DESCRIPTION OF THE TAHLEQUAH QUADRANGLE.

By Joseph A. Taff.

GEOGRAPHY.

Location and area.—The Tahlequah quadrangle is bounded by parallels of latitude 35° 30′ and 36° and meridians of longtitude 94° 30′ and 95°, and contains 969 square miles. It is in the Cherokee Nation, Indian Territory, except a narrow, triangular tract in the northeastern part, which is in Washington County, Ark. Its name is taken from the capital town of the Cherokee Nation, which is located in the northwestern part of the quadrangle.

PHYSIOGRAPHIC RELATIONS.

The Tahlequah quadrangle is situated in the extreme southwestern part of the Ozark region. Its southern end includes a small area of the Arkansas Valley region, which bounds the Ozark region on the south. Fifteen miles west of the Tahlequah quadrangle the Ozark region merges into the Prairie Plains. A brief consideration of the salient topographic features of the Ozark and Arkansas Valley regions will assist the reader in understanding the topography of the Tahlequah quadrangle.

Ozark region.—The Ozark region is a broad and relatively flat dome-shaped dissected plateau. In parts, notably the southern and eastern, the greater elevations attain the prominence of mountains and are widely known as the Boston Mountains and the St. Francis Mountains. Elsewhere there are numerous lower elevations, remnants of dissected subordinate plateaus, to which names have been given and which are locally called mountains, although not generally deserving recognition as such. In general the region is known as the Ozark Mountains, but the name has not been applied to any mountain or definite group of mountains in the province. The sketch map below, fig. 1, shows the main physical features of the region and the location of the Tahlequah quadrangle.

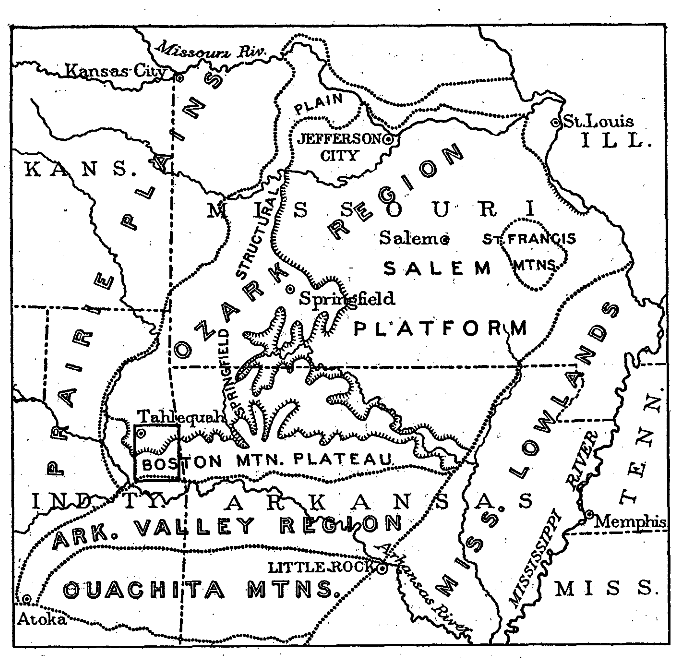

FIG. 1.—Diagram showing relations of Ozark region to surrounding physiographic provinces; also principal divisions of the Ozark region.

Physiographically the Ozark region is bounded as follows: On the north and west the gently sloping upland grades almost imperceptibly into the Prairie Plains. On the east it is sharply outlined by the Mississippi lowland along the line of the St. Louis, Iron Mountain, and Southern Railway. On the south it extends to the southern border of the Boston Mountains. In outline the Ozark region has rudely the form of a quadrilateral whose sides are nearly 225 miles in length.

On the north, east, and south sides the Ozark region is limited approximately by Missouri, Mississippi, and Arkansas rivers, respectively. On the west it is followed closely by Neosho (or Grand) River in Indian Territory and in part by Spring and Osage rivers in Missouri. White, Black, St. Francis, Meramec, and Gasconade rivers have their sources in the plateau near the main watershed and flow out through narrow, sinuous valleys.

Considered in a broad sense the Ozark region is made up of three dissected plateaus, the general character and the topographic details of which are dependent upon the character and attitudes of the rocks. These plateaus succeed one another concentrically westward from the St. Francis Mountains as a center. They cross the axis of the main uplift and main watershed, giving an effect of deformed plains. The physiography of the Ozark Plateau in Missouri has been clearly set forth by C. F. Marbut (Missouri Geol. Survey, vol. 10, 1896). Geologic mapping by the Arkansas Survey shows the same features in the southern extension of these plateaus in Arkansas (Arkansas Geol. Survey, vol. 4, 1890).

The first of these plateaus has been termed by the Missouri Survey the Salem platform. It occupies southeastern Missouri and a large part of northeastern Arkansas. The magnesian limestones, cherts, and saccharoidal sandstones of the Cambrian and Ordovician periods occur in this plateau, and are inclined at low grades away from the St. Francis Mountains. The edges of the lower of these deposits face the lowlands surrounding the St. Francis Mountains in distinct escarpments. Higher formations of limestone and chert outcrop in succession farther away, making subordinate platforms and escarpments. The intervening softer saccharoidal sandstone beds occur in the lower back slopes of benches and in the bases of the escarpments. The Salem platform is generally deeply cut by stream erosion, and the tops of the higher ridges and hills of the dissected escarpments fall in the same general level. Thus the Salem platform has been developed on the truncated edges of a number of formations.

Surrounding the Salem platform on the north, west, and south is an even structural plain which has been developed on the surface of the Boone formation of chert and limestone. This plain or plateau has been named by Marbut the Springfield structural plain. Its inner border south of Osage River is marked by a strong escarpment, the exposed edge of the Boone formation, which overlooks the Salem platform. The Springfield plain inclines at low angles toward the west in Missouri and south and west in northern Arkansas, in the direction of the dip of the formation. In Missouri Pennsylvanian shales succeed the Boone formation, forming lowland. In northeastern Indian Territory and Arkansas limestone, shale, and sandstone occur successively above the Boone formation, making numerous low terraced hills and mountains standing as remnants of the Boston Mountains on the Springfield structural plain. Such features of this plain are typically seen in the northern half of the Tahlequah quadrangle. The Springfield plain is also deeply dissected by the larger streams which flow through it in narrow, crooked valleys. Between the larger drainage lines are large tracts of land from which younger formations have been removed, leaving broad, flat surfaces of deeply weathered chert. Near the inner border of the Springfield plain the Boone formation is deeply dissected on the divides between the streams, giving the escarpment a very irregular outline. Hills and buttes, cut off from the escarpments, stand out above the Salem platform, their crests indicating the former extension of the Springfield plain.

A third plateau—that of the Boston Mountains—rises back of and above the Springfield plain. The rocks capping the Boston Mountains and extending down the southern slope are made up of thick deposits of sandstone and shale of the Winslow formation. The sandstones, being more resistant to erosion, govern the physical features of the mountains. Structurally the mountains make a deformed monocline in which the southward dip of the rocks is slightly greater than the general southward slope of the surface. The Boston Mountain plateau, like the other plateaus of the Ozark region, is deeply dissected by streams which flow down its southern slopes and by drainage which has eaten by headwater erosion into its northern border. The crests of the ridges which slope southward from the main divide to the border of the Arkansas Valley may be said to define approximately a structural plain. Viewed from eminences on the Springfield plateau, the Boston Mountains have the appearance of a bold, even escarpment with a level crest. Instead, however, of presenting an even northward front the escarpment sends out finger-like ridges and foothills, descending by steps as successively lower hard rocks come to the surface. Toward the northern ends many of these foothills are intersected, becoming flat-topped outliers on the Springfield plain. Toward the east end of the Boston Mountains, where the capping sandstone formations are thicker and lie more nearly horizontal, and where White River in its deep valley approaches its northern front, the escarpment attains its greatest height. Here high, flat-topped, precipitous ridges 1000 to 1500 feet high project northward on a level with the mountain top, making a high and rugged escarpment. In the western part of the Boston Mountains, toward the Arkansas-Indian Territory line, the Winslow formation, especially its sandstone beds, thins out or becomes shaly. In proportion as these rocks change in thickness and nature the Boston plateau decreases in elevation and in distinctness of topographic form. The change in the character of the rocks and in the topography northward from the west end of the Boston Mountains is pronounced. In the Tahlequah quadrangle the hard rocks of the Winslow formation are approximately 1000 feet thick, and the northern edge of the beveled Boston plateau rises but 500 feet above the Springfield plain. Farther north, on the east side of Neosho River, the sandstones of the Winslow formation gradually decrease in thickness until they lose their identity in the northeast corner of Indian Territory. Correspondingly, the topographic forms change from the low, westward-sloping, dissected plateau to the lowland plain bordering the Springfield plateau in the southeastern part of Kansas.

Arkansas Valley.—There is a small area of the Arkansas Valley topography near the southern border of the quadrangle. As already stated, on the north the Arkansas Valley region is bounded by the Boston Mountains. On the south it is limited by the Ouachita Mountains. In the Arkansas Valley is a great thickness of sandstone and shale of the Pennsylvanian series. These beds have been thrown into many imbricated or lapping folds, which together make a deep structural trough, corresponding with the Arkansas Valley, from eastern Indian Territory to the Mississippi embayment opposite Little Rock in Arkansas. These folded rocks have been beveled off by erosion until their edges form a peneplain now standing approximately 800 feet above sea level. A few exceptions to this general statement may be noted in some of the broader synclinal folds in the south side of the valley. Protected by massive sandstone strata and aided by their attitude in the broad, basin-like folds, the rocks remain as conical mountains with crests 1000 to 2000 feet above the general level of the valley. Such are Sansbois, Cavanal, Sugarloaf, and Magazine mountains, and their crests give some idea of the former high level of the whole region. Since the formation of the Arkansas Valley peneplain erosion has cut more rapidly into the shaly beds, and the sandstones have been left as low, narrow, and sharp-crested but generally level ridges. In many of the smaller synclinal folds remnants of sandstone beds cap low buttes and hills in the general level of the peneplain. The small plain in the vicinity of Akins, near the southern border of the Tahlequah quadrangle, is developed on soft Pennsylvanian shales in the Sallisaw syncline, and its southern border in the adjoining quadrangle is marked by sharp-crested, level-topped ridges.

TOPOGRAPHY OF THE QUADRANGLE.

The Springfield structural plain and the Boston Mountain plateau have nearly equal areas in the Tahlequah quadrangle, the former occupying approximately the northern half.

SPRINGFIELD STRUCTURAL PLAIN.

In the Tahlequah quadrangle, as elsewhere in the western part of the Ozark dome, the Springfield plain is developed principally on the Boone formation. In this part of the region the Boone formation consists almost entirely of beds of cherty limestone and flint. On weathering, a surface mantle of disintegrated porous chert is formed, which is exceedingly durable. Waters falling upon it readily pass downward and reach the valleys gradually beneath the weathered mantle or issue in springs through subterranean solution channels. Thus only the valleys of considerable size afford streams of sufficient power to corrade the fresh rock or even to remove the fragmentary chert. The general result of these conditions is that broad, level tracts are developed on the durable surface of the Boone formation between the principal drainage lines. From these level tracts flat-topped ridges extend out in the level of the plain between the subordinate drainage channels to the narrow, steep-sided valleys of the rivers and larger creeks.

The valleys of the Springfield plain are of two kinds and have been developed by two distinct processes, solution and corrasion. They may be characterized as trough and canyon valleys. In the trough valley the two processes are combined only in parts of the valley's course, and in no instance does corrasion predominate. In the canyon valley, while solution plays a large part in cutting the valley, it is subordinate to corrasion. The canyon type of valley has been produced by the rivers and their larger tributary perennial streams. In those parts of the solution valleys where the grade is steep and the basins are sufficiently large to collect a large volume of water, the disintegrated chert is removed from the beds of the streams, but the general trough form remains unchanged. Where the two types of valley occur in the course of a single stream the change is gradual from one to the other.

Trough valleys.—The upper parts of those valleys which have their beginnings in the plain farthest removed from the canyons are generally wide and flat, and the entire slopes are covered by weathered chert. In the lower courses of the valleys, where the grade is steep and where large volumes of water accumulate during heavy rains, the disintegrated chert is removed from the stream channel. Lower in the course, where the grade becomes lower, usually near the junction with the larger valleys, the load of chert carried down is so great in many instances as to choke the channel. In occurrences of this nature the valley floor is almost a plain. In the middle and lower courses of these valleys the slopes of the sides increase gradually from the flat bottoms outward until the maximum grade of rest for talus accumulations is reached near the tops of the hills.

There is another phase of trough valley of common occurrence in the Springfield plain. Valleys of this nature have been formed in the sides of the larger trough and canyon valleys. They are short and their grades are steep. A deep covering of angular chert forms the sides and heads of the valleys and descends in steep slopes down to their bases. No streams of water are in view and no fresh exposures of rock can be found. The disintegrated chert descends from the head and sides of such valleys down to their bases by the aid of gravity with the assistance of percolating waters, frost, and changes of temperature. These accumulations continue to move in this manner until a larger valley is entered or a point is reached where water accumulates during heavy rains in sufficient volume to transport the talus. Valleys of this type are produced entirely by solution of lime from the beds of chert.

Canyon valleys.—Both the Barren Fork and Illinois River have narrow, steep-sided, canyon-like valleys. These valleys are of even, low grade, essentially parallel to the surface of the Springfield plain. Their bottoms are flat, the bed-rock floor being covered with chert which has been brought in by tributary streams. The rivers meander from side to side, touching the valley walls, but rarely reaching bed rock in their floors. The steep valley walls are nearly 250 feet in height and are covered with weathered chert except in an occasional cliff where the rivers in the recent cutting have exposed the fresh rock. In the larger creeks, such as Caney and Sallisaw, there is a gradation from the trough to the canyon phase through their middle and lower courses.

BOSTON MOUNTAIN PLATEAU.

The Boston Mountains, which form the southern and most elevated plateau of the Ozark region, become gradually lower toward the west and finally end in low hills and ridges near the mouth of Neosho River. This declining western part of the mountains forms practically the southern half of the Tahlequah quadrangle. The crest of the Boston Mountain plateau slopes westward from an elevation of 2000 feet near the St. Louis and San Francisco Railroad in Arkansas to 1600 feet near the Arkansas-Indian Territory line and 900 feet in the southwest corner of the Tahlequah quadrangle. In this quadrangle the plateau is marked by the tops of the ridges and hills of the mountainous district, which slopes southward at an average grade of 100 feet to the mile. Throughout the Boston plateau in Arkansas the north-facing escarpment is dissected by streams which flow northward. In the Tahlequah quadrangle the entire plateau district is dissected by streams which flow southward across it from the Springfield plain. These streams are Little Lee, Sallisaw, and Vian creeks, and their sources are among the detached hills near the northern edge of the Boston Mountain plateau. They have eroded their valleys to a depth of 300 to 800 feet in the plateau. Between them the country is intricately dissected, and the tributary streams which flow only during abundant rainfall descend in steep, sharp valleys.

It has been stated that the Boston Mountains are made up of the Winslow formation, which consists of many beds of sandstone and shale alternately stratified. In the upper third of the formation there are some thick, hard sandstone beds which now cap the higher ridges of the plateau. Where these beds have come to the surface there are small tracts of table-land or flat benches such as may be found in the top and southern spurs of Brushy Mountain and in some of the high, flat-topped ridges east of Little Lee Creek. Similar phases of topography occur where certain hard sandstone beds at the base of the Winslow formation cap the northern foothills of the Boston plateau and detached mesas in the central and western parts of the quadrangle.

The Morrow, Pitkin, and Fayetteville formations, composed of resistant beds of limestone and sandstone alternating with soft shale, are exposed on the lower northern slopes of the Boston plateau and on the outlying hills on the Springfield plain. They produce distinct bench and terrace forms of topography. The crests of the hills and ridges are usually flat, being protected by the harder beds of rock.

GEOLOGY.

STRATIGRAPHY.

The rocks of the Tahlequah quadrangle are all stratified deposits and were formed in Ordovician, Silurian, Devonian, and Carboniferous times. The sequence of the formations is represented on the columnar section sheet, and their correlations with the formations in other parts of the Ozark region are shown in the correlation table. Almost nothing is known of the geologic history of the quadrangle during parts of the Ordovician, Silurian, and Devonian periods. The stratigraphic relations between the formations present, however, and the occurrence in the contiguous region in northern Arkansas of certain deposits which were laid down during other parts of the Silurian and Devonian periods afford some idea of the geologic history of these times. These ideas are expressed under the heading "History of sedimentation," on page 5.

Ordovician System.

BURGEN SANDSTONE.

The Burgen sandstone is a massive, moderately fine-grained, light-brown rock. The beds are thick and planes of stratification are usually indistinct. The rock consists of a nearly pure siliceous sand of rounded grains, with a matrix scarcely sufficient to cement them together.

In natural exposures the rock breaks readily under the stroke of the hammer, crumbling into loose sand. The formation varies in thickness from a thin stratum to beds aggregating more than 100 feet. It is exposed in the Tahlequah quadrangle in but a single area, on Illinois River northeast of Tahlequah, where it rises in bluffs to a height of nearly 100 feet, and the base is not exposed. The full thickness, therefore, is certainly not less than 100 feet.

The formation takes its name from a small valley opening into Illinois River northeast of Tahlequah.

No fossils have been found in the Burgen sandstone. Its age can be inferred only from its stratigraphic position. The sandstone underlies and is seemingly stratigraphically conformable with the Tyner formation, which is high in the Ordovician section. A formation of magnesian limestone and dolomite, known as the Yellville limestone, occurs in the northwestern part of the Fayetteville quadrangle, which joins the Tahlequah on the northeast. It contains an Ordovician fauna considerably older than that of the Tyner, and in the region of Yellville in Arkansas is succeeded by a sandstone in all respects the same as the Burgen.

TYNER FORMATION.

Greenish or bluish shale, brown sandstone, calcareous, cherty sandstone, and limestone, abundant in the order named, constitute the Tyner formation. For 75 to 80 feet above the base the formation consists of greenish and relatively soft, fissile clay shale with a few beds of brown and yellow, fine-grained sandstone. These interbedded sandstones are usually less than 3 feet in thickness. At the top of the shale there is generally a bed consisting of sandstone in the lower part with calcareous sandstone or siliceous cherty limestone above. This bed is lithologically variable along its outcrop, a sandstone occurring in places above the cherty layer. It varies in thickness also below an extreme of 8 feet 10 inches, and is believed to be absent in places. A bluish limestone succeeds the cherty layers and continues to the base of the Devonian black shale, its thickness ranging from a thin layer to massive beds aggregating 20 feet. These descriptions apply to the district of the Illinois Valley northeast of Tahlequah. In this district fossils have been found in the cherty limestone and associated calcareous sandstone. Some fossils of common occurrence in these beds are listed below. The determinations of fossils and the discussions of age, classification, and correlations of the formations based upon them are by Dr. E. O. Ulrich.

Correlation table of formations in the Tahlequah quadrangle and northwestern Arkansas.

Time scale.		Formations mapped in Tahlequah quadrangle, Indian Territory.	Formations mapped by G. I. Adams and E. F. Burchard in Fayetteville quadrangle, Arkansas.	Formations in north Arkansas as published in reports of the Arkansas Geological Survey.		
Carboniferous	Pennsylvanian	(Akins shale member.) Winslow formation.	Winslow formation.	Penn.		Millstone grit.
		Morrow formation.	(Kessler limestone lentil.)	Mississippian	Boston group	Kessler limestone.
			Morrow formation.			Coal-bearing shale.
			(Brentwood limestone lentil.)			Pentremital limestone.
		(Hale sandstone lentil.)				Washington sandstone.
	Mississippian	Pitkin limestone.	Pitkin limestone.			Archimedes limestone.
						Marshall shale.
		(Wedington sandstone member.)	(Wedington sandstone member.)			Batesville sandstone.[1]
		Fayetteville formation.	Fayetteville formation.			Fayetteville shale.
			Batesville sandstone.			Wyman sandstone.
		Boone formation.	Boone formation.			Boone chert and limestone.
			(St. Joe limestone member.)			Eureka shale (typical).
Devonian		Chattanooga formation.	Chattanooga formation.	Eureka shale (in part)		
		(Sylamore sandstone member.)	(Sylamore sandstone member.)	Sylamore sandstone.		
Silurian		St. Clair marble.		Silurian		St. Clair limestone (restricted sense).
						Cason shale.
Ordovician		Tyner formation.		Polk Bayou limestone.		
				Izard limestone.		
		Burgen sandstone.		Saccharoidal sandstone.		
			Yellville formation.	Magnesian limestone.		
				Sandstones and cherts.		

[1]In the vicinity of Fayetteville, Ark., the Wedington sandstone member of the Fayetteville formation was erroneously correlated with the Batesville sandstone.

- Camarocladia rugosa Ulrich.
- Orthis tricenaria Conrad.
- Liospira americana Billings.
- Lophospira sp. of the type of perangulata.
- Hormotoma gracilis var.
- Leperditia, near L. fabulites Conrad.
- Leperditia n. sp. (about 5 mm. in length).
- Ceraurus pleurexanthemus Greene.

This association of species indicates lower Trenton or Black River age.

In Baumgartner Hollow and along the banks of the Barren Fork Valley only the upper part of the formation is exposed and its thickness does not exceed 20 feet. In these exposures the upper part of the formation consists of interbedded brown sandstone, calcareous sandstone, and bluish or greenish shale. The thin sandstone and shale exposed on Barren Fork and Tyner Creek and probably in Baumgartner Hollow are believed, both from the character of the rocks and from the fossils, to be stratigraphically above the limestones at the top of the formation on Illinois River. Some fossils collected from thin, sandy beds in this locality are listed below.

- Psiloconcha inornata Ulrich.
- Psiloconcha sinuata Ulrich.
- Psiloconcha cf. subovalis Ulrich.
- Rhytimya sp. undet.
- Whiteavesia sp. undet.

These fossils appear to be of Lorraine age, and therefore are considerably higher in the Ordovician than the fauna from the limestone.

The variability in the thickness and the absence of the upper beds of the formation in places are due to erosion preceding the deposition of the overlying Chattanooga shales.

The Tyner formation occurs in but three places in the Tahlequah quadrangle, and these are near the northern border, in the Illinois and Barren Fork valleys and in Baumgartner Hollow. This is the first description of the formation, and its name is that of a small creek along which it is exposed near the northern border of the quadrangle.

Silurian System.

ST. CLAIR MARBLE.

This rock is a pinkish white and, in most parts, coarsely crystalline marble. Only the upper part is exposed and the beds are thick and massive. The marble is even textured, but in parts it contains small, irregular cavities about which the rock is more coarsely crystalline. This characteristic renders the rock locally weak and, in such parts, unfit for the finer uses to which marbles are adapted.

The St. Clair marble is found in the bottoms and lower slopes of several small valleys in the south-central part of the quadrangle. The streams in these valleys have worn down through the overlying strata into the marble, but have not cut through it. As it occurs in the bottoms of the valleys, subject to the direct wear of the streams, fresh exposures are common. At four of the localities the marble is cut off by faults and the part on the southeast side is thrown down to a depth of more than 100 feet below the surface. The exposures showing the thickest beds of the marble are in the large area opposite the station of Marble on the Kansas City Southern Railroad. Here a small tributary of Sallisaw Creek has cut a deep gorge, exposing about 100 feet of the marble, and prospect drills have penetrated nearly an additional 100 feet without reaching the base of the formation. The outcrop extends from this gorge northeastward a distance of 3 miles along the fault bordering Sallisaw Creek Valley. A small area is exposed in Illinois River a few feet above low water opposite Cookson. Here the rock is light gray or nearly white and the beds are thinner than elsewhere.

The St. Clair marble has yielded a considerable number of fossils from the upper part of the formation. The fossils indicate that the formation is of Niagara age and that its upper part at least is equivalent to the St. Clair limestone of northern Arkansas, with which the marble is correlated. It is correlated also by Dr. E. O. Ulrich, who has studied the formation and determined its fossils, with the Lockport limestone of New York and the Osgood limestone of Indiana.

The following list of fossils occurring in the upper part of the marble indicates the Niagara age of the rocks:

- Caryocrinites sp. nov.
- Callicrinus corrugatus Weller.
- Pisocrinus gemmiformis Miller.
- Stephanocrinus osgoodensis Miller.
- Dalmanella elegantula (Dalman).
- Plectambonites cf. transversalis (Wahlenberg).
- Strophonella striata Hall.
- Atrypa nodostriata Hall.
- Cypricardinia arata Hall.
- Orthoceras cf. medullare Hall.
- Gyroceras ? elrodi White.

Devonian System.

Devonian rocks in the Tahlequah quadrangle are represented by a single formation of black shale with rather pure siliceous sandstone or local bituminous phosphatic conglomerate at the base. These deposits in the Tahlequah quadrangle are the extreme southwestern occurrence of like deposits that are exposed at intervals eastward from Indian Territory to the Mississippi embayment in northeastern Arkansas. In northern Arkansas the two parts of the formation have been recognized by geologists of the Arkansas Geological Survey and described as separate formations. In the eastern part of the Mississippi Valley, in the southern Appalachian region, the Devonian black shale occurs widely in the same stratigraphic position as that in Arkansas and Indian Territory and carries locally a phosphatic sandstone at its base. In Tennessee River Valley in East Tennessee and elsewhere in the southern Appalachians the same formation has been described as the Chattanooga shale.

Fossils in this black shale are few and for the most part without very definite diagnostic characteristics. No fossils were found in the black shale in Indian Territory, and only fragments of large fish bones were noted in the sand at the base. The occurrence of the bones, however, together with the stratigraphic identity and striking lithologic similarity between these deposits and those in northern Arkansas and east of Mississippi River, would place them without reasonable doubt in the Devonian and permit the use of Chattanooga as the formation name.

CHATTANOOGA FORMATION.

This formation consists of a black bituminous shale of uniform lithologic character, with a local or lenticular deposit of conglomerate or sandstone, known as the Sylamore sandstone member, at its base. In fresh cuts the black shale is massive at the surface, but in slightly weathered exposures it breaks usually into flat blocks of rudely rectangular form, due to cross jointing. These surface blocks of shale, on more complete weathering, disintegrate into thin, paper-like sheets. For some time after the separation of the shale into fissile laminæ its original hardness is generally maintained, and in roads and other places where the soil has been removed it forms a compact surface.

The black shale of the Chattanooga formation is variable in thickness and occurs unconformably on the Tyner formation and the St. Clair marble in different parts of the quadrangle. Northeast of Tahlequah, in Illinois and Barren Fork valleys and in Baumgartner Hollow, it is approximately 40 feet thick and lies on the Tyner formation. In Illinois Valley opposite Cookson it is 40 feet thick and occurs on the Sallisaw marble. In the vicinity of Marble, west of the fault, the black shale is approximately 20 feet thick. Here the Sylamore sandstone member, 20 to 30 feet thick, occurs between the black shale and the St. Clair marble. In Walkingstick Hollow, near the southwest corner of sec. 36, T. 14 N., R. 23 E., there are excellent exposures of the shale and underlying sandstone member. The surface of the sandstone here is uneven, appearing as if worn in shallow, oval, pothole-like depressions and irregular elevations, in and over which black shale has been deposited. A peculiar feature of the contact phenomena here is that no detrital sandstone material related to the underlying beds is found in the base of the black shale. The Chattanooga shale crops out at two localities in Barren Fork Valley near the northeast corner of the quadrangle, in a small stream 1 mile south of Elm Springs Mission, and at places near the sources of Caney and Terrapin creeks. At all of these localities the streams have cut into the black shale without penetrating it. At two localities, $1\frac{1}{2}$ miles north and 4 miles northwest of Bunch, erosion has penetrated to the Sallisaw marble, and has shown that both the shale and the Sylamore sandstone members are in these places absent.

Sylamore sandstone member.—The Sylamore member of the Chattanooga formation consists of rather coarse, rounded, limpid quartz sand in which pebbles and grains of dark-brown or black, hard phosphatic rock are scattered at random. More rarely small fish teeth, fragments of large fish bones, and particles or fragments of rock similar to the subjacent contact beds are found. The sand grains are almost identical in composition, size, and form with the particles making the Burgen sandstone, of Ordovician age, occurring beneath, but nowhere in this district found in contact with, the Chattanooga formation.

The Sylamore sandstone has been found in four localities in the Tahlequah quadrangle, one on the east side of Illinois River near the northern boundary of the quadrangle, and the other three close together in the west side of Sallisaw Creek Valley northwest and north of Marble.

The rock at the locality first named consists of dark ferruginous quartz sand with many pebble-like lumps of hard, ferruginous, and probably phosphatic rock, which give the mass a conglomeratic appearance. Occasional bluish shaly fragments similar to certain shaly beds in the underlying Tyner formation are also included. This deposit is thin and was seen only in a small area near the head of a small gulch. At the other localities near Marble the Sylamore sandstone is 20 to 30 feet thick and massive, has a generally even texture, and is whitish to light brown in color. The phosphatic pebbles are small and few in number. Fragments of fish bone were occasionally observed in the sand. The sand is calcareous near the base, and in places seems to blend with the top of the St. Clair marble, though no inclusions of marble were seen. The sand terminates abruptly at the top in Walkingstick Hollow, where the contact is clearly exposed. At one locality noted in this valley, where the erosion of the stream had just reached the top of the sand, the surface is uneven, the black shales filling irregular depressions a foot and less in depth and 2 to 3 feet in width. The contact between the shale and the sand is clean, no sand being included in the shale, even in the basin-like depressions.

The only fossils from this member of the Chattanooga formation seen are more or less macerated fragments of large fish bones, apparently of the genus *Dinichthys*. This "terrible fish" swarmed in the late Devonian seas, and its bones are perhaps the most characteristic fossil of the upper Devonian Ohio black shale in Ohio and other States east of the Mississippi.

Carboniferous System.

MISSISSIPPIAN SERIES.

BOONE FORMATION.

The rocks of the Boone formation consist of interstratified chert and cherty limestone. At the base there are in places thin limestones free from chert, while at other localities the chert rests on the Chattanooga shale without intervening limestone beds. The limestone beds at the bottom, being distinct in lithologic character from the body of the formation and variable in thickness, are properly characterized as a member of the formation.

The base of the Boone formation is exposed in twelve localities, and in four of these limestone was found beneath the chert. Of the known occurrences of limestone beneath the chert two were found bordering the small areas of the Chattanooga shale in Barren Fork Valley south of Westville. In the smaller area in the west side of sec. 34, T. 17 N., R. 26 E., the limestone is about 5 feet thick. At the other locality, 3 miles down the stream, it is 10 to 15 feet thick. At these places it consists of fine-textured and dense, white to pinkish, even-bedded limestone. Light-colored crinoidal limestone beds 10 to 15 feet thick occur at the base of the Boone formation in the south bank of Barren Fork at the road crossing in the NW. $\frac{1}{4}$ sec. 13, T. 17 N., R. 23 E. No fossils were collected from this limestone at the three localities named, but its position in the formation and its lithologic character strongly indicate that it should be correlated with the basal St. Joe member of the Boone formation exposed in the northern part of the Fayetteville quadrangle and farther east in northern Arkansas.

A fourth locality of the basal limestone member of the Boone formation is in a small valley leading into Illinois River in sec. 36, T. 18 N., R. 22 E., very near the north border of the quadrangle. Here the beds consist of dull blue and earthy fossiliferous limestone in the lower part, followed above by thicker and harder limestone beds, the thickness of the whole being 6 feet. These beds belong stratigraphically below the lighter-colored crinoidal limestones, both being locally developed. They contain the following fossils, together with a number of undetermined and mostly undescribed species, all indicating Kinderhook age:

Leptæna rhomboidalis Wilckens.
Productella concentrica Hall.
Spirifer cf. peculiaris Shumard.

The lighter-colored, often pink, and generally crystalline crinoidal limestone, together with the lower part of the cherty limestone overlying it, contains a Burlington fauna. The common fossils in this division include the following species:

Schizoblastus sayi Shumard.
Platycrinus and fragments of other crinoids.
Spirifer grimesi Hall.
Syringothyris sp.
Productus cf. semireticulatus.

The middle member constitutes almost the whole of the Boone formation as exposed in this quadrangle, and is made up essentially of calcareous chert or flint with variable bands or beds of limestone.

Fresh exposures occur in but few places and these are in steep bluffs and cliffs where the larger streams meander against the sides of their valleys, or more rarely in the beds of the smaller streams in their middle or lower courses where the grades are sufficiently steep and the volume of water great enough to induce active erosion. The chert element predominates so greatly over the limestone in abundance, and is so resistant to the effects of erosion, that almost the entire surface rock consists of angular chert bowlders and fragments.

The cherts in the upper part of the formation are locally very fossiliferous. The following list includes the species most commonly found, and their association is decidedly indicative of Keokuk age:

Amplexus fragilis White and St. John.
Glyptopora keyserlingi Prout.
Fenestella multispinosa Ulrich.
Polypora maccoyana Ulrich.
Hemitrypa proutana Ulrich.
Pinnatopora striata Ulrich.
Spirifer logani Hall.
Reticularia pseudolineata Hall.
Productus setigerus Hall.
Orthotetes keokuk Hall.
Capulus equilaterus Hall.

The limestone overlying the chert was believed to be a part of the Boone formation at the time the Tahlequah quadrangle was surveyed and is included with it in the mapping. Later studies of this limestone made in connection with the survey of the Muscogee and Winslow quadrangles, west and east of the Tahlequah, have shown that locally, at least, a thin bed of black shale occurs between this limestone and the Boone chert. An abundant fauna, also, which has been collected from it, shows that it is higher geologically than the Boone and should be classed with the Fayetteville formation.

The thickness of the Boone formation is variable. It ranges from a minimum of 100 feet to a maximum approximating 300 feet. Except in a few localities the top and base are separated in outcrop by several miles, and the rocks are so concealed by surface chert débris that the determinations of thickness are at best only approximate.

The Boone formation outcrops over nearly one-half of the quadrangle and extends eastward into northwestern Arkansas, where, in Boone County, it was described and named by the State geologist of Arkansas. It also occupies a large area in southwest Missouri, including the zinc belt of the Joplin region.

FAYETTEVILLE FORMATION.

This formation consists of shales, black to blue in color, thin limestone, and shaly sandstone. The larger part of the formation consists of shale, and the limestone beds are inclosed in it as thin lentils or local beds near the base and top, while the sandstone is found above the middle of the formation inclosed in shale. The sandstone being locally thick enough in the northeastern part of the Tahlequah and in the adjoining Fayetteville quadrangle to be regarded as a member, separates the shale locally into two parts. The sandstone attains its greatest thickness in Wedington Mountain, in the southwestern part of the Fayetteville quadrangle, and is known as the Wedington sandstone member of the Fayetteville formation. Thus the formation consists of three parts or members—an upper and lower of shale, and a middle member, the Wedington, of sandstone.

Lower shale member.—The lower shale member of the Fayetteville formation consists of black to blue laminated clay shale, with beds of dark-blue to black fossiliferous limestone near the base. It grades upward into the Wedington sandstone member through sandy shales. The shale in the lower part of this member is invariably blacker, harder, and more distinctly fissile than in the upper part, which has shades of dark to light blue on fresh exposure. The upper part contains numerous thin and small clay-ironstone concretions.

The thickness of the shale is variable, decreasing from approximately 110 feet in the northeastern to about 20 feet in the southwestern portion of the quadrangle. The limestone in the lower part has a great influence on the variation of thickness of the member, as it likewise becomes thinner toward the west. As the shale thins, its upper part gradually becomes darker until in the western portion of the quadrangle all of it is dark blue or black.

Aside from the small goniatites and other cephalopods found in the few limy concretions that occur in the black shale, the fauna of the lower member is confined to the limestone near its base.

The principal fossils of this limestone are the following:

1. A large undescribed crinoid, related to Eupachycrinus, but with uniserial arms. The plates of the calyx, being thick and bulbous, are striking fossils.
2. Archimedes cf. communis Ulrich.
3. Orthotetes kaskaskiensis McChesney.
4. Chonetes n. sp., of the type of C. geinitzanus Waagen (rare).
5. Productus cf. cora and tenuicostus.
6. Productus cestriensis Worthen.
7 Productus of the type of P. splendens.
8. Productus sp. undet.
9. Seminula subquadrata Hall.
10. Cleiothyris sublamellosa Hall.
11. Spirifer increbescens Hall.
12. Spirifer of the type of S. pinguis; cf. S. scobina Meek.
13. Spiriferina transversa McChesney.
14. Camarotœchia sp. undet.
15. Dielasma cf. formosum Hall.

Of the above list Nos. 1, 7, and 14 are very abundant and characteristic.

Wedington sandstone member.—The Wedington sandstone member in the Tahlequah quadrangle consists of thin-bedded and shaly brown sandstone which grades downward gradually into the lighter blue shales at the top of the lower shale member of the Fayetteville formation. It has the form of a lens or wedge, its thickness near the northeast corner of the quadrangle, in Alberty and West mountains, being about 40 feet. It thins toward the south and west, the shaly sandstone in the lower part increasing in the relative amounts of clay, and the sandstone becoming thinner and more shaly. In the lithologic change the lower part becomes indistinguishable from the upper part of the lower shale member. To the south, in the north slopes of Muskrat Mountain, and to the west, in Walkingstick Mountain, the lithologic character of the Wedington sandstone member is lost to view. Toward the northeast the Wedington sandstone increases rapidly in thickness, reaching a maximum more than 150 feet in Wedington Mountain, 2 to 6 miles northeast of the Tahlequah quadrangle.

Upper shale member.—The upper shale member of the Fayetteville formation is composed of bluish clay shales with ferruginous limy clay segregations and local thin layers of fossiliferous limestone. In the northeastern part of the quadrangle this member is so obscured by the débris from the Hale sandstone lentil of the overlying Morrow formation that its character is not easily determined. The interval between the Wedington sandstone and the succeeding Pitkin limestone, however, indicates that the shale does not exceed 30 feet in thickness. As this shale is thin and occurs in bluffs or steep slopes, it is included on the map within the area of the Wedington member. West and south of the occurrence of the Wedington sandstone the upper shale member is not distinguishable from the blue shales in the upper part of the lower shale member. The upper shale member, together with the whole formation, thins westward, until in the western part of the quadrangle the whole is found to be a black fissile shale except the limestone bed that occurs near the base and locally near the top.

The fauna of the upper shale member is distinguished from the other fossiliferous horizons of the formation by the much greater abundance and variety of its Bryozoa; also by the presence of a pentremite. These, in conjunction with the absence of the fossils that are most abundant and characteristic of the other two horizons, impart a very different aspect to its fauna. The species most commonly found are the following:

Pentremites sp. undet. (a large form between P. godoni and P. conoidens.)
Septopora cestriensis Prout.
Fenestella sp. nov. (a common Chester form).
Archimedes compactus Ulrich.
Archimedes communis Ulrich.
Archimedes intermedius Ulrich.
Archimedes swallovanus Hall.
Polypora corticosa Ulrich.
Productus cestriensis Worthen.

Productus sp. of the type of P. cora.
Productus sp. of the type of P. punctatus.
Seminula subquadrata Hall.
Reticularia setigera Hall.
Spiriferina spinosa N. & P.

The Fayetteville formation occurs in bases of escarpments or hills bordering the plain developed by the erosion upon the Boone formation, or in benches between the more elevated hilly country made by the Morrow formation and overlying sandstones above and the hard limestones and chert of the Boone below. In most instances the bed of shale outcrops on the watersheds and drainage divides at the sources of the streams. This is invariably its position where the Fayetteville shale bounds isolated areas of higher rocks. The outcrops of the shale are usually soil covered or concealed by débris from the overlying rocks.

The Fayetteville formation is widespread. It is exposed westward in the Muscogee quadrangle to the valley of Neosho River. It occurs eastward throughout a large part of northwestern Arkansas, and is typically developed in the vicinity of Fayetteville, where it was first described and named in vol. 4 of the report of the Arkansas Geological Survey for 1888.

PITKIN LIMESTONE.

The Pitkin limestone varies from rusty-brown, granular, earthy, and shaly strata at one extreme to fine-textured, massive, bluish beds at the other. The characteristics first named are usually found where the formation is thinnest and in the upper and lower beds elsewhere. Blue clay shale locally occurs interbedded with the limestone.

In thickness the Pitkin limestone varies from a thin shaly layer to massive beds aggregating 70 feet. The changes in thickness are irregular, though there is a general increase toward the southwest. As illustrations of this variability the following instances are cited. In Walkingstick Mountain the formation consists of a thin bed of brownish earthy limestone, while in the small mountain 3 miles west the strata are massive and make a section 40 feet thick. This limestone in the mountain east of Stilwell is 20 feet, while in the western and southwestern parts of the same township it is 40 to 60 feet thick. In T. 15 N., R. 24 E., the formation varies between 20 and 30 feet. The same is true for the northeastern part of the adjoining township (T. 15 N., R. 23 E.), but in the western and southwestern parts and in T. 15 N., R. 22 E., the thickness increases to more than 60 feet. In the vicinity of Bunch and elsewhere in T. 14 N., R. 24 E., the formation is usually about 20 feet thick, while farther west, toward the border of the quadrangle, there is a general increase of the section, the thickness ranging from 40 to 60 feet.

The Pitkin limestone outcrops generally at the bases of hills and in steep slopes, bluffs, and escarpments, usually beneath sandstones. The talus from these overlying sandstone beds frequently conceals the edges of the Pitkin formation, so that a complete section can rarely be found. While the Pitkin limestone varies in thickness and locally becomes thin, it has been found at every place where its horizon reaches the surface. Toward the east, beyond the Tahlequah quadrangle, the Pitkin limestone occurs in isolated areas and outcrops along the northern foothills of the Boston Mountains in northwestern Arkansas. Typical exposures occur in the north slopes of the Boston Mountains on the St. Louis and San Francisco Railroad, near Pitkin, from which place the limestone receives its name.

The Pitkin limestone is considered to be the top of the Mississippian series of the Carboniferous. The reasons supporting this determination are given in the discussion of the correlation of formations, on page 2.

The fossils of this limestone are with few exceptions the same as those found in the limestone near the top of the Fayetteville formation.

PENNSYLVANIAN SERIES.

MORROW FORMATION.

The Morrow formation consists of three distinct classes of rocks, which have considerable range in thickness and occurrence and are variable in character. These rocks are sandstones, limestones, and shales; they can be segregated more or less distinctly in the order as named from the base upward, and are properly classed as members. The limits of these members have been traced from Neosho River in eastern Cherokee Nation eastward through a considerable part of northwestern Arkansas north of the Boston Mountains. These members vary in both composition and thickness from northeast to southwest. Toward the southwest the quantity of lime increases to such an extent that at the west side of the Tahlequah quadrangle and in the Muskogee quadrangle the formation consists of limestone with scarcely any deposits of sand and clay. In the opposite direction the amount of limestone grows less, until in parts of the Fayetteville and adjoining quadrangles the formation consists locally almost entirely of shale and sandstone. Still farther east, in the vicinity of St. Joe, it is reported by Dr. Ulrich that the limestone is entirely absent from the lower part of the formation, this absence being accounted for by overlap.

The lowest member or lentil of the formation is sufficiently distinct lithologically to be mapped and has received the name Hale sandstone, because of its strong development in Hale Mountain, in the Winslow quadrangle near the northeast corner of the Tahlequah quadrangle. The middle member consists of limestone with minor deposits of clay shale, which usually grades into the upper member, consisting of shale with occasional strata of limestone and thin sandstone interbedded. The middle member grades into the upper, and the boundary between them is not usually distinguishable. For these reasons they are not mapped or distinguished by names, but will be separately described.

The formation is named for the village of Morrow, near which a typical section of the rock is exposed, in Washington County, Ark., 4 miles east of the Tahlequah quadrangle.

Hale sandstone lentil.—The Hale sandstone in its typical development consists of thick-bedded, massive, calcareous sandstone in the upper part and where it is thickest. In such instances the beds are nearly pure quartz sand of even and moderately fine grain. This member varies in composition locally. In places parts of the member (usually the lower and middle) become so calcareous as to be classed as siliceous limestones. Again it is shaly, consisting of clay and sandy shale with strata of sandstone, especially where the member becomes thin.

The Hale sandstone decreases in thickness westward, but the change is irregular. The thickest section is exposed in the slopes of the valley east of Muskrat Mountain, where the member is 110 feet thick. The lower 40 feet are calcareous sandstone. In the central part are 25 feet of thin-bedded siliceous limestone. The upper 40 feet consist of massive brown and nearly pure siliceous sand. In the low mountain in T. 16 N., R. 26 E., the sandstone becomes thinner in an irregular manner and varies between 10 and 50 feet. In T. 15 N., R. 24 E., it becomes coarser and more massive, especially in sec. 21, where it reaches a thickness of 70 feet. Farther west the sandstone decreases in thickness, becoming at the border of the quadrangle too thin to be mapped. In the adjoining Muscogee quadrangle it has not been recognized in mappable thickness. In the valley of Vian Creek, near the southwest corner of the quadrangle, the upper beds of this member are exposed and the sand is so coarse as to be classed as a grit or fine conglomerate.

This member was originally described as a formation. In the Arkansas Survey reports treating of the geology of Washington County, it was named the Washington sandstone, for Washington Mountain, where it is typically exposed. Washington being preoccupied as a formation name, Hale, the name of a mountain near which it is well exposed, is adopted instead.

The Hale sandstone contains locally siliceous limestone beds that are fossiliferous. The fauna has been only partially worked up. The most prominent species is a *Spirifer* apparently not distinguishable from the lower Pennsylvanian *S. boonensis* Swallow. Some of these calcareous layers contain numerous fenestellid Bryozoa and fewer Brachiopoda. Some at least of these fossils belong to species found abundantly in the overlying limestone, but others appear to be confined to the Hale sandstone. So far as studied the fossils from this member contain nothing that casts doubt on the view that the whole of the Morrow group is younger than Mississippian.

Limestone of the Morrow formation.—The middle portion of the Morrow formation consists of relatively hard, blue, fine-textured limestone with a deposit of blue clay shale, usually in the middle part. Locally there are thin sandstone and limestone beds interstratified with this shale. Shale also occurs near the top of the member interbedded with the limestone in places. In such instances there is a gradation from limestone to shale from the middle to the upper member. Again, there is an abrupt change from limestone to shale where the two members are quite distinct. There is a gradual change in the lithologic character of the middle member of the Morrow formation toward the west by increase of limestone and decrease of clay. Near the eastern border of the quadrangle the limits of this member are not well defined and it consists in large part of shale interbedded with limestone, while near the western border and beyond, in the Muscogee quadrangle, it is composed almost entirely of limestone. The thickness also is variable, in an irregular way, ranging from 50 to 200 feet. This variation may be due, however, to the erosion of some of the upper beds prior to the deposition of the succeeding formation.

Some layers of this important limestone member are full of small gasteropods and pelecypods, of species mainly undescribed. Other layers are charged with many kinds of Bryozoa. These, also, are nearly all new to science, but when compared with known species their alliances are in nearly every case nearer Pennsylvanian than Mississippian types. A subramose *Michelinia* (near *eugeneæ* White) is abundant; also another coral comparing rather closely with *Trachypora austini* Worthen. Both of these corals are of service in distinguishing the horizon from the lithologically similar Pitkin limestone. Among the brachiopods, which class is represented by a number of undetermined species, a *Hustedia* cf. *mormoni* Marcou affords perhaps the most reliable evidence of the Pennsylvanian rather than Mississippian age of the Morrow formation. Several very fine species of crinoids occur in the lower limestone, but as they are all new they throw little light upon the age of the bed. The generic types represented occur in late Mississippian rocks and, in part at least, in much later Pennsylvanian deposits. However, so few crinoids are known from the latter series of rocks that it is as yet impossible to properly estimate the evidence of the crinoids. *Pentremites rusticus* Hambach is one of the common fossils. The old name of the member—Pentremital limestone—was derived from it.

Shale in the Morrow formation.—The uppermost part of the Morrow formation consists of blue and black clay shale with few local beds of limestone and more rarely thin layers of sandstone and sandy shale near the top. The character of the limestone is practically the same as that of the beds making the upper part of the limestone below. The shale also resembles that interbedded with the limestone of the middle member, except that it is usually more arenaceous and more distinctly laminated. In the hills 2 miles west of Stilwell this member culminates in shaly calcareous sandstone, thin sandstone, and limestone interstratified. In such places the top of the Morrow formation can not be clearly defined, since the succeeding formation consists of sandstone and shale. The limestone layers of this member are not numerous and occur in various positions in the shale, chiefly in the upper part. In many places limestone beds can not be found, and there is no assurance that they are everywhere present.

This member varies in thickness, reaching a maximum of about 100 feet. The changes in thickness occur in various parts of the quadrangle, but there is a general decrease toward the west. These changes are undoubtedly due, in part at least, to local erosion prior to the deposition of the succeeding Winslow sandstone, which occurs unconformably on the Morrow formation.

The limestone beds of this member are locally very fossiliferous, but the fauna consists of rather few species. All of the forms observed by the writer occur also, and in better condition, in the underlying limestone. The fauna consists principally of brachiopods and bryozoans. Mollusks are notably few or absent. The mollusks, however, especially gasteropods, occur in some of the thin sandstones and shales above the limestone.

The shale between the main limestone and the thinner beds of limestone near the top of the formation contains a thin bed of coal at one locality in the Muscogee quadrangle and at a number of places in northwestern Arkansas, some of which are in the Fayetteville quadrangle. Associated with the coal in the Fayetteville quadrangle are black shales containing fossil plants. Collections of these fossil plants were determined by David White and correlated with certain plant remains from the Sewell formation of the Pottsville stage in the southern Appalachian region. This correlation, published in 1895 and again in 1900 (Bull. Geol. Soc. America, vol. 6, 1895, p. 316; Twentieth Ann. Rept. U. S. Geol. Surv., pt. 2, 1900, p. 817), showed that the rocks above the main limestone (Pentremital limestones of the Arkansas Survey), at least, belong to the Pennsylvanian series. Studies made recently by Messrs. Ulrich and Girty show that the limestones both above and below the plant-bearing shale contain a united fauna and that the whole Morrow formation should be classed as Pennsylvanian.

WINSLOW FORMATION.

The Winslow formation consists of bluish and blackish clay shale, sandy shale, and brown sandstone, with rarely small accumulations of conglomerate near the base. For convenience of discussion the formation may be separated into three members, which are distinguishable by the increase of sandstone near the middle of the formation. Generally speaking the sandstones are thin bedded and variably shaly. This is especially the case in the lower member of the formation, where also clay shale is more abundant than in the middle member. The change in abundance of sand in the sediments from the lower to the upper member is gradual and the boundary between the two can not be continuously traced. The stratigraphic relation between the middle and upper members, however, is different. The change from the middle member, which is chiefly sandstone, to the upper member, which is composed for the most part of shale, is more abrupt than the transition from the lower to the middle member. The parting between the two members is sufficiently distinct in the Tahlequah quadrangle to be mapped and to be distinguished by name. It is named the Akins shale member, from the village located on it near the southern boundary of the quadrangle. Westward, however, across the Muscogee quadrangle, the sandstones of the middle member become thinner and more shaly and the base of the Akins shale member can not be mapped. Otherwise the Akins shale deserves to be distinguished as a formation.

In the lower member, from the base upward about 450 feet, to approximately the middle of the formation, the two classes of sediments occur in many beds alternately deposited. The sandstones are generally shaly or thinly stratified. Locally near the base the sandstones are massive and thick, and in such places are often coarse, consisting of small quartz pebbles embedded in a brown sand matrix. In a few places these pebbles are sufficiently coarse to justify the classification of the rocks as conglomerates.

Above these sandstones and shales there is a nearly equal thickness of rocks composed principally of brown sandstone, which constitutes the middle member. A part of this member is composed of thinly stratified or shaly sandstone, and minor beds of shale occur interstratified with them. As a whole these beds become thicker and more massive upward, and they increase in thickness eastward. Certain beds in the upper part are also harder than the sandstone in the lower part, and their effect is strong in controlling the topography of the southeastern part of the quadrangle. Above the thick sandstone beds are deposits of blue and black shales with a few beds of sandstone, which culminate in sandstone and shaly beds, aggregating about 50 feet.

The hard beds of the Winslow formation occur in the southeastern part, making the most rugged topography of the quadrangle. The lower beds cap many hills and low mountains in the central and western parts of the quadrangle. Except the hard sandstone beds near the middle of the formation and certain more resistant sandstones and conglomerates at the base, the rocks of the Winslow formation are generally concealed by sandstone talus. As a result few even of the sandstone beds can be traced for any considerable distance.

Akins shale member.—Only the lower part of the Akins shale occurs in the Tahlequah quadrangle. It consists of blue and black clay shales and shaly sandstone with a few thin sandstone beds. A thin bed of coal occurs near the base of this member in the northwestern part of the adjoining Sallisaw quadrangle. It has been prospected and worked for local use in the Sallisaw Creek Valley a few miles south of the Tahlequah quadrangle.

In this quadrangle coal should outcrop near Sallisaw Creek and in the vicinity of Akins, but it has not been found at these places. The lower part of the shale, and probably that part including the horizon of the coal, is concealed by faulting along the north side of the Akins shale exposure in the Tahlequah quadrangle.

The Akins shale outcrops in a narrow, elongated area that extends from the Tahlequah quadrangle southwestward to the Arkansas River Valley. It occurs here in an elliptical basin which is known as the Sallisaw syncline. The thickness of the shale in this basin is estimated to be 600 to 700 feet, and the lower 150 to 200 feet are exposed in the Tahlequah quadrangle.

It has been determined by areal geologic mapping in the Sallisaw quadrangle, which joins the Tahlequah on the south, that the Akins shale member represents the upper part, approximately the upper third, of the McAlester formation, the lower limits of which are not determinable in the Tahlequah quadrangle or elsewhere north of Arkansas River.

The average thickness of the lower and middle members of the Winslow formation is estimated to be approximately 900 feet, which, with the exposed part of the upper or Akins shale member, will aggregate 1050 to 1100 feet in the quadrangle.

Correlation of Formations.

The determinations of the age, the classification, and the correlation of the rocks occurring in the Tahlequah quadrangle are based on direct stratigraphic connection between the formations in this quadrangle and those mapped in Arkansas to the northeast and Indian Territory to the south and on paleontologic determinations by Messrs. G. H. Girty and E. O. Ulrich, paleontologists of the United States Geological Survey, from observations and collections made in the field seasons of 1901, 1902, and 1904. The most abundant collections were obtained from the Carboniferous section, where the more important age distinctions and revisions of former classifications were made. Especially valuable is the more definite knowledge gained concerning the boundary between the rocks of Mississippian and Pennsylvanian age.

The Burgen sandstone is much like the saccharoidal sandstone of northern Arkansas and southern Missouri, and its stratigraphic position above the Yellville limestone, the uppermost group of the "Magnesian series," strongly favors its correlation with the saccharoidal sandstone recognized by the Arkansas Geological Survey. It is not known to contain fossils.

The Tyner formation contains a considerable fauna in the limy layers and in some sandy beds above and near the top, which indicates that the rocks range from Trenton to Lorraine in age.

The St. Clair marble, at least the upper exposed part, contains a Niagara fauna. Both the fossils and the rock characteristics show it to be a westward continuation of the St. Clair marble of northern Arkansas.

The correlation of the Devonian black shale and sandstone of this area with the Chattanooga shale of the southern Appalachian region is based upon stratigraphic relations to older and younger rocks, identical lithologic character, and the occurrence of similar fish remains in the phosphatic sands in the lower parts of the two beds.

The Boone formation is widespread in occurrence and has been traced by areal mapping from the Tahlequah quadrangle to localities first described in northern Arkansas.

The Fayetteville formation at its type locality about Fayetteville, Ark., as well as at many places in Indian Territory, contains a well-preserved and abundant fauna. It has been mapped from Fayetteville westward through the Tahlequah and Muscogee quadrangles. Special studies by Dr. Ulrich in the region of Batesville, Ark., show that in that locality the Marshall shale (so named by the Arkansas geologists) is rich in fossil shells and contains a fauna correlative with that of the Fayetteville shale. Thus the Batesville sandstone, which, at Batesville, its type locality, occurs beneath the Marshall shale, belongs beneath instead of above the Fayetteville shale and is to be classed with the Wyman sandstone which is found near Wyman and in the Fayetteville quadrangle.

The sandstone overlying the Fayetteville shale and mapped as the Batesville sandstone by the Arkansas Survey (Geology of Washington County, vol. 4, 1888) is now known as the Wedington member of the Fayetteville formation. The formation described as the Marshall shale in the Washington County report, which is separated but locally by the Wedington sandstone from the shale beneath, necessitated the combination of the two with the included sandstone into the Fayetteville formation.

The Pitkin limestone (Archimedes limestone of the Arkansas Survey) marks the upper limit of the Mississippian series of the Carboniferous in northwestern Arkansas and northeastern Indian Territory. Field studies and office investigations of the fauna of the Pitkin and Morrow formations by Dr. Girty and Dr. Ulrich have developed conclusive evidence of this classification. Dr. Girty reports the following: "There is a rather marked faunal change at the stratigraphic plane between the Morrow and Pitkin formations or between the 'Archimedes' and 'Pentremital' limestones of the Arkansas Survey classification. The Pitkin fauna is related to that of the Mississippian epoch. The faunas of the different limestone beds in the Morrow formation are closely allied to one another. They both exclude many of the Mississippian types found in the Pitkin limestone and include many which are foreign to it, and some which are distinctly Pennsylvanian. For example, *Squamularia* is substituted for *Reticularia*, and *Hustedia* for *Eumetria*. The flora of the 'Coal-bearing' shale which occurs between the limestones of the Morrow formation is that of the Pottsville, a division of the Pennsylvanian series in the Appalachian province."

Formations of Pennsylvanian age in the Tahlequah quadrangle can not be correlated definitely with rocks of related age on the south side of the Arkansas Valley. In both localities fossiliferous limestones occur at the base. In the area lying on the south side of the valley and extending westward to the Arbuckle Mountains the formation is known as the Wapanucka limestone, and is described in the Coalgate and Atoka folios. It is probably the equivalent, in part at least, of the Morrow formation. Above the Wapanucka there is a shale and sandstone formation having a thickness of 6000 to 7000 feet. It thins toward the west, decreasing to 3000 feet in the Atoka and Coalgate quadrangles, where it has been named the Atoka formation. The Atoka formation is the stratigraphic equivalent of probably the lower 600 to 800 feet of the Winslow formation in the Tahlequah quadrangle. Neither formation has been found to contain sufficient fossils for paleontologic correlation. The limestones at the base of each are probably equivalent, as stated, and it has been determined by areal mapping that the Hartshorne sandstone, which overlies the Atoka formation on the south side of the Arkansas Valley, has a stratigraphic equivalent in the upper part of the Winslow formation in the Tahlequah quadrangle.

HISTORY OF SEDIMENTATION.

All the rocks in the Tahlequah quadrangle were deposited in water and are composed of the waste of neighboring lands and of the remains of animals and plants which lived in or near the borders of the seas when the sediments were being laid down. These rocks, as described above, are limestones, shales, sandstones, and conglomerates, and when they were deposited consisted of limy ooze, mud, sand, and gravel, respectively. The characters of these rocks, when traced and studied over a wide field, tell the story, though not complete, of the manner of their formation. As ages passed and formations were successively deposited the generations of animal life changed or migrated and were succeeded by other forms. At certain stages in the sedimentation gaps occur in the life record, accompanied by discordance in the character and structure of the rocks, showing oscillations of the land and sea. The variations in the coarseness, composition, and thickness of the formations record evidence of the depth of the water in which they were deposited and give some idea of the extent of the submergence and the nature of the contiguous lands. The fossil remains not only show the relative ages of the successive strata, but aid in identifying and correlating the formations which came to the surface in separated localities.

Stratigraphically below the lowest rocks at the surface in the Tahlequah quadrangle lie magnesian limestones, conglomerates, sandstones, cherts, etc., of Cambrian and Ordovician ages, which come up around the older igneous rocks of the St. Francis Mountains in southeastern Missouri and also in northern Arkansas. They reveal a record of sedimentation which is not essential to the geologic history of the Tahlequah quadrangle. It is sufficient here to say that the older formations which approach the crystalline rocks of the St. Francis Mountains overlap against them, thus recording the fact that they were remnants of the land mass which probably persisted during their deposition. That a large part of the region underwent numerous oscillations of level above and below the sea is recorded by the rapid alternation of saccharoidal sandstone and magnesian limestone and the occurrence of conglomerate.

One of these saccharoidal sandstones, probably the uppermost, is represented by the Burgen sandstone.

During its deposition the sea bottom was raised and the beach bordering the lowland advanced and receded back and forth across the district, leaving a thick deposit of homogeneous clean sand. Such deposits are known to be formed only in shallows near wave-washed shores. After the Burgen deposition, an erosion period possibly intervening, the shores retreated, the retreat being accompanied by a subsidence of the sea bottom, so that fine waste from the land was laid down as mud in thin laminæ corresponding to successive floods on the land or rhythmical variations of the currents of the sea. At certain stages of the deposition thin sheets of fine sand were deposited over the bottom, and finally, near the close of the Tyner epoch, muddy sediments did not reach this area and limestones were formed.

Above these sandy and shaly sediments was deposited the material which now makes the St. Clair marble. The marble is surrounded and concealed in the Tahlequah quadrangle, outside of a few exposures, by younger rocks which rest unconformably on it. Massive white crystalline limestone 200 feet or more in thickness, such as the St. Clair marble, indicates deposition in clear water, which may have been either some distance from land or at considerable depths in the vicinity of very low land.

After the deposition of the St. Clair marble there is a break in the record, corresponding to the closing portion of Silurian and early Devonian times. In this long interval the rocks were folded in low undulations and uplifted into land. Probably while the folding was in progress, and certainly after it had taken place, the land was reduced by erosion to a low and nearly level surface. This land was submerged in late Devonian times. These conditions prevailed not only in the vicinity of the Tahlequah quadrangle, but extended over a large part of the Ozark uplift. The record of this submergence is found in the Chattanooga shale, which was deposited over a very broad extent of country. This shale, which is such as would be formed in a broad, shallow sea, was deposited on the eroded surface of several formations, consisting of various kinds of sandstones, shales, limestones, and dolomites. In the small areas exposed in the Tahlequah quadrangle the Chattanooga shale occurs on all three of the older formations, and though the Tyner shale and Burgen sandstones are friable rocks, material from them does not enter appreciably into the composition of the shale. After the deposition of the Chattanooga shale submergence of the region continued well into Mississippian time, until the formation of the Boone limestone and chert was completed. The broad extent of this submergence is shown by the fact that patches of the Boone formation occur almost up to the crest of the Ozark dome. In later Mississippian time there was an elevation of the sea bottom and at least a part of the Ozark region became land. Oscillations of land and sea, however, occurred until the entire Mississippian series was deposited, as shown by the locally variable formation of sand, clay, and limestone.

In mid-Carboniferous time the sea withdrew, leaving the Ozark region as land beyond the boundary marked by the exposed top of the Mississippian sediments. The evidence of the broad land at this time is shown in the erosion of the highest Mississippian formation where the Pennsylvanian rocks come in contact with them. In the south and southwest sides of the uplift, notably in the Tahlequah quadrangle, the unconformity is not great, but farther up, toward the crest of the dome, higher rocks of the Pennsylvanian series come in contact with successively lower beds of the Mississippian. In southwestern Missouri and toward the center of the uplift the Boone formation shows evidence of mid-Carboniferous erosion, and the depressions in its surface yet contain remnants of Coal Measures conglomerates and shales. Thus it is seen that after the elevation of the Ozark region in mid-Carboniferous time it was again submerged, but to what extent is not known, since so large a part of the formations of Pennsylvanian age in the Tahlequah quadrangle and elsewhere in the region record a history differing from that of previous sediments. The waters in which they were deposited were shallow, the bottoms of the seas frequently reached the surface, and the lands were low, as attested by the alternating shale, sand, and conglomerate and the irregularity of their bedding. The lands were more extensive than the confines of the Ozark uplift. The Pennsylvanian sediments increase greatly in quantity of coarse material and in thickness toward the south and east, indicating the direction of the land from which the great abundance of sand especially was derived. Additional evidence of this is the fact that the later beds of the Pennsylvanian deposits which overlap the rocks of the Ozark dome decrease in thickness northward and contain little coarse sediment.

After the close of the Carboniferous the whole region was raised above the sea, and there is no record of sedimentation to indicate that it has since been submerged. The features of the Ozark region and the occurrence of later rocks on its eastern border show that the surface has oscillated and that the rocks have been locally deformed, but these are records of physiographic and structural history, and are described elsewhere.

STRUCTURE.

GENERAL STATEMENT.

All stratified rocks are originally deposited in nearly flat positions. This may be said to be universally true of the finely divided sediments, such as fine sand, clay, and limestone, and of practically all deposits having broad extent. All the rocks of the Tahlequah quadrangle are included in this classification of stratified rocks.

In the discussion of the history of sedimentation it was pointed out that the rocks of the Ozark region, of which the Tahlequah quadrangle formed a part, oscillated from sea bottom to land and from land to sea bottom at various times between the Cambrian period and late Carboniferous time, and that these oscillations were accompanied by slight and variable folding of the strata. Since rocks lower than the Carboniferous crop out in but few and small areas in the Tahlequah quadrangle, but little can be said of their structure apart from that involved in the Carboniferous rocks. At some time after the Carboniferous period the region was uplifted and the flat strata were bent into a broad dome. A better understanding may be had of the structure of the Tahlequah quadrangle after a brief description of the Ozark uplift and the Arkansas Valley, of which it forms parts.

OZARK UPLIFT.

The Ozark uplift comprises southern Missouri, that part of Arkansas included in and lying north of the Boston Mountains and west of the Mississippi lowlands, northeastern Indian Territory east of Neosho River, and the southeast corner of Kansas. Its approximate outline will be seen in fig. 1, which shows the physiographic divisions of the Ozark province. The boundaries can not be clearly defined because the uplift merges into the bordering provinces of the Prairie Plains and the Arkansas Valley. On the north and west the inclination of the strata continues downward at a gradually increasing grade beneath the Prairie Plains. The limits are more distinct on the south as a result of the more abrupt change from the monocline of the Boston Mountains to the folded rocks of the Arkansas Valley. On the eastern border of the dome the structure is concealed for the most part by the northern extension of the Tertiary and Quaternary flat sediments of the Mississippi lowlands. The exposed limit, however, is sharply marked here by the western border of these flat-lying sediments, along which the St. Louis, Iron Mountain and Southern Railroad has been built. The eastern boundary crosses Mississippi River near the mouth of the Ohio, curves northward and then westward, and includes a small area in southern Illinois.

The Ozark uplift has the form of an elongated dome, the axial part trending approximately S. 70° W., through the St. Francis Mountains in eastern Missouri to the vicinity of Tahlequah in northeastern Indian Territory. Thus the Tahlequah quadrangle lies on the southwest end of this structural dome. The axis of this uplift is not marked by a definite crest, such as is usual in distinct smaller upward folds. For long distances across the axial part the strata are flat or but slightly undulating and are locally broken by normal faults. As already explained, the formations incline at low angles from the northwest side of the broad dome. Likewise, the strata pitch at a low degree along the axis toward the southwest. Between the axial part of the uplift and the Boston Mountains the structure is undulating and the rocks are locally faulted, resulting in a low slope toward the southeast. In the southern slopes of the Boston Mountains the tilting is increased by a succession of strong southward-dipping monoclines accompanied by local faulting.

ARKANSAS VALLEY TROUGH.

The Arkansas Valley structural province lies between the Ozark Mountains and the Ouachita Mountains and corresponds very closely with the physiographic province. It is a wide and deep but unsymmetrical trough composed of many relatively short lapping folds. There is a gradual transition from the strong and close folding of the Ouachita uplift northward into the Arkansas Valley. The depth of the folds decreases northward from the Ouachita Mountains to the Boston Mountains. North of Arkansas River the folds are shallow and relatively broad. From the Mississippi lowland at Little Rock to eastern Indian Territory the trough is of even width and bears almost due west. Opposite the west end of the Boston Mountains the Arkansas Valley structure curves southwestward and comes to an end between the Ouachita Mountains and the Arbuckle Mountains in southwest Choctaw Nation. Near the Arkansas–Indian Territory line, where the Arkansas Valley folds change their bearing from west to southwest, they approach the Boston Mountain monocline at angles of 30° to 45°. A fold of this class is the Sallisaw syncline, which enters the south end of the Tahlequah quadrangle.

STRUCTURE OF THE QUADRANGLE.

GENERAL STATEMENT.

The Tahlequah quadrangle lies on the southern slopes of the Ozark dome, near its southwest end, and extends from near the axis to the edge of the trough of the Arkansas Valley. In a general view of the structure of the quadrangle (see fig. 2) it may be seen that the form of the north half is almost flat. The undulations in an east-west direction are very slight, with the exception of a small basin southwest of Westville. Toward the southwest the inclination is increased, and the beds descend 600 feet from the northeast corner to the southwest corner of the quadrangle. The deformation increases in a southeasterly direction across the general trend of the uplift. In the northern part of the quadrangle the tilting toward the southeast is very slight. Southward the inclination of the strata increases by a succession of tilted and faulted synclinal folds. The southern half of the quadrangle includes the southwest end of the Boston Mountains, where the rocks are tilted southeastward in monoclines, locally increased by faulting.

STRUCTURE SECTIONS AND MAPS.

To aid in understanding the structure of the quadrangle two illustrations are introduced. One of these is a sheet showing the geology with two sections drawn across the strike of the rocks, and is known as a structure-section sheet. These structure sections show the approximate attitude of the formations beneath the surface, as if the rocks were sliced vertically and their cut surfaces exposed to view. The scale to which these sections are necessarily drawn is too small to show the minor undulations and details of folding; and of course the sections show the structure only near the line along which they have been drawn.

In order to represent more adequately the structure of the rocks in the Tahlequah quadrangle a model showing the deformed surface of the Boone formation, the one most widely exposed, has been constructed. In the model the vertical dimension is exaggerated three times as compared with the horizontal. Fig. 2 shows this model with the light falling on it at a low angle from the left.

FIG. 2.—Model of the deformed surface of the Boone formation in the Tahlequah quadrangle.
The vertical scale is exaggerated to approximately three times the horizontal in order to bring out the smaller undulations. Contour interval is 50 feet. To give the proper impression of the structure the light is made to fall on the surface from the upper left-hand corner.

The contour lines on this figure represent vertical intervals of 50 feet, and the numbers on them show elevations above sea. The relief of the deformed surface in any part of the quadrangle is shown by the contours.

FOLDS AND FAULTS.

The rocks of the Tahlequah quadrangle, besides being tilted southward in a broad monocline, have been thrown into moderate basin-like folds bearing northeast and southwest parallel to the general trend of the Ozark uplift. Associated with each of these basins on either one side or the other, or, in one instance, on both sides, are normal faults. With one exception these faulted folds occur in the central and western parts of the quadrangle. From the central part northwestward there are five such faults, which are downthrows toward the northwest, and are separated by basin-shaped faulted blocks inclined southward. The deepest parts of the basins are coincident with the greatest downward displacement, suggesting a close relation between the faulting and the folding, to be pointed out more fully below. All of these faults pass beyond the boundary of the quadrangle, but, with the exception of one immediately south of Tahlequah, which extends to the middle of the adjoining Muscogee quadrangle, die out within a few miles. At Cookson a small fault displaces the rocks downward toward the southeast, producing the effect of an elevated, narrow faulted block in the north side of the larger, downthrown block.

In the northeastern part of the quadrangle there are two small faults associated with minor folds. The one near Barren station, on the Kansas City, Pittsburg and Gulf Railroad, strikes in a northerly direction and is nearly coincident with the axis of a small structural basin. In this instance the down-thrown rocks are on the west side. The other small fault is east of Stilwell and strikes in an easterly direction, with downthrow toward the south, apparently across the axis of a poorly defined syncline. It is the only instance noted in the quadrangle where faulting and folding do not correspond in direction.

A long, sinuous fault extends from the southwest corner to the middle of the quadrangle. In this instance the rocks are thrown down on the southeast side of the fault. A broad tract between this fault and the next on the northwest has been only slightly deformed by folding and is an elevated block with respect to the rocks on each side. It is anticlinal in form, but almost flat in cross section except at the borders where the rocks are locally flexed downward because of dragging on the down-thrown sides. Longitudinally the strata incline gradually downward toward the southwest. A fault similar to the one just described, but smaller, bears more easterly from the vicinity of Bunch. These two faults mark the northwest side of the Boston Mountain monocline. Southeast of these faults the strata are more steeply tilted toward the south and continue with minor undulations almost to the southern border of the quadrangle.

A small dome-like anticline occurs nearly midway in the Boston Mountain monocline, trending northwest and southeast. On the map it is located at the head of Salt Creek, opposite the east end of Brushy Mountain. The fold probably does not exceed 3 miles in extent and the rocks in its center are bulged upward probably a thousand feet above their normal position in the monocline.

Near the south side of the quadrangle occurs a narrow, steep monocline bearing nearly east and west. It marks approximately the boundary between the structure of the Ozark uplift and the folded trough of the Arkansas Valley in the Tahlequah quadrangle. A synclinal fold of the Arkansas Valley province enters the center of the south side of the quadrangle, trending northeast, and the above-mentioned monocline is a prominent feature of its northeast end. The steeply dipping rocks on the northwest side of the syncline continue southwestward beyond the quadrangle. Toward the northeast there is an abrupt change in the steepness of dip and direction of strike along the well-defined line of the monocline. From the vicinity of Akins westward to Sallisaw Creek and probably a mile or two beyond, the rocks are faulted along the south side of the monocline. The rock south of the fault is shale and is not sufficiently exposed to show structural details. On the opposite side, however, certain sandstone beds of the Winslow formation are terminated along the southern edge of the monocline.

RELATIONS OF FAULTS TO FOLDS.

It may be noted by reference to the structure map and fig. 2 that in the rocks north of the Boston monocline the faults are all associated with and, except possibly in one instance, already referred to, are parallel to and in most instances occur near the axes of the synclinal folds. In the four instances of faulting from the vicinity of Tahlequah southward it may be noted that the folding is confined to the down-thrown sides of the faults and that the deepest parts of the folds are coincident with the greatest displacement. Such relations between the folds and faults point strongly to the probability that the same forces produced the two types of structure and that their occurrences were closely related in time.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The Tahlequah quadrangle has not been found to contain any of the ores of metals or nonmetallic products of economic value other than building stone, limestone, clay, and soil. To these products may be added water, which is a resource of considerable value.

The surface rocks in the northern part of the Tahlequah quadrangle are the same as those of the zinc region in southwestern Missouri and parts of northern Arkansas, and the structural conditions are very similar; that is, the rocks are essentially horizontal and are broken by normal faults, but no zinc ores are known to occur in appreciable amount.

BUILDING STONE.

Stone suitable for building construction may be found in the St. Clair marble, in certain beds occurring locally at the base and top of the Boone formation, in parts of the Morrow formation, and in certain beds of the Winslow formation.

The St. Clair marble is a massive, thick bed of white to cream-colored and moderately hard crystalline limestone. It is believed to be too coarse in texture to produce a stone of high grade for ornamental or decorative purposes. It is sufficiently strong, however, to be suitable as a building stone and its color is pleasing and durable. Four of the six localities of its exposure are in the Sallisaw Creek Valley and near the Kansas City Southern Railroad. All of the localities are in the bottoms of valleys or lower slopes of hills, and it is considered that except in the two largest areas, located near Bunch and Marble, the rock is not accessible for successful quarrying.

Certain marble-like limestone beds occur at the base of the Boone formation. These have been found at only two localities, both on Barren Fork east of the Kansas City Southern Railroad, surrounding small areas of Chattanooga shale. This limestone occurs in even and moderately thin beds and its texture is fine. Its situation near the river level, however, will prevent its successful quarrying on a large scale. Certain limestone beds on the top of the Boone formation are adapted to use as ordinary building stone. The beds occur in moderately thin strata. The rock is light blue and hard. This limestone occurs above the chert beds and as a whole varies in thickness between 0 and 30 feet. It is included in the basal part of the Fayetteville shale and crops out in belts surrounding the localities of this formation in the northern half of the quadrangle.

The Pitkin and Morrow formations contain deposits of limestone very similar in bedding, color, and hardness to that overlying the Boone formation. These limestones vary to a small extent in quality in different parts of the formations. There are also changes in thickness and character from place to place across the quadrangle, which are discussed in the geological description of the formations. The occurrences of these limestones are shown on the geologic map.

The Winslow formation contains some sandstone beds which may be utilized for foundations and ordinary farm improvements. The sandstones are brown, of generally fine texture, and moderately hard. Certain beds in the upper part of the formation, exposed near the southern border of the quadrangle, are even bedded and will cleave in suitable dimensions for building purposes. Good exposures of such stone occur along the Kansas City Southern Railroad 1 to 2 miles from the southern border of the quadrangle.

LIMESTONE.

Certain of the beds of limestone in the formations referred to as containing building stone may be used in the manufacture of lime. It is believed that the St. Clair marble is the best adapted for this purpose. The limestone at the base of the Boone formation exposed on Barren Fork east of the Kansas City Southern Railroad is of similar grade. The limestone at the top of the Boone and in the Pitkin and Morrow formations is variable in quality and of generally lower grade, but certain layers may be of sufficient purity to produce lime.

CLAY.

Clay shales occur in abundance in the Tyner, Chattanooga, Fayetteville, Morrow, and Winslow formations. All of these clay-shale deposits vary in their different parts in percentages of lime, sand, and iron, but none were found of sufficient purity to produce a clay of high grade. A large part of the Tyner formation consists of greenish or bluish clay shale. There are thick beds of moderately soft, even-textured shale of this formation exposed in the valleys of Illinois River and Barren Fork northeast of Tahlequah.

The Chattanooga shale is invariably an even, hard, laminated, siliceous clay shale containing an intimate mixture of finely divided bituminous matter. On burning or long weathering it changes to whitish hues. The Fayetteville shale is similar in character to the Chattanooga, but less homogeneous and softer. It contains less bituminous matter in the upper part, but more iron, which occurs in the form of ocherous concretions.

The shales of the Morrow formation occur in the middle and upper parts. Those in the middle lie between beds of limestone and probably contain a large percentage of lime. The shales of the upper part are thicker, but more variable in constituents of lime and siliceous sand, being interstratified with both limestone and shaly sandstone beds. There are beds of even-textured shale, however, which may produce a brick clay.

It is estimated that one-half of the Winslow formation consists of shales, which occur chiefly in the lower and upper parts. They range from very sandy deposits to clay shales which may be utilized in the production of bricks. Clay shales of the better quality outcrop in Skin Bayou Valley. They invariably contain a percentage of disseminated iron, but are believed to be almost free from lime. That part of the Akins member of the Winslow which is exposed in the Tahlequah quadrangle consists almost entirely of shales, a large part of which are similar to the better grades found in the upper part of the Winslow formation. These shales disintegrate readily, forming clay soils, and are not usually exposed.

SOIL.

The soils of the Tahlequah quadrangle, with the exception of very limited tracts of bottom land of transported soil distributed along the larger valleys, are formed in place by the weathering of the rocks beneath them. The geologic map, therefore, may be considered as a soil map also.

The St. Clair, Tyner, Burgen, and Chattanooga formations come to the surface in small tracts in narrow valleys or steep slopes where soils of any importance are not permitted to form.

The Boone formation produces two kinds of soil. The first and more fertile of these is formed by the limestone at the top of the formation. Considerable level fertile areas of this soil occur about Westville and Stilwell, and smaller tracts are found in many places on the level upland and near the edge of the Fayetteville shales. Elsewhere, and over the larger part of the quadrangle, the Boone formation produces a cherty soil. On weathering the chert breaks into angular blocks and fragments and, because of its great durability, forms a surface layer. The little soil it produces is fertile, but is carried downward and away by the rains or forms a substratum toward the base of the weathered chert zone. Thus over a large part of the Boone formation, especially in the more hilly districts, the soil is at too great a depth to be accessible to agricultural processes. The soil under these conditions can be of service only to the forest, which thrives seemingly in accumulations of loose stone. In certain areas that have remained flat for a long time the soil is at the surface or sufficiently near it to be cultivated. This is the case about Tahlequah and Parkhill and in other smaller tracts on the level divides in the northern part of the quadrangle.

The Fayetteville shale forms a thin and poor soil and its area is not sufficient to require further consideration.

The Morrow formation produces the most fertile soil in the region, even on steep slopes, where much of the rock is exposed. Its fertility is attested by the luxuriance of the forest and the occurrence of walnut, locust, and other trees that are found naturally only on fertile soils. The topographic features of the Morrow formation, however, are not favorable for the utilization of its soils, being confined almost entirely to hilly tracts. The Hale sandstone member of the Morrow formation produces a fertile sandy loam that is especially well adapted to fruit culture.

The Winslow formation contains but little soil of agricultural value except in the few level tracts in the tops of the ridges near the eastern border of the quadrangle, in the table-land of Brushy Mountain, and in the district south of Blackgum post-office between Vian Creek and Illinois River. In these tracts the soil is a light sandy loam and is best adapted to the cultivation of vegetables and fruits. Elsewhere the formation is too hilly and the surface too stony and steep to serve any valuable purpose except to support a forest.

WATER.

The ground-water supply of the Tahlequah quadrangle is limited almost entirely to the area of the Boone formation. The rocks above the Boone formation, which consists chiefly of sandstone and shales, are practically impervious to water and afford no springs.

The Boone formation, on the contrary, while originally an impervious deposit of siliceous limestone, is intersected by underground solution channels that extend both across and along the bedding of the rocks. The water from many of these underground channels comes to the surface in the valleys and issues as springs, while that of others rises, probably in joint fissures or faults in the rocks. The group of large springs at Tahlequah and one on the fault 2 miles south afford a large volume of water. Large springs occur also at Parkhill, Wauhillau, Stilwell, Bunch, and many other localities, affording an abundance of fresh water. A group of saline springs occurs at the outcrop of the Boone formation near the head of Salt Creek, opposite the east end of Brushy Mountain. The rocks here are steeply upturned and the springs appear to issue from the bedding planes of the chert and limestone of the Boone and Morrow formations. These springs have a small but unfailing flow of saline and sulphur waters, the quantity of common salt (sodium chloride) being of greatest abundance, varying in the different springs from a small percentage to a quantity sufficient to produce strong brine. Apparently the sulphur issues entirely as a hydrogen sulphide gas. The water of one of the springs issuing from the Morrow formation throws down a crimson precipitate which becomes black on long standing. This water has a bitter as well as a common saline taste.

March, 1904.