



# OKLAHOMA GEOLOGY NOTES



## OGS EXHIBIT AT INTERNATIONAL PETROLEUM EXPOSITION

Tulsa was the site of the International Petroleum Exposition (IPE) for the 5-day period of May 17-21. The IPE holds its exposition once every 5 years, in the Expo Building of the Tulsa State Fairgrounds, and the 1976 show, conducted on IPE's 53d anniversary, completely filled a 10-acre building and extended outside to a 5½-acre display area.

This year's exhibit constituted the biggest display of energy equipment and technology that IPE has ever put on. Nearly 500 firms from the United States, Canada, the United Kingdom, France, Japan, West Germany, Rumania, and Italy exhibited equipment and services. An estimated 50,000 people attended.

The Oklahoma Geological Survey prepared two educational exhibits that were shown as part of the Energy-Science Panorama. An Energy Fuels Map of Oklahoma (right side of photograph), constructed for the Survey by Phillips Petroleum Company, was used to show the distribution of oil and gas fields, coal deposits, refineries, gas-processing plants, petrochemical plants, coal mines, and other items of interest. The second exhibit showed current mining and land-reclamation practices in eastern Oklahoma's coal field (left side of photograph). Coordination of the Survey's role in the IPE was handled by John F. Roberts.

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**Oklahoma Geology Notes** is published bimonthly by the Oklahoma Geological Survey. It contains short technical articles, mineral-industry and petroleum news and statistics, an annual bibliography of Oklahoma geology, reviews, and announcements of general pertinence to Oklahoma geology. Single copies, seventy-five cents; yearly subscription, \$3.00. 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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Compiled by ELIZABETH A. HAM<sup>2</sup> and WILLIAM D. ROSE<sup>2</sup>

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## TGS Field-Trip Participants Examine Coal Beds and Tar Sands

The annual field trip of the Tulsa Geological Society, attended April 30-May 1 by about 47 persons, covered parts of the Oklahoma-Kansas-Missouri tri-state area during sunshine and rain. Survey geologists L. R. Wilson and S. A. Friedman were leaders for the trip, along with George W. Krumme (Krumme Oil Co., Tulsa), Allan Bennison (con-

sultant, Tulsa), Richard Norman (consultant, Jenks, Oklahoma), Larry Brady (Kansas Geological Survey), Jack S. Wells (Missouri Geological Survey), and Frederick N. Murray (Mapco, Tulsa), who expertly coordinated geologic and logistic aspects of the trip.

Participants viewed coal and heavy-oil deposits in the northeastern shelf area of the Oklahoma coal field and in adjacent areas of Kansas and Missouri. The thinning of the intervals between the Rowe, Mineral, and Croweburg coals, and the Verdigris Limestone (from the northern part of the Oklahoma coal field to southeastern Kansas and southwestern Missouri) and the stratigraphic relationships of the coal beds and associated strata were demonstrated at 3 strip mines in Oklahoma, 2 in Kansas, and a roadcut and a mine in Missouri.

A stop was made at the U.S. Energy Research and Development Administration research center (formerly operated by the U.S. Bureau of Mines) in Bartlesville, where ERDA personnel described current projects on tertiary recovery of petroleum. Another field stop was made at an open pit "tar sand" mine in Missouri, where heavy oil occurs in the Blue-jacket Sandstone. This oil-impregnated sandstone is mined for direct use in road construction.

The guidebook for the field trip was edited by Robert Scott (Amoco Production Research) and includes an article on coal palynology by Dr. Wilson and one on coal reserves by Friedman. A limited number of books are available, at a cost of \$4.00, through the Tulsa Geological Society, 2745 East 15th Street, Tulsa, Oklahoma 74104.

## New Theses and Dissertations Added to OU Geology Library

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

*Crystalline Silica in Mudrocks*, by Douglas J. Schultz.

*Experimental Analysis of Folding in Simple Shear*, by Ronald E. Manz.

*Structural Analysis and Mapping of the Eastern Caddo Anticline, Ardmore Basin, Oklahoma*, by Leonard C. Dionisio, Jr.

The following Ph.D. dissertations have also been added to the library:

*Intergranular Pressure Solution in the Tuscarora Orthoquartzite*, by Duncan Fawcett Sibley.

*Secular Variation of the Intensity of the Geomagnetic Field During the Past 3,000 Years in North, Central, and South America*, by Sheng-Shyong Lee.

## Hunton Bulletin Released by OGS

A major publication on one of Oklahoma's most important oil and natural-gas zones has just been released by the Oklahoma Geological Survey. Issued as Bulletin 121, *Hunton Group (Late Ordovician, Silurian, and Early Devonian) in the Anadarko Basin of Oklahoma* represents the results of years of investigation by Thomas W. Amsden, OGS geologist, who has long possessed an international reputation as a specialist on Silurian and Devonian strata.

The 214-page illustrated volume is a stratigraphic, biostratigraphic, and sedimentological study containing detailed data on porosity and permeability, geochemistry, and oil and gas production for each formation represented in the Hunton Group. A 4-part appendix to the bulletin lists core descriptions, well-sample descriptions, chemical analyses of cores, and porosity and permeability data from wells drilled in the Anadarko basin.

Accompanying the book are 10 large maps showing geology, structure, thickness of beds, insoluble residues, and  $\text{MgCO}_3$  content of beds. A separate sheet contains four stratigraphic cross sections of Hunton strata. The soft-cover text and the 11 folded panels come packed together in an attractive, sturdy slipcase.

Bulletin 121 can be obtained from the Oklahoma Geological Survey, 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73019. The price is \$10.00.

## Topographic-Map Prices Boosted Again

In response to increased costs of reproduction and distribution, the U.S. Geological Survey has announced an increase in prices for topographic maps. The Oklahoma Geological Survey, an authorized USGS map dealer, will raise its prices accordingly. The last general price increase was in 1972.

Effective July 15, standard topographic maps of the 7.5- and 15-minute series, including orthophotomaps and orthophotoquads, will cost \$1.25 each. The 1:250,000-scale,  $1^\circ \times 2^\circ$  maps, formerly published by the Army Map Service, will cost \$2.00 each.

Price information for other USGS maps can be obtained by writing Publications Division, U.S. Geological Survey, National Center 341, Reston, Va. 22092.

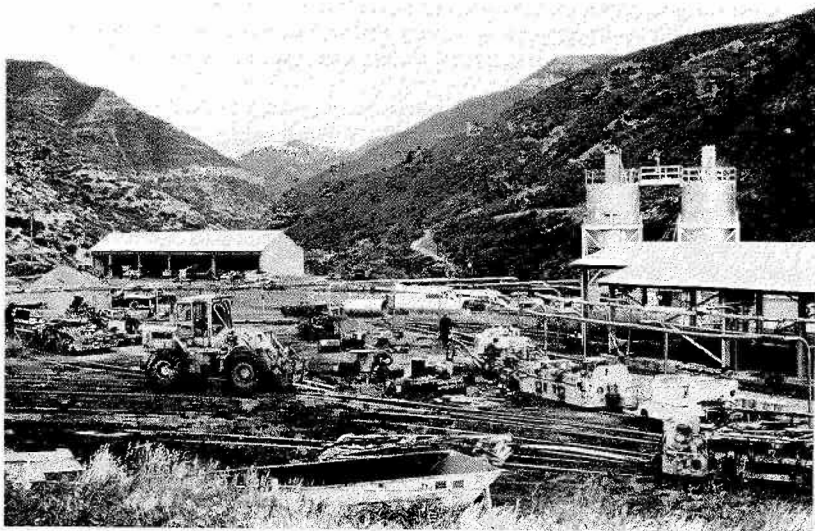


## Energy-Fuels Course Sponsored by OU

A study of energy fuels in the Piceance basin of Western Colorado will be carried out in a field-course program sponsored by The University of Oklahoma School of Petroleum and Geological Engineering. The field course, directed for the fourth straight summer by Kenneth S. Johnson, economic geologist with the Oklahoma Geological Survey, will be conducted for 3 weeks in the vicinity of Grand Junction. Enrollment is expected to be 15 to 20 students from The University of Oklahoma and other institutions.

Entitled the Energy Fuels Field Course and Workshop, the program extends from August 2 through August 20 and involves examination of petroleum deposits, oil shales, coal, tar sands, asphaltite, uranium ores, and examples of tests to stimulate natural-gas production through massive hydraulic fracturing and through nuclear stimulation. Informal discussion and instruction by engineers and geologists actively engaged in energy production are invaluable to the success of the program. The study area includes such scenic sites as the Colorado, Dinosaur, Black Canyon of the Gunnison, and Arches National Monuments.

For information concerning enrollment and expenses, contact Dr. Johnson at the Oklahoma Geological Survey, The University of Oklahoma, Norman, Oklahoma 73019 (phone 405/325-6541 or 325-3031).



Equipment and surface facilities at the underground coal mine of U.S. Steel Corporation, at Somerset, Colorado, on the western slope of the Rocky Mountains, were viewed last year by fuels-course participants.

## OKLAHOMA ABSTRACTS

### AAPG-SEPM ANNUAL MEETINGS NEW ORLEANS, MAY 23-26, 1976

The following abstracts are reprinted from the April 1976 issue, v. 60, of the *Bulletin* of The American Association of Petroleum Geologists. Page numbers are given in brackets below each abstract. Permission of the authors and of Gary Howell, AAPG managing editor, to reproduce the abstracts is gratefully acknowledged.

#### **New Approach to Geologic Estimates of Oil and Gas Resources by U.S. Geological Survey**

GORDON L. DOLTON, RICHARD B. POWERS, and EDWARD G. SABLE,  
U.S. Geological Survey, Denver, Colorado

Geologic interpretation and evaluation of potentially petroliferous areas provide the basis for oil and gas resource assessment. The Resource Appraisal Group, in conjunction with other personnel of the U.S. Geological Survey, systematically collected, summarized, and inventoried a large amount of geologic and geophysical data on a regional scale for the appraisal of undiscovered recoverable oil, natural gas, and natural-gas-liquid resources of the onshore and offshore United States. These data are amenable to treatment by many different resource-appraisal methods and eventually to computerized data-bank storage and retrieval procedures.

Geologic factors considered to be critical to the oil and gas resource appraisal methods used in this study include area, thickness, and age range of potential strata; character, volume, and age of producing and prospective reservoir beds; source beds, seals, and organic maturity; dominant lithologies; depositional environments; regional and local aspects of structure and tectonics; types of traps; indications of hydrocarbons; and known or suspected presence of hydrocarbons.

Engineering, development, and historical factors used include stage of exploration, production and reserve data, field and reservoir information, other resource estimates, and overall qualitative ratings of each province or region based on geologic and yield-analog procedures. [665]

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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.

## **Application of Remote Sensing (LANDSAT Data) to Petroleum Exploration**

MICHEL T. HALBOUTY, Consulting Geologist and Petroleum Engineer,  
Independent Producer and Operator, Houston, Texas

The LANDSAT project is the most significant mission ever flown by NASA. The program offers the mineral and energy industries in the United States an opportunity to improve the nation's domestic-resource base in a shorter time and at a more reasonable cost than would have been possible otherwise.

Properly interpreted information from these images can save corporations millions of dollars in unnecessary exploration and development efforts while providing possible geologic clues which could lead to the discovery of tremendous reserves. The more the LANDSAT data are used, the more innovations for their use will be established.

LANDSAT data have broad use in the minerals/fuel field, including the following general applications:

(1) Detection of large-scale, previously unknown geologic structures which may be significant with respect to the localization of hydrocarbons. Such features commonly are not recognizable on traditional aerial photographs.

(2) The detection of very subtle tonal anomalies that may represent alteration of the soils resulting from miniseeps of gas from hydrocarbon reservoirs.

(3) The potential for detecting natural marine oil seeps with consequent improvement in efficiency of off-shore exploration.

(4) Detection on outcrops of important minerals and metals, especially in hostile environments.

(5) The monitoring of ice distribution and movement in Arctic areas, such as may affect transport of materials in and out of the Arctic, the cost of seismic exploration in Arctic Sea ice areas, and the safety of exploration and production operations.

(6) The monitoring of oil-field development and transport facilities, such as the Alaska pipeline, and an assessment of this development upon the environment.

(7) The potential for improved communication and decision making within petroleum companies.

The proper use of LANDSAT imagery affords the explorationist a rapid and inexpensive tool which can add immeasurably to this geologic knowledge. [677]

## **USGS-AAPG Digitized Oil and Gas Field Map of North America—Status Report**

WILLIAM W. MALLORY, U.S. Geological Survey, Denver, Colorado

The USGS-AAPG digitized oil and gas field map of North America is an ongoing cooperative project closely associated with the U.S. Geological Survey's Petroleum Data System, a computerized oil and gas pool data bank. The objectives of the project are multiple. The nominal product is

an oil and gas field map of North America to be published by the survey at a scale of 1:5,000,000.

The unique aspect of this project is that field images are digitized and filed with the Petroleum Data System; thus allowing field images to be retrieved in any projection at any scale on a TV screen or in hard copy using any of the pool parameters in the system. This capability allows a wide variety of visual exhibits. For example, fields can be displayed by age of producing formation, by discovery method, by size groups, or by type of trap. The images so retrieved then can be overlaid upon any useful type of base map. Thus, all the fields which produce from Lower Cretaceous rocks of Colorado could be superposed on a map showing the lithofacies and thickness of these strata.

Nearly all the manuscript state maps are complete. Editing, drafting, and digitization are under way. The oil and gas field map of Michigan has been completed and the computer capabilities of this example are on display at the U.S. Geological Survey exhibit at this meeting.

The rapidity with which oil and gas information may be retrieved and the versatility of selection and combination of data will provide a new tool for domestic oil and gas explorationists. [694]

#### **Probabilistic and Computer Methodologies Used by U.S. Geological Survey for Geologic Estimates of Undiscovered Oil and Gas Resources in United States**

BETTY M. MILLER and HARRY L. THOMSEN, U.S. Geological Survey, Denver, Colorado

Recent assessments of undiscovered recoverable oil and gas resources for the United States, published in U.S. Geological Survey Circular 725 (1975), were made: (1) by assembling and reviewing a comprehensive bank of geologic and geophysical information gathered on more than 100 petroleum provinces by more than 70 specialists within the U.S. Geological Survey; (2) by applying a variety of resource appraisal methods to each potential petroleum province; and (3) through group appraisals by petroleum geologists using subjective probability. These methods included the application of subjective-probability-assessment procedures, computer applications to probability distributions, and the computation of cumulative functions and statistics for regional and total-resource aggregations by Monte Carlo procedures.

Resource-appraisal procedures and methodologies employed by the Resource Appraisal Group for the latest published survey assessments of remaining oil and gas resources are reviewed, with emphasis on probabilistic assessment techniques and computer applications of Monte Carlo procedures.

The results are summarized for the undiscovered recoverable oil and gas resources in 15 regions in the United States, onshore and offshore to water depths of 200 m. Probability distribution curves are demonstrated for oil and gas resource assessments on selected regions. [698]

## **Interactive Computer Program to Analyze Coal-Energy Resources (PACER)**

ALLISON C. OLSON and SIMON M. CARGILL, U.S. Geological Survey, Reston, Virginia

The requirement for a rapid and timely retrieval and analysis of coal-resource inventory information has resulted in the development of software to adapt the Geologic Retrieval and Synopsis Program (GRASP) for application to the National Coal Resources Data System. The PACER system utilizes the basic search, retrieval, and analysis functions of GRASP, but also provides an interactive-editing capability to add, delete, or modify coal-resource and chemical-analysis records. It further permits tabular summary of information aggregated by location, coal rank, depth, and reliability for tonnage records and by location, rank, chemical, and BTU content for analysis records. The added editing capability provides a method for the user to enter new data into the master file and provides a check for data names not already in the dictionaries. It permits universal changes to a data element for all records residing in a selected data subfile, or selection by index key of a record previously identified for data change. This editing software, although unique to the assigned-record structure for a given master file, can be modified easily to accept additional files that have differing record structures. The coal-resource (tonnage) and analysis files contain information from published documents. Time-shared interactive software provides the user with the ability to respond to queries for resource-inventory information and to disseminate this information in comprehensible, hard-copy summaries. The editing capability ensures up-to-date maintenance for an ever-changing data base. [703]

## **AAPG Oil and Gas Field Data Bank Project, United States and Canada**

JOHN T. ROUSE, Consulting Geologist, Billings, Montana; ROBERT S. AGATSTON, Atlantic Richfield Co., Dallas, Texas; JERLENE BRIGHT, The University of Oklahoma, Norman, Oklahoma; and RICHARD M. PROCTER, Geological Survey of Canada, Calgary, Alberta, Canada

In 1973 the AAPG Research Committee started work on the "Oil and Gas Field Data Bank and Map Project of the United States and Canada." The purpose of the project is to check, update, and enhance the data in a functional oil and gas field and pool data base, developed by The University of Oklahoma Office of Research Administration under a contract with the U.S. Geological Survey. It is referred to as the Petroleum Data System (PDS) which has been developed over the past 6 years. This system is supported by the General Information Processing System (GIPSY) developed at The University of Oklahoma. GIPSY is a complete information-management system with utility provisions for building, moving, protecting, updating, and deleting information.

The PDS data base contains available nonproprietary geologic and other related information, such as the official field and pool name, location, and discovery date; producing formation(s), age, depth, and thickness; geologic basin; cumulative oil and/or gas productions; API gravity;

reservoir lithology; porosity; and oldest formation penetrated. In some fields proved acreage, reservoir temperature, pressure, gas/oil ratio, and sulfur content are included. The file does not contain all information on every field, but includes as much information as is available publicly.

More than 100 AAPG volunteer workers throughout the United States and Canada are contributing their time and talents to the project. A grant to the AAPG from the U.S. Geological Survey covers operating expenses.

The Petroleum Data System is being updated constantly and enhanced with data from many other sources such as the International Oil Scouts Association and AAPG's Committee on Statistics of Drilling. However, in some areas, the sparsity of data makes it nearly impossible to complete most items for individual fields.

The PDS file is another useful tool in exploring for new oil and gas reserves. It is available through time-sharing at the University of Oklahoma. [716]

### **Chemical and Isotopic Investigation of Stratigraphic and Tectonic Dolomites in Arbuckle Group, Arbuckle Mountains, South-Central Oklahoma**

K. A. SARGENT, Department of Geology, Furman University, Greenville, South Carolina

In the Arbuckle Mountains of south-central Oklahoma are excellent exposures of limestones and early diagenetic dolomites of Early Ordovician age. These units contain irregular bodies of late diagenetic dolomite associated with structures produced by a Late Pennsylvanian-Early Permian deformation.

Samples of limestone, early diagenetic dolomite, late diagenetic dolomite, and vein dolomite which cuts across all other structure were analyzed for 10 trace elements to determine if chemical differences are present between the early diagenetic and late diagenetic dolomites. On the basis of the trace-element analyses 20 samples were selected for carbon and oxygen isotopic analysis. The resulting trace-element and isotopic data were studied using standard statistical techniques and the multivariate linear-discriminant-function technique.

Four trace elements, Na, Li, Ni, and Cu, and the isotopic values  $\delta O^{18}$  and  $\delta C^{13}$  were found to discriminate at a high level between early diagenetic and the late diagenetic dolomite in the study area. A computer program was written for the IBM 1130 to utilize the functions generated by the linear-discriminant-function statistical technique to test unassigned dolomite samples and place these into the correct dolomite grouping.

The limestones and early diagenetic dolomites were similar in  $O^{18}$  content with  $\delta O^{18}$  averages of -6.9 and -6.8 respectively. This would indicate that the early diagenetic dolomitizing solutions were similar in isotopic composition to sea water. The late diagenetic dolomites were characterized by  $\delta O^{18}$  values higher than for the limestones and late diagenetic dolomites indicating that the late diagenetic dolomitizing solutions differed in isotopic composition from sea water. [719]

## **Lineament and Structural Analyses of Southeastern Kansas**

R. C. SHUMAKER, C. I. PIERCE, and W. K. OVERBEY, JR., University of West Virginia, Morgantown, West Virginia

Analysis of satellite and low-altitude remote-sensing imagery over the shoestring sand area demonstrates that the lineaments mapped reflect northeast- and northwest-trending regional joint sets. A north-south set of lineaments has no corresponding joint set.

Surface drainage lineaments in flat Permian sedimentary rocks reflect major subsurface structure formed during Late Mississippian and Pennsylvanian Ouachita deformation.

Review of the regional geology preparatory to geologic analyses of lineament patterns suggests that: (1) the late Paleozoic Nemaha ridge follows a late Precambrian and/or Cambrian rift; (2) late Paleozoic deformation formed diamond- and wedge-shaped upthrusts by left-lateral movement along the Nemaha and Beaumont structural trends; (3) left-lateral movement along the Nemaha fault zone and within the Anadarko basin imparted a slight clockwise rotation to the southwestern part of the Ozark crustal block; (4) fault patterns within the Ozark block appear to have been formed by tensional stress; (5) joints within the Permian rocks of southeastern Kansas approximate the normal-fault directions of the Ozark block; (6) the varied joint patterns over different types of producing fields suggest that secondary recovery rates and induced fracturing direction might vary considerably within this comparatively small area. Joint fractures and remote-sensing lineament studies could be useful in designing recovery projects and oil-field development patterns which consider induced fracture orientations. [722]

## **Basinward Facies Changes in Wapanucka Limestone (Lower Pennsylvanian), Indian Nations Turnpike, Ouachita Mountains, Oklahoma**

PATRICK K. SUTHERLAND and ROBERT C. GRAYSON, JR., School of Geology and Geophysics, The University of Oklahoma, Norman, Oklahoma

Important new exposures of the Wapanucka Limestone in the frontal belt of the Ouachita Mountains are on the new Indian Nations Turnpike, about 16 mi (26 km) south of McAlester, Oklahoma. The Wapanucka Formation in this area is repeated four times by faulting within a north-south distance of less than 2 mi (3 km). These exposures demonstrate a basinward change in facies southward, showing increases in thickness and in shales and an increase in spiculites as compared to crinoidal and oolitic grainstones. These exposures apparently represent the first documented case of basinward facies change southward from the main Wapanucka Limestone ridge.

The northernmost Wapanucka roadcut represents typical Wapanucka Limestone, as seen at many points along the frontal Ouachita belt. This exposure, 364 ft (111 m) thick, consists predominantly of interbedded spiculiferous, crinoidal, and oolitic limestones. Exposures south

of this ridge are much more subdued topographically, because of increasing percentages of shale. The third faulted "Wapanucka" exposure is 1.0 mi (1.6 km) south of the main ridge. Here the section measures 714 ft (218 m) from the lowest to the highest limestone, and is predominantly shale, with a few thin spiculiferous limestones. This sequence is considered to represent a basinward and deeper water facies of the Wapanucka, as present in the north, and was deposited approximately contemporaneously.

Conodonts from the lowest exposures in both sections suggest a correlation with a horizon probably no lower than the Dye Member of the Bloyd Shale of the type Morrowan in northwestern Arkansas. Goniatites from the middle part of the section have been placed by Mackenzie Gordon in the *Diaboloceras neumeiri* Zone, which is in the Trace Creek Member of the Bloyd Formation in northwestern Arkansas. Conodonts from this interval support the correlation. Conodonts from the highest beds indicate either a latest Morrowan or early Atokan age. [727]

### **Aulacogens and Megashears—Natural Habitat for Oil and Mineral Deposits**

JACK L. WALPER, Texas Christian University, Fort Worth, Texas, and  
J. M. Browning, J. M. Browning Consultants, Ltd., Calgary, Alberta, Canada

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

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

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

Three of these features are examined, the Athapuscow aulacogen of northern Canada, the Wichita aulacogen of southern Oklahoma, and the Huancabamba deflection of central South America. Problems related to their time of formation are discussed and their sedimentary and tectonic evolution described so as to point up the formation of local structures



and depositional basins and their relation to the evolution of the major tectonic feature.

Several other regional features having oil and gas potential, e.g. the Delaware basin of West Texas, the Bathurst Inlet of northern Canada, and the Mississippi embayment of the Gulf Coast, that now are being termed aulacogens are noted and some comparisons made. [730]

### **Preservation Window as Subunconformity Petroleum Source**

GREGORY W. WEBB, Department of Geology and Geography, University of Massachusetts, Amherst, Massachusetts

Oklahoma City field is an unconformity trap with a second crop of oil and gas, the first having escaped at the unconformity surface prior to Pennsylvanian burial. The large second crop apparently was generated in the "preservation window," the shallower and thermally immature part of the pre-unconformity section which was preserved from erosional beveling, and thus could become source rocks after deep post-unconformity burial. A simple method of approximating the time of source-rock maturity, applying the methods of Connan and Hood and others to local age and thickness data, supports the preservation-window explanation both for Oklahoma City and for similar interpretations of post-unconformity maturation of pre-unconformity sources in the North Sea. Kimmeridgian shales in the Viking graben and the Moray Firth basin matured long after burial by the tight-sealing Cretaceous formations, and Carboniferous coals yielded gas to unconformably overlying Permian sandstones after deposition of the Zechstein salt cover.

The analysis indicates that much of the Jurassic of the Grand Banks had matured prior to Early Cretaceous uplift and beveling, suggesting the possible loss of a petroleum crop at that time. Scattered preservation windows exist but their later yield may have been both limited and inadequately trapped. The unconformity-cut dome east of Atlantic City resembles the Oklahoma City situation, and likewise may have leaked a first petroleum crop and received subsequently another from post-unconformity maturation. [732]

### **GSA ANNUAL MEETING, NORTH-CENTRAL SECTION KALAMAZOO, MICHIGAN, APRIL 29-30, 1976**

#### **Interactive Computer Graphics and Petroleum Exploration**

THOMAS A. JONES, CARLTON R. JOHNSON, and DANNY C. PHILLIPS, Exxon Production Research Company, P.O. Box 2189, Houston, Texas

The computer can be a valuable tool in geologic analysis because of its speed and its ability to handle large amounts of data. Maps and cross sections can rapidly be generated at the interactive terminal. These dis-

plays provide a method for analyzing multiple working hypotheses with a minimum of delay and effort. In addition, the interactive computer provides valuable instruction in three-dimensional analysis of geologic data.

Exxon recently developed procedures, which we call *Interactive Exploration*, which stress direct control of the computer by the explorationist via an interactive terminal in the field office. Such control offers distinct advantages in editing and updating data files and combining seismic interpretation, well tops, and lithofacies information into a single, integrated time-stratigraphic framework. This framework contains the salient structural and stratigraphic features, and can be supplemented with lithologic data from well cuttings to build a 3-D computer model that can provide geologic cross sections between any points; in addition, structure, isopach, or geologic maps may be obtained. These displays can be plotted within seconds for immediate use.

These capabilities are illustrated in a brief color movie made to demonstrate interactive exploration. It shows geophysicists and geologists utilizing the interactive terminal on an exploration prospect, a capability that may be an important key to a comprehensive, rapid, and more effective search for future oil and gas reserves. [484]

## THE UNIVERSITY OF OKLAHOMA

### Structural Analysis of Asymmetrical Folds Using the Finite Element Method

JAMES MICHAEL ANTHONY, The University of Oklahoma, M.S. thesis, 1976

Fold shapes and strain distributions produced in stiff single layers inclined up to 20° to the direction of principal shortening were investigated using finite-element computer models. The finite-element model was formulated for constant strain triangles using the constitutive equation for a compressible, linearly viscous fluid. The model of a stiff layer imbedded in a less viscous medium was designed to accommodate 2½ Biot wavelengths. Inclinations of the stiff layer to the shortening direction were 0°, 5°, 10°, 15° and 20°. At each inclination, folds were produced with viscosity ratios of 17:1, 24:1 and 42:1. Folds were initiated by prescribing symmetric sinusoidal perturbations with limb dips of 2°. Results from models with 0° initial inclinations are similar to results obtained by others. Folds are sinusoidal and symmetric, and strain distributions are symmetrically disposed about axial planes in both the matrix and stiff layer. As layer inclination is increased, these features change. The folds become asymmetric (as measured by the ratio of limb lengths), and the amount of asymmetry increases with inclination. Finite strain distributions in both the stiff layer and matrix are not symmetrically disposed about the axial plane. Strains in the matrix tend to parallel the long limb of the stiff layer, and are 'refracted' through the long limb at a larger angle than through the short limb. The long limb thickens more than the short limb, and fold shapes change from sinusoidal to shapes that approach kink folds.

## **Geology of the Lower Ordovician Rocks of the Choctaw Anticlinorium, Southeastern Oklahoma**

JOSEPH F. DUNAGAN, JR., The University of Oklahoma, M.S. thesis, 1976

Previous investigations dealing with the geology of the inner Choctaw Anticlinorium have been contradictory and generally unsatisfactory and have usually interpreted the area as very gently deformed. This study attempts to provide an accurate map of lithologic distributions and a more realistic structural interpretation.

Map units were defined on the basis of lithologic contrasts. Shale is the most common rock type in the area, with less common occurrences of sandstone and shale. Samples of the three map units were examined, in hand specimen and thin section, but no significant differences between samples of similar lithology (that is, belonging to the same map unit) could be observed. Structural data such as orientations of fold hinges and cleavage and bedding surfaces were collected where possible. The major structural elements found in the map area are numerous small, disharmonic, isoclinal recumbent folds, and prominent slaty cleavage at consistently low angles that tends to obscure bedding in shales.

Field observations fail to demonstrate large-scale folding or high-angle faulting but do indicate that the area has been subjected to severe deformation with a pronounced low-angle component.

The distribution of rock types, the evidence of intense deformation, and the lack of evidence for large-scale folding and/or high-angle faulting suggest that a mechanism involving low-angle thrust faulting is responsible for the features observed in the map area. Such a mechanism of thrust faulting, combined with the lithologic types common in the map area, suggest that the pre-Bigfork Chert rocks of the inner Choctaw Anticlinorium acted as a major decollement zone, deforming in response to loading and subsequent gravity sliding of the entire sequence. Intense deformation accompanied by large accumulations of strain occurred in the pre-Bigfork rocks, while the younger strata were transported with relatively little deformation.

## **Contemporaneous Faults: A Mechanism for the Control of Sedimentation in the Arkoma Basin, Oklahoma**

MICHAEL WILLIAM McQUILLAN, The University of Oklahoma, Ph.D. dissertation, 1976

Basal Atokan and Morrowan deposition in the Arkoma basin was influenced by three down-to-the-basin growth faults similar to those that have been reported from the Gulf Coast. Across the faults, from the up-thrown northern to the down-thrown southern side, there are abrupt increases in the thickness of the lower Atokan and Morrowan strata. The increase in the lower Atokan is about 2,000 feet across the Kinta fault, and 3,000 to 4,500 feet across the San Bois fault. The increase in the Morrowan section is less dramatic and amounts to 100 to 200 feet; the changes in stratigraphic section in proximity to faults also occurs subjacent to the antithetic and synthetic faults within the major blocks.

The basal Atokan sand has been subdivided into a lower Spiro "B," and overlying Spiro "A" facies. The Spiro "A" is a below-wave-base, sub-marine sand, deposited by density currents in trends subparallel to depositional strike. The trends of maximum Spiro "A" thickness, and best sorting, occur subjacent to faults; Spiro "A" exhibits thinning and more above-wave-base, marine offshore bar sand, accumulating and restricted to pods that exhibit thickening over fault block paleotopographical highs. The distribution of the Spiro "B" facies is restricted to a 50-square-mile area in Tps. 8 and 9 N., Rs. 22, 23 and 24 E. The Spiro "B" represents an interruption of the early stage of transgression over the eroded Wapanucka Limestone; it was following by a transgression and the deposition of the overlying Spiro "A" sand.

The Spiro "A" sand is very fine to medium (0.11 to 0.35 mm), sub-angular to well rounded, and poorly to well sorted. The textural maturity is poorest over the crestal portions of fault blocks and is best subjacent to the bounding faults.

Intergranular pore space in the Spiro "A" and "B" sands has been reduced by the formation of secondary quartz cement. Chlorite coatings on the surface of the detrital quartz grains preserved intergranular porosity by retarding the formation of secondary quartz overgrowths. The distribution of porous versus non-porous sand due to diagenetic alteration is related to depositional environment. In those areas of the fault blocks where the sand is somewhat shaly (e.g., crestal portions), the best porosities and permeabilities are preserved. Along the margins of the fault blocks where the sand is thickest and best sorted, alteration by diagenetic quartz was most severe. This relationship resulted in the best reservoir rock (those wells with the greatest gas deliverability rates) occurring over and near the crests of fault blocks where the sand is somewhat shaly and least affected by secondary quartz cement.

The Cromwell has been subdivided (in descending order), into three facies, the Cromwell I, II and III sands. All three sands were mapped subparallel with depositional strike and subparallel with the fault pattern. The distribution of the Cromwell I is limited to the area around the Kinta fault block. The Cromwell II and III sands are present throughout the area, but as a whole are quite shaly. The shaly character is related to sediment supply and rate of subsidence—when sand supply was low and subsidence slow, shaly and poorly developed sands were deposited. The secondary quartz cement alteration history of the Cromwell sands was found to be similar to that of the Spiro sands. The best preserved porosity and permeability occurs in areas where the Cromwell is somewhat shaly; however, the overall shaly character of the Cromwell results in only limited favorable reservoir facies.

The source of the Spiro sand was to the east and northeast, with a limited contribution of sediment from the north. The Spiro may be the western, distal portion of an early Pennsylvanian clastic wedge originating in the Appalachian area. The source of the Cromwell was probably similar to that of the Spiro; local sources however, may have contributed substantial amounts of sediment.

The Arkoma basin was an area of basinal subsidence at a rapid rate, beginning as early as Morrowan and increased in intensity during deposition of the basal Atokan. The rapid rate of subsidence and growth fault

controlled sedimentation continued throughout deposition of the Atokan section.

The growth-fault mechanism might explain the transition from shelf and miogeosynclinal facies on the north to the eugeosynclinal (Stanley, Jackfork, and Johns Valley) facies to the south of the Choctaw fault. Perhaps the Choctaw fault was an ancient growth fault along which movement was reversed during the Ouachita disturbance.

The growth faults cutting the Morrowan basal Atokan section probably originated by movement in the basement and were perpetuated by basement movement and/or sedimentary loading and slumping.

### **Paleontology of the Garber Formation (Lower Permian), Tillman County, Oklahoma**

LARRY C. SIMPSON, The University of Oklahoma, M.S. thesis, 1976

The Lower Permian vertebrate-bearing sites in Tillman County, Oklahoma, the N. E. Frederick and W. Grandfield sites, were studied to expand the knowledge of vertebrate paleontology of the Garber Formation as well as to determine the paleoecology at these two sites.

At the N. E. Frederick site the fossiliferous zones are in a large lense of predominantly gray claystone that contains a large fauna and flora. Included at the site are remains of many vascular plants, pelecypods, tubular worms, fish (*Xenacanthus*, *Orthacanthus*, *Anodontacanthus*, *Hybodus*, *Sagenodus*, paleoniscoids), amphibians (*Eryops*, *Trimerorhachis*, *Diplocaulus*, *Diadectes*, *Archeria*) and reptiles (*Captorhinus*, *Ophiacodon*, *Edaphosaurus*, *Dimetrodon*). The sediments as well as the fauna indicate that the gray claystone lense is a lacustrine deposit situated in red flood-plain deposits of a deltaic or coastal-plain stream. Evidence is preserved to indicate that the lake dried up, killing all of the aquatic animals. The basin later refilled with water, and the fauna and flora were reestablished before the final filling by sediments. This site not only contains the largest fauna presently known from the Garber Formation but also represents the only Garber occurrence of *Anodontacanthus*, *Hybodus*, *Sagenodus*, *Archeria*, and *Ophiacodon*.

At the W. Grandfield site the section consists of reddish-brown mud-rock which contains conglomeratic channel-fill deposits. There is evidence that a scanty vegetation existed along the channels. Except for a few water-worn scraps of *Xenacanthus* and *Trimerorhachis*, the fauna is represented by three genera, *Eryops*, *Dimetrodon*, and *Araeoscelis*, all of which are either capable of locomotion on dry land or are completely terrestrial. Most of the vertebrate remains were found concentrated in a bone bed adjacent to one of the channels. The concentration of the specimens appears to have occurred in a backwash of the channel. This site appears to represent a relatively barren area traversed by a few shallow channels. *Araeoscelis* is new for the Garber Formation and represents the first discovery of the genus in Oklahoma.

## New Zip Code for OGS

Persons who order publications or request other information from the Oklahoma Geological Survey should note our new zip code, 73019, which has been designated for The University of Oklahoma and all its departments. All student mail for the university should be sent to 73026, and mail for the Oklahoma Center for Continuing Education should be coded 73037.

The 73069 zip code, which used to apply to all Norman residents, is restricted as of July 1 to addresses west of Porter Street and Classen Boulevard. All addresses on or east of Porter Street and Classen Boulevard are assigned a 73071 zip, and post-office boxes at the main office and the Boulevard station are assigned to zip code 73070.

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