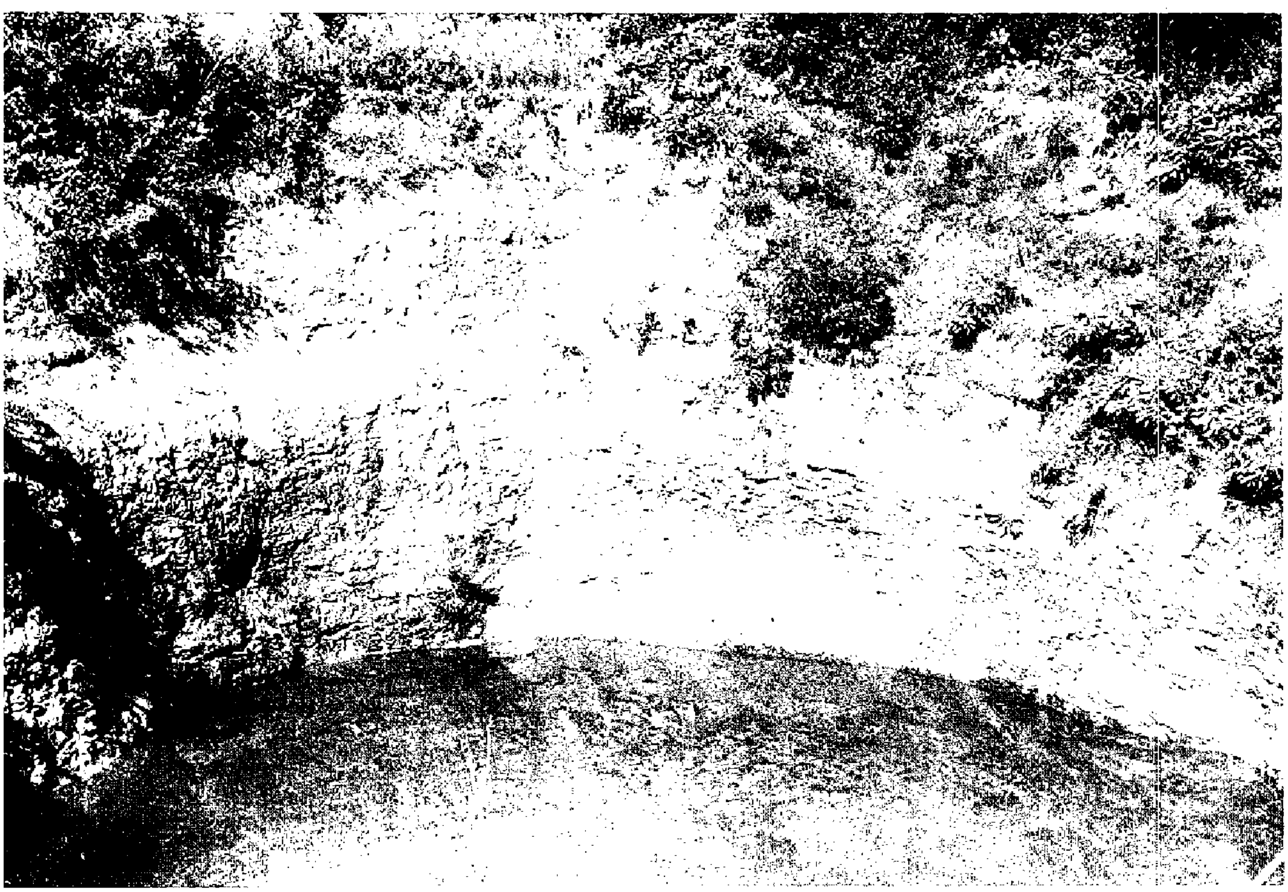
Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY / VOL. 43, NO. 2 - APRIL 1983



On the cover –

Shaft Collapse, West of Picher, Oklahoma

Numerous cave-ins are associated with the abandoned underground lead-zinc mines in northeastern Oklahoma. On the cover is a view of a 180- × 100-ft elliptical collapse at the Gordon No. 2 mine (T29N-R23E, sec. 18) that occurred between 1964 and 1972. The water level is approximately 40 ft from the surface.

Approximately 2,500 acres are underlain by underground lead-zinc mines near Picher, Oklahoma. About 50 surface-acres have been disturbed by mine-related cave-ins. Mine-workings maps and field surveys indicate that more than 1,000 shafts once existed in the Oklahoma portion of the Picher Field. There are 481 shafts either open or in some stage of collapse.

Surface collapse in the Oklahoma portion of the Picher Field is related to shaft deterioration, mining of multiple ore zones, large stopes, and (or) weak roof-rock (thin Chesterian strata). Most of the cave-ins are related to shaft failure. Generally, a 40- to 60-ft-thick sequence of interbedded shale and sandstone (Krebs Group) occurs near the surface. The material is highly susceptible to erosion and often caves in toward the shaft. Many of the cave-ins are between 20 and 60 ft in diameter. Some cave-ins extend into the underground workings, involving spectacular-looking surface collapses like the one shown on the cover.

Kenneth V. Luza

For a related article on a recently completed report of subsidence problems in the Picher Field area, see page 36 of this issue.–ed.

Oklahoma Geology Notes

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

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

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This publication, printed by the Transcript Press, Norman, Oklahoma, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes, 1981, Section 3310, and Title 74, Oklahoma Statutes, 1981, Sections 231—238. 1,800 copies have been prepared for distribution at a cost to the taxpayers of the State of Oklahoma of $2,227.

OKLAHOMA EARTHQUAKES, 1982

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

Introduction

The earliest documented earthquake in Oklahoma occurred near Jefferson, Grant County, on December 2, 1897 (Stover and others, 1981). The next oldest Oklahoma earthquake happened 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 1981, 384 earthquakes have been located in Oklahoma (Lawson and others, 1979; Lawson and Luza, 1980, 1981, 1982).

Fifty-seven earthquakes were located in Oklahoma in 1982. Only the largest of these, with a magnitude of 3.1 (mbLg), was known to be felt. This earthquake, Modified Mercalli Intensity VI (table 1), caused the slab of a house in Durant, Oklahoma, to move sufficiently to crush water supply pipes beneath.

Instrumentation

A statewide network of 11 seismograph stations is 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 14 paper-drum recorders and one digital recorder. Accurate timing is assured by a microprocessor clock that is continually locked to the National Bureau of Standards cesium-beam clocks by low-frequency radio transmissions broadcast by WWVB (Lawson, 1980). Seven semipermanent volunteer-operated seismograph stations, three radio-telemetry seismograph stations, and one volunteer-operated

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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. Buildings 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.

triggered-digital seismograph complete the Oklahoma Geological Survey's seismic network. The operation and maintenance of 11 of the remote stations is being supported by the U.S. Nuclear Regulatory Commission (Luza, 1978).

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 radio-telemetry unit. The telemetry unit amplifies the seismometer output and uses this output to frequency-modulate an audiotone. A 500-milliwatt, crystal-controlled transmitter limits the line-of-sight transmission to 80 km. Seismograms from the radio-telemetry stations are recorded at the Oklahoma Geophysical Observatory.

In May 1982, a new station, OCO, was opened at the Omniplex museum in Oklahoma City. Omniplex staff are responsible for seismogram changing

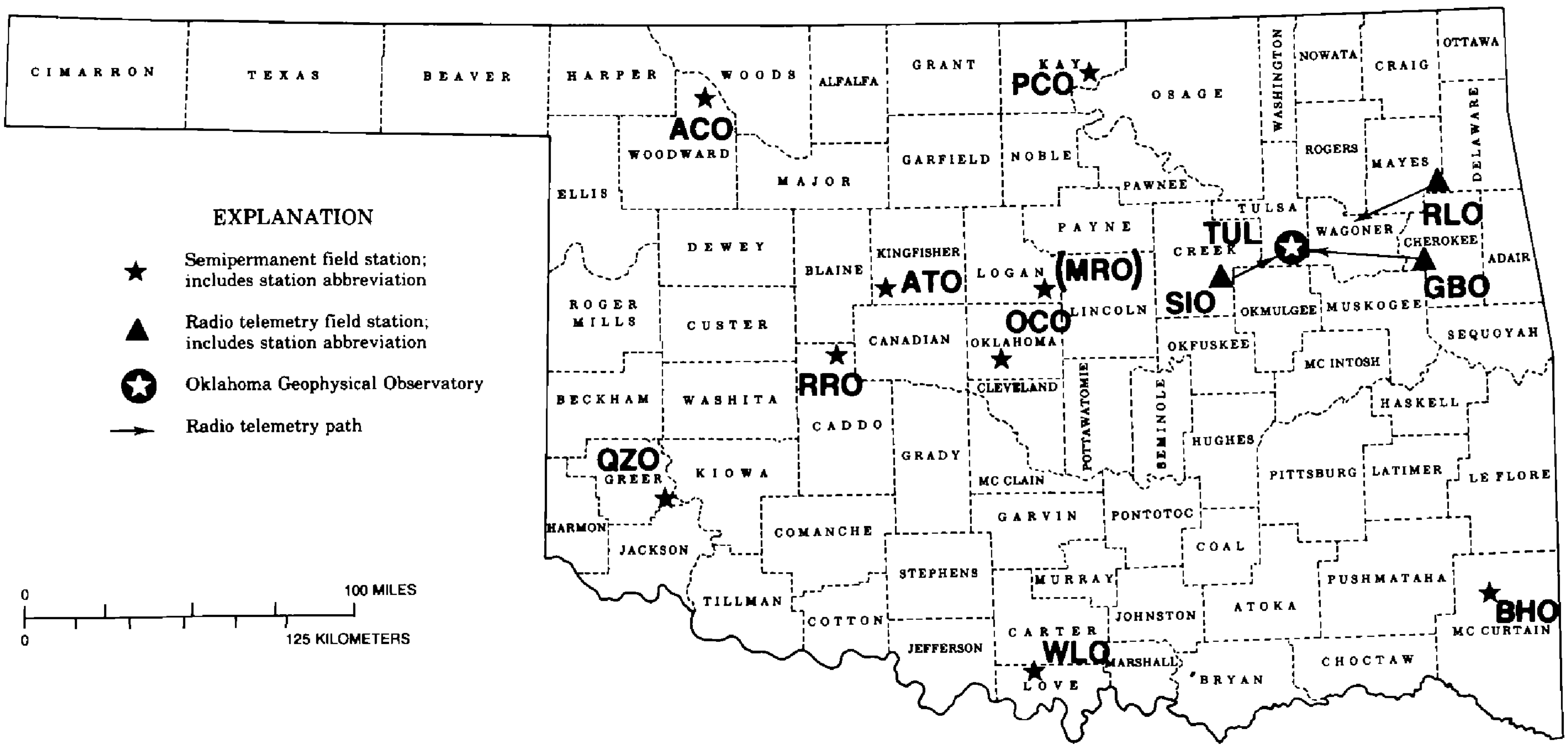

Figure 1. Active seismograph stations in Oklahoma.

and most maintenance. Oklahoma Geophysical Observatory staff help supervise the operation of OCO, interpret the data, and archive the seismograms with all other Oklahoma network seismograms.

In November the Meridian station (MRO) was moved to a location near Altona (ATO), in Kingfisher County. The temporary five-station microearthquake array near El Reno, Canadian County, was closed, but the best station of the array, Shell Creek (SCE1), was made semipermanent (Lawson and Luza, 1982).

At SCE1, a DR-100 unit is located in an outbuilding, where it is well grounded and connected to AC power. A WWVB antenna, which is attached to a 2-m galvanized pipe driven into the ground near the outbuilding, is connected via cable to the recorder. The cable is connected to a 4.5-Hz vertical geophone that is buried 0.3 m deep. Volunteers change the tapes weekly, and the tapes are mailed to the Observatory for processing.

Data Reduction and Archiving

Arrival times from all visible teleseisms (phases from distant earthquakes) at TUL, RLO, BHO, GBO, and OCO are sent to the U.S. National Earthquake Information Service and the International Seismological Centre in England. P-wave and surface wave amplitudes from TUL, plus selected arrival times from SIO, ACO, QZO, and other stations, are also included. These reduced seismic data are sent to more specialized agencies such as the USAF Tactical Air Command, which monitors worldwide underground nuclear tests.

From station TUL, at the OGO near Leonard, five short-period vertical seismograms (with differing frequency responses) are searched exhaustively for local and regional earthquake phases. Also searched are two TUL short-period horizontal seismograms; two short-period vertical seismograms from each of RLO, SIO, and OCO; and one short-period vertical seismogram from each of the nine other stations.

Fourteen to 16 daily TUL seismograms, as well as 15 daily seismograms from the remote stations, are permanently archived at the OGO. Fourteen of the daily TUL seismograms are lent to the U.S. National Geophysical Data Center (NGDC) for microfilming. One complete set of microfilms is kept at the NGDC, which supplies on request additional copies for the world seismological community. In addition to the originals, the OGO archives also contain one complete set of microfilms of the TUL seismograms.

In November, some thirty thousand seismograms recorded by the University of Arkansas (station FAY 1951–1969, FAV 1969–1979) were placed in the OGO archives. Outside of seismograms recorded in Oklahoma, these are the most important seismograms for the study of earthquakes in Oklahoma and adjacent areas.

Earthquake Distribution

All Oklahoma earthquakes recorded on seismograms from three or more stations are located. In 1982, 57 Oklahoma earthquakes were located (fig. 2, table 2). Only one earthquake, at Durant, Oklahoma, was reported felt in 1982. This earthquake damaged water pipes at one house and had a Modified Mercalli (MM) intensity of VI. The felt area for the Durant earthquake (event no. 406) was probably restricted to a few tens of square kilometers away from the epicentral location. The 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 constructions, or natural features (table 1).

Twenty-three earthquakes occurred in a 30-km-wide zone that extends 50 km southward from Blanchard through McClain, Grady, and northern Garvin Counties. Only three earthquakes occurred in Love County in 1982.

Also in 1982 the first known earthquakes in Stephens and Murray Counties brought the number of Oklahoma counties in which earthquakes are known to have occurred to 60.

The damaging earthquake in Bryan County, near Durant, was the only known earthquake to occur there in any year except 1968, when a swarm of 14 earthquakes occurred. It is interesting that the May 3, 1982, Bryan County earthquake had the same intensity (MM VI) as the largest of the 1968 earthquakes.

In 1982, Alfalfa County had its fourth earthquake since 1977. The Creek-Okfuskee county border area had four more earthquakes in 1982, bringing the total to 14. Alfalfa County and Creek-Okfuskee Counties are two areas of minor seismicity that are rather isolated from other trends of seismicity.

The 1982 earthquake epicentral data, when combined with previous earthquake data, produced at least four seismic trends worthy of discussion.

One trend is located in north-central Oklahoma (fig. 3). The pre-1977 earthquake data (circles) and the 1977–82 earthquake data (triangles) are shown in figure 3. There appears to be a 40-km-wide and 145-km-long earthquake zone that extends northeastward from near El Reno toward Perry (Noble County). Most of the earthquakes within this zone have occurred in the vicinity of the El Reno-Mustang area, which has been the site of numerous earthquakes since 1908. Ten of the 1982 earthquakes plot within this zone. Prior to installation of the statewide earthquake-station network, more than one-half of the known Oklahoma earthquakes occurred in the vicinity of El Reno. However, after the El Reno earthquake of 1952, magnitude 5.5 (mb), no earthquakes were reported for this region until 1978.

The correlation of historical and recent earthquake activity to known structural features remains unclear. Some fault features that cut pre-

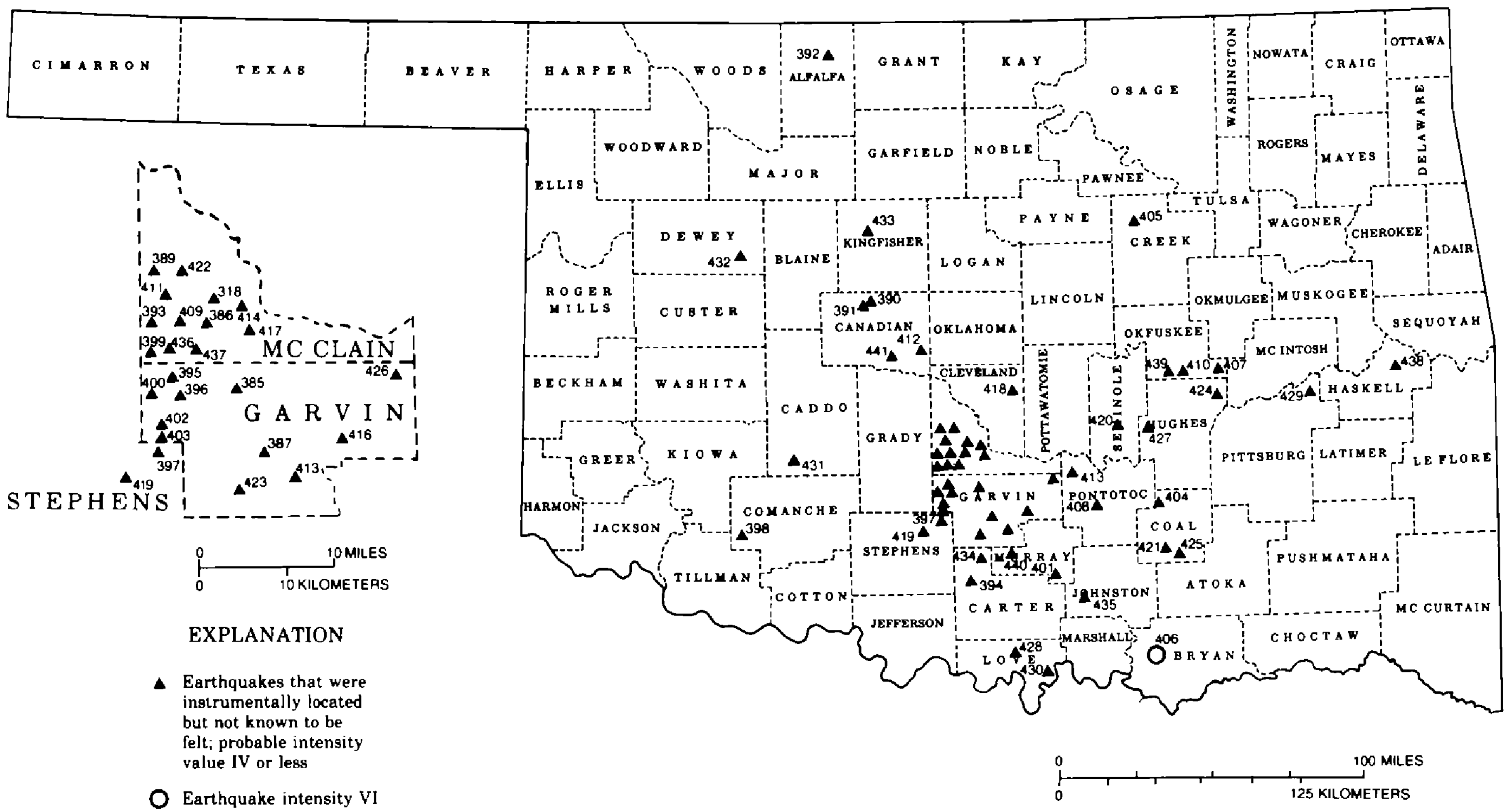

Figure 2. Distribution of Oklahoma earthquakes for 1982. Numbers correspond to event numbers in table 2.

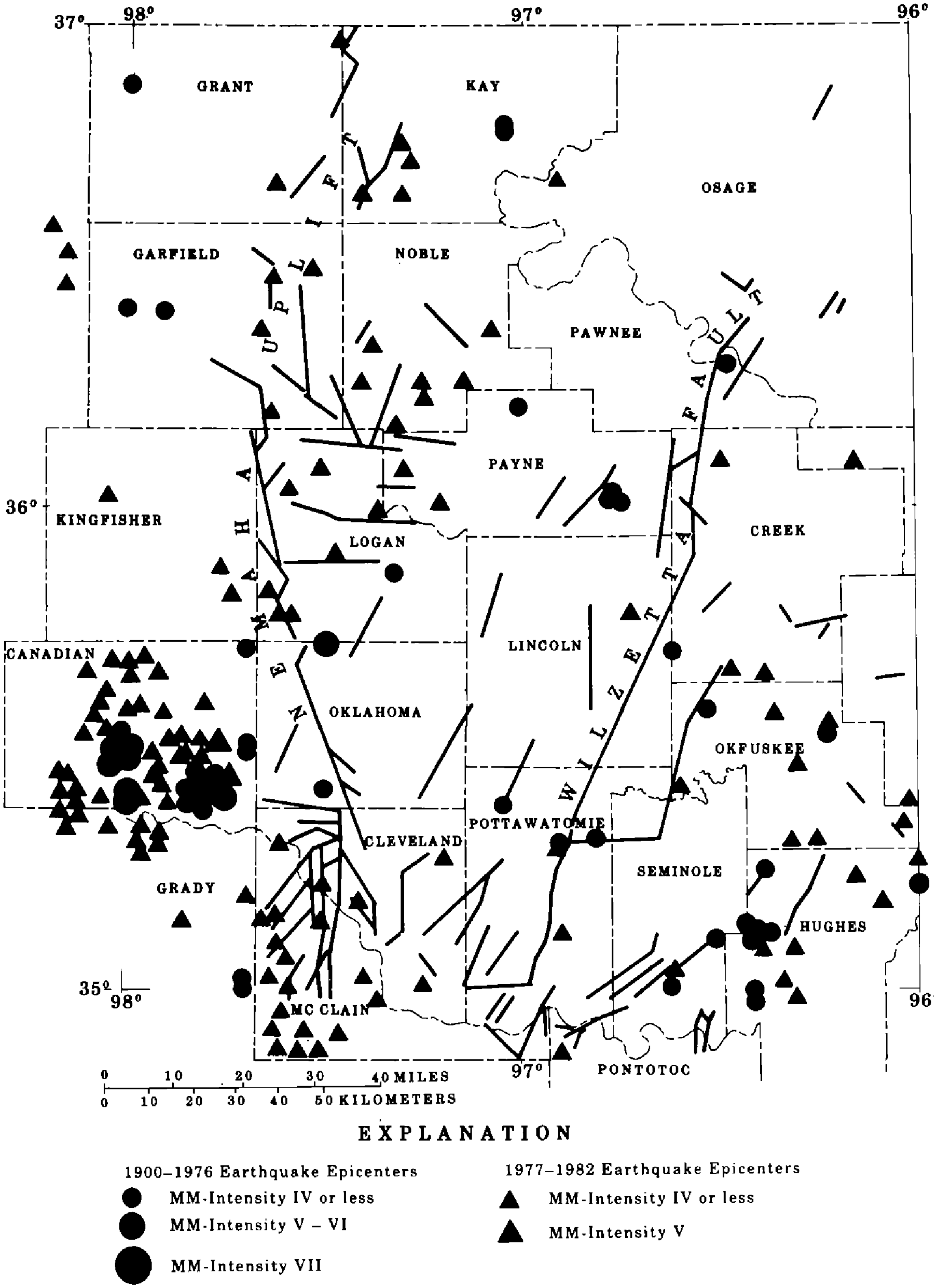

Figure 3. Distribution of faults that cut pre-Pennsylvanian strata, and earthquake epicenters for north-central Oklahoma (Wheeler, 1960; Jordan, 1962; unpublished reports).

Pennsylvanian rocks are shown in figure 3, using information compiled from Jordan (1962), Wheeler (1960), and unpublished reports. The El Reno–Perry trend appears to cut diagonally across the Nemaha Uplift structures at about a 30° angle. The southern end of this trend appears to be more active than the middle and northern parts. The recent as well as the historical earthquake data seem to support this observation.

A second trend is situated between Norman and Pauls Valley. Twenty-three earthquakes were instrumentally located in this region. This trend closely parallels the McClain County fault zone that is about 40 km wide and 60 km long. Perhaps this highly complex fault zone, containing numerous subparallel faults, is the southernmost extension of the Nemaha Uplift. When the 1982 data alone are taken, only this second trend is conspicuous.

In south-central Oklahoma, earthquakes are concentrated in the Wilson area, in Carter and Love Counties. In the past this area has also been the site of numerous small earthquakes. A fourth general area of earthquake activity lies along and north of the Ouachita front (Arkoma Basin), in southeastern Oklahoma. This fourth area experienced only limited seismicity in 1982, and that seismicity was unusually concentrated in Pontotoc, Hughes, and Coal Counties.

Catalog

An HP-9825T 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 2 contains 1982 Oklahoma earthquakes displayed in a modified version of the regional earthquake catalog. Each event is sequentially numbered and arranged according to date and origin time. The numbering system is compatible with the system used for the *Earthquake Map of Oklahoma* (Lawson and others, 1979).

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,

TABLE 2. — OKLAHOMA EARTHQUAKE CATALOG FOR 1982

Event Number	Date and Origin Time (UTC)		County	Intensity (MM)	Magnitudes 3Hz	bLg	DUR	Latitude (°N.)	Longitude (°W.)	Depth (km)[1]
385	JAN 12	234025.00	GARVIN		2.0			34.742	97.406	5.0R
386	JAN 13	005638.98	McCLAIN		2.0	1.8		34.949	97.492	5.0R
387	JAN 13	040424.42	GARVIN		2.4	2.2	2.1	34.643	97.337	5.0R
388	JAN 13	070447.65	McCLAIN		2.2	2.0	2.1	34.961	97.477	5.0R
389	JAN 13	071308.26	McCLAIN		1.8	1.8		35.025	97.561	5.0R
390	JAN 15	095216.96	CANADIAN		2.8	2.7	2.6	35.714	98.029	5.0R
391	MAR 13	014149.93	CANADIAN		2.6	2.5	2.6	35.699	98.038	5.0R
392	MAR 15	065825.60	ALFALFA		2.4		2.0	36.908	98.226	5.0R
393	MAR 15	210750.27	McCLAIN		1.8		1.8	34.934	97.600	5.0R
394	MAR 15	211818.92	CARTER		1.8		1.8	34.358	97.467	5.0R
395	MAR 15	213910.98	GARVIN		2.3		2.2	34.832	97.608	5.0R
396	MAR 15	223009.37	GARVIN		2.3		2.1	34.780	97.600	5.0R
397	MAR 15	234439.84	STEPHENS		1.6		1.7	34.663	97.600	5.0R
398	MAR 16	002142.02	COMANCHE		2.4		1.9	34.593	98.805	5.0R
399	MAR 16	015856.74	McCLAIN		1.5		1.5	34.895	97.653	5.0R
400	MAR 16	063627.90	GARVIN		1.7		1.7	34.776	97.623	5.0R
401	MAR 16	205029.41	MURRAY				1.7	34.347	96.961	5.0R
402	MAR 16	210154.45	GARVIN		2.0		1.7	34.749	97.610	5.0R
403	MAR 18	095152.95	GARVIN		1.9		2.0	34.715	97.608	5.0R
404	MAR 23	141.709.98	COAL		2.5	2.4	2.0	34.729	96.399	5.0R
405	MAR 24	044836.20	CREEK		2.4		1.7	36.051	96.452	5.0R
406	MAY 3	075448.65	BRYAN	6	2.8	3.1	2.6	33.990	96.473	5.0R
407	MAY 12	014140.74	OKFUSKEE		2.1	1.5	1.8	35.324	95.987	5.0R
408	MAY 21	163844.02	PONTOTOC		1.9	1.8	1.9	34.703	96.668	5.0R
409	MAY 29	204317.32	McCLAIN		2.1	2.3	2.4	34.934	97.539	5.0R
410	MAY 30	234325.24	OKFUSKEE		2.3		1.6	35.301	96.213	5.0R
411	JUN 13	041342.83	McCLAIN		1.8	1.8	1.8	34.992	97.557	5.0R
412	JUN 13	061536.73	CANADIAN		2.1	1.7	1.8	35.451	97.698	5.0R
413	JUL 8	011537.52	PONTOTOC		1.8		1.7	34.856	96.8[illegible]2	5.0R
414	JUL 9	033811.35	McCLAIN		2.0			34.963	97.432	5.0R
415	JUL 9	042746.80	GARVIN		1.5			34.586	97.240	5.0R
416	JUL 9	070054.95	GARVIN		1.9			34.644	97.150	5.0R
417	JUL 9	090250.59	McCLAIN		2.2	1.9	2.3	34.925	97.418	5.0R
418	JUL 9	092934.61	CLEVELAND		1.9			35.226	97.180	5.0R
419	JUL 20	033646.22	STEPHENS		2.0	2.1	2.2	34.590	97.694	5.0R
420	JUL 26	044921.61	SEMINOLE		2.0	2.1	2.1	35.063	96.561	5.0R
421	AUG 3	193206.24	COAL		2.0	2.2	2.1	34.481	96.303	5.0R
422	AUG 5	101043.31	McCLAIN		2.3	1.9	2.2	35.043	97.497	5.0R
423	AUG 11	211726.83	GARVIN		2.3	2.1	2.1	34.565	97.432	5.0R
424	AUG 13	155807.15	HUGHES		1.8	2.2	2.2	35.242	96.006	5.0R
425	AUG 18	101856.86	COAL		2.6	2.7	2.5	34.465	96.227	5.0R
426	AUG 22	010102.42	GARVIN		2.3		1.8	34.840	96.936	5.0R
427	AUG 22	044615.32	HUGHES		2.0		1.9	35.069	96.459	5.0R
428	SEP 8	123510.75	LOVE		2.6	2.5	2.4	34.014	97.338	5.0R
429	SEP 10	113116.69	PITTSBURG		2.1		2.1	35.223	95.464	5.0R
430	SEP 21	115555.82	LOVE		2.2	2.3		33.866	97.003	5.0R
431	SEP 22	040033.69	CADDO		2.6	2.2	2.4	34.894	98.429	5.0R
432	NOV 16	060228.42	DEWEY		2.3		1.5	35.839	98.705	5.0R
433	NOV 16	082725.90	KINGFISHER		2.2	1.6	1.6	35.972	97.991	5.0R
434	DEC 14	214955.09	CARTER		2.2	2.7	2.1	34.463	97.378	5.0R
435	DEC 15	043321.62	JOHNSTON		1.8		1.7	34.246	96.440	5.0R
436	DEC 18	084112.09	MCCLAIN		2.0	1.9	2.1	34.887	97.588	5.0R
437	DEC 19	051542.94	MCCLAIN		3.1	2.9	2.7	34.891	97.584	5.0R
438	DEC 19	214500.07	HASKELL				1.8	35.290	94.950	5.0R
439	DEC 20	221046.13	OKFUSKEE		2.3	2.3	2.4	35.305	96.256	5.0R
440	DEC 21	180848.38	MURRAY		2.1	2.2	2.0	34.489	97.237	5.0R
441	DEC 22	174253.73	CANADIAN		2.4	2.8	2.4	35.396	97.932	5.0R

[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.

1974). This magnitude is derived from the following expression:

$$m3Hz = \log(A/T) - 1.63 + 0.87\log(\Delta),$$

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 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.

In 1979 St. Louis University (Stauder and others, 1979) modified the formulas for m3Hz. This modification was used by the OGO beginning January 1, 1982. The modified formulas had the advantage of extending the distance range for measurement of m3Hz out to 400 km, but also had the disadvantage of increasing m3Hz by about 0.12 units compared to the previous formula. Their formulas were given in terms of log (A) but were restricted to wave periods of 0.2 sec to 0.5 sec. In order to use log (A/T), we assumed a period of 0.35 seconds in converting the formulas for our use. The resulting equations are:

(epicenter 10 to 100 km from a seismograph)

$$m3Hz = 0.88 \log(\Delta) + \log(A/T) - 1.46$$

(epicenter 100 to 200 km from a seismograph)

$$m3Hz = 1.06 \log(\Delta) + \log(A/T) - 1.82$$

(epicenter 200 to 400 km from seismograph)

$$m3Hz = 1.29 \log(\Delta) + \log(A/T) - 2.35.$$

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. Before 1981, if the Pn wave was the first arrival, the interval between the earthquake-origin time and the decrease of the coda to twice the background-noise amplitude was measured instead. Beginning January 1, 1982, the interval from the beginning of the P wave (whether it was Pg, P*, or Pn) and the decrease of the coda to twice the background noise amplitude was used.

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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REPORT ON SUBSIDENCE PROBLEMS OF PICHER FIELD MINE AREA COMPLETED BY OGS AUTHOR

A study of potential subsidence problems associated with abandoned underground lead and zinc mines in northeastern Oklahoma has been completed by Kenneth V. Luza, engineering geologist with the Oklahoma Geological Survey.

The report concentrates on the Picher Field in Ottawa County, in the northeast corner of the State. This area is part of the Tri-State Mining District, which extends beyond Oklahoma into southeastern Kansas and southwestern Missouri. The district was, in the first quarter of this century, one of the world's leading producers of lead and zinc. Production reached a peak in 1925, and by 1958 all major operations were closed. Some mining began again in 1960, and the last recorded production was in 1970.

Luza's report contains a table identifying and describing the remaining mining shafts in the area, and makes suggestions for remedial action for numerous examples of ground failure associated with these orphan-mine shafts. An inventory in the report shows at least 1,064 shafts in the Picher Field, more than 50 percent of which were concealed or filled, leaving 481 shafts that are either open or in some state of collapse.

Also accompanying the report are three maps at a scale of 1:24,000 that show mines and shafts; open mine shafts, pits, and collapse features; and accumulations of mine and mill waste.

Another table included in the report lists and describes more than 80 subsidence events, with suggestions for actions that could be taken to make the areas of potential subsequent collapse less hazardous. Fortunately, little property destruction has resulted from these events, although Luza reports that in 1967, 18 people lived in houses affected by a 1.5-acre collapse that occurred north of Picher High School and dropped 25 ft in the center, taking two houses with it and inflicting minor injuries on five people. One of the shafts he lists is within the city limits of Quapaw, a shaft that has a history of recurring collapses.

The piles of waste material present another problem. Most of the tailings have been worked and reworked for maximum recovery, and what is left from the mills consists mostly of chert fragments—chat—which was heaped into piles, some more than 200 ft high. Some of this chat can be sold for construction aggregate, but the chat has no organic content and will not support vegetation; it must be almost completely removed for successful reclamation of the land. This has been done in some cases. Another table contained in the report presents the results of an inventory of these tailing piles and tailing ponds, describes their present condition, and gives suggestions of action that could be taken.

Other sections in the report discuss the hydrology of the area and regulations and laws that now cover mining in Ottawa County.

All lands mined following 1955 come under an Oklahoma statute requiring open vertical shafts to be protected by fencing or by plugging and filling. It is the abandoned mines operated by companies that went out of business before 1955 that are more of a problem. The Surface Mining Control and Reclamation Act (P.L. 95–87), passed in 1977, sets up a trust fund for mined-land reclamation, supported by a production tax on coal. Regulations amended in 1982 permit this fund to be used to fill and seal openings of abandoned non-coal mines if such openings constitute a public hazard.

Luza describes the general hydrology of the mined area, stating that although Tar Creek and its main tributary, Lytle Creek, flow through the area, ground water from the Roubidoux and Boone Formations is the principal source of water for both domestic and industrial use, with most of the water used in Ottawa County coming from the Roubidoux. The chief concern is for possible contamination of the Roubidoux by mine water, and the lateral migration of mine water through the Boone into domestic water wells and stock wells.

The report, *A Study of Stability Problems and Hazard Evaluation of the Oklahoma Portion of the Tri-State Mining Area,* is on file at the Oklahoma Geological Survey. Because a limited number of copies have been printed, it is available only for examination. The report, completed under a grant from the U.S. Bureau of Mines, was prepared by Luza with assistance in field inspections from Donald A. Preston, former OGS petroleum and subsurface geologist, and William E. Harrison, OGS petroleum geologist and geochemist. Similar studies will be released by the Kansas and Missouri geological surveys.

AIPG OKLAHOMA SECTION MEETS, ANNOUNCES NEW OFFICERS

William E. Harrison, president of the Oklahoma Section of the American Institute of Professional Geologists, announced 1983 officers of the section at its annual meeting in Norman March 26. Harrison, a petroleum geologist and geochemist for the Oklahoma Geological Survey, automatically succeeded to the presidency from his office of first vice president last year.

Other officers for 1983 include James E. O'Brien, Mannford consultant, first vice president and president-elect; Dawson F. Lasseter, Geological Engineering Consultants, Norman, second vice president; and Robert A. Northcutt, Bass Enterprises Production Co., Oklahoma City, secretary-treasurer.

Completing the Oklahoma Section executive committee are J. Philip Boyle, consultant, Oklahoma City district representative; Murray McComas, M. R. McComas & Associates, and John A. Blair, Northern Natural Gas, joint Tulsa district representatives; Douglas C. Kent, Oklahoma State University, representative-at-large; and Gary F. Stewart, Oklahoma State University, past president.

Also at the meeting, Harrison identified the need to revitalize the section's legislative affairs committee for more effective monitoring of legislative activities and pending legislation that might affect the professional practice of geology in Oklahoma.

A general discussion ensued on ways in which the Oklahoma Section could help to increase the vitality and pertinence of AIPG to the membership.

Charles J. Mankin, director of the Oklahoma Geological Survey, felt that involving the membership in issues of particular interest to geologists as a whole would be a good approach. He cited proposed legislation to amend the Natural Gas Policy Act of 1978 and current efforts to enact legislation relative to the domestic minerals industry as two national issues worthy of AIPG attention.

John S. Wickham, director of the School of Geology and Geophysics at The University of Oklahoma, suggested the possibility of holding a symposium to address one or more such issues and the desirability of sponsoring such a meeting in cooperation with other Oklahoma groups such as the Tulsa, Oklahoma City, and Ardmore geological societies.

Following the business meeting, most AIPG members joined arriving geologists from the Tulsa Geological Society in a joint field trip to the Arbuckle Mountains.

1982 MINERAL INDUSTRY OF OKLAHOMA

The value of nonfuel minerals produced in Oklahoma totaled an estimated $235 million in 1982, according to the Bureau of Mines, U.S. Department of the Interior. Oklahoma retained its position as the nation's leading iodine producer, although basic construction materials continued to represent the bulk of output value.

Oklahoma's second commercial iodine facility, a joint venture between Beard Oil Co. of Oklahoma City and two Japanese firms, should be on stream early in 1983. Originally planned for mid-1982 completion, the project-construction schedule was stretched out as demand for iodine weakened during the year and domestic producers built up inventories.

National Zinc Co. temporarily closed its Bartlesville plant in the summer because of weak demand for zinc and an excessive buildup of zinc stocks. This was the first shutdown of the plant since it was established in 1907, the year that Oklahoma became a state. The Bartlesville operation of Somex, Ltd., a division of Phibro-Salomon, Inc., was closed by a strike in the autumn. Somex recovered vanadium concentrates from oil-burning-

TABLE 1. — NONFUEL MINERAL PRODUCTION IN OKLAHOMA[1]

Mineral	1981 Quantity	1981 Value (thousands)	1982[p] Quantity	1982[p] Value (thousands)
Clays .... thousand short tons. .	838	$ 2,064	816	$ 2,105
Gem stones	NA	2	NA	2
Gypsum .... thousand short tons. .	1,177	9,870	1,146	10,090
Helium:				
High purity ..... million cubic feet. .	49	1,274	—	—
Crude .... do.....	22	264	—	—
Pumice .... thousand short tons. .	1	W	1	W
Sand and gravel .... do.....	[p]11,700	[p]38,117	11,500	37,350
Stone:				
Crushed .... do.....	29,930	83,407	31,090	87,000
Dimension .... do.....	18	738	18	968
Combined value of cement, feldspar, iodine, lime, salt, tripoli, and values indicated by symbol W	XX	100,876	XX	97,486
Total	XX	236,612	XX	235,001

[p]Preliminary. NA Not available. W Withheld to avoid disclosing company proprietary data; value included in "Combined value" figure. XX Not applicable.

[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

powerplant soot obtained from domestic and foreign sources. Oke-Iron Co. obtained a permit to mine brown iron ore in the Arbuckle Mountains near Scullin in Murray County, while Paragon Pipe Co. began production of casing and line pipe for the oil industry at its highly automated mill near Sapulpa. The mill is the first of its kind in Oklahoma.

Republic Gypsum Co. of Dallas, Texas, held its annual meeting in Duke in southwestern Oklahoma, and, in contrast to most gypsum producers, reported a good profit for fiscal 1982, owing largely to its Oklahoma operations. Tar sands near Sulphur, about 70 miles south of Oklahoma City, received renewed attention when tests showed a good-quality, residual, grade-6 sand byproduct that, if marketable in quantity for asphalt, glass, and ceramic uses, would enhance the present marginal economics of bitumen recovery.

Tar Creek, in northeast Oklahoma, continued to be a focal point of mineral-related pollution problems. In November 1981, it was listed by the Environmental Protection Agency as the worst polluted site in the nation. The area was subjected to at least $705,000 in studies and investigations through 1982 to determine an effective course of action to control the lead-, zinc-, and cadmium-bearing water from abandoned mines in the Tri-State District and to protect the underlying regional Roubidoux aquifer.

OGS EMPLOYEES ATTEND COAL FORUM

Samuel A. Friedman, senior coal geologist, LeRoy A. Hemish, coal geologist, and Michelle Summers, geological data coordinator, represented the Oklahoma Geological Survey at the Seventh Forum of Coal Geologists of the Western Interior Basin held at Columbia, Missouri, March 17--18, 1983. Geologists from Kansas, Missouri, and Nebraska, as well as the U.S. Geological Survey, also participated in the meeting. Charles E. Robertson, chief, Mineral Fuels Section of the Missouri Department of Natural Resources, Division of Geology and Land Survey, chaired the meeting.

Jerry Vineyard, Missouri's assistant state geologist, welcomed the group. He reported that the mineral industry as a whole was depressed during 1982 in his state, and that the Missouri Department of Natural Resources had experienced budget problems. Robertson said that coal production in Missouri had dropped from 5.2 million tons in 1981 to 5.1 million tons in 1982, and that 16 mines were in operation. He also noted that some tonnage of Pennsylvanian cannel coal was being mined from sinkholes or from pre-Pennsylvanian valleys. The coal is 15 to 90 feet thick and overlies rocks ranging from Ordovician to Mississippian in age around the flanks of the Ozark Mountains. Cannel coal is a nonbanded variety of bituminous coal that yields a high percentage of volatile matter, ignites easily, and burns with a luminous smoky flame.

Ray Burchett, Conservation and Survey Division, University of Nebraska, reported that no coal was being mined in his state, and no production is anticipated. However, a private company has expressed an interest in deep coal beds in the Forest City Basin of southeastern Nebraska, southwestern Iowa, northeastern Kansas, and northwestern Missouri, and some exploration drilling has been done in the area.

Lawrence L. Brady, chief, Mineral Resources Section of the Kansas Geological Survey, reported a 6-percent increase in coal production in his state during 1982. Seven mines produced 1,396,000 tons valued at approximately $37 million. In-state cement plants, and power plants in and out of state are the major users of Kansas coal, which generally falls in the high-sulfur category. Of the 11 to 12 million tons of coal consumed in Kansas, approximately 9 million tons is shipped in from Wyoming.

Friedman reported a drop in coal production from a record-setting 5.7 million tons in 1981 to 4.8 million tons in 1982. Thirty-one coal companies were producing coal from 48 mines in Oklahoma during 1982. Turner Brothers, Inc., led in production with 996,000 tons, taking over the top spot from Peabody Coal Co., which reported 741,000 tons.

Friedman said that seven power plants in Oklahoma had received 14 million tons of Wyoming subbituminous coal during 1982. He also said that the Grand River Dam Authority Unit 2 Plant (expected to go on line in 1985) may become a major consumer of Oklahoma coal. The plant is expected to consume a blend of 15-percent Oklahoma bituminous coal and 85-percent Wyoming subbituminous coal.

Debbie Carter, U.S. Geological Survey, Reston, Virginia, reported that the National Coal Resources Data System (NCRDS) budget had been cut but that funds were still available for states wishing to participate in the cooperative program offered by the federal government. Under this program, coal data, such as coal analyses, reserve and resource figures, and stratigraphic information, are made available by the states for storage in the federal computer system. The stored information can be classified as either confidential or nonconfidential, according to the wishes of the cooperating state. Data can be retrieved for use in constructing various types of geologic maps (including three-dimensional maps), cross sections, or tables of resources and reserves.

In the Western Region of the Interior Coal Province the states of Arkansas, Iowa, Kansas, and Missouri are currently involved in cooperative programs with NCRDS. Summers reported that Oklahoma plans to become involved with the NCRDS program. She discussed actions that are being taken in the initial planning phases.

On the agenda for most of the afternoon of the first day of the meeting was a discussion of research and related matters. Burchett spoke briefly about research in the Forest City Basin; Brady and George Sziget, of Kansas, discussed their state's involvement with NCRDS, a forthcoming publication on chemical coal data, and stratigraphic studies in the eastern part of the state. Friedman reviewed three 1982 coal publications by the Oklahoma Geological Survey. Hemish reported on the progress of the State's coal-mapping project and displayed samples of unpublished data, such as coal maps, coal analyses, and stratigraphic information, that are on open file at the OGS offices and that are available for use by the public.

Robertson and Vineyard reported briefly on Missouri's research and distributed copies of several coal-related publications released in 1982.

A field trip to Missouri's largest coal mine — the Prairie Hill Mine — which produces about 3.8 million tons annually for use in the Associated Electric Cooperative's (AEC) Thomas Hill power-generating station, was on the agenda for the second day of the meeting. The mine and power plant are in north-central Missouri, about 45 mi north of Columbia. The NEMO Coal, Inc., Mine 25, in the same vicinity, was also toured. Coal produced at these mines is bituminous in rank, comes from three seams, and is high in sulfur content, averaging about 4 percent. The heat value of the coal is 10,500 to 11,000 Btu per pound.

The next annual meeting of the Coal Geologists of the Western Interior Basin has been scheduled for Lincoln, Nebraska, in the spring of 1984. The Conservation and Survey Division, University of Nebraska, will host the meeting.

LeRoy A. Hemish

CEMENT-FIELD WATER RESOURCES EVALUATED IN OGS REPORT

A new publication of the Oklahoma Geological Survey assesses water supply and quality in parts of two Oklahoma counties, Caddo and Grady. The report has been prepared to provide information on available water supplies for use in efforts to extract oil remaining in the ground from wells whose yields have decreased — to keep the wells flowing or to reactivate inactive wells.

With about one-third of the oil in producing wells recoverable through the use of traditional primary recovery methods, the application of secondary or even tertiary techniques of enhanced oil recovery (EOR) to obtain maximum yields from the wells obviously is desirable. Such applications are of particular significance in a state like Oklahoma, where so many wells have been drilled and where production from many wells is now declining.

Most techniques currently used for EOR require large amounts of fresh water containing low concentrations of dissolved solids; high calcium and magnesium content are especially undesirable. Appraisals of both quantity and quality of fresh-water resources are therefore virtually essential before proceeding with EOR programs.

The 64-page report was published by the Survey as Special Publication 82-5, *An Evaluation of Water Resources for Enhanced Oil Recovery Operations, Cement Field, Caddo and Grady Counties, Oklahoma,* and it presents the results of such an appraisal in a representative oil field. As authors Donald A. Preston, William E. Harrison, Kenneth V. Luza, Lynn Prater, and Raja Reddy explain in their introduction to the published report, the Cement Field was selected for the investigations because of the subsurface control available from records of more than 1,850 wells and because of its 30-year history of production and its large area of 25,000 acres. Some wells in the field are already being waterflooded to induce further productivity.

It is expected that similar evaluations will be conducted for other Oklahoma oil fields.

The current report offers data on quantity and quality for three categories of water resources within a 25-mile radius of the Cement Field: surface water, including reservoirs, lakes, ponds, and streams; ground water, or water in underground aquifers shallow enough to be producible through normal water wells and that yield at least 25 gallons per minute; and subsurface water, or water in formations penetrated by deeper wells. This information is discussed in the text and is also displayed graphically in tables and illustrations and on five folded maps.

Information is also given for runoff, precipitation, open-flow potential, resistivity and permeability, and deliverability. The authors have included sections on the general surface and subsurface geology, stratigraphy, and structure of the area as well. Thus, the publication should be of value to petroleum geologists, producers, hydrologists, environmentalists, and others interested in the geology of the surrounding area.

This report was originally issued in open-file form and represents results of investigations conducted under a grant from the U.S. Department of Energy for the Bartlesville Energy Technology Center. The publication is available from the Oklahoma Geological Survey at the address given inside the front cover. The price is $10.

PUBLICATION DESCRIBES ORDOVICIAN ROCKS AND FOSSILS IN EASTERN OKLAHOMA

The Oklahoma Geological Survey has just issued a bulletin that will provide a better understanding of the character and correlation of Middle and Upper Ordovician rock units in eastern Oklahoma. These units, assigned to the Bromide Formation and the newly designated Viola Group, are present at the surface in the Arbuckle Mountains of south-central Oklahoma and along the southern flank of the Ozark Uplift in eastern Oklahoma.

By tracing these rock sequences in the subsurface through the intervening Arkoma Basin, authors Thomas W. Amsden and Walter C. Sweet have demonstrated not only the position of the rocks in the basin but have reconstructed the basin's early depositional history. Amsden is a geologist for the OGS, and Sweet is a professor in the Department of Geology and Mineralogy at Ohio State University.

The 76-page volume, *Upper Bromide Formation and Viola Group (Middle and Upper Ordovician) in Eastern Oklahoma,* was issued as OGS Bulletin 132.

As the Arkoma Basin is a major gas-producing province, this study should be of value in further petroleum exploration in the basin by providing a more exact definition of these rock units.

The bulletin is divided into three sections. Part I, prepared by Amsden, offers a detailed description of the surface and subsurface expressions of the Bromide and Viola rocks, including a revision of nomenclature and stratigraphic relationships.

Part II presents results of an extensive study by Sweet of conodont zonation in the rocks under investigation. Sweet has based his conclusions, which are shown in several graphs and charts, on examination of more than 18,000 specimens recovered. He describes one new conodont species, *Aphelognathus gigas.*

In the third part of the bulletin, Amsden has revised the nomenclature of one family of brachiopods. Also, he has described two new brachiopod subfamilies and one new genus, *Hiscobeccus.*

The bulletin is well illustrated throughout and includes 14 plates showing conodont and brachiopod specimens and thin sections of rocks.

OGS Bulletin 132 can be obtained from the Oklahoma Geological Survey at the address given inside the front cover. The price is $12 for clothbound copies and $8 for paperbound.

WATT ANNOUNCES NEW SYSTEM FOR SUMMARIZING WATER RESOURCES

Interior Secretary James Watt has announced steps to implement a system to produce an annual National Water Summary that will make water-resources information more readily available and useful to policy makers and managers at local, state, and national levels.

"Nothing can be more basic than water resources in planning the future growth and health of our nation," Watt said, "yet past assessments of the adequacy of our nation's water resources have been too infrequent and too complex to be generally helpful to decision makers.

"In keeping with administration policy that the responsibility for water-resources management rests with the states, the Interior Department has an important role in providing state and local agencies with current, accurate evaluations of water conditions and critical water problems," Watt said.

To accomplish this goal, the Secretary has directed Interior's U.S. Geological Survey and the Office of Water Policy (OWP) to take the following steps:

- The USGS will prepare annual National Water Summary reports targeted for initial publication in October 1983. The initial report will summarize national water conditions and subsequent annual reports will also focus on selected water problems. The OWP will coordinate with state and local decision makers to ensure that the information presented in the reports is responsive to the users' needs.
- The USGS will develop a water-resources information system that will contain summary data about the nation's water resources. The new information system will be used in conjunction with existing water data bases to retrieve, analyze, and display information about water-resources conditions and to track changes over time. The OWP will coordinate responses and suggested improvements to the system from policy makers and managers.
- Using data supplied by the USGS and other agencies in the public and private sector, OWP will work with state officials to identify critical water problems. The department will then respond to specific local needs and requests and develop programs to provide needed assistance.

"I am directing the Office of Water Policy to seek comments from agencies and groups at the national, state, and local level about the criteria, format, and goals of subsequent annual reports," Watt said. "We will also work closely with state and local agencies in the development and implementation of the information system, because they will continue to be the people most involved in water-resources development and management.

"At the same time, I am directing the USGS to begin working immediately with OWP to put together a demonstration of the potential of the new water-resources information system," Watt said.

RIFT SYSTEM STUDIED IN KANSAS AND OKLAHOMA

Scientists at the Kansas Geological Survey have traced a late Precambrian rift system, which extends southwestward and southward from the Lake Superior region through Wisconsin, Iowa, and Nebraska, into north-central Kansas.

The finding is based on recent measurements of gravity levels in south-central Kansas, according to survey geophysicist Harold Yarger. These gravity measurements indicate that the rift might extend all the way through Kansas, from Washington County in the north to Harper County in the south.

Geologists theorize that the rift, termed the Central North American Rift System, formed a little more than a billion years ago when the North American continent began to pull apart slowly. When this happened, mafic, or iron-rich, igneous rock welled up through the earth's crust to fill the rift. This type of rock is more dense than the surrounding rock, resulting in higher gravity readings along this part of the geologic "basement."

Associated studies by the Oklahoma Geological Survey have confirmed gravity highs in north-central Oklahoma similar to those in Kansas. Survey geologist Kenneth V. Luza believes that these high gravity readings indicate the presence of mafic dikes, which have intruded the predominantly granitic basement rocks, accounting for anomalous readings on both gravity and magnetic recorders.

Although Luza says that the rift itself might not extend into Oklahoma, the trend of geophysical anomalies extends southward from Harper County, Kansas, directly on line into Grant County, Oklahoma, and

Trace of Central North American Rift System through Kansas and possibly into Oklahoma.

southward into Kingfisher County. Thus the Central North American Rift System, some 800 miles long, possibly terminates in Oklahoma.

ISP AWARDED AAPG CONTRACT

Geological data from all areas of the nation will be computerized under a contract awarded to The University of Oklahoma's Information Systems Programs by the American Association of Petroleum Geologists (AAPG).

"The collecting and processing of these data for all areas of the United States into a computer-retrievable format has been a dream of geologists for years," said Gene Garove, ISP technical project coordinator.

ISP, a division of OU's Energy Resources Institute (ERI), received a $37,000 contract to computerize information gathered in AAPG's Correlation of Stratigraphic Units of North America (COSUNA) project. Dr. Charles J. Mankin, executive director of ERI, is also director of the Oklahoma Geological Survey.

"The data will be invaluable to geologists looking for natural, underground traps where oil and gas can be found," Garove said. "Researchers in government institutions will find the information useful in a broad variety of geological studies. Earth science instructors can use the data in the research or as a teaching aid."

With a grant from the U.S. Geological Survey, the AAPG has sponsored the COSUNA project for more than six years. The project is a national research effort involving approximately 200 geologists who are volunteering their time to assemble stratigraphic correlation charts of selected regions in the United States.

In the first phase of the project, geologists sketched stratigraphic column diagrams depicting layers of rocks found in core samples and drill tests, or collected from other information sources. The drawings were combined to develop correlation charts showing types of formations and ages of rock found in different areas of the nation.

"ISP is involved in the second phase of the COSUNA project," Garove said. "We are taking the detailed information assembled from the correlation charts and developing a publicly accessible databank for AAPG.

"At the end of September 1983, when the contract expires, we will have completed two-thirds of the databank. We hope the contract will be renewed at that time so that we may complete the project," he said.

Meanwhile, AAPG is expected to begin publishing charts from the COSUNA project this spring.

"ISP was chosen to build this database because of its acknowledged expertise in building oil and gas databases, specifically the Petroleum Data System developed and maintained by ISP," Garove said.

"Involvement in the COSUNA project is certainly a plus for us because we will become the repository for this geological information. I think the recognition ISP receives because of the COSUNA project will reflect well on the university's reputation as a center for energy research and study."

SME TECHNICAL SESSIONS SELECTED

The 1983 Society of Mining Engineers of AIME Fall Meeting and Exhibit, to be held October 19–21 in Salt Lake City, Utah, will include technical programming by the four SME Divisions — Coal, Industrial Minerals, Mining & Exploration, and Mineral Processing — and the SME Minerals Resource Management Committee.

The Coal Division will sponsor seven sessions in addition to one joint session each with M&E and MRM. The Coal sessions include Underground Mining; Environmental — "Potpourri of Coal Related Environmental Problems"; Human Factors, Aspects of Health & Safety; Coal Preparation; Research and Development; Coal Utilization; and Coal Surface Mining. The joint session with MRM will discuss Economics of Western Coal Transportation. Mine Ventilation will be the topic of the Coal/M&E session.

The Industrial Minerals Division has planned six sessions and one joint session with MRM. Economics of Western Industrial Minerals will be discussed in the IndMD/MRM session. Other IndMD sessions will discuss The Role of Marketing and Supporting Services in Industrial Minerals; The Last Four Years — Present and Future Impacts of the Reagan Administration; Waste Products as Industrial Minerals — Impact of Recycling; Water Resources in the Western States; Role of Alternate Fuels; Technology and Energy Conservation in Industrial Minerals; and Mineral Material for Insulation.

In addition to the joint session with Coal, the Mining & Exploration Division will conduct 10 sessions: Open Pit; Geology I, II, & III; Solution Mining I, II, & III; Operations Research; Hydrology; and Underground Mining.

In addition to the joint sessions with Coal and IndMD, the Minerals Resource Management Committee will present five technical sessions. The sessions will discuss Marketing & Economics of Byproducts; Impact of Fiscal and Monetary Policy on Mining Capital — An Autopsy; Management Practices — Production Analysis and Improvement; Commercialization of Synfuels; and Ore Reserve Estimation.

A Technological Information Exchange Exhibit will also provide meeting attendees with the opportunity to view the latest mining technology. Each booth will contain the latest technological information, products, services, or equipment; an explanation of government agencies; or program information from colleges and universities.

For more information on the meeting or exhibit, contact Meetings Dept., Society of Mining Engineers, Caller D, Littleton, CO 80127.

OKLAHOMA ABSTRACTS

GSA Annual Meeting, North-Central Section
Madison, Wisconsin, April 28–29, 1983

The following abstracts are reprinted from *Abstracts with Programs* of the Geological Society of America, v. 15, no. 4. Page numbers are given in brackets below the abstracts. Permission of the authors and of the GSA to reproduce the abstracts is gratefully acknowledged.

Calcareous and Hematitic Oolites at the Ordovician–Silurian Boundary of the Central United States

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Oolites occur sporadically at the Ordovician–Silurian boundary throughout central United States. These oolitic units, composed of either calcareous or hematitic ooids, can be distinguished geographically by means of their composition. Calcareous oolites predominate in south-central United States and are represented by the Keel and Pettit Formations of Oklahoma; the Noix Formation of Illinois and Missouri; the Cason Shale of Arkansas; and basal "Silurian" beds in Texas, Kansas, and Nebraska. Hematitic oolites, represented by the Neda Formation of Wisconsin, Iowa, Illinois, and Michigan, as well as similar units in Indiana, Missouri, Kansas and Nebraska, are confined primarily to north-central United States.

Both types of oolites share similar modes of occurrence, suggesting a depositional relationship. Both types exhibit patchy geographic distributions and seldom exceed one or two meters in thickness. More importantly, they occur in the same stratigraphic and depositional successions, being underlain by late Ordovician shale and unconformably overlain by early Silurian carbonates. The most significant difference between the two types is the characteristic flattened shape and mud support of the hematitic ooids.

The calcareous ooids were deposited under normal marine shoaling conditions which developed during late Ordovician glacio-eustatic sealevel

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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.

changes. Several different processes have been suggested to account for the formation of hematitic oolites, including the replacement of calcareous ooids, replacement of chamositic ooids which originally developed in a sheltered reducing environment, and development of limonitic ooids within a soil. Which model applies to the Neda Formation has not yet been determined. [222]

Oolitic Strata of the Keel Formation and Edgewood Group (Late Ordovician and Early Silurian), Texas Panhandle to the Mississippi Valley

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The Keel Formation and Edgewood Group comprise a thin sequence of oolites and associated skeletal limestones extending from the Texas Panhandle across Oklahoma, Arkansas, and the Mississippi Valley region of eastern Missouri and western Illinois. These strata are mainly Late Ordovician (Gamachian; Hirnantian) but are in places also Early Silurian. Keel–Edgewood beds are underlain by Late Ordovician (Cincinnatian) shales and limestones and unconformably overlain by late Early Silurian (late Llandoverian, C) limestones. The characteristic facies is an oolite bearing an exclusively marine, predominantly benthic fauna dominated by pelmatozoans. Associated with this facies are skeletal limestones with a similar fauna. In Texas and Oklahoma the Keel has minimal terrigenous detritus, but along the Mississippi Valley the silt-clay content increases and in places the Edgewood includes beds of calcareous shale. The Keel–Edgewood sediments were deposited in a widespread, shallow sea situated to the west of the Appalachian Basin, which supplied some fine detritus to the eastern Edgewood sea.

The northern and western parts of this region lie within the North American Late Ordovician–Silurian dolomite province, and here Keel–Edgewood strata are partly to heavily dolomitized. Locally in Oklahoma and northern Arkansas the primary Keel texture has been partly to completely replaced by Fe–Mn mineralization. This mineralization is severe in strata bordering the Ordovician–Silurian boundary and decreases in intensity into younger and older strata. The source and mode of emplacement are uncertain, but these deposits are believed to be genetically related. [222–223]

Distribution and Age of Dolomitic and Hematitic Oolites at the Ordovician–Silurian Boundary in Nebraska and Kansas

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The upper Maquoketa (Late Ordovician) of Kansas is characteristically a greenish-gray dolomitic shale which grades northward across Nebraska into a light gray granular dolomite. In southeastern Nebraska and immediately adjacent areas of Kansas, a red shale with oolitic hematite concretions commonly occurs at the top of the Maquoketa and is considered equivalent to the Neda of Iowa.

The Silurian consists of dolomite with varied amounts of chert and commonly contains dolomitic oolites near its base. This lower unit is present throughout northeastern Kansas but appears to be overlapped by younger Silurian rocks northward across Nebraska. The oolitic interval has been equated with the Noix (Missouri) and Keel (Oklahoma) oolites which are considered to be Late Ordovician. In Nebraska, the dolomitic oolites are associated with an early upper Llandovery fauna (Silurian). [223]

Late Pennsylvanian (Virgilian) Conodont Biofacies Correlated with Lithofacies in the Heebner Shale, the Core Member of the Oread Megacyclothem, S. Kansas and N. Oklahoma, U.S.A.

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Heebner Shale outcrops in S. Kansas and N. Oklahoma provide a rare opportunity to examine lateral lithofacies relationships of a core member of a Late Pennsylvanian cyclothem as it approaches a palaeo-shoreline, and to correlate these with changes in accompanying conodont faunas.

Cavusgnathus, numerical dominance of which is indicative of nearshore, marine conditions, is conspicuously absent in the Heebner Shale of S. Kansas in black fissile shales indicative of deep-water anoxic depositional environments. In nearby N. Oklahoma where both lithofacies and megafauna support a shallow-water, normal marine interpretation for the Heebner Shale, *Cavusgnathus* increases noticeably. Parallel trends can be demonstrated for *Cavusgnathus* in the underlying and overlying Leavenworth and Plattsmouth limestones, respectively, although the different outcrop limits of these members cause their trends to be modified.

The distribution of other conodont genera, when related to a postulated N. Oklahoma shoreline during Virgilian deposition, is not as well defined. For example, the abundance of species of *Streptognathodus, Idiognathodus* and *Idioprioniodus* in the most southerly outcrops of the Heebner Shale known is anomalous in terms of previously proposed biofacies models.
[230]

Breezy Hill Limestone, Prelude to the Major Widespread Pennsylvanian Cyclothems of Midcontinent North America

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The Breezy Hill Limestone, uppermost Cherokee Group (Desmoinesian Stage), from Oklahoma to Illinois, overlies a detrital sequence of deltaic

and fluvial origin, and represents a minor transgressive–regressive pulse of the sea before the onset of the more characteristic widespread "Kansas-type" eustatic cyclothems of the Middle and Upper Pennsylvanian.

From Illinois into southeastern Kansas, the Breezy Hill is separated from the overlying black phosphatic Excello Shale by coal and underclay, and is an argillaceous, non-fossiliferous carbonate, interpreted as shoreline to terrestrial in origin. From southern Kansas into Oklahoma, the Breezy Hill directly underlies the Excello Shale, and is mainly a calcilutite with a diverse marine biota, previously interpreted as the transgressive unit of a cyclothem that includes the Excello as the offshore shale and the overlying Blackjack Creek Limestone (Lower Fort Scott) as the regressive carbonate.

Stratigraphic and petrographic evidence suggest that the apparently disparate lithologies of the Breezy Hill represent laterally adjacent facies of a minor transgressive–regressive pulse of a sea shallowing to the north. The upper Breezy Hill of Oklahoma and southern Kansas is mainly a regressive limestone and not part of the overlying cyclothem. [257]

Word Processors for Geologic Reports

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Word processors have added a new dimension in the production of geologic reports. Although word processors have been in use for many years and are routinely used for a variety of typed products, an added feature is the compatibility of word processor disks and printer's typesetting equipment so that typeset text can be printed directly from specially coded material. This added capability permits the printing of a variety of type styles (boldface, italic, and others), symbols, and various levels of indentation and type for rankings of headings. Some, but not all, of these features can be done with a standard word-processor printer, but the resulting type may still not resemble typeset letters.

Another attraction of word processor interfacing with typesetting equipment is the elimination of proofreading beyond the word processor phase of printing. The coded word processor disks are used as direct input for typesetting.

This versatility of typeset products makes this technique attractive for preparing camera-ready manuscripts for journals, and student theses and dissertations, for example. An example is discussed of a recently printed product of the Minnesota Geological Survey using this method, the *Bibliography of Minnesota Geology, 1951–1980.* [264]