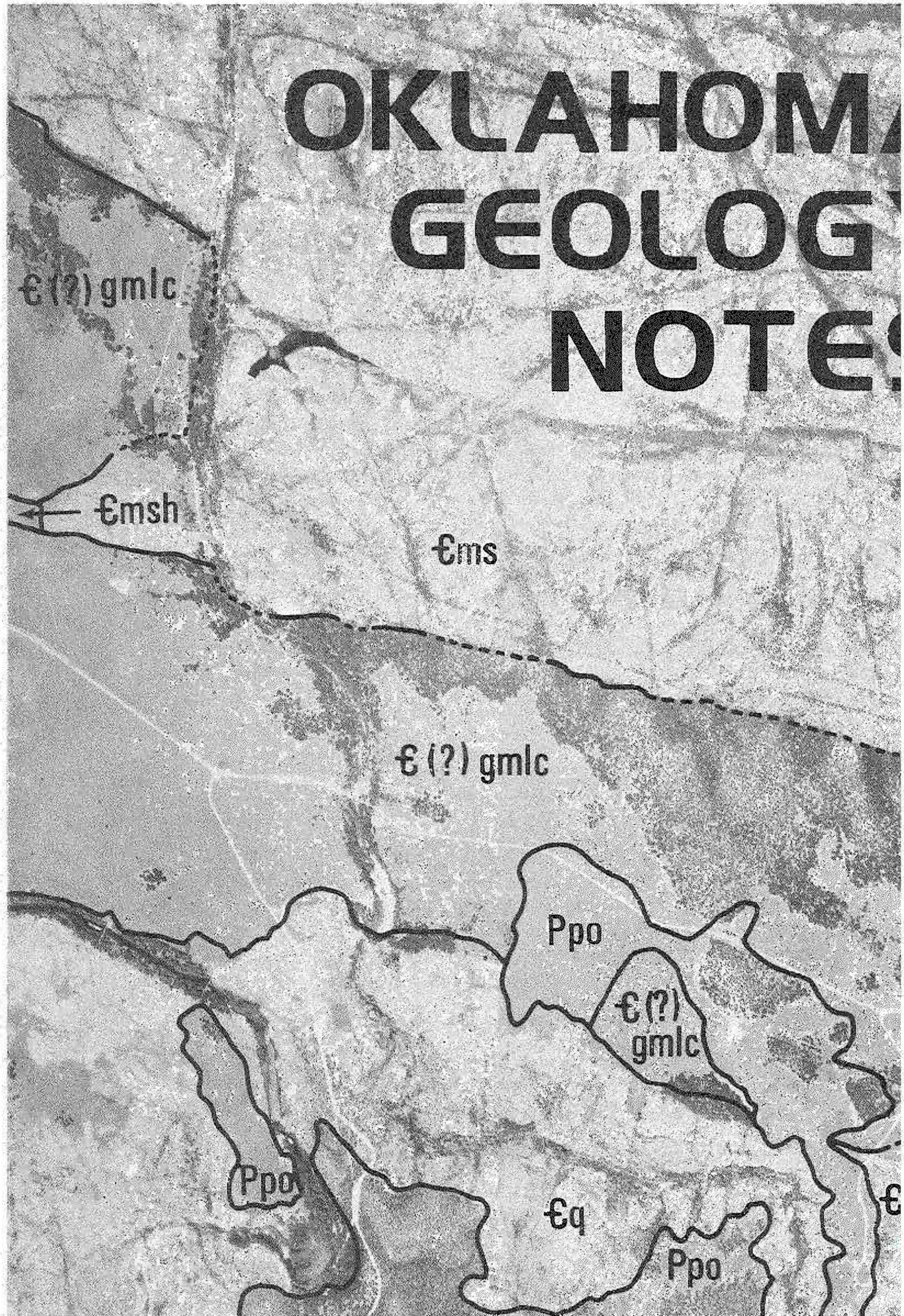
VOLUME 38 NUMBER 2 APRIL

OKLAHOM
GEOLOG
NOTE



Cover Picture

LAKE BURFORD AREA, WICHITA MOUNTAINS WILDLIFE REFUGE

The vertical aerial photograph, taken in May 1961, was supplied by the U.S. Department of Agriculture. The scale is about 1:20,000, giving a width to the view of about 1.8 miles. The area shown is a part of T. 3 N., R. 14 W., Comanche County; State Highway 49 trends westerly across the photo. Four man-made lakes shown are: Lake Burford, the light area near the center; Lost Lake in the southwest corner; Osage Lake in the southeast corner; and Apache Lake, the dark area in the northwestern part.

Although some may be faults, most of the prominent lineaments are fractures. Most of the lineaments formed during Pennsylvanian orogeny, but some of these structures probably resulted from emplacement of Wichita granites and extrusion of related Carlton rhyolites and are therefore Cambrian in age.

The oldest unit in the area is the Cambrian(?) Glen Mountains layered complex (Ꞓ?gmlc), part of the Raggedy Mountain Gabbro Group. Overlying this unit as a sill is the Cambrian Mount Scott Granite (Ꞓms). A small hybrid zone (Ꞓmsh) along the gabbro-granite contact is barely seen at the western edge of the photo. The Cambrian Quanah Granite (Ꞓg) intrudes the Glen Mountains layered complex on the south, but the Quanah–Mount Scott contact was eroded away in this area during Pennsylvanian-Permian time. Finally, remnants of the Permian Post Oak Conglomerate (Ppo) partly fill the lower area underlain by the gabbro and cover parts of the Quanah Granite.

—M. Charles Gilbert

Editorial staff: William D. Rose, Elizabeth A. Ham, Judy A. Russell.

Oklahoma Geology Notes is published bimonthly by the Oklahoma Geological Survey. It contains short technical articles, mineral-industry and petroleum news and statistics, an annual bibliography of Oklahoma geology, reviews, and announcements of general pertinence to Oklahoma geology. Single copies, seventy-five cents; yearly subscription, $4.00. All subscription orders should be sent to the address on the front cover.

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

This publication, printed by The University of Oklahoma Printing Services, Norman, Oklahoma, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes 1971, Section 3310, and Title 74, Oklahoma Statutes 1971, Sections 231-238. 1,500 copies have been prepared for distribution at a cost to the taxpayers of the State of Oklahoma of $2,268.00.

PALLISERIA ROBUSTA WILSON (GASTROPODA) IN OIL CREEK FORMATION, ARBUCKLE MOUNTAINS, OKLAHOMA

Ronald D. Lewis[1] **and Ellis L. Yochelson**[2]

Palliseria, a large macluritid gastropod with a protruding base, known previously only from the Great Basin in the United States and the Rocky Mountains in Canada, has been found to occur in Oklahoma. The genus is a guide fossil for the Whiterockian Stage of earliest Middle Ordovician age and is extremely widespread, with an abundance of specimens recovered from central and southern Nevada and adjacent parts of eastern California (Ross, 1964a, 1964b, 1970). Records of the U.S. Geological Survey show a few additional occurrences in Idaho. In western Canada the genus is found in Alberta and British Columbia (Yochelson, 1957; Norford, 1969). The presence of *Palliseria* in Oklahoma is documented definitely for the first time in this report.

Ross (1964a, 1964b) considered *Palliseria* and associated fossils to be facies controlled, and, on the basis of brachiopod zones, he interpreted the facies as progressively younger from east to west across southern Nevada and eastern California. The *Palliseria* assemblage and underlying *Rhysostrophia* assemblage in the northern Inyo Mountains of California were judged to be younger than the Whiterockian Stage (Ross, 1964b, figs. 5, 6). Subsequent refinements in ranges of fossils in the *Rhysostrophia*-zone assemblage led Ross to conclude that the *Palliseria* assemblage is not diachronous and should be considered a subzone of the *Anomalorthis* zone of the Whiterockian Stage (Ross, 1970, p. 47–48).

Palliseria is better known from its subjective synonym *Mitrospira*, which was described by Kirk (1930) from the Antelope Valley Limestone of Nevada. Kirk (1930, p. 3) noted that "Dr. E. O. Ulrich informs me that he has at least two species of *Mitrospira*, one from Canada and another from Oklahoma." Ulrich's material from Canada is from the Phillipsburg area of Quebec and appears to be deformed, weathered specimens of *Maclurites* (Yochelson, 1957). The Oklahoma material referred to by Kirk was reportedly from the Joins Formation; it has not been located in spite of repeated searches through the collections of the U.S. National Museum of Natural History during more than two decades. Because Ulrich's specimens could not be reexamined, the occurrence of *Palliseria* in Oklahoma has remained unverified heretofore.

During the summer of 1977, the senior author and his wife, Kathy, collected three specimens of *Palliseria* from the upper part of the Oil Creek Formation at the excellent exposure along Interstate Highway 35 in the southern Arbuckle Mountains (figs. 1, 2). This discovery supports Kirk's report and his correlation of the *Palliseria* beds of the Pogonip Group of Nevada with the Simpson Group of Oklahoma.

---

[1] Graduate student, Department of Geological Sciences, The University of Texas at Austin, Austin, Texas.

[2] Geologist, U.S. Geological Survey, Washington, D.C.

The three specimens were collected close together from the southern part of the exposure along the west side of the northbound lane in the SE¼ sec. 24, T. 2 S., R. 1 E., Carter County, Oklahoma. One specimen (fig. 3, *3, 4*) was found *in situ* in a 60-cm-thick bed of nodular biomicrite and shale that occurs 138.2 m above the base of the formation. The other two specimens (fig. 3, *1, 2, 5, 6*) were found loose a few meters away and may have been derived from this or adjacent beds. The specimens have been reposited in the U.S. National Museum as USNM nos. 251993, 251994, and 251995.

Compared with material from Nevada, these three specimens show less

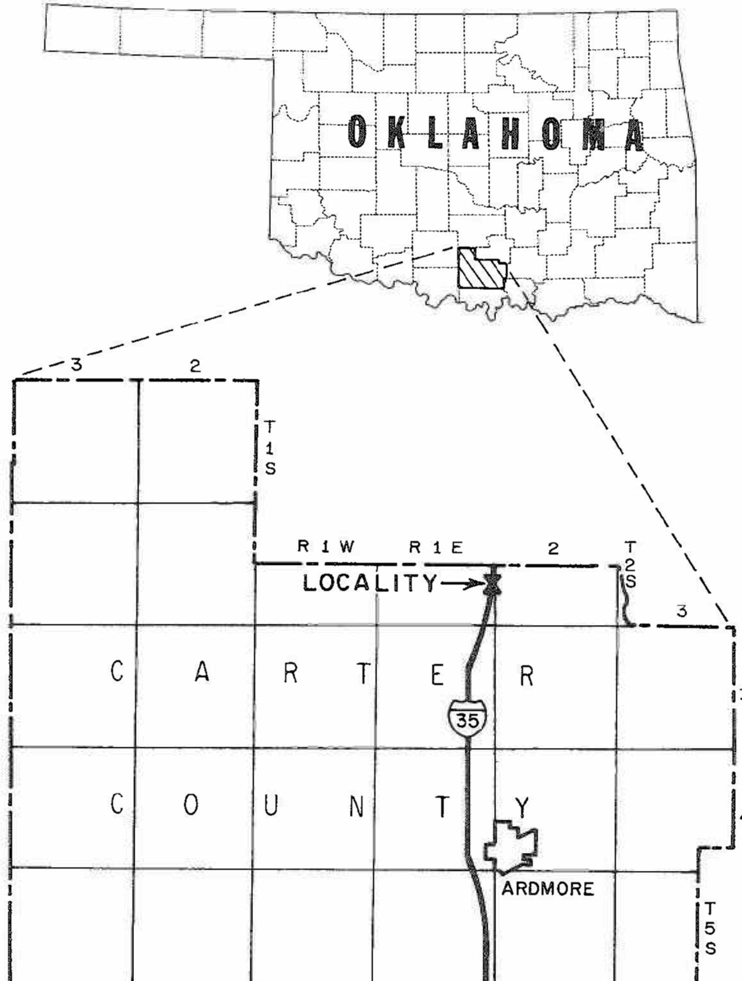


Figure 1. Outline map of Carter County showing locality of fossil-collecting site and measured section.

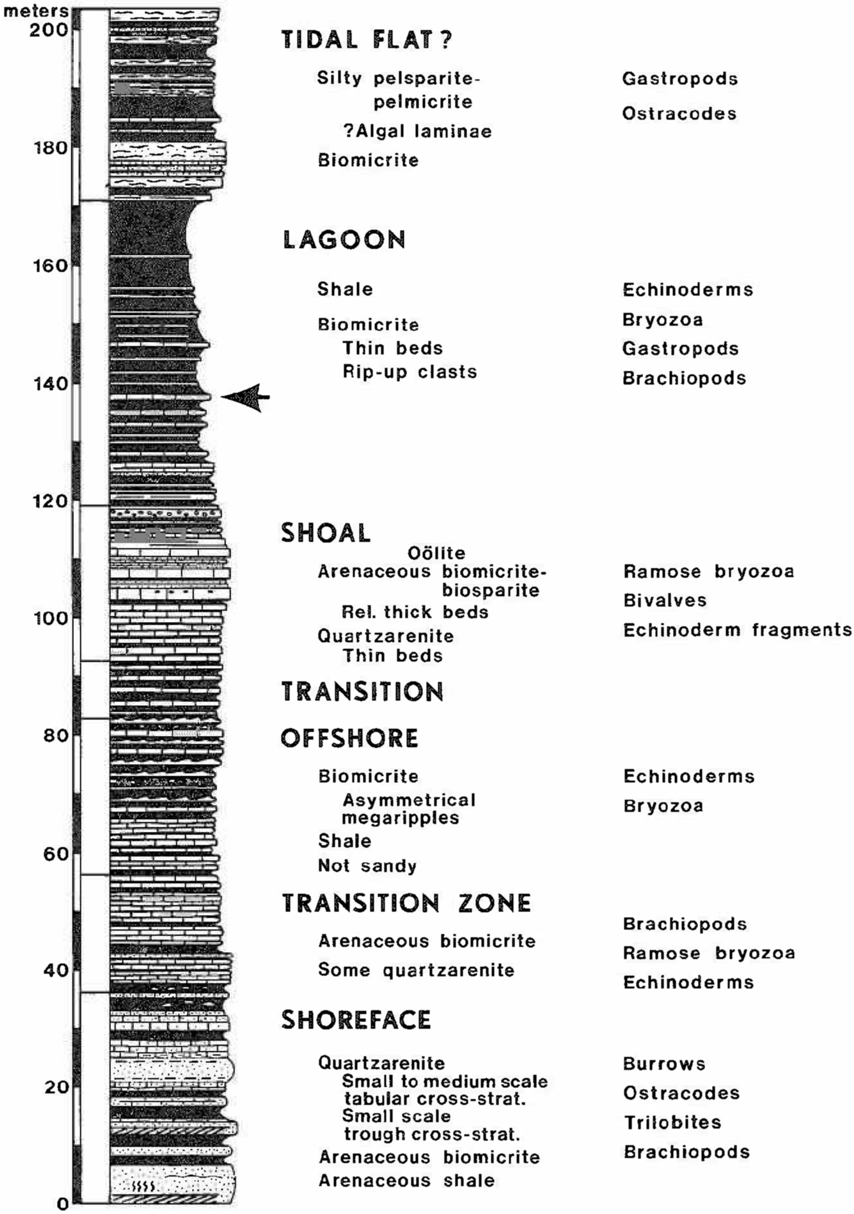


Figure 2. Graphic representation of Oil Creek Formation as exposed along Interstate Highway 35 and U.S. Highway 77, with summaries of environmental interpretations, characteristic lithologies, and major elements of fauna. Stratigraphic position of **Palliseria** indicated by arrow.

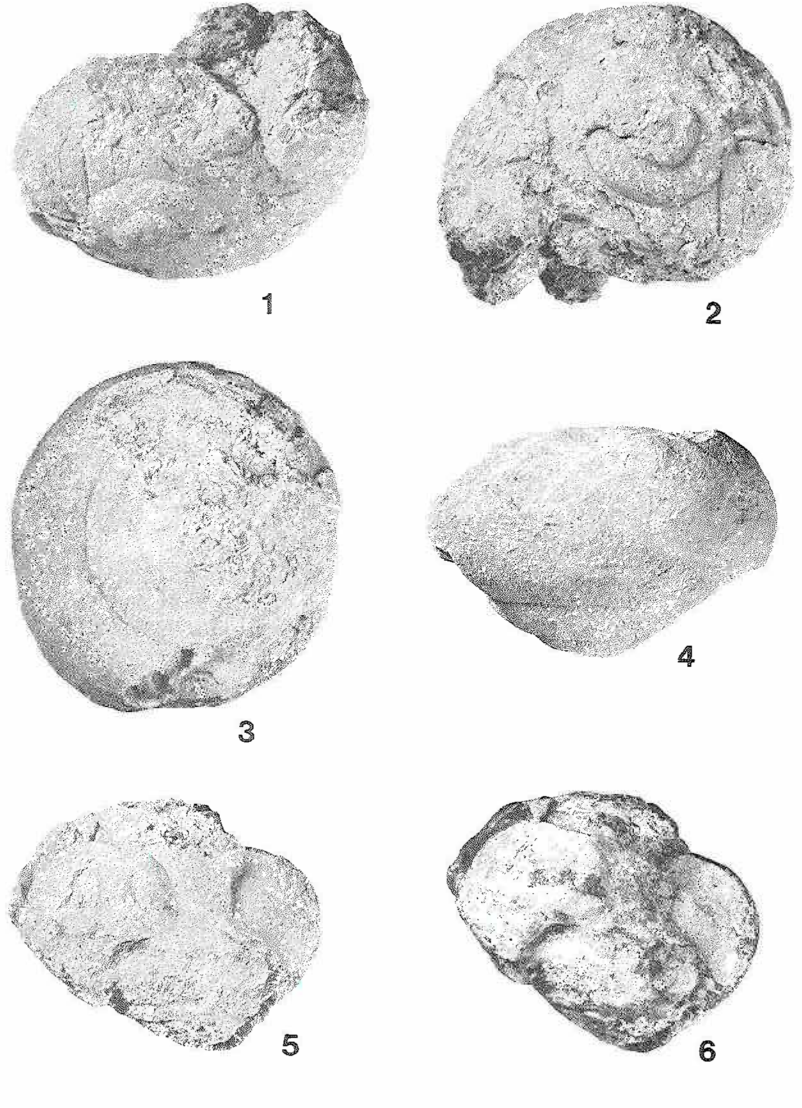


Figure 3. **Palliseria robusta** Wilson from Oil Creek Formation in Carter County, Oklahoma. All specimens were prepared by means of hand tools. Specimens *1–5* were coated with ammonium chloride; view shown in *6* was moistened with water. *1*, *2*, oblique apertural view and oblique basal view, respectively, ¾ natural size; USNM 251993. *3*, basal view, showing large amount of whorl overlap, natural size; *4*, side view, showing prominently protruding base that is diagnostic for genus, natural size; USNM 251994. *5*, *6*, side view of specimen broken subparallel to columella, coated with ammonium chloride and moistened with water, respectively, ¾ natural size; USNM 251995.

variation than some of the specimens that Kirk included in his original description. Yochelson (1957) indicated that Kirk's species *Mitrospira longwelli* was conspecific with the original poorly known type lot of *Palliseria robusta* Wilson, and, accordingly, these three individuals are also placed in *P. robusta*.

The Oil Creek Formation has been dated as Whiterockian in age chiefly on the basis of brachiopods (Cooper, 1956, 1976) and conodonts (Bergström, 1971; Sweet and Bergström, 1976). By confirming the occurrence of *Palliseria* in the formation, we corroborate this age determination with evidence from another taxonomic group.

The senior author, whose doctoral dissertation is a study of the depositional environments and paleoecology of the Oil Creek Formation (see Lewis, 1977), interprets the interval in which *Palliseria* was found as a lagoonal facies deposited during the regressive phase represented by the upper part of the formation (fig. 2). This interpretation is based upon the stratigraphic sequence and the abundance of terrigenous shale. Because the shoal facies is not distinctively developed in some areas, we infer that the shoal was not an effective barrier to water circulation. Essentially normal salinity is indicated for the lagoonal facies by the relatively diverse assemblage of echinoderms, brachiopods, and bryozoans. The bed yielding *Palliseria* contains abundant *Maclurites* and common receptaculitids.

Maclurites and receptaculitids are commonly associated with *Palliseria* in Nevada and western Canada, where *Palliseria* is most abundant in thick-bedded limestones that are rich in the alga "*Girvanella*" (Ross, 1964a, p. C79–C80). *Palliseria* is not known from Whiterockian units in the Pogonip Group in eastern Nevada and western Utah where "*Girvanella*" is not as common as in southern Nevada (Ross, 1970; Hintze, 1951; Hintze and others, 1969). In the Oil Creek Formation of Oklahoma, *Palliseria* is rare and is not associated with "*Girvanella*." We speculate with Ross (written communication, 1977) that "*Girvanella*" may have been a preferred food item for *Palliseria* and that the former organism may have in part controlled the distribution and abundance of the latter.

References

Bergström, S. M., 1970 [1971], Conodont biostratigraphy of the Middle and Upper Ordovician of Europe and eastern North America, *in* Sweet, W. C., and Bergström, S. M. (editors), Symposium on conodont biostratigraphy: Geological Society of America Memoir 127, p. 83–161, 2 pls.

Cooper, G. A., 1956, Chazyan and related brachiopods: Smithsonian Miscellaneous Collections, v. 127, pt. 1, text, p. 1–1024, 3 figs., 1 chart; pt. 2, plates, p. 1025–1245, 269 pls.

——— 1976, Early Middle Ordovician of the United States, *in* Bassett, M. G. (editor), The Ordovician System—proceedings of a Palaeontological Association symposium, Birmingham, September 1974: Cardiff, University of Wales Press and National Museum of Wales, p. 171–194.

Flower, R. H., 1971, Cephalopods of the Whiterock Stage, *in* Dutro, J. T., Jr. (editor), Paleozoic perspectives—a paleontological tribute to G. Arthur Cooper: Smithsonian Contributions to Paleobiology, no. 3, p. 101–111, 2 pls.

——— 1976, Some Whiterock and Chazy endoceroids: New Mexico Bureau of Mines and Mineral Resources Memoir 28, pt. 2, p. 13–39, pls. 6–16.

Hintze, L. F., 1951, Lower Ordovician detailed stratigraphic sections for western Utah: Utah Geological and Mineralogical Survey Bulletin 39, 100 p.

Hintze, L. F., Braithwaite, L. F., Clark, D. L., Ethington, R. L., and Flower, R. H., 1969, A fossiliferous Lower Ordovician reference section from western United States, *in* The Ordovician symposium—third annual field trip: El Paso Geological Society and Permian Basin Section of Society of Economic Paleontologists and Mineralogists, p. 8–30.

Kirk, Edwin, 1930, *Mitrospira,* a new Ordovician gastropod genus: U.S. National Museum Proceedings, v. 76, article 22, p. 1–6, pls. 1–3.

Lewis, R. D., 1977, Depositional environments and paleoecology of the Oil Creek Formation (Middle Ordovician), Arbuckle Mountains, Oklahoma [abstract]: Geological Society of America Abstracts with Programs, v. 9, p. 59 (reprinted in Oklahoma Geology Notes, v. 37, p. 32–33).

Norford, B. S., 1969, Ordovician and Silurian stratigraphy of the southern Rocky Mountains: Geological Survey of Canada Bulletin 176, 90 p., 19 pls.

Ross, R. J., Jr., 1964a, Middle and Lower Ordovician formations in southernmost Nevada and adjacent California, *with a section on* Paleotectonic significance of Ordovician sections south of the Las Vegas shear zone, by R. J. Ross, Jr. and C. R. Longwell: U.S. Geological Survey Bulletin 1180-C, p. C1–C101, 1 pl.

——— 1964b, Relations of Middle Ordovician time and rock units in basin ranges, western United States: American Association of Petroleum Geologists Bulletin, v. 48, p. 1526–1554, 10 figs.

——— 1970, Ordovician brachiopods, trilobites, and stratigraphy in eastern and central Nevada: U.S. Geological Survey Professional Paper 639, 103 p., 22 pls.

Shaw, F. C., 1974, Simpson Group (Middle Ordovician) trilobites of Oklahoma: Journal of Paleontology, v. 48, no. 5 (Paleontological Society Memoir 6), 54 p., 12 pls.

Sweet, W. C., and Bergström, S. M., 1976, Conodont biostratigraphy of the Middle and Upper Ordovician of the United States Midcontinent, *in* Bassett, M. G. (editor), The Ordovician System—proceedings of a Palaeontological Association symposium, Birmingham, September 1974: Cardiff, University of Wales Press and National Museum of Wales, p. 121–151.

Yochelson, E. L., 1957, Notes on the gastropod *Palliseria robusta* Wilson: Journal of Paleontology, v. 31, p. 648–650, 5 figs.

Colorado Survey Compiles Coal Map

The Colorado Geological Survey recently published a map entitled *Coal Resource and Development Map of Colorado.* Included on the map are locations of Colorado's coal resources; active, abandoned, and proposed mines; coal treatment and conversion facilities; power plants (current and proposed); railroads (current and proposed); and proposed slurry-pipeline routes. The map has compilations of depth, quality, and classification of the coals, with estimates of original and remaining resources, including production for 1977 of major mines; and it includes information on geologic formation, age, and rank of coals. With nearly a third of Colorado's land underlain by coal, this map is a valuable reference tool.

The 40-inch by 58-inch map is in 2 colors and is published at a scale of 1:500,000 (approximately 1 inch = 8 miles). The map, MS-9, is available from the Colorado Geological Survey, Room 715, 1313 Sherman Street, Denver, Colorado 80203, prepaid for $4.00. The Survey requests that mail orders include $0.50 extra for handling and postage.

REGIONAL SEISMIC AND GEOLOGIC EVALUATIONS OF NEMAHA UPLIFT OKLAHOMA, KANSAS, AND NEBRASKA

Kenneth V. Luza[1]

Introduction

The Midcontinent area of the United States has a number of population centers that have undergone rapid growth since 1945. This increased growth, in conjunction with the increase in fossil-fuel costs, has stimulated electrical-generation companies to consider nuclear power plants as a viable means for providing additional energy. Currently there are two operating and four proposed nuclear power plants in Nebraska, Kansas, and Oklahoma. All of the existing and proposed plants are within or adjacent to an area that has been designated as seismic risk zone 2. This zone may have earthquakes that cause moderate damage and earthquake-intensity values up to Modified Mercalli (MM)[2] Intensity VII.

The U.S. Nuclear Regulatory Commission (NRC) has rigorous guidelines that must be adhered to before a permit to construct a nuclear power plant is granted. Local, as well as regional, seismicity and structural relationships play an integral role in the final design criteria for nuclear power plants. This requires that a value for the maximum expectable seismic event be assigned at a proposed site. The existing historical record of seismicity is inadequate in a number of areas of the Midcontinent region because of the lack of instrumentation or the frequency-response characteristics of the instruments deployed to monitor earthquake events. This inadequacy has made it necessary to rely on the delineation of major tectonic provinces based on broad regional geologic structure and associated seismicity. The delineation of tectonic provinces, which accurately reflect the potential magnitude of seismic events, is an important cost and risk factor in assigning design criteria for nuclear power plants.

Hadley and Devine (1974) and King (1951) categorized the geologic regions of the United States into tectonic provinces. The largest of these tectonic provinces is the Stable Central province. This province extends from the western margin of the Appalachian Plateau to the eastern edge of the Rocky Mountain uplift and from the Gulf Coast Plain to the Canadian border. Compared to the Appalachian tectonic province, the Stable Central region has displayed little tectonic activity since Late Pennsylvanian time. The historical record of faulting and seismicity has been limited, with a notable exception being the New Madrid, Missouri, area and adjacent regions in Kentucky, Tennessee, and Illinois. Nevertheless, the area is so large that despite the broad-scale picture of relative historical stability, there is within it considerable geologic diversity and sufficient seismic history to require a moderately high seismicity classification

---

1 Geologist, Oklahoma Geological Survey.

2 An arbitrary scale of earthquake *intensity* based on actual observations of the effects ranging from I (not felt by people) to XII (damage nearly total).

for use in locating nuclear power plants. There is a possibility that by studying the Nemaha uplift a major source of the seismic activity can be identified and the areas of risk pinpointed so that the seismicity classification used in locating nuclear power-plant sites can be reduced for other parts of the region. Costly overdesign can thus be avoided while, at the same time, the best possible geographic locations can be selected.

Nemaha Uplift

The Nemaha uplift, 670 km long and 20 to 40 km wide, extends northward from central Oklahoma through Kansas into Nebraska. Earthquakes

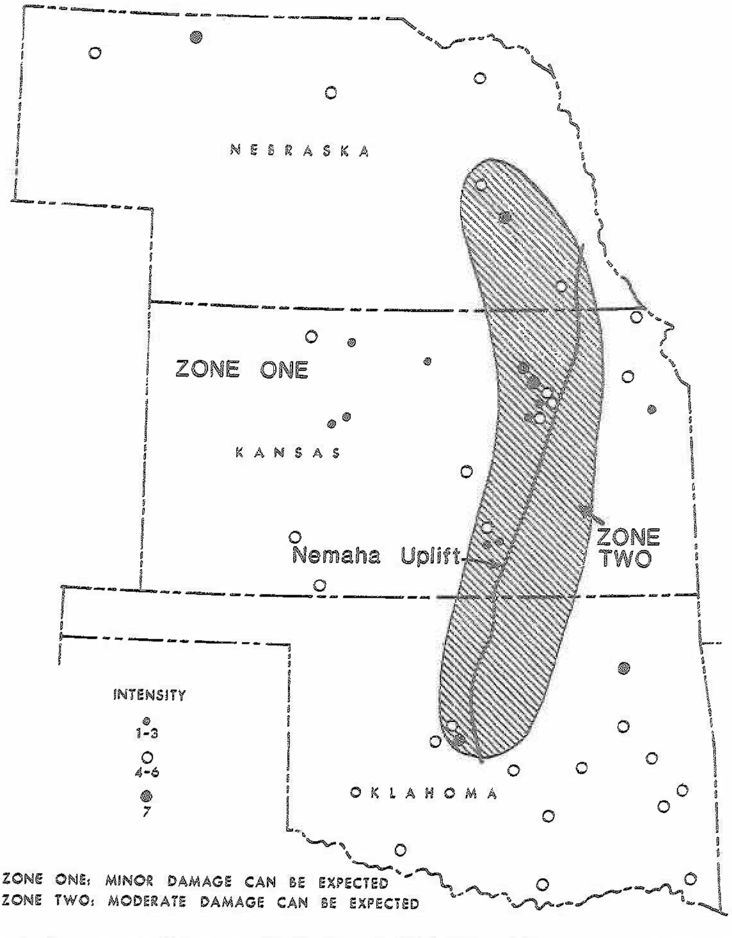


Figure 1. Map of earthquake distribution in Nebraska, Kansas, and Oklahoma with the Nemaha uplift and seismic-risk zones shown (modified from Coffman and von Hake, 1973; ESSA/Coast and Geodetic Survey, 1969; Merriam, 1956).

have occurred along or west of the Nemaha uplift, with those at El Reno, central Oklahoma, Manhattan-Lawrence area, Kansas, and northwest of Lincoln, Nebraska, being the most intense (fig. 1). The Nemaha uplift developed mainly during the Pennsylvanian Period as a number of small crustal blocks that were raised sharply along the axis of the uplift (Huffman, 1959). These crustal blocks typically are 5 to 8 km wide and 8 to 35 km long and are bounded by faults on the east and west. Uplift blocks were eroded during Pennsylvanian time and then covered by Late Pennsylvanian and Permian sediments. Some of these later rocks may have been affected by reactivation of deep-seated faults, but this has not yet been adequately determined.

The state geological surveys of Kansas, Nebraska, and Oklahoma, in cooperation with the U.S. Nuclear Regulatory Commission (NRC), initiated a 5-year program in July 1976 to study the regional tectonic framework and to establish seismicity levels for the area of the Nemaha uplift and its related structures. Although the principal goal is to provide fundamental data for evaluating the seismic risk of potential nuclear power-plant sites, the same information may be used by the construction industry to plan and design large projects such as reservoirs, hospitals, and high-rise structures. On the basis of its seismicity and geologic record, the Nemaha area may be separated from other tectonic components in the Midcontinent region. The program should lead to a better understanding of the relationship between geologic structures and past and future seismicity.

Seismology

Oklahoma Program

The overall program is composed of three basic elements: seismological, geological, and geophysical. The seismological element entails principally the establishment of a regional network of 16 semipermanent seismograph stations capable of locating and detecting earthquakes of Richter[3] magnitude 2.1 or greater (fig. 2). The University of Oklahoma Earth Sciences Observatory near Leonard, southeast of Tulsa, under the direction of Robert L. Dubois and assisted by James L. Lawson, Jr., is responsible for establishment of the Oklahoma network of seismograph stations and the coordination of seismological data generated from the Oklahoma-network stations as well as data coming from the seismometers in Kansas and Nebraska. A bulletin giving location, magnitude, and station data for local earthquakes in the three-state study area will be compiled semiannually.

Seven semipermanent, volunteer-operated seismograph stations and three radio-telemetry stations will eventually constitute the Oklahoma portion of the NRC-supported network. The regional seismograph network, supplementing the existing seismological capabilities at the OU Observatory, will more accu-

[3] Range of numerical values of earthquake *size or magnitude* (microearthquakes have negative values; the upper limit is slightly less than 9). The measurements are based on records from a standard type of seismograph at a distance of 100 km from the epicenter.

rately locate and detect earthquake activity in Oklahoma. Each semipermanent station consists of a Geotech S-13 short-period vertical seismometer and a Sprengnether MEQ-800-B unit including amplifier, filters, ink-recording unit, and temperature-compensated crystal-oscillator counter (clock) to record minutes and hours. The installation of this equipment usually requires 2 days. During the first day, the tank vault is installed in the field and the concrete left to harden overnight (fig. 3). The amplifier-filter-recorder-clock system and a WWV (continuous short-wave transmission of time signals from National Bureau of Standards) radio are installed in a protected area. The recorder and clock are activated, and while the recorder is recording a straight line, the volunteer operator is instructed in record changing, labeling, radio-time-mark

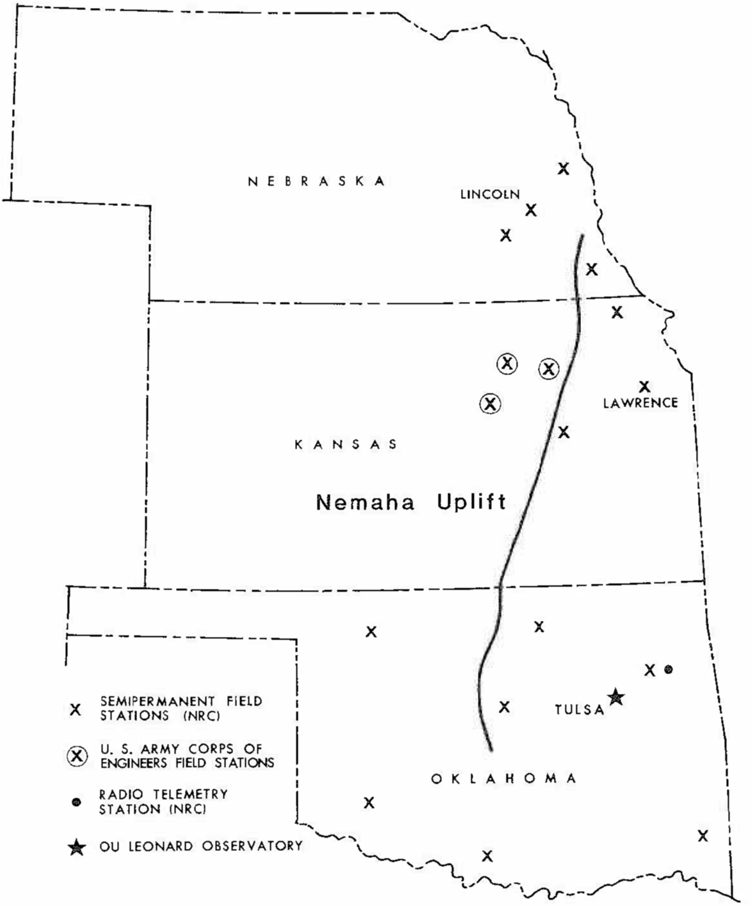


Figure 2. Approximate locations of seismograph stations in the three-state regional network.

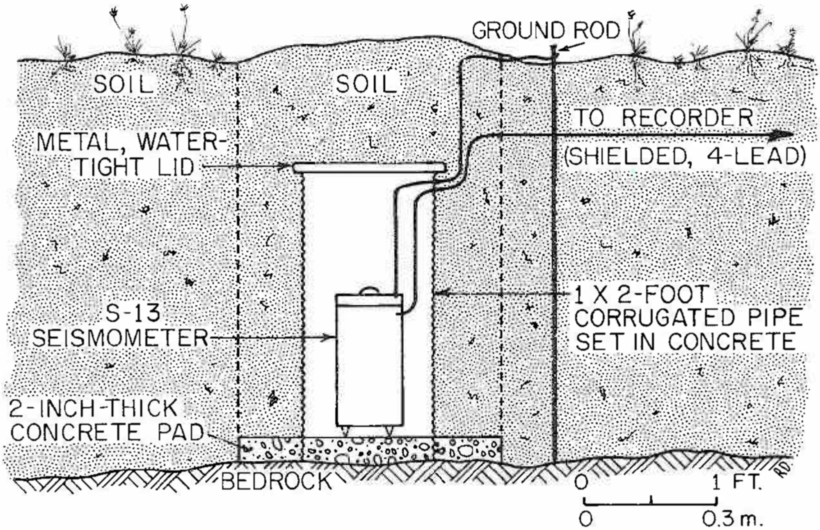


Figure 3. A diagrammatic representation of an S-13 seismometer installation.

recording, and clock corrections. During the remainder of the first day, a four-wire shielded cable is buried a few inches deep going from the building housing the recorder to the tank vault. At the end of the first day, the volunteer is again instructed in record changing by removing the record, which by then has several hours of straight lines and time marks recorded on it. A new record is mounted to run overnight. On the second day, the tank vault is finished and the seismometer is installed and all connections completed. The volunteer again reviews the record-changing procedures, and seismic recording commences. A supply of recording paper, ink, and stamped mailing tubes for weekly mailing of records is left. The volunteer is asked to phone the OU Observatory if any malfunction occurs.

In general, the volunteer's ability, without technical training, to operate a seismograph station has exceeded our expectations. Unfortunately, the amount of major maintenance has also exceeded our expectations. This maintenance is most frequently related to the MEQ-800-B timing-system failure usually caused by nearby lightning strikes.

In addition to the 7 semipermanent stations, 3 radio-telemetry seismographs, linked to the OU Observatory, are used to act as part of the overall network for earthquake detection. They provide real-time visual recordings of seismic activity and allow for the making of decisions concerning the placement of portable instruments to obtain additional detailed data on seismicity. Also, they provide information to suggest which net stations are closest to a particular event.

Each radiolink system consists of one Geotech S-13 seismometer and one Enheiser Rand telemetry unit. Each Enheiser Rand unit consists of four modules; this unit amplifies the seismometer output and uses this output to frequencymodulate an audio tone. A 100-milliwatt crystal-controlled transmitter limits the line-of-sight transmission to approximately 80 km. Seven-element and five-element Uda-Yagi antennas are used for transmitting and receiving, respectively.

The first radiolink-transmitting site is located at a State forestry lookout tower, 76 km northeast of the OU Observatory. This site was chosen because it was: (1) one of the farthest points in any direction with a path following the line of sight to the observatory, (2) one of the areas with the least man-made development in the State, and (3) one of the highest points in the region.

The State Forestry Service permitted us to use their 40-foot-high tower to attach a 7-element Uda-Yagi transmitting beam. Also, we were able to place the electronics in a secure place inside the lookout-tower cab, where 110 DC was available. The seismometer tank vault is approximately 250 feet from the lookout tower.

The 75-km radiolink station provided excellent records when operating. However, repeated equipment difficulty, primarily receiver failures, has limited its early operation to about 30 percent of total installed time. Since the path may be only slightly above marginal, a preamplifier was installed at the base of the receiving tower. This increased the operating time to about 97 percent. However, nearby lightning strikes still cause equipment failures. The remaining two radiolinks will probably be installed and operating by the end of June 1978.

Kansas and Nebraska Program

Don Steeples and Frank Wilson, Kansas Geological Survey, are responsible for the installation and operation of the Kansas seismograph network. Their network consists of 6 short-period vertical seismometers supported by the NRC, 3 short-period verticals supported by the Kansas City District of the U.S. Army Corps of Engineers, and 1 existing teleseismic station at Manhattan and 1 at Lawrence, Kansas (fig. 2). The network is designed for central recording at Lawrence via telephone telemetry.

The general locations of the stations in the Kansas network were selected to conform with the overall NRC seismological goals. An extensive field reconnaissance is made with a Geotech Portacorder to determine if a station has to be relocated to an alternate site where the cultural or natural earth noises are lower. Once written permission is obtained from landowners for a seismograph field station, installation commences. A 4¾-inch borehole is drilled with the Kansas Geological Survey's Failing 1500 Holemaster core-drill rig to depths of 50 to 60 meters. Each hole is cased with 2.5-inch steel pipe to within 2 feet of the surface. The upper part of the drill hole is covered by a partially buried, waterproof steel box that acts as a shelter for the batteries, amplifier, and voltage-controlled oscillator (fig. 4). The borehole seismometer, which is lowered to the bottom of the hole, is a Geospace VLF-1 or equivalent and is approximately 2 inches in diameter. Thus far, 6 field stations are in operation, and 6 more will be installed before the end of 1978.

The Nebraska seismograph network consists of three short-period vertical seismometers arranged in an array around Lincoln (fig. 2). The stations were installed and are presently maintained by Ray Burchett, Nebraska Geological

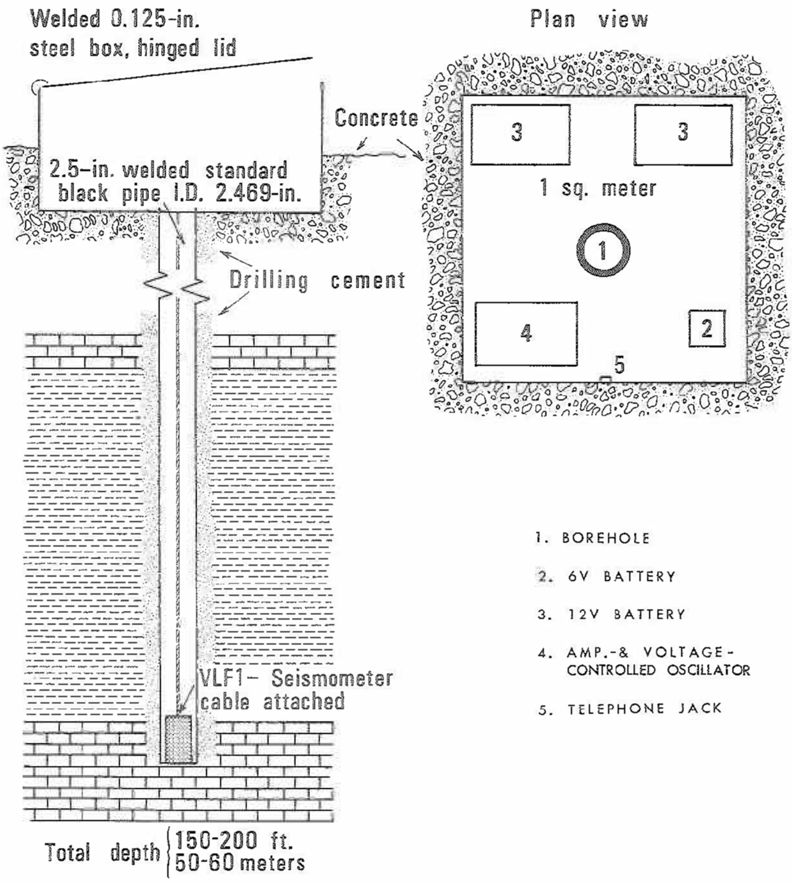


Figure 4. Kansas Geological Survey's plan for seismograph stations; station size is approximately 1 meter by 1 meter (Wilson, 1976).

Survey, and Russell Smith, University of Nebraska. The stations are monitored with volunteer operators. The records are routinely sent to Jim Lawson, OU Observatory, for cataloging and evaluation. Their data, along with Kansas and Oklahoma earthquake data, are compiled and stored on magnetic tape for easy access and retrieval. Periodically the earthquake data compiled from the network stations will be released as a three-state earthquake bulletin.

Microearthquake System

Four portable microearthquake systems with instrumentation similar to the semipermanent seismograph systems will be acquired this year. The portable seismometers will be committed to: (1) immediate field deployment to monitor aftershock activity in the epicentral area of any earthquake exceeding approximate magnitude 2.8 (Richter), (2) reconnaissance for microearthquake concentrations not detected by the semipermanent network, (3) reconnaissance studies of designated tectonic structures that have been determined by geologic studies, (4) precise location of microearthquakes in active areas as indicated by reconnaissance studies, and (5) operation in conjunction with semipermanent stations to gather sufficient first-motion information so that fault planes can be accurately located. These instruments will be available for use by all three states.

Geology and Geophysics

Comprehensive geologic investigations began concurrently with the installation of the seismological network. The initial phases of the investigation consist of compilation and synthesis of regional surface and subsurface geological data. Geophysical borehole logs and geological borehole descriptions are being utilized to compile a series of structure maps on the top of the Oswego Formation (Middle Pennsylvanian), the base of the Pennsylvanian, and the top of the Viola Formation (Ordovician) in Oklahoma and the base of the Kansas City Group (Pennsylvanian) in Kansas and Nebraska. These maps will be used to determine subsurface structure and age relationships of subsurface faults in the Nemaha uplift area. The structure mapping in Oklahoma is approximately 90 percent complete, whereas the Nebraska mapping is complete and the Kansas project is in progress.

Preliminary evaluation of the structure maps for Oklahoma reveals a complex fault pattern and geologic history of the Nemaha uplift. Some of the fault systems have been periodically reactivated at least through Middle Pennsylvanian time. In some cases, the direction of movement becomes reversed as one traces a fault zone from the Viola Formation to Middle Pennsylvanian strata. Thus far, none of the faults associated with the Nemaha uplift in Oklahoma can be recognized at the surface. However, exposures of Permian strata have sharp dip reversals over the Humboldt fault zone, which is a feature associated with the Nemaha uplift in southeastern Nebraska and northeastern Kansas. This area is now the site for detailed surface and subsurface geologic investigations by the Nebraska and Kansas geological surveys. A detailed subsurface study of the El Reno area, the site of numerous earthquakes, is in progress and is approximately 30 percent complete. The principal objectives of the El Reno study are to present as completely as possible the structural features of this area, including their locations, possible relationships to the Nemaha uplift, and tectonic history and to determine if any relationships exist between seismic activity and Paleozoic structural features. We expect this study to be almost completed by the end of June 1978.

Detailed aeromagnetic measurements and gravity profiles will be taken to upgrade the existing data base in critical areas of sparse coverage. The gravity and magnetic data, in conjunction with the structure-contour maps, will be utilized to refine the Precambrian basement configuration, structure, and lithology. This in turn will help to define the style and location of faulting along the Nemaha uplift. The information will also be used in correlating earthquake events with structural features in the subsurface and in providing a better understanding of the paleo-development of the Nemaha uplift.

Data Presentation

The state surveys of Oklahoma, Nebraska, and Kansas are preparing a series of regional maps that include maps of Precambrian basement rocks, areomagnetic surveys, Bouger-gravity surveys, surface lineations, bedrock geology, earthquake epicenters and intensities, and structure contours on selected horizons. The project maps will be compiled at a scale of 1:500,000. As the maps are completed, they will be released by each state survey. At the end of the project, the data will be recompiled on 1:1,000,000-base maps and issued as a 3-state project report. A progress summary for some of the project maps is included in table 1.

TABLE 1.—PROGRESS SUMMARY FOR SOME PROJECT MAPS

MAP	OKLAHOMA	KANSAS	NEBRASKA
Precambrian	completed	completed	completed
Aeromagnetic	[1]completed	completed	completed
Bouger-gravity	[1]completed	completed	completed
Surface-lineation	——	in press	completed
Bedrock-geology	[2]completed	completed	completed
Earthquake	completed	in press	completed
Structure-contour	90% complete	in progress	completed

[1] Regional gravity and magnetic reconnaissance maps completed prior to beginning of project.
[2] Detailed maps, 1:250,000, in final drafting stages.

In addition to the regional studies, detailed field examinations are being conducted in areas that have had a long seismic history. Drilling and trenching, augmented with detailed gravity surveys, are being conducted on the Humboldt fault zone in southeastern Nebraska and northeastern Kansas. Also, a detailed subsurface study, along with a microearthquake survey of the El Reno, Oklahoma, area, is in progress. As these studies are completed, topical reports will be issued to the NRC by the state geological surveys.

The initial phases of this study have focused on the regional tectonic development of the Nemaha uplift. We are attempting to determine what relationship, if any, exists between the Keweenawan mafic belt and its associated geophysical anomaly, the Midcontinent gravity anomaly (MGA), to the development of the Nemaha uplift. The Nemaha structures closely parallel the east flank of the MGA from southeastern Nebraska to central Kansas and perhaps into central Oklahoma. In Nebraska, the northern end of the Nemaha uplift terminates against the offset of the central part of the MGA. A thick sequence of mafic igneous rocks is associated with the MGA, whereas granitic rocks make up the core of the Nemaha uplift. The margins of the deep Anadarko and the Forest City basins and their interaction with the Nemaha structures are not fully understood; neither is the role that the development of the Ouachita fold system and the Wichita and Arbuckle Mountains uplifts played in the final development of the Nemaha uplift. It is felt that an understanding of the development of the Nemaha uplift and its relationship to regional geologic structures will lead to an understanding of the causes of past and future seismicity.

References Cited

COFFMAN, J. L., and VON HAKE, C. A., 1973, Earthquake history of the United States: National Oceanic and Atmospheric Administration Publication 41–1, revised edition through 1970, 208 p.

ESSA/Coast and Geodetic Survey, 1969, Seismic risk map of the United States: Department of Commerce.

HADLEY, J. B., and DEVINE, J. F., 1974, Seismotectonic map of the eastern United States: U.S. Geological Survey Miscellaneous Field Study map MF-620, 8 p., 3 sheets.

HUFFMAN, G. G., 1959, Pre-Desmoinesian isopachous and paleogeologic studies in central Midcontinent region: American Association of Petroleum Geologists Bulletin, v. 43, no. 11, p. 2541–2574.

KING, P. B., 1951, The tectonics of middle North America—east of the Cordilleran system: Princeton, N. J., Princeton University Press, 203 p.

MERRIAM, D. F., 1956, History of earthquakes in Kansas: Seismological Society of America Bulletin, v. 46, p. 87–96.

WILSON, F. W., 1976, Regional tectonics and seismicity of Kansas—first quarterly progress report, Oct. 1 to Dec. 1976: Open-file report submitted to U.S. Nuclear Regulatory Commission, 13 p.

William Menard Nominated for USGS Director

H. William Menard has been nominated by President Carter to be the 10th Director of the U.S. Geological Survey, succeeding Vincent E. McKelvey. Dr. Menard brings with him outstanding qualifications to head one of the Interior Department's largest agencies, the 99-year-old USGS. He was selected by the federal administration from a slate of qualified persons put together by the National Academy of Sciences.

Dr. Menard is a well-respected and internationally recognized scientist, having many articles and four books to his credit. He is no stranger to politics, since he has served on several National Academy of Sciences and White House committees, including a committee to study the impact of a jetport on the Everglades and a panel to study the Santa Barbara oil spill of 1969. He has also been a member of the NAS Committee on Science and Public Policy, the NAS Commission on Natural Resources, and the NAS committee to advise the Council on Environmental Quality on the probable impact of developing offshore oil, and he was a technical advisor in the Office of Science and Technology, responsible for marine science and much of atmospheric and solid-earth science.

Dr. Menard has been a professor of geology at Scripps Institution of Oceanography in San Diego since 1955. He holds a bachelor's degree in geology from the California Institute of Technology in Pasadena. He also received his M.S. degree from CalTech, in 1947. His Ph.D. was from Harvard, in 1949.

With experience and background in marine, atmospheric, and solid-earth sciences, Dr. Menard will be the first USGS director to be an expert in marine geology and resource exploration. This could be an indicator of the expanding role and responsibilities toward natural-resources investigations of this agency.

U.S. Board on Geographic Names Decisions

The U.S. Board on Geographic Names recently approved 9 Oklahoma place names, which were published in the October through December 1977 issue of *Decisions on Geographic Names in the United States* (Decision List 7704).

Bell Creek has been adopted to identify a stream, 5.6 kilometers (3.5 miles) long, that heads at 35°08′58″ N., 97°22′52″ W. and flows south-southwest to the Canadian River, 3.2 kilometers (2 miles) south of Noble, Cleveland County, Oklahoma; sec. 3, T. 7 N., R. 2 W.; Indian Meridian (35°06′26″ N., 97°24′07″ W.).

Forrester (not: Forester, Lank, Lank City) has been adopted to identify a community, 7.2 kilometers (4.5 miles) east-southeast of Heavener, Le Flore County, Oklahoma; sec. 26, T. 5 N., R. 26 E.; Indian Meridian (34°52′19″ N., 94°31′30″ W.).

Haw Creek (not: Haws Creek, Hicks) has been adopted to identify a community, 15.3 kilometers (9.5 miles) southeast of Heavener, Le Flore County, Oklahoma; sec. 31, T. 4 N., R. 26 E.; Indian Meridian (34°46′23″ N., 94°30′34″ W.).

Haw Creek (not: Haws Creek) has been adopted for a stream, 20.1 kilometers (12.5 miles) long, that heads in Arkansas at 34°48′44″ N., 94°20′17″ W. and flows west into Oklahoma to the Black Fork, 12.9 kilometers (8 miles) southeast of Heavener, Le Flore County, Oklahoma, and Scott County, Arkansas; sec. 25, T. 4 N., R. 26 E.; Indian Meridian (34°47′25″ N., 94°31′28″ W.).

Hontubby Creek has been adopted for a stream, 6.4 kilometers (4 miles) long, that heads at 34°48′37″ N., 94°34′10″ W. and flows north to the Poteau River, 3.7 kilometers (2.3 miles) southeast of Heavener, Le Flore County, Oklahoma; sec. 33, T. 5 N., R. 26 E.; Indian Meridian (34°51′30″ N., 94°34′10″ W.).

Hontubby Falls (not: Hantubby Falls) has been adopted for a waterfall in the course of the Poteau River, 3.8 kilometers (2.4 miles) south-southeast of Heavener, Le Flore County, Oklahoma; sec. 32, T. 5 N., R. 26 E.; Indian Meridian (34°51′23″ N., 94°35′07″ W.).

Jech Creek has been adopted for a stream, 7.2 kilometers (4.5 miles) long, that heads at 35°48′00″ N., 97°50′56″ W. and flows north to Trail Creek, 8 kilometers east of Kingfisher, Kingfisher County, Oklahoma; sec. 16, T. 16 N., R. 6 W.; Indian Meridian (35°51′35″ N., 97°50′22″ W.).

Thompson Creek (not: Thompson Branch) has been adopted for a stream, 10.5 kilometers (6.5 miles) long, that heads at 34°53′27″ N. 94°38′23″ W. and flows northwest to the Poteau River, 11.3 kilometers (7 miles) northwest of Heavener, Le Flore County, Oklahoma; sec. 31, T. 6 N., R. 25 E., Indian Meridian (34°56′42″ N., 94°42′22″ W.).

Trail Creek has been adopted for a stream, 19.3 kilometers (12 miles) long, that heads at 35°47′05″ N., 97°49′53″ W. and flows north-northwest to Kingfisher Creek, 8 kilometers (5 miles) northeast of Kingfisher, Kingfisher County, Oklahoma; sec. 30, T. 17 N., R. 6 W., Indian Meridian (35°54′49″ N., 97°52′44″ W.).

Map and Catalog of Oklahoma Earthquakes Available from OGS

A map and catalog showing locations and intensities of earthquakes that have occurred in Oklahoma from 1908 through 1976 have been placed on open file by the Oklahoma Geological Survey. Both can be ordered from the Survey, by writing to the address on the front cover, for a total cost of $1.00.

The map, at a scale of 1:1,000,000, locates both instrumentally recorded and "felt" earthquakes. Earthquake intensities, indicated by Modified Mercalli values, are divided into four categories which are described in the accompanying explanation on the map.

The catalog documents tremors from July 19, 1908, through December 19, 1976, and gives the location, intensity, magnitude, and sources of information for each. An explanatory text describes the methods used in obtaining the data presented.

Both the map and catalog are an outgrowth of a 5-year program, funded by the U.S. Nuclear Regulatory Commission, to investigate the seismicity and tectonic relationships of the Nemaha uplift, a subsurface feature that extends northward from central Oklahoma through Kansas into southeastern Nebraska. The geological surveys of these three states are cooperating in the study. The details and scope of this project are treated in a separate article in this issue, beginning on page 49.

The authors of the map and catalog are Robert L. DuBois and James E. Lawson, Jr., geophysicists, and Paul Foster, electrical engineer, all at The University of Oklahoma. Their studies were conducted largely through a seismic network linked to the OU Earth Sciences Observatory at Leonard, near Tulsa. One of the Midcontinent's most complete centers for the study of seismicity, this facility was built in 1961 for Jersey Production Research Co. and was presented to The University of Oklahoma in 1967 by what is now Exxon Corp.

FLEXIBLE CRINOIDS FROM PITKIN FORMATION (CHESTERIAN) OF OKLAHOMA AND ARKANSAS

Harrell L. Strimple[1]

With the eventual goal in view of providing useful stratigraphic indices, I have attempted throughout the past 40 years to document Upper Mississippian (Chesterian) faunas of the continental interior of North America. As is shown in a review of available data (Horowitz and Strimple, 1974), significant progress toward this goal has been made. The flexible crinoids have proved to be good stratigraphic markers (Burdick and Strimple, 1971, 1973), because their populations exhibit readily discernible progressive evolutionary grades.

This present report records for the first time in the Chesterian Pitkin Formation the genera *Taxocrinus* Phillips and *Onychocrinus* Lyon and Casseday, with *Taxocrinus whitfieldi* (Hall, 1858) reported from a locality near Locust Grove, Arkansas, and *Onychocrinus pulaskiensis* Miller and Gurley, 1895, recovered from a site near Gore, Oklahoma.

Both *Taxocrinus* Phillips and *Onychocrinus* Lyon and Casseday show a progressively reduced number of nonaxillary brachials in their arms during Chesterian time. The early forms of *Taxocrinus* have a secundibrach series of four plates; the genus later progressed through a period characterized by either three or four secundibrachs, finally stabilizing with three plates in *T. shumardianus*. Forms characterized by two or three plates, referred by Burdick and Strimple (1973, p. 226) to *T. cestriensis*, became essentially stabilized with two plates in the secundibrach series in *T. whitfieldi*. A few individuals of *Taxocrinus* from the Glen Dean–Tar Springs, Hombergian Stage, in Pulaski County, Kentucky, retain three secundibrachs in some rays, as is also the case in those from the Fayetteville Formation of northeastern Oklahoma. A population from the Menard Formation (Elviran) at Chester, Illinois, consistently has two secundibrachs (*T. whitfieldi*). Although a population of *Taxocrinus* from the Pitkin Formation is not available, there are four half rays preserved in the specimen recovered, with all four rays having two secundibrachs; the specimen has therefore been assigned to *T. whitfieldi*. It is possible that the upper part of the Pitkin Formation in the area near Locust Grove, Arkansas, is somewhat younger than in the type area, where the formation is relatively thin.

Onychocrinus is represented by three species from Chesterian strata in the United States. *O. magnus* Worthen, 1875, and *O. distensus* Worthen, 1882, have four (although some have three) primibrachs per ray and are known from lower Chesterian strata. *O. pulaskiensis* Miller and Gurley, 1895, has three primibrachs and is known from the Glen Dean–Tar Springs Formations of Indiana and Kentucky. Burdick and Strimple (1973) recorded specimens from the Fayetteville Formation of northeastern Oklahoma as *Onychocrinus* sp., and these, together with additional specimens from the Pitkin Formation, are as-

---

[1] Curator and research investigator, Department of Geology, The University of Iowa, Iowa City, Iowa.

signed here to *O. pulaskiensis*. The Oklahoma specimens from both the Fayetteville and Pitkin Formations have granular surfaces, whereas the eastern representatives of the species have smooth surfaces. Although this single character (granulations) is not sufficiently diagnostic to warrant specific differentiation, it should be taken into account, because the Scottish species of *Onychocrinus* also have granular surfaces. *O. wrighti* Springer, 1920, and *O. liddelensis* Wright, 1954, are both from upper Viséan strata in Scotland, and the latter species has three primibrachs, as does *O. pulaskiensis*. Differences lie in the distal axillaries, which bear spines in *O. pulaskiensis* but are nonspinose in the two Scottish species.

Occurrence and Stratigraphy

Specimens referable to *Onychocrinus* from the Pitkin Formation (Chesterian) were all collected on a shelf high in the bluffs forming a natural hillside overlooking the Arkansas River west of Gore, Oklahoma, in the SE¼ sec. 27, T. 13 N., R. 20 E., Muskogee County, an exposure that has been referred to as "Rattlesnake Hollow" by some knowledgeable collectors. According to Huffman (1958), the Pitkin at this locality is overlain by rocks of Morrowan age. The one available specimen of *Taxocrinus* was collected in a small quarry west of Locust Grove, Independence County, Arkansas (SE½ sec. 6, T. 12 N., R. 7 W., Concord 7.5-minute quadrangle).

Weller (1948) correlated the Pitkin Formation with the Clore, Degonia, and Kinkaid Formations of the Illinois section. Furnish and Saunders (1971) gave a somewhat wider range for the Pitkin, including in their correlation the older Palestine and Menard Formations, as well as the younger Grove Church Formation, which is equivalent to the Arnsbergian Stage (E_2) of British usage. Thompson (1972) followed Furnish and Saunders (1971) in correlating the Pitkin of northern Arkansas and southwestern Missouri with strata of the Illinois section, basing his decision on biostratigraphic data obtained from conodonts. Saunders (1973) revised the correlations of Furnish and Saunders, extending the Pitkin downward into the upper Pendeleian Stage (E_1). On the basis of crinoid material available at present and the data obtained from ammonoids, it is not possible to support the range suggested by Saunders in his revision. The Pitkin Formation, although relatively thin in the type area, as has been noted above, contains much thicker deposits in the Locust Grove locality that could conceivably include younger beds, making the earlier correlation of Furnish and Saunders (1971) and Thompson (1972) feasible. All the flexible crinoids considered here appear to be from strata high in the Pitkin, and no associated ammonoids have been recovered.

Material Studied

Abbreviations used with sample numbers are: SUI, Geology Department Repository, The University of Iowa, Iowa City, Iowa; USNM, U.S. National Museum.

Systematic consideration of the two species was given by Burdick and Strimple (1973). The assignment of the *Onychocrinus* sp. specimen (SUI 35517) reported by those authors was supported by specimens I collected from the shale of the Fayetteville Formation that were mentioned in the same paper (p. 230) as material reposited in the U.S. National Museum (National Museum of Natural History). The supporting specimens are better preserved and are considered here in more detail, together with specimens from the Pitkin Formation.

Onychocrinus pulaskiensis Miller and Gurley, 1895

Figure 1, *1, 3, 4*

USNM 184651 and USNM 184652, sec. 11, T. 25 N., R. 21 E., Craig County, Oklahoma; Fayetteville Formation, Chesterian.

USNM 184647 and USNM 184648, SE¼ sec. 27, T. 13 N., R. 20 E., Muskogee County, Oklahoma; Pitkin Formation, Chesterian.

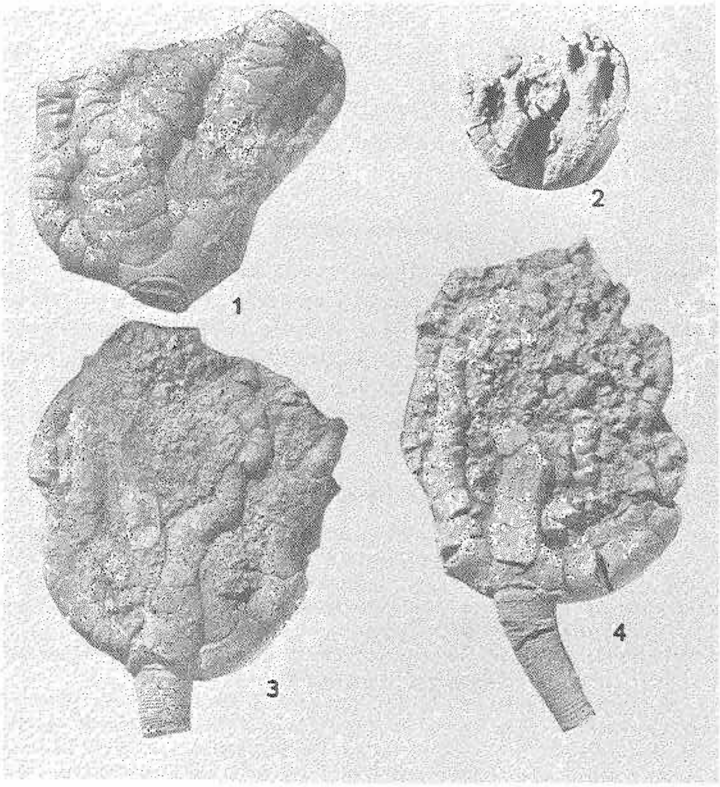


Figure 1. Flexible crinoids from Chesterian strata of Oklahoma and Arkansas:
1, **Onychocrinus pulaskiensis**, USNM 184647, Pitkin Formation, ×1.2.
2, **Taxocrinus whitfieldi**, SUI 40000, side view of crown from Pitkin Formation, ×1.5.
3, **Onychocrinus pulaskiensis**, USNM 184651, Fayetteville Formation, ×1.2.
4, **Onychocrinus pulaskiensis**, USNM 184652, D-ray view, Fayetteville Formation, ×1.2.

Two specimens, USNM 184651 (fig. 1, *3*) and USNM 184652 (fig. 1, *4*), are well-preserved crowns with an average overall length of 47 mm and a width of 37 mm. Nodose axillary brachials are visible in distal portions of the arms, and the entire outer surface of the crown is marked by fine granulations. There are three primibrachs in all preserved arms.

Two crowns, USNM 184647 (fig. 1, *1*) and USNM 184648, have an average length of 60 mm and a width of 29 mm. Nodose axillary brachials are present in distal portions of USNM 184648, a partial crown (not illustrated). Outer surfaces are marked by granulose ornamentation. There are three primibrachs in all preserved rays.

Taxocrinus whitfieldi (Hall, 1958)

Figure 1, *2*

SUI 40000, SE½ sec. 6, T. 12 N., R. 7 W., Independence County, Arkansas; Pitkin Formation, Chesterian.

The single specimen available, SUI 40000 (fig. 1, *2*), is a partial crown having a length of 12.8 mm and a width of 11.4 mm. Three secundibrachs are present in all four exposed rays.

Acknowledgments

Claude Bronaugh of Afton, Oklahoma, and Cave Creek, Arizona, originally called attention to the Oklahoma collecting site of the present study and donated some specimens. J. A. McCaleb, while a graduate student at The University of Iowa, directed me and a field party to the quarry near Locust Grove, Arkansas. The manuscript was perused by M. M. Furnish and T. J. Frest, The University of Iowa, and it was typed by Mrs. Marilyn Meade. I would like to thank them all for their kind assistance.

References Cited

Burdick, D. W., and Strimple, H. L., 1971, Crinoids from the Beech Creek Limestone, lower Golconda Group, St. Clair County, Illinois, *pt. 2 of* Furnish, W. M., Saunders, W. B., Burdick, D. W., and Strimple, H. L., Faunal studies of the type Chesteran, Upper Mississippian, of southwestern Illinois: University of Kansas Paleontological Contributions, Paper 51, p. 15–47, pls. 3–7.

———, 1973, Flexible crinoids from the Fayetteville Formation (Chesterian) of northeastern Oklahoma: Journal of Paleontology, v. 47, p. 226–230.

Furnish, W. M., and Saunders, W. B., 1971, Ammonoids from the middle Chester Beech Creek Limestone, St. Clair County, *pt. 1 of* Furnish, W. M., Saunders, W. B., Burdick, D. W., and Strimple, H. L., Faunal studies of the type Chesteran, Upper Mississippian, of southwestern Illinois: University of Kansas Paleontological Contributions, Paper 51, p. 1–14, pls. 1, 2.

Horowitz, A. S., and Strimple, H. L., 1974, Chesterian echinoderm zonation in eastern United States: International Congress of Carboniferous Stratigraphy and Geology, 7th, Krefeld, 1971, Compte rendu, v. 3, p. 207–220.

Huffman, G. G., 1958, Geology of the flanks of the Ozark uplift, Oklahoma: Oklahoma Geological Survey Bulletin 77, 281 p., 6 pls.

Saunders, W. B., 1973, Upper Mississippian ammonoids from Arkansas and Oklahoma: Geological Society of America Special Paper 145, 110 p., 8 pls.

Thompson, T. L., 1972, Conodont biostratigraphy of Chesterian strata in southwestern Missouri: Missouri Geological Survey and Water Resources Report of Investigations 50, 48 p., 1 pl.

Weller, J. M., and others, 1948, Correlation of the Mississippian formations of North America: Geological Society of America Bulletin, v. 59, p. 91–196, 2 pls.

WHATEVER HAPPENED TO BEER CITY— OR FOR THAT MATTER, GENE AUTRY? —See **Ghost Towns of Oklahoma**

What do Beer City (named for its chief industry), Gene Autry (named in 1942 for the famous singing cowboy, who bought a 2,000-acre ranch nearby), and Yewed (that's Dewey spelled backwards, because the founding fathers wanted the name Dewey, but it was already in use) have in common? They are 3 of the 130 towns selected by John W. Morris, a professor emeritus of geography at The University of Oklahoma, for inclusion in his book, *Ghost Towns of Oklahoma.*

Morris' three criteria for defining a ghost town are—communities that no longer exist, having been destroyed, deserted, or covered by water (as was the case with Beer City); communities that have buildings or houses still standing but largely unused (as in Yewed); and communities that had a decrease in population of at least 80 percent from their maximum size (as in Gene Autry). With these criteria as a guide, Oklahoma has over 2,000 ghost towns, but since not all could be included, Morris chose representative towns that showed varied histories of development and decline. Using over 300 black and white photographs and maps, plus brief descriptions, he gives us a glimpse of the towns and the people who settled them and had dreams for their growth. Morris illustrates, through his descriptions of ghost towns, the birth and growing pains of a State.

Ghost Towns of Oklahoma should be as enjoyable to the history buff who may want to go for a visit as to the casual easy-chair reader. The 229-page book sells for $14.95 (hard cover) and $6.95 (paper cover); it was published in 1977 by the University of Oklahoma Press, Norman.

—*Judy A. Russell*

OGS Program to Assess Oklahoma's Uranium-Resource Potential

The Oklahoma Geological Survey has received a $384,258 grant from Bendix Field Engineering Corp. and the U.S. Department of Energy (DOE) for a 2-year project to assess the uranium-resource potential in Oklahoma. These investigations are part of the National Uranium Resource Evaluation (NURE) program, a nationwide effort sponsored by DOE to assess the domestic supply of this important energy resource.

The study in Oklahoma will cover 2 large regions making up about 20 percent of the State (fig. 1). One region is in west-central Oklahoma, extending west from El Reno and including the geologic province of the Anadarko basin, a significant area of past and present exploration and production of petroleum and natural gas. The other region lies in the north-central section of the State, encompassing all the land north of an approximate line from Sapulpa, Cushing, and Dover to the Kansas-Oklahoma border. These areas were selected because of known occurrences of uranium-bearing rocks in surface outcrops and subsurface strata.

The program entails a preliminary examination of existing geologic data to evaluate and assimilate the results of previous assessments of uranium in Oklahoma. This information is to be supplemented by field studies and investigations of subsurface strata. Samples of rocks, sediments, and water will be collected for analysis in the Survey's geochemical laboratories. Kenneth S. Johnson, OGS economic geologist, is project coordinator. Other Survey staff members participating in the study are Robert O. Fay and Arthur J. Myers, geologists; William E. Harrison and John F. Roberts, petroleum geologists; and David A. Foster, analytical chemist.

This study is expected to aid industry and government in assessing Oklahoma's uranium potential and determining if newly discovered uranium deposits are large enough and rich enough to warrant commercial development.

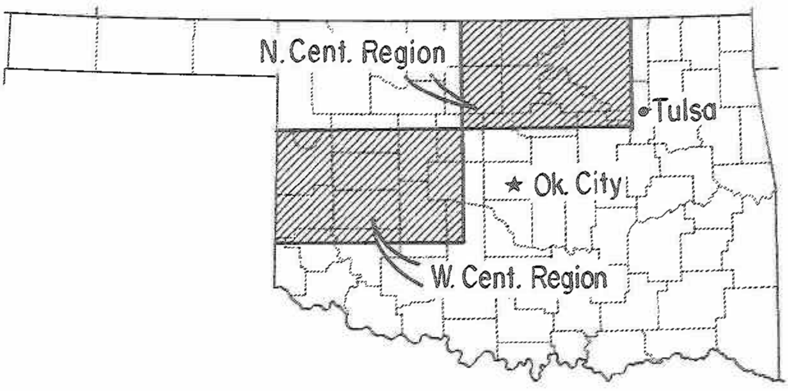


Figure 1. Map showing the two regions involved in the OGS uranium-assessment program.

USGS Issues Water Reports on Oklahoma

The U.S. Geological Survey has issued three data reports on Oklahoma water resources, as follows:

PB-272 785: *Water Resources Data for Oklahoma, volume 1, Arkansas River Basin—Water Year 1976*, 520 p., $15.25.

PB-272 786: *Water Resources Data for Oklahoma, volume 2, Red River Basin—Water Year 1976*, 222 p., $9.25.

PB-272 939: *Water Resources Data for Oklahoma—Water Year 1975*, 546 p., $15.50.

Weeks Tower to Be Dedicated by AAPG

The new Lewis G. Weeks Energy Resources Tower, a sizable extension of The American Association of Petroleum Geologists' headquarters in Tulsa, will be dedicated Friday, May 19. Construction of the five-story tower was made possible through a generous donation by the late Lewis G. Weeks of Westport, Connecticut, a past president and honorary member of AAPG. Mrs. Weeks will be a special guest at the dedication ceremonies, which will begin at 2:00 p.m. on May 19.

The association's original headquarters building was recently remodeled, and the headquarters staff will be available to conduct tours of the complete facilities on the day of the dedication. All AAPG members are invited to come and to participate.

OKLAHOMA ABSTRACTS

GSA Annual Meeting, South-Central Section
Tulsa, Oklahoma, March 6-7, 1978

The following abstracts are reprinted from the *Abstracts with Programs* of The Geological Society of America, v. 10, no. 1. Page numbers are given in brackets below the abstracts. Permission of the authors and of Mrs. Jo Fogelberg, managing editor of GSA, to reproduce the abstracts is gratefully acknowledged.

Chronology of Middle and Late Precambrian Crust-Forming Events in the Midcontinent Region of North America

M. E. BICKFORD and W. R. VAN SCHMUS, Department of Geology, University of Kansas, Lawrence, Kansas

Major crust-forming igneous events that range in age from 1850 to 1400 m.y. have been identified in the Midcontinent region. The earliest was formation

---

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.

of basaltic to felsic volcanic rocks and tonalitic to granitic plutons 1850–1820 m.y. ago in northern Wisconsin during the Penokean Orogeny. Rhyolite and associated granitic plutons then formed in southern Wisconsin about 1765 m.y. ago and may also underlie much of northern Illinois. Granitic rocks ranging in age from 1600 to 1750 m.y. are also known from the basement of northern Kansas and Missouri. A similar major period of silicic volcanism and plutonism began about 1500 m.y. ago in southern Missouri and continued until about 1400 m.y. ago in northeastern Oklahoma and southern Kansas. Plutons of this age, apparently emplaced anorgenically, are also known in Wisconsin and in the basement of Nebraska, northern Kansas, and central Missouri. There is no evidence for a distinct event, sometimes referred to as the Elsonian Orogeny, about 1300 m.y. ago in the Midcontinent region.

These 1765–1400 m.y. old igneous events are notable for the lack of mafic and intermediate rocks produced. Other than the Sioux, Barron, and Baraboo quartzites and other minor occurrences of quartzite and schist in the basement of Kansas and Nebraska, sedimentary rocks are unknown. These relationships argue against formation of these igneous rocks at a Pacific-type plate margin. It is not yet clear whether the petrographic and age variations from north to south are the result of successive accretionary events on the southern margin of a growing continent, or whether they result from access to successively deeper portions of the crust from south to north. [2]

Geology of the Denison Dam Oklahoma-Texas Quadrangle, Bryan and Marshall Counties, Oklahoma and Grayson County, Texas

JAMES R. BROOME, Department of Geology, The University of Texas at Arlington, Arlington, Texas; CALVIN F. MILLER, Hunt Oil Company, Dallas, Texas; and DONALD F. REASER, Department of Geology, The University of Texas at Arlington, Arlington, Texas

The area of investigation encompassing approximately 645 sq. km. (230 sq. mi.), is along the Red River in north-central Texas and south-central Oklahoma. There Cretaceous strata and Quaternary terrace deposits are well exposed in the vicinity of Lake Texoma. Lower Cretaceous rocks are about 140 m. (475 ft.) thick and have been subdivided into eleven units as follows: Antlers (Trinity Group); Walnut, Goodland (Fredericksburg Group); and Kiamichi, Duck Creek, Fort Worth, Denton, Weno, Pawpaw, Main Street, Grayson (Washita Group). Upper Cretaceous Woodbine and Eagle Ford range in thickness from 138 m. (460 ft.) to 165 m. (560 ft.) and are best exposed in uplands south of the lake.

Two prominent, northwest-trending folds, the Preston anticline and Kingston syncline transect the study area. The broad Preston anticline is 18–20 km. (11.3–12.5 mi.) wide and can be traced southeastward more than 160 km. (100 mi.) into east Texas. To the northwest, the fold appears to die out near the Criner Hills in Oklahoma. The hinge of the fold is well exposed along Lake Texoma near the small community of Preston, Texas. Some Cretaceous units thin across the anticline and possibly indicate structural growth during late Mesozoic time.

Tectonically, the map area is near the "Dallas junction," the intersection between the Wichita-Criner Hills structural trend and the Ouachita thrust belt. There Cretaceous structural features show a pronounced northwest-southeast trend parallel to the Wichita fault system. Recent theories on the origin of the Gulf of Mexico suggest that these structural trends may be related to the movement of strike-slip faults along Paleozoic fractures. [3]

The Lithostratigraphy and Depositional Environments of the Pitkin Formation (Mississippian) in Adair County, Northeastern Oklahoma

DAVID R. CLUPPER, School of Geology and Geophysics, The University of Oklahoma, Norman, Oklahoma

The Pitkin Formation (Chesterian), a carbonate unit, is conformable with the underlying Fayetteville Shale, and is unconformably overlain by the Hale Formation (Lower Pennsylvanian). In southeastern Adair County, the Pitkin is 33 feet thick. Fifteen miles to the northwest the Pitkin is absent and the Hale directly overlies the Fayetteville Formation. The truncated Pitkin surface is highly irregular. The maximum local relief observed exceeds 4 feet in a lateral distance of 10 feet. Outcrop isopach trends in Adair and adjoining counties in Arkansas maintain a northeast-southwest orientation, indicating a maximum rate of truncation to the northwest.

Five dominant lithofacies have been recognized in the Pitkin Formation immediately to the east in Arkansas by Tehan and Warmath (1977). Lithofacies similar to 4 of theirs have been recognized in Adair County: 1) skeletal packstone-wackestone facies; 2) oolite facies; 3) nodular limestone-shale facies; 4) mudstone facies. Their mound facies has not been observed in Oklahoma. The dominant lithofacies in Adair County is bioclastic in nature. Oolitic limestones, mudstones, and nodular limestones with interbedded shales are secondary in abundance.

Depositional environments include: oolite shoals, inter-shoal areas, and anoxic reducing environments. Oolite shoals provided an effective wave barrier between which skeletal packstones and wackestones were deposited in more restricted inter-shoal areas. Dark gray to black mudstones and shales accumulated where local anoxic conditions prevailed.

Mound developments in northwestern Arkansas decrease to the west in that area and are located stratigraphically higher in the western most sections. Mounding in Adair County is believed to have been removed if originally present by post Pitkin erosion. [3–4]

Redbed-Type Stratabound Copper in the Lower Permian of North-Central Oklahoma

E. ROY COX and ZUHAIR AL-SHAIEB, Department of Geology, Oklahoma State University, Stillwater, Oklahoma

Anomalously high concentrations of copper, lead, and zinc sulfide minerals have been found within the Wellington Formation of Early Permian age, in the shallow subsurface of Grant County, Oklahoma. Geochemical analyses and microscopic examination of over 1,800 well-cutting samples reveal a significant copper mineralization zone consisting of thin carbonate beds, interstratified with shales and siltstones in the upper Wellington Formation. As many as four mineralized beds have been identified and traced laterally in the subsurface of Grant County. Chalcocite is the principle copper sulfide phase; it fills vugs in carbonate beds, and is clearly of epigenetic origin. Chalcocite has replaced pyrite and minute organic debris in gray shales. Less distinct zones of lead and zinc mineralization, chiefly galena and sphalerite, are found in several gray shales in the middle and lower Wellington Formation. [4]

Bixby, Oklahoma—A Case Study in Flood Plain Management

W. B. CREATH, Environmental Sciences Corporation, 4515 South Yale, Tulsa, Oklahoma

Bixby, Oklahoma, was founded as a farm-oriented town in a flood plain because the flood plain was the site of the fertile soils and the focus of the agricultural activity. Current residential and commercial growth causes ever increasing property damage from flood waters. Because a no-growth policy is not acceptable to the community, alternative solutions are being sought to adapt construction and development policy to the flood-prone environment. The town recognizes the unique difference between the types of land to be developed and adopted and proposed flood management ordinances are based upon geomorphic boundaries rather than political boundaries. The building on artificial fill is prohibited, stemwall construction is limited, development must allow unrestricted flow and cause no displacement to water. Subdivision roads are lowered below grade to provide for temporary water storage, and adjacent communities are held accountable for their lack of water management practices. Development assessments in flood hazard areas pay for required drainage and are a public responsibility; detention facilities in the uplands are the responsibility of individual developers. The current practices in Bixby are adaptable to the other 5100 communities in the United States built in flood plains. [4]

Late Pennsylvanian and Permian Cornstones (Caliche) in Oklahoma

R. NOWELL DONOVAN, Department of Geology, Oklahoma State University, Stillwater, Oklahoma

Nodular limestones in Late Pennsylvanian and Permian rocks in Oklahoma are cornstones (caliche) which formed during early diagenesis under pedogenic control. Various alluvial fans, fluvial and floodplain lithologies host the cornstones which vary in thickness from 0.1 to 3.0 m. In thicker cornstones massive carbonate textures characterize the upper part of cornstone profiles with nodular textures below. The cornstones indicate tectonic stability, slow rates of sedimentation and a semiarid climate during their formation. [4]

Stratigraphy of Layered Anorthosites in the Eastern Wichita Mountains, Oklahoma

LARRY D. ESTES, JOSEPH F. FISCHER, and RICKY J. TAYLOR, Department of Geology, The University of Texas at Arlington, Arlington, Texas

Anorthosites exposed along Medicine Creek in the Wichita Mountains of Oklahoma form part of a layered sequence with a minimum thickness of 300 meters. The base is a contact with younger granite. The lowest exposed rock is an anorthosite pegmatite, composed mainly of plagioclase crystals up to 15 cm. in length, without apparent lamination. The pegmatite is overlain by layers ranging from 4 to 60 m. thick, forming at least 10 mappable units with sharp contacts. Layers and lamination dip about 35° to the northwest. The layers are composed of 3 main types of rock: 1) an extremely well-laminated anorthosite with platy plagioclase grains 10x10x2 mm., and minor intercumulous olivine, pyroxene and Ti-magnetite; 2) a leucogabbro containing chunky plagioclase grains about 10x8x6 mm., with intercumulous pyroxene and olivine; and 3) a white sugary-textured anorthosite composed of plagioclase grains 1 to 2 mm. across with scattered olivine oikocrysts up to 3 cm. across. There is no discernible repeated cyclicity to the layering. Intraclasts of gabbro are found in the laminated anorthosite, and *vice versa*. Tight folding, with wavelengths of 5 to 20 cm., has been found within the laminated anorthosite.

We propose the following: 1) this sequence may be a separate intrusion from the layered anorthosites in the Raggedy Mountains, 25 km. to the west; 2) the crystals of some of the layers were transported from the nucleation and growth site to the depositional site by mass flow which ripped up parts of the floor; and 3) the folding of the laminated anorthosites may be from deposition on a slope, or from penecontemporaneous deformation by high energy flows. Both possibilities suggest base of slope deposits. [5]

Structural Control of Ground-Water Flow in the Arbuckle Mountain Area, South-Central Oklahoma

ROY W. FAIRCHILD and ROBERT E. DAVIS, U.S. Geological Survey, WRD Rm. 621, 201 N.W. 3rd, Oklahoma City, Oklahoma

Rocks that underlie the Arbuckle Mountain area, and that make up the Arbuckle aquifer, have undergone intensive folding and faulting associated with major uplift of the area during Early to Late Pennsylvanian time. A major part of the aquifer consists of limestone and dolomite of the Arbuckle Group (Late Cambrian to Early Ordovician age). Rocks that make up the Arbuckle aquifer crop out in about a 375-square-mile area. The aquifer is recharged directly by rainfall on the outcrop area. Water enters the aquifer through fractures that have been enlarged by solution of the limestone. The general direction of movement through the aquifer is toward the south. The Tishomingo Granite of Pre-Cambrian age acts as a subterranean barrier to ground-water flow in the aquifer. A ground-water mound exists on the north side of this barrier. Water is discharged from the ground-water mound by way of springs. Of about 80 springs inventoried in the area, most are associated with faults and fractures in the limestone. Although small seeps and springs may dry up, especially during the summer, the larger springs contribute sufficient discharge to sustain flow in major streams on a perennial basis. Wintertime baseflow from the area amounts to about 0.53 cubic feet per second per square mile for a total of 130 million gallons per day. [5]

Quanah Granite—Gabbro Relations, Wichita Mountains

M. C. GILBERT, Oklahoma Geological Survey, The University of Oklahoma, Norman, Oklahoma

Most of the recent regional map compilations show Quanah Granite in fault contact with Raggedy Mountain Gabbro (RMG) wherever the units are adjacent to each other. Remapping of this contact, plus review of data in the files of the Oklahoma Geological Survey, indicate this is in error. Quanah Granite intrudes the layered series of the Raggedy Mountain Gabbro as evidenced by:

1) contact that commonly is sinuous
2) apophyses and dikes of Quanah projecting into RMG
3) occurrence of hybrid rock near or at the contact
4) chilling of Quanah against RMG, in rare cases

While the contact appears nearly vertical at some outcrops, trace of the contact on the map indicates a more horizontal attitude regionally. Thus, the contact could actually be "stepped." The Quanah may bear a sill-like relation to the RMG comparable to that shown by the Mt. Scott Granite. Possible implications bearing on the crystallization history of the Quanah will be discussed. [6]

Wichita Mountains Mapping Project

M. C. GILBERT, Oklahoma Geological Survey, The University of Oklahoma, Norman, Oklahoma

The Oklahoma Geological Survey is engaged in a new effort to compile a geological map of the igneous rocks outcropping in the Wichita Mountains of southwestern Oklahoma. Compilation is at the scale of 1:24,000 and is based upon 1) previously published work, where at a useful scale, 2) thesis studies, both completed and those in progress, 3) unpublished data in the files of the Survey, 4) unpublished data supplied cooperatively by non-Survey workers, and 5) new Survey mapping to resolve conflicts and to fill in blank areas.

The need for such a compilation has arisen both because of the critical role a detailed understanding of the basement rocks provides in later development of the Mid-Continent Paleozoic section, and because renewed interest in Wichita Mountains igneous age relations and petrogenesis requires a clear understanding of the field relations.

The aim is to recognize a consistent set of mappable units and nomenclature valid over the whole extent of the surface exposures. This also yields more definition within the three main igneous groups: Raggedy Mountain Gabbro, Wichita Granite, and Carlton Rhyolite. [6]

Relations of the Mafic Rocks Exposed in the Meers Area, Wichita Mountains, Oklahoma

KENNETH R. HAHN, Department of Geology, Rice University, Houston, Texas

Three mafic units outcrop in the Meers area: cumulates of the layered series of the Wichita complex; a biotite gabbro; and dikes of basaltic to dioritic compositions. The biotite gabbro contains pods and stringers of hornblende-feldspar-rich material, which may represent: 1) assimilated blocks of the Meers Quartzite; 2) late stage fluids associated with the biotite gabbro; or 3) injections related to emplacement of the Mount Scott Granite. The contact between the biotite gabbro and cumulus rocks is often obscured. Lenses of layered series rocks, a few tens of meters in width, are enclosed by the biotite gabbro and seem to suggest an intrusive nature for the biotite gabbro. The cumulates include anorthosites, gabbroic anorthosites and troctolites and show some degree of rhythmic layering. Post-magmatic alteration of the layered series rocks is evidenced by the introduction of secondary minerals such as serpentine, chlorite, uralitic amphibole, "saussurite" epidote, prehnite and sulfides. The occurrence of these secondary minerals appears to be restricted to an area near the inferred contact between the biotite gabbro and the cumulus rocks. This restricted spatial distribution suggests a possible genetic relationship between the secondary minerals and late stage fluids originating from the biotite gabbro. The youngest mafic units exposed are the dikes which are a few meters in width, and cross-cut both the biotite gabbro and the layered series. They can be grossly subdivided into biotite-bearing and non-biotite-bearing dikes. The biotite-bearing dikes are found in the biotite gabbro, while those found in the cumulus rocks are biotite-free. Their relationship to one another remains unclear. [6–7]

Petrology and Occurrence of a Magnetite-Ilmenite-Olivine Rock in the Wichita Mountains

CATHERINE L. HANKS, Department of Geology, Rice University, Houston, Texas

Located two miles southeast of Roosevelt, Oklahoma is a unique exposure of magnetite-ilmenite-olivine rock in the layered series of the Wichita complex. Field relations are ambiguous. A preliminary geophysical survey suggests a dike, indicating a tabular body dipping to the northwest, opposite to the northeast regional dip of the layered series. Contacts between the magnetite-ilmenite-olivine rock and the layered series consist of an extensively sheared zone, suggesting a fault slice. The body itself exhibits a rhythmic layering consisting of alternating olivine and magnetite-ilmenite rich layers. These layers also dip to the northwest. Stringers of a biotite-bearing gabbro are intimately associated with the magnetite-ilmenite-olivine rock.

Petrographically, the rock appears to be a mesocumulate or adcumulate, with olivine, magnetite and ilmenite as the cumulus phases (average: 40% mt., 15% ilm., 30% ol.). Plagioclase, biotite and pyroxene are interstitial. A pleonaste spinel is found as inclusions in the magnetite grains. The stringers of biotite

gabbro display a gradational boundary with the magnetite-ilmenite-olivine host rock.

The presence of olivine and magnetite as cumulus phases suggest that this rock is an upper member of the layered series which has been down-faulted. Rotation of the fault block could explain the dike-like character of the exposure. Alternatively, the magnetite-ilmenite-olivine rock may be a cumulate genetically related to the biotite gabbro and not comagmatic with the layered series.

[7]

Structural Influence of Growth Faults on Middle Atokan Sandstone Distribution in the Oklahoma Portion of the Arkoma Basin

GARY W. HART, Independent Petroleum Geologist, 417 Cravens Bldg., Oklahoma City, Oklahoma

The Arkoma Basin in eastern Oklahoma and northwestern Arkansas is a major east-trending asymmetrical basin which formed primarily during the Atokan Epoch of the Pennsylvanian Period. In late Morrowan and early Atokan, represented by "Wapanucka and Spiro equivalents," the basin was a broad gently south-dipping plain with sand deposition primarily in south-trending channels but some in east-trending strandline environments. After Spiro deposition in early Atokan time, the Arkoma basin proper began to subside. The basin formed by movement along a series of major east-west normal, down-to-basin growth faults. Abrupt thickening on the downthrown sides was accompanied by marked changes in sand development. Middle Atokan (Red Oak) sands on upthrown blocks were swept over fault scarplets at various places and were redistributed by westerly currents. These sands are thought to have formed as turbidites which were reworked and deposited in depression areas roughly corresponding to downthrown blocks of growth faults. Growth faulting continued through late Atokan time; it apparently ceased in early Des Moinesian time represented by the "Hartshorne equivalent."

Texturally the Middle Atokan Red Oak Sandstone is very fine- to medium-grained, white, frosted in part, quartzitic to friable in part, and subrounded to subangular.

These redistributed Middle Atokan sandstones contain some of the largest gas reserves on a per well basis in the Oklahoma portion of the Arkoma basin.

[7]

Major Sources of Chlorides in the Arkansas River in Oklahoma

KENNETH S. JOHNSON, Oklahoma Geological Survey, The University of Oklahoma, Norman, Oklahoma and S. THOMAS GAY, U.S. Army Corps of Engineers, Tulsa, Oklahoma

Thick deposits of Permian rock salt (halite) in the shallow subsurface of northwest Oklahoma are being dissolved by ground water, and the resultant brine is being emitted at the surface at four principal salt plains on the Salt Fork of Arkansas River and on the Cimarron River. The brine reaching the surface is thus degrading the quality of water flowing in these two major tributaries to the Arkansas River, and this limits the possible uses that can be made of the water for hundreds of miles downstream from the salt plains.

Salt-bearing units being dissolved beneath each salt plain are generally 50 to 300 feet thick, and consist of rock salt interbedded with red-bed shale and some siltstone and sandstone. The top of the salt units typically ranges from 100 to 400 feet below land surface. The Lower Cimarron salt is the source of brine at Great Salt Plains east of Cherokee, the Upper Cimarron salt is providing brine at Salt Creek canyon near Southard, and the Flowerpot salt is the source bed at Big Salt Plain and Little Salt Plain west of Freedom. [8]

Use of LANDSAT Imagery for Prediction of Recharge and Pollution Susceptibility in a Fractured Chert and Carbonate Aquifer

DOUGLAS C. KENT, KENNETH R. WATTS, and ESMAIEL AZIMI, Department of Geology, Oklahoma State University, Stillwater, Oklahoma

Analog and digitally enhanced LANDSAT imagery are used for the evaluation of fracturing and related pollution susceptibility and recharge in an unconfined chert-carbonate aquifer, the Boone Formation, in northeastern Oklahoma. The orientation and the density of fracturing are estimated from the orientation and density of LANDSAT linears. A map of LANDSAT linear density was prepared and used in conjunction with available soil and land-use information to develop a pollution susceptibility map. This map shows the predictable levels of pollution-susceptibility and recharge areas overlying the Boone aquifer adjacent to the Illinois River.

The variability in well yield and ground-water quality of the area is compared with fracture density and predicted levels of pollution susceptibility. One-way analysis of variance indicates a high reliability of correlation between low fracture density and relatively low well yields and higher concentrations of SO_4, Cl, Fe, and total hardness. The validity of the pollution susceptibility and recharge predictions is strengthened by these correlations. [8]

Surface-Mined-Lands Inventory and Related Land-Use Practices in Oklahoma

KENNETH V. LUZA and KENNETH S. JOHNSON, Oklahoma Geological Survey, The University of Oklahoma, Norman, Oklahoma

Significant quantities of zinc, lead, copper, coal, limestone, sand, gravel, gypsum, and other mineral commodities have been recovered in Oklahoma, and many mining operations are productive at present. The Oklahoma Mining Lands Reclamation Acts of 1968 and 1971 require that mined lands now be reclaimed; however, a substantial number of acres have been left in their disturbed state prior to the enactment of these laws.

A program was undertaken to conduct an inventory of both past and present mining activities in the State. This involved the collection of information on: 1) the extent of mining, 2) types of material and quantities removed, 3) conditions resulting from mining activity, and 4) methods of reclamation and the

success of such reclamation at each site. The latest aerial photographs for each county were used to identify and locate all surface manifestations attributed to mining activity. Pits and quarries were outlined, and acreage calculations of the disturbed land were made using a planimeter and/or a specially constructed transparent overlay. These procedures were followed by field investigations to determine the commodity mined, volume and tonnage removed, present conditions of the land, and any adverse environmental effects at the mine site and/or adjacent properties. During the field assessment, mined land was classified as "unreclaimed," "partly reclaimed," or "reclaimed." Some of the abandoned surface-mined lands are currently being restored for pasture, cropland, recreational, park, and housing-development uses. [22]

Ouachita Turbidites, Southeastern Oklahoma: A Summary

RICHARD J. MOIOLA, Mobil Research and Development Corporation, Field Research Laboratory, Dallas, Texas

The Carboniferous sequence in the Ouachita Mountains of southeastern Oklahoma comprises more than 7,000 meters of rhythmically interbedded sandstones and shales (Stanley Group, Jackfork Group, Johns Valley Formation and Atoka Formation) that were deposited primarily by turbidity current and hemipelagic processes. These strata, which exhibit characteristics analagous to the classic flysch of the Alpine and Carpathian areas of Europe (Cline, 1970), are thought to have accumulated in bathyal to abyssal water depths (Chamberlain, 1971, 1975). Paleocurrent studies indicate that the dominant transport direction was parallel to the axis of the geosyncline (Briggs and Cline, 1967). Ouachita turbidites generally consist of very fine- to medium-grained sand and are typically 10 cm. to 1 m. thick. They display a magnificent array of sole marks (i.e., flute, groove, load, prod, brush and bounce casts) and trace fossils of the *Nereites* and *Chondrites* facies are often present. Internally, most of the turbidites are characterized by base-cut-out sequences of the B-C type (i.e., parallel laminated→ripple cross-laminated and convolute laminated). Complete Bouma sequences are rare and when present, A divisions are thin and slightly graded or relatively thick and massive. Common associated features include dish and pillar structures and soft-sediment faults. Using the facies association scheme of Walter and Mutti (1973), most of the turbidites fall into the mid (depositional lobe) to outer submarine fan association. Channelized and/or amalgamated units typical of the channeled suprafan and inner fan associations, however, are seldom present in southeastern Oklahoma. [22]

Water Quality in Abandoned Zinc Mines in the Picher Field, Tri-State Mining District

STEPHEN J. PLAYTON, ROBERT E. DAVIS, ROGER G. McCLAFLIN, U.S. Geological Survey, Rm. 621, 201 N.W. 3rd, Oklahoma City, Oklahoma

Onsite measurements of pH, specific conductance, and water temperature show that water in seven mine shafts in the Picher Field of northeastern Oklahoma and southeastern Kansas is stratified. Specific conductance and water temperature tend to increase, and pH tends to decrease as depth increases. Concentrations of chemical constituents in mine-shaft water, such as dissolved solids, total and dissolved metals, and dissolved sulfate also increase with depth. During the course of the study, September 1975 to June 1977, the water level in a well penetrating the mine workings rose at an average rate of 1.2 feet per month. Generally, the water-level rise was greater than average after periods of relatively high rainfall, and lower than average during periods of relatively low rainfall. Water in the mine shafts is unsuited for most uses without treatment. The relative inability of current treatment practices to effectively remove high concentrations of toxic metals, such as cadmium and lead, precludes use of the water for public supply. [24]

Bimodal Gabbroic Magmatism in the Wichita Province, Oklahoma

BENJAMIN N. POWELL, Department of Geology, Rice University, Houston, Texas

Intrusive relationships among rocks of gabbroic affinity in the Wichita complex, Oklahoma, imply more than one episode of basaltic magmatism. Modal mineralogy and phase chemistry suggest further that at least two chemically distinct parental magmas are represented. The dominant body (layered series) consists of feldspathic cumulates containing variable amounts of augite, bronzite-hypersthene and olivine, with accessory magnetite and ilmenite. The absence of primary hydrous phases (e.g. biotite and amphibole), even among pore materials in G-zone mesocumulates, testifies to a comparatively anhydrous parental magma. Intrusive into the layered series are several dikes and bodies of gabbro characterized by the presence of primary red-brown biotite. Other primary phases include plagioclase, augite, orthopyroxene, with accessory apatite, magnetite and ilmenite. In addition, olivine is present in small amounts in the lower exposed portion of the Mt. Sheridan sill and is a major phase in other bt-gabbro bodies in the western part of the complex. Dikes of biotite-olivine gabbro typically contain notable amounts of primary pinkish brown Ti-bearing amphibole (3% TiO_2). These primary hydrous phases suggest that the parental magma(s) of the bt-gabbros possessed a higher water content than that of the layered series. Further chemical distinctions are implied by Ti and Al contents of pyroxenes, which suggest that parental magma for the bt-ol gabbros had a higher Ti content than that of the layered series which in turn exceeded that of the Mt. Sheridan bt-gabbro. Ni contents of olivines are less diagnostic yet are consistent with a lack of consanguinity between the layered series and the biotite-bearing gabbros. Thus a complexity of petrogenesis is revealed among rocks which were inferred by most earlier workers to be co-genetic. [24]

Depositional Environment of Pennsylvanian Marchand Sandstone, Northwest Norge and Northwest Chickasha Fields, Oklahoma

JOHN W. SHELTON, Department of Geology, Oklahoma State University, Stillwater, Oklahoma; and TODD M. WILSON, Texas Oil and Gas Company, Midland, Texas

In the Chickasha, Oklahoma, area the Marchand Sandstone, basal unit of the Hoxbar Group of the Pennsylvanian Missourian Series, is a slope deposit which formed in areas analogous to the middle fan of modern deep-sea fans. As much as 200 feet of sandstone, derived in large part from the Ouachita system, were deposited dominantly by sediment-gravity mechanisms in water depths of at least 300 feet.

The Marchand Sandstone is present as bifurcating channel deposits in each of the two distinct depositional lobes which formed west of a depositional shelf-edge in the Anadarko basin. Large lenticular complexes of multistoried and multilateral channel deposits, exhibiting sharp lateral and basal contact, compose the sandstone. In the Northwest Chickasha and Northwest Norge fields the sandstone is more than 5 miles wide in an east-west direction and more than 7 miles long in a north-south direction.

Although internal features do not compose an idealized vertical sequence characteristic of well known depositional environments, texture and sedimentary structures indicate that progradational, interstratified sequences of shale and siltstone-sandstone dominated deposition prior to channelization. Medium and small-scale cross-bedding, flowage features, and massive bedding are the dominant sedimentary structures in the moderately well sorted, uniformly fine-grained channel sandstone. Shale interstratification and clay clasts are also common.

A gradual shift of the depocenter out of the area is indicated by an upper lenticular sequence of shale and siltstone-sandstone. The overlying "Hot Shale" reflects a transgression associated with the shift and/or change in sea level.

[25]

Anatomy of an Arkansas River Sand Bar

RICHARD STEINMETZ, Amoco Production Company, Security Life Bldg., Denver, Colorado

The sand bar is located in the Arkansas River valley approximately 16 km. upstream from Tulsa, Oklahoma. From aerial photo sequences, plus discharge and river stage records, it was determined that the entire sand bar (460,000 m^3) was deposited in 156 hours. Deposition occurred during two floods, May 19 to 22, 1957 (60 hours) and October 3 through 6, 1959 (96 hours).

The sand bar was studied in detail along a natural cutbank (150 m. long) parallel to the valley axis and in a trench (215 m. long by 4.5 m. deep) dug perpendicular to the cutbank. Sand peels and box cores were taken, and cross-bed types were recorded. Closely spaced cross-bed measurements (N=210) recorded at 12 vertical sections, and grain size analyses were performed on 210 samples from the same sections.

Results show that the highly variable patterns of cross-bed dips match the erratic and changing flow directions prevalent during flood stages. In some of the vertical sections, cross-bed dip directions are at all angles to the overall east-west orientation of the Arkansas River valley. Mean grain size ranges from 0.07ø (0.95 mm.) to 4.44ø (0.05 mm.), and standard deviation ranges from 0.26ø to 1.48ø. At most of the vertical sections, grain size distributions show no systematic change from bottom to top. [26]

Depositional Environment of the Pennsylvanian Cottage Grove Sandstone, South Gage Field, Oklahoma

DANNY J. TOWNS, Department of Geology, Oklahoma State University, Stillwater, Oklahoma; and HERBERT G. DAVIS, Independent Geologist, Oklahoma City, Oklahoma

The Pennsylvanian Cottage Grove Sandstone of the Lansing-Kansas City Group of the Missourian Series produces oil and gas in the South Gage Field, a stratigraphic trap in central Ellis County, Oklahoma. The Cottage Grove, which lies above the Hogshooter Limestone and below the Tonkawa Sandstone, is interpreted as a shallow-marine bar deposit greater than 7 miles long, approximately 2 miles wide, and as thick as 90 feet. The unit consists of very fine-grained sandstone and coarse siltstone which grades laterally into marine shale. Although the lower boundary of the sandstone is rather sharp, the unit appears as a convex-upward sand buildup, with no apparent channeling. The upper boundary is gradational.

Sedimentary structures within the unit include (1) a lower zone of small-scale cross-stratification, and (2) an upper intensely burrowerd zone, the uppermost part of which shows interstratification of sandstone and shale. Constituents include quartz, mica, and interstitial clays. Carbonate cement commonly is concentrated in thin intervals which serve as local stratigraphic markers for correlation. Fossil fragments are present near the top and at the base of the sandstone. [27]

The Significance of Sandstones in the Trace Creek Shale Member of the Pennsylvanian Bloyd Formation in Adair County, Northeastern Oklahoma

GRANT D. ZIMBRICK, Department of Geology and Geophysics, The University of Oklahoma, Norman, Oklahoma

The Trace Creek Shale is the highest member of the Bloyd Formation in Washington County, Arkansas. This shale locally contains, in Washington County, calcareous and non-calcareous sandstone lenses and layers. This member is overlain and underlain respectively by the Atoka Formation, composed of interbedded sandstones and shales, and the Kessler Limestone Member of the Bloyd Formation.

The Kessler Limestone is a persistent lithologic unit in Washington County and westward in Adair County, Oklahoma. The Bloyd-Atoka formational boundary in Washington County has traditionally been placed at the base of the first cliff-forming sandstone above the Kessler Limestone.

In Adair County there is commonly at least one well developed sandstone layer within the Trace Creek Shale and such layers can be lithologically distinguished in the field from the higher Atoka sandstones. The Trace Creek sandstones are crinozoan-bearing, calcareous, fine to medium-grained sandstones. They are usually three to seven feet thick in eastern Adair County but are locally up to twenty feet thick in the western part of the county, where they become progressively less calcareous. They show thick to massive bedding and probably represent a series of discontinuous sand bodies as evidenced by their variable position above the Kessler Limestone. The higher Atoka sandstones are limonitic or clay-bonded coarse siltstones to very fine sandstones. They are usually thin- and wavy-bedded and commonly over thirty feet thick.

Field evidence suggests that the sandstones within the Trace Creek Shale in Adair County become still more numerous and thicker westward and that the Trace Creek Shale interval is a facies of the lower part of the Atoka Formation to the west in Cherokee County. [28]

North American Paleontological Convention II Echinoderm Paleobiology Symposium Lawrence, Kansas, August 9, 1977

The following abstracts are reprinted from the *Journal of Paleontology*, v. 51, no. 2, supplement pt. III. Page numbers are given in brackets below each abstract. Permission of the authors and of Doris L. Woofter, business manager of SEPM, to reproduce these abstracts is gratefully acknowledged.

Ostracode Assemblage Zones in the Upper Austinian and Tayloran (Campanian) of Arkansas and Oklahoma

J. E. HAZEL, U.S. Geological Survey, Washington, D.C.; ELISABETH BROUWERS FORESTER, U.S. Geological Survey, Lakewood, Colorado

Ostracodes are abundant and diverse in the Brownstown, Ozan, Annona, and Marlbrook Formations of southwestern Arkansas and southeastern Oklahoma. Over 200 species have been identified from over 100 samples. Multivariate analyses (Principal Coordinates Analysis and pair-group Cluster Analysis) of most of the samples allows recognition of seven biostratigraphically important assemblages of zone or subzone rank. These units are applicable in Arkansas, Oklahoma and, tentatively, northeast Texas. Using range zones and concurrent range zones, the chronozones of the delineated assemblage zones can be recognized widely in the Coastal Plain. Correlation of the Arkansas units with those in Texas and the eastern Gulf Coastal Plain are suggested; some of the correlations differ considerably from published interpretations.

The boundary between the Austinian and Tayloran Provincial Stages is between the Brownstown Marl and the overlying Buckrange Sand Member of the Ozan Formation, although on the basis of total fauna the Buckrange is somewhat more similar to the Brownstown than the rest of the Ozan. This suggests that the boundary between the *Globotruncana fornicata* and *Archeoglobigerina*

blowi planktic foraminifer zones is not suitable for recognition of the Austinian and Tayloran boundary. The chalky beds in McCurtain County, Oklahoma, that contain the ammonite *Delawarella* are early Tayloran age. The base of the Ozan in the northeastern part of the outcrop area is younger than it is to the southwest, but the underlying Brownstown is the same age as it is in the southwest. The lower Marlbrook is faunally like the Annona, but the upper Marlbrook is clearly differentiated. [14]

Biostratigraphy and Paleoecology of Late Pennsylvanian Crinoids in the Central United States

R. K. PABIAN, Conservation and Survey Division, University of Nebraska, Lincoln, Nebraska; H. L. STRIMPLE, Department of Geology, University of Iowa, Iowa City, Iowa

Chronological correlation of Upper Pennsylvanian crinoid faunas of the North American midcontinent is complicated by provincialism in assemblages of both inadunate and flexible species and their sporadic distribution. Inadunate provincialism is shown by a *Stellarocrinus-Erisocrinus* dominant fauna with a relatively unimportant *Delocrinus* contribution in Illinois; a *Delocrinus-Erisocrinus* dominant fauna with a relatively unimportant *Stellarocrinus* contribution in southwestern Iowa and southeastern Nebraska; and a *Delocrinus-Erisocrinus* dominant assemblage with an important *Lecythiocrinus* element (normally absent in Illinois, Iowa, and Nebraska) in southeastern Kansas and northeastern Oklahoma. Flexible crinoid provincialism is shown by a *Paramphicrinus* rich fauna in Illinois, and a *Cibolocrinus* rich fauna in Kansas and Oklahoma; both genera are present in Iowa and Nebraska but only as minor constituents in the total crinoid fauna. Tentative ranges have been established for a number of species and these crinoid ranges are compared to ranges of other invertebrate groups. Several long-ranging lineages such as *Delocrinus hemisphericus* (Shumard) and *Erisocrinus typus* Meek and Worthen show systematic changes in populations which may help effect chronologic correlations more precisely than individual specimens.

Abundance and diversity of crinoids in the upper Pennsylvanian usually varies with the abundance and diversity of the total fauna, and the taxonomic make up of the crinoid faunas is related to the environments of deposition of typical midcontinent megacyclothems. [20]

Echinoderm Faunas and Paleoecology of the Bromide Formation (Middle Ordovician) of Oklahoma

JAMES SPRINKLE, Department of Geological Sciences, The University of Texas, Austin, Texas; MARK W. LONGMAN, Cities Service Oil Co., Tulsa, Oklahoma

The Middle Ordovician Bromide Formation of southern Oklahoma contains one of the largest and most diverse echinoderm faunas (10,000+ specimens representing 39 genera and 11 classes) ever found in a single Ordovician formation. Three rich zones making up about 16% of the Bromide section have produced more than 99% of the known echinoderms through surface collecting and trenching. A 1–2 m. lower zone in the middle Mountain Lake Member has a rich but patchy echinoderm fauna usually dominated by the inadunate crinoid *Hybocrinus* and the paracrinoid *Platycystites*. A 1–4 m. upper zone at the top of the Mountain Lake is widespread and usually dominated by the paracrinoid *Oklahomacystis*. The top 14 m. of the overlying Pooleville Member in the Criner Hills contains an echinoderm fauna dominated by archaeocrinid camerate crinoids occurring in discrete patches or "gardens."

These echinoderm-bearing zones in the Bromide were deposited in a variety of open shelf environments at water depths ranging from 5–75 m. in areas having a mixture of clay (or lime mud) and skeletal debris. The lower zone is best developed along a NW-SE trending hingeline on the NE margin of the subsiding Southern Oklahoma Aulacogen. Away from this area the lower zone has a much less abundant and diverse echinoderm fauna dominated by opportunistic genera that are usually rare. The upper echinoderm zone also shows considerable change in paracrinoid abundance across the aulacogen margin. Mountain Lake echinoderms seem to be most abundant around small bryozoan buildups or bioherms; many stemmed echinoderms apparently used the bryozoans for attachment to keep themselves above the soft substrate.

[26]

The University of Oklahoma

The Lithostratigraphy of the Atoka Formation (Lower Pennsylvanian) along the Southwestern Margin of the Arkoma Basin, Oklahoma

BRUCE EDWARD ARCHINAL, The University of Oklahoma, M.S. thesis, 1977, Houston Oil and Mineral, 242 The Main Bldg., 1212 Main, Houston, Texas

The Atoka Formation (Lower Pennsylvanian) outcrops along the southwestern margin of the Arkoma basin in Coal and Pontotoc Counties, Oklahoma. Previous studies of the Atoka here produced only general information which cannot be used to discern the formation's depositional setting or local structural relationships.

The unconformable contact between the Wapanucka Limestone and the overlying Atoka is not easily located because of poor exposures. The conformable contact between the Atoka and the overlying Hartshorne Sandstone can be traced to the Hartshorne's westernmost exposure in sec. 24, T. 1 N., R. 8 E. The Atoka is truncated and overlapped by the McAlester Formation in T. 1 N., R. 7 E.; the location of the contact between the two is arbitrary. Detailed surface mapping and measured stratigraphic sections show the Atoka to be a heterogeneous unit of shale and mudstone interbedded with thin, clean, fine, sheet, and lensing sandstones. Rare, thin, sandy limestones containing biostratigraphically significant fusulinid faunas are found near Clarita, Oklahoma. The Atoka Formation was deposited by a transgressing marine sea, on a shallow shelf where there was minor medium clastic influx. The sandstones observed are lower foreshore beach, barrier bars, or longshore bars deposited during brief stillstands or minor regressions.

The Clarita anticline was a positive structural feature and the Clarita-Phillips fault was an active down-to-the-north growth fault during Atoka deposition. A thickened Atoka sequence containing numerous sandstones was deposited north of these features. The entire sequence thins onto and across the fault and the anticline. This relationship was unrecognized by previous workers who thought that *Fusulinella* occurred two hundred feet stratigraphically above the top of the Morrowan and only a hundred feet stratigraphically above *Profusulinella*, when the actual stratigraphic separation is over a thousand feet. Previously unrecognized block faulting cuts the Atoka Formation and is the cause of the unusual aerial distribution of the formation. Most of the faulting is down-to-the-north, into the Franks graben.

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

BRADLEY BLAKE JONES, The University of Oklahoma, M.S. thesis, 1977, Cities Service Oil Co., Box 1919, Midland, Texas

A paleoenvironmental interpretation of the basal Atoka Formation in northeastern Oklahoma was developed using primary sedimentary structures and stratification sequences as the principal source of information. Seven recognizable and recurring, clastic, shallow marine facies assemblages were established and ordered with respect to energy level. Depositional trends and vertical relationships for these facies assemblages were defined using a statistical matrix analysis.

The paleoenvironment of the basal Atoka Formation, based on the facies data, is interpreted as being a series of small deltaic complexes that are prograding in a southeasterly direction across a shallow marine shelf. Periodic encroachment of these prograding systems by a transgressing sea is evidenced at various intervals within the Atoka section. The regional unconformity between the Morrow Group and Atoka Formation is thought to end along an approximate northeast-southwest strand line running through southeastern Adair County, Oklahoma.

Depositional History of the Devil's Kitchen Sandstones and Conglomerates in the Ardmore Basin, Southern Oklahoma

OLA MAGNE SAETHER, The University of Oklahoma, M.S. thesis, 1976, University of Colorado, Dept. of Geological Sciences, Boulder, Colorado

Numerous stratigraphical and structural studies have been done on sedimentary rocks of Pennsylvanian age in the Ardmore Basin. However, detailed interpretations of the sedimentary structures and petrography of clastic rocks are few.

In this paper the depositional environment and the provenance of Early

Desmoinesian sediments were derived from analyses of stratigraphy, sedimentology, paleocurrent distribution, and petrography.

The sediments bounded stratigraphically by the Pumpkin Creek Limestone below and the Arnold Limestone above are believed to be the result of a shoreline prograding from the southeast into an epeiric sea.

Secondary quartz overgrowths, sedimentary and low-grade metamorphic rock fragments, and the presence of mineralogically mature sandstones suggest that the detrital components are polycyclic. A primary mode for the cross-bedding dip directions and a decrease in thickness and chert pebble size within the conglomerates towards the northwest, are used as evidence for a southeastern origin of the sediments in the southern outcrop area. Sedimentary and low-grade metamorphic rocks of the Ouachita facies are suggested to be the source rocks.

A higher content of feldspar in the western part of the area studied is thought to be derived from a source area consisting of basement rocks located west or southwest of the Ardmore Basin. It is proposed that this is the Waurika-Muenster Arch located in the subsurface along the Oklahoma-Texas borderline.

OKLAHOMA GEOLOGY NOTES

Volume 38 | April 1978 | Number 2

Page