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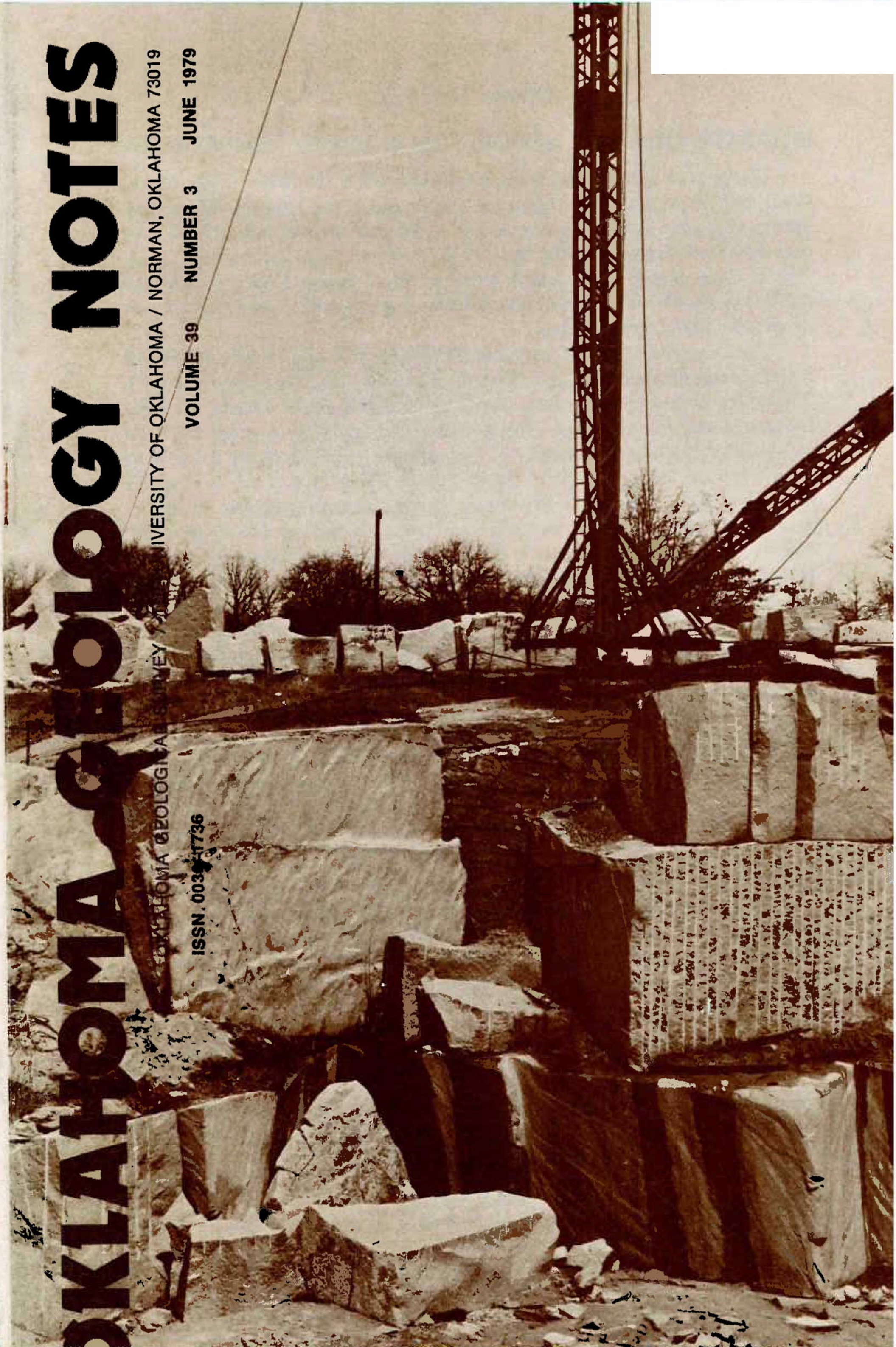

Cover Picture

GRANITE QUARRY, JOHNSTON COUNTY, OKLAHOMA

The granite industry of Oklahoma is centered in the Wichita Mountains, Greer and Kiowa Counties, and in the central part of the Arbuckle Mountains, Johnston County. In 1977, approximately 10,000 tons of Oklahoma granite were quarried. Since the early 1900's, Oklahoma granite has been quarried for monumental stone, rough and finished building stone, paving blocks, riprap, and crushed stone. The color varies from different shades of red to gray, and textures range from fine to coarse grained.

The Century Granite Co., south of Hill Creek, Johnston County, has mined the medium-grained, biotite-rich Troy Granite since 1952 (cover photograph). The quarry is developed in a low, rounded granite hill, chosen because the stone is massive and free of closely spaced joints. The first step in quarrying is to isolate large blocks approximately 12 feet wide by 16 feet long by 8 feet deep from the solid ledge. A vertical channel about 8 feet deep is cut around the large block by jet piercing, a process that disaggregates the granite by the intense heat given off through burning a mixture of diesel fuel and oxygen. The second step involves the separation of smaller blocks from the main block either by the jet-piercing method or by a process wherein holes are drilled vertically into the rock and the spaces between the holes (webs) are cut out or broached. The smaller block is separated from the main block by drilling horizontal holes at the base and blasting it free with explosives. The block, approximately 8 feet by 3 feet by 4 feet, and weighing about 7 tons, is removed from the quarry by one of two stationary cranes (cover photograph). The granite blocks are shipped to Century's plant at Frederick, southwestern Oklahoma, for sawing and processing into polished slabs for tombstones and exterior trim.

—*Kenneth V. Luza*

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, $1.00; yearly subscription, $4.00. All subscription orders should be sent to the address on the front cover.

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

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OKLAHOMA EARTHQUAKES, 1978

James E. Lawson, Jr.,[1] and Kenneth V. Luza[2]

Introduction

Oklahoma is part of a geologic region referred to as the Stable Central Province (King, 1951; Hadley and Devine, 1974). This province extends from the western margin of the Appalachian Plateau to the eastern edge of the Rocky Mountain Uplift and from the Gulf Coastal Plain to south-central Canada. Compared to other tectonic provinces, such as the Appalachian Province, the Stable Central Region has displayed little tectonic activity since Late Pennsylvanian time. The historical seismological record has been limited, with a notable exception being the New Madrid, Missouri, area and adjacent regions in Kentucky, Tennessee, and Illinois.

The New Madrid earthquakes of 1811 and 1812 are probably the earliest historical earthquake tremors felt in Oklahoma (then Arkansas Territory) by early residents in southeastern Oklahoma settlements. The earliest documented earthquake in Oklahoma occurred near Cushing in December 1900. This event was followed by two additional earthquakes in the same area in April 1901 (Wells, 1975). The largest known Oklahoma earthquake occurred near El Reno on April 9, 1952. This magnitude-5.5 (mb) earthquake was felt in Austin, Texas, as well as Des Moines, Iowa, and covered a felt area of approximately 362,000 square km (Docekal, 1970; Kalb, 1964; von Hake, 1976). From 1900 through 1978, 182 earthquakes have been located in Oklahoma (Lawson and others, 1979).

Instrumentation

A statewide network of 10 seismograph stations are recording seismological data in Oklahoma (fig. 1). The Oklahoma Geophysical Observatory station, TUL, has been recording earthquake data since December 1961. The Observatory, located near Leonard, Oklahoma, in southern Tulsa County, operates seven seismometers, three long period and four short period, which are installed in a vault detached from the main building. The seismic responses at TUL are recorded on 11 paper-drum recorders; 16 seismograms are recorded on 16-mm film. Seven semipermanent, volunteer-operated seismograph stations and two radio-telemetry stations constitute Oklahoma's regional network. The installation and maintenance of these stations are being supported by the U.S. Nuclear Regulatory Commission (NRC) (Luza, 1978). The regional seismograph network supplements the existing seismological capability at the Oklahoma Geophysical Observatory by providing more accurate location and detection of earthquake activity in Oklahoma.

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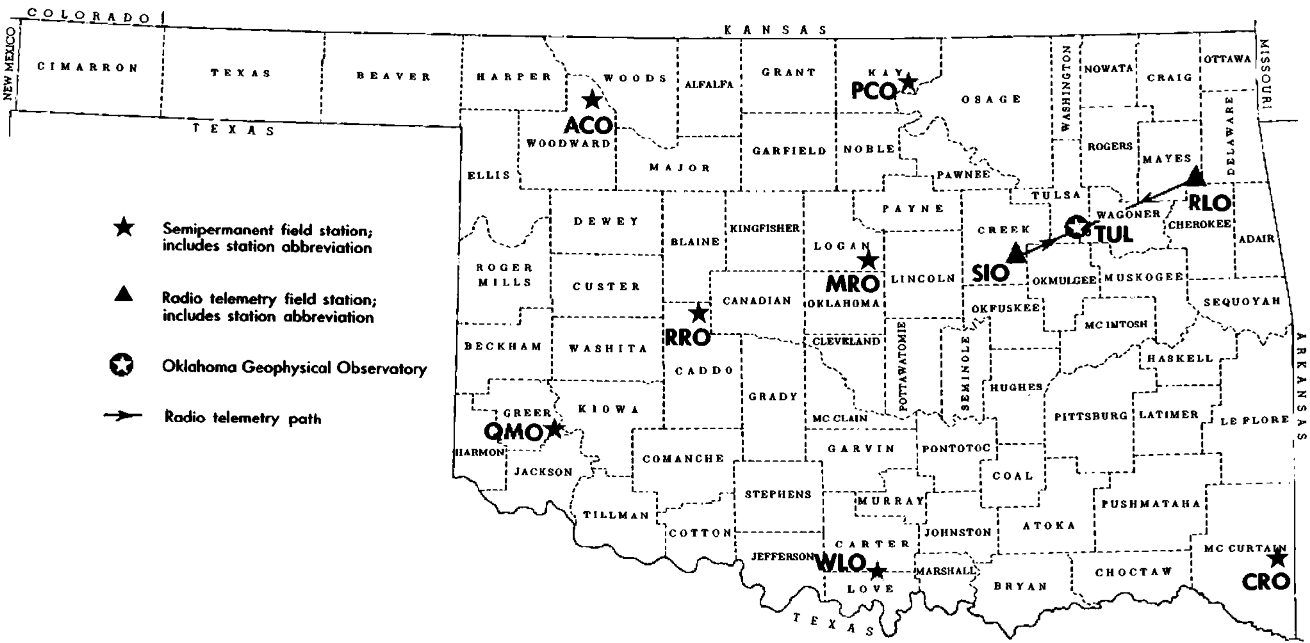

Figure 1. Active seismograph stations in Oklahoma.

Each of the seven volunteer-operated seismograph stations consists of a Geotech S-13, short-period, vertical seismometer; a Sprengnether MEQ-800-B unit, including amplifier, filters, ink-recording unit and a clock; and a Kinemetrics time-signal-radio receiver for high-frequency WWV time signals. Each radio-telemetry system consists of one Geotech S-13 seismometer and one Emheiser Rand telemetry unit. The Emheiser Rand unit amplifies the seismometer output and uses this output to frequency-modulate an audiotone. A 100-milliwatt, crystal-controlled transmitter limits the line-of-sight transmission to 80 km. Seismographs from the radio-telemetry stations are recorded at the Oklahoma Geophysical Observatory.

Earthquake Distribution

In 1978, 35 Oklahoma earthquakes were located (fig. 2) by the Oklahoma Geophysical Observatory staff. Magnitude values range from a low of 1.3 (m3Hz) in Okfuskee County to as high as 3.1 (m3Hz) in Le Flore County. The listing only represents those earthquakes that could be located by using three or more seismograph records. Only four earthquakes were reported felt by people living in the vicinity of the earthquake epicenters. These earthquakes include the March 9 earthquake in Love County, MM II (modified Mercalli intensity), the May 18 earthquake in Canadian County, MM I, and two earthquakes on May 19 in Canadian County, MM III and MM II. Felt and observed effects of earthquakes are generally given values according to the modified Mercalli intensity scale, which assigns a Roman numeral to each of 12 levels described by effects on humans, man-made construction, or natural features (table 1).

The 1978 earthquake epicentral data, which form a limited data set, when combined with previous earthquake data produce some seismic trends worthy of discussion. Five 1978 earthquakes, of which three were felt, occurred near El Reno in Canadian County. This location is near the site of the April 9, 1952 earthquake with the magnitude of 5.5 (mb). Three additional earthquakes occurred northeast of El Reno in Logan County. These earthquakes, when combined with the historical earthquakes in this area, form a zone 30 km wide and 145 km long that crosses the Nemaha Uplift at a 30° angle. It is not clear what this trend represents; however, it is subparallel to a regional northeast-southwest structural grain in northeastern Oklahoma. In south-central Oklahoma, there is a concentration of earthquakes in the Wilson area, Carter and Love Counties. This area has also been the site of numerous small earthquakes in the past. The subsurface geology near Wilson consists of deformed, complexly faulted Paleozoic rocks. Several 1978 epicenters as well as pre-1978 earthquake epicenters fall within and (or) along the northern front of the Ouachita Mountains. Several of these epicenters are within 1 or 2 km of known surface faulting.

Catalog

An HP-9825A desk-top computer system is used to calculate local earthquake epicenters. A catalog containing date, origin time, county, intensity, magnitude, location, focal depth, and references is printed in page-size format. Table

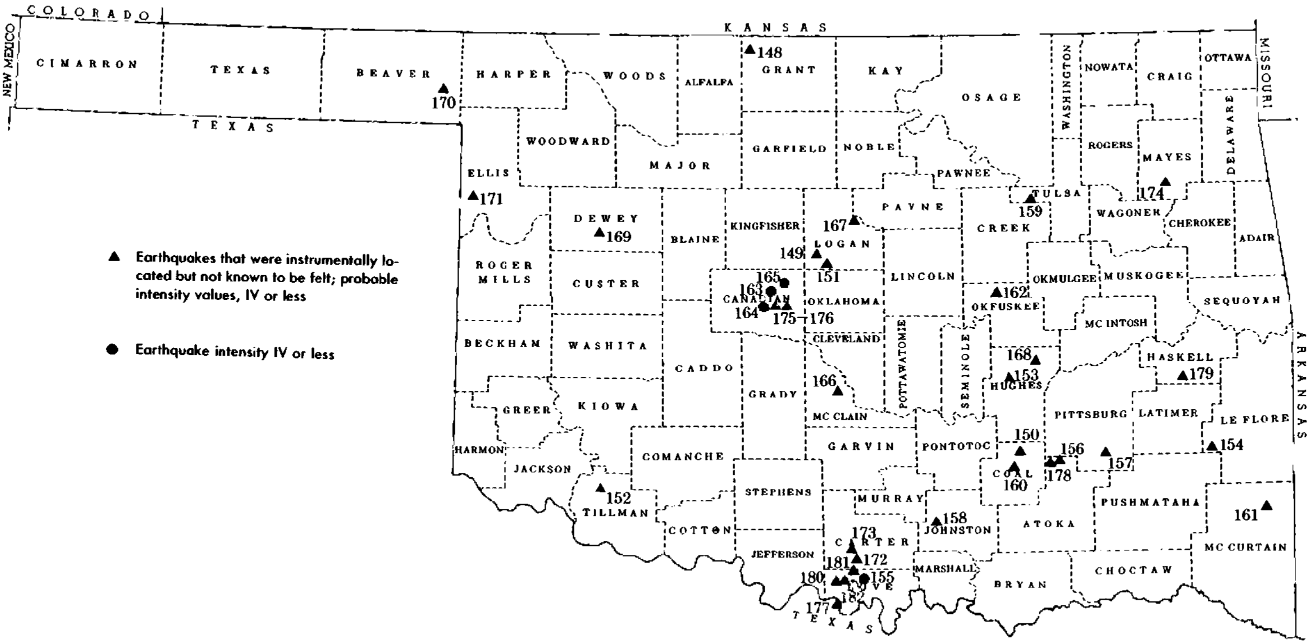

Figure 2. Distribution of Oklahoma earthquakes for 1978. Numbers correspond to event numbers in table 2.

TABLE 1. MODIFIED MERCALLI (MM) EARTHQUAKE-INTENSITY SCALE (abridged)
(Modified from Wood and Neumann, 1931)

I	Not felt except by a very few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Suspended objects may swing.
III	Felt quite noticeably indoors, especially on upper floors of buildings. Automobiles may rock slightly.
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, doors, windows disturbed. Automobiles rocked noticeably.
V	Felt by nearly everyone, many awakened. Some dishes, windows, etc. broken; unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all; many frightened and run outdoors.
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction. Shock noticed by persons driving automobiles.
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings; great in poorly built structures. Fall of chimneys, stacks, columns. Persons driving automobiles disturbed.
IX	Damage considerable even in specially designed structures; well-designed frame structures thrown out of plumb. Building shifted off foundations. Ground cracked conspicuously.
X	Some well-built wooden structures destroyed; ground badly cracked, rails bent. Landslides and shifting of sand and mud.
XI	Few if any (masonry) structures remain standing. Broad fissures in ground.
XII	Damage total. Waves seen on ground surfaces.

2 contains the 1978 Oklahoma earthquakes displayed in a modified version of the regional earthquake catalog.

The date and time are given in UTC. UTC refers to Coordinated Universal Time, formerly Greenwich Mean Time. The first two digits refer to the hour on a 24-hour clock. The next two digits refer to the minute, and the remaining digits are the seconds. To convert to local Central Standard Time, subtract 6 hours.

Earthquake magnitude is a measurement of energy and is based on data from seismograph records. There are several different scales used to report magnitude. Table 2 has three magnitude scales which are mbLg (Nuttli), m3Hz (Nuttli), and MDUR (Lawson). Each magnitude scale was established to accommodate specific criteria, such as the distance from the epicenter, as well as the availability of certain seismic data.

For earthquake epicenters located from 11 km to 222 km from a seismograph station, Otto Nuttli developed the m3Hz magnitude scale (Zollweg, 1974). This magnitude is derived from the following expression:

$$\mathrm{m3Hz} = \log(A/T) - 1.63 + .87\log(\Delta),$$

where A is the maximum center-to-peak vertical-ground-motion amplitude sustained for three or more cycles of Sg waves, near 3 hertz in frequency, measured

TABLE 2. OKLAHOMA EARTHQUAKE CATALOG FOR 1978

Event number	Date and origin time (UTC)			County	Intensity (MM)	Magnitudes 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)	Depth (km)[1]
148	Jan	08	041633.56	Kay		1.5		1.5	36.971	97.463	5.0 R
149	Jan	08	101917.65	Logan		2.1	2.0	2.2	35.824	97.642	5.0 R
150	Feb	10	064202.39	Coal		2.1	1.5	1.9	34.712	96.157	5.0 R
151	Feb	14	010938.64	Logan		1.7		1.7	35.777	97.585	5.0 R
152	Feb	21	111248.11	Tillman		2.5	2.2	2.0	34.535	99.003	5.0 R
153	Mar	03	022437.28	Hughes		2.5	2.1	2.4	35.086	96.278	5.0 R
154	Mar	05	144650.48	Le Flore		3.1	2.9	2.7	34.699	95.033	7.0 R
155	Mar	09	063050.82	Love	II		2.6	2.5	34.010	97.378	5.0 R
156	Apr	02	213248.08	Atoka		2.5	2.3	2.5	34.635	96.057	5.0 R
157	Apr	11	085102.43	Pittsburg		1.7		1.8	34.693	95.681	5.0 R
158	Apr	13	034350.76	Johnston		1.9	2.0	1.9	34.351	96.820	5.0 R
159	Apr	19	142054.06	Tulsa		1.5		1.1	36.088	96.136	5.0 R
160	Apr	20	081304.00	Coal		1.7		1.6	34.586	95.293	5.0 R
161	May	01	225913.38	McCurtain		2.1	2.2	2.2	34.400	94.673	5.0 R
162	May	04	043552.89	Okfuskee		1.3		1.5	35.588	96.345	5.0 R
163	May	17	231115.65	Canadian	I	2.1	2.3	2.0	35.525	97.910	5.0 R
164	May	18	001922.43	Canadian	III	2.5	2.7	2.6	35.502	97.949	5.0 R
165	May	18	003217.57	Canadian	II	2.2	2.1	2.1	35.601	97.828	5.0 R
166	May	19	003937.46	McClain		1.7	2.0	1.9	35.135	97.503	5.0 R
167	May	19	062732.70	Logan		1.8		1.4	36.002	97.367	5.0 R
168	May	28	091900.22	Hughes		2.1		1.8	35.213	96.144	5.0 R
169	Jun	22	051015.54	Dewey		2.0		2.2	35.923	99.089	5.0 R
170	Aug	03	003537.09	Beaver		2.3	2.1	2.4	36.689	100.162	5.0 R
171	Aug	06	042856.83	Ellis		3.0	2.2	2.6	36.073	99.935	5.0 R
172	Aug	08	120748.69	Carter		2.3	2.2	1.9	34.127	97.463	5.0 R
173	Aug	26	145751.99	Carter				1.4	34.178	97.463	5.0 R
174	Sep	08	051606.60	Mayes				1.4	36.155	95.275	5.0 R
175	Sep	26	211717.72	Canadian		2.2	2.2	2.2	35.519	97.866	5.0 R
176	Sep	27	015603.81	Canadian		2.2	2.1	2.2	35.519	97.843	5.0 R
177	Sep	27	205603.75	Love		2.4		1.9	33.883	97.477	5.0 R
178	Dec	08	111853.92	Atoka		2.0	1.8	1.7	34.676	96.063	5.0 R
179	Dec	19	020028.87	Haskell		1.2	1.7	1.7	35.086	95.125	5.0 R
180	Dec	27	220030.02	Love		2.0		1.9	33.996	97.512	5.0 R
181	Dec	28	053032.43	Love		1.4	1.9	1.5	34.080	97.462	5.0 R
182	Dec	28	135409.81	Love		1.9	2.1	1.9	33.991	97.456	5.0 R

[1]The hypocenter is restrained (R) at an arbitrary depth of 5.0 km, except where indicated, for purposes of computing latitude, longitude, and origin time.

in nanometers; T is the period of the Sg waves measured in seconds; and Δ is the great-circle distance from epicenter to station measured in kilometers.

Otto Nuttli's (1973) earthquake magnitude, mbLg, for seismograph stations located between 55.6 km and 445 km from the epicenter, is derived from the following equation:

$$mbLg = \log(A/T) - 1.09 + 0.90\log(\Delta).$$

Where seismograph stations are located between 445 km and 3,360 km from the epicenter, mbLg is defined as

$$mbLg = \log(A/T) - 3.10 + 1.66\log(\Delta),$$

where A is the maximum center-to-peak vertical-ground-motion amplitude sustained for three or more cycles of Sg waves, near 1 hertz in frequency, measured in nanometers; T is the period of Sg waves measured in seconds; and Δ is the great-circle distance from station to epicenter measured in kilometers.

The MDUR magnitude scale was developed by Lawson (1978) for earthquakes in Oklahoma and adjacent areas. It is defined as

$$MDUR = 1.86\log(DUR) - 1.49,$$

where DUR is the duration or difference, in seconds, between the Pg-wave arrival time and the time the final coda amplitude decreases to twice the background-noise amplitude. If the Pn wave is the first arrival, the interval between the earthquake-origin time and the decrease of the coda to twice the background-noise amplitude is measured instead.

The depth to the earthquake hypocenter is measured in kilometers. For most Oklahoma earthquakes the focal depth is unknown. In almost all Oklahoma events, the stations are several times farther from the epicenter than the likely depth of the event. This makes the locations indeterminate at depth, which usually requires that the hypocenter depth be restrained to an arbitrary 5 km for purposes of computing latitude, longitude, and origin time. All available evidence indicates that no Oklahoma hypocenters have been deeper than 15 to 20 km.

Earthquake detection and location accuracy have been greatly improved since the installation of the statewide network of seismograph stations. The frequency of earthquake events and the possible correlation of earthquakes to specific tectonic elements in Oklahoma are being studied. It is hoped that this information will provide a more complete data base that can be used to develop numerical estimates of earthquake risk, giving the approximate frequency of the earthquakes of any given size for different regions of Oklahoma. Numerical risk estimates could be used to better design large-scale structures, such as dams, high-rise buildings, and power plants, as well as to provide the necessary information to evaluate insurance rates.

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Field Trip to Eastern Oklahoma on Tap

A one-day field trip to study Morrowan facies of eastern Oklahoma is scheduled for June 23 by the Tulsa Geological Society. Patrick K. Sutherland, professor in the School of Geology and Geophysics at The University of Oklahoma, will lead the trip, which will examine Morrowan sand, shale, and carbonate facies and the pre-Morrowan unconformity.

The trip is limited to 42 persons and costs $25.00, including OGS Guidebook 18, a box lunch, and refreshments. For information and registration, contact Lyle Bruce, TGS field-trip chairman, Helmerich & Payne, Inc., Utica at 21st Street, Tulsa, Oklahoma 74114 (phone, 918—742-5531).

OGS Issues Bulletin on Bryan County, Oklahoma

A new bulletin, *Geology and Mineral Resources of Bryan County, Oklahoma*, by George G. Huffman, Thomas A. Hart, Laurence J. Olson, John D. Currier, and Robert W. Ganser, was recently released by the Oklahoma Geological Survey.

The 113-page publication, issued as Bulletin 126, contains 49 figures, 11 tables, and a color geologic map at a scale of 1 inch to the mile. Part I of the report deals with the areal geology of the county and includes such categories as geography, stratigraphy, economic resources, and structural geology. Part II covers the geologic aspects of oil and gas development including subsurface stratigraphy and structure. Also included in this section is a subsurface map and eight cross sections. An appendix describes 54 measured stratigraphic sections.

George Huffman, the bulletin's principal author, is a professor of geology and geophysics at The University of Oklahoma. His coauthors are former graduate students who mapped portions of Bryan County under his supervision. The project was supported by the Oklahoma Geological Survey as part of its long-term program of detailed geologic mapping on a county-by-county basis.

OGS Bulletin 126 can be obtained from the address on the front cover. The price is $8.50 for paperbound and $12.50 for hardbound copies.

NURE Report on Lawton Quadrangle Issued

A report on the results of stream-sediment and ground-water reconnaissance in the Lawton 1:250,000-scale, 2° quadrangle was placed on open file by the U.S. Department of Energy (DOE). The report, GJBX-27(79), *National Uranium Resource Evaluation Program, Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Lawton NTMS Quadrangle, Oklahoma/Texas,* was prepared by the Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, as part of the National Uranium Resource Evaluation (NURE) program.

Stream sediments were collected at 782 sites, and ground waters from 703 sites. Results of uranium analysis of water samples by fluorometric and mass-spectrometry-isotope-dilution methods are presented. Uranium in stream sediments was analyzed by fluorometry and neutron-activation-delayed-neutron counting. The uranium concentrations range from less than 0.20 to 172.00 ppb in water samples and from less than 0.25 to 7.17 ppm in sediments.

Analytical data and field measurements are presented in tables, diagrams, maps, and statistical plots. Also included are a geologic map and summary of the geology of the area.

The 135-page report, GJBX-27(79), plus seven oversize plates and microfiche of basic-data location, is on open file at several locations, including the Oklahoma Geological Survey. The report is available on microfiche from the DOE's Grand Junction Office for $5.00. Prepaid orders should be sent to Bendix Field Engineering Corp., Technical Library, P.O. Box 1569, Grand Junction, Colorado 81501. Checks should be made payable to Bendix.

A computer-readable magnetic tape containing measurements, analyses, and location data is available for $80.00 from Dalton Atkins, GJOIS Project, UCC-ND Computer Applications Department, 4500 North Building, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tennessee 37830.

State Receives Grant for Surface-Mining Reclamation

Oklahoma has recently received a federal grant of $468,249 under the Surface Mining Control and Reclamation Act of 1977. The grant will be used to cover additional costs incurred in administering and enforcing the second year of the act, which was passed to alleviate the harmful effects of coal-mining operations. (See related article in the *Notes*, v. 38, p. 241).

The program is administered by the U.S. Department of the Interior's Office of Surface Mining. The Oklahoma Department of Mines, headed by chief mine inspector Ward Padgett, will handle the grant.

The grant will be used to train and equip additional personnel to increase the scope and effectiveness of Oklahoma's regulatory program. The grant will also update the current system used to indicate which mines are complying with the interim regulations.

U.S. Board on Geographic Names Decisions

The U.S. Board on Geographic Names recently approved two Oklahoma place names, which were published in the October through December 1978 issue of *Decisions on Geographic Names in the United States* (Decision List 7804).

Holt Canyon (not North Canyon, Red Canyon) has been adopted to identify a canyon 11.3 km (7 miles) long that heads in Colorado at 37°03′23″ N., 102°47′36″ W., and trends southeast into Oklahoma to Picture Canyon, 20.9 km (13 miles) northeast of Kenton, Cimarron County, Oklahoma, and Baca County, Colorado; 36°59′06″ N., 102°45′12″ W.

Picture Canyon (not North Canyon) has been adopted to identify a canyon 26 km (16 miles) long that heads in Colorado at 37°03′23″ N., 102°47′38″ W., and trends south-southeast into Oklahoma to the Cimarron River valley, 20.9 km (13 miles) east-northeast of Kenton, Cimarron County, Oklahoma, and Baca County, Colorado; 36°56′22″ N., 102°43′55″ W.

THE ELUSIVE GEOLOGIC GUIDEBOOK NOW HAS AN UPDATED KEY

Geologic guidebooks contain a wealth of information about small geographic areas. Guidebooks typically contain road logs and usually describe the geology, geography, and natural history of their respective areas via photographs, charts, maps, and diagrams. Occasionally aspects of biology and anthropology are included.

Guidebooks are usually prepared for field trips held by geological groups, and often only enough copies are produced for the field trip participants. If additional copies are published, notices in lists of new publications or reviews are rare. Only by checking a society's publication list can the user determine that a field guide exists, in many cases. Therefore, most guidebooks are valuable but ephemeral pieces of geologic literature.

If you seek a guidebook from a library, you must know the sponsoring society or possibly, the compilers. Looking in a card catalog under a geographic area—for example, "Ouachita Mountains" or "guidebooks"—will yield little, if any, success.

To alleviate these hurdles in locating guidebooks, a committee of the Geoscience Information Society compiled the first edition of *Geologic Field Trip Guidebooks of North America, A Union List Incorporating Monographic Titles*, published in 1968. A second edition was issued in 1971.

In 1975, I was asked to serve on an eight-person committee to seek information from corporate, public, governmental, and academic libraries concerning the guidebooks they held. Based upon information supplied by 108 responding geoscience libraries, the 253-page *Union List of Geologic Field Trip Guidebooks of North America* was compiled. The American Geological Institute, in cooperation with the Geoscience Information Society, published this much expanded and updated third edition in 1978. The list is available from AGI, 5205 Leesburg Pike, Falls Church, Virginia 22041, for $20.00, prepaid.

The title and year of the field trip are listed under the sponsoring society's name. For example, The American Association of Petroleum Geologists sponsored a field trip, "Carbonate Rocks and Hydrogeology of Yucatán Peninsula," as its field trip no. 3 for the 1976 annual meeting. In addition to this listing, a "see reference" also exists under the New Orleans Geological Society and the Society of Economic Paleontologists and Mineralogists, which were cosponsors of the field trip.

If you want a list of guidebooks covering specific geographic areas, the geographic index may be the most valuable section of the union list. For example, listed under Oklahoma is "Ouachita Mountains," which contains 17 references for guidebooks describing that geologic province.

In the front of the volume is a directory of libraries contributing to the union list and the kinds of services they provide. Guidebooks contain an abundance of knowledge in various formats, and the union list provides a means for identifying and locating a particular guidebook, the group responsible for its existence, and a list of libraries in which it is available.

—Claren M. Kidd

USGS Releases New Open-File Reports

Four recent open-file reports of the U.S. Geological Survey that should be of interest to Oklahomans are:

Report 79–209, *Ground-Water Resources of the Palo Duro Creek Basin, Texas and Oklahoma*, by P. L. Rettman. This 64-page report contains 15 figures and 4 tables and is available from USGS, Water Resources Division, 649 Federal Building, 300 East Eighth Street, Austin, Texas 78701.

Report 79–219, *Statistical Summaries of Surface-Water-Quality Data for Selected Sites in Oklahoma, through 1975 Water Year*, by J. K. Kurklin. The 185-page report contains 1 figure and 5 tables and is available from USGS Water Resources Division, Room 621, 201 NW Third Street, Oklahoma City, Oklahoma 73102.

Report 79–243, *Late Diagenetic Indicators of Buried Oil and Gas: II, Direct Detection Experiment at Cement and Garza Oil Fields, Oklahoma and Texas, Using Enhanced Landsat I and II Images*, by T. J. Donovan, P. A. Termain, and M. E. Henry. The 49-page report contains 29 figures and is available from the Open-File Services Section (OFSS), Branch of Distribution, U.S. Geological Survey, Box 25425, Federal Center, Denver, Colorado 80225. The cost is $3.50 for microfiche and $22.50 for paper copy.

Report 79–256, *Flood of August 27–28, 1977, West Cache Creek and Blue Beaver Creek, Southwestern Oklahoma*, by R. K. Corley and T. L. Huntzinger, with 1 plate. The report is available from the Oklahoma City Water Resources Division office at the address given previously.

COBALT IN OKLAHOMA

The Oklahoma Geological Survey has received inquiries concerning cobalt in Oklahoma. Over a period of 5 years, I have collected information on mining areas and found almost no literature on cobalt. The 26 samples listed in the table yielded small amounts of cobalt (less than 20 ppm). David Foster, former OGS analytical chemist, conducted spectral analyses on 66 selected samples, with the following results:

Locality number	Section location		County	Mine	Formation	Cobalt (in ppm)
7	SE-SE-SE	14-5S-23E	McCurtain	Kit Carson	Womble	< 10
8	SW-NW-NW	10-7S-32W	Sevier, Ark.	Davis	Stanley	< 10
12	NE-NE-NW	30-4S-31W	Polk, Ark.	Brock	Stanley	< 20
13	NE-SE-NW	14-2S-26E	McCurtain	Buffalo Cr.	Stanley	< 20
16	C-W line	7-2S-27E	McCurtain	Brooks	Stanley	< 20
17	SE-SE-NW	33-1S-26E	McCurtain	Eades	Stanley	< 20
18	250 ft. S. of E quarter cor.	12-5S-23E	McCurtain	Ashcroft	Womble	< 20
22	Center	10-2S-26E	McCurtain	Harpending	Stanley	< 20
23	Center	10-2S-26E	McCurtain	Harpending	Stanley (deep)	< 20
24	NE-NW-SW-	10-2S-26E	McCurtain	Duncan	Stanley	< 20
26	C-SW-SW	16-5S-27E	McCurtain	Johnson	Stanley	< 20
28	SE-NE-SE	8-1S-1W	Murray	Hennepin	Honey Creek	< 20
33	SE-SW-NE	30-6N-1ECM	Cimarron	Wiggins #6	Sheep Pen	< 20
37	NE-SE-SE	3-31N-35E	Union, N.Mex.	San Miguel	Sheep Pen (ss.)	< 20
44	NE-SE-SE	3-31N-35E	Union, N.Mex.	San Miguel	Sheep Pen (ore)	< 20
47	NE-NE-NE	15-15N-10W	Blaine	outcrop	Cedar Springs	< 20
49	C-NE	35-25N-3W	Grant	outcrop	Garber	< 20
54	SE-SW	17-4S-11W	Cotton	outcrop	Wellington	< 20
55	C-NE	13-4S-12W	Cotton	outcrop	Wellington	< 20
58	NW-NW-NW and C-NW	28-22N-3E	Pawnee	outcrop	Doyle	< 20
61	NE-NE-SW	23-20N-3E	Payne	Hesser	Fort Riley	< 20
62	SE-SE-NW	24-22N-3E	Pawnee	Pawnee Min. & Milling Co.	Wreford	< 20
63	NW-NW-NW	24-22N-3E	Pawnee	Pawnee Min. & Milling Co.	Matfield	< 20
64	C-NW	19-22N-4E	Pawnee	Pawnee Min. & Milling Co.	Wreford	<, 20
65	NW-NW-SE	8-22N-4E	Pawnee	Lee D. Uto	Wreford	< 20
66	NE-SE-SW	34-6N-5E	Seminole	SE Konawa	Hart	< 20

—*Robert O. Fay*

LATE PLEISTOCENE MOLLUSCS SOUTHEASTERN TULSA COUNTY, OKLAHOMA

James E. Cunliffe[1]

Abstract—Recently a small fauna of molluscs was found in Pleistocene deposits exposed along Mingo Creek in southeastern Tulsa County, Oklahoma. This appears to be the first time Pleistocene fossils were found in the county. Based on the species of fossils and the fining-upward nature of the sediments, the environment of deposition was a point-bar–flood-plain system of a meandering stream. The flow of the stream was northward. The age of the sediments was not exactly determined but is estimated as late Pleistocene, based on the age and climatic preferences of the fauna and geomorphic relationships of the strata to other dated strata.

Pleistocene fossils occur in an outcrop (fig. 1) along the upper reaches of Mingo Creek, just southwest of the corner of Mingo Road and East 58th Street (SE¼ sec. 36, T. 19 N., R. 13 E., Tulsa County). The major part of the outcrop is a near-vertical exposure 8 to 9 feet high. At the top of the exposure is 2 to 3 feet of fill. This overlies 4 to 5 feet of yellowish-brown clayey silt and fine sand. At the base the silt grades abruptly into olive-gray, poorly sorted, shale-pebble gravel. The gravel in turn overlies the gray Nowata Shale (Pennsylvanian, Desmoinesian), into which the Mingo Creek has eroded 2 to 3 feet.

Fossils found at this locality consist of two species of fresh-water clams (*Sphaerium striatinum* and an unidentified unionid bivalve), two fresh-water snails (*Helisoma trivolvis* and *Physa anatina*), one terrestrial snail (similar to *Polygyra texasiana*), and one caudal vertebra from a small mammal. Most of these fossils were found in a layer about 1 foot thick that straddles the contact between the gravel and overlying silt. Some of the terrestrial snails were found a little higher in the section.

The fauna is dominated by *S. striatinum* and *H. trivolvis*; the two other gastropods are less abundant. Only one poorly preserved unionid clam was found, although it was articulated and in living position. The one slightly rounded mammal vertebra was found in the same layer as most of the invertebrates.

Deposition of the fossiliferous Mingo Creek terrace deposits occurred in the point-bar–flood-plain system of a small meandering stream as indicated by the fining-upward nature of the sediments and the largely fresh-water molluscan fauna preserved near the base of the terrace. The flow in this predecessor to Mingo Creek, as in the extant creek, was northward. This is suggested by flat pebbles of Nowata Shale in the basal gravel, which are imbricated and dip southward.

Attempts to trace the fossiliferous zone along Mingo Creek were only partially successful. About 500 feet downstream some additional fossils of the same species listed earlier were found, but only as float. Upstream about 100 feet the underlying Nowata Shale rises to 5 feet above stream level, and the Pleistocene fluvial sediments pinch out against it. A half mile farther upstream are barren exposures of poorly sorted Pleistocene colluvial gravels, which are about 8 feet thick.

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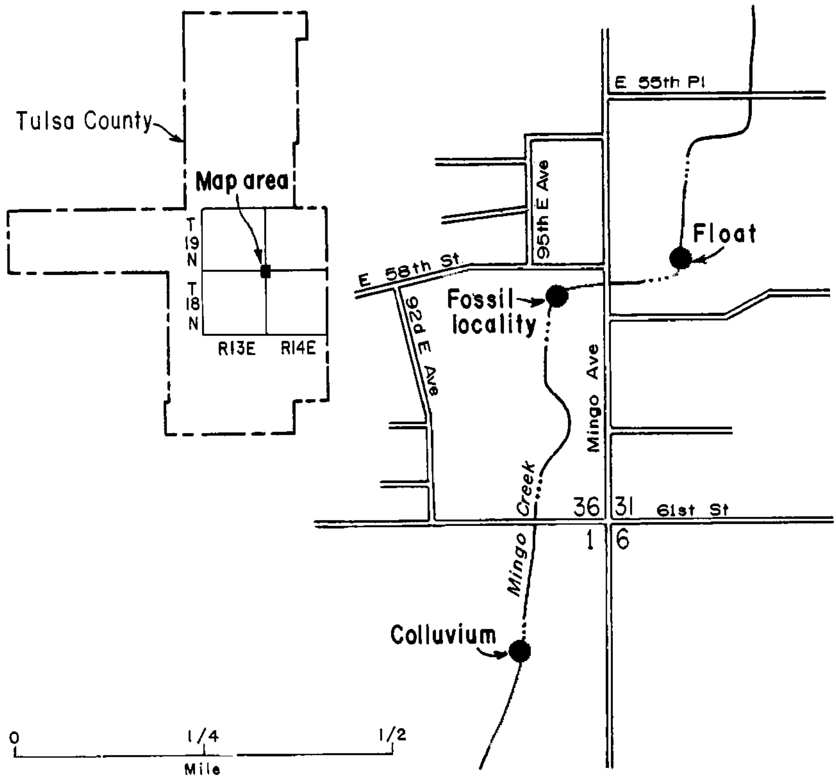

Figure 1. Index map showing location of fossiliferous fluvial sediments along Mingo Creek in southeastern Tulsa County, Oklahoma.

The age of the Mingo Creek terrace deposits can be estimated by considering the age and climatic preferences of the fauna and by geomorphic relationships of the strata to other dated strata. Unfortunately, none of these methods yields an unequivocal age.

A consideration of the age ranges of the species found could be the most accurate dating method, short of radiometric dating. The dominant members of the fauna, *S. striatinum* and *H. trivolvis*, range (respectively) from Pliocene to the present and from Nebraskan to the present. *Physa anatina* ranges from Pliocene to present, while *P. texasiana* ranges from Pleistocene(?) to the present (La Rocque, 1967, 1968; Branson and others, 1962). In short, ranges of these species are not sufficiently limited to allow an age assignment more restricted than Nebraskan through Holocene.

Some limitations on the age of the sediments could be established if it were possible to determine the temperature preferences of the molluscs. For instance, Branson and others (1962) described what they believed to be a late Pleistocene glacial (probably Illinoian) fauna from Caddo and Canadian Counties, west-central Oklahoma. They found 53 species of molluscs, including *S. striatinum*, *H. trivolvis*, and *P. anatina*. A glacial age was interpreted, because the fauna includes several species now living in cooler, more northern climates. Their data, however, also indicate that the three species found at both the Mingo Creek and west-central Oklahoma sites are still living in Oklahoma today. Since the present is an interglacial or postglacial age, the climatic affinities of the Mingo Creek fauna cannot be determined. These molluscs were apparently eurythermal. This is confirmed by the present wide geographic distributions cited by Taylor (1960) and La Rocque (1967, 1968), especially for *S. striatinum* and *H. trivolvis*.

Additional clues to the age of these deposits can be found in the work of Stone and others (1972). While studying the Quaternary geology of Tulsa County, they recognized three terraces adjacent to the Arkansas River. From highest to lowest, these are the Sand Springs, Yale Avenue, and Newblock Park Terraces. Although it has not been proved by rigorous age dating, it would seem reasonable to expect that each of these three terraces, plus the present flood-plain deposits, was formed from aggradational fluvial processes accompanying melting of each major Pleistocene glacier. Early in each interglacial age, and in the Holocene, meltwaters from mountain glaciers in the Rockies would have been heavily charged with sediment, causing aggradation downstream. High interglacial base levels would have augmented the tendency for sediments to accumulate at these times. If this were the method by which terrace sediments were deposited, then the Sand Springs Terrace would be Aftonian, the Yale Avenue Terrace would be Yarmouth, and the Newblock Park Terrace would be Sangamon. Fluvial incision through the interglacial valley fill may have occurred in association with the lowered sea levels of the glacial ages.

Stone and others (1972) determined elevations of Arkansas River terraces and flood plains in Tulsa County. Projection of the approximately 700-foot elevation of the Mingo Creek fossiliferous sediments onto their graph of these elevations falls midway between elevations for the Yale Avenue and Newblock Park Terraces. Since the flood plain of a subsidiary stream cannot be lower than the stream into which it flows, and assuming that Mingo Creek was then, as now, a subsidiary of the Arkansas (by way of Bird Creek and the Verdigris River), it seems likely that the fossiliferous strata along Mingo Creek were deposited during deposition of the Newblock Park Terrace. As suggested earlier, the age of the Newblock Park Terrace may be Sangamon.

Recently a diverse fauna of molluscs was described from fluvial-terrace sediments incised by the Fall River in southeastern Kansas (Miller, 1978). The fauna contained 39 molluscs, including all the identified species found in the Mingo Creek terrace. Radiocarbon dating of a unionid clam from the Fall Creek fauna yielded an age of about 31,000 years (Wisconsinan). This throws some doubt on the advisability of assigning terrace deposition to interglacial periods, as suggested above. In light of the Fall Creek age date, it would probably be prudent to describe the Mingo Creek fauna simply as late Pleistocene in age until further evidence is uncovered.

Acknowledgments

I would like to thank Aurele La Rocque of The Ohio State University, Eugene Gaffney of the American Museum of Natural History, and Artie Metcalf of The University of Texas at El Paso for their assistance in identifying fossils from the Mingo Creek site.

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New OGS Guidebook Describes Carboniferous Rocks of Ozark and Ouachita Regions

A new guidebook published by the Oklahoma Geological Survey was used by participants in a post-meeting field trip of the Ninth International Congress of Carboniferous Stratigraphy and Geology (IX–ICC), which convened last month for technical sessions in Urbana, Illinois. The book, issued as Guidebook 19 is entitled *Mississippian-Pennsylvanian Shelf-to-Basin Transition, Ozark and Ouachita Regions, Oklahoma and Arkansas.* The guide was prepared for field trip 11, which was held May 27–June 1 under the leadership of Patrick K. Sutherland and Walter L. Manger.

Sutherland, professor in the School of Geology and Geophysics at The University of Oklahoma, and Manger, associate professor of geology at The University of Arkansas, Fayetteville, also served as editors for the 81-page illustrated volume, which documents in detail the changes in depositional environments of the Carboniferous-age (Mississippian-Pennsylvanian) strata in the Ozark Shelf and Ouachita Basin regions. The guidebook includes numerous stratigraphic sections and correlation charts accompanied by photos depicting outcrops and thin sections of the rocks traversed on the trip and discussed in the text.

Sutherland and Manger are the authors of an introductory article in the guidebook, in which they compare lithologies and depositional patterns in the two areas. They have also prepared stop descriptions for three days of the five-day excursion. Other stops have been described by Charles G. Stone and John D.

McFarland III of the Arkansas Geological Commission, Boyd R. Haley of the U.S. Geological Survey, and Robert C. Grayson, Jr., a recent Ph.D. graduate of OU who now is a member of the faculty at Baylor University in Waco, Texas.

A general purpose of the Carboniferous Congress was discussion and comparison of all aspects of the geology of Mississippian-Pennsylvanian rocks and their equivalents throughout the world. An auxiliary purpose was examination of such strata in their classic exposures. Oklahoma and Arkansas are uniquely equipped for such field investigations in having the shared structures of the Ouachita and Ozark Mountains, both having extensive outcrops of rocks of this age. Guidebook 19 should prove a great aid in these studies.

The guide, with its striking cover photograph reproduced in bright turquoise showing the bottom surface of a turbidite sandstone (sole markings), is a companion to OGS Guidebook 18, also edited by Sutherland and Manger, which describes other Carboniferous rocks of the Ozark Shelf.

Guidebook 19 can be obtained by writing to the address on the front cover. The price is $4.00.

Professional Day Held at OU

The second annual Professional Day was held Friday, April 13, in the School of Geology and Geophysics at The University of Oklahoma. Included in this year's events were two workshops, one on geochemistry and one on geophysics, and a field trip to the Arbuckle Mountains.

The keynote speaker was M. Dane Picard, sedimentary petrologist from the University of Utah, whose topic was depositional environments and petroleum potential of the Nugget Sandstone in southwestern Wyoming and northeastern Utah. Ten students presented papers on a variety of research projects. From these 10, the best paper, runner-up best paper, and outstanding presentation were chosen. The best paper award went to Elisabeth Goodwin, who spoke on fracture densities in the Rattlesnake Mountain drape fold, northwestern Wyoming. The runner-up was Darryl Carter for his study on the Washita Valley Fault in the Arbuckle Mountains. Joe Curiale had the outstanding presentation for his explanation on the applications of a new method for simultaneous determinations of source-rock potential and maturity.

Following the talks, an awards banquet was held at the Oklahoma Memorial Union. P. W. J. Wood, Cities Service Co., as guest speaker outlined the future of international exploration. Others given awards at the banquet were: Becky Pope, W. A. Tarr Award, presented to a graduating senior; Paul Bauernfeind, E. L. McCullough Award, presented to a graduate student; Karen Bellis, Sigma Gamma Epsilon Scholarship Award; Burr Silver and K. Frank Wantland, Faculty Honor Roll; and Claren Kidd, Special Recognition Award.

The students in charge, members of the Geoscience Club and Sigma Gamma Epsilon, are to be commended for an outstanding job in making Professional Day a success.

IT'S AIPG ONCE AGAIN, MEMBERS TOLD AT OKLAHOMA SECTION MEETING

At their annual business meeting held April 27 at the Mayo Hotel in Tulsa, members of the Oklahoma Section of the Association of Professional Geological Scientists (APGS) were informed by national secretary-treasurer John S. Fryberger that a recent vote of the membership had resulted in an overwhelming mandate (89 percent) to change the name of the organization back to American Institute of Professional Geologists (AIPG). The meeting was presided over by Wilgus B. Creath, president of the Oklahoma Section.

The professional group was originally founded in 1963 as AIPG, but the name was changed to APGS at the beginning of 1976 in response to the membership's desire to create a single unified body which would be affiliated with the American Geological Institute and which would serve the professional (as distinct from the scientific) interests of a broader group of geological scientists.

Other matters considered at the business meeting included a report on the Oklahoma Section's contribution to new regulations on waste disposal with respect to maintaining professional standards in geologic work; a recommendation from the national executive committee that the state sections take a more active role in legal affairs, especially as they might affect the professional practice of geology; a report from president Creath that the Great Plains Water Conference, co-sponsored by the Oklahoma Section in April, was a solid success though sparsely attended; and a recommendation that the section needs to be represented at hearings conducted by the Oklahoma Securities Commission to consider new regulations that might adversely affect the routine activities of geologists.

Also at the meeting, Gary A. McDaniel, the section's first vice-president, reported that he had been collaborating with representatives of petroleum-oriented groups in Oklahoma to look into the feasibility of uniting in a statewide coalition of petroleum associations to monitor and address matters of mutual interest in the State legislative and regulatory area. He said that he would continue to keep Oklahoma AIPG members informed through the section's executive committee.

Suzanne Takken announced that Oklahoma Section member John H. Gatchell had been appointed to the Oklahoma City Planning Commission by Mayor Patience Latting.

An all-day seminar held April 28 was successful by all counts. Entitled "The Independent Practice of Geology," the seminar was sponsored by the Oklahoma Section and attracted 186 registrants from five states. It was oriented toward practicing geologists who were considering going into business for themselves or who had recently done so.

The morning's session was kicked off by Bradford S. Baker, an attorney with Farmer & Woolsey, Tulsa, who explained various types of partnerships, corporations, and other business associations to be considered in starting a new business or in reorganizing an old one.

Harold Crago, Williams Bros. Engineering Co., Tulsa, told the group how to calculate overhead and set fees to establish a sound financial basis for operating a business.

Murray McComas, a Tulsa AIPG member, detailed the various factors to consider in bidding on a geologic project.

William V. Knight, also an AIPG member from Tulsa, recommended that geologists as a group become more aware of the need for entering into contracts and obtaining sound legal counsel when appropriate.

The luncheon speaker was Jim Deutsch, representing the Great Plains Legal Foundation, whose headquarters are in Kansas City. Oklahoma is one of the states served by the foundation, and the Oklahoma Section was invited to join in cooperative efforts to promote better legislation and better ethics in public affairs.

In beginning the afternoon session, Wilgus B. Creath discussed the various considerations to be weighed in deciding whether to add new employees, how to select the right employee for the job, and how to integrate a new employee into the existing staff.

H. F. Keplinger of Houston spoke on the topic of petroleum reserves from his standpoint as an advisor to the Securities and Exchange Commission. He explained a new accounting method based on the valuation of proved reserves called reserves recognition accounting (RRA). He outlined how RRA differs from previously used methods and warned of the possibility of professional liability in certain circumstances.

L. H. Veltman, Consolidated Insurance Agency, Tulsa, wound up the session with a discussion of various financial plans the consultant can consider for providing future financial security.

Kenneth S. Johnson, associate director of the Oklahoma Geological Survey, spoke in a concurrent morning session oriented toward students. His topic was "Career Opportunities in Geology."

—William D. Rose

Crustal-Evolution Guides Released by NAGT

An innovative series of teaching aids developed by the National Association of Geology Teachers (NAGT) for use in earth-science education in grades 8–10 has been issued by Ward's Natural Science Establishment. The series contains 32 units that were designed for classroom use by both teachers and students.

These study guides, known as CEEP modules (for the NAGT Crustal Evolution Education Project), are the result of a long-term program initiated in September 1974 at a conference of selected teachers, researchers, and curriculum specialists held at Western Hills State Lodge, Wagoner, Oklahoma. The stated goal has been to incorporate into pre-college science curricula the changing concepts in geology and geophysics. Original funding was a grant of $22,100 from the National Science Foundation, and Edward C. Stoever, Jr., was named director. NSF has supported the program from its inception to its completion.

Stoever, former professor in the School of Geology and Geophysics at The University of Oklahoma, is now chairman of the Department of Earth Sciences at Southeast Missouri State University at Cape Girardeau. He has been a motivating force and coordinator of the program at all stages. A later NSF grant of $206,200 in 1976, when actual development work began, also named him as project director, as did a later grant of $321,400.

The CEEP modules were prepared by teams operating in six writing centers across the United States, and more than 200 NAGT members were actively involved. As designed, the grades are divided into three recommended groups: (1) introduction to the basic elements of plate-tectonic theory, (2) study of the earth's crustal history, and (3) plate tectonics and earth history. Assignments allow students to perform first-hand investigations through preparation and manipulation of models, including measurements, calculations, interpretations, and deductions. Results obtained should provide both student and teacher with a fairly clear concept of dynamic earth processes.

The modules are offered in class packs containing a teacher's guide and 30 student investigation booklets for $16.00. Additional copies or single copies are available at varying prices, depending upon the quantity ordered. For information, contact Ward's Natural Science Establishment, Inc., P.O. Box 1712, Rochester, New York 14603; or P.O. Box 1749, Monterey, California 93940.

AAPG Publishes Color Guide to Sandstones

A Color Illustrated Guide to Constituents, Textures, Cements, and Porosities of Sandstones and Associated Rocks, by Peter A. Scholle, was recently published by The American Association of Petroleum Geologists (Memoir 28, catalog no. 637). The book is used for basic identification and classification of sandstone in thin section. Topics covered include detrital grains, clays and shales, sandstone classification, textures, cements, replacement, and porosity.

The 201-page book includes 360 full-color photos and 56 SEM photos and is a companion volume to AAPG Memoir 27 (catalog no. 623), *Color Guide to Carbonates*, by the same author.

Memoirs 27 and 28 sell for $19.50 each and can be ordered from AAPG, P.O. Box 979, Tulsa, Oklahoma 74101.

New OGS Publication List Available

The Oklahoma Geological Survey has recently updated its *List of Available Publications* to May 15, 1979. The previous list was issued January 1, 1978. Anyone who would like to have the new list can write the Survey at the address shown on the front cover or call 405—325-3031.

OKLAHOMA ABSTRACTS

AAPG-SEPM Annual Meetings
Houston, Texas, April 1–4, 1979

The following abstracts are reprinted from the March 1979 issue, v. 63, no. 3, of the *Bulletin* of The American Association of Petroleum Geologists. Page numbers are given in brackets below each abstract. Permission of the authors and of Ira Lutsey, AAPG publications manager, to reproduce the abstracts is gratefully acknowledged.

Late Ordovician–Early Silurian Strata in Mid-Continent Area

THOMAS W. AMSDEN, Oklahoma Geological Survey, Norman, Oklahoma 73019

Late Ordovician–Early Silurian strata extend from the Texas Panhandle across Oklahoma and Arkansas into eastern Missouri and Illinois. The sequence consists of upper and lower sections of organic-detrital limestone separated by calcareous shales (Sylvan, Cason, Maquoketa Shales); the limestones directly above the shales are commonly oolitic (Keel, Noix Formations). The carbonate rocks have a rich megafauna and microfauna, and the shales yield graptolites and chitinozoans. The Ordovician-Silurian boundary, as here defined, usually falls above the oolite, but locally it occurs in the shale. The faunal and stratigraphic relations suggest continuous deposition through the oolitic beds, although there is substantial lateral gradation between shale and limestone. At most places, Late Ordovician (late Ashgillian) strata are overlain by Late Silurian (late Llandoverian) strata; earliest Silurian beds are poorly represented or absent. Physical evidence for an unconformity at this horizon is common, pointing to interruption in deposition accompanied, at least locally, by erosion. Late Ordovician glaciation reported from Africa and South America was possibly of sufficient magnitude to have caused an appreciable lowering of sea level; this could explain the absence of earliest Silurian strata. The Late Ordovician shales are almost devoid of benthic fossils, a condition that might have been caused by various factors including colder water; however, these shales are closely associated with organic-detrital limestones and oolites which bear a large, sessile and vagrant benthos, suggesting temperate to tropical waters. [410]

Role of Temperature and Burial Depth in Development of Subnormal and Abnormal Pressures in Gas Reservoirs

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The aquathermal-pressuring concept shows that isolated, water-filled reser-

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

voirs become abnormally pressured when temperature rises owing to increasing depth of burial. When reservoirs contain free gas, the situation is more complex and abnormal or subnormal pressures may develop depending on the gas/water ratio and the initial and final depth of burial. Because zones that have non-hydrostatic pressures must be effectively isolated from their surroundings (or the pressure should be equalized), a model would be a sand lens encased in shale. Consider, for example, where isolation occurs at 4,000 ft (1,200 m) where temperature is 123°F (51°C), and subsequent burial moves it to 8,000 ft (2,400 m) at 178°F (81°C). The pressure in the gas will start at 1,860 psi (12,815 kPa) hydrostatic at 4,000 ft (1,200 m), but the temperature rise will increase it to 2,035 psi (14,021 kPa), at 8,000 ft (2,400 m). However, the hydrostatic pressure at 8,000 ft (2,400 m) is 3,720 psi (25,630 kPa), so the gas reservoir will be 1,685 psi (11,610 kPa) underpressured. Real gas reservoirs contain both gas and water. Calculations show that for trapping at 4,000 ft (1,200 m) followed by burial to 8,000 ft (2,400 m) the reservoir will show various amounts of underpressuring if it contains more than 3 vol.% gas. With less than 3 vol.% gas it will overpressure. At greater trapping depths, high percentages of gas are needed to produce underpressuring, for example, 16 vol.% at 12,000 ft (3,600 m). Temperature decrease owing to uplift and removal of overburden produces the opposite effects, and reservoirs containing high percentages of gas develop abnormally high pressures.

This theoretical model provides an explanation for the common occurrence of underpressured gas, particularly in stratigraphic traps with low water contents. It also explains the underpressured gas in the bottom of basins (such as San Juan, Wattenberg, and western Canada "Deep Basin") and shows how abnormal and subnormal pressures can be developed in adjacent gas reservoirs in a restricted geographic area (such as the Appalachians). Regional tilting may bury a formation in one area but uplift it in another leading to regional trends from subnormal to abnormal pressures. An example of this is provided by the "gas sands" of the Morrow in western Oklahoma. [414]

Potential for Subsurface Disposal of Industrial Wastes in Oklahoma

KENNETH S. JOHNSON and JOHN F. ROBERTS, Oklahoma Geological Survey, Norman, Oklahoma 73019

The main goal in selection of a subsurface disposal site is that the waste be emplaced in such a manner that it is isolated from freshwater supplies and the biosphere during its hazardous life. This can be accomplished only through detailed investigation of the lithology, porosity, permeability, thickness, lateral extent, depth, fluid content, and compatibility of a potential reservoir. Additional data for the area around a potential disposal site are also needed concerning the structure, geologic framework, confining rocks, hydrology, mineral resources, and the presence of boreholes or other excavations.

Rock types that are most desirable for subsurface waste disposal in Oklahoma are porous and permeable sedimentary rocks, such as sandstone, limestone, and dolomite, although fractured shale or mined caverns in shale and salt may also be suitable. Thick sequences of sedimentary rock make up most geologic provinces in the state, and it appears that most areas are underlain by reservoir rocks that locally can safely contain industrial wastes.

Major sandstone reservoirs that are locally capable of accepting liquid wastes include the Simpson Group, Springer Formation, Pennsylvanian sandstones, granite wash, and Permian sandstones; major carbonate reservoirs include the Arbuckle Group, Hunton Group, Mississippian limestones, Brown dolomite, and Permian dolomites. Where used for waste disposal, these reservoirs typically have porosities ranging from 5 to 20% and permeabilities ranging from 20 to 2,000 md.

At present, 17 wells are being used in Oklahoma to inject acids, caustics, solvents, process waters, salt water, paints, urea, detergents, metal-bearing solutions, and cement slurries into reservoirs 385 to 7,350 ft (116 to 2,205 m) below the surface. Most facilities inject at average rates of 40,000 to 400,000 gal/day and with injection pressures that range from 380 to 450 psi (2,618 to 3,100 kPa). [475]

Simple Pyrolysis Technique Using Well Cuttings to Map Source Rocks, Gas-Condensate Maturity, and Abnormal Fluid Pressures Associated with Fracture Reservoirs: Example from Anadarko Basin

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P. Trask showed that when small samples of kerogen-rich rock are pyrolyzed in a test tube, oil-like material may be generated and condensed as a brown residue around the walls of the tube. This technique is adaptable to the use of well cuttings and may be utilized to identify source rocks capable of generating oil. For any given source rock, the amount of pyrolysis yield decreases with increased thermal maturity as verified by vitrinite reflectance analysis. Samples from stages of maturity corresponding to the gas-condensate and dry-gas generation "windows" yield no pyrolysis residue because of their inability to generate dark oily liquids.

We have used the test-tube-pyrolysis technique to map quickly and accurately (1) source rocks capable of generating oil, and (2) the maturity threshold of gas-condensate generation in part of the Pennsylvanian section of the Anadarko Basin.

The area of gas-condensate generation within the Atoka Formation, as mapped by the pyrolysis technique, is coincident with the presence of (1) abnormally high formation-fluid pressures, (2) fracture-type reservoirs, and (3) water-free gas-condensate production. Abnormal pressures are believed to be caused by high generation rates, volume expansion during conversion of kerogen to a gas phase, and rock-framework collapse. Indigenous fracturing is caused by a favorable stress condition accompanied by critically high formation-fluid pressure. Water-free hydrocarbon production is the result of the nearly complete saturation of available reservoir space by relatively large volumes of generated and only partially expelled gas-condensate.

We believe that the simple pyrolysis technique and its interpretations are applicable to many basins. The method requires only a library of sample cuttings, a supply of test tubes, and a propane torch (or similar heat source) for implementation. [480]

Exploration Research Along Ardmore-Anadarko Basin Trend

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Consideration of southern Oklahoma geologic history in the context of plate-tectonic analogies to present continental margins suggests several avenues of investigation that help explain some oil and gas accumulations and could lead to more discoveries. Postulated origin as the abandoned arm (aulacogen) of a rift triple junction in the late Precambrian and early Paleozoic suggests the potential for fault-controlled sedimentation and early generation of oil and gas by magmatic heating. Collision-related late Paleozoic deformation suggests displacement of early Paleozoic reservoirs by wrench faulting the formation of traps by wrench-controlled thrust faulting. The search for fracture reservoirs involves facies relationships to the precollision continental margin, fracturing during collision, and prediction of open fractures based on stress orientation related to formation of the Gulf of Mexico. Position of the early Paleozoic continental margin with its unrealized potential for oil and gas accumulation remains an enigma concealed by late Paleozoic emplacement of the Ouachita thrust complex unknown distances over the edge of the early Paleozoic continental edge and subsequent burial by Mesozoic sediment during formation of the Gulf of Mexico. [540]

Hydrocarbon Occurrence as Function of Thermal Alteration of Organic Material

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Fourteen wells from the Lenora gas field, Dewey County, Oklahoma, have been studied by vitrinite reflectance microscopy to determine maximum paleotemperature and temperature gradients.

Various types of petroleum hydrocarbons (oil, distillate, and gas) are formed at varying temperatures which have been empirically related to the degree of vitrinite reflectance (R_0). R_0 values at the depth of petroleum accumulation are consistent with the types of hydrocarbons encountered. Geochemical data obtained from well cuttings indicate that the petroleum originated in surrounding shales. Therefore, the R_0 values obtained reflect accurately the maximum temperature to which the petroleum and its precursors were subjected.

Reflectance gradients calculated for each well by taking R_0 measurements at several depths in each borehole reveal a gradient anomaly directly over the reservoir when compared to the gradients existing beside the reservoir. The reservoir itself is a small sand lens, possibly of barrier-island or bar origin. It is possible, then, that determination of paleotemperature gradients by vitrinite microscopy and the identification of gradient anomalies in a basin may be useful in the search for new reservoirs. [544]

GSA Annual Meeting, North-Central Section
Duluth, Minnesota, May 10–11, 1979

The following abstract is reprinted from the *Abstracts with Programs* of The Geological Society of America, v. 11, no. 5. The page number is given in brackets below the abstract. Permission of the author and of Mrs. Jo Fogelberg, managing editor of GSA, to reproduce the abstract is gratefully acknowledged.

Geographic Variations in the Upper Ordovician Brachiopod Lepidocyclus capax **(Conrad)**

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Collections of the key Upper Ordovician species, *Lepidocyclus capax* (Conrad) were examined from widely distributed localities, including the Ohio Valley, Iowa, Oklahoma, Tennessee, and west Texas. Members from Richmondian strata in Ohio were used as the basis of comparison with specimens from other localities. The Ohio Valley form is intermediate in size and in surface costation. By comparison, specimens from the Fernvale Formation in Tennessee are smaller and distinctly more costate; those from the Viola Formation in Oklahoma are larger and distinctly less costate; those from the Maquoketa Formation in Iowa are larger and slightly more costate; and those from the Aleman Formation in west Texas are similar in size and slightly less costate. Tests at the 95 percent confidence level suggest that the differences in the number of costae between the Ohio Valley specimens and those from the Maquoketa Formation in Iowa and those from the Aleman Formation in Texas may be insignificant.

Ecologic factors, geographic separation, and possibly age differences produced differences in numbers of surface costae and specimen size but these factors did not significantly alter other morphologic attributes noted in the various samples. In summary, specimens from Oklahoma and Tennessee diverge the farthest from the norm represented by the Ohio Valley specimens. [232]

Symposium on Exploration for Petroleum and Natural Gas to Be Held

"Symposium II on Unconventional Methods in Exploration for Petroleum and Natural Gas" is planned for September 13–14 at the Dallas Hilton Inn. Under the auspices of Southern Methodist University, the second such symposium brings together scientists to share exploration methods.

The symposium is expected to attract 500 attendants and will include topics such as "Uses of Temperature Data in Petroleum Exploration," "Exploration Radiometrics: Post Survey Drilling Results," and "Electromagnetic Sounding in the Near Zone."

Information about registration is available from the Institute for the Study of Earth and Man, Southern Methodist University, Dallas, Texas 75275 (phone, 214—692-3488).

New Theses Added to OU Geology Library

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

A Structural Interpretation of the Cove Fault and Petrofabric Study of the Tuscarora Sandstone, Fulton County, Pennsylvania, by Linda D. Main.

Subsurface Geology of the Madill-Cumberland-Aylesworth Area, Marshall County, Oklahoma, by Michael Louis Merritt.

Tectonics of the Oklahoma City Uplift, Central Oklahoma, by Leonid R. Koff.

The Depositional Environment of the Pennsylvanian Upper Marchand Sandstones, Northeast and East Binger Fields, Oklahoma, by Randall Keith Baker.

The Geology of the Hartshorne Coals in the Spiro and Hackett Quadrangles, Le Flore County, Oklahoma, by Victor F. Agbe-Davies.

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