OKLAHOMA

GEOLOGY NOTES

OKLAHOMA GEOLOGICAL SURVEY
THE UNIVERSITY OF OKLAHOMA • NORMAN, OKLAHOMA

$2.00 per year, $0.25 per copy

MAY 1963

Volume 23, Number 5

Cover Picture

DEVONIAN ROCKS OF NORTHEASTERN OKLAHOMA

SALLISAW FORMATION NEAR MARBLE CITY

On this month's cover is illustrated an outcrop of the Sallisaw Formation (Lower Devonian) in NE¼ sec. 14, T. 13 N., R. 23 E., near Marble City, Sequoyah County, Oklahoma (approximately 2½ feet of strata shown in photograph). The Sallisaw is an arenaceous carbonate, with nodules and lenses of chert, locally grading into an arenaceous chert. The acid-insoluble content ranges from approximately 1 percent to 45 percent, averaging about 9 percent; insolubles are mostly in the form of sand-size, subangular quartz grains, few of which exceed 0.4 mm in diameter. The inset photomicrograph illustrates the typical texture of the Sallisaw carbonate facies. The clear areas are mostly quartz grains set in a carbonate matrix; the large fragments are brachiopod shells. The rock from which this thin section was cut is a limestone with a low magnesium carbonate content (approximately 1%), but in places the Sallisaw is a calcitic (and arenaceous) dolomite with as much as 26 percent magnesium carbonate.

—T. W. A.

New Pennsylvanian *Diaboloceras* from Northwest Arkansas

James H. Quinn* and Leo C. Carr†

The genus *Diaboloceras* (Miller and Furnish, 1940, p. 527) was "established for forms that resemble typical *Paralegoceras* rather closely but have somewhat more primitive sutures." Each suture forms eight lobes with an incipient pair approximately centered on the umbilical wall. The incipient lobes on the umbilical walls of *Diaboloceras* resemble those occurring on *Paralegoceras texanum* at a diameter of about 15 mm except that the latter are on or slightly inside the umbilical seam. Externally *Diaboloceras* resembles *Branneroceras* in shape and ornamentation but has the second lateral lobe on the flank on the conch, whereas that of *Branneroceras* is on the umbilical wall.

The type species of *Diaboloceras* is *D. varicostatum* Miller and Furnish (1940, p. 527-529). A single type specimen was not designated but the syntypes "came from the Smithwick horizon in the Magdalena formation. . . .in the Sierra Diablo of Culberson County, Texas" (p. 529).

Plummer and Scott (1937, p. 242-243, pl. 13, figs. 5, 7, 8) described *Gastrioceras smithwickense* which, together with material they referred to *Branneroceras,* was purportedly obtained from the same beds as type *Diaboloceras* and may well represent early whorls of *Diaboloceras.* At the same time Plummer and Scott (p. 241-243) provided a description and measurements of *Gastrioceras occidentale* and four additional closely related species, including "Holotype of *G. smithwickense,* n. sp., from north of Marble Canyon, Brewster County, in Bureau of Economic Geology." One of the localities from which they obtained *Gastrioceras occidentale* is that given for the "holotype" of *G. smithwickense.* The description of *Gastrioceras smithwickense* (p. 242-243) includes measurements of "one of the cotypes" (P-8163), which are identical with those on the previous page labeled "holotype." Also on page 243 under the heading *types,* they listed "cotypes in Plummer collection." Specimen P-8163 is illustrated (pl. 13, figs. 5, 8); the plate caption mentions the specimen simply as a "fragment." The Bureau of Economic Geology, The University of Texas, has loaned us Plummer and Scott's specimens. Their "holotype" P-8163 is in precisely the same condition as it was when illustrated. Some of the measurements given could not have been made directly on specimen P-8163; others are inaccurate. For example, *T* is given as 13 mm in a table on their page 239; on page 241 they provided a measurement of 18 mm for the "last whorl" and 14 mm for the "penultimate whorl" (although only part of one whorl is preserved). Because the specimen is slightly crushed and broken on the side not illustrated, this measurement cannot be made accurately but it is about 12.7 mm. On their page 243, a

*Department of Geology, University of Arkansas.
†Humble Oil & Refining Co., Midland, Texas.

paragraph is devoted to the description of the suture which is figured (p. 247, fig. 52b) and labeled *Gastrioceras smithwickense.* The suture appears to have been drawn from University of Texas no. 9445. The umbilical wall is indicated to include the ribbed area and the second lateral lobe as in *Branneroceras* or *Gastrioceras.* This area seems to be improperly illustrated, but the conch is strongly cadicone and the umbilical border is uniformly rounded so that the position of the umbilical shoulder may be a matter of conjecture.

The conch of *G. smithwickense* resembles that of *Branneroceras* in ornamentation but at comparable sizes is much more cadicone or flat. At a width of 14± mm the whorl is no more than 5 mm in height above the venter, a ratio of about 0.36, whereas that of *Branneroceras branneri* is about 0.55. The mean and median for 14 specimens are about 0.55.

Gastrioceras smithwickense resembles *Diaboloceras varicostatum* in ornamentation and suture pattern, the main difference being the absence of the incipient umbilical lobe. Because of the general similarity, *G. smithwickense* should be transferred to the genus *Diaboloceras* and is hereafter so considered. It is necessary to retain both species because *D. smithwickense* is considerably less advanced than *D. varicostatum* although the types of both are reportedly from the same locality.

Curiously, material referable to the genus from The University of Texas collection, retaining the suture, appears to belong in the more primitive species. Material in the State University of Iowa collection appears to belong to the more advanced species. According to Furnish (personal communication) all the specimens were found loose on a shale slope, and it seems possible two horizons are represented.

A second and probably important criterion linking the holotype of *D. smithwickense* with *Diaboloceras* of Miller and Furnish is the angular configuration of the preserved portion of coil, which indicates that the adolescent whorls of the specimen were triangularly coiled. Miller and Furnish (1958, p. 255-256) mentioned persistent adolescent triangular coiling in connection with *Diaboloceras* and *Paralegoceras*. They had earlier suggested (1940, p. 522) that according to the principles of proterogenesis *Paralegoceras* might have prominently triangular descendants but not ancestors. Primitive representatives of *Paralegoceras* in terms of retention of the

TABLE I.—GONIATITES OF THE WINSLOW FORMATION (*Winslowoceras* biostratigraphic zone)
Pronorites arkansasensis Smith
Pseudoparalegoceras kesslerense (Mather)
Pseudoparalegoceras compressum (Hyatt)
Eoasianites smithwickensis (Plummer and Scott)
Paralegoceras texanum? (Shumard)
Gastrioceras sp.
Winslowoceras henbesti Miller and Downs
Wiedeyoceras sp.
Neodimorphoceras sp.

"incipient umbilical lobe" to diameters of 100 or more mm occur in the Winslow Formation (Quinn, 1962, p. 119) and possess strongly developed adolescent triangular coiling (Plummer and Scott, 1937, pl. 12, fig. 8). Still more primitive forms occur at the base of or below the Winslow Formation in strata recently named the Trace Creek Shale Member of the Bloyd Formation (Henbest, 1962b, p. D43-44, fig. 131.1). There numerous fossils representing a variety of genera and species are contained in a lens of black partly oölitic limestone. The locality was discovered by Donald L. Neumeier in 1959, at that time a graduate student in geology at the University of Arkansas. The assemblage includes several genera of goniatites which closely resemble those of the Winslow Formation (table I). Some of the specimens are referable to *Diaboloceras* and range in size from a few whorls

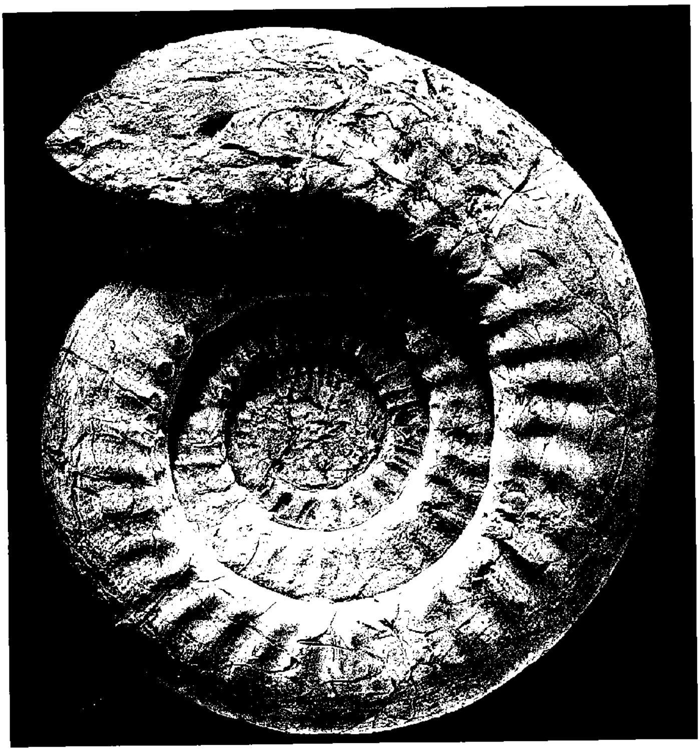
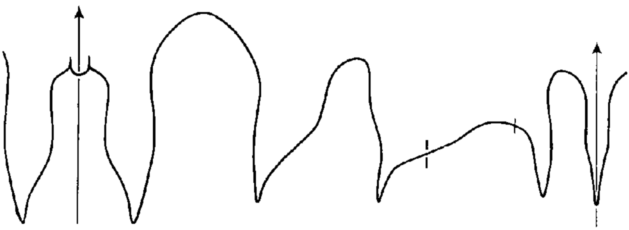


Plate I

Diaboloceras neumeieri, **new species**
Side view of holotype x⅔

to as much as 170 mm. Adolescent whorls are triangular in a few cases and regularly coiled in others. Two triangular specimens are strongly cadicone or very flat dorsoventrally insofar as adolescent whorls are concerned. The circular specimens retain a rounded cross section to very small size (text-fig. 2). In both cases the suture seems to follow a precisely similar pattern. There is no "incipient umbilical lobe" at any known size. The second lateral lobe occupies a position on the umbilical shoulder in at least some specimens of adolescent size. At larger diameters it is located on the flank of the whorl (pl. I, text-fig. 1) as in *Paralegoceras*.



Text-figure 1. Suture diagram, x1, of type of Diaboloceras neumeieri, **new species, at a diameter of about 170 mm (Prepared by J. A. McCaleb)**

The shell ornamentation of *Diaboloceras* is strongly accentuated and tubercles tend to develop on the umbilical shoulder. In this regard, the ornamentation is much more like that of *Branneroceras* than that of *Paralegoceras*. Despite these reservations the Trace Creek materials seem to be within the generic specifications proposed by Miller and Furnish, but appear to be specifically separable from *D. smithwickense* and *D. varicostatum*. We are therefore proposing a new species under the genus *Diaboloceras*. It is named in honor of Mr. Neumeier, who discovered the locality (text-fig. 3).

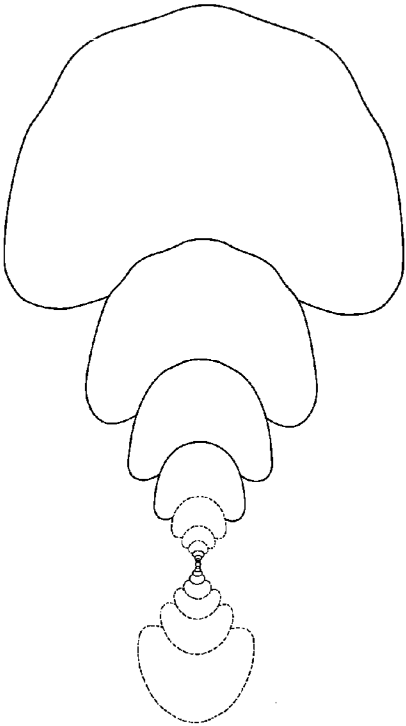
Diaboloceras neumeieri, new species
Plate I; text-figures 1, 2

A number of specimens of the new species have been collected from University of Arkansas locality 11 Wo, which is approximately three miles southwest of West Fork, Washington County, Arkansas, in the bed of Lee Creek. Of the specimens which range from 2 to 170 mm in diameter a conch of which one side has been partly destroyed by weathering is selected as the type (pl. I, text-figs. 1, 2, University of Arkansas no. L 11 Wo 1).

The diameter of the conch is 170 mm, width is about 94 mm, and height of the outer whorl is approximately 73 mm. The shell is septate throughout with impressions of shell ornamentation present.

The conch is evolute and expands rapidly. The type has about 11 whorls. The diameter of the umbilicus (measured to the umbilical seam) is slightly greater than half the entire diameter of the conch

(54 percent). The dorsal area is impressed to about 24 percent of the total whorl height. The conch is helmet-shaped in cross section (text-fig. 2). At approximately 85 mm a slightly rounded keel appears in the position of the secondary ventral saddle on the type. Along with this, two sets of longitudinal grooves occur. The first set coincides with the position of the prongs of the ventral lobe. The second set occurs in the position of the first lateral lobe. These two sets of grooves are separated by a low convex ridge which occupies the position of the first lateral saddle (pl. I). It is uncertain that these ridges and grooves are other than unique or accidental.

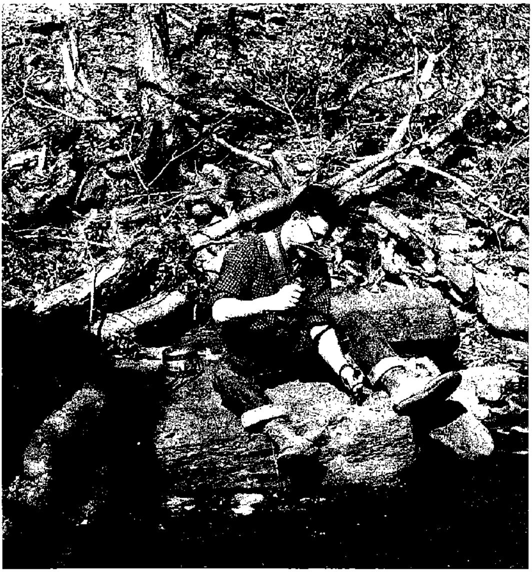


Text-figure 2. Cross section, x⅔, of type of Diaboloceras neumeieri, **new species, at a diameter of 170 mm. The left side is restored from the right; the small central whorls are drawn from a second specimen; the three intermediate whorls are indicated by dashed lines because they are imperfectly preserved on the type.**

Ribs are present on the lateral portion of the shell, between the rounded umbilical shoulder and the second lateral groove, but do not extend across the venter. The ribs of the type specimen at 170 mm number approximately 35 to the volution on the outer two whorls. The earlier whorls are not sufficiently well preserved for the ribs to be counted. The surface of the test is strongly reticulate with transverse lirae crossed by longitudinal lirae.

The external suture (text-fig. 1) forms a bifid ventral lobe with moderately narrow attenuate prongs widely separated by the ventral saddle; high, slightly asymmetrical, very broad, and rounded first lateral saddle; narrow, acuminate, asymmetrical first lateral lobe; high, slightly asymmetrical, narrow second lateral saddle; shallow, V-shaped second lateral lobe; and a low, asymmetrical third saddle, which extends diagonally across the umbilical slope and seam.

The internal suture forms a deep, narrow, symmetrical dorsal lobe; high, slightly asymmetrical, relatively broad first lateral saddle; nar-



Text-figure 3. Type locality of Diaboloceras neumeieri, new species. The type was recovered from the left-forward corner of the block. Mr. Neumeier, who discovered the locality, is shown removing a large coiled nautiloid from the right corner of the block. The parent ledge crops out behind and somewhat above the position of the large block and is obscured by rubble. Location is on a headwater tributary of Lee Creek, sec. 18, T. 14 N., R. 30 W., Washington County, Arkansas.

row, asymmetrical, V-shaped first lateral lobe; shallow second lateral saddle, which terminates in the external second lateral lobe beyond the umbilical seam.

Remarks.—*Diaboloceras neumeieri* resembles *Branneroceras* and its adolescent whorls may be confused with those of *Branneroceras*. Large specimens are distinguished from *Branneroceras* most easily by the external suture. *D. neumeieri* as large as 30 mm diameter has the first and second lateral lobes on the flank of the whorl, but *Branneroceras* has only a first lateral lobe on the flank with the second on the umbilical shoulder, regardless of size. The conch of small *Diaboloceras neumeieri* tends to be more robust than that of *Branneroceras*. The first lateral lobe and second lateral saddle of *Diaboloceras* are narrower than those of *Branneroceras*. In other respects the two are similar in shape, ribbing, ornamentation, and general proportions.

This goniatite species is, as far as is now known, restricted to a position in the Trace Creek Shale Member of the Bloyd Formation below the Greenland Sandstone Member of the Winslow Formation.

Material referable to *Diaboloceras* also occurs in the Greers Ferry horizon (table II), which is at the base of the Dye Member of the Bloyd Formation (Henbest, 1962). The material from Greers Ferry is confined to one or two specimens, poorly preserved and not identifiable as to species.

Associated genera of goniatites at the Neumeier locality, in the Trace Creek Shale Member of the Bloyd Formation are as follows:

Diaboloceras neumeieri, new species
Pseudoparalegoceras compressum?
Pseudoparalegoceras kesslerense (Mather) 1915
Pronorites arkansasensis (Smith) 1903
Wiedeyoceras sp.
Boesites scotti (Miller and Furnish) 1941
Gastrioceras sp.
Eoasianites?

TABLE II.—GONIATITES OF BLOYD FORMATION BELOW THE TRACE CREEK MEMBER
(*Axinolobus* biostratigraphic zone)

Axinolobus modulus Gordon
Pronorites arkansasensis Smith
Pseudoparalegoceras kesslerense (Mather)
Eoasianites oblatus (Miller and Moore)
Diaboloceras sp.
Cravenoceras? *morrowense* Miller and Moore
Gastrioceras grileyi Miller and Owen
Gastrioceras adaense Miller and Owen
Gastrioceras occidentale (Miller and Faber)
Bisatoceras greenei? Miller and Owen
Proshumardites sp.
Pygmaeoceras sp.
Anthracoceras sp.

Occurrence.—The Trace Creek Member of the Bloyd Formation is of Morrowan age according to Henbest's (1962b) arrangement. It appears to mark the upper limits of occurrence of *Diaboloceras neumeieri.* The earliest member of the genus occurs in the Dye Member of the Bloyd Formation, probably equivalent to the "cap rock" of Henbest (1953; Quinn, 1962, fig. 1).

Gastrioceras occidentale occurs in the Dye Member but has not been found in the Trace Creek Shale Member of the Bloyd Formation. *Boesites* has been found in the latter but not in the former. Both occur in the "Smithwick" horizon of the Magdalena Formation which is the type locality of *Diaboloceras smithwickense,* indicating that the "Smithwick" horizon of West Texas is probably late Morrowan in age also.

The figure of plate I and the suture drawing (text-fig. 1) were prepared by J. A. McCaleb, State University of Iowa. The cross section (text-fig. 2) was prepared by R. G. Miller, formerly of the University of Arkansas. The authors are indebted to Dr. W. M. Furnish of the State University of Iowa for helpful suggestions and to Dr. P. T. Flawn of the Bureau of Economic Geology, The University of Texas, for making Plummer and Scott's types available. The type of *D. neumeieri* is stored at the repository, State University of Iowa.

References Cited

Henbest, L. G., 1953, Morrow group and lower Atoka formation of Arkansas: Amer. Assoc. Petroleum Geologists, Bull., vol. 37, p. 1935-1953.

——— 1962a, Type sections for the Morrow Series of Pennsylvanian age, and adjacent beds, Washington County, Arkansas: Art. 130 **in** U. S. Geol. Survey, Prof. Paper 450-D, p. D38-41.

——— 1962b, New members of the Bloyd Formation of Pennsylvanian age, Washington County, Arkansas: Art. 131 **in** U. S. Geol. Survey, Prof. Paper 450-D, p. D42-44.

Miller, A. K., and **Furnish, W. M.,** 1940, Studies of Carboniferous ammonoids, Parts 5-7: Jour. Paleontology, vol. 14, p. 521-543.

——— 1958, Middle Pennsylvanian Schistoceratidae (Ammonoidea): Jour. Paleontology, vol. 32, p. 253-268.

Plummer, F. B., and **Scott, Gayle,** 1937, Upper Paleozoic ammonites in Texas: Texas, Univ., Bull. 3701, 516 p.

Quinn, J. H., 1962, Age of Union Valley cephalopod fauna: Okla. Geol. Survey, Okla. Geology Notes, vol. 22, p. 116-120.

New Survey Bulletins Issued

Bulletin 91. Geology and water resources of Okmulgee County, Oklahoma, by M. C. Oakes and W. S. Motts. 164 pages, 2 plates, including colored geologic map, 19 figures. April 17, 1963. Cloth bound $4.00, paper $3.00.

Bulletin 94. Early Devonian brachiopods of Oklahoma, by T. W. Amsden and W. P. S. Ventress: Part I, Articulate brachiopods of the Frisco Formation; Part II, Articulate brachiopods of the Sallisaw Formation; Part III, Supplement to the Haragan brachiopods. 238 pages, 21 plates, 51 figures, April 22, 1963. Cloth bound $4.00, paper $3.00.

West Edmond Storage, a Natural-Gas Storage Facility Logan and Kingfisher Counties, Oklahoma

Norman G. Wallace*

Underground off-season storage has become a significant factor in the over-all economy of gas production, transmission, and consumption because of the seasonal demand for natural gas as a fuel. Although industrial users consume some of the excess gas available during the seasonal slack in residential use, it is desirable to flatten out the annual curve even more. In order to utilize the pipeline capacity the year around and to stabilize the gas-producing industry in Oklahoma, off-season storage is often the only solution. The winter season makes greater demands on pipelines and sources of natural gas. The fuel must be readily available near transmission lines during these periods of greater residential consumption. In summer the excess volumes under contract to be purchased must be stored or otherwise distributed.

These goals can best be accomplished by storage of gas in underground reservoirs near transmission lines to an industrial complex such as Oklahoma City. The availability of gas when needed near an industrial area is favorable to industrial growth. Oklahoma Natural Gas Company, as an intrastate distributor of natural gas for residential and industrial uses, has five underground storages in the State.

The earliest project of the company, Osage Storage, was carried out in 1943 to serve the Tulsa area. Later in 1944, the Haskell Storage was completed to supply Tulsa and Muskogee. In 1950, the company built the Depew Storage in Creek County for the Oklahoma City and Tulsa areas. The Sayre Storage in Beckham County was established in 1953 for the Clinton-Sayre area (Jordan, 1959, 1962). These four facilities have a total reservoir capacity of 160,000 million cubic feet (14.65 psi at 60°F).

In 1958, Oklahoma Natural Gas Company decided that more capacity for storing natural gas was needed to supply peak load in the Oklahoma City area. Investigation was started in a part of the West Edmond field, 10 miles north of the city, where the Bartlesville sand, an oil, gas, and condensate reservoir, was nearly depleted. The area selected as a suitable site for an underground natural-gas storage facility is approximately one and one-half miles wide and seven and one-half miles long across the lower part of T. 15 N., Rs. 4, 5 W., in Kingfisher and Logan Counties (fig. 1). The boundaries of the storage area, registered and approved by the Corporation Commission of Oklahoma, enclose 6,080 acres. The majority of wells in the field area had been drilled in 1950 and 1951, although the reservoir had been discovered in 1944 when Cities Service Gas Company drilled the 1 Gaffney (SE¼ NE¼ sec. 29, T. 15 N., R. 4 W.) looking for Hunton (Devonian) production. Forty-two wells were completed in the Bartlesville sand, of which 13 were oil productive and 29 were gas produc-

*Geologist, Oklahoma Natural Gas Company, Tulsa, Oklahoma.

tive. Most of the gas wells were single completions, but a few were dually completed with the Hunton reservoir. The Hogshooter lime in the higher Missourian section of the Pennsylvanian is also oil productive at places in the area and is dually completed with the Hunton (Bois d'Arc dolomite).

Gas with condensate from the Bartlesville reservoir was produced from the updip area to the east, and oil from the downdip area to the west. The original gas-oil contact in the sandstone body was at a subsea elevation of 5,584 feet with 9,805 acre-feet of productive oil zone and 41,239 acre-feet of gas-condensate volume. The original reservoir pressure was 2,922 pounds per square inch gauge (psig), and total reservoir capacity is 58 billion cubic feet at that pressure. Cumulative production to 1961 was approximately 460,000 barrels of oil and 56.7 billion cubic feet of gas. Recoverable reserves of gas were minimal.

The Bartlesville,* a Desmoinesian sandstone, Middle Pennsylvanian in age, is encountered in the field area at an average depth of 6,550 feet and is 40 to 100 feet above the base of the Pennsylvanian.

*Although this sandstone is called Bartlesville, Ford (1954) believed that it is in reality equivalent to a sandstone in the Red Fork zone, and that the Bartlesville section is absent in this area.

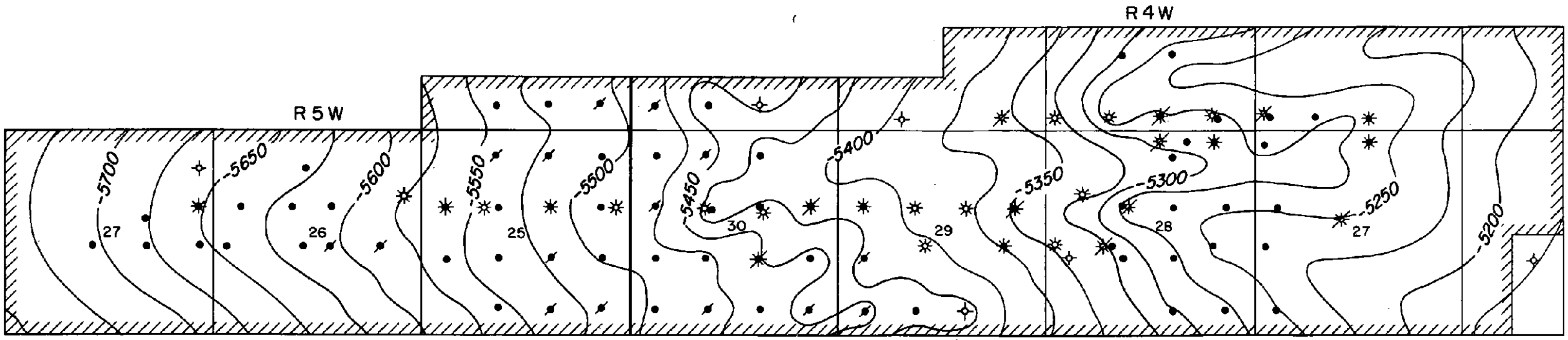


Figure 1. Structure contour map of top of Bartlesville zone, West Edmond field, Kingfisher and Logan Counties, Oklahoma. Contour interval is 25 feet.

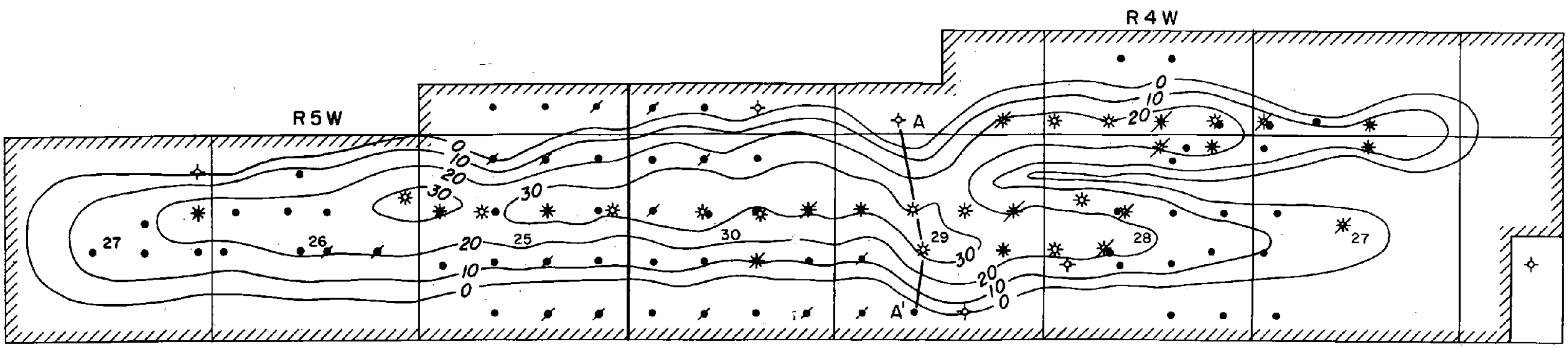


Figure 2. Thickness of porous and permeable sandstone in Bartlesville zone shown by 10-foot contours in West Edmond natural-gas storage of the Oklahoma Natural Gas Company in Kingfisher and Logan Counties. Line A-A′ indicates location of cross section of figure 3.

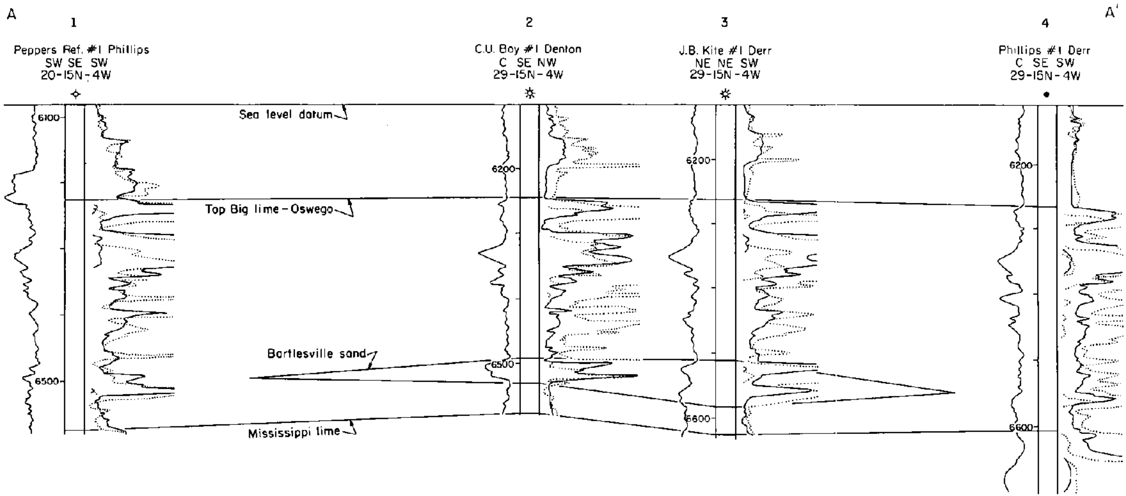


Figure 3. North-south section A-A′ across West Edmond natural-gas facility showing porous and permeable sandstone of the Bartlesville grading to sandy shale and shaly sandstone.

Because the sandstone is both overlaid and underlaid by shale and grades laterally into sandy shale, it is an excellent trap for hydrocarbons and therefore for gas storage (fig. 3). The sandstone lens dips to the west at a rate of 75 feet per mile (fig. 1). Westward elongation of the porous and permeable sandstone body is anomalously at right angles to the expected depositional strike, but it may be related to a drainage pattern similar to that in T. 14 N., Rs. 4, 5 W., as suggested by Swesnik (1948). Maximum thickness of productive pay is 32 feet with an average of 18 feet over the 3,300 acres within the limit of the zero contour shown on the isopach map (fig. 2).

The Bartlesville is a fine- to medium-grained, well-sorted, fairly clean, locally micaceous sandstone; it grades laterally in all directions into black sandy shale. The average porosity of the gas-productive sandstone is 17.5 percent, and average permeability is 56 millidarcys based on core analyses from eight wells. An average connate-water saturation of 18 percent was calculated from porosity values determined from core analyses and from resistivity values of electric logs. Microdevices were not used in connection with electrical surveys of wells penetrating the Bartlesville zone in the area. The average residual-oil saturation from cores in the gas cap is 4.5 percent.

The conversion of the Bartlesville reservoir into the West Edmond Storage was a million-dollar project of Oklahoma Natural Gas Company. The land was leased and remaining reserves of hydrocarbons were purchased. In order to make the storage safe and to prevent leakage, considerable expense was incurred for work-over of the old wells which had been Bartlesville-Hunton producers and still produced from the Hunton. Storage wellheads were installed on the 15 injection and withdrawal wells.

The storage facility is currently receiving gas from the Northwest Okeene field of Blaine and Major Counties, and the North Okarche field of Kingfisher County. A 24-inch line, approximately 20 miles long, has been installed by Oklahoma Natural Gas Company from the storage to better serve the Oklahoma City industrial complex. Gas can also be diverted to or from other areas of the distribution system.

References Cited

Ford, W. J., 1954, The subsurface geology of southwest Logan County, Oklahoma: Okla. City Geol. Soc., Shale Shaker, vol. 5, no. 2 (Oct.), p. 5-27, **also in** Shale Shaker Digest I, p. 327-343 (1955).

Jordan, Louise, 1959, Natural gas storage in Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 19, p. 182-191.

__________ 1962, Underground storage of natural gas in Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 22, p. 175-182.

Swesnik, R. M., 1948, Geology of West Edmond oil field, Oklahoma, Logan, Canadian, and Kingfisher Counties, **in** Structure of typical American oil fields, vol. 3: Tulsa, Amer. Assoc. Petroleum Geologists, p. 391-398.

A Compressed Geologic Time Scale

The following is a tabular comparison of geologic time to one 365-day year. Assuming that the Earth was created at midnight of New Year's Eve and that the present is the same time one year later, the following dates and hours can be assigned to the beginning of each geologic period or epoch. The conversion factor used was 1 day equals approximately 12.329 million years.

The oldest rocks in Oklahoma are the granites in the Arbuckle Mountains. These rocks were formed about 1,350 million years ago. In comparison with the calendar year these would have formed at noon on September 12.

Era	Geologic Period	Geologic Epoch	Beginning (Million Years Ago)*	Comparative Date: Day	Hr	Min	Sec
CENOZOIC	Quaternary	Recent	.01	December 31	23	58	50
		Pleistocene	1	December 31	22	03	12
	Tertiary	Pliocene	12	December 31	0	38	24
		Miocene	23	December 30	3	13	36
		Oligocene	35	December 29	3	52	
		Eocene	55	December 27	12	56	
		Paleocene	70	December 26	7	44	
MESOZOIC	Cretaceous		135	December 21	1	12	
	Jurassic		180	December 17	9	36	
	Triassic		220	December 14	3	44	
PALEOZOIC	Permian		270	December 10	2	24	
	Pennsylvanian		320	December 6	1	04	
	Mississippian		350	December 3	14	40	
	Devonian		400	November 29	13	20	
	Silurian		430	November 27	2	56	
	Ordovician		490	November 22	4	37	
	Cambrian		600	November 13	16	00	
	Precambrian		4,500	January 1	0	00	

*Data from: Kulp, J. L., 1960, The geologic time scale: Internat. Geol. Cong., 21st, Copenhagen 1960, Proc., sec. 3, p. 18-27.

—A. J. M.

Morphological Variation of *Thymospora pseudothiessenii* (Kosanke) Wilson and Venkatachala, 1963*

L. R. Wilson and B. S. Venkatachala†

Thymospora pseudothiessenii (Kosanke) Wilson and Venkatachala, 1963, is an important component of the Dawson coal, Tulsa County, Oklahoma. Thousands of specimens were encountered, and in certain levels they constitute as much as 90 percent of the spore assemblages. These specimens exhibit many variations in size, shape, ornamentation, and thickenings. These variations are described in this paper.

SYSTEMATIC DESCRIPTION

Thymospora Wilson and Venkatachala, 1963

Type species:—*Thymospora thiessenii* (Kosanke) Wilson and Venkatachala, 1963.

Thymospora pseudothiessenii (Kosanke) Wilson and Venkatachala, 1963

Synonymy:—*Thymospora verrucosa* (Alpern, 1958) Wilson and Venkatachala, 1963.
Thymospora perverrucosa (Alpern, 1959) Wilson and Venkatachala, 1963.
Torispora perverrucosus Alpern, 1959.

Holotype.—Kosanke, 1950, pl. 5, fig. 10.

Diagnosis.—(from Kosanke, 1950, p. 30)

> Spores are bilateral, monolete, elongate to oval in the plane of longitudinal symmetry, round or oval in transverse plane. The outline in both longitudinal and transverse planes is broken by the sculpturing of the spore coat. The holotype measures 37.8 x 29.4 microns. The known size range is from 26 to 46 microns in the longitudinal plane. The ornamentation is various depending upon the degree of maceration. In general, the spore coat is verrucose to obvermiculate and sometimes appears reticulate. The monolete tetrad mark extends well over half the length of the spore. The spore varies in thickness, due to ornamentation, from 1.5 to 3.5 microns.

The morphological variations appear to fall into four major cate-

*One project supported by National Science Foundation Grant G-22083.
†B. S. Venkatachala, Birbal Sahni Institute of Palaeobotany, Lucknow, India, takes this opportunity to thank the United Nations Technical Assistance Organization for providing him a fellowship during the tenure of which the present work at the School of Geology, The University of Oklahoma, was completed.

gories, which are described below. The authors do not suggest that these are taxonomic entities but rather that they are morphologic variations due possibly to positions occupied by the spore tetrads in the sporangium. In an attempt to determine the relative abundance of each morphologic type, one thousand specimens were counted. The percentages are given under the description of each type.

The Dawson coal seam at the locality studied is 30 inches thick, and in all of the 15 segment samples of the channel collection the variations of *Thymospora pseudothiessenii* discussed here are present. Because of the presence of these variations and transitional forms in all of the levels, it is considered that they belong to the same species. Type 1 is the most abundant form (52%); consequently it represents the typical member of the species.

DESCRIPTION OF MORPHOLOGIC TYPES

Type 1. *Verrucae regularly distributed*

Plate I, figures 1-4

Description.—Oval; 25 to 50 microns; verrucose, verrucae overlapping in many cases to form obvermiculate, rugose pattern, simulat-

---

Explanation of Plate I

Thymospora pseudothiessenii **(Kosanke) Wilson and Venkatachala, 1963**

Figure 1. Type 1, showing regularly distributed verrucae; 28 x 20.6 microns. Dawson coal OPC 352 F-9-3.

Figure 2. Type 1, showing regularly distributed verrucae; 27.6 x 20.7 microns. Dawson coal OPC 352 C-1-12.

Figure 3. Type 1, showing pseudotrilete mark; 28 microns. Dawson coal OPC 352 F-9-1.

Figure 4. Type 1, tetrad, individual spores 32.2 x 20.7 microns. Dawson coal OPC 352 F-9-8.

Figure 5. Type 2, showing irregularly distributed verrucae; 33.6 x 23 microns. Dawson coal OPC 352 F-2-7.

Figure 6. Type 2, showing irregularly distributed verrucae and lopsided thickening; 32.2 x 23 microns. Dawson coal OPC 352 C-6-1.

Figure 7. Type 2, showing irregularly distributed verrucae and lopsided thickening parallel to the monolete mark; 32.2 x 25.13 microns. Dawson coal OPC 352 F-5-2.

Figure 8. Type 2, showing irregularly distributed verrucae on the equatorial margin; 36.8 x 27.6 microns. Dawson coal OPC 352 G-2-2.

Figure 9. Type 2, showing irregularly distributed verrucae of various sizes along the equatorial margin and the pseudotrilete mark; 32.2 x 30 microns. Dawson coal OPC 352 F-10-2.

Figure 10. Type 2, showing irregularly distributed verrucae and lopsided thickening on one side of the equator; 46 x 39 microns. Dawson coal OPC 352 H-7-2.

Figure 11. Type 2, showing irregularly distributed verrucae and lopsided thickening on one side of the spore; 39.2 x 33.6 microns. Dawson coal OPC 352 H-7-4.

Plate I

ing a pseudoreticulum; equatorial margin corrugated owing to the distribution of verrucae; monolete mark prominent, more or less three-fourths the length of the spore. Fifty-two percent of the spores belong to Type 1.

Type 2. *Verrucae irregularly distributed*
Plate I, figures 5-11; plate II, figure 12

Description.—Oval to circular; 25 to 50 microns; verrucose ornamentation prominent, with interspersed grana, verrucae irregular, broad, almost tuberculate, obvermiculate, crowded on one side on many specimens with the result that the spore appears to have lateral lopsided thickening; the monolete mark in some instances forking to give the appearance of a trilete mark (pl. I, fig. 9); exine 3 to 5 microns thick. Twenty-eight percent of the spores belong to Type 2.

Explanation of Plate II

Thymospora pseudothiessenii **(Kosanke) Wilson and Venkatachala, 1963**

Figure 1. Type 3, showing verrucae crowded around the equator forming a crassitudinous rim; 34.5 x 25.3 microns. Dawson coal OPC 352 C-3-5.

Figure 2. Type 3, showing verrucae crowded around the equator forming a crassitudinous rim; 35.2 x 20.7 microns. Dawson coal OPC 352 C-4-7.

Figure 3. Type 3, showing verrucae crowded around the equator forming a crassitudinous rim; 32.5 x 23 microns. Dawson coal OPC 352 F-2-7.

Figure 4. Type 4, showing irregularly distributed verrucae and angular thickening perpendicular to the monolete suture; 35.2 x 23 microns. Dawson coal OPC 352 F-8-1.

Figure 5. Type 4, showing irregularly distributed verrucae and prominent thickening parallel to the monolete suture; 46 x 27.6 microns. Dawson coal OPC 352 F-9-1.

Figure 6. Type 4, showing irregularly distributed verrucae forming a thickening perpendicular to the monolete suture; 46 x 18.4 microns. Dawson coal OPC 352 G-1-1.

Figure 7. Type 4, showing irregularly distributed verrucae and angular thickening perpendicular to the monolete suture; 32.2 x 23 microns. Dawson coal OPC 352 F-2-1.

Figure 8. Type 4, showing irregularly distributed verrucae and angular thickening perpendicular to the monolete suture; 43.7 x 23 microns. Dawson coal OPC 352 F-2-2.

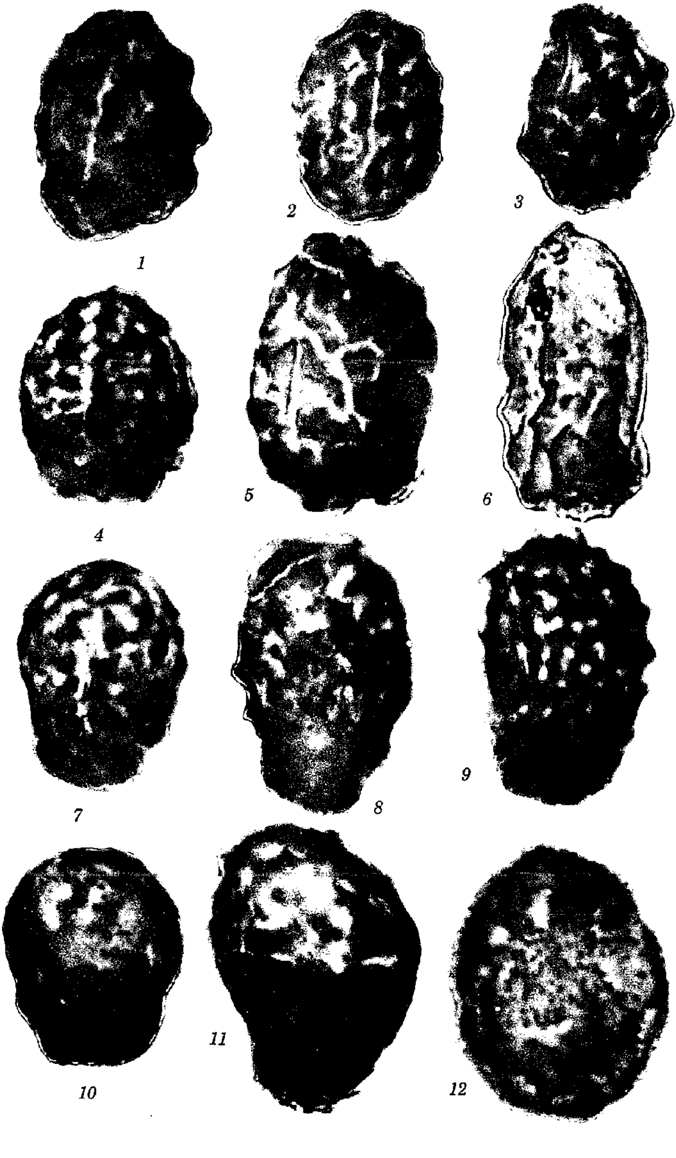
Figure 9. Type 4, showing irregularly distributed, obvermiculate verrucae and lopsided thickening perpendicular to the monolete suture; 41.4 x 27.6 microns. Dawson coal OPC 352 F-9-10.

Figure 10. Type 4, showing broad angular thickening; 33.6 x 23 microns. Dawson coal OPC 352 F-10-1.

Figure 11. Type 4, showing very prominent angular thickening; 39 x 27.6 microns. Dawson coal OPC 352 F-9-9.

Figure 12. Type 2, showing irregular verrucae and interspersed grana; 31.3 x 25.2 microns. A slightly over-macerated specimen. Dawson coal OPC 352 F-2-7.

Plate II



Type 3. *Verrucae crowded around the equator*

Plate II, figures 1-3

Description.—Circular to broadly oval; 25 to 50 microns; verrucose ornamentation, sculptural elements crowded, in many cases forming a thick crassitudinous rim around the equator; ornamentation present on both proximal and distal faces; monolete mark prominent, up to three-fourths the length of the spore. Six percent of the spores belong to Type 3.

Type 4. *Verrucae forming a crescentic or broadly rectangular thickening on one side*

Plate II, figures 4-11

Description.—Oval to oblong; 30 to 50 microns; acorn-shaped with a well-demarcated, irregular thickening on one side of the equatorial axis; in many cases the thickening appears to broaden and may cover the spore completely. Monolete mark more or less two-thirds the length of spore, perpendicular to the thickening; exine ornamented with irregular verrucae, forming an obvermiculate pattern. Fourteen percent of the spores belong to Type 4.

DISCUSSION

A survey of the literature on Paleozoic spores reveals that a number of genera referred to by various authors fall into the above-outlined categories. Types 1 and 2 correspond with *Thymospora pseudothiessenii* (Kosanke) Wilson and Venkatachala. Type 3 corresponds with *Pericutosporites potoniei* Imgrund, 1952. Type 4 corresponds with *Torispora verrucosa* Alpern, 1958, and *T. perverrucosus* Alpern, 1959. After an examination of typical specimens received from Dr. Alpern, we feel that these two species are synonymous with *Thymospora pseudothiessenii.* The differences enumerated by Alpern (1958a, 1958b, 1959) are not sufficient to warrant their assignment to different species. These variations have also been observed in the material from the Dawson coal.

Thymospora and *Torispora* occur in rocks of Westphalian-Stephanian age in Europe and America, whereas *Pericutosporites* is recorded only from a deposit assigned to the Lower Permian of the Kaiping Basin, China (Imgrund, 1960). The spore association, however, is more characteristic of the uppermost Pennsylvanian.

The genus *Torispora* was established by Balme (1952) to accommodate spores answering to the following diagnosis:

> Spores elliptical or subcircular when compressed in proximo-distal orientation, bilaterally symmetrical about the plane of the major axis when seen in full proximal or distal view. Distinctly monolete with a well-marked suture line parallel to the major axis of the ellipse. The exine is differentially thickened particularly at one extremity of the spore where it is expanded into a crescentic or broadly rectangular projection. The thinner area of the exine is finely punctate and notched along the periphery.

Except for *T. laevigata* Bhardwaj, 1957, all the species attributed to this genus are ornamented (granulose, verrucose, or microreticulate). Guennel and Neavel (1961) illustrated all gradations from spores with fully developed hemispherical thickenings to unthickened spores in the same assemblage. Alpern's illustrations (1959, pl. 11, figs. 294-298, pl. 12, figs. 299-343; 1958b, pl. 16, figs. 82-93; 1960, pl. 3, figs. A1-D8) also demonstrate the amount of variation that is encountered in specimens referable to *Torispora*. These specimens have been referred to *T. perverrucosa* and *Thymospora verrucosa*. It is probable, as suggested by Neavel and Guennel (1960) and Guennel and Neavel (1961), that the exine of *Torispora* thickened in a manner similar to cuticularization. The thickened side thus represents the part of the exine that was exposed on the periphery of the sporangium. The shape, size, and orientation of the thickening appear to be related to the position of the spore in the sporangium. Probably all the spore types referred to here could have been derived from *Bicolaria*-type of sporangium as illustrated by Horst (1957) and Guennel and Neavel (1961).

References Cited

Alpern, Boris, 1958a, Description de quelques microspores du permo-carbonifère français: Revue Micropaléontologie, vol. 1, no. 2, p. 75-86, 2 pls.

__________ 1958b, Répartition stratigraphique de quelques microspores du carbonifere superieur francais: 1st Internat. Congr. Coal Petrology, Heerlen, p. 173-176, 6 pls.

__________ 1959, Contribution à l'étude palynologique et pétrographique des charbons français: Theses, Faculté Sciences, Univ. Paris, pt. II, p. 103-198, 17 pls.

__________ 1960, Quelques problèmes actuels de la palynologie houillère: 4th Congr. pour l'avancement des études de stratigraphie et de géologie du carbonifere, Heerlen, p. 13-24, 1 pl.

Balme, B. E., 1952, On some spore specimens from British Upper Carboniferous coals: Geol. Mag., vol. 89, p. 175-184.

Bhardwaj, D. C., 1957, The palynological investigations of the Saar coals (Part I—Morphography of **Sporae dispersae**): Palaeontographica, vol. 101, Abt. B, p. 73-125, 10 pls.

Guennel, G. K., and Neavel, R. C., 1961, **Torispora securis** Balme: Spore or sporangial wall cell?: Micropaleontology, vol. 7, p. 207-212.

Horst, Ulrich, 1957, Ein Leitfossil der Lugau-Oelsnitzer Steinkohlenflöze: Geologie Zeitschrift für das Gesamtgebiet der Geologie und Mineralogie sowie der angewandten Geophysik, Berlin, vol. 6, p. 698-721, 8 pls.

Imgrund, Reinhard, 1952, Die **Sporites** des Kaipingbeckens, ihre paläontologische und stratigraphische Bearbeitung im Hinblick auf eine Parallelisierung mit dem Ruhrkarbon und dem Pennsylvanian von Illinois: Techn. Hochschule, Aachen, 1952, 96 p. [Diss.]

__________ 1960, Sporae dispersae des Kaipingbeckens, ihre paläontologische und stratigraphische Bearbeitung im Hinblick auf eine Parallelisierung mit dem Ruhrkarbon und dem Pennsylvanian von Illinois: Amt für Bodenforschung, Hannover, Geologisches Jahrbuch, vol. 77, p. 143-204, 4 pls.

Kosanke, R. M., 1950, Pennsylvanian spores of Illinois and their use in correlation: Ill. State Geol. Survey, Bull. 74, 128 p.

Neavel, R. C., and **Guennel, G. K.,** 1960, Indiana paper coal: composition and deposition: Jour. Sed. Petrology, vol. 30, p. 241-248, 1 pl.

Wilson, L. R., and **Venkatachala, B. S.,** 1963, **Thymospora,** a new name for **Verrucososporites:** Okla. Geol. Survey, Okla. Geology Notes, vol. 23, p. 75-79, 1 pl.

New Printing of Bethel Topographic Quadrangle

Among the more recent topographic maps issued by the U. S. Geological Survey is the Bethel 15-minute quadrangle (scale 1:62,500), compiled in 1955 and released in 1960. The area represented by the map is in the Ouachita Mountains in McCurtain County. The geology of the area has been described by O. B. Shelburne, Jr., in *Geology of the Boktukola syncline, southeastern Oklahoma* (Okla. Geol. Survey, Bull. 88, 1960). Some of the more prominent topographic features within the quadrangle are Spring Mountain, Second Mountain, White Rock Mountain, Boktukola Mountains, and Big Horseshoe Mountain, all sinuous ridges reflecting the highly folded structure of the Ouachitas. The maximum elevation is 1,917 feet in the northeast corner and the minimum is less than 540 feet on Glover Creek at the southern limit of the area.

In March 1963, the U. S. Geological Survey issued a new printing of the map, differing from the original edition in that shaded relief has been added. This is an innovation for topographic maps of Oklahoma at a scale larger than 1:250,000. The shading strikingly brings out the relief of this beautifully rugged mountainous area. In addition to making the map easier to read in the field, the shading aids greatly in the interpretation of the physiography and geology of the region. In conjunction with the original standard version, the new version will be an invaluable aid in the teaching of map reading to secondary and college students of earth sciences, as the comparison of the two dramatically demonstrates the significance of contour lines.

OKLAHOMA GEOLOGY NOTES

Volume 23 May 1963 Number 5

IN THIS ISSUE