notes, v. 39, p. 51–57. 1979.

Charles J. Mankin

Gas resources and reserves: Environment, v. 21, no. 1, p. 25. 1979.

Oklahoma Geological Survey annual report, July 1, 1977–June 30, 1978: Oklahoma Geology Notes, v. 38, p. 207–221. 1978.

John F. Roberts

Potential for subsurface disposal of industrial wastes in Oklahoma [abstract]: American Association of Petroleum Geologists Bulletin, v. 63, p. 475 (with Kenneth S. Johnson). (Reprinted in Oklahoma Geology Notes, v. 39, p. 104–105.) 1979.

William D. Rose

It's AIPG once again, members told at Oklahoma Section meeting: Oklahoma Geology Notes, v. 39, p. 100–101. 1979.

Oklahoma APGS members meet in Oklahoma City: Oklahoma Geology Notes, v. 38, p. 242–243. 1978.

Oklahoma Geology Notes: Oklahoma Geological Survey, v. 38, nos. 4–6, v. 39, nos. 1–3, 257 p. (editor, with Elizabeth A. Ham and Judy A. Russell). 1978–79.

Volume issued on petroleum exploration: Oklahoma Geology Notes, v. 38, p. 236–237. 1978.

JUDY A. RUSSELL

Dutton's 1882 report on the Grand Canyon: Oklahoma Geology Notes, v. 39, p. 50 (cover-photo description). 1979.

Oklahoma Geology Notes: Oklahoma Geological Survey, v. 38, nos. 4–6, v. 39, nos. 1–3, 257 p. (editor, with Elizabeth A. Ham and William D. Rose). 1978–79.

Proceedings of Thirteenth Annual Forum on Geology of Industrial Minerals: Oklahoma Geological Survey Circular 79, 107 p. (editor, with Kenneth S. Johnson). 1979.

## APPENDIX D

### Papers and Talks Given by Survey Staff at Public Meetings 1978–79 Fiscal Year

Bachelor of Liberal Studies Program, Oklahoma Center for Continuing Education

Norman, Oklahoma, July 20, 1978

KENNETH S. JOHNSON

Strip mining and land reclamation

Energy resources of Colorado Plateau

Annual Industrial Development Institute Workshop

Norman, Oklahoma, August 7–10, 1978

CHARLES J. MANKIN

Energy resources—alternatives and trends

Oklahoma City Geological Society, Discussion Group

Oklahoma City, Oklahoma, September 12, 1978

KENNETH V. LUZA

Regional seismic and geologic studies of the Nemaha Uplift

"Open Line," a KNOR Radio Program

Norman, Oklahoma, September 12, 1978

CHARLES J. MANKIN

Energy and the creation of the Energy Resources Center at OU

University Business Assistance Center, Advisory Board Meeting
Oklahoma City, Oklahoma, September 26, 1978

KENNETH V. LUZA
Surface disposal of industrial wastes in Oklahoma

Lions Club Luncheon
Purcell, Oklahoma, September 26, 1978

CHARLES J. MANKIN
Mineral and energy resources of Oklahoma

St. Lukes United Methodist Church Luncheon
Oklahoma City, Oklahoma, September 29, 1978

CHARLES J. MANKIN
Role of the Oklahoma Geological Survey in the development of the State's mineral and energy resources

Sigma Xi Chapter Meeting
Butte, Montana, October 2, 1978

KENNETH V. LUZA
Geology and seismic history of the Nemaha Uplift

University of Oklahoma, Gamma Chapter Meeting of Sigma Gamma Epsilon
Norman, Oklahoma, October 17, 1978

CHARLES J. MANKIN
The myth of alternate energy resources

Association of Engineering Geologists, Annual Meeting
Hershey, Pennsylvania, October 18, 1978

KENNETH V. LUZA and KENNETH S. JOHNSON
Regional studies for assessing general favorability of rock units for disposal of industrial wastes

Association of Professional Geological Scientists—Oklahoma Section, Annual Meeting
Midwest City, Oklahoma, October 21, 1978

KENNETH S. JOHNSON
Summary of geologic studies by government agencies in Oklahoma

Geological Society of America, Annual Meeting
Toronto, Ontario, Canada, October 23, 1978

KENNETH S. JOHNSON
Regional geologic characteristics important for storage of radioactive waste in salt deposits of United States (with Serge Gonzales and T. F. Lomenick)

Big Eight Business Managers Luncheon
Norman, Oklahoma, October 30, 1978

CHARLES J. MANKIN
The nation's energy future

Oklahoma State University, Department of Geology Colloquium
Stillwater, Oklahoma, November 16, 1978

KENNETH S. JOHNSON
Energy resources of northern Colorado Plateau

Custer County Mineral Owners Association
Clinton, Oklahoma, November 16, 1978

CHARLES J. MANKIN
Mineral and energy resources of Oklahoma

Intercollegiate Legislature Energy Seminar
Oklahoma City, Oklahoma, January 13, 1979

CHARLES J. MANKIN
Role of oil and gas in Oklahoma

Oklahoma Electric Cooperative Meeting
Norman, Oklahoma, February 15, 1979

S. A. FRIEDMAN
Coal resources in Oklahoma

American Institute of Mining, Metallurgical, and Petroleum Engineers, Annual Meeting
New Orleans, Louisiana, February 20, 1979

KENNETH S. JOHNSON
Gypsum resources of the Permian Basin

Banner School 4-H Meeting
Canadian County, Oklahoma, February 23, 1979

LEROY A. HEMISH
Petroleum geology

University of Oklahoma, Gamma Chapter Meeting of Sigma Gamma Epsilon
Norman, Oklahoma, February 27, 1979

SALMAN BLOCH
Some factors controlling the steady-state of the ocean

Forum of Western Interior Coal Geologists, Third Annual Meeting
Norman, Oklahoma, February 28–March 1, 1979

S. A. Friedman
Progress of the coal-investigations program at the Oklahoma Geological Survey

LeRoy A. Hemish
Progress of the coal-geology study in Craig and Nowata Counties, Oklahoma

Geological Society of America, Northeast Section Annual Meeting
Hershey, Pennsylvania, March 3, 1979

Kenneth S. Johnson
Regional assessment of United States salt-bearing basins for disposal of radioactive wastes (with Serge Gonzales)

Phillips Petroleum Co., Computer Services Group
Shangri-la Lodge, Grand Lake, Oklahoma, March 5, 1979

Charles J. Mankin
A view of national energy policy

University of Oklahoma, School of Geology and Geophysics Colloquium
Norman, Oklahoma, March 7, 1979

Kenneth S. Johnson
Energy resources of northern Colorado Plateau

American Association of Petroleum Geologists–Society of Economic Paleontologists and Mineralogists, Annual Meeting
Houston, Texas, April 2–4, 1979

Thomas W. Amsden
Late Ordovician–Early Silurian strata in Mid-Continent area

Kenneth S. Johnson and John F. Roberts
Potential for subsurface disposal of industrial wastes in Oklahoma

Oklahoma State University, Department of Geology Colloquium
Stillwater, Oklahoma, April 5, 1979

Kenneth V. Luza
Seismicity and tectonic relationships of the Nemaha Uplift

University of Oklahoma, School of Geology and Geophysics Colloquium
Norman, Oklahoma, April 18, 1979

Kenneth V. Luza
Seismicity and tectonic relationships of the Nemaha Uplift

Conference on the Nemaha Uplift in Nebraska, Oklahoma, and Kansas
Lawrence, Kansas, April 27, 1979

KENNETH V. LUZA
Seismicity and tectonic relationships of the Nemaha Uplift in Oklahoma

Association of Professional Geological Scientists—Oklahoma Section, Spring Meeting
Tulsa, Oklahoma, April 28, 1979

KENNETH S. JOHNSON
Career opportunities in geology

First International Conference on the Future of Heavy Crude and Tar Sands
Edmonton, Alberta, Canada, June 5, 1979

WILLIAM E. HARRISON, CHARLES J. MANKIN, STEPHEN J. WEBER, and JOSEPH A. CURIALE
Oil-sand and heavy-oil potential of Oklahoma

## OGS Core Catalog Updated

A new catalog of the well cores reposited in the Oklahoma Geological Survey's Core and Sample Library was released September 20 by the Survey. The listing, which includes material on file as of August 1979, was compiled by Eldon R. Cox, with assistance from Gary L. Wullich.

Cores are identified by locality (section, township, and range), by operator, by fee (owner of mineral rights on the lease), by depth, and by the geological formation identified by the operator. The catalog is computerized through the facilities of The University of Oklahoma's Energy Resources Center, and it can be easily updated.

Cox, who has been manager of the Core and Sample Library since June 1971, reports that 1,851 wells are represented in the collection. Cores from these wells were obtained through donations from petroleum and natural-gas producers. Materials are held confidential for a period of 1 year, if so requested by the donor; following that time they become accessible to the public. Cores can be examined at the library for $3.00 per box, or they can be borrowed for a slightly larger fee plus shipping charges.

The OGS Core and Sample Library is located at 2725 Jenkins Avenue in Building 193 on the South Campus of The University of Oklahoma in Norman. The phone number is (405) 325-4386.

Core Catalog 5 can be obtained from the Oklahoma Geological Survey for $1.00 by writing to the address on the front cover.

# APPLICATION OF WATEQF COMPUTER MODEL (RUNNELLS VERSION) TO INTERPRETATION OF HYDROGEOCHEMICAL DATA FROM CLINTON QUADRANGLE, WEST-CENTRAL OKLAHOMA

**Salman Bloch**[1]

**Abstract**—The Oklahoma Geological Survey is currently involved in a reconnaissance program to assess the uranium potential of two 1° × 2° quadrangles (Clinton and Enid) in Oklahoma. Evaluations are based partially on interpretation of published data generated during the U.S. Department of Energy's Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) program. Examination of some of the HSSR data from the Clinton Quadrangle using the Runnells version of the WATEQF computer program, developed by D. D. Runnells at the University of Colorado, for calculating chemical equilibria of natural waters showed this technique to be superior to methods used previously in geochemical evaluation of ground-water data.

## Introduction

The use of geochemical methods has become widely accepted in prospecting for mineral deposits, including uranium. The most common procedures involve examination of soils, rocks, stream sediment, ground water, vegetation, and vapor, with particular emphasis on stream sediment, surface water, and ground water. Surveys for ore-metal content of stream sediments and surface waters are of value only if deposits under reconnaissance are near or at the surface and are undergoing active erosion (Hawkes, 1976). Ground-water content, on the other hand, can be useful in detecting buried deposits.

Evaluation of data generated during geochemical prospecting is aimed at detecting "true" anomalies that may be indicative of the presence of ore bodies in the investigated area, an anomaly being a deviation (generally positive) from the background value typical for a given area of geochemical-geological-geomorphological environment (Siegel, 1974). In geochemical prospecting, the common practice is to select as the background value for a single population of values (for example, uranium concentrations in ground water from a given aquifer) either the median (50 percentile value) or the arithmetic mean plus one standard of deviation. After this background has been determined, anomalous values (or areas) can then be defined.

Boyle (1971, cited in Levinson, 1974) suggested that samples with a metal content twice as great or more as that of the background are anomalous. Hawkes and Webb (1962) proposed that values that exceed the mean plus twice the

[1] Geologist, Oklahoma Geological Survey.

standard deviation should be considered anomalous. These authors indicated that the best approximation in the use of this criterion is to take the median value as background and to consider only the highest 2.5 percent as anomalous.

### Hydrochemical Prospecting for Uranium: Brief Review

Geochemical ground-water surveys are used routinely in many exploration programs. The feasibility of using well waters as a means of tracing uranium occurrences was pointed out by Dyck and others (1976). Grutt (1972) reported that ground water from host rocks in six of the nine major uranium-producing regions of the United States contained more than 10 ppb (parts per billion) dissolved $U_3O_8$. Fix (1956) found that in uraniferous areas of the United States ground waters contain from 1 to about 120 ppb U. In uranium mines, the range increases to 15–400 ppb U. For comparison, the regional background in the western United States is 0.1 ppb U (Fix, 1956).

Because the amount of uranium in water is controlled by the rate of flow, the rate of chemical weathering, and the migration capacity of the uranium—not by the initial concentration of U (metal) in the rock in the zone of water flow only—interpretation of hydrogeochemical data is extremely difficult. Also, the migration capacity depends in turn on such factors as the concentration of different common ligands, Eh-pH conditions, and sorptive properties.

As is well known, the uranium content in many ground-water samples correlates well with $HCO_3^-$ (Mangini and others, 1979, and references therein), a relationship attributed to the formation of uranyl carbonate complexes that greatly increase the mobility of uranium. The mobility of U is also strongly controlled by the oxidation potential (Eh) of ground water. The $U^{4+}$ oxide ($U^{4+}O_2$) is very slightly soluble under reducing conditions, but upon oxidation by through-flowing oxygen-rich (high-Eh) waters in the presence of carbonate species, dissolution increases markedly, particularly for amorphous uraninite. Thus, a water sample taken from a well close to a U deposit in a reduced part of an aquifer might contain less U than a sample from an essentially barren but oxidized part of an aquifer; and in the oxidized area, U concentrations could build up from disseminated sources of no economic value.

Another difficulty encountered in the interpretation of hydrogeochemical data results from the fact that the minerals containing uranium in its hexavalent state (carnotite, tyuyamunite) are least soluble at pH values in the 5–8.5 range (Langmuir, 1978). Since most waters found in the United States have pH values ranging from about 6.0 to 8.5 (Hem, 1970), dissolved U contents in equilibrium with these minerals may often be a poor indicator of possible mineralization. According to Langmuir (1978), the solubilities of carnotite and tyuyamunite in the 5–8.5 pH range are so low that less than 1–2 ppb U could be present in a ground water saturated with these minerals.

It is clear that the extremely complex geochemical behavior of uranium requires the application of computer models to characterize the transport and deposition of this element in ground-water flow systems.

**WATEQ Computer Model and Runnells Version of WATEQF Model**

The first version of the WATEQ computer program for calculating chemical equilibria in natural waters was published by Truesdell and Jones (1974). Described briefly, WATEQ utilizes the chemical analysis of water and on-site measurements of temperature, pH, Eh (or dissolved oxygen), and alkalinity in order to distribute the total concentration of species among all the known associated and unassociated species according to their equilibrium constants. Distribution of dissolved species is accomplished by iteration and correction of the free anion concentration for each successive cycle. The ionic strength and activity coefficients are also corrected on each iteration.

The output from WATEQ provides information on the speciation of the dissolved chemical elements as well as on the state of saturation of the water with respect to solid minerals and compounds. To determine whether or not a solid compound will precipitate from the water, the ion activity product (IAP) is compared with the true thermodynamic solubility constant ($K_T$) for the same mineral. The principle involved in this comparison is illustrated below, using tyuyamunite as an example. The solubility of tyuyamunite can be shown by the reaction:

$$\tfrac{1}{2}Ca(UO_2)_2(VO_4)_2 + 2H^+ \rightarrow \tfrac{1}{2}Ca^{2+} + UO_2^{2+} + H_2VO_4^-$$

The solubility is affected by temperature, pressure, ionic strength, crystallinity, complexing capacity of the solution, and kinetic barriers.

The negative logarithm of $K_T$ for the above reaction is:

$$pK = -\log K_T = -\log \frac{[Ca^{2+}]^{1/2}[UO_2^{2+}][H_2VO_4^-]}{[H^+]^2}$$

This expresses the equilibrium concentration in terms of the activity of each of the dissolved species. When complexing is accounted for, the ion activity product, IAP, can be calculated from a complete water analysis. The ratio of the IAP to $K_T$ gives the degree of saturation of a water with respect to tyuyamunite. When expressed in terms of a free energy difference, $\triangle G$, the following expression is obtained:

$$\begin{aligned}\triangle G &= \triangle G^0 + 2.303RT\log \frac{[Ca^{2+}]^{1/2}[UO_2^{2+}][H_2VO_4^-]}{[H^+]^2}\\ &= -2.303\,RT\log K + 2.303\log(IAP)\\ &= 2.303\,RT\log(IAP/K)\end{aligned}$$

The term log (IAP/K) is called the saturation index (SI). SI values greater than zero suggest that the water is supersaturated with respect to the solid (tyuyamunite in this example); values of zero indicate equilibrium, and negative values indicate that the water is undersaturated and capable of dissolving a given mineral.

For example, a value of SI equal to $-3.0$ indicates that the IAP for a given mineral is only $1 \times 10^{-3}$ as large as its solubility product, $K_T$, which must be exceeded in order for the precipitation of that mineral to take place from the water.

Plummer and others (1976) revised WATEQ and developed the WATEQF computer model. WATEQF considers simultaneous chemical equilibrium among 94 minerals and 113 dissolved chemical species.

Donald D. Runnells and his students at the University of Colorado, Boulder, have modified and enlarged the computer model WATEQF to include many dissolved species and solid compounds of uranium and vanadium. The enlarged model is capable of computing the state of saturation of an aqueous solution with respect to approximately 213 solid compounds and 197 dissolved species (Runnells and others, in press). The Runnells version of WATEQF is a potentially useful tool, not only in exploration for U–V deposits but also in the study of their genesis and *in-situ* mining.

## Discussion

Uranium occurrences in the Clinton 1° $\times$ 2° Quadrangle in west-central Oklahoma have been reported from Washita, Beckham, and Roger Mills Counties (Beroni, 1956; Fay and Hart, 1978; Al-Shaieb, 1978). The surface mineralization is primarily in the form of carnotite and tyuyamunite and is associated with the Doxey Shale (Custerian Series of the Permian System). The surface uranium occurrences may be indicative of subsurface uranium mineralization. Such mineralization could, under favorable conditions, be detected by hydrogeochemical sampling.

Results of the HSSR program indicate that in the Clinton Quadrangle uranium in ground waters correlates very well with specific conductance, boron, calcium, lithium, magnesium, sodium, and sulfate (Arendt and others, 1979). A very poor interrelationship exists between high values of uranium and elements often found useful for delineating potential uranium mineralization in sandstones, such as arsenic, molybdenum, selenium, and vanadium (pathfinder elements). High values of uranium in ground water from the Clinton Quadrangle have been interpreted as being associated with saline formational water and (or) the dissolution of carbonates and evaporites (Arendt and others, 1979). It is obvious that dissolution of carbonates and evaporites alone will not result in a high uranium content in ground waters, as the uranium concentration in these rocks is very low. However, dissolution of carbonates provides a source of aqueous carbonate species that can produce uranyl carbonate complexes, with uranium taken into solution.

In an attempt toward better understanding of data generated by the HSSR program in the Clinton Quadrangle, the Runnells version of the WATEQF model was used in interpreting the information collected.

Figures 1 and 2 show the location of selected wells and the saturation indices for tyuyamunite, as well as the uranium content of ground-water samples from these wells.

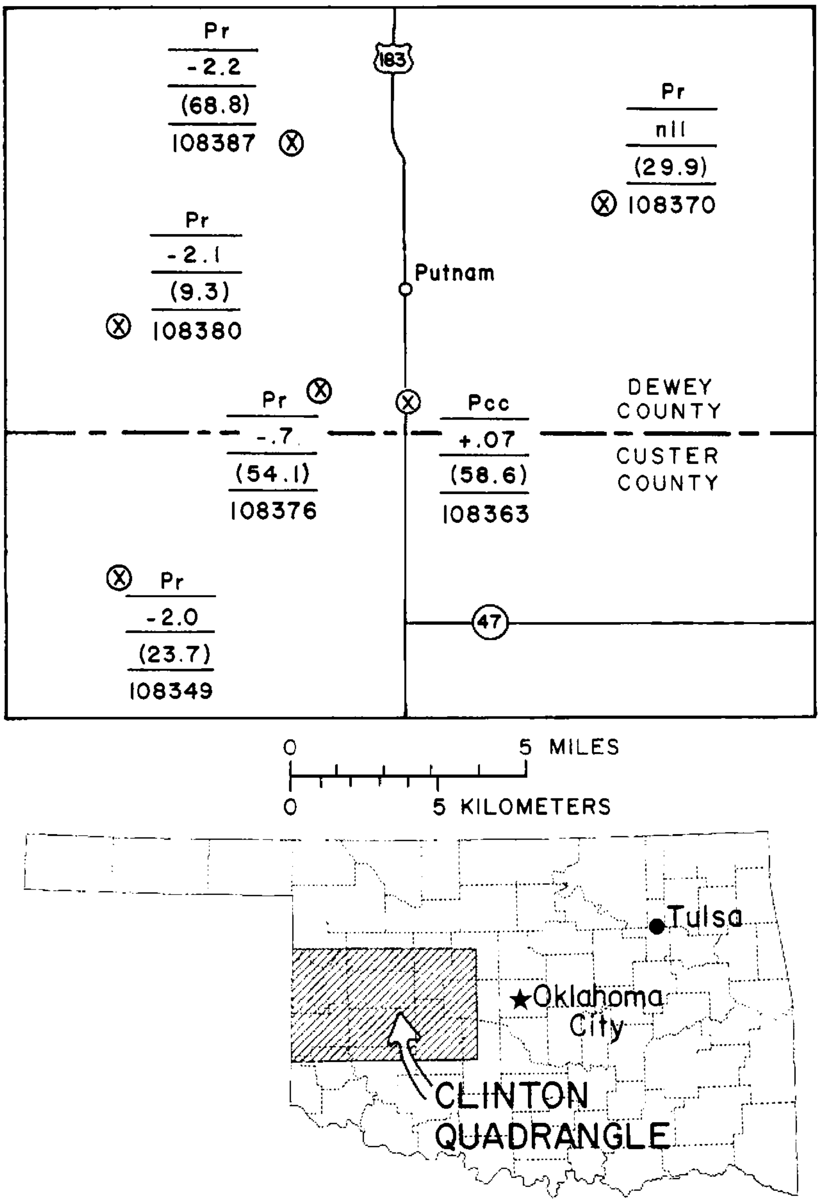


Figure 1. Map of area around Putnam, in north-central part of Clinton Quadrangle, showing ground-water analyses from selected sites. Explanation of symbols, from top to bottom: (1) **Pr**, Rush Springs Formation; **Pcc**, Cloud Chief Formation; (2) saturation index for tyuyamunite; (3) concentration of uranium, in ppb (in parentheses); (4) sample number.

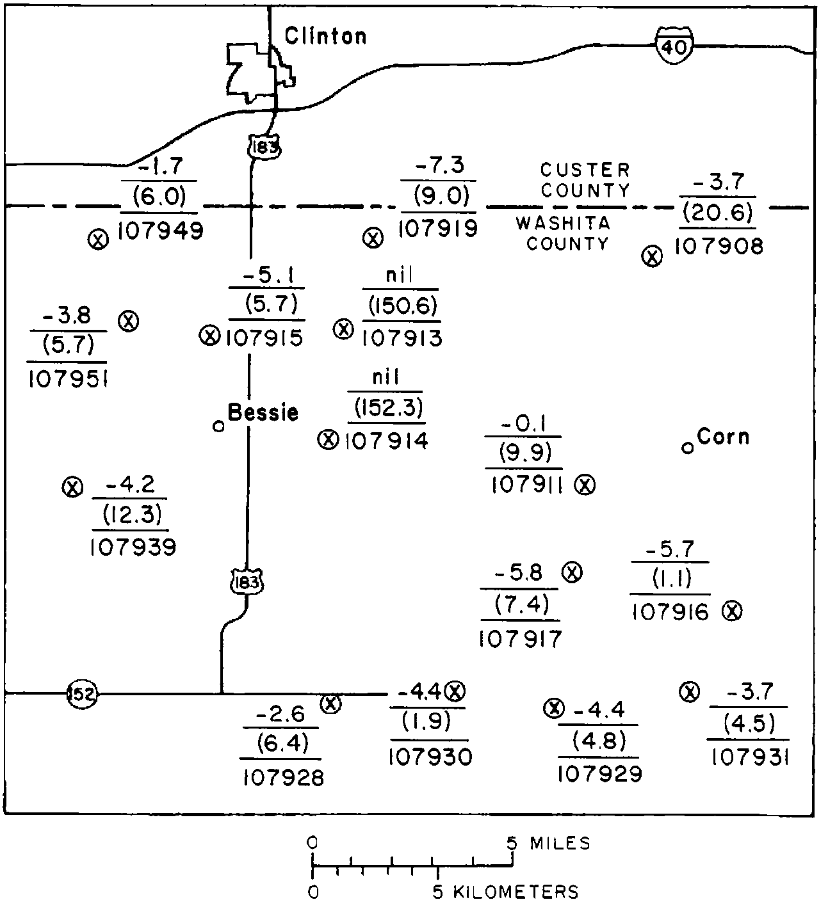


**Figure 2.** Map of area south of Clinton, in central part of Clinton Quadrangle, showing analyses from selected sites of ground water from Cloud Chief aquifer. Explanation of symbols, from top to bottom: (1) saturation index for tyuyamunite; (2) concentration of uranium, in ppb (in parentheses); (3) sample number.

One of the samples (108363; fig. 1) from the Cloud Chief Formation is supersaturated, while one (108376) from the Rush Springs Formation is only slightly undersaturated with respect to tyuyamunite. Both of these samples have high concentrations of uranium (58.6 and 54.1 ppb), and the anomalies could be equally well defined by plotting the concentrations of total uranium instead of the saturation index. For comparison, the median for U in Rush Springs ground water is 4.7 ppb, while for Cloud Chief ground water it is 7.7 ppb. All other samples shown in figure 1 are greatly undersaturated (SI is a large negative number). Sample 108387 represents an interesting case. In spite of its high

U content (68.8 ppb), the solution is strongly undersaturated (SI = —2.2) with respect to tyuyamunite. The high U content of this sample does not seem to represent a true anomaly.

All three samples mentioned previously are strongly undersaturated with respect to other U minerals. For example, the SI for uraninite equals —3.4 in sample 108363, —3.7 in sample 108376, and —4.0 in sample 108387.

Figure 2 also illustrates one of the advantages of using a comprehensive computer model in the interpretation of ground-water chemistry. The U content in sample 107911 from the Cloud Chief Formation is 9.9 ppb. This figure is only slightly higher than the median U concentration of 7.7 ppb for this formation, yet the sample is close to being in equilibrium with respect to tyuyamunite and has an apparent SI significantly higher (SI = —0.1) than other samples containing much more uranium. For example, sample 107908, with a U content more than twice that of sample 107911, has an SI of only —3.7.

Samples 107913 and 107914 in figure 2 contain 150.6 and 152.6 ppb U, respectively. However, precipitation of tyuyamunite from these solutions apparently cannot take place. This is due primarily to their exceedingly low vanadium content. It must be emphasized that these two samples are also strongly undersaturated with respect to all other uranium minerals. For example, the SI for uraninite is —3.9 for sample 107913 and —3.5 for sample 107914.

## Conclusions

The examples discussed illustrate clearly the inadequacy of selecting anomalous areas on the basis of just one parameter, the U content in ground-water samples. Also, pathfinder elements may not be reliable in some geologic situations. The modified (Runnells) version of the WATEQF program, although still "too simplistic to gain a full understanding" of the geochemical behavior of U in natural waters (Runnells and others, in press), represents a significant improvement over previously used techniques of interpreting water-geochemistry data for exploration purposes.

The most serious problem affecting the interpretation of the geochemistry of ground waters by any technique (including the Runnells version of WATEQF) is the difficulty in obtaining meaningful Eh values. This parameter is very important because of the extreme sensitivity of the SI for uranium minerals to the input value of Eh.

## Acknowledgments

I thank Don Runnells for his, as always, very thoughtful review.

Constructive criticism of the manuscript by Ken Johnson and Don Preston, both of the Oklahoma Geological Survey, is greatly appreciated. I am also grateful to Joe Zovak for preparing the illustrations.

This project was supported by Bendix Field Engineering Corp., Grand Junction, Colorado, as a part of the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program.

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# Donald Preston, New OGS Petroleum Geologist

On September 1, Donald A. Preston joined the Oklahoma Geological Survey staff as petroleum and subsurface geologist. Don comes to OGS from Shell Oil Co., which he served in many capacities over the past 28 years.

At Shell his most recent work involved structural analyses that required integrating seismic and magnetotelluric data with surface studies and satellite imagery. He also prepared computer models of areas in the Great Basin and the western Columbia Plateau in reference to specific drilling prospects.

While working for Shell Development Co.'s Bellaire Research Center in Houston during 1963–74, Don conducted extensive field investigations in areas of the Montana-Wyoming Folded Belt, the California Coastal Ranges, the central Appalachians, southern Oklahoma, Texas, the Canadian foothills, the Uinta Basin, the Midland Basin, the Bahamas, and Mexico. He did experimental work in structural research, utilizing rock mechanics and stress-analysis techniques; other laboratory experiments concerned fracture porosity and acoustical anisotropy in rocks. He was project leader for a computer group that prepared and evaluated computer programs related to structural geology and statistical geological sampling. He compiled a catalog of rock properties and set up a computer model of fractured reservoirs, using surface and subsurface analyses, and another computer model of tar-sand evaluation. He also worked on a surface-subsurface geothermal investigation of The Geysers area in northern California and served as project leader for an evaluation of coals in the southern Appalachians.

Prior to this period, he worked in exploration and prospect evaluations in California, Alaska, and Utah. He also served as project leader for a study of solid hydrocarbons in Utah, Wyoming, Colorado, and Nevada and as a hydrodynamicist in Utah.

Don received his academic training at the University of California at Los Angeles (UCLA), earning a B.A. degree in geology in 1950 and doing graduate work at the same university. In addition, as background for his work, he completed numerous engineering courses at the Massachusetts Institute of Technology, the University of Utah, the University of Michigan, and UCLA. He has authored several publications in rock mechanics and computer applications to geology. He is a member of The American Association of Petroleum Geologists and the American Geophysical Union.

Don is a native of Minneapolis, Minnesota. His wife, Hazel, who hails from Kingston, Georgia, headed her own insurance agency for 30 years. The Prestons have six children, all of whom are grown.

Don has an interesting combination of hobbies: photography (with some beautiful examples of his work hanging in his office), sailing, philately, and medieval history.

Don has lost no time getting into the swim of Survey work. He already has one OGS publication to his credit, a statistical summary of Oklahoma's petroleum industry for 1978, which appeared in the last issue of *Oklahoma Geology Notes* (October 1979, v. 39, no. 5, p. 163–173).

## Petroleum-Geochemistry Volume Published

As Hollis D. Hedberg, professor emeritus of geology at Princeton University, says in the foreword of a new book on petroleum geochemistry, "The continually rising standards of petroleum geoscience and oil search require an ever greater knowledge of the fundamental nature of petroleum, its origin, and its behavior in the rocks of the earth's crust."

*Petroleum Geochemistry and Geology*, by John M. Hunt, a 617-page text released recently by W. H. Freeman and Co., adds to this knowledge by explaining basic principles of geochemistry and their applications to the search for petroleum and natural gas. This book should prove a practical fundamental addition to the libraries of those involved in petroleum exploration.

*Petroleum Geochemistry and Geology* can be ordered from W. H. Freeman and Co., 660 Market Street, San Francisco, California 94104. The price is $30.00 postpaid.

## OSM Issues Bibliography on Coal-Land Reclamation

A bibliography covering 50 years of reclamation of lands mined for coal is available to the public from the federal Office of Surface Mining (OSM).

The publication, third in the series *Coal and the Environment*, is sponsored by OSM, the Environmental Protection Agency, and Bituminous Coal Research, Inc. It updates a 1975 publication, *Reclamation of Coal Mined-Land: a Bibli-*

*ography with Abstracts*. Each abstract in the new bibliography is coded to subject classification, the year of publication, and the sequence of its listing in the bibliography.

Copies are available, as long as the supply lasts, from OSM's Region IV Office, 818 Grand Avenue, Kansas City, Missouri 64108.

## Census Is Coming!

The Twentieth Decennial Census of Population and Housing begins officially April 1, 1980.

With a forecast count of 222 million people and 86 million housing units, the Bureau of the Census, U.S. Department of Commerce, will contact, through a mailed questionnaire, all residents of the United States, Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Trust Territories of the Pacific Islands. The query will cover 57 items under categories defined as housing, living environment, employment, lifestyles, and population.

All these data will provide statistical information essential to planning at all levels of government, education, and commerce. This information is also important for forecasting energy needs based on usage of energy resources in homes and in commuter transportation.

Trends between 1950 and 1975 have been toward an increase in natural-gas usage in households from 23 percent to 57 percent, with usage of coal and wood reduced to less than 1 percent for each fuel. The usage of solar energy in residences is still too limited to affect statistics in 1980, according to the Bureau of the Census, but an increase in household usage of wood and coal is predicted.

Recent surveys show also that air conditioning was added to housing units between 1960 and 1975 at an average rate of 6,000 per day. In 1975, 23 million households were cooled through central units, and 15 million additional households had one or more room air conditioners. The number of housing units with central heating more than quadrupled between 1940 and 1975, and nearly 40 percent of housing units built since 1970 are being heated with electricity.

Surveys of transportation have shown a shift away from metropolitan areas, with most homeowners living 10 to 29 miles from their places of employment. Some 40 percent of these suburbanites are dissatisfied with their public-transportation systems. Renters live closer to work, are less likely to own private cars, and feel in general that public transportation is satisfactory.

With more than 70 percent of American houses occupied as single-family units, with at least 75 percent of these houses located in suburban or rural areas, and with many commuters dissatisfied with their public transportation, a lot of gasoline is being and is likely to be consumed.

Such information to be compiled from data gained through Census '80 is of obvious significance not only to an energy-producing State like Oklahoma but to the nation as a whole.

## New AAPG Course Notes Oriented toward Geophysics

The latest publications in the AAPG series Continuing Education Course Notes have a definite geophysical slant.

No. 13 in the series, *Stratigraphic Modeling and Interpretation—Geophysical Principles and Techniques*, by Norman S. Neidell, 145 pages, catalog no. 887, is available for $7.00 each ($6.00 each for 10 or more copies).

No. 14, *Well Log Formation Evaluation*, by Richard H. Merkel, 85 pages, catalog no. 888, is available for $6.00 each ($5.00 each for 10 or more copies).

Both publications can be ordered from The American Association of Petroleum Geologists, P.O. Box 979, Tulsa, Oklahoma 74101. Oklahoma residents should remember to add the 2-percent sales tax (4 percent for Tulsa residents).

## OWRB Releases Garber-Wellington Report

A report on the Garber-Wellington aquifer in three central Oklahoma counties, issued recently by the Oklahoma Water Resources Board (OWRB) as Hydrologic Investigations Publication 86, indicates potential for increased development of ground water from these Lower Permian sandstones. The 1,200-square-mile area covered includes southern Oklahoma County, part of western Pottawatomie County, and all of Cleveland County.

The publication, which represents the initial step toward a plan for efficient development and management of the Garber-Wellington as required by a 1973 State ground-water law, gives an estimate of 31 million acre-feet of available fresh water, with recharge of the aquifer currently exceeding depletion. In addition to this quantitative information, the report provides information on well locations, depth to water, thickness of producing zones, water quality, and direction of flow.

The report states that care must be taken to avoid drilling a fresh-water/salt-water interface, present 50–100 feet below bottom perforations in most municipal wells (and more than 1,000 feet below ground level). Also, the lenticular character of the deltaic sandstones could make finding the producing beds difficult. But an understanding of the geologic setting, coupled with proper management techniques, can overcome these problems.

The author of the report, Ginia Wickersham, chief of the board's planning division, stresses the need for close monitoring of water quality in Garber-Wellington wells to avoid pollution from abandoned oil-well test holes in the area and from both surface and subsurface disposal of wastes.

With numerous central Oklahoma communities, institutions, and industries supplied by water from this aquifer, and with the rapid expansion of residences into rural areas in this part of the State, this analysis of the Garber-Wellington is an important and timely contribution.

OWRB Hydrologic Investigations Publication 86, *Ground Water Resources of the Southern Part of the Garber-Wellington Ground Water Basin, in Cleveland and Southern Oklahoma Counties and Parts of Pottawatomie County, Oklahoma*, can be obtained on request from the Oklahoma Water Resources Board, P.O. Box 53585, Oklahoma City, Oklahoma 73152 (phone, 405—271-2555). The report consists of three large map sheets, with accompanying texts, packaged in an envelope.

## AAPG Explorer **Launched**

The American Association of Petroleum Geologists has begun publication of a bimonthly newspaper for members called the *AAPG Explorer*. The result is an attractive, highly informative, timely newsletter. It is printed in an 11½- by 15½-inch newspaper format.

As AAPG president John D. Haun explains in the first issue (September 1979), the *AAPG Explorer* "is designed to fill many gaps in communication between the Association and its membership. It will provide current news of interest to a majority of our members."

John goes on to say that because of the *Explorer*'s short publication lead time, much information heretofore published in the AAPG *Bulletin* will now be carried in the *Explorer*, such as lists of new members, the section At Home and Abroad, parts of the Association Round Table, the Bulletin Board, and much of the editorial comment that previously appeared in the President's Page.

Much additional information can now be transmitted to the membership through the *Explorer*, including reports of conferences, continuing-education news, scientific-news items and comments, and a Readers' Forum.

Examples of some of these features include, in the first two issues, an interview with U.S. Senator Henry Bellmon, full-page tabulations of the status of current national legislation and regulations, articles by Hollis Hedberg and Wallace Pratt, and an interview with Sheila Hollis, director of the Office of Enforcement of the Federal Energy Regulatory Commission. AAPG executive director Fred Dix is a regular contributor to the publication, via the Director's Corner.

The editorial staff of the *Explorer* includes Rex H. Blakey, editor and communications director; Rebekah Edmond, assistant editor; and Mark Scofield, designer.

The six annual issues of the *AAPG Explorer* are available to nonmembers for a subscription rate of $10.00. Inquiries should be addressed to AAPG, P.O. Box 979, Tulsa, Oklahoma 74101.

We doff our hats to the *Explorer* and its staff!

## DOE Issues Microfiche Reports

To aid the public in evaluating areas that may be favorable for the occurrence of uranium, the Grand Junction office of the U.S. Department of Energy recently issued 44 reports that contain results of investigations carried out by the U.S. Atomic Energy Commission (AEC) during the 1950's and 1960's. The reports cover areas in Colorado, New Mexico, North and South Dakota, Texas, and Wyoming. The reports are available on microfiche only.

For information on the AEC reports and a list including number, title, author, date, number of pages, and cost of each report, contact Bendix Field Engineering Corp. Technical Library, P.O. Box 1569, Grand Junction, Colorado 81502.

## Catalog of OU Geology Theses Released by OGS

The Oklahoma Geological Survey has issued a new publication that lists all theses and dissertations prepared as partial requirement toward degrees granted in geology and geophysics at The University of Oklahoma from 1904 through 1977. The catalog contains approximately 700 entries, which are listed chronologically and by author and are indexed according to localities covered. An outline map of Oklahoma counties is appended for convenient reference.

Compilation of the 129-page publication was done by Katherine L. Keener, former geology librarian at The University of Oklahoma, Elizabeth A. Ham, OGS associate editor, and Claren M. Kidd, who is the current geology librarian for OU's extensive geological collections. The catalog was printed from typescript prepared by Betty D. Bellis.

In the early years, through 1912, a written thesis was required toward a bachelor's degree in geology, and 28 of these B.A. and B.S. reports are listed. The first inclusion is a paper on "A Preliminary Study of the Canadian River," by Charles Townsend Kirk, who earned a B.A. in 1904. Entries subsequent to 1912 cover theses accepted toward master's degrees and dissertations prepared for doctoral degrees.

It is of interest to note that a woman, Mamie L. Brady (B.A. 1911), who wrote on "The Physiography of the Falls Creek Region," is among the recipients of early degrees awarded in geology at OU. Her thesis comes complete with a photo of long-skirted coeds taking a break from field work on a Woodford Formation outcrop on an Arbuckle mountain (see cover photo for August 1974 issue of *Oklahoma Geology Notes*, v. 34, no. 4).

Included in the publication are theses prepared toward advanced degrees in geological engineering prior to 1964, at which time geological engineering became part of the College of Engineering.

*Catalog of Theses and Dissertations Granted by The University of Oklahoma in Geology, Geophysics, and Geological Engineering, 1904–1977* can be obtained from the Oklahoma Geological Survey by writing to the address on the front cover. The price is $2.00.

# OKLAHOMA ABSTRACTS

## GSA Annual Meetings
## San Diego, California, November 5–8, 1979

The following abstracts are reprinted from *Abstracts with Programs* of The Geological Society of America, v. 11, no. 7. Page numbers are given in brackets below the abstracts. Permission of the authors and of Mrs. Jo Fogelberg, managing editor of GSA, to reproduce the abstracts is gratefully acknowledged.

### The Hydrogeochemistry of the Oklahoma Section of the High Plains

NOEL C. KROTHE and JOSEPH OLIVER, Department of Geology, Indiana University, Bloomington, Indiana 47401

The Ogallala Formation and associated Quaternary deposits form the principal aquifer supporting irrigation in the High Plains region. Water is being withdrawn in excess of the rate of recharge; thus water levels are declining in most of the High Plains. Water quality has deteriorated in some areas due to leaching caused by irrigation and the upward leakage of poorer quality water from lower aquifers. This paper is part of a 5-year study of the High Plains

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

Regional Aquifer System being conducted by the United States Geological Survey.

Regional ground-water flow is from west to east across the Oklahoma Panhandle and the specific conductance of ground water increases in the direction of flow. The increase in dissolved solids may be influenced by residence time but bedrock appears to control the ground-water chemistry. The Ogallala Formation is underlain by Mesozoic rocks in the western part of the Oklahoma Panhandle. The average specific conductance of water in Mesozoic rocks is $650\mu$ (micromhos at 25°C). The average specific conductance of the water in the overlying Ogallala in this area is $482\mu$. In the eastern part of the Oklahoma Panhandle the Ogallala Formation is underlain by Permian rocks. The average specific conductance of water in the Permian rocks is $6773\mu$. The water in the overlying Ogallala Formation has an average specific conductance value of $883\mu$. $Ca^{2+}$, $SO_4^{2-}$, $Na^+$ and $Cl^-$ also increase in the ground water from west to east in the Ogallala Formation indicating more bedrock influence by upwelling water from Permian deposits in the east. [461]

**Depositional Cycles in North American Upper Paleozoic Strata**

CHARLES A. ROSS, Department of Geology, Western Washington University, Bellingham, Washington 98225

Recent studies (Ramsbottom, 1977, 1978; and Saunders and others, 1979) suggest that upper Chesterian, Morrowan, and equivalent strata were deposited by eleven or twelve transgressive-regressive depositional cycles (mesothems) which were the result of eustatic changes in sea level. The remainder of North American Carboniferous and Lower Permian strata appears to be delimited as at least thirteen mesothems.

On the outer part of carbonate platforms in southwestern North America, the interval between the Morrowan and Desmoinesian Series, commonly called Atokan, and locally called Derryan Series, appears to represent a single major transgressive-regressive cycle which did not extend beyond the deeper parts of the marginal basins and geosynclines. The Desmoinesian Series includes five mesothems which are recognizable in carbonate sequences in southeastern Arizona. Missourian strata consists of two mesothems. Virgilian and early to middle Wolfcampian strata include five mesothems. The lowest three are Carboniferous, although only the lowest two are generally included in the midcontinent Virgilian. The third is represented by the Admire Group and lower part of the Council Grove Group in the midcontinent (and Bursum Formation in New Mexico). The upper two mesothems are early Permian and include early and middle to late Wolfcampian equivalents. Mesothems reflecting major changes in eustatic sea level are not apparent in post-Wolfcampian strata suggesting that eustatic sea level changes became less extreme. [505]

# GSA Annual Meeting, South-Central Section
# Mountain View, Arkansas, April 9–10, 1979

The following additional abstracts are reprinted from *Abstracts with Programs* of The Geological Society of America, v. 11, no. 2. Some abstracts from this meeting had been published previously in the April 1979 issue of *Oklahoma Geology Notes* (v. 39, no. 2), beginning on page 69. Page numbers are given in brackets below the abstracts. Permission of the authors and of Mrs. Jo Fogelberg, managing editor of GSA, to reproduce the abstracts is gratefully acknowledged.

## Mineralogy and Paragenesis of Red-Bed Copper Mineralization in the Permian of South-Central Kansas

MICHAEL W. LAMBERT and EDWARD M. RIPLEY, Department of Geology, Indiana University, Bloomington, Indiana 47401

Red-bed copper sulfide mineralization occurs sporadically within the Permian Wellington Formation of south-central Kansas. The sulfide minerals are found about 500 feet below the base of the Flowerpot Shale, the host for the well known red-bed deposits of Oklahoma. Sulfides occur principally as spore replacements and irregular stringers, and normally constitute less than 1 volume percent of the host shale or dolomite.

Two distinct types of copper sulfide occurrences have been noted. The first, found in the southern part of the study area, is much like that reported from the Flowerpot Shale of Oklahoma. The megaspore *Triletes* is replaced in the following sequence: pyrite → chalcocite-digenite → malachite. Host rocks for this type of mineralization are alternating red-beds and gray-green shales ± dolomite. In the northern part of the area a sulfide assemblage previously unreported in Kansas has been documented. Here the paragenetic sequence is: pyrite → chalcopyrite → bornite → digenite. This sequence is found in part of the Wellington composed of gray-green shales, dolomite, and evaporites.

The distinct sulfide assemblages are thought to be the result of variations in sulfur availability and copper content of the ore fluid. Differences in copper content may be a function of the distance between source and depositional site.
[163]

## Late Stage Folding along the Southeast Margin of the Broken Bow Uplift, Oklahoma

K. C. NIELSEN, Programs in Geosciences, The University of Texas at Dallas, Richardson, Texas 75080

Detailed mapping of middle Paleozoic units near the Broken Bow Reservoir, Oklahoma has outlined a sequence of northeast trending folds superimposed on the dominant tight east-southeasterly trending fold system. These late stage folds are variable in geometry depending on which limb of the earlier fold system is examined. The overturned, generally steeper dipping early fold limbs are refolded into upright, slightly asymmetric east-northeast trending folds. The upright, shallower dipping early fold limbs are refolded into upright, open, symmetric buckles with a more northeasterly trend. Associated with these folds is a locally developed crenulation cleavage (055°/75°SE) and fracturing of the resistant Arkansas Novaculite. These late stage folds produce subtle modification of the otherwise straight Novaculite ridges; consequently the axial traces of individual folds have been followed approximately 5 km along trend. This young fold pattern suggests that the Broken Bow Uplift is a large scale interference structure resulting from the superposition of the northeast trending folds on an earlier east-west fold system. [164]

**Biotite Gabbros of the Wichita Province, Oklahoma**

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Magmatism is broadly bimodal in the Wichita Province, in which rhyolites and granites of Cambrian age overlie and crosscut previously eroded anorthositic and gabbroic intrusions of equivocal age. Of relatively minor abundance are rocks of intermediate composition and age. Most work to date has been on the granites and rhyolites and on feldspathic cumulates known as the layered complex. Less abundant than these rock types yet potentially significant to the magmatic evolution of the province are widely distributed small bodies of gabbro which are intrusive into the layered complex and distinguishable from it by the presence of primary red-brown biotite (primary hydrous phases are absent in the layered complex). Most of the bt-gabbros contain olivine (up to 20%) and several contain primary titaniferous ferroan pargasite, frequently in excess of biotite (also titaniferous). Chemically the bt-gabbros exhibit a tholeiitic affinity and a similarity to mid-Atlantic ridge basalts, although showing somewhat higher $TiO_2$ contents. Ni fractionation modelling together with phase chemical data suggest that some of the bt-gabbros could be genetically related to one another through low pressure crystal fractionation while different parental magmas are implied for others. Any genetic relationship between the layered complex and the bt-gabbros is highly unlikely. These chemical differences reveal a complexity of petrogenesis among the basic rocks of the Wichita province. Certain similarities to the hypabyssal intrusions of Keweenawan age in N.E. Minnesota (associated with the midcontinent rift) may result from origin and evolution in a similar tectonic setting. [164]

**Possible Periglacial Origin for Boulder Fields and U-Shaped Valleys in West-Central Arkansas and East-Central Oklahoma**

CHARLES G. STONE and JOHN DAVID McFARLAND III, Arkansas Geological Commission, Little Rock, Arkansas 72204

Over 100 large and numerous small cirque-like declivities, steep slopes and streams filled or covered with large subrounded quartzitic sandstone boulders of the Lower Pennsylvanian Jackfork Sandstone occur from about 1500 feet to 2650 feet above mean sea level on Rich, Black Fork and adjacent mountains in the Ouachita Mountains of west-central Arkansas and east-central Oklahoma. There are several types of these boulder deposits including lobate and tongue-shaped trains or "rock glaciers," a few of which are nominally active at present. Some individual deposits cover approximately twenty acres and are estimated to contain as much as two million tons of rock.

U-shaped valleys with bases between about 900 feet to 1000 feet in elevation are present on the northern slopes of Poteau and Sugar Loaf Mountains (maximum elevation of over 2500 feet) some 12–20 miles to the north in the southern Arkoma Basin. According to Haley (1966) large boulder deposits are locally found to the north of some of these U-shaped valleys at relatively lower levels.

These boulder fields and U-shaped valleys are likely the relicts of periglacial conditions—semipermanent snowfields coupled with multiple freeze-thaw cycles that are postulated to have occurred in the higher elevations during the late Pleistocene (i.e. Illinoian and Wisconsin) glacial stages. The boulder deposits in the southern Arkoma Basin below U-shaped valleys may represent alluvial fans formed by mud and debris flows caused by major thaws during a late Wisconsin interstade.

Many recent workers on the Pleistocene in Arkansas and Oklahoma have described alluvial deposits and geomorphic features formed predominantly in interglacial stages and semiarid conditions. It is our suggestion that there are also some deposits and features related to a time of periglacial/glacial conditions that have been previously unrecognized as such. [167]

**Submarine Slumping and Debris Flows in Paleozoic Rocks of the Ouachita Mountains, Arkansas and Oklahoma**

CHARLES G. STONE, Arkansas Geological Commission, Little Rock, Arkansas 72204

In the Ouachita Mountains of Arkansas and Oklahoma all the exposed formations ranging from the Early Ordovician Collier Shale to the Middle Pennsylvanian Atoka Formation contain features indicating post-depositional soft-sediment deformation. These formations are considered deep-water in origin and have a combined thickness of about 48,000 feet, with the turbidite deposits of Carboniferous age composing most of the sequence.

The types of soft-sediment deformation include: (1) plications within a bed; (b) distortions and debris flows in a single bed; (c) multiple bed chaotic intervals; and, (d) slumps involving a formation or several formations. With the probable exception of the Carboniferous rocks in the Athens Plateau of the southern Ouachita Mountains all the slumps and debris flows are thought to have originated from the north. Examples of sedimentary pull-a-parts, balled sandstone masses, load structures and related features are present in many beds. Extrabasinal erratics occur in several intervals including: meta-arkose—granite boulders in conglomerate facies in the Ordovician Blakely Sandstone; and wildflysch intervals with some immense boulders composed mostly of Arbuckle and Ozark rock types in the Early Pennsylvanian Johns Valley Shale.

An origin by submarine slumping is suggested for the often chaotic imbricated "melange-like" intervals in the Early Pennsylvanian middle Jackfork Sandstone of the frontal Ouachita Mountains near Little Rock, Arkansas. Some of the early "structural fold systems" in the Ouachita Mountains may also be formed by submarine slumping rather than Late Paleozoic tectonic events.

It is thought that the erratic-bearing debris flows and the larger slumps represent periods of major instability (basin rifting and subsidence) with some limited igneous activity within, or adjacent to, the deep Ouachita trough.

[167]

# AAPG Eastern Section and U.S. Department of Energy Joint Meeting Morgantown, West Virginia, October 1–4, 1979

The following abstracts are reprinted from the September 1979 issue, v. 63, no. 9, of the *Bulletin* of The American Association of Petroleum Geologists. The page numbers are given in brackets below the abstracts. Permission of the authors and of Gary D. Howell, AAPG science director, to reproduce the abstracts is gratefully acknowledged.

## Paleozoic Disruptive Deformation in North American Continent and Its Relation to Formation and Development of Interior Basins and Deformation within Orogenic Core

ROBERT C. SHUMAKER, West Virginia University, Morgantown, West Virginia 26506

The two major disruptive tectonic events during the Paleozoic which affected the North American craton seem to be associated with Appalachian-Ouachita orogenic events. The first Paleozoic cratonic disruption was tensional

rifting, which occurred during the Avalonian intrusive-metamorphic event ($\pm$560 m.y.). Evidence continues to mount that these Cambrian rifts of the Appalachian-Ouachita foreland, such as the Rome trough of Kentucky and West Virginia, are not Cambrian aulacogens. By time and position, the rifts seem to be incipient basins along a developing back-arc trough. However, this disruptive deformation was not restricted to the developing arc trough, but extended far into the craton where it commonly involved reactivation of older rift zones. These zones formed the axial portion of the subsequently developed Paleozoic basins. The Paleozoic basins developed by epeirogenic movement after a period of relative quiescence during Late Cambrian through Early Ordovician (pre-Taconic) time.

The second Paleozoic continental disruption created large upthrust blocks in the craton during the Pennsylvanian and early Permian, probably by compressional deformation. This event ties, both by time and position, the deformation within the Ouachita part of the orogenic core. Upthrust crustal blocks in the craton may be bounded by reactivated faults of precursor rifts. When they formed, the upthrusts often developed near the axial part on the middle Paleozoic basins to form the late Paleozoic yoked basins. The occurrence of axial rifts within interior and foreland basins, and of axial upthrusts in the craton-margin basins, suggests an interrelation among rifts, basin formation, and the late-forming yoked basins. The developing foreland trough (the Appalachian-Ouachita geosyncline) has a tectonic history similar to that of the cratonic basins but, along its trend, tensional bending of the basement predominated. [1588]

**Revision of U.S. Geological Survey and U.S. Bureau of Mines Coal Resources Classification System**

GORDON H. WOOD, JR., and THOMAS M. KEHN, U.S. Geological Survey, Reston, Virginia 22092

In 1976, the U.S. Geological Survey and U.S. Bureau of Mines published a system of coal-resources classification that incorporated definitions and criteria to be used by the two agencies. This system was adopted by many state geological surveys. However, because of criticism and ambiguities, the two agencies decided to revise, enlarge, and make more precise the definitions and criteria and to include advice, suggestions, and recommendations aimed at guiding those engaged in resource estimation. In addition, a decision was made to include conversion data for the English and metric systems of measurement. Finally, a report was to be written that would be a compendium on the methodologies and criteria for the classification of coal resources and reserves.

Advice from the state geologists of the principal coal-bearing states was solicited. Similarly, the existing 1976 classification system was discussed with representatives of the nations cooperating in the International Energy Agency's

(IEA) World Coal Reserves and Resources Data Bank Service. Their comments were considered and incorporated in the revision that is nearing completion.

In 1977, the U.S. Department of Energy took over most of the coal-related functions and personnel of the U.S. Bureau of Mines. The revision is under the auspices of the Department of Energy and the U.S. Geological Survey.

Throughout the revision, every effort has been made not to negate the hundreds to thousands of coal-resource estimates already published or being prepared by geologists and engineers in the United States. Also, foreign resource specialists have indicated that the revision should have international comparisons as an objective. This objective has been accomplished. [1591]

## Gulf Coast Association of Geological Societies and SEPM Regional Meeting, Gulf Coast Section San Antonio, Texas, October 10–12, 1979

The following abstract is reprinted from the September 1979 issue, v. 63, no. 9, of the *Bulletin* of The American Association of Petroleum Geologists. The page number is given in brackets below the abstract. Permission of the author and of Gary D. Howell, AAPG science director, to reproduce this abstract is gratefully acknowledged.

### Outer Deep-Sea Fan Depositional Lobe Sequence from Jackfork Group of Southern Arkansas

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Sediments accumulating on the lower parts of the continental slope and the adjacent rise have been shown to contain significant organic materials and are regarded as important prospective hydrocarbon source beds. It is likely that future technologic developments will result in important production from these environments. A search for stratigraphic traps will require an understanding of depositional processes on deep-sea fans, gained partly from study of ancient examples exposed on land. The Carboniferous sequences of the Ouachita Mountains of Oklahoma and Arkansas provide an outstanding opportunity for examination of sediments from these environments.

The outcrops of Jackfork Group turbidites (Pennsylvanian) exposed in the walls of the spillway at De Gray Dam, Arkansas, have been described by R. C. Morris. This sequence shows a rhythmic alternation between turbidite units with high sandstone/shale ratios (facies C of E. Mutti and F. Ricci-Lucchi)

and units with low sandstone/shale ratios (facies D). Facies C is interpreted as material deposited on active fan lobes, and facies D consists of lobe-fringe and interlobe sediments. A pattern of frequent lobe shifting can be recognized analogous to the way the main distributary system switches from side to side of a delta. Individual lobes range in thickness from 3 to 70 m, with a mean of about 25 m. This association is characteristic of the outer fan environment of A. Bouma and T. Nilson.

The upper part of the De Gray section contains massive sandstones and pebbly sandstones interpreted as deposits of a major distributary channel. It is possible that buildup of the fan sediments had brought the area into the middle-fan environment by this time.

Many of the critical characteristics of these sediments would be recognizable on well logs, and the De Gray section is a good example of one association that might be drilled on the continental rise. [1606]

# AGU Midwest Meeting Columbus, Ohio, September 13–14, 1979

The following abstract is reprinted from the program booklet for the 1979 Midwest Meeting of the American Geophysical Union. The page number is given in brackets below the abstract. Permission of the author and of A. F. Spilhaus, Jr., AGU executive director, to reproduce the abstract is gratefully acknowledged.

## Seismicity in Oklahoma

KENNETH V. LUZA and JAMES E. LAWSON, JR., Oklahoma Geological Survey, Norman, Oklahoma 73019, and Leonard, Oklahoma 74043

In July 1976 a program was initiated to install a statewide network of seismograph stations capable of locating and detecting mbLg magnitudes of 2.1 or greater. The network consists of 7 semipermanent, volunteer-operated seismograph stations, 3 radio-telemetry stations, and the Oklahoma Geophysical Observatory, near Tulsa, which operates 7 seismometers. From January 1, 1977, to May 1, 1979, approximately 100 earthquakes, which range from mbLg 2.9 to mbLg 1.7, have been located. The historical-earthquake data—129 earthquakes—when combined with the earthquakes located by the network stations, define 3 general areas of earthquake activity in Oklahoma: (1) diffuse seismicity along and north of the Ouachita front (Arkoma Basin) in southeastern Okla-

homa; (2) concentrated seismic activity in Love-Carter Counties, southern Oklahoma; and (3) seismic activity along a linear zone in central Oklahoma, 40 km wide by 140 km long, that begins near El Reno and extends northeastward to Perry.

The El Reno area has been the site of numerous earthquakes since 1908. Prior to the installation of the network, more than one-half of the known earthquakes have occurred in the vicinity of El Reno. After the El Reno earthquake of 1952, mb 5.5, no earthquakes were reported for this region until 1978. In March 1979, 27 earthquakes, mbLg 1.7 to mbLg 2.9, occurred over a 2-day period southwest of El Reno. There is reliable instrumental evidence to suggest that similar earthquake swarms have not occurred in this area since 1961, when the first seismographs began operating in Oklahoma. [9]

## Oklahoma State University

### A Basic Evaluation of the Uranium Potential of the Morrison Formation of Northwestern Cimarron County, Oklahoma, and Adjoining Areas of New Mexico and Colorado

MARVIN MILTON ABBOTT, Oklahoma State University, M.S. thesis, 1979

Scope and Method of Study: The study was undertaken to evaluate possible uranium enrichment of the Morrison Formation and to predict areas for future exploration. Samples from outcrops were analyzed for V, Co, Ni, Pb, Cu, Cr, Mo, Fe, Mg, Sr, Zn, Ti, Ag, Mn, Cd, and Ca by means of atomic-absorption spectrophotometry, and for U by means of fluorometry. A carborne radiometric survey was conducted using a scintillometer and a gamma-ray spectrometer. Petrographic and clay-mineralogy studies were conducted on the potential host rock to determine stratigraphic and diagenetic trends.

Findings and Conclusions: A previously unreported occurrence of uranium mineralization was found near Kenton, Oklahoma. The U shows high positive correlation with Ti, Pb, Sr, and Mg, and high negative correlation with Mn. The localities of mineralization are controlled by low permeability. Thick accumulations of the Morrison were found to be above or closely associated with changes in basement lithologic provinces and with Precambrian faults. The areas that have high potential for uranium mineralization were found to be associated with thick Morrison sequences and to be located along two trends. The eastern trend is located along a line from Kenton, Oklahoma, to Clayton, New Mexico. The western trend is located immediately east and parallel to the crest of the Sierra Grande Uplift.

### A Computer Ground-Water Model for the Tillman Alluvium in Tillman County, Oklahoma

ABDULAZIZ JASEM AL-SUMAIT, Oklahoma State University, M.S. thesis, 1978

Scope and Method of Study: The alluvial terrace and floodplain deposits in the western half of Tillman County are associated with the Red and North Fork of the Red River, and extend over an area of approximately 285 square miles. Ground water in these deposits supply about 850 wells for domestic and irrigation purposes. Cotton, wheat and alfalfa are the major irrigated crops.

A finite-differencing model was used to simulate well drawdown over a 20-year period between July 1, 1973, to July 1, 1993. A maximum annual yield was determined based on pumpage prior to 1973 and subsequent allocated pumpage at different trial rates. Calibration techniques were also compared. A pattern recharge of 2.87 inches was selected for optimum design. Computer input include evapotranspiration and well rate at the surface; water level, land and bedrock elevations; specific yield, coefficient of storage and leakage rate of the river bed.

Findings and Conclusions: Computer output is used to show a rate of one acre foot per acre could be recommended as an allocation to each one-quarter section of the 285 square mile aquifer area. At this rate, only one-half of the aquifer area would go dry during the 20-year period. On this basis, 70,048 acre feet per year was established as the maximum annual yield. This annual discharge rate will yield a total volume of 1,400,967 acre feet pumped from July 1, 1973, to July 1, 1993. The model results indicate that more than one half of the wells which belong to prior appropriative right owners would go dry if annual allocation was permitted at the recommended rate. Only four percent of the prior appropriative wells would go dry if annual allocation was not permitted.

### Use of Remote Sensing for Fracture Discrimination and Assessment of Pollution Susceptibility of a Limestone-Chert Aquifer in Northeastern Oklahoma

ESMAEIL AZIMI, Oklahoma State University, M.S. thesis, 1978

Scope and Method of Study: The primary purpose of this investigation was to determine the utility of Skylab S190A, Standard LANDSAT photography and of digitally-enhanced LANDSAT imagery for evaluation of fracturing and related pollution susceptibility and recharge in an unconfined limestone-chert aquifer. The aquifer was the Boone Formation, which is located in northeastern Oklahoma. The orientation and the density of fracturing were estimated from the orientation and the density of LANDSAT and Skylab linears.

Land-use maps of the area were prepared from the aerial photographs and soil maps. Three LANDSAT linear density maps and one drainage density map were prepared and used in conjunction with available soil and land-use information to develop pollution susceptibility maps. These maps show the predictable level of pollution susceptibility and recharge in areas overlying the Boone aquifer adjacent to the Illinois River.

Findings and Conclusions: The variability in well yield and groundwater quality of the area were compared with linear, drainage densities, numbers of linear intersections and predictable levels of pollution susceptibility. The analysis of variance indicates a high reliability of correlation between high fracture density and relatively lower concentrations of sulfate ($SO_4$), chloride ($Cl$), iron ($Fe$), and total hardness. Higher well yield and high fracture density also correlated well. The validity of the pollution susceptibility and recharge predictions using Skylab photography and LANDSAT imagery were strengthened by these correlations.

The utility of Skylab-4 photography was also examined for regional reconnaissance in the Ozark region. Twenty-one of the previously mapped faults were identified on the Skylab photography. Thirteen of the previously mapped faults were compared with linears taken from LANDSAT imagery. Other linears which did not correspond with known structural features were parallel to the trends of faults and other structural features.

## Geology of the Hartshorne Coal, McCurtain and Lafayette Quadrangles, Haskell and Le Flore Counties, Oklahoma

LEE EDWARD CATALANO, Oklahoma State University, M.S. thesis, 1978

Scope and Method of Study: Datums from coal-test borings, drillhole logs and completion tickets were used in the construction of a structural contour map, a coal-thickness map, a parting-thickness map, and an overburden map of the Hartshorne coal. Isopleth maps of fixed carbon, ash and sulfur were based on chemical analyses of coal samples. A correlation cross-section, based on drillers' descriptions of coal-test borings, was made to show stratigraphic relationships among units of the McAlester Formation. Measured, indicated and inferred coal reserves were estimated from the coal-thickness map and the overburden map. Field work supplemented and tested structural and stratigraphic interpretations.

Findings and Conclusions: The Hartshorne coal is believed to represent an extensive peat-swamp that developed on a deltaic plain created by a basin-wide regression. The thinness of a shale bed between the Upper and Lower Hartshorne coals, relative to other portions of the Arkoma Basin where the split reaches a thickness of 180 feet, most likely records a more stable portion of the peat-swamp. Moderately intense folding and normal and reverse faulting have deformed strata of the study area. The Hartshorne coal is best suited for use as coking coal. Total remaining resources are estimated to be about 354,000,000 short tons. Of this amount, 6,700,000 short tons are economically strippable (150 ft. or less of overburden) and 173,000,000 short tons are nonstrippable but recoverable reserves.

## OSM Awards Funds to Operators of Small Oklahoma Coal Mines

The Office of Surface Mining (OSM) of the U.S. Department of the Interior has awarded $208,600 to the State of Oklahoma to help operators of small coal mines in Oklahoma meet requirements of the new federal surface-mining law. The assistance program applies to qualified miners producing more than 250 tons but less than 100,000 tons of coal a year. These operators, according to Secretary of the Interior Cecil D. Andrus, "operate 84 percent of all surface and underground mines and produce almost 20 percent of the nation's coal."

Funds come from reclamation fees paid by current mine operators, who pay 35 cents per ton of surface-mined coal, 15 cents per ton of underground-mined coal, and 10 cents per ton of lignite. Ten percent of such monies collected (up to $10 million nationwide) can be used to aid operators of small coal mines, with the remaining 90 percent used to fund reclamation of abandoned mined lands.

Mine operators in Oklahoma who are interested should contact the Oklahoma Department of Mines, 4040 North Lincoln Boulevard, Suite 107, Oklahoma City, Oklahoma 73105, for information.

## Oklahoma Mining Institute Receives Grant

The Oklahoma Mining and Mineral Resources Research Institute at The University of Oklahoma has received funding from the U.S. Office of Surface Mining in the amount of $165,037 for its second year of operation, according to Kenneth S. Johnson, director of the Institute.

Of this amount, $110,000 constitutes a basic grant for administration, development of courses for students, and faculty support. The additional $55,037 is for two research grants to faculty members of The University of Oklahoma.

Michael J. Mueller, assistant professor in the OU Division of Economics, will receive $31,367 for investigations of "Economics of Oil-Shale Exploitation: Technology, Finance and Environment." John A. Harrington, Jr., assistant professor in the Department of Geography, and Charles E. Barb, Jr., associate professor in the School of Civil Engineering and Environmental Science, will share a grant of $23,670 for their work on developing "A Low-Cost Landsat Digital Technology Training Package." These two research grants were awarded on a competitive basis, with only 58 proposals selected from 372 proposals submitted nationwide.

Funding for the grants is provided under the Surface Mining Control and Reclamation Act of 1977, which established mining centers in 22 states having significant mineral resources under production. The Institutes were created as research and training centers to aid in alleviating the problems created by a growing need for mineral supplies in this country. Their purpose also is to develop new mining and refining technologies and to train scientists and engineers to work in the development and conservation of mineral resources.

Johnson, who is also associate director of the Oklahoma Geological Survey, was named director of the Oklahoma Institute in September 1978. Joan M. Davenport, Assistant Secretary of the U.S. Department of the Interior for energy and minerals, says, "The research grants reflect the commitment the Institute and its Director, Dr. Kenneth S. Johnson, have in seeking answers to the Nation's mining and minerals problems."

## Microform Well Data Donated to Survey

The Oklahoma Geological Survey was the recent recipient of a set of completion cards in microform by Petroleum Information Corp. (PI). The set represents the complete Oklahoma files of Petro Well, Inc., a company acquired by PI several months ago.

The data set covers the completion history of 175,000 Oklahoma well units, going back more than 35 years. Through the courtesy of PI, these well records will be updated periodically.

The well file is on standard microfilm reels and is available for public use at the Survey office, 830 Van Vleet Oval, Room 163, on The University of Oklahoma campus in Norman.

This set of Oklahoma well data can be purchased on microfiche from PI's offices in Oklahoma City, Denver, and Houston. Local inquiries should be directed to Petroleum Information, P.O. Box 26304, Oklahoma City, Oklahoma 73126 (phone, 405—947-6655).

## New Theses Added to OU Geology Library

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

*Study of a Possible Hawaiian Mantle Plume Model Using Shallow Reflections of Earthquake-Generated Body Waves*, by Dortha Lea Dougherty. 149 p., 34 figs., 18 tables.

*Fracture Densities in the Rattlesnake Mountain Fold, Wyoming*, by Elisabeth Rayner Krause Goodwin. 90 p., 12 figs., 1 table.

*Evidence for the Origin of Pc 3 Micropulsations outside the Magnetosphere*, by Emmitt Scott Lockard, Jr. 116 p., 14 figs., 1 table.

*Lithostratigraphy and Depositional Environments of the Morrowan Series (Lower Pennsylvanian) in Parts of Cherokee, Wagoner and Mayes Counties, Oklahoma*, by Mark D. Orgren. 163 p., 6 figs., 13 pls., 2 tables.

*Grain Size Distribution of Quartz As a Function of Distance from Shoreline, Blaine Formation (Permian), Western Oklahoma*, by Matthew Wayne Totten. 77 p., 25 figs., 8 tables.

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## OGS Issues Study of Late Paleozoic Reptiles

A book published recently by the Oklahoma Geological Survey has significantly advanced the understanding of the cranial anatomy of a family of small prehistoric reptiles that have been found in central and western Oklahoma and north-central Texas. A new genus of primitive reptile, *Eocaptorhinus laticeps* Heaton, is described in detail.

Issued as Bulletin 127, the 84-page publication is entitled *Cranial Anatomy of Primitive Captorhinid Reptiles from the Late Pennsylvanian and Early Permian, Oklahoma and Texas.* Its author, Malcolm J. Heaton, is a professor of biology at Erindale College, University of Toronto, in Mississauga, Ontario.

Heaton studied a number of well-preserved specimens of the fossil reptiles, which were provided to him by Jiri Zidek, a professor in The University of Oklahoma School of Geology and Geophysics and curator of vertebrate paleontology for the Stovall Museum of Science and History at OU.

One of the strong points of the publication is a series of finely detailed drawings by the author showing the various aspects of skull morphology.

"Extremely well-preserved specimens from Oklahoma reveal all soft anatomy reflections on the bone," Heaton says. "It is possible to identify the origins and insertions of the musculature on the skull and mandibles as well as to trace most major, and many minor, arteries, veins, and nerves."

Bulletin 127 can be ordered from the Survey at the address on the front cover for $6.50 paperbound and $10.50 clothbound.

# OKLAHOMA GEOLOGY NOTES

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