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Cover Picture

SILURIAN ROCKS OF NORTHEASTERN OKLAHOMA

ST. CLAIR LIMESTONE

Quarry of the St. Clair Lime Company in the upper part of the Silurian St. Clair Formation near Marble City, Sequoyah County, Oklahoma. The St. Clair-Frisco (Lower Devonian) contact lies a short distance above the mine opening. Much of the St. Clair is a high-calcium limestone of exceptional purity, which has been extensively quarried and mined as a source of lime. The inset photomicrograph shows the typical St. Clair texture (area covered is approximately 4 mm in diameter). The St. Clair is largely a biosparite, rich in pelmatozoan debris, but with local concentrations of brachiopods, bryozoans, trilobites and other invertebrates.

—T. W. A.

Brine-Well Production of Permian Salt at Sayre, Beckham County, Oklahoma

Kenneth S. Johnson

INTRODUCTION

The largest production of salt in Oklahoma during most of the last 28 years has come from a plant two miles southwest of Sayre, in central Beckham County (fig. 1). By injecting fresh water into a well 1,518 feet deep, salt is dissolved from beds of Permian age and the brine is recovered from a second well 310 feet away. Early drilling for oil and gas south of Sayre led to the discovery of the salt bed which is now being exploited. This area is in the southwestern part of the Oklahoma portion of the Anadarko basin and lies two miles northwest of the Sayre (gas) district.

The discovery well in the Sayre district was drilled three miles south of Sayre in 1922, and subsequent development of the field proved the existence of a domal structure in the shallow beds. Using the top of the Blaine Formation as the datum, Gouin (1927, pl. 1) presented

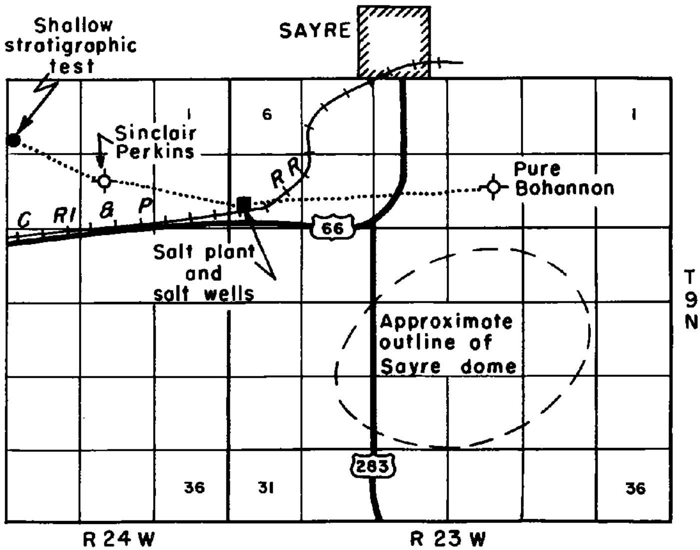

Figure 1. Location of salt plant near Sayre, Beckham County, Oklahoma. Dotted line through wells is line of stratigraphic cross section shown in figure 3. Outline of Sayre dome is based on closure at top of the Blaine Formation (modified from Gouin, 1927, pl. 1).

a structural contour map which shows the Sayre dome to have a diameter of approximately three miles, a closure of 100 to 125 feet, and its center in sec. 22, T. 9 N., R. 23 W.

Development of the Sayre district during the 1920's and early 1930's showed that the area was underlain by beds of salt at shallow depth. Three Permian salt-bearing sequences are known to have been penetrated in the salt well: they are (ascending order) the Upper Cimarron salt, the Flowerpot salt, and the Blaine Formation. The salt bed being exploited is in the Upper Cimarron salt.

SALT PRODUCTION

In 1934 Oklahoma Salt Industries, Inc., a subsidiary of the United Carbon Company, drilled a salt-producing well in NW¼ SW¼ sec. 7, T. 9 N., R. 23 W. Located 4½ miles northwest of the center of the Sayre dome, the well was drilled to a depth of 1,518 feet with a rotary rig. Ground level at the well is 1,812±2 feet above sea level.

Although indications of salt were noted at many depths from 667 feet down to the bottom of the hole, the drilling was stopped only after penetrating 38 feet of salt between 1,475 and 1,513 feet. Water wells, drilled to depth of 36 feet in Quaternary terrace deposits, supplied fresh water which was pumped inside the tubing to the bottom of the hole. Brine formed by the solution of salt was brought to the surface through the annulus between the tubing and casing. Salt was produced by evaporation of the brine, marking the first recorded production from underground salt beds in Oklahoma.

Early in 1942 a second salt well was drilled 310 feet southwest of the first. It also was drilled to a depth of 1,518 feet, and brine was produced from it in the same manner as from the original well.

In 1945 the solution cavities of the two wells coalesced, making possible the adoption of the present production method whereby fresh water is pumped into one well and brine is extracted from the other. The water is injected under a pressure of approximately 225 psi (pounds per square inch), whereas fluid pressure at the surface at the recovery well is about 35 psi.

The recovered brine generally has 80 to 100 percent salt saturation, although at times the saturation may drop to 75 percent. The brine flows into the settling tank (fig. 2) and then into a gas-heated evaporator, where much of the water is volatilized and driven off. The remaining supersaturated liquid is returned to the settling tank, and in it the salt is precipitated. Wet salt is conveyed from the bottom of the tank to a centrifuge, where most of the water is extracted. The extracted liquid is returned to the settling tank, whereas the moist salt is fed into a rotary dryer. Heat from a gas furnace at one end of the rotary dryer completes the dewatering of the salt. Dry salt is then crushed to a powder and sacked in 100-pound bags.

Ownership of Oklahoma Salt Industries, Inc., passed from the United Carbon Company to a private individual in 1945. The plant was sold again in 1961 and at present is operated under the name Tom-Feld Salt Company, P. O. Box 146, Sayre, Oklahoma. Operation

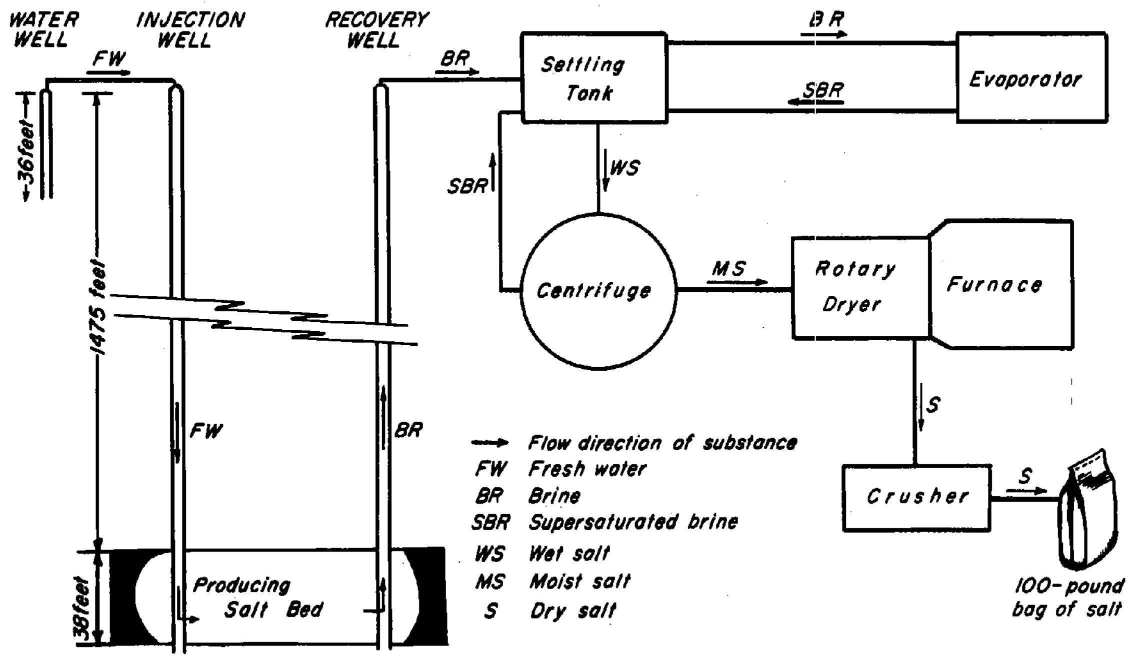

Figure 2. Schematic flow diagram of Tom-Feld salt plant at Sayre.

of the plant was temporarily suspended from 1958 through the summer of 1962, at which time production was resumed.

The salt is sold primarily as stockfeed and as a recharger for water softeners. Some brine is sold and used in salt-based drilling fluids. In addition, some of the current salt production of the Tom-Feld Salt Company has been sold to chemical-process industries, where it has been readily accepted, as the salt blends easily with other ingredients and quickly forms a saturated solution when mixed with water.

Appreciation is expressed to C. K. Springfield, engineer, formerly with the United Carbon Company, and Buck York, plant foreman at Tom-Feld Salt Company, for information regarding the history of the plant and production methods used. Mr. O. B. Thomas, partner in the Tom-Feld Salt Company, has kindly read the original manuscript and has offered useful criticisms.

Production figures covering the years 1953-1957 are given in table I. The average yearly production was 6,780 short tons, or 33,902 short tons during the five-year period, and the average yearly value of the salt was $54,181. Peak production during that period came in 1956 when 7,944 short tons of salt were sold for $68,160. From 1934 to January 1, 1953, 156,512 short tons of salt were sold; therefore, cumulative production to January 1, 1958, was 190,414 short tons. These figures do not include the value or estimated tonnage of salt sold as brine. Available market has been the controlling factor in the sale of salt to date, as the production potential of the plant has always greatly exceeded sales.

In past years salt from the Sayre plant has been sold over a wide area, including parts of New Mexico and southern Kansas, as well as most of Texas and Oklahoma. The plant is 0.3 mile north of U. S. Highway 66 and is adjacent to the Chicago Rock Island and Pacific Railroad. The current price is between $0.65 and $1.10 per 100-pound sack, depending upon the quantity purchased.

CHEMICAL ANALYSES

Samples of fresh water being introduced through the injection well, brine coming from the recovery well, and commercial salt precipitated from the brine were obtained on November 28, 1962. The

TABLE I.—SALT PRODUCTION FROM PLANT AT SAYRE, 1953-1957

YEAR	SHORT TONS	VALUE
1957	4,991	$42,823
1956	7,944	68,160
1955	7,302	56,340
1954	6,291	47,686
1953	7,374	55,895
Total	33,902	$270,904
Average	6,780	54,181

TABLE II.—CHEMICAL ANALYSES OF FRESH WATER, BRINE, AND SALT FROM PLANT AT SAYRE

(Samples obtained Nov. 28, 1962. J. A. Schleicher, analyst)

	Fresh Water	Brine		Commercial salt
	no. 10607	no. 10608		no. 10609
Sp. G. (18°C)	0.999	1.204		
pH	7.75	6.5		
	GRAMS/LITER	GRAMS/LITER	WEIGHT % OF DISSOLVED SOLIDS	WEIGHT %
Ca	0.113	4.018[1]		0.5[2]
Mg	0.029	2.318		0.17
K	0.012	0.850		0.076
Li	trace[3]	0.108		0.029
Br	nil[4]	0.180		0.0143
I	nil	0.002		0.0001
B	nil	nil		nil
HCO_3	0.444	0.067		0.0151
CO_3	none	none		0.0084
SO_4	0.036	1.663		0.4578
Fe_2O_3	0.001	0.001		0.0023
Al_2O_3	0.007	0.004		0.0567
SiO_2	0.044	nil		nil
Insol. Res.	0.018	0.014		0.0158
NaCl (by diff.)	0.072	288.671		97.42
Total Dissolved Solids — Determined				
grams/liter	0.594	311.680		
grams/kilogram	0.594	258.870		
Calculated Theoretical Compositions				
$Ca(HCO_3)_2$	0.457	0.089	0.03	
$CaCO_3$				0.014
$CaSO_4$		2.357	0.76	0.6487
$CaCl_2$		9.145	2.93	0.8409
$Mg(HCO_3)_2$	0.120			0.0183
$MgSO_4$	0.045			
$MgCl_2$		9.076	2.91	0.6538
KBr		0.268	0.09	0.0214
KCl	0.023	1.450	0.47	0.1312
LiCl	trace	0.665	0.21	0.1768
LiI		0.002	0.001	0.0001
R_2O_3	0.008	0.005	0.001	0.059
SiO_2	0.044			
Insol. Res.				0.0158
NaCl (by diff.)	0.072	288.671	92.60	97.42
Total	0.769	311.728	100.002	100.0000
Total Dissolved Solids — Calculated				
grams/liter	0.769	311.728		
grams/kilogram	0.769	258.910		

[1]Includes 0.100 grams/liter Sr.
[2]Includes 113 ppm Sr.
[3]Less than 0.001 grams/liter.
[4]Not detected by standard methods of analysis.

chemical analyses and the calculated theoretical compositions of these samples are given in table II.

Salt (NaCl) comprises 288.67 grams per liter, or about 25 percent (grams per 100 grams), of the brine analysed. Salt constitutes 92.6 percent of the total dissolved solids in the brine. Calcium and magnesium chlorides are the next most abundant compounds in the brine, each representing about 2.9 percent of the dissolved solids. Other constituents present in excess of 0.1 percent are calcium sulfate, potassium chloride, and lithium chloride; these components represent 0.21 to 0.76 percent of the dissolved solids. Calcium bicarbonate, potassium bromide, lithium iodide, and R_2O_3 are each present in concentrations of less than 0.1 percent.

Comparison of the ion concentrations of the fresh water and the brine proves that practically all the dissolved matter in the brine comes directly from the salt bed and is not introduced with the fresh water. The only ions and molecules not having greater concentrations in the brine than in the fresh water are bicarbonate and the oxides of iron, aluminum, and silicon.

In comparing the weight percent of dissolved solids in the brine with the weight percent of compounds in the commercial salt, a marked increase in the amount of sodium chloride in the finished product is obvious. Sodium chloride increases from 92.6 percent of the total dissolved solids in the brine to 97.42 percent of the processed salt. The weight percent of all other soluble constituents, except R_2O_3, is less in the commercial salt than in the brine. Most of this loss probably occurs in the evaporator, where these constituents are expelled into the atmosphere with water vapor.

The commercial salt contains 97.42 percent sodium chloride. Principal impurities are calcium sulfate, probably in the form of gypsum ($CaSO_4 \cdot 2H_2O$), 0.649 percent; calcium chloride, 0.841 percent; and magnesium chloride, 0.654 percent. Potassium and lithium chlorides each represent about 0.15 percent of the weight, and other soluble constituents are present in amounts less than 0.06 percent. Insoluble matter makes up 0.016 percent of the processed salt. About 95 percent of the finished salt passes a 60-mesh screen, and about 10 percent passes an 80-mesh screen.

At present the company makes no attempt to recover any elements separately from the brine. It is possible, however, that future economics may warrant the production of calcium chloride, bromine, lithium, potassium, and magnesium salts.

GEOLOGY

A description of the rock cuttings from the first salt well was made by C. K. Springfield as drilling progressed. The upper 660 feet was described in 10-foot sections, whereas below 660 feet descriptions were based upon samples from 4- and 5-foot sections. The descriptions included the percentages of gypsum, shale, and sandstone obtained from each sampled interval, as well as notations of any shows of salt in the cuttings. A salt-based drilling mud was used to prevent solution of salt samples before they reached the surface.

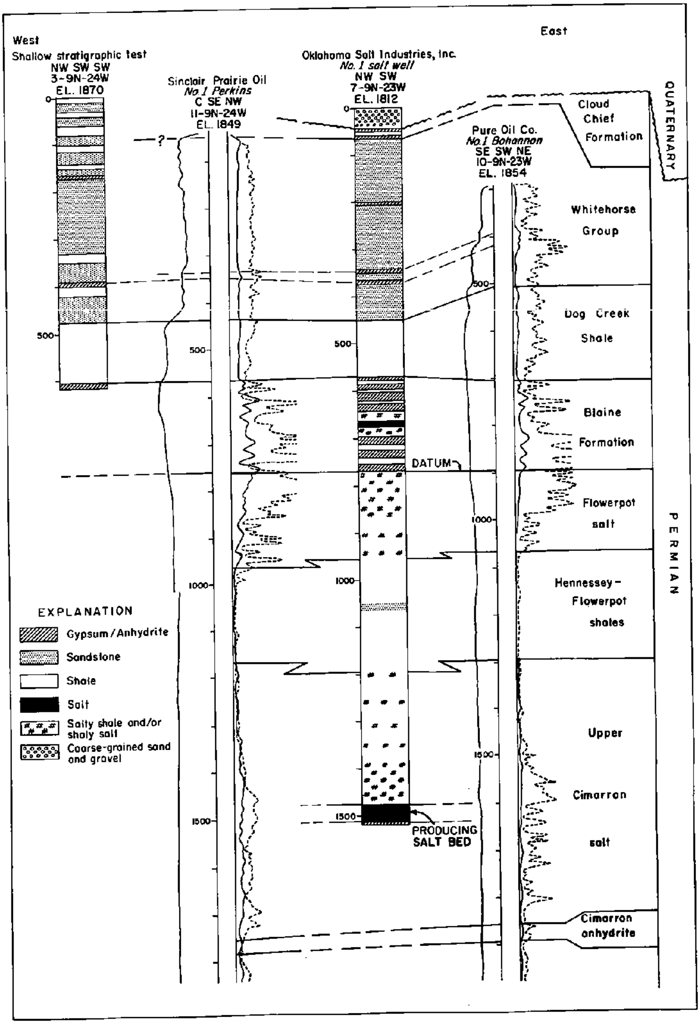

Figure 3. Cross section comparing interpretive lithologic log of the salt well at Sayre with electric logs and a sample log of nearby wells (locations shown in fig. 1). Lithology shown in the salt well has been interpreted to indicate the actual succession of strata penetrated. Nomenclature for beds below the base of the Blaine Formation is after Jordan and Vosburg (in press).

Based upon this description of cuttings from the salt well, field work, and subsurface studies, an interpretive lithologic log of the salt well was compiled to indicate the actual succession of strata penetrated. This log is compared with electric logs of nearby wells to ascertain the stratigraphic position of the producing salt bed (fig. 3). Electric logs used for comparison are from the Pure No. 1 Bohannon, sec. 10, T. 9 N., R. 23 W., and the Sinclair No. 1 Perkins, sec. 11, T. 9 N., R. 24 W. Also used in the cross section is the sample log of a shallow stratigraphic test drilled in sec. 3, T. 9 N., R. 24 W.

All strata penetrated in the salt well are Permian in age, except for the uppermost 45 feet, which is Quaternary terrace deposits. Permian strata encountered include (ascending order) the Upper Cimarron salt unit of the Cimarron evaporites, Hennessey-Flowerpot shales, Flowerpot salt, Blaine Formation, Dog Creek Shale, Whitehorse Group, and the Cloud Chief Formation. Nomenclature for all units below the Blaine Formation is adopted from a forthcoming report by Jordan and Vosburg (in press).

Salt-bearing strata were penetrated in the basal 323 feet (from 1,195 to 1,518) of the salt well. These beds are part of the Upper Cimarron salt unit of the Cimarron evaporites. The salt bed being exploited is in this unit. It is 38 feet thick and its top is at a depth of 1,475 feet. Strata directly above the salt bed, from 1,195 to 1,475 feet, are approximately 80 percent red shale and 20 percent blue shale, with traces of gypsum and shows of salt. Underlying the salt bed is three feet of anhydrite, which in turn is underlain by two feet of blue shale. Drilling was stopped in this blue shale.

From regional studies, Jordan and Vosburg (in press) projected the stratigraphic position of the Cimarron anhydrite unit of the Cimarron evaporites into the Sinclair No. 1 Perkins, and the present writer estimates that the base of the salt bed is 230 feet above the top of the Cimarron anhydrite as so correlated. The salt bed is about 1,150 feet above the top of the Upper anhydrite unit of the Wellington evaporites as defined by Jordan and Vosburg.

Although drilling has established the presence of salt deposits in the Cimarron evaporites underlying this area, it is not possible to correlate the producing salt bed with a definite equivalent in the nearby wells. For this reason it is at present impossible to determine its thickness or its distribution elsewhere. The salt strata noted in nearby wells may be correlative with the salt bed being exploited, or they may be stratigraphically higher or lower. Subsequent drilling may make possible approximations of the thicknesses and areal extents of the various salt beds in the Upper Cimarron salt near Sayre, but accurate interpretations can be obtained only from a coring program.

Shows of salt in the Upper Cimarron salt were reported at 1,195, 1,256, 1,307, 1,324, 1,351, 1,375-1,395, 1,399-1,407, 1,411-1,435, 1,439-1,459, and 1,463-1,471 feet. The bed of salt itself is at 1,475-1,513 feet. All reports of salt shows between 770 and 1,475 feet were based upon samples containing inclusions of salt crystals in shale (C. K. Springfield, oral communication, 1962).

Overlying the Upper Cimarron salt is 242 feet of the Hennessey-

Flowerpot shales. The Hennessey-Flowerpot unit in the salt well (between 953 and 1,195 feet) is reported as dominantly red and blue shales with some gypsum. No shows of salt were noted in this section during drilling. Samples from 1,047 to 1,063 feet contained 25 to 50 percent sandstone. This sandstone may have come from one of the beds in the Duncan Sandstone, present at this stratigraphic position to the south and east (Scott and Ham, 1957, pl. 2; Johnson, 1962, pl. 2), but, as it was not described from the well cuttings, one cannot be certain that it has not caved in from sandstone beds above the Dog Creek Shale.

The Flowerpot salt overlies the Hennessey-Flowerpot shales, and was encountered in the salt well between depths of 770 and 953 feet. This 183-foot sequence is described as being red and blue shales with 5 to 15 percent gypsum, although as much as 60 percent gypsum was reported in several samples. The rock reported as gypsum probably is anhydrite. Shows of salt were recorded at depths of 855, 909, 941, 945, and 953 feet. The Flowerpot salt is locally 170 to 200 feet thick and lies immediately below the Blaine Formation.

Interbedded gypsum and shale characterize the Blaine Formation in western Oklahoma. The individual gypsum members of the Blaine have already been correlated into the shallow subsurface in southwestern Oklahoma (Johnson, 1962, pl. 2), and they can be correlated throughout the entire western three-fourths of the Oklahoma portion of the Anadarko basin.

In the salt well, between 570 and 770 feet, the Blaine is described as being 50 percent gypsum (probably anhydrite) and 50 percent shale. Six feet of bedded salt was reported from 667 to 673 feet, in the middle of the formation, above the Collingsworth Gypsum Member and below the Mangum Dolomite Member of surface nomenclature. Salt beds are present in the subsurface at this stratigraphic level throughout the southern portion of the western half of the Anadarko basin in Oklahoma. On the basis of electric-log interpretation it is believed that 30 to 40 feet of salty strata overlie the Collingsworth in the Pure No. 1 Bohannon and Sinclair No. 1 Perkins. In the Elk City area, 15 miles to the east-northeast, Ham and Jordan (1961, fig. 1) showed 40 feet of salt between 1,460 and 1,500 feet, immediately overlying the Collingsworth. Other salt beds of the Blaine in the Elk City area are not known to be present in the salt well, but the presence of some salty strata through much of the Blaine is suggested in logs of the nearby Bohannon and Perkins wells.

In the two wells shown in figure 3 the Blaine Formation is 190 to 195 feet thick. It is reasonable to project a similar thickness for the Blaine into the salt well, for all three wells were drilled off the flanks of the Sayre dome. However, the Blaine Formation is only 135 feet thick in the Shell No. 1 Randle (SE¼ SW¼ sec. 15, T. 9 N., R. 23 W.), near the top of the Sayre dome, 1.5 miles south of the Pure No. 1 Bohannon. Most of the thinning of the Blaine over the dome is due to the absence of salt beds which are present in the wells on the flanks, but some of the individual gypsum and shale beds may also be thinner. The sequence between the base of the Blaine and the top of the Upper anhydrite unit of the Wellington evaporites is also thinner on the Sayre dome; it is 1,835 feet thick in the Pure No. 1 Bohannon and 1,550 feet thick in the Shell No. 1 Randle.

Overlying the Blaine Formation is the Dog Creek Shale. In the nearest areas of outcrop, to the south and southeast, the Dog Creek is reddish-brown gypsiferous shale with thin beds of greenish-gray shale and light-gray dolomite, and locally with thin gypsum and siltstone beds (Scott and Ham, 1957, p. 29; Murphey, 1958, p. 38). The measured thickness on the surface is 80 to 85 feet in these areas.

In the subsurface the Dog Creek has a wide range of thickness. It is 125 feet thick in the Sinclair No. 1 Perkins and in the shallow stratigraphic test drilled in sec. 3, T. 9 N., R. 24 W., whereas in the Pure No. 1 Bohannon it is about 200 feet thick. The marked increase in thickness of the Dog Creek in the Bohannon well is accounted for, at least in part, by additional salty beds within that sequence. In the Elk City area, about 15 miles to the east-northeast, as much as 285 feet of salt overlies the uppermost anhydrite of the Blaine Formation.

Samples of the Dog Creek Shale from the salt well were recorded as being about 75 percent "fine-grained red sandstone cemented with gyppy shale," 15 percent red and blue shale, and 10 percent gypsum. Most of the sandstone in these samples had probably caved in from the overlying, generally friable sandstones of the Whitehorse Group. The top of the Dog Creek is therefore picked at 450 feet, where 10 feet of shale was recorded. This means that the Dog Creek is 120 feet thick in the salt well.

The Whitehorse Group overlies the Dog Creek Shale. Scott and Ham (1957, p. 31) reported that 387 feet of Whitehorse strata crops out 12 miles east-southeast of the salt well. On the surface this group, comprising the Marlow Formation below and the Rush Springs Sandstone above, is dominantly fine-grained friable red sandstone. Examination of the electric logs of wells drilled within a 10-mile radius of the salt plant indicates that to the north the thickness of the Whitehorse Group is 400 to 450 feet.

Whitehorse strata are encountered at depths of 65 to 450 feet in the salt well. Samples from this 385-foot section were described as "fine-grained red sandstone cemented with gyppy shale." Gypsum, reported in most samples, averaged about 10 percent, with as much as 70 percent logged from 370 to 380 feet.

Twenty-five to 35 percent gypsum was observed in the samples from depths of 45 to 65 feet. This 20-foot section undoubtedly represents the gypsum beds which lie at the base of the Cloud Chief Formation in this part of southwestern Oklahoma.

Ham and Jordan (1961, p. 8) reported 430 feet of Cloud Chief in the subsurface 15 miles to the east-northeast. At that locality the Cloud Chief is mainly interbedded red gypsiferous very fine-grained sandstone and red silty shale, with anhydrite beds in the basal 60 feet. At the salt plant most of the Cloud Chief has been eroded, and only the lowermost 20 feet remains.

Forty-five feet of Quaternary terrace deposits rests upon the basal gypsum of the Cloud Chief. The terrace material is composed of coarse-grained sand and gravel into which the water wells were drilled to a depth of 36 feet.

At present this is the only plant in the State producing from wells which have tapped the vast salt reserves known to occur in the Permian of Oklahoma. In the western half of the State there are numerous other areas where the Upper Cimarron salt beds, as well as other salt-bearing strata, are penetrated at shallow depths.

References Cited

Gouin, Frank, 1927, Oil and gas in Oklahoma, Beckham County: Okla. Geol. Survey, Bull. 40-M, 17 p., **also in** Bull. 40, vol. 2, p. 165-177 (1930).

Ham, W. E., and **Jordan, Louise,** 1961, A Permian stratigraphic section in west-central Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 21, p. 4-9.

Johnson, K. S., 1962, Areal geology of the Sentinel-Gotebo area, Kiowa and Washita Counties, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 99 p.

Murphey, C. W., 1958, Areal geology of the Erick area, Beckham and Greer Counties, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 102 p.

Scott, G. L., and **Ham, W. E.,** 1957, Geology and gypsum resources of the Carter area, Oklahoma: Okla. Geol. Survey, Circ. 42, 64 p.

Jordan, Louise, and **Vosburg, D. L.** (in press), Permian salt and associated evaporites in the Anadarko basin of the western Oklahoma-Texas Panhandle region: Okla. Geol. Survey, Bull. 102.

An Oklahoma Fossil Crustacean

Professor H. K. Brooks of the University of Florida recently described a new species of crustacean (Eumalacostraca) from the Delaware Creek Member of the Caney Shale, of Pontotoc County, Oklahoma. The species is named *Archaeocaris graffhami* after its collector, Allen Graffham of Ardmore. The holotype is no. 5849 in the collection of the Harvard Museum of Comparative Zoology, and its counterpart is OU 4411 in the paleontology collection of The University of Oklahoma.

Brooks, in describing or redescribing North American Eumalacostraca, presents a new taxonomic arrangement. The Oklahoma form belongs in the new superorder Eocarida, new order Palaeostomatopoda, family Perimecturidae. The paper describes this and other rare forms, rare in number of localities and known horizons, not necessarily in number of specimens, for hundreds of specimens have been collected from concretions in the Francis Creek Shale (Pennsylvanian) of Illinois.

The paper is *The Paleozoic Eumalacostraca of North America,* Bulletin of American Paleontology, vol. 44. (no. 202), p. 163-335, 16 text plates, plates 29-66. The Oklahoma form is described on pages 214-216 and figured on text plate 8, figure b, plate 47, figures 1-4.

—C. C. B.

An Emendation

of

Vestispora Wilson and Hoffmeister, 1956*

L. R. Wilson and B. S. Venkatachala†

Recent palynological studies of the Dawson coal of Oklahoma have revealed two new species of *Vestispora* Wilson and Hoffmeister, 1956. This discovery has made it necessary to review the status of the genus in light of publications that have appeared since the original description of *Vestispora profunda,* the type species.

The Dawson coal crops out in the vicinity of Tulsa, Tulsa County, Oklahoma, and is a seam in the Skiatook Group of the Missouri Series in the Pennsylvanian System. The European equivalent is in the lower part of the Stephanian.

A reexamination of the holotype of *Vestispora profunda* and of other specimens of the species in the Croweburg coal confirms the following characteristics. The spores of *Vestispora* are radially symmetrical; have trilete dehiscence, an outer spore wall with irregular concentric muri on the proximal surface, and closely arranged muri, regularly developed into a foveolate pattern on the distal surface (see Wilson and Hoffmeister, 1956, p. 28, figs. 1a, 1b); and have a circular area on the proximal surface of approximately one-third of the spore diameter developed into an operculate structure, which, when detached, exposes a portion of the central body and its trilete dehiscence mark. The latter is restricted to the opercular area. The inner body is observed through the translucent outer wall and is attached to it at and around the opercular cavity. The diameter of the inner body varies slightly and is generally between eight to twenty microns less than that of the total when the spore is seen in proximal or distal views. No ornamentation occurs on the inner body, but compression folds sometimes simulate such structures. When the genus *Vestispora* was established, no mention was made of the operculate nature of the spores. The holotype of *V. profunda* has lost the operculum, and the triradiate scar is exposed. The holotype is reillustrated here on plate I, figures 1 to 6. Other specimens in the same preparation possess laevigate opercula.

The genus *Vestispora* has been emended by Bhardwaj (1957). He illustrated the operculate nature of the exine and redefined the morphology of the spore in the light of his own findings and reexamination of several other species. The emended diagnosis given by Bhardwaj (1957, p. 115) restricts the genus to spores with ". . . peripheral

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†B. S. Venkatachala, Birbal Sahni Institute of Palaeobotany, Lucknow, India, takes this opportunity to thank the United Nations Technical Assistance Organization for providing him a fellowship during the tenure of which the present work at the School of Geology, The University of Oklahoma, was completed.

bladder ornamented with thin, occasionally branched muri running circumcentrically and building a regular to irregular network enclosing triangular to polygonal meshes of various sizes, exine in the meshes thin, translucent, laevigate or infragranular."

In his emendation Bhardwaj (1957) stressed the importance of the ornamentation as a generic character. This concept the present authors think is incorrect and instead consider the presence of a trilete dehiscing inner spore body which is attached to the outer spore wall only in the area of a proximal operculum as fundamental. Ornamentation is viewed here as a specific rather than generic character. The genus *Vestispora,* therefore, contains all the species hitherto included in *Foveolatisporites* Bhardwaj, 1955, *Novisporites* Bhardwaj, 1957, *Glomospora* Butterworth and Williams, 1958, and *Cancellatisporites* Dybová and Jachowicz, 1957. It also includes the species *Punctatisporites quaesitus* Kosanke, 1950, which appears to be the operculum of *Vestispora fenestrata.* A detached operculum is illustrated here (pl. I, fig. 12).

The description of *Foveolatisporites* Bhardwaj, although dated 1955, was issued in December 1956 (see statement in *The Palaeobotanist,* vol. 7, no. 1); whereas *Vestispora* Wilson and Hoffmeister was published on April 13, 1956 (see *List of Available Publications,* Oklahoma Geological Survey, Norman, Oklahoma).

Glomospora has been transferred to *Vestispora* by Potonié (1962, p. 52-53) who also suggested that *Cancellatisporites* may be synonymous with *Vestispora.* With these transfers the authors agree.

Bhardwaj (1957, p. 118) rightly stated that Wilson and Hoffmeister (1956, p. 27) erred in their assumption that because of the bladdered and trilete nature of *Vestispora,* it might be related to *Endosporites* and *Wilsonia* (now *Wilsonites*). The same type of spore is found within the Sphenopsida and Remy (1955) has illustrated similar operculate spores from *Sphenophyllum hauchecornei* (Weiss) Remy, *Anastachys aquensis* Remy, *Koinostachys beinerti* Remy, *K. waldenburgensis* Remy, *K. aquensis* Remy, *K. verticillata* (Schlotheim) Remy, and *K.* sp. The ornamentation in all of these spores ranges from laevigate, granulose, to reticulate. The operculate structure can be clearly recognized in all of the above species.

The exine morphology of *Vestispora* has been variously considered. Wilson and Hoffmeister (1956, p. 27) described the outer wall as a bladder. This term was utilized for description rather than with intent to designate the morphological structure which is named the saccus. Bhardwaj (1957, p. 115, 118) also described it as a bladdered form but apparently, at least in part, used the word in the descriptive rather than the strictly morphological sense because he recognized the ornamentation as an extrareticulate feature rather than intrareticulate such as that found in the sacci of gymnosperms. Potonié (1960, p. 52) considered the outer wall as a perine. A study of various overmacerated specimens from the Dawson coal (plate I, figure 14) suggests that the outer wall may represent an exoexine and the inner transparent body may be the endoexine. The terminology that should be used to describe the stratification of the spore exine requires further study.

Vestispora Wilson and Hoffmeister, 1956, here emended

Synonymy: *Vestispora* (Wilson and Hoffmeister, 1956) Bhardwaj, 1957.
Foveolatisporites Bhardwaj, 1955.
Novisporites Bhardwaj, 1957.
Cancellatisporites Dybová and Jachowicz, 1957.
Glomospora Butterworth and Williams, 1958.

Type species: *Vestispora profunda* Wilson and Hoffmeister, 1956.

Spores radially symmetrical; trilete dehiscence; shape spherical or subspherical, generally flattened and discoid or oval; spore consisting of an outer wall and an inner trilete-bearing body which is detached except at and near the edge of the opercular area on the proximal

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Explanation of Plate I

Figure 1. Vestispora profunda **Wilson and Hoffmeister, 1956; 70.2 microns, operculum 35.4 x 40.8 microns. Croweburg coal WH 7-5, showing irregular continuous muri and the opercular area on the proximal side.**

Figure 2. Same spore showing branching of the muri on the proximal side.

Figure 3. Same spore showing foveolate pattern on the distal side.

Figure 4. Same spore showing distal muri.

Figure 5. Same spore showing the opercular area and the triradiate scar on the inner body, under oil immersion.

Figure 6. Same spore showing the distal ornamentation under oil immersion.

Figure 7. Vestispora profunda **Wilson and Hoffmeister, 1956; 68.9 microns; operculum 28 x 31 microns. Dawson coal OPC 352 C-1-11.**

Figure 8. Vestispora laevigata **sp. nov. 65.2 x 63.8 microns; operculum 28.4 x 31.7 microns. Holotype. Croweburg coal WH 7-5.**

Figure 9. Vestispora laevigata **sp. nov. 53.6 x 71.4 microns; operculum 30.7 microns long. Dawson coal OPC 352 O-3-1.**

Figure 10. Vestispora laevigata **sp. nov. 68.9 microns; operculum 25.5 x 30 microns long. Dawson coal OPC 352 O-1-2.**

Figure 11. Vestispora laevigata **sp. nov. 61.2 x 66.3 microns; operculum 30.6 microns. Dawson coal OPC 352 O-1-1.**

Figure 12. A separated operculum of Vestispora **sp. 35.2 x 39.6 microns. Iron Post coal OPC 624 I-1-1 (Gibson, 1961).**

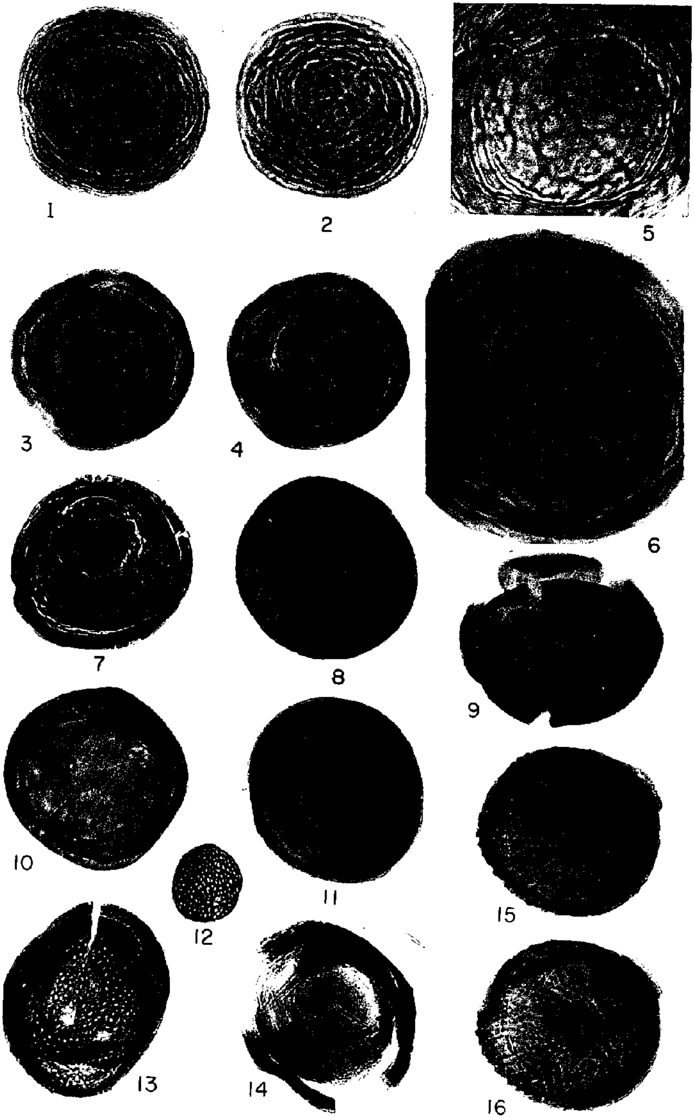
Figure 13. Vestispora fenestrata **(Kosanke and Brokaw in Kosanke, 1950) comb. nov. 61.6 x 74.5 microns. Rowe coal OPC 207 D-5-3 (Davis, 1961).**

Figure 14. Vestispora fenestrata **(Kosanke and Brokaw in Kosanke, 1950) comb. nov. Inner body 62.7 microns. Dawson coal OPC 352 B-7-2. Overmacerated specimen showing the inner body and the triradiate scar.**

Figure 15. Vestispora **sp. 73.9 microns; operculum 31 microns. Dawson coal OPC 352 N-2-1. Showing the proximal ornamentation.**

Figure 16. Same spore showing the distal ornamentation.

Plate I



hemisphere; operculum approximately one-third of the total spore diameter; ornamentation of the outer wall variable: laevigate, scabrate, reticulate, foveolate, or possibly of other types; inner wall normally smooth but may exhibit compression folds which simulate muri of various patterns; observed size range of spores in the genus 45 to 80 microns; relative size of the inner body normally 8 to 20 microns less than total diameter of spore in the compressed state.

Vestispora laevigata sp. nov.

Plate I, figures 8-11

Spores radial, trilete, spherical, 60 to 75 microns in diameter; operculum 25 to 32 microns in diameter, opening to expose the inner body which bears the trilete mark; inner body as well as exoexine laevigate; in some specimens the inner body folded to appear like outer ornamentation. Several specimens with faint scabrate ornamentation on the distal side have been observed.

Holotype.—Specimen WH 7-5 (pl. I, fig. 8). Total dimensions 65.2 by 63.8 microns; operculum 28.4 by 31.7 microns. Croweburg coal, Ashley property, north of Bushyhead, sec. 9, T. 23 N., R. 17 E., Rogers County, Oklahoma. The holotype is in the palynological collections of the Oklahoma Geological Survey.

Comparison.—Vestispora profunda possesses distinct muri both on proximal and distal sides. *V. fenestrata* and other species possess well-pronounced muri forming foveolate pattern on the exoexine. *V. laevigata* sp. nov. is distinct in possessing a more or less laevigate exoexine.

Distribution.—Vestispora laevigata has been observed in the Rowe coal of the Krebs Group, Des Moines Series in the Pennsylvanian System, upward to the Dawson coal of the Skiatook Group, Missouri Series, also in the Pennsylvanian System. The European equivalent of this range is from Westphalian C to the lower part of the Stephanian.

Vestispora sp.

Plate I, figures 15, 16

Spores spherical, trilete, 73.6 microns in diameter; operculum distinctly seen on the proximal side, diameter 30 by 36 microns; proximal muri form regular radial pattern converging toward the operculum, which is also similarly ornamented; muri generally anastomose to form a network; distal muri form foveola of various sizes and shapes; exine approximately four microns thick.

Radially arranged muri on the proximal side distinguish this species.

Illustrated specimen.—OPC 352 N-2-1, Dawson coal, 21st Street and Maplewood Avenue, Tulsa, Tulsa County, Oklahoma.

Range.—A single specimen has been found in Dawson coal and another in the Tebo coal of Muskogee County, Oklahoma. The latter was collected and studied by Ruffin (1961), OPC 649 C-1-1. The Tebo coal is stratigraphically located near the bottom of the Cabaniss Group of the Des Moines Series, Pennsylvanian System. This coal is of Westphalian C age.

The following species, the writers consider, belong to the genus *Vestispora*, and some are here given new taxonomic assignments:

1. *Vestispora profunda* Wilson and Hoffmeister, 1956. Type species.
2. *Vestispora fenestrata* (Kosanke and Brokaw, 1950) comb. nov.
   Synonymy: *Punctatisporites fenestratus* Kosanke and Brokaw (in Kosanke, 1950).
   Foveolatisporites fenestratus (Kosanke and Brokaw) Bhardwaj, 1955.
   See also *F. fenestratus* (Kosanke and Brokaw) Bhardwaj; in Alpern, 1959, pl. 5, figs. 107, 108.
3. *Vestispora foveosa* (Kosanke, 1950) comb. nov.
   Synonymy: *Punctatisporites foveosus* Kosanke, 1950.
   Foveolatisporites foveosus (Kosanke) Bhardwaj, 1955.
4. *Vestispora quaesita* (Kosanke, 1950) comb. nov.
   Synonymy: *Punctatisporites quaesitus* Kosanke, 1950.
   Foveolatisporites quaesitus (Kosanke) Bhardwaj, 1955.
   See also *F. quaesitus* (Kosanke) Bhardwaj; in Alpern, 1959, pl. 5, figs. 102-105.
   Remarks: depicts a detached operculum.
5. *Vestispora foveata* (Kosanke, 1950) comb. nov.
   Synonymy: *Punctatisporites foveatus* Kosanke, 1950.
   Foveolatisporites foveatus (Kosanke) Bhardwaj, 1955.
6. *Vestispora costata* (Balme, 1952) Bhardwaj, 1957.
   Synonymy: *Endosporites costatus* Balme, 1952.
   Glomospora costata (Balme) Butterworth and Williams, 1958.
7. *Vestispora brevis* Bhardwaj, 1957.
8. *Vestispora vinculata* (Ibrahim) Bhardwaj, 1957.
   Synonymy: see Bhardwaj, 1957, p. 119.
9. *Vestispora velensis* (Bhardwaj, 1957) comb. nov.
   Synonymy: *Foveolatisporites velensis* Bhardwaj, 1957.
10. *Vestispora magna* (Butterworth and Williams, 1954) comb. nov.
    Synonymy: *Reticulatisporites magnus* Butterworth and Williams, 1954.
    Novisporites magnus (Butterworth and Williams) Bhardwaj, 1957.
11. *Vestispora irregularis* (Kosanke, 1950) comb. nov.
    Synonymy: *Reticulatisporites irregularis* Kosanke, 1950.
    Novisporites irregularis (Kosanke) Bhardwaj, 1957.
12. *Vestispora cancellata* (Dybová and Jachowicz, 1957) comb. nov.
    Synonymy: *Cancellatisporites cancellatus* Dybová and Jachowicz, 1957.
13. *Vestispora lucida* (Butterworth and Williams, 1958) Potonié, 1960.
    Synonymy: *Glomospora lucida* Butterworth and Williams, 1958.
14. *Vestispora laevigata* sp. nov. (in this publication).
15. *Vestispora* sp. (in this publication).

References Cited

Alpern, Boris, 1959, Contribution à l'etude palynologique et pétrographique des charbons français: Thesis, Faculty of Science, Univ. Paris, 314 p.

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

Butterworth, M. A., and **Williams, R. W.,** 1954, Descriptions of nine species of small spores from the British Coal Measures: Ann. Mag. Nat. History, vol. 12, no. 7, p. 753-764.

__________ 1958, The small spore floras of coals in the Limestone Coal Group and Upper Limestone Group of the Lower Carboniferous of Scotland: Roy. Soc. Edinburgh, Trans., vol. 63, p. 353-392.

Bhardwaj, D. C., 1955, The spore genera from the Upper Carboniferous coals of the Saar and their value in stratigraphical studies: Palaeobotanist, Lucknow, vol. 4, p. 119-149.

__________ 1957, The spore flora of Velener Schichten (Lower Westphalian D) in the Ruhr Coal Measures: Palaeontographica, ser. B, vol. 102, p. 110-138.

Davis, P. N., 1961, Palynology of the Rowe coal (Pennsylvanian) of Oklahoma: Okla., Univ., unpublished Master of Science thesis.

Dybová, Soňa, and **Jachowicz, Aleksander,** 1957, Microspores of the Upper Silesian Coal Measures: Instytut Geologiczny, Prace, vol. 23, 328 p.

Gibson, L. B., 1961, Palynology and paleoecology of the Iron Post coal (Pennsylvanian) of Oklahoma: Okla., Univ., unpublished Ph.D. dissertation.

Ibrahim, A. C., 1933, Sporenformen des Ägirhorizontes des Ruhr-Reviers: Würzburg, Konrad Triltsch, Berlin, 47 p.

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

Potonié, Robert, 1960, Synopsis der Gattungen der Sporae dispersae. Teil III. Nachtrage Sporites, Fortsetzung Pollenites mit Generalregister: Amt für Bodenforschung, Hannover, Beihefte zum Geologischen Jahrbuch, vol. 39, 189 p.

__________ 1962, Synopsis der Sporae in situ: Amt für Bodenforschung, Hannover, Geologischen Jahrbuch, no. 52, 204 p.

Potonié, Robert, and **Kremp, G. O. W.,** 1955, Die Sporae dispersae des Ruhrkarbons. Teil II: Palaeontographica, Abt. B, vol. 99, p. 85-191.

Remy, Winfried, 1955, Untersuchungen von Kohlig erhaltenen fertilen und sterilen **Sphenophyllum** und Formen unsicherer systematischer Stellung: Deutschen Akademie der Wissenschaften zu Berlin, Abh., Klasse für Chemie, Geologie und Biologie, no. 1, p. 5-40.

Ruffin, J. H., 1961, Palynology of the Tebo coal (Pennsylvanian) of Oklahoma: Okla., Univ., unpublished Master of Science thesis.

Wilson, L. R., Stratigraphic ranges of Pennsylvanian spores in Oklahoma: Unpublished manuscript.

Wilson, L. R., and **Hoffmeister, W. S.,** 1956, Plant microfossils of the Croweburg coal: Okla. Geol. Survey, Circ. 32, 57 p.

Dasciocrinus IN OKLAHOMA

HARRELL L. STRIMPLE

The discovery of *Dasciocrinus aulicus,* new species, in the Fayetteville Formation (Chesterian) of northeastern Oklahoma increases the known stratigraphic range of the genus into Late Mississippian time and the geographic range a considerable distance westward. Certain characters of the species show close affinity with those of *Perimestocrinus granulosus* (Strimple, 1939) as demonstrated by new illustrations of that species. It appears that *Perimestocrinus* Moore and Plummer (1938), as restricted by Strimple (1961), may be a descendant of *Dasciocrinus.*

Genus *Dasciocrinus* Kirk, 1939

Dasciocrinus aulicus Strimple, new species

Plate I, figures 8, 9; text-figures 1-4

The crown of *Dasciocrinus aulicus* is long and slender, with arms not closely apposed in repose. The long, slender anal sac culminates in three spines that project upward and outward and may extend beyond the upper limits of the arms. The dorsal cup is rather shallow and bowl shaped, with a decidedly depressed basal area. Cup plates have uneven curvatures. The column is round with numerous cirri developed close to the cup.

The dorsal cup is composed primarily of three circlets of plates and three anal plates. Five small infrabasals form a small disk at the base of the basal concavity and are mostly covered by the proximal columnals. Five basals, of moderate size and tumid, form the walls of the basal depression with upper extremities curved upward to be visible in side view of the cup. Five large radials are the dominant cup plates, forming most of the lateral sides of the cup and thereby the cup height. The radials are pentagonal elements and have unusual protrusion just below the articular processes, in which development a shelf is formed below the outer ligament ridge. The bulged area is augmented in most specimens by a row of nodes. The articular facets slope outward and are well defined but difficult to observe in the present material. The facets have a denticulate outer ridge and the relatively deep outer ligament pit, backed by a strong transverse ridge, is also markedly denticulate. A lateral furrow lies on each side of the facet. The muscle areas are shallowly impressed and slope steeply downward from rather high lateral ridges.

In a few instances a radial plate is separated from the calyx, a condition which gives an opportunity to observe the thickness attained by the plates as well as to see the deep ligament fossae of the sutural faces. Preservation has not been so good as could be desired but is adequate for some observations. An expansion is in the midportion of each sutural face, and the fossae contract as the outer corner of the plate is approached. This condition is reflected on the exterior by tumidity of midportions and by depressions formed at the angles of the plates, other than at the summit of the cup. A flattened rim surrounds the depressed areas and in many cases is marked by crenellae. The foregoing observations are illustrated in text-figure 1.

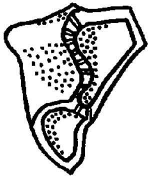
Three anal plates occupy the posterior interray and are in normal, or primitive, arrangement; that is, the anal X rests directly upon the posterior basal, with the obliquely placed radianal to its lower right and a small RX to the right above. The upper portion of anal X and most of RX project above the summit of the dorsal cup.

Curvature of all cup plates is such that depressions are formed at the meeting of angles, at the corners of the plates, except within the infrabasal circlet.

The arms are long and slender, with well-rounded exteriors, all bifurcating on the first primibrach and normally branching again isotomously with the fifth or sixth secundibrach. Thereafter the bifurcations appear to be restricted to the outer rays (endotomous), where a branching is found on or about the eighth tertibrach. A short spine has been observed on the thirteenth tertibrach of an inner ray, although the plate is not axillary. This could be atavistic, indicating a point of bifurcation in an ancestral form. First primibrachs are rather high and strongly protuberant, and upper midportions are projected as long, flattened spines. In addition to surface granulations, fine ridges ornament the spines, parallel to their length. Subsequent nonaxillary plates are more or less quadrangular and are mildly cuneiform. Axillary secundibrachs and tertibrachs are only slightly larger than normal brachials and are produced as long, round spines. Ornamentation is also augmented by long, fine, rather straight ridges. Each brachial supports a single, long, slender pinnule. The pinnules are on alternate sides, the longer side of each brachial being pinnule bearing.

The column is round and is composed of alternately expanded segments. The larger segments are laterally projected and have a sharp ridge. Intervening segments are waferlike and small, and the articular surfaces are marked by rather broad, short crenulations. A segment with a diameter of 1.5 mm has been noted with 24 crenulations. The lumen is small and substellate. A short distance below the cup cirri are developed, but the preservation is such that close observation is not possible, and in fact the column is in few cases observed beyond a few proximal segments. A nodal with a diameter of 2.3 mm may have a cirral 0.8 mm in diameter. The cirrals are circular in outline, have broad, short crennellae, and are tightly coiled in instances where they have been observed.

The anal sac is composed of circlets of thin, roughly hexagonal segments. Normally two folds occur on a lateral side and join with similar folds on the adjacent plates. Under magnification the same granulose ornamentation marking the rest of the animal is apparent. As previously noted, the sac terminates with three upwardly directed, rounded spines. They are ornamented in the same manner as the axillary primibrachs. In the figured paratype, a spinose sac plate is preserved below the termination. Text-figure 2 is a drawing of the three terminal spines.



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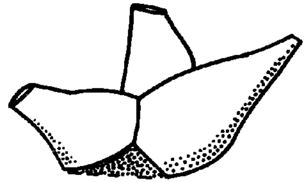

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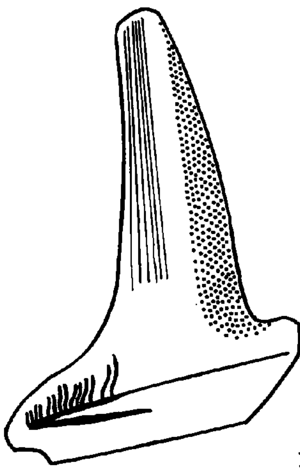

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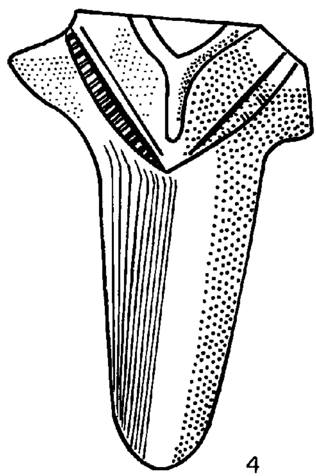

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Dasciocrinus aulicus, **new species (SUI 10985)**

Enlarged drawings made with the aid of a camera lucida.

Text-figure 1. Oblique side view of radial plate showing ligament fossae, denticles, swollen surface areas.

Text-figure 2. Terminal spines of the anal sac.

Text-figures 3, 4. Axillary primibrach viewed from below and from above, with fine ridges shown as long, thin lines on the unshaded sides of the spines. Strongly shaded areas in all drawings shown by stippling.

Material.—Eleven partial to complete crowns have been available for study. All but one were excavated from the small colony in the north side of the hill in NW¼ SW¼ sec. 11, T. 25 N., R. 21 E., Craig County, Oklahoma. Because of the loose structure of the crown, it is truly remarkable that complete specimens have been preserved.

Measurements in millimeters.—

	SUI 10990	SUI 10985	SUI 10991
Length of crown	27.8	45.0	—
Height of cup	2.4*	—	8.5
Width of cup	6.7*	13.0*	3.0**
Diameter of proximal columnals	1.8	2.3	2.0

* Approximate or average

**Undistorted, measured to transverse ridge

Relationship.—The species *Dasciocrinus florealis* (Yandell and Shumard) has more numerous secundibrachs and the axillary brachials have relatively short spines as compared to those of *D. aulicus*. Springer (1926, pl. 16, figs. 9, 9a) figured a specimen with four terminal spines forming a small platform at the top of an elongate anal sac. In a paratype of *D. aulicus* (SUI 10990) are three terminal spines, but they are directed upward rather than outward as in *D. florealis*.

Stratigraphically, *D. aulicus* is the youngest known species of the genus and there does not appear to be any significant advancement in characters as compared with those of the oldest known species, *D. cachensis* (Weller), from the Paint Creek Formation of Illinois. The Fayetteville species is more ornate than is *D. cachensis* or are any of the other species.

Close comparison with *Perimestocrinus granulosus* (Strimple, 1939) indicates affinity between *Dasciocrinus* and *Perimestocrinus*

Explanation of Plate I

Figures 1-7. Perimestocrinus granulosus **(Strimple).**

1. **Lectoparatype, x2. Young crown from side.**
2. **Lectoholotype, x2. Partial crown from side.**
3. **Lectoparatype, x2. Partial crown with anal sac preserved viewed from posterior.**

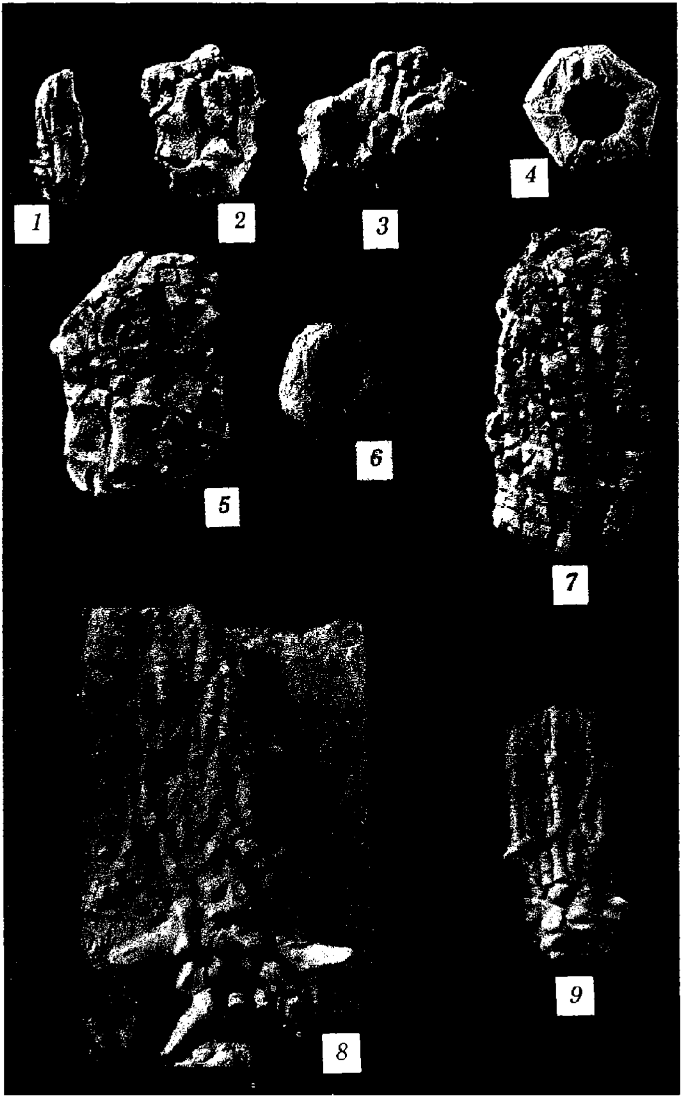
4, 6. **Lectoparatype, x2. Dorsal cup viewed from above and below.**

5. **Lectoparatype, x2. Partial crown from left posterior.**
7. **Lectoparatype, x2. Upper portion of a set of arms with terminating spines of the anal sac exposed above.**

Figures 8, 9. Dasciocrinus aulicus **Strimple, new species.**

8. **Holotype, x1.5. Crown in side view.**
9. **Paratype, x1.5. Crown in side view with terminating spines shown projecting slightly above arm terminations.**

Plate I



Moore and Plummer (1938), as restricted by Strimple (1961). A remarkable uniformity in the plates of the posterior interradius is shown by the closely related members of this group.

The specific name is the Latin *aulicus,* courtier, and is a masculine substantive in apposition.

Occurrence and locality.—Approximately 10 to 15 feet below the top of the Fayetteville Formation, Chester Group, Mississippian; paratype (SUI 10990) from a natural wash and holotype with nine paratypes from an excavation on the northern tip of a hill, all in NW¼ SW¼ sec. 11, T. 25 N., R. 21 E., Craig County, about 7 miles northeast of Vinita, Oklahoma.

Types.—Figured holotype (SUI 10985) and figured paratype (SUI 10990) are in the paleontological collection, State University of Iowa, Iowa City; paratype (OU 5172) is in the paleontological collections, The University of Oklahoma, Norman; two paratypes (USNM 141502, 141503) are in the Springer Collection, U. S. National Museum, Washington, D. C.

Perimestocrinus Moore and Plummer, 1938

Synonymy.—*Perimestocrinus* Strimple, 1948; *Triceracrinus* Bramlette, 1943; *Utharocrinus* Moore and Plummer, 1938 (in part, after Strimple, 1961); *Perimestocrinus* emended by Strimple, 1961.

Perimestocrinus granulosus (Strimple), 1939

Plate I, figures 1-7

The illustrations of this interesting species, given by Strimple (1939), left much to be desired and new photographs have been prepared under the direction of Porter M. Kier, U. S. National Museum, and are presented herein. The nature of the anal sac with its small cluster of upward directed terminal spines is shown, as well as the typical arm structure of the genus as restricted to characters of the genotype species.

Under the original description, as *Utharocrinus granulosus,* six specimens were illustrated and considered as syntypes. The specimen figured on plate 2, figure 2 was designated as the lectoholotype by Strimple (1950). The other five specimens are herein designated as lectoparatypes.

This species is rather typical of forms formerly assigned to *Utharocrinus* by Moore and others but it was transferred to *Perimestocrinus* when *Utharocrinus* was restricted to its genotype species (Strimple, 1961). The arms are narrow, have well-rounded exteriors, are mildly cuneiform, and branch with elongate, axillary first primibrachs in all rays. The axillary plates are extended as spines in their uppermost portions. A second bifurcation normally takes place with the fourth or fifth secundibrach, and yet another branching takes place in some rays. The dorsal cup has a shallow basal concavity, the bottom of which is flat and is occupied by a small infrabasal circlet. Basal plates are tumid. Anal plates are normal, or primitive, in number and arrangement. Radial plates are wide and pentagonal. Columnals are round and alternately expanded. All segments are covered by minute, spinelike nodes, much like those of *Dasciocrinus aulicus.*

Relationship.—An over-all discussion of intraspecific relationships is not attempted here other than to point out the compatibility of species formerly assigned to *Utharocrinus* in the nature of the articular facets, the arms as preserved, the general structure of the dorsal cups, and the spinose, granular ornamentation, all of which characteristics are shared by *Dasciocrinus aulicus.*

Occurrence and location.—All of the above discussed type specimens are from a crinoidal shale in the Wann Formation, Ochelata Group, Missouri Series, Pennsylvanian; north side of the hill, locally termed the "Mound," just west of the city limits of Bartlesville, Oklahoma, and just west of the boundary between Osage and Washington Counties, in Osage County.

References Cited

All cited references may be found in Bassler, R. S., and Moodey, M. W., 1943, **Bibliographic and faunal index of Paleozoic pelmatozoan echinoderms:** Geol. Soc. America, Spec. Paper 45, 734 p., with the following exceptions:

Bramlette, W. A., 1943, **Triceracrinus,** a new Upper Pennsylvanian and Lower Permian crinoid: Jour. Paleontology, vol. 17, p. 550-553.

Strimple, H. L., 1961, Late Desmoinesian crinoid faunule from Oklahoma: Okla. Geol. Survey, Bull. 93, 189 p., 19 pls., 23 text-figs.

New Survey Publication

On March 19, 1963, the Oklahoma Geological Survey issued Guide Book XII, *A Guide to the State Parks and Scenic Areas in the Oklahoma Ozarks,* by G. G. Huffman, T. A. Cathey, and J. E. Humphrey. The book describes a region, which occupies 4,000 square miles of northeastern Oklahoma and is one of the more widely known vacation areas of the Southwest. Sections are on history, geology, plant life, and animal life of the areas. The book has 95 pages and 56 figures, including photographs of historical places and geologic maps of lake regions. The rock sequence is illustrated by diagrams, and a geologic time scale is given. Price: $3.00 paper bound.

Glenn Scott Dillé

1896 - 1963

Glenn Scott Dillé, consulting geologist of Tulsa, Oklahoma, died on January 22, 1963. He was born at Shannon, Illinois, on July 13, 1896. In 1917 he served in the Field Artillery. Glenn was graduated from Coe College in 1921 and served as assistant professor of geology at that college from 1921 to 1927. He was married in 1923. He did graduate work at State University of Iowa, earning the Master of Science degree in 1924, the Doctor of Philosophy degree in 1929. In 1927 he joined the Texas Company as paleontologist, a position he held until 1936, when he went into consulting. Excepting for a short term as vice president of Deep Rock (1944-1946), he was a consultant from 1936 until his passing.

Glenn was active in geological societies. For the Tulsa Geological Society he served as editor (1934), vice president (1935), president (1942). He was vice president of the Tulsa Stratigraphic Society in 1934, president in 1935. He was a member of the American Association of Petroleum Geologists and of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

Dillé is survived by his widow and by three children, one of whom, Allan, received his Master of Science degree in geology at The University of Oklahoma in 1956.

Dillé published on bituminous shale in Iowa, Iowa anticlines, oölitic limestone in the Devonian of Iowa, a glacial pond in Iowa, meteorites, the Minnelusa Formation of the Black Hills, and on pre-Pennsylvanian stratigraphy of western Nebraska. He wrote the chapter on oil and gas of Tulsa County in Oklahoma Geological Survey Bulletin 69 (1952, p. 104-125).

Dillé was noted for his generous services to his fellow geologists and he is sorely missed.

—C. C. B.

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