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GEOLOGY OF THE KREBS GROUP, INOLA AREA, ROGERS AND MAYES COUNTIES, OKLAHOMA

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CHAPTER I

INTRODUCTION

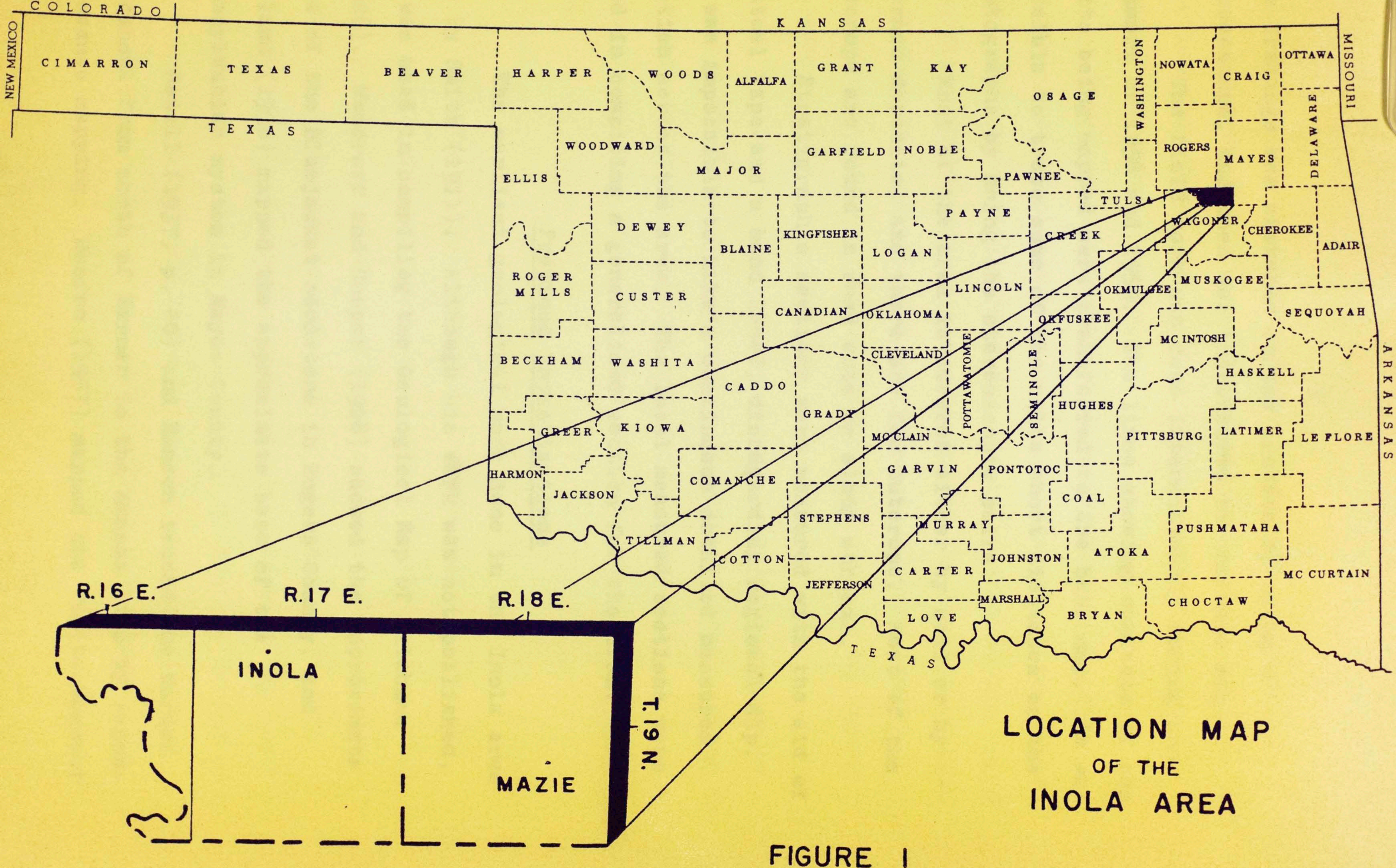
Location

The Inola area is about twenty-five miles east of Tulsa in southeastern Rogers and southwestern Mayes Counties, and includes the town of Inola in Rogers County. The area is Township 19 North, Ranges 16, 17, and 18 East.

Purpose and Methods of Investigation

The purpose of the investigation was to make a detailed geologic map and report of the stratigraphy and structure of the area. Part of this work will be published in a report on Rogers and Mayes Counties.

The preliminary study of the area, including work previously done in the area, was started during the summer of 1958. The base map was made on a scale of 3.1 inches equal one mile, which was the average scale of the aerial photographs used. These were obtained from the Oklahoma Geological Survey and covered with transparent acetate.



LOCATION MAP OF THE INOLA AREA

FIGURE 1

The drainage was sketched on the acetate by using a stereoscope, and then was transferred to the base map.

The field work was done intermittently during the summers of 1958 and 1959. The lines showing contacts of the units being mapped were transferred to the base map. It was possible to trace some of the units short distances on the photographs by using the stereoscopic pairs.

Most of the area is covered either by soil or by terrace deposits, and there are few outcrops. Most of the outcrops are found in road cuts or along streams.

Stratigraphic sections were measured with the aid of a steel tape and a hand level, disregarding regional dip. It was impossible to make a continuous detailed measured section across the area. The local measured sections were used in compiling a generalized section for the area.

Previous Investigations

The earliest geological work done in the Inola area was by Smith (1911). Although his work was not published, it was used in compiling the Geological Map of Oklahoma (1926). Woodruff and Cooper (1928) showed the approximate base of the Bluejacket sandstone in Rogers County, and Ireland (1930) mapped the approximate base of the Pennsylvanian system in Mayes County.

Newell (1937, p. 40) and Hanson traced the Warner sandstone from north of Warner to the Kansas line by reconnaissance mapping. Renfro (1957) mapped the Vinita-Wagoner district and traced several units across the Inola area.

Wright (1949) made a micropaleontological study of the Spaniard limestone, and Scruton (1950) made a petrographic study of the Warner sandstone.

Three graduate students from the University of Oklahoma have completed maps of areas adjacent to the Inola area. Tillman (1952) mapped the adjoining area to the north and Blythe (1957) mapped the outcrops of the Atoka formation which form the eastern edge of the area. Govett (1959) mapped Wagoner County, which borders the area on the south and west.

Dr. Carl C. Branson has spent considerable time in the field studying the geology of the Pennsylvanian system in northeast Oklahoma. Some of his work is available in various published works and some of it is in his personal file.

Geography

The Inola area consists of approximately seventy square miles, and two towns are located in the area. Inola, with a population of about 300, lies just south of state Highway 33 in Rogers County, and on the Missouri Pacific Railroad. Mazie is located near the east edge of the area in Mayes County. It is adjacent to U. S. Highway 69 and on the Missouri Kansas and Texas Railroad. Approximately eighty-five per cent of the section lines have roads along them which are graded and in most cases graveled. They are maintained by the county.

The western part of the Inola area is in the Claremore Cuesta Plains Physiographic province and the eastern part is in the Neosho Lowland province (Oklahoma Geological Survey, 1957).

The Verdigris River and its tributaries provide the main drainage for three-fourths of the area, but the eastern fourth drains into tributaries of the Neosho (Grand) River. Both of these rivers flow into the Arkansas River about twenty miles south and five miles east of the Inola area. Bull Creek, Pea Creek, Inola Creek, and Commodore Creek drain into the Verdigris River. Flat Rock Creek and Brush Creek drain into the Neosho River. All of the creeks in the Inola area are intermittent.

The topography of the area is that of a low undulating plain. This is broken at places by gently sloping cuestas and small buttes which rise above the plain. The general strike of the beds is nearly north-south and the regional dip is to the west at approximately 40 to 50 feet per mile. The cuestas have eastward-facing escarpments.

The maximum elevation in the Inola area is about 800 feet and the minimum is about 540 feet; the maximum relief is about 260 feet. Inola Mound is a butte about a mile southeast of Inola with a height of about 150 feet and is the most prominent topographic feature in the area. The

Figure 2. South side of Inola Mound. The top is capped by a Taft sandstone and the prominent lower flat shelf is supported by the Bluejacket sandstone. Sec. 10, T. 19 N., R. 17 E.

buttes and cuestas are capped by sandstone, and most of them have a height of less than 50 feet. Three buttes near the west edge of Mayes County have a height of approximately 100 feet.

Agriculture is confined mostly to the seed grasses. Approximately one-third of the land is used for grazing, on which both beef and dairy cattle are raised.

The average temperature in northeast Oklahoma varies from about 40 degrees in December to about 80 degrees in July (U. S. Dept. of Commerce, 1959). Usually there are a few days in the winter when the temperature drops a few degrees below zero and a few days in the summer when the temperature is above 100 degrees.

The average monthly rainfall varies from about 2 inches in February, the month of least average precipitation, to about 5 inches in May, the month with maximum average precipitation. About 5 inches of rain was recorded about 10 miles north of the Inola area in July, 1958, and about 9 inches of rain was recorded there in July of 1959.

CHAPTER II

STRATIGRAPHY

General Statement

The Inola area has rocks of the Pennsylvanian system cropping out at the surface. These are locally overlain by deposits of Quaternary age. The Pennsylvanian rocks belong to the Krebs group of the Des Moines series. Shales, lenticular sandstone, thin limestones and thin coals are present. The Quaternary deposits are represented by Recent flood plain deposits of alluviam and by river terrace deposits of probable Pleistocene Age.

Krebs Group

Definition

The Krebs group was named by Oakes (1953, p. 1523) from the town of Krebs in T. 5 N., R. 15 E., central Pittsburg County, Oklahoma. The Krebs group consists of the following four formations in ascending order: Hartshorne formation, McAlester formation, Savanna formation, and Boggy formation. It is underlain by the Atoka formation. It is the oldest group in the Des Moines series; which consists of the Krebs, Cabaniss and Marmaton groups, in ascending order. The Krebs and Cabaniss groups are composed of rocks that used to be called the Cherokee group.

Distribution

The Krebs group crops out from the northeast flank of the Arbuckle Mountains eastward into Arkansas and northeastward into Kansas in an arcuate pattern.

Thickness and Character

The McAlester basin was a deep structural and depositional trough north of the Ouachita Mountains, and west of McAlester; along its axis, the Krebs is about 6,000 feet thick. It is more than 8,000 feet thick near Poteau, and part of the Boggy has been eroded. The Krebs group thins towards the Arbuckle Mountains, and to the northeast. It is about 550 feet thick near the Arkansas River, and only about 350 feet thick along the Kansas-Oklahoma line.

Dark to gray shale is the dominant rock in the Krebs group, with some silty shale. The sandstones are mostly silty and fine to medium grained, with a few locally coarse grained. Most of them are lenticular. Some thin, local lenticular limestones are present south of the Canadian River, and two thin limestones crop out between the Canadian River and the Arkansas River. At least four fairly continuous limestones crop out north of the Arkansas River. Several coal beds are present in the Krebs group.

Stratigraphic Relations

The Krebs group is unconformable with the underlying formations, Atoka at most places, but in northeast Oklahoma it overlaps the Mississippian and in the Arbuckle Mountains it rests on rocks of Ordovician age. The Krebs is unconformable with the overlying formations in the Cabaniss group. There are local unconformities within the Krebs group.

Hartshorne Formation

Definition

The Hartshorne sandstone was named by Taff (1899, p. 436-437). He did not designate a type locality, but it is thought the name was given to rocks that crop out near the town of Hartshorne, in Pittsburg County, Oklahoma. Newell (1937, p. 35) placed the upper boundary of the Hartshorne at the top of the first sandstone below the Upper Hartshorne coal. Oakes and Knechtel (1948, p. 21) have found that this sandstone pinches out in Le Flore County and the Lower Hartshorne coal and the Upper Hartshorne coal coalesce. They placed the upper boundary at the top of the Upper Hartshorne coal.

Branson (1954, p. 6) defined the top of the Hartshorne in northeastern Oklahoma as the top of the Riverton coal. He placed the base of the formation at the base of a conglomerate in an unnamed coal cycle beneath the Riverton coal cycle.

Distribution

The Hartshorne formation crops out from the northeast flank of the Arbuckle Mountains eastward into Arkansas. It forms an arcuate pattern in eastern Oklahoma, cropping out on the south and west flanks of the Ozark Uplift. The Hartshorne crops out on the east side of the Inola area. The top of the formation is exposed in a road cut on state Highway 33 in sec. 4, T. 19 N., R. 18 E., but it is covered in most of the Inola area.

Thickness and Character

Oakes and Knechtel (1948, p. 25) reported the Hartshorne to be about 100 feet thick in Haskell County. Newell (1937, p. 35) reported the Hartshorne sandstone to vary in thickness from 3 to 25 feet in the Muskogee-Porum district. Branson (1956, p. 83) stated that the Hartshorne is about 40 feet thick on the platform. About 15 feet of Hartshorne is exposed in the Inola area.

The base of the Hartshorne is covered in the Inola area, and a siltstone about 15 feet below the Riverton coal is the lowest part of the formation that is exposed. Sideritic concretions are found in the shale just above this siltstone.

A 2- to 4-inch thick fossiliferous clay-ironstone that is just a few inches above the siltstone is exposed at several places in the area. This clay-ironstone is exposed

Figure 3. Mazie clay-ironstone, above pick, and underlying siltstone in Hartshorne formation. On south line of sec. 15, T. 19 N., R. 18 E.

just west of Mazie in a road cut on the west line of sec. 23, T. 19 N., R. 18 E., about one-fourth of a mile north of the south line of sec. 23, T. 19 N., R. 18 E. Better exposures are found about a mile from here on the south line of sec. 15, T. 19 N., R. 18 E. Here the Mazie caps a small mound about two-fifths of a mile from the east edge of the section, and caps a low ridge one-fourth of a mile from the west edge of the section. It is present below the Warner sandstone escarpment in sec. 4, T. 19 N., R. 18 E., between Highway 33 and Longview public school. It is also found in the south half of sec. 16, T. 19 N., R. 18 E., about two-fifths of a mile from the east edge of the section. The name Mazie limestone was used by Newell and Hanson (personal communication, Dr. Branson) when they mapped the Warner sandstone from the Verdigris River to Vinita in 1936. This clay-ironstone probably is equal to the "Elm Creek limestone" that Branson (1954, p. 4) shows to be near the base of the Krebs group.

Riverton Coal Bed. The Riverton coal was named by Pierce and Courtier (1937, p. 62) for the village of Riverton in southeastern Cherokee County, Kansas. The Riverton coal was exposed in a road cut on the south side of Highway 33, about one-eighth of a mile west of the east side of sec. 4, T. 19 N., R. 18 E., but is now covered by slump. The underclay below it is exposed at this location.

Stratigraphic Relations

The Hartshorne formation is probably unconformable with the underlying Atoka formation on the shelf. The Hartshorne is conformable with the overlying McAlester formation.

Correlation

Howe (1956, p. 26) stated that the Hartshorne sandstone is not recognized in northern Oklahoma, southeast Kansas, or Missouri. Howe (1956, p. 29) defined the Riverton formation of southeast Kansas to include all lower Des Moines beds below the top of the uppermost of the Riverton coal beds. This would make the Hartshorne formation equal to at least part of the Riverton formation of southeast Kansas.

McAlester Formation

Definition

Taff (1899, p. 437) named the McAlester shale, but he did not designate a type locality. However, he described the formation from outcrops near the town of McAlester. Taff stated that the Hartshorne coal was at the base of the McAlester. The top of the McAlester was placed at the base of the Savanna sandstone. The base of the McAlester was redefined by Oakes and Knechtel (1948, p. 27) as the top of the Upper Hartshorne coal. Oakes and Knechtel (1948, p. 29-30) placed the top of the formation at the top of the first shale above the Keota sandstone. The Keota sandstone is a lensing sandstone and has not been traced north out of the basin onto the platform. Branson (1954, p. 6) placed the base of the McAlester formation on the shelf at the top of the Riverton coal. A thin black shale separates the Riverton coal from the overlying Warner sandstone. Branson (1954, p. 2) defined the top of the formation in the shelf area as the base of the Spaniard limestone.

Distribution

The McAlester formation crops out in eastern Oklahoma forming an arcuate pattern on the south and west flanks of the Ozark Uplift. It is exposed in southern Oklahoma from the northeast flank of the Arbuckle Mountains eastward into Arkansas. The McAlester formation crops out in the eastern quarter of the Inola area, and in the core of an anticline in sec. 27, T. 19 N., R. 17 E.

Thickness and Character

The McAlester formation was reported by Oakes (1948, p. 28) to range from a few hundred feet thick on the north flank of the Arbuckle Mountains to 2,800 feet thick southeast of Red Oak in Latimer County. The formation thins northward out of the basin and is about 2,000 feet thick in southern Haskell County, about 700 feet in northern Haskell County, and about 200 feet thick in the vicinity of Muskogee. Govett (1959, personal communication) reported a thickness of

40 to 100 feet in Wagoner County, which is on the platform. It is about 70 feet thick in the Inola area.

Most of the formation is covered in the Inola area, and shale is assumed to be the predominant rock. There are three sandstones and one coal exposed in the Inola area.

Subdivisions of the McAlester Formation

Warner Sandstone Member. Wilson (1935, p. 508) applied the name Warner sandstone to exposures of sandstone near the town of Warner, Oklahoma. Newell (1937, p. 37) described the type locality, which is in sec. 16, T. 12 N., R. 19 E.

The Little Cabin sandstone was named by Ohern (1914) for exposures of this sandstone on Little Cabin Creek in Craig County, Oklahoma. Reconnaissance mapping by Newell (1937, p. 39-40) assisted by Hanson, in 1936 correlated the Warner sandstone of the McAlester formation with the Little Cabin sandstone of northeast Oklahoma. Renfro (1947, p. 20) also reached this conclusion. Branson verified this correlation with his work in northeast Oklahoma during the early 1950's. The name Warner sandstone is now the preferred name for this sandstone. It is known as the Booch sand in the subsurface.

In the Inola area the Warner sandstone ranges in thickness from 6 to 12 feet. It is a buff to brown, ferruginous, silty to fine-grained, micaceous sandstone. A nine-inch black shale that separates the Warner sandstone from

Figure 4. Black shale, Riverton coal horizon, and underclay exposed below thin-bedded Warner sandstone in Highway 33 Road-cut. Point of hammer is at contact between underclay and black shale. Sec. 4, T. 19 N., R. 18 E.

Figure 5. Mound capped by Warner sandstone in sec. 36, T. 19 N., R. 18 E.

Figure 6. Warner sandstone escarpment just south of Mazie in sec. 26, T. 19 N., R. 18 E.

the underlying Riverton coal is exposed in a Highway 33 road cut in sec. 4, T. 19 N., R. 18 E.

The Warner sandstone forms a prominent escarpment across most of the west edge of the Inola area. The interval between the Warner sandstone and the overlying unnamed sandstone is covered.

Unnamed Sandstone Member and overlying Shale. A sandstone makes a low escarpment about 20 feet above the Warner sandstone in secs. 16, 18, 21, and 22, T. 19 N., R. 18 E. It is gray to buff, silty to fine grained, thin bedded, and weathers dark brown. It is a lensing sandstone, ranging in thickness from 0 to 6 feet in the Inola area. It may be the same sandstone that is exposed in the southwest corner of sec. 27, T. 19 N., R. 17 E., where it is 25 feet below the Spaniard limestone.

About 10 feet of black shale and 5 feet of tan shale are exposed above this sandstone in sec. 27, T. 19 N., R. 17 E.

Unnamed Sandstone Member and overlying Shale. A sandstone about 5 feet below the Spaniard limestone is exposed on the east bank of Bull Creek in the southeast corner of sec. 23, T. 19 N., R. 17 E. This sandstone is light gray, micaceous, ferruginous, fine grained, and weathers dark brown. It ranges in thickness from 0 to 5 feet.

Figure 7. Sandstone near top of McAlester formation on east bank of Bull Creek in SE 1/4 sec. 23, T. 19 N., R. 17 E.

Figure 8. Stigmaria in sandstone exposed in center of Bull Creek anticline in SE 1/4 sec. 27, T. 19 N., R. 17 E.

A black shale lies immediately below the Spaniard limestone in sec. 1, T. 19 N., R. 17 E. A one-inch coal and an underclay are present below the Spaniard limestone in sec. 27, T. 19 N., R. 17 E.

Stratigraphic Relations

The McAlester formation is conformable with the overlying Savanna formation and with the underlying Hartshorne formation.

Correlation

The McAlester formation is correlated with the Warner formation and part of the Rowe formation of southeastern Kansas (Howe, 1956, p. 32-35).

Savanna Formation

Definition

Taff (1899, p. 437-438) gave the name "Savanna sandstone" to rocks that crop out near the town of Savanna in Pittsburg County, Oklahoma. He did not designate a type locality. He mentioned five principal sandstone beds whose combined thickness was less than that of the shale in the formation.

The upper limit of the Savanna formation was placed at the top of the Bluejacket sandstone by Wilson (1935, p. 509). Newell (1937, p. 43) placed the top of the Savanna formation at the top of the Spiro sandstone. Branson

(1952, p. 192) stated that the Oklahoma Geological Survey placed the contact between the Savanna and the Boggy formation at the base of the Bluejacket sandstone. Branson (1954, p. 2) defined the base of the Savanna in the shelf area as the base of the Spaniard limestone.

Distribution

The Savanna formation crops out north of the Arbuckle Mountains and continues eastward into Arkansas. The Savanna outcrop forms an arcuate pattern from the McAlester basin northward into Kansas.

The Savanna crops out in a wide band across the central part of the Inola area, and on the flanks of the syncline in T. 19 N., R. 18 E.

Thickness and Character

Oakes and Knechtel (1948, p. 48) reported 1,000 to 1,300 feet of Savanna in the vicinity of McAlester, 1,700 feet in the vicinity of Poteau, and 500 to 1,150 feet in southern Haskell County. Bell (1959, p. 37) found about 200 feet of Savanna in northern Muskogee County. Govett (1959, personal communication) reported 80 to 200 feet present in Wagoner County. It is about 150 feet thick in the Inola area.

Three marine limestones, one fresh water limestone, and four coals are present in the Savanna formation in the Inola area. Shale is the most abundant rock and varies from

Figure 9. Spaniard limestone and underlying coal exposed in SE 1/4 sec. 27, T. 19 N., R. 17 E. Tip of hammer is at contact of coal and underclay.

Figure 10. Spaniard limestone exposed in gully in SE 1/4 sec. 27, T. 19 N., R. 17 E.

black to gray to buff. Clay-ironstone concretions and calcareous nodules are present in the shale. The Spiro sandstone and an unnamed sandstone form escarpments across part of the area.

Subdivisions of the Savanna Formation

Spaniard Limestone Member and overlying Shale. Lowman (1933, p. 31) named the Spaniard limestone from exposures on Spaniard Creek, Muskogee County, in sec. 11, T. 13 N., R. 18 E. He divided the Spaniard limestone into three lithic units. The top unit is a dark-gray, fine-grained limestone that weathers brown to buff and is 1 foot 2 inches thick at the type locality. Wright (1949, p. 47-49) stated that only the top unit is present as far north as the Inola area. He based this belief on a micropaleontological study he made.

In the Inola area the Spaniard limestone is a dark-gray to blue, calcareous, fossiliferous, clay-ironstone that weathers light gray to buff to ferruginous red. It varies in thickness from 3 to 15 inches. Wright (1949, p. 50) reported *Fusulinella sp.* and *Caninia torquia* in the Spaniard limestone in sec. 27, T. 19 N., R. 17 E.

There are several exposures of the Spaniard limestone in the Inola area. It is difficult to make positive identification, due to the similarity in appearance of the overlying Sam Creek limestone, unless both limestones are present.

Figure 11. Head of hammer is at base of coal exposed beneath Sam Creek limestone in SE 1/4 sec. 27, T. 19 N., R. 17 E.

Figure 12. Sam Creek limestone on south bank of creek in NE 1/4 sec. 24, T. 19 N., R. 17 E.

The Spaniard limestone is exposed in a creek on the east side of sec. 1, T. 19 N., R. 17 E., about one-eighth of a mile south of Highway 33.

About 8 feet of tan shale lies above the Spaniard limestone and below an unnamed coal in the Inola area.

Unnamed Coal Bed and overlying Shale. A coal about three inches thick is present between the Spaniard limestone and the Sam Creek limestone in the Inola area. It is exposed in Bull Creek Anticline in sec. 27, T. 19 N., R. 17 E., and on the west bank of Bull Creek about 50 feet west of the railroad bridge over Bull Creek in sec. 26, T. 19 N., R. 17 E.

A thin underclay is present beneath the coal and about 4 feet of buff shale is present above the coal and beneath the overlying Sam Creek limestone.

Sam Creek Limestone Member and overlying Shale. The Sam Creek limestone was named by Lowman (1932) from exposures of limestone in Sam Creek, sec. 15, T. 14 N., R. 18 E. Lowman included 8 feet, 7 inches of limestone and shale in his type section of Sam Creek. Newell found that only the upper 6-inch bed of limestone of the type section was persistent. Newell (1937, p. 49) redefined the Sam Creek and suggested that the term be restricted to the thin persistent limestone below the Spiro sandstone.

In the Inola area the Sam Creek is a blue-gray calcareous, clay-ironstone which weathers to a ferruginous reddish-brown and contains abundant "Marginifera". It varies

Figure 13. Eastward facing escarpment capped by Spiro sandstone in secs. 20 and 29, T. 19 N., R. 18 E.

Figure 14. Thin-bedded Spiro sandstone at top of escarpment between secs. 20 and 29, T. 19 N., R. 18 E.

in thickness from 4 to 8 inches. About 5 feet of tan shale separates it from the overlying Spiro sandstone.

Spiro Sandstone Member and overlying Shale. The name "Spiro sandstone" was first published by Wilson (1935, p. 509) who took the name from an unpublished map by Thom. Thom named it from the town of that name. It caps ridges just north of Spiro, LeFlore County, in secs. 13 and 14, T. 9 N., R. 25 E., Newell (1937, p. 50) described it as being thin and non-resistant in most of the Muskogee-Porum area and resting directly on the Sam Creek limestone. In the southern part of the area it consists of a massive, cliff-forming sandstone.

In the Inola area it is a lensing sandstone and varies in thickness from 0 to 15 feet. It forms a prominent ridge in secs. 17, 20, and 29, T. 19 N., R. 18 E.

Most of the interval between the Spiro sandstone and the overlying Rowe coal is covered in the Inola area and the rock is assumed to be shale. There is a underclay about 2 feet thick beneath the Rowe coal on the west side of Inola Mound. A ferruginous red, pisolitic, lenticular, underlime about 1 foot thick is exposed beneath this underclay at this locality. This is believed to be the only known exposure of this underlime in northeast Oklahoma.

Rowe Coal Bed. The Rowe coal was named by Pierce and Courtier (1937, p. 65) for the Rowe school in sec. 34, T. 30 S., R. 25 E., in Kansas.

Two exposures of Rowe coal in the Inola area are on the west side of Inola Mound and on the south side of sec. 27, T. 19 N., R. 17 E., about 50 feet west of Bull Creek. It has been mined in several strip pits in the area, but slump and vegetation have concealed these exposures. These strip pits are located on the north and south sides of Inola Mound, in secs. 26 and 28, T. 19 N., R. 17 E., and in sec. 17, T. 19 N., R. 18 E.

Doneley Limestone Member and overlying Shale. The Doneley limestone is a cap rock limestone and overlies the Rowe coal in most of northeast Oklahoma. Branson (1952, p. 192) named it the Doneley limestone and described it at the type section as a calcareous clay-ironstone 3 inches thick, and lying 8 inches above a thin coal. The type section is in sec. 16, T. 26 N., R. 20 E. In the Inola area its thickness varies from 1 to 10 inches and its position varies from immediately above the coal to 3 inches above it.

The Spaniard limestone, the Sam Creek limestone, and the Doneley limestone are known in the subsurface as the Brown limes.

A buff to tan shale lies above the Doneley limestone in the Inola area where exposures were observed.

Unnamed Sandstone Member and overlying Shale. A sandstone that is gray to buff, ferruginous, fine grained, and lenticular is present a few feet above the Doneley limestone.

Figure 15. Stigmaria exposed in shale in Savanna formation on west side of Inola Mound. Sec. 10, T. 19 N., R. 17 E.

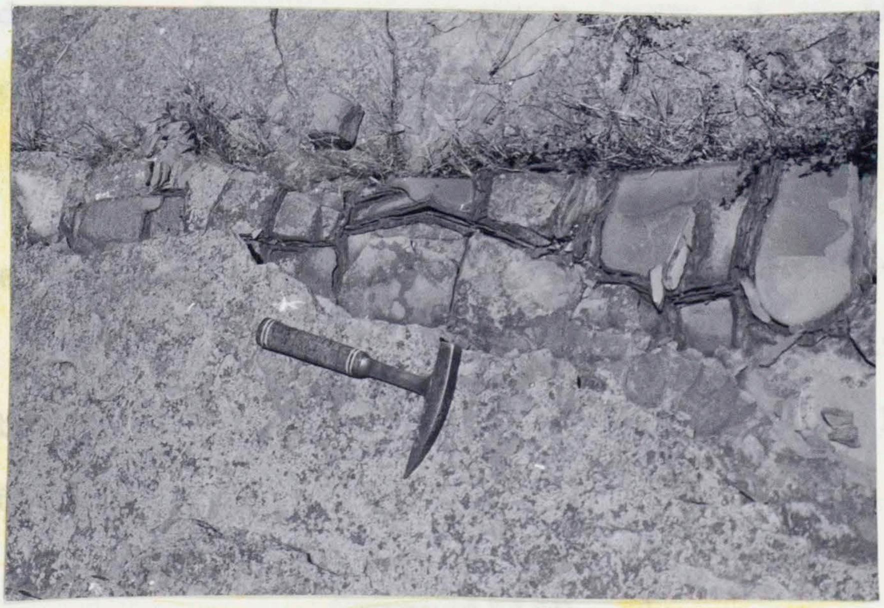


Figure 16. Box structure in Spiro sandstone in SE 1/4 sec. 35, T. 19 N., R. 17 E.

About 30 feet of gray to black shale occupy the interval between this sandstone and a coal about 25 feet below the Bluejacket sandstone.

Unnamed Coal Bed and overlying Shale. A coal is present on the west side of Inola Mound that is about 25 feet below the Bluejacket sandstone. A two-inch underclay is present here and the coal is approximately 3 inches thick. Gray, black and buff shales, and thin hard clay-ironstone nodules lie between this coal and the Drywood coal.

Drywood Coal Bed and overlying Shale. The Drywood coal was named by Searight (1953, p. 2747) and the type section is in sec. 4, T. 32 N., R. 33 W., in Missouri. A coal that may be the Drywood coal is exposed on the north side of Inola Mound and is about 5 feet below the base of the Bluejacket sandstone. A two-inch coal and thin underclay are exposed here. A buff shale is present below the base of the Bluejacket sandstone.

Stratigraphic Relations

The Savanna formation is conformable with the underlying McAlester formation. The Savanna formation is unconformable with the overlying Boggy formation (Branson, 1956, p. 86).

Correlation

The Savanna formation is equivalent to the upper part of the Rowe formation, the Drywood formation, and the lower part of the Bluejacket formation of southeast Kansas (Howe, 1956, p. 35-40).

Boggy Formation

Definition

Taff (1899, p. 438-439) named the Boggy shale from outcrops in Boggy Creek in Coal, Pittsburg and Pontotoc Counties. Taff defined the Boggy as extending from the top of the highest Savanna sandstone to the base of the Thurman. Branson (1952, p. 192) stated that the Oklahoma Geological Survey defines the base of the Boggy as the base of the Bluejacket sandstone. The top of the Boggy is the top of the Krebs group. The Thurman sandstone rests on the top of the Boggy in the basin, and is overlapped by the Staurt shale northward out of the basin. The Senora formation rests upon the Boggy on the platform . Branson (1956, p. 85) stated that the contact is poorly exposed and may be a shale-shale contact. The top of the Boggy is west of the Inola area.

Distribution

The Boggy formation crops out on the east flank of the Arbuckle Mountains and eastward into Arkansas and northward into Kansas. The Boggy is present in the northwest part of the Inola area, and along the southern boundary near the center of the area. It also caps four prominent outliers that are several miles to the east of the outcrop, Inola Mound being the highest one.

Figure 17. Bluejacket sandstone bluff on the east bank of the Verdigris River. Sec. 14, T. 19 N., R. 16 E.

Figure 18. Stringers of coal exposed near the base of the Bluejacket sandstone bluff on the east bank of the Verdigris River. Sec. 14, T. 19 N., R. 16 E.

Thickness and Character

The Boggy formation attains a maximum thickness of 4,000 feet (Oakes, 1948, p. 55) in the Cavanal Mountains in LeFlore County, Oklahoma. Campbell (1958, p. 12) reported 575 feet of Boggy in northern Muskogee County. There is 80 feet of Boggy exposed on Inola Mound.

The Boggy formation is cyclic in the Inola area, as are the other formations of the Krebs group. The shales are black to gray to tan and compose most of the section. The Bluejacket sandstone and the Taft sandstones are lensing, fine grained, gray to buff, silty, thin bedded to massive sandstones. Branson (1956, p. 85) reported that on the shelf they are thought to be off-shore bars of an onlapping sea. The Inola limestone lies between the Bluejacket and Taft. Two thin coals, the Bluejacket and Inola, are present. Most of the Boggy is covered by terrace and alluvial deposits in the Inola area, and the best exposures are on Inola Mound.

Subdivisions of the Boggy Formation

Bluejacket Sandstone Member and overlying Shale. The Bluejacket sandstone was named by Ohern (1914, p. 28-29) from exposures of sandstone west of Bluejacket, Oklahoma. Howe (1951, p. 2088-90) redefined the Bluejacket and mentioned sec. 25, T. 27 N., R. 20 E. as a typical exposure. The Bluejacket sandstone displays lensing characteristics of an off-shore bar on the shelf. Within one-half a mile in the Inola area it thins from a 40 feet thick sandstone cliff to a low bluff where it is less than 10 feet thick. On Inola Mound it thins from 12 to 0 feet. The Bluejacket holds up the prominent flat shelf on Inola Mound, and caps three outliers on the west edge of Mayes County. It forms a ridge in the northwest part of the area, and is present near the southern edge of the area.

It is a silty to fine-grained, light-brown to buff, limonitic sandstone that weathers gray to dark brown. It is known as the Bartlesville sand in the subsurface of eastern Oklahoma.

A buff to gray to black platy shale occupies the interval between the top of the Bluejacket sandstone and the Bluejacket coal. Its thickness depends upon the thickness of the Bluejacket sandstone, and varies from 5 to 10 feet in the Inola area. A thin underclay is present below the coal.

Bluejacket Coal Bed and overlying Shale. The name Bluejacket coal (Searight et al., 1953, p. 2747) was given to the coal above the Bluejacket sandstone and below the Inola limestone. It is about 2 inches thick on Inola Mound and this is the only place in the Inola area that it is exposed. The interval between this coal and the overlying Inola limestone varies from 2 to 10 feet, and most of it is covered. The difference in thickness is probably due to the fact that the Inola limestone weathers rapidly and that the lowermost limestone is covered.

Figure 19. Bluejacket coal exposed by hammer and weathered pieces of Inola limestone above it on slope on west side of Inola Mound in sec. 10, T. 19 N., R. 17 E.

Inola Limestone Member and overlying Shale. Lowman (1932) named the Inola limestone from exposures of limestone on Inola Mound. He described it as a single bed of gray, fossiliferous, limestone about 10 inches thick. Branson (1952, p. 192) stated that:

> About the middle of the Boggy formation and a few feet above the Bluejacket sandstone is the Inola limestone of Lowman.... The Inola limestone has been found to consist of four separate fossiliferous beds each lying in a separate cyclothem and with coal seams under the first, third, and fourth. The term Inola is here restricted to the lower limestone of the four. The type locality is Inola Mound, but the type section is here designated as the section exposed in the south road cut on Oklahoma Highway 20 on the west face of the hill just east of the Rogers-Mayes County line, near the northwest corner of sec. 18, T 21 N, R 18 E..... One or more of the limestone can be found at scattered localities from the northern edge of Mayes County to northern McIntosh County, but their discontinuity of outcrop precludes use as a mapping horizon.

Two limestones separated by a coal were found at one exposure on the west side of Inola Mound, but at most exposures there was evidence of only one limestone. This was probably due to the fact that these limestones weather rapidly. The lowest limestone, or Inola restricted, is about 5 inches thick, gray, nodular, fossiliferous, and weathers buff. A one-inch coal and underclay separate it from the overlying limestone that is one inch thick, gray, fossiliferous and weathers buff. The other exposures of the Inola limestone are located in a section line road about 1/2 a mile east of the southwest corner of sec. 2, T. 19 N., R. 16 E. The Inola limestone (restricted) and the associated limestones are useful in differentiating the Bluejacket sandstone from the overlying Taft sandstones. It is known as the Inola lime in the subsurface.

The following fossils were collected from the Inola limestone on Inola Mound.

Wedekindellina sp.

Lophophyllidium sp.

Marginifera haydenensis
Composita sp.
Neospirifer cameratus
Spirifer rockymontanus
Chonetes granulifer

Astartella sp.

A gray to black shale is present between the Inola limestone and a thin sandstone about 15 feet above it.

Taft Sandstone Members and overlying Shale. Wilson (1935, p. 510) describes the Taft sandstone and gives the type locality as south of the town of Taft in sec. 19, T. 15 N., R. 17 E. There are at least three or four sandstones that occupy this approximate interval in northeast Oklahoma. They are similar to most of the other sandstones in the Krebs group in that they are buff, silty to fine grained, ferruginous, and change thickness in a short distance. A Taft sandstone caps Inola Mound and is about 60 feet above the Inola limestone. Gray to tan shale, silty shale, and clay-ironstone nodules are present below the Taft sandstone that caps Inola Mound. The Taft sandstones are known as the Red Fork sands of the subsurface.

Stratigraphic Relations

The Boggy formation is unconformable with the underlying Savanna formation. The top of the Boggy is west of the Inola area. Branson (1956, p. 85) stated that the unconformity at the top of the Boggy corresponds to the Pottsville-Allegheny break of eastern United States.

Correlation

The Boggy formation is equivalent to most of the Bluejacket formation and the Seville formation of southeast Kansas (Howe, 1956, p. 39-44).

Quaternary System

The Quaternary System consists of terrace deposits of two levels and flood-plain alluvium of the Verdigris River and the larger streams of the area.

Terrace Deposits

Terrace deposits are probably of Pleistocene age and were deposited while the rivers and the streams in the area were at a higher level than at the present. The rivers had a greater carrying capacity than at the present time and sand, silt, and chert gravels were deposited. Glaciers were a few hundred miles to the north during this period of greater precipation. A light yellow mixture of silt and clay was deposited on a terrace level that is higher than the unconsolidated gravel terrace deposit.

The surface of the terrace deposits is dotted with pimple mounds. These mounds are about 4 feet high and have a diameter of about 10 to 40 feet. They make a characteristic pattern on aerial photographs. Melton, (1954, p. 109) in discussing their process of origin, stated that:

> II. In the writer's opinion...there are two common geological processes which acting separately and together in different degrees, have formed the great majority of the natural mounds under discussion. One process is small stream or rill erosion followed by the rounding effects of rain wash and soil creep. The other is the entrapment of dume sand in small clumps of growing vegetation.

Melton (1954, p. 110) believes that the pimple mounds in Oklahoma are due in main to the process of small stream erosion and that there is but slight accumulation of entrapped wind blown sand on the mounds.

Alluvial Deposits

Recent alluvial deposits are present in the flood plains of the Verdigris River and the larger streams in the area. These deposits consist of dark gray, unconsolidated, fine sand, silt, and clay. Cross-bedding is noticeable on the east bank of the Verdigris River in sec. 14, T. 19 N., R. 16 E., and on the south bank in sec. 35, T. 19 N., R. 16 E.

CHAPTER III

GEOLOGIC HISTORY

Pennsylvanian rocks of the lower part of the Des Moines series, Krebs group, are at the surface of the Inola area. Rocks of this age crop out in a continuous belt to the east in Arkansas, and to the north in Kansas, Missouri, and Iowa.

The McAlester basin in southeast Oklahoma continues into Arkansas where it is known as the Arkansas coal basin. Rocks of basinal facies were deposited here and Branson (1956, p. 83) suggested the term Arkoma basin for this geosyncline. Subsidence began in Atokan time and continued through the Desmoinesian.

The platform facies was deposited north of the basin and the hinge line was in the general position of the Arkansas River valley. The shelf was under deeper water than was the basin, although both were under shallow water. There was a narrow platform in northeast Oklahoma during Atokan time and clastic carbonates, but no coals, were deposited (Branson, 1956, p. 83).

A change in the depositional environment took place at the beginning of the Desmoinesian. Northeast Oklahoma was a stable shelf during most of the Desmoinesian and thin stratigraphic units with widespread distribution and marine fossils were deposited here. It was also the site of cyclic sedimentation. Branson (1954, p. 1) stated:

> The ideal cyclical sequence, the cyclothem, consists of ten units
>
> | | |
> |---|---|
> | dark shale, thin limestone beds | marine fauna |
> | limestone | fusulinids |
> | limestone | brachiopods and bryozoa |
> | calcareous shale | molluscan fauna |
> | cap rock, limestone, clay-iron stone or black fissile shale | phosphatic fossils |
> | coal | |
> | underclay | rootlets |
> | underlime, nodular, pisolitic | fresh water mollusks |
> | silty shale, micaceous sandstone, shale | plant remains |
> | sandstone, conglomerate | |
> | disconformity | |
>
> No geologist has ever seen an ideal cyclothem, but the pattern is approached by many sequences. Cyclothems are fairly well developed in northeastern Oklahoma, particularly in the lower part of the Des Moines series, but none is close to the ideal section. The normal type of cyclothem in northeastern Oklahoma is:
>
> shale, clay-ironstone concretions
> limestone, or clay-ironstone, the limestone fusulinid-bearing
> coal
> underclay
> micaceous silty shale
> sandstone
>
> Only one underlime is known, and there are few instances of typical development of the marine upper portion of the cyclothem.

Figure 20. <u>Stigmaria</u> collected from an underclay in a creek bank near south line of SE 1/4 sec. 35, T. 19 N., R. 17 E.

Low swamp lands with abundant flora were present in the early Desmoinesian during periods of emergence. The organic material was preserved in the euxenic environment which developed here, and was later transformed into coal seams. Some of the logs floated into off-shore bars and were preserved here as coal.

These periods of emergence were followed by periods of transgression in which marine sediments were deposited. These seas were both shallow and extensive. The sea is thought to have retreated rapidly at the end of the cyclothem (Branson, personal communication, 1959), after which the cycle would be repeated.

There are two generally advanced theories as to the cause of this cyclic deposition. Weller (1930, p. 118-135) postulated that cyclic diastrophism was responsible, that the land rose and fell in relation to the sea, and that the sand was supplied from the rising land. Wanless and Shepard (1936, p. 1205-1206) have suggested that the land was inactive and that the cyclic retreat of the sea was due to eustatic changes in sea level, probably brought about by advancing and retreating glaciers in the Southern Hemisphere.

The Ozark Dome was positive during the Desmoinesian and was the main source of sediments deposited on the platform (Scruton, 1950, p. 425-426). Dott (1927, p. 12) reported that the Ouachita Mountains and the Hunton Arch were the probable source area of the basinal facies.

The base of the Hartshorne formation is covered in the Inola area, but Branson (1956, p. 85) stated that a basal conglomerate is present at this horizon on the shelf. Blythe (1959, p. 48) states that fusulinids provide evidence that there was a short hiatus between the top of the Atoka and the overlying Hartshorne formation. The Hartshorne formation overlaps the Atokan on the platform in northern Mayes County (Blythe, 1959, p. 24).

There is a conformable relationship between the top of the Hartshorne and the base of the McAlester formation. The base of the Savanna is conformable with the McAlester. There was a break in sedimentation between the top of the Savanna formation and the base of the Boggy formation, or before deposition of the Bluejacket sandstone. There is a larger break at the top of the Boggy.

A renewed uplift of the Ozark area occurred at the end of Krebs time. Tensional forces were present and they produced the minor folds and the en-echelon faults in northeast Oklahoma.

CHAPTER IV

STRUCTURAL GEOLOGY

The regional structures in northeast Oklahoma are the Ozark Uplift; the Prairie Plains homocline, which is on the west flank of the Ozark Uplift; and the northeast-southwest trending en-echelon faults. The Inola area is situated on the west side of the Ozark province (Arbenz, 1956, map) and adjacent to the Central Oklahoma platform, which is the southern portion of the Prairie Plains homocline.

Uplift of the Ozark dome tilted the strata in the Inola area and they dip gently to the west at about 40 to 50 feet per mile, giving a regional dip of about one-half a degree per mile. Any beds having a visible dip have been disturbed by either faulting, folding, or in a few places by slumping.

Folds

Bull Creek anticline is present in SW 1/4 sec. 27, T. 19 N., R. 17 E. It was named by Wright (1952, p. 116) for Bull Creek which cuts across the east flank of the structure. It is a faulted anticline with a sandstone about 25 feet below the Spaniard limestone exposed in the core by a small tributary to Bull Creek. The Spaniard and Sam Creek limestones help to outline the structure.

An unnamed syncline is present about a mile east of the Rogers-Mayes County line, and two Bluejacket sandstone capped outliers in secs. 17 and 20, T. 19 N., R. 18 E. are near its axis. The Spiro sandstone outlines the structure.

Faults

Several faults are present in the Inola area, most with a northeast-southwest trend. The amount of displacement can not be determined for these faults, due to the nature of the sediments. Shale is the predominant rock in which most of the faulting occurs. The following criteria were used as evidence for these faults: fault drag, interpretation of the outcrop pattern, and alignment of drainage. The courses of several of the streams and part of the course of the Verdigris River are controlled by faulting.

A fault that may be a continuation of the Seneca fault zone enters the Inola area in the northwest corner of sec. 5, T. 19 N., R. 18 E., and leaves the area in sec. 33, T. 19 N., R. 17 E.

Blythe (1959, p. 35) stated that the folding probably shortly preceded the faulting. The horst and graben type of faulting that is present in northeast Oklahoma is a indication of normal faults that have been formed by tensional forces. Most of the faulting occurred in post-Boggy, pre-Senora time.

Figure 21. Fault drag fold in thin-bedded sandstone on south line of SE 1/4 sec. 34, T. 19 N., R. 17 E.

Figure 22. Spiro sandstone tilted by a fault in SE 1/4 sec. 35, T. 19 N., R. 17 E.

CHAPTER V

ECONOMIC GEOLOGY

Oil and Gas

Sandstone members of the Krebs group have been some of the principal producing oil and gas sands in the Mid-Continent. These sandstone bodies are lenticular and surrounded by shale, making them excellent reservoirs.

The Krebs group crops out in the Inola area, and there is no production from it here. The Bluejacket sandstone, (Bartlesville sand of subsurface) and the Taft sandstones (Red Fork sands of subsurface) are at or near the surface of the Inola area. The Spaniard, Sam Creek, and Doneley limestones (Brown limes of subsurface) are useful as marker beds, but produce no oil. The Warner sandstone (Booch sand of subsurface) crops out near the east edge of the area, but does not produce within the area.

The only oil field that was in the Inola area was the Inola field that was situated about 4 miles west of Inola in secs. 3, 4, 9, and 10, T. 19 N., R. 16 E. The first production was in 1913 (Snider, 1920, p. 204) and initial production was about 1,100 barrels per day from some of the early wells. The field reached its peak early in 1914, and had declined to less than 2,000 barrels per day before the year was over. Production was from the Atoka formation (Dutcher sand of subsurface). There is no production from the field now.

A few gas wells were drilled near Mazie in 1924 that produced from the Simpson group, but there is no production there now.

Over 100 wells have been drilled in the Inola area since 1918. Over 75 per cent have been dry, and most of the others had small production of about 5 to 10 barrels per day or were small gas wells.

The deepest well that was drilled in the area that the Corporation Commission has a record of was drilled in 1956 on Bull Creek anticline, and hit granite after drilling through 2,415 feet of sediments.

There are 3 or 4 small producing oil wells in the area at the present time. Due to the fact that the Krebs group crops out in the area, there is little prospect for future oil finds of commercial size.

Coal

Coal has been mined in the past in the Inola area, and several abandoned strip pits bear evidence to this. The Rowe coal was mined at the largest operation, which was in sec. 26, T. 19 N., R. 17 E., where the now abandoned town of

Keith was located. Smaller abandoned strip pits are located in secs. 27, 28, and 34, T. 19 N., R. 17 E., on the north and south sides of Inola Mound, and in sec. 17, T. 19 N., R. 18 E. A small amount of coal may be mined locally by a few residents of the area, but no commercial mining is now attempted. Most coals in the area are 1 to 3 inches thick, and at only a few localities was a coal about a foot thick found. It is doubtful that any future mining will be attempted.

Water Supply

There are more than 150 small ponds in the Inola area, and five have been added in the past year. These were formed by the damming of gullies and small intermittent creeks and serve both as a water supply for the stock and to stop erosion.

Although all of the streams in the area are intermittent, with the exception of the Verdigris River, some of the larger creeks have deep holes that contain water even during periods of drought.

Lensing sands make the locating of good water wells difficult. Good water wells from 30 feet to at least 150 feet are present, but many of the wells dug have gas in the water, rendering them unfit for use.

Gravel

Terrace deposits of sand, silt and gravel are common in the western part of the Inola area. Gravel has been taken from several pits in the area, and is used to surface many of the section line roads. Several pits are in secs. 2 and 11, T. 19 N., R. 16 E. and one is in sec. 27, T. 19 N., R. 17 E.

Building Stone

Some of the sandstones are used locally in building bridges and other small structures. The Warner sandstone that caps a small outlier in sec. 27, T. 19 N., R. 18 E., was used for building the school at Mazie. Most of the sandstones are too friable for use as building stone.

CHAPTER VI

SUMMARY

The Inola area is about 25 miles east of Tulsa in southeastern Rogers and southwestern Mayes Counties, Oklahoma. The purpose of the investigation was to make a detailed geologic map and report of the stratigraphy of this area.

Rocks of the Des Moines series of the Pennsylvania system and of the Quaternary system are present at the surface of the Inola area. The Krebs group of the Des Moines series is represented by rocks of the Hartshorne formation, McAlester formation, Savanna formation, and the Boggy formation, in ascending order. These formations are predominantly shale, but contain lenticular sandstones and a few thin limestones and coals. The Quaternary system consists of river terrace and alluvial deposits.

The formations in the Krebs group in northeast Oklahoma were deposited in a shallow sea on a stable shelf. Cyclic sedimentation occurred during this period.

The regional structure is homoclinal, with the beds dipping to the west at about one-half a degree per mile.

Several faults with a northeast-southwest trend are present, and one may be a continuation of the Seneca fault zone. One anticline and one syncline are present in the area. All of the structural features are probably related to movements in the Ozark Uplift.

Most of the coal, natural gas, and oil in the Inola area have already been discovered and depleted. Only a small portion of the rock in the area is suitable for building purposes. River terrace gravels are used for surfacing most of the section line roads.

REFERENCES CITED

Arbenz, J. K., 1956, Tectonic map of Oklahoma: Okla. Geol. Survey, Map GM-3.

Blythe, Jack G., 1957, The Atoka formation on the north side of the McAlester Basin: Unpublished Doctor of Philosophy Dissertation, University of Oklahoma.

Blythe, Jack G., 1959, Atoka formation on the north side of the McAlester Basin: Okla. Geol. Survey circular 47.

Branson, Carl C., 1952, Marker beds in the lower Desmoinesian of northeastern Oklahoma: Oklahoma Academy of Science Proceedings, vol. 33, p. 190-194.

Branson, Carl C., 1954, Field conference on Desmoinesian rocks of northeastern Oklahoma: Okla. Geol. Survey Guide Book II.

Branson, Carl C., 1956, Pennsylvanian history of northeastern Oklahoma: Tulsa Geol. Soc. Digest, vol. 24, p. 83-86.

Campbell, David G., 1958, Geology of the Jamesville Area, Muskogee and Okmulgee Counties, Oklahoma: Unpublished Master of Science Thesis, University of Oklahoma.

Dott, R. H., 1927, Notes on Pennsylvanian paleogeography with special reference to south-central Oklahoma: Okla. Geol. Survey, Bull. 40-J.

Govett, Ray, 1959, Areal Geology of Wagoner County, Oklahoma: Unpublished Doctor of Philosophy Dissertation, University of Oklahoma.

Howe, Wallace B., 1951, Bluejacket sandstone of Kansas and Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 35, p. 2087-2090.

Howe, Wallace B., 1956, Stratigraphy of pre-Marmaton Desmoinesian (Cherokee) rocks in southeastern Kansas: Kansas Geol. Survey, Bull. 123, p. 20-44.

Ireland, H. A., 1930, Geology of Mayes, Ottawa, and Deleware Counties, Okla. Geol. Survey, Bull. 40-NN.

Lowman, S. W., 1932, Lower and Middle Pennsylvanian Stratigraphy of Oklahoma East of the Meridian and North of the Arbuckle Mountains: Tulsa Geol. Soc. Digest, vol. 1, (Unnumbered p. 33-36).

Lowman, S. W., 1933, Cherokee structural history in Oklahoma: Tulsa Geol. Soc. Digest, vol. 2, p. 31-34.

Melton, F. A., 1954, Natural mounds of northeastern Texas, southern Arkansas, and northern Louisiana: The Hopper, vol. 18, p. 971-1009.

Miser, H. D., 1954, Geologic map of Oklahoma: U. S. Geol. Survey and Okla. Geol. Survey.

Oakes, Malcolm C., and Knechtel, M. M., 1948, Geology and Mineral Resources of Haskell County, Oklahoma: Okla. Geol. Survey, Bull. 67.

Oakes, Malcolm C., 1953, Krebs and Cabaniss Groups of Pennsylvanian age in Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 37, p. 1523-1526.

Ohern, D. W., 1914, Geology of the Nowata and Vinita Quadrangles: Unpublished manuscript on file at the office of the Okla. Geol. Survey.

Oklahoma Geological Survey, 1957, Physiographic map of Oklahoma: Educational Series map no. 4.

Pierce, W. G., and Courtier, W. H., 1937, Geology and coal resources of the southeastern Kansas coal field: Kansas Geol. Survey Bull. 24.

Renfro, H. B., 1947, Lower Pennsylvanian sediments of northeastern Oklahoma: Unpublished Doctor of Philosophy Dissertation, University of Wisconsin.

Scruton, P. C., 1950, The Petrography and Environment of the Deposition of the Warner, Little Cabin, and Hartshorne Sandstones in Northeastern Oklahoma: Amer. Jour. Science, vol. 248, p. 408-426.

Searight, Walter V., 1955, Guide Book, Field Trip, Second Annual Meeting Association of Missouri Geologists.

Searight, Walter V., Howe, W. B., Moore, R. C., Jewett, J. M., Condra, G. E., Oakes, M. C., and Branson, Carl C., 1953, Classification of Desmoinesian (Pennsylvanian) of northern Mid-Continent: Amer. Assoc. Petroleum Geologists, Bull., vol. 37, p. 2747-2749.

Smith, C. C., 1911, Geology of the Claremore Quadrange, Unpublished manuscript map on file at the office of the Okla. Geol. Survey.

Snider, L. C., 1920, Oil and gas in the Mid-Continent fields: Oklahoma City, Oklahoma, Harlow Publishing Co. p. 204.

Taff, Joseph A., 1899, Geology of the McAlester-Lehigh coal field, Indian Territory: U. S. Geol. Survey, 19th Annual Report, Part 3.

Tillman, Jack L., 1952, Geology of the Tiawah Area, Rogers and Mayes Counties, Oklahoma: Unpublished Master of Science Thesis, University of Oklahoma.

U. S. Department of Commerce, 1959, Climatological Data, Oklahoma: U. S. Dept. of Commerce, Weather Bureau, Annual Summary, 1958, vol. LXVII, no. 13.

Wanless, H. R., and Shepard, F. P., 1936, Sea level and climatic changes related to late Paleozoic cycles: Geol. Soc. America, Bull., v. 47, p. 1177-1206.

Weller, J. M., 1930, Cyclical sedimentation in the Pennsylvanian period and its significance: Jour. Geol., vol. 38, p. 97-135.

Wilson, Charles W., Jr., 1935, Age and correlation of Pennsylvanian surface formations, and oil and gas sands of Muskogee County, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 19, p. 503-520.

Wilson, Charles W., Jr., and Newell, Norman D., 1937, Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma: Okla. Geol. Survey, Bull., 57.

Woodruff, E. G., and Cooper, C. L., 1928, Geology of Rogers County: Okla. Geol. Survey, Bull., 40-U.

Wright, Leo M., 1949, The micropaleontology of the Spaniard limestone member of northeast Oklahoma and its relationship to the underlying Atoka formation: Unpublished Master of Science Thesis, University of Tulsa.

APPENDIX

MEASURED SECTIONS

1. MEASURED UP NORTH SIDE OF INOLA MOUND IN SECTION 10, T. 19 N., R. 17 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
Boggy formation	
Taft sandstone, buff, fine-grained, ferruginous .	1.4
Covered	5.0
Shale, buff, silty	16.5
Shale, tan, silty	17.0
Shale, gray, contains clay-ironstone nodules . .	9.5
Shale, dark gray	3.1
Sandstone, buff, weathers tan, fine-grained ferruginous	0.3
Shale, dark gray	5.2
Limestone, black, weathers light gray, silty, hard	0.6
Shale, black	4.8
Inola limestone, blue to gray, weathers buff, fossiliferous	0.4
Covered	5.7
Bluejacket sandstone, light gray to brown, weathers gray, fine-grained, micaceous, silty .	2.5
Savanna Formation	
Covered	6.3
Drywood coal	0.2
Underclay, gray, soft	0.1

2. MEASURED ON WEST SIDE OF INOLA MOUND IN SECTION 10, T. 19 N., R. 17 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
Boggy Formation	
Limestone, light gray, fossiliferous	0.1
Covered	2.5
Coal	0.1
Underclay, light gray, weathers tan, soft	0.1
Inola limestone, gray, nodular, fossiliferous	0.3
Covered	1.7
Coal	0.05
Underclay, light gray, soft	0.2
Covered	12.0
Bluejacket sandstone, gray, very fine-grained	4.3

3. MEASURED UP GULLY ON WEST SIDE OF INOLA MOUND IN SECTION 10, T. 19 N., R. 17 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
Boggy Formation	
Inola limestone, blue to gray, weathers buff, fossiliferous	0.2
Covered	8.3
Shale, gray	2.2
Bluejacket coal	0.2
Underclay, light gray, soft	0.1
Shale, tan	4.1
Siltstone, gray, calcareous	0.1
Shale, buff, platy	4.5
Siltstone, buff	2.1
Bluejacket sandstone, tan, weathers dark brown, very fine-grained, ferruginous	3.6
Savanna Formation	
Shale, buff, platy	9.7
Shale, black	15.5
Shale, dark gray	0.4
Clay iron-stone, orange to maroon, nodular, hard	0.1
Shale, black	1.1
Coal	0.3
Underclay, light gray, soft	0.2
Shale, light gray, weathers buff, brittle, contains clay-ironstone nodules	3.4
Shale, gray	5.6

Shale, tan, weathers buff, contains calcareous clay-ironstone nodules	3.5
Shale, dark gray, contains clay-ironstone nodules	15.9
Shale, gray to tan	11.4
Covered	11.3
Rowe coal	0.2
Underclay, light gray, soft	1.0

4. MEASURED IN GULLY ON WEST SIDE OF INOLA MOUND IN SECTION 10, T. 19 N., R. 17 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
Savanna Formation	
Doneley limestone, gray, hard, nodular	0.9
Rowe coal	0.7
Underclay, gray	2.1
Clay, light gray, weathers gray to yellow to ferruginous red, soft	3.4
Underlime, red, weathers dark ferruginous red, pisolitic	0.9
Shale, dark gray, fissile	0.5

5. MEASURED UP TRIBUTARY AND ROAD CUT FROM EAST BANK OF BULL CREEK TO SECTION LINE ROAD IN SOUTHEAST 1/4 OF SECTION 23, T. 19 N., R. 17 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
Savanna Formation	
Spiro sandstone, buff, fine-grained	8.3
Covered	6.0
Sam Creek limestone, blue-gray weathers ferruginous red, fossiliferous	0.2
Shale, tan to buff	8.3
Shale, blue to gray to tan	5.5
Shale, gray, calcareous, soft, fossiliferous	0.3
Spaniard limestone, dark gray, hard, fossiliferous	0.2

McAlester Formation	
Shale, gray, calcarerous, soft, fossiliferous . .	0.6
Covered	3.6
Sandstone, light gray weathers dark brown, fine-grained, ferruginous, micaceous	4.7

6. MEASURED FROM WATER LEVEL TO TOP OF BLUEJACKET SANDSTONE BLUFF ON EAST SIDE OF VERDIGRIS RIVER IN NORTHEAST 1/4, SECTION 14, T. 19 N., R. 16 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
Boggy Formation	
Sandstone, yellow to buff, fine-grained, micaceous	2.0
Sandstone, buff, weathers light gray, fine-grained, massive	11.0
Sandstone, buff, fine-grained, thin bedded . . .	25.0
Coal	0.2
Sandstone, buff, fine-grained	0.3
Coal	0.4
Sandstone, buff, fine-grained	1.4
Coal	0.2
Sandstone, buff, fine-grained	0.2
Savanna Formation	
Shale, dark gray, weathers light gray, platy .	1.7

7. MEASURED ON EAST BANK OF VERDIGRIS RIVER IN NORTHEAST 1/4, SECTION 36, T. 19 N., R. 16 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
Savanna Formation	
Shale, black, weathers gray, contains clay-iron stone nodules	7.2
Coal	0.1
Underclay, gray, soft	1.7
Siltstone, gray, weathers ferruginous red	0.5
Shale, gray	1.7
Siltstone, light gray, calcareous, hard	1.9
Shale, gray, weathers light gray, platy	1.1
Shale, black	0.1
Shale, gray, platy	2.5

Limestone, gray, hard, fossiliferous	0.1
Shale, gray, fossiliferous	0.3
Shale, gray, contains clay iron-stone nodules . .	1.8

8. MEASURED UP SOUTH SIDE OF BULL CREEK ANTICLINE IN SOUTHEAST 1/4 SECTION 27, T. 19 N., R. 17 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
Savanna Formation	
Sam Creek limestone, blue, weathers ferruginous red, fossilliferous	0.6
Covered	3.5
Coal	0.2
Underclay, light gray to yellow	0.1
Covered	8.2
Spaniard limestone, gray, weathers light gray to tan, fossiliferous	1.3
McAlester Formation	
Coal	0.1
Underclay, light gray to yellow	0.3
Covered	9.0
Shale, tan	3.0
Shale, black, fissle	11.4
Shale, black, silty, calcareous	0.2
Sandstone, gray to tan, fine-grained, Stigmaria abundant	1.1

9. MEASURED FROM FIELD NORTH OF LONGVIEW PUBLIC SCHOOL TO TOP OF ROAD CUT ON SOUTH SIDE OF HIGHWAY 33 IN NORTHEAST 1/4 OF SECTION 4, T. 19 N., R. 18 E.

DESCRIPTION OF UNIT	THICKNESS IN FEET
McAlester Formation	
Warner sandstone, tan, very fine-grained, subangular, thin bedded, argillaceous	8.0
Shale, black, very carbonaceous	0.8
Hartshorne Formation	
Underclay, light gray to yellow, soft	1.2
Covered	12.4
Mazie clay-ironstone, yellow-brown, weathers dark brown, limonitic, fossiliferous	0.2

10. MEASURED ALONG NORTH SIDE OF NORTHWEST 1/4 OF SECTION 22, T. 19 N., R. 18 E., AND THEN SOUTH TO TOP OF BLUFF.

DESCRIPTION OF UNIT	THICKNESS IN FEET
McAlester Formation	
Sandstone, light gray to buff, weathers dark brown, very fine-grained, subangular, argillaceous, hard	5.5
Covered	15.0
Warner sandstone, brown, weathers dark brown, very fine-grained, subangular, micaceous	6.5
Covered	1.0
Hartshorne Formation	
Covered	10.5
Mazie clay-ironstone, yellow, weathers dark gray to dark yellow, fossiliferous	0.3
Shale, buff, silty	0.2
Siltstone, gray, weathers light orange to maroon to tan, micaceous, argillaceous	3.1