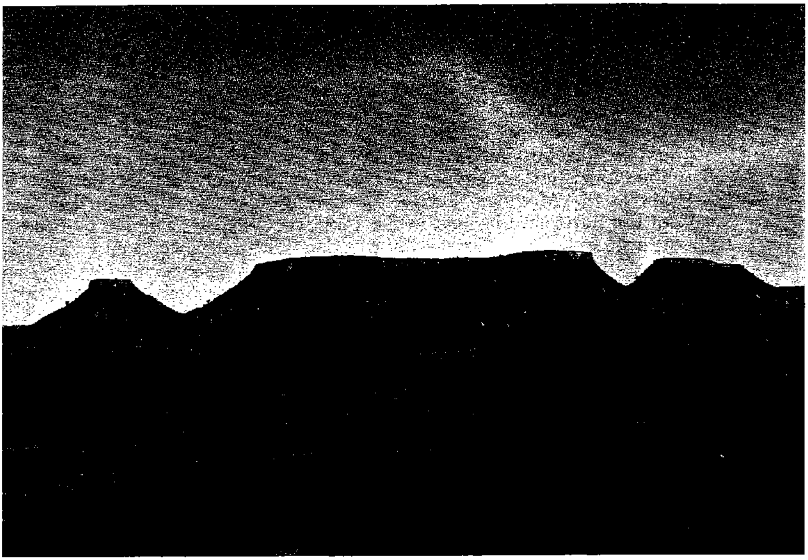
OKLAHOMA GEOLOGY NOTES

OKLAHOMA GEOLOGICAL SURVEY
THE UNIVERSITY OF OKLAHOMA • NORMAN, OKLAHOMA



$2.00 per year, $0.25 per copy

AUGUST 1963

Volume 23, Number 8

Cover Picture

PERMIAN ROCKS OF NORTHWESTERN OKLAHOMA

GYPSUM IN THE FLOWERPOT SHALE AND BLAINE FORMATION

Pictured on the cover are three of the numerous gypsum-capped buttes, which are common along the Cimarron River. These are in S½ sec. 27, T. 25 N., R. 17 W., northeastern Woodward County.

The cap rock of the buttes shown is the basal Medicine Lodge Gypsum Member of the Blaine Formation. It is a massive light-gray gypsum, approximately 26 feet thick. The high area at the left end of the center butte is capped by the Nescatunga Gypsum Member, 13 feet above the Medicine Lodge. Beneath the Medicine Lodge the slopes of the buttes are formed in the Flowerpot Shale, a maroon and reddish brown gypsiferous shale interbedded with silty shale and calcareous clay shale, of which approximately 120 feet is exposed. Gypsum beds in the Flowerpot Shale make it a relatively resistant rock, resulting in the formation of such topographic scenic features as Chimney Rock (located immediately to the right of the area in the photograph) and Stoney's Castle Rock.

Alabaster Caverns State Park, about 9 miles to the northwest of the area shown, has 4 known caves formed in the gypsum beds of the Blaine, the largest being Alabaster Cavern in the Medicine Lodge Gypsum. Blaine gypsum is quarried near Southard, Blaine County, for the manufacture of gypsum wallboards, laths, sheathing, and plaster.

The Blaine and Flowerpot Formations contain salt in the subsurface. Solution of the salt gives rise to salt springs along the Cimarron River and Buffalo Creek. During the summer months the water of the Cimarron sometimes becomes oversaturated with salt so that it precipitates out. Salt is extracted commercially from the Cimarron in T. 27 N., R. 19 W.

—A. J. M.

A NEW SPECIES OF *Graphiocrinus*

HARRELL L. STRIMPLE*

In a study of *Graphiocrinus stantonensis* Strimple, 1939, made by the author in 1962, it was noted that undescribed species were known from the Oologah Limestone Formation (Desmoinesian) of Tulsa County, Oklahoma, from the Wann Formation (Missourian) of Osage County, Oklahoma, and from the Bennett Shale Member, Red Eagle Formation, Lower Permian of Cowley County, Kansas. Subsequently the Oologah species was described as *Graphiocrinus deflectus* Strimple (1962b) and the Red Eagle species as *Graphiocrinus? kansasensis* Strimple (1963). The species from the Wann Formation is described below as *Graphiocrinus lineatus,* new species.

Genus *Graphiocrinus* de Koninck and LeHon, 1854

Graphiocrinus lineatus Strimple, new species

Figures 1-3

Graphiocrinus lineatus is represented in the collections by ten specimens, of which one is a nearly complete crown that is taken as the holotype. The other specimens are dorsal cups and are designated as paratypes. They are somewhat smaller than typical specimens of *Graphiocrinus stantonensis,* with which species they are associated in their type locality. Some specimens of *G. stantonensis* are smaller than typical specimens of *G. lineatus* yet retain the characters of mature forms other than increased length of primibrachs in young specimens.

The crown is long and slender. The dorsal cup is low, bowl-shaped, with a small shallow basal concavity. Five infrabasals are small, mildly downflared, and are mainly covered by the column. Five basals are of moderate size with their proximal extremities in the basal concavity but curving sharply upward to participate in the lateral walls of the cup. The posterior basal is longer than the other four and has an upper facet for the reception of the single anal plate. The basals are tumid and all sutures are sharply impressed.

The five radials are wide pentagonal plates, mildly tumid, with articular facets directed slightly outward. A well-defined outer ligament furrow is bounded by a faint outer ridge. The outer ligament pit, short and sharply invaginated, is bounded above by the straight transverse ridge. A pair of oblique furrows are well defined; the muscle areas are shallowly depressed; the outer muscular notch is not particularly deep, but the intermuscular area is strongly marked by a pair of pits. The single anal plate rests broadly upon the truncated posterior basal, with its upper two-thirds extending above the height of the cup as delineated by the transverse ridge. It is a hexagonal plate, rather

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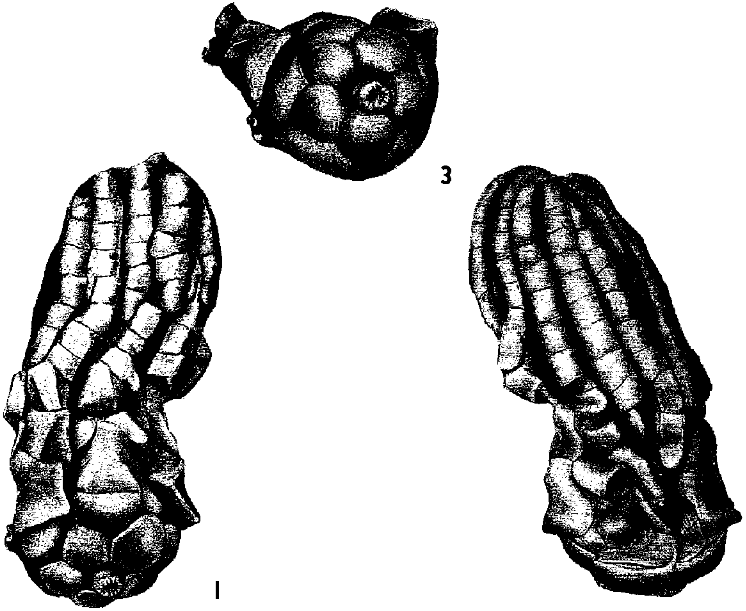

Figures 1-3. Graphiocrinus lineatus **Strimple, new species**

Holotype, ca. x3.1, viewed from left posterior, right anterior, and base.

narrow at the base, maximum width at summit of cup, and only slightly narrower at upper facet. The upper facet is short and has no appreciable impressions.

Ten arms are moderately long, slender, and uniserial. Bifurcation is with the first primibrach in all rays. The axillary primibrachs are slightly elongate and are mildly tumid at their apex. Each arm has about twelve or fifteen secundibrachs in the holotype, and these have moderately curved exteriors, as compared to the almost flattened surfaces of the coexistent *G. stantonensis* and *Apographiocrinus typicalis.* The arms taper only slightly.

The entire crown is covered by closely packed granules, which are visible under low magnification. In some paratypes dimplelike depressions, similar to those found in *Endelocrinus,* occur at the angles of the plates.

The column is moderately large, round, and pierced by a round lumen. Two or three proximal columnals are preserved with the holotype and reflect a pronounced surface curvature and strongly impressed sutures. The perimeter is marked by about fifteen short, well-defined crenulations.

Measurements in millimeters:

	HOLOTYPE
Length of crown (as preserved)	22.8
Length of arms	18.5
Height of dorsal cup	3.0
Width of dorsal cup (maximum)	8.0
Length of basal (left anterior)	2.9*
Width of basal (left anterior)	3.1*
Length of radial (anterior) to transverse ridge	3.0*
Width of radial (anterior)	4.8*
Maximum width of anal plate—approximate	2.7*
Diameter of proximal columnals	1.2

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*Along surface curvature.

Remarks.—*Graphiocrinus lineatus* is coexistent with *Graphiocrinus stantonensis* but is readily separable from it and other known species of the genus by the pronounced tumidity of the cup plates, the presence of a basal concavity, and the relatively narrow width of the arms with their rounded exteriors. The granulose surface of *G. lineatus* is coarser appearing than the typical ornamentation of the genus. The general contour of the cup and the tumidity of the plates are somewhat like that of the associated *Apographiocrinus typicalis* Moore and Plummer. The latter species has a smooth surface, the anal plate is faceted for reception of two tube plates, and distinctive projections are between the radial articular facets.

Pennsylvanian representatives of *Graphiocrinus* are characterized by the absence of a distinct basal concavity. The type species, *G. encrinoides* de Koninck and LeHon, is Mississippian in age and has a pronounced basal invagination, which is an "advanced" condition (as in *G. lineatus*), but the arm segments have almost perfectly parallel horizontal sutures, which is a "primitive" condition (the sutures are oblique in *G. lineatus*).

The Permian species, *Graphiocrinus*? *kansasensis,* has upflared infrabasals, which may reflect a retrogressive trend. Progressive evolution is generally considered to be from a cone-shaped (upflared infrabasals) to flat-bottomed (subhorizontal infrabasals) to invaginated base (downflared infrabasals).

The specific name comes from the Latin adjective *lineatus, a, um,* meaning linear.

Occurrence.— The horizon is a local weak sandy limestone within the Wann Formation, Ochelata Group, Missouri Series, Pennsylvanian, near C S½ sec. 15, T. 25 N., R. 12 E., Osage County, Oklahoma.

Types.—Holotype, SUI 11244, paratype, SUI 11246, and paratypes (four), SUI 11245, are in the geology repository, State University of Iowa, Iowa City. One paratype is to be deposited in the Springer Collection, U. S. National Museum, Washington, D. C. Paratype OU 5190 is in the paleontological collections, The University of Oklahoma, Norman.

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———— 1963, Class Crinoidea, in Mudge, M. R., and Yochelson, E. L., Stratigraphy and paleontology of the uppermost Pennsylvanian and lowermost Permian rocks in Kansas: U. S. Geol. Survey, Prof. Paper 323, p. 67-73.

CHONETID BRACHIOPODS IN OKLAHOMA

CARL C. BRANSON

Dr. Helen Muir-Wood has written an authoritative and important contribution to understanding of the concavoconvex and planoconvex brachiopods with hinge spines. They are placed in the suborder Chonetoidea and into two superfamilies, although the dual classification is obscured by an error in page make-up on page 30. The superfamily Chonetacea ranges from Upper Ordovician or Lower Silurian to Upper Permian.

Although the name *Chonetes* was given by Fischer in 1830 and the form was described by him in 1837, no recognizable data were given before those of de Koninck in 1842. The type species, *Terebratulites sarcinulatus* Schlotheim, Lower Devonian, was selected by de Verneuil in 1845. The genus ranges from Lower Devonian to Lower Mississippian, but is not certainly known in North America.

Anopliopsis Girty, 1938, is a monotypical genus, the species *A. subcarinata* having been described from the Fort Payne of Tennessee and recorded from the Moorefield of Oklahoma.

Chonetina is a poorly understood genus of the Permian, which has been erroneously recorded from Oklahoma Pennsylvanian rocks. To *Rugosochonetes* are assigned 17 Mississippian species, including *R. burlingtonensis* and *R. chesterensis*, the latter recorded from the Hindsville and Fayetteville of Oklahoma (Huffman, 1958, p. 63, 68).

Dyoros is from the Texas Leonardian and Wordian.

Eolissochonetes was established by Hoare in 1960 for the species *Chonetes laevis* Keyes, 1888 (homonym of *Chonetes laevis* Davidson, 1866). Muir-Wood gives the replacement name *E. keyesi* to the species. She left *E. bilobatus* Hoare in the genus. *E. keyesi* was described from the Des Moines of Iowa and has been recorded (probably mistakenly) from the Morrow Group in Oklahoma.

OKLAHOMA GEOLOGISTS AND GEOPHYSICISTS IN 1963

CARL C. BRANSON

The continued weak condition of the petroleum industry, a weakness first apparent in 1957, has resulted in a decline in number of geologists and geophysicists in the State. In 1960 the Oklahoma Geological Survey printed a directory of these people. Between 1960 and the present 344 have left the State, 8 are known to have died, and the names of 349 others no longer appear on membership lists of societies. New to the State are 383, leaving a net loss of 318 and a present number of 1,844.

In 1957, presumably the peak year, it was estimated that there were 1,983 geologists and geophysicists in Oklahoma, the estimate based upon 3,967 memberships in societies and upon assumed average of two memberships per person. Since 1957 the Shawnee Geological Society and the Okmulgee Geological and Engineering Society have disbanded.

Many men have left the profession, and not by any means all of them weak ones. Of those traced, three own motels, two are with the FBI, three are in insurance, one operates a gasoline bulk plant, two are in the ministry, three are in banking, three are in history of science, and two are building contractors. Of course, some of the girls are now housewives and mothers.

An analysis of the AAPG 1963 membership list shows that 154 men have dropped membership, 220 have left Oklahoma, 95 have

TABLE I.—GEOGRAPHIC DISTRIBUTION OF OKLAHOMA GEOLOGISTS AND GEOPHYSICISTS BY CITIES

	TULSA	OKLAHOMA CITY	NORMAN	PONCA CITY	BARTLESVILLE	ARDMORE	OTHER
Geological Society of America							
Fellows	24	2	9	1	3	0	1
Members	41	27	9	7	5	2	9
American Association of Petroleum Geologists	494	467	44	17	96	63	117
Society of Economic Paleontologists and Mineralogists	42	17	15	4	5	6	3
Society of Exploration Geophysicists	280	93	2	38	45	14	35
Paleontological Society	14	5	13	0	0	1	0
Society of Vertebrate Paleontologists	1	2	3	0	0	0	1
	896	613	95	67	154	86	166

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TABLE II.—CHANGES IN SOCIETY MEMBERSHIPS IN OKLAHOMA

	1957	1961	1963
American Association of Petroleum Geologists	1,259		1,298
Geological Society of America	125		140
Society of Economic Paleontologists and Mineralogists	74		92
Society of Exploration Geophysicists	391		507
Paleontological Society	23	24	33
Society of Vertebrate Paleontologists	4	7	
Tulsa Geological Society	666	515	
Geophysical Society of Tulsa	401	404	
Oklahoma City Geological Society	697	733	
Geophysical Society of Oklahoma City	98	92	
Ardmore Geological Society	159		106
Shawnee Geological Society	40		0
Okmulgee Geological and Engineering Society	30		0

changed company affiliation, 222 have come into Oklahoma, and 8 have died. Somewhat astonishingly, 869 of the total have made no changes except in city or address. AAPG now has 1,298 members in Oklahoma, an increase of 39 in six years. The Ardmore Geological Society has lost a third of its members, the Society of Exploration Geophysicists has gained 20 percent in Oklahoma, the Geological Society of America has gained 22 members and lost 7 Fellows, and the Society of Vertebrate Paleontologists has increased its State membership 75 percent (from 4 to 7).

The number of geologists and geophysicists in Oklahoma will probably continue to drop for years to come. The drop may not be so much from the poor condition of exploration work as from shortage of available employees. Universities of the area have less than 10 percent of the normal number of students. Interviewers will find short lists of names this coming year and for at least five years to come.

Sources Used

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Paleontological Society
Membership of the Paleontological Society: Jour. Paleontology, vol. 37, p. 728-745, May 1963.

Society of Exploration Geophysicists
Alphabetical membership list, p. 9-140, Geophysical membership list, p. 145-169, as of Oct. 15, 1961: Soc. Exploration Geophysicists, Yearbook, 1963.

Ardmore Geological Society
1963 directory, 20 p., 1963.

Oklahoma City Geological Society
1962 annual membership photo-directory of the Oklahoma City Geological Society and the Geophysical Society of Oklahoma City, 102 p., 1962.

Geological Society of America
Membership list of the Geological Society of America, corrected to March 15, 1962, 125 p., August 1962.

American Association of Petroleum Geologists
Membership directory: Amer. Assoc. Petroleum Geologists, Bull., vol. 47, p. 3-215, March 1963.

Tulsa Geological Society and Geophysical Society of Tulsa
1960-1961 joint directory, 154 p., 1961(?).

Anadarko Basin Logs to be Published

Guide Book XIII, *Sample descriptions and correlations for wells on a cross section from Barber County, Kansas, to Caddo County, Oklahoma,* will be published by the Oklahoma Geological Survey in August. The book is a supplement to U. S. Geological Survey Oil and Gas Investigations Chart OC-61, which is a graphic cross section based upon the descriptions given in Guide Book XIII. The work is by W. L. Adkison and Mary G. Sheldon and consists of detailed lithologic descriptions of 19 wells. The book may be ordered from the Survey, $3.50 paperbound.

The wells described are:

KANSAS—

1. Pure Oil Co., 1 W. Palmer, sec. 10, T. 33 S., R. 10 W.
2. Harbar Drilling and Atlantic Refining Co., 1 Knorp, sec. 27, T. 34 S., R. 10 W.

OKLAHOMA—

3. Ohio Oil Co., 1 W. O. Parr, sec. 9, T. 28 N., R. 10 W.
4. Olson Drilling Co., 1 Atchison, sec. 12, T. 24 N., R. 11 W.
5. Superior Oil Co., 28-22 Schultz, sec. 22, T. 23 N., R. 10 W.
6. Superior Oil Co., 41-27 Manning, sec. 27, T. 22 N., R. 10 W.
7. Superior Oil Co., 63-30 Fuller, sec. 30, T. 21 N., R. 10 W.
8. Superior Oil Co., 81-17 H. W. Norris, sec. 17, T. 19 N., R. 10 W.
9. Atlantic Refining Co., 1 Vilhauer, sec. 22, T. 18 N., R. 9 W.
10. Galt-Brown Co., 1 Campbell, sec. 6, T. 16 N., R. 7 W.
11. Camco Oil and Trust Co., 1 F. Parrington, sec. 14, T. 15 N., R. 8 W.
12. Ramsey Petroleum Co., 1 Mansfield, sec. 16, T. 14 N., R. 9 W.
13. Exploration Oil and Gas Co., 1 E. Hadlock, sec. 30, T. 13 N., R. 9 W.
14. Cities Service Oil Co., 1 Petree Ranch, sec. 18, T. 11 N., R. 8 W.
15. Denver Producing and Refining Co., 1 School Land, sec. 16, T. 10 N., R. 9 W.
16. Denver Producing and Refining Co., 1 Sah-Cam, sec. 33, T. 10 N., R. 10 W.
17. Superior Oil Co., 51-11 Weller, sec. 11, T. 8 N., R. 12 W.
18. Sinclair Prairie Oil Co., 1 German, sec. 1, T. 6 N., R. 13 W.
19. Amerada Petroleum Co., 1 M. Silverhorn, sec. 24, T. 6 N., R. 13 W.

PROGRESS OF TOPOGRAPHIC MAPPING IN OKLAHOMA

CARL C. BRANSON

Topographic maps, virtually all made by U. S. Geological Survey, Topographic Branch, are useful (almost necessary) in the work of highway builders, city planners, geologists, irrigators, tax assessors, and many others.

It would require 317 quadrangle maps to cover Oklahoma at the 1:62,500 scale (approximately one inch to one mile). Through 1958, 55 had been published; by 1963, 97 had been published and 15 were in progress. However, standards have changed and only a scale of 1:24,000 (approximately 2½ inches to the mile) is considered adequate. By 1958, 48 of these quadrangle maps had been published. By June 1963, 114 maps had been published, 118 were being made. Complete State coverage would consist of 1,157 quadrangles and 60 border quadrangles, less than half of each area in Oklahoma.

A report of the U. S. Geological Survey, State Summary, November 1962, stated that of the 69,283 square miles of the State, 6,773 (10 percent) are mapped on the 1:24,000 scale; 18,626 square miles on the 1:62,500 scale. Considering duplications, the percentage of the State mapped was 32. At the current rate the mapping will be completed in some far-off year.

The only county completely mapped on the 1:24,000 scale is Tulsa. On the 1:62,500 scale, Beckham, Washita, and Lincoln Counties are complete. Maps on both scales cover Oklahoma County. When present projects are completed, Custer, Roger Mills, Cotton, Marshall, Cleveland, Comanche, Pottawatomie, and McClain Counties will be completely mapped, McClain and Cleveland on the 1:24,000 scale. At this time no map has been published or is scheduled for any part of Adair, Craig, Nowata, Grant, Woods, Woodward, Harper, Beaver, Texas, and Cimarron Counties.

The present status of topographic mapping in Oklahoma is summarized in figure 1. Omitted from the illustration are 30-minute quadrangles (scale, 1:125,000) published between 1887 and 1916. These number 37 and cover most of the eastern and south-central parts of the State and are only partly superseded by newer maps. Thirty-minute quadrangles covering eastern Oklahoma (E of long. 96°30′) are: Pawhuska, Nowata, Vinita, Wyandotte (Okla.-Ark.), Hominy, Claremore, Pryor, Siloam Springs (Okla.-Ark.), Nuyaka, Okmulgee, Tahlequah (Okla.-Ark.), Winslow (Okla.-Ark.), Wewoka, Canadian, Sans Bois, Sallisaw, Coalgate, McAlester, Tuskahoma, Winding Stair, Poteau Mountain (Okla.-Ark.), Atoka, Antlers, Alikchi, Lukfata, and DeQueen (Okla.-Ark.).

The area of the south-central part of the State (between longs. 96°30′ and 98°) is covered by the following 30-minute quadrangles: Kingfisher, Chickasha, Rush Springs, Pauls Valley, Stonewall, Adding-

(text continued on page 202)

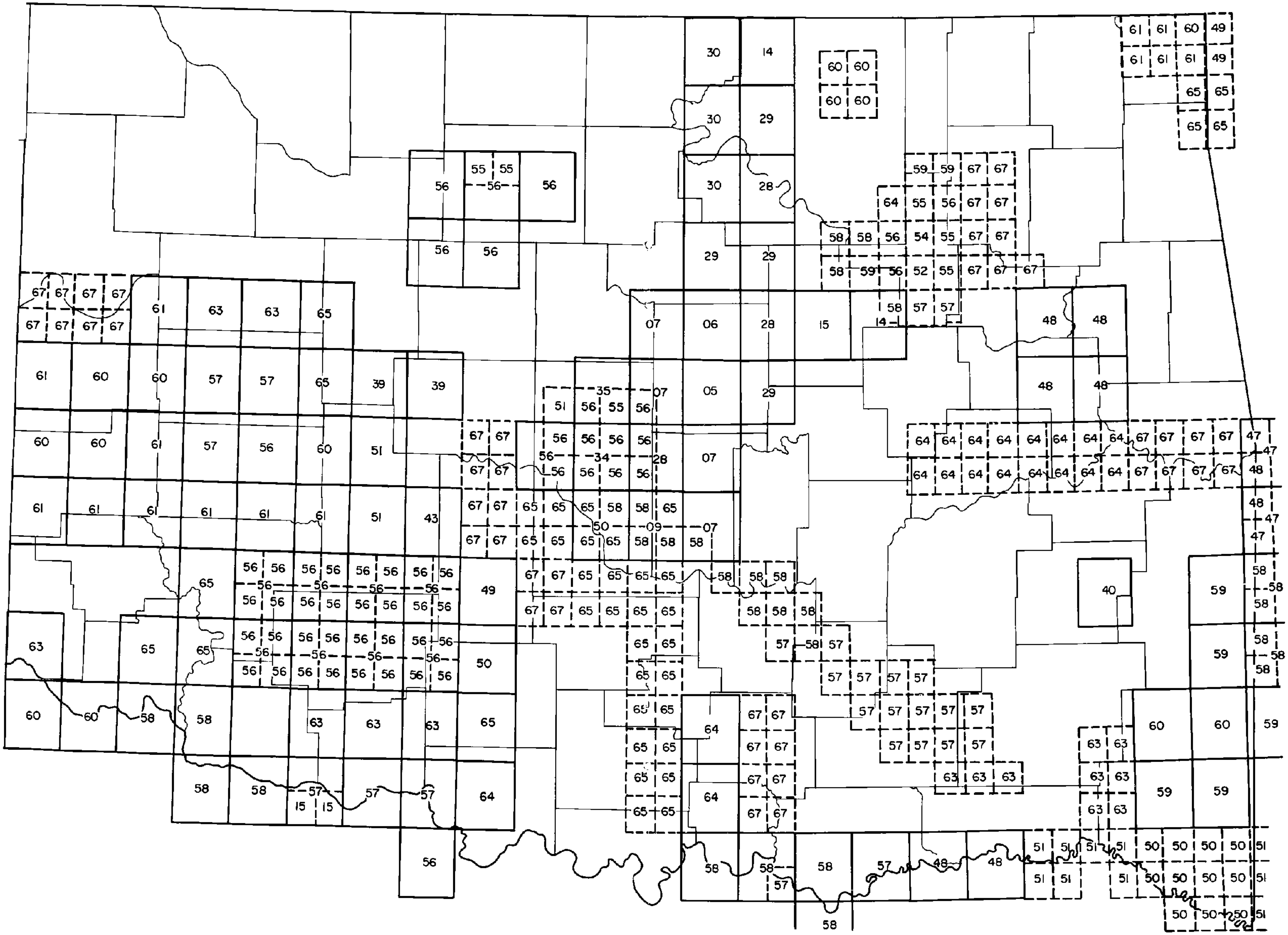

Figure 1. Current status of topographic mapping in Oklahoma. Only 15-minute quadrangles (scale, 1:62,500; outlined by solid lines) and 7½-minute quadrangles (scale, 1:24,000 outlined by dashed lines) are shown. Numbers indicate year completed or year of expected completion.

ton, Ardmore, Tishomingo, Montague (Okla.-Texas), Gainesville (Okla.-Texas), and Denison (Okla.-Texas).

Mapping is accomplished best by match-funds cooperation, as was done by Oklahoma City Metropolitan Commission (12 quadrangles), Tulsa Metropolitan Commission (17 quadrangles), and Oklahoma City Water District (28 quadrangles). Otherwise priorities are determined by Federal agencies, and all current projects are of this type. Early this year an Oklahoma Mapping Advisory Committee was activated under the chairmanship of Frank D. Lyons, Director, Oklahoma Highway Commission. Formation of the committee was requested by Daniel Kennedy, Central Region Engineer, U. S. Geological Survey, and the existence of the committee assures that needs of State agencies will be known.

Minerals of Oklahoma

A recently issued privately published book, *Minerals of Oklahoma,* will be of particular interest to Oklahoma rockhounds and rockhounding geologists. The book is the work of E. L. Gilmore, veteran Oklahoma collector, who compiled the information during a 7-year period from Oklahoma Geological Survey publications and other scientific papers, as well as from his own observations and those of his fellow collectors. The book contains 77 pages, listing 675 localities and 124 mineral species from 73 counties in the State. It is conveniently arranged with mineral species listed alphabetically, the description and collecting localities being given under each species. A cross-index in the back of the book is a list of occurrences by counties. Copies may be purchased from the author, 1206 W. 19th St., Tulsa, Oklahoma. Price: $2.50 paperbound.

SUBSIDENCE STRUCTURES IN NORTHWESTERN ARKANSAS

JAMES HARRISON QUINN*

Unusual geological features in northwestern Arkansas appear in some places as small, steeply dipping ovoid synclinal structures oriented in a northeasterly direction and in other places as narrow grabens oriented east-west (fig. 1). The synclinal forms may be 2,000 feet wide and 1 mile long. The grabens are as much as 25 miles long and fractions of a mile wide. In both, displacement may reach 300 feet or more. The ovoid structures are aligned along a series of synclinal axes which trend about N35°E (Quinn, 1959, p. 29). Strata may be inclined as much as 90°, but in most places dips are from 15° to 30°. The beds in the grabens dip steeply also and the structures appear as

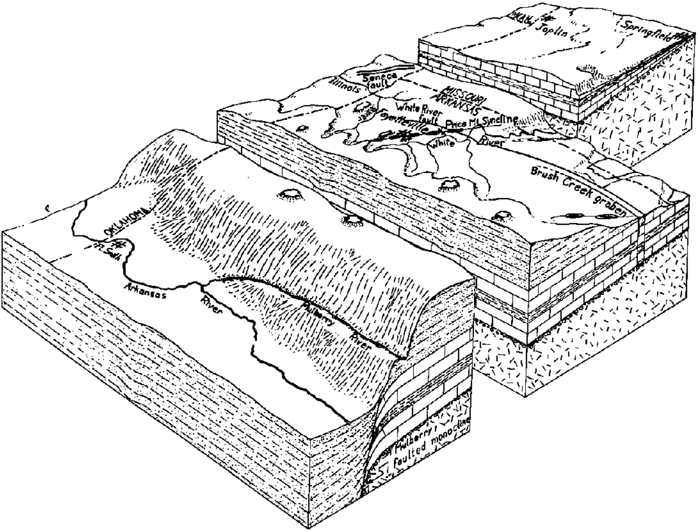

Figure 1. Block diagram of northwestern Arkansas illustrating stratigraphy, structure, physiography, and geography of the area. The Oklahoma-Arkansas state line trends nearly north-south.
(Prepared by L. E. Poole, McAlester Fuel Co.)

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*Department of Geology, University of Arkansas.

synclinal grabens (Croneis, 1930, p. 206). Some structures are symmetrical but many are intricately folded and faulted (fig. 2). Blocks of strata are unequally lowered so that along a creek traversing one of the synclinal structures the stream flows alternately on beds of Hale, Winslow, Hale, and Fayetteville age all within a single mile. Rocks involved in the disturbed areas are considerably weathered (fig. 3). This condition, coupled with absence of comparable anticlinal folds, has led to the hypothesis that the features are products of gradual and relatively uniform subsidence induced by solution of limestone in deep-seated calcareous strata. For this reason the features are termed subsidence structures rather than collapse structures.

Both the grabens and the synclines are of relatively recent origin because the rocks are excessively jointed and broken but neither joints nor fault planes have been extensively recemented. Presence of limestone strata at and near the surface within the structures does not preclude removal of calcareous deposits at depth. Alignment of the subsidence features along the axis of Price Mountain fault and syncline (Croneis, 1930, p. 190, 202), including the Glade Creek fault to the northeast and the Onda and Cove Creek faults to the southwest, presents the possibility that the displacement is due to diastrophic rather than erosional causes; however, the faults are related to—or younger than—the subsidence structures.

The sedimentary strata of northwestern Arkansas include a considerable amount of limestone and rest on an igneous basement complex of Precambrian rocks (fig. 1) more or less covered with a blanket of weathered detritus. Lower Paleozoic rocks include sandstone units as well as calcareous deposits, and these are interbedded with some extensive shale units. The igneous complex lies near the surface in southwestern Missouri but is progressively more deeply buried to the south because its surface dips an average of 1.5° in that direction.* In the southern Missouri area the elevation of the surface is 1,200 to 1,500 feet above sea level. In the Arkansas Valley surface elevations are about 500 feet above sea level, or 800 to 1,000 feet lower than those in southern Missouri. Strata cropping out in southern Missouri would be as much as 10,000 feet below sea level in the Arkansas Valley. Wells in the Arkansas Valley drilled to these strata, which may confine meteoric water in the form of a potential artesian system, should enable entrapped water to escape to the surface. Any natural path of escape, such as fractures, also might permit relatively active flow along a suitable trend from north to south. The flow in turn might promote deep-seated solution and removal of calcareous material resulting in localized subsidence.

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*About 21 miles south of the Missouri border the granite is approximately 530 feet below sea level. At the southern border of Washington County it is 3,021 feet below sea level. Halfway across Crawford County it is 5,875 feet. In northern Sebastian County it is 10,545 feet. In these estimates depth from the Everton Formation to the basement is calculated at 2,545 feet. The figure is obtained by averaging the thickness of each formation (Caplan, 1957, p. 10).

Rates of dip are about 1° for the northern part, less than 2.5° for the middle part, and nearly 3° for the southern part, or an average of 1.5°.

Siebenthal (1915, p. 33-38) proposed an artesian system as an explanation for the source of minerals in the Tri-State area. He suggested that the Chattanooga Shale caps the southwestern axial prolongation of the Ozark dome. Water enters Ordovician-Cambrian strata in the outcrop area on the crest of the dome and flows southward (and westward) down the dip of the strata where it may escape through artesian wells by way of faults or in places where the shale is missing. Siebenthal (1908, p. 197-198) had earlier discussed the Seneca fault (fig. 1) in northeastern Oklahoma as "double and in places multiple letting down a long narrow block . . . the strata for some distance, in places for a mile or two on either side dip towards the fault . . . the amount of throw is variable in short distances . . . the fault line coincides . . . closely with the drainage lines . . . The width of the down-dropped block ranges from less than 200 feet to more than 1,500 feet . . . The amount of displacement [ranges from] . . . 90 . . . to 140 feet." Distribution of minerals in the Seneca fault area suggests that the structure was formed at or before the time of mineral emplacement. Also the fault serves as a barrier to deep-seated movement of water, indicating that the disturbance extends to the base of the sedimentary column. That the Seneca fault structure, or graben, is a product of solution of calcareous material at depth and concomitant subsidence of the section probably along the axis of an already existing syncline is indicated. The mineralization is suggestive of greater age or earlier subsidence of Seneca graben compared to those of northwestern Arkansas.

The synclinal folds in northwestern Arkansas are associated with comparable anticlines and occur in subsurface rocks in the Boston Mountains area. In orientation they are approximately parallel to the Seneca structure. The Arkansas folds (Quinn, 1959, p. 29) seemingly were formed in Morrowan time and buried beneath Atokan and possibly Winslow strata. Because the folds seem asymmetrical with the steepest flank to the southeast, they may have been produced by relative movement of the basement complex toward the north or northwest and the folds may extend to or into these Precambrian rocks. Under the circumstances the intensity of folding might be greatest at or near the base of the Paleozoic section.

The degree of folding over anticlinal crests appears to provide greater or lesser amounts of fracturing in response to tension, a condition widely recognized as a principal contributing factor to anticlinal breaching by erosion. Similarly, synclinal folding produces tension and, in all probability, tension fractures, which occur on the bottoms rather than the tops of beds along synclinal axes. Tension fractures might therefore provide openings for migration of ground water along the axes of folds.

In the subsurface, below the water table, solution along anticlinal fracture zones would result in lowering the next higher bed to fill the space leached. Because the base of the overlying bed would be under compressional stress, the passageway would tend to become sealed.

Along the axis of a syncline, where the tension fractures occur on the undersides of the beds, removal of material by solution would continuously add to tension and engender further fracturing as settling

Figure 2. Steeply dipping and "faulted" strata adjacent to the "nose" of the Lake Lucille subsidence structure in Fayetteville, Arkansas. The rock cropping out behind graduate students Paul Mayes (left) and Tom Mooney (right) is the Greenland Sandstone of Henbest (1953). The displacement may be a product of movement of the block below Mayes' left foot to the left into the subsidence structure rather than movement of the overlying block to the right. Other evidence indicates movement down and to the left along the plane under Mooney's feet.

(Photograph by University of Arkansas Editorial Service.)

proceeded. Gravity might also contribute to distribution of the fractures across the area of subsidence to provide sufficient lengthening of beds as they subside.

The distribution of subsidence structures along synclinal axes thus becomes understandable. All that is needed in addition to the sloping, fractured strata is an outlet at some point where the surface is topographically lower than that at the head of the potential artesian system.

All the conditions necessary to an artesian system in the rocks of northwestern Arkansas are fulfilled by the difference in elevation between southern Missouri and the valley of the Arkansas River (800 to 1,000 feet), coupled with the presence of a fault system along the north side of the valley (fig. 1). The fault system known as Mulberry fault in the western part of the Arkansas Valley is related to or associated with a large, buried monoclinal fold (Quinn, 1959, p. 43), which appears to extend eastward across the Boston Mountains front and probably marks the boundary between shallower or deeper wells drilled to Morrowan rocks. This boundary is roughly between Tps.

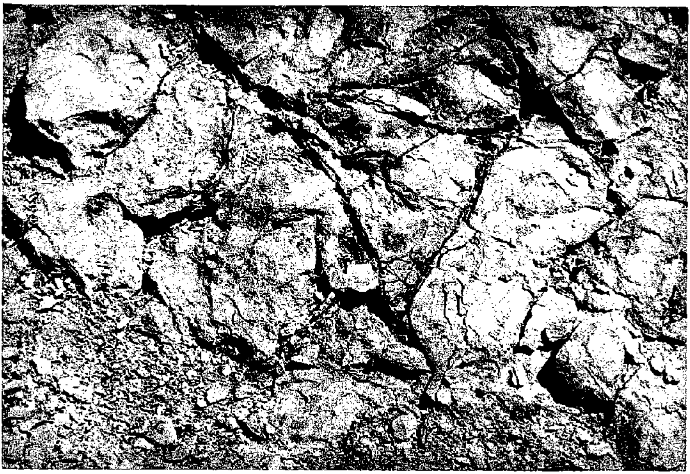

Figure 3. Jointing or fracturing of shale bed a few yards to the left of the position occupied by Mayes in figure 2.

10, 11 N. where the rocks are abruptly depressed 1,000 feet or more (Sheldon, 1954, pl. 1). The faults are probably sufficiently deep-seated to bisect the basal Paleozoic deposits and provide a potential pathway of escape for water entrapped in the Paleozoic strata.

The topography of the Arkansas Valley indicates relative recency of the excavation to its present depth (Quinn, 1958, p. 41-43). An earlier artesian system emptying into the Arkansas Valley area would need to have antedated the emplacement of Winslow and Atokan strata. (Late Morrowan disturbance did occur and may be related to subsidence rather than diastrophism.) Otherwise, until the present valley was formed, the southward-trending system would not have existed in northwestern Arkansas. This qualification cannot have applied to the Seneca fault, or graben, in northeastern Oklahoma and may account for the presumed greater age and maturity of that system.

Although the Seneca graben is continuous, the subsidence structures along the Arkansas synclines are local and discontinuous. Seemingly as the process of leaching and subsidence progresses, the structures become more numerous and extended so that finally a depressed zone similar to the Seneca graben may be produced.

The synclinal grabens of northwestern Arkansas along White River fault and Brush Creek graben (fig. 1) seem to be more continuous and more maturely developed than are those along the northeastward-trending synclines. Because the "grabens" are oriented more or less east-west, they may have drained to the west along east-westward-trending folds or faults and may have begun development at an

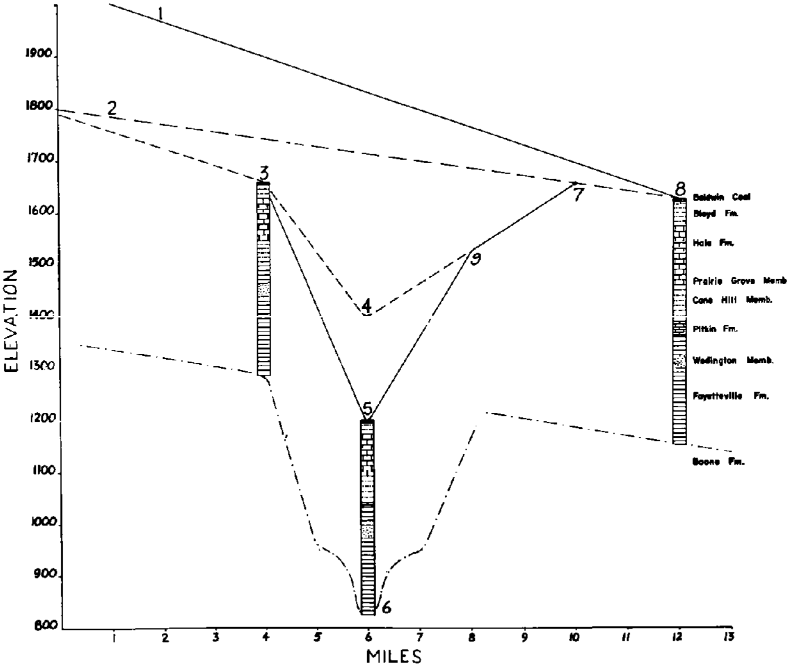

Figure 4. Cross-section diagram oriented north-south across the Price Mountain syncline indicating displacement of Baldwin coal and other beds.

1. Calculated position of coal bed at points north of White Oak Mountain based on a dip of about 33 feet per mile.
2. Line projected on elevations of coal outcrop in two places (7, 8) on White Oak Mountain (dip about 15 feet per mile).
3. Calculated depth of column north of Price Mountain syncline.
4. Calculated position of coal at Lake Lucille based on a projection of a line from the outcrop at 7 and an outcrop on East Mountain at 9 (which may indicate synclinal displacement).
5. Actual position of coal along the axis of the Lake Lucille subsidence structure.
6. Projected position of the upper surface of the Boone Formation across the axis of the Lake Lucille subsidence structure. The dashed and dotted line represents the calculated upper surface of the Boone Formation across the Price Mountain syncline and the Lake Lucille subsidence structure.
7. Position of Baldwin coal on northern part of White Oak Mountain about 33 feet higher than its position at 8.
8. Column on southern outcrop of White Oak Mountain. Coal at the top of column. Boone Formation at the base. (The Baldwin coal is included in the Bloyd Formation.)
9. Position of Baldwin coal outcrop on East Mountain.

(Prepared by L. E. Poole, McAlester Fuel Co.)

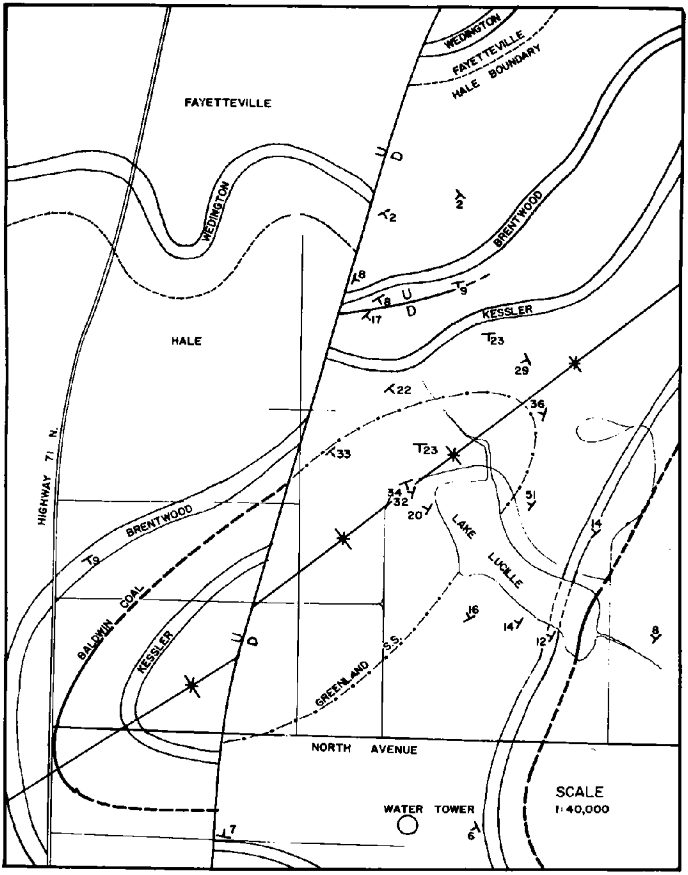

Figure 5. Sketch map of Lake Lucille area. The configuration of the subsidence structure is outlined by the outcrop pattern of the Greenland Sandstone to the right and the Kessler Member of the Bloyd Formation to the left of the major fault. Most of the asymmetry of the adjacent beds and of the apparent offset of the axis of the subsidence structure is a reflection of topographic conditions.

(Drafted by Marshall Goins, University of Arkansas.)

earlier time than seems to be true of those of the northeastward-trending structures. The position of the grabens is coincident with a reduction in the quantity of water in deep sands. To the north water is abundant, to the south it is much less. Both areas may now drain into the northeastward-trending structures.

The most clearly defined of the northeastward-trending subsidence systems occurs along the Cove Creek, Onda, Price Mountain, and Glade faults to the west and the Drakes Creek and Moody Hollow faults about 15 miles to the east (Croneis, 1930). The primary structures appear to be broad, shallow asymmetrical synclines possibly complicated by secondary folds (Quinn, 1959, p. 31; p. 35, fig. 2). The faulting is intermittent and complex with short spurs extending in various directions. The displacement is probably related to differential movement in the subsidence structures with which the faults are invariably associated.

In the vicinity of Fayetteville, Arkansas, the Baldwin coal crops out in a number of places and provides a useful and unmistakable datum plane. It may be assumed that at the time the coal was deposited the terrain was reasonably level and sloped gently southward toward the strand line (fig. 4, line 1-8). About six miles southeast of Fayetteville the coal is exposed on White Oak Mountain at an elevation of 1,630 feet. If the dips were calculated to be one-half degree the coal should crop out in Fayetteville at an elevation of about 1,930 feet. The highest level of occurrence in Fayetteville is on East Mountain (erroneously labeled "Mt. Sequoyah," U. S. G. S. topographic sheet, Fayetteville, Ark., 1958) where the coal crops out, 100 feet lower than on White Oak Mountain instead of at the calculated level 300 feet higher. The East Mountain outcrops are nearly horizontal and are on the west and north face of the mountain at about 1,530 feet elevation. About three-fifths of a mile northwest, on the south end of Lake Lucille (fig. 5), the coal is exposed at 1,410 feet in the southeast limb of a synclinal subsidence structure and has a dip of about 14° NW. Adjacent exposures across the structure provide dip measurements of increasing magnitude near the axis of the fold which is readily discernible. The coal would occupy a position at about 1,200 feet along this part of the axis of the syncline. The northwest limb of the fold is faulted so that the coal does not crop out north of the fold axis (fig. 5).

The nose of the syncline has been uncovered by erosion along the path of the spillway at the northeast corner of the lake. The strata are smoothly flexed over the nose of the structure except for a single fracture. South of the spillway, excavation of a road along the edge of the lake contributed to uncovering a large area of strata dipping steeply into the syncline. The beds are strongly jointed with some oxidation of the rocks along the fractures (fig. 3). Some faulting and secondary folding has occurred in connection with a thick sandstone quartz-pebble conglomerate, the Greenland Sandstone (Henbest, 1953), lying above the Bloyd beds (fig. 2). The southwest end of the subsidence structure is obscurely exposed and appears to have been displaced by faulting (fig. 5). In turn, the position of the fault indicates subsidence on a larger scale, laterally, than is suggested by the dimensions of the subsidence structure. Likewise the fault appears to postdate the initiation of the subsidence structure.

Several problems concerning displacement of strata are thus involved. The average dip of strata, conservatively estimated at less than one-half degree (actually 33 feet per mile) in the absence of folding of any kind, would indicate that the Baldwin coal should be at an elevation of more than 1,800 feet in the area of the syncline, or subsidence structure, at Lake Lucille. The difference in elevation of the coal at points 7 and 8 (fig. 4) on White Oak Mountain is only half as much as it should be, or about 15 feet per mile. This is probably a reflection of presence of the Price Mountain syncline to the northwest. The position of the coal on East Mountain at 1,530 feet may result from lowering in the syncline or in the subsidence structure, or in both. Position of the coal along the axis of the subsidence structure at about 1,200 feet, or some 330 feet lower than its position on East Mountain, may be partly due to lowering of the syncline, as indicated by line 3-4-9, figure 4. Calculations based on the steeply dipping strata in the Lake Lucille subsidence structure indicate a displacement there of some 200 feet. It seems certain, however, that the solution subsidence in the area is considerably more extensive than is indicated by the recognizable subsidence structures. This conclusion is based on the fact that faulting extends across and beyond the Lake Lucille and adjacent structures but appears to be related to them.

In alignment with the Lake Lucille subsidence, similar structures appear to the southwest and northeast. One of these is in the vicinity of Dickson Street and the Frisco Railway tracks in Fayetteville, Arkansas. According to Simonds (1891, p. 124), the coal formerly cropped out there at an elevation of 1,340 feet. Two blocks north at Maple Street the Fayetteville fault is exposed in a railroad cut (Simonds 1891, pl. facing p. 113). Displacement on the fault equals the thickness of the upper part of the Hale Formation combined with the Bloyd section below the cap rock or a little above the coal. From Simond's section measured on East Mountain, this thickness might be as much as 100 feet. Simonds (p. 113) described the Fayetteville fault but did not estimate the amount of displacement. At the same time he misidentified the strata as Pitkin (*Archimedes* limestone), whereas it is actually of Hale age. Otherwise, Simonds recognized that the coal on Dickson Street is contained in "a small synclinal basin."

To what extent the northeastward-trending synclines in northwestern Arkansas may be attributed to folding and to what extent they may be attributed to solution subsidence is a matter of conjecture.

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New Thesis Added to O. U. Geology Library

The following Master of Science thesis was added to The University of Oklahoma Geology Library in June 1963:

Physical paleoecology of the Francis Formation (Pennsylvanian) near Ada, Oklahoma, by Albert H. Giles.

OKLAHOMA GEOLOGY NOTES

Volume 23 August 1963 Number 8

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