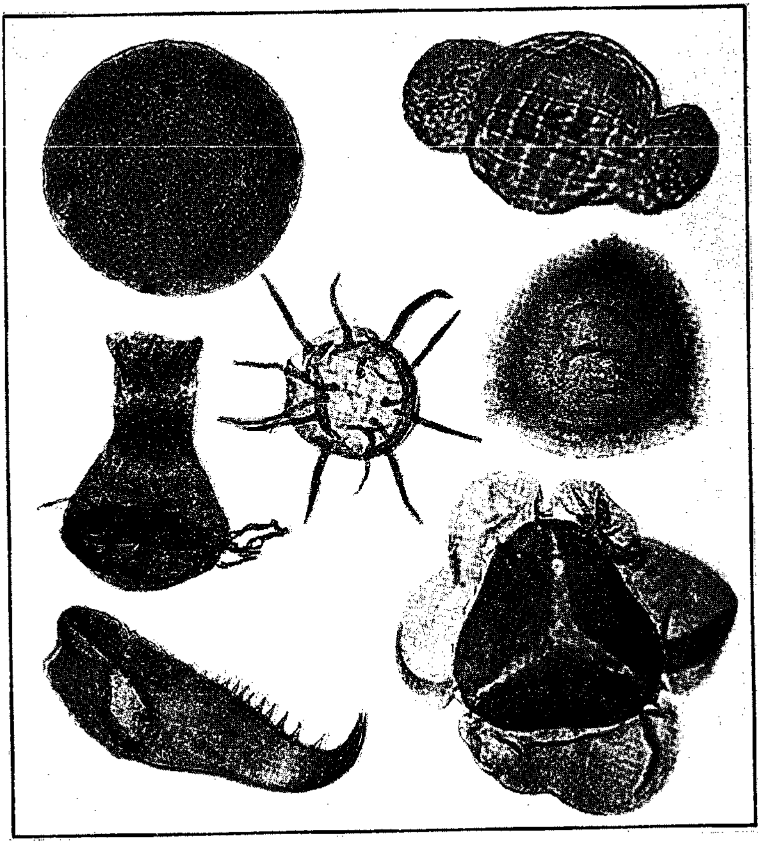
OKLAHOMA GEOLOGY NOTES



OKLAHOMA GEOLOGICAL SURVEY

NORMAN, OKLAHOMA

VOLUME 20, NUMBER 5

MAY, 1960

SINGLE NUMBER $0.25

SUBSCRIPTION $2.00

Plate I

SILICEOUS SPHERULES IN TRACHEIDS OF CORDAITEAN WOOD

L. R. WILSON AND R. T. CLARKE

A specimen of silicified cordaitean wood, containing minute siliceous spherules within the tracheids, was recently found near Ada, Pontotoc County, Oklahoma, by Mr. Kit C. Farwell, Jr., of Norman. Presumably the specimen came from one of the Upper Pennsylvanian formations which crop out near Ada. It was transmitted to us by Dr. David B. Kitts, University of Oklahoma. Originally 1½ x 3 x 5 inches, the specimen was cut and made into ten thin sections which are now in the Oklahoma Geological Survey fossil plant collection (OPC No. 347-1 to 347-10).

A search of paleobotanical literature has failed to reveal a previous description of the presence of siliceous spherules in the tracheids of fossil woods. Consequently the following observations appear to be worth recording.

The Ada silicified wood shows degradation of the secondary walls and some degradation of the primary walls. Bordered pits are poorly preserved whereas the primary walls are generally intact. It appears from these preserved structures that the specimen was deposited in an anaerobic environment which limited degradation to the above extent before mineralization took place.

The transverse sections show the tracheids to be rectangular to oblong, ranging from 15 to 25 microns in their greatest diameters (plate I, fig. 1). No evidence of growth rings is apparent. Wood rays are abundant, generally one cell wide, and are separated by one to six rows of tracheids. In the tangential section the wood rays are uniseriate and some are biseriate near the middle (plate I, fig. 2). The cells are slightly higher than they are broad. Most of the rays are less than ten cells high, although the number of cells ranges from 2 to 29. No pits were observed on the tangential walls

EXPLANATION OF PLATE I

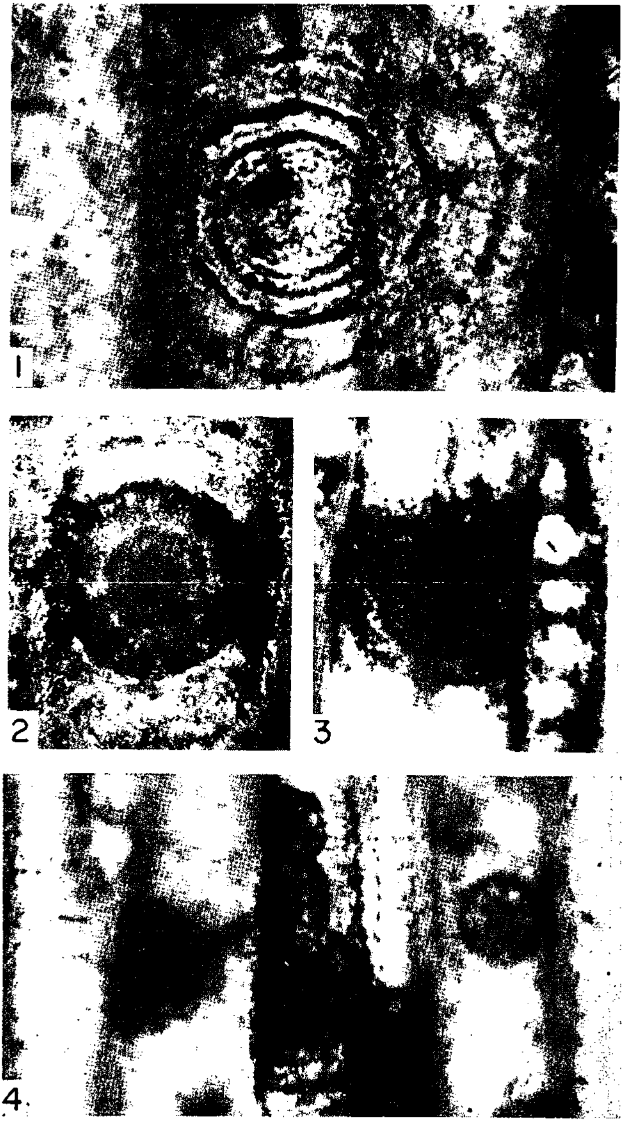
Thin Sections of Specimen of Silicified Cordaitean Wood

Figure 1. Transverse section showing three spherules within the lumina of the tracheids. Degradation has partially removed the secondary walls of the tracheids. Diameter of the spherule on the left is 39 microns. OPC No. 347-3-22.

Figure 2. Tangential section showing three spherules which completely fill tracheid lumina. Minute opaque particles are shown dispersed in the siliceous matrix and concentrated upon the cell walls and outer surfaces of the spherule layers. OPC No. 347-8-26.

Figure 3. Radial section showing three spherules in tracheid lumina and opaque particles concentrated upon the cell walls and outer surfaces of the spherule layers. Diameters of topmost spherule, 46.8 by 67.6 microns. OPC No. 347-7-15.

PLATE II



of the tracheids. Considerable degradation has occurred on the radial walls of the tracheids and only faint outlines of bordered pits are discernable. The bordered pits occur in single rows and each pit is approximately two-thirds the diameter of the tracheid. Wood rays seen in the radial section are composed of cells the lengths of which span one to three tracheid diameters. The preservation of the wood-ray walls is poor and no detailed structure is visible.

The Ada specimen is structurally similar to the fossil wood described by Tynan (1959) as *Cordaites michiganensis* Arnold, 1931, from near Beggs, Okmulgee County, Oklahoma. The ages of the two specimens are approximately the same. However, until better material is discovered, only a generic affinity can be given to the Ada specimen.

The presence of minute siliceous spherules (10 to 70 microns diameter) within the tracheids appears to be related to the process of mineralization and not necessarily to the degradation stage of the wood. The spherules are distributed throughout the silicified wood and, except for a few, are restricted to single tracheids. Those which extend into adjoining tracheids are connected by way of the wall perforation of the bordered pits (plate II, figs. 1-3). Not all the spherules are centrally located within the lumina of tracheids; most are randomly located on the tracheid walls.

Mr. Rodger E. Denison examined the thin sections with the petrographic microscope and reported that the spherules are optically continuous with the siliceous matrix of the wood. There is no clear line of differentiation between the two.

Examination of a series of spheres illustrating stages of structural development indicates that they grew around a nucleus and are concentrically layered after the fashion of oolites. The nuclei of some are nearly transparent whereas others appear to be an aggregation of minute opaque

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Explanation of Plate II

Photomicrographs Showing Details of Spherule Structure

Figure 1. Spherule occupying two tracheids seen in tangential wood section. The spherule began development in the tracheid on left and after penetrating the cell wall via a radial wall pit continued growth in the adjacent tracheid. The symmetry of the spherule is maintained in the second tracheid. Greatest diameter 57.2 microns. OPC No. 347-3-22.

Figure 2. Spherule developed in single tracheid and seen in radial wood section. Three concentric layers fill the tracheid lumen and two additional layers are developed above and below the spherule. Opaque particles are shown concentrated toward the outer surface of each layer and upon the tracheid walls. The most dense concentration of opaque particles is toward the center of the spherule and upon the tracheid walls. Dimensions, 40 x 70.2 microns. OPC No. 347-7-15.

Figure 3. Spherule occupying two tracheids seen in tangential wood section. Dimensions 74 x 74 microns. OPC No. 347-3-28.

Figure 4. Group of three asymmetric spherules seen in tangential wood section. OPC No. 347-8.

particles (plate II, figs. 1-4). The same type of opaque particles occurs throughout the thin sections and is illustrated in the photomicrographs. Because of the small size of the particles it was not possible to make optically a mineralogical identification. It is postulated that they may be a form of iron silicate. The inner layers of the spherules are in many cases more opaque than the outer layers. The outer surface of each layer is defined by a concentration of the opaque particles. The thicknesses of the concentric layers appear to have no uniformity except that successive outer layers are generally thicker. The number of defined layers ranges from two to six. At present there is no recognized evidence which would explain the layering phenomenon but the structure of each layer suggests that some cyclic condition may have been responsible. The development of the spherules appears to have been essentially synchronous with mineralization of the wood because the development of the spherules which cross tracheid boundaries must have taken place before bordered pit perforations were sealed off by silicification.

The fact that no other similar structures have been observed in silicified woods of Oklahoma may aid in tracing the Ada specimen to its source and in interpreting its depositional environment.

References Cited

Arnold, C. A., 1931, Cordaitean wood from the Pennsylvanian of Michigan and Ohio: Bot. Gazette, vol. 91, p. 77-87.

Tynan, E. J., 1959, Occurrence of *Cordaites michiganensis* in Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 19, p. 43-46.

TREATISES OF PALEONTOLOGY

Carl C. Branson

The financial burden on a working paleontologist is heavy because of the multiplicity of expensive books. The French *Traité de Paléontologie* is to be in eight volumes, of which six volumes and a part of another have appeard. The German *Handbuch der Paleozoologie*, edited by Schindewolf, has been coming out in parts for 25 years, and the end is not in sight.

The American *Treatise on Invertebrate Paleontology*, edited by R. C. Moore, will have 24 volumes of which 8 have been issued.

The Russian *Osnovy Paleontologii* (Editor, Y. A. Orlov) is to be in 15 volumes, of which volume 1 and volume 6 are at hand. The price of volume 1 is 41 rubles, 55 kopeks, and of volume 6 is 55 rubles, 6 kopeks. Volume 6 was ably reviewed by Connors and Yochelson in *Journal of Paleontology*, vol. 34, no. 1, p. 203-205, January, 1960. Volume 1 is concerned with paleontological principles and with Protozoa. It consists of 482 pages, 1,096 figures and 13 plates, as well as of pictures of Cuvier, Lamarck, Rouillier, Darwin, Kovalevski, Karpinski, Dollo, Suschkin, and Borisiak.

The Russian series is designed to treat only of genera found in Russia. Volume 1 contains two new generic names, *Turrispiroides* Reitlinger, for

Turrispira Reitlinger, 1950 [not *Turrispira* Conrad, 1866, nor *Turrispira* Petho, 1906], and *Cribrisphaeroides* Reitlinger, said to be "gen. nov.," but appears to be a new name for *Cribrosphaera* Reitlinger, 1954 [not *Cribrosphaera* Popofsky, 1906].

New genera introduced are *Pseudolamarckina* Mjatiuk, genotype *Pulvinula rjasanensis* Uhlig, 1883; *Planoendothyra* Reitlinger, genotype *Endothyra aljutovica* Reitlinger, 1950; *Plectogyrina* Reitlinger, genotype *Endothyra* (?) *fomichaensis* Lebedeva, 1954 (genus said to occur in the Kinderhook of North America); *Globoendothyra* Reitlinger, genotype *G. pseudoglobulus* new name, for *Endothyra globulus* of Moeller, 1878 [not *Endothyra globulus* Eichwald]; *Chernyshinellina* Reitlinger, genotype *Ammobaculites pygmeus* Malachova, 1954; and *Quasifusulinoides* Rauser and Rosovskaya, genotype *Pseudotriticites fusiformis* Rosovskaya, 1952.

Two genera are noted as new, but were described in 1958. These are *Nonionellina* Voloshinova (genotype *Nonionina labradorica* Dawson, 1860), and *Mesoendothyra* Dain. Both of these genera were described first in *Mikrofauna S.S.S.R.*, no. 9, 1958. The ten volumes of Mikrofauna are a subseries of VNIGRI (Vsesoyuznogo Neftyanogo Nauchno-issledovatelskogo Geologorazvedochnogo Instituta), Trudy. The subseries is as follows:

Year	VNIGRI, Trudy, new series	Mikrofauna USSR
1948	Vypusk 31	Sbornik I
1949	Vypusk 34	Sbornik II
1950	Vypusk 50	Sbornik III
1950	Vypusk 51	Sbornik IV
1952	Vypusk 60	Sbornik V
1953	Vypusk 69	Sbornik VI
1954	Vypusk 81	Sbornik VII
1956	Vypusk 98	Sbornik VIII
1958	Vypusk 115	Sbornik IX
1959	Vypusk 136	Sbornik X

The new Russian handbook series will be invaluable for summarizing the vast outpouring of generic names offered in Russian journals and books, many virtually unobtainable. The text is reasonably well printed, the figures are good, and the plates are only acceptable.

Soil Survey of Creek County

A recently issued U. S. Department of Agriculture, Soil Conservation Service document, *Soil Survey of Creek County, Oklahoma*, is now available. This report, intended primarily for use by farmers, consists of 43 pages of text which describe and evaluate the 46 soil and land types whch were mapped in the County. It is illustrated by 85 aerial-photograph maps on the scale of approximately 3 inches to the mile.

The document may be purchased ($3.50, paper bound) from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

TOPOGRAPHIC CONTROL BY PRIMARY IGNEOUS STRUCTURES IN THE RAGGEDY MOUNTAINS, SOUTHWESTERN OKLAHOMA

H. E. HUNTER

The Raggedy Mountains of southwestern Oklahoma include a chain of low hills extending northwest from the Wichita Mountains Wildlife Refuge to Roosevelt, Oklahoma. The central part of this range is made up of a series of disconnected, approximately parallel ridges or elongate hills underlain by basic intrusive rocks (figs. 1, 2). Ridges developed in these rocks are mantled by soil and boulders which support considerable vegetation. The vegetation-covered slopes of the basic-rock ridges are in sharp contrast to the barren surfaces of the rounded granite hills that border the basic rocks on all sides. The granitic and basic rocks are part of the Wichita Mountains igneous complex which is believed to be Late Precambrian in age.

Preliminary mapping has shown that the basic rocks can be subdivided into at least four units. Distribution of the rock units indicates that they are tabular bodies. Individual units are probably not more than a few hundred feet thick although present data are not sufficient to permit accurate calculation of thicknesses. The rock units show marked differences in susceptibility to weathering, and as a result topographic features have some characteristics normally associated with sedimentary strata.

The ridges trend in a general east-west or southeast-northwest direction. Transverse profiles (fig. 2) show that many of the ridges are asymmetrical, with the steeper slopes facing south or southeast. Asymmetry of some ridges is readily evident from field observation (fig. 3), and the opposite slopes of these ridges invariably have discernibly different characteristics. The boulder cover on north slopes is made up of a single rock type or an assemblage in which one type is predominant. Boulder accumulations on south slopes are more heterogeneous. On north slopes boulders tend to lie with their long dimensions parallel to the ridge slope whereas similar boulders lie in random orientation on south slopes.

Outcrops on north slopes form more or less planar surfaces that strike parallel to ridge elongation and dip in the direction of the ridge slope. The rocks tend to erode into blocky, subrectangular boulders that have basal planes parallel to the outcrop surface and vertical planes parallel to joints in the bedrock. On the south slope the outcrops are narrow ledges generally at or near the crests of the ridges.

Features of the flat outcrop surfaces are controlled primarily by preferred orientation of mineral grains in the rock (fig. 4). The essential minerals of the basic rocks comprise plagioclase, monoclinic pyroxene, orthorhombic pyroxene, and olivine. The ferromagnesian minerals show no megascopically recognizable planar or linear development and consequently no preferred orientation of these minerals can be distinguished in hand specimens or outcrops. Plagioclase habit is predominantly tabular parallel to 010. Preferred planar orientation of plagioclase ranging from distinct to slight is present in all rocks in which the tabular habit is well developed. Preferred linear orientation of plagioclase has not been observed. Erosion

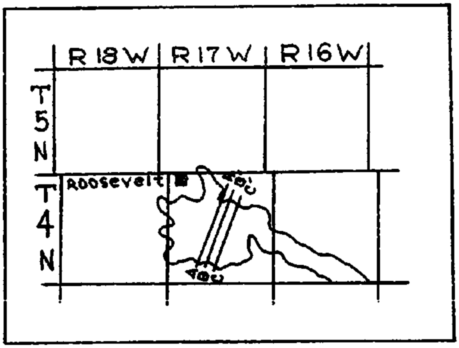

Figure 1. Approximate extent of outcrop of basic rocks in the Raggedy Mountains. (Location of profiles in fig. 2: A-A', B-B', C-C')

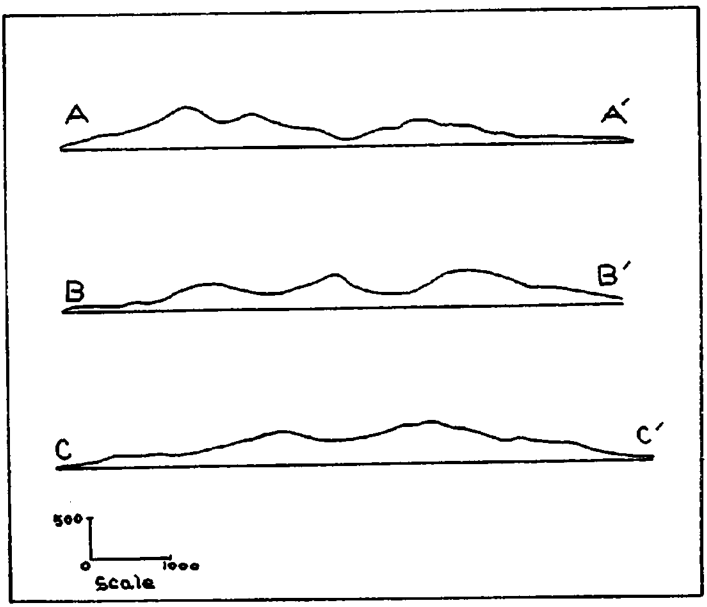

Figure 2. Northeast-southwest profiles in vicinity of Glenn Creek.

Figure 3. Asymmetrical ridge with gentler slope to the northeast. Outcrop forms a ledge along the crest of the southwest slope. NE¼ SW¼ SW¼ sec. 33, T. 4 N., R. 16 W.

Figure 4. Northeast-dipping outcrop surface parallel to plane of preferred plagioclase orientation. SW¼ NE¼ NE¼ sec. 29, T. 4 N., R. 16 W.

slopes develop parallel to the plane of preferred orientation and the degree of planarity of the erosion surface depends on the degree of preferred orientation of the plagioclase grains.

The ledge-like character of outcrops on the south slopes results from the differential weathering of the various units. Rocks containing appreciable ferromagnesian minerals weather more readily than those consisting

Figure 5. "Camel Rock." An erosional remnant of diallage gabbro capped by resistant anorthosite. SW¼ SW¼ SW¼ sec. 13, T. 4 N., R. 17 W.

primarily of plagioclase. In gross aspect the basic rocks comprise a series of units distinguished by the relative proportions of felsic and mafic minerals and by the kinds of mafic minerals present. In detail, individual units show abrupt variations in proportions of these minerals and many outcrops have a layered appearance with zones containing appreciable ferromagnesian minerals alternating with zones of anorthosite. Contacts between zones of different mineralogical composition are parallel to the plane of preferred plagioclase orientation and to the planar outcrop surfaces (fig. 4). As the great majority of outcrop surfaces dip in a northerly direction, the more rapid erosion of layers containing appreciable ferromagnesian minerals tends to undercut the more resistant units on the south slopes of the ridges. Differential weathering has resulted in erosional remnants that are somewhat unusual in igneous rocks. "Camel Rock" (fig. 5) is formed of relatively non-resistant diallage gabbro capped by a thin layer of anorthosite.

The gross topographic features of that part of the Raggedy Mountains underlain by basic igneous rocks therefore appear to be the result of preferred orientation of plagioclase and the layered character of the intrusive body. Textures observed in hand specimens and in thin sections demonstrate conclusively that these are primary features of the basic rocks. The general pattern appears to be a series of tabular units striking northwest and dipping northeast. A complex system of faults and possibly some broad folds are superimposed on this pattern. Current work is designed to set up criteria for the correlation of horizons within the intrusive body. Delineation of such horizons would make it possible to clarify structural relationships within the igneous complex of the Wichita Mountains and to determine the exposed thickness of the basic rocks.

RELATIONSHIP OF PALEOZOIC BOUNDARIES TO MARINE TRANSGRESSIONS AND OROGENIC MOVEMENTS

GEORGE G. HUFFMAN

Orogenic movements in geosynclinal areas or mobile belts and extensive marine transgressions of the craton may occur simultaneously. Intersystemic boundaries are sharply defined in areas of orogenic movement by unconformity and flysch-molasse relations; corresponding boundaries on the craton are often poorly defined because of continuous or essentially continuous deposition. Major marine regressions on the craton occur during times of maximum subsidence or depression in the geosynclinal areas. Intersystemic boundaries are sharply defined on the craton following regression; the unconformity decreases toward the geosycline where essential conformity exists.

The Paleozoic history in North America includes four major marine transgressive-regressive cycles (fig. 1). Marine transgressions and regressions of secondary rank characterized Ordovician, Mississippian, and Pennsylvanian periods during orogenic movements (Blountian, Vermontian, Ouachita, Wichita, and Arbuckle disturbances). Third order marine transgressions and regressions during the Late Paleozoic gave rise to cyclic deposition on platform areas in Late Mississippian, Pennsylvanian, and Early Permian times.

Early and Middle Cambrian deposition was limited to the Appalachian and Cordilleran orthogeosynclines. Late Cambrian seas advanced across the craton during one of North America's greatest transgressions. Lower Ordovician Canadian beds overlie the Upper Cambrian beds with essential conformity and similar distribution. No orogenic movement is known to have affected North America at the close of Cambrian time; however, local disconformity and low-angle unconformity are present in parts of eastern North America. Early Ordovician seas withdrew from the craton, leaving a widespread disconformity.

Middle and Late Ordovician inundation is complicated by secondary orogenic movements in the Appalachian region (Blountian and Vermontian disturbances) during which transgressions and regressions of second order magnitude occurred. Maximum transgression occurred in latest Ordovician (Richmondian) time and continued into Silurian time, reaching a second maximum in Middle Silurian (Niagaran) time. The Taconian orogeny in the mobile belt of eastern North America produced angular relations between the Ordovician Queenston redbeds and the overlying Silurian Shawangunk conglomerate and sandstones. This unconformity decreases in magnitude toward the craton where Lower Silurian (Orchard Creek) shale lies conformably upon Upper Ordovician (Richmond) strata.

Late Silurian regression led to restriction of the sea to portions of the geosynclines and to intracratonal basins. Silurian-Devonian beds, although separated by widespread disconformity on the craton where Middle Devonian beds rest upon Middle Silurian strata, are conformable in the Appalachian trough where Lower Devonian Coeymans limestone rests without significant break on Upper Silurian Manlius limestone. Thus once more

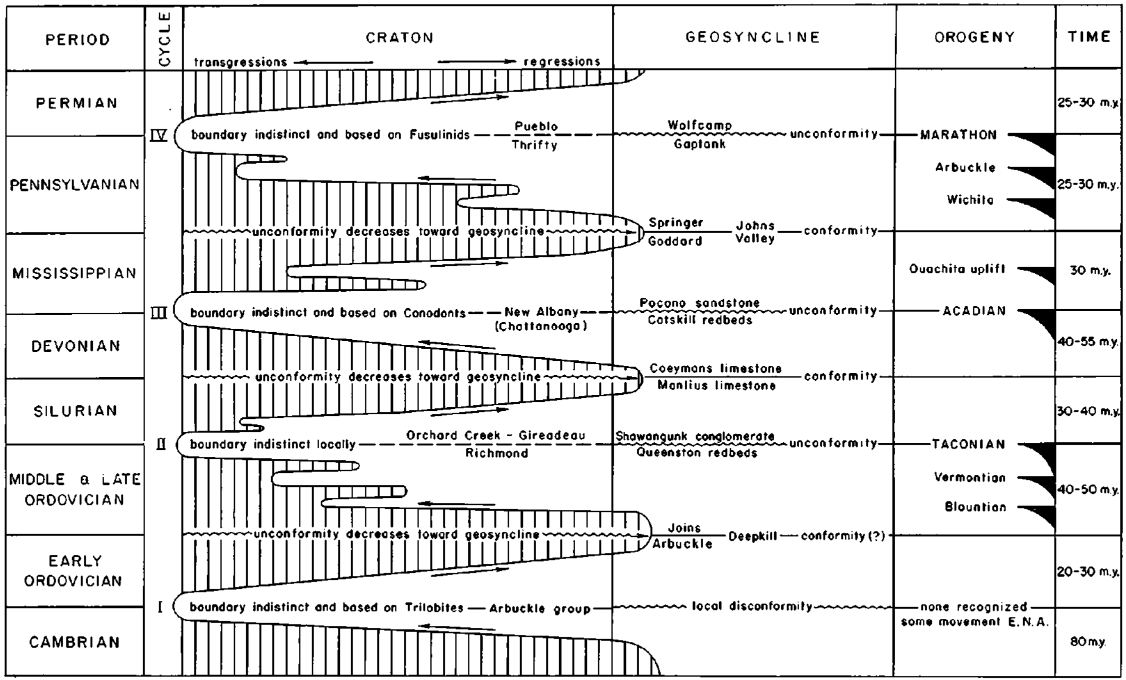

Figure 1. Time-transgression diagram for the Paleozoic Era.

we note essentially continuous deposition in the geosyncline during time of maximum regression on the craton.

Early Devonian sediments are limited essentially to the marginal geosynclines and to adjacent intracratonal basins. Middle and Late Devonian seas were transgressive with maximum flooding in latest Devonian time. Late Devonian orogenic movement (Acadian disturbance) in eastern North America produced sharp stratigraphic boundaries and unconformity between the Lower Mississippian Pocono sandstone and the underlying Chemung-Catskill sequence. This unconformity decreases toward the craton and disappears in the Late Devonian-Early Mississippian black shales (Chattanooga, New Albany, Woodford, Antrim, etc.). The Devonian-Mississippian boundary on the craton is drawn arbitrarily on the basis of conodont faunas. Distribution of Early Mississippian Kinderhook and Osage series coincides with that of Late Devonian deposits.

Uplift during early Meramecian time in the Ouachita area gave rise to a secondary transgression-regression cycle which is reflected in the Stanley-Jackfork sequence and the overlapping platform facies of the Sycamore-Moorefield and the offlapping Caney-Goddard and Fayetteville-Pitkin.

During Late Mississippian (Chesterian) time there was a gradual regression of the sea toward the geosynclinal areas. There Upper Mississippian black shales are succeeded conformably by black shales of Pennsylvanian age and the boundary, now drawn on limited faunal evidence, is somewhere within the Goddard-Springer sequence of the Ardmore basin, the Johns Valley shale of the Ouachitas, and the Parkwood formation of Alabama. On the craton, Middle Pennsylvanian (Desmoinesian) beds overlap the Lower Pennsylvanian beds and lie upon eroded beds of Middle Mississippian age.

A major marine transgression characterized Middle and Late Pennsylvanian time with significant interruption and secondary transgressions and regressions related to the Wichita and Arbuckle orogenies. Third order transgressions and regressions related to minor crustal movement and/or multiple glaciation gave rise to cyclic deposition (cyclothems) in parts of the Mid-Continent, Eastern Interior, Michigan, and Appalachian basins. In the Marathon region, Late Pennsylvanian orogenic movements produced angular discordance between the Lower Permian Wolfcamp beds and Upper Pennsylvanian Virgil beds. Northward from there, the base of the Permian is drawn on the basis of fusulinid evidence rather than on a recognizable physical break. Elsewhere the boundary is usually based on faunal and floral criteria and not on a depositional break.

The Permian period is characterized by progressive marine regression from a maximum inundation in Wolfcampian time to a minimum in late Permian Ochoan time when Permian seas withdrew into the confines of the Delaware basin of West Texas and New Mexico. The Appalachian orogeny of post-Dunkard (early Permian) and pre-Newark (Late Triassic) time is generally considered to have brought the Paleozoic era to a close.

Plotting of the estimated duration of Paleozoic periods in millions of years indicates that Paleozoic transgressions and regressions are periodic and that the time necessary for a complete transgression and regression and associated orogenic movement varies from 50 to 60 m.y. in the Pennsylvanian-Permian cycle to 100 to 110 m.y. for the Cambrian-Early Ordovician cycle. The Ordovician-Silurian cycle required some 70 to 90 m.y. and the Devonian-Mississippian cycle 70 to 85 m.y. Thus each succeeding Paleozoic cycle required less time for its completion than did the preceding one.

The writer wishes to express his appreciation to John Speer with whom this problem has been discussed. Some of his suggestions and comments have been incorporated in the text of this paper.

New Data on Graptolites

Oklahomans are conscious of the value of stratigraphic dating by means of graptolites because for 36 years Dr. C. E. Decker worked to make those of the Oklahoma area known and useful. The Texas Bureau of Economic Geology has just published on extensive report on the graptolites of the Marathon region, a report in which many facts of interest in Oklahoma stratigraphy are presented. The author is William B. N. Berry, who visited O. U. and the Survey to consult with Dr. Decker and Dr. Ham, to examine the Decker graptolite collection, and to visit localities in the field with Dr. Pitt.

Berry found 15 graptolite faunal zones in the Ordovician of the Marathon region. Of these zones, Zone 3 (zone of *Tetragraptus approximatus*) is correlated with the middle part of the Kindblade formation of Oklahoma; Zone 4 falls within the Mazarn shale of Arkansas; Zone 6 correlates with the upper part of the West Spring Creek formation of the Arbuckle Mountains; Zone 7 with the Joins formation; Zone 9 appears to fall within the Blakely sandstone of Arkansas on the basis of graptolites, and Dr. R. W. Harris identified the ostracods as of Oil Creek type. Zone 10 has been placed as McLish in age by M. E. Upson, and Zone 11 as Tulip Creek, on the basis of ostracods. Zone 11 also carries Womble graptolites. Zone 13 is correlated with the lower part of the Viola limestone and with the upper part of the Womble. Zone 14 is equivalent to the Bigfork chert, and with the middle and upper parts of the Viola. Zone 15 has the Polk Creek-Sylvan graptolite fauna.

Berry states that Decker found some poorly preserved specimens of *Tetragraptus reclinatus* in the West Spring Creek limestone of the Arbuckle Mountains, *Climacograptus bicornis* and *C. eximius* are reported as represented in the Decker Collection from the Womble shale of Arkansas and from the Stringtown shale of Oklahoma. Berry found specimens of *Orthograptus calcaratus incisus* from the same two units in the Decker Collection.

Berry rather curiously fails to list in his bibliography Decker's 1944 paper on pendent graptolites in which he figured *Didymograptus protobifidus* from the Marathon region (*Jour. Paleontology*, vol. 18, p. 378-386). The 15 faunal zones will prove most useful in stratigraphic work. Berry and the Texas Bureau are to be congratulated on this fine monograph. It is "Graptolite faunas of the Marathon region, West Texas," by William B. N. Berry, Texas, Univ., Publ. No. 6005, 179 pages, 3 figures, 20 plates, 3 tables, March 7, 1960.

—C. C. B.

TABLE I. — DRILLING ACTIVITY IN OKLAHOMA, 1959

	1959						1958	1960
	Oil	Condensate	Gas	Dry	Service	Total	Total	Forecast
All wells								
Number of completions	2,677	106	392	2,072	112	5,359[1]	6,354[2]	5,450
Footage	9,606,208	810,846	2,297,427	7,316,520	264,570	20,295,571	21,013,444	20,582,000
Average footage	3,566	7,649	5,861	3,019	2,362	3,787	3,307	3,790
Exploration wells								
Number of completions	97	20	73	637		827	854	801
Percent of completions	11.7	2.4	8.8	77.1				
Footage	597,866	162,849	486,259	2,849,153		4,096,127		
Development wells								
Number of completions	2,580	86	319	1,435	112	4,532	5,500	4,649
Footage	9,008,342	647,997	1,811,168	4,467,367	264,570	16,199,444		

[1] Cable, 1,025; rotary, 4,334.
[2] Cable, 1,358. rotary, 4,996.

1959 STATISTICS OF OKLAHOMA'S PETROLEUM INDUSTRY

LOUISE JORDAN

The source for much of the following data concerning the petroleum industry, except where noted, is the annual review-forecast section of the *Oil and Gas Journal*, vol. 58, no. 4, January 25, 1960. The acceptance of one source for current statistics is necessary in that there are always differences between sources. Final statistics are published in mimeographed form by the U. S. Bureau of Mines about 23 months after the end of a year and reprinted in *Oklahoma Geology Notes*. Several years later the Bureau of Mines *Minerals Yearbook* volume on fuels is printed. The latest Yearbook now available is that for 1956 which contains final figures for 1955.

Petroleum Facts and Figures, Centennial Edition, 1959, published by the American Petroleum Institute, brings together for the first time authoritative current and historical information about the industry for the world, the United States and the individual states. This eight-by-twelve-inch book contains 472 pages of information which will be of value to oil men, students, educators, journalists, and all others interested in the statistical story of petroleum.

TABLE II. — HYDROCARBON PRODUCTION IN OKLAHOMA, 1958-59

	1958	1959
Crude oil and lease condensate		
Total annual production (1,000 bbls.)	200,699[1]	196,704[2]
Value ($1,000)	594,069[1]	570,442[2]
Cumulative production (1,000 bbls.)	7,836,373[3]	8,033,077
Daily production (bbls.)	547,817	533,510
Total number of producing wells	79,425	79,867
Daily average per well (bbls.)	6.9	6.7
Wells flowing naturally at end of year	2,771	2,987[4]
Oil wells on artificial lift	76,981	78,128[4]
Natural gas (MMCF)		
Total annual marketed production	696,504[1]	701,500[2]
Cumulative marketed production (1906-1959)		15,112,600
Value ($1,000)	70,347[1]	72,300[2]
Total number of gas and gas-condensate producing wells	4,801[4]	5,121[4]
Natural gas liquids (1,000 Gals)		
Total annual marketed production	1,097,912[1]	1,124,300[2]
Value ($1,000)	51,851[1]	53,400[2]

[1] U. S. Bureau of Mines final.
[2] U. S. Bureau of Mines preliminary.
[3] Amer. Petroleum Institute, 1959, *Petroleum Facts and Figures*, Centennial Edition, p. 41.
[4] *World Oil*, February 15, 1960.

Production from Oklahoma's 20 "Giant" fields (Allen, Avant, Bowlegs, Burbank, Cement, Cushing, Earlsboro, West Edmond, Elk City, Eola [Roberson consolidated Aug., 1959], Fitts, Glenn Pool, Golden Trend, Healdton, Hewitt, Little River, Oklahoma City, Seminole, Sho-Vel-Tum, St. Louis, and Tonkawa) amounted to 82,220,000 barrels or 42.2 percent of total annual production in 1959.

TABLE III — ESTIMATED PROVED RESERVES IN OKLAHOMA*

	1-1-58	1-1-59	Changes in 1959
Crude oil (1,000 bbls)	1,898,128	1,864,749	— 33,379
Natural-gas liquids (1,000 bbls)	357,507	367,569	+ 10,062
Total liquid hydrocarbons	2,255,635	2,232,318	— 23,317
Natural gas (MMCF)	15,206,769	16,651,291	+ 1,444,523

* Report of the American Petroleum Institute's Committee on Petroleum Reserves and Committee on Natural Gas Reserves of the American Gas Association; reprinted in part in *Oil and Gas Journal*, vol. 58, no. 12, March 21, 1960.

TABLE IV. — CRUDE-OIL AND REFINED-PRODUCTS PIPELINES IN OKLAHOMA*

	1-1-56	1-1-59
Mileage		
Gathering lines, crude and natural gasoline	12,805	13,158
Product pipelines	2,756	2,815
Crude trunklines	7,761	5,626
Pipeline fill (Bbls)		
Total crude lines	6,069,000	5,119,000
Product lines	1,025,000	1,001,000

* Messner, W. G., 1959, Crude-oil and refined-products pipeline mileage in the United States, January 1, 1959: U. S. Bureau of Mines, Information Circular 7942.

TIFF MEMBER OF GODDARD FORMATION

C. W. Tomlinson* and Allan Bennison

In 1956, M. K. Elias (p. 74) described a fossiliferous lentil in the Goddard formation, but did not name the lentil. The description was as follows:

> "Projecting the top of the Sand Branch formation (or the local top of the Mississippian) into the geological section in the southern Arbuckle Mountains has been helped considerably by the recent discoveries by Allan Bennison of two goniatite-bearing horizons in the Goddard shale. One is in the upper part of the lower half of the formation in the area west of Sycamore Creek, which yielded only one goniatite species, *Cravenoceras* (*Richardsonites*) *richardsonianum* (Girty); and the other is in the upper part of the Goddard formation in the central part of the Caddo anticline northwest of Ardmore. The latter, a very recent discovery, is of particular importance because here was identified for the first time in the Ardmore basin a true representative of *Eumorphoceras*, which is indicative of Sand Branch age. Additional collecting from this locality may result in a decision whether its fossils indicate the earlier or later phase of Sand Branch time."

The fossiliferous member was found by Bennison in 1955, and he showed the outcrop to Tomlinson. Bennison sent fossils to M. K. Elias, who reported the presence of *Eumorphoceras* and of conodonts (letter to Bennison, Feb. 23, 1955). He identified *Ozarkodina* and *Prioniodus solidifundus* [now placed in *Neoprioniodus*] from the locality (letter to Bennison, Feb. 28, 1955), and later identified *Polygnathodella* (letter to Tomlinson, March 4, 1955).

In 1959, Tomlinson (p. 323) gave the name Grindstone Creek member to the unit and described it as follows:

> "NE¼ SE¼ SE¼ SE¼ Sec. 16, T. 3 S., R. 1 E., in gully at north end of large cutbank at east side of Grindstone Creek. One foot of dark dense limestone, weathering white, over 4-foot covered interval, over 8 feet of glauconitic grit. Goniatites and other shells in both limestone and grit. Limestone float extends sparsely about 400 feet southeast over grassy divide to next draw. Type locality. About 500 feet below Rod Club member [of Springer formation]."

Tomlinson subsequently learned that the name Grindstone Creek had been used previously for a member of the Millsap Lake formation of north-central Texas. He proposed the new name, Tiff, by means of rubber stamp imprint on reprints of his article. The name has been registered with the Geologic Names Committee of the U. S. Geological Survey. Tiff was a rural community one mile north and two miles east of the type section, and was on the Caddo anticline in Carter County.

The unusual petrology of the Tiff member sets it apart from the other members of the Goddard formation. It consists of 10 to 40 feet of light to dark gray pelletal or gritty claystone. The pellets range from

* Dr. C. W. Tomlinson died at 2:30 A. M. on April 3, 1960, in his home at Ardmore.

approximately 0.2 to 2 millimeters in diameter throughout its outcrop range and are composed principally of hard phosphatic claystone that is partly glauconitized or pyritized. These are similar to the much larger "golfball" phosphatic concretions in the Delaware Creek formation. The matrix is a relatively soft but firm claystone containing much carbonaceous matter including locally sizable lignitized logs. In the more carbonaceous strata a meshwork of gypsum needles and a yellow sulphurous coating are sporadically developed.

Large flattish septarian concretions, composed of argillaceous to silty limestone, occasionally yield small ammonoids referred to elsewhere in this note and abundant fern and *Calamites* impressions and woody fragments. Indeterminate crushed and leached pelecypods possibly related to *Caneyella* sp. occur in thin erratic layers.

Conodonts are abundant in several zones of the Tiff member. M. K. Elias recently collected and provisionally identified the following conodonts from the type locality:

Hindeodella sp.
Neoprioniodus aff.* *N. ligo* Hass
Neoprioniodus cf. *scitulus* Branson and Mehl
Neoprioniodus cf. *solidifundus* Elias
Prioniodella cf. *biden* Elias
Ozarkodina cf. *roundyi* (Hass)
Ozarkodina sp.
Gnathodus (Harltonodus) cf. *bilineatus* Roundy
Gnathodus (Harltonodus) aff.* *glaber* Elias
Gnathodus (Harltonodus) cf. *modocensis* Rexroad
Spathognathodus cf. *miniden* Elias
Polygnathodella aff.* *ouachitaensis* (Harlton)
Geniculatus (?) sp.

*Aff. indicates related form, probably a new species.

References Cited

Elias, M. K., 1956, Upper Mississippian and Lower Pennsylvanian formations of south-central Oklahoma, *in* Petroleum Geology of Southern Oklahoma, vol. 1: Amer. Assoc. Petroleum Geologists, p. 56-134.

Tomlinson, C. W., 1959, Best exposures of various strata in Ardmore basin, 1957, *in* Petroleum Geology of Southern Oklahoma, vol. 2: Amer. Assoc. Petroleum Geologists, p. 302-334.

U.S.G.S. Projects in Oklahoma

The recently issued index maps showing the locations of geologic and geophysical field projects of the Geologic Division of the U. S. Geological

Survey as of July 1, 1959, list six projects concerning Oklahoma geology.

The geological studies are:

Anadarko basin oil and gas investigation; Project No. F390; Party chief, W. L. Adkison. A preliminary chart (regional cross section from Barber Co., Kansas, to Caddo Co., Oklahoma) is now in press.

McAlester basin oil and gas investigation; Project No. F814; Party chief, S. E. Frezon. A preliminary chart (regional cross section from Franklin Co., Arkansas, to Coal Co., Oklahoma) is currently under review in Washington and will be published by the Oklahoma Geological Survey.

Midcontinent Pennsylvanian shales investigation; Project F1016; Party chief, W. Danilchik. The area of study includes parts of western Missouri, southeastern Kansas and northeastern Oklahoma. Part of this study has been published in U.S.G.S. Trace Elements Investigations Report 590 (Dec. 1955, p. 253-257).

Permian sediments, North Texas and Southern Oklahoma; Project No. F1025; Party chief, E. J. McKay. This is a regional stratigraphic study which extends into Jefferson, Cotton, Stephens, Tillman and Comanche Counties and includes a part of northern Washita County. Part of this study has been published in U.S.G.S. Trace Elements Investigations Reports 590 (Dec. 1955, p. 257-262) and 640 (Dec. 1956, p. 208-216).

The geophysical studies are:

Research on methods of interpretation; Project No. Geo 342; Party Chief, R. G. Henderson. The data for this project include an airborne geophysical survey of parts of Kiowa and Comanche Counties.

Correlation of airborne radioactivity data and areal geology; Project No. Geo 376; Party Chief, R. Guillou. This project covers 15 counties in the northeastern corner of Oklahoma.

Energy Production in the United States

Preliminary data published in the March 3 issue of the *Monthly Petroleum Statement* (No. 451), Bureau of Mines, U. S. Department of the Interior, show the 1959 production of mineral energy fuels and energy from water power (on the basis of Btu equivalents) to be distributed among the following sources:

	Percent
Bituminous coal and lignite	26.7
Anthracite	1.2
Crude petroleum	37.0
Natural gas, wet	30.9
Water power	4.2
	100.0

The total national production was 40,307 trillion Btu equivalents, an increase of 8,751 since 1949. From these and other data it is estimated that Oklahoma crude production accounted for about 2.6 percent of the total energy produced.

DISTILLATE OR CONDENSATE?

FRANK W. COLE*

The term distillate has been in the oil man's vocabulary for many years, probably almost as long as oil has been produced in the United States. The term was used to describe the amber or colorless liquid recovered from gas wells, or from the gas gathering lines of gas produced from oil wells. This liquid had a high API gravity, generally above 50° API, was extremely volatile and would evaporate quite readily. It would collect in low places in gathering lines and in surface separation facilities.

Few problems were encountered in the early days of the industry in describing this distillate since most of the production came from relatively shallow depths, and the actual volume of distillate recovery was small. In recent years, with the advent of deeper drilling, other hydrocarbon reservoirs have been discovered which yield a liquid identical in appearance and composition to the distillate which had been produced from the shallower wells. During this period additional information was gained concerning the chemical composition and phase behavior of hydrocarbon fluids. As more became known about the phase relationships of these hydrocarbon fluids it became obvious there was a graduation from the black-oil reservoirs to the dry-gas reservoirs, it being possible to have a hydrocarbon reservoir with almost any composition between the two limits of the black-oil and dry-gas reserviors. The term distillate became inappropriate for describing the liquid produced from these deep reservoirs, because many of the reservoirs contained large volumes of this "distillate" in place originally. In the days when the liquid had practically no economic value, because of the small quantity involved, it mattered little whether the term had been used properly. However, when the economic value of this liquid became significant, a more adequate description became necessary.

This liquid is condensed from the gas. Condensation may take place, (1) in the reservoir, or (2) after the gas leaves the reservoir and is on the way to the surface, or (3) in the surface separation facilities. Then the proper term of this liquid is *condensate*, because it is a condensation of liquid from the material which has previously been in the vapor phase. The term distillate implies that the liquid has been distilled from some previous product, which of course is not the case.

It is very easy to determine by simple laboratory tests on representative samples of reservoir fluid whether this condensate will be formed at any time in the life of the reservoir. Results of these tests are usually presented as pressure-temperature phase diagrams, such as shown in figure 1. The line a,c,p,t,b, is called the phase envelope. If the pressure and temperature of the reservoir are located within the phase envelope, then the reservoir fluid will be composed of two phases. This is the initial condition of a so-called "black-oil" reservoir containing an initial gas cap. If the initial pressure and temperature of the reservoir are outside the phase envelope then the reservoir fluid will initially be composed of a single phase. This single phase may be liquid, it may be gas, or it may be a

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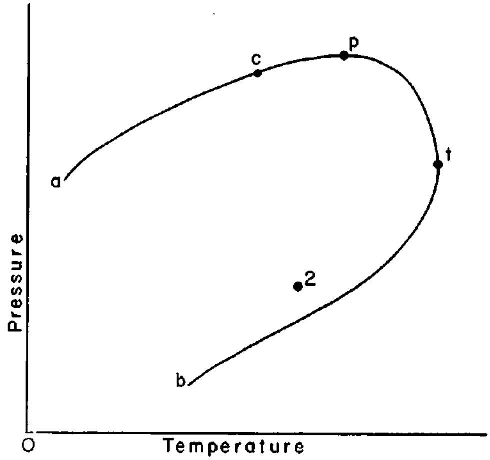

Figure 1. Pressure-temperature phase diagram.

composition which is in the critical region. In the latter case it will be impossible to classify the initial reservoir contents as either liquid or gas. If the initial reservoir conditions are located to the right of the point "t" on the phase envelope, the reservoir fluid is usually referred to as a gas and will be considered to be in the vapor state. However, if the surface conditions of separation are within the phase envelope, such as at point 2 in figure 1, then some liquid will be recovered at the surface. This liquid recovery was formerly called distillate, but is now more properly classified as condensate.

Canadian County Report Issued

Oklahoma Geological Survey Bulletin 87, *Ground Water Resources of Canadian County, Oklahoma*, by J. L. Mogg, S. L. Schoff, and E. W. Reed, was issued April 7, 1960. The bulletin contains 112 pages of text and is illustrated by three figures and two plates. Plate I is a map showing the aquifers of Canadian County. Plate II comprises five maps showing bedrock surface, water table, depth to water, thickness of alluvium, and saturated thickness in the North Canadian River valley.

The bulletin is available at the Survey office. Price: $2.75 bound in blue cloth, $2.00 paper bound.

Some Oklahoma Carboniferous Cephalopods

A recent paper by Mackenzie Gordon, Jr., although primarily concerned with Arkansas species, contains much material of importance in Oklahoma geology.

Rayonnoceras girtyi Foerste and Teichert, 1930, from "a boulder in the Caney shale," in the Ouachita Mountain area (spelled Washita by the authors) is suppressed as a synonym of *R. vaughanianum* Girty, 1909, an Oklahoma Caney species. Two specimens referred to *R. vaughanianum* by Foerste and Teichert are given the new specific name *R. foerstei*. The holotype is a silicified specimen from the hill on the east side of Oil Spring crossing of Hickory Creek, sec. 27, T. 2 S., R. 1 W., Carter County, Oklahoma (Criner Hills area, not Washita Mountain area). The paratype is from the Caney facies of the Johns Valley shale and was collected in Johns Valley, Pushmataha County, Oklahoma. The specimen doubtfully referred to the species by Foerste and Teichert (p. 264, pl. 51, fig. 1) is "probably from some locality in Oklahoma." The new genus *Reticycloceras* is established with *R. croneisi* new species, an Arkansas Pitkin species, as genotype. *Cycloceras sequoyahense* Snider, 1915, from the Fayetteville and Pitkin north of Gore, Oklahoma, is referred to the new genus in the new combination *Reticycloceras sequoyahense* (Snider).

The new genus *Mitorthoceras* is based upon the new species *M. perfilosum* from the Chainman shale of Utah, a species also found in the Ruddell shale of Arkansas, the Barnett shale of Texas, and the Caney shale of Le Flore County, Oklahoma. Oklahoma species referred to the new genus are *Orthoceras crebriliratum* Girty, 1909, and *O. choctawense* Girty, 1909, both from the Caney shale of southern Oklahoma.

Paracravenoceras new genus is erected for *P. ozarkense* new species (genotype) and for *Nuculoceras barnettense* Plummer and Scott, 1937. Gordon states that both species are rare in the Caney shale of Oklahoma.

The new monotypical genus *Fayettevillea* is established with *F. planorbis* new species as genotype. A specimen described as *Gastrioceras richardsonianum* and figured by Girty (1909, pl. 11, fig. 10) is doubtfully referred to *Fayettevillea*. The specimen is from Caney shale of Pittsburg County, Oklahoma.

A new genus, *Pygmaeoceras*, is erected for *Gastrioceras pygmaeum* Mather, 1915 (Morrow of Arkansas and eastern Oklahoma), genotype, and includes *Gastrioceras venatum* Girty, 1911, of the Wewoka formation of Oklahoma, a species referred to *Eudissoceras* and to *Gonioglyphioceras* by authors.

Axinolobus is a new genus erected for a single specimen collected from the Morrow of Muskogee County and described as *A. modulus* new species.

The reference is "Some American Midcontinent Carboniferous cephalopods" Journal of Paleontology, vol. 34, no. 1, p. 133-151, January, 1960.

—C. C. B.