OKLAHOMA GEOLOGICAL SURVEY
Chas. N. Gould, Director

Bulletin No. 46

THE
PENNSYLVANIAN SYSTEM
IN THE
ARDMORE BASIN

By
C. W. Tomlinson

NORMAN
March, 1929

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Errata

Page 44, Pl. X. Location should read "R. 2 E."

Page 49, Pl. XII. Location should read "Center" instead of "CNL."

Page 69, line 2. Delete "or not".

Page 79, footnote 154. Delete last two sentences.

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THE PENNSYLVANIAN SYSTEM IN THE ARDMORE BASIN[1]

PREVIOUS INTERPRETATIONS AND PRESENT REVISION

PIONEER WORK

The marine Pennsylvanian strata of the Ardmore basin in southern Oklahoma occupy an isolated area, separated by unconformable younger sediments from the marine Pennsylvanian area of north-central Texas, and cut off from that of the main Western Interior coal basin by the Arbuckle Mountain uplift. Their detailed correlation with other areas has therefore been difficult, although this is a matter of exceptional interest because of the extraordinary thickness and economic importance of these strata, the record they hold of the greatest Paleozoic orogeny in central North America, and their key position between the two larger Pennsylvanian areas just mentioned.

The first published descriptions of the Pennsylvanian system in Oklahoma south of the Arbuckle Mountains were those of Taff,[2]

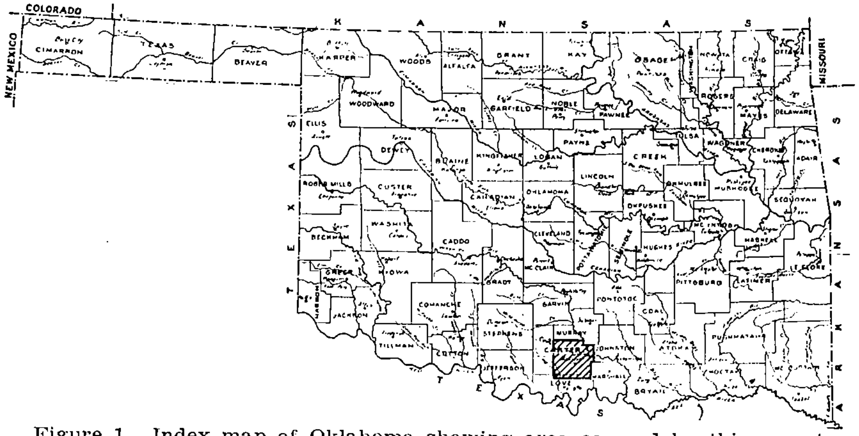

Figure 1. Index map of Oklahoma showing area covered by this report.

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[1] Published by permission of the Schermerhorn-Ardmore Co. Grateful acknowledgment is made to R. A. Birk for careful and constructive criticism of the manuscript; to Hugh D. Miser, Raymond C. Moore, Frederick B. Plummer, and Sidney Powers for helpful discussion and criticism; and to Charles N. Gould, C. L. Cooper, and their associates of the Oklahoma Geological Survey, for pushing the work along and aiding in its preparation for the press.

[2] Taff, J. A., U. S. Geol. Survey, Geol. Atlas, Tishomingo folio (No. 98), 1903. Also, Preliminary report on the geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma; U. S. Geological Survey, Prof. Paper 31, 1904. (Bull 12, Oklahoma Geol. Survey, 1928.)

who named and mapped the Caney shale and the overlying Glenn formation, describing them in general terms. His work has stood the test of time remarkably well.

In 1922 Goldston[3] subdivided the Glenn formation into five members; naming them, in order from lowest to highest, the Springer, Otterville, Cup Coral, Deese, and Hoxbar. These subdivisions have been found very convenient and in the present bulletin it is proposed to raise three of them to formation rank.

CONFLICTING DEFINITIONS OF GLENN AND CANEY

In the following year Girty and Roundy[4] criticized Goldston's work, contending that his Springer and Hoxbar members did not belong in the Glenn formation. They pointed out that Goldston's Otterville limestone member, immediately overlying the Springer, carries a distinctive fauna very similar to that which occurs in certain strata near Bromide, Oklahoma, at the east edge of the Arbuckle Mountains, which had been mapped as the basal part of the Wapanucka limestone but which they were inclined to regard as belonging rather to the underlying Caney shale[5]. Therefore, they argued that the Springer member, being older than the Wapanucka, should be regarded as part of the Caney shale and that the Glenn should begin with strata of Wapanucka age.

Following this interpretation, Miser's geologic map[6] of Oklahoma includes Goldston's Springer member, except the false "Springer" around the Criner Hills, discussed below, with the Caney shale rather than with the Glenn formation; except east of Washita River, where no published maps have differentiated the Springer from the higher members of the Glenn.

On the other hand, Taff's map of the Tishomingo quadrangle[7] includes in the Glenn formation the area which is actually occupied by Goldston's Springer member south of the Arbuckle Mountains, in the northeast corner of the Ardmore basin. Although he drew no hard and fast line between the Caney and the Glenn, Taff showed only a narrow belt of Caney shale along the south edge of the mountains, immediately overlying the Mississippian Sycamore limestone. He estimated the thickness of the Caney shale there, though with some hesitation due to suspicion of complex folding, at only 1,600 feet.[8] This estimate possibly should be raised to 2,000 or 2,500 feet, exclusive of the Springer.

RECOGNITION OF THE SPRINGER AS A SEPARATE FORMATION

The Caney shale as thus mapped and described by Taff in that area consists wholly of dark shales, mostly black and bituminous, with thin ferruginous and other concretionary layers, but containing no substantial sandstone or limestone members. Taff's descriptions[9] include no sandstone of any consequence in the Caney. Goldston's Springer member, 3,000 to 3,500 feet thick, definitely overlies the Caney as thus restricted by Taff in the Ardmore basin, and includes not only shales similar to the Caney but also several resistant sandstones which form prominent topographic ridges, and could not possibly have been overlooked by Taff in his description of the Caney shale if he had intended to include them in that formation. The sandstones of the Springer are persistent along many miles of outcrop and one of them is 100 feet thick. For structural and stratigraphic convenience and for the purposes of petroleum geology, it is very desirable to separate this member from the underlying uninterrupted black shales of the Caney.

One sandstone is present in the upper Caney as mapped by Taff on the northeast flank of the Arbuckle Mountains, in the vicinity of Bromide and elsewhere. It is possible that this represents a portion of the Springer member.[10] However, it is not certain that either this sandstone or the fossiliferous uppermost Caney (or basal Wapanucka) of the Bromide area cited by Girty and Roundy is represented in the type area of the Caney shale in Pushmataha County, Oklahoma.[11] [12] In the latter locality the Wapanucka limestone is not recognized, and the still younger Atoka formation is shown by Miser[6] as lying directly on the Caney shale. The limited Caney mapped by Taff at the west edge of the Tishomingo quadrangle quite possibly includes all of the Caney as defined at the type locality of that formation.[13]

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[3] Goldston, W. L. Jr., Differentiation and structure of the Glenn formation: Bull. Am. Assoc. Pet. Geol., vol. 6, pp. 5-23, 1922.

[4] Girty, Geo. H., and Roundy, P. V., Notes on the Glenn formation of Oklahoma, with consideration of new paleontologic evidence: Bull. Am. Assoc. Pet. Geol., vol. 8, pp. 331-349, 1923. Especially pp. 332-333.

[5] Girty, Geo. H., and Roundy, P. V., op. cit., pp. 333-337. For Girty and Roundy's lists of fossils from the Ardmore basin, see appendix to this bulletin. These lower Wapanucka or upper Caney beds are probably the source of the "higher fauna of the Caney shale" referred by Geo. H. Girty to the Pottsville in a contribution to Bulletin 44 of the Oklahoma Geol. Survey, p. 24, 1927.

[6] Miser, H. D., Geologic map of Oklahoma: U. S. Geol. Survey, et al., 1927.

[7] Taff, J. A., op. cit., geologcl map in the Tishomingo folio.

[8] Taff, J. A., op. cit., Tishomingo folio, p. 5, and columnar section on last sheet.

[9] Taff, J. A., Tishomingo folio, p. 5; also Prof. Paper 31 (cf. footnote 2, above), pp. 33-34. On his columnar section on the last sheet of the Tishomingo folio he describes the upper part of the Caney as "Blue shale with thin sandy lentils and small ironstone concretions". This is his only mention of sandy members.

[10] Cf. discussion of the Overbrook sandstone member, page 17.

[11] Taff, J. A., Note on the type locality of the Caney, quoted by Chas. N. Gould; Index to the stratigraphy of Oklahoma: Oklahoma Geol. Survey, Bull. 35, pp. 23-24, 1925.

[12] Ulrich, E. O., Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them: Oklahoma Geo. Survey, Bull. 45, pp. 38 and 42, 1927. Ulrich reports early Pennsylvanian fossils (from boulders?) in the Caney shale elsewhere in the Ouachita Mountain region, but not from the type locality in John's Valley, Pushmataha County.

[13] Ulrich (footnote 12) now contends that the Caney of the type locality is younger than the Caney bordering the Arbuckle Mountains, and he proposes for the former the new name "John's Valley shale." But H. D. Miser disputes Ulrich's claim, and presents a strong case for the indigenous rather than imported character of the Mississippian fauna found in the Caney of John's Valley. Miser, H. D. and Honess, C. W., Age relations of the Carboniferous rocks of the Ouachita Mountains of Oklahoma and Arkansas: Oklahoma Geol. Survey, Bull. 44, footnote by H. D. Miser on p. 23, 1927.

Even with the Springer member thrown out, there is a greater thickness of Caney shale in the Ardmore basin than has been described anywhere else.

OTHER NEW FORMATIONS

Outcrops of Goldston's uppermost or Hoxbar member of the Glenn formation in the Tishomingo quadrangle are confined to a few small areas at the west edge of the quadrangle in Tps. 3 and 4 S., R. 3 E., south of the Washita River. Taff apparently felt that these should be differentiated from the Glenn in later detailed work, for he said:[14]

> Cretaceous sands on one side and the river deposits on the other so obscure these Carboniferous rocks on the south side of Washita River that their position in the section can not be determined. Since they can not be distinguished from the rocks of the Glenn formation occurring on the north side of the river they are necessarily at present included with them in mapping.

Goldston's Cup Coral and Deese members, as well as the Hoxbar, are represented in the Tishomingo quadrangle south of the Washita River; but the Cup Coral and the lower part of the Deese occur also in Taff's type area of the Glenn formation farther west, and therefore are certainly to be regarded as part of the Glenn.

Taff says[14] that: "Limestone conglomerates occur above the Glenn on the south side of the Arbuckle uplift in the Ardmore quadrangle interstratified with shales, sandstones, and limestones."

This passage was cited by Girty and Roundy[15] as evidence that Taff "did not intend to include in the Glenn the highest Pennsylvanian rocks of the Ardmore quadrangle (those exposed south of Ardmore itself)." However, it is possible that the conglomerates Taff had in mind were those which exist in the unconformably overlying Pontotoc series, instead of those in the Hoxbar. Elsewhere on the same page Taff says:

> Limestone conglomerate beds interstratified with clays occur in sec. 32, T. 3 S., R. 3 E., just west of the Tishomingo quadrangle, but their relation to the Glenn formation is obscured by the surficial deposits lying immediately east.

This passage doubtless refers to conglomerates and clays of the Pontotoc series, which cover nearly all of sec. 32, T. 3 S., R. 3 E.[16]

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[14] Taff, J. A., Tishomingo folio, p. 5.

[15] Op. cit. (footnote 4), p. 332.

[16] Cf. map by Birk, Ralph A., The extension of a portion of the Pontotoc series around the western end of the Arbuckle Mountains: Bull. Am. Assoc. Pet. Geol., vol. 9, pp. 983-989, 1925; Fig. 1, p. 985.

Miser mapped the Hoxbar as part of the Glenn.[5] The thickness (1,000 to 3,000 feet) hesitantly assigned by Taff to the Glenn formation in his Tishomingo columnar section is less than the true thickness of the Springer member alone, and might be cited as evidence that Taff meant to limit the term Glenn very narrowly indeed. But Taff himself had no faith in this estimate. On page 5 of the Tishomingo folio he says: "The beds of the Glenn formation are not sufficiently distinctive or well exposed to give full information concerning their structure, and the thickness of the formation can not therefore at present be determined." In Professional Paper 31 at page 35 he says: "On account of the excessive folding the thickness of the Pennsylvanian sediments in this district can not now be estimated." In the same passages he mentions that there are 10,000 to 11,000 feet of Pennsylvanian formations above the Wapanucka limestone northeast of the Arbuckle Mountains.

To summarize: Goldston included both the Springer and the Hoxbar in the Glenn formation; Girty and Roundy would include neither; Taff appears to have included the Springer but not the Hoxbar; and Miser has done just the reverse. What is the Glenn? The simplest answer, as suggested by Gould,[17] is to drop the name entirely.

Even without the Springer and Hoxbar members, the Glenn formation includes a measurable thickness of 8,000 feet of sediments north of Ardmore, increasing southward to about 11,000 feet in Love County. This is an unwieldy thickness for a single formation, especially in strata which are easily differentiable into smaller units.

It is here proposed to set up as separate formations[18] Goldston's Springer and Hoxbar members, and to divide the remainder of the Glenn into the Dornick Hills formation below and the Deese formation above. Each of these four new formations has a maximum thickness in excess of 3,000 feet. All four consist dominantly of shales, interrupted by numerous resistant ledges of other rocks; among these, sandstones dominate in the Springer and Deese formations, and limestones in the Dornick Hills and Hoxbar. The Dorn-

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[17] Personal communication.

[18] It is recognized that it might be more appropriate, and would surely be more in harmony with the established scales of Pennsylvanian nomenclature in Kansas and north-central Texas, to call these stratigraphic units "groups" instead of "formations," as has been recommended in a personal communication by Dr. Raymond C. Moore. But this would raise to formation rank many of the subdivisions here listed as members, and would require the invention of many new formation names to complete the list of subdivisions of these "groups." It seems unnecessary so to burden stratigraphic literature with additional names which detailed correlation may in the near future make it possible to drop in favor of names already in use elsewhere in the Mid-Continent region.

ick Hills formation is believed to be at least partially equivalent to the Bend group of Texas, the Deese formation at least partially equivalent to the Strawn, and the Hoxbar at least partially equivalent to the Canyon group.

THE SPRINGER FORMATION

DEFINITION

The base of the Springer formation is drawn at the bottom of the Rod Club member, which includes the lowest sandstone known in the Carboniferous of the Ardmore basin. The top of the Springer is drawn at the base of the lowest fossiliferous Pennsylvanian limestone, the Jolliff member of the Dornick Hills formation. This horizon also coincides approximately with the top of the black shale sequence, and with the first evidence of Pennsylvanian orogeny; for the limestone just mentioned is locally conglomeratic.

The Springer formation as thus defined corresponds closely with Goldston's Springer member of the Glenn in its type area at the village of Springer and elsewhere north of Ardmore, around the Caddo anticline, and along the south flank of the Arbuckle Mountains. It comprises some 3,000 to 3,500 feet of black bituminous shales with ferruginous and calcareous concretions, with which are interspersed four conspicuous persistent sandstone members.

SPRINGER vs. HOXBAR AROUND THE CRINER HILLS

South of Ardmore, on the other hand, Goldston mapped as Springer an altogether different group of beds surrounding the Criner Hills—a group of tan, bluish and variegated shales, including a number of prominent fossiliferous limestone members, with sandstones as only a relatively inconspicuous constituent west, north or south of the Hills. The true Springer does outcrop in a narrow strip some distance east of the Criner Hills, and comes almost or quite into contact with the Hills near Overbrook, but no gradation between the two types is found anywhere.

In 1923, Girty and Roundy challenged Goldston's correlation of this wholly dissimilar group of beds around the Criner Hills, with his Springer member of the type area. They collected fossils from the former group near the north and south ends of the Hills,[19] and interpreted them to signify late Pennsylvanian rather than early Pennsylvanian age[20]. They stated that this group could not be Springer at all, and that the beds from which their southern collections were made were at least as young as Goldston's uppermost or Hoxbar member of the Glenn.

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[19] See faunal lists in appendix to this bulletin; also discussions of the Confederate and Crinerville limestone members of the Hoxbar formation, pages 39 and 42.

[20] Girty, Geo. H., and Roundy, P. V., op. cit., (footnote 4) pp. 340-341.

Beyond suggesting[21] that unconformity was involved, Girty and Roundy did not attempt to present an analysis of local structure which would explain the presence of late Pennsylvanian beds around the Criner Hills in contact with pre-Pennsylvanian rocks. Goldston had shown an essentially continuous monoclinal sequence of Pennsylvanian beds extending northeastward from the older Paleozoic rocks of the Criner Hills to the Cretaceous overlap in the Ardmore syncline. He had noted certain overturned folds[22] in this area, but had not recognized that any of them involved more than one of his five members of the Glenn.

STRUCTURAL PROOF OF GIRTY AND ROUNDY'S CONTENTION, THE OVERBROOK ANTICLINE

It can now be demonstrated by structural and stratigraphic means that Girty and Roundy were right. Goldston's error arose through oversight or misinterpretation of the Overbrook anticline, an overturned fold with a structural height of at least 10,000 feet, which can be traced continuously for 15 miles through the belt of Pennsylvanian rocks which lie between Ardmore and the Criner Hills. (See map and cross-sections, Plate XVII.) This anticline involves all of Goldston's members of the Glenn, exposing the true Springer along its axis and bringing his Deese and Hoxbar members down into the deep, narrow, faulted Pleasant Hill syncline, which lies between the Overbrook anticline and the Criner Hills, both northwest and southeast of the village of Overbrook. At least four fossiliferous limestone members of the group which Goldston had mapped as Springer on the other side of the Hills can be identified in this Pleasant Hill syncline, and in Goldston's Hoxbar member in its type locality between Ardmore and Hoxbar.

Goldston's oversight can be partially explained by the fact that the west flank of the Overbrook anticline, in the northern part of its course, is overturned as much as 30 degrees past the vertical, giving an appearance of continuous northeastward dips across the Pleasant Hill syncline and the Overbrook anticline in this vicinity. In the central and southern portion of the anticline it is not overturned, but the beds on the west flank close to the anticlinal axis are nearly vertical. Thrust faulting parallel to the axis extends along the west margin of the axial strip for the full length of the anticline, cutting out a varying portion of the Springer and Dornick Hills formations west of the axis.

This overthrusting has been accompanied by thinning out of the remaining shale members of the Pennsylvanian system on the steeper flank of the fold, so that a section involving 11,000 feet of strata on the northeast flank is concentrated into an apparent thick-

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[21] Op. cit., p. 340.

[22] Goldston, W. L. Jr., op. cit., p. 18, and Fig. 1, p. 22, (footnote 3).

ness of only 2,500 to 4,000 feet on the west flank; where the resistant sandstone and limestone members are crowded together with very little shale between them. A portion of this thinning may be due to overlapping against the Criner Hills massif of older rocks, which was progressively uplifted during Pennsylvanian times; but much of the thinning was certainly produced during the late Pennsylvanian folding of the Overbrook anticline, because the monoclinal section of beds dipping northeast from the Criner Hills into the Pleasant Hill syncline in T. 5 S., R. 1 E., is considerably thicker than the section occupied by the same formations on the overturned east flank of the same syncline.

PENNSYLVANIAN OR MISSISSIPPIAN ?

Girty and Roundy[23] assign definite early Pennsylvanian age to the Otterville limestone member of the Dornick Hills formation, a little above the Springer, and late Mississippian age to the lower part of the Caney shale. Only two of the fossil collections used by Girty in his study of the fauna of the Caney shale were obtained south of the Arbuckle Mountains, and these contained only two identifiable species[24]. Fairly typical and varied collections of Mississippian Caney fossils have been made, however, but not yet described, by Chas. E. Decker, from the basal 300 or 400 feet of the formation at exposures along Henryhouse Creek near the east line of the NE. ¼ sec. 31, T. 2 S., R. 1 E.

Girty and Roundy failed to find any specifically identifiable fossils in the true Springer formation[25], and Goldston's supposed Springer collections may all have come from the younger beds near the Criner Hills, which, as discussed above, he erroneously called Springer. He did not cite the localities from which his collections were derived. A single good fossil locality (see below, page 17) has since been found in one of the sandstone members near the middle of the Springer formation, and preliminary examination of the collections from that locality suggests very early Pennsylvanian (earliest Morrow) age.[26] At least 2,000 feet of strata from which no fossils have yet been described intervene between that horizon and the fossiliferous basal Caney.

Pending further paleontologic study, therefore, the Springer formation is probably to be regarded as of earliest Pennsylvanian age; although it would be preferable from a structural point of view to place the period division at the top of the Springer, when extensive diastrophism began in southern Oklahoma.

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[23] Girty, Geo. H., and Roundy, P. V., op. cit., p. 337.

[24] Girty, Geo. H., The fauna of the Caney shale of Oklahoma: U. S. Geol. Survey, Bull. 377, pp. 10 and 75, fossil lots 5143 and 5944, 1909. The species were *Lingula albapinensis* and *Eumorphoceras bisulcatum.*

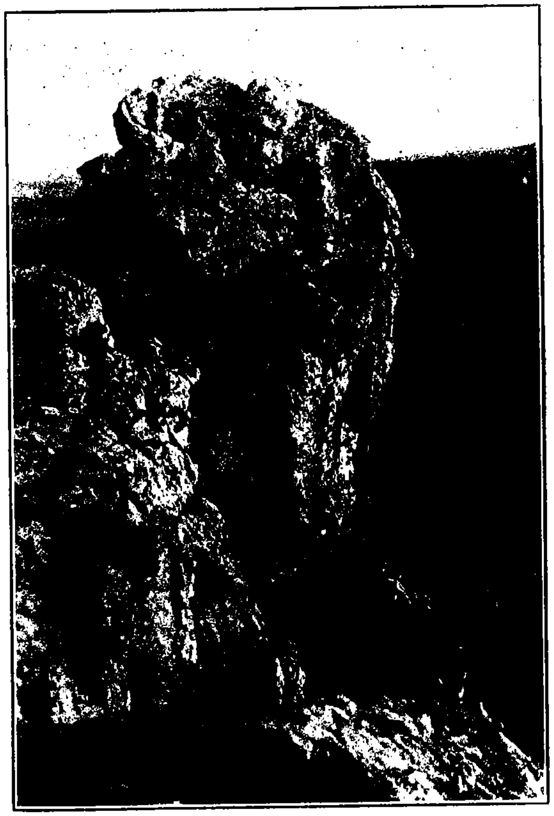
[25] Girty, Geo. H., and Roundy, P. V., op. cit., (footnote 4), p. 338. They speak of the "Springer member, which is paleontologically a blank."

[26] Decker, Charles E., and Moore, Raymond C., verbal communications.

ROD CLUB SANDY MEMBER

At the base of the Springer formation is the Rod Club member, so-called from its semicircular outcrops at the smaller Rod and Gun Club lake in the NW. ¼ sec. 7, T. 4 S., R. 2 E., on the southeastward-plunging nose of the Caddo anticline. It is recognized that the names here assigned to some of the individual resistant members of the Pennsylvanian formations in the Ardmore basin, are derived from geographic terms of less consequence than is most desirable for stratigraphic nomenclature. Unfortunately this is unavoidable, as the steep dips of this region have crowded more than 60 such members into an area covering only six or seven townships. There are not nearly enough distinctive names of towns or creeks

PLATE I



A PINNACLE OF ROD CLUB SANDSTONE

Basal part of Springer formation. Castle Rock, near cen. sec. 16, T. 3 S., R. 1 E., looking southeast along southwest side of axial strip of Caddo anticline. Dip approximately vertical.

to go around. Ultimately it may be possible to identify some of these units positively with some already named in northeastern Oklahoma or in north-central Texas; but until that time local names are much needed.

The Rod Club member is not a solid sandstone but a sandy zone from 250 to 400 feet thick, ordinarily containing four or more ledges, each from 2 to 25 feet thick, of rather hard greenish to buff, fine to medium-grained sandstone. This member forms the inner rim or topographic ridge encircling the Caddo anticline. It is not known to be exposed along the south front of the Arbuckle Mountains, where the Overbrook member appears to be the lowest sandstone in the Springer formation.

Some scattered sandstone outcrops near the axis of the Overbrook anticline in secs. 25 and 36, T. 5 S., R. 1 E., are probably assignable to the Rod Club member. This correlation is borne out not only by areal and structural relationships to higher members, but by heavy-mineral analyses and other tests made by Weidman.[27]

Sediments between the Sycamore and Wapanucka limestones are reported to have a maximum thickness of only 1,600 feet north and east of the Arbuckle Mountains,[28] where they are all assigned to the Caney shale; as compared with fully 5,000 feet in the Ardmore basin, where the corresponding strata include the Caney and Springer formations. This great increase in thickness calls to mind the even greater increase in thickness of supposed early Carboniferous formations eastward from the Atoka-Coalgate area, to the Stanley-Jackfork section in the Ouachita Mountains. The hard greenish sandstones of the Rod Club member resemble sandstones which occur in the Stanley shale along the state highway between Antlers and Finley, in Pushmataha County, Oklahoma. However, the fauna of the lower part of the Caney shale underlying the Rod Club member in the Ardmore basin is reputed to be the same as that of the Caney shale overlying the Jackfork sandstone (which is above the Stanley shale) in the Ouachita country; so the Rod Club member more probably represents merely a later western repetition of the Stanley-Jackfork type of sedimentation.

In that case, it should be noted that this Caney-Springer sequence affords an exception to the usual rule of northwestward thinning which holds good for the Pennsylvanian section generally throughout eastern Oklahoma and north-central Texas. The Sycamore-Wapanucka interval is three times as great at the type locality of the Springer formation, as it is 45 miles due east of that point.

A few plant impressions (*Calamites*) have been found at the top of the Rod Club member in the NE. ¼ sec. 12, T. 4 S., R. 1 E.

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[27] Weidman, Samuel, unpublished material.

[28] Taff, J. A., U. S. Geol. Survey, Geol. Atlas, Coalgate folio, (No. 74), 1901. U. S. Geol. Survey, Geol. Atlas, Atoka folio, (No. 79), 1902. Also Morgan, Geo. D., Geology of the Stonewall quadrangle, Oklahoma: Bureau of Geology, Norman, Oklahoma, Bull. No. 2, p. 53, 1924.

OVERBROOK SANDSTONE MEMBER

About 1,000 feet above the Rod Club is the Overbrook sandstone, so named from an excellent outcrop across the middle of the N. ½ sec. 6, T. 6 S., R. 2 E., one-fourth mile east of the village of Overbrook at the north edge of Love County, Oklahoma. This sandstone ranges from 45 to 100 feet in thickness. It is typically medium fine-grained, white and massive, varying to slabby but practically free from shale partings. Well developed ripple-marks locally appear on its bedding planes. It forms the second encircling ridge around the Caddo anticline, and gaps in this ridge afford the dam sites for the City Lake and Lake Ardmore. Its steep dip slope forms a celebrated hazard on the Dornick Hills golf course in sec. 7, T. 4 S., R. 2 E.

The Overbrook sandstone is thoroughly saturated with asphalt for at least 2½ miles along its outcrop, from the NW. ¼ sec. 12 to the NE. ¼ sec. 4, T. 3 S., R. 1 W., near Woodford. It is not known to be producing oil or gas as yet in the Ardmore district, though it is believed to underlie at great depth all the oil fields in northwestern Carter County, and most of the Overbrook anticline also.

Fucoids are common in the Overbrook member, and *Calamites* occur sparingly. Collections showing a varied fauna and containing plant impressions have been made by C. E. Decker and C. L. Cooper, of the Oklahoma Geological Survey, from a sandstone of the Springer formation, believed to be the Overbrook sandstone, in the SE. ¼ sec. 19, T. 2 S., R. 1 W., north of Milo; but these have not yet been described.

A fossiliferous sandstone not dissimilar to the Overbrook member, with which it may conceivably be correlated, occurs in the upper part of the Caney shale (as mapped) near the NW. cor. sec. 35, T. 1 S., R. 8 E., between Bromide and Clarita, in southwestern Coal County, Oklahoma. This is correlated by Fitts[29] of Ada with a sandstone in similar position in the Caney of the Lawrence uplift in Pontotoc County. The latter sandstone outcrops beside the road near the center of the south line of sec. 29, T. 3 N., R. 7 E. It is tentatively correlated by Fitts with the Cromwell oil sand.

LAKE ARDMORE SANDSTONE

Five hundred feet or less above the Overbrook sandstone occurs the Lake Ardmore member, a persistent sandstone of quite similar character, but only 15 to 20 feet thick. It derives its name from a sportsman's lake of that name in sec. 2, T. 4 S., R. 1 E., where this ledge forms narrow peninsulas and islets. It has not been certainly identified on the Overbrook anticline. A few casts of coiled cephalo-

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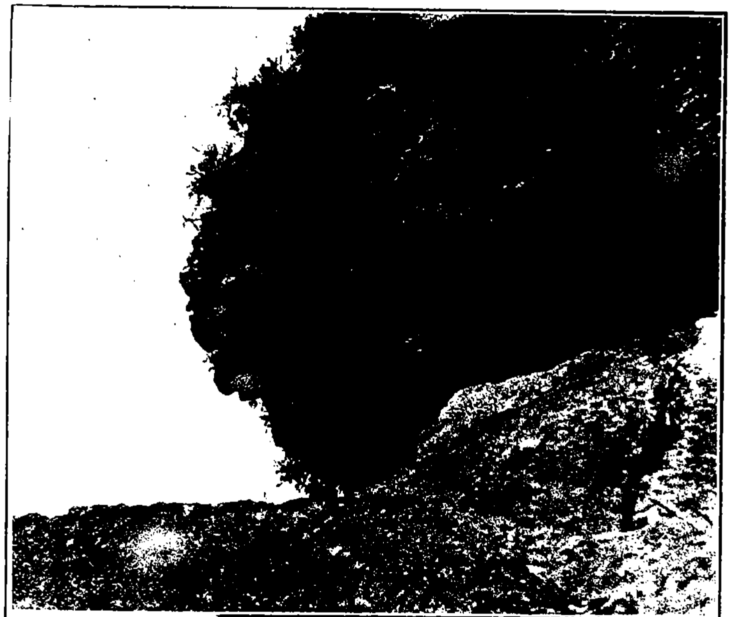
[29] Fitts, John, Personal communication.

PLATE II

DIP SLOPE OF OVERBROOK SANDSTONE

PLATE III



DIP SLOPE AND HIGH KNOB OF OVERBROOK SANDSTONE

Member of Springer formation, NE. ¼ sec. 21, T. 3 S., R. 1 E., on southwest flank of the Caddo anticline, looking southeast.

pods, not specifically identifiable, have been found in float on the outcrop of this sandstone near the SW. cor. sec. 6, T. 3 S., R. 2 E., just north of Springer. Similar specimens were collected by Goldston[30] and by Girty and Roundy[31] in a railroad cut north of Berwyn, either from this member or from the Primrose sandstone.

PRIMROSE MEMBER

From 250 to 500 feet higher in the section is a zone from 150 to 250 feet thick of very calcareous, hard semi-crystalline thin-bedded sandstone, interrupted by frequent shale partings. It is called the Primrose member from Primrose Ridge in sec. 7, T. 4 S., R. 2 E., on which stand the buildings of the Primrose dairy farm. The ridge is formed by this sandstone.

The Primrose member locally contains two or three feet of fairly pure bluish limestone. Because of its calcareous quality, the ridge formed by this member is almost everywhere bare and grassy, though the lower sandstones of the Springer support in most places a dense growth of small oaks. Open grasslands characteristically occupy the black-shale valleys between and above these sandstones, and also cover the underlying true Caney black shales. The Primrose is confidently identified in a few places on the Overbrook anticline (see map, Plate XVIII), and is traceable for many miles from its type locality on the nose of the Caddo anticline.

A peculiar feature of the Primrose member is the occurrence in its sandstone and limestone beds of numerous flattish pebbles or small lenticular streaks of hard slate-colored shale. They occur also in a 10-foot sandstone several hundred feet higher in the section (close to the top of the formation), which is known at two localities south and east of Springer. This feature is found also in sandy limestone of very similar character which constitutes the lower member of the Wapanucka limestone as mapped in sec. 34, T. 3 N., R. 7 E., southeast of Ada, Oklahoma, and in similar limestones in the same stratigraphic position below the main body of the Wapanucka at Limestone Gap in Atoka County, where that formation is more fully developed. A correlation of these members with the Primrose calcareous sandstone or the similar sandstone above it is entirely reasonable, as the second resistant member above the Primrose is the Otterville limestone, which is faunally correlated with the Wapanucka. The intervening shales are much thicker in the Ardmore district than in Atoka County or near Ada, but that is true of the entire Caney-Springer section.

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[30] Goldston, W. L. Jr., op. cit. (footnote 3), p. 7.

[31] Girty, Geo. H., and Roundy, P. V., op. cit. (footnote 4), p. 334.

EARLY PENNSYLVANIAN OROGENY

ORIGIN OF THE CRINER HILLS

The pebbles of the conglomerates in the Dornick Hills formation, described on following pages, consist chiefly of pre-Pennsylvanian limestones and chert such as now outcrop in the Criner Hills. The conglomerates are thickest and the pebbles are largest in the area immediately adjacent to the Hills, and the pebbles grow smaller and less numerous both to the southeast and northwest along the strike, as distance from the Criner Hills increases. North of Ardmore, these conglomerates play out entirely into sandstones and limestones. The evidence is conclusive that the pebbles were derived from a mountain mass in the vicinity of the present Criner Hills.

PLATE IV

BOSTWICK CONGLOMERATIC LIMESTONE
Anadarche Creek, SE. ¼ NW. ¼ SE. ¼ sec. 23, T. 6 S., R. 2 E.

These are believed to be the oldest conglomerates of any orogenic significance in southern Oklahoma west of the Ouachita Mountains, after the Cambrian. The earlier Paleozoic sediments contain no records of sharp angular unconformity or mountain folding from upper Cambrian time to the close of Springer time. A conglomerate one foot thick occurs at the base of the Simpson formation (Ordovician), and still thinner conglomerate beds are reported at two or three levels in the underlying Arbuckle limestone,[32]

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[32] Decker, Charles E., and Merritt, Clifford A., Physical characteristics of the Arbuckle limestone: Oklahoma Geol. Survey, Cir. 15, pp. 8, 10, 21-25, and Plate I-A, 1928.

but no evidence of angular unconformity at any of those horizons has been reported. The unconformity beneath the Chattanooga shale in Oklahoma implies widespread warping, but no true orogeny or steep folding.

It appears, therefore, that at or shortly before the beginning of Dornick Hills time a mountain uplift took place, raising the Criner Hills high enough to be a source of coarse clastic sediments for the first time. Uplift and erosion here were of such magnitude that members of this early Pennsylvanian conglomerate series overlap several underlying formations and appear in unconformable contact with the Viola limestone (Ordovician) and with the Simpson formation, in a sort of embayment in the Criner Hills near the center of sec. 35, T. 5 S., R. 1 E., and probably also at the east edge of the Hills in the SE. ¼ NE. ¼ sec. 22, T. 5 S., R. 1 E. Erosion during and after the uplift but prior to Bostwick time had here removed more than a mile of sediments, mostly soft shales.

No conglomerates have been noted in the upper part of the Dornick Hills formation, above the Bostwick member, nor does the overlying Deese formation, although 7,000 feet thick, contain any conglomerates for whose pebbles the Criner Hills seem a likely source. Yet around the north end of the Hills uppermost Deese or lower Hoxbar beds lie upon and unconformably truncate the pre-Pennsylvanian rocks clear down to the Arbuckle limestone (Cambro-Ordovician). In the Brock oil field also, west of the Criner Hills, well logs show peaks of Ordovician rock rising up into the base of the Hoxbar formation.[33]

It is evident, therefore, that the Criner Hills persisted as an island or submerged range, rising above the general level of sedimentation around it, from the close of Springer time until the end of Deese time at least. The subsurface structure of the Brock field shows that the projecting mass was larger in area than the present outcrops of pre-Pennsylvanian rocks here. The absence of conglomerates derived from this range during the long interval from the close of Bostwick time until the probable complete burial of the range in Hoxbar time, may be explained by the supposition that their summits were submerged, so that erosion was negligible or nil.

OTHER RANGES OF THE WICHITA (?) MOUNTAIN SYSTEM;

A sub-Pennsylvanian angular unconformity similar to that in the Brock field and the Criner Hills occurs also in the Hewitt[34] and Healdton[35] oil fields to the northwest, in the Empire and Duncan

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[33] See discussion of Crinerville limestone member, page 42.

[34] Burton, George E., The Hewitt oil field: Oklahoma Geol. Survey, Bull. 40-Z, Figs. 7-9 and p. 46, 1928.

[35] Powers, Sidney, The Healdton oil field, Oklahoma: Econ. Geol. vol. 12, pp. 594-606, 1917. Also Powers, Sidney, Age of the oil in southern Oklahoma fields: Trans. Am. Inst. Min. Eng. vol. 59 pp. 564-575, 1918. Also Bartram, John G., and Roark, Louis, The Healdton field, Oklahoma: Bull. Am. Assoc. Pet. Geol. vol. 5, pp. 470-472, 1921.

pools of Stephens County, Oklahoma,[36] and in the Nocona, Bulcher, and Muenster oil fields of Montague and Cook counties, Texas. Evidence so far accumulated indicates that only the later Pennsylvanian beds overlapped the buried mountain ranges of older rocks in any of these localities. There were, therefore, at least two roughly parallel lines of *en echelon* mountain ranges formed in early Pennsylvanian time in the Red River region.

Certain wells[37] in the vicinity of the Oscar and Nocona oil pools in Jefferson County, Oklahoma, and Montague County, Texas, have reported granite at depths less than 2,000 feet. The fact that no pre-Cambrian rock has yet been encountered in the Carter County (Oklahoma) group of buried hills at Brock, Hewitt, and Healdton suggests that the Nocona range was elevated to greater height and eroded more deeply than these in early Pennsylvanian time; although there was probably a somewhat thinner cover of sediments over the Nocona area prior to the mountain-building, so that less erosion was required to expose the granite there.

In spite of this evidence that granite summits were exposed in the southern group of this early Pennsylvanian system of mountain ranges, and the possibility that even higher granite peaks existed at the same time in the area of the modern Wichita Mountains farther west, absolutely no arkose has been found in the Pennsylvanian sediments of the Ardmore basin, below the Pontotoc series. (See following discussions of upper Deese, upper Hoxbar, and Pontotoc strata.) So far as published descriptions indicate, the same is true of the Pennsylvanian of north-central Texas below the Cisco group. It is probable, therefore, that these granite summits possessed in early and middle Pennsylvanian time such a moist climate, or such low relief, or both, as to prevent the formation of arkosic sediments. It is also possible that these ranges were completely submerged shortly after the granite was exposed, thus putting a stop to erosion.

Gouin[36] states that "Wichita Mountain Uplift * * * must have taken place not later than early Mississippian time", but late Mississippian or early Pennsylvanian time is equally possible as a date for this uplift: for the evidence he cites consists of "early Glenn rocks" lying unconformably above Ordovician formations in and near the Empire and Duncan oil fields, southeast of the Wichitas. It is entirely possible that the first major uplift of the Wichita Mountains took place at the same time as that of the Criner Hills, where the orogenic date can be more precisely fixed. Powers'[38] conception that the Criner Hills uplift "is a part of the ancestral

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[36] Gouin, Frank, The geology of the oil and gas fields of Stephens County, Oklahoma: Oklahoma Geol. Survey, Bull. 40-E, p. 17, 1926.

[37] E. g., Humble Oil & Refining Co's. well, No. 1 Alexander, NW. ¼ NE. ¼ NE. ¼, sec. 19, T. 7 S., 5 5 W., which logged pink granite from 1924 feet to total depth of 1,980 feet.

[38] Powers, Sidney, Crinerville oil field, Carter County, Oklahoma: Bull. Am. Assoc. Pet. Geol., vol. 11, p. 1072, 1927.

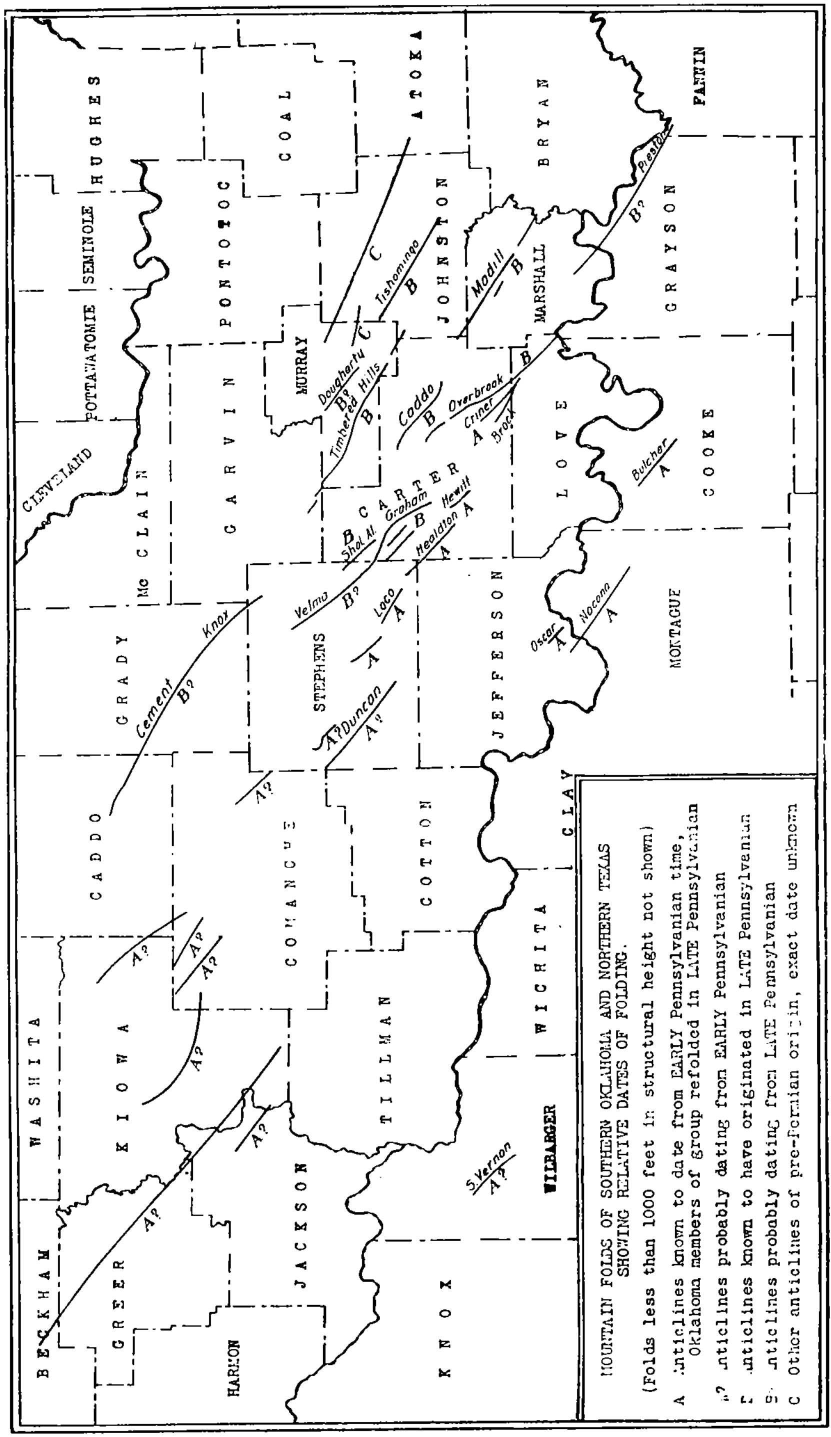

Figure 2.

Wichita Mountains, and that these mountains were once continuous as far southeast as Gainesville, Texas,'' is entirely reasonable.

THE NORTHERN ARBUCKLE MOUNTAINS

No conglomerates have been noted along the south front of the Arbuckle Mountains in the Dornick Hills formation, nor in the overlying Deese formation except in its uppermost members, described in more detail below. Near the town of Mill Creek in the Mill Creek syncline, however, north of the main Tishomingo range of the Arbuckles, there is some conglomerate which may belong to the Dornick Hills formation. It consists chiefly of limestone pebbles in a limestone matrix, and lies a short distance above a fossiliferous, partly oolitic limestone which is tentatively correlated with the Otterville and Wapanucka limestones. The conglomerate therefore occupies the relative position of the very member of the Ardmore basin Pennsylvanian which it most closely resembles—the Bostwick member of the Dornick Hills formation, which carries coarse limestone conglomerates near the Criner Hills. It is quite different from the still coarser Pontotoc conglomerates near Sulphur, which were also mapped by Taff[39] as Franks conglomerate.

Morgan[40] reports an abundance of *Campophyllum torquium* in a fossiliferous horizon at the top of this Pennsylvanian section in the Mill Creek syncline, presumably not far above the conglomerates. While this alone is not adequate for precise correlation, it fits very nicely into the picture to suggest that this horizon may represent the Pumpkin Creek member of the Dornick Hills formation (see below, page 33).

Although the value of this orogenic evidence at Mill Creek must be discounted somewhat for possible confusion due to faulting, and for uncertainty of correlation until more thorough paleontologic studies are published, it at least suggests an early Pennsylvanian uplift in that vicinity, originating at the same time as the Criner Hills. As similar evidence is wholly lacking 10 or 12 miles to the south, along the south front of the Arbuckles, and contrary evidence exists there[41], it is safer to place this uplift north of Mill Creek. This is supported by the testimony of Morgan[42] and others, and of the areal relations of Pennsylvanian formations north of the Arbuckle Mountains, to progressive orogeny in the northern part of the Arbuckles during the Pennsylvanian period.

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[39] Taff, J. A., op. cit., Tishomingo folio.

[40] Morgan, Geo. D., Stratigraphic position of the Franks and Seminole formations of Oklahoma: Oklahoma Geol. Survey, Cir. 12, p. 16, 1923.

[41] Cf. discussion of late Pennsylvanian orogeny, pages 47-51.

[42] Morgan, Geo. D., Geology of the Stonewall quadrangle, Oklahoma: Bureau of Geology, Norman, Oklahoma, Bull. 2, especially pp. 18-19, 1924. Morgan, Geo. D., Boggy unconformity and overlap in southern Oklahoma: Bureau of Geology, Norman, Oklahoma, Cir. 2, 1924.

Morgan[43] states that ''Conglomerates bearing easily identifiable fragments of Hunton and Viola limestones have been found (north of the Arbuckle Mountains) in abundance in the Wewoka formation, the Thurman sandstone, the Boggy formation, the Savanna and the McAlester; consequently, the idea that the Arbuckle Mountains were not uplifted during the Pennsylvanian until Seminole time may be abandoned.'' This statement may be allowed to stand for the northern part of the Arbuckle region, near Ada and Franks, but can not, as shown below in the discussion of later Pennsylvanian orogeny, be sustained for the southern and western portions. It should also be noted that far less uplift and erosion would have been required to expose the Viola limestone (Ordovician) in the northern Arbuckles in early Dornick Hills time than actually took place then in the Criner Hills; for in the latter area strata at least 3,000 feet below the Viola were exposed by this process, and the cover which had to be removed from above the Viola appears to have been fully 3,000 feet thicker than in the northern district. Morgan estimates the average thickness of the Caney shale in the Stonewall quadrangle at only 800 feet,[44] which corresponds to 5,000 feet or more of the Caney and Springer formations in the Ardmore basin.

OROGENIC SIGNIFICANCE OF BOULDERS IN THE CANEY SHALE

Ulrich[45] suggests that the erratic boulders of various earlier Paleozoic formations which occur at one or more horizons in the Caney shale at many localities in the Ouachita Mountain region, may have been derived from the Arbuckle Mountains. Because some of these boulders contain Ordovician, and others Silurian, faunas which are found in the Arbuckle region but nowhere in the United States to the east of that area, he concludes that: ''Obviously, then, the pre-Devonian boulders in the Ouachita Caney could have been floated there only from the west and evidently mainly from weathered exposures of the concerned formation on the northeast side of the Arbuckle uplift.''[45]

Ulrich contends that these boulder-bearing shales are of Pennsylvanian age. Insofar as this is true, the early Pennsylvanian uplift in the northern Arbuckles could be regarded as a possible source for the boulders. In the type section of the Caney shale in Johns Valley (in the Ouachita Mountains), as described by Miser,[46] however, these erratic boulders occur only in the lower 50 to 100 feet of the shale, underlying a greater thickness (''perhaps several hundred feet'') of black platy shale which carries a fairly abundant indigenous Mississippian Caney fauna. Miser's description is convincing as to the indigenous nature of this fauna,

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[43] Morgan, Geo. D., op. cit., Franks and Seminole formations, p. 7.

[44] Morgan, Geo. D., op. cit., Stonewall quadrangle, p. 53.

[45] Ulrich, E. O., op. cit., (footnote 12), p 10.

[46] Miser, H. D., Age relations of the Carboniferous rocks of the Ouachita Mountains of Oklahoma and Arkansas: Oklahoma Geol. Survey, Bull. 44, footnote 17-a, pp. 22-23, 1927.

although Ulrich[47] is still skeptical of it and even suggests that Miser's Johns Valley section may be upside down. That seems highly improbable, in view of its location in the center of a broad and open synclinal basin.

Ulrich, in replying to Miser after verbal discussion of this subject with him, states Miser's conclusions more fully than Miser has yet stated them in print himself. He says that "Mr. Miser recognizes two main boulder beds in the Ouachita Caney shale—one in the lowermost 50 to 100 feet of the shale and the other in the topmost 100 feet of the formation. The lower bed he regards as underlying the shale containing the Mississippian Caney fauna and the upper as overlying a bed of limestone that is lithologically and faunally similar to the Wapanucka (Pennsylvanian) limestone."[48]

The boulders of this upper bed at least could conceivably have been derived from the northern Arbuckle region as suggested by Ulrich. But if Miser's views as to the age of the lower bed are correct, as the weight of evidence indicates, the boulders in the lower bed must have been derived from some area where most if not all of the earlier Paleozoic formations now outcropping in the Arbuckle Mountains were exposed to erosion in Mississippian time. Unfortunately for the idea that this source could have lain within the limits of the modern Arbuckle Mountains, no evidence has been reported within or bordering those mountains of any adequate uplift between the Cambrian and Pennsylvanian periods. There is good reason to believe that the Caney shale, the underlying Sycamore limestone and most if not all of the older Paleozoic formations now known in the Arbuckle Mountain region extended continuously across all of that region in Mississippian-Caney time, and that no formation older than the Caney was then exposed there.

Ulrich and Miser agree in ascribing the transportation of these boulders to floating ice, which seems the only agency capable of carrying such large masses intact and distributing them as they are now found, isolated from each other and scattered erratically through the shale matrix. Ice-floes can pick up boulders from the beach and shallow water even on a low shore, and the undermining of a sea-cliff by the waves could supply loose material of great size as well as smaller boulders. The case does not necessarily demand high relief in the source area, nor glaciation on land, but it does call for uplift and erosion sufficient to cut through several thousand feet of sediments. This is not believed to have taken place anywhere in the modern Arbuckle region as early as Mississippian Caney time. (Disregarding Cambrian and pre-Cambrian possibilities, which are irrelevant to the case in point.)

Furthermore, as Ulrich himself notes,[49] no erratic boulders have been described as occurring in the Caney shale anywhere in or on the borders of the present Arbuckle Mountains. It is inconceivable that ice could have transported hundreds of thousands of boulders from a shore in the Arbuckle district out to sea in the Ouachita region, without dropping a few in the intermediate areas now occupied by boulderless Caney shale. The ice could not have moved so far without some melting or attrition, though the melting process and the resultant dropping of sediment may have been concentrated to a considerable extent near the end of the journey, especially if that lay in a great eddy or semi-stagnant area.

In the light of present evidence, therefore, it seems that the source of the erratic boulders in the lower part of the Caney shale must be sought in some area east or southeast of the present Arbuckle Mountains, if the Ozarks be ruled out on paleontologic grounds. Such an area of pronounced Mississippian or pre-Mississippian uplift may exist as suggested by Sidney Powers[50] in the hidden east end of the Arbuckle Mountain system or an adjacent buried range, beneath the Gulf Coastal Plain or under some of the overthrust fault-sheets in the Ouachita region. The boulders in the upper part of the Ouachita Caney may reasonably be ascribed to the same source. The upper boulder bed probably is represented by boulderless strata of the same age in or adjacent to the Wapanucka limestone in the area between the Ouachita and Arbuckle Mountains, rendering the latter improbable as a source of the upper boulders also.

Black shales seem to be more characteristic of cool or cold waters than of tropical seas. Although other factors may be more important than temperature in producing their color and lack of oxidation, and the bituminous content and barren nature of much of the Caney shale, the color is at least not out of harmony with the hypothesis of floating sea-ice in Caney waters. Ulrich[51] calls attention to a similar occurrence of ice-borne boulders in the Levis (Ordovician) black shale of Quebec. The semi-stagnant conditions above suggested as favorable to concentration of ice-floe melting have also been emphasized by several writers[52] as conducive to the formation of black shales.

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[47] Ulrich, E. O., op. cit., pp. 36-40.

[48] Ulrich, E. O., op. cit., p. 36.

[49] Op. cit., p. 42.

[50] Personal Communication. Cf. Dake, C. L., The problem of the St. Peter Sandstone: Missouri Univ. School of Mines and Metal., Bull. Tech. ser. vol. 6, no. 1, pp. 54-55, 1921. Also Van der Gracht, W. A. J. M. van W., letter to Dr. Chas. N. Gould, July 7, 1926, mimeographed by the Oklahoma Geological Survey.

[51] Ulrich E. O., op. cit., pp. 5-6.

[52] Cf. summary by Twenhofel, Wm. H., Treatise on sedimentation: The Williams and Wilkins Co., Baltimore, p. 295, 1926.

DORNICK HILLS FORMATION

GENERAL DESCRIPTION

The Dornick Hills formation includes Goldston's Otterville and Cup Coral members of the Glenn, and a little more. It comprises a series of bluish, tan, and rarer reddish and brown shales, with limestones, limestone conglomerates and sandstones.

This formation shows a greater change in thickness within the Ardmore basin, than any other part of the Pennsylvanian system. In the north edge of Love County, where the conglomerates are best developed, the formation has its maximum observed thickness, about 4,000 feet. This decreases northward to about 2,500 feet near Ardmore, and probably to less than 1,500 feet near Glenn village, where conglomerates are wholly lacking. A large part of the decrease in thickness takes place in the shale members between the limestones.

Although a considerable part of this variation in thickness may be attributed to local accumulation of sediments derived from the Criner Hills area, it is noteworthy that the direction of thinning corresponds to that of the Pennsylvanian system as a whole throughout eastern Oklahoma and north-central Texas.[53] After all local sources are allowed for, it is still probable that the chief source of Dornick Hills sediments lay to the southeast in Llanoria.

Corroborative data as to northwestward thinning exist in well logs of the Graham and Sholom Alechem fields in northwestern Carter County, Oklahoma, beneath a cover of red beds unconformably overlying the marine Pennsylvanian section. The Graham field stretches some 8 miles from southeast to northwest. In that distance, the shale members within the series of productive oil and gas sands, which is believed to belong at least in part to the Dornick Hills formation,[54] diminish in thickness about 25 per cent.

Beginning near the northwest end of the Graham field, the Sholom Alechem field continues the story another 8 miles to the northwest. The most noteworthy change there is a northwestwardly increasing quantity of limestone in a 600-foot series of beds above the productive series, which is possibly the same as at Graham. As stated by Plummer and Moore[55] such a change "indicates a farther off-shore phase."

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[53] Levorsen, A. I., Convergence studies in the mid-continent region: Bull. Am. Assoc. Pet. Geol. vol. 11, pp. 657-682, 1927; also Plummer, Frederick B. and Moore, Raymond C., Stratigraphy of the Pennsylvanian formations of north-central Texas: Univ. Texas Bull. No. 2132, p. 63, 1921.

[54] Cf. Tomlinson C. W., Geologic relations of the Graham-Fox area: contribution to bulletin of George, H. C. and Bunn, John R., Petroleum engineering in the Fox and Graham oil and gas fields, Carter County, Oklahoma: U. S. Bureau of Mines, et al (mimeographed), pp. 4-7, 1924.

[55] Plummer, Frederick B., and Moore, Raymond C., op. cit., Pennsylvanian north-central Texas: p. 63.

JOLLIFF MEMBER

The lowest Pennsylvanian conglomerate occurs south of Ardmore as a minor local phase in association with a thin ledge of tan fossiliferous limestone, called the Jolliff member from excellent outcrops in Jolliff Prairie, on the allotment of Norman Criner Jolliff, in sec. 24, T. 5 S., R. 1 E., a trifle east of the axis of the Overbrook anticline. This limestone is only about 4 feet thick in the type locality, but the member tentatively correlated with it north of Ardmore attains a thickness of 10 to 15 feet. Aside from the calcareous Primrose sand, and ferruginous concretionary carbonate layers in the black shales of the Caney and Springer formations, this is the first limestone above the Sycamore (Mississippian) in the Ardmore district. It is here regarded as the basal member of the Dornick Hills formation.

OTTERVILLE MEMBER

The Jolliff member was mapped by Goldston[56] south of Ardmore, and also in sec. 15, T. 3 S., R. 1 E., as the Otterville limestone. In northern Love County, however, the Jolliff member lies about 1,000 feet stratigraphically below the limestone[57] which Girty and Roundy assumed to be Goldston's Otterville near the northeast corner of sec. 6, T. 6 S., R. 2 E.,[58] and in which they found the same distinctive fauna as in the limestone mapped by Goldston as Otterville in sec. 2, T. 3 S., R. 2 E., north of Ardmore.

In secs. 12 and 13, T. 4 S., R. 1 E., three miles northwest of Ardmore, Goldston seems to have traced his Otterville limestone across a fault into a bed (the Lester limestone described below) near the top of his Cup Coral member, 1,400 feet higher in the section. His name "Otterville" was therefore applied by him to different limestone ledges as much as 2,400 feet apart stratigraphically, though he described it as a single limestone only 70 feet thick.[59] It is desirable to confine the term to the limestone from which Girty and Roundy made their "Otterville" collections. This is probably, though not quite certainly, identical with the Otterville of Goldston's type locality in sec. 3, T. 3 S., R. 1 W., near the site of the abandoned hamlet of Otterville. It attains an observed thickness of 25 feet, and may locally, including shaly layers, reach Goldston's figure of 70 feet.

Due to northward thinning of the intervening shale, the true Otterville lies only about 300 feet above the Jolliff limestone on the north line of sec. 15, T. 3 S., R. 1 E., near the village of Glenn. Like the Jolliff member, the Otterville locally carries limestone

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[56] Goldston, W. L. Jr., op. cit., (footnote 3), Glenn formation, Pl. 1.

[57] Pointed out to the writer by P. V. Roundy in the fields in September, 1925.

[58] Girty, Geo. H., and Roundy, P. V., op. cit., p. 343; their station 4062. For their lists of fossils, see appendix to this bulletin.

[59] Goldston, W. L. Jr., op. cit., p. 8.

conglomerate in Love County. Oolite is common in the Otterville, but the most characteristic facies of this member is a slightly ferruginous, platy, granular limestone composed chiefly of tiny shell fragments.

The Otterville is faunally correlated with the lower part of the Wapanucka limestone,[60] with part of the Morrow group[61] of northeastern Oklahoma and Arkansas, and with part of the Marble Falls limestone of central Texas.[62] In lithologic character the Otterville precisely duplicates the upper member of the Wapanucka limestone as that formation is mapped in sec. 34, T. 3 N., R. 7 E., in the Lawrence Uplift in Pontotoc County, where the lower member of the Wapanucka closely resembles the most calcareous phase of the Primrose sandstone member of the Springer formation.[63] Three successive resistant members—the Overbrook, Primrose, and Otterville—participate in the correlations here suggested between the Ardmore basin and the Lawrence Uplift.

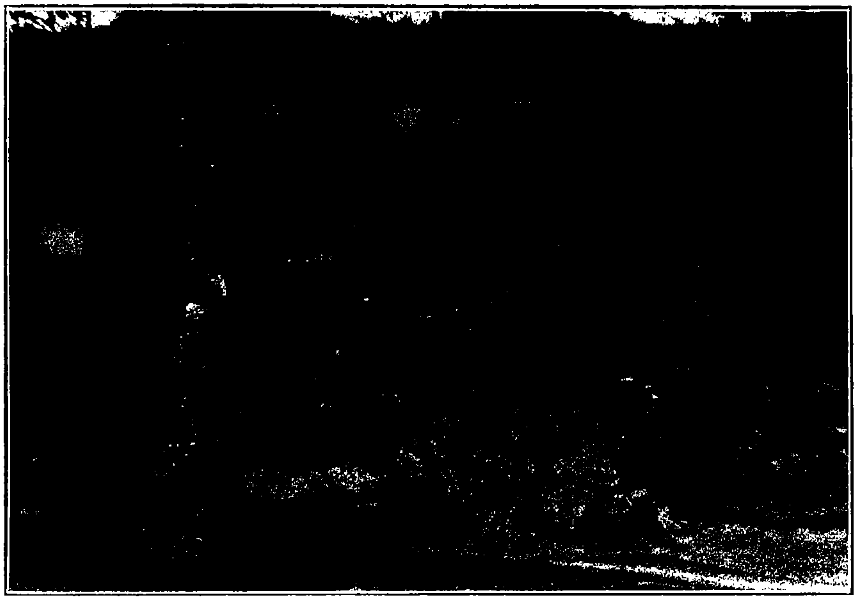
BOSTWICK MEMBER

The most resistant portion of the Dornick Hills formation is the Bostwick member, occurring at a uniform interval of about 750 feet above the Otterville limestone, and averaging 1,200 to 1,500 feet above the base of the Dornick Hills. This member includes the most distinctive feature of the formation south of Ardmore, the massive limestone conglomerates which were mentioned in the foregoing discussion of early Pennsylvanian orogeny as having had their source in the Criner Hills. The Bostwick member, with a maximum thickness of about 300 feet, includes all of those conglomerates except small amounts locally appearing in the Jolliff and Otterville members, in the lower part of the same formation.

With associated sandstones and limestones, these conglomerates form Bostwick Ridge, the conspicuous topographic ridge which Goldston mapped south of Ardmore as the base of his Deese member of the Glenn. The type locality of the Bostwick member is on the dairy farm of the same name in the W. ½ NE. ¼ sec. 11, T. 5 S., R. 1 E., whose buildings stand upon this ridge.

The conglomerates are thickest and coarsest near the line Criner Hills, where pebbles over 6 inches in diameter occur, and between Carter and Love counties, in the outcrops nearest to the those over 2 inches are abundant. Although the member as a whole suffers little or no diminution in thickness from that vicinity southeastward toward its point of disappearance under the Trinity sand, the pebbles decrease to some extent in number and size in that direction, and ordinary gray and white limestones, not conglomeratic, form an increasingly important constituent of the member. Northward into Carter County the pebbles dwindle even more rapidly until the conglomerates disappear entirely, or play out into sandstone carrying chert grains, north of Ardmore. Due west of Ardmore the pebbles are of pea to nut size, and the weathered conglomerate has been used as road material.

PLATE V



BOSTWICK LIMESTONE AND LIMESTONE CONGLOMERATE
Anadarche Creek, SE. ¼ NW. ¼ SE. ¼ sec. 23, T. 6 S., R. 2 E.

The most persistent limestone stratum in the Bostwick member is a bluish-white, fine-grained type. The sandstones, which are more conspicuous in the northern outcrops of the member, are commonly dark brown and more or less iron-stained.

Bostwick Ridge extends continuously for 15 miles along the northeast flank of the Overbrook anticline as a string of bare hills from 50 to 100 feet in height, and is traceable for two additional miles to the southeast by interrupted outcrops in valleys which have cut through the unconformably overlying Trinity sand. The ridge appears to have had a similar relief in early Trinity time. It is broken here and there by small cross-faults, but their stratigraphic displacement is less than the thickness of the Bostwick

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[60] Girty and Roundy, op. cit., pp. 335-337. See foregoing discussion of conflicting definitions of Glenn and Caney, page 8.

[61] Mather, Kirtley F., Pottsville formations and faunas of Arkansas and Oklahoma: Am. Jour. Sci., vol. 43, pp. 133-139, 1917.

[62] Plummer, F. B., and Moore, R. C., op. cit., (footnote 53), p. 54.

[63] See foregoing discussions of the Primrose member and the Overbrook sandstone, pages 17, 19.

member. The ridge is duplicated at intervals along the west side of the Overbrook anticline, though it is here broken by large cross-faults, is more obscured by the Trinity in Love County, and is cut out by the Overbrook thrust fault along much of the northern portion of the anticline. The longest nearly continuous outcrop in this western row extends about two miles north and south near the west side of secs. 24, 25 and 36, T. 5 S., R. 1 E., ending at the south in a horseshoe bend involving several beds of coarse limestone conglomerate in the axis of the Pleasant Hill syncline, which here plunges northward. A corresponding horseshoe bend, plunging in the opposite direction, marks the reappearance of this fold in the same Bostwick conglomerates south of the widest part of the Overbrook anticline, near the center of the S. ½ sec. 6, T. 6 S., R. 2 E. In secs. 16 and 22 and in the SW. cor. sec. 15, T. 6 S., R. 2 E., the Bostwick member is involved in a complex series of small folds in the axial area of the Overbrook anticline.

The Bostwick member is unquestionably to be correlated with the sandstones and limestone forming the ridge on which the clubhouse of the Dornick Hills Country Club stands, on the south line of the SW. ¼ sec. 7, T. 4 S., R. 2 E., north of Ardmore; although Goldston's map showed this ridge as part of his Springer member. Eight successive ledges take part in this revised correlation between the type locality of the Dornick Hills formation and the north end of Bostwick Ridge, just 4 miles away, in the south half of sec. 21, T. 4 S., R. 1 E.: they include, in order from the lowest upward, three parts of the Bostwick member, a lower sandstone, the bluish-white limestone, and an upper sandstone; the Lester limestone, which is unmistakable both lithologically and in its abundant fauna; two unnamed sandstone ledges: and two separate ledges of gray limestone in the Pumpkin Creek member. In addition, the Otterville limestone occurs in the same relation to Bostwick Ridge farther south as to the corresponding ridge at Dornick Hills.

The Bostwick member disappears within a mile along the strike in each direction from the Country Club, due either to strike faulting or to unconformity within the Dornick Hills formation, or to a combination of these two factors. It has not yet been certainly identified anywhere north of that locality.

As noted above in the discussion of early Pennsylvanian orogeny, the Bostwick member is possibly to be correlated with a limestone conglomerate in the Mill Creek syncline, heretofore mapped as Franks conglomerate.

LESTER LIMESTONE MEMBER

Above the Bostwick member occur five or six richly fossiliferous limestones, which were included by Goldston in his Cup Coral member north of Ardmore, but in his Deese member south of Ardmore.

The lowest of these which is substantial enough to be mappable for considerable distances, is called the Lester limestone member from a good exposure on the D. B. Lester farm beside the paved highway, about 800 feet south of the NE. cor. sec. 13, T. 4 S., R. 1 E. It is white and rather coarsely crystalline, and carries considerable oolite at the type locality, but much less elsewhere. Its maximum thickness is about 20 feet. Bryozoans of the *Fenestella* type are especially conspicuous in its abundant fauna. The Lester limestone at the type locality was mapped by Goldston as Otterville, although the bed most commonly mapped by him as Otterville and so designated in this bulletin, is well exposed some 1,700 feet farther north on both sides of the road, a few rods from it. This confusion probably was due to the presence of oolite in both members, and to displacement along a cross-fault, overlooked by Goldston, in the SW. ¼ SE. ¼ sec. 12, T. 4 S., R. 1 E.

The interval between the Bostwick and Lester members north of Ardmore is 400 to 500 feet, but it increases southward to twice this figure. Included in this interval are two or three other highly fossiliferous limestones from a few inches to two feet thick.

PUMPKIN CREEK MEMBER

The uppermost member of the Dornick Hills formation is designated the Pumpkin Creek limestone, from excellent outcrops on Pumpkin Creek in the SE. ¼ sec. 19, T. 6 S., R. 3 E. The upper limestones of the Dornick Hills formation are also well exposed in secs. 10 and 15, T. 6 S., R. 2 E., where the main part of the Pumpkin Creek member forms a strong topographic ridge and reaches a thickness of 70 feet, including 20 feet of shaly beds. Its limestone strata here vary from medium to coarse-grained, pure to sandy, nearly barren to quite fossiliferous. The most distinctive type, which is found also on the other side of the Overbrook anticline in the north half of sec. 7, T. 6 S., R. 2 E., and in nearly all outcrops of this member between there and Dornick Hills (north of Ardmore), is a very coarsely granular, cross-bedded, rather sandy gray limestone which weathers to a sort of coarse gray calcitic sand.

About 150 feet below the main Pumpkin Creek limestone on the south line of sec. 10, T. 6 S., R. 2 E., occurs another bed of fossiliferous limestone only 2 feet thick. Between the two are some very fossiliferous shales in which the cavities in some of the shells, especially crinoid stems and high-turreted gastropods, are filled with bluish chert. Disc-shaped masses of siliceous (sponge?) spicules, the discs up to 2½ inches in diameter, constitute a unique element in this fauna.

Four or five hundred feet lower in the section, at the same locality, occurs a 15-foot stratum of lumpy, chalky limestone closely interbedded with chalky shales, all highly fossiliferous. This type of rock occurs in much closer association with the main Pumpkin Creek ledge north of Ardmore, where it has been mapped as part of that member, and is probably the bed mentioned by Goldston[64] as carrying *Campophyllum torquium*, near the top of his Cup Coral member. It weathers in many places to a white chalky soil, full of a great abundance and variety of easily-collected fossils, including large cup corals.

On the south line of sec. 10, T. 6 S., R. 2 E., the main ledge of the Pumpkin Creek member occurs about 2,000 feet above the top of the Bostwick member. This interval diminishes rapidly northwestward, with especially pronounced convergence in secs. 4 and 5, T. 6 S., R. 2 E. North and west of Ardmore, it is only 900 to 1,000 feet.

The Pumpkin Creek limestone has been identified east of the area covered by the detailed maps accompanying this bulletin, on the northwest-plunging nose of the Mannsville anticline on the south line of the SW. ¼ sec. 18, T. 4 S., R. 4 E., in Johnston County, Oklahoma.

Goldston's term "Cup Coral member" is discarded as confusing and inappropriate. As mapped by him, its stratigraphic limits were rather variable, and the name gives no clue to a type locality which might define it. Furthermore, cup corals are common at certain horizons in the overlying Deese formation[65] and occur also in the Jolliff,[66] Otterville,[67] and other limestone members[68] of the Dornick Hills formation, and at one locality in the Hoxbar.[69]

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[64] Goldston, W. L. Jr., op. cit., (footnote 3), p. 8.

[65] E. g., (1) in the lower part of the Deese about 900 feet east and 100 feet north of the center of sec. 26, T. 5 S., R. 1 E.; (2) in the limestone and calcareous shale near the middle of the Devil's Kitchen member, 500 feet south and 80 feet east of the NW cor. sec. 4, T. 6 S., R. 2 E.; (3) in a higher member of the formation 200 feet SW. cen. E. ½ NW.¼ sec. 14, T. 5 S., R. 1 E.; and in the highest limestone in the type Deese section, at the cen. W. line NW.¼ sec. 33, T. 3 S., R. 1. E.

[66] In the type locality near the center of the SW. ¼ NE. ¼ NW. ¼ sec. 24, T. 5 S., R. 1 E.; and in the ditch at the east side of the Santa Fe R. R., 1,100 feet north of the south line of the SW. ¼ sec. 30, T. 5 S., R. 1 E.

[67] Girty, Geo. H. and Roundy, P. V., op. cit., p. 342, their station 4056. *Lophophyllum* occurs in the fossil list of Girty and Roundy from the Otterville limestone near the cen. S. line sec. 2, T. 3 S., R. 2 E.

[68] In a thin limestone 150 feet below the Lester member, 500 feet south and 275 feet west of the NE. cor sec. 13, T. 4 S., R. 1 E. Also in what is probably the Lester limestone, 99 feet west of the SE. cor. sec. 13, T. 5 S., R. 1 E. (in ditch beside road), and at the old asphalt quarry 100 yards east of the NW. cor. SW. ¼ SW. ¼ sec. 24. T. 5 S., R. 1 E.

[69] Abundant cup corals occur on the gentle dip slope of a limestone doubtfully correlated with the Westheimer member of the Hoxbar formation, in the bed of a ravine near the center of the SE. ¼ SW. ¼ sec. 7, T. 6 S., R. 2 E.

DEESE FORMATION

DEFINITION

The Deese formation as here defined coincides very nearly with Goldston's Deese member of the Glenn, as mapped by him in the type locality in sec. 33, T. 3 S., R. 1 E., adjoining the village of Deese. The village itself lies on the thin edge of the red beds overlying the Hoxbar formation. The Deese formation is limited below by the top of the Pumpkin Creek limestone member of the Dornick Hills formation, and above by the base of the Confederate limestone member of the Hoxbar. The Deese is about 7,000 feet thick in Love County, diminishing to about 6,000 feet northwest of Ardmore. It is characterized by a succession of sandstone beds and chert conglomerates separated by bluish, tan and red shales, with minor and relatively inconspicuous limestone members.

The best exposure of the red shale facies is a patch of badlands in the east bluff of the Washita River Valley in sec. 36, T. 3 S., R. 3 E. and sec. 1, T. 4 S., R. 3 E., southeast of Berwyn, Oklahoma. Here is exposed fully 50 feet of dark red barren shales and white sandy shales overlying massive cross-bedded sandstones, with a single layer of highly fossiliferous brown marine limestone, two or three inches thick, near the top of the section. These beds are probably in the lower part of the Deese.

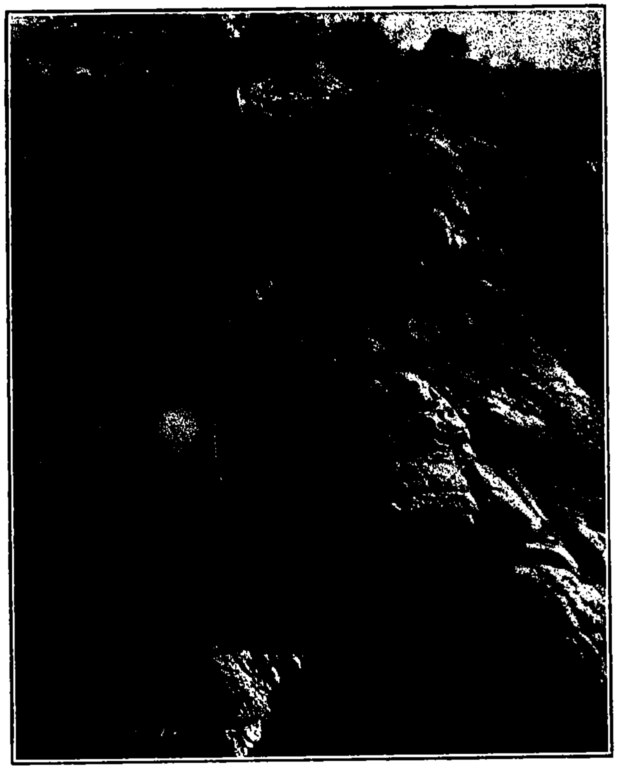
In the lower 800 feet of the formation there is one massive buff sandstone up to 100 feet thick, and several thinner calcareous sandstones.

DEVIL'S KITCHEN MEMBER

The Devil's Kitchen member, some 500 feet thick, begins about 800 feet above the top of the Pumpkin Creek limestone. At its base is a medium-grained buff sandstone 100 to 200 feet thick. Above this is a shale interval with 10 feet or more of fossiliferous impure limestone and calcareous shale. At the top is another thick sandstone which contains chert grains, and develops southeastward from Ardmore into a coarse conglomerate of angular to subangular chert pebbles. This phase grows thicker and more dominant southeastward as far as the member can be traced, to its easternmost outcrop in sec. 29, T. 6 S., R. 3 E.

This suggests a temporary strengthening of erosion and drainage on some land area not too far away, and most probably to the southeast, in the region of Llanoria. Even aside from the matter of direction so definitely indicated, it is not likely that the source of the chert was in the Criner Hills, for limestones are far more abundant there than chert, and the complete absence of limestone

PLATE VI



CROSS-BEDDED ASPHALTIC SANDSTONE IN DEESE FORMATION
Abandoned Overbrook asphalt quarry, NW. ¼ SW. ¼ SE. ¼ sec. 7, T. 6 S., R. 2 E.

pebbles from the Devil's Kitchen conglomerate indicates that there was no great relief above sea level in the Criner Hills at this time.

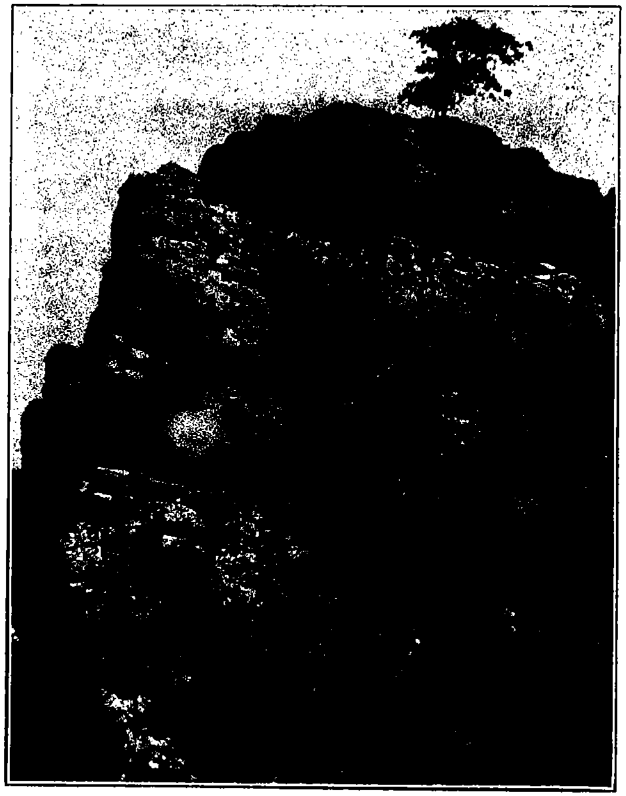
The name of this member is taken from a glen in sec. 10, T. 6 S., R. 2 E., which is sheltered by overhanging cliffs of the chert-pebble conglomerate.

The Devil's Kitchen member includes a greater thickness of sandstone than any other equal part of the Pennsylvanian system in this district. It forms a conspicuous oak-clad ridge, 50 to 150 feet in height (see Plate VII), along most of its outcrop.

ARNOLD MEMBER

Near the middle of the Deese formation, northwest of Ardmore, occurs a fossiliferous thin-bedded limestone, more or less earthy and lumpy and interbedded with calcareous shale, which

PLATE VII



DEVIL'S KITCHEN CONGLOMERATE
Anadarche Creek, near SE. cor. sec. 14, T. 6 S., R. 2 E., cliff of upper beds only.

PLATE VIII

TYPICAL DEVIL'S KITCHEN CONGLOMERATE

attains a maximum thickness of about 50 feet. It carries lenses of smoky chert, and is highly fossiliferous. One hundred feet or so below the limestone, on the W. line SW.¼ SE.¼ sec. 28, T. 3 S., R. 1 E., occurs a belt of richly fossiliferous shales associated with float of smoky chert, which also fills cavities in some of the fossils after the fashion noted also in the shale underlying the main Pumpkin Creek limestone (see above).

The above described strata, together with a 50-foot medium-grained massive buff sandstone beginning about 50 feet above the limestone, and the intervening shales, constitute the Arnold member; so called from Arnold's Reef on the farm of the same name in sec. 33, T. 3 S., R. 1 E. It makes a well-defined topographic ridge in which both the limestone and the sandstone are traceable for five miles or more along the southwest flank of the Caddo anticline. As usual in this region, the sandstone is marked in most places by a strip of scrub oak timber, while the paralleling limestone outcrop is grassy and devoid of trees, forming in places a narrow open lane through the woods.

OTHER DISTINCTIVE STRATA

Thin earthy limestones, less than two feet thick, associated with fossiliferous shales, occur at four or five other horizons in the middle portion of the Deese formation north of Ardmore, but have not been noted to the south. Within 500 feet of the top of the formation, near Deese, there are two additional 10-foot thin-bedded limestone members about 100 feet apart, sparingly fossiliferous. The lower one is interbedded with shale, the upper with a conglomerate of variegated chert pebbles in a matrix of sandy limestone. About 1,400 feet below the top of the Deese in the same vicinity, is a ridge-making sandstone 20 feet or more in thickness, full of white chert grains, resembling the finer-grained phases of the Devil's Kitchen conglomerate. This member may possibly be correlated with a coarser chert-pebble conglomerate at Cisco school on the north line of sec. 33, T. 5 S., R. 2 E., where the interval below the top of the formation is somewhat greater.

Sandstone members of the Deese are extensively saturated with asphalt, and have been quarried for their asphalt content, on both flanks of the Overbrook anticline and on the southwest flank of the Caddo anticline.

The arkose reported by Powers[70] as occurring in the Deese and Hoxbar formations "east of the Criner Hills" is more probably in the unconformably overlying Pontotoc beds.

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[70] Powers, Sidney, The Crinerville oil field, Carter County, Oklahoma: **Bull. Amer.** Assoc. Pet. Geol., vol. 11, p. 1072, 1927.

A member strikingly similar to the Devil's Kitchen and higher chert-pebble conglomeratic sandstones of the Deese formation occurs in the Mineral Wells formation of north-central Texas. This is the Brazos River or Garner sandstone,[71] well exposed in its scarp on the road from Mineral Wells to Millsap, Texas. A similarity should also be noted to a conglomeratic member at the base of the Wewoka formation, outcropping on the south line of the SW. ¼ sec. 4, T. 3 N., R. 7 E., east of Ada, Oklahoma.

HOXBAR FORMATION

GENERAL DESCRIPTION

The Hoxbar formation in the type area southeast of Ardmore includes about 4,000 feet of strata, and coincides very nearly with Goldston's Hoxbar member of the Glenn. It is the youngest formation exposed beneath the Pontotoc series in the Ardmore basin. It disappears unconformably beneath the red beds near Ardmore and beneath the Trinity sand in Love County. It recurs north and west of the Criner Hills[72] and in the Pleasant Hill syncline, where many of the members differentiable in the type area are recognized in the same sequence and relationship. The lower part of the formation is exposed also northeast and northwest of Ardmore.

The Hoxbar consists chiefly of shales, including much brownish, yellow, and reddish shale as well as the usual bluish to tan variety. Among the resistant members interbedded with the shale, there are more limestones than sandstones.

CONFEDERATE LIMESTONE MEMBER

The base of the Hoxbar formation has been drawn at the base of the lowest persistent member of this upper Pennsylvanian sequence of limestones. The basal member is called the Confederate limestone because it is well exposed and has been quarried a short distance back (west) of the Oklahoma Confederate Veterans' Home in the SE. ¼ sec. 36, T. 4 S., R. 1 E., on the southwestern outskirts of Ardmore.

This member thins in general to the southeast, and thickens in the opposite direction to a maximum at its northwesternmost exposure, near the center of sec. 29, T. 3 S., R. 1 E.; where it comprises two resistant ledges, each 15 to 20 feet thick, of coarsely granular, semi-crystalline gray to buff limestone, sparingly fossiliferous, separated by a 30-foot interval of weaker material, part of which is also limestone.

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[71] Plummer and Moore, op. cit., (footnote 53), p 75-76, and Plate II.

[72] See foregoing passages on Springer vs. Hoxbar around the Criner Hills, *et. seq.*, page 12.

Girty and Roundy collected fossils[73] from two horizons about 90 feet apart stratigraphically, on the east edge of sec. 2, T. 6 S., R. 1 E., just west of the south end of the Criner Hills. The higher of these two collections probably came from a limestone which is very similar to the Confederate member and is tentatively correlated with it on the accompanying map (Plate XX), although it could be equally well correlated with the Union Dairy member, 400 feet higher. Regarding these collections they say:[74]

> So many horizons in the thick Carboniferous section about Ardmore are paleontologically unknown that any statement about them is more than ordinarily subject to correction by new evidence. With this proviso clearly understood, we venture the opinion that these younger Carboniferous beds (represented by lots 4064 and 4065, and possibly 4061) are younger than Goldston's Deese and possibly younger even than his Hoxbar. We know almost nothing of the paleontology of the latter * * * *.

Two of the four Deese collections (their own) on which Girty and Roundy based this comparison came from horizons very close to the top of the Deese formation.

Without attempting to refute this testimony, or offering any contrary evidence, Powers[75] throws these beds into the Deese, and places the base of the Hoxbar in the Brock (Crinerville) field at the base of the Crinerville limestone member, 1,160 feet higher in the stratigraphic section there as measured by Birk.[76] This claim is regarded as highly improbable, and cannot be conceded until supporting evidence is published.

Northeast of Ardmore a limestone conglomerate occurs in association with the lowest limestone of the upper Pennsylvanian series of limestones, at the proper interval above the identifiable members of the Deese formation. This conglomerate has been mapped as the base of the Hoxbar, but its exact equivalence to the Confederate limestone is not yet certain at this writing. The individual resistant members of the Hoxbar in the vicinity of Berwyn have not yet been correlated with those in the type area of the formation.

UNION DAIRY MEMBER

Some 400 feet above the Confederate limestone is the Union Dairy member, named from Union Dairy Hill in NE. ¼ sec. 7, T. 5 S., R. 2 E. It includes a basal buff sandstone from 5 to 20 feet thick, an interval of 20 or 30 feet of calcareous shale, and a limestone at the top which reaches a maximum observed thickness of 25 feet, including shaly layers. The limestone is gray to cream-colored, and varies from earthy to finely-crystalline and

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[73] Lots 4064 and 4065, listed in the appendix of this bulletin.
[74] Girty, Geo. H. and Roundy, P. V., op. cit., (footnote 4), pp. 339 and 346-347.
[75] Powers, Sidney, op. cit. Crinerville oil field, pp. 1072-1074.
[76] Birk, Ralph A., unpublished data.

even coarsely-crystalline types. It locally carries abundant *Fusulinas*, pelecypods, brachiopods, etc. The *Fusulinas* are not diagnostic, at least not without accurate specific identification, as they do not appear in all exposures of this member,[77] and the genus is found also in three higher members of the Hoxbar formation,[78] and in the Devil's Kitchen,[79] Arnold,[80] and other members[81] of the Deese.

Girty's and Roundy's fossil collection No. 4064 may have come from the Union Dairy member.[82]

PLATE IX

WESTHEIMER SANDY LIMESTONE
NW. ¼ SE. ¼ sec. 7, T. 6 S., R. 2 E.

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[77] They are particularly numerous in shale partings near the top of the Union Dairy limestone in the west wall of the Santa Fe R. R. cut 900 feet west of the center of sec. 6, T. 5 S, R. 2 E., at the south edge of Ardmore; and are noted also 700 feet south and 300 feet east of the NW. corner of the same section, and in the SE. ¼ SW. ¼ NW. ¼ SW. ¼ sec. 8, T. 5 S., R. 2 E.

[78] (1) In the Westheimer(?) limestone (the "Q" bed of R. A. Birk's unpublished detailed map of the Brock field), near the center of the SW. ¼ SE. ¼ sec. 2, T. 6 S., R. 1 E.; near the center of the north line of the NE. ¼ section 11 in the same township; and especially in the west bank of Hickory Creek near the center of the S. ½ SE. ¼ sec. 12, T. 6 S., R. 1 E.

(2). In the Crinerville limestone in the bed and right bank of Marsden Creek in the NW. ¼ NW. ¼ SW. ¼ sec. 2, T. 6 S., R. 1 E.; also in section 11 of that township, near the center of the NW. ¼ NE. ¼ and near the center of S. ½ NE. ¼.

(3). In a crinoidal limestone about 180 feet above the Anadarche limestone about 1,050 feet north of the center of sec. 10, T. 5 S., R. 1 E., and also 700 feet east and 250 feet south of the center of that section.

[79] 500 feet south and 80 feet east of the NW. cor. sec. 4, T. 6 S., R. 2 E.

[80] Near the NW. cor. sec. 28, T. 3 S., R. 1 E., in road; also 350 feet south and 275 feet west of the center of the NE. ¼ sec. 10, T. 4 S., R. 1 E.

[81] In a 2-foot earthy limestone about 800 feet below the Arnold limestone, 500 feet west of the center of sec. 3, T. 4 S., R. 1 E.

[82] See preceding discussion of Confederate limestone member, page 39 and lists of fossils in appendix to this bulletin.

WESTHEIMER MEMBER

Some 800 feet above the Union Dairy limestone in secs. 27 and 34, T. 5 S., R. 2 E., in the type area of the Hoxbar formation, occurs the Westheimer member. It includes a 10-foot pinto limestone conglomerate of variegated pebbles of chert, shale and limestone in a limestone matrix, together with a calcareous sandstone or sandy limestone of similar thickness, a few feet below the conglomerate. This pair of beds is confidently identified with a corresponding pair in the same stratigraphic position in the Pleasant Hill syncline, both north and south of Overbrook. They outcrop in a striking *W*-trace in the axis of the syncline in SE. ¼ SW. ¼ sec. 14, T. 5 S., R. 1 E., where the east arm of the *W* is overturned 30° past the vertical. The overturning is proved by areal and structural relations and also by cross-bedding of the most convincing type, in the conglomerate.

These beds are also well exposed in the NW. ¼ SE. ¼ sec. 7, T. 6 S., R. 2 E., on the property of Westheimer & Daube and about 200 yards east of the asphalt prospect belonging to that firm, whence the name is derived. In these localities in the Pleasant Hill syncline the lower bed of the pair is less sandy and more calcareous than near Hoxbar, and in section 14 it is somewhat fossiliferous.

The Westheimer is tentatively correlated with a *Fusulina*-bearing limestone about 400 feet below the Crinerville member in secs. 11 and 12, T. 6 S., R. 1 E., together with an almost immediately overlying limestone which locally carries variegated pebbles of shale and limestone, and may represent the Westheimer pinto conglomerate.

CRINERVILLE MEMBER

Four to five hundred feet above the Westheimer conglomerate in the Pleasant Hill syncline in sec. 14, T. 5 S., R. 1 E., occurs a limestone 10 to 30 feet in thickness, the lower layers of which are crammed with *Fusulinas*. A corresponding bed, also carrying abundant *Fusulinas*, makes the trace of an inverted *U* in the NE. ¼ SW. ¼ sec. 7, T. 6 S., R. 2 E., in the southward-plunging southern portion of the same syncline. In the first-named locality, this bed plays out rather suddenly westward into sandstone. It is correlated with a limestone traversing the E. ½ NE. ¼ sec. 34, T. 5 S., R. 2 E., in the type Hoxbar area, where it also seems to grow sandier along the strike, northwestward.

This member is confidently correlated with the Crinerville limestone, the lower of the two most conspicuous ridge-making limestones in the Brock oil field and vicinity; which carries abundant *Fusulinas* in secs. 2 and 11.[83] T. 6 S., R. 1 E., though they have not been noted farther north along its crop. The type locality of this member is near the center of the west half of sec. 28, T. 5 S., R. 1 E., a few rods north and northeast of Crinerville schoolhouse. The Crinerville and Anadarche limestones also circle the north end of the Criner Hills. The Crinerville bed was probably the source of Girty's and Roundy's fossil collection No. 4061 (see appendix for list).

The Crinerville limestone is the surface stratum at the discovery well of the Brock field, Amerada Petroleum Corporation's No. 1 Sammy Baptiste, in sec. 20, T. 5 S., R. 1 E., where Powers[84] regarded it as the basal member of the Hoxbar formation. That view is incompatible with the paleontologic evidence presented by Girty and Roundy,[85] and is rendered untenable by careful correlation of the whole sequence of Hoxbar members in the Brock anticline, the Pleasant Hill syncline, and the type Hoxbar area southeast of Ardmore. The Deese formation does not appear at the surface, nor does it probably reach within 800 feet of the surface, in the productive portions of the Brock anticline. Basal members of the Hoxbar formation probably rest directly on the higher summits of the buried hills of Ordovician rock beneath that field.

ANADARCHE MEMBER

The Anadarche member, 100 to 200 feet thick, is well exposed at the type locality on Anadarche Creek, one-eighth mile south of the NW. cor. sec. 35, T. 5 S., R. 2 E. (See photographs, Plate X.) It is 500 to 800 feet above the Crinerville limestone, and approximately 2,200 feet above the base of the Hoxbar. The lower part of this member is a limestone conglomerate about 10 feet in maximum thickness, which contains pebbles not only of pre-Pennsylvanian limestones and cherts, but also of early Pennsylvanian limestone members. As this conglomerate, unlike the chert pebble conglomerates of the Deese, grows thinner to the southeast from the type locality as well as disappearing to the west, it resembles the conglomerates of the Dornick Hills formation in indicating a nearby local source for its pebbles. However, this conglomerate has not been noted at all in the outcrops of the Anadarche member west of the Overbrook anticline, which seems to rule out the Criner Hills as a source. The development of limestone conglomerate near the base of the Hoxbar northeast of Ardmore suggests that some part of the Arbuckle region in that direction may have been subject to erosion at intervals during Hoxbar time.[86]

The top portion and most characteristic and persistent feature of the Anadarche member is a very dense, hard bluish-gray limestone, up to 20 feet thick. It contains plump brachiopods of two

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[83] For exact localities see paragraph (2) footnote 78, p. 41.

[84] Powers, Sidney, op. cit., Crinerville oil field, p. 1074.

[85] See foregoing discussion of the Confederate limestone member, page 39.

[86] See the following discussion of Late Pennsylvanian orogeny, page 47.

or three common species, which rarely weather out well but which pop out neatly from the imbedding limestone under hammer-blows. In all respects above cited, this limestone is identical with the Palo Pinto limestone at the base of the Canyon group in the Pennsylvanian of north-central Texas.

This is the highest limestone exposed in the Pleasant Hill syncline, where it outcrops in an overturned *U* near the center of the west line of sec. 14, T. 5 S., R. 1 E. It outlines very beautifully the north end and west flank of the Brock anticline.

DAUBE MEMBER

PLATE X

ANADARCHE LIMESTONE NEAR TYPE LOCALITY
Near Anadarche Creek, WL. NW. ¼ NW. ¼ sec. 35, T. 5 S., R. 3 E.

Some 400 to 600 feet above the Anadarche member occurs the 10-foot Daube limestone, so named from its occurrence at the abandoned coal mine of Daube and others in the SE. ¼ sec. 8, T. 5 S., R. 2 E. It is of quite similar character to the Anadarche limestone, with the added peculiarity of containing numerous large brachiopods whose shells show in brown cross-sections on weathered surfaces giving the "limestone the appearance of being fretted with dark thin, curved lines". The quotation is from Plummer's and Moore's[87] description of the Adams Branch limestone, at the top of the Graford formation in the Canyon group of Texas. The Adams Branch, in the north half of the area covered by Plummer's and Moore's monograph, occurs from 400 to 500 feet above the Palo Pinto limestone. It is possible that the Anadarche and Daube limestones are identical with the Palo Pinto and the Adams Branch limestones, respectively.

Just below the Daube limestone occurs the only bed of coal known in the Ardmore basin. It reaches a maximum reported thickness of 4 feet, and is known for at least 4 miles along the strike in T. 5 S., R. 2 E. About 1890 an attempt was made by Westheimer, Munzesheimer, Daube, and Zuckermann, to mine this coal in the SE. ¼ of section 8, in that township. The steep dip (about 40°) is said to have contributed to the failure of this enterprise. At this locality the Daube member includes also a variegated conglomeratic cross-bedded limestone containing pebbles of chert, limestone, and shale.

PLATE XI

LIMESTONE CONGLOMERATE IN HOXBAR FORMATION
Associated with Daube limestone, NE. ¼ NW. ¼ SE. ¼ sec. 8, T. 5 S., R. 2 E.

The only extensive exposures of the Daube member are in the type area of the Hoxbar formation southeast of Ardmore; but small outcrops of typical Daube limestone occur also close to the Criner fault near the SE. cor. sec. 17, T. 5 S., R. 1 E., near the center of the west line of the NW. ¼ of section 8 in the same township, and in several places beneath the overlapping Trinity sand along the southwest flank of the Brock anticline. The varie-

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[87] Plummer, Frederick B. and Moore, Raymond C., op. cit., (footnote 53), p. 102 and plate II.

gated conglomerate is possibly identical with a similar bed which outcrops above the Anadarche limestone in the NW. ¼ sec. 10, T. 5 S., R. 1 E.

In that section and also in the NW. ¼ sec. 1, T. 6 S., R. 2 E., there is exposed in the interval between the Anadarche and Daube members a slabby limestone 3 to 8 feet thick full of large crinoid stems, and underlain by massive sandstones.

ZUCKERMANN MEMBER

This member also takes its name from the coal mine above mentioned, for it occurs there 400 to 500 feet above the Daube limestone. It includes about 30 feet of strata, chiefly white to buff coarsely crystalline calcareous sandstone, with a finer-grained layer at the top and a local development of (intraformational ?) conglomerate of gray limestone pebbles up to ¼-inch in diameter, in a calcareous matrix.

UPPERMOST HOXBAR

The highest exposed members of the Hoxbar formation appear only in and near sec. 26, T. 5 S., R. 2 E. They include 500 feet or more of tan to brownish shales above the Zuckermann sandstone, with two or three sandy limestones or calcareous sandstones similar to the Zuckermann member. One of them includes a little conglomerate, also similar to what is found in that member. No fossil collections have been reported above the Daube limestone.

Powers' statement[70] that arkose occurs in the Deese and Hoxbar formations "east of the Criner Hills" is so vague geographically that it can only be denied categorically until specific localities are cited in support of it. Unless that statement can be substantiated, no feldspar whatever has been noted in either of these formations anywhere in the Ardmore basin. It is probable that Powers confused them with the strongly arkosic conglomerates in the basal portion of the overlying Pontotoc series, which lies with angular unconformity on these formations, and transgresses from the highest known members of the Hoxbar in sec 26, T. 5 S., R. 2 E., down across the section until it conceals the Confederate limestone at the west edge of Ardmore. He may have been misled by Goldston's map,[56] which did not differentiate the Pontotoc in this area, but drew a Hoxbar-Trinity contact irregularly through the territory which is actually occupied by the Pontotoc series.[88]

The angular unconformity at the base of the Pontotoc is naturally least conspicuous where the maximum thickness of the

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[88] See following discussion of the Pontotoc series, page 51.

Hoxbar formation is exposed; for the uppermost Hoxbar beds there possess a minimum dip of 15 degrees or less, and the stratigraphic hiatus and time interval represented by the unconformity are also at a minimum.

LATE PENNSYLVANIAN OROGENY

REJUVENATION OF THE WICHITA (?) SYSTEM

After the close of Hoxbar deposition, there was renewed folding and uplift throughout much or all of the Wichita Mountain system in southern Oklahoma and north Texas, which had been almost or entirely buried beneath Hoxbar sediments. Dips ranging from 20 to 35 degrees were produced in the upper Pennsylvanian beds of the Brock and Hewitt oil fields, and dips of 8 or 10 degrees in the Healdton field,[89] together with large-scale faulting in all three of these fields. The east half of the Criner Hills uplift, comprising the present area of the Hills, was sharply re-elevated and steepened.

The southern group of buried early Pennsylvanian ranges, in Cooke and Montague counties, Texas, and Jefferson County, Oklahoma, does not seem, on the whole, to have been refolded quite so steeply at this time; although the arkosic conglomerates in red beds of probable post-Pontotoc age (cf. following discussion of Cisco(?) red beds) in the two counties last named indicate the presence of exposed granite or granite wash not very far away; possibly as far as the modern Wichita Mountains, but quite as probably in some reuplifted nearer range or ranges in the southern row of early Pennsylvanian mountain folds, not now exposed, but buried beneath still younger strata.

Eloquent testimony to this late Pennsylvanian re-elevation of the Red River region is found in the changes in character of sediments in the Cisco and Wichita-Albany groups, from terrigenous and near-shore types along Red River to marine and farther offshore phases farther south.[90]

THE ARBUCKLE MOUNTAINS

At the same time, about the end of the Hoxbar epoch, still more intense folding was induced in the region north and northeast of the Red River (Wichita ?) mountain system, the region now occupied by the Ardmore basin and the southern and western portions of the Arbuckle Mountains: which throughout earlier Pennsylvanian time had evidently been a subsiding basin of sedimentation or geosyncline, receiving sediments from the ranges to

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[89] Geo. E. Burton reports local dips of 60° in the southeast part of the Healdton field. (Verbal communication).

[90] Cf. following discussion of post-Pontotoc (Cisco?) red beds, especially passages on local arkosic conglomerates and close relation of red beds ot preceding orogeny, pages 57-66.

the south and from the Llanorian highland to the southeast. There is no evidence, either stratigraphic or structural, that the main uplift of the western Arbuckle Mountains (the Timbered Hills range), west of the Washita River, began prior to late Deese time at the earliest.[91] The Dornick Hills formation and the lower Deese, on the south flank of the Arbuckles, are free from the conglomerates which characterize the same horizons near the Criner Hills. In the former area no angular unconformity interrupts the essential parallelism of strata from the upper Cambrian Reagan sandstone to the top of the upper Pennsylvanian Hoxbar formation. There a tremendous break occurs, for the basal red beds (Pontotoc series) along their outcrop northwest of Ardmore overlie and truncate successively all the formations from the Hoxbar down to the Reagan sandstone (in the northwest end of the Arbuckle Mountains), transgressing about 25.000 feet of sediments.

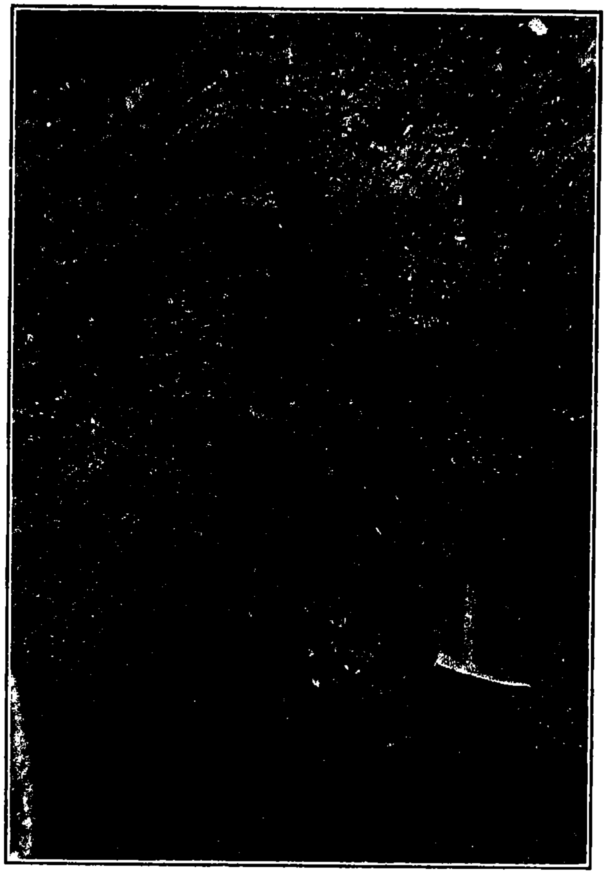
The evidence above cited to establish the fact that the area now occupied by the western Arbuckle Mountains suffered no pronounced orogeny from late Cambrian until late Pennsylvanian time, is true in almost equal degree along the south front of the Arbuckles east of Washita River. The main Tishomingo range of the Arbuckles probably originated at the same time as the Timbered Hills Range west of the river. At any rate, it seems to have supplied no coarse conglomerates to the pre-Hoxbar formations which now outcrop along its southern margin, and no conspicuously angular unconformity appears there except at the base of the Pontotoc.[92]

Limestone conglomerates in the Hoxbar formation[93] and the top of the Deese suggest that this uplift in the Arbuckle region began near the close of Deese time; but no angular unconformity appears in the Ardmore basin within the Deese or Hoxbar formations or between them, and the Hoxbar appears to have shared to the fullest extent in the late Pennsylvanian deformation. The source of these conglomerates, insofar as they are not intraformational, may have lain in the northern Arbuckle region, north of the present Mill Creek syncline, where there is evidence of still earlier Pennsylvanian uplift;[92] or in some unknown area to the southeast, now hidden beneath Comanchean strata.

MINOR MOUNTAIN FOLDS

Contemporaneously with this great mountain building of the western and southern Arbuckles near the close of the Pennsylvanian period, the area between those ranges and the Red River or Wichita (?) mountain system to the south was also intensely folded, producing the Overbrook anticline, the Caddo anticline north of Ardmore, and the steep anticlines of the Graham, Fox and Sholom Alechem oil fields in northwestern Carter County, Oklahoma. Both the Caddo and Overbrook anticlines are locally overturned and the latter is accompanied by thrust faulting on no mean scale. The Preston anticline in Marshall County, Oklahoma, and Grayson County, Texas, in the Carboniferous beds which have been penetrated beneath its gently-arched Comanchean cover, is very similar to these folds, and is probably of contemporary

PLATE XII



ANTICLINE IN SHALE OF SPRINGER FORMATION
(Below Overbrook sandstone?) Axis of Overbrook anticline, 400 feet south and 70 feet east of CNL. sec. 6, T. 6 S., R. 2 E.

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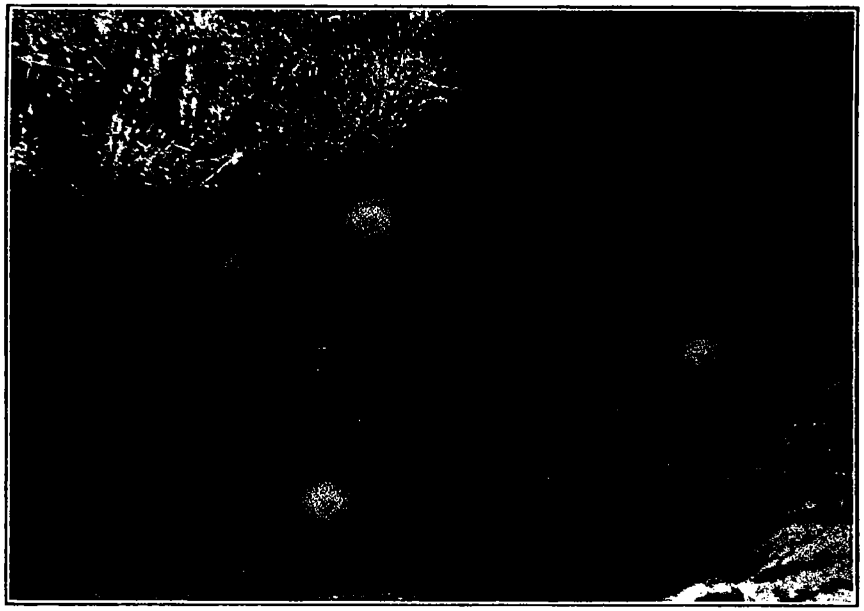
[91] Sidney Powers once assigned this uplift to the close of the Mississippian period, but stated no evidence. Powers, Sidney, Age of the oil in southern Oklahoma fields: Trans. Am. Inst. Min. Eng., vol. 59, p. 1973, 1918.

[92] See discussion of early Pennsylvanian orogeny in the northern Arbuckle mountains, page 24.

[93] See foregoing descriptions of the Confederate, Westheimer, Anadarche, Daube and Zuckermann members of the Hoxbar, pages 39-47.

PLATE XIII



HAIRPIN FOLD IN BOSTWICK MEMBER
Close to axis of Overbrook anticline, WL. SE. ¼ NE. ¼ SE. ¼ sec. 16, T. 6 S., R. 2 E.

origin. The Mannsville-Madill anticline in Johnston and Marshall counties, Oklahoma, probably is of late Pennsylvanian origin also.

ESTIMATED CRUSTAL SHORTENING

Disregarding the ranges south of the Criner Hills because they are not yet sufficiently well known to afford a satisfactory basis for such an estimate, and disregarding also the close crumpling of incompetent strata near the axial planes of the steeper anticlines, it is estimated that a crustal shortening of at least 40 per cent—more than 16 miles—was accomplished by this late Pennsylvanian folding. The estimate is based on the cross-section in Plate XVII, along a line drawn from the Brock oil field to the syncline in the Washita valley east of the Timbered Hills range.

ECONOMIC IMPORTANCE OF OROGENIC DATES

The date of folding of a given mountainous anticline in this region is of vital importance to the oil producer who is testing its commercial possibilites. In the folds formed first in early Pennsylvanian time, the drill passes through a relatively thin section of upper Pennsylvanian beds into exceedingly steeply folded pre-Pennsylvanian strata lying unconformably beneath them.

In these older rocks no commercial oil or gas production of importance has yet been obtained south of the Arbuckle Mountains, although the possibilities have by no means been exhausted. In the folds in northern Carter County which appeared for the first time in the late Pennsylvanian, on the other hand, there is every reason to expect a complete section of the Pennsylvanian system lying unconformably above the older rocks. In none of these fields has the drill yet penetrated entirely through the Pennsylvanian, although a depth of 5,120 feet has been reached in the Graham field without reaching lower than the uppermost part of the Springer formation.

PONTOTOC SERIES

VANOSS FORMATION

The late Pennsylvanian Arbuckle Mountains gave rise to a great deposit of arkosic limestone conglomerates on the north flank of the mountains. Coarse limestone conglomerates reach a thickness of several hundred feet in the vicinity of Sulphur. These were formerly regarded as part of the Franks conglomerate, but were segregated by Morgan[94] as part of his Vanoss formation (uppermost Pennsylvanian?) of the Pontotoc series. No such thickness of coarse limestone conglomerates of this age outcrops in the Ardmore basin south of the Arbuckle Mountains, where the formation is completely missing in places, and elsewhere is apparently represented by 50 to 200 feet of deep red shales and coarse arkose. Limestone conglomerate occurs only as a minor local feature, with pebbles averaging much smaller than in the Sulphur area.

This contrast is probably to be explained by the fact that a broad belt south of the Arbuckle Mountains was intensely folded contemporaneously with the main western Arbuckle uplift itself, whereas the belt of steep mountain folding stopped abruptly at the north edge of that uplift. Even though the anticlinal crest of the Timbered Hills range and that of the Tishomingo range may have coincided approximately with the drainage divide during the epoch of mountain building and most rapid erosion, the streams flowing to the north from the divide must have had much steeper gradients than those which flowed to the south across the wide belt of secondary mountain folds. The northward-flowing streams suffered an abrupt reduction of gradient at the foot of the mountains where these conglomerates were deposited; whereas the southward-flowing streams had neither the steep gradient near their heads necessary to carry such coarse material, nor the abrupt reduction in gradient unless it occurred far to

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[94] Morgan, Geo. D., op. cit., Stonewall quadrangle, pp. 121-122, (footnote 42).

the south beyond the south edge of the belt of mountain folding in Texas. If conglomerates were deposited there, they are now concealed beneath the Comanchean sediments of the Gulf Coastal Plain.

A local pocket of Vanoss conglomerate comparable in thickness to the deposits near Sulphur, though less coarse, may occur buried in a synclinal basin northwest of Lone Grove, Oklahoma, as cored and logged in a dry hole drilled in 1926 by the Cameron Refining Co. in NW. ¼ NE. ¼ NW. ¼ sec. 8, T. 4 S., R. 1 W. The Schermerhorn-Ardmore Co.'s well, No. 1 Russell in sec. 11, T. 1 S., R. 4 W., Stephens County, logged 240 feet of arkosic gravel, at depths between 1,850 and 2,160 feet, belonging to the Pontotoc series and possibly to the Vanoss formation, but containing few pebbles over ¼ inch in diameter. Lesser thicknesses have been recorded in several wells in adjacent sections of that township.

Five or ten feet of variegated and rather fine-grained limestone conglomerate occur rather persistently near the top of the thin Vanoss section northwest of Ardmore, close to the Hart limestone horizon. A somewhat greater thickness of coarser material, more nearly approaching the Sulphur conglomerate in character, occurs in secs. 25 and 36, T. 3 S., R. 2 E., south of Berwyn, Oklahoma, and in adjoining sections to the east and southeast. A peculiar feature of these beds, as described by Birk[95] citing J. T. Richards, is the presence of limestone pebbles or nodules of supposed algal origin, built up of successive thin calcareous layers surrounding a nucleus of foreign material—usually a grain or small pebble of limestone, chert, quartz or feldspar. According to Birk and Richards, similar pebbles occur in conglomerates of the Vanoss formation north of the Arbuckles. They occur also in the Ardmore basin scattered through red shales near the horizon of the thin Vanoss conglomerates above described. This phase, and the arkoses, serve to identify as part of the Pontotoc the basal portion of the red beds in places where the limestone conglomerate and the Hart limestone are missing, or unexposed.

TRINITY vs. CARBONIFEROUS RED BEDS IN REVISED MAPPING

Arkosic conglomerates up to 25 feet thick, with pebbles rarely exceeding an inch in diameter, outcrop not only along the eastern edge of the red beds area from Ardmore northwest, but also near the Criner Hills,[96] and southeast of Ardmore. In the last named area they were mapped by Goldston (followed by Miser) in the main as part of the Trinity sand, but they are wholly different from the Trinity and are interbedded with maroon clay shales typical of the red beds. It is not quite certain that the arkoses southeast of Ardmore belong in the Vanoss formation rather than higher in the Pontotoc, for a 4-foot limestone resembling in some respects the Hart member (see below) outcrops just below them near the center of the NE. ¼ sec. 16, T. 5 S., R. 2 E. This, however, may possibly belong to the upper Hoxbar, above the Zuckermann sandstone. Red shales carrying limestone nodules occur in association with the overlying arkoses, in the same quarter-section.

The basal member of the Trinity sand in the Ardmore district typically consists of coarse quartz sand or fine to medium-grained conglomerate of chert and clear quartz pebbles, without feldspar. West of Ardmore it is commonly cemented to an almost quartzitic hardness, with a chalk-white matrix emphasizing the transparent quality of the quartz grains embedded in it. Locally it is stained dark brown or black by limonite. Sandy clays and impure massive sands in the Trinity locally weather to a dull and rather light brick-red not unlike some sandy soils on the Carboniferous red beds, and this resemblance makes it difficult to be certain of the exact boundary in some places where the Trinity rests on the red beds; but the dark maroon so commonly seen in the red beds shales is confined in the known Trinity on the borders of the Ardmore basin to an occasional streak of clay shale two or three

PLATE XIV

TYPICAL BASAL TRINITY CONGLOMERATE
Near CEL. SE. ¼ SW. ¼ sec. 24, T. 6 S., R. 2 E.

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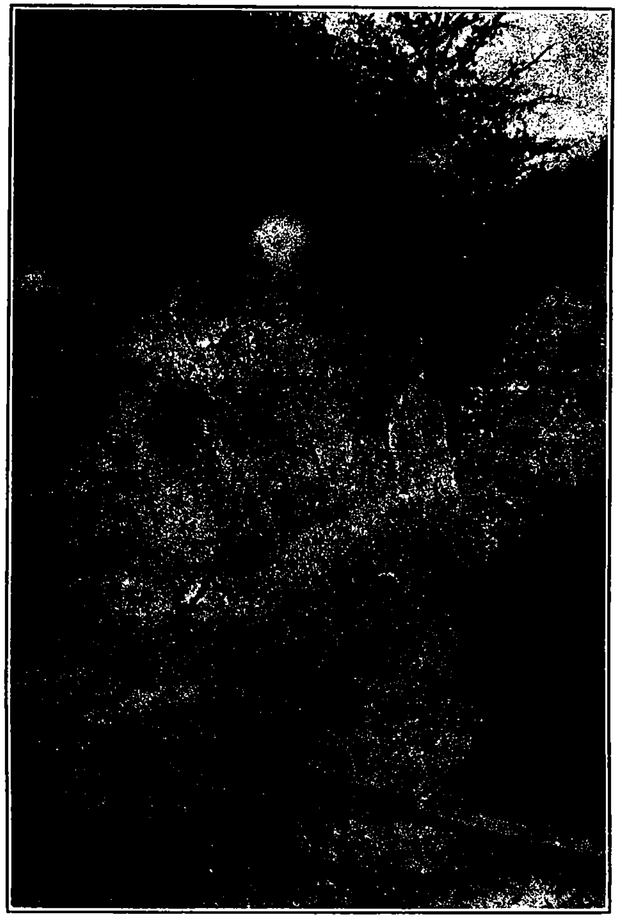
[95] Birk, Ralph A. The extension of a portion of the Pontotoc series around the western end of the Arbuckle Mountains: Bull. Am. Assoc. Pet. Geol., vol. 9, pp. 987-988, 1925.

[96] Birk, R. A., op. cit., p. 986.

feet thick at the most. Where the Trinity lies directly on the Hoxbar or older formations, there is no red arkosic conglomerate between the two, nor in the Trinity. It is not found anywhere in the Ardmore basin in beds which are known certainly to be Trinity.

PLATE XV



GULLY IN MASSIVE TRINITY SANDSTONE
SE. cor. sec. 21, T. 6 S., R. 3 E.

The typical Trinity quartzitic conglomerate or sandstone above described occurs in many places with striking angular unconformity immediately below it, and lying upon beds (in many instances fossiliferous) of unmistakable Carboniferous or pre-Carboniferous age. No beds definitely underlying it have been proved to be younger than Carboniferous anywhere on the borders of the Ardmore basin. The base of this stratum has therefore been drawn as the base of the Trinity west of Ardmore. Goldston[97] drew this boundary farther north in that area, including in the Trinity not only Pontotoc outcrops but possibly younger (Cisco ?) red beds. Outcrops along the highway between Ardmore and Lone Grove, west of the Overbrook anticline with its exposures of the Deese and Dornick Hills formations, include nothing but strata typical of the post-Hoxbar Carboniferous red beds. It is admitted that residual Trinity sand may cover some uplands in that area and that residual pebbles and fragments of petrified wood from the Trinity are common on high ground several miles north of the present limits of Trinity bedrock; but it is believed that the Trinity as restricted on the accompanying map (Plate XVII) of Carter County includes all of the bedded Trinity now remaining in place, with the possible exception of some very small outliers. Higher beds of quartzitic sandstone and conglomerate are reported by Bullard[98] in the Trinity of Love County, Oklahoma, but no confusion due to this is believed to exist on the present map.

For these reasons, the accompanying map (Plate XVII) shows more red beds and less Trinity both west and southeast of Ardmore, than Goldston's map, though the Trinity as here mapped is still more extensive than on Taff's original map[99] of this region. Miller[100] was one of the first to note the presence of pre-Trinity red beds southeast of Ardmore.

For similar reasons, the red beds north of Orr in western Love County, and along Mud Creek (especially on its west bank) a few miles farther south, are unhesitatingly assigned to the Carboniferous rather than to the Comanchean.[101]

East of Ardmore, the basal sand of the Trinity is too poorly consolidated in some places to outcrop as a distinct mappable ledge. Farther east, along the east line of Carter County and beyond, a massive, chalky, barren, somewhat conglomeratic limestone appears at the base of this formation.[102]

HART LIMESTONE AND HIGHER PONTOTOC

As described by Birk,[103] the Hart limestone member of the Stratford formation, next above the Vanoss in Morgan's Pontotoc terrane, consists in T. 1 S., R. 2 W., of:

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[97] Goldston, W. L. Jr., Differentiation and structure of the Glenn formation: Bull. Am. Assoc. Pet. Geol., vol. 6, Pl. I, 1922.

[98] Bullard, Fred M., Geology of Love County, Oklahoma: Oklahoma Geol. Survey, Bull. 33, pp. 15-17, 1925.

[99] Taff, J. A., Preliminary report on the geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma: U. S. Geol. Survey, Prof. Paper 31, Pl. I, 1904; also Oklahoma Geol. Survey, Bull. 12, 1928.

[100] Miller, W. Z., verbal communication, 1922.

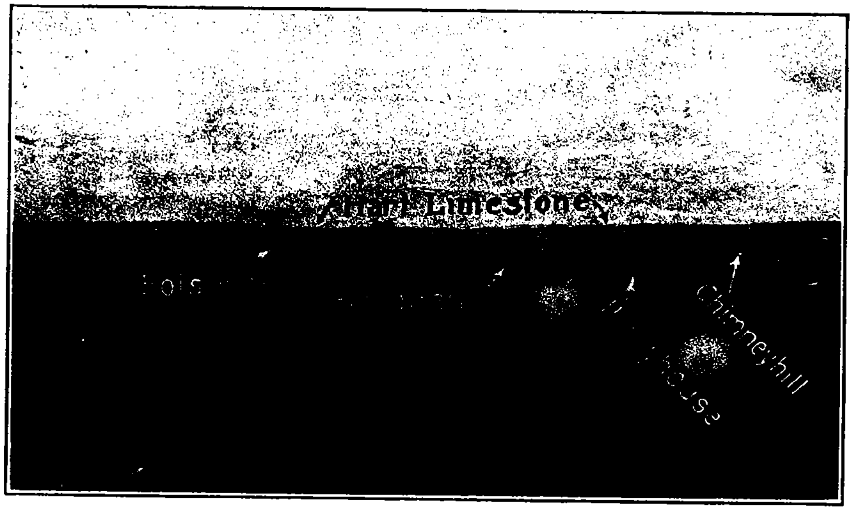
[101] But cf. views of C. W. Shannon, as quoted by Bullard, F. M., op. cit., pp. 15-16.

[102] Tomlinson, C. W., Buried Hills near Mannsville, Oklahoma: Bull. Am. Assoc. Pet. Geol., vol. 10, pp. 138-143, 1926.

[103] Birk, R. A., op. cit., pp. 984-986.

> "* * * massive but lenticular beds of limestone and shale, with some limestone conglomerates, beds of arkose, and a few asphaltic sandstones. The limestones vary in color from white through a yellowish brown and from gray to black. They are non-fossiliferous, except at a locality in sec. 10, T. 1 S., R. 2 W., reported * * * by Rud. Brauchli, and seldom contain bedding planes or lines of cleavage. The limestones are secondary and were formed with reworked material from the Ordovician limestones in the Arbuckle Mountains. In a great many places they weather out so as to be identical in appearance with the Ordovician. The beds of limestone change in thickness abruptly. * * * In sec. 9, T. 1 S., R. 2 W., logs of the shallow wells show from 50 to 200 feet of solid lime, and there is about 40 feet of almost solid lime exposed at the surface. About 4 miles to the east, where the limestone formation overlaps the west end of the mountains, the limestone beds are about 10 feet in thickness and are interbedded with red shale. They also seem to thin out rapidly farther away from the mountains* * *.
>
> About a mile south of Woodford the limestone disappears beneath a deposit of river gravel, but a few miles farther along the trend of the limestone formation, a series of arkoses and arkosic limestone conglomerates are found which were mapped to a point 2 miles west of Ardmore. One thin limestone ledge was found in the series a short distance west of Ardmore. It is thought that this arkosic series is a little below the lime formation in the stratigraphic section.

PLATE XVI



ANGULAR UNCONFORMITY BETWEEN PONTOTOC SERIES AND OLDER ROCKS
Looking norhtwest from NW. ¼ sec. 12, T. 2 S., R. 2 W. Pontotoc series (upper Pensylvanian red beds) in background and Siluro-Devonian rocks in the foreground.

The Hart limestone is the lowest member of the upper Carboniferous which now extends continuously around and over the west end of the Arbuckle Mountains, above the great angular unconformity which marks the post-Hoxbar orogenic and erosional interval. Above that:[104]

> * * * the basal sandstone in the Asher formation was traced from a point west of Byars and south of Canadian River, southwest* * *. It gradually overlaps the shale intervening between it and the Hart limestone member, and in sec. 1, T. 1 S., R. 2 W., it is found directly above the lime * * * *. From this point on around the west end of the Arbuckles the Asher sandstone is resting on the Hart limestone member, except for a strip of the intervening (Stratford) shale that is exposed in the center of T. 1 S., R. 2 W.
>
> The average dip of the Hart limestone at the west end of the mountains is 120 feet per mile, while that of the Asher sandstone is from 20 to 40 feet per mile* * *.
>
> Morgan places the Pennsylvanian-Permian contact at the base of the Hart limestone member of the Stratford formation although his evidence consisted of one plant fossil of somewhat doubtful age. It is the writer's opinion that the contact should be placed at the upper limits of the Stratford shale or the base of the typical red beds.

The maximum known thickness of the Pontotoc series at its outcrop in Carter County, Oklahoma, is about 400 feet. A greater thickness, probably due to the addition of lower arkosic beds, is suspected in the synclinal basin northwest of Lone Grove. (See foregoing discussion of Vanoss formation).

POST-PONTOTOC (CISCO ?) RED BEDS

GENERAL DESCRIPTION

Above the Pontotoc series as mapped by Birk there outcrop in Carter County, Oklahoma, approximately 1,000 feet of typical "red beds", so-called from the dark red shales and reddish-buff cross-bedded sandstones which make up much of the sequence. However, much of the sandstone is buff, brown, gray or white rather than red, and there are bluish, tan, green, and white shales as well as red. Perhaps the most common type of sandstone is semi-crystalline and almost white when fresh, but mottled with dark-brown specks and blotches (probably of ferruginous stain) in the weathered portions.

CORNISH SANDSTONE MEMBER

One of the highest members of the red beds of Carter County is a white, massive cross-bedded sandstone which forms a scarp fronting northeast along the southwest side of the Healdton field in T. 4 S., R. 3 W., and underlies gentle dip slopes extending from the scarp to the southwest corner of the county, interrupted by valleys and ravines which have cut to lower strata. This mem-

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[104] Birk, R. A., op. cit., p. 989.

ber immediately underlies the city of Ringling and the neighboring village of Cornish in eastern Jefferson County, Oklahoma, taking its name from that village. Outcrops of this and closely associated (mostly lower) sandstone beds are traceable through most of Jefferson County, where in general they underlie a much-dissected plateau surface, finally disappearing northwestward beneath higher strata.

The red beds below the Cornish sandstone member generally possess ruggedly dissected topography, clad with oak woods. The higher beds include more shales, giving rise to broad upland prairies.

LOCAL ARKOSIC CONGLOMERATES

In the vicinity of the Oscar or Hambro oil pool in southeastern Jefferson County, Oklahoma, there appear near and below the horizon of the Cornish sandstone several strata of coarse arkosic sandstone or conglomerate, containing pebbles of chert, granite, feldspar, and quartz up to an inch or more in diameter. These were described in some detail by Robinson,[105] who perhaps overemphasized a little their undoubtedly lenticular character. Similar beds, believed to be parts of the same series, outcrop in and near the Nocona oil pool, just across Red River in Montague County, Texas.

PERMIAN OR PENNSYLVANIAN (?)

In conformity with recent Kansas practice,[106] the contact between the Pennsylvanian and Permian systems in northern Oklahoma is drawn on Miser's new geologic map of the state[6] at the base of the Cottonwood limestone. It was formerly drawn about 150 feet higher, at the base of the Wreford limestone;[107] but Beede preferred to draw it from 40 to 150 feet below the Cottonwood, somewhere between the top of the Neva limestone and the base of the Elmdale shale.[108]

Farther south, in the Stonewall quadrangle, Morgan[109] placed the Permian-Pennsylvanian contact at the base of his Hart limestone, the lowest member of the Stratford formation, near the middle of the Pontotoc series. This has the merit of coinciding with the horizon of tremendous angular unconformity at the west end of the Arbuckle Mountains, produced by late Pennsylvanian

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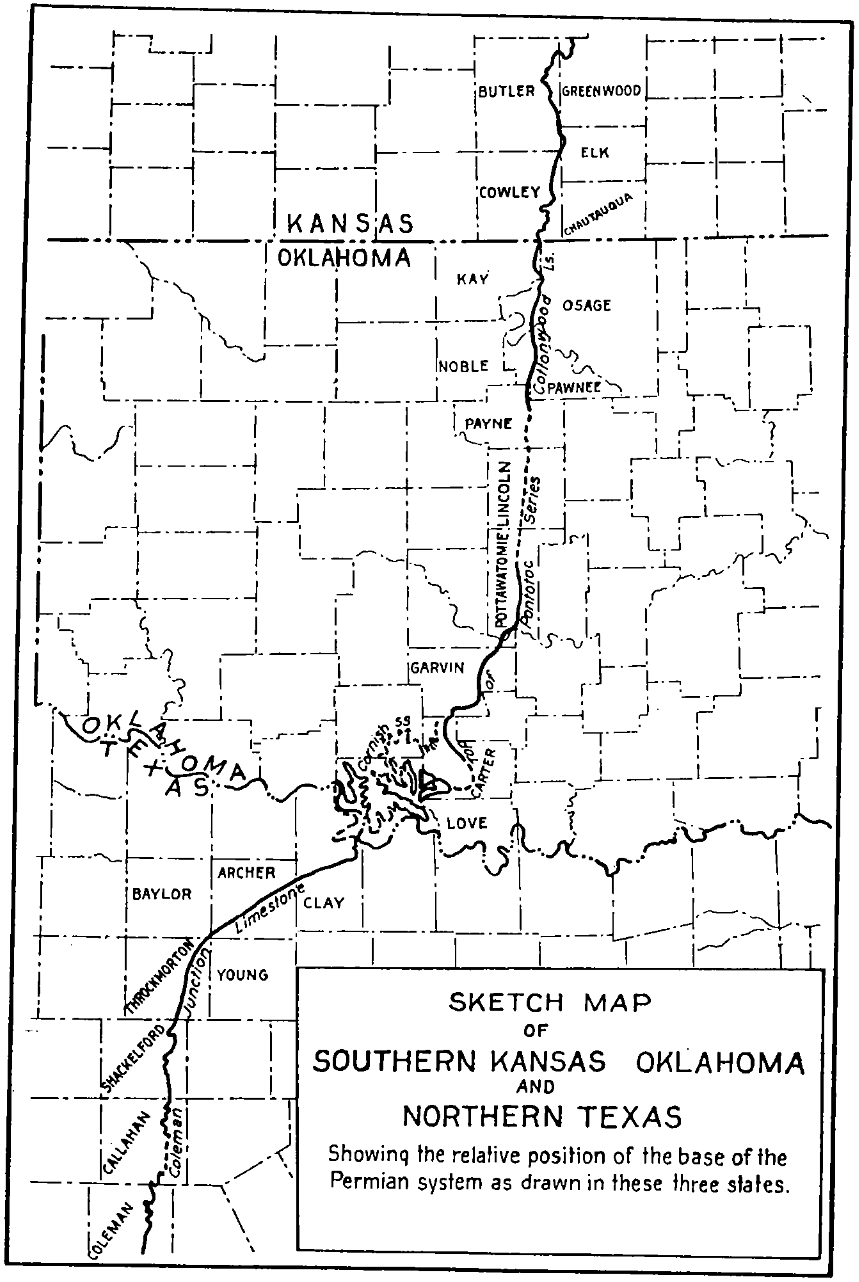
[105] Robinson, Heath M., Geologic structure and oil and gas prospects of a part of Jefferson County, Oklahoma: U. S. Geol. Survey, Bull. 726, pp. 276-302, 1921.

[106] Moore, Raymond C., and Haynes, Winthrop, P., Oil and gas resources of Kansas: State Geol. Survey of Kansas, Bull. 3, pp. 107-11, 1917.

[107] Adams, G. I., U. S. Geol. Survey, Bull. 238, 1904; Haworth, E., Kansas Univ. Geol. Survey, vol. 9, 1908; Gould, C. N., Ohern, D. W. and Hutchison, L. L., Proposed groups of Pennsylvanian rocks of eastern Oklahoma: State Univ. of Oklahoma, Research Bull. No. 3, 1910.

[108] Beede, J. W., The Neva limestone in northern Oklahoma: Oklahoma Geol. Survey, Bull. 21, pp. 21-23, 1914.

[109] Morgan, Geo. D., op. cit., (footnote 42), pp. 136-140.



SKETCH MAP
OF
SOUTHERN KANSAS OKLAHOMA
AND
NORTHERN TEXAS
Showing the relative position of the base of the Permian system as drawn in these three states.

Figure 3.

mountain building and erosion. However, Miser's map shows clearly that this horizon is lower than that of either the Cottonwood limestone or the Neva, and lower than the Cushing limestone. It probably corresponds roughly to the top of the Buck Creek formation of northern Oklahoma, some 350 feet below the Cottonwood. The latter apparently would coincide with some horizon nearer to the top of the Pontotoc terrane.

All of the above-mentioned horizons, as well as the one suggested by Birk,[110] are lower in the section than the Asher sandstone. Birk's tracing of the latter around the west end of the Arbuckles brings it into a position at the base of the post-Pontotoc red beds of Carter County, described above, and certainly several hundred feet below the Cornish sandstone. That places all of the post-Pontotoc red beds in the Permian, leaving the Carter County Pontotoc debatable, but probably Pennsylvanian.

On the other hand, reconnaissance mapping of Jefferson County, Oklahoma, indicates that the Cornish sandstone, or at least part of the outcrops here assigned to that member, is to be correlated with a sandstone outcropping around Ryan, Oklahoma. A recent field conference of geologists from Ardmore and Wichita Falls in the Ryan area established the fact that the Ryan sandstone is either to be correlated with, or is not more than 50 feet below, a sandstone just across Red River in Clay County, Texas, which has been traced by V. E. Tims, with the aid of adjacent beds above and below it, almost continuously into a horizon immediately overlying the Coleman Junction limestone in Archer County, Texas. As the base of the Coleman Junction limestone has been generally accepted as the approximate base of the Permian system in north-central Texas, this southwestward correlation would throw into the Pennsylvanian system (Cisco group of Texas) all of the red beds of Carter County, Oklahoma, nearly, if not quite, up to the Cornish sandstone.

Uncertainty as to the exact position of the Pennsylvanian-Permian boundary in north-central Texas is expressed by Plummer and Moore. They[113] say:

> It is not easy to draw a definite line of division between the Pennsylvanian and Permian rocks in north-central Texas. The division as made by Cummins was based largely upon the lithologic character of the sediments, and Drake offers no good reason for drawing his line at the bottom of the Coleman Junction limestone rather than at the top, or at some other nearby horizon.

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[110] See quotation (page 55) in the foregoing discussion, of the Hart limestone and higher Pontotoc.

[113] Plummer, F. B. and Moore, R. C., op. cit., p. 190.

> Ammonites of Permian aspect occur in strata south of Coleman 114 feet above the Coleman Junction limestone, so that beds 100 feet higher are quite surely of Wichita age. Obviously the question as to just which stratum is the first to contain Permian forms can be settled only by a careful study of large collections of the fossils. The fauna of these beds is not sufficiently well known as yet. Not unlikely a general gradation from the Pennsylvanian into the Permian has taken place without any abrupt change. If this is true, one line appears to be as acceptable as another close to it, and therefore, the persistent Coleman Junction limestone, which is a good horizon marker for the top bed of the "thin limestone strata" of the Cisco group, has been chosen as the most readily traceable and suitable line of division.

Plummer and Moore[114] mapped the Coleman Junction limestone to the north edge of Callahan County, and Hubbard and Thompson[115] carried it on across Schackelford and Throckmorton counties and much of the way across Archer County, to a point north of Archer City, some 30 miles from Red River. The limestone itself disappears in southern Archer County, but its approximate horizon was mapped beyond that point by tracing adjacent sandstone layers both above and below it.

It is very difficult to escape the conclusion that the Cisco group is represented in the lower part of the southern Oklahoma red beds which are shown on Miser's map as pertaining to the Clear Fork and Wichita formations.

Confirmatory evidence exists in the presence of feldspar grains and pebbles in conglomerates of the Cisco group in Jack and Young counties, Texas, for feldspar does not occur in the Carboniferous of the Ardmore basin, below the Pontotoc series. These Cisco conglomerates evidently were formed after or during the great post-Hoxbar orogeny, and are closely related to the arkoses near the Nocona and Oscar oil pools.

Still another bit of confirmation lies in the tentative correlation of the Anadarche and Daube limestones, above the middle of the Hoxbar formation, with the Palo Pinto and Adams Branch limestones, in the lower and middle portions of the Canyon group of Texas. The Pontotoc series, which disappears beneath the Comanchean near the northwest end of the Criner Hills, may be represented in the upper Canyon or lower Cisco of Texas, either by sediments or by a hiatus.

CLOSE RELATION OF RED BEDS TO PRECEDING OROGENY

A very striking feature of the Carboniferous stratigraphy of the mid-continent region is the change of late Pennsylvanian and early Permian sediments from typical marine sediments in

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[114] Op. cit., Plate I.

[115] Hubbard, W. E., and Thompson, W. C., The geology and oil fields of Archer County, Texas: Bull. Am. Assoc. Pet. Geol. vol. 10, fig. 1, p. 460, and pp. 463-464, 1926.

Kansas and northern Oklahoma, and in north-central Texas, to red beds in central and southern Oklahoma and the Red River region of Texas. As the belt of Pennsylvanian orogeny in southern Oklahoma and northern Texas is approached from either side along the strike of these beds, gray gives place to red, limestones to sandstones and conglomerates, and highly fossiliferous marine beds to almost wholly barren red beds, containing very scanty remains of land plants and land vertebrates. There are continuous sheets of sediments of this age extending from Kansas, through saddles in the eroded Pennsylvanian ranges, into Texas—marine on both ends and typical red beds in the middle. These sheets of sediments may not have been laid down on a strictly level surface, but on a plain of aggradation sloping away both to the north and to the south from the uplifted orogenic belt; above sea level near the mountains and below it farther out.

This close relationship of the red beds to late Pennsylvanian orogenic uplift is an important part of the testimony[116] in favor of a dominantly non-marine origin for the red beds of Oklahoma and Texas. Certainly they are very different from the typical assuredly marine strata into which they grade, and were formed under radically different conditions from those.

The southward change of the Pennsylvanian system in Kansas and Oklahoma is well described by Gould and others[117] as follows:

> In Kansas it has been noted that on passing from the center of the State to the Oklahoma line the various limestone ledges frequently thin out and some of them disappear before the line is reached. Others pass for several miles into Oklahoma before disappearing, but except in eastern Kay County, comparatively few limestones reach the Arkansas River. Of the half dozen or more which persist south of that stream only one ledge, so far as known, exceeds 10 feet in thickness.
>
> It has also been found that as the limestones thin out to the south and finally disappear, sandstones often come in.* * * In other cases the ledges become more arenaceous to the south, until finally the ledge which was a limestone has become a sandstone. It frequently happens, also, that additional sandstone ledges come in, first as mere arenaceous bands in the shales, then as thin lenses which thicken to the south and finally become ledges of hard sandstone 20 to 50 feet thick, which resist erosion and give rise to pronounced escarpments. * * *
>
> Another factor is the gradual thickening of the entire series to the south.* * *
>
> In its southwestern extension the Sapulpa group (Lenapah limestone up to Elgin sandstone, inclusive) passes into and

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[116] Cf. among others Dorsey, Geo. E., The origin of the color of red beds: Jour. Geol., vol. 34, pp. 131-143, 1926. Tomlinson, C. W., The origin of red beds: Jour. Geol. vol. 24, pp. 153-179, 238-253, especially pp. 251-253, 1916.

[117] Gould, Chas. N., et al., op. cit., (cf. footnote 107).

> includes the eastern part of the Oklahoma red beds, being part of the so-called Chandler beds.* * *
>
> In southern Pawnee and northern Payne counties the color of the rocks in the Ralston group (Pawhuska to Garrison formations, inclusive) changes and becomes a deep brick-red and so continues to the southern limits. This area includes the greater part of the so-called Chandler beds.* * *

The reciprocal northward change in Texas is described by Udden and others:[118]

> The Cisco formation* * * is composed of beds of blue clay, more or less shaly; of sandstone, usually conglomeratic or even of real conglomerate; and of limestone, occurring in thin and isolated beds* * *. In the Central Mineral Region this formation contains more beds of limestone than in the southern part of north Texas. Farther toward the north the calcareous material diminishes still more, and north of Young County it disappears entirely, or is represented only by irregular nodular masses of earthy limestone in a matrix of clay. With the thinning of the limestone beds, the shales and sandstones gain in thickness toward the north. In the southern part, up to Stephens County, the shales show principally a bluish color and the sandstones are gray; farther north these colors gradually change into red until this color predominates in the vicinity of Red River. There the formation is mainly composed of red or gray sandstone, red clay, and sandy shales with few beds of blue shales and bluish to grayish white sandstone.
>
> The total thickness of the Cisco formation is perhaps about 800 feet both in the central region and in the north; in the extreme northern region the thickness cannot be exactly determined on account of the impossibility of finding a precise division line between the Cisco and the overlying Wichita formation. Both are there lithologically quite similar.

And further:[119]

> The Wichita formation is from 1,000 to 1,500 feet in thickness* * *. The Wichita consists of red, bluish, and gray-white sandstones, red concretionary clays, occasional blue shales, and clay-ball conglomerate. The dominant color is red. To the southwest the Wichita is believed to grade into the marine clays and limestones of the Albany. The Albany clays and shales are blue-black and gray* * *.

Plummer and Moore speak as follows of the Graham formation, the lowest of the formational units into which they have subdivided the Cisco:[120]

> The formation as a whole changes so much in character (southward) from its thick massive sandstones and numerous and varied limestones and shale members in Jack County, to its thin, predominantly calcareous shales and limestone phase in Brown County * * *.

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[118] Udden, J. A., Baker, C. L., and Bose, Emil, Review of the geology of Texas: Univ. of Texas, Bull. 44, p. 44, 1916.

[119] Op. cit., p. 49.

[120] Plummer, F. B. and Moore, R. C., op. cit., p. 126.

and of the Albany-Wichita group:[121]

> There is such a striking difference between the massive, white, escarpment-making limestones and marls of the Permian in the vicinity of Albany and the typical red beds facies of the strata in the Wichita district* * *.

ARE THESE RED BEDS MARINE OR NON-MARINE?

These changes of marine into non-marine sediments culminate in the Ardmore district, in the heart of the Pennsylvanian mountain system. The term "non-marine" is used after full consideration of the arguments of Branson[122] in favor of the hypothesis of marine origin for certain red beds in the Rocky Mountain states; for even according to the diagnostic characters set up by Branson to distinguish marine from non-marine red beds,[123] the Carboniferous red beds of the Ardmore district would be adjudged non-marine by preponderance of evidence. Even bedding is rare. Individual members, to borrow a phrase from Hubbard and Thompson,[124] are "regionally persistent but locally very erratic," insofar as they are persistent at all. In the main, they are poorly sorted, though quantitative data on this point are not available at present. Ripple marks are present, though not especially abundant. Persistent thin beds are rare or absent. No bedded gypsum has been noted. The only limestone is the Hart limestone member of the Pontotoc series, which Birk calls secondary,[125] and which fades out away from the limestone plateau of the Arbuckle Mountains, which seems to have furnished its material. No fossils have been reported except remains of land plants.

The red color is approximately coextensive with the other evidences of non-marine origin. This fact supports the idea that the red color in itself, other things being equal, is evidence of non-marine origin.

Branson says that: "The red color is independent of the question of marine or non-marine origin, and has not been investigated during the writer's studies."[126] He makes no attempt to refute Dorsey's testimony[127] as to the chemical impossibility of extensive marine red beds except where true marine conditions have been temporarily pushed farther off-shore "by a sudden influx of abnormal amounts of continental material."

It should be noted, moreover, that the "marine" conditions under which Branson believes certain western red beds to have

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[121] Plummer, F. B., and Moore, R. C., op. cit., p. 191.

[122] Branson, E. B., Triassic-Jurassic "Red Beds" of the Rocky Mountain region: Jour. Geol., vol. 35, pp. 607-630, 1927.

[123] Op. cit., p. 630.

[124] Hubbard, W. E. and Thompson, W. C., op. cit., p. 457.

[125] See quotation on p. 57.

[126] Branson, E. B., op. cit., p. 628.

[127] Dorsey, Geo. E., op. cit.

been formed were very special ones, radically different from ordinary marine conditions. His "sea" was too saline to support life in appreciable quantity, and it therefore contained, according to his theory, too little organic matter to reduce the red ferric oxide. It was a mediterranean (but not wholly landlocked) sea in an arid climate,—far more arid than that of the present Mediterranean. Not even the modern Red Sea, lying between deserts and receiving very little inflow of fresh water, seems capable of fulfilling Branson's specifications; for its average salinity is only about 25 per cent greater than that of the open ocean, and its color is due not to sediments but to red marine algae.[128]

It is admitted that the Carboniferous red beds of southern Oklahoma and north Texas, above described, grade and dovetail into true marine sediments both to the north and to the south, are locally interbedded with marine sediments, and may be partially marine themselves, especially near their borders; for the volume of red sediments may at certain places and times have been too great for effective reduction by the usual marine agencies. However, there is no evidence whatever for the existence of land barriers at the borders of the area of red sediments, such as could have converted that area, shortly before uplifted on a grand scale, into a mediterranean sea. Such barriers would have had to shift most erratically back and forth to account for the dovetailing of red sediments into typical marine beds. And such a sea would have had an axial mountain chain running through its middle, supplying it with arkosic sediments. The picture is most improbable.

It would appear that this debate over the marine or non-marine origin of red beds is in part at least a question of definition of terms, and of emphasis. Branson admits that part of the Chugwater red beds of Wyoming are non-marine, and describes the rest of them as marine only in a special sense of the word. And on the other hand, all of the advocates of non-marine origin for the bulk of the red beds have admitted that they contained, or might readily contain, marine members.

PALEOGEOGRAPHY OF THE RED BEDS

To summarize, there seems to be no good reason to doubt that the Carboniferous red beds of the Ardmore district are either dominantly or entirely of non-marine origin, although they grade out into marine deposits both to the north and to the south, approximately where the red color disappears. They were formed in large part as gravels, sands and silts of a piedmont alluvial

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[128] Jenkins, J. T., Textbook of oceanography: E. P. Dutton & Co., New York, p. 79, 1920, or later.

plain bordering the Arbuckle-Wichita mountain system on each side. The western Arbuckles, and possibly the rest of the Arbuckle group of ranges also, were worn down in Pontotoc time to a peneplain, above which rose finally only a few monadnocks of pre-Cambrian rock. In and near the modern Wichita Mountains, however, granite and limestone ranges of considerable height and areal extent persisted much longer, probably until after the deposition of the youngest red beds which can possibly be correlated with the Cisco; certainly until after the time of the Cornish sandstone. The Arbuckle and Wichita Mountains, therefore, may conceivably have been the sole source of the Carboniferous red beds of the Ardmore district, including those which overlapped the Arbuckle peneplain.

It is not certain whether or not the Wichita Mountains were ever completely covered by later red beds. Their western extension, the Amarillo Mountains, was so covered; disappearing completely beneath the products of their own disintegration, supplemented by sediments from more persistent highlands at a distance. Arkosic conglomerates in the Fountain and Maroon formations of Colorado and in the Manzano group of northern New Mexico, together with the areal and stratigraphic relations of those formations, testify to the existence of an extensive Pennsylvanian mountain system in those states; which probably persisted into Permian time as a source of sediments, and may have contributed material to the red beds of Oklahoma. The Nemaha Mountains to the north were buried too early to have helped in this respect. The Ouachita Mountain region and the ancient Llanorian upland may have continued to furnish sediments; but, in contrast to the earlier Pennsylvanian rocks, no definite evidence pointing to an eastern source has been described from the red beds of southern Oklahoma. To the southwest, as far as the Pecos Valley in western Texas and southern New Mexico, a persistent Permian basin continued to subside and to accumulate sediments, including great thicknesses of limestone, anhydrite, and salt. The same is true in a minor degree of part of Kansas, on the other side of the Amarillo-Wichita-Arbuckle mountain chain.

METHODS OF CORRELATION IN THE ARDMORE BASIN

The correlations of individual members of the Pennsylvanian formations within the Ardmore basin shown on the accompanying maps (Pls. XVIII to XX), are based primarily upon the actual tracing of outcrops of resistant members, careful observation of the minor variations of such members along the strike, and correlation of long successions of resistant members, aided by thorough structural study. Fossil collections were made from 27 different members, and furnished in many instances valuable confirmation of the results arrived at by other methods; but the study so far made

of these collections has been rather empirical, and in no case has the identification of any stratigraphic member depended upon knowledge of the precise time-range of a species or variety, or group of species. Acknowledgment is due, however, to Girty and Roundy for having first determined the late rather than early Pennsylvanian age of the beds around the Criner Hills, and for having done it on a purely paleontologic basis.

In a sequence like the marine Pennsylvanian of the Ardmore basin, the value of a succession of lithologic types as a basis for correlation within a small area is not open to reasonable question. In the four pre-Pontotoc formations above discussed, use has been made of 63 distinct lithologic members—33 resistant limestones, sandstones, and conglomerates, and 30 intervening shales. Nearly half of the resistant members are limestones ranging in thickness from 4 to 30 feet. Each and every one of the resistant members can be traced for miles along its surface outcrops, and several of them have been mapped along 30 miles or more of outcrops.

With a few exceptions, variations in lithology of any one member along its outcrop are slight in comparison to the change in type from that member to those above and below it. Lithologic characters in the limestone members are fully as persistent as their fossil content. Even though a given lithologic type may be repeated in the section, the grouping of types and the intervals between them are very different in units of the Pennsylvanian section in the Ardmore basin; and these differences persist along the strike throughout the area.

Several of the limestones have lithologic characteristics which are unique in the entire series. In almost all cases, the lithologic distinctions between adjacent members are much more pronounced than the paleontologic differences, and are proportionally more reliable for mapping purposes. Numerous species of invertebrates can be collected from a certain Hoxbar limestone, for instance, at a given point, which cannot be found at all in the same limestone a mile away along the same continuous outcrop; and there is great variation in abundance of fossils along the strike.

Even where continuity of a given lithologic unit can be demonstrated by uninterrupted tracing, it has been denied in some instances that such continuity means contemporaneity of deposition throughout the extent of the unit. However, in an area as small as the Ardmore basin, having 63 distinct stratigraphic units in a definite sequence, each of them continuous over all or a large part of the basin, and including a number of thin limestones, essential contemporaneity of each member throughout its extent is very probable indeed. The situation is similar to that in the Pennsylvanian system of Kansas, in which 43 distinct members, shales alternating with limestones, have been recognized and a majority of the 21 limestones have been carefully mapped along continuous outcrops for more than 100 miles[129].

SUCCESSFUL USE OF LITHOLOGIC CORRELATION IN PETROLEUM GEOLOGY

Lithologic correlation and the tracing of continuous lithologic types are the chief weapons of petroleum geologists in surface exploration for new oil fields. The commercial validity of these methods is proved many times a year by their successful application in the search for petroleum. The value of a field geologist to an oil company depends largely on his skill in lithologic correlation, which depends in turn on his keenness of observation, thoroughness and persistence, and breadth of understanding of sedimentary rocks and their surface alteration. Lithology can be successfully used where paleontology is wholly lacking, and can be used just as successfully hand in hand with paleontology.

INSTANCES OF RELIABLE CORRELATION OVER WIDE AREAS BY MEANS OF LITHOLOGIC SUCCESSION

In some instances, at least, lithologic correlations are paleontologically substantiated over wide regions. The following general sequence holds good through much of the Rocky Mountain region from Montana to Utah, and in part into Arizona.

Jurassic marine shales.

Triassic red beds.

Permian limestones, chert, and phosphatic shales.

Late Pennsylvanian sandstones.

Mississippian and early Pennsylvanian limestones.

Late Devonian (or early Mississippian?) black shales.

Middle Devonian bituminous dolomites.

Although some of the lithologic types in the above list doubtless represent variable stretches of geologic time in different areas, this succession of lithologic types is just as characteristic as the accompanying succession of faunas, and the lithologic types are reliably identifiable in the absence of fossils.

Similarly, certain lithologic elements of the Cretaceous section persist in the same order of sequence from Montana to New Mexico. Whether or not each member is of exactly the same age throughout its extent or not is of little consequence from a structural or economic viewpoint; but the continuity of the types and of their stratigraphic relation to possible oil sands is of prime economic importance.

Practically all areal geologic mapping is done by means of lithologic types. Lithology is the key by which even the paleontologist must trace a bed from the locality of one fossil collection to that of another. Structural and stratigraphic relations had to be known before the first correct paleontologic sequence could be determined.

It is probable that some of the indictments which have been penned by paleontologists against lithologic correlation have not been directed against correlations such as those above cited, based on long sequences of distinctive types, and jumping no wide intervals between continuous exposures. Each specific example of mistaken lithologic correlation cited by Berry[130] in his presidential address before the Paleontological Society of America in 1924 was a long-range correlation based on a single lithologic type only, and each one dated from the nineteenth century.

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[129] Moore, Raymond C. and Haynes, Winthrop P., Oil and gas resources of Kansas: Kansas State Geol. Survey, Bull. 3, table opp. p. 24, and Pls. XXVIII to XXIX, incl., 1917.

[130] Berry, E. W., On correlation: Bull. Geol. Soc. Am., vol. 36, pp. 270-272, 1925.

APPENDIX

FOSSIL LISTS

Lists of fossils reported (up to 1928) from the Pennsylvanian system in the Ardmore basin, arranged in stratigraphic order.

POST-PONTOTOC (CISCO ?)

Fossil leaves Wegemann[155] Near Dixie & Pooleville

(Wegemann & Heald[156] SE SW 4-4S 3W)

Callipteris sp? White
Walchia? gracilis Daws & White
Pecopteris sp? White
Noeggerathis ? White
Neuropteris cf. gleichenioides
Cardicarpon ?

HOXBAR FORMATION

ANADARCHE LIMESTONE

[Girty & Roundy[141] (4060) W SE cor. 27-5S 2E]

Fusulina sp.
Spirifer triplicatus
Squamularia perplexa
Composita subtilita

ANADARCHE LIMESTONE (?)

(Harlton[251] NW cor. 20-5S 1E)

Bairdia hoxbarensis Harlton, n. sp.
Hollina granifera Ulrich
Amphissites centronata Ulrich & Bassler

CRINERVILLE (?) LIMESTONE

[Girty & Roundy[144] (4016) CWL 4-5S 1E]

Pustula nebraskensis
Composita subtilita
Aulacorhynchus millepunctatum
Leda arata
Nucula parva
Deltopecten occidentalis
Myalina swallowi
M. wyomingensis
Pseudomonotis ? aff. equistriata
P. ? sp.
Schizodus meekanus ?
Bucanopsis bella
Goniospira lasallensis
Naticopsis scintilla
N. ? cf. diminutiva
Pseudorthoceras knoxense ?

BIRK'S 'Q' BED (LOWER WESTHEIMER LIMESTONE ?)

Cornuspira involvens Reuss Harlton[149] NW NW NW 12-6S 1E

(Harlton[143] SW SE SE 12-6S 1E)

Ammobaculites rectum H. B. Brady
Cribrostomum jeffersonensis Harlton
Climacammina antiqua H. B. Brady
Archealagena kansasensis Harlton
Tetrataxis decurrens H. B. Brady
Globivalvulina bulloides H. B. Brady
Endothyra bowmani Phillips
E. crassa H. B. Brady
Ammodiscus incertus d'Orbigmy
Healdia boggyensis Harlton n. sp.
Harlton[151] NW. NW. NW. 12-6S 1E.

(Harlton[151] SW SE SE 12-6S 1E)

Cytherella incurvescens Jones & Kirby
Healdia oklahomaensis Harlton n. sp.
H. glennensis Harlton n. sp.
Glyptopleura costata McCoy
Hollina grahamensis Harlton n. sp.

CONFEDERATE LIMESTONE (?) (POSSIBLY UNION DAIRY LIMESTONE)

[Girty & Roundy[142] (4064) CEL NE SE 2-6S 1E]

Crinoid fragments
Echinocrinus sp.
Polypora sp.
Septopora biserialis
Rhombopora lepidodendroides
Derbya crassa
Productus insinuatus
Pustula nebraskensis
Spirifer cameratus
Spiriferina kentuckyensis
Composita subtilita
Sanguinolites costatus ?
Deltopecten occidentalis
Myalina subquadrata
M. kansasensis ?
Pseudomonotis equistriata
Schizodus sp.
Pharkidonotus percarinatus
Bucanopsis meekana ?
Euphemus nodicarinatus
Phanerotrema grayvillense ?
Pleurotomaria sp.
Goniospira lasallensis ?
Naticopsis sp.
Goniatites ? sp.

CONFEDERATE LIMESTONE OR UPPERMOST DEESE

[Girty & Roundy[143] (4065) less than 1/4 mi. N of 4046]

Wewokella solida
Crinoidal fragments
Echinocrinus sp.
Fistulipora carbonaria
Septopora biserialis var. nervata
Rhombopora lepidodendroides
Productus cora
P. insinuatus ?
P. semireticulatus
Pustula nebraskensis
Spirifer triplicatus
Composita subtilita
Allerisma terminale ?
Edmondia aspinwallensis
E. gibbosa
Chaenomya cooperi
Myalina kansasensis
Pinna peracuta
Schizodus affinis
Pharkidonotus percarinatus
Bucanopsis meekana

GOLDSTON'S[148] HOXBAR LISTS

(No locality given)

Fusulina cylindrica
Productus semireticulatus
P. cora
Composita argentea
Spirifer cameratus
Bellerophon sublaevis

DEESE FORMATION

UPPERMOST DEESE (POSSIBLY IN PART CONFEDERATE)

[Girty & Roundy[137] (4050) CEL 32-3S 1E]

Axophyllum rude
Crinoid fragments
Echinocrinus cratis ?
Derbya affinis
Chonetes granulifer
C. mesolobus var. decipiens
Tegulifera ? kansasensis
Pustula nebraskensis
Squamularia perplexa
Composita subtilita
Cliothyridina orbicularis
Edmondia sp.
Nucula anadontoides
Leda bellistriata
Astartella aff. gurleyi
Dentalium semicostatum
Bellerophon stevensianus ?
Trepospira ? sp.
Pleurotomaria sp.
P. sp.
Meekospira peracuta
Pseudorthoceras knoxense

UPPERMOST DEESE (OR BASAL HOXBAR ?)

[Girty & Roundy[140] (4059) Near SE cor. 28-5S 1E]

Septopora biserialis
Rhombopora lepidodendroides
Composita subtilita
Myalina subquadrata
Bellerophon sp.
Phanerotrema ? sp.
Pleurotomaria sp.
Naticopsis sp.
N. ? sp.
Schizostoma catilloides
Aclisina sp.
A. sp.
Zygopleura n. sp.
Cyclonema sp.

UPPER DEESE

Archealagena parkeriana H. B. Brady
Endothyra elegans Harlton
Harlton[149] SE SE SE 3-6S 2E
Harlton[149] CEL SE 20-5S 2E

(Harlton[151] NW NW NW 18-5S 2E)

Bairdia subelongata Jones & Kirkby
B. oklahomaensis Harlton n. sp.
Amphissites dattonensis Harlton n. sp.

ARNOLD LIMESTONE

[Girty & Roundy[138] (4054) N of W ¼ cor. 28-3S 1E]

Productus coloradoensis
Pustula semipunctata
Pustula symmetrica ?

(Harlton[140] ? NW NW NW 18-5S 2E)

Cribrostromum lucilleae Harlton
Endothyra ameradaensis Harlton
Endothyra globulus d'Eichwald
Harlton[149] SW NW 20-5S 2E

(Harlton[150] SW SW NW 20-5S 2E ?)

Bradyina holdenvillensis Harlton
Lituotuba centrifuga H. B. Brady
Globigerina seminolensis Harlton
Harlton[150] (not given)

ABOVE DEVIL'S KITCHEN LIMESTONE

[Girty & Roundy[139] (4058) Bet. 19-20-5S 2E]

Orbiculoides aff. capuliformis
Productus cora
Spirifer rockymontanus
Leda sp.
Deltopecten occidentalis ?
Pteria ohioensis
Pseudomonotis sp.
Schizodus insignis ?
Schizodus sp.
Pleurophorus sp.
Bellerophon ? sp.
Euphemus ? sp.
Phanerotrema ? sp.
Goniospira sp.
Nautilus sp.

(Goldston's 'Deese'[147] (May include some upper Dornick Hills)

Rhombopora lepidodendroides
Stenopora carbonaria
Spirifer condor
S. cameratus
Chonetes verneuilianus
Composita argentea
Productus semireticulatus
Productus cora
Pustula punctata
Spiriferina kentuckyensis
Squamularia perplexa
Marginifera wabashensis
Myalina subquadrata
Pleurophorus subcostatus

DORNICK HILLS FORMATION

PUMPKIN CREEK LIMESTONE (?) (LESTER LIMESTONE ?)

[Girty & Roundy[133] (4035) SW SW 4-3S 1E]

Campophyllum torquium
Crinoidal fragments
Fistulipora sp.
Phractopora sp.
Lingulodiscina illinoisensis ?
Chonetes aff. granulifer
Productus cora
P. coloradoensis
Pustula semipunctata
P. nebraskensis
Marginifera wabashensis
Dielasma bovidens
Spirifer rockymontanus
Spirifer cameratus
Squamularia perplexa
Composita subtilita
Composita n. sp.
Cliothyridina orbicularis
Acanthopecten carboniferus
Pleurotomaria ? sp.
Goniospira sp.
Anomphalus rotulus ?
Platyceras n. sp.
Nautilus ? sp.
Griffithides scitulus
Ostracoda

[Girty & Roundy[134] (40′ below 4035) SW SW 4-3S 1E]

Campophyllum torquium
Lophophyllum profundum
Eupachycrinus tuberculatus ?
Hydreionocrinus acanthophorus
H. Mucrospina
Crinoid stems & plates
Fistulipora sp.
Stenopora carbonaria
Fenestella sp.
Pinnatopora sp.
Polypora sp.
Septopora sp.
Crystodictya aff. carbonaria
Prismopora serrata
Streblotrypa lepidodendroides
Chonetes mesolobus
Productus coloradoensis
P. cora
Pustula nebraskensis
Marginifera wabashensis
Spirifer cameratus
Spiriferina kentuckyensis
Squamularia perplexa
Composita subtilita
Allorisma terminale
Yoldia ? sp.
Myalina swallowi
Schizodus ? sp.
Astartella sp.
Phanerotrema ? sp.
Schizostoma catilloides
Aclisina sp.
Zygopleura sp.
Orthoceras n. sp.

[Girty & Roundy[135] (4055) SW cor. 4-3S 1E]

Campophyllum torquium
Productus coloradoensis
P. cora
Marginifera wabashensis
Spirifer rockymontanus
Composita subtilita
Cliothyridina orbicularis
Pseudomonotis hawni var. equistriata
Pleurotomaria sp.
Orthoceras sp.

Archealagena plummerae Harlton n. sp. Harlton[149] SW SW SE 19-5S 2E

GOLDSTON'S[146] 'CUP CORAL' (MOSTLY PUMPKIN CREEK)

Campophyllum torquium
Axophyllum rude
Fenestella sp.
Composita argentea
Squamularia perplexa
Marginifera wabashensis
Spirifer boonensis
S. cameratus
Chonetes mesolobus
C. granulifer
Meekospira peracuta
Ambocoelia planoconvexa
Dielasma bovidens
Nucula bellistriata
Nucula concentricata
Astartella concentrica
Productus semireticulatus
P. costatus
Pustula symmetrica
P. punctata
Hustedia mormoni
Spiriferina kentuckyensis
Bellerophon crassus
Platyceras sp.
Coloerus sp.
Orthotetes crassus
Euconospira turbiniformis

LESTER (?) OR LOWER PUMPKIN CREEK

(Harlton[149] CEL 9-6S 2E)

Stacheia congesta H. B. Brady
Nodosinella glennensis Harlton n. sp.
Tetrataxis conica var. compressa H. B. Brady
Tetrataxis conica Ehrenberg
Jonesina bradyana Jones & Kirby
Bairdia glennensis Harlton

Nummulostegina ardmorensis
Harlton[149] CEL SE 9-6S 2E
Harlton[149] SW SW 10-6S 2E
Harlton[150] CEL SE 9-6S 2E (?)
Harlton[151] CEL SE 9-6S 2E
Harlton[152] CEL SE 9-6S 2E (?)

JOLLIFF (?) (OR PUMPKIN CREEK ?)

[Girty & Roundy[136] (4063) SL SW 34-4S 1E]

Crinoid stems and plates
Rhipidomella carbonaria
Schizophoria sp.
Chonetes granulifer
C. levis
Productus cora
P. coloradoensis
Pustula semipunctata
P. n. sp.
Spirifer rockymontanus
Squamularia perplexa
Nuculopsis ventricosa
Yoldia aff. stevensoni
Parallelodon tenuistriatum
Euchondria neglecta ?

Lima retifera
Astartella sp.
Bellerophon sp.
Pleurotomaria n. sp. aff. persimplex
P. aff. scitula
P. sp.
Bulimorpha sp.
Sphaerodoma sp.
Platyceras occidentale
Anomphalus rotulus ?
Orthoceras sp.
Nautiloid
Paralegoceras iowense
Goniatites aff. lunatus ?
Gastrioceras aff. nolinense

GOLDSTON'S[145] 'OTTERVILLE'

(Prob. all Dornick Hills; Jolliff, Otterville, and Lester ls. members)

Axophyllum rude
Michelinia eugeneae
Fenestella sp.
Rhombophora lepidodendroides
Hustedia mormoni
Productus cora
P. semireticulatus
Productus punctatus
Composita argentea
Spirifer cameratus

Spirifer boonensis
Marginifera wabashensis
Squamularia perplexa
Spiriferina kentuckyensis
Chaetetes milleporaceus
Leda bellistriata
Abundant, unidentified, gastropods, pelecypods, and cephalopods.

OTTERVILLE LIMESTONE

[Girty & Roundy[132] (4062) SW NE cor. 6-6S 2E]

Cladochonus fragilis
Echinocrinus sp.
Leioclema sp.
Parallelodon pergibbosum ?
Fenestella tenax
Prismopora concava ?
Cystodictya aff. brentwoodensis
Schizophoria aff. resupinoides
Derbya n. sp.
Productus cora
P. aff. inflatus
Pustula nebraskensis ?

Marginifera muricata
Spirifer rockymontanus
Spiriferina kentuckyensis
Composita subtilita
Hustedia mormoni
H. brentwoodensis
Edmondia sp.
Nucula subrotundata
N. parva ?
N. elongata
Leda meekana
L. inflata ?

OTTERVILLE LIMESTONE, CONT'D.

L. n. sp.
L. ? (n. g. ?) n. sp.
Yoldia n. sp.
Anthraconeilo kesslerlana
Aviculopecten aff. occidentalis
A. n. sp.
A. sp.
Myalina orthonotus
Solenomya ? sharonensis
Pleurophorus sp.
Astartella sp.
Laevidentalium sp. ?
Bellerophon crassus
Bucanopsis aff. meekana

Euphemus carbonarius
Phanerotrema n. sp.
P. aff. grayvillense
Pleurotomaria n. sp.
Pleurotomaria n. sp.
P. sp.
Naticopsis nana ?
Schizostoma catilloides
Aclisina sp.
Sphaerodoma sp.
Meekospira peracuta
Orthoceras sp.
Griffithides sp.
Platyceras aff. pulchellum

OTTERVILLE LIMESTONE, OR LOWER

[Harlton[150] NE. cor. 14-5S 1E (?)]

Stacheia pupoides H. B. Brady
Endothyra radiata H. B. Brady

Jonesina craterigera Jones & Kirby

SHALES BETWEEN JOLLIFF AND OTTERVILLE MEMBERS (?)

(Water[154] 30-3S 2E)

Hyperammina gracilis Waters n. sp.
H. gracilis Waters n. sp. var. rugosa Waters n. var.
Nodosinella laheeii Waters n. sp.
N. brevis Waters n. sp.
N. crassa Waters n. sp.
Ammodiscus semiconstrictus Waters n. sp.

A. semiconstrictus var. regularis (Waters n. var.)
Ammolagena contorta Waters n. sp.
Ammobaculites minuta Waters n. sp.
Stacheia subglobosa Waters n. sp.

OTTERVILLE (JOLLIFF ?) LIMESTONE

[Girty & Roundy[131] (4056) CSL 2-3S 2E]

Lophophyllum ? sp.
Cladochonus fragilis ?
Agassizocrinus ? sp.
Delocrinus ? sp.
Rhopalonaria ? sp.
Leioclema n. sp.
Fenestella tenax
Phanerotrema n. sp.
Worthenia ? n. sp.
Productus cora
P. aff. gallatinensis
Pustula symmetrica
Prismopora concava
Cystodictus aff. brentwoodensis
Rhombopora sp.
Schizophoria aff. resupinoides
Chonetes aff. glaber
Productus aff. coloradoensis
Nucula parva ?
N. subrotundata
Nuculopsis ? sp.

Leda meekana
L. inflata
Leda ? (n. g. ?) n. sp.
Yoldia n. sp.
Y. n. sp.
Aviculopecten sp.
Solenomya ? sharonensis
Astartella ? sp.
Naticopsis sp.
Glyptobasis ? n. sp.
Schizostoma catilloides
Meekospira peracuta
Marginifera muricata
Spirifer rockymontanus
Spiriferina aff. spinosa
Composita subtilita
Hustedia mormoni ?
H. brentwoodensis
Edmondia sp.
Cardiomorpha ? sp.
Parallelodon obsoletum

P. sangamonense
Nucula elongata
Pleurotomaria n. sp.
P. n. sp.
Pleurotomaria sp.
Bellerophon crassus ?
Bucanopsis aff. meekana
Euphemus carbonarius
Orthoceras sp.
Nautilus sp.
Goniatites sp.
Griffithides sp.

BASE OF DORNICK HILLS FORMATION (JOLLIFF ?)

(Harlton[149] SW NW NE 16-6S 2E)

Nodosinella ardmorensis Harlton
Ammobaculites powersi Harlton

(Harlton[151] NW NW NE 16-6S 2E)

Cythereis ? ardmorensis Harlton n. sp.
Jonesina arcuata Bean
Healdia overbrookensis Harlton n. sp.
Hollina tricollina Ulrich
Harlton[151] SW NW NE 16-6S 2E

SPRINGER FORMATION

TOP SPRINGER

Hyperammina elongata var. clavatula Howchin Harlton[149] SW NW NE 16-6S 2E
Healdia caneyensis Harlton Harlton[151] SW NW NE 16-6S 2E

PRIMROSE OR LAKE ARDMORE ss.

Haplophragmoides marga Harlton n. sp. Harlton[153] NW SE SE 1-3S 2E

OVERBROOK SANDSTONE ?

Archaelagena adaensis Harlton Harlton[149] ? SW SW SW 25-3S 1E

SOURCES INDICATED BY FOOTNOTE REFERENCES IN THE FOREGOING LISTS

131. Girty, George H., and Roundy, P. V., Notes on the Glenn formation of Oklahoma with consideration of new paleontologic evidence: Bull. Amer. Assoc. Pet. Geol., vol. 7, pp. 331-347, 1923. Station 4056, pp. 342-343: center S. line sec. 2, T. 3 S., R. 2 E. Otterville limestone member. Dornick Hills formation.

132. Ibid., station 4062, p. 343. SW. (or about 600 feet S.) of NE. cor. sec. 6, T. 6 S., R. 2 E. Otterville limestone member, Dornick Hills formation.

133. Ibid., station 4035, p. 344. SW. ¼ SE. ¼ sec. 4, T. 3 S., R. 1 E. Upper part of Dornick Hills formation, probably Pumpkin Creek limestone member but possibly Lester limestone member.

134. Ibid., station 4035-A, p. 344. Same locality but about 40 feet below station 4035. Mainly from shale. Upper part of Dornick Hills formation.

135. Ibid., station 4055, p. 344. Along road a little north of SW. cor. sec. 4, T. 3 S., R. 1. E. Upper part of Dornick Hills formation, probably Pumpkin Creek limestone member.

136. Ibid., station 4063, p. 345. Cen. S. line SE. ¼ SW. ¼ sec. 34, T. 4 S., R. 1 E. Dornick Hills formation, but identity of member in doubt. Possibly Jolliff limestone member.

137. Ibid., station 4050, p. 345. Cen. E. line sec. 32, T. 3 S., R. 1 E. Probably uppermost Deese formation, within 50 feet of base of Confederate limestone member of the Hoxbar formation, and possibly in part from the latter member. Locality described as "center west edge of sec. 32", but that is in red beds, and correct position is indicated by the further comment "about ¾ mile north of Deese, Okla.", which places it on the east line of sec. 32.

138. Ibid., station 4054, p. 345. W line NW¼ sec. 28, T. 3 S., R. 1 E. Arnold limestone member of the Deese formation.

139. Ibid., station 4058, pp. 345-346. 1/10 mile N. of SW. cor. sec. 20, T. 5 S., R. 2 E. Lower middle part of Deese formation, above Devil's Kitchen member.

140. Ibid., station 4059, p. 346, near the SE. cor. sec. 28, T. 5 S., R. 2 E. Uppermost Deese if location is accurate. Could be basal Hoxbar if location were ⅛ mile east of this section corner.

141. Ibid., station 4060, p. 346. Just W. of SE. cor. sec. 27, T. 5 S., R. 2 E. Anadarche limestone member of Hoxbar formation.

142. Ibid., lot 4064, pp. 346-347. Near cen. E. line NE.¼ SE.¼ sec. 2, T. 6 S., R. 1 E. Probably Confederate limestone member of Hoxbar formation; possibly Union Dairy member.

143. Ibid., lot 4065, p. 347. A little less than ¼ mile N. of lot 4064, stratigraphically about 90 feet lower. Probably uppermost Deese; possibly basal Hoxbar.

144. Ibid., lot 4061, p. 347. Near cen. W. line sec. 4, T. 5 S., R. 1 E. Probably Crinerville limestone member of Hoxbar formation.

145. Goldston, W. L. Jr., Differentiation and structure of the Glenn formation: Bull. Amer. Assoc. Pet. Geol., vol. 6, pp. 5-23, 1922. List of fossils from the Otterville limestone member, p. 11, probably includes collections from the Jolliff and Lester limestone members also, as precise localities are not given and Goldston locally mapped these other members as Otterville. However, these collections probably all came from the Dornick Hills formation. (His list from the Springer member, p. 10, is not quoted here because Goldston mapped other Pennsylvanian formations as Springer around the Criner Hills, and does not cite the precise locality of any of his collections.)

146. Ibid., list for the "Cup Coral Member," p. 11. Probably all from the Dornick Hills formation, and mostly from the Pumpkin Creek limestone member.

147. Ibid., list for the "Deese Member", p. 11. May include some collections from the upper part of the Dornick Hills formation, mapped as Deese by Goldston south of Ardmore; otherwise, all from the Deese formation.

148. Ibid., list for the "Hoxbar Member", p. 11. All from the Hoxbar formation, precise horizon unknown.

149. Harlton, Bruce H., Some Pennsylvanian foraminifera of the Glenn formation of southern Oklahoma: Jour. Paleontology, vol. 1, pp. 15-27, 1927.

150. Ibid., but horizon in doubt because of confusion in description of locality. **Bradyina holdenvillensis** (p. 18) and **Globigerina seminolensis** (pp. 24-25) are described as from "SW. ¼ of SW. ¼ of NW. ¼ of sec. 20, T. 5 S., R. 1 E., about 4 miles north of Ardmore," but the section named is 7 miles **southwest** of Ardmore. If the sectional description is relied on, these fossils are from the upper middle part of the Hoxbar formation, above the Anadarche member. It is suspected, however, that sec. 20, T. 5 S., R. **2** E., about 4 miles **south** of Ardmore, was meant; placing these collections in the Deese formation near the horizon of the Arnold ls. member. The locality for **Lituotuba centrifuga** is described merely as a surface outcrop in southern Oklahoma, in the lower part of the Upper Glenn formation. **Tetrataxis conica** is described as collected from a point ¼ mile N. of the SE. cor. sec. 9, T. 5 S., R. 1 E., but it is believed that T. 6 S., R. 2 E. was meant. **Endothyra radiata** and **Stacheia pupoides** are described as coming from the center of the N. line sec. 14, T. 5 S., R. 1 E., which would place them in the upper Springer; but it is suspected that the collection was made nearer to the NE. corner of that section, from the Otterville limestone member of the Dornick Hills formation.

151. Harlton, Bruce H., Some Pennsylvanian ostracoda of the Glenn and Hoxbar formations of southern Oklahoma and of the upper part of the Cisco formation of northern Texas: Jour. Paleontology, vol. 1, pp. 203-218, 1927.

152. Ibid., but horizon in doubt because of confusion in description of locality. **Bairdia hoxbarensis** and **Hollina granifera** are described as coming from a surface outcrop at the NW. cor. sec. 20, T. 5 S., R. 1 E., "about 2 miles south of Ardmore," but the point named is some 7 miles southwest of Ardmore. It is possible that R. 2 E. was meant, but that would throw this collection into the upper part of the Deese formation instead of the Hoxbar. The same sectional description is given for **Amphissites centronata** but is said to be "4½ miles southwest of Ardmore". **Bairdia glennensis** is described as collected from a point "¼ mile N. of SE. ¼ sec. 9, T. 5 S., R. 1 E., about 2 miles south of Ardmore", but the point described is about 5 miles southwest of Ardmore, in upper Deese or basal Hoxbar. It is possible that CEL SE. 9-6S-2E was meant. **Jonesina craterigera** is said to come from center of N. line of sec. 14, T. 5 S., R. 1 E., which would be in the upper part of the Springer formation; but it is suspected that its source was nearer the NE. corner of that section in the Otterville limestone member of the Dornick Hills formation.

153. Harlton, Bruce H. Pennsylvanian foraminifera of Oklahoma and Texas: Jour. Paleontology, vol. 1, pp. 305-310, 1928.

154. Waters, James A., A group of foraminifera from the Dornick Hills formation of the Ardmore basin: Jour. Paleontology, vol. 1, pp. 129-134, 1927. This collection is believed to be from shales between the Jolliff and Otterville limestones, as stated by Waters. The locality is in the NW. ¼ sec. 31, T. 3 S., R. 2 E., instead of in the SE. ¼ sec. 30, T. 3 S., R. 2 E., as stated. (Letter from James A. Waters to C. W. Tomlinson under date of June 6, 1928.)

155. Wegemann, C. H., The Duncan gas field, Stephens County, Oklahoma: U. S. Geol. Survey, Bull. 621-D, p. 45, 1915. "About 25 miles southwest of the Duncan field, in Cotton County, the bones of primitive amphibians have been found, and fossil leaves of Permian age have been collected in the Healdton field and near Dixie (sec. 14, T. 3 S., R. 4 W.) and Pooleville (sec. 34, T. 1 S., R. 2 W., sec. 3, T. 2 S., R. 2 W.) southeast of the Duncan field. In the field itself certain sandstone beds bear the marks of plant stems, but the impressions are so indistinct that the nature of the plants cannot be determined. They are perhaps algae. Some of the thin beds of calcareous sandstone contain also very much broken fragments of shells, among which bits of crinoid stem were recognized." The collection near Pooleville probably came from a horizon not far above the Hart limestone, and may be of Pontotoc age. The one near Dixie came from higher beds, but below the Cornish sandstone.

156. Wegemann, C. H., and Heald, K. C., The Healdton oil field, Carter County, Oklahoma: U. S. Geol. Survey, Bull. 621-B, p. 19, 1915.
SE. ¼ SW.¼ sec. 4, T. 4 S., R. 3 W., in the Healdton field; approximately 100 feet below Cornish sandstone.