LEAD AND ZINC.

MINERAL RESOURCES OF NORTHEASTERN OKLAHOMA.

By C. E. Siebenthal.

INTRODUCTION.

The field reconnaissance on which this report is based was made during June and July, 1907, occupying in all about six weeks. The itinerary comprised two excursions—the first from Miami to Choteau, Claremore, Chelsea, Coodys Bluff, Centralia, and Chetopa; the second from Bluejacket to Coffeyville, Tulsa, Catoosa, Broken Arrow, Mounds, Haskell, Morris, Muskogee, Tahlequah, Choteau, Vinita, and Miami. The object of the reconnaissance was to determine the mutual relations of the Pennsylvanian formations of the Wyandotte, Independence, and Muskogee quadrangles. Incidentally, considerable material bearing on the stratigraphic and economic geology of the area was accumulated. This material is brought together here and summarized with all available data from other sources, in order to satisfy as best it may, until detailed surveys are made, the demand for information concerning this part of the new State.

GEOGRAPHY.

The area covered by the accompanying map (Pl. II) is 83 miles broad from east to west and 104 miles in length from north to south. It includes the northeastern portion of the Creek Nation, practically the whole of the Cherokee Nation, and all of the seven small reservations in northeastern Oklahoma, viz, the Seneca, Wyandotte, Ottawa, Shawnee, Modoc, Peoria, and Quapaw.

The topographic maps of the Five Tribes Survey were available for the region and, though somewhat out of date as regards culture, were adequate for the purposes of the reconnaissance. The region is embraced in nine 30-minute quadrangles—the Wyandotte, Vinita, Nowata, Claremore, Pryor, Siloam Springs, Tahlequah, Muskogee, and Okmulgee—also including a portion of the Nuyaka quadrangle.

The Wyandotte quadrangle has been recently surveyed topographically and geologically, and the report is now in course of preparation, a summary of the principal geologic features being incorporated herein. The Siloam Springs quadrangle was touched by this reconnaissance on the northwest and southwest corners only. The geology of the Tahlequah and Muskogee quadrangles is described in detail in the geologic folios on those areas by Joseph A. Taff, and has been summarized on the accompanying map for the purpose of showing the relation of the geologic structure in that section to the structure in the northeastern portion of the region.

In addition to this detailed geologic mapping, there have been several previous reconnaissances. Drake [a] in 1897 published a paper dealing particularly with the coal fields of Indian Territory, but embodying a map and a general description of the geology. Adams [b] in 1901 gave a preliminary account of the geology and development of the Kansas-Oklahoma oil and gas field, with an accompanying geologic map of the area. The same author [c] in 1903 correlated and described various limestone beds in the Cherokee and Osage nations and delineated their outcrop on a map. Taff [d] in 1905 described the coal measures of the Indian Territory and gave two maps, one covering approximately the area shown on the map accompanying this report; the other covering the area adjoining it on the south, showing the main coal fields of the State and based in large part on the detailed folio mapping of those fields. Taff and Shaler [e] in 1905 gave a brief description of a small oil field near Muskogee, with an account of the geologic column and the general structure.

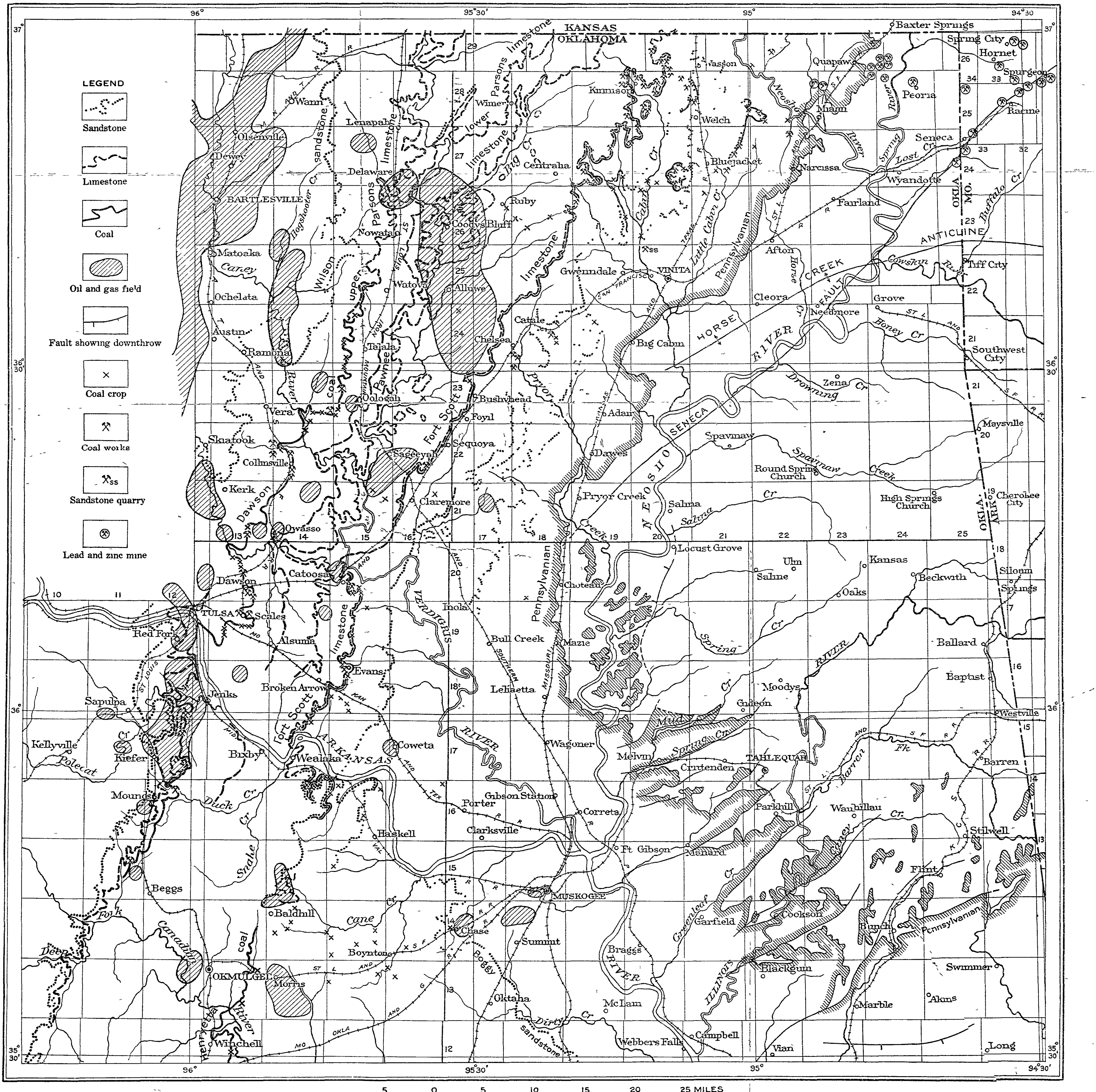
The map accompanying the present report contains considerably more detail than others which have preceded it covering the same territory, and is designed to supplant them. In studying the distribution of the geologic formations or the structure of the west border of the Ozark uplift, it will be found helpful to use this map in connection with Pl. I of Bulletin No. 260, both having the same scale and joining along the parallel of 35° 30′.

STRATIGRAPHY.

ORDOVICIAN ROCKS.

The Ordovician rocks outcrop only in the valleys of the larger streams that dissect this part of the Ozark uplift, and in general only where local elevations bring them within reach of the drainage. In the Tahlequah quadrangle they are exposed in the valleys of Barren Fork and Illinois River. They are there made up of the Burgen

[a] Drake, N. F., Proc. Am. Phil. Soc., vol. 36, 1897, pp. 226–419.
[b] Adams, G. I., Bull. U. S. Geol. Survey No. 184, 1901, pp. 5–28.
[c] Bull. U. S. Geol. Survey No. 211, 1903, pp. 61–65.
[d] Taff, J. A., Bull. U. S. Geol. Survey No. 260, 1905, pp. 382–401.
[e] Taff, J. A., and Shaler, M. K., Bull. U. S. Geol. Survey No. 260, 1905, pp. 441–445.



GEOLOGIC SKETCH MAP OF NORTHEASTERN OKLAHOMA sandstone, 100 feet thick, overlain by the Tyner formation, which consists of shale with subordinate limestone and sandstone, the whole 60 to 100 feet in thickness. What is presumably the Tyner formation is exposed in the bottom of Spring Creek 10 miles above the mouth. In the vicinity of Spavinaw dolomites and fossiliferous cherts are exposed in an area about a mile long, which has been described by Drake.[a] According to Ulrich the fossils show the age of these rocks to be the same as that of the Jefferson City formation. The Ordovician sediments at this locality are intruded by a dike of reddish granitic rock, 75 feet or more in width, and probably 1,800 feet in length. Drake reports also an exposure of Ordovician rocks on Illinois River extending downstream from the Arkansas line for a distance of about 12 miles. He states that the thickness exposed here, as at Spavinaw, is about 200 feet. Similar dolomites and magnesian limestones with oolitic opalescent chert lenses outcrop in the Wyandotte quadrangle in the bluff of Neosho River,[b] 4 miles above the mouth of Cowskin River. From 10 to 13 feet of the formation is shown above low water. Where the Horse Creek anticline crosses Buffalo Creek, 3 miles above Tiff City, it brings to the surface 26 feet of the Ordovician rocks, consisting of dolomite with a little chert, in some places oolitic. Both the Neosho River and Buffalo Creek exposures are nonfossiliferous.

SILURIAN ROCKS.

The only rocks of Silurian age in the area here discussed are found in the southern part of the Tahlequah quadrangle, and have been described by Taff in the Tahlequah folio as the St. Clair marble.

DEVONIAN ROCKS.

The Chattanooga shale is exposed in almost all the deeper stream valleys between Tahlequah and Cowskin River. In the east bluff of Neosho River, 3 miles above the mouth of Cowskin River, the thickness is 26 feet; on Buffalo Creek it is 20 feet, at Southwest City 50 feet, at the mouth of Honey Creek 83 feet, and at Spavinaw 90 feet. On Spring Creek 25 feet, not the full thickness, was noted. Taff reports the thickness in the northern part of the Tahlequah quadrangle as 40 feet, and in the southern part as 20 feet.

The Sylamore sandstone member, which reaches a thickness of 20 to 30 feet in the Tahlequah quadrangle, does not appear in the Spavinaw region. On Buffalo Creek a thin bed of sandstone with a maximum thickness of 4 inches intervenes between the Ordovician rocks and the Chattanooga shale, and is tentatively referred to the Sylamore member.

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[a] Proc. Am. Phil. Soc., vol. 36, 1897, p. 343.

[b] This river is mapped as the Neosho in accordance with a decision of the United States Geographic Board. The portion below Spring River is known locally as Grand River.

CARBONIFEROUS ROCKS.

MISSISSIPPIAN SERIES.

The Boone formation is made up of an alternating series of limestones and cherts, approximately 300 to 350 feet in thickness where fully developed. It forms the surface rock over by far the largest part of the area of Mississippian rocks. At the base of the formation there is always present a limestone member, consisting at the top of a heavy ledge of coarsely crystalline encrinital limestone, or marble, which is usually 10 to 15 feet in thickness. This bed is separated by several feet of shaly limestone from a lower ledge of flaggy limestone, locally rather cherty and in many places irregularly bedded, which lies upon the Chattanooga shale. The upper ledge usually outcrops as a smooth, wall-like bluff, from which large blocks, the full thickness of the ledge, break away. It has been correlated with the St. Joe limestone member in the Tahlequah and Fayetteville folios. This limestone is normally overlain by a series of dark limestones and cherts from 50 to 80 feet thick. Above these, to the top of the formation, are lighter colored cherts and limestones, with one or more massive ledges of limestone 10 to 20 feet in thickness. The Short Creek oolite member, noted in the Joplin district, is found in the east half of the Wyandotte quadrangle wherever its horizon is exposed, though west of Spring and Neosho rivers it usually pinches out or loses its oolitic character.

The Chester group outcrops in a strip several miles wide inside the border of the Mississippian area. In the southern part the Fayetteville formation and the Wedington member are represented, but in the Wyandotte quadrangle the group comprises the Batesville, Fayetteville (with its Wedington member), and Pitkin formations. These are persistent formations northward almost to the Kansas line, but in the area which has been subject to underground solution they occur chiefly in patches occupying solution depressions or ancient sink holes.

PENNSYLVANIAN SERIES.

Correlation of the Cherokee formation.—The Cherokee formation as defined by the Kansas geologists, includes all the various shales and sandstones in southeastern Kansas which lie between the base of the Pennsylvanian and the Fort Scott limestone. This limestone, as will be noted on the map, has been traced from a point near Chetopa, Kans., to and beyond Arkansas River. Here, in Concharty Mountain, the limestone is overlain by a bed of sandstone, the cap rock of the mountain, and underlain by a bed of coal. The sandstone strikes off southwestward, extending nearly to Baldhill. The Henryetta coal sets in a few miles south of Baldhill, in the same line of strike, and is probably the equivalent of the coal below the Fort Scott that is mined at Evans, Catoosa, and many other points to the northeast. The Henryetta coal has been traced by Taff and Shaler for many miles to the southwest, outcropping beneath a prominent escarpment of sandstone, apparently the equivalent of the Calvin sandstone of the Coalgate quadrangle. Beneath the Calvin sandstone the following formations, with the thickness indicated, outcrop successively toward the east along the parallel of 35°: Senora sandstone, 500 feet; Stuart shale, 275 feet; Thurman sandstone, 250 feet; Boggy formation, 1,200–2,000 feet; Savanna sandstone, 1,150 feet; and McAlester shale, 2,000 feet. Beneath the McAlester, in the Atoka quadrangle to the south, lie the Hartshorne sandstone, 200 feet thick, and the Atoka, 3,000 feet. This 9,000+ feet of Pennsylvanian shales and sandstones is represented at the Kansas line by a thickness of but 500 feet of Cherokee. There is a pronounced thinning of these formations both northward and southwestward from the vicinity of Canadian River, where there was apparently a basin in which the deposits were much heavier than elsewhere. As described by Taff the formations from the McAlester to the Senora inclusive decrease in thickness 50 per cent in passing from east to west across the Coalgate quadrangle. To the north a similar thinning takes place, but in addition there has been a warping of the west end of the Ozark dome, which resulted in the transgression and overlap of the later formations upon the older ones. This is shown by the pinching out of the Savanna formation just south of the area shown on the accompanying map (see Bulletin No. 260, Pl. I, p. 382) and by the discordance of the strike of the Boggy formation with that of the Fort Scott limestone and overlying formations. The base of the Boggy formation, traced northwestward, strikes Arkansas River 6 or 7 miles below Haskell. On the north side of the river the topography is gentle and the stratigraphy is partly concealed by heavy deposits of silt and sand that have been blown up from the Arkansas bottoms in the dry season by the prevailing southwest winds. As well as may be judged, however, the strike swings to the northeast in alignment with the strike of the overlying formations. This would locate the beginning of the warping of the uplift in the period between the Winslow and the Boggy and would account for the cutting out of the outcrop of the Savanna formation. The continuation of the sandstone and the shales of the Winslow beneath the overlapping formations would naturally be sought in the line of strike of the present outcrop of those rocks. Because of the probable curvature of the shore line of the uplift, the buried extension of the Winslow should be expected somewhere between Chelsea, Nowata, and Coffeyville, Kans. In this connection there arises an interesting speculation as to the relation of these buried Winslow sandstones to the oil sands of the Alluwe-Coodys Bluff field, which will be considered elsewhere, in the discussion of the oil fields.

The Cherokee formation is thus apparently the equivalent of the various formations from the Boggy to the Senora inclusive, though it may be that the upper formations overlap a portion of the Boggy, and that the Cherokee represents only the upper portion of the Boggy together with the overlying formations. The question can be settled only by detailed work in the region involved.

Fort Scott limestone.—The distribution of the Fort Scott limestone has been considered to some extent in the preceding discussion. In the Kansas reports it was at first called the Oswego limestone and it is known by that name to most drillers in the Midcontinent field. In the type locality, at Fort Scott, Kans., it consists of two beds of limestone separated by 7 feet of very dark shale. The upper limestone is from 10 to 14 feet thick, and the lower one, which is the rock used for hydraulic cement, is 4½ feet thick. Below the lower limestone there is black shale for a few feet, underlain by a bed of coal, 18 to 22 inches thick. This bed has been mined considerably in the vicinity of Fort Scott and in the Kansas reports is called the Fort Scott coal. Though in reality classed in the Cherokee formation, it has been at times more or less loosely included with the Fort Scott. As shown in the section on coal (p. 215), the bed which is extensively stripped east of Centralia lies between two limestones of the Fort Scott formation. Toward the north, however, the lower of the two limestones disappears, leaving the coal beneath all the limestone, and thus in the same position as the Fort Scott coal. This indicates a possibility that the dark shale and the coal beneath the Fort Scott formation should, in reality, be included in that formation.

In the vicinity of Coodys Bluff the Fort Scott is about 115 feet thick and consists of four limestone beds separated by shale. The limestone beds, from the top down, are respectively 10, 40, 10, and 8 feet thick and the intervening shales 5, 10, and 35 feet thick. At Sageeyah, as shown by the drill, a bed of coal comes in between the two limestones which make up the formation and outcrops in the escarpment to the east. At Catoosa, according to the drill record, the formation has a thickness of 154 feet, comprising six beds of limestone with intervening layers of shale and two beds of coal. To the south some of the beds of limestone disappear, and the intervening shales become sandy or give place to sandsone. A drill log shows that near Broken Arrow the formation has a thickness of 130 feet and contains two thin beds of limestone, one at the top and the other at the bottom. A thin bed of coal occurs just below the upper limestone and another one just below the lower limestone. The lower coal is taken to be the coal mined at Evans, 4 miles east of Broken

Arrow. The sandstone in the middle of the formation becomes more prominent south of Arkansas River, and forms the cap rock of Concharty Mountain, in the northern and eastern bluffs of which the lower limestone is exposed, underlain by coal. The extension of the formation beyond Concharty Mountain has already been considered.

Labette shale.—At the Kansas-Oklahoma line, according to the Kansas geologists, the Pawnee limestone is separated from the Fort Scott limestone by the Labette shale, which there has a thickness of only a few feet, though farther north in Kansas it is 60 feet thick, and to the south it increases to more than 200 feet. In the vicinity of Coodys Bluff and farther south a bed of massive fine-grained buff sandstone 15 to 50 feet thick is included in the upper portion of the shale.

Pawnee limestone.—The Pawnee limestone, generally known as the "big lime" by drillers, is the lower member of the formation which has been called the Oologah limestone. Its thickness ranges from 25 to 45 or 50 feet on the outcrop, but is reported to reach 80 to 100 feet in drill holes, possibly owing to confusion with some overlying or underlying bed of limestone. In many places it splits up into two or more beds separated by shale members, as exemplified in the section of the bluff east of Nowata, given on page 221, in the discussion of cement materials. Considerable white to light-buff spongy chert is included in the upper part of the limestone and forms a residual mantle over the surface. This part of the formation is especially apt to be massive and to form a perpendicular cliff from which large rectangular blocks from 10 to 25 feet in dimensions break off. The Pawnee makes a prominent escarpment along the west bluff of Big Creek and Verdigris River from the Kansas line to Catoosa and caps the high ridge from that point to Broken Arrow, beyond which it becomes thinner and difficult to trace.

Bandera shale.—The Pawnee limestone is separated from the Parsons formation above by a bed of shale, known as the Bandera formation in Kansas and there ranging from 50 to more than 140 feet in thickness. Near Coffeyville, Kans., it is shown by drill records to be 135 feet thick, and at Wimer, Okla., its thickness must be more than 100 feet. Southwestward it thins rapidly, and in the vicinity of Delaware, Nowata, Oologah, and Collinsville is but 10 or 20 feet thick. As well as can be made out from the available drill records, the shale disappears altogether in the vicinity of Owasso, and is absent from that place westward, allowing the lower limestone of the Parsons to rest directly upon the Pawnee. Between Tulsa and Catoosa, however, the shale thickens up and the two limestones are again separated by an interval of 100 feet. To the southwest the interval is as great or greater, though the correlation in that direction is not very satisfactory.

Parsons formation.—The Parsons formation is made up of two limestone beds separated by a shale member.

Drake proposed the name Oologah for the limestone outcropping in the vicinity of the town of that name. Adams[a] quoted Bennett as recognizing that there are two limestones at Oologah, the upper one of which he determined to be the equivalent of the lower limestone of the Parsons. The lower Oologah limestone, as already shown, is to be correlated with the Pawnee limestone.

The lower limestone of the Parsons has a thickness of 15 to 30 feet. It is a bluish, fine-grained crystalline limestone with considerable chert which weathers out and mantles the surface. South of the Kansas line this limestone caps the escarpment parallel to the outcrop of the Pawnee limestone along Big Creek and from 2 to 3 miles west of it. It crops out at the base of the hills on the east side of Verdigris River from Coffeyville to a point opposite Lenapah, where it crosses the river and gradually rises in the west bluffs until, in the vicinity of Nowata, it covers the tops of the hills of which the Pawnee forms the east escarpment. This relative position persists through Talala and Oologah to the vicinity of Owasso. South of Owasso the limestone spreads out along the valley of Mingo Creek to a point west of Broken Arrow, where it becomes inconspicuous. South of Arkansas River the lower limestone of the Parsons seems to be represented by the thin bed of calcareous claystone with lumps of blue limestone, weathering yellow, which crops out in the ridge 1½ miles west of Bixby and becomes more prominent in the vicinity of Duck Creek, 5 miles southwest of Bixby.

The middle member of the Parsons formation is a sandy shale 55 feet in thickness at the State line southeast of Coffeyville. It thickens to 130 feet at Nowata, and continues to increase in thickness to the south. West of Watova the Dawson coal sets in 100 feet below the upper limestone, and, as shown on the map, is traced to and beyond Mounds. In a drill hole 6 miles west of Broken Arrow the shale has a thickness below the coal of approximately 500 feet.

The upper limestone of the Parsons in Oklahoma has a thickness of 15 to 20 feet, and is a bluish, densely crystalline, clinky limestone with light blotches, which weather out as opaque white cherty lumps, in places thickly distributed through the residual clay. The formation is typically exposed in the quarry at the rock crusher 2 miles north of Lenapah. Farther south it has a broad outcrop east of the railway, extending to Delaware, beyond which it forms a low escarpment on the west side of the railway. At Nowata, where the member is 20 feet in thickness, the lower part consists of earthy encrinital limestone, the middle part is shaly, and the upper part is earthy limestone weathering into pebbly lumps. A thin limestone representing

[a] Adams, G. I., Bull. U. S. Geol. Survey No. 211, 1903, p. 62.

this member caps the hill 2 miles northwest of Watova. Beyond this point no more is seen of the limestone until the vicinity of Tulsa is reached. Southwest of Tulsa, according to Taff,[a] limestone which weathers yellow lies about 100 feet above the Dawson coal in the vicinity of Mounds and elsewhere, as shown on the accompanying map. This bed, in all probability, is a continuation of the upper Parsons limestone.

Drum limestone.—The Drum limestone outcrops with a thickness of 22 feet on the point of the ridge at the State line 3 miles southwest of Coffeyville, Kans., and extends westward adjacent to the State line for about 4 miles, to a point where it thins out and disappears. It does not outcrop at a corresponding elevation on the south side of Opossum Creek and was not identified elsewhere. Limestone outcrops in the valley of Opossum Creek on the headwater streams of Hickory and California creeks, but it is believed to belong to the Coffeyville formation, which lies between the Drum and the Parsons and, though in the main a sandstone and shale formation, carries some lentils of limestone.

Wilson formation.—The Wilson formation consists of the sandstones and shales which make up most of the western part of the broad ridge between Verdigris and Caney rivers. The crest of the ridge is formed by a bed of sandstone that appears as a fairly conspicuous escarpment from the Kansas line to the point where it crosses Arkansas River, 7 or 8 miles above Tulsa. This outcrop is outlined on the map (Pl. II) because it is easily traced and not because it marks the eastern limit of the formation, as do the other boundary lines here shown. The sandstone which forms the prominent escarpment west of Mounds and stretches away to the southwest occupies an analogous position above the Dawson coal and the upper limestone of the Parsons and apparently belongs to the Wilson formation, though possibly it should be correlated with some of the sandy members of the Coffeyville formation.

The Piqua limestone is the uppermost member of the Wilson formation. It outcrops at the base of several outliers of the Buxton formation on the Kansas line, due north of Wann, and also 3 miles northwest of that place. It is reported to be only 1 or 2 feet in thickness at the State line, but apparently thickens toward the south. As pointed out elsewhere, it is believed to be the limestone in use at the Portland cement plant at Dewey.

Buxton formation.—The Buxton is a shale and sandstone formation which occurs in the outliers above mentioned and forms the prominent sandstone escarpment that closely parallels the meridian of 96° from the Kansas line southward to the vicinity of Ramona and veers west of south from that locality to Arkansas River.

[a] Taff, J. A., Bull. U. S. Geol. Survey No. 260, 1903, p. 396.

STRUCTURE.

THE OZARK UPLIFT.

The area under consideration embraces the extreme southwestern prolongation of the Ozark dome. Along the southern limit of the area of Mississippian rocks, as shown on the map, the gentle southwestward dip of the attenuated uplift changes to a more pronounced dip to the southeast and south, and shows here and there the characteristics of a definite monoclinal fold. This feature is strengthened toward the east, in Arkansas, and, together with parallel faults having a southward downthrow, serves to limit the plateau of the Boston Mountains on the south, as pointed out by Newsom.[a]

WARPING.

As has been remarked in the section on the correlation of the Cherokee formation, the discordance of strike of the Winslow, Savanna, and Boggy with the Fort Scott and overlying formations shows a warping of the west end of the Ozark uplift somewhere in the period between the close of the Winslow deposition and the early part of the Cherokee. The southern portion was elevated, crowding the shore line far to the southwest, while the northern portion was depressed, allowing the sea to advance to the east. The northeast-southwest orientation of the shore line was well established early in Cherokee time, and this relative attitude was maintained through the remainder of the Pennsylvanian, the various formations of this age outcropping in this region in lines parallel to the Fort Scott limestone, with gentle northwesterly dips ranging from 30 feet per mile in the northern portion of the area to 50 feet in the southern portion.

FOLDING AND FAULTING.

The folds and faults of the area are so closely related that their joint discussion seems preferable.

The axis of that part of the Ozark uplift included in Oklahoma trends from northeast to southwest, and the margin of the uplift is serrated by an interesting system of parallel normal faults, which Taff has described in the Tahlequah and Muskogee folios. These faults trend parallel to the axis of the uplift, and at either end usually develop into monoclines or asymmetric anticlines and gradually die out. An inspection of the map will show the close relation of the minor drainage to the faults. Northwest of Tahlequah the parallelism of the faults is not so pronounced and the system is somewhat complicated by intersecting cross faults. These faults are

[a] Newsom, J. F., Am. Geologist, vol. 20, July, 1897.

of post-Winslow age, but no relation to later formations can be established.

Extending southward from Locust Grove is a prominent fault with the downthrow to the west, which brings the Chester down to a level 100 to 150 feet lower than the top of the Boone chert hills immediately east.

The next prominent structural feature toward the north is the Seneca fault, which extends from a point midway between Choteau and Pryor Creek to a point several miles northeast of Spurgeon, beyond the limits of the area shown on the accompanying map, having an almost due northeast course parallel to the main axis of the uplift and roughly parallel to its northwest margin. This fault is double and in places multiple, letting down a long, narrow block of Boone, Chester, and overlying rocks into the Boone formation. In addition to the downthrown block, the strata for some distance, in places for a mile or two on either side, dip toward the fault. This combination has had a strong influence on the drainage, as may be seen from the map. From Seneca toward the northeast the fault closely follows the valley of Lost Creek. South of Seneca it crosses the divide to Sycamore Creek and follows down that valley to Neosho River. From the mouth of Sycamore Creek the fault cuts across the various meanders of Neosho River to a point just above the mouth of Spavinaw Creek. Southwest of this point it traverses the flat upland to and beyond Pryor Creek. Near the Neosho, where the rocks on either side are the cherty limestones of the Boone formation, it is easy to trace the down-dropped strip of Chester consisting of limestone and sandstone. Farther to the southwest, where the Chester formations become the prevailing surface rocks, the fault is difficult to follow. In the Pennsylvanian area it is quite impossible to trace the fault, but whether this is due to its absence, to the uniformity of the rocks, or to the concealment of the faulted Winslow by the overlapping Cherokee was not determined. If the last explanation is correct, as is quite likely, the fault is post-Winslow and pre-Cherokee and probably of the same age as the parallel faults of the Tahlequah-Muskogee region and as the warping to which all the faults are with little doubt genetically related. Owing to the fact that the amount of throw is variable within short distances along the fault and to the further fact that the fault line coincides so closely with the drainage lines, the Chester formations are preserved but here and there along the fault.

The intersections of this fault line with the meanders of Neosho River afford many fine cross sections of the faulted area. The width of the down-dropped block ranges from less than 200 feet to more than 1,500 feet. The fault ranges in character from a simple pair of opposed breaks with the downthrown block between them, and with the strata of the wall rock on either side dipping more or less steeply toward the faulted block, to a sort of faulted syncline, the limbs of which are made up of distributive faults with the cumulative downthrow toward the axis of the syncline. The best view of the latter phase is shown in the west bluff of the Neosho opposite the mouth of Cowskin River, where the south limb dips from 2° to 5° N., the angle increasing toward the axis, and shows four distinct dislocations, one being opposed to the other three, but leaving a resultant throw of 14 feet to the north. On the north side there is a faulted zone 55 feet wide in which there is an upthrow of 18 feet, but this is more than counterbalanced by three small faults and one with a throw of 22 feet to the south, and by the southerly dip of 2° some distance from the fault and of 11° adjacent to the fault.

The amount of displacement on either side of the block varies from place to place. In the west bluff of Neosho River 2 miles below the mouth of Horse Creek it is more than 90 feet. At the Becker mines, south of Seneca, it is from 100 to 140 feet. Between Seneca and Spurgeon it must be as much as 100 feet in many places, for it serves to bring the Chester formations down to the level of the valley, though the Boone forms the top of the hills on either side.

The Horse Creek anticline is an asymmetric fold which starts at a point on Cabin Creek, 5 miles southeast of Big Cabin station and trends east-northeastward by Cleora to the mouth of Cowskin River, where it intersects the Seneca fault. East of this point it swings a little more eastward to the vicinity of Tiff City, where it trends nearly due east for 10 miles and farther east gradually dies out. The anticline has a gently sloping northern limb and a steeper southern limb. To the south of the anticline and parallel to it is a long, low synclinal trough beyond which the strata rise again to the south, with a gentle incline. The average dip of the northern limb of the anticline is about 2°; the dip of the southern limb ranges from 5° to 18°. West of Neosho River the fold expresses itself topographically in an abrupt faultlike escarpment to the south and a low upland slope to the north. East of the Neosho the anticline is cut through on either side by many short, steep hollows, and forms the greatly dissected highland known as the Seneca Hills. In places, notably where the fold is cut through by Neosho River, the rocks lie nearly flat, but where it is crossed by Buffalo Creek and Horse Creek the dip is about 5° SE. About 2 miles west of Horse Creek Gap the dip is 18° SE. For the most part the dip of the southern limb is concealed by débris washed down from the steep slope, and can be made out only in exceptional places. It is entirely possible that for short distances along the axis west of Horse Creek the anticline may break down into small faults. Though cut across in several places by streams, this fold is nowhere breached parallel to the axis, a fact due doubtless to its monoclinal nature.

The Owasso dome lies 2 miles west of Owasso, partly in sec. 26 and partly in sec. 35 of T. 21 N., R. 13 E. One of the upper beds of the lower limestone of the Parsons formation swells up in a perfect low dome, nearly circular in outline and about three-fourths of a mile in diameter. The center of the dome has an elevation 50 feet higher than the rim, and the limestone beds conform in shape to the surface of the uplift. It is possible, however, that the quaquaversal structure extends for some distance beyond the limestone all about the dome, but is concealed owing to the lack of outcrop.

UNDERGROUND SOLUTION.

The effects of solution, which are so prominent in the Joplin mining region,[a] are here limited chiefly to a small area in the northeast corner of the territory covered by the accompanying map, occurring altogether northeast of a line drawn through Miami, Wyandotte, and Tiff City. This line is fairly parallel to the eastern margin of the Winslow formation, a parallelism which is doubtless due to their common relation to the Winslow shore line. After the close of Winslow deposition each margin retreated from the original shore line with the progress of erosion, the margin of the Winslow retreating seaward through simple erosion of its outcrop, and the margin of the area affected by underground solution retreating landward through the effacement of the shallow coast sink holes in the degradation of the surface. As a structural process, underground solution deserves consideration here chiefly because of its inseparable connection with the ore deposits of the area which it affects. In the rest of the region the contact of the Pennsylvanian with the Mississippian is that of a simple erosional unconformity; in this area it is a solution unconformity in which the results of erosion are complicated by the effects of underground solution. Advancing over the sink-hole topography of the Mississippian land, the Cherokee sea filled up the valleys and sink holes with various sediments. After the erosion of the Pennsylvanian the shales and sandstones filling the depressions were left as outliers of various shapes and sizes, forming the solution patches referred to in the description of the ore deposits.

BRECCIAS.

A basal breccia was formed where the later shale formations were deposited upon and in the residuum which mantled the surface and in part filled the caverns of the limestone land that was subject to underground solution. Such breccias, also called "mixed" or "confused" ground, are the loci of ore deposition in many places.

[a] See Geologic Atlas U. S., Joplin district folio (No. 148), 1907.

Locally a chert member of the Boone, with thin interstratified limestone strata, was finely shattered by warping or other tension, the more elastic limestone escaping brecciation. On being recemented in place this rock formed a sheet breccia. When the limestone was replaced later by ore and ore-bearing jasperoid, it became "sheet ground." Though important in the Joplin district, sheet ground was apparently not extensively developed in this area.

When the interbedded limestone in such a series was dissolved, but not replaced, it allowed the chert to settle irregularly, resulting in strong brecciation, in many places completely obscuring the bedding. Shale may have been carried into the openings or they may have been filled with ore or jasperoid. A horizontal tabular body of breccia, which differs in origin and in form from the sheet breccias, was thus developed. Such a formation may be called a blanket breccia. The lead and zinc ore in the Quapaw district is generally found in a breccia of this kind. In the "sheet ground" of the Joplin district the characteristic thing is the occurrence of sheets of ore and jasperoid between the ledges of chert. In the Quapaw district, however, sheets as much as a few feet in length are extremely rare, the ore being generally disseminated through the breccia. In distinction from the "sheet ground" deposits in the sheet breccias, the Quapaw ore bodies in the blanket breccias may be called "blanket ground," the term "blanket vein" comprehending both classes. Zonal breccias, after the type described as occurring in the Joplin district, have been observed in the area here considered, but are not important structurally or economically. Fault breccias were developed by the faulting which has been described as occurring around the margin of the uplift, but only in the regions affected by underground solution has siliceous cementation rendered them prominent or ore deposition rendered them important. The breccias of this kind to be considered, therefore, are limited to those associated with the Seneca fault. Typical examples occur at the mines on Sycamore Creek; at the Becker mines, southwest of Seneca; in the south bluff of Lost Creek at Seneca; and in general on each side of the Seneca fault block from Seneca northeastward to and beyond Spurgeon.

MINERAL RESOURCES.

LEAD AND ZINC DEPOSITS.

GENERAL CONDITIONS.

The workable deposits of lead and zinc ores, so far as at present known, are limited to the northeastern corner of the region here discussed, the area in which they occur being entirely within the Wyandotte quadrangle and coincident with the territory which was subject to underground solution. They are found mainly in the chert breccias in the Boone formation, but also to a considerable extent in sandstone breccias in the Chester, particularly in the new Miami district. More or less limestone and shale are included in the breccias, incorporated either at the time of their formation or since. The ores are galena ("lead") and sphalerite ("jack") with a relatively small amount of smithsonite and calamine (both known as "silicate"). The associated or gangue materials are jasperoid, which occurs as a fine-grained gray to black siliceous rock cementing the breccia, pyrite ("mundic"), calcite ("tiff"), and dolomite ("spar").

The districts where mining has been carried on, or where the indications have encouraged extensive prospecting, arranged chronologically, are the Peoria, Sycamore Creek, Quapaw, and Miami. In the following pages mines typifying the different classes of ore bodies are described somewhat fully under each of these districts, the other mines being mentioned but briefly or entirely omitted.

The ore bodies have various forms, depending on the structural features of the associated rocks. In basal, zonal, and fault breccias there are "runs" and, though rarely in this area, "circles." Sheet breccias, carrying "sheet ground" deposits, so prominent in the Joplin district, have not as yet been discovered in Oklahoma. Blanket breccias, with "blanket ground" deposits, are the main source of ore, being especially well displayed in the Quapaw district.

PEORIA DISTRICT.

General description.—The mines at Peoria were opened in 1891, on land the first lease of which is held by the Peoria Mining, Construction and Land Company, a New Jersey corporation. The most productive area adjoins the village on the northwest, and underlies the bottom and north bluff of Peoria Creek. In the creek bottom, over an area 300 feet long east and west by 100 feet wide, known as the Playhouse diggings, a solid sheet of galena was found in chert at a depth of 7 to 10 feet. This sheet, narrowing to 60 feet, extended northward for 600 feet under Monkey Hill and is reported to have been from 6 to 22 inches thick. Other shallow deposits of lead have been worked on the first and second hills west of Monkey Hill. Not much sphalerite has been mined at these places. A sheet of sphalerite from 4 to 18 inches in thickness, with a thin sheet of galena just above it, which yielded two carloads of ore, was struck about 12 feet above the level now worked for silicate.

Silicate mine.—The Silicate mine is operated by Gordon & Wilkins. The shaft is in the face of the hill just north of the creek, about 50 feet west of the edge of the Playhouse diggings, and some of the drifts extend under those old workings. The face of ore ranges from 1 to 7 feet in height, averaging 2½ feet. The drifts are carried 6 to 8 feet in height and from 10 to 12 feet in width, and have a total length of approximately 1,000 feet, covering an area less than 200 feet square. The ore occurs either in slabs or as "fish-egg silicate," in clay interbedded with red tallow clay and layers of soft, rotten chert, the whole conforming to the limestone horses and bowlders which are present here and there. In one place the walls of the run closed in, nearly pinching out the ore, which continued on through the opening in the solid limestone. The ore in the main is plainly the result of a carbonate replacement of the limestone country rock, associated with more or less underground solution, the latter in part antedating the ore deposition, giving rise to the openings through which the ore-bearing solutions passed, and in part contemporaneous with the ore deposition. The ore is concentrated on hand jigs, the quantity of fine fish-egg silicate associated with flat shapes requiring an elaborate scheme of concentration. Women and girls are employed to hand pick the screenings—probably the only instance of such employment in the Joplin region.

Chicago Syndicate Mining Company.—In 1907 the Chicago Syndicate Mining Company erected a mill over some old workings half a mile northwest of Peoria. The level worked at the mill shaft is 120 feet deep, but at another shaft on the edge of a small, oblong solution patch of shale and sandstone of Chester age, the mining was done at the 160-foot level. A considerable amount of lead was taken from this shale patch at a depth of 12 to 22 feet, the ore occurring near the base of the sandstone and shale. In the drifts now being worked the ore is sphalerite disseminated in rather coarse crystals through the bluish-gray jasperoid cement of chert breccia. In places this cement makes up one-third to one-half of the mass of the breccia, the chert bowlders and slabs being suspended in it. Considerable spar is present here and there, and where decomposition has progressed far there is much tallow clay.

Other mines.—The Poor Boys Mining Company is operating a silicate mine, and several other companies are prospecting in the immediate vicinity of Peoria.

Three miles due east of Peoria, on a tract of land belonging to S. L. Davis and adjoining the State line, in the vicinity of the Pinnick mines, there have been some recent strikes of ore. The Grimes & Williams shaft is sunk near the border of a circular solution patch, bordered by an outcrop of brecciated chert with a jasperoid matrix showing impressions of sphalerite crystals which have been leached out. Within the circle there are scattered sandstone bowlders of Chester age. The ore is sphalerite and occurs at the 90-foot level in the matrix of the chert breccia. This matrix consists of jasperoid in some places and of dolomite in others; in still others the ore itself acts as the cement. In the McKisson shaft, on the same tract, a 3-foot run of lead was struck at the 60-foot level in yellow flint ground.

SYCAMORE CREEK DISTRICT.

South of Seneca the Seneca fault cuts diagonally across the divide between Lost and Sycamore creeks, striking the latter 1½ miles west of the Missouri-Oklahoma line. At this point considerable prospecting has been done in and along the fault block, though without developing any paying bodies of ore. The first prospecting, which yielded some silicate, was done by means of a drift under the south bluff of Sycamore Creek a few feet above water level. Here the fault block is about 180 feet in width, and the throw is not sufficient to bring the sandstone of the Chester down to the present level of the surface. The limestones of the block, probably opened up more or less by the faulting, have been subjected to much solution, with the result that the space between the side faults, as exposed in the bluff, consists of a great mass of chert blocks lying topsy-turvy, the interstices being filled with tallow clay and residual clay. In the ravine just south of the bluff, near the southeast edge of the block, is a shaft from which drifts at the 75-foot and 104-foot levels extend southwestward for about 100 feet each. Thin ore was encountered in the lower drift, and better ore in the upper one. The ore consists of galena, sphalerite, and silicate. The silicate was too heavy to be separated from the sphalerite on hand jigs, and the ore could not be sold at a profitable price. Another shaft, 250 feet southwest of the deep shaft, encountered some large chunks of galena, which had to be broken up before they could be brought to the surface. Southwest of this point the displacement by the fault is greater, and at a distance of 400 feet sandstone and sandy shale of Chester age are present to a depth of 65 feet, with some galena and sphalerite in crevices in the sandstone and in the secondary limestone cement of associated chert breccia.

MINES ALONG THE SENECA FAULT.

The Sycamore Creek mines mark the southwesternmost known occurrence of ore along the Seneca fault. Northeast of this locality the fault has been prospected at short intervals to the vicinity of Spurgeon, Mo. The Becker mines (formerly the Potwin and Holmes mines) are just in Missouri, a mile south of Seneca. The ore, which is galena, sphalerite, and calamine, occurs in the chert and sandstone breccias of the southeast margin of the fault block and in the solution breccias of the adjacent Boone chert and limestone. These mines have been recently reopened, after lying idle for fifteen years. A 150-ton mill has been erected, several shafts have been sunk on shallow ore, and the original shafts have been sunk to deeper levels.

A mile northeast of Seneca are the old Huber mines, operated by the Seneca Lead and Zinc Company. The ore was found at a depth of 70 to 100 feet in broken chert ground adjacent to the northwest margin of the Seneca fault block. Breccia bowlders in the waste piles show jasperoid cement with impressions of sphalerite crystals.

The Gallemore mines are situated in the shallow saddle where the faulted area crosses a flint ridge one-half mile west of Racine. Sphalerite was struck in the shaft of the Racine Mining Company, at a depth of 105 feet. For the first 40 feet the shaft penetrated Pennsylvanian shale, in which an 18-inch bed of coal was found. This shale occurs very irregularly, not showing at all in some shafts near by, and is evidently a solution patch, the fault brecciation offering most favorable conditions for solution. Small quantities of sphalerite were taken from several shafts near by and considerable shallow lead was found in yellow flint ground adjacent to the fault on the northwest.

The Buzzard mines, on the Newman land, 2 miles northeast of Racine, have been operated more or less continuously since their discovery in 1882. They are adjacent to the fault block on its southeast side. The original discovery was of lead ground, 1½ to 2 feet in thickness, averaging 50 per cent of galena, at a depth of 8 to 10 feet, lying upon a solid sheet of Short Creek oolite and overlain by yellow clay and chert bowlders. The oolite dips slightly toward the fault and is reached at a depth of 28 feet in the shaft at present worked, at the foot of the low ridge which marks the breccia zone. Under the foot of this hill the ore consists of lead, sphalerite, and calamine, and as the fault zone is approached dips steeply downward toward it. The ore is associated with more or less chert breccia, with dark jasperoid cement. The Shaffer diggings, adjoining the Buzzard mines on the southwest, have not been worked for many years. The Hunt mines were a quarter of a mile north of the Buzzard mines, on the northwest side of the fault block.

The Baxter mines are on the fault block and along its northwest margin, in the NW. ¼ sec. 1, T. 25 N., R. 33 W. The surface of the block seems to be entirely covered with the sandstones and shales of the Chester. Much shallow lead has been taken out, at depths ranging from 2 to 30 feet, in broken sandstone and clay ground resting upon the Boone chert. Galena and sphalerite are found at deeper levels in the residual and basal breccias.

The Henderson mines join the Baxter diggings on the east and lie partly in the section just north. The mines extend from the north margin of the fault block completely across and for some distance beyond it, though most of the ore was found near the south fault zone. It consisted entirely of galena, and came from depths of 15 to 60 feet, in much the same relations as the shallow lead on the Baxter land.

The fault block has been prospected at short intervals all the way from the Henderson mines to a point half a mile northeast of Spurgeon. On the west edge of the Bucklin land at Spurgeon the sandstone outcrop marking the limits of the fault block is about 250 feet in width. Between this point and the village the sandstone and shale area widens out until it is 1,600 feet across. This widening is due mostly, however, to solution, as the fault block can be easily traced across the tract by a slight trough bounded on the northwest by the outcropping chert. The ore, consisting of galena and sphalerite, occurs in breccias—sandstone breccias in the upper levels and chert breccias in the deeper levels. Many of the sandstone fragments of Chester age in these breccias have been changed into quartzite through secondary enlargement of the sand grains. The surface of such fragments shows a glistening sheen which has given rise to the local name " glass rock."

QUAPAW DISTRICT.

General description.—The Quapaw mines extend from 1 to 4 miles east of Quapaw station, and from 5 to 7 miles south of Baxter Springs. The ore-bearing ground has been proved by drilling to extend for some distance beyond these limits on all sides, notably to the west, in the vicinity of Quapaw station, where a good strike was made in drilling the town well. The main ore deposits occur at a depth of 80 to 150 feet in blanket-ground formation, rarely in confused broken ground. Ore at shallower depths is limited chiefly to the region lying immediately south of Lincolnville, the village at the Quapaw mines. On the eastern edge of the Quapaw district the blanket ground rests upon the Short Creek oolite member of the Boone formation, which is usually penetrated by the mine sump. Though doubtless the blanket breccia forms an uninterrupted sheet throughout the area of the Quapaw mines, the oolite is not found in the western mines. This is because the bed, as noted in its description, thins out or loses its oolitic character along a north-south line which bisects the district. The ores found in the blanket ground are sphalerite and lead in about the proportion of 5 to 1. In a part of the blanket ground there has been some oxidization in the upper part and a little calamine is present. No ore is mined below the Quapaw blanket ground, although the drill has shown ore at deeper levels. In the shallow ground the ore, which is principally silicate and galena, occurs in runs and circles. In addition to the circular solution patch (with a probable circular ore deposit) on the Cherokee Lead and Zinc Mining Company's land, described below, there are several other shale and sandstone patches of the same shape. A circular shale patch at the F F F mine had much sphalerite and pyrite in the lower part of the shale, and ore continued in broken ground down to the main blanket ground at 90 feet. There is a large circular solution patch on the Red Eagle tract, in the NE. ¼ SE. ¼ sec. 31, T. 29 N., R. 24 E. The shale area is 350 feet in length north and south by 300 feet in width. A shaft near its southeastern margin shows a thickness of 70 feet of shale. The shale area is surrounded by a low rim of chert which dips away from the center on all sides. Near its contact with the shale the chert is brecciated and recemented with jasperoid from which considerable sphalerite has been leached. It seems reasonably certain that the ore here, should it occur in workable quantity, will be found in circular shape.

There are in the Quapaw district 25 steam concentrating plants, with a daily capacity of 3,300 tons, besides 7 mines operating hand-jig plants. In the typical blanket ground hand jigs can not be operated to much advantage, as the ore must be crushed very fine to free it from the rock. Those in operation are working with dirt from the shallow ground or the more oxidized portions of the blanket ground. In addition to the mines with concentrating outfits there are about 30 prospects which have shafts down to the ore. The owners of some of these prospects have planned to build mills; others are waiting for ore prices to become better.

Cherokee Lead and Zinc Mining Company.—In a field on the Cherokee Lead and Zinc Mining Company's lease just southwest of Lincolnville several wagon loads of calamine were picked up, having been plowed up and cast aside in ignorance of its value. Aproximately 50 tons of silicate with a little lead were taken from shallow open cuts less than 15 feet in depth, along the southwest margin of a circular solution patch at this place. Limestone and sandstone of Chester age cover the surface except for the circle 125 to 150 feet in diameter. The border of the circle is marked by a ring of sandstone bowlders. Inside this ring shafts and borings strike Cherokee shale with a little coal. Between the sandstone ring and the adjacent limestone there is, along the southwest margin, a strip of chert breccia with a matrix of jasperoid. This matrix has been ore bearing, as shown by the cavities from which sphalerite has been leached. The ore found in the shallow diggings lay mainly between the breccia and the limestone, but also extended in clay seams into both the limestone and the jasperoid. In the shaft just west of the circle ore was found at a depth of 35 feet in the clay and limestone bowlder filling of a solution chamber at the base of the limestone of Chester age.

A sheet of lead ranging up to 6 inches in thickness was struck at a depth of 40 feet in the shaft of the Alabama Mining Company, a hundred yards south of the locality just mentioned.

Good Luck mine.—Soft "confused ground" occurs at the Good Luck mine, as well as in some other mines in the northeastern portion of the Quapaw district. In the No. 1 shaft of the Good Luck mine the soft ground joins the blanket ground along a north-south line and the east-west drift is partly in each kind of ground. The blanket ground exposed by the drift is fractured and broken, but not recemented, and in places the bedding is entirely obscured. Clay and shale occur in the fractures and joints and between the chert beds. The blanket ground was evidently much softened by the solution which is responsible for the confused ground adjoining. The latter is the typical soft ground of chert and limestone bowlders in soapstone and yellow clay. Tiff and pink spar are present in veins and pockets in the unoxidized ground and impressions of spar and sphalerite occur in the jasperoid cement of the oxidized ground. Weathered lead occupies seams and fractures in the jasperoid. The No. 2 shaft was sunk on a drill hole showing rich lead cuttings that were found to have come from a solid chunk of galena a foot or two in thickness, which did not reach completely across the shaft. When followed to the south the lead gave out within 2½ feet of the shaft, but the drift soon ran into good zinc ore. The ground here consists of dull chert and rotten limestone bowlders in a matrix of shale, clay, and tallow clay. Some of the bowlders are of secondary limestone, highly crystalline and very rich in ruby sphalerite in grains of the same size as those of the limestone. In some of these limestone bowlders the sphalerite constitutes from 15 to 25 per cent of the mass.

Mission mine.—The Mission mine may be chosen to exemplify the blanket-ground mines because it is typical, because its underground workings are the most extensive, and because it is the best-known mine in the district, having been the " show " mine from the beginning of the camp. The mined area extends over approximately 5 acres in the NE. ¼ sec. 1, T. 28 N., R. 23 E. The blanket ground is about 30 feet in thickness, the top of the ore being reached at about 50 feet from the surface and the limestone upon which it rests at about 80 feet. Only the upper 18 to 20 feet of this ground has been worked, though at the time the mine was visited a lower stope 10 or 12 feet in height was being taken up from the pump shaft.

In this mine, as generally in the district, there is at the top of the blanket ground 2 or 3 feet of soft ground, containing more or less black shale and yellow clay. Locally solution has progressed so far that slabs only of limestone and chert occur in the shale and clay. There is as a rule more or less spar and tiff in veins and pockets, and here and there a little bitumen. Much of the shale is slickensided. This zone is apparently not one of general movement, but one of accommodation to the slight stresses resulting from underground solution and the weight of the superincumbent strata. It seems likely that the opening at the top of the blanket breccia, into which the clay and shale have been drawn, was largely a result of the settling of the chert beds when the interbedded limestone was dissolved. The fact that the roof did not settle into this space would be explained if the solution in the blanket cherts went on by areas, portions remaining to support the roof until after the portions first dissolved and fractured had been recemented by jasperoid and rendered capable of sustaining the roof. This upper, softer sheet is in many places richer in ore than the harder ground below, but on the other hand it is here and there entirely barren.

Below the soft ground the blanket breccia consists of greatly fractured "live" blue flint, which in the more unbroken portions shows small dark spots one-eighth to one-fourth of an inch in diameter, surrounded by a lighter border. At many points the stratification of the chert is completely obscured by the brecciation, but in general it can be made out either from the chert or from the jasperoid sheets between the broken chert beds.

The brecciation of the chert ledges is uneven. In places the whole ledge is broken up; elsewhere it is broken into large bowlders with finer brecciation between them; elsewhere still the sheets are comparatively unbroken, with chert fragments suspended in the jasperoid interstrata. In many of the more unbroken portions of the chert strata traces of a former fine brecciation may be distinguished. The outlines of the fragments are faint, and the cementing material resembles a network of thin dark veins. These are not ore bearing and possibly correspond to the older sheet brecciation in the sheet-ground deposits of the Joplin district. At numerous places in the mine the chert is fractured vertically or nearly so. Some of these fractures come so close together as to constitute "sheeting" and to conceal the bedding of the chert completely. They are ordinarily not slickensided, but are usually stained dark by the circulating waters. In general they are open, containing neither ore nor jasperoid. They are probably equivalent to the sheeting in the mines of the sheet ground in the Joplin district, where also the sheeting is later than the ore deposition.

The ore in the Mission mine consists of sphalerite and lead in the proportion of 2 or 3 to 1. The latter is found in fissures and crevices in the chert, and the former is disseminated in the jasperoid as well as in the crevices and fissures. Where both the ores occur in a pocket, the galena shows a tendency to be crystallized in the upper parts and the sphalerite in the lower parts. In the mine as a whole not much differentiation can be seen, more lead occurring in the upper portion in some places and near the bottom in others.

MIAMI DISTRICT.

The Miami mines, 4 miles due north of the town, are the youngest in the State of Oklahoma, ore having been reached in the first shaft in 1907. The ore is sphalerite with some galena, and is found at depths of 90 to 130 feet, the variation being due in the main to the westward dip of the rocks. The surface formation is Cherokee shale, below which are sandstone and limestone of Chester age, resting upon the Boone chert and limestone. In certain areas the limestone of the Chester group has been carried away by solution, allowing the sandstone to settle down upon the Boone. In this settling the sandstone was more or less fractured and broken. The ore was first discovered in this sandstone breccia, though in some of the recent drilling it has been found to continue on down into the Boone chert. The main one of these old solution channels, as at present developed, crosses the Miami road near the southwest corner of sec. 6, T. 28 N., R. 23 E., and bears north-northwest. The territory has not yet been extensively drilled, and the available drill records are too few to determine the courses of any of the solution channels other than the one just mentioned, but it seems highly probable that other ramifications of the old underground drainage will be discovered. With this end in view, systematic preservation of drill records, whether they represent blank holes or not, is very desirable.

The sandstone in which the ore occurs is strongly impregnated with a heavy crude oil or bitumen. This material occurs in exactly the same fashion as the ore, in crevices in the fractured rock and between the laminæ of the sandstone. There is also in many places considerable fine-grained pyrite. Neither calcite nor dolomite has been observed in association with the ore, though they will likely be found when mining has extended downward into the Boone. The sphalerite, where it occurs in the openings between the laminæ, is very fine grained, though in the fracture openings larger masses of ore are found. The galena constitutes about one-sixth of the total amount of ore, and is found more often in the crevices than between the laminæ of the sandstone. The intimate association of the sandstone and ore requires close crushing to effect their separation, and this in turn necessitates the use of concentrating tables to save the fine ore. The bitumen must have a tendency to float off the fine-ore slimes. Experience has shown also that the bitumen collects in the jigs, and in the first cell of the cleaner jig it forms round balls with the ore. In a short time these balls completely cover the grating of the cell to a depth of 1 or 2 inches, so that it is necessary to clean off the jig bed every shift. The introduction of a jet of hot water into this cell simply delays the balling up and clogging until the next cell of the jig is reached. A single assay of the sphalerite concentrate is reported thus: Zinc, 44 per cent; lead, 4 per cent; iron, 7 per cent. Against these values penalties were assessed by the ore buyer, as follows: Moisture, 2 per cent; bitumen, 2 per cent; iron, 7 per cent. A deduction of $1 per ton of ore is made for each 1 per cent of these impurities, making a combined penalty in this case of $11 per ton. From this showing it seems imperative that means be adopted to remove the bitumen and effect a better separation of the iron. Some process of oil flotation, or of roasting and magnetic separation, would be likely to accomplish that end, but to roast the crushed ore before concentration would probably not be profitable. Possibly, if the crude ore were crushed in hot water, the bitumen might be freed and mechanically skimmed or allowed to float off from the surface of a settling tank. Roasting and magnetic separation might be employed after concentration.

The richness of the drill cuttings and of the ore itself, where it has been reached, has caused the prospecting, shaft sinking, and mill building to go on unabated. Development was pushed rapidly in 1907. Eight shafts were sunk to ore, many others were started, one mill was completed, and two others were begun, both of which are now finished.

A circumstance which has delayed the development of the district is that each undertaking requires the raising of 500 to 750 gallons of water per minute. This of course has been the case in most of the new camps in the Joplin region. With the lowering of the underground water level to the level of mining, the amount of pumping ordinarily becomes inconsiderable. In the Miami district, however, the situation is somewhat exceptional. The surface of the ground is low, not more than 25 feet above Tar Creek, the drainage level for the region, and the water-bearing ore stratum is capped by the unbroken Cherokee shale. The mine water is different from the surface water in other camps, being highly charged with H_2S, like the deeper artesian waters, and the height to which it rises may represent artesian head rather than the underground water table. If this be so there may be no great diminution of the amount of water with time, but on the contrary a possible increase with the development of the underground workings.

As the water pours into the mine, the dissolved H_2S gas escapes and renders the air so noxious that the miners are unable to work a full shift, though there is much individual variation in the ability to withstand the gas. As the gas is heavier than air, the ordinary blower at the surface will not force it out of the workings, so that an exhaust fan, with the intake at the bottom of the drift, is commonly employed in ventilating the mines.

OIL AND GAS.

DISTRIBUTION.

The areas which have yielded oil and gas are outlined on Pl. II. The most productive areas are the Alluwe-Coodys Bluff, or "shallow sand" field; the Bartlesville, or "deep sand" field; and the Glenn "pool," near Kiefer. Between the Bartlesville and Glenn fields and in line with them, there is a series of smaller pools at such close intervals as practically to constitute one continuous field from Kiefer to the Kansas line. New but promising areas are the Delaware, Hogshooter, and Morris-Baldhill fields. Many other smaller outlying areas, generally gas bearing, are indicated on the map. Sufficient data are not at hand to discuss the depth, character, and mutual relations of the oil- and gas-bearing sands, or the origin and character of the oil.

GENERAL CONSIDERATIONS OF STRUCTURE.

Probably the most striking fact in connection with the distribution and shape of the pools, as will be noted from the map, is their grouping into belts with north-south alignment and their individual prolongation in that direction. This characteristic manifests itself with perfect independence of the topography and likewise of the general structure. The general structure of that portion of the Midcontinent field included in this report is, as noted in the preceding pages, that of a gentle monocline, dipping to the north of west. The study of a complete series of well records in connection with detailed leveling might reveal important minor features, such as low anticlines and terraces (flats or arrested anticlines), but it is difficult to see how such features could exist and be influential in the distribution of the oil and gas without showing their influence in the outcrop of the formations, unless they antedated the deposition of those formations. If the distribution of the oil and gas depends on the existence of elongated lenses of sandstone, it is likewise difficult to account for the diagonal position of these lenses with reference to surface outcrops, unless they were deposited when the land and sea relations were decidedly different from those which existed later, when the formations now at the surface were laid down. It seems a fair assumption, then, that the oil and gas reservoirs had their origin in conditions, which, whether orographic or geographic, antedated the deposition of the Cherokee and overlying formations. In the section on structure it has been shown that the warping, folding, and faulting which affected the western portion of the Ozark uplift were post-Winslow and apparently pre-Cherokee—that is to say, they were probably contemporaneous with the development of the structure influencing the distribution of the oil and gas. That they were related to that development is very probable. The orographic structure of the west end of the Ozark uplift has a very pronounced northeast-southwest trend. It is not easy to see how a north-south structure could be developed in the adjacent oil field at the same time and by the same forces which produced the structure of the uplift, or even independent of them. There remain for consideration the geographic relations of the sedimentation of pre-Cherokee time. In the section descriptive of the Cherokee formation it has been shown that there is a wide divergence in strike between the formations correlated with the Cherokee in the south and those preceding the Cherokee, and it has been pointed out that the most rational explanation of this discordance is that the west end of the Ozark uplift was warped so that the southern portion was elevated, crowding the shore line far to the southwest, while the northern was depressed, allowing the sea to spread farther to the east and to completely overlap the deposits laid down during pre-Cherokee Pennsylvanian time. The continuation of the Winslow sandstones would naturally be sought in the line of strike of the present outcrop of those rocks. Allowing for the probable curvature of the shore line of the uplift, we should expect to find the buried extension somewhere between Chelsea, Nowata, and Coffeyville, Kans. Similarly, the continuation of the Boggy formation would be expected to lie parallel to the buried Winslow, somewhat farther west, and the Savanna formation, if sedimentation in the northern portion of the area proceeded as in the southern, would be sought to the west of the buried outcrop of the Boggy. Lenses of sand with their elongation parallel to the old shore line or disconnected patches showing that alignment would naturally occur. Such sand patches, after being overlapped by the Cherokee shale, might become saturated with oil and gas forming "pools." The linear grouping of known pools into belts, the discordance of such belts with the strike of outcropping rocks, and the parallelism of these belts with the pre-Cherokee shore lines strongly suggest that they represent such sand lenses and patches laid down along those shore lines. If this be the fact, it has an important bearing on the distribution of the oil and gas sands in that the pools may in general be expected to develop greatest length in a north-south direction, thus explaining a characteristic of the known pools to which attention has already been called. Furthermore, the upper contour of the thickened lenses of sandstone determines the attitude of the succeeding deposits, developing therein a structure which may likewise influence the distribution of oil and and gas. For instance, the rapid thickening toward the west of the sandstone lentil in the Labette shale in the vicinity of Coodys Bluff might locally counterbalance the normal westerly dip, producing a depositional feature in the overlying sediments akin to a structural terrace or arrested anticline. Sandstones overlying an oil-bearing sand of pronounced lens shape might also be oil bearing over the same area.

This speculation as to the origin of the pools could be readily proved or disproved by the construction of several cross sections from a sufficient number of drill records. The records available at this writing are not adequate to affirm or deny its truth. It is a fact that the Cherokee, or, more precisely, the Pennsylvanian below the Fort Scott limestone, thickens toward the southwest. At the outcrop of the Cherokee on the Kansas line the formation is about 500 feet thick; at Centralia, 570 feet; at Nowata, 600 feet; at Chelsea, 600 feet; on the Verdigris River west of Chelsea, 700 feet; at Claremore, 900 feet; at Catoosa, 920 feet; and southeast of Tulsa, 700 to 850 feet. Two miles northwest of Coffeyville, Kans., the thickness of the Cherokee is but 440 feet—less than it is at the outcrop of the formation farther east. This fact, however, is not a fatal objection to the idea of a progressive overlap, for the landward edge of a marine sedimentary deposit will ordinarily be thicker than the seaward edge, and there may thus be a continual transgression without greatly increasing the vertical section at the initial point. In fact, it might easily happen, owing to more favorable conditions of erosion during its deposition, that the overlapping bed would be thicker at its outcrop than the combined overlying and overlapped beds at the initial point. This involves the same principle as that according to which a section at right angles to the shore line, measured across the outcropping edges of a series of deposits, sums up the maxima of thickness and thus gives an exaggerated idea of the total thickness of the series.

In corroboration of this suggestion, and quite independent of any consideration of the land and water relations of Oklahoma during early Pennsylvanian time, Haworth[a] points out that "the heavy gas-bearing sandstones of Laharpe and Iola" and "the sandstone and coal at the very base of the Cherokee and Cherryvale" imply shore conditions at those points just as strongly as do the sandstone and coal deposits at the margin of the Pennsylvanian, farther east.

COAL.

A number of beds of coal occur in the Cherokee formation and to the south in the sandstones and shales that have been correlated with the Cherokee. These beds are for the most part thin and of no great linear extent, so far as may be judged by the openings and exposures. However, two or possibly three of these beds have been worked to supply a market more than purely local. These, with other beds higher in the geologic column, will be briefly described.

Bluejacket coal.—A bed of coal ranging from 12 to 16 inches in thickness has been stripped in a small way in a number of places east and southeast of Bluejacket, and is penetrated by wells in that town. A higher bed occurring just beneath the sandstone cap of the hill, 3 miles southwest of town, has been considerably mined. The area of the flat top of the hill is about 2 square miles, but the coal has been worked only along the west escarpment. At the Williams & Esry

[a] Univ. Geol. Survey Kansas, vol. 3, 1898, p. 30.

coal bank, in the NE. ¼ sec. 34, T. 27 N., R. 20 E., the coal averages 36 inches in thickness and is underlain by 2 to 6 inches of blue clay shale which rests upon 25 or 30 feet of buff sandstone. Above the coal is an 8 to 10 foot bed of irregularly bedded and curly sandstone with ironstone lenses and thin streaks of coal. This sandstone ranges from buff to red in color and is coarse grained in places and coarsely micaceous.

The preceding description would answer as well for the other coal banks on the west bluff of the hill. The coal is of good quality, and a blocky variety with rusty joint planes, locally known as "red coal," is in especial demand.

A coal bed overlain by a similar coarse-grained red sandstone has been stripped in several places on the ridge near the railroad 2 miles north of Welch station. It is very probably the Bluejacket coal. The sandstone associated with the coal does not always form a ridge, a fact which makes it difficult to trace.

In the valley of Cabin Creek, 2 miles west of Bluejacket Hill, the only coal reported is a bed 6 inches thick which can hardly represent the Bluejacket coal. Three miles farther west, near the junction of the middle and west forks of Cabin Creek, a bed of coal 18 to 24 inches thick has been opened in a number of places and stripped to a considerable amount. It is more likely that this is the continuation of the Bluejacket bed.

About 6 miles southwest of Bluejacket Hill, in sec. 13, T. 26 N., R. 19 E., coal 32 to 36 inches in thickness is reported. This is on the line of strike of the Bluejacket coal and is probably that bed.

Coarse dark-red sandstone forms a north-south escarpment 4 miles east of Chelsea, crossing the railroad at Catale and bearing northeastward along the railroad for several miles. A mile east of Catale two shafts are sunk to a bed of coal which ranges in thickness from 32 to 36 inches. This coal is about 150 feet below the sandstone, which in appearance much resembles the sandstone over the Bluejacket coal. An outlier of similar sandstone, with coal croppings reported beneath it, lies midway between Catale and Big Cabin.

In sec. 31, a mile south of Chelsea, and in the SW. ¼ sec. 1, 3 miles south of Chelsea, there are a number of old pits where a bed of coal about 16 inches thick was stripped to a considerable extent. The relation of the coal to the coarse red sandstone was not made out, but they are evidently not separated by a very great vertical interval. It is rather probable that the coal comes just under the sandstone, in that case corresponding more closely to the Bluejacket coal than the coal mined at Catale. The coarse red sandstone outcrop was followed southward to a point about 12 miles from Chelsea, but no exposures of coal were reported.

Coal near Boynton.—Coal from 12 to 16 inches thick outcrops on Pecan Creek 8 miles east of Boynton. Another bed from 14 to 22 inches thick has been opened in a number of places on the tributaries of Cloud Creek both south and east of Boynton. A bed of similar thickness has been stripped and mined considerably on Dog Creek, near Wellington, 1 and 2 miles northwest of Boynton. On practically all the tributaries of Cane Creek in the territory northwest of Boynton there are coal outcrops from 16 to 26 inches in thickness. In sec. 19, T. 14 N., R. 15 E., at the Renty bank, the coal is reported to be 4 feet thick. Considerable coal has been taken out at this opening.

Fort Scott coal.—In the Kansas reports the term Fort Scott is applied to the bed of coal in the Cherokee formation a short distance below the Fort Scott limestone. It is here taken to include as well the coal which is found interstratified with the latter formation. From the vicinity of Centralia northeastward to the Kansas line, an 18 to 22 inch bed of coal has been stripped at short intervals. On the point of the bluff east of Centralia the coal underlies a bed of limestone with numerous *Fusulina*, being separated from it by 5 feet of shale. There is another bed of limestone a short distance below the coal. This lower limestone persists about halfway to the Kansas line, to a point in the vicinity of Kinnison, where it disappears. Beyond that point the coal occurs below the limestone series, in a position analogous to that of the Fort Scott coal in Kansas. From Centralia to Catoosa, as pointed out in the section on stratigraphy, there are two beds of coal associated with the Fort Scott. They range from 1 to 2 feet in thickness and have been stripped in numerous places.

In surface wells in Catoosa coal is penetrated beneath the upper limestone of the Fort Scott formation. Three miles southeast of Catoosa, mainly in the NE. ¼ sec. 33, T. 20 N., R. 15 E., there are several large strip pits connected with the railroad at Catoosa by a tramway. The coal, which ranges from 18 to 24 inches in thickness, is of good quality and has been extensively mined. This bed is distinct from the coal mentioned as underlying the town of Catoosa, and occurs beneath a lower limestone.

At Evans, 4 miles east of Broken Arrow, there are extensive strip pits reached by a 3-mile spur from the Missouri, Kansas and Texas Railway. The coal averages from 24 to 28 inches in thickness, with a maximum of 40 inches. It is overlain by 15 to 18 feet of blue shale, which is capped by a thin limestone weathering yellow. A 3 to 5 foot bed of shelly reddish limestone outcrops in the draw near the store, and is apparently several feet beneath the coal, with fire clay in the interval.

Southwest of Evans the outcrop of the coal is traceable by scattered exposures as far as Arkansas River. No coal is known to occur beneath the limestone at Wealaka. It is present, however, in the bluffs of Concharty Mountain, and near the township corner southeast of Wealaka, where it has been opened, it has a thickness of 18 inches. From this point to Baldhill the outcrop was not followed.

Henryetta coal.—Several outcrops of coal near Baldhill, having a thickness of 16 to 18 inches, presumably represent the coal below the Fort Scott, and they almost certainly are equivalent to the Henryetta coal, as their outcrops occur within a mile or so of that bed, at nearly the same elevation, in rocks practically flat. The following notes are quoted from Taff's description of this coal at the type locality:[a]

> The bed is 3 feet thick and mines in block, separating into two or three benches along stratification lines of distinct cleavage. In the southernmost strip pits east of the town a shale parting was discernible near the middle of the coal. Three and one-half miles southeast of Henryetta an outcrop of the coal shows that the shale parting has increased to 10 inches, separating the bed into two benches, the upper 12 to 15 inches, and the lower 15 to 20 inches in thickness. At the mines 2 miles north of Henryetta, 2 miles southeast of Schulter, and east of Okmulgee, the Henryetta coal maintains its thickness of 3 feet to 3 feet 4 inches and shows no appreciable changes in character except the presence of a thin shale in the openings near Okmulgee. The outcrop has been traced between these localities and to a point 6 miles east of Okmulgee.

Dawson coal.—When the upper limestone of the Parsons is traced southward from Nowata, it is found to thin out and disappear in the vicinity of Watova, but a thin bed of coal makes its appearance 100 feet or so below the horizon of the limestone and is traceable far to the southwest. At Sunday's coal bank, 3 miles northwest of Oologah, there was a great deal of coal taken out formerly, though the bank is now practically abandoned. The thickness is reported to range from 26 to 30 inches. Three miles south of west of Oologah, near the southwest corner of sec. 30, T. 23 N., R. 15 E., there are several pits where considerable coal has been raised from a bed 30 inches thick. This bed outcrops at short intervals between that locality and Collinsville. Through this distance and at Collinsville it is from 18 to 20 inches thick. In the vicinity of the latter place it has been stripped along the valley of Middle Branch in a practically continuous line from Horsepen Creek to a point 4 miles farther south. The next exposure reported is 3 miles due west of Owasso, where two small strip pits on the west side of a small stream have opened a coal bed 24 inches thick. The next exposures are south of the wide valley of Bird Creek. From Flat Rock Creek through Mohawk to Dawson, a distance of over 3 miles, the outcrop is very closely stripped and several shafts from 32 to 64 feet in depth reach the coal at points where it is too deep for stripping. The average thickness in this region is about 26 inches. At Scales the coal has been and is exten-

[a] Taff, J. A., Bull. U. S. Geol. Survey No. 260, 1905, p. 396.

sively mined in strip pits and by slopes. The thickness here averages 32 inches. The coal has been somewhat prospected in places for 2 or 3 miles southwest of Scales, beyond which it passes beneath the alluvial deposits of the Arkansas River valley.

The following notes on the occurrence of this bed southwest of Tulsa are quoted from Taff:[a]

Outcropping in association with the coal on the west and occurring nearly 90 feet above it is a thin bed of light-blue limestone which weathers to a bright yellow color. The outcrop of this limestone has been mapped from Tulsa southwestward nearly 50 miles and beyond the known occurrence of the coal. This peculiar limestone is easily recognized and its outcrop is a ready reference in locating the coal. The Dawson coal is here unusually clean for a bituminous coal. It mines in block, separating near the middle along a distinct bedding plane, and resembles very closely the Henryetta coal in physical characteristics. A very thin parting of bony coal occurs near the center, separating the bed into two benches. The shale gradually grows thicker southward, reaching about 4 inches near Mounds. It continues to increase southward beyond Mounds at the expense of the coal until the latter has decreased to 8 inches northwest of Beggs. South of Mounds the Dawson coal is not known to be of any commercial value. * * * At points 6 and 9 miles south of Red Fork the coal is 2 feet 6 inches to 3 feet 4 inches thick, and 3 feet 4 inches, respectively, where strippings have been made. Two miles northeast of Mounds the Dawson coal is 2 feet 2 inches to 2 feet 6 inches thick and contains a parting of shale near the middle.

PORTLAND CEMENT MATERIALS.

OCCURRENCE AND CHARACTER.

The formations which make up the Pennsylvanian column in the northeastern part of Oklahoma comprise an alternating series of limestones and sandstones with intervening shales, the whole dipping gently to the north of west. The limestones and sandstones, being more resistant to the effects of erosion than the shale, tend to form long gentle westward dip slopes, with steeper eastern slopes of shale, the harder rock outcropping along the crest of the ridge. Where this rock is limestone which has been protected from weathering by a thin covering of shale, the essential materials are in the most favorable position for cement-plant sites. Where, in addition, adequate supplies of fuel, especially natural gas, and good transportation facilities are available, the climax of advantageous position has been reached. It is to just such a fortunate combination of advantages that the rapid increase in the number of cement plants in the adjoining parts of Kansas is due. That a like development will overtake the eastern part of Oklahoma is not to be doubted.

In the semicircular area of the outcrop of the Mississippian rocks contiguous deposits of suitable shale and limestone will not often be

[a] Op. cit., pp. 396–397.

found, except along the border of the Pennsylvanian, where the pure limestones of the Chester are in association with the shales of the Pennsylvanian. Away from the border the limestone of the Mississippian is ordinarily interstratified with too much flint to be available. Near the base of the Mississippian, however, overlying the Chattanooga shale, there is a bed of encrinital, coarsely crystalline limestone, the St. Joe member, which is in general quite free from chert. No doubt the limestone and shale could be combined in suitable proportion to make Portland cement. Owing to the fact that the limestone and shale are exposed only where the body of the Mississippian rocks is cut through, they usually outcrop near the valley bottoms, as a rule in places unfavorable for economical quarrying. Furthermore, the localities of outcrop in the main have poor transportation facilities and are rather distant from fuel supplies. It is not likely, therefore, that cement plants will be located in this area under the present conditions; that is to say, without a betterment of transportation facilities and the discovery of nearer supplies of fuel.

Along the contact of the Mississippian and the Pennsylvanian there are many suitable locations for cement plants. The limestones of the Chester are generally heavy bedded, of good quality, and from 20 to 40 feet in thickness. The basal formations of the Pennsylvanian—the Cherokee at the north and the Winslow at the south—consist largely of shale generally suitable for Portland cement manufacture. From Wagoner northeastward the contact of the two series is in general not more than 5 or 6 miles from a railroad, and at many points closely coincides with one. The remaining factor is fuel. Good supplies of natural gas can be found within 20 or 25 miles of any point along the contact between Wagoner and Vinita. Northeast of Vinita the distance to the gas fields is greater.

In the area between the contact which has just been described and the outcrop of the Fort Scott limestone—that is, in the area underlain by the Cherokee formation and its southern equivalents—there are few if any beds of limestone of workable thickness, and consequently a lack of available sites for cement manufacture.

The map (Pl. II) shows that there are in the area lying west of the outcrop of the Fort Scott limestone a series of limestones with outcrops parallel to that of the Fort Scott and extending for varying distances to the southwest. These limestones themselves consist in places of different members separated by beds of shale. In addition there are various limestone lenses whose outcrops are not shown on the map.

The outcrop of the Fort Scott limestone in Kansas is marked by many cement manufactories. The formation is made up of several limestone and shale members, and some of these limestone beds outcrop along the streams to the west of the line marked on the map, which shows only the east edge of the formation. Below the lower limestone member is a bed of coal, which, as already noted, has been mined at short intervals throughout the length of the outcrop from the Kansas line to Arkansas River, and which, if not the exact equivalent of the Henryetta coal, is not far from it. The area of outcrop of the Fort Scott formation coincides in part with the Alluwe-Coodys Bluff, Sageeyah, and Catoosa fields, and is not far from the Morris field. The formation is, therefore, well situated as to supplies of natural gas. From Catoosa northward to a point a few miles beyond Chelsea the outcrop is but a short distance from the Frisco Railway. North of that point branch railways would be necessary for the commercial manufacture of Portland cement along the outcrop of this limestone.

The Pawnee limestone, a massive bed forming the escarpment on the west bluff of Big Creek and Verdigris River, reaching from the Kansas line southward to and beyond Catoosa, is well situated for cement manufacture from the vicinity of Nowata southward. North of this point the outcrop swings some distance to the east of the railway. The line of outcrop diagonally crosses the Alluwe-Coodys Bluff field and passes near the Sageeyah and other fields, small as at present developed, which occur at intervals from Nowata to Broken Arrow. The new cement plant planned at Nowata is to be located upon this formation.

The upper and lower limestones of the Parsons formation where they cross the Kansas line are of suitable quality and thickness to be used for Portland cement. To the south the upper limestone becomes argillaceous and probably is not available for such use south of Delaware, except from Tulsa toward the southwest. The lower limestone of the Parsons north of Delaware is for the most part too far from railway facilities to be of much value from the cement standpoint at present, but from Delaware southward to a point near Arkansas River it lies convenient to railways and to supplies of natural gas.

Between the upper limestone of the Parsons and the Wilson sandstone there are a number of lentils of limestone that outcrop in several localities between Nowata and the Kansas line. They apparently represent the Dennis or Mound Valley limestone lentils of the Coffeyville formation. The Drum limestone of Kansas thins out and disappears within half a mile south of the State line and was not seen again farther south. The limestone that is to be used at the proposed Tulsa cement plant outcrops southward to and far beyond Mounds and may be correlated with one of those lentils, though the probabilities seem to favor its being the upper limestone of the Parsons.

Limestone outcrops about Dewey and Bartlesville and in the escarpment which stretches southward along the line between the Cherokee and Osage nations—that is, the ninety-sixth meridian—and crosses Arkansas River 10 miles or so above Tulsa. To judge from its position, this limestone represents the Piqua limestone, which, thinning from 45 feet in the northern part of the Independence quadrangle, Kansas, to 2 or 3 feet at the State line, probably thickens again toward the south.

PORTLAND CEMENT PLANTS.

The Dewey Portland Cement Company has recently completed a plant at Dewey with a daily capacity of about 2,500 barrels. This plant has five rotary kilns, each 8 feet in diameter and 100 feet in length. The machinery is driven by electricity throughout, the power being furnished by gas engines using natural gas. The limestone used is probably the Piqua member, as suggested above, and the shale probably belongs to the Buxton formation. There is also considerable shaly material interbedded with the limestone, and when necessary some residual clays are used in addition to give the right constitution to the clay. On account of the variations in the quarry, no set ratio of limestone to shale can be given. The plant is situated in an excellent gas field, where the wells are noted for their large capacity, some of them yielding upward of 50,000,000 cubic feet per day. There is switch connection with both the Santa Fe and the Missouri, Kansas and Texas railways. Analyses of the limestone and shale are given in the table on page 222. The following analysis of the cement is given on the authority of the company's chemist, P. R. Chamberlin:

Analysis of cement made at Dewey plant.

Silica (SiO_2)	23.31
Alumina (Al_2O_3)	6.79
Ferric oxide (Fe_2O_3)	2.90
Lime (CaO)	63.38
Magnesia (MgO)	1.54
Sulphur trioxide (SO_3)	1.68
	99.60

The Tulsa Portland Cement Company proposes to build a plant 4 miles west of Tulsa, on the south side of Arkansas River. The limestone bed, probably the upper limestone of the Parsons, is 35 feet thick and overlies the shale at an elevation of more than 100 feet above the bottom upon which the plant is to be built, enabling the material to be handled by gravity. The capacity will be 2,500 barrels daily, with five rotary kilns, each 8 feet in diameter and 125 feet in length.

All machinery will be driven by electricity generated by gas engines. Ample supplies of gas are available in the vicinity. The plant is situated on a connecting line of the Frisco system and has ample railroad facilities. Analyses of the limestone and shale are given in the table on page 222, and show the proper ratio of limestone to shale to be 100 to 24. The preliminary tests with this ratio, made by the department of experimental engineering of Cornell University, gave a cement of this composition:

Analysis of test cement made from materials to be used in Tulsa Portland Cement Company's plant.

Silica (SiO_2)	21.22
Alumina (Al_2O_3)	11.99
Lime (CaO)	62.57
Magnesia (MgO)	1.33
Sulphur trioxide (SO_3)	1.19
	98.30

Another Portland cement plant is projected at the quarries of the Tulsa Limestone Ballast Company, 1½ miles west of the locality just described.

The British-American Portland Cement Company is promoting a 2,500-barrel plant near Nowata. The site chosen is about 3 miles east of the town, in the valley of Verdigris River. The Pawnee limestone outcrops in the bluff, a section of which was measured along the road at the south side of sec. 22, T. 26 N., R. 16 E., about a mile north of the proposed site, as follows:

Section of west bluff of Verdigris River east of Nowata.

	Feet.
Shelly blue limestone, weathering yellow, chert scattered over surface	2–10
Bluish clay shale	35
Heavy-bedded, fine-grained gray limestone; no chert	7
Black shale	5
Blue fine-grained limestone; some interbedded shale in lower part; no chert	14
Black shale to river bottom	11

The lower two limestone beds belong to the Pawnee formation. To the southeast the strata rise gently, and a massive sandstone, 30 to 40 feet thick, is exposed about 40 feet below the lower limestone. It is proposed to pipe natural gas from the field 14 miles west of this site and after the exhaustion of the gas to use crude petroleum from the Alluwe-Coodys Bluff field, within the limits of which the plant is to be located. The analyses of the limestone and shale are given in the table (p. 222). These indicate a ratio of limestone to shale of

100 to 26. The test cement made with this ratio, as analyzed by J. Robert Moechel, has the following composition:

Analysis of test cement made from materials to be used in plant near Nowata.

Silica (SiO_2)	23.58
Alumina (Al_2O_3)	8.04
Ferric oxide (Fe_2O_3)	3.12
Lime (CaO)	63.40
Magnesia (MgO)	1.20
Sulphur trioxide (SO_3)	.45
Alkalies (Na_2O, K_2O)	Trace.
Ignition	.19
	99.98

The subjoined table includes analyses of the constituent materials of cements for the plants described in the foregoing paragraphs:

Analyses of Portland cement materials.

	Limestones.					Shales.					
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Silica (SiO_2)	4.35	2.06	2.62	2.48	4.3	52.54	61.64	59.40	56.08	63.61	62.5
Alumina (Al_2O_3)	1.73	1.52	1.76	.71	1.2	19.10	14.97	20.34	21.02	16.89	20.1
Iron oxide (Fe_2O_3, FeO)	1.14	------	------	.79	1.2	5.30	2.88	6.78	9.86	8.63	6.4
Lime carbonate ($CaCO_3$)	92.02	95.30	94.05	93.43	91.9	9.64	1.29	.28	.32	4.18	1.6
Magnesium carbonate ($MgCO_3$)	------	1.11	1.29	2.71	0.6	------	------	1.69	3.37	2.59	.7
Sulphur trioxide (SO_3)	------	------	------	.54	Tr.	------	------	------	------	.50	Tr.
Alkalies (Na_2O, K_2O)	------	------	------	------	------	------	------	------	------	1.08	------
Loss, etc	------	------	------	------	.4	12.40	17.00	------	------	------	6.1
	99.24	99.99	99.72	99.66	99.6	98.98	97.78	88.49	90.65	97.08	97.4

1, 6, 7. From quarries of Dewey Portland Cement Company, Dewey. Analyses on authority of P. R. Chamberlin.
2, 3, 8, 9. From proposed site of Tulsa Portland Cement Company, near Tulsa. Analyses by department of experimental engineering of Cornell University, Ithaca, N. Y.
4, 5, 10, 11. From proposed site of British-American Portland Cement Company, near Nowata. Analyses by J. Robert Moechel, Kansas City, Mo.

BUILDING STONE.

The northeastern portion of Oklahoma is well supplied with building stones—limestone, sandstone, and granite. The following notes relate to formations and sites suitable for quarrying on a commercial scale with adequate machinery, and comprise such as came to the notice of the writer during his reconnaissance. Rock suitable for supplying small local demands can be found almost anywhere within a mile or so of the place where it is wanted.

Spavinaw dike rock.—In the vicinity of Spavinaw the Ordovician rocks are intruded by a reddish granitic dike, 75 feet or more in width, which outcrops in three places in an approximately straight line. If the outcrops are connected beneath the soil covering, the total length of the dike is about 1,800 feet. At any rate, there is in sight enough rock to supply several quarries for a long time. The stone has a pleasing warmth of color and would doubtless make a durable building stone. It is well situated for quarrying and needs only railway facilities to become a valuable deposit.

Boone limestone.—At the base of the Boone formation, just above the Chattanooga shale, the upper part of the St. Joe member usually shows from 10 to 15 feet of solid gray crystalline limestone, which, though it has a flaggy appearance on the outcropping edge, is, as a matter of fact, of massive character and breaks off in blocks the full thickness of the ledge. Where favorably situated for quarrying this rock will be found well adapted for all monumental or building purposes. It is called the St. Joe marble in the reports of the Geological Survey of Arkansas.

About 200 feet above the base of the Boone formation, 30 or 40 feet below the Short Creek oolite member, there is usually a ledge of massive limestone from 12 to 25 feet or more in thickness. This bed is free from chert and generally free from stylolitic seams, so that blocks of any desired size can be quarried from it.

The Short Creek oolite member reaches a thickness of 8 to 10 feet in the vicinity of Wyandotte, Okla., and Seneca, Mo., where it has been quarried to some extent. Where cemented firmly enough to be durable, its massive character and light color would give it value for trimmings and ornamental purposes. A perfect oolite, it is texturally a beautiful stone.

An item to be taken into account in considering for quarry purposes any of these limestones of the Boone formation is that they generally outcrop in high, steep slopes upon which the cost of stripping in a quarry would soon become prohibitive.

Chester group, limestone and sandstone.—The several limestones and sandstones of the Chester group for the most part outcrop on the flats and hilltops. At the base of the group there is a series of flaggy, sandy limestones, which, on account of ease in quarrying, have generally supplied the local demand. Near the top of this series lies a thin laminated calcareous sandstone with oolitic spherules along the partings. This stone splits into wide, thin sheets suitable for flagging, and into thicker layers that are good for building purposes. The more massive sandstones and limestones of the upper part of the Chester have also been quarried here and there.

Cherokee and related sandstones.—Massive to heavy-bedded sandstones suitable for quarrying occur at many places in the area occupied by the outcrops of the Cherokee formation and of the related formations to the south. Only the more flaggy of these sandstones have been opened up to supply local demands, for the reason that machinery is necessary to operate a quarry in the massively bedded rocks.

Four miles northwest of Vinita, in the NW. ¼ sec. 5, T. 25 N., R. 20 E., there is a quarry working a bed of massive fine-grained buff sandstone. This stone is largely used in Vinita. The same bed outcrops 2 miles northwest of Bluejacket and 2 miles southwest of Welch.

The ridge 4 miles west-southwest of Pryor Creek is capped by a 45-foot ledge of soft buff fine-grained nonmicaceous even-textured sandstone. The rock is massive and blocks as large as a house break off and roll down the hill. To all appearances it is well adapted to quarrying purposes and would furnish blocks as large as could be handled.

A very similar sandstone is exposed in the south bluff of Arkansas River midway between Wealaka and Haskell, outcroping for some distance just above the level of the river, adjacent to the railroad. It forms a bench and over considerable areas would require very moderate stripping. It is more than 30 feet thick and is a soft, massive, fine-grained sandstone suitable for quarrying by machinery.

Sandstone lentil in the Labette shale.—A soft, massive buff sandstone 15 feet in thickness outcrops in the bluff 1 mile southeast of Coodys Bluff post-office. A similar sandstone 30 to 40 feet thick is exposed in the west bluff of Verdigris River 2 miles west of the post-office. In both places it is suitable for quarrying purposes. Farther north this sandstone occurs in Centralia Mound, and to the south it outcrops in the bluff east of Talala and Oologah.

Pawnee and overlying formations.—The Pawnee limestone occurs massively in some places and is available for rough masonry, but as a rule is not suitable for general building purposes on account of its roughness and irregular texture.

Various other sandstones and limestones lying higher in the Pennsylvanian series have been used locally in the western part of the area. In the west bluff of Fourmile Creek, a mile west of Oologah, a heavy sandstone, showing large blocks on the outcrop, has been quarried more or less. It lies between the Dawson coal and the horizon of the upper limestone of the Parsons. In the vicinity of Seminole station, 6 miles north of Lenapah, a sandstone belonging to the Coffeyville formation outcrops in large blocks and would be suitable for quarry purposes. A mile southwest of Mounds a quarry has been opened in the heavy buff sandstone which forms the long escarpment west of that place.

BRICK CLAYS AND SHALES.

Surface clays for the manufacture of common brick and shales suitable for vitrified brick can be found in any part of the area occupied by the Pennsylvanian rocks. Where such deposits are within a convenient distance of transportation lines and have available a plentiful supply of natural-gas fuel, they are well situated for the extensive manufacture of such brick. It stands to reason that in a new, rapidly growing community with little timber these advantages will lead to the establishment of a thriving industry, such as characterizes the corresponding part of Kansas. Plants for the manufacture of vitrified brick are in operation at Bartlesville, Muskogee, Tulsa, and elsewhere, and numerous brick and tile plants are scattered over the area.

WATER RESOURCES.

GENERAL CONDITIONS.

The area underlain by the Mississippian rocks is abundantly supplied with water. Innumerable fine bold springs gush from the chert bluffs of the Boone formation, and all the larger and many of the smaller valleys contain perennial streams of clear pure water. Near the mouth of Salina Creek an exception to the rule occurs in the brine springs and shallow salt wells which were the site of a primitive salt industry in pioneer days.

In parts of the area underlain by Pennsylvanian rocks, however, the problem of obtaining a good water supply is perplexing. So much of the country is underlain by shale, which sheds the rainfall instead of storing it, that in a season of drouth the shallow wells and small streams go dry. At the same time Caney and Verdigris rivers, together with the smaller streams flowing through the area, are apt to have obnoxious quantities of oil floating on their surfaces. Where sandstone or limestone can be reached, however, a deep surface well will ordinarily furnish sufficient water for domestic purposes.

ARTESIAN WELLS.

It is not claimed that the following notes describe all the artesian wells in the area covered; they relate only to those which came to the notice of the writer.

In the eastern part of the area the flowing wells, with a few exceptions, obtain their supply below the Chattanooga shale. At Needmore two wells, each about 60 feet in depth, flow a gallon per minute of slightly sulphureted water, which is derived from the Boone formation. These flows depend on a slight local dip of the rocks.

At Miami there are three flowing wells—one at the waterworks, one piped to the ice plant from a point half a mile east of town, and the third 2 miles north of town. The third well has a small flow of sulphur water from a bed just below the Chattanooga shale. The well used at the ice plant is 1,680 feet in depth, and the one at the waterworks 1,000 feet. Both draw their supply from various horizons between 600 and 1,000 feet. The water is soft, with a very slight sulphur odor. The temperature is 65½° F. The pressure at the ice-plant well is about 12 pounds and the flow is more than 100 gallons per minute An analysis of the water is given in the table on page 227. These two wells affect each other decidedly, though half a mile apart.

Two miles east of Fairland there is a well 1,152 feet deep which is reported to have had originally a head of 16 feet and a flow of 30 to 50 gallons per minute. Through defective casing the flow has been reduced to about one-half gallon per minute. The water is slightly sulphureted. In a well 889 feet deep in the town of Fairland the water rises within 30 feet of the surface. The flow comes from sandstone 400 feet or more below the Chattanooga shale. The water is pure and sweet, as shown by the analysis given in the table on page 227.

The town well at Afton has a flow of about 4 gallons per minute of strongly sulphureted water. It comes from a depth of 650 feet. A very small flow was obtained at 600 feet, about 200 feet below the Chattanooga shale. The analysis of this water is given in the table. Two miles northwest of Afton, in the northwest corner of sec. 29, T. 26 N., R. 22 E., on J. L. Courtney's place, there is a well 788 feet in depth which at one time had a small flow, but in which the water now stands from 1 to 20 feet below the surface. The water is similar to that of the Afton well and probably comes from the same horizon. On J. M. Smith's place, in the NW. ¼ sec. 13, T. 26 N., R. 21 E., a well 1,020 feet in depth yields a fine flow of fairly strong sulphur water, which comes from a sandstone 500 feet below the Chattanooga shale. Water was also struck at shallower depths, but did not rise above the surface.

At Welch a well 1,001 feet deep draws water from a sandstone in the Ordovician rocks about 300 feet below the Chattanooga shale. The water is sulphureted and rises 4 feet above the surface of the ground.

At Bluejacket, in a well 730 feet in depth, a flow of 1 gallon per minute was struck at 660 feet and one of 7 gallons per minute at 730 feet. The bottom of the well is about 300 feet below the Chattanooga shale. The water has a fairly strong sulphur taste.

In Vinita and vicinity there are numerous artesian wells. A strong flow of slightly sulphureted water is struck just beneath the Chattanooga shale. The analysis of a typical sample of these waters is given in the table on page 227.

At Chelsea a heavy flow of slightly salty and considerably sulphureted water is struck at 794 feet in a 30-foot bed of sandstone lying just beneath the Chattanooga shale and probably corresponding to the Sylamore sandstone. The water has an artesian pressure of 35 pounds per square inch. It is used in a small bath house.

At Pryor Creek a sulphosaline water struck just below the Chattanooga shale is used at the bath house and sanatorium.

At Claremore the medicinal properties of the strongly saline sulphur water obtained below the Chattanooga shale are utilized in several sanatoriums. There are three deep wells on adjacent corners at the intersection of two streets in the northeast part of the town. The deepest one, 1,500 feet in depth, is owned by the Claremore Radium Wells Company, which operates the adjacent bath house. The water is reported to have an artesian pressure of 60 pounds to the square inch. The Radium Water Company has a well 1,150 feet in depth, and operates a bath house in conjunction with it. Analyses of the water from both these wells are given in the accompanying table. The water from the George Eaton Radium well, 1,115 feet in depth, is piped to a sanatorium and bath house in the business part of town. All these wells obtain water at about the same horizon, from 1,075 to 1,110 feet in depth. In addition to the local use, there is a considerable sale of the bottled water from the wells.

At Nowata the water from a flowing well is utilized by the Nowata Radium Sanitarium Company, which operates a bath house. The water comes from a depth of 1,315 feet, just below a 47-foot bed of black shale, which is apparently the Chattanooga. The water probably comes from the same horizon as many of the other sulphosaline waters noted above. The analysis of the water is given separately below, for the reason that the hypothetical combination of the constituents made by the chemist is not comparable with the other analyses without recalculation.

In addition to the wells described in the foregoing notes, there are numerous wells drilled for oil and gas which found flows of salt water instead.

The subjoined tables contain analyses of water from several of the artesian wells already mentioned.

Analyses of artesian waters from northeastern Oklahoma.

[Grains per United States gallon.]

	1.	2.	3.	4.	5.	6.
Iron and aluminum carbonate (Fe_2CO_3+Al_2CO_3)	1.18					
Calcium carbonate ($CaCO_3$)	21.88	19.73	3.10	4.55	5.30	4.69
Magnesium carbonate ($MgCO_3$)	1.94	2.56	1.72	2.52	1.75	1.68
Sodium carbonate (Na_2CO_3)			13.04	1.33	1.58	
Calcium chloride ($CaCl_2$)	236.94	218.46				
Magnesium chloride ($MgCl_2$)	110.47	106.26			2.34	1.16
Sodium chloride ($NaCl$)	1,833.08	1,789.71	36.74	21.28	3.97	9.73
Magnesium sulphate ($MgSO_4$)						.65
Sodium sulphate (Na_2SO_4)			1.49	.98		
Iron and aluminum oxides (Fe_2O_3+Al_2O_3)			.07	.04		
Silica (SiO_2)			.60	.77		.55

1. Claremore Radium Wells Company's well, Claremore. Analysis by E. H. Keiser, Washington University, St. Louis, Mo.
2. Brown's Radium well, Claremore. Analysis by E. H. Keiser, Washington University, St. Louis, Mo.
3. Frisco Railway artesian well, Vinita. Analysis by Kennicott Water Softener Company, Chicago, Ill.
4. Deep well, Afton. Analysis by Kennicott Water Softener Company, Chicago, Ill.
5. Deep well, Fairland. Analysis by department of chemistry, Oklahoma Agricultural and Mechanical College, Stillwater.
6. Deep well at ice plant, Miami. Analysis by John F. Wixford, St. Louis, Mo.

Analysis of water from Nowata Radium Sanitarium Company's well, Nowata.

[By J. Robert Moechel, Kansas City, Mo.]

	Grains per United States gallon.
Ferrous bicarbonate ($Fe(HCO_3)_2$)	1.36
Calcium bicarbonate ($Ca(HCO_3)_2$)	524.28
Magnesium bicarbonate ($Mg(HCO_3)_2$)	62.29
Sodium bicarbonate (Na_2CO_3)	1,111.56
Calcium chloride ($CaCl_2$)	247.47
Magnesium chloride ($MgCl_2$)	182.37
Sodium chloride ($NaCl$)	1,230.78
Calcium sulphate ($CaSO_4$)	20.86
Magnesium sulphate ($MgSO_4$)	23.27
Silica (SiO_2)	2.47
Alumina (Al_2O_3)	2.78
Ammonium nitrate (NH_4NO_3)	7.41

SURVEY PUBLICATIONS ON LEAD AND ZINC.

The following list includes the more important publications on lead and zinc published by the United States Geological Survey. In addition to the publications cited below certain of the geologic folios, especially the Joplin district folio (No. 148) and the Lancaster-Mineral Point folio (No. 145), contain discussions of the lead and zinc resources of the districts of which they treat.

ADAMS, G. I. Zinc and lead deposits of northern Arkansas. In Bulletin No. 213, pp. 187–196. 1903.

——— (See also Bain, H. F., Van Hise, C. R., and Adams, G. I.)

ADAMS, G. I., and others. Zinc and lead deposits of northern Arkansas. Professional Paper No. 24. 118 pp. 1904.

BAIN, H. F. Lead and zinc deposits of Illinois. In Bulletin No. 225, pp. 202–207. 1904.

——— Lead and zinc resources of the United States. In Bulletin No. 260, pp. 251–273. 1905.

——— A Nevada zinc deposit. In Bulletin No. 285, pp. 166–169. 1906.

——— Zinc and lead deposits of the upper Mississippi Valley. Bulletin No. 294. 155 pp.

——— (See also Van Hise, C. R., and Bain, H. F.)

BAIN, H. F., VAN HISE, C. R., and ADAMS, G. I. Preliminary report on the lead and zinc deposits of the Ozark region [Mo.-Ark.]. In Twenty-second Ann. Rept., pt. 2, pp. 23–228. 1902.

BOUTWELL, J. M. Lead. In Mineral Resources U. S. for 1906, pp. 439–457. 1907.[a]

——— Zinc. In Mineral Resources U. S. for 1906, pp. 459–489. 1907.[a]

CALKINS, F. C. (See Ransome, F. L., and Calkins, F. C.)

CLERC, F. L. The mining and metallurgy of lead and zinc in the United States. In Mineral Resources U. S. for 1882, pp. 358–386. 1883.

ELLIS, E. E. Zinc and lead mines near Dodgeville, Wis. In Bulletin No. 260, pp. 311–315. 1905.

EMMONS, S. F. Geology and mining industry of Leadville, Colo., with atlas. Monograph XII. 870 pp. 1886.

EMMONS, S. F., and IRVING, J. D. Downtown district of Leadville, Colo. Bulletin No. 320. 72 pp. 1907.

GRANT, U. S. Zinc and lead deposits of southwestern Wisconsin. In Bulletin No. 260, pp. 304–310. 1905.

HOFFMAN, H. O. Recent improvements in desilverizing lead in the United States. In Mineral Resources U. S. for 1883–84, pp. 462–473. 1885.

ILES, M. W. Lead slags. In Mineral Resources U. S. for 1883–84, pp. 440–462. 1885.

[a] Earlier volumes of the Mineral Resources of the United States contain discussions relating to the lead and zinc industries of the United States.

IRVING, J. D. (See Emmons, S. F., and Irving, J. D.)

KEITH, A. Recent zinc mining in East Tennessee. In Bulletin No. 225, pp. 208–213. 1904.

RANSOME, F. L. Ore deposits of the Cœur d'Alene district, Idaho. In Bulletin No. 260, pp. 274–303. 1905.

RANSOME, F. L., and CALKINS, F. C. Geology and ore deposits of the Cœur d'Alene district, Idaho. Professional Paper No. 62. In press.

SMITH, G. O. Note on a mineral prospect in Maine. In Bulletin No. 315, pp. 118–119. 1907.

SMITH, W. S. T. Lead and zinc deposits of the Joplin district, Missouri-Kansas. In Bulletin No. 213, pp. 197–204. 1903.

——— (See also Ulrich, E. O., and Smith, W. S. T.)

ULRICH, E. O., and SMITH, W. S. T. Lead, zinc, and fluorspar deposits of western Kentucky. In Bulletin No. 213, pp. 205–213. 1903. Professional Paper No. 36. 218 pp. 1905.

VAN HISE, C. R. Some principles controlling the deposition of ores. The association of lead, zinc, and iron compounds. Trans. Am. Inst. Min. Eng., vol. 30, pp. 102–109, 141–150. 1901.

——— (See also Bain, H. F., Van Hise, C. R., and Adams, G. I.)

VAN HISE, C. R., and BAIN, H. F. Lead and zinc deposits of the Mississippi Valley, U. S. A. Trans. Inst. Min. Eng. [England], vol. 23, pp. 376–434. 1902.

WINSLOW, A. The disseminated lead ores of southeastern Missouri. Bulletin No. 132. 31 pp. 1896.

WOLFF, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin No. 213, pp. 214–217, 1903.