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Cover Picture

Fault Linears in South Norman Area

The cover photograph is a vertical view of a portion of the South Norman area as defined in the study presented on pages 260-266 of this issue entitled *Geophysical delineation of fault zones, South Norman area, Cleveland County, Oklahoma.* It shows portions of secs. 8 and 17, T. 8 N., R. 2 W., Cleveland County, Oklahoma. The scale of the photograph is approximately 1:5,160. The photograph is a semicontrolled mosaic composed of two aerial photographs taken by Midwest Aerial Photographic Survey, Inc., 3401 NE 23rd St., Oklahoma City, on February 6, 1962.

On the photograph the length of the seismic profile discussed in the article is indicated by line S_1—S_2 along the road (see fig. 1, p. 261, this issue). Locations where shallow faulting was recorded by the refraction seismograph are indicated by short lines intersecting the road along the seismic profile. The angle of the intersection is coincident with the direction of the linears observable on the photograph. This photograph, with its high contrast, readily reveals the general trend of these linears. The linears in the seismic test area show definite coincidence with the shallow fault displacements found below the surface. The left half of the photograph discloses the existence of other linears, some with strong photocontrast effect. The latter were not tested by seismic methods. The linears tested with the refraction seismograph have an approximate direction of N35°E. Some of the linears in the left half of the photograph also have a similar trend.

Letters A and B on the photograph designate the locations of two wells. At A is the Pure Oil Co. N. J. Valouch 1, a producer. At B is the Trice Production Co. G. H. Fore 1, a dry hole. Both wells are represented in the electric-log cross section shown on page 262 of this issue.

—J. A. E. N. & J. L. K.

Conostichus, a Scyphomedusan Index Fossil

Carl C. Branson

The fossil scyphomedusan *Conostichus* is now firmly recorded from Pennsylvanian rocks of all series (Morrowan to Virgilian) and from the states of Ohio, Indiana, Illinois, Missouri, Iowa, Kansas, Arkansas, and Oklahoma. A species recorded as from Devonian of Bolivia is believed to occur in Pennsylvanian rocks (Branson, 1961).

Two specimens of medusid sand cast have been described and figured from Alaska (Imlay, 1961; p. 39, pl. 1. figs 1, 2, 9, 10) as *Kirklandia?* sp. The explanation of Imlay's plate 1 indicates that figures 1 and 2 are USNM 128592 from locality 25918 and that figures 9 and 10 are USNM 128591 from locality 25803. USNM 128591 is figured as figures 1 and 9 and the specimen is from the Torok Formation at USGS Mesozoic locality 25803. It was collected by Whittington. The specimen is a basal disk 27 mm in diameter and is a sand cast in fine gray quartzitic sandstone (pl. I, fig. 3).

Imlay illustrated USNM 128592 as figures 2 and 10. It is a sand cast preserved as brownish-gray fine-grained sandstone. The specimen is from the Kukpowruk Formation at USGS Mesozoic locality 25918 and was collected by R. S. Bickel. It is a basal disk 15 mm in diameter (pl. I, fig. 4). In a table (Imlay, 1961, p. 34) the locality is shown as yielding the worm tube *Ditrupa cornu* and adjacent localities as yielding an echinoid spine and *Entolium utokokense*.

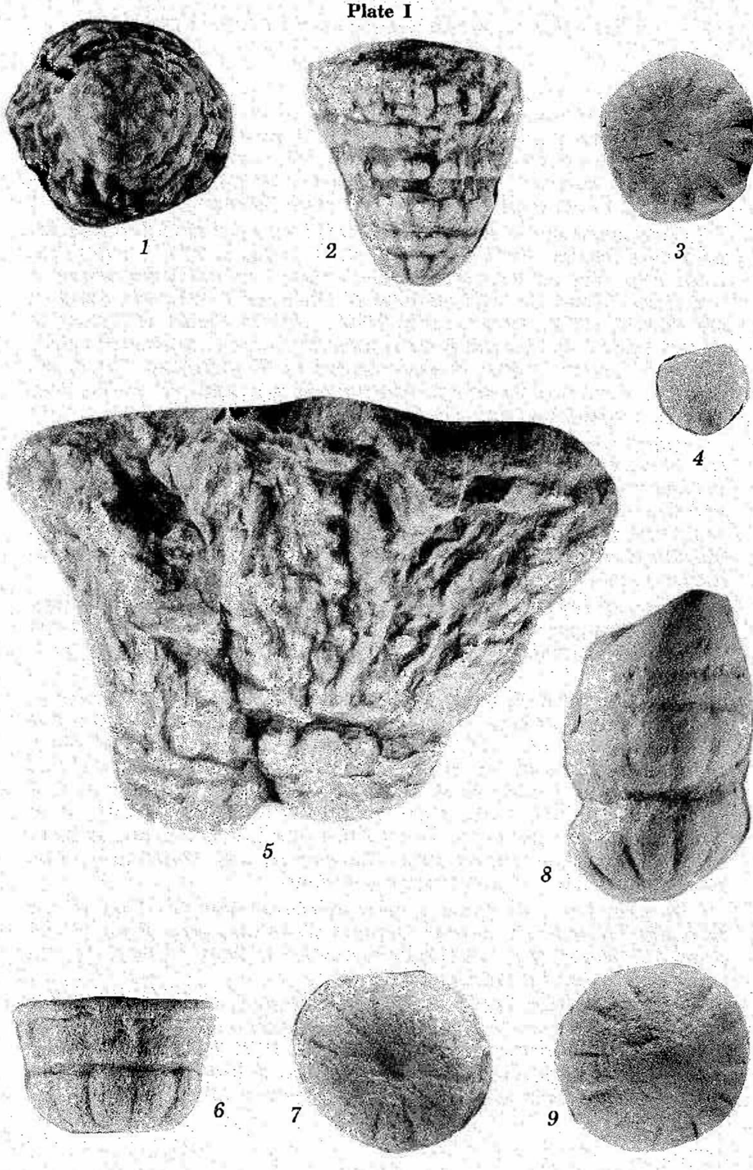
Each of these specimens is almost certainly *Conostichus* and they represent two species. It is probable that they occur in pebbles derived from Pennsylvanian rocks and redeposited in Lower Cretaceous clastics.

In May, 1962, Richard Stewart of the U. S. Geological Survey at the Ashland, Kentucky, office took me to two localities in the Lee Formation. The first of these is a deep gulley in the bed of which specimens of *Conostichus* are abundant below the ledge of the lowest sandstone. The locality is along Beauty Ridge, one mile southeast of Bethlehem Church, Portsmouth quadrangle, Greenup County, Kentucky. The other locality is on a refilled pipe-line trench and is about two miles from the first locality. The specimens are fluted cones with basal twelve-scalloped disk preserved on some.

Stewart has also found a poor specimen near the base of the Breathitt Formation in Carter County and a fluted cone about 15 feet above the base of the Conemaugh Formation in Boyd County. He lent me the specimens for examination.

Allen Graffham has sent a coarse-grained specimen with eroded disk and fluted cone from the Wapanucka Limestone, SE¼ sec. 8, T. 1 N., R. 7 E., Pontotoc County, Oklahoma. P. K. Sutherland found a coarse-grained specimen with weathered disk in beds of Desmoinesian age on the east slope of Jicarilla Peak, 12 miles south of Penasco, New Mexico.

Plate I



J. H. Quinn of the University of Arkansas continues to supply specimens of *Conostichus.* He found a large broad cone similar to *C. broadheadi* in float, probably from the Atoka, in sec. 6, T. 14 N., R. 29 W., Washington County, Arkansas. He found five moderate-sized cones, some with basal disk, in the Bloyd Formation about halfway between the Baldwin coal and the Kessler Limestone in SE¼ sec. 26, T. 14 N., R. 32 W., Washington County, Arkansas.

He sent specimens collected by R. H. Mapes and C. H. Vyles in the middle part of the Atoka Formation in the bluff on the Arkansas River in the southern part of Van Buren, Crawford County, Arkansas. One specimen (OU 5053) consists of two individuals interlocked, the disks touching and the fluted cone of one appearing to be embedded in the side of the other. They appear to belong to *C. quinni* (pl. I, fig. 5). Another specimen (OU 4892) sent by Quinn was collected by E. S. Hale in sec. 8, T. 3 N., R. 27 W., Scott County, Arkansas. The specimen was found in float, probably from the Atoka. In it the grooves of the basal disk are prominent and they extend well up the side of the cylindrical specimen (pl. I, figs. 8, 9). A specimen (OU 5052) composed of ferruginous sandstone was collected by Michael Barnes, about five miles south of Mansfield, Sebastian County, Arkansas, probably in the Atoka. It is a symmetrical, evenly grooved disk and two segments, and is similar to the specimen described above (pl. I, figs. 6, 7).

Quinn sent a fine specimen of *C. arkansanus* collected from the Bloyd along Highway 23 south of Huntsville, Madison County, Arkansas. The basal disk is steeply conical away from the truncated central area. The grooves are deep and extend up the steep sides of the disk onto successive segments and merge into the flutings of the side of the cone. The specimen is OU 5051 (pl. I, figs. 1, 2).

References Cited

Branson, C. C., 1961, New records of the scyphomedusan **Conostichus:** Okla. Geol. Survey, Okla. Geology Notes, vol. 21, p. 130-138.

Imlay, R. M., 1961 [1962?], Characteristic Lower Cretaceous megafossils from northern Alaska: U. S. Geol. Survey, Prof. Paper 335, 74 p., 20 pls.

Explanation of Plate I

Figures 1, 2. Conostichus arkansanus. **Lateral and basal views of a specimen from Bloyd Shale in Madison County, Arkansas. OU 5051.**

Figure 3. Basal disk of Conostichus sp.**, probably from a pebble in the Torok Formation on the south bank of Quartz Creek in northern Alaska. USNM 128591.**

Figure 4. Basal disk of Conostichus sp.**, probably from a pebble in the Kukpowruk Formation on the west bank of Utukok River, northern Alaska. USNM 128592.**

Figure 5. Conostichus quinni? **Lateral view of two closely packed individuals from the Atoka Shale at Van Buren, Arkansas. OU 5053.**

Figure 6, 7. Lateral and basal views of a specimen of Conostichus quinni? **from Atoka? in Sebastian County, Arkansas. OU 5052.**

Figures 8, 9. Lateral and basal views of a specimen of Conostichus quinni? **from Atoka? float in Scott County, Arkansas. OU 4892.**

(Photographs by William H. Bellis)

Pre-Pennsylvanian Rocks of Oklahoma

Louise Jordan

A map of Oklahoma showing the present distribution of surface and subsurface rocks older than Pennsylvanian was issued on August 27, 1962, by the Oklahoma Geological Survey. The map at a scale of 1:750,000 is in four colors on a black base which shows county boundaries, townships, and ranges. A geologic section shown at the base of the map extends from the Hollis basin of southwestern Oklahoma, northeastward through the Oklahoma City and Cushing oil fields to the northeastern corner of Craig County in northeastern Oklahoma. The colors are similar to those used on the *Geologic Map of Oklahoma,* that is , blue for Mississippian, purple for Devonian and Silurian, red for Ordovician. The Ordovician-Cambrian Arbuckle Group is not subdivided. A shade of brown is used for basement rocks which include those of probable Early or Middle Cambrian age as well as those of Precambrian age. Surface contacts and faults are shown as dashed lines, whereas those of the subsurface are solid lines. Figure 1 illustrates, at the printing scale, a portion of the central part of the map without the colors.

Notable geologic features revealed on the map by the removal of the overlying Pennsylvanian, Permian, or Cretaceous and younger rocks are:

1) The Central Oklahoma arch extending from the Pauls Valley-Hunton-Belton uplift northward to the northern boundary of the State where rocks of the lower part of the Mississippian System (Osage Group) are overlain by Middle Pennsylvanian (Des Moines) rocks. Faulted structures are present near the eastern and western boundaries of the arch. These structures are arranged in part en echelon along the Nemaha ridge where pre-Mississippian rocks underlie those of Pennsylvanian age (fig.1). Similar structures, Cushing and Terlton, are shown along the eastern boundary of the arch. Southwestward-trending faults along this boundary do not interrupt the mapped pattern and therefore are not shown.

2) The broad extent of basement rocks, of which the Wichita Mountains are but a small part, is bounded at the north and south by northwestward-trending fault zones.

3) The northwestward-trending faults which bound the Marietta basin.

4) The large subsurface extent of the Pauls Valley-Hunton-Belton and Arbuckle-Tishomingo uplifts.

Compilation of the map was conceived and begun in 1955 by Carl C. Branson, director of the Survey, and completed by Louise Jordan with the assistance of William H. Bellis and Tom L. Rowland. Many geologists and oil companies helped by giving information. The map was drafted by Roy D. Davis, chief geologic draftsman, assisted by Eileen Krall and Marion E. Clark.

The map, GM-5, is available at the price of $1.00 from the Oklahoma Geological Survey, Norman. It may be obtained flat in a roll, or folded in a 9.5-inch by 12-inch envelope.

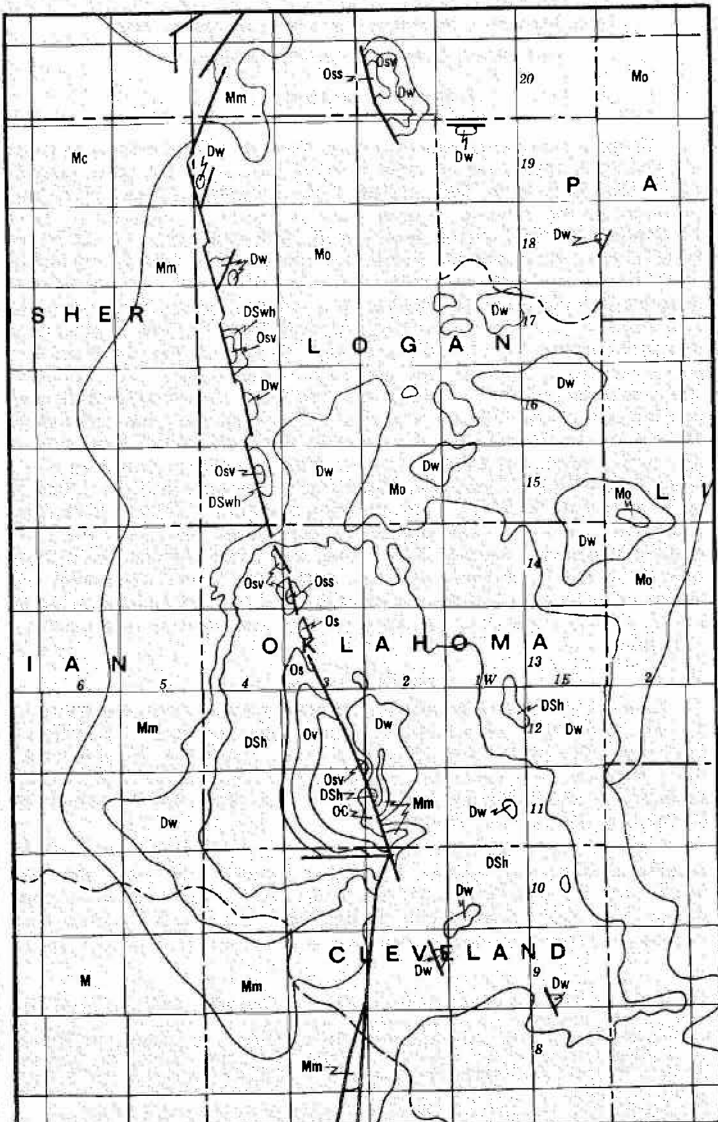


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Figure 1.

The Mineral Industry of Oklahoma in 1961*
(Advance Summary of Final Figures)

Robert B. McDougal†

Value of Oklahoma mineral production was $776.7 million in 1961; mineral fuels accounted for more than 94 percent of the total, according to the Bartlesville, Okla., office of the Bureau of Mines, U. S. Department of the Interior. Overall value of minerals produced in 75 of 77 counties was $4.3 million less than in 1960—the drop was due largely to adverse developments within the mineral fuels industry. Already under competitive pressure from other mineral fuels, the Oklahoma coal industry was significantly affected by a reduced transportation rate for coal shipped from Kentucky, Virginia, and West Virginia to steel centers in California and Utah. Nationally, Oklahoma was the third largest producer of natural gas and natural-gas liquids, and fourth in crude petroleum. Total construction (residential, nonresidential, and public works) established a record in 1961 as the value reached nearly $1.1 billion, an increase of 26 percent in 1961; residential construction was most important. Mining activity increased when American Zinc, Lead, & Smelting Co. and The Eagle-Picher Co. reopened their custom mills in March to receive lead and zinc ore from Tri-State producers. Lead and zinc output was affected by anticipated passage of the Government's subsidy program. In October, legislation was enacted to provide payment to small lead and zinc producers; however, funds for the program, to be administered by the Office of Minerals Exploration of the U. S. Department of the Interior, had not been appropriated by yearend.

MINERAL FUELS

Coal.—For the fourth consecutive year, output of coal decreased—in 1961, it dropped 23 percent in tonnage and 26 percent in value as compared with 1960. Coal shipments from Kentucky, Virginia, and West Virginia were made to California and Utah markets previously serviced by Oklahoma producers. Lone Star Steel Co. reopened its Carbon No. 5 mine near Hartshorne.

Natural gas.—Marketed natural gas decreased slightly from 1960. Anadarko basin, particularly Kingfisher County, was again the Nation's most active drilling area. A seventh gas-storage field, under construction in West Edmond field of Kingfisher and Logan Counties, will increase underground storage facilities in the State by 58 billion cubic

*This report, U. S. Bureau of Mines, Mineral Industry Surveys, Area Report IV-143, has been prepared under a cooperative agreement for the collection of mineral data, except mineral fuels, between the Bureau of Mines, U. S. Department of the Interior, and the Oklahoma Geological Survey, William E. Ham, Geologist. The report was prepared August 13, 1962. Preliminary figures were published in Area Report IV-135 which appeared in the March 1962 issue of the Oklahoma Geology Notes, pages 79-82.

†Geologist (Mineral Deposits), U. S. Bureau of Mines, Division of Mineral Resources, Region IV, Bartlesville, Oklahoma.

TABLE I.—MINERAL PRODUCTION IN OKLAHOMA[1]

Mineral	1960 Quantity	1960 Value (thousands)	1961 Quantity	1961 Value (thousands)
Clays[2] (thousand short tons)	734	$ 739	792	$ 801
Coal (thousand short tons)	1,342	9,113	1,032	6,784
Helium (thousand cubic feet)	289,068	4,691	313,244	5,872
Lead (recoverable content of ores, etc.) (short tons)	936	219	980	202
Natural gas (million cubic feet)	824,266	98,088	822,600[3]	98,712[3]
Natural gas liquids:				
Natural gasoline and cycle products (thousand gallons)	531,995	33,074	521,237	33,358
LP gases (thousand gallons)	762,258	32,409	817,082	30,141
Petroleum (crude—thousand 42-gallon barrels)	192,913	563,306	191,834[3]	558,237[3]
Salt (common) (thousand short tons)	3	16	3	19
Sand and gravel (thousand short tons)	6,424	7,468	5,310	5,513
Stone (thousand short tons)	14,054[4]	16,098[4]	14,981	16,561
Zinc (recoverable content of ores, etc.) (short tons)	2,332	602	3,148	724
Value of items that cannot be disclosed: Asphalt (native, 1960), bentonite, cement, gem stones (1960), gypsum, lime, pumice, stone (crushed granite, 1960), and tripoli	----	16,757	----	21,920
Total Oklahoma[5]	----	$780,942[6]	----	$776,669

[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producer).
[2]Excludes bentonite; included with "Value of items that cannot be disclosed."
[3]Preliminary figure.
[4]Excludes crushed granite; included with "Value of items that cannot be disclosed."
[5]Total adjusted to eliminate duplicating value of clays and stone.
[6]Revised figure.

feet. Current underground capacity in the six fields is 104.1 billion cubic feet of working-gas volume (above minimum working pressure).

Natural-gas liquids.—Recovery of natural-gas liquids by 67 natural-gasoline plants and 5 cycling plants totaled about 1.3 billion gallons, an increase of 3 percent over 1960. Proved recoverable reserves of natural-gas liquids were estimated at 329 million barrels on December 31.

Petroleum.—Crude petroleum produced in Oklahoma amounted to 191.8 million barrels, a slight drop from 1960. Estimated recoverable reserves of 1.8 billion barrels of petroleum remained unchanged. Total number of oil wells dropped from 83,594 in 1960 to 80,814 wells in 1961. Well-plugging by the U. S. Army Corps of Engineers, Tulsa District, on land to be inundated by the Oologah Reservoir in Rogers County, was responsible for the decline. Sixty-seven counties reported petroleum output of which Osage, Stephens, Carter, Garvin, and Creek

Counties led in order of value. Petroleum produced in Kingfisher County, valued about $13,790,400, was 386 percent greater than in 1960 and reflected increased activity in Anadarko basin. On January 1, 1961, Oklahoma had 15 refineries with a total daily capacity of 409,680 barrels of crude oil and 152,185 barrels of cracked gasoline.

HELIUM

Helium, extracted from natural gas at the Keyes helium plant, Texas County, increased 7 percent over the previous year. Under the Helium Act of 1960, the Federal Bureau of Mines increased the wholesale helium price from $19 to $35 per thousand cubic feet, effective November 18.

NONMETALS

The 10 nonmetals produced in 1961 were valued at $42.6 million—5 percent of the State's total mineral production value—an increase of 8 percent from 1960. Dewey Portland Cement Co., Division of American-Marietta Co., dedicated its new $12 million, 1.25 million-barrel-per-year cement plant northeast of Tulsa in June. Oklahoma Cement Co. revealed plans to double the capacity of its 1-million-barrel-per-year plant southeast of Pryor. In October, Dewey Portland Cement Co. ceased production of cement at its Dewey plant for the remainder of the year.

Cement.—Output of finished cement in 1961 increased 45 percent from 1960; shipments of cement into the State increased 19 percent in the same period.

Gypsum.—Gypsum output was 5 percent greater than in 1960, reflecting increased demand for gypsum building products. Most of the gypsum produced was used in manufacture of wallboard and plaster products; the remainder was used as soil conditioner and in portland cement.

Lime.—Lime produced from limestone in Sequoyah County rose 34 percent in 1961. The product was used by chemical plants in the Pryor area and by municipal water plants.

Sand and gravel.—Output of sand and gravel in 43 counties was 17 percent below 1960. Tulsa, Pontotoc, Johnston, Muskogee, Oklahoma, and Pushmataha Counties supplied 63 percent of the quantity and 74 percent of the total value.

Stone.—A 6-percent increase in 1961 was noted in output of stone, including limestone used for cement and lime. Tulsa, Comanche, Pontotoc, Murray, and Pittsburg Counties—the five leading stone producing counties in order of value—accounted for more than half of the stone quarried in Oklahoma.

Tripoli.—Tripoli output in eastern Ottawa County declined 14 percent.

METALS

Lead.—Many mines were reopened as small lead and zinc producers anticipated passage of the lead and zinc subsidy payment program. Though tonnage of recoverable lead mined in Ottawa County increased 5 percent, value dropped 8 percent as the lead market continued to be depressed.

Zinc.—Output of recoverable zinc in Ottawa County was 35 percent greater and the value 20 percent more than in 1960.

TRI-STATE DISTRICT

Depressed lead-zinc markets, which led to a general shutdown of all major mining operations in the Tri-State District in mid-1958, continued in 1961. However, amounts of lead and zinc concentrates recovered rose 5 percent and 20 percent, respectively, above 1960. Oklahoma produced 41 percent of the District's lead concentrate and 56 percent of its zinc concentrate; Kansas produced 59 percent of the District's lead concentrate and 44 percent of the zinc concentrate. No lead or zinc has been produced in the Missouri (southwest) portion of the Tri-State District since 1958.

New Theses Added to O. U. Geology Library

The following Master of Science theses have been added to The University of Oklahoma Geology Library during August 1962:

Areal geology of the Stanley Group (Mississippian) in northeastern Pushmataha County, Oklahoma, by Donald Dean Bradshaw.

Stratigraphy, petrology, and partial geochemistry of the Excello Shale, Pennsylvanian (Desmoinesian), of northeastern Oklahoma, by Martin M. Cassidy.

Isopach and lithofacies study of Virgilian and Missourian series of north-central Oklahoma, by James Warren Fambrough.

Subsurface geology of northern Lincoln County, Oklahoma, by D. Bryan Ferguson.

Areal geology of the Sentinel-Gotebo area, Kiowa and Washita Counties, Oklahoma, by Kenneth S. Johnson.

A subsurface study of the Fernvale and Viola Formations in the Oklahoma portion of the Arkoma basin, by Tom Mairs.

Headquarters Granite of the Wichita Mountains, Oklahoma, by Richard Alan Wasteneys.

A subsurface study of the Lower Tuscaloosa Formation (Cretaceous) in southern Mississippi, by H. Vaughan Watkins, Jr.

—L. F.

Geophysical Delineation of Fault Zones, South Norman Area, Cleveland County, Oklahoma

J. A. E. Norden, J. E. King, and G. O. McDaniel, Jr.

INTRODUCTION

Successful petroleum exploration near Norman, Oklahoma, during recent years has concentrated more effort and activity for the development of oil production in this area. The general geology and subsurface conditions in the vicinity of Norman have been studied and reported on by several geologists. In particular the work of Lynn Jacobsen (1949), R. W. Disney (1952), and C. E. Cronenwett (1956) furnished the information on stratigraphy and the structural relationship of this area. Recently G. O. McDaniel, Jr., in his Master's thesis, "Parameters of subsurface structural reconnaissance in the Simpson Group (Ordovician), south Norman area, Oklahoma" (1962), presented a study on the subsurface structural conditions and the relationships of the petroleum reservoirs controlled by faulting. This recent investigation of the fault systems in the South Norman area has been geophysically complemented by several profiles of vertical magnetic intensity surveys. The magnetic profile was first run across a known fault zone. The result of this survey encouraged the further use of the vertical magnetometer as a reconnaissance tool in the delineation of faulting.

PURPOSE OF THIS INVESTIGATION

Results of the vertical magnetic reconnaissance surveys across the fault zones in the South Norman area (McDaniel, 1962) directed attention to the possible application of other geophysical instruments for the detection of fault zones. A test profile was selected where subsurface well-log control indicated faulting and several geophysical surveys were made to investigate the resolving power of these methods for the detection of faulting in this area. The character, trend, and throw of the faulting have important bearing on the location of a fault-controlled petroleum reservoir. This is particularly true for the South Norman area. A geophysical test run in an east-west direction was chosen along the boundary between sections 7, 8, and 9 to the north and sections 18, 17, and 16 to the south, T. 8 N., R. 2 W. Cleveland County, Oklahoma (fig. 1). This test profile is 1.5 miles south of Norman, and the area is here called the South Norman area.

The profile line was selected to run along subsurface well ties with geologically known fault displacement between the wells. The wells which were correlated along this test profile are:

1. APCO Norman 1 (NE NE NE sec. 18, 8N, 2W)
2. Pure Oil Co., N. J. Valouch 1 (SE NW NW sec. 17, 8N, 2W)
3. Trice Prod. Co. G. H. Fore 1 (NW NW NE sec. 17, 8N, 2W)
4. Petr. Inc. Madole 1 (NE NW SW sec. 16, 8N, 2W.)

For reconnaissance a longer magnetic profile was run and for greater detail the magnetically indicated fault zone was checked by gravimetric and seismic-refraction profiles (fig. 1).

MAGNETIC PROFILE

Fourteen magnetic observation stations were established along the test profile. The survey was made with a Ruska Type V-3 Vertical Magnetometer, No. 5708. The instrument sensitivity was set to 10.01

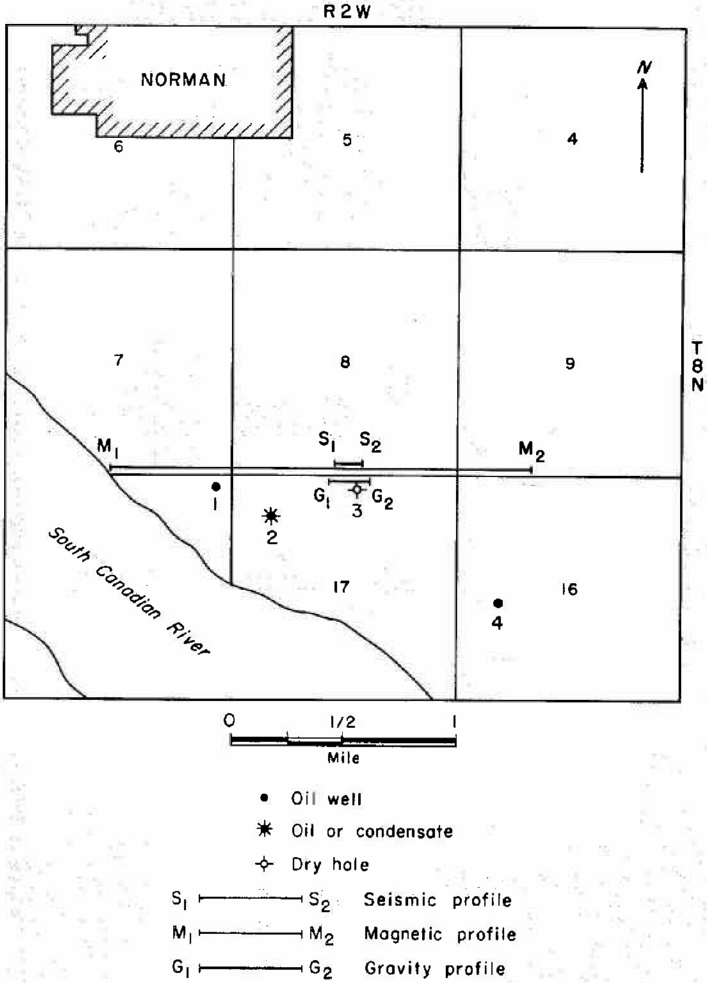

Figure 1. Location of map of South Norman area showing positions and lengths of geophysical profiles discussed in this report.

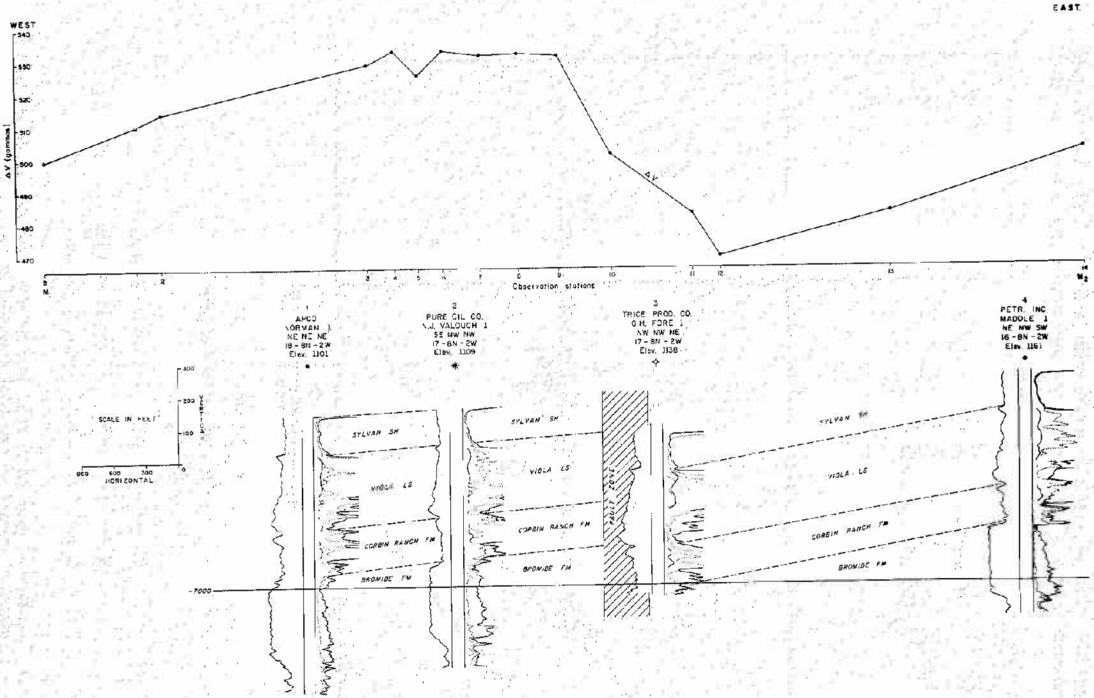

Figure 2. Profile of variation of vertical magnetic intensity (Δ V) along line M_1-M_2 of figure 1 and electric-log cross section of Upper Ordovician rocks in nearby wells.

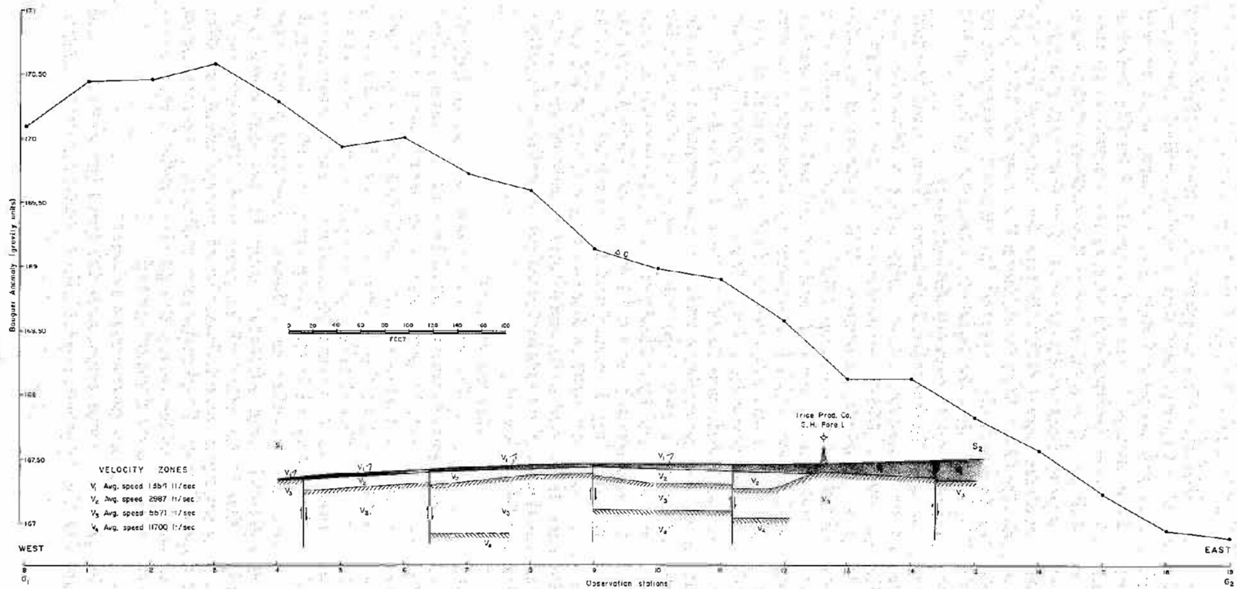

Figure 3. Gravity (Δ G) and seismic profiles across fault zone adjacent to Trice Production Co. G. H. Fore 1 dry hole. Ratio of horizontal to vertical scales of seismic profile is 1:1.

gammas per scale division. The temperature correction factor was +0.1 gamma per 1°C. Observed field data, after corrections for temperature, diurnal, and geomagnetic longitude variations, were plotted (fig. 2). The sudden change in vertical magnetic intensity between stations 9 and 12 is due to faulting indicated in the immediate vicinity of the dry hole (well 3). The total relief of this sudden vertical magnetic intensity change amounts to 62 gammas. For this magnetic relief the polarization contrast equals 0.000098 and the corresponding susceptibility contrast (for H= 0.558) would be in the range of 175×10^{-6}. This susceptibility is generally expected for igneous and/or metamorphic rocks. It is likely that the magnetic indication of faulting has a deep source represented by a basement displacement.

Surface exposures of the Permian Hennessey Shale along the profile were checked for magnetic susceptibility using a Magnetic Susceptibility Bridge, model MS-3, manufactured by the Geophysical Specialties Company, Hopkins, Minnesota. This instrument provides accurate measurements of rock susceptibilities, which are made in a magnetic field of the same order of magnitude as that of the earth's field. The field used in the MS-3 is produced by alternating current, and the instrument neither measures nor is affected by remanent magnetization (Geophysical Specialties Co., 1962). Susceptibility measured on the Hennessey Shale was found to be in the range of 29.3×10^{-6}, which is far too low in contrast with the one computed from the magnetic relief on the fault zone. One can assume, therefore, that the magnetic anomaly was caused by a displacement in the basement. This fact is verified by the magnitude of the throw on the Viola Limestone disclosed by electric logs (fig. 2, wells 2 and 3). The base of the Viola Limestone between these two wells is displaced by a throw of 150 feet. The throw between these two wells constitutes a zone of several displacements, as was disclosed by detailed gravimetric and seismic-refraction surveys across the fault zone.

GRAVITY PROFILE

A detailed gravimetric profile was run across the zone of tectonic displacement for closer fault location control because the casing effect of the nearby dry hole (well 3) prevented closer magnetic investigation. Nineteen gravimetric stations were established across the fault zone. The instrument used in this survey was a La Coste-Romberg Gravity Meter, no. 17. This detailed gravimetric survey required a topographic elevation control of one-inch accuracy. Field observations were reduced for the difference in the topography as well as longitudinal variations and are presented as a Bouguer anomaly profile (fig. 3). A 3.68 gravity-unit (368 microgal) drop to the east along the gravity profile is due to the effect of the fault zone. The decrease of gravity is not shown by a smooth line, but at several places steplike variations of approximately 75 microgals are indicated. To investigate these zones of steplike changes along the gravity profile a seismic refraction line was surveyed for detailed control.

SEISMIC-REFRACTION PROFILE

Twelve continuous seismic lines, each 100 feet long, were recorded by an Engineering Seismograph, model MD-1, made by the Geophysical Specialties Co., Minneapolis, Minnesota. The computed and correlated seismic-refraction horizons are plotted in figure 3.

Four seismic media were recognized:

V_1 medium, average velocity 1354 ft/sec

V_2 medium, average velocity 2987 ft/sec

V_3 medium, average velocity 5571 ft/sec

V_4 medium, average velocity 11700 ft/sec

Steplike changes in the gravimetric profile, when compared with the interpreted seismic-refraction plot, seem to correlate with the parts of the seismic section where faults were recorded. With a sledge hammer used for the source of energy, the penetration depth was 50 feet when a 200-foot line was applied. Throws recorded by stepup or stepdown times were computed to be in the magnitude of a few feet. A 9.35-foot throw was recorded, however, at one place on the west side of the seismic profile. The refraction seismic check furnished quantitative evidence of sets of faults within the fault zone indicated by the magnetic and gravimetric profiles. Because of the seismic evidence of faulting of the shallow subsurface beds of Permian age, it is possible that these shallow faults were developed as the result of secondary readjustment of the sediments above the faulted zone in the deeper beds, where, as previously mentioned, a 150-foot throw on the base of the Viola Limestone can be established. Thus the tectonic readjustment affected both Permian and Pennsylvanian beds across the unconformity. These readjustments may be regarded as a "rejuvenation" of pre-Pennsylvanian faulting with a reduced scale of displacement in the younger beds.

This secondary rejuvenation of faulting within the near-surface beds may have bearing in the development of linear trends recognized in aerial photographs. In fact, aerial photographs of the South Norman area definitely disclose this linear trend, and it has been verified that these fine strain lines cross the test profile where the refraction seismograph recorded the presence of shallow faults.

CONCLUSION

Detailed geophysical control on faulting in the South Norman area has revealed that both magnetic and gravimetric surveys may be useful as reconnaissance tools for the detection and delineation of fault zones.

Shallow refraction seismic control across the fault zone gave quantitative evidence for the upward continuation of faulting due to readjustment along fault lines of deeper origin.

Photogeologic linear trends in the South Norman area can be correlated with these shallow fault zones recorded by the refraction seismograph.

The economy and speed in this geophysical control of faults in the South Norman area, combined with the results obtained, fully warrant further application of these methods.

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Blaine County Bulletin Issued

Bulletin 89, *Geology and mineral resources of Blaine County, Oklahoma,* was issued September 18, 1962. The book consists of three parts and has 247 pages, 9 plates, 61 figures, and 14 tables. Plate I, *Geologic map of Blaine County,* is printed in full color at a scale of one inch to one mile and may be purchased separately from the Survey for $1.75. Plate IV, also in full color, is a map of surficial deposits, topographic contours on base of upland gravels, and geologic section of Blaine County. Both maps are by Dr. Robert O. Fay of the Survey.

Part I, *Stratigraphy and general geology of Blaine County,* was written by Dr. Fay and includes an appendix giving twenty-four measured stratigraphic sections. Part II, *Economic geology and petrology of gypsum and anhydrite in Blaine County,* is by Dr. William E. Ham of the Survey, and Part III, *Petroleum geology of Blaine County* was prepared by John T. Bado, geologist for the Gulf Oil Corporation, and Dr. Louise Jordan of the Survey.

The price of the book is $4.00 paper bound and $5.00 cloth bound. The published abstract is given below.

Blaine County, comprising nearly 1,000 square miles in central western Oklahoma, is a part of the Great Plains, ranging in elevation from 1,900 feet in the northwestern part to 1,100 feet in the northeastern part. The Cimarron, North Canadian, and Canadian Rivers flow southeastward through the county.

Part I.—Stratigraphy and general geology. The geologic section of Blaine County consists of 1,200 feet of Permian redbeds, chiefly of the Leonardian and Guadalupean Series, overlain by a thin veneer of unconsolidated Pleistocene deposits, generally less than 100 feet thick. In ascending order, the Permian rocks consist of the Cedar Hills Member of the Hennessey Shale (Leonardian), overlain by the El Reno Group (Guadalupean), which consists of the Flowerpot Shale, Blaine Formation, and Dog Creek Shale. The El Reno Group is overlain by the Whitehorse Group (Guadalupean), consisting of the Marlow Formation and overlying Rush Springs Sandstone. The overlying Cloud Chief Formation is here considered to

belong to the Guadalupean Series. All formations are conformable with beds above and below.

The Cedar Hills Member is a reddish-brown clay shale with some thin light greenish-gray siltstone beds, about 105 feet thick. The Flowerpot Shale is a 450-foot-thick reddish-brown silty blocky clay shale, with a southward-thickening wedge of Chickasha conglomerate, sandstone, and siltstone in the middle. The upper 50 feet of the Flowerpot Shale contains much gypsum. The Blaine Formation consists of 75 to 100 feet of rock containing four named massive gypsum members; three immediately underlain by named dolomite beds separated by unnamed sequences of reddish-brown gypsiferous silty clay shales: (ascending) Cedar Springs Dolomite (new name), Medicine Lodge Gypsum, Kingfisher Creek Gypsum (new name), Magpie Dolomite, Nescatunga Gypsum, Altona Dolomite, and Shimer Gypsum. The Dog Creek Shale is an even-bedded reddish-brown clay shale, 157-200 feet thick, with two prominent thin dolomite beds, named the Watonga and Southard Dolomites (new names), approximately 50 and 100 feet above the Altona Dolomite, respectively. The lower 50 feet of the Dog Creek Shale is highly gypsiferous. The Whitehorse Group is a moderate reddish-brown to reddish-orange fine-grained cross-bedded sandstone, subdivided by the Emanuel and Relay Creek Dolomite Beds of the Marlow Formation. The Marlow is approximately 100 feet thick, with the thin Emanuel Dolomite Bed at the top and the Relay Creek Dolomite about 20 feet below the Emanuel Dolomite. These dolomites are normally about one inch thick, except in the type area where they are a foot or more thick. The Rush Springs Sandstone is approximately 180 feet thick in northern Blaine County and 230 feet thick in southwestern Blaine County and adjacent Custer County. The Cloud Chief Formation consists of approximately 100 feet of fine-grained sandstone similar to the Whitehorse, the base being marked by a thin pinkish-white crinkly bedded dolomite, tentatively correlated as the Weatherford Dolomite. Near the top of the exposed Cloud Chief are several thick fine-grained white to pink to gray variegated dolomites.

The Pleistocene deposits consist of 100 feet or less of gravel, sand, silt, and clay deposited in three to five terraces along the main rivers. The high-terrace level of each river system contains volcanic ash of the Pearlette (Late Kansan) type. In each terrace level on either side of each river, there are thick deposits of gravel and sand on the northeastern side of the river and thin deposits of clay and silt on the southwestern side of the river.

The Permian beds dip about 14 feet per mile southwest and strike north-northwest in the northern part of the county and west-northwest in the southern part of the county, with many minor crenulations and terraces. A broad southwestward-plunging synclinal trough is probably present in the Canton area, and a southwestward-plunging nose is probably present in the Greenfield-Hitchcock area.

Part II.—Economic geology and petrology of gypsum and anhydrite. Blaine County is the center of gypsum mining in Oklahoma and is a leading source of high-purity gypsum and gypsum products in the United States. Cumulative recorded production within the state since 1894 is slightly more than 12 million tons, of which approximately 95 percent originated from gypsum members of the Blaine Formation in Blaine County. Three companies operating in the county—United States Gypsum Company, Universal Atlas Cement Company, and S. A. Walton and Son—produced an all-time record of 454,000 tons in 1960.

White, flat-lying beds of the Shimer and Nescatunga ledges are of equal commercial importance, each yielding about half the annual tonnage. They range in thickness from 8 to 15 feet, and are worked in open-face quarries after removal of 5 to 30 feet of shale overburden. Chemical analysis shows that the gypsum is 97.25 to 98.92 percent pure. It is processed to make plasters, wallboard, special cements, and fillers. Crude gypsum is used as portland-cement retarder and as a soil conditioner.

Reserves of gypsum, of the same chemical quality, and which are workable under the same conditions as that presently being mined, are estimated to be 280 million tons. At the 1960 rate of consumption these deposits would supply the United States demand for 19 years.

Anhydrite crops out in the lower half of the Nescatunga Member in the northern part of Blaine County, and has a workable surface reserve of 42 million tons. In subsurface, down to a total depth of 500 feet, the Nescatunga is anhydrite with an average thickness of 13 feet. Available by underground mining is a recoverable reserve of 2.9 billion tons, sufficient for unlimited large-scale production of anhydrite for future chemical use.

Thin-section and geochemical investigations show that all the gypsum of the Blaine Formation has been derived from the hydration of anhydrite. The anhydrite itself has passed through three stages of crystallization before being transformed into gypsum at the surface. It is judged to have been deposited as hemihydrate or gypsum, as the desiccation product of evaporating shallow seas. Conversion into anhydrite probably took place at slight depths below the sea floor, while the sediment was bathed with water rich in strontium and boron. The resulting anhydrite contains 1,475 ppm strontium and 72 ppm boron, each of which is absorbed or isomorphously present in the space lattice. On weathering and conversion into gypsum, the strontium and boron of the anhydrite are rejected by the gypsum space lattice but are retained in the gypsum rock as epigenetically formed discrete clusters of celestite, probertite, ulexite, and priceite. These minerals, together with dolomite, calcite, and thenardite, characterize the modern gypsum deposits.

Gypsum beds of the Blaine show three stages of crystal development. The first or incipient stage of gypsification results from the isolated sprouting of selenite porphyroblasts in anhydrite. They invariably retain oriented microscopic inclusions of anhydrite. The succeeding microgranular or alabaster stage, marked by crystalloblastic grains 20 to 50 microns in diameter, comprises about half the beds and probably is a direct replacement of anhydrite, whereas the latest stage consists of visibly crystalline panidiomorphic to idiomorphic selenite grains that evidently grew by recrystallization of the alabaster. The complex history of gypsum development is recorded by the presence of all three stages in single hand specimens.

Part III.—Petroleum geology. Since the discovery of commercial natural gas in 1956 in Northwest Okeene Field, northern Blaine County, six additional areas have been found with gas and gas-condensate production from reservoirs in Late Mississippian and Early and Middle Pennsylvanian rocks. Exploration of the county is still in its early stage and many townships have not yet had a significant exploration test. No field area has been delineated. Hydrocarbons are found in stratigraphic-type traps. Calculated open flow in initial potential tests ranges from 1 to 43 million cubic feet of gas per day.

Rocks of all systems, dipping gently southwestward toward the Anadarko syncline and penetrated by drilling for oil and gas, range in age from Early Ordovician to Late Permian. The rock section above the Hunton Group (Devonian-Silurian) ranges in thickness from 8,500 feet in the north to more than 13,000 feet in the southernmost townships. The top of the Arbuckle Group (Early Ordovician), penetrated at 9,700 feet in northeastern Blaine County, is believed to be at a depth of more than 18,500 feet below the land surface in the southwestern part of the county. Most of the drilled holes have not tested the rock sequence older than Late Mississippian.

Tulsa Rock and Gem Show

The Tulsa Rock and Mineral Society will present its second Rock and Gem Show on October 26, 27, and 28, 1962, in the Women's Building at the Tulsa State Fairgrounds. The first show, held two years ago, attracted about 6,000 visitors from 18 states and more than 50 cities in Oklahoma. Attendance this year may reach 15,000 people.

Individuals and dealers will display their collections of rocks, minerals, fossils, and jewelry. As many of the exhibits will be entered on a competitive basis, the quality of the specimens and the techniques of display should be excellent. This will be the first showing of the many well-preserved mastodon, camel, horse, bison, and saber-toothed tiger bones that were recently discovered in a Pleistocene deposit on the Verdigris River.

The Oklahoma Geological Survey is contributing a display of fossils commonly found in Oklahoma, and will also have a booth for the sale of its many publications.

Further information about the Rock and Gem Show can be obtained from the show chairman, James N. Slack, 1320 West Marshall, Tulsa, Oklahoma.

—K. S. J.

SUPPRESSION OF *Ethelocrinus texasensis*

HARRELL L. STRIMPLE

Moore and Plummer (1940, p. 381) directed attention to the close relationship between Texas specimens called *Ethelocrinus texasensis* Moore and Plummer (1940) and the Oklahoma species *Ethelocrinus oklahomensis* Moore and Plummer (1937). They noted: "The Brentwood species (*E. oklahomensis*) is about one-half as large as *E. texasensis*, is a little more smooth in outline, and, so far as known, constantly has two anals in the cup instead of having three as do some of the Texas forms." They were unable to discern any appreciable difference in surface ornamentation. They concluded that the Texas form was larger and was more primitive in having three instead of two anal plates.

Strimple (1940) identified a crown from the Wapanucka Formation as *E. oklahomensis*. Some of the plates were disarticulated and the cup was distorted but there was no question that all plates belonged to the same specimen. The species has only ten robust, biserial arms, whereas *Ethelocrinus*, which is also highly ornate, typically has 16 comparatively narrow, biserial arms. The species was referred to the genus *Metacromyocrinus* by Strimple (1961, p. 69). There now appears to be some question as to the wisdom of such a designation, although its removal from *Ethelocrinus* is not affected. New evidence in the form of several dorsal cups from the Brentwood Limestone Member, Bloyd Formation, Morrowan, exposed at Greenleaf and Ft. Gibson Lakes, discloses the existence of three anal plates within the cup. Although only two anal plates were within the cups of the two original type specimens, the new material is decidedly conspecific and this fact requires a modification of the specific concept of *Metacromyocrinus oklahomensis*. The Ft. Gibson Lake specimen is larger than that originally ascribed to the species but is only about two-thirds that of the Texas specimens.

Jack Hood, Tulsa, Oklahoma, collected several displaced slabs of the gray-green limestone that occurs high in the spillway of Greenleaf Lake, southeast of Braggs, Oklahoma, and allowed them to weather in his yard. He was recovering blastoids, but in the processing of the material, he obtained 18 dorsal cups of crinoids, which I purchased for this and subsequent studies.

The delicate surface ornamentation is preserved in this horizon by thin layers of gray-green clay. Nine of the specimens are identified as *Metacromyocrinus oklahomensis*. Of these, six specimens have three anal plates instead of two, and one specimen is too poorly preserved to show this character. All the specimens are smaller than the holotype. Two of the specimens having only two anal plates are much smaller than the average of the group, which means that the presence of three plates is not a youthful characteristic.

In one of the small specimens the radianal is in broad contact with the left posterior radial so that anal X is no longer in contact with the posterior basal. The position of RX in this specimen is indicated by a shallow notch for its reception between anal X and the right posterior radial in the arm-articulating areas. The plate has not been considered as a true cup element because it does not extend below the summit of the cup in the lateral wall of the cup. The posterior interradius of this specimen reflects a rather advanced condition. The species is somewhat variable in this respect. In most specimens in which the RX is present, it is a slender element and has a narrow juncture with the RA.

A specimen collected by L. R. Laudon, University of Wisconsin, in the abandoned quarry on the east side of Ft. Gibson Lake, east of Wagoner, Oklahoma, has three anal plates and is a rather large specimen with a width of 26.6 mm.

In view of the preceding evidence there is every reason to consider *Ethelocrinus texasensis* as conspecific with *Metacromyocrinus oklahomensis*. The presence of three anal plates suggests possible affinity with *Dicromyocrinus;* however, that genus has uniserial or cuneiform arms. In my proposed classification of the Cromyocrinidae (1961, p. 65) *Metacromyocrinus* was restricted to forms with two anal plates. For the present at least, it seems desirable to amend the generic concept to admit forms with three anal plates. This condition is included in what I have termed "Developmental Trend B" (Strimple, 1960, text-fig. 2).

As presently defined, the species *M. oklahomensis* has a wide range. The type locality is not definitely known although it is most likely Keough quarry, sec. 36, T. 16 N., R. 19 E., north of Ft. Gibson, Oklahoma.

According to Moore and Plummer, the holotype is in the paleontological collections of the Oklahoma Geological Survey and came from north of Muskogee. The present location of the holotype is in question, but a plastoholotype is in the collections of the Geology Department, State University of Iowa, Iowa City, Iowa. A paratype is reported as a calyx collected by R. Rose, with no data for locality or repository. Paratypes (separated plates) are listed as follows: Kansas University (radials) 41914a-f; (basals) 41914g-k; (IBB disk) 41914l, all from Keough quarry; Brentwood Limestone Member, Bloyd Formation, Morrowan, Pennsylvanian. Moore and Plummer also reported the species as occurring on Braggs Mountain, and in a road-cut on U. S. Highway 71 opposite Woolsey, Arkansas. Strimple (1940) reported the species from Canyon Creek in the east-central part of sec. 8, T. 1 N., R. 7 E., six miles southeast of Fittstown, Pontotoc County, Oklahoma, from shale in the lower part of the Wapanucka Formation, Morrowan. Disarticulated plates were also found by Strimple in the prolific exposure 900 feet north of SE cor. sec. 8, T. 1 N., R. 7 E., Stonewall quadrangle. This is location 28 of Morgan (1924), which he considered to be lower Wapanucka. The exposure is entirely covered by grass and weeds now but was prolific several years ago.

Moore and Plummer (1940) reported *Ethelocrinus texasensis* (= *Metacromyocrinus oklahomensis*) from the Marble Falls Limestone, Bend Group, Morrowan. The holotype and three paratypes were from 200 feet north of a cattle tank on the left side of the Wallace Creek road, about 11.5 miles southwest of San Saba, Texas (horizon about 10 feet above the base of the Marble Falls). A badly weathered specimen was reported 4 to 6 feet above the base of the Marble Falls Limestone on the Cherokee-Chappel road 0.1 mile northeast of the road fork near bench mark 1317, San Saba County, Texas.

All of the Texas specimens are in the Plummer Collection, "holotype," 11182, "paratype," 11181, 11182A, and 11181A, Bureau of Economic Geology, The University of Texas. Four hypotypes from the present study (Greenleaf Lake specimens) are in the paleontological collections, The University of Oklahoma, OU 5008. As previously noted, these are from rather high in the Brentwood Limestone Member, Bloyd Formation, Morrowan. Five hypotypes from the same exposure as that just given are deposited in the paleontological collections, State University of Iowa, SUI 10941. One hypotype, SUI 10940, is from the Brentwood Limestone, Bloyd Formation, Morrowan, of the abandoned quarry on the east side of Ft. Gibson Lake in SE¼ SE¼ sec. 31, T. 17 N., R. 19 E., Cherokee County, Oklahoma.

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