Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY / VOL. 43, NO. 5 - OCTOBER 1983

On the cover—

New Report Describes Copper Deposits in Oklahoma Panhandle

The cover photo of the Wiggins no. 5 prospect is one of the illustrations included in a new circular issued recently by the Oklahoma Geological Survey. The photo, looking south on the south side of a creek, shows a 40-ft inclined adit in the Sheep Pen Sandstone near C SE SE SW sec. 30, T6N, R1ECM, Cimarron County, Oklahoma. The photograph can be found on page 13 of Circular 86.

This publication locates and describes some of the historic copper prospects that have been discovered in the Oklahoma Panhandle and nearby areas of Colorado and New Mexico. The author of the volume is OGS geologist Robert O. Fay.

A geologic map in color showing Triassic formations in the area and the copper deposits is included with the circular. The scale of the map is 1:31,680 (1 inch equals ½ mile).

Copper mineralization in the Sheep Pen Sandstone is lenticular and occurs in veins and pods distributed along bedding planes, joints, and fractures or is disseminated in the sandstone. In places it is found in vertical clastic plugs of the sandstone that can be more than 200 ft deep. The ore is chalcocite, malachite, and azurite and is associated with hematite.

There are, according to the author, 210 known prospects in the entire tri-state area, all in the Sheep Pen Sandstone. Fay's current work, however, offers the first detailed descriptions of the prospects and analyses of the ores.

In addition to the large map, which comes folded into a pocket attached to the back cover of the book, the circular contains five small maps, a table giving results of chemical analyses of the ores, and 17 photos, some of which are in color.

Oklahoma Geological Survey Circular 86, *Copper Deposits in Sheep Pen Sandstone (Triassic) in Cimarron County, Oklahoma, and Adjacent Parts of Colorado and New Mexico,* can be ordered from the Oklahoma Geological Survey at the address given inside the front cover. The price is $12 for hardback and $8 for paperback copies.

Oklahoma Geology Notes

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

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

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

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Contents

This publication, printed by The University of Oklahoma Printing Services, Norman, Oklahoma, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes, 1981, Section 3310, and Title 74, Oklahoma Statutes, 1981, Sections 231–238. 1,800 copies have been prepared for distribution at a cost to the taxpayers of the State of Oklahoma of $2,322.

POSSIBLE QUATERNARY MOVEMENT ON THE MEERS FAULT SOUTHWESTERN OKLAHOMA

R. Nowell Donovan,[1] M. Charles Gilbert,[2] Kenneth V. Luza,[3] David Marchini,[4] and David Sanderson[4]

Abstract—The surface Meers Fault of southwestern Oklahoma appears to be Quaternary. This fault is principally down to the south with a left-lateral component. The relation between this surface break and the large subsurface offsets of the frontal fault zone of the Wichita Uplift is problematical. The surface break could have been associated with a large-magnitude earthquake.

Introduction

The Meers Fault, a profound structural dislocation in southwestern Oklahoma, forms the southern margin of the Wichita frontal fault zone between the Wichita Uplift to the south and the Anadarko Basin to the north (Harlton, 1951; Harlton, 1963) (fig. 1). Major movement in Pennsylvanian to early Permian time resulted in vertical stratigraphic displacement (downthrown to the north) of several kilometers; at depth the fault appears to be a reverse structure (Brewer, 1982). In addition, left-lateral strike-slip movement in a transpressive stress regime is clearly expressed by the style and orientation of minor structures to the north of the fault (Donovan, 1982; Donovan and others, 1982).

Most of the movement along the frontal fault zone had concluded by Permian time, as the zone is overlain by the Pontotoc Group on the north and the Post Oak Conglomerate–Hennessey Shale on the south. However, a distinct fault trace cuts the Permian conglomerate and shale for at least 26 km from near Saddle Mountain to Cache Creek. The characteristics of this fault trace, in sum, are so unusual for the Midcontinent as to warrant specific mention and analysis.

Brief Review of Meers Fault Nomenclature

The Meers Fault was first formally described by Harlton in 1951 as the Thomas Fault, although the field work leading to this designation had begun

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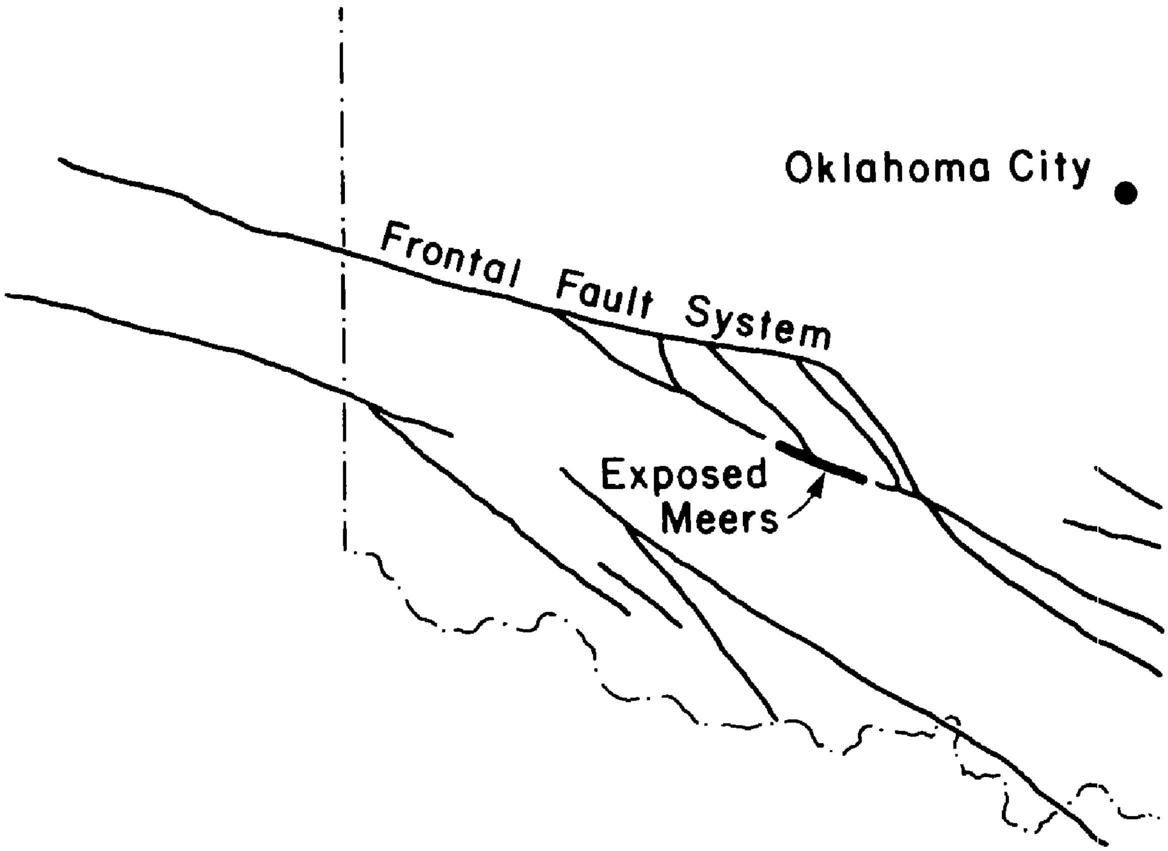

Figure 1. Regional fault system associated with the Wichita Uplift. The frontal fault zone is the complex of south-dipping faults separating the Anadarko Basin on the north from the Wichita Mountains on the south. These faults are Pennsylvanian in age and are buried by younger Permian strata. Only the Meers Fault is thought to have a distinct surface trace.

in the late 1930's. Harlton recognized the necessity for a large structural offset between the surface outcrops of the Wichita Mountains igneous complex of rocks on the south and the stratigraphically overlying Timbered Hills and Arbuckle Groups on the north. He further recognized a distinct lineament transecting the countryside and apparently assumed this was the trace of the structural offset. Interestingly, although he originally described the fault as down to the south (Harlton, 1951), his later, more comprehensive, paper (Harlton, 1963) showed it as down to the north. Harlton (1963) also provided further regional and subsurface data documenting the existence of a major fault in the vicinity of the surface Meers Fault and its linkage with the Pennsylvanian frontal fault zone. Relevant basement data are found in Ham and others (1964).

Miser (1954) used the designation "Meers Valley" Fault on the geologic map of Oklahoma. "Meers (Thomas)" appears on the more recent Lawton

1:250,000 sheet (Havens, 1977) and reflects the fact that "Meers" is the commonly accepted designation now.

Here we note that no definite evidence exists as to whether or not the surface trace is precisely on the line of the subsurface Pennsylvanian-age fault. By analogy to the Blue Creek Canyon Fault (the only exposed major fault in the area cutting basement and the lower Paleozoic sedimentary section), the subsurface Meers Fault is probably a zone of dislocation rather than a single plane (Donovan, 1982).

Description of the Meers Fault Trace

For most of its 26-km length, the fault is a single plane of movement that trends N60°W (300°). To the northwest, two or three minor braided branches are present, and at its termination in this direction a faint parallel offset can be detected on aerial photographs. To the southeast, the broad flood plain of Cache Creek seems to terminate the trace. Regardless of relief, the fault trace is straight. To the northwest, rocks cut by the fault are limestone-pebble conglomerates (Post Oak), whereas to the southeast they are sandstones and calcrete-bearing shales (Hennessey). Regardless of lithology, there is a consistent topographic downthrow to the south (figs. 2, 3), reaching a maximum of 3 to 5 m near the trace's center in the vicinity of State Highway 58. Modern drainage appears to have been locally controlled by the fault scarp, which interrupts otherwise smooth topographic profiles on both shale and conglomerate (fig. 4).

Fractures associated with the surface fault plane show no slickensides, cut individual pebbles (fig. 5), and are vertical and unmineralized. Orientation of these fractures is shown in figure 6 and can be interpreted either as Riedel shears or as *en-echelon* tension joints.

Sense of Movement and Dip of Fault

A major element of movement was a clearly expressed downthrow to the south. In addition, left-lateral strike-slip displacement is indicated by the orientation of minor fractures and by the sense of displacement of pebbles cut by fractures parallel to the fault (fig. 5). Furthermore, the straight fault trace implies a vertical fault plane, as is expected with offsets having strike-slip components. We note that left-lateral displacement is in accord with the Pennsylvanian fault movements but that downthrow to the south is the reverse of that expected.

The vertical attitude of the surface fault plane is not in accord with known shallower dips in the frontal fault zone (fig. 7). Both Harlton (1963) and Takken (1968) showed 40°-45° dips to the south on the subsurface Mountain View Fault. Brewer (1982) interpreted both the Meers and the Mountain View

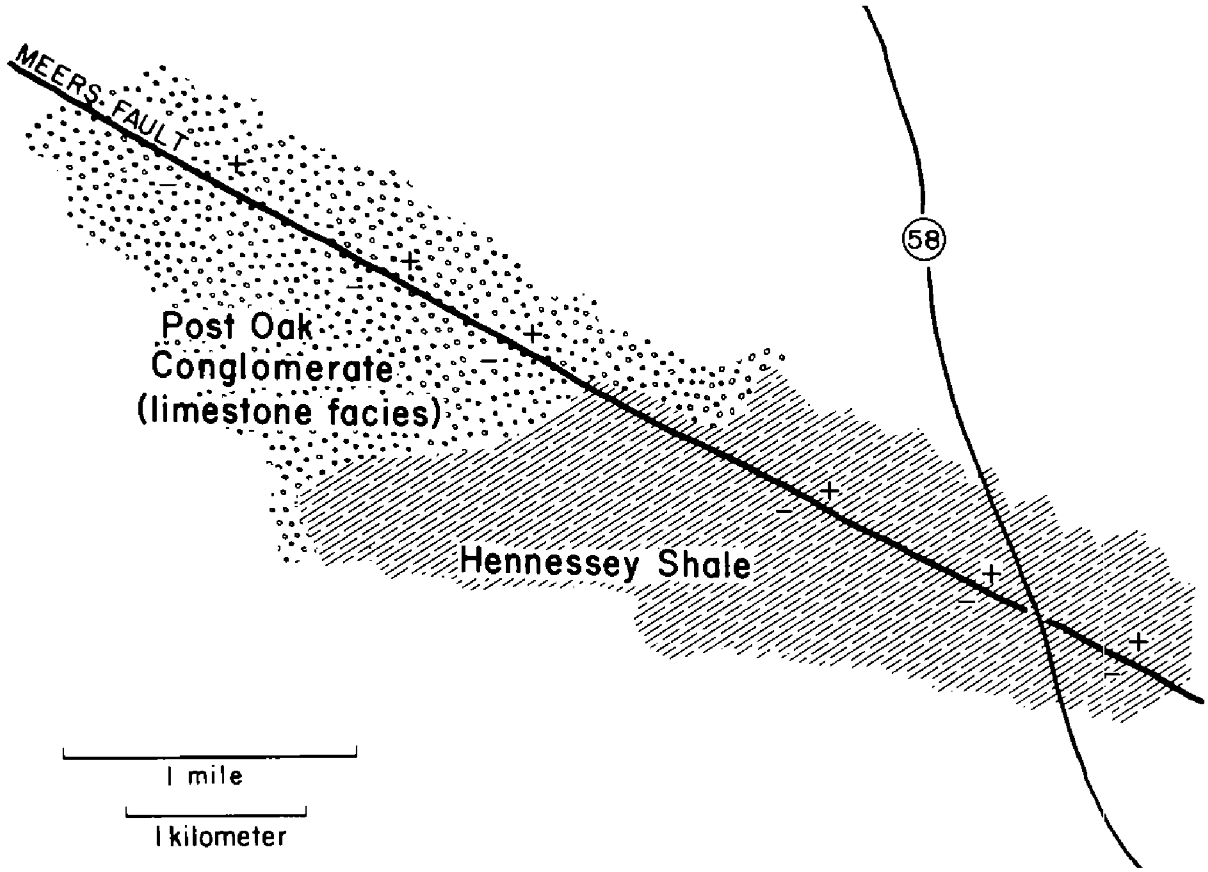

Figure 2. Areal geologic map along the Meers Fault trace west of State Highway 58. Relative topographic relief along trace is indicated as: high side, + ; low side, -.

Faults as deep thrusts, maintaining 30°-40° dips to the south to a depth of 20–24 km. It is also clear that most of the frontal faults are truncated by a pre-Pontotoc unconformity, whereas the surface Meers is cutting much younger Hennessey-Post Oak beds.

Dating the Movement

Dating of movement on the Meers Fault depends on whether the topographic displacement across the fault is interpreted as a fault-line scarp or as a true fault scarp (Gilbert, 1983a). If the former interpretation is preferred, then the most likely date of movement would be Permian—that is, a last adjustment between the Anadarko Basin on the north and the Wichita Uplift on the south (albeit with a downthrow in the "wrong" direction). If the fault trace is regarded as a true fault scarp, then movement took place recently.

The argument for recent movement is most strongly supported by the consistent continuation of the fault trace across areas where the Permian units consist of shales. Where the fault cuts conglomerates, it can be argued that

Figure 3. Photograph of Meers Fault scarp looking northwest. Downthrow is to the right (south). Geologist is walking along the scarp in the near ground. The scarp in the far ground is directly along the projection from the viewer through the geologist.

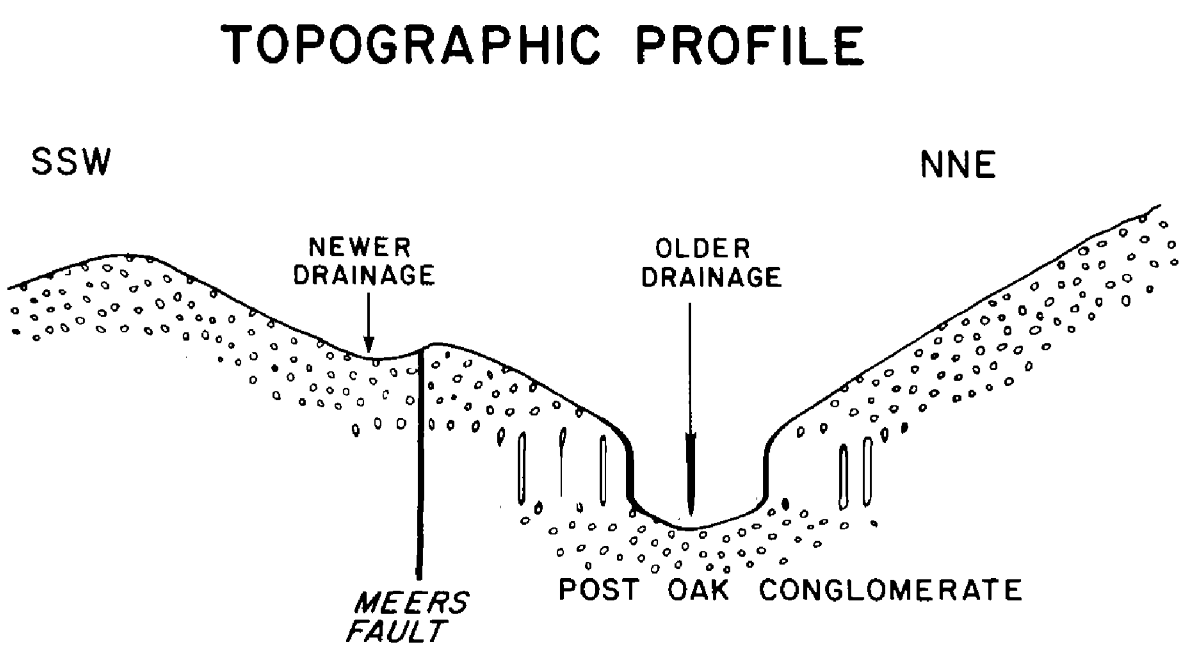

Figure 4. Topographic profile across view of figure 3.

Figure 5. Photograph of cobble along the Meers Fault trace, showing down-dropped slices to the south. Lens cap at the top of the picture (on the north) is 6 cm in diameter.

the trace is exhumed—that softer rocks overlying the conglomerate have been removed on both sides of the fault by erosion or that different degrees of cementation on opposite sides of the fault have caused unequal erosion. However, in areas underlain by shales, relief is unlikely to have survived from Permian time. Unfortunately, close inspection of the shales shows that calcrete horizons occur on both sides of the fault; these pedogenic carbonates resist weathering and have exerted a small but definite control on elevation. Thus the "exhumation" argument cannot be completely dismissed.

Nevertheless, there are other supporting arguments in favor of recent movement. For example, stream-valley profiles that have eroded along the fault line are more "youthful" than those developed elsewhere. In addition, open joints associated with the fault are not mineralized, despite the fact that they cut the Post Oak, which is a limestone conglomerate well cemented by calcsparite. While the argument is not definitive, we feel that the weight of evidence is in favor of recent movement.

Consequences of Quaternary Movement

The authors are not aware of any examples of Quaternary fault movements that affect bedrock in Oklahoma. Knechtel and Rothrock (1935) suggested

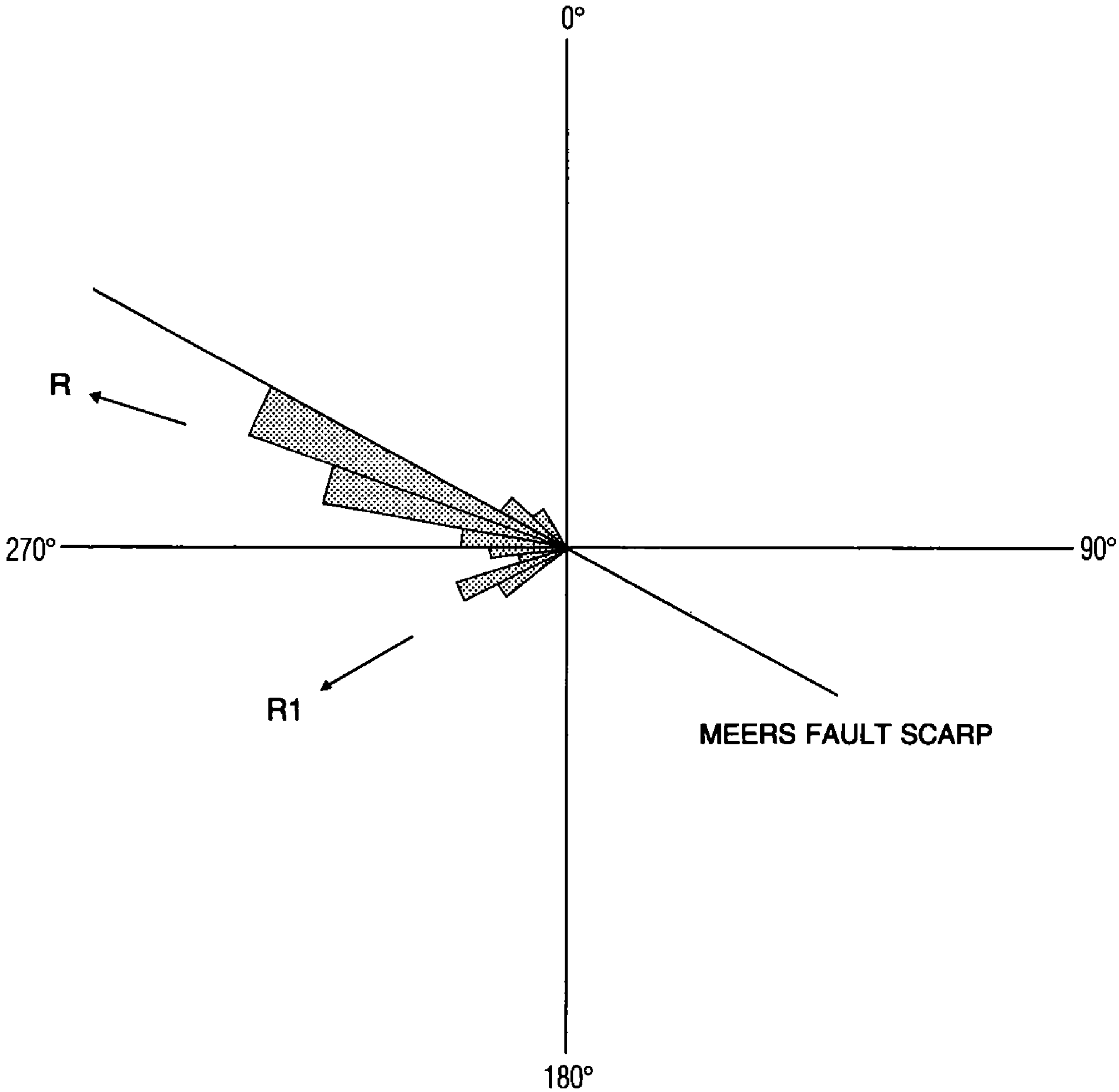

Figure 6. Orientation of minor fractures associated with the Meers Fault that cut the Post Oak Conglomerate. The major mode can be interpreted either as Riedel shears or as *en-echelon* tension joints. (R = Riedel fractures, N 73° W; R_1 = conjugate Riedel fractures, S 60° W; 126 readings.) Both interpretations are consistent with left-lateral movement.

that there may be active strike-slip faulting along a ridge in the western part of the town of Atoka, Oklahoma. Their argument was supported by a linear trend of water- and sewer-main breaks along the slope of a ridge on the west side of town. However a 1976 study by Shannon & Wilson, Inc., for Black & Veatch, consulting engineers working on a proposed nuclear-power-plant site east of Tulsa, Oklahoma, concluded that the surficial disturbances resulted from mass-wasting processes and expansive clays.

If the 26-km-long Meers fault-surface break and accompanying 3–5 m offset occurred at one time, an earthquake of considerable magnitude could

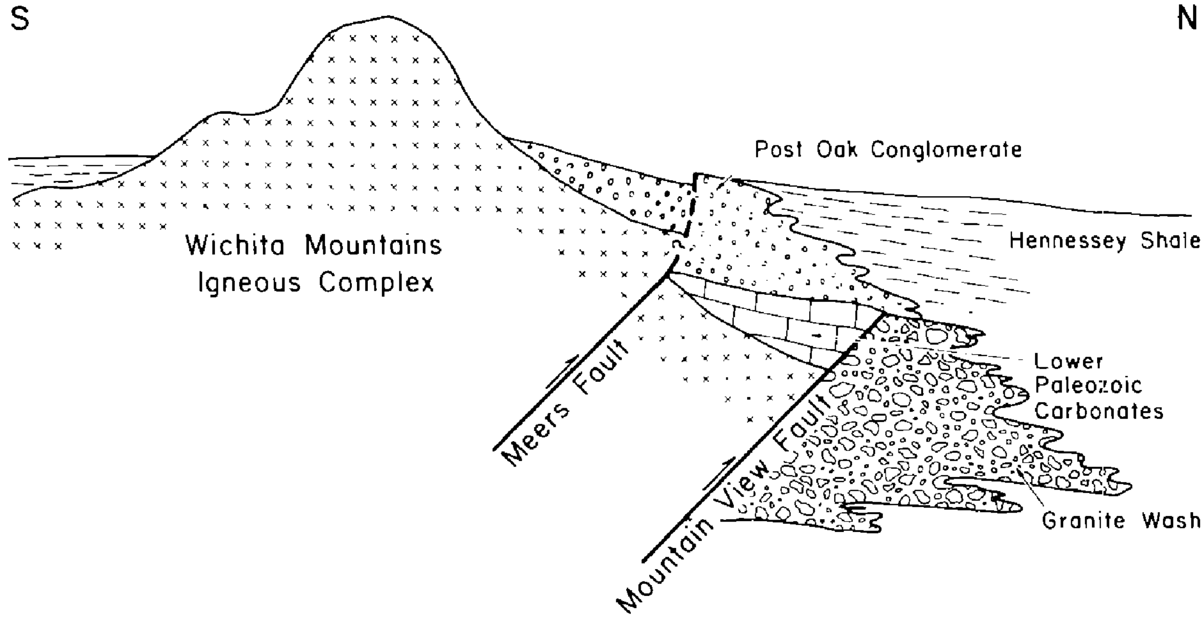

Figure 7. Schematic cross section showing attitudes of the surface Meers Fault and the subsurface frontal faults.

have resulted (Gilbert, 1983b). A review of earthquake data from 1897 to 1982 clearly indicates that the Wichita Mountains are historically very quiet (fig. 8). Because the Wichita Uplift consists of older layered gabbros, pinned by later gabbros, and overlain by granite sheets, perhaps the rigidity of the uplift may be greater than surrounding regions. Thus, stress could be built up to higher levels without release in the Wichitas compared to, say, Canadian County or Carter County, areas locally quite seismically active. When the stress in the Wichita Mountain area is relieved, as by a substantial break and its concomitant large earthquake, it would be expected that the crust in this region would then experience very low activity for considerable time. Of course, the existence of seismic gap for this region remains very speculative.

One consequence for Quaternary geologists and geomorphologists is that an earthquake of such magnitude could have affected many landforms in the region. For example, in the locally steep-relief landscape of the Wichita Mountains, toppled tors and landslides which have occurred since removal of Permian shale should be sought.

Another consequence for regional structural geologists is that the surface Meers trace may not directly reflect, in either position or character, the subsurface older fault. Further studies, such as several seismic-reflection profiles and closely spaced core-holes, would substantially enhance our knowledge of this fault zone.

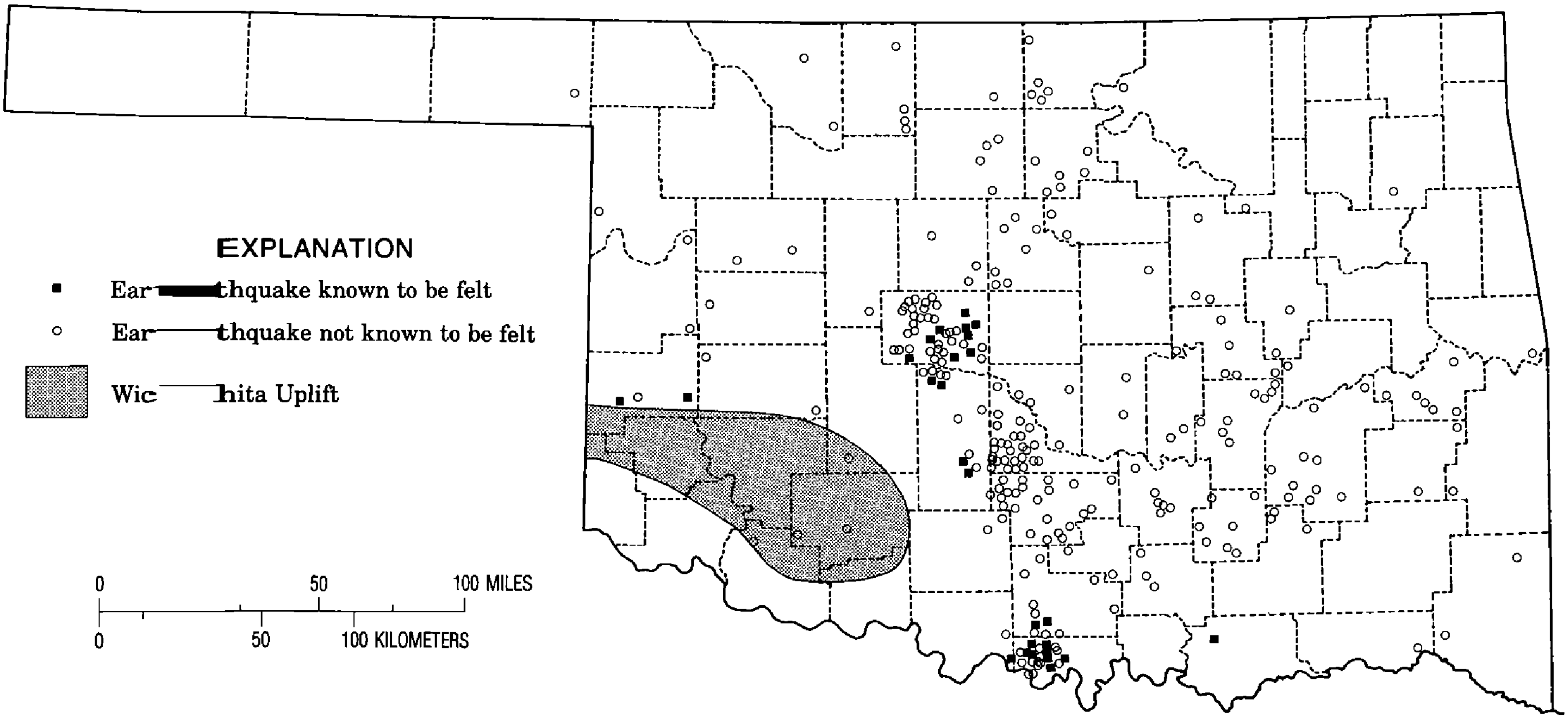

Figure 8. Earthquake distribution for Oklahoma, January 1, 1977, through December 31, 1982 (modified after Luza and Lawson, 1983).

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UPDATE ON OGIRS: THE OKLAHOMA GEOGRAPHIC INFORMATION RETRIEVAL SYSTEM

W. Anthony Blanchard[1] and Stephen J. Walsh[2]

Abstract—The Oklahoma Geographic Information Retrieval System (OGIRS) is a minicomputer-based geographic-information system developed at the Center for Applications of Remote Sensing (CARS) at Oklahoma State University. The second generation of the OGIRS software now has added capabilities and improved operating efficiencies.

Introduction

The Oklahoma Geographic Information Retrieval System (OGIRS) was developed at the Center for Applications of Remote Sensing (CARS) at Oklahoma State University in an effort to provide an efficient data-management tool for remotely sensed map and other collateral information (Blanchard and Walsh, 1982). The system requirements were defined by several external conditions as well as by the needs of the user community. In general, the basic framework of the system required a method of converting tabular, map, and digital-image data formats into a spatial context and a common digital format for efficient mass-media storage. In addition, data-display and integration-manipulation functions were needed.

The first generation of OGIRS satisfied the above requirements, although many of the data entry, storage, and retrieval techniques were not space or time efficient (Blanchard, 1982). The data entry, storage, and retrieval subsystems were redesigned to remedy the problems, but the overall concept and system capabilities have not been altered (fig. 1).

Data Entry

Data input into OGIRS still requires the use of an on- or off-line graphics digitizer, a remote terminal, or a digital image product. Two important improvements have been made to facilitate the data-entry process: (1) a new

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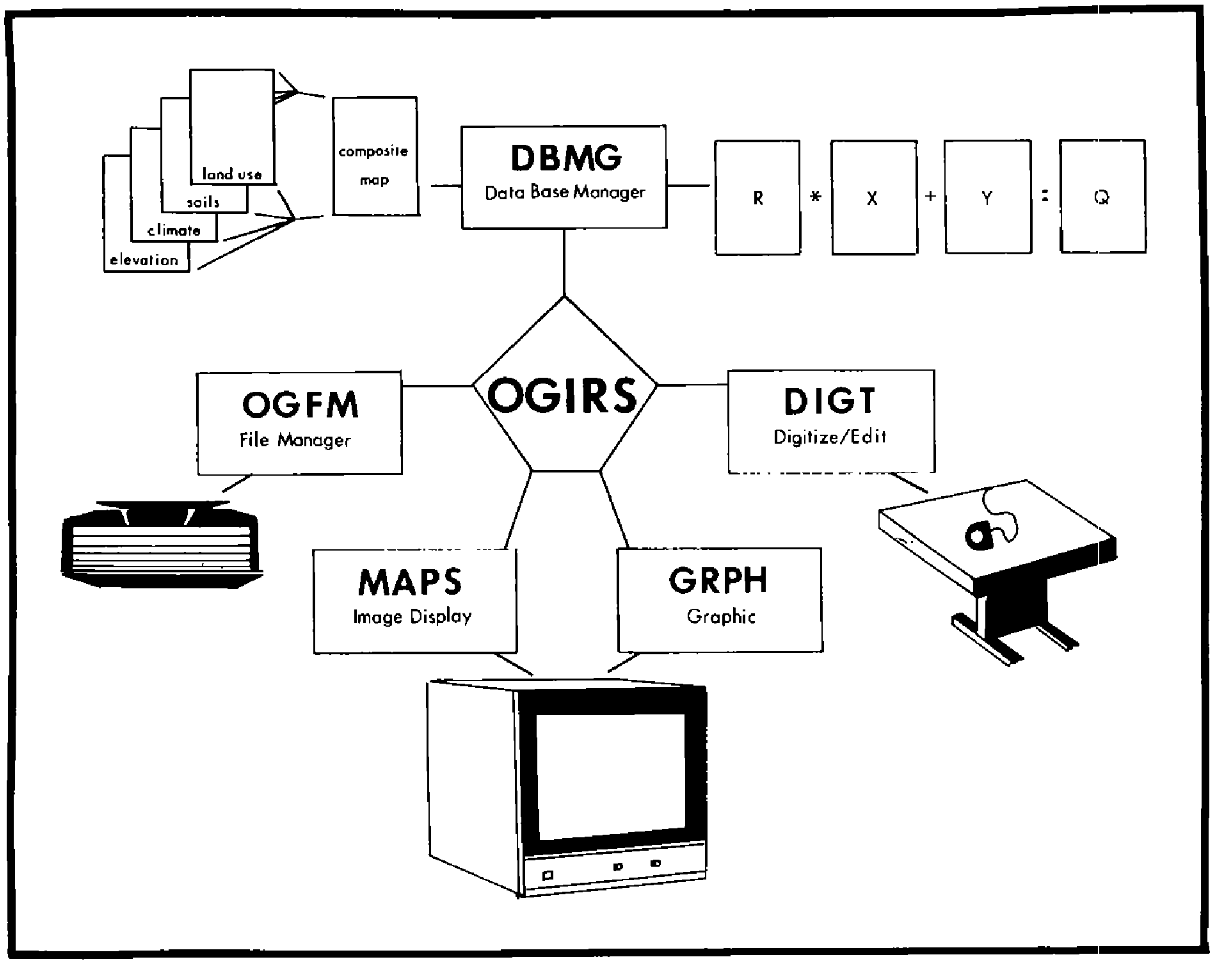

Figure 1. Program organization of OGIRS.

digitizer-interface program and (2) an assembly-language subroutine for data input and output.

Previously, the OGIRS Digitize/Edit subprogram required every cell in a map grid to be manually digitized. This rather slow and tedious procedure has been replaced by a line-scan method (Miller, 1982). The line-scan method of digitization vastly increases the speed of manual digitization, even with large and complex maps. In short, a new point is entered along a line only when the Z-value changes. Interim fill and scaling are accomplished automatically by the program. The program functions in both line and element and UTM coordinate systems.

Originally, only Landsat Multispectral Scanner (MSS) digital data were integrated into the OGIRS data-storage files. Subsequent research at CARS, using NOAA-6 satellite Advanced Very High Resolution Radiometer (AVHRR) digital data to study evapotranspiration and drought stress, has produced a need to incorporate these data into the information-system framework.

A more generalized technique was required to reformat digital data from different satellite data-gathering sources and different image-production facilities. An assembly-language subroutine was chosen because of its ability to handle input, output, and transformation functions on a bit by bit basis, thereby avoiding any higher level inconsistencies. Although only Landsat MSS, Landsat-4 Thematic Mapper (TM), NOAA-6 AVHRR, and GOES/SMS Visible Infrared Spin Scan Radiometer (VISSR) data are currently available for system integration, digital imagery from any remote-sensing platform may be entered into OGIRS thematic libraries with a minimum of processing.

Data Storage

The format formerly chosen for data storage reflected the dominant storage medium then in use, magnetic tape. Sequentially accessible disk files have the advantage of simple structure, and access speed is negligible for small data sets. As the size and complexity of data sets increased significantly, the slow speed of the sequential access files became apparent and untenable.

A packed-word, channel interleaved by line data storage format was selected for the efficiency in space and time and compatibility with other image-processing software at CARS. Data are still organized into thematic libraries; however, a single header record containing the data-set dimensions, other housekeeping information, and map titles replaces the individual map-header records. The packed-word format (this means one element of a map grid is stored as one byte; therefore, with the 32-bit architecture of the Perkin-Elmer minicomputer, four elements are stored per word) fits very well with the channel interleaved by line format to maximize critical disk-storage space.

Arithmetic Functions

A set of arithmetic functions was added as a complement to the relational modes and mapping functions of OGIRS. The set includes the usual arithmetic operands as well as trigonometric functions. All operations may be performed between a single thematic library channel and user-defined constants, or between two or more thematic library channels. Arithmetic functions extend the model-building capabilities of OGIRS by providing the user with the ability to enter spatial data-base parameters into equations as variables.

Image Display

A pseudo-color image-display subsystem was incorporated into OGIRS to take advantage of the image-display facilities at CARS and add a new dimension to data presentation. Thematic library channels may be displayed in normal or enlarged modes. In addition, color tables may be constructed over the full 256-value range, brightness to contrast ratio (b/c) functions may be built, and multiple channels may be displayed simultaneously. Other features include value highlighting and nonlinear b/c function control for image enhancement.

Conclusion

The Oklahoma Geographic Information Retrieval System is evolving into a sophisticated minicomputer-based spatial-information and image-analysis system. New functions include better data entry and storage, arithmetic functions, and a color-image display capability. Previously, these functions either were not available or were available only through other software systems. These and future improvements will increase the user's ability to manage large, complex, spatially oriented data bases with efficient algorithms and data-handling software.

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OGS ISSUES NEW INDEXES TO GEOLOGIC MAPPING IN OKLAHOMA

A new set of map indexes delineating surface and subsurface areas mapped in Oklahoma from 1977 through 1979 has been released by the Oklahoma Geological Survey. Issued as OGS Map GM-26, *Indexes to Surface and Subsurface Geologic Mapping in Oklahoma, 1977–79,* the indexes provide a convenient source of information to anyone interested in the geology of the State. The maps were compiled by Kenneth V. Luza, engineering geologist with the Survey, Elizabeth A. Ham, associate editor with the Survey, and Philip R. Sanders, former assistant to Luza; assistance was given by George A. Laguros and Rosann E. Rayome.

The set consists of two plates, one showing surface areas mapped during the time period covered, and the other designating subsurface areas. Areas outlined on each map are numbered, with numbers corresponding to bibliographic references listed on each plate. Eighty-one references to map sources that were used in the compilations are included.

GM-26 represents an updating through 1979 of previous indexes to geologic mapping that have been published by the Oklahoma Geological Survey, the first of which was issued in 1961. OGS Map GM-21, issued in 1981, covers the period from 1901 through 1976 for surface mapping; GM-22, also issued in 1981, shows subsurface mapping for 1967 through 1976.

These maps are available from the Oklahoma Geological Survey, 830 Van Vleet Oval, Norman, OK 73019 (phone: 405-325-3031). The price for GM-26 is $4; GM-21 is $4; GM-22 is $5.

BARTLESVILLE ENERGY CENTER OFFICIALLY CHANGES HANDS

The former Bartlesville Energy Technology Center, opened 65 years ago, is now the National Institute for Petroleum and Energy Research (NIPER). The facility changed hands officially in a ceremony held in late September of this year.

The Illinois Institute of Technology Research took over the center that was formerly operated by the U.S. Department of Energy. The new institute will perform research for state and local agencies, for private industry and, under a cooperative arrangement with the Energy Department, for the federal government.

The technology center has been the leading federal laboratory for research in developing petroleum technology.

MANKIN AWARDED CITATION FOR CONSERVATION SERVICE

Dr. Charles J. Mankin, director of the Oklahoma Geological Survey and executive director of OU's Energy Resources Institute, was recently awarded the Citation for Conservation Service Award of the Department of the Interior by Interior Secretary James Watt.

Mankin's work encouraging federal and state agencies toward greater cooperation was cited, as well as his "many contributions to the National Welfare through service to the Department of the Interior and to the earth-sciences profession." The certificate also says that Mankin's name "is one that immediately comes to mind when a major task involving mineral natural resources or the earth sciences, viewed from almost any perspective, needs to be undertaken."

Among Mankin's many duties was a recent seat on the Commission on Fiscal Accountability of the Nation's Energy Resources, the blue-ribbon panel composed of eminent individuals from academia, the legal profession, the oil industry, and the federal government. After the commission's recommendations were made, Mankin assisted the recently created Minerals Management Service (MMS) that was charged with implementing the recommendations.

"His assistance to MMS has been of major importance in its successful and timely response to the 60 recommendations of the Commission," Watt said.

GEOSCIENCE RESEARCH DRILLING OFFICE ESTABLISHED

The U.S. Department of Energy, Office of Basic Energy Science, has established the Geoscience Research Drilling Office at Sandia National Laboratories, Albuquerque, New Mexico. The mission of this office is to implement the Continental Scientific Drilling Program (CSDP) field activities related to drilling and borehole research.

Specific office functions include: (1) logistical support to field activities, (2) the development and maintenance of borehole-compatible instrumentation as required by the various drilling programs, and (3) coordination of field activities in order to keep program costs within budgetary constraints.

Initial office activities will center around the implementation of the Four-Lab proposal to drill in the Valles Caldera, Long Valley/Mono Craters, and Salton Sea area. The Office will also provide support to investigators drafting proposals for drilling intermediate depth holes at other sites.

The Geoscience Research Drilling Office is included in Sandia's Geothermal Technology Development Division, 6241. James Kelsey is the division supervisor, and Peter Lysne is responsible for the drilling office operations.

ERI AWARDS FUNDS TO OU FACULTY

Approximately $230,000 in State funds was awarded to 14 energy-research projects approved by the OU Energy Resources Institute (ERI) Advisory Committee for fiscal year 1984, which began July 1.

Faculty members submitted 49 proposals to the committee, requesting a total of $878,456 in funding, said Robbie Jameson, ERI's energy-information coordinator. The committee consists of the deans of those colleges from which proposals were submitted and representatives from ERI.

The School of Geology and Geophysics received three awards, and two projects in botany and microbiology were funded.

Funding in the College of Engineering was as follows: two projects in electrical engineering and computer science; one in aerospace, mechanical, and nuclear engineering; one in chemical engineering and material science; and one in petroleum and geological engineering.

Four awards were made to interdisciplinary research teams composed of workers in mechanical engineering, geology, mathematics, chemistry, and chemical engineering.

Approximately 16 student research-assistant positions have been created as a result of the awards, Jameson said.

MARKER PAYS TRIBUTE TO EXPLORATION TECHNIQUE

Oklahoma's role as birthplace of the reflection seismic technique of oil exploration has been honored on a historical marker recently placed on I-35, about 20 mi north of Ardmore.

The marker, placed at the first scenic outlook south of exit 51 on I-35, is the 19th in a series of markers co-sponsored by the Oklahoma Historical Society and the Oklahoma-Kansas Oil and Gas Association.

The first pilot seismic survey using the seismic technique took place in July 1921 a few miles from the site of the new marker.

SURFACTANT MIXTURES UNDER STUDY AT OU

It has long been known in the oil fields that mixtures of surfactants are more effective than pure surfactants in recovering oil. Dr. John Scamehorn, an OU chemical engineer, is trying to discover what combinations of surfactants work best and why.

Surfactant flooding is used when an oil well has stopped producing oil in sufficient amounts using conventional recovery methods. Surfactant flooding involves injecting water mixed with certain chemicals into the well to increase production again.

"Using mixtures of surfactants has several advantages," Scamehorn said. "Surfactants are not absorbed by the rocks in the producing formation as readily, nor do surfactants precipitate out of the water as easily when surfactant mixtures are used as when pure surfactants are used," Scamehorn said.

"I am trying to develop surfactant formulations which more effectively recover oil at a lower cost," he said. "I am taking a systematic look at the molecular structures involved to determine the optimum mixture of surfactants necessary under specified in-hole conditions to produce the greatest amount of oil from a well," he explained.

Using kaolinite, a nonswelling clay commonly found in oil producing formations, Scamehorn is studying the levels of adsorption and precipitation of mixtures of various commercially available surfactants to see how effective they are at recovering oil under varying salinity, temperature and other conditions. A nonswelling clay like kaolinite is easier to study than other commonly found clays that swell when surfactants are added.

Scamehorn's original study was supported by a grant from OU's Energy Resources Institute. The Energy Resources Institute provides limited funding to faculty members involved in exploring new concepts in energy research.

Scamehorn has received additional grants from the National Science Foundation and American Chemical Society totaling $60,000 to continue his studies.

"Surfactant flooding is the most versatile of all the enhanced oil recovery techniques," Scamehorn said. "Sometime in the next century, it could become the most widely applied enhanced oil recovery method if we solve the problems that remain," he concluded.

LEAFLET PROVIDES FACTS ON OIL AND GAS IN STATE

The importance of the petroleum industry in the economy of Oklahoma is highlighted in the new edition of a leaflet published by the Oklahoma-Kansas Oil and Gas Association.

Entitled "The Petroleum Industry in Oklahoma," it contains facts about drilling and production, refining, transportation, and marketing in the State. The industry's tax role is also indicated. In compiling the information, the association used data supplied by industry and public sources.

In fiscal 1982, the leaflet points out, taxes on oil and gas production paid to the State of Oklahoma amounted to $744,628,676. These taxes, which include the gross production taxes on oil and gas, the gas conservation excise tax, and petroleum excise tax, accounted for 27.2 percent of the total State tax revenue.

With the addition of the motor fuel tax receipts, for which the petroleum industry serves as a tax collector, the total tax burden on the industry and its customers was 32.2 percent of all State taxes collected. This includes direct State taxes only and does not include income tax, sales tax, or other taxes paid by the petroleum industry and its employees.

Oklahoma ranks third among all states in the amount of natural gas produced and fifth in oil production, the leaflet points out.

An indication of the widespread importance of the industry is the fact that oil or gas is produced in 73 of Oklahoma's 77 counties. In addition, petroleum accounts for 95.3 percent of the total value of all minerals produced in the State.

During each of the past several years Oklahoma has ranked second among all the states in the number of wells drilled, and the total footage of all Oklahoma wells drilled in 1982 was 62,693,790—a total of 11,874 miles into the earth.

At the start of 1983, there were 92,331 producing oil wells in the State, with average daily production per well of 4.6 barrels. There were also 20,742 producing gas wells. The total value of petroleum (both liquids and gas) produced in the State last year was nearly $10.5 billion.

The all-time value of crude oil produced in Oklahoma through the end of 1982 was $47.2 billion.

Copies of "The Petroleum Industry in Oklahoma" are available in limited quantities, free of charge, from the Oklahoma-Kansas Oil and Gas Association, 700 Adams Office Building, Tulsa, OK 74103.

NOTES ON NEW PUBLICATIONS

Oil and Gas Fields Bibliography

The Information Services Division of the University of Tulsa, producer of *Petroleum Abstracts* and the TULSA Database, has announced the availability of a portion of its new Oil and Gas Fields Bibliography, containing pre-1965 information on oil and gas fields throughout the world.

The entire bibliography contains nearly 4,600 citations to exploration and production information on oil and gas fields and dates from the early 20th century to 1965. The portion now available covers oil and gas fields worldwide, except for North America, and is one-third of the final bibliography; the remaining two-thirds, scheduled for completion later this year, will cover oil fields in the United States, Canada, and Mexico. The bibliography is indexed by geographical location, field name, and producing formation.

The Oil and Gas Fields Bibliography is a subfile of the TULSA Database, a computerized file of more than 300,000 bibliographic references to technical literature and patents on petroleum exploration and production. This database can be accessed only through the SDC Information Services' ORBIT Search System, which is an online database service. The special feature of the Oil and Gas Fields Bibliography is that while TULSA currently contains references only as far back as 1965, this bibliography provides historical oil-field information dated prior to 1965 that is available from no other source.

For further information, contact: Sherry Reese, University of Tulsa, Information Services Division, 600 S. College, Harwell 1st floor, Tulsa, OK 74104 (telephone: 918-592-6000, ext. 3005).

Development and Distribution of Rift Systems (1983)

Kevin Burke presented this 1-hour-and-52-minute slide-tape program as part of the 1982-83 AAPG Distinguished Lecture series. He discusses the origin and development of rifts and rift systems.

Order from: AAPG, P.O. Box 979, Tulsa, OK 74101. Catalog no. 919 consists of 70 slides and 4 tapes and requires 1 projector. The price is $175 in the U.S., $275 outside the U.S.

Principal Structural Features of Oklahoma

PennWell's new eight-color map of Oklahoma incorporates major geologic and geographic features into one 40- by 50-in. map at a scale of 1:500,000.

The map includes basins, mountain ranges, major anticlinal and synclinal trends, thrust faults, wrench or strike-slip faults, and other major faults. The inner margin of the Gulf Coastal Plain is also identified, as well as State and county boundaries, county seats, other city and town locations, and township and range lines. Five insets depict the surface conditions occurring in Oklahoma during the Paleozoic Era. Also provided is a correlation chart of Paleozoic tectonic movements in Oklahoma that depicts depositional and uplift occurrences in three regions of the State.

Order from: PennWell Maps, P.O. Box 21278, Tulsa, OK 74121. The price is $40 per copy in the United States and Canada, $58 export.

Deep Water Canyons, Fans and Facies: Models for Stratigraphic Trap Evaluation

Compilers Roderick W. Tillman and Syed A. Ali have gathered a 596-page grouping of papers offering a cross section of the type of work done on deep-water sediments during the past 30 years.

The book divides 30 papers from past AAPG *Bulletins*, section publications, and special publications into two sections. The first examines deep-water exploration models, deep-water fields, and fan development, while the second section looks at the final resting places of deep-water deposits and the processes that move them to these locations, specifically, delta-related deep-sea deposits, canyons, deep-water channels, and basin-controlled deposits.

A special 60-page bibliography compiled by Tillman and Ali concludes the book and offers a look at the literature available on deep-water deposits. The references are listed both alphabetically and geographically.

Order from: AAPG, P.O. Box 979, Tulsa, OK 74101. The price is $14 for AAPG-SEPM members, $18 for nonmembers.

Dynamics of Oil and Gas Accumulations

This entirely revised and updated edition of Alan Perrodon's work was published recently in France. The text, translated by Nissim Marshall, covers evolution of sedimentary basins, petroleum provinces, exploration philosophy, and hydrocarbon occurrences as linked to the geology and chemistry of source rocks, reservoir genesis, migration, and traps. The 368-page book is hardbound, with 220 figures, 5 tables, and 4 plates.

Order from: Elf Aquitaine, Documentation Centre Micoulau, 64018 Pau/France. The price is $32.

Texas Gulf Coast Oil and Gas Map

The second in a three-map series of U.S. Gulf Coast offshore oil and gas activity, this map is produced in 11 colors and includes federal and state lease block structure and status, pump and compressor stations, refineries and petrochemical plants with capacities, as well as a number of other features.

Order this 40- by 50¼-in., 1:500,000-scale map from: PennWell Books, P.O. Box 21288, Tulsa, OK 74121.

Studies in Continental Margin Geology

AAPG Memoir 34 was originally presented in January 1981 at a continental-margins research conference co-sponsored by the American Association of Petroleum Geologists and the University of Texas Marine Science Institute (now the University of Texas Institute for Geophysics). This volume is a companion to AAPG Memoir 29, *Geological and Geophysical Investigations of Continental Margins*, edited by J. S. Watkins, L. Montadert, and P. A. Dickerson, and published in 1979.

Memoir 34, edited by J. S. Watkins and C. L. Drake, is divided into two sections. "Field Investigations of Margin Structure and Stratigraphy" covers rifted margins and convergent margins, while "Model Investigations of Margin Environmental and Tectonic Processes" covers environmental processes and tectonic processes.

Order catalog no. 657 from AAPG, P.O. Box 979, Tulsa, OK 74101. The price is $38 for AAPG–SEPM members, $46 for nonmembers.

Maps of Sediment Thickness and Depth to Basement in the Western North Atlantic Ocean Basin

This two-map set by Brian E. Tucholke, Robert E. Houtz, and William J. Ludwig is based on seismic data collected by Lamont–Doherty Geological Observatory, Woods Hole Oceanographic Institution, the U.S. Geological Survey, Scripps Institution of Oceanography, the U.S. Navy, and the University of Texas Marine Science Institute.

Accompanying the map set is a 16-page explanatory-text booklet written by Brian E. Tucholke, Robert E. Houtz, and William J. Ludwig.

The set consists of two sheets covering the area from 15° N latitude to 45° N latitude, and from 40° W longitude to 85° W longitude. One sheet shows sediment thickness, and one sheet shows depth to basement. Map scale: 1 in. = 1° of longitude.

Order from: AAPG, P.O. Box 979, Tulsa, OK 74101. The price for catalog no. 649 is $16.

Water-Level Changes in the High Plains Regional Aquifer, Northwestern Oklahoma, Predevelopment to 1980

This 1:500,000-scale map, by John S. Havens, consists of one sheet outlining the aquifer changes for Harper, Ellis, Woodward, Dewey, Roger Mills, Cimarron, Texas, and Beaver Counties in Oklahoma.

The map was generated by a computer-graphics program using both predevelopment water-table altitudes and 1980 water-table altitudes.

For information on obtaining WRI Report 83-4073, contact: U.S. Geological Survey, Water Resources Division, Rm. 621, 215 Dean A. McGee St., Oklahoma City, OK 73102 (telephone: 405-231-4256).

OKLAHOMA ABSTRACTS

AAPG Mid-Continent Section Biennial Meeting Wichita, Kansas, October 16–18, 1983

The following abstracts are reprinted from the *Bulletin* of the American Association of Petroleum Geologists, v. 67, no. 8. Page numbers are given in brackets below the abstracts. Permission of the authors and of AAPG to reproduce the abstracts is gratefully acknowledged.

Ravia Nappe, Bryan County, Oklahoma: A Gravity Slide Block off the Tishomingo Uplift

MARK I. JACOBSON, Chevron U.S.A., Inc., Denver, CO

The Ravia nappe in Bryan County, Oklahoma, is located along the southwestern flank of the Tishomingo uplift, between the Cumberland and East Durant oil fields. This mass of Cambrian–Ordovician through Mississippian sediments tectonically overlies younger Springer shales (Pennsylvanian) of the Ardmore basin. Previously, this feature has been interpreted to have been thrust southward along the Cumberland fault, a fault parallel to the Ravia thrust. Reinterpretation of this area, with additional well data, indicates the Ravia nappe is a gravity slide block off the uplifted Tishomingo mountains.

The Ravia nappe subcrops below the Cretaceous unconformity as a 16 mi^2 (41 km^2) triangular-shaped mass with a maximum thickness of 4,800 ft (1,450 m). The fault surface along its base has a bowl-like shape. This surface is neither the Cumberland fault nor the Ravia fault, but appears to be a separate fault surface. The nappe consists of overturned Caney through Simpson rocks (Mississippian–Ordovician) along its southwestern edge (toe), whereas right-side-up Arbuckle carbonates (Cambrian–Ordovician) occur on the northeastern side (heel) of the nappe. Arbuckle carbonates of the nappe overlie an overturned-to-the-south syncline of Arbuckle through Springer rocks. This overturned syncline, on the footwall side of the Ravia fault, is present north of the Cumberland oil field and trends southeastward into Sec. 9, T6S, R8E. At this location the structural style of the Tishomingo footwall rocks changes from an overturned syncline south of the Ravia thrust to another thrust with a footwall fold. The Ravia thrust possibly terminates near this

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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.

change in structural style with the other northeast-dipping thrust continuing southeastward to the East Durant oil field.

The Ravia nappe is interpreted to have been originally the southwest overturned limb of the Tishomingo uplift. Prior to the major thrusting on the Ravia thrust, but after compressional folding and uplift of the Tishomingo mountains, a breakaway fault formed across the most intensely folded beds. This breakaway fault undercut the overturned southwestern limb of the Tishomingo uplift in a concave-upward fault surface. Gravitational forces caused the Ravia nappe Mississippian Caney rocks to Cambrian–Ordovician Arbuckle rocks to slide rotationally southwestward 2.5 mi (4 km). Topographic relief prior to the slide may have been as much as 9,000 ft (2,700 m). The slide occurred sometime during late Morrowan to early Desmoinesian.

Analogs of this type of deformation are present in the Owl Creek Mountains, central Wyoming; Front Range, northern Colorado; Qal'eh Raisi, southwestern Iran; and Belton anticline and Sulphur syncline, Oklahoma. These analogous structures and the Ravia nappe, show three common elements: (1) they are competent, erosion-resistant units which slide off the flanks of folded anticlines across softer shaly units; (2) the heel portion of the slide surface is a bedding plane fault; and (3) the driving mechanism is the gravitational force associated with tectonic uplift. [1325]

"Simpson" Reservoirs in Arkoma Basin and Ouachita Mountains, Oklahoma and Arkansas

RAYMOND W. SUHM, Texas Exploration Corp., Oklahoma City, OK

The Simpson Group and its equivalents are shown to have reservoir potential in the Arkoma basin and Ouachita overthrust region of Oklahoma and Arkansas.

The Simpson in Oklahoma, the Everton/St. Peter in Arkansas, and the Crystal Mountain/Mazarn/Blakely of the Ouachitas were studied in outcrop, and from well cuttings and logs to derive an understanding of (1) their stratigraphic relationships, (2) the nature and distribution of "Simpson" reservoir sands, (3) depositional and source environments, and (4) geologic history.

It was determined that sandstones of the Calico Rock, Newton, and St. Peter of Arkansas are equivalent to the Oil Creek, McLish (Burgen), and Bromide sandstones of Oklahoma, respectively. Further, the Crystal Mountain, lower Blakely, and upper Blakely sandstones of the Ouachitas are stratigraphically equivalent to the Oil Creek (Calico Rock), McLish (Newton), and Bromide (St. Peter), respectively.

The Everton/St. Peter is a mixed sandstone–carbonate association throughout most of the Arkoma but changes facies to carbonates in the eastern Arkoma basin and Mississippi embayment and is dominantly sandstone and shale in the southern and southwestern portions of the Arkoma basin in Arkansas. Similarly, the Simpson is a mixed sandstone–carbonate association in the Arkoma basin of Oklahoma, but is dominantly shale in the southern and southwestern portions of Oklahoma.

Sandstones of the Simpson and Everton/St. Peter were derived from a source to the north and were deposited in shifting strandline and shelf environments. Crystal Mountain and Blakely sands also were derived probably from the north but were deposited in deeper water fanlike environments via chutes on the downthrown sides of growth faults at the Arkoma basin (shelf) geosyncline transition. Substantial amounts of clay, however, were derived from a source to the south.

Regional cross sections, sand distribution maps, and paleogeographic maps are used to illustrate these ideas and to point out areas favorable for oil and gas exploration. [1327-1328]

Shallow Gas in Arkoma Basin—Pine Hollow and South Ashland Fields

JOHN WONCIK, Consultant, Tulsa, OK

The Pine Hollow and South Ashland fields located in Pittsburg and Coal Counties, Oklahoma, established a combined reserve exceeding 200 bcf of gas. The Hartshorne Sandstone of early Desmoinesian (Pennsylvanian) age is the producing zone at a depth of 4,000 ft (1,200 m). Gas, probably of biogenic origin, migrated into the reservoir shortly after deposition. Subsequent folding and faulting of the Ashland anticline resulted in repositioning of the gas in a downthrown fault trap. The upthrown anticline portion of the Hartshorne is water-bearing. Moderate well costs and high individual reserves have resulted in excellent economics. Competitive bidding on federal leases has resulted in a high bid exceeding $1 million for one tract in the South Ashland field. [1328]

Red Fork Sandstones (Lower Pennsylvanian) in Deeper Parts of Anadarko Basin, Oklahoma

PHILIP H. WHITING and STEVEN D. LEVINE, Tenneco Exploration & Production Co., Denver, CO

Red Fork sandstones in the deeper part of the Anadarko basin are the downdip equivalents of fluvial and deltaic sandstones in the Cherokee Group. The sandstones have repetitive, ordered sequences of sedimentary structures in vertical section. Individual bedsets display sharp basal contacts, gradational tops, and contorted bedding. The characteristics indicate these basinal sandstones were deposited by turbidity currents.

The sandstones occur as narrow, linear constructional channels that are dip-trending. The lateral change from channel-fill to overbank facies takes place abruptly. Channel sandstones display incomplete "AE" bedsets up to

12 ft (3.6 m) thick. Overbank deposits have thin "BE," "BCE," and "CE" Bouma sequences and generally are dominated by shale.

The sandstones are very fine-grained litharenites with an average composition of 58% quartz, 8% feldspar, 17% rock fragments, 5% other grains, and 12% matrix. Cement consists mainly of calcite ranging from 2 to 40% of the bulk volume. Quartz content tends to decrease upward and matrix increases upward within bedsets. The compositional grading is accompanied by a decrease in grain size upward within bedsets, indicating deposition during a decreasing flow-regime.

Red Fork sandstones are low-permeability reservoirs with an average porosity and permeability of 7.8% and 0.1 md, respectively. Natural gas reservoirs occur mainly in the thicker, channel sequences.

The bedding character of the channel and overbank facies is reflected in gamma-ray log responses. Log characters of the two facies are used to interpret turbidite sections of uncored areas. The interpretations are adapted to the East Clinton field for prediction of constructional channel reservoirs. The interpretation of dip-trending turbidite deposits may aid in exploration and development of the Red Fork sandstones. [1328]

Annual Meeting of Gulf Coast Association of Geological Societies and SEPM Gulf Coast Section, Jackson, Mississippi, October 26–28, 1983

The following abstracts are reprinted from the *Bulletin* of the American Association of Petroleum Geologists, v. 67, no. 9. Page numbers are given in brackets below the abstracts. Permission of the authors and of AAPG to reproduce the abstracts is gratefully acknowledged.

Suggested Nomenclature Change and New Reference Locality for DeQueen Formation, Pike County, Arkansas

THOMAS L. HAM and RANDAL J. LANDRY, Centenary College, Shreveport, LA

The DeQueen Formation of the Trinity Group, Comanchean Cretaceous, crops out in southwestern Arkansas and southeastern Oklahoma. The outcrop, located in the Highland gypsum quarry of Pike County, southwestern Arkansas, is described in detail in this paper and presented as a reference locality. Data from the locality provide the basis for a nomenclature change from the DeQueen Limestone Member to the DeQueen Formation. The formation consists of 64.23% clastic sediments, 24.72% gypsum, and 11.05% limestone. Hopper salt casts, ripple marks, scattered pyrite and marcasite nodules, celestite, and chickenwire gypsum can also be found. The DeQueen Formation is underlain by clays and the Ultima Thule Gravel lentil, while the

top is unconformably overlain by Upper Cretaceous Tokio gravels.

The general paleoenvironment represents a normally low-energy subtidal environment ranging from brackish to normal to hypersaline waters in a lagoonal setting that shallows upward. [1465]

Textures of Chert and Novaculite: An Exploration Guide

WALTER D. KELLER, University of Missouri-Columbia, Columbia, MO; CHARLES G. STONE, Arkansas Geological Commission, Little Rock, AR; and ALICE L. HOERSCH, LaSalle College, Philadelphia, PA

Textures of chert and novaculite observable in scanning electron micrographs (SEMs) are useful as a practical, geologic thermometer for estimating the maximum temperature of those rocks since deposition. Such information may be further applied during exploration for hydrocarbons (maturation or degradation), and for metallic and nonmetallic minerals, in those and associated rocks.

Scanning electron micrographs taken of cherts and novaculites that crop out in the Ouachita Mountain foldbelt of Arkansas and Oklahoma, and in areas adjacent to exposed and buried intrusives, show a sequential range in textures from cryptocrystalline, anhedral quartz in the [nonmetamorphosed] chert and novaculite to coarse euhedral, polygonal, triple-point quartz 60 μm in diameter. A similar range of textures occurs in chert of a contact metamorphic aureole on the Isle of Skye, Scotland, where classic metamorphic mineral suites from talc through tremolite, diopside, and forsterite grades are represented. Hence, some chert and novaculite of the Ouachita Mountain foldbelt shows textures morphologically correlative with classic representatives of varied metamorphic conditions.

Measurements were made of grain sizes of the quartz along transects across the SEMs of chert and novaculite from the Ouachita foldbelt. From them an isopleth map was made showing mean grain sizes of the polygonal triple-point texture developed. The map defines a linear 25 to 65 km (15 to 40 mi) wide belt that extends from Little Rock, Arkansas, about 250 km (155 mi) west to Broken Bow, Oklahoma. The texture increases from the margins to the core of the Ouachita Mountain foldbelt and contains two coarse-grain anomalies, one near Little Rock (35 μm diameter) and another near Broken Bow (15 μm diameter). This textural belt, with anomalies, conforms to the most intense, predominant late Paleozoic, structural deformation in the Ouachita Mountains. Previous interpretations have considered the rocks in the core of the foldbelt to have attained a maximum metamorphic grade in the zeolite to lower greenschist facies.

Cherts and novaculites adjacent to Magnet Cove, a Cretaceous age pluton in the eastern Ouachita Mountains of Arkansas, illustrate a superposed over-

printing of polygonal triple-point texture. It ranges from a background of about 2 μm (talc grade) in chert 1,370 m (4,500 ft) from the pluton to about 45 um (forsterite grade) from near the contact. Private drilling operations indicate that the pluton contact dips about 45° beneath much of the sedimentary rock that exhibits locally anomalous crystallinity. Homogenization temperatures of vein quartz, determined by H. Jackson in 1973, show a gradient along this profile of slightly more than 200°C (390°F) in quartz 1,370 m (4,500 ft) from the pluton, to about 440°C (825°F) near the contact. Novaculite xenoliths in the adjoining Potash Sulphur Springs intrusive are coarser in texture, 60 μm or larger, and represent the higher temperature periclase metamorphic grade, approximately 760°C, 1,400°F, at Crestmore, California, according to Carpenter.

The triple-point texture and coarseness of chert and novaculite are related to the degree of thermal maturation resulting from various heating events. The crystal morphology is equivalent in the two processes described (regional and contact metamorphism), but the changes due to individual agents, temperature, physical deformation, time, depth of burial, and mineralizers have not yet been resolved separately.

Very small quantities of chert and novaculite, by using SEM techniques, can serve as a guide to areas that have undergone elevated rock temperatures resulting from deep burial, mechanical stresses, intrusions, exhalations, and other thermal events. These investigations are relevant in determining temperature levels that may mature or degrade hydrocarbons, and offer clues in exploration for thermally related metallic and nonmetallic minerals. SEM studies of cherts and novaculite now provide another method of ascertaining the thermal maturation of rocks. [1466]