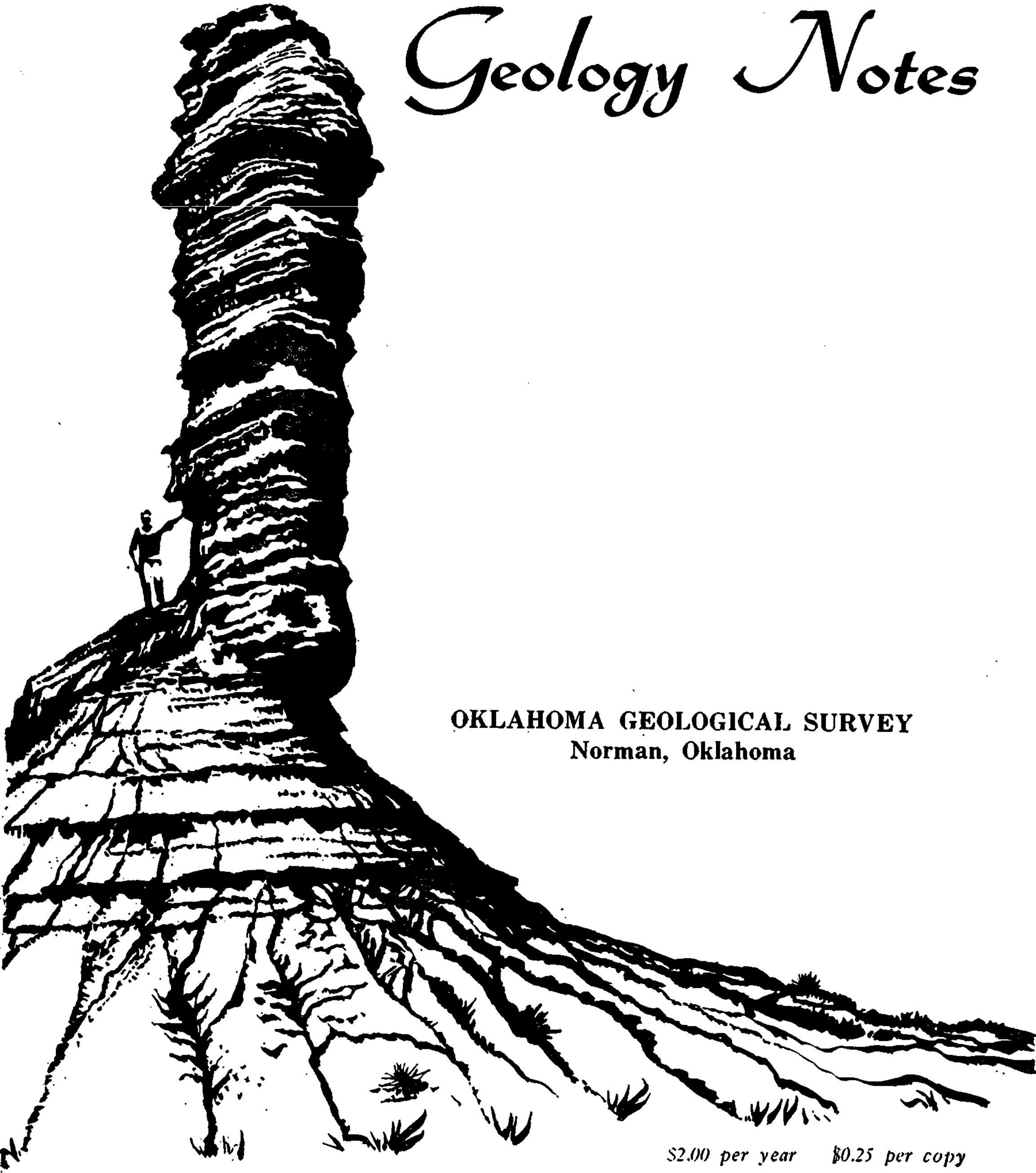
OKLAHOMA

Geology Notes



OKLAHOMA GEOLOGICAL SURVEY
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VOLUME 21   APRIL, 1961   NUMBER 4

New Theses Added to O. U. Geology Library

The following Master of Science theses were added to The University of Oklahoma Geology Library during the month of March 1961:

Areal geology of the Duke area, Oklahoma, by Albert J. Copley.

The subsurface geology of northeast Payne County, Oklahoma, by Dale V. Dalton.

Mississippian rocks on western flank of Oklahoma City uplift, by Robert T. Ellzey, Jr.

Subsurface study of Pennsylvanian rocks of the south Wetumka area, northeastern Hughes County, Oklahoma, by John H. George.

The geology of the western Glen Mountains, Oklahoma, by M. Charles Gilbert.

Subsurface geology of the Hoffman gas area, Okmulgee and McIntosh Counties, Oklahoma, by Burt E. Hamric.

Ferromagnesian minerals in basic igneous rocks, Raggedy Mountains area, Wichita Mountains, Oklahoma, by William Louis Hiss.

Mineralogical study of altered basic intrusive rocks, Wichita Mountains, Oklahoma, by Henry Derr Johnson.

Areal geology of the Quartermaster area, Roger Mills and Ellis Counties, Oklahoma, by Frank D. Lovett.

Sedimentary analysis of the Pennsylvanian system of southernmost Sangre de Cristo Mountains, New Mexico, by Charles Edward Rambo.

Areal geology of Farris quadrangle, Pushmataha and Atoka Counties, Oklahoma, by George Dale Ray.

Preferred orientation of plagioclase in basic rocks, Raggedy Mountains, southwestern Oklahoma, by Pat Malone Rotan.

Investigation of reservoir conditions of lower Deese sandstones (Pennsylvanian) for a flood project in the North Alma Pool, Stephens County, Oklahoma, by John Reed Vanbuskirk.

Dimensional Grain-Orientation Studies of Recent Canadian River Sands

L. M. Young* and C. J. Mankin

The field of grain-orientation study is not extensive, and relatively little work has been attempted on the sands of a recent fluvial environment. Most of the work done on grain orientation in sediments consists either of a description of a method for determining orientation, or of experimental results of grain orientation in current flow. In addition, some work has also been done on grain orientation in beach sands and in eolian deposits.

Wayland (1939) showed that the long axes of clastic quartz grains tend to parallel the trend of the crystallographic *c*-axis. Later workers have confirmed this conclusion which is of prime importance in the determination of quartz orientation by optical means. Ingerson (1940) used the results obtained by Wayland and found that the orientation of quartz grains in ripple marks is radically different from that in pseudo-ripple marks. (Pseudo-ripple marks are ripple-like features that are the result of post-depositional processes). In ripple marks the *c*-axes tend to be sub-parallel to the ripple-mark axis, but in the pseudo-ripple marks the quartz *c*-axes are normal to the pseudo-ripple trend.

Schwarzacher (1951) used the universal stage in conjunction with a binocular microscope and observed that the long axes of the quartz grains (as well as larger clastic particles) tend to align themselves parallel to the current and dip upstream. Dapples and Rominger (1945) obtained approximately the same results as did Schwarzacher, and in addition observed that the larger ends of the grains point upstream. Rusnak (1957a, b) arrived at the same conclusions.

Curray (1956) studied grain image projections of beach sands and found that the grains are aligned with their long dimensions perpendicular to the beach trend, and that eolian deposits have the long axes of the grains parallel to wind direction.

In a recent study (Young, 1960), a series of oriented, artificially cemented samples were collected from the Canadian River in order to determine whether some type of grain orientation exists in the small-scale sedimentary features of a recent fluvial environment.

The Canadian River originates in northeastern New Mexico, flows across the northern part of the Texas Panhandle and from west-central to east-central Oklahoma, where it joins the Arkansas River. From its source to the area of investigation the Canadian is underlain by rocks of Paleozoic and Cenozoic age.

A careful analysis of sedimentary parameters (size and shape properties) of the Canadian River sands has been made by Pollack (1959). In this study he investigated samples along the entire course of the river from its source in northern New Mexico to its junction with the Arkansas River in eastern Oklahoma.

The area of this investigation is in secs. 2 and 3, T. 8 N., R. 3 W., and secs. 34 and 35, T. 9 N., R. 3 W., Cleveland County, Oklahoma. In this

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region the Canadian River is a broad, shallow stream with a channel width-to-depth ratio of about 75:1. The river here flows upon recent alluvium and cuts laterally into its own floodplain. The gradient is approximately 4 to 5 feet per mile.

Texture and Composition

Investigation of samples collected from the above-mentioned area revealed that the sand is subangular to subrounded by visual estimation with Powers' scale (1953). The principal mode lies in the fine-sand class: about 60 percent of the grains have diameters between 2.0ϕ and 3.0ϕ (fine sand), and about 20 percent of the sand grains have diameters between 3.0ϕ and 4.0ϕ (very fine sand). The silt-clay content is commonly less than 10 percent, but locally may be as high as 30 percent, and with a high silt-clay ratio.

Mechanical analyses and calculation of statistical parameters according to the method of Folk and Ward (1957) and Folk (1959) show that the sand has a mean size of 2.71ϕ. The sorting ranges from moderately sorted to poorly sorted ($\sigma_I = 0.56\text{-}0.87$). These sorting values are in agreement with the values obtained from other river environments and with the values obtained by Pollack (1959) in his earlier investigation of the Canadian River.

All the cumulative curves from the analyzed samples show a positive skewness ($Sk_G = 0.25\text{-}0.58$), indicating an excess of fine material. The kurtosis values rank from mesokurtic to leptokurtic ($K_G = 1.04\text{-}1.18$), indicating a somewhat better sorting in the central part of the curves than in the tails.

A combination of these parameters suggests that the Canadian River sand is bimodal, with the dominant mode occurring in the fine-sand class, and the secondary mode in the silt-clay class. The bimodality may reflect variations in the source of sediments, or fluctuations in the transporting power of the environment owing to variation in the amount of discharge.

The Canadian River environment also contains sand dunes. The dune sand ($M_z = 1.75\phi$) is coarser than the common river sand and is thus classed as a medium sand. This sand is well sorted ($O_I = 0.46$), is only slightly skewed ($Sk_G = 0.012$) in the positive direction, and has a mesokurtic value ($K_G = 0.99$), indicating an almost perfect Gaussian distribution throughout the entire curve.

There is a slight mixing by wind of the coarser dune sand with the normal river deposits, causing most size analyses to show a tail of coarser material. The addition of coarser material is a contaminating effect, and does not reffect the normal depositional energies available in the river proper.

The river sand contains 75-80 percent quartz, less than 10 percent plagioclase (some of which is virtually unaltered), about three percent potash feldspar, and minor amounts of other minerals, including chert, metamorphic rock fragments, carbonate rock fragments, mica, and heavy minerals. The heavy minerals constitute 0.01-0.03 percent of the sand by weight. The principal minerals are magnetite, hematite, zircon, garnet, ilmenite-leucoxene, tourmaline, epidote, apatite, and pyroxenes/amphiboles. Pollack (1959) has done a study of the shape and roundness for each of the minerals present in the Canadian River.

A study of the quartz types indicates that the sediments contain straight to slightly undulose extinction and stretched composite extinction types in subequal amounts. Using texture and composition in accordance with Folk's (1959) classification, the Canadian River deposits are classed as fine sand: mature subarkose.

Methods for Grain-Orientation Determination

A multitude of methods for grain orientation and petrofabric study are known, but few of them are applicable to this problem. Many of these procedures (Krumbein and Pettijohn, 1938; Krumbein, 1939) were evolved for the study of pebbles and other coarse-grained material and are therefore unsuitable for a study of the fine sand of the Canadian River. Methods that involve an enlargement of grain images and subsequent graphical analyses were also discarded (Dapples and Rominger, 1945; Curray, 1956; Rusnak, 1957a). These techniques were considered too cumbersome and time-consuming.

Martinez (1958) has described a method for rapid orientation analysis utilizing a petrographic microscope and photometric equipment. The method tests for optic alignment of quartz grains by measuring the variation in the intensity of light passed through a gypsum plate as the slide is rotated through different positions. From these intensity readings one can calculate the preferred optical alignment, if one is present. This method is based on the assumptions that the sediment is essentially monomineralic and that the thickness of the slide is uniform.

The method devised for this study involved the use of the universal stage with the petrographic microscope. The orientation of the *c*-axes of the quartz grains was obtained by procedures described by Emmons (1943) and Fairbairn (1949) for optic orientation of uniaxial minerals. The *c*-axes of the quartz grains were oriented either parallel (equatorial orientation) or perpendicular (polar orientation) to the axis of the microscope. The azimuth and plunge of each *c*-axis were recorded, along with the type of orientation. The results of each slide were plotted upon a Schmidt equal-area stereographic net. The procedure for plotting is described in Fairbairn (1949).

In the past, many workers have plotted results upon a stereonet and then contoured the points to determine the areas of concentration (Fairbairn, 1949). A superior practice that is currently being used is to apply rigid statistical tests to the results. This procedure has been used in this investigation. The test applied to the results of this study is the chi-square (x^2) test. This test measures the amount of departure of any given distribution from a theoretical uniform distribution. The greater the departure from a uniform distribution, the greater the probability that the observed distribution is the result of some external agent. A more detailed explanation of the general aspects of this test is given by Dixon and Massey (1951).

Depending upon the direction of sectioning of the slide (parallel or perpendicular to current direction), azimuth and plunge can have interchangeable meanings. Therefore it is necessary to be able to test for both types of orientation. The tests used for this purpose are specialized versions of the general chi-square test.

A test devised by Winchell (1937) was used to test for plunge. The net is divided into a series of ten concentric bands of equal area. Each band represents a range of plunge angles, and the concentration of points within each band is compared with a uniform distribution. If the value of P (probability) is 0.05 or less, it is considered to have significant plunge orientation. A value of 0.05 means that there are five chances in 100 that a random distribution would have equal or greater concentration.

A test devised by Tukey (1954) and Rusnak (1957a) is used to test for azimuth orientation. This test measures departure from a uniform 0°-180° distribution. The stereonet is divided into a series of nine wedges between 0° and 180°, and the number of points within each wedge is recorded and compared with a uniform distribution. Points in the other half of the circle (180°-360°) are treated as supplements and placed in the proper wedges (e. g., points lying between 20°-40° and 200°-220° are all placed in the 20°-40° wedge). The 0°-180° line on the plot is a diameter drawn parallel to the long dimension of the slide. In order to interpret azimuth orientation results correctly, it is extremely important to note whether the slide has been cut parallel to or perpendicular to current direction.

In the Tukey-Rusnak test values of P greater than 4.61 have the same significance as do values of 0.05 or less for the Winchell test.

Sampling and Sample Descriptions

Samples were collected from several small-scale sedimentary features present in the Canadian River environment. The sampling method decribed by Young and Mankin (1960) is a simplified version of the method described by Brown and Patnode (1953).

Two aspects should be kept in mind when studying dimensional orientation of sand grains. The features sampled should be representative of the recent environment. The features should also be those which will tend to be preserved in the geologic record. In order to obtain a representative sample from any feature vertical control is important. In this study the sample was taken from the top inch or less of any of the sampled features. The uppermost surface was excluded because of the chance of modifying effects by wind action upon the fluvial feature.

Channel Deposits

Minor (rill) channel deposits.—The largest channels included under this heading are developed upon the floodplain proper (fig. 1). These features are properly classified as rill channels and enter the stream channels at right angles. These rill channels are commonly 10 to 14 inches wide, about 4 feet long, and 1 inch or less deep. Small delta-like deposits are present at the mouths of these rills.

Other channels included in this category are much smaller than the above mentioned types. These develop along the outer margins of sand bars, and commonly are only a few inches wide and less than 0.5 inches deep.

Floodplain channel deposits. — These channel deposits are the result of encroachment of water from the main channel onto the floodplain during flood stage. The features exhibit almost straight paths, and measure 4 to 6 feet in width, about 18 inches in depth, and several hundred feet in length.

Ripple Marks

These structures are the result of current action. Two distinct classes are recognized, apparently a result of differences in current strength. Both classes exhibit a marked asymmetry, with steep lee slopes (30°-35°), and more gently dipping stoss or upstream slopes (5°-10°). The trend of these ripple marks is always perpendicular to current direction.

Linear ripple marks.—These features are characteristic of gentle to moderate current action (fig. 2). The ripples have wave lengths between 4 and 8 inches, amplitudes of approximately 0.5 inches, and uniform trends that may extend for several feet. This type of ripple mark is common both on channel bottoms and on the floodplain itself where it results from overflow of adjacent channels. In the Canadian River the maximum depth of water under which these linear ripples form probably does not exceed one foot because few channels in which they occur exceed this depth.

Linguloid ripple marks.—These ripple marks are characteristic of a more rapid current than are the linear types (fig. 3). The more vigorous current action produces irregularly trending ripples, consisting of a series of intersecting arcs. Each arc is 6 to 10 inches wide, with an amplitude of 1.5 inches. Wave length from crest to crest averages about 12 inches. These ripples are developed near the centers of large channels and on the floodplain. The maximum depth of water does not exceed 18 inches.

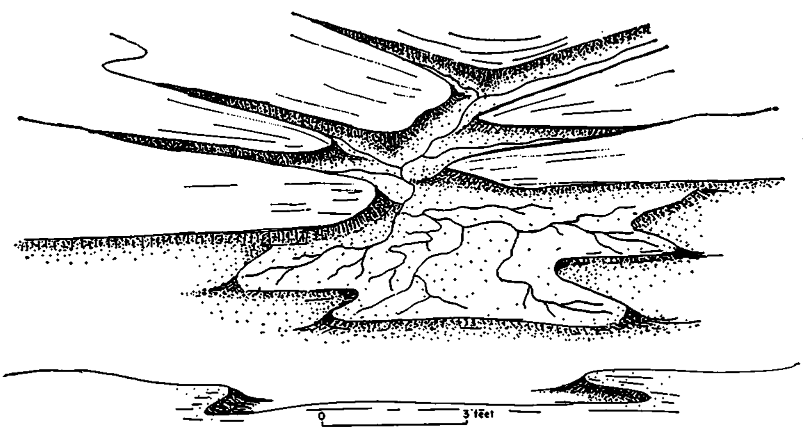

FIGURE 1. *Rill channel in the Canadian River. Channel with small delta-like feature entering main channel at right angle. Bar scale is approximate.* (Drawing by Roy D. Davis)

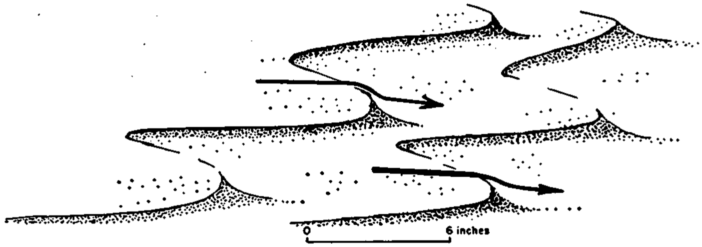

FIGURE 2. *Linear ripples. Ripple trend with current direction shown by arrows. Bar scale is approximate.*
(Drawing by Roy D. Davis)

Bar Deposits

The larger bars present in the Canadian River form when part of the floodplain is cut off and incorporated into the main channel (fig. 4). Smaller sand bars are common on the floodplain and are associated with pieces of drift. Their origin is thus a function of local variation in current velocity, and consequently of load deposition. These features are small, commonly a few feet in length and breadth, and are as much as one foot high. In places the bars have been reworked by subsequent currents and show a terracing effect along the outer margins.

RESULTS OF GRAIN-ORIENTATION STUDIES

The results of the dimensional orientation studies are based upon the *c*-axis orientation of 100 grains in each of 17 slides.

Channel Deposits

These studies have shown that grain orientation exists in all types of channel deposits. In nearly all cases there was good agreement between results and theoretical prediction. The grains were found to have a strong tendency to align themselves with the long dimensions (*c*-axes) parallel to the current direction (fig. 1). This is in accord with the observations of Rusnak (1957b). However, there is no conclusive evidence to show imbrication.

Ripple Marks

Although the mechanics of formation of asymmetric current ripples are incompletely understood, their origin is related to a critical stream velocity at which the sand particles begin to move.

Ingerson (1940) analyzed ripple marks and discovered that the sand grains are oriented with their long dimensions parallel to the ripple trend. Analyses of the Canadian River sands demonstrate that linear ripples have grain orientations parallel to the ripple trend but linguloid ripples have grain orientations perpendicular to their trends.

Because linear ripples are the result of gentle to moderate current action, there is a tendency for the grains to undergo a rolling motion and to pile together with their long dimensions perpendicular to the current direction (fig. 2).

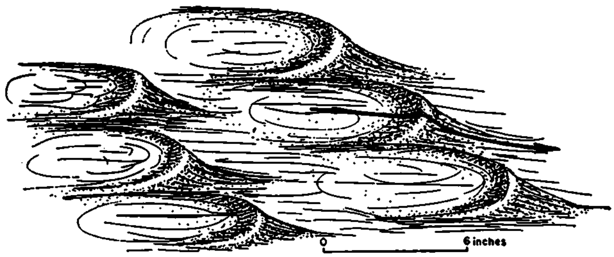

FIGURE 3. *Linguloid ripples. Ripple trend with current direction shown by arrow. Bar scale is approximate.*
(Drawing by Roy D. Davis)

For linguloid ripples the current is more vigorous, and the grains tend to assume a position of least resistance to the flow as they are piled together. Thus the grains orient with their long dimensions parallel to current direction, and the ripple marks consist of grains that have been dumped or piled together with this orientation (fig. 3).

Bar Deposits

Grain orientation studies of bar deposits support the idea that the grains are aligned sub-parallel to current direction (fig. 4). Only two samples of bar deposits were analyzed and therefore the results cannot be considered meaningful.

CONCLUSIONS

Previous work has shown that pebbles, coarse sands, and even medium sands locally exhibit definite grain orientation.

The results of this investigation confirm the idea that there should be a dimensional orientation of sands in a fluvial environment and that this orientation exists in very-fine sand (3-4ϕ range). Owing to dif-

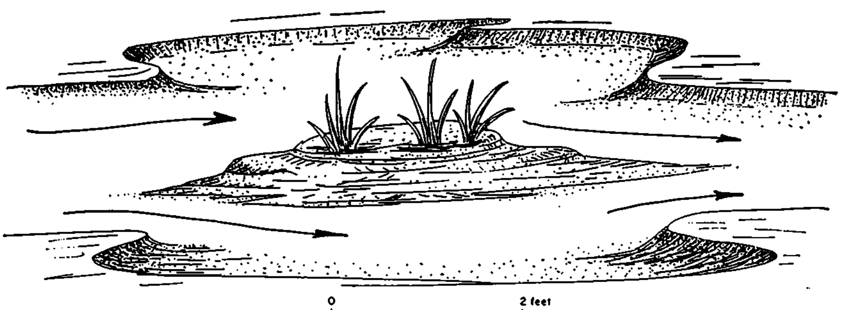

FIGURE 4. *Small bar in Canadian River channel. Bar is partly stabilized by plants. Current direction is shown by arrows. Bar scale is approximate.*
(Drawing by Roy D. Davis)

ferences in grain orientation of linear and linguloid ripples, it is believed that the stream velocity is the governing factor in the type of grain orientation developed.

In spite of the positive results obtained from this study (i. e., presence of grain orientation in the Canadian River sands), the application to paleo-fluvial environments is chiefly in a negative sense. The principal suggested application of grain orientations has been in lineation or trend studies. To this end this study can offer little encouragement, because it has revealed complexities that have apparently either been neglected or unanticipated in the river environment.

At present the Canadian River has a braided main channel that meanders freely. During the rainy season the river frequently floods and encroaches upon the floodplain. Consequently, the river deposits are constantly changing in space and time.

Acting within a strictly uniformitarian framework, one can deduce that streams in the geologic past must have resembled the Canadian River in such features as meanders, braided channels, sand bars, and floodplain development. If this premise is accepted, it is possible to see why most paleo-trend studies have met with little success.

To gather grain orientation samples successfully from the Canadian River, one must exercise a vertical control of inches (or less) in order to ensure homogeneity of the sample. Cores taken from drill holes cannot meet this condition. Thus working in the subsurface one is faced not only with the problem of knowing what he is sampling, but one cannot even be certain that the sampling is confined to a single feature.

Because there are many trends rather than a single trend present in a fluvial environment, and because of the sampling difficulties involved, most subsurface trend prediction studies based upon grain orientation are of dubious value.

Of secondary importance is the discovery that Ingerson's method (1940) of distinguishing pseudo-ripple marks will not work in all cases. The present study indicates that linguloid and linear ripples have opposite grain orientation, and that the orientation observed in the linguloid type corresponds to the orientation in pseudo-ripple marks.

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New Survey Publications

During the month of March the Oklahoma Geological Survey issued two circulars.

One is Circular 54, *Coal mining and landscape modification in Oklahoma*, by Dr. A. H. Doerr, associate professor of geography, The University of Oklahoma. The report describes the effects of coal mining upon the physical and cultural landscape in the coal-mining areas of eastern Oklahoma. It consists of 48 pages and 16 figures. Price: $1.00 paper bound.

The other is Circular 56, *Pollen and spores from the Permian deposits of the Cherdyn' and Aktyubinsk areas, Cis-Urals*, by S. R. Samoilovich, translated by M. K. Elias. This significant Russian paper describes a number of spores and pollen that are also found in the Permian of Oklahoma. The book consists of 109 pages and 17 plates. Price: $2.25 cloth bound, $1.50 paper bound.

A Large Pennsylvanian Orthocone from Oklahoma

A. G. Unklesbay*

One of the largest Pennsylvanian orthoconic cephalopods on record is a specimen of *Mooreoceras normale* Miller, Dunbar, and Condra, in the collections at the University of Tulsa (fig. 1). It is from the Fort Scott limestone, probably the Blackjack Creek member, east of Tulsa.

This specimen is exceptionally well preserved. It consists of an internal mold of all the living chamber and much of the phragmacone. It is 455 mm long and when theoretically reconstructed at the adapical end it seems to have been nearly 700 mm long when complete. The mold is essentially circular in cross section and expands rather gradually orad from the apical end to a position about 50 mm behind the apical end of the living chamber. From here forward the rate of expansion is reduced for about half the length of the living chamber. The adoral half of the living chamber is rather abruptly constricted and then expands orad at a very slow rate. At the adapical end of this specimen the diameter is 38 mm. At the position mentioned above, 50 mm behind the living chamber, the diameter is 75 mm. At the mid-length of the living chamber, which is the adapical end of the constriction, the diameter is 80 mm. At the deepest part of the constriction, which is 15 mm anterior to the last measurement, the diameter is reduced to 70 mm, and at the extreme adoral end, which appears to represent the aperture, the diameter is 74 mm. Whether this constriction represents a decrease in the outside diameter of the shell, or a thickening of the shell which reduced only the inside diameter cannot be ascertained.

Only small bits of the test adhere to part of the specimen and they are not well enough preserved to give any information regarding the nature of the shell. The only ornamentation visible is the ventral ridge which is common on many orthoconic nautiloids. In this specimen this ridge is straight, low, and inconspicuous. It is about 1.5 mm wide.

The septa are simple and saucer shaped, and directly transverse. In the adapical part of the specimen they are about 7 mm apart. Near the middle of the phragmacone they are about 10 mm apart, but the last few, just apicad of the living chamber, are more closely spaced, indicating that this is a gerontic individual. The sutures are essentially straight.

The siphuncle is small, circular in cross section, and located ventrad of the center. Where the mold is 42.5 mm in diameter the siphuncle is 3.5 mm in diameter, and its center is 16.4 mm inside the ventral wall.

Although common and widely distributed, few specimens of this species are well preserved and many consist of internal molds of only a few camerae, and many are fillings of only one. The specimen described here is one of the largest and most complete Pennsylvanian ortho-

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FIGURE 1. *Large specimen of* Mooreoceras normale *Miller, Dunbar, and Condra, x0.4, from Fort Scott limestone, east of Tulsa, Oklahoma.*
(Photograph by Neville M. Curtis, Jr.)

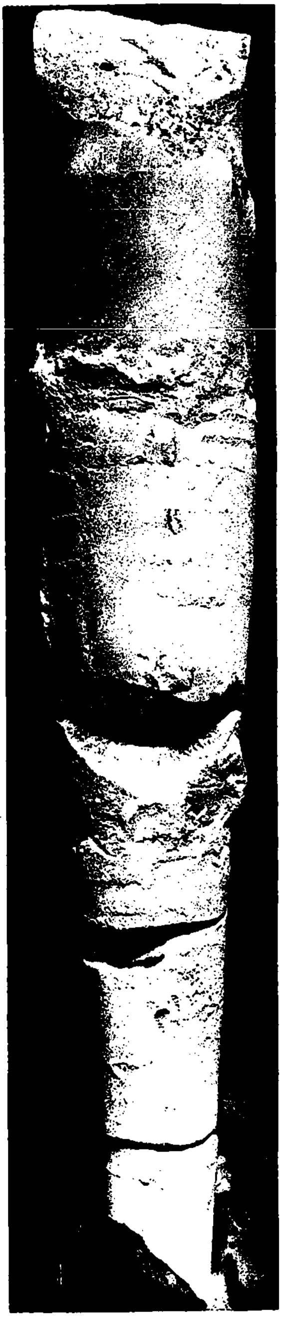

Figure 1

cones in North America. Miller and Owen (1934) described a specimen from the Cherokee of Henry County, Missouri, which was about 400 mm long, and was completely septate.

This specimen was made available for study by the Department of Geology at the University of Tulsa.

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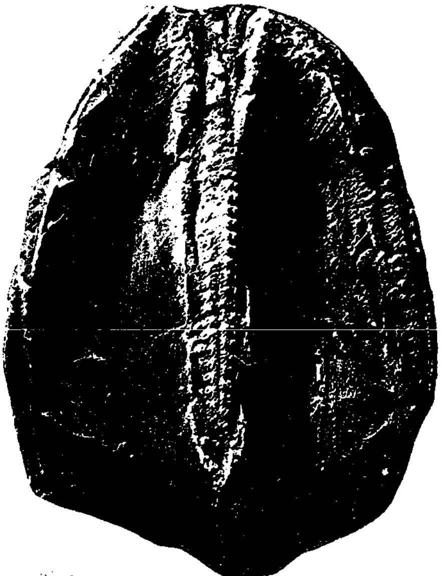
THE TYPE OF *Devonoblastus* REIMANN 1935

ROBERT O. FAY

The type specimens of *Pentremites leda* Hall 1862 (pl. I, fig. 11), the type species for the genus *Devonoblastus* Reimann 1935, are on deposit at the New York State Museum, Albany, New York. There are two cotypes numbered 451 and 452, and one hypotype numbered 5162. These specimens are slightly crushed and are not well preserved.

Devonoblastus leda (Hall) 1862
Plate I, figures 1-4

Calyx 17 mm long by 9 mm wide, with vault 14.5 mm high and pelvis 2.5 mm long, greatest width below midheight; pelvic angle 130 degrees, giving truncated ovoidal appearance in side view, with L/W 1.9 and V/P 5.8; stem round, about 1.5 mm in diameter, with about 50 crenellae extending approximately one-third of the radial distance toward the round lumen from the periphery; basals 3, medium sized, confined to aboral surface, with prominent rounded ridges; radials 5, long, overlapping deltoids, with long narrow sinus; deltoids short, visible in side view; spiracles presumed to be 5, normally disposed, with anispiracle between a hypodeltoid and a superdeltoid; hypodeltoid rests on two unnamed plates; ambulacra narrow, linear, with lancet plate exposed along main food groove in adoral half of each ambulacrum and completely covered by the side plates in the aboral half of each ambulacrum; side plates normally disposed, with 26 side plates in 10 mm, each primary side plate broadly quadrangular, with a secondary or outer side plate resting on the bevelled adoral and abmedial corner of each primary side plate and a pore between the aboral face of a side-plate handle and the adoral face of the adjacent secondary side plate at the ambulacral margin; brachiolar pit near center of primary side plate along suture of secondary side plate, with large brachiolar facets on side plates just abmedial to brachiolar pit, and approximately three side-cover-plate sockets per side food groove and five main-cover-plate sockets per side plate along main food groove; hydrospires presumed to be five on each side of an ambulacrum. The



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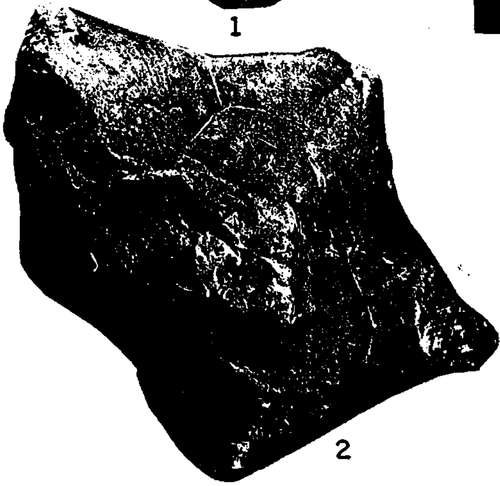

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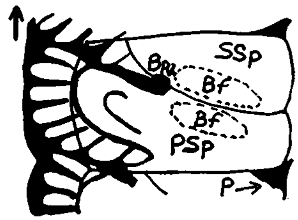

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PLATE I

Devonoblastus leda *(Hall) 1862 Hamilton group, western New York*

FIGURE 1. *Cotype 451, right posterior radial view, x4.4.*
FIGURE 2. *Cotype 451, basal view, x5.8.*
FIGURE 3. *Cotype 452, detailed ambulacral view, x38.9.*
FIGURE 4. *Cotype 452, sketch of side plates, x38.9. Arrow points toward oral opening.*

Bf—brachiolar facet | *P—pore*
Bp—brachiolar pit | *PSp—primary side plate*
SSp—secondary side plate

surfaces of the calyx plates have concentric striae or growth lines subparallel to outer margins showing that the deltoids grew aborally from the region of the mouth, that the radials grew outward from the radial lip, and that the basals grew outward from a center close to the stem.

Other specimens of the species have been sectioned and these show 5 hydrospire folds on each side of an ambulacrum.

The only stratigraphic and geographic information accompanying the types is Middle Devonian, Hamilton group, western New York.

Remarks.—Devonoblastus may be distinguished from *Pentremites* by the fact that *Pentremites* lacks a superdeltoid, 2 unnamed anal plates, and the hypodeltoid in the anal interradius; its lancet is completely exposed along its entire length, giving a petaloid appearance to each ambulacrum, and it occurs in Mississippian rocks. If *Pentremites* were derived from *Devonoblastus*, the superdeltoid, unnamed plates, and hypodeltoid would have had to fuse to form one anal deltoid and the lancet plate would have had to migrate outward to support the side food grooves.

In the original article by Reimann (1935) in which he proposed the name *Devonoblastus*, no mention was made of a type species for the new genus. In order to rectify this oversight, Reimann (1942) proposed the species *Pentremites leda* Hall 1862 as the type. In neither article are the specimens described in detail nor are they figured. One had to rely on the original description and illustration for morphological information.

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Reimann, Irving, 1935, New species and some new occurrences of Middle Devonian blastoids: Buffalo Soc. Nat. Sciences, Bull., vol. 17, no. 1, p. 23-45, pls. 1-4.

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North Okarche Field, Kingfisher County, Oklahoma

John T. Bado*

North Okarche Field is approximately three miles southwest of Kingfisher and one mile north of Okarche in south-central Kingfisher County, Oklahoma. The field, with a 640-acre spacing pattern, at present covers four sections in the southwest corner of T. 16 N., R. 7 W., and nine sections in the western third of T. 15 N., R. 7 W. (fig. 1). It extends seven miles from north to south and is two to three miles wide. As of February 1961, 13 wells were producing gas with some condensate and three holes were being drilled (see *Note*, page 115).

Production in the area was discovered in August 1958 by Calvert Drilling Company, of Oklahoma City, in its No. 1 Grummer (sec. 19, T. 15 N., R. 7 W.) in the Manning zone, a reservoir in the lower part of the Chester series (Late Mississippian). Calculated open-flow potential of the well was 13,164,000 cubic feet of gas per day with a reported 25 barrels of 60°-gravity condensate per million. In 1959, Ohio Oil Company completed the second well about three quarters of a mile to the east. Then in 1960, Apache Oil Corporation drilled a third test in sec. 5 of the same township. This was the discovery of the Southwest Kingfisher Field. The Oklahoma Nomenclature Committee, Mid-Continent Oil and Gas Association, on December 21, 1960, combined the North Okarche and Southwest Kingfisher Fields and all contiguous oil and gas producing areas, and redesignated the area as the North Okarche Field. Table I gives the development history of the field.

North Okarche Field is classified as a stratigraphic trap because there is little evidence of structural closure or nosing on the structure-contour map at the top of the Manning zone (fig. 1). The trap exists near the updip truncated edge of the Manning zone. Between the dry hole (sec. 14, T. 15 N., R. 8 W.) drilled to the west in 1953 and the producing well (sec. 8, T. 15 N., R. 7 W.), illustrated in figure 2, 165 feet of Mississippian section was removed previous to Middle Pennsylvanian deposition.

The Manning at many places in the field consists of an upper sandstone ranging from 35 to 50 feet in thickness, and a lower limestone 20 to 25 feet thick. Gray shale may separate the two rock types. The upper sandstone, at places slightly oil stained, is light buff, fine to medium grained with thin interbeds of gray, slightly calcareous shale. Porosity ranges from 3 to 11 percent. The underlying limestone is buff, mottled, finely crystalline, slightly oolitic, and sandy. However, in the Apache Oil Corporation No. 1 Duggan-Bowman Unit (fig. 2) the lower member is represented by calcareous sandstone underlain by gray sandy shale.

Depth to the producing zone ranges from 7,780 to 8,240 feet depending on the structural position of the well location (table I, fig. 1). Thickness of the productive zone averages between 9 and 14 feet. Cal-

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TABLE I.—DEVELOPMENT HISTORY, NORTH OKARCHE FIELD

Operator- Well name- Completion date-	Location- Elevation (feet)	Depth to top of Manning (feet)	Perforations- Total zone perforated-	Initial potential	Total depth- Deepest formation penetrated- Remarks-
Calvert No. 1 Grummer August 6, 1958	C NE 19-15N-7W 1212 KB	8,172	8,200-8,210 10 feet	COF 13,164 MCF/D & 25 bbls condensate per MMCF, grav. 60°	8,480 Meramec? Discovery well N Okarche Field
Ohio No. 1 Gruntmeir Unit June 17, 1958	SE NW 20-15N-7W 1,221 KB	8,104	8,131-8,141 10 feet	F 10,625 MCF/D & 35 bbls condensate in 5 hrs	8,272 Chester
Apache No. 1 Snow Unit March 9, 1960	SE NW 5-15N-7W 1,121 KB	7,798	7,814-7,817 7,819-7,824 7,830-7,838 7,840-7,846 7,852-7,857 27 feet	F 4,700 MCF/D with spray condensate	8,070 Chester Discovery well SW Kingfisher Field
Ohio No. 1 Mallen Unit May 18, 1960	NW SE 18-15N-7W 1,197 KB	8,157	8,179-8,192 13 feet	COF 13,590 MCF/D & est. 6 bbls condensate per MMCF	8,275 Chester
Apache-Pan American No. 1 Duggan-Bowman Unit July 6, 1960	SW SW NE 8-15N-7W 1,147 KB	7,860	7,870-7,880 7,889-7,891 7,898-7,901 15 feet	COF 15,800 MCF/D	8,254 Meramec
Ohio-Pan American No. 1 Vogt Unit July 6, 1960	SE NW 29-15N-7W 1,217 KB	8,135	8,160-8,172 8,176-8,178 14 feet	COF 8,100 MCF/D & 6.75 bbls condensate in 5 hrs	8,255 Chester
Calvert No. 1 Schroder July 27, 1960	SE NW 17-15N-7W 1,172 KB	8,005	8,026-8,042 16 feet	F 5,000 MCF/D	8,551 Meramec
Post No. 1 Loosen-McCarthy August 6, 1960	SW NE 6-14N-7W 1,249	8,382	None	Plugged & abandoned	8,500 Chester Non-producing

Pan American No. 1 Mueggenborg September 12, 1960	NE SW 29-16N-7W 1,092 KB	7,753	7,765-7,768 7,771-7,773 7,778-7,782 9 feet	F 3,105 MCF/D	7,889 Chester
Apache-Pan American No. 1 Sioux Unit September 27, 1960	NE SW 32-16N-7W 1,100 KB	7,786	7,805-7,815 7,825-7,848 33 feet	COF 12,800 MCF/D	7,903 Chester
Ohio No. 1 J. Vogt October 3, 1960	NW SE 31-16N-7W 1,086 KB	7,847	7,860-7,878 18 feet	COF 17,500 MCF/D	7,972 Chester
Pan American No. 1 Mitchell Unit October 21, 1960	NE SW 33-16N-7W 1,127 KB	7,623	7,626-7,628 7,631-7,633 7,638-7,640 7,643-7,645 8 feet	F 3,600 MCF/D	8,045 Meramec
Pan American No. 1 Kuntz Unit October 31, 1960	NE SW 4-15N-7W 1,129 KB	7,688	None	Plugged & abandoned	7,900 Chester Non-producing
Calvert No. 1 Ahlden November 16, 1960	SE NW 28-15N-7W 1,176 KB	7,978	None	Plugged & abandoned	8,200 Meramec Non-producing
Pan American No. 1 Bates Unit November 29, 1960	NE NE NE SW 6-15N-7W 1,095 KB	7,926	7,940-7,942 7,953-7,955 7,971-7,973 7,984-7,986 8 feet	F 3,758 MCF/D & 16 bbls condensate in 20 hrs	8,040 Chester
Pan American No. 1 Vogt Unit February 8, 1961	NW SE 7-15N-7W 1,138 KB	8,025	8,027-8,029 8,042-8,044 8,079-8,081 6 feet	F 2,805 MCF/D $\frac{1}{4}$-inch TC	8,202 Chester
Ohio No. 1 Lefler Unit	SW NE 30-15N-7W 1,212 KB	8,286			8,420 Chester
Pan American No. 1 Watta "B"	NW SE 1-15N-8W				
Pure No. 1 Redbird	W/2 NW NE 30-16N-7W				

NOTE: The Pure No. 1 Redbird has since been completed with the discovery of a new pay zone in the Red Fork sand. KB 1,093. Top of Red Fork 7,618, base 7,660. Perforations 7,644-50, 7,653-55, 7,658-60. F 4,500 MCF/D.

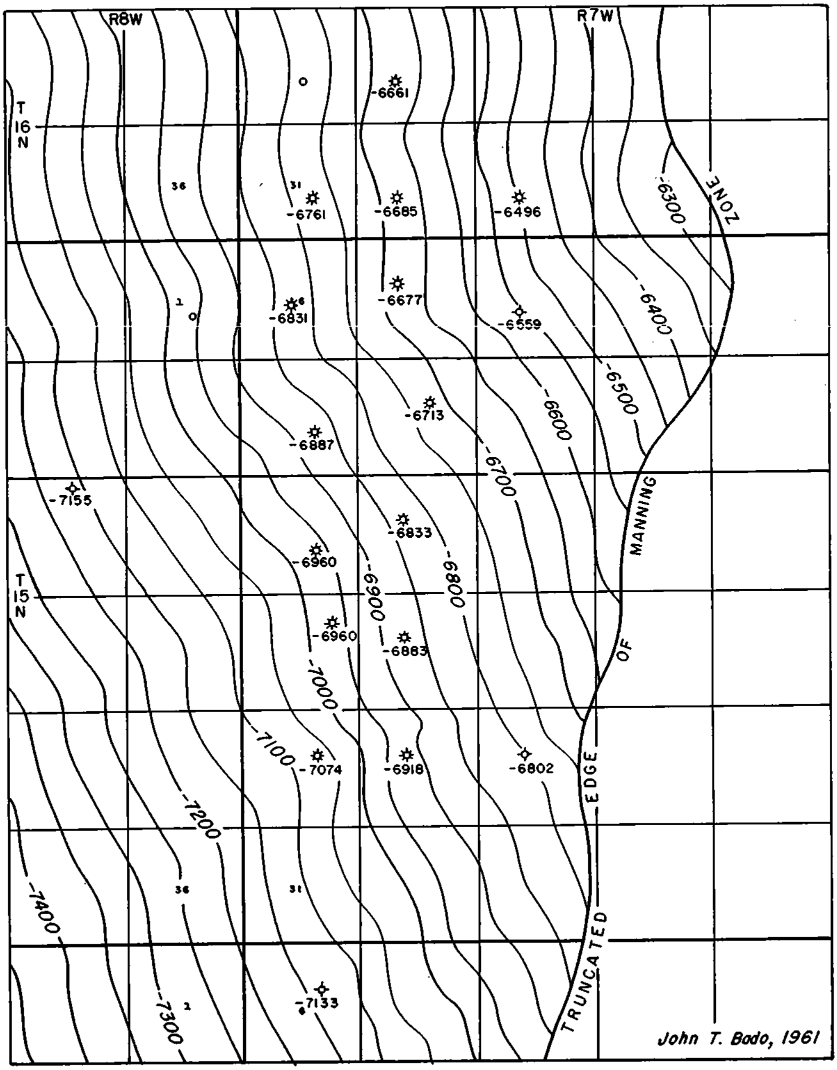

FIGURE 1. *Structure map of North Okarche Field contoured on top of Manning zone (Late Mississippian) showing postulated eastern limit of zone. Contour interval is 50 feet.*

culated open-flow production of individual wells ranges from 3,758,000 to 17,500,000 cubic feet of gas per day. Some crude oil was obtained from Pennsylvanian sandstone, called "Layton," at a depth of 6,331-6,352 feet in the Apache-Pan American No. 1 Sioux Unit by drill-stem testing, and later from perforations, but the amount was not considered commercial. Production and reserve statistics are not available at present.

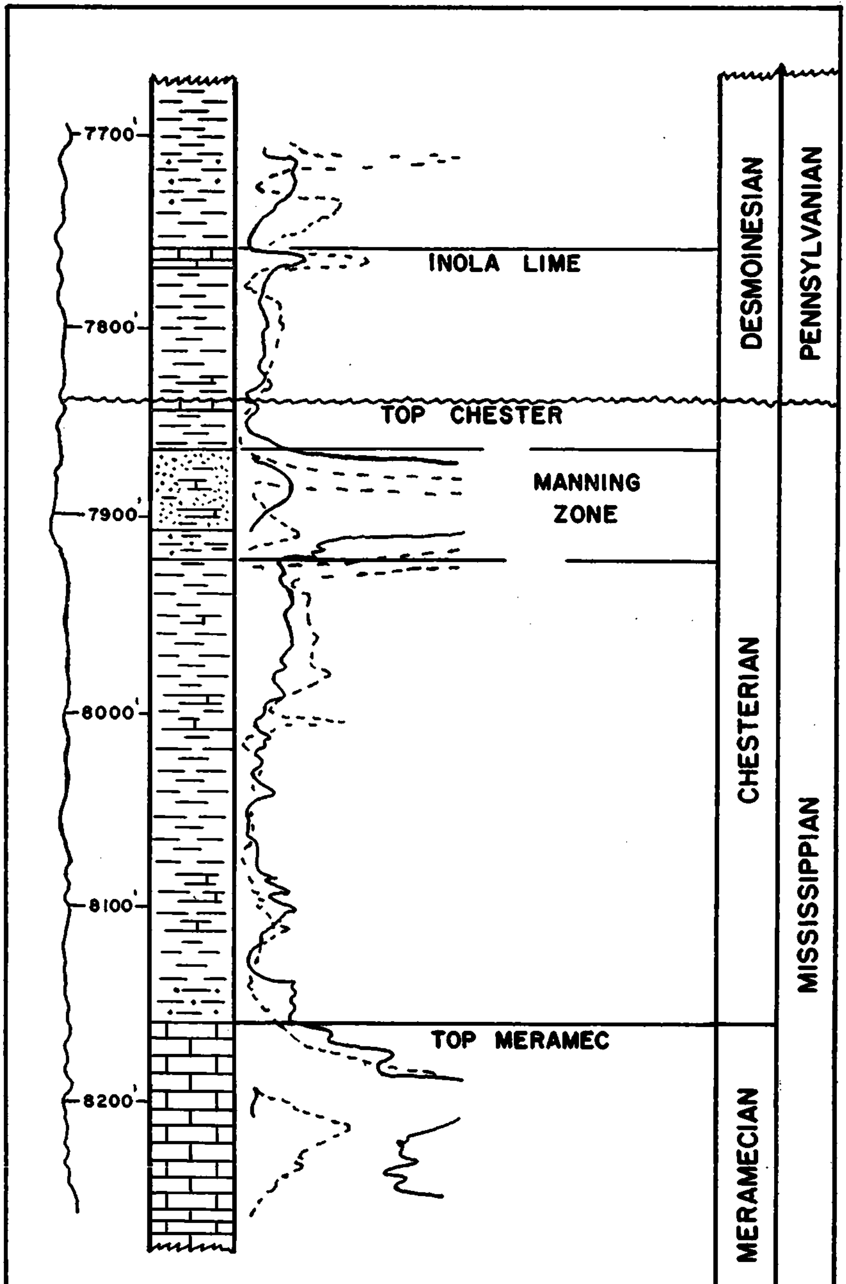

FIGURE 2. *Electric and lithologic log of Apache-Pan American No. 1 Duggan-Bowman Unit, SW¼ SW¼ NE¼ sec. 8 T. 15 N., R. 7 W., in North Okarche Field, Kingfisher County, illustrating position of Manning zone below the Mississippian-Pennsylvanian angular unconformity and above the Meramecian calcareous siltstone or silty limestone.*

The Stockton Field— Key to the Marietta Basin?

C. C. Reeves, Jr.* and W. F. Brazelton*

The Marietta basin, one of the smaller structural units of south-central Oklahoma and the dominant structural feature of Love County, extends to the northwest into adjoining Jefferson County, to the north into southwestern Carter County, and to the southeast into Cooke and Grayson Counies, Texas (fig. 1). The fact that the Marietta basin is bounded on the north by the Wichita-Criner Hills arch and on the south by the Waurika-Muenster arch, both of which are outstanding oil-productive trends, long ago directed exploratory attempts to the basin itself, yet to date, no large oil field and only a few small ones are found within the basin.

During the twenty-year period 1900-1920 some of the great producing fields of south-central Oklahoma, such as Graham, Healdton, Hewitt, Loco, and Velma were discovered, many of which lie close to the margin of the Marietta basin. Finally, in 1924, the shallow Oscar and Spring fields were discovered (fig. 1), and with their discovery a doubtfully successful exploratory program was initiated which continues even today. This sporadic 36-year exploratory program has experienced periods of poor results but these have been offset by field discoveries such as Stockton in 1936, Sivells Bend in 1946, Woodrow in 1950, North Pike and Northeast Oswalt in 1951, and Thackerville and Northeast Leon in 1952 (fig. 1). Several minor discoveries, one of which produced only 339 barrels, have not necessarily discouraged exploration but have emphasized the fact that oil is present in the basin.

Today the Marietta basin is once again the target of several exploratory efforts, especially since the 1957 discovery of basal Oil Creek sand production in the southeast Marietta area and the mid-1959 discovery of Hunton production at North Orr (fig. 1). The recent (December, 1960) discovery of production from Pennsylvanian sandstone southwest of Marietta (fig. 1) is sure to renew interest in the Sivells Bend-Walnut Bend area. In light of the conspicuous exploratory failures of the past, the recent discoveries suggest the need for a re-evaluation of the entire basin. Fortunately a cursory examination of a producing field such as Stockton, the third Marietta basin discovery and the first commercial oil field of Love County, is sufficient for this purpose.

Field Discovery Data.—The Stockton Field, located in the trough of the Marietta basin, covers parts of secs. 26, 27, 34, 35, and 36, T. 6 S., R. 2 W. (fig. 2). Discovery in 1936 was by Sinclair-Prairie No. 1 Stockton, a test which received considerable publicity at the time because of its 10,388-foot depth. Drilling problems, other than excessive caving of Cisco sands, were not encountered in the nearly flat-lying Pennsylvanian strata, but when the wells were drilled below the basal Pennsylvanian unconformity into Simpson rocks of Ordovician age at approximately 7,900 feet, excessive deviation occurred. More than 2,000 feet of inter-

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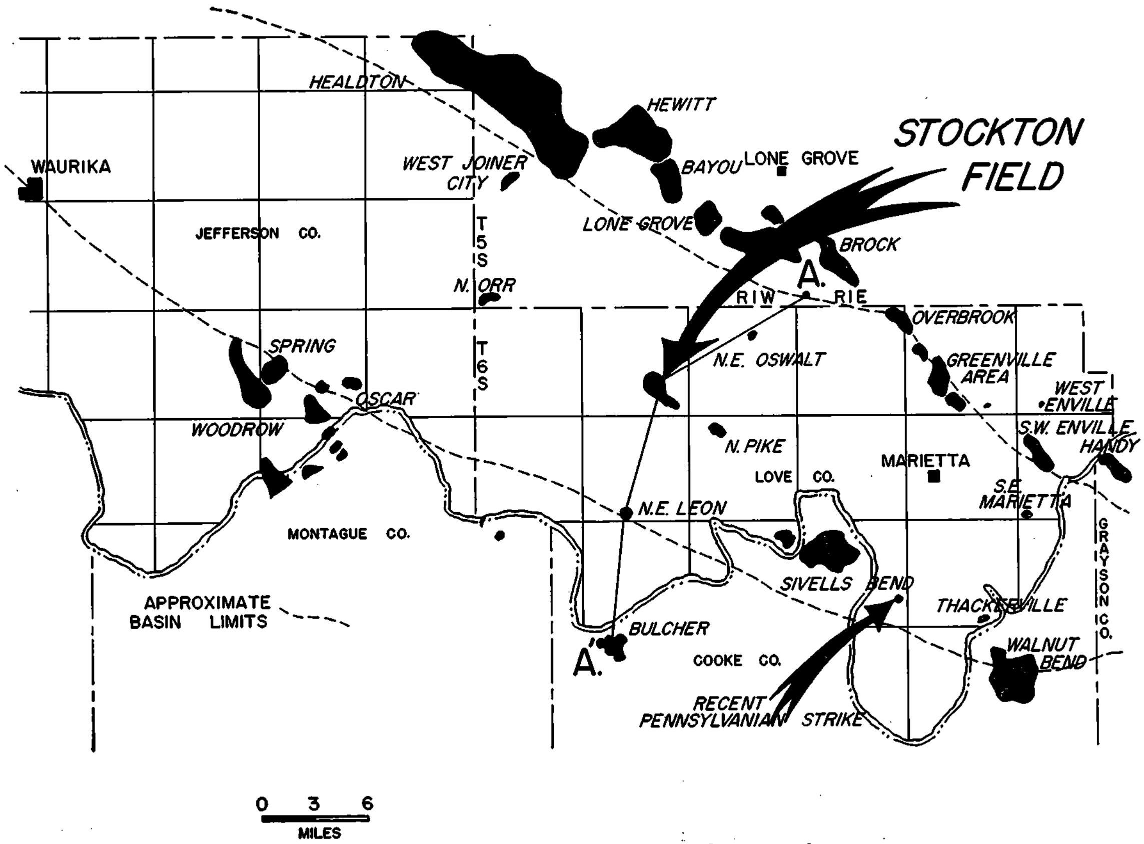

FIGURE 1. *Index map of Marietta basin and surrounding area.*

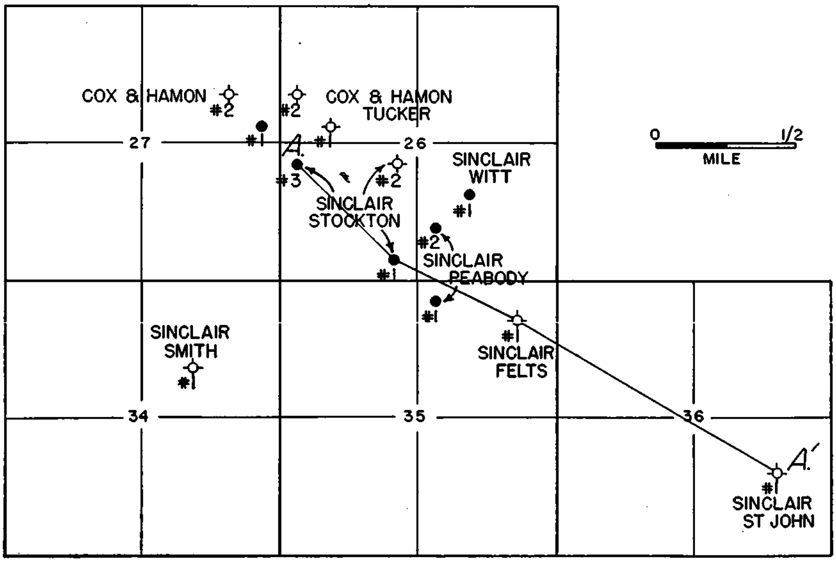

FIGURE 2. *Base map of Stockton field.*

mediate casing was set in the early wells to correct the Cisco caving but today increased efficiency in mud technology permits the use of only enough casing to protect the Cretaceous fresh-water sands.

Development in the field was slow after the discovery, and after the 1938 abandonment of the Sinclair-Prairie No. 1 Felts, little was done until the 1948-1951 period. To date 13 wells have been drilled on the Stockton structure, 6 of which continue to produce by pumping.

Production-Reservoir Data.—In the Sinclair-Prairie No. 1 Stockton the Oil Creek "Birdseye" lime zone was treated with 10,000 gallons of acid, and it initially yielded 302 barrels per day. The yield rate quickly dropped to 47.5 barrels per day on swab. The Stockton well was then plugged back to 6,920 feet to produce from the Stockton sand. Present production ranges from 6 to 25 barrels per day per well, with cumulative production as of January 1, 1959, set at 386,200 barrels.

Core analysis of the Stockton sand zone in two field wells shows an average porosity of 12.9 percent, average permeability of 45.5 millidarcys, an average water saturation of 55.5 percent, an average connate water saturation of 33 percent, and an oil saturation of 22.1 percent. The gas-oil ratio in the field, at discovery, was 800 to 1 with an original saturation pressure of 2,400 pounds per square inch.

Field Stratigraphy.—The surface formation of the Stockton Field area is the Lower Cretaceous Trinity sand and is underlain by approximately 2,000 feet of Permian and Pennsylvanian Cisco red beds. The Pennsylvanian system, which is here predominantly shales and sandstones and sandy shale with thin limestones in the upper part and massive sandstones, shaly sandstones, and limy shales in the lower part, is represented by the Hoxbar and Deese groups (figs. 5, 6). The Hoxbar, which is about

SYSTEM	EPOCH	GROUP	FORMATION
Cretaceous	Comanchean	Trinity	
Permian	Wolfcampian	Pontotoc	
			ARBUCKLE OROGENY
Pennsylvanian	Virgilian	Cisco	
	Missourian	Hoxbar	Zuckermann Daube Anadarche Crinerville Confederate
			MUENSTER UPLIFT
	?	Deese	Chubbee* Deese Maroon* Peabody* Stockton*
	Desmoinesian		
			OUACHITA OROGENY
	Atokan	Dornick Hills	BOSTWICK UPLIFT
	Morrowan		
			WICHITA OROGENY
Ordovician	Blackriveran	Simpson	Bromide Tulip Creek McLish
	Chazyan		Oil Creek Joins
	Canadian	Arbuckle	
Cambrian	Croixan		
		Timbered Hills	
Precambrian			

*Subsurface name.

FIGURE 3. *Generalized stratigraphic column, Stockton field.*

2,300 feet thick in the field area, correlates poorly with the section found on either side of the basin; but the Daube, Anadarche, Crinerville and Confederate members are recognizable (fig. 5). When correlated southeast toward the Grayson County area the Hoxbar expectantly thickens, and when correlated to the northwest an increase in thickness to approximately 3,700 feet in a very few miles is observed. This is astonishing considering the small closure of the Stockton structure and is definitely inconsistent with the known facts of earlier depositional history. Apparently the Marietta basin, by Missourian time, was of regional character, for the Muenster arch as well as the Criner Hills were buried.

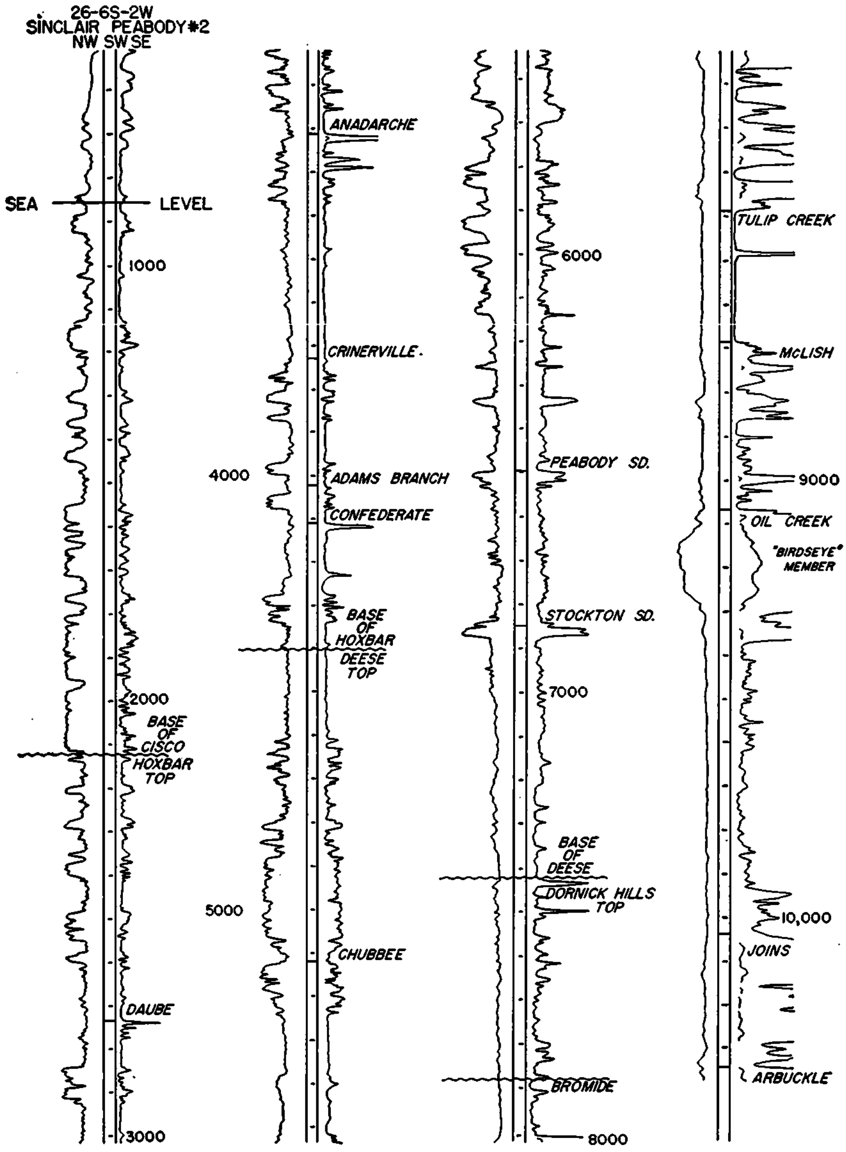

FIGURE 4. *Typical electrical log of Stockton field.*

Because of the rapid increase in thickness northwest of Stockton the possibility of faulting is not to be entirely ignored.

The Hoxbar is composed chiefly of shale separated by sandstones and thin, grayish-white, fine-crystalline limestones which at many places show evidence of past hydrocarbon saturation.

The Deese section, which is approximately 3,000 feet thick, contains

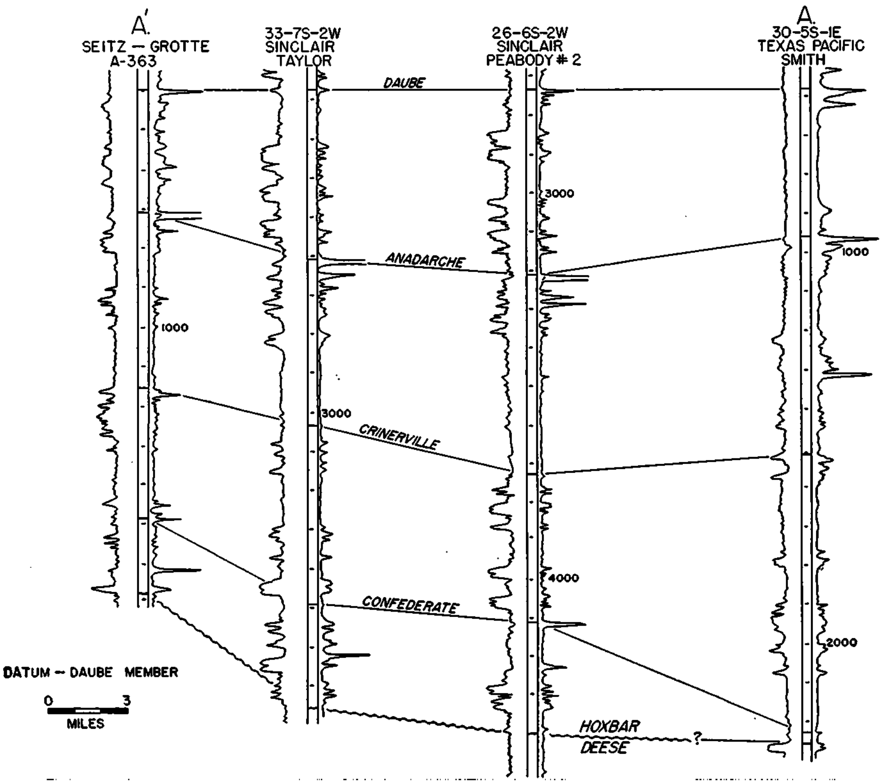

FIGURE 5. *Correlation of limestones in lower part of Hoxbar group from Bulcher field in Cooke County, Texas, northeastward across Marietta basin to southern Carter County, Oklahoma. Line of cross section shown on figure 1.*

several limestones, red to maroon shales, and massive, medium-grained sandstones. These sandstones, a typical Deese group rock type, are present in the Stockton area, the Stockton sand being important because it is oil productive. The top of the Deese is marked by the appearance of red, arenaceous shales with local rounded, imbedded quartz grains. Even though this contact appears somewhat correlative to the Missourian-Desmoinesian contact of the Ardmore basin the authors have found by previous investigation that the Deese Maroon, which marks the contact in the Ardmore basin, appears approximately 1,000 feet beneath the youngest Deese sandstone (Chubbee?) of the Stockton area. The Deese thins with rapid uniformity when traced northwest of the Stockton area.

Underlying the Deese is a 450-foot section of coarse-grained, locally conglomeratic limestones, interbedded gray to red shales and lensing sandstones which represent a Dornick Hills remnant (fig. 4).

No post-Simpson pre-Pennsylvanian rocks are present on the crest of the Stockton structure because of pre-Atokan erosion; however, the normal column probably occurs to either side. The Bromide formation,

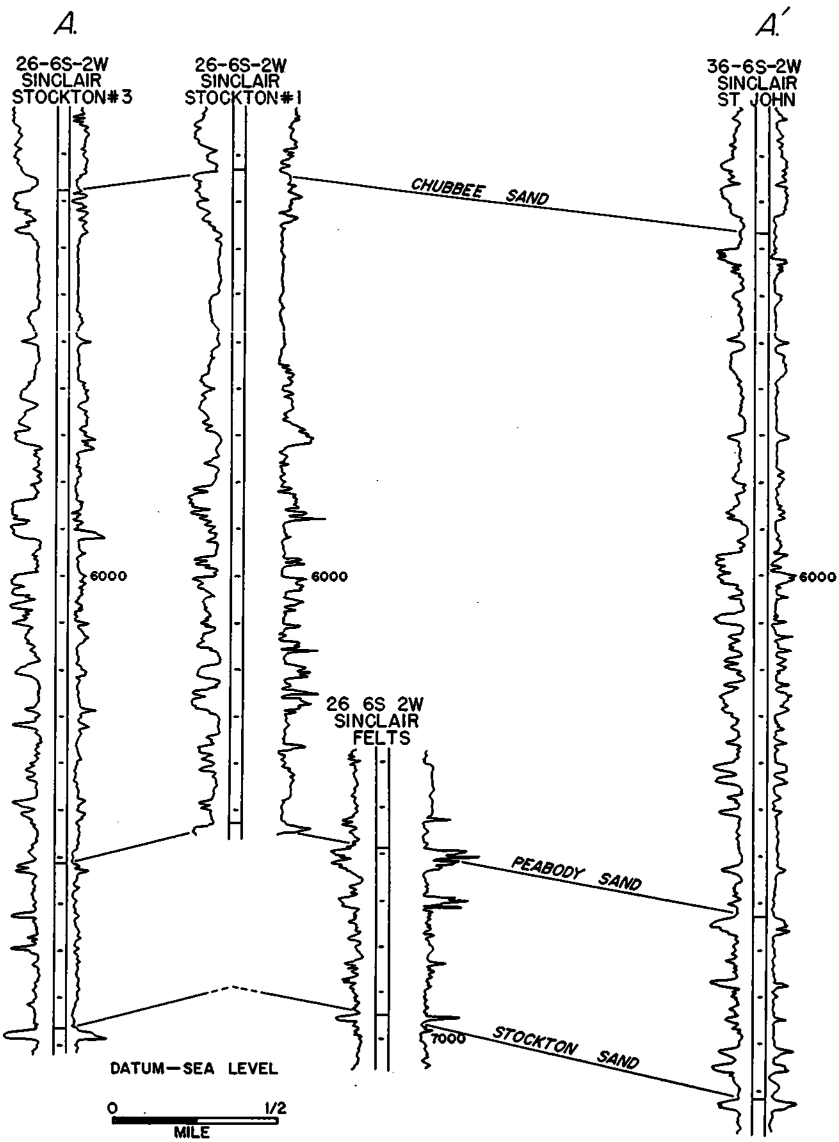

FIGURE 6. *Correlation of Deese units in Stockton field.*

composed of interbedded gray, medium-grained, sandy shale and grayish-white, medium-crystalline limestone, contains an upper limy sandstone-sandy limestone member which closely resembles the producing zone at Southwest Enville. The Tulip Creek does not contain a basal sandstone member and is wholly a green, slightly pyritic, splintery shale. The underlying McLish is predominantly a gray to brownish-white, medium-

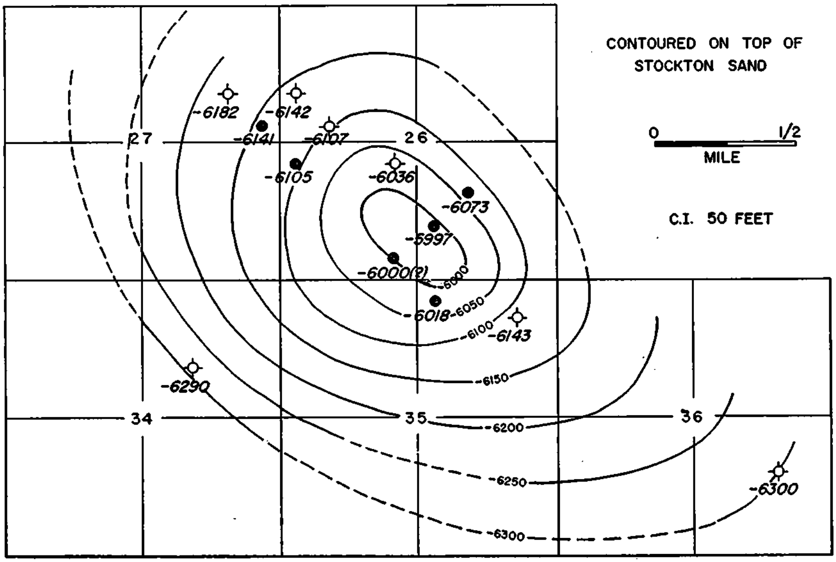

FIGURE 7. *Structure map of Stockton field contoured on top of Stockton sand.*

crystalline limestone with thin shale interbeds. The basal McLish sandstone has graded to a limestone with shale lentils.

It has been the habit of the operators to place the "Birdseye" lime section in the basal McLish immediately beneath the McLish sand interval, and to call the Oil Creek top at the "Birdseye" base, more or less in keeping with original definition. Yet in several producing areas of southern Oklahoma, such as Southwest Enville, Caddo, and Southwest Ardmore, the "Birdseye" is considered to be the upper member of the Oil Creek formation. Because the "Birdseye" of the Stockton area is found beneath the unit correlative to the basal McLish sand of nearby Southwest Enville, the authors consider the "Birdseye" as the upper member of the Oil Creek formation. Beneath the "Birdseye" limestone the Oil Creek is an interbedded sequence of dull-green shales and some grayish-white, medium-crystalline limestones. The basal Oil Creek sand, which has and is still yielding spectacular discoveries only 21 miles to the southeast, has graded to limestone. A 300-foot section of impermeable Joins rests upon the Arbuckle at a depth of approximately 10,350 feet.

Field Structure.—The Stockton trap is formed by approximately 300 feet of closure (fig. 7) in the Pennsylvanian strata immediately over a much more accentuated pre-Pennsylvanian anticline, trend of both structures being northwest-southeast. Basal Pennsylvanian rests directly upon Simpson Bromide in the field area.

Depositional History.—During early Paleozoic time a broad regional geosyncline covered south-central Oklahoma as well as great areas of the surrounding states. Quiescent deposition, interrupted perhaps by local movements, proceeded until the more violent pre-Woodward uplift.

This disturbance, which resulted in the stripping of much of the upper Hunton from parts of south-central Oklahoma, seems to have been localized along trends which were later to become the Pennsylvanian orogenic belts. After the pre-Woodford uplift the area once again received widespread quiescent deposition until shortly after Springer time. Pennsylvanian time was characterized by several orogenic uplifts which have been used to define the Pennsylvanian formations and groups. After deposition of Permian redbeds, south-central Oklahoma experienced gentle uplift and peneplanation, remaining above sea level until Lower Cretaceous time. Cretaceous deposition was followed by general uplift which resulted in the present-day physiographic character of the area.

Summary and Conclusions.—Fortunately the geologic history, depositional and deformational, of any area is revealed by sample and electrical log examination of its stratigraphic column. The geologic study, by these means, of Stockton field wells reveals the following facts upon which future exploratory programs within the Marietta basin must rely for some measure of success:

1) General absence of sandstone in the basal Simpson formations in the Marietta basin is due to facies change rather than to nondeposition or erosion.
2) Carbonate reservoirs, with possible commercial porosities/permeabilities, exist in the Simpson section.
3) Token "Birdseye" production in 1936, combined with additional sample shows of oil from the Simpson section, is indicative of accumulation.
4) Extensive truncation of pre-Pennsylvanian structures by the pre-Atokan unconformity occurred.
5) Pennsylvanian strata exhibit closures over pre-Pennsylvanian structures.
6) Dornick Hills carbonates are typically conglomeratic.
7) Dornick Hills strata are generally underlain and overlain by thin, impermeable shales.
8) Thinning of the Deese section takes place to the northwest.
9) An abbreviated Hoxbar section occurs in the Stockton area, and increases in thickness to the northwest and southeast.

The northwestward lithologic change of basal Simpson sandstones to limestones, which occurs between the Enville and Stockton areas, creates interesting stratigraphic prospects, especially when the possibility of substantial Simpson carbonate production is considered. Admittedly, Simpson carbonates in the Marietta basin have consistently exhibited poor porosities and permeabilities, yet they just as consistently yield good oil shows. Obviously this production will remain non-commercial until industry is driven to develop more efficient means of stimulation, or perhaps finds local areas of secondary permeability due to pre-Atokan erosion.

Precise correlation of post-Pennsylvanian tests may point out previously unsuspected pre-Pennsylvanian structures as well as small but widespread post-Pennsylvanian closure. Specifically, Dornick Hills lithology and stratigraphic position is conducive to oil entrapment, thinning of Deese and Hoxbar sections is suggestive of overlap, onlap, pinchout, or fault traps, and local unconformable relations between the Hoxbar and Deese are indicative of additional stratigraphic prospects.

Within the last few months independents and majors alike have leased substantial areas within the Marietta basin. It is interesting to note that these leased areas are defined when the geology of the Stockton area is correlated to the regional geologic picture. Apparently others have considered the Stockton area the key to the basin's oil future. Although the outlook for the Marietta basin is far from good, at least an air of optimism exists.

Acknowledgements.—The cooperation of W. B. Holder, and V. A. Peterson, Sinclair Oil Company, Dan R. Dunnett, Oklahoma Corporation Commission, D. O. Chapell and J. P. Gill of Jake L. Hamon, Oil Producer, is acknowledged.

Oklahoma Geological Survey Palynology Type Collection

Recently the Oklahoma Geological Survey received from Jersey Production Research Company the holotype specimens of two Libyan Silurian spore spceles described in *Micropaleontology*, vol. 5, p. 331-334, by Dr. W. S. Hoffmeister. These specimens have been added to the type- and published-specimen collection of the Oklahoma Geological Survey. The collection was begun four years ago and now contains, in addition to Dr. Hoffmeister's Libyan types, those of L. R. Wilson, E. J. Tynan, J. L. Morgan, J. B. Urban, R. W. Hedlund, and M. J. Higgins. Types by the last four workers are described in The University of Oklahoma theses. In addition, this collection includes all the specimens illustrated in their theses except some published by J. L. Morgan in 1955. Most of the other palynological and paleobotanical specimens published from The University of Oklahoma and the Oklahoma Geological Survey are also in the collection.

The type- and published-specimen collection is housed in an inner room of the Oklahoma Geological Survey publication vault. The construction of this vault is ideal for such a collection as it is dry and has a uniformly cool temperature in addition to being fire, water, and tornado proof. Access to the collection is possible only by permission of the Director of the Oklahoma Geological Survey, and though examination of the types and other specimens is encouraged this must be done on the premises because microscope preparations are easily damaged in transport. For those unable to come to the Oklahoma Geological Survey, photomicroscope color transparencies of the specimens are available on loan or may be purchased. Many of the types are illustrated by photomicrographs taken at more than one focal level in order to show specific morphological characters.

— L. R. W.

Reticulatia IN THE BELLE CITY LIMESTONE

CARL C. BRANSON

The productid genus *Reticulatia* Muir-Wood and Cooper is recorded from Virgilian rocks of Missouri, Kansas, Texas, and Oklahoma, and from Early Permian rocks of Texas, Oklahoma, Kansas, and Nebraska. Two specimens collected from the Belle City limestone by W. F. Tanner and labeled *Dictyoclostus americanus* appear to belong to the genus. The locality is SW¼ sec. 17, T. 7 N., R. 7 E., Seminole County, Oklahoma, and is Tanner's Station 3088 (1956, p. 141, list on p. 82). The specimens are No. 1247 in The University of Oklahoma Paleontology Collection.

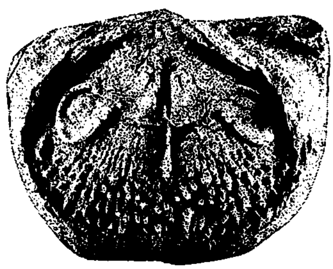

FIGURE 1. Reticulatia *sp., interior of brachial valve, x1.*
(Photograph by Neville M. Curtis, Jr.)

One of the specimens is part of a ventral valve. It is strongly cancellated on the posterior area, marked by strong plications of unequal size and by a few scattered spine bases on the anterior portion. The ear is well developed, is marked by low indistinct costae, bears a spine at the outer corner and another spine at the hinge line near the outer corner. The other specimen is the interior of a brachial valve (fig. 1). The cardinal process is not well preserved. The adductor scars are large, complexly lobate. A short median septum is situated at mid-length of the shell. The brachial ridges are lateral, roughly spoon-shaped, prominent. Endospines are arranged in rows on the shell surface.

If the specimens are correctly assigned to the genus *Reticulatia*, the range of the genus is extended downward to the middle part of the Missouri series. The Belle City limestone is correlated with beds not far below the Dewey limestone of northern Oklahoma and the Cement City member of the Drum limestone of Kansas.

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