Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY/VOL. 44, NO. 4—AUGUST 1984

On the cover—

Molybdenite Sample Recovered

August's cover shows a photograph of a molybdenite (MoS_2) sample taken from the Willis quarry (sec. 6–T6N–R12W), in Greer County, Oklahoma. The photograph was submitted to the *Notes* by Zuhair Al-Shaieb, of Oklahoma State University. Al-Shaieb said this is the first reported molybdenite occurrence in the Wichita Mountains province.

"Molybdenite mineralization occurs as fracture fillings and as disseminations in the Reformatory granite. The mineralized zone is enriched in hornblende, and with biotite to a lesser extent," Al-Shaieb added.

Oklahoma Geology Notes

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

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

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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 $2,375.

THE VIOLA SPRINGS FORMATION (ORDOVICIAN) OF OKLAHOMA, A HEAVEN FOR GRAPTOLITE SPECIALISTS

Stanley C. Finney,[1] Leo Frederick Gentile,[1] and Randy Asbery[1]

The Middle to Upper Ordovician Viola Springs Formation of the Viola Group is well known in Oklahoma not only for its excellent exposures in the Arbuckle Mountains but also for its record in the subsurface as a petroleum reservoir. It is a relatively thick formation in the lower Paleozoic of Oklahoma, with its thin- to medium-bedded micrites and interbedded calcareous shales occupying a conspicuous stratigraphic position above the birdseye limestone and coarse-grained, richly fossiliferous limestones of the Bromide Formation and below the massive, coarse-grained, fossiliferous limestones of the Welling Formation (see Amsden and Sweet, 1983, text-fig. 2). The lithostratigraphy is known from several older studies (e.g., Decker, 1933; Wengerd, 1948; Glaser, 1965) and more recently has been the subject of detailed investigations (Smith, 1982; Galvin, 1983; Gagnier and Laury, 1984; Gentile, in progress). Unfortunately, an extensive knowledge of the biostratigraphy necessary for regional correlation of lithofacies is lacking. Needless to say, this greatly limits any interpretation of the depositional history.

Previous biostratigraphic studies of the Viola Springs Formation are of limited use for detailed lithostratigraphic correlations. The shelly fauna, consisting of brachiopods (Alberstadt, 1973), nautiloid cephalopods, and conularids is rather poor. Conodonts, chitinozoans, and graptolites, which are biostratigraphically useful fossils, are abundant. However, previous studies of these fossils either are limited to a few sections (Jenkins, 1969; Amsden and Sweet, 1983), are outdated (Ruedemann and Decker, 1934), or lack precise stratigraphic control (Ruedemann and Decker, 1934). Because graptolites are so abundant and are extremely well preserved in the Viola Springs Formation and because they are highly useful index fossils, they are now the focus of a major research program at Oklahoma State University. This program is being supported by the donors to the Petroleum Research Fund of the American Chemical Society and by the Oklahoma Geological Survey.

Being abundant, conspicuous megafossils, graptolites have been noted in most reports on the Viola Springs Formation. Ruedemann and Decker (1934) provided the first description of the complete fauna; the descriptions, however, were based on specimens flattened on shale surfaces. Whittington (1954,

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1955) and Skevington (1960), in their descriptions of a few species, showed that the Viola Springs graptolites are commonly beautifully preserved in full relief and can be etched from the rock by acid treatments. Such specimens display the morphology of the graptolites excellently; this is a great help in determining their taxonomy, which in turn increases the biostratigraphic utility of these fossils. In addition, isolated (etched) specimens provide important information on graptolite growth (astogeny and ontogeny), which has led to a better understanding of graptolite evolution and modes of evolution in general (Finney, in press). For these reasons, the OSU research program was initiated with extensive collecting and detailed study of isolated specimens. The purpose of this note is to illustrate many of these specimens, which not only are aesthetically pleasing but also are an Oklahoma resource of great interest to graptolite specialists and Ordovician workers worldwide. These specimens are so well preserved that collections of them have been obtained by most major North American and European museums of natural history. They do indeed make the Viola Springs Formation a heaven for graptolite workers.

The study of isolated specimens is being carried out together with a biostratigraphic evaluation based on detailed collecting from many measured sections throughout the Arbuckles as well as from correlative strata in the Ouachitas. Preliminary results have led to a reevaluation of the Middle to Upper Ordovician graptolite zonation and include the recognition that the base of the Viola Springs Formation is diachronous and that this interval of diachrony correlates with a major lithofacies change in the Ouachitas (Finney, in preparation). A peripheral study on the sedimentology of the graptolites has documented paleocurrent directions during deposition of the Viola Springs Formation (Gentile and others, 1984). The ultimate goal of the project is use of the graptolite biostratigraphy as a temporal basis on which to examine the complete depositional history of the Middle and Upper Ordovician of the south-central United States.

The graptolites are isolated from the limestone by gentle etching in HCl. Although specimens flattened on shale surfaces are commonly large and complete, isolated specimens tend to be fragmentary because of removal of the matrix that holds cracked fragments together and unavoidable fracturing in the etching process. Many of the isolated specimens are small, unbroken, early growth stages. They can be arranged in growth series that allow mode and tempo of growth to be determined for each species.

We have already isolated several thousand specimens from collections at six sections in the Arbuckle Mountains. After comparing them to specimens flattened on shale surfaces and to the specimens illustrated by Ruedemann and Decker (1934), we feel that their faunal list of 26 species should be reduced to 11 at most. Many of their species and subspecies are based on specimens of different preservational aspects or astogenetic age. Several are misidentified. In this paper (figs. 1, 2) we illustrate eight species for which we have specimens with fairly complete rhabdosomes.

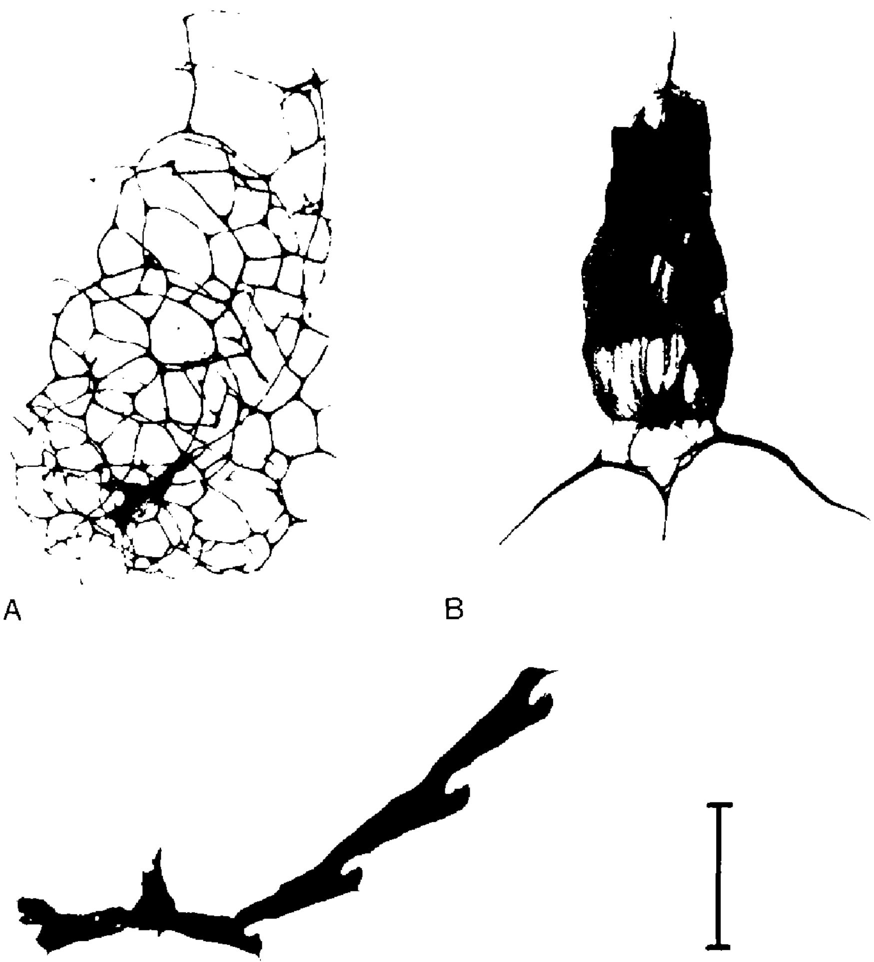
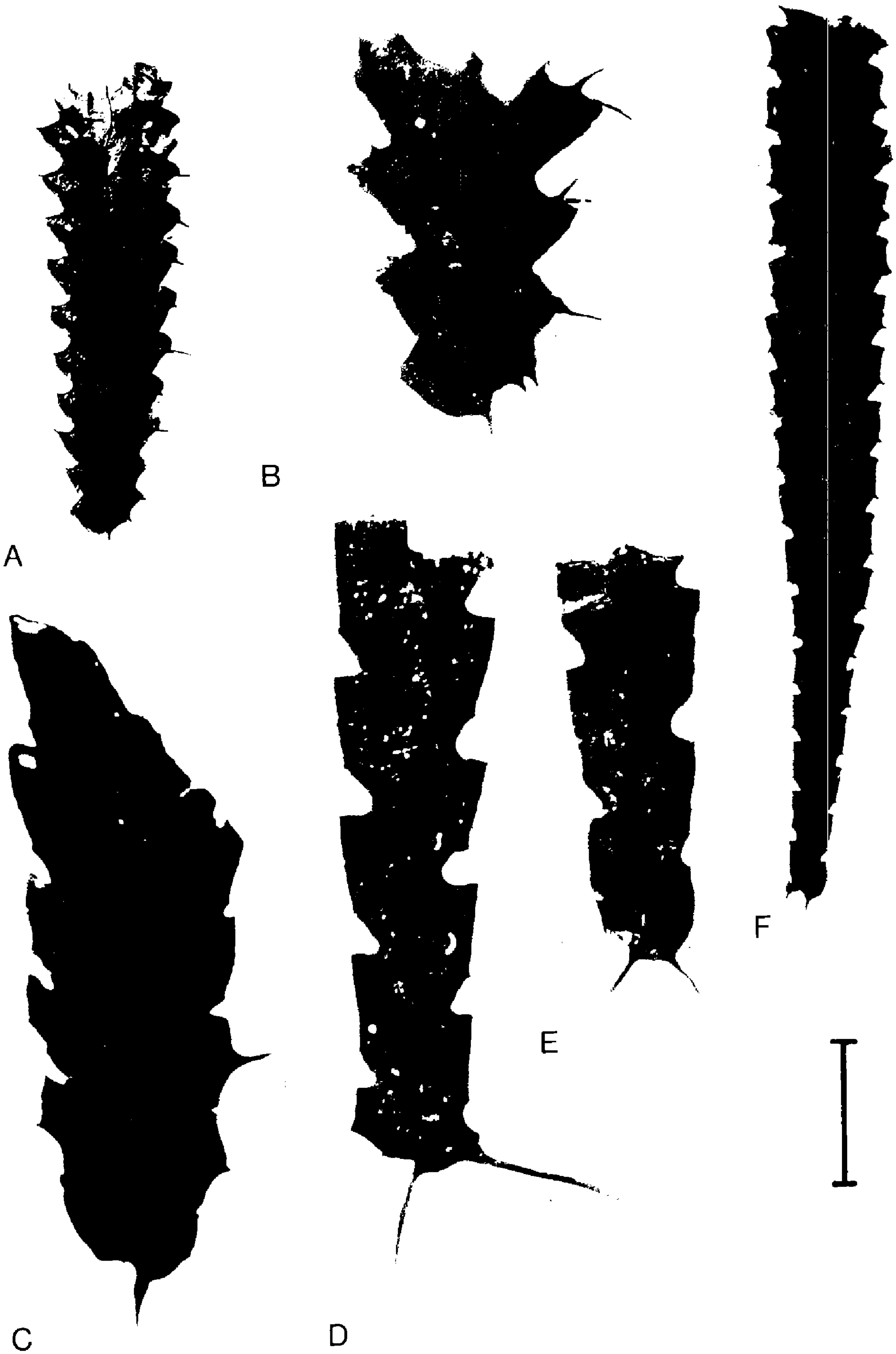


Figure 1. Graptolites isolated from Viola Springs Formation, Arbuckle Mountains, Oklahoma. *A, Phormograptus sooneri* Whittington, a graptolite in which rhabdosome is reduced to framework of thin rods; however, sicula remains completely skeletonized; USNM 377414. *B, Cryptograptus insectiformis* Ruedemann is characterized by two rows of thecae being side by side and prominent spines on proximal end, USNM 377415. *C,* rhabdosome of *Dicellograptus forchammeri flexuosus* Lapworth, consisting of prominent upright sicula and two, uniserial, reclined stipes; part of one stipe and top of sicula broken; USNM 377416. Bar scale equals 1 mm.

Figure 2. Graptolites isolated from Viola Springs Formation, Arbuckle Mountains, Oklahoma. *A,* nearly complete rhabdosome of *Orthograptus quadrimucronatus* (Hall) with characteristic spines arising from thecal apertures, USNM 377408. *B,* early growth stage of *O. quadrimucronatus* (Hall) showing position of spines on thecal apertures and partially constructed thecae at upper growing end of rhabdosome, USNM 377409. *C,* fragment from biserial proximal end of *Dicranograptus nicholsoni geniculatus* Ruedemann and Decker, showing thecal morphology, USNM 377410. *D, Climacograptus bicornis* (Hall) with characteristic spines on proximal end, USNM 377411. *E, C. spiniferous* Ruedemann that differs from *C. bicornis* in shape of proximal end; fine structure in skeletal wall represents fusellar periderm; USNM 377412. *F,* large rhabdosome of *C. typicalis* Hall, the most abundant graptolite in Viola Springs Formation with characteristic flanges arising from each theca, USNM 377413. Bar scale equals 2 mm for *A* and *F,* 1 mm for *B*-*E.* All specimens deposited at U.S. National Museum (USNM), Washington, D.C.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ORIENTED GRAPTOLITES AS PALEOCURRENT INDICATORS IN THE LOWER VIOLA SPRINGS FORMATION (ORDOVICIAN) IN THE ARBUCKLE MOUNTAINS AND CRINER HILLS, OKLAHOMA

Leo Frederick Gentile,[1] R. Nowell Donovan,[1] and Stanley C. Finney[1]

Introduction

The lower part of the Viola Springs Formation (Ordovician) of Amsden (1983) consists of dark-gray, millimeter-laminated, calcareous, phosphate- and chert-rich mudstone with a high organic-carbon content. Graptolites are abundant, and on many bedding surfaces they are obviously oriented. Although Galvin (1982) proposed a pelagic model of sedimentation on a deep carbonate ramp for the lower Viola Springs, scours and small-scale crossbedding suggest that pelagic sedimentation was disturbed by occasional bottom current. Oriented graptolite rhabdosomes also suggest the influence of currents on the sediments as shown in other areas by Jones and Dennison (1970), Schleiger (1968), and Williams and Rickards (1984).

Smith (1982, p. 29) measured the orientations of scours in the lower Viola Springs and recorded a predominantly northwest-southeast trend. Both he and Galvin (1982, p. 50) reported oriented graptolites on bedding surfaces. Here we record the directions and character of these orientations and relate them to the basin setting.

Character of the Data

Eight slabs bearing oriented graptolites were analyzed in detail (fig. 1). Three of the slabs are from outcrops along Interstate Highway 35 (sec. 25, T2S., R1E.) in the Arbuckle Mountains. The remainder were collected from the banks of an unnamed tributary of Hickory Creek in the northern Criner Hills (sec. 27, T5S., R1E.). Specimens are stored in the Department of Geology at Oklahoma State University. The major modes of oriented graptolites on 30 additional bedding surfaces were recorded in the field. All readings were corrected for tectonic tilt. The orientation and length of 385 graptolite rhabdosomes and fragments were measured on the eight slabs; orientation was re-

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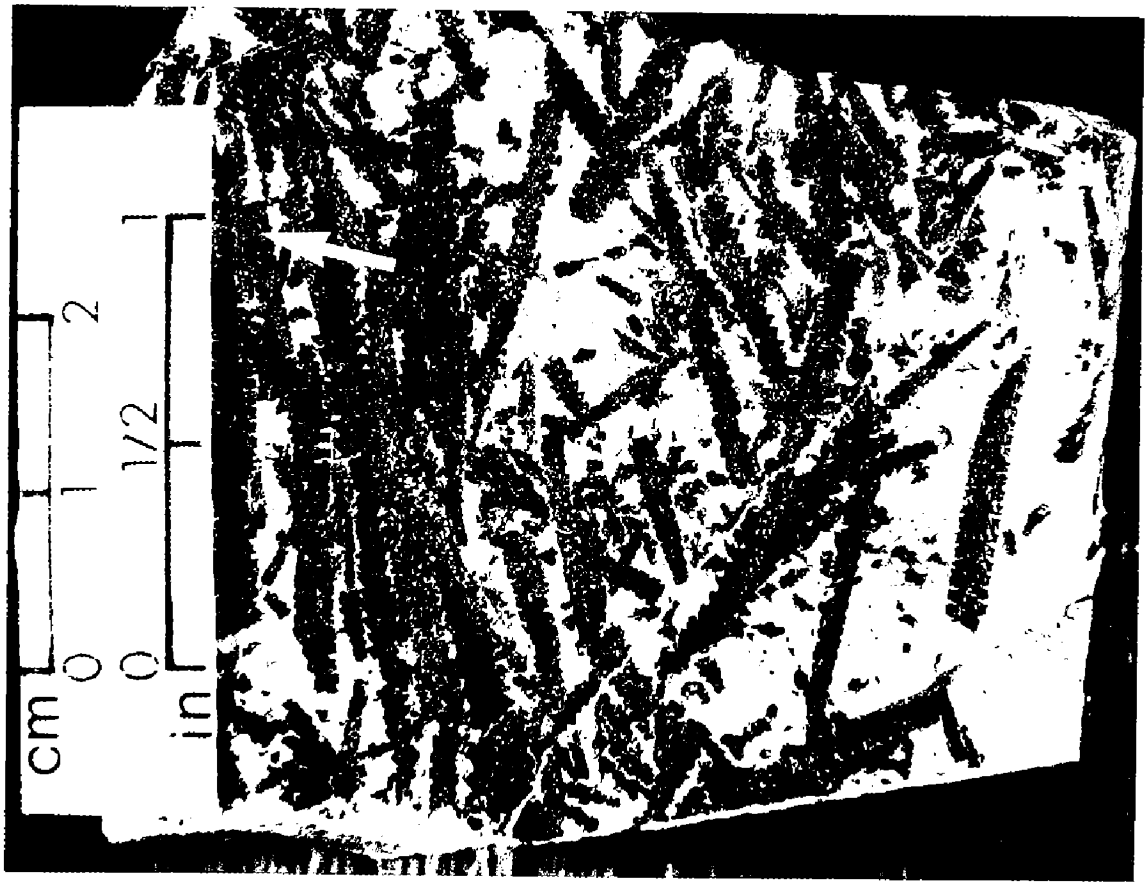
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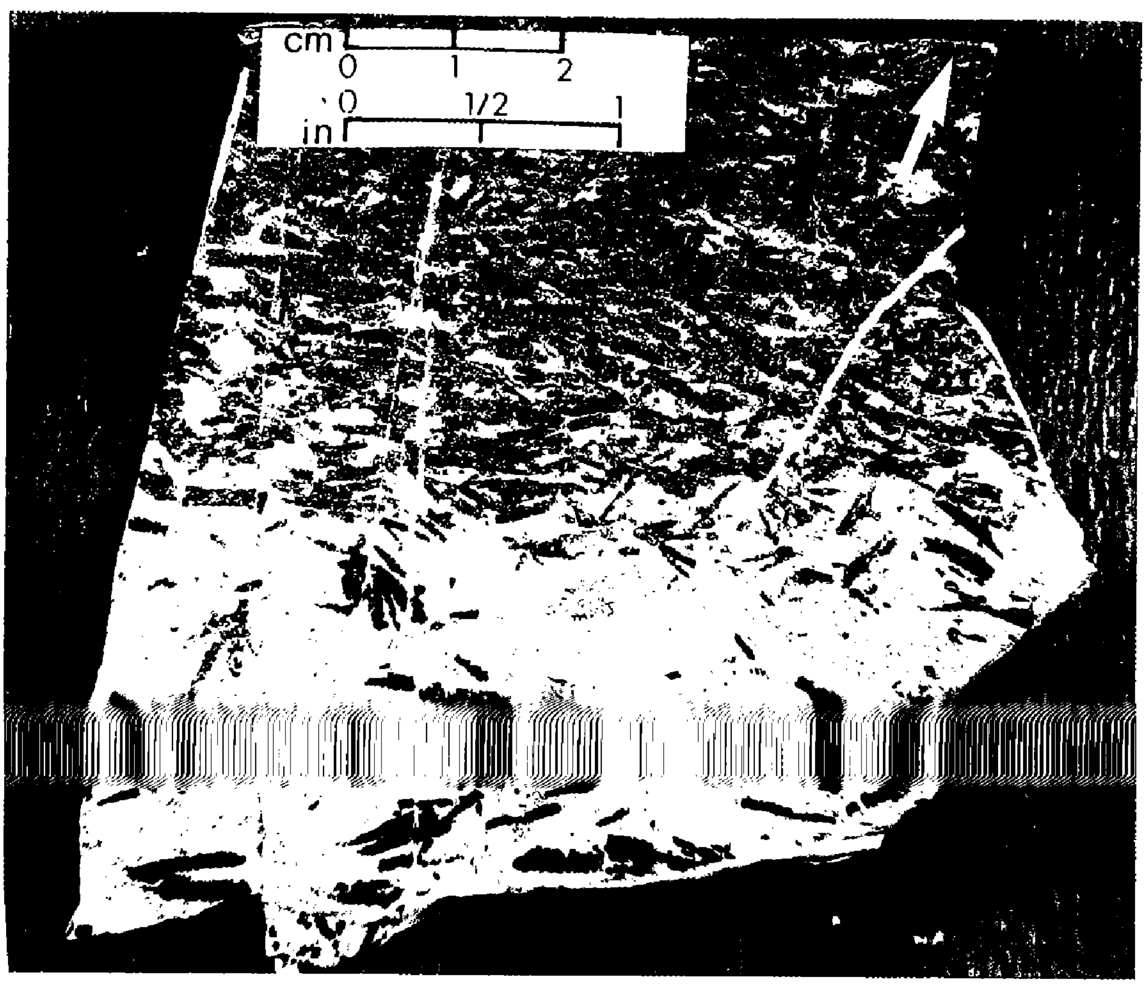
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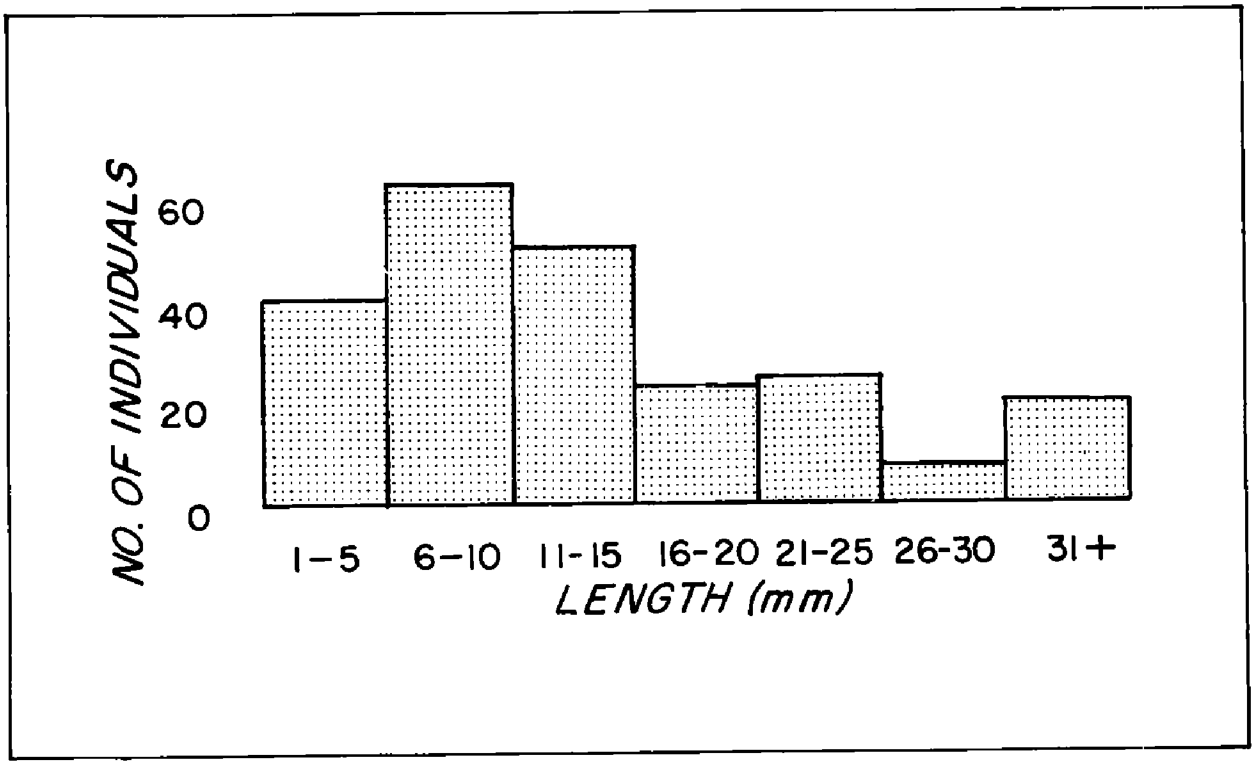

Figure 2. Graph of size distribution for all graptolite rhabdosomes in this study.

corded with respect to the direction of the proximal end of each graptolite. Rhabdosome length was plotted on a histogram in order to illustrate the size distribution of the population (fig. 2). The orientations of the individuals were plotted on rose diagrams (fig. 3). Most of the specimens observed were assigned to *Climacograptus typicalis* Hall and *Orthograptus amplexicaulis* Hall.

Discussion

Rhabdosomes found oriented on bedding surfaces ranged in size from 3 to 44 mm in length (fig. 2). Schleiger (1968, p. 464) suggested that short rhabdosomes aligned themselves normal to the current direction, and long ones parallel, with the proximal end pointing into the current. Such relationships were not seen in the present study. It is assumed that the major modes record alignment parallel to the current direction as suggested by Jones and Dennison (1970) and Schleiger (1968).

The major mode of orientation on all the graptolite-bearing slabs is approximately east–west (fig. 3). Minor modes may be either a result of random ori-

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Figure 1. Bedding surface of Viola Springs Formation, showing current-oriented *Climacograptus typicalis* Hall (above) and *Orthograptus amplexicaulis* Hall (below). Arrow points north.

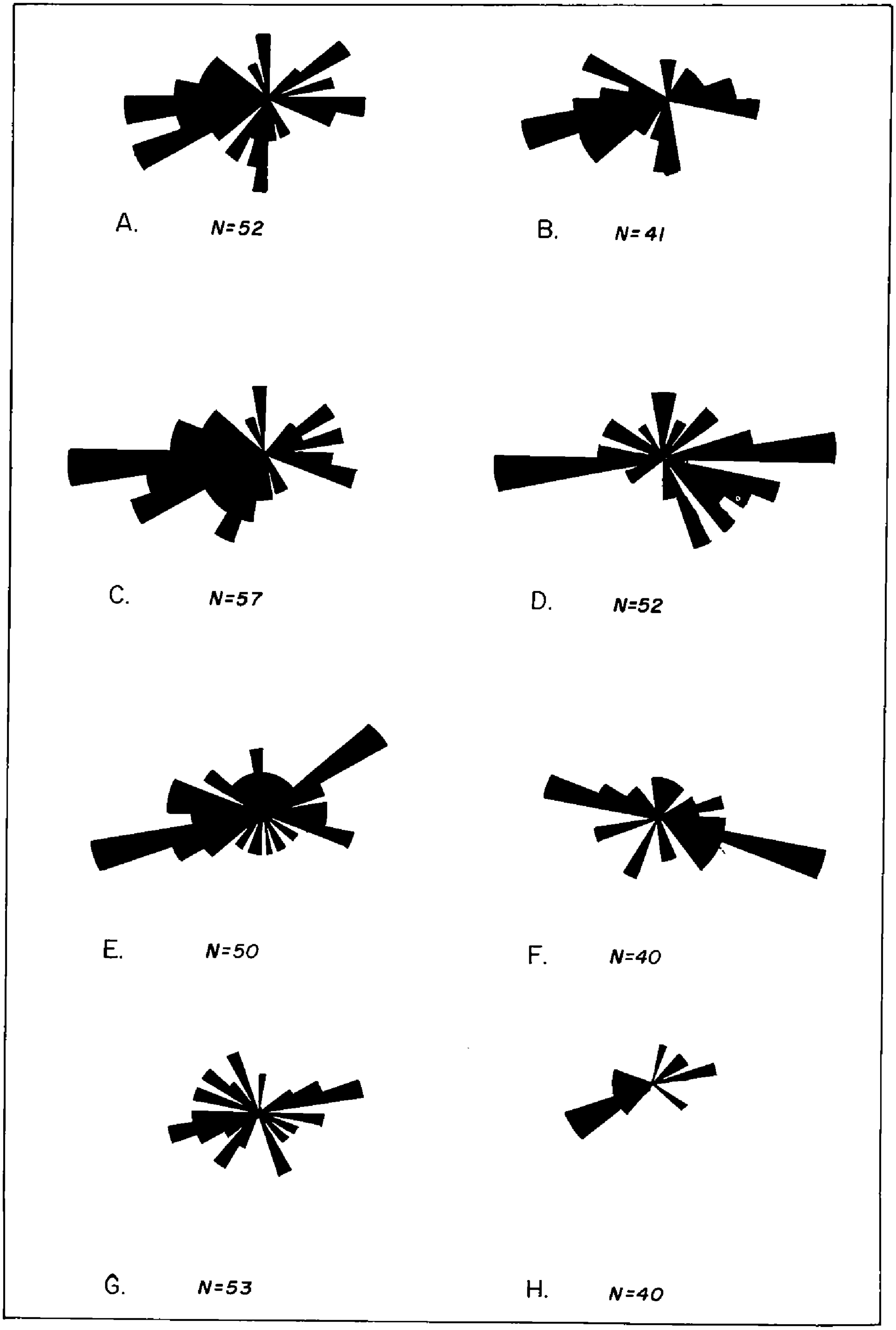

Figure 3. Rose diagrams illustrating graptolite orientation on individual slabs. *N*, number of individual rhabdosomes. *A* - *E* from Criner Hills locality; *F* - *H* from Interstate Highway 35 locality. Top of page is north.

entation owing to suspension sedimentation or a record of subtle current variations. It is significant that the major trend coincides with that of the sedimentary basin of the Viola Springs Formation (i.e., the Southern Oklahoma Aulacogen). The paleocurrent direction indicates that currents orienting the graptolites were parallel to the axis of the aulacogen and thus flowed parallel to the contours of the basin. By uniformitarian analogy, these currents may have been induced by thermohaline density differences or strong winds.

Such bottom-hugging-contour currents have been recognized in modern ocean settings by Heezen and Hollister (1964) and Heezen and others (1966) and as a dispersal mechanism in ancient sediments by Bein and Weiler (1976) and Bouma (1972). Bouma (1972) lists the following characteristics as typifying sediments deposited by contour-parallel currents: relatively thin bedding, fine lamination, crossbedding, fine grain size, and good sorting with a low matrix percentage. Only the last named characteristic is difficult to demonstrate in the Viola Springs deposits, largely owing to the extensive diagenetic alteration of the original rock texture. Where present, oriented graptolites on bedding surfaces in the Viola Springs Formation indicate a current flow with an east-west trend. Variations in the length of the individual rhabdosome are not related to the orientation modes. The approximate east-west orientations reflect current movement subparallel to the elongation of the Southern Oklahoma Aulacogen. Incorporation of the sedimentary features mentioned above with the paleocurrent data is sufficient evidence that the lower Viola Springs Formation sediments are contour current deposits.

Acknowledgments

Gentile gratefully acknowledges support from the Oklahoma Geological Survey. Part of the work was supported by a grant to Finney. For that grant, acknowledgment is made to the donors of the American Petroleum Research Fund, administered by the American Chemical Society.

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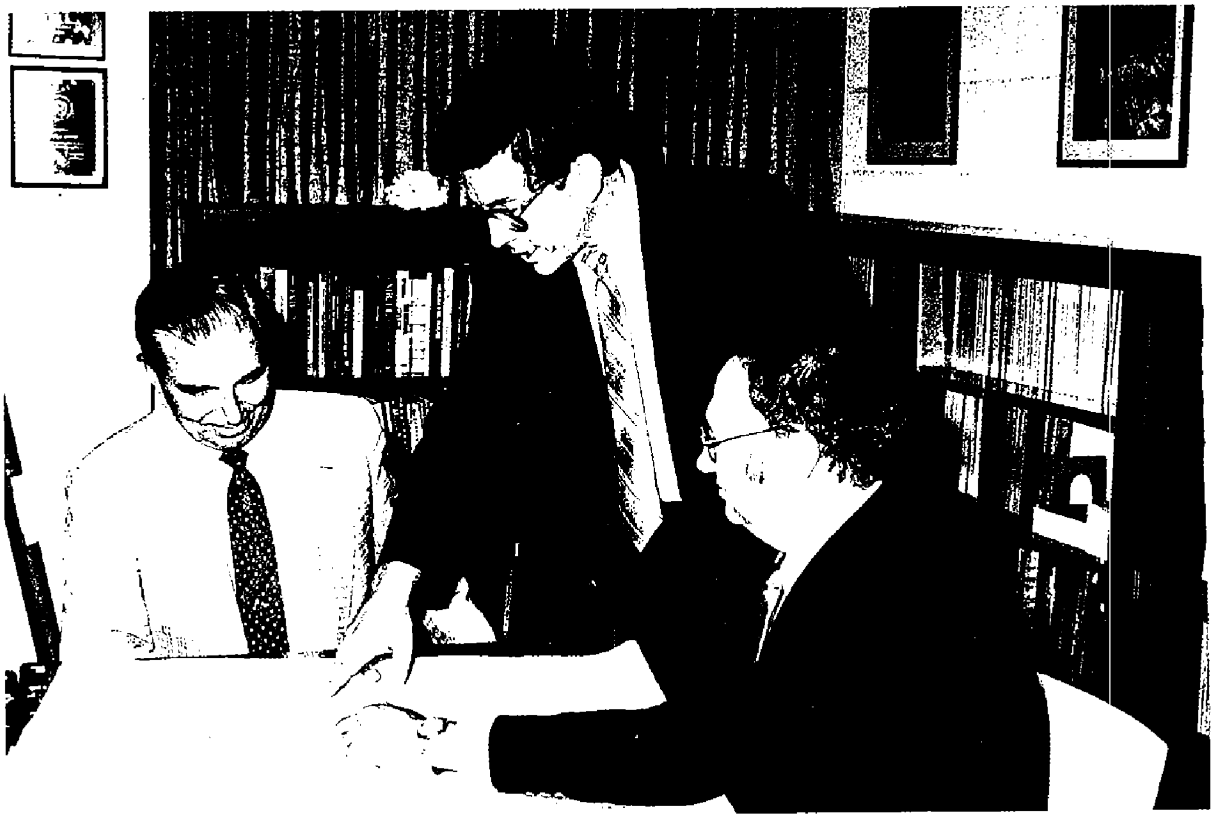

Left to right: Charles J. Mankin, Michael L. Merritt, and Wes Rice, director of Conoco's Geoscience Systems Division in Ponca City, look over a subsurface-structure map of Marshall County, Oklahoma, prepared by George G. Huffman of OU's School of Geology and Geophysics.

GENEROUS CONOCO GIFT SPARKS PUBLICATION FUND

A $5,000 gift from Conoco, Inc., is the first contribution to a new program through which the Oklahoma Geological Survey hopes to restore funding for its publishing operation.

OGS is seeking approximately $100,000 from private sources to offset recent budget cuts that have caused the Survey to delay publication of a number of important book and map manuscripts.

Conoco's contribution will be used specifically to publish a bulletin describing the surface and subsurface geology and mineral resources of Marshall County. One of the bulletin's coauthors, Michael L. Merritt, is a geologist with Conoco in Ponca City and a graduate of OU's School of Geology and Geophysics. George G. Huffman, professor in the School, is the principal author of the work.

Other potential donors have shown interest in contributing to the fund, Charles J. Mankin, OGS director, said. Donations can be made to the OGS Publication Fund through the OU Foundation, 100 Timberdell Road, Norman, OK 73019.

MCGEE AND SIMMONS RECEIVE AAPG HONORS

Oklahomans Dean A. McGee and J. J. Simmons III were honored in San Antonio, Texas, at the annual convention of the American Association of Petroleum Geologists May 20-23.

McGee, a director of Kerr-McGee Corp., was awarded the association's Human Needs Medal "in recognition of outstanding contributions as a geologist and industry leader in the quest for energy resources and their utilization to improve the quality of life." Under his leadership, Kerr-McGee launched the offshore oil and gas industry in 1947 by bringing in the first commercially productive well in the Gulf of Mexico out of sight of land. Kerr-McGee also was the first oil company to engage in development of the four primary fuels, oil, gas, uranium, and coal.

Simmons was given the association's Public Service Award "for his honorable service to the Nation in the Federal government and for his accomplishments as geologist and engineer in the petroleum industry." Simmons, an Oklahoma native and former oil company executive, served with distinction in the U.S. Department of the Interior for more than 10 years, and was most recently Undersecretary of the Interior.

INTERIOR RELEASES REPORT ON DEVELOPMENT AND ASSESSMENT OF OFFSHORE RESOURCES

A report summarizing the proposals and recommendations of more than 200 experts from government, the academic community, and the private sector for developing offshore mineral and energy resources was released recently by Interior Secretary William Clark.

"A year ago the President issued a proclamation establishing the Exclusive Economic Zone out to 200 miles off the coast of the United States and its island territories. With the EEZ proclamation, the President nearly doubled the territory of the United States and opened up almost 4 billion acres for resource assessment and possible development," Secretary Clark said.

The 308-page report provides a range of perspectives and recommendations provided by 214 people from industry, academia, and government who participated in an Interior Department-sponsored symposium, "A National Program for the Assessment and Development of the Mineral Resources of the United States Exclusive Economic Zone," held November 15-17, 1983.

"Preliminary geologic reconnaissance of the EEZ has already indicated

areas favorable for a variety of energy and mineral resources, including oil and gas, phosphorites, copper, lead, zinc, cobalt, nickel, silver, cadmium, and manganese," Clark said. "But the assessment and development of these resources cannot be done by the federal government alone. We need the full cooperation and expertise of industry, universities, state governments, and other groups."

Leasing and development of these deep ocean resources cannot occur at any time soon because of the many unknowns involved, the Secretary emphasized, adding, "We must proceed with caution, and that is all the more reason to launch our studies without lengthy delays." In February 1984, he noted, joint Federal-State working groups were formed to begin studying the economic, engineering, and environmental aspects of possible ocean mining offshore of Oregon and Hawaii.

To implement the recommendations of the symposium, the Department has assembled a coordinating committee from the U.S. Geological Survey, the Minerals Management Service, and the Bureau of Mines. As soon as their initial review is complete they will meet with an interagency committee including the National Oceanic and Atmospheric Administration and the National Science Foundation to develop a comprehensive national program concerned with nonliving resources of the sea floor.

Copies of the 308-page report, *Symposium Proceedings: A National Program for the Assessment and Development of the Mineral Resources of the United States Exclusive Economic Zone,* published as USGS Circular 929, are available upon request to the Text Products Section, Distribution Branch, U.S. Geological Survey, 604 South Pickett St., Alexandria, VA 22304. Orders must specify Circular 929.

NOTES ON NEW PUBLICATIONS

U.S.A. Oil Industry Directory

The 550-page, 23d edition of the directory lists 27,500 key personnel from over 4,000 companies in over 8,500 locations. Company descriptions have been updated and many corporate parent or corporate subsidiary companies have been identified. Included is a statistical survey that summarizes profit and product data for 400 major U.S. oil- and gas-producing companies. The catalog number is P1014.

Order the directory from: PennWell Directories, P.O. Box 21278, Tulsa, OK 74121. The price is $75 U.S. and Canada, $87.50 export.

Oil Industry Outlook for the United States

The *Oil Industry Outlook* can be used to provide guidelines for oil-industry analysis and decision making. Some of the contents are Worldwide Outlook-Demand, Capital Expenditures, and Exploration and Production.

Order catalog number P1400 from: PennWell Directories, P.O. Box 21278, Tulsa, OK 74121. The price is $125 U.S. and Canada, $156 export. A special discount with purchase of *U.S.A. Oil Industry Directory* brings the price to $100 U.S. and Canada; $125 export.

The Computer Graphics Directory

This first edition of *The Computer Graphics Directory* covers hardware, software, services, key company personnel, and industry data in a comprehensive 125-page text. The catalog number is P1600.

Order from: PennWell Directories, P.O. Box 21278, Tulsa, OK 74121. The price is $80 U.S. and Canada, $90 export.

Directory of Online Databases

This twice-yearly updated directory was designed to help subscribers keep abreast of information contained in online data bases—computer-readable collections of data—available for interactive access by users from remote computer terminals. There are more than 1,300 entries for 1,600 varied data bases containing numeric and textual information.

Order from: PennWell Directories, P.O. Box 21278, Tulsa, OK 74121. The prices are Spring Edition '84, catalog no. P1816, $45 U.S. and Canada, $56.50 export; Fall Edition '84, catalog no. P1818, $45 U.S. and Canada, $56.50 export; and '84 subscription (2 editions), catalog no. P1820, $60 U.S. and Canada, $67.50 export.

Geochemical Aspects of Radioactive Waste Disposal

This 347-page book by Douglas G. Brookins emphasizes a rock-chemistry approach to provide a background for understanding significant issues associated with radioactive-waste disposal. Natural analogs are used to demonstrate how radioactive substances interact with rocks, soil, and water in their geological environment. Alternative disposal methods, low-level wastes, toxicity, waste forms, disposal packaging, and disposal burial are discussed.

Order from Springer-Verlag, New York, Inc., P.O. Box 2485, Secaucus, NJ 07094. The price is $44.50.

Why Scientists Believe in Evolution

Norman D. Newell, of the American Museum of Natural History, is the author of a new pamphlet issued by the American Geological Institute that summarizes geological and biological evidence for the evolution of life forms. The illustrated pamphlet, written for "educators, students, parents, and concerned citizens," also describes the geologic time scale and the development of age dating of rocks. It closes with a statement that evolution does not represent a threat to religion and that "to attack science in the name of religious orthodoxy is detrimental to both science and religion."

Single copies of *Why Scientists Believe in Evolution* can be obtained free on request to Andrew J. Verdon, Jr., Director of Education, American Geological Institute, 4220 King St., Alexandria, VA 22302. The price for two to 10 copies is 30¢ per copy; the price decreases for larger quantities.

Tills and Related Deposits: Genesis, Petrology, Application, Stratigraphy

This 464-page volume from the proceedings of the INQUA symposia on the genesis and lithology of Quaternary deposits, 1981, by Edward B. Evenson, C. Schluchter, and Jorge Rabassa, contains information on the Pleistocene deposits from formerly glaciated regions in both hemispheres. The book gives data on the geopotential of the Quaternary strata and information on the most recent geologic history of the globe and the evolution of the natural environment.

Order from: A. A. Balkema Publishers, 92 State St., Boston, MA 02109. Price: $45, hardbound.

Vertical Seismic Profiling: Techniques, Applications and Case Histories

A. H. Balch and Myung W. Lee's 448-page reference book discusses vertical seismic profiling (VSP). The book gives case studies on how VSP has been used to solve specific problems and shows how widely VSP applications range. It also features an extensive bibliography on VSP to date.

Order from: IHRDC Publications, 137 Newbury St., Boston, MA 02116. Price: $58, clothbound.

Oil and Gas Map Series, Tennessee

The fourth and final sheet of an open-file pipeline-map series by Robert A. Miller, of the Tennessee Division of Geology, is now available. The map covers western Tennessee, and is drawn at a scale of 1:250,000. It shows all known pipeline systems in the map area, including both collector and distributor lines.

Order from: Division of Geology, 701 Broadway, Nashville, TN 37203. Price: $3.50, single map cost.

Reclamation of Mined Lands in the Western Coal Region

Reclamation effects were observed at 22 coal mines in seven western States in October and November of 1978. Specific practices and key factors affecting the reclamation status for those mines are tabulated for comparison. An overview of mining and reclamation history provides a background to the evolution of reclamation practices and to an understanding of the diverse status of current reclamation.

The effectiveness of present reclamation efforts is highly site specific, owing to the characteristics of climate, landform, overburden, soils, biology, vegetation, and operational techniques, but, in general, reclamation objectives probably can be achieved.

Circular C 0872 consists of 56 pages, and was authored by P. F. Narten and others.

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

Preliminary Appraisal of the Hydrology of the Rock Island Area, Le Flore County, Oklahoma

Water-Resources Investigations Report 83-4013 has been issued by the U.S. Geological Survey in conjunction with the Energy Minerals Rehabilitation Inventory and Analysis Program. This report describes the hydrology and potential impacts of mining in the vicinity of the town of Rock Island in northeastern Le Flore County, Oklahoma, where the upper and lower Hartshorne coals are at or near the surface and amenable to surface mining.

Included in this 35-page report are 10 figures, 9 tables, and 3 plates. The plates include a 1:24,000-scale geologic map of the Rock Island area, a 1:24,000-scale potentiometric map with locations of data-collection sites in the area, and a 1:24,000-scale map showing flood-prone areas near Rock Island.

For more information on this publication, contact: U.S. Geological Survey, Water Resources Division, Rm. 621, 215 NW 3rd St., Oklahoma City, OK 73102 (telephone: 405-231-4256).

Landslide Overview Map of the Conterminous United States

Landslide incidence and susceptibility are illustrated for the major physical subdivisions of the United States, with a view to the assessment of environmental hazards in national planning and land development.

Natural factors influencing slope stability are discussed in detail for the Colorado Plateau, the Appalachian Highlands, the Coast Ranges of California, and the Southern Rocky Mountains, which are among the most landslide-prone areas in the U.S.

The book, by D. H. Radbruch-Hall and others, consists of 25 pages and one plate in a pocket.

Order Professional Paper P 1183 from: Eastern Distribution Branch, Text Products Section, U.S. Geological Survey, 604 South Pickett St., Alexandria, VA 22304.

Water Resources Data: Oklahoma, Water Year 1981

Water-resources data for Oklahoma for the 1981 water year are presented in this volume that was prepared by the U.S. Geological Survey in cooperation with the Oklahoma Geological Survey and other State agencies.

Data consist of records of stage, discharge, and water quality of streams and stage, contents, and water quality of lakes and reservoirs. The report contains records on discharge for 135 gaging stations, stage and contents for 25 lakes and reservoirs, and water quality for 49 gaging stations and 3 lakes. Also included are data for 44 crest-stage partial-record stations and additional water data collected at various sites not part of the systematic data-collection program.

A limited number of copies is available from: U.S. Geological Survey, Water Resources Division, 215 NW Dean A. McGee St., Rm. 621, Oklahoma City, OK 73102 (telephone: 405-231-4256).

Geological Evaluation of Fractured Reservoirs (1983)

Ronald Nelson's 55-minute slide-tape program discusses both the qualitative and quantitative aspects of effective fractured-reservoir evaluation. Nelson treats the geological and petrophysical data necessary to make an early evaluation, either during the exploration or early-development phases. As such, prediction rather than detection is emphasized. Nelson presented this talk as part of the 1982-83 AAPG Distinguished Lecture series.

Order from: AAPG, P.O. Box 979, Tulsa, OK 74101. Catalog no. 918 consists of 52 slides and 2 tapes and requires 1 projector. The price is $125 in the U.S., $225 outside the U.S.

Dolomitization (1983)

Various models for dolomitization are presented by Lynton Land, who describes them and offers examples. The mineralogy, geochemistry, and petrology of dolomite are introduced and summarized as pertaining to the timing and mechanisms of dolomitization. Land presented this talk (2 hours and 40 minutes) as his part in the 1982 AAPG Fall Education Conference in Denver.

Order from: AAPG, P.O. Box 979, Tulsa, OK 74101. Catalog no. 917 consists of 78 slides and 6 tapes and requires 1 projector. The price is $295 in the U.S., and $420 outside the U.S.

FRIDAY THE 13TH A GOOD DAY FOR OU COLLEGE OF GEOSCIENCES

Friday the 13th, April 1984, turned out to be a lucky day for the College of Geosciences. The annual Geoscience Day at OU was held on this date and turned out to be a big success for those involved.

For those readers who are not familiar with this event, Geoscience Day is a day set aside for students and faculty from the College of Geosciences to gather to present short informal talks. These talks may range from thesis/dissertation topics to research projects and personal-interest topics. On this day, individuals from the School of Geology and Geophysics, the Department of Geography, and the School of Meteorology, and members of the Oklahoma Geological Survey, share ideas with their "sister" sciences; this year, however, Meteorology was not able to participate in the talks.

After a very slow start early in the year, the total number of talks blossomed from less than 10 to 27 by April 13th (of course, a little incentive was added by an offer of a $50 prize to the best undergraduate and graduate talk). During the day, two talks were given simultaneously in separate rooms from 8:30 a.m. to 5:00 p.m. Of the 27 talks, eight were given by geographers, three by members of the Oklahoma Geological Survey, and 16 by students of the School of Geology and Geophysics. Each of the talks was well received and attendance was even better than expected.

A new twist was added to Geoscience Day this year through a beautiful 33-page program that was created and made available free to anyone wanting a copy. The program contained a schedule of the day's events and abstracts of each of the 27 talks.

Lectures were not the only item on the agenda for Geoscience Day. During the afternoon lunch break, Sigma

(Opposite page) The near-perfect weather on Geoscience Day allowed participants to enjoy a noon meal outdoors on the shady lawn near Gould Hall. Pictured are (left to right): John Hidore, Kathy Goodman, Bill Colpine, Kevin Nick, Virginia Loucks, Bill Dunn, Robert DuBois, and Rick Ditmars.

Gamma Epsilon, an honorary geology organization, sponsored a cook-out in the courtyard behind the geology building (Gould Hall). The weather was absolutely perfect and there were good food and good times for everyone.

After the last of the talks was over, we had a short "recess" before assembling inside the Oklahoma Memorial Union for a reception and banquet. During the hour-long reception, members of the College and their families and friends had fun and talked about events of the day. Estelle Harrington also soothed the soul by playing the harp during the reception.

More than 110 people attended the Geoscience Day banquet, where the agenda consisted of a meal followed by a short piano recital. Douglas Neese, a geology Ph.D. candidate, played Rachmaninoff's Piano Concerto No. 2, second movement, accompanied by Dr. Todd Welbourne, an associate professor of piano here at OU. Each of the directors of the Geoscience departments said a few short words about their respective departments and their achievements throughout the year. Numerous

Chefs Doug Neese and Vicki Thomson oversee the cooking of the gourmet hamburgers at the noon luncheon.

Hamburger fans line up to vie for the mustard, ketchup and pickles. The group above includes (left to right): Doug Elmore, Greg Webb, Steve Roberts, Fred Molloy, and John Walters.

awards were presented throughout the night, along with a check for $4000 from Conoco presented to Dr. Raymond Rene, of the Geophysics faculty, to aid in geophysical research in Utah.

The guest speaker for the evening was Francis Stehli, Dean of the College of Geosciences. Dean Stehli addressed a topic of interest to the entire audience as he discussed where the College has been and where it is going in the near future. Needless to say, prospects look good for each of the departments.

The only unfortunate aspect of the day was that, this year, Geoscience Day was not scheduled on the day of an alumni advisory meeting as had been done in the past. Because of this, many of the alumni were unable to attend. In the future, we hope these two events can be scheduled simultaneously to assure Geoscience Day an even larger success.

We of the Graduate Student Executive Committee (Geology and Geophysics), who helped organize this event, look forward to a new year and an even more successful Geoscience Day.

Michael H. Carter

OKLAHOMA ABSTRACTS

SEG Annual International Meeting
Dallas, Texas, October 17-21, 1982

The following abstract is reprinted from *Geophysics*, published by the Society of Exploration Geophysicists, v. 48, no. 4. Page numbers are given in brackets below the abstract. Permission of the authors and of the SEG to reproduce the abstract is gratefully acknowledged.

Integration of Geologic, Geochemical, and Geophysical Data of the Cement Oil Field, Oklahoma, Using Spatial Array Processing

PATRICIA TERMAIN ELIASON, TERRENCE J. DONOVAN, and PAT S. CHAVEZ, JR., U.S. Geological Survey, Flagstaff, AZ 86001

Surface indicators of petroleum deposits have long been important in locating exploratory drill sites. Because the most obvious and easily found petroleum deposits have already been discovered, explorationists have necessarily geared their efforts to finding geologically inconspicuous deposits. This effort has spurred the development of highly sophisticated geophysical and geochemical technology.

The extensive use of remotely gathered information, especially within the U.S. space program, has resulted in the development of sophisticated image processing techniques. This paper summarizes a study of the Cement oil field, Oklahoma, test site in which various image processing techniques were applied to a variety of radiometric and potential field data. Previous work documented anomalous geochemical and geophysical signatures at Cement which result from hydrocarbon microseepage-induced alterations of surface and near-surface rocks. Our intent was to evaluate the utility of presenting radiometric and potential field data as enhanced images which allow visual and statistical correlation among the measured variables and the known surface and near-surface geochemical alteration patterns. [474–475]

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.

GSA Annual Meeting, Southeastern Section and North-Central Section Lexington, Kentucky, April 4–6, 1984

The following abstracts are reprinted from *Abstracts with Programs* of the Geological Society of America, v. 16, no. 3. Page numbers are given in brackets below the abstracts. Permission of the authors and of the GSA to reproduce the abstracts is gratefully acknowledged.

Conodont Biostratigraphy of the McLish and Tulip Creek Formations of South-Central Oklahoma

JEFFREY A. BAUER, Department of Geology and Mineralogy, Ohio State University, 125 South Oval Mall, Columbus, OH 43210

A thick section of the Middle Ordovician McLish and Tulip Creek Formations, reasonably well-exposed along U.S. Highway 35 in the Arbuckle Mountains of south-central Oklahoma, has been sampled in detail for conodonts. A collection of 12,890 conodont elements referable to 25 genera recovered from that section provides important data for biostratigraphic studies.

The McLish-Tulip Creek conodont fauna is dominated by Midcontinent provincial forms. Elements of *Phragmodus flexuosus* Moskalenko make up over 75 percent of the total collection.

The distribution of *"Polyplacognathus" friendsvillensis* Bergström and a species of *Eoplacognathus* transitional between *E. foliaceaus* (Fåhraeus) and *E. reclinatus* Fåhraeus in the section indicates a Chazyan age and also assists in relating most of the McLish-Tulip Creek succession to the North Atlantic *Pygodus serra* Zone.

Interestingly, conodont species associated with a much older fauna were found in samples near the base of the McLish. That fauna is characterized by *Neomultioistodus* (*Multioistodus* of previous reports), *Paraprioniodus,* and *Scandodus*?. Although no conclusive evidence was recognized, it is assumed that those conodonts have been reworked from older strata. [124]

Distribution of Rugosa & Tabulata of the Upper Pennsylvanian (Missourian) Rocks of Kansas

J. M. COCKE, Geology Department, Central Missouri State University, Warrensburg, MO 64093

Traditionally, dissepimental corals of the Upper Pennsylvanian Missourian rocks of the American Midcontinent have been assigned to 4 genera. Jeffords (1948) noted the presence of 2 genera: *Pseudozaphrentoides* (=Caninia) in

11 formations, and *Dibunophyllum* in 10 Missourian units in Kansas. More recent study also reveals prolific faunas of *Neokoninckophyllum* and *Geyerophyllum* in 8 formations, but *Caninia* in only 3 Missourian formations, and *Dibunophyllum* in 8 units.

Dissepimental corals are abundant in thick limestones; their presence in thick shale beds or thin limestones has not been verified. Four informal zones established on the distribution of the 4 dissepimental genera have been recognized in 5 states.

Nondissepimental genera *Lophophyllidium, Stereostylus,* and *Lophamplexus* are common, but their occurrence has not been carefully investigated in this study. The genus *Zaphrentis* noted by Jeffords in 5 Kansas formations has been found only in the Iola in southern Kansas. *Leonardophyllum,* recently collected, is present at a single locality in Southeastern Kansas. ? *Amplexocarinia* has been collected at one locality in the Westerville Limestone Member in Kansas City.

The favositid genus *Michelinia* is known to occur in 4 Kansas formations; *Cladochonus* in one. Both genera are common in the Dewey and Hogshooter formations of Oklahoma near the state line. *Striatopora* is unknown in Missourian rocks of Kansas. *Syringopora* has been collected from a single locality in Kansas. *Sutherlandia* has been collected in 2 Kansas formations, and in 3 Oklahoma units, and in 1 Missouri formation. A new favositid genus has been collected from Washington County, Oklahoma near the state line. [129]

The Stratigraphy and Paleogeography of the Lagonda Interval (Middle Pennsylvanian) in Southeast Kansas and Northeast Oklahoma

STEPHEN L. DENESEN, Department of Geology, University of Iowa, Iowa City, IA 52242

The upper part of the Cherokee Group above the Verdigris limestone in Kansas, or the Cabaniss Group in Oklahoma comprises the Lagonda interval. This interval consists of two or three incomplete cyclic parcels of limestone, coal, shale, and sandstone. Delta outbuilding and abandonment along the shoreline appear to account for these laterally discontinuous cycles.

Analyses of geophysical logs from 700 wells in a 12 county area of southeastern Kansas and northeastern Oklahoma show that the Lagonda interval varies in thickness from 35 ft. in the south to 120 ft. in the north. Through much of east-central Kansas lenticular sandstones up to 100 feet thick are conspicuous, while shale and limestone are the dominant rock types within the interval in northeastern Oklahoma. Channel sandstones that cut out over 100 feet of sub-Lagonda rocks lie within a sinuous northeast-southwest-trending belt in extreme southeast Kansas and northeast Oklahoma near the northwest flank of the Ozark Uplift. These channels may have originated through the erosion of strata uplifted by the Ozark epeirogeny. In contrast to these, shales up to 100 feet thick lie in a narrow belt in the northwest part of the study area. These may have formed through the "ponding" of fluvially-introduced silts and clays in water located between delta mouths and the Nemaha Uplift. [133]

Late Morrowan and Early Atokan (Pennsylvanian) Conodonts from the Eastern Margin of the Arbuckle Mountains, Southern Oklahoma

ROBERT C. GRAYSON, JR., Department of Geology, Baylor University, Waco, TX 76798

Platform conodonts from exposures of the Wapanucka and Atoka Formations on the northeastern and eastern margins of the Arbuckle Mountains provide new data for correlation of this important stratigraphic interval. Two conodont zones occur in the Wapanucka Formation, these are: the *Idiognathoides convexus* Zone of Lane (Lane and others, 1971), and the *Neognathodus* n. sp./ *Idiognathoides ouachitensis* Zone of Lane (1977) and Grayson (1979). The Atoka Formation conodont succession is not formally zoned but is subdivided into two assemblages. The lower *Idiognathoides noduliferus* assemblage contains the lowest Atokan occurrence of neognathodids including *N. bassleri* and *N. bothrops*. The appearance of *N. medadultimus* marks the succeeding assemblage which is similar in composition to the older *I. noduliferus* assemblage but exhibits some significant differences in abundances.

The *Idiognathoides convexus* Zone indicates correlation of the lower major portion of the Wapanucka in the Arbuckle Mountains with the Kessler Limestone Member of the type Morrowan Bloyd Formation. Based on the present definition of the Atokan Series (Spivey and Roberts, 1946), a Morrowan age is established for occurrences of the *Neognathodus* n. sp./ *Idiognathoides ouachitensis* Zone in the Arbuckle Wapanucka. Compared to the more complete sequence in the Ouachita Mountains, one and possibly part or all of a second conodont assemblage is missing below occurrences of the *I. noduliferus* assemblage in the Atoka Formation. This faunal gap is interpreted to represent the magnitude of the lower Atoka unconformity. Both the *I. noduliferus* and *N. medadultimus* assemblages are thought to be Middle Atokan in age. [142]

Tectonic and Sedimentary History of the Ouachita Foreland

DAVID W. HOUSEKNECHT and GEORGE W. VIELE, Department of Geology, University of Missouri, Columbia, MO 65211

Following the late Precambrian-earliest Paleozoic rift opening of the proto-Atlantic ocean, the southern margin of North America evolved into an Atlantic-type margin that persisted through the middle Paleozoic. The prism of sediment deposited along this rifted margin includes shelfal facies that underlie the Ouachita foreland as well as slope, rise, and ocean basin facies that are exposed in the Ouachitas.

In contrast, Carboniferous strata of the Arkoma basin and Ouachita Mountains record the change of the passive, rifted margin into an active, convergent margin along an ocean basin being consumed by southward subduction beneath a growing subduction complex. Mississippian through lowermost Atokan strata indicate that shelf sedimentation continued with little change, but to the south the deep ocean evolved into a flysch basin, receiving sediment derived [predominantly] from the evolving Ouachita subduction complex to the south and east.

Lower and middle Atokan strata record the breakdown of the shelf-slope-rise geometry as the subduction complex advanced northward over the margin of North American crust, which was undergoing normal faulting induced by flexural bending. These normal faults influenced bathymetry, controlled sediment dispersion, and caused growth fault-like thickness increases in Atoka strata, which grade southward from shallow shelf to submarine fan facies. By late Atokan time, the subduction complex had collided with North America, thereby forming a foreland basin in which molassic sedimentation continued through the Desmoinesian. Age and distribution of these tectonostratigraphic units along the strike of the Ouachita foreland suggest that the collision was diachronous. [147]

Philosophical Objectives of the Coal Resource Classification of U.S. Geological Survey Circular 891

THOMAS M. KEHN, U.S. Geological Survey, Reston, VA 22092

During the past 100 years, nine national and many State or regional coal-resource estimates have been published. Three of the national estimates have remarkably similar totals, but these and all other estimates have fundamental differences related to philosophical changes in criteria, guidelines, terminology, definitions, methodologies and increases in geologic data bases. In addition, most early and many modern estimates are incompatible because of geologic parameters and availability of new data. Since the early 1970's, it has been apparent that the need is great for a commonly accepted coal resource and reserve [system] that would: a) produce compatible estimates; b) provide guidelines for collecting accurate and unbiased geologic data for preparation of the estimates; and c) permit State, national, and international assessments to be either compatible or more easily related.

In 1976, the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines published a [standardized] system of coal-resource classification that incorporated geologic- and engineering-related definitions and criteria to be used by both agencies. This system was adopted by many State geological surveys. However, because of ambiguities and constructive criticism, it was decided to revise, enlarge, and more precisely define the criteria, guidelines, terminology and definitions used by [and] for those engaged in resource estimation, and to include a methodology. This revision was published in 1983 as the classification system of the U.S. Geological Survey. The revised system provides a method for the inclusion of new geologic data as it becomes available, to quantify coal into more reliable categories, and to provide for verification of an estimate by other estimators using the same data. It also permits integration of geochemical data with the resource estimates so that quantities of coal having desired qualities can be identified.

Past confusion between estimates of resources will continue unless a coal-resource classification and assessment system is universally adopted that incorporates uniform terminologies, criteria, guidelines, definitions and a methodology and that is understood and used by coal scientists, governments, industry, consultants, and the public. USGS Circular 891 provides a classification and assessment system that meets these objectives. [148-149]

AAPG Annual Convention
San Antonio, Texas, May 20–23, 1984

The following abstracts are reprinted from the *Bulletin* of the American Association of Petroleum Geologists, v. 68, no. 4. Page numbers are given in brackets below the abstracts. Permission of the authors and of the AAPG to reproduce the abstracts is gratefully acknowledged.

Porosity Evolution of Pennsylvanian Morrow Formation in Anadarko Basin, Oklahoma

ZUHAIR AL-SHAIEB, Oklahoma State University, Stillwater, OK

The Anadarko basin is one of the most outstanding hydrocarbon producers in the North American continent. Examination of more than 50 cores from the Pennsylvanian Morrow sandstones reveals a complex diagenetic history. Although quartzarenite is the major lithology, shell fragments, glauconites, and clayey matrix occur in significant amounts throughout the section. This diagenetic complexity is a function of depositional environment, burial, and thermal history of the basin.

Porosity in the Morrowan sandstones throughout the Anadarko basin is chiefly secondary. Such porosity results from the dissolution of clayey matrix, carbonate fragments and cement, glauconite, and quartz grains and their overgrowth.

Evolution of secondary porosity is related directly to the generation of hydrocarbons. CO_2 gas, with concentrations ranging from 0.3 to 4.7% by volume, was detected in more than 150 natural gas wells examined in the basin. Based on geothermal and geopressure gradients, and on experimental investigations of the solubility potential of CO_2 in formation fluids under elevated temperatures and pressures, a good estimate of solubility of CO_2 in the Morrow Formation water may be attained. Because the concentration of CO_2 appears to increase with depth in the basin, secondary porosity should not be restricted to a particular zone or to particular depths, but definitely would persist with depth. Organic acids at shallow depths and H_2S in deeper zones may be important in enhancement of secondary porosity.

Amounts of porosity and the geometry of pore space are directly related to original lithology. A better understanding of lithofacies is critical in evaluating reservoir quality. [447]

Dakota Sandstone Facies, Western Oklahoma Panhandle

ERKAN ATALIK and CHARLES F. MANSFIELD, University of Tulsa, Tulsa, OK

The Cretaceous Dakota Sandstone in Cimarron County comprises three sandstone units and intervening mudrocks; it overlies the Kiowa Shale Member of the Purgatoire Formation. Deposits include shoreface, beach (foreshore) and dune, estuarine and tidal channel, marine marginal bay and swamp/marsh in a generally progradational sequence associated with marine regression in the Western Interior.

The shoreface sand, characterized by ripple lamination, bioturbation and the trace fossils *Teichichnus* and *Thalassinoides,* is fine-grained, 5–10 m (15–30 ft) thick and grades into the underlying Kiowa Shale. Beach and associated dune deposits are 2–5 m (6–16 ft) thick, medium to fine-grained, medium to thick-bedded, tabular-planar cross-bedded, and lenticular; cross-bed paleocurrent headings are northeasterly and northwesterly. Estuarine channel deposits are 3–5 m (10–16 ft) thick, trough to tabular-planar cross-bedded, and medium to coarse-grained with local conglomerate overlying the scoured base which commonly cuts into the Kiowa Shale or overlying shoreface sandstone; rip-up clasts and wood pieces are common but trace fossils are rare; southeasterly and southwesterly paleocurrents predominate.

Tidal channel deposits are thinner (up to 2 m or 6 ft) and finer grained (medium to fine-grained) than the estuarine channel deposits; they occur within fine-grained sandstone and mudrock sequences, are trough cross-bedded, and commonly contain trace fossils (e.g., *Skolithos*) and wood fragments. Marine marginal (tidal flat or bay?) deposits comprise fine-grained sandstone, siltstone and interbedded shale, that are 1–3 m (3–10 ft) thick with abundant burrows, small ripple marks, and parallel lamination. These grade into the fine to very fine-grained sandstones, siltstones, shales, and coals of the swamp/marsh deposits that are 1–5 m (3–16 ft) thick and contain ripple marks, burrows, other trace fossils, and parallel lamination. [449–450]

Dolomitization Stages in a Regressive Sequence of Hunton Group, Anadarko Basin, Oklahoma

GEOFFREY B. BEARDALL, JR., and ZUHAIR AL-SHAIEB, Oklahoma State University, Stillwater, OK

The Upper Silurian Henryhouse Formation, of the Hunton Group (Upper Ordovician–Lower Devonian), is a major hydrocarbon reservoir in the Anadarko basin. Detailed examination of Henryhouse cores were conducted at many localities in the basin, west of T10 W. Sedimentary structures, lithology, fossil content, and fabric relationships were used as criteria to recognize various depositional facies. Subtidal, intertidal, and supratidal facies can be distinguished readily, and their spatial relationships consistently indicate a shallowing-upward sequence. Previously unreported nodular anhydrite (replaced and unreplaced) occurs at the top of the sequence, suggesting that hypersaline conditions developed in supratidal environments.

Three stages of dolomitization were documented in the Henryhouse Formation. Petrographic, cathodoluminescent, and isotopic techniques were used to investigate the genesis and textural relationships of various dolomite types. The following paragenetic sequence was discerned: (1) penecontemporaneous hypersaline dolomite occurring as brownish, hypidiotopic, 60–80 μm rhombs concentrated in the supratidal and intertidal facies; (2) marine water-fresh water mixing dolomite occurring as white rims around preexisting hypersaline dolomite and as anhedral, white rhombs in vugs and molds; (3) deep burial vug, mold, and fracture-filling baroque dolomite.

Cathodoluminescence reveals that typical Henryhouse dolomite exhibits dully luminescing cores with outer bright rims corresponding to the dark core and light rim seen in plane light. This zonation represents two stages of dolomitization.

Oxygen isotope ratios range from −2.2 to −9.9 (mean −4.6)‰ vs. PDB, whereas the carbon isotope ratios range from 0 to +3.3 (mean +1.4)‰ vs. PDB. The considerably light $\delta^{18}O$ reflects a fresh water influence. Values of $\delta^{13}C$ may represent initial composition because of their resistance to alteration. [452]

Basin and Range-Age Reactivation of the Ancestral Rocky Mountains in Texas Panhandle: Evidence from Ogallala Formation

ROY T. BUDNIK, Bureau of Economic Geology, Austin, TX

The Ogallala Formation (Neogene) is a widespread syntectonic alluvial apron that was shed eastward from the Rio Grande rift and related uplifts in Colorado and New Mexico during Basin and Range extension.

In the Texas Panhandle, the Ogallala completely buried Ancestral Rocky Mountain (Pennsylvanian) structures. Renewed movement on these older structures during the Neogene influenced the thickness and facies distribution of the Ogallala. The Ogallala thickens into the Palo Duro, Dalhart, and Anadarko basins. Major distributary channels on Ogallala alluvial fans coincide with the axes of these basins, whereas major interchannel areas overlie intervening uplifts. Second-order structures subtly influenced the unit as well. For example, in the Carson basin, a Pennsylvanian rhomb graben along the Amarillo uplift, the Ogallala is over 250 m (820 ft) thick compared with 90 m (275 ft) in adjacent areas. Within the Palo Duro basin, local highs controlled the distribution of thin, interchannel flood-basin and lacustrine deposits. Thicker, braided-stream channel deposits follow local lows.

Later movement on the Amarillo uplift broadly folded the Ogallala. The southern high plains surface subtly reflects basement structure, with topographic highs overlying basement highs, suggesting post-Ogallala deformation within the Palo Duro basin.

The Amarillo uplift is approximately perpendicular to the Rio Grande rift and parallel to the direction of Basin and Range extension. Thus, the stress field that produced the rift may have caused strike-slip movement and reactivation of the Carson basin along the Amarillo uplift. [459]

Oil and Gas Fields of Oklahoma

MARGARET R. BURCHFIELD, Oklahoma Geological Survey, Norman, OK

At the end of April 1983, there were 3,088 active oil and/or gas fields in the state of Oklahoma, as well as 32 officially named abandoned fields, according to the Nomenclature Committee of the Mid-Continent Oil and Gas Association. Oil and/or gas fields are located in 73 of Oklahoma's 77 counties, and represent over 4 million acres (1.5 million ha.) in surface area.

The Oklahoma Geological Survey has prepared a new, up-to-date map of all officially named oil and/or gas fields in the state, at a scale of 1:500,000.

Each field is outlined, assigned an index number for reference, and designated by color code as either an oil field, gas field, or combination oil and gas field. As an improvement over oil and gas field maps available from commercial sources, the OGS has attempted to define better the geographic boundaries of each field. An alphabetical listing of all fields with their reference numbers and locations is featured on the map, along with a listing of smaller fields that have been combined into Oklahoma's major oil and gas "trends."

The map is designed for use as a reference by all oil and gas professionals in the state. The OGS oil and gas field map has been prepared in conjunction with the development of a computerized oil and gas field file for Oklahoma. Production of updated versions of the map in future years will be facilitated by digitization of information shown on the present map. [459]

U.S. Geological Survey Oil and Gas Atlas of the United States

SHERWOOD F. FREZON and KATHARINE L. VARNES, U.S. Geological Survey, Denver, CO

The U.S. Geological Survey is compiling a series of oil and gas maps that the Survey will publish as an oil and gas atlas of the United States. The maps in the series will synthesize information both on the national scale and for individual basins, and will include geologic, geochemical, geophysical, and exploratory data.

The maps displayed are the preliminary publications (open-file reports) of this new series. The national-scale maps for the conterminous United States show (1) location and names of basins, (2) total thickness of sedimentary rocks, (3) location of oil and gas wells drilled deeper than 15,000 ft (4,500 m), and (4) locations of oil and gas wells drilled deeper than 20,000 ft (6,000 m). Basin maps of the north slope of Alaska show (1) well locations, (2) isopachs, and (3) structure contours. [478]

Diagenesis of Burbank Sandstone, North Burbank Field, Osage County, Oklahoma

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The Pennsylvanian (Desmoinesian) Burbank sandstone in Tract 97 of Osage County, Oklahoma, is 2,845-2,945 ft (867-897 m) deep. Samples of the Burbank from cored intervals of five wells were analyzed to determine depositional environment, diagenetic alterations, and the effects of diagenesis on reservoir rock properties.

The Burbank sandstone consists of very fine to fine-grained lithic arenites deposited under fluvial-deltaic conditions. Though quartz dominates in the detrital fraction, rock fragments, primarily metamorphic, and feldspars constitute as much as one-third of the grains. Compaction, authigenesis, replacement, and dissolution have significantly altered the texture and composition of the Burbank sandstone. Compaction is relatively minor due to early cementation. However, multiple stages of authigenesis have given rise to abundant silica and carbonate cements and clay minerals, which together constitute approximately one-fourth of the bulk volume of the sandstone. Clay minerals, dominantly iron-rich chlorite with minor illite, occur as pore lining, pore filling, and replacement of silicate grains. Replacement of detrital particles by carbonate cement is ubiquitous; such replacement seems to be susceptible to dissolution. Dissolution of grains and particularly cement has yielded the present average porosity of 15%.

Hydrocarbon recovery from the Burbank sandstone is complicated by depositional changes and diagenesis. For a tertiary recovery program to be successful, the effects of cementation, dissolution, and authigenesis must be considered in the design. [489]

Depositional Environments, Reservoir Trends, and Diagenesis of Red Fork Sandstones in Parts of Blaine, Caddo, and Custer Counties, Oklahoma

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The Red Fork sandstone was divided into the upper and lower Red Fork which are separated by a consistent marker bed. The Red Fork interval thickens markedly across the study area from 250 ft (75 m) in the northeast to over 1,300 ft (400 m) in the southwest. Most of the thickening is within the lower Red Fork. The lower Red Fork is believed to have been deposited in shelf-to-basin transitional terrain. Sands were located in delta-front, submarine-channel-fill, and possible submarine-fan terrain. The upper Red Fork is believed to represent the maximum progradation of a deltaic complex.

Sandstones of the lower Red Fork are sublithic to lithic arenites; the upper Red Fork is sublithic arenite. The dominant lithic fraction is mudstone fragments. The main diagenetic alterations of both the upper and lower Red Fork sandstones were destruction of primary porosity by compaction and cementation. Dissolution chiefly of mud fragments has produced well-developed secondary porosity. Clays of the lower Red Fork mainly are authigenic chlorite; clays of the upper Red Fork primarily are authigenic kaolinite.

Present oil and gas production from Red Fork sandstones is most abundant from localities on the paleoshelf. [492]

Maturity Parameters of Woodford Shale, Anadarko Basin, Oklahoma

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The Upper Devonian–Lower Mississippian Woodford Shale is an important source rock in the Anadarko basin. Because of its stratigraphic relationship to the Hunton Group and other productive reservoirs, it has been the subject of several recent studies attempting to evaluate hydrocarbon potential. Standard geochemical analyses were performed on a 5-well cross-section beginning in the northeastern shelf of the Anadarko basin at a depth of 5,700 ft (1,737 m) and ending in the southeastern part of the deep Anadarko basin at 22,000 ft (6,706 m). The data reveal systematic changes in geochemical parameters with increasing depth and maturity level. Such changes are consistent with maturation effects seen in other basins around the world.

Vitrinite reflectance data for progressively deeper wells yielded mean R_o values of 0.60, 0.88, 1.23, 1.86, and 2.03%. These values are indicative of maturation levels ranging from the main zone of oil generation to the zone of dry gas generation. Bitumen ratios (expressed as milligrams of soluble organic matter per gram of total organic carbon) agree well with these maturation levels. Infrared spectroscopy, used to assess the changes in functional groups of the soluble organic matter and kerogen, shows a corresponding increase in the aromaticity of the organic compounds with increasing maturity level. Elemental analysis of kerogen (carbon, hydrogen, nitrogen, and oxygen) and gas chromatography of whole-rock bitumen extracts exhibit maturation effects similar to those noted in other basins.

In addition, organic matter (O.M.) isolated by conventional palynologic techniques was examined under white light and shows progressive changes from yellow-amber and translucent O.M. at $R_o = 0.60\%$, to dark brown, partially translucent and partially opaque O.M. at $R_o = 0.88\%$. Samples with R_o values of 1.23% and greater are completely opaque. Visual kerogen studies support the obtained geochemical parameters. [493–494]

Overview of the Central North American Basins and Their Relation to Deep Crustal Structure

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As our knowledge of deep structure of major central North American basins has increased, it has become clear that they have experienced long and complicated tectonic histories. A knowledge of these histories is especially important to efforts to formulate exploration strategies for deeper horizons and frontier areas. Regional geophysical and geologic studies of these basins indicate that Precambrian features have often exerted considerable control on basinal development (e.g., Anadarko basin, Rome trough, Rough Creek graben, Pedregosa basin). A particularly important tectonic event was the Eocambrian continental breakup which extensively rifted the southern margin of North America. Although this rifting event is manifested in various ways, its extent can be estimated by mapping the deep-seated crustal anomalies which probably formed at this time. Although age relations are uncertain in most cases, deep-seated anomalies are associated with the Arkoma basin, Anadarko basin, Illinois basin, Mississippi embayment, and Permian basin. There are many similarities in the development of these basins, but they all can be shown to have unique tectonic histories. [495]

Regional Gravity and Tectonic Study of the Ouachita System

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A regional study of the Ouachita system has been undertaken using gravity and deep-drilling data. An integrated analysis of gravity maps, computer models, and geologic data suggests that the crust beneath the Gulf coastal plain is variably attenuated continental crust. The transition zone between this crust and the craton, which is marked by a steep gravity gradient that lies along the trend of the Ouachita system, may have been created by Mesozoic reactivation of a crustal zone of weakness inherited from a plate collision during the late Paleozoic Ouachita orogeny. Gravity minima along the frontal zone of the Ouachita system are due to a thick sedimentary rock pile in conjunction with a gulfward dipping intracrustal or crust/mantle boundary in some areas. The arcuate Ouachita gravity maximum is the result of denser (metamorphic) rocks of the interior zone, with uplifts and upper crustal mafic intrusions making contributions in some areas. Gravity anomalies in the Gulf coastal plain are a combined effect of variable crustal attenuation, subsidence, and densification of the upper crust. Maxima in the southern Oklahoma aulacogen area are the result of uplifts and upper crustal mafic intrusions and/or lower crustal upwarps. [497]

Petrography, Diagenesis, and Depositional Setting of Glenn (Bartlesville) Sandstone, Berryhill Unit, Glenn Pool, Oklahoma

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Petrography and physical stratigraphy of the "Glenn" (Bartlesville) sandstone in the 160-acre Berryhill unit, Glenn Pool, were established from 10 cores and more than 60 modern well logs. The reservoir mostly is sublitharenite to litharenite; lithic constituents chiefly are metamorphic rocks and rip-up clasts. Principal diagenetic minerals are kaolinite, chlorite, and illite. This evidence and data from the regional and local stratigraphic framework indicate that sands were upper delta-plain deposits. Logs of the closely spaced wells show moderately complex short-distance change in geometry of the sandstone and attendant reservoir heterogeneity. All this information is integral in ongoing plans for enhanced recovery and in current research on enhancement of well logs by signal processing. [498]

Cenozoic Epeirogenic Uplift of Palo Duro Basin, Texas, and Its Influence on Structure, Salt Dissolution, and Topography

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Sufficient data are available to interpret a general history of Cenozoic epeirogenic uplift and its influence on structure, salt dissolution, and topography in the Palo Duro basin. Much of the structural warping and deformation of Middle and Upper Permian rocks in the Palo Duro basin occurred during Cenozoic epeirogenic uplift. Cretaceous marine strata in the Texas and Oklahoma Panhandles and eastern New Mexico were uplifted 3,000–4,000 ft (914–1,219 m). The "Tubb Sand" (Permian) exhibits about 4,000 ft (1,219 m) of structural relief over the Amarillo uplift and Bravo dome.

Differential uplift of the margins of the basin caused draping, fracturing, and faulting, which increased the amounts and rates of erosion and salt dissolution coincident with fault-bounded structures. Structural control of topography around the southern high plains is indicated by the coincidence of the Caprock escarpment and structural highs in Permian rocks, as well as the coincidence of many stream segments and segments of the Caprock escarpment with subsurface fault trends. [505]

Interpretive Seismic Modeling in Anadarko Basin

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Seismic forward modeling is a powerful aid when interpreting seismic profiles of complex structure. Considered here is the frontal fault system that is the boundary between the Anadarko basin and the Wichita Mountains.

COCORP deep seismic reflection data collected across the basin may reveal new evidence of thrust faulting in the frontal fault system. North–south lines 2 and 2a of the COCORP survey are interpreted using AIMS™ (Advanced Interpretive Modeling System) installed on the University of Oklahoma's IBM 3081 computer. Line 2a stretches southward from the relatively undisturbed sedimentary rocks in the basin across the N85°W-trending frontal fault system to the south. The modeling begins at the north end of line 2a because of the relatively simple structural geometry and well control in that area.

The initial modeling began with an hypothesis based on well logs, COCORP data, and other geologic information. After the subsurface structures were defined, depth and velocity plots were produced. Normal incidence rays were then traced from each horizon to specified shot points. The ray-tracing plot gives a good indication of the quality of resolution one can expect from a particular subsurface geometry. The synthetic profile was produced by first applying a broad-band pulse, then applying a Ricker wavelet to each trace. A gain function was applied to enhance the section for interpretation. Forward seismic modeling in the Anadarko basin enhances interpretation by giving an idea of the seismic resolution one can expect and letting the interpreter test a geologic hypothesis against the seismic profiles. [505–506]

Use of Conodont Genus *Gondolella* in High-Resolution Biostratigraphic Zonation of Middle-Upper Pennsylvanian Rocks, Central North America

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Several conodont taxa have been suggested for use as biostratigraphic tools in the Pennsylvanian, but each has its limitations. Some are severely restricted paleobiogeographically or paleoecologically. Others existed through a relatively short interval of time, leaving the bulk of the Pennsylvanian column unzoned. Frustratingly, the single most promising group, the *Idiognathodus-Streptognathodus* plexus, has eluded taxonomic treatment that is both phylogenetically sound and biostratigraphically useful.

Gondolella Stauffer and Plummer, 1932 (type-species *G. elegantula*, O.D.), is subject to many of these restrictions, especially geographically and paleoecologically, but offers a highly precise zonation in the rocks where it does occur that can serve as an interim standard for some (mostly Missourian) and a supplement for others (mostly Desmoinesian). Enough occurrences have been amassed to facilitate interregional, and in some cases, intercontinental correlations.

Desmoinesian gondolellids are known from 9 stratigraphic units in the Illinois basin and 5 from the Mid-Continent, and 5 zones are recognized. Distribution is relatively uniform, and zonation of this part of the column is almost total. This zonation is less detailed than the contemporary *Neognathodus* zonation, but it is a valuable supplement to it. The most dense concentration of *Gondolella* -bearing units is in the Mid-Continent Missourian where 15 units have produced gondolellids. These and the 6 Illinois basin units can be assigned to at least 6 zones, totally contiguous in the lower Missourian, less so upward. The Virgilian cannot be completely zoned, but the 2 productive Mid-Continent units are assigned to different zones. [507]

Regional Facies Distribution and Tectonic Evolution of Appalachian and Ouachita Thrust Belts

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A series of 12 tectonic and lithofacies maps representing critical periods of the evolution of the Appalachian-Ouachita orogen were compiled from published sources and interpretation of seismic and subsurface data. The distribution of sediments supports the concept of multiple deformation that resulted from the collision and accretion of small plates or irregular margins of larger plates with North America.

During the Eocambrian and Early Cambrian, a series of rifts developed within the craton subparallel to the continental margin of the Iapetus Ocean. Ouachita sediments were deposited in this rift zone along the southern margin of the craton. However, the rift zone did not persist in the Appalachians, and the sediments in that belt were deposited along the continental margin.

In the Middle Ordovician, the extensional regime continued in the Ouachita belt while compression associated with plate collision began in the Appalachians. The northwest-southeast-trending boundary between these areas persisted throughout the evolution of the orogens. The sedimentary records indicate that the initial compressional deformation in the Ouachita belt began during the Late Mississippian, and the final phase of deformation in the Appalachians was initiated slightly later, during the Early Pennsylvanian.

Structural features associated with thrusting basin sediments over foreland areas were controlled to a great extent by the presence or absence of buttresses. The Ouachita Mountains area provides the best illustration of contrasting structural styles along the thrust belt. Elsewhere along the thrust belts the evidence is either covered by younger sediments or altered by a complex tectonic history. [507]

Facies Analysis of Upper Jackfork Formation (Pennsylvanian), DeGray Dam, Arkansas

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The DeGray Dam spillway cut displays perhaps the best exposed section of the upper Jackfork formation (Pennsylvanian) in the Ouachita Mountains of Arkansas and Oklahoma. Comprising more than 321 m (1,050 ft) of interbedded sandstone and shale, this deep-water succession was originally interpreted as a sequence of alternating proximal and distal turbidites, and subsequently as outer-fan depositional lobes. Recent detailed facies analysis, however, demonstrates that the succession represents a mid-fan association of channel and interchannel deposits.

Channelized intervals consist of stacked thinning-upward and/or amalgamated packages characterized by Mutti and Ricci Lucchi facies A, B, C, and G. Associated interchannel intervals consist of facies C, D, E, and G beds that are randomly interbedded or form thickening-upward packages that superficially resemble depositional lobes. These lobe-like packages, which are generally less than 4 m (13 ft) thick, are interpreted as crevasse-splay deposits. A similar association of channel and interchannel deposits can also be observed in nearby outcrops of the underlying lower Jackfork.

A longitudinal submarine fan system, analogous to the present-day Bengal fan, is visualized as the overall depositional setting for the Jackfork formation. [509]

Surface and Subsurface Structural Analysis of a Part of Washita Valley Fault Zone, Southern Oklahoma

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The Washita Valley fault zone is one of the major northwest-trending structures in southern Oklahoma. This fault system is believed to have originated as a series of normal faults during the formation of the southern Oklahoma aulacogen by late Precambrian or early Cambrian time and to have been reactivated during the Arbuckle orogeny in the Pennsylvanian. Descriptions of movement along the Washita Valley fault zone during Pennsylvanian deformation include numerous interpretations, the most common being left-lateral strike slip with 30–40 mi (50–65 km) of displacement. Structures in the area, however, suggest an alternate model.

A detailed field study of small folds, faults, fracture arrays, slickensides, and drainage patterns was conducted along the southeastern half of the Washita Valley fault zone. An attempt has been made to relate these small-scale features to the major structures in the area to determine the orientation of the major compressive stress during deformation and the relative amounts of strike-slip vs. reverse dip-slip movement along the fault zone.

Exploration for oil and gas along the Washita Valley fault zone has identified several overturned folds and repeated sections. Field observations in the study area include small drag folds and thrust faults parallel to the trend of the Washita Valley fault zone. The two major anticlines in the area, the Arbuckle and the Tishomingo, are both nearly parallel to the trend of the fault zone. These data suggest a model of deformation involving a large component of reverse dip-slip faulting with major duplication of strata. [514]

A Channelized, Sand-Rich, Deep-Sea Fan Deposit, Lower Atoka Formation (Pennsylvanian), Ouachita Mountains, Oklahoma and Arkansas

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The lower member of the Pennsylvanian Atoka Formation exposed in the Ouachita Mountains of Oklahoma and Arkansas is part of a thick (more than 10,000 m or 32,800 ft) turbidite sequence deposited in a remnant ocean basin (the Ouachita geosyncline) during the Carboniferous. Paleocurrent data indicate a predominantly longitudinal sediment dispersal pattern westward down the basin axis.

Nine lithofacies are recognized: massive, amalgamated sandstones (A1), graded, matrix-supported sandy mudstones (A2), six different types of classic turbidites (C1, C2, C3, D1, D2, and D3), and chaotic deposits (F) including debris flows. These occur in two principal lithofacies associations, both representing deposition in an areally extensive, sand-rich, channelized deep-sea

fan environment. Lithofacies association 1 consists of packages of lithofacies A1 (and to a lesser extent A2 and C3) 1–30 m (3–98 ft) thick, interbedded with intervals comprised of lithofacies A2, C1, C2, C3, D1, D2, and D3, in which the sandstone:shale ratio is generally high (amalgamated to 1:5). Thickening- and thinning-upward sequences are arranged symmetrically about the lithofacies A1 packages, producing stacked symmetrical sequences 1 to 20 m thick. Lithofacies association 2 consists of lithofacies C3, D1, D3, and minor amount of D2, arranged in symmetrical as well as individual thickening- and thinning-upward sequences 1–40 m (3–130 ft) thick. The sandstone:shale ratio is highly variable (amalgamated to 1:50). Although thickness trends in this lithofacies association can be highly complex, thinning-upward sequences (10–40 m or 33–130 ft thick) are prominent. Slumped chaotic deposits (lithofacies F) are intercalated throughout both lithofacies associations. Common crevasse splays that develop into new channel segments, and filling of distributary channels are the inferred processes involved in the development of the two lithofacies associations.

The absence of deposits of major depositional lobes and the extensive development (both vertically and laterally) of a channelized (distributary channel) fan environment suggest that current submarine-fan models are not generally applicable to this deposit. [531]

SME FALL MEETING IN DENVER ANSWERS MYRIAD OF MINING QUESTIONS

"So You Think You Want to Be in the Talc Business" is the intriguing title of a session scheduled by the Industrial Minerals Division of the Society of Mining Engineers of AIME for the fall meeting and exhibit that is scheduled for October 24-26 in Currigan Hall, in Denver. The meeting will include technical programming by all four SME Divisions—Coal, Mining and Exploration, Mineral Processing, and Industrial Minerals—and the SME Minerals Resource Management (MRM) Committee.

Along with the session on the talc business, the Industrial Minerals Division sessions include: Kimberlite Exploration, Wyoming Trona, Chemicals from Brines, and Economics of Industrial Minerals (with MRM). The division will also present one symposium on Borates—Economic Geology and Production.

The Coal Division will sponsor nine sessions on Health and Safety—Preselection Engineering for a Safer Work Force, Coal Utilization, Surface Mining, Research and Development, Health and Safety—Applications and Results, Underground Ventilation, Environmental, Coal Underground Mining, and Coal Preparation.

The Mining and Exploration Division has seven general sessions planned along with two symposia. The general sessions include: Geochemistry, Open Pit Mining, Underground Grouting, Geophysics, Operations Research I and II, and Hydrology. One symposium—Geomechanics—will consist of Geomechanics Applications in Underground Hardrock Mining I through IV. The other symposium—Geology—will be composed of Applied Mining Geology: Problems of Sampling and Grade Control I through III.

The Mineral Processing Division will present 12 sessions. Among them are: Fundamentals of Oil Shale Processing, Materials Handling, and Operating Control.

The Minerals Resource Management Committee will hold six sessions, including: Economics of Small Mine Projects, Impact of Recession Aftermath on Mining Companies, and Economics of Industrial Minerals.

In addition to the technical sessions, a Technological Information Exchange Exhibit will provide meeting attendees with the opportunity to view the latest mining technology. Each booth will contain the latest technological information, products, services, or equipment; government representatives to explain agencies or policies; or program information from colleges and universities.

For more information, contact Meetings Dept., Society of Mining Engineers, Caller No. D, Littleton, CO 80127; (303) 973-9550; telex 45-0446.