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 Branneroceeras in shape and ornamentation but has the second lateral lobe on the flank on the conch, whereas that of Branneroceeras is on the umbilical wall.

The type species of Diaboloceras is D. varicosatum 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 Branneroceeras, 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

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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 $14 \pm 2$ 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.—GONIATITIES 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. |

112
"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 oolitic 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 1). 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 x\(\frac{1}{2}\)

113
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, xl, of type of Diaboloceras neumeieri, new species, at a diameter of about 170 mm](image)

*(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. varicosatum*. 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, x\frac{3}{4}, 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 Floyd 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 Floyd 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 Floyd 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
*Gastroceras* sp.
*Eoasianites*?

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**Table II.—Goniatites of Floyd Formation Below the Trace Creek Member**

(Axinolobus biostratigraphic zone)

<table>
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<th>Species</th>
<th>Author(s)</th>
</tr>
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<td><em>Pronorites arkansasensis</em> Smith</td>
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</tr>
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<td><em>Pseudoparalegoceras kesslerense</em> (Mather)</td>
<td>1915</td>
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<td><em>Eoasianites oblatus</em> (Miller and Moore)</td>
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<td><em>Diaboloceras</em> sp.</td>
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<td><em>Cravenoceras? morrowense</em> Miller and Moore</td>
<td>1941</td>
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<td><em>Gastroceras grileyi</em> Miller and Owen</td>
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<td><em>Gastroceras adaense</em> Miller and Owen</td>
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<tr>
<td><em>Gastroceras occidentale</em> (Miller and Faber)</td>
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<td><em>Bisatoceras greenei?</em> Miller and Owen</td>
<td>1903</td>
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<td><em>Proshumardites</em> sp.</td>
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<tr>
<td><em>Pygmaeoceras</em> sp.</td>
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<td><em>Anthracoceras</em> sp.</td>
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</table>
Occurrence.—The Trace Creek Member of the Boyd Formation is of Morrowan age according to Henbest’s (1962b) arrangement. It appears to mark the upper limits of occurrence of Diaboloceras neu-meieri. The earliest member of the genus occurs in the Dye Member of the Boyd 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 Boyd 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. neu-meieri is stored at the repository, State University of Iowa.

References Cited


New Survey Bulletins Issued


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 (SE1/4 NE1/4 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.
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 pro-
ductive at places in the area and is dually completed with the Hun-
ton (Bois d'Arc dolomite).

Gas with condensate from the Bartlesville reservoir was pro-
duced from the updip area to the east, and oil from the down dip 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. Cumu-
lative production to 1961 was approximately 460,000 barrels of oil
and 55.7 billion cubic feet of gas. Recoverable reserves of gas were
minimal.

The Bartlesville, a Desmoinesian sandstone, Middle Pennsylva-
ian 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, Okla-
oma. Contour interval is 25 feet.

Figure 2. Thickness of porous and permeable sandstone in Bartlesville zone shown by 10-foot contours in West Ed-
mond 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 hydro-
carbons 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 elonga-
tion of the porous and permeable sandstone body is anomalously at
right angles to the expected depositional strike, but it may be re-
lated 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 deter-
mimed 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 re-
sidual-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 Com-
pany. 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 pro-
duced from the Hunton. Storage wellheads were installed on the 15
injection and withdrawal wells.

The storage facility is currently receiving gas from the North-
west Okeene field of Blaine and Major Counties, and the North Okar-
che 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

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p. 5-27, also in Shale Shaker Digest I, p. 327-343 (1955).

Jordan, Louise, 1969, Natural gas storage in Oklahoma: Okla. Geol. Survey,


Swesnik, R. M., 1948, Geology of West Edmond oil field, Oklahoma. Logan,
Canadian, and Kingfisher Counties, in Structure of typical American
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.

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—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


**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-

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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 pseudotrilite 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 pseudotrilite 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.
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 orna-
mentation 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 lop-
sided 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 22 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 27.5 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 mi-
crons. 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 mi-
crons. 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 22 mic-
crons. 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

Figure 12. Type 2, showing irregular verrucae and interspersed grana;
31.3 x 25.2 microns. A slightly over-macerated specimen. Daw-
son coal OPC 352 F-2-7.
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 pseudo-thiessenii* (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 pseudo-thiessenii*. 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 Kaping 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 *Thyniospora 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


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

New Pennsylvanian Diabloceras from Northwest Arkansas
J. H. Quinn and L. C. Carr ........................................... 111

West Edmond Storage, a Natural-Gas Storage Facility, Logan and Kingfisher Counties, Oklahoma
Norman G. Wallace ..................................................... 119

Morphological Variation of Thymospora pseudothiessenii (Kosanke) Wilson and Venkatachala, 1963
L. R. Wilson and B. S. Venkatachala ................................ 125

Sallisaw Formation near Marble City .................................. 110
New Survey Bulletins Issued .......................................... 118
A Compressed Geologic Time Scale .................................... 124
New Printing of Bethel Topographic Quadrangle ..................... 132