OKLAHOMA GEOLOGICAL SURVEY

CARL C. BRANSON, DIRECTOR

Circular 44

STRATIGRAPHY AND PALEONTOLOGY OF THE HUNTON GROUP IN THE ARBUCKLE MOUNTAIN REGION

PART I—INTRODUCTION TO STRATIGRAPHY

BY

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Norman

1957

PREFACE

A thorough study of the rocks and fossils of the Hunton group is being made by Dr. Amsden. Hunton rocks are the reservoir rocks for the petroleum produced in such fields as West Edmond and Short Junction. Geologists have been perplexed by their difficulties in picking the top of the Haragan and other units in wells. This report shows why these difficulties exist and in this detailed study of the exposed Hunton rocks gives the oil field stratigrapher much needed help in his interpretations. The report is a perfect example of the importance of careful paleontologic work in solving complex stratigraphic problems. It may well provide important aid in further search for petroleum in Silurian and Devonian rocks.

Carl C. Branson

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STRATIGRAPHY AND PALEONTOLOGY OF THE HUNTON GROUP IN THE ARBUCKLE MOUNTAIN REGION

PART I—INTRODUCTION TO STRATIGRAPHY

Thomas W. Amsden

FOREWORD

The writer is making a stratigraphic and paleontologic study of the Hunton, a group of strata which includes all of the Silurian and most of the Devonian* rocks in the Arbuckle region of south-central Oklahoma. Thus far the investigation has been concentrated in the eastern areas of the Arbuckles with rather complete coverage of the region east of Mill Creek. West of Mill Creek the only localities studied in detail are at White Mound, Henryhouse Creek and Vines Dome. The work is continuing and eventually all of the outcrop area will be investigated. Figure 1 shows the location of sections examined by the writer, as well as of the principal geographic features, including all type localities. The Hunton group is well exposed within the Arbuckle complex and is also known to have a wide distribution in the subsurface (Tarr 1955, pp. 1851-1858), but to date no attempt has been made to expand the present study to the subsurface, the investigation being confined to work on the stratigraphic and faunal relationships within the outcrop area. In the future the writer plans to prepare a detailed account of the Hunton, covering the stratigraphy, lithology, and faunas. However, it seems desirable at this time to present a summary of the stratigraphic results thus far determined. The scope of the present paper is, therefore, to outline the stratigraphic divisions recognized, give a brief description of each of these formations and members, and to present a short account of their relationship to each other. The evidence for the interpretations herein given is only touched upon, a fuller statement being reserved for later

* The overlying Woodford formation is generally considered to be at least in part Devonian.

stratigraphic and paleontologic reports which will include faunal descriptions, measured sections, geologic maps and other data compiled during the field and laboratory work. In the near future the writer hopes to complete one of these reports describing the Haragan brachiopods, and the present paper will serve as the stratigraphic background for that paper.

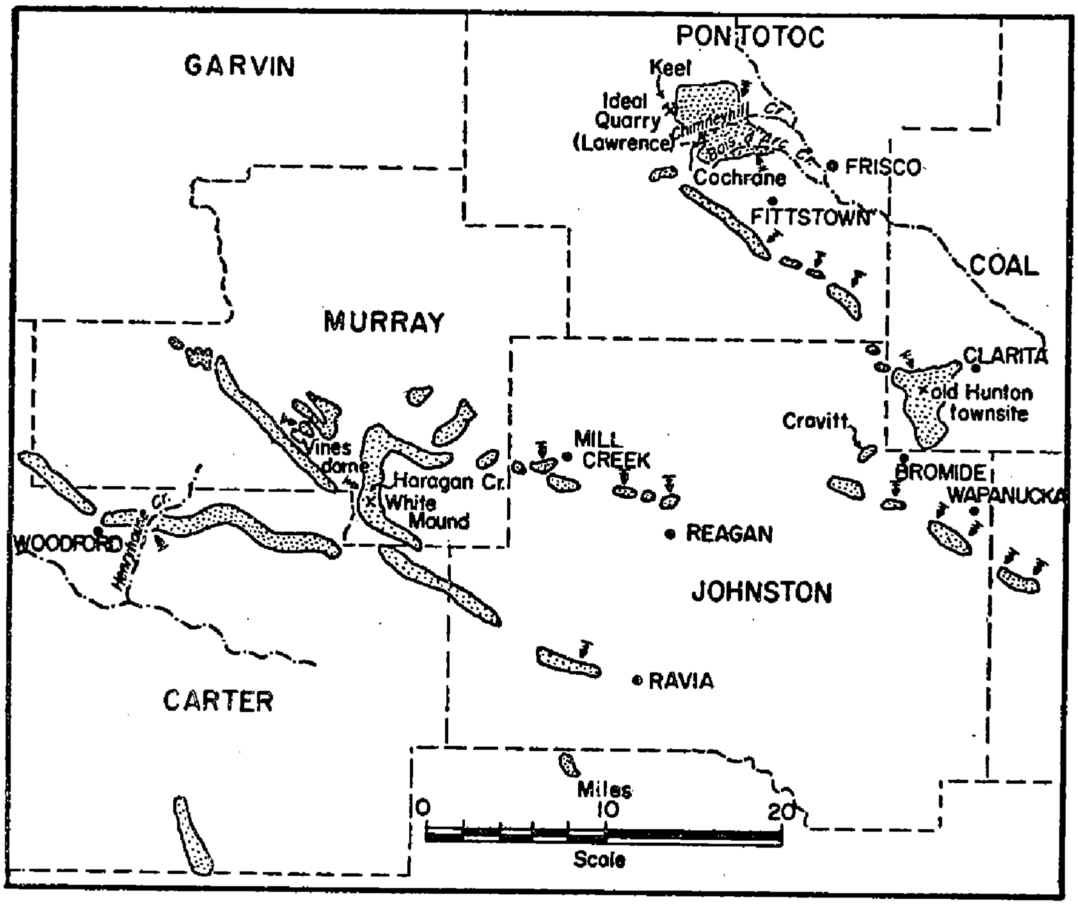

Figure 1. Generalized outcrop map of the Hunton group showing the principal geographic features referred to in the text. Areas which have been studied in detail are indicated by barred arrows.

The writer wishes to take this opportunity to acknowledge the generous help of W. E. Ham, with whom he has consulted freely on all aspects of Hunton stratigraphy.

SUMMARY OF PAST INVESTIGATIONS

These strata were first described by Taff (1902, 1904, pp. 29-31) as the Hunton limestone, the name being taken from the town of Hunton in Coal County (fig. 1; no trace of this town remains). In 1911 C. A. Reeds summarized the results of an extensive stratigraphic and faunal study of the Hunton and proposed the following subdivision:

Bois d'Arc limestone
Haragan shale
Henryhouse shale
Chimneyhill limestone
  Pink-crinoidal member
  Glauconitic member
  Oolitic member

Some years later Reeds (1926) removed the upper part of his Bois d'Arc limestone to a new formation, the Frisco limestone, which he assigned to the Oriskanian (Deerparkian). At this time he elevated the Hunton from a formation to a group.

The next major study was by Ross Maxwell, who made the Hunton the subject of a Master of Science thesis at the University of Oklahoma (1931) and of a doctoral dissertation at Northwestern University (1936). The results of this study have never been published except in abstract form (1936). Maxwell recognized several additional subdivisions and proposed some new names, including member names for Reeds' Chimneyhill divisions. Maxwell's classification is compared in Figure 2 with that of Reeds. Maxwell presented extensive faunal lists but did not describe or illustrate any Hunton species. He made one change in the age assignments, shifting the Dillard (Pink-crinoidal member of Reeds, here named the Clarita) from the Alexandrian to the Niagaran.

Both Reeds and Maxwell contributed substantially to an understanding of Hunton stratigraphy and paleontology. Their writings have been freely consulted and although the conclusions reached in the present study are somewhat different from those of either of these authors, the writer wishes to acknowledge his indebtedness to both.

In 1954 W. E. Ham's map of the Arbuckle Mountains was published, and in 1955 Ham prepared a guide book for an Arbuckle field conference which included valuable information on Hunton stratigraphy (Ham 1955, fig. 11; pp. 41, 49, 59, 61).

Reeds – 1911, 1926			Maxwell – 1926		
Oriskanian		Frisco limestone		Frisco limestone	Oriskanian
Helderbergian		Bois d'Arc limestone		Bois d'Arc limestone	Helderbergian
			Kite Group	Cravatt limestone	
		Haragan shale		Haragan formation	
Niagaran		Henryhouse shale		Henryhouse formation	Niagaran
Alexandrian	Chimneyhill limestone	Pink-crinoidal member	Chimneyhill limestone	Dillard limestone	
		Glauconitic member		Cochrane limestone	Alexandrian
		Oolitic member		Keel limestone	
				Hawkins limestone	

Figure 2. Chart comparing the stratigraphic classification of C. A. Reeds with that of R. Maxwell.

Much of the Hunton is richly fossiliferous and a number of papers have been written describing various biologic and stratigraphic assemblages from this group. This paleontological work is summarized in the writer's *Catalog of Hunton Fossils* published in 1956.

HUNTON LITHOLOGY

The Hunton group consists of a sequence of limestones and marlstones which are underlain by the Sylvan formation (unconformably*) and unconformably overlain by the Woodford formation. Before proceeding with the lithologic descriptions some explanation is needed of the term marlstone as herein used. This name has been applied for many years to those earthy limestones of the middle Hunton, in particular to the Henryhouse and Haragan formations. It is a short term which is convenient for use in abbreviated descriptions, although these Hunton strata do not precisely fit the definition given by Pettijohn. According to that author (1957, p. 369, 410) a marlstone is a carbonate rock containing between 35 and 65 percent clay. The writer has prepared a number of insoluble residues** of the Hunton marlstones and finds that they range from 8 to 36 percent, the average falling between 17 and 22 percent. Moreover, a microscopic examination of these residues shows silt-size as well as clay-size particles (only traces of sand-size material observed). Thus much of this rock is actually an argillaceous and silty calcilutite, but the name marlstone is so convenient that it will be retained.

The thickness of the Hunton group ranges up to slightly more than 400 feet, but at most places it is much less, due at least in part to unconformities and facies changes. In those areas where it is relatively thick and complete, the typical sequence consists of a basal series of calcilutites and calcarenites (Chimneyhill formation), overlain by marlstones (Henryhouse and Haragan formations), followed by cherty marlstones (lower Bois d'Arc formation) and calcarenites (upper Bois d'Arc formation and, locally, the Frisco formation). This lithologic sequence commonly produces a distinctive topographic profile: the Chimneyhill limestones and the Bois d'Arc cherty marlstones and limestones form two ridges, separated by a saddle cut in the marlstones. As a rule

* The writer has no first hand knowledge concerning the unconformable nature of the Sylvan-Hunton contact.

** All insoluble residues of Hunton rocks were prepared by digesting the sample in warm (not hot or boiling) 20% hydrochloric acid; the percentages were calculated by weight.

the Bois d'Arc ridge is much more prominent than is that of the Chimneyhill.

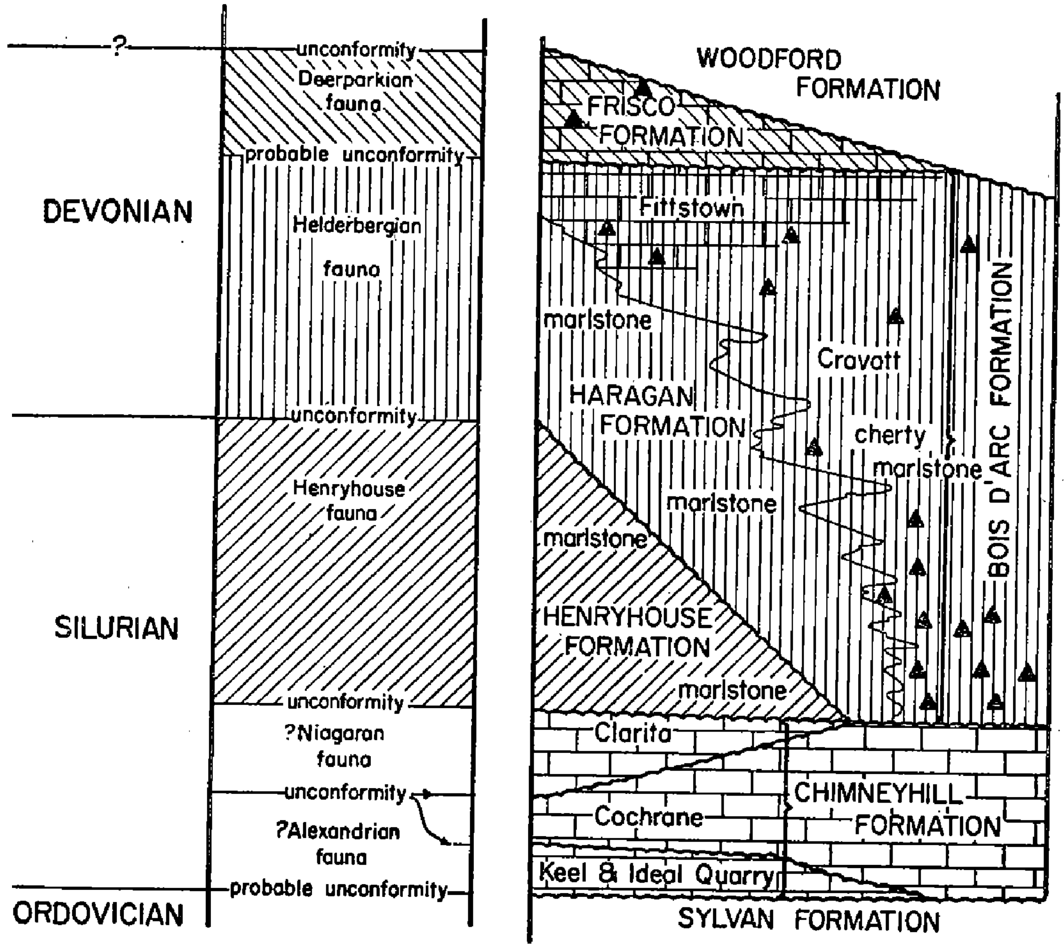

Figure 3. Diagramatic section summarizing the stratigraphic and faunal relationships of the Hunton formations and members.

STRATIGRAPHIC CLASSIFICATION

The writer's interpretation of the stratigraphic and faunal relationships within the Hunton group differs somewhat from that given by previous workers, and this has necessitated some revision in the classification. The names introduced by these earlier authors, even those proposed in abstract form, are retained provided they are not preoccupied, but some of the original descriptions have been expanded or even altered. The writer's classification is given below (an asterisk indicates a new name):

Hunton group	Hunton marlstone	Frisco formation
		Bois d'Arc formation
		*Fittstown member
		Cravatt member
		Haragan formation
		Henryhouse formation
		Chimneyhill formation
		*Clarita member
		Cochrane member
		Keel member
		*Ideal Quarry member

The relationship of these formations and members to one another is complicated both by unconformities and by facies changes. These relationships are summarized in figure 3.

DESCRIPTION OF FORMATIONS AND MEMBERS

On the following pages each of the Hunton formations and members is described in chronological order, starting with the oldest. For each of these divisions the type locality is first discussed, followed by sections on *Lithology, Comparison with strata above and below, Thickness and distribution, and Fossils and age.*

CHIMNEYHILL FORMATION. This formation was named for Chimneyhill Creek, which appears on most maps as the South Fork of Jackfork Creek.* Reeds, who proposed the name, stated that the type locality was at the confluence of three small creeks, sec. 4, T. 2 N., R. 6 E., but this section number is undoubtedly an error. The writer has mapped the Hunton in this area and finds that the only Chimneyhill limestone present in sec. 4 is in the very southwest corner and this outcrop is not on the creek. There are, however, excellent exposures of this formation along Chimneyhill Creek in the southeast quarter of

* Reeds changed the name from South Fork of Jackfork Creek to Chimneyhill Creek, then named the formation after the creek. In this paper it is called Chimneyhill Creek throughout; see figure 1. Reeds earlier (1910) used the name Mosely in a figure explanation (plate XV) for strata which were probably the same as his Chimneyhill formation. He gave no description and the name has not been used again for Hunton strata.

sec. 5, T. 2 N., R. 6 E.; this is undoubtedly the locality referred to by Reeds and is here designated the type section.

The Chimneyhill formation is a complicated stratigraphic sequence which includes several members separated from one another by unconformities. Considering these complications it might well be deemed advisable to drop this name, elevating each member to the rank of formation. The Chimneyhill formation is, however, here retained because it makes a convenient stratigraphic unit. All its members are similar in lithology, being fairly pure limestones with a low silt and clay content. These limestone members, individually or collectively, are generally easily distinguished from the more shaly strata above and below. As is shown in figure 4, the stratigraphic relationships are such that various formations of the overlying strata rest upon different members of the Chimneyhill, but regardless of which units are brought into contact the limestones of the Chimneyhill are almost everywhere easily recognized. Finally, each of the members is thin, making it difficult to show them separately on most maps and sections. It should be emphasized that the Chimneyhill formation includes strata which represent a rather long time span, probably including representatives of both the Lower and the Middle Silurian. Paleontologic collections made from this formation should have their stratigraphic position precisely determined, and in all cases the member should be indicated.

Lithology: All of the Chimneyhill members are composed of fairly pure limestone. The insoluble residues commonly range from less than 1 percent up to 6 percent; one specimen from the Clarita member on Vines Dome (fig. 1) yielded 8 percent, but this is unusual, most specimens falling below 5 percent. The $MgCO_3$ content in nearly every case is low, generally less than 2 percent; one sample from the Ideal Quarry member on Chimneyhill Creek contained 13 percent, but this is exceptionally high. All specimens examined by means of thin-sections and peels show significant amounts of fossil material with a texture ranging from that of a calcilutite to a calcarenite (for additional details on lithology see under the different members).

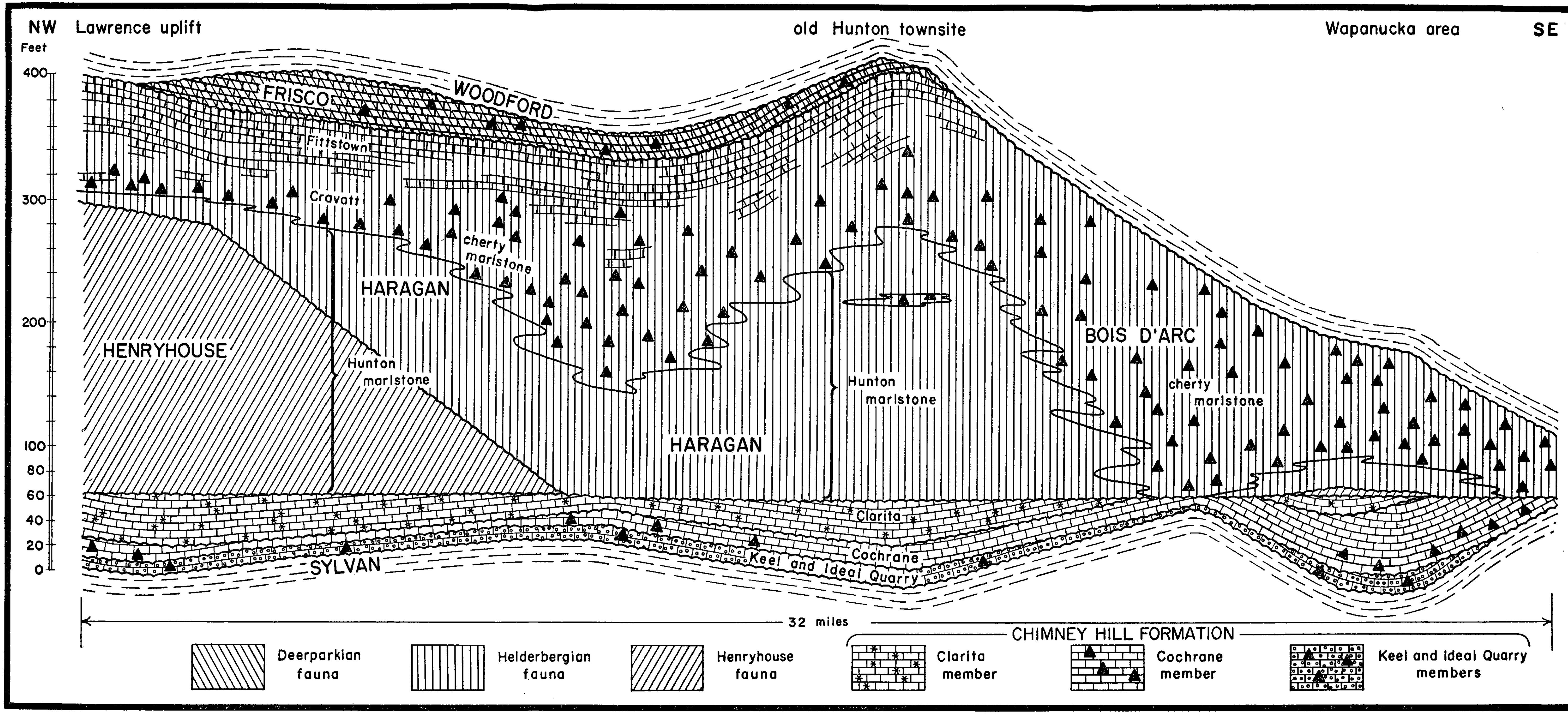

Figure 4. Geologic section of the Hunton group showing the inferred stratigraphic and faunal relationships; it is based upon measured stratigraphic sections, but has been somewhat simplified to avoid excessive distortion caused by the vertical exaggeration. This section is located along the eastern margin of the Arbuckle region, extending from the Lawrence uplift south into Atoka County.

Thickness and distribution: The thickness at the type locality is 60 feet with all of the members present. At most places the Chimneyhill is somewhat thinner, but at old Hunton townsite the formation is 70 feet thick with all members present. Southwest of Wapanucka (SE¼ sec. 27, T. 2 S., R. 8 E.) this formation is again 70 feet, but here the Clarita is absent, the Cochrane alone having a thickness of 57 feet. The Chimneyhill is completely absent in some areas; for example, in the belt north of Reagan (secs. 18 and 19, T. 2 S., R. 6 E.) the Bois d'Arc appears to rest directly upon the Sylvan, no Chimneyhill being observed in this area.

IDEAL QUARRY MEMBER. This is a new name to replace Maxwell's (1936, p. 134) name Hawkins limestone* which is preoccupied by the name of a Carboniferous formation in Washington and by the name of a Cambrian formation in New Mexico. The name Ideal Quarry is taken from the quarry of the Ideal Cement Company at Lawrence, sec. 36, T. 3 N., R. 5 E., where the type section is located (these quarries extend into adjacent sections). The Sylvan shale is being removed along the east side of these quarries and this produces some excellent exposures of the Ideal Quarry and Keel members along the rim of the excavations. This member is also well exposed in the type locality of the Chimneyhill formation along Chimneyhill Creek.

Lithology: The Ideal Quarry member actually represents the basal part of the Keel, and grades upwards into that member through transitional beds. Its upper contact is therefore arbitrary, but below this transitional zone the strata have a distinctive lithology and color which warrants their separation from the overlying Keel. Reeds (1911, p. 259) recognized this as a distinct rock type, although he did not make it a separate member, merely treating it as a part of his Oolitic member.

The rock is a brown-weathering calcarenite, locally with small chert nodules, which commonly has an earthy appearance. It is generally a light brown (5YR 4/4 to 5YR 5/6) to yellowish

* Maxwell gave the type locality as NE¼ sec. 8, T. 2 N., R. 6 E., which is located about a quarter of a mile southeast of Chimneyhill Creek.

brown (10YR 5/4) but locally it is an olive gray (5Y 6/1)*. Thin-sections and peels show a large amount of fossil debris and in places 60 percent or more may be recognizable fossil material; much of this is composed of pelmatozoan plates, but brachiopods, snails and other groups are represented. These fragments are commonly well over 1/16 mm in diameter, so much of the rock is a bioclastic** calcarenite. The upper part of this member has oolites and grades upward into the Keel oolite. Locally the oolites are numerous in the Ideal Quarry member, and as it becomes increasingly oolitic the brown color tends to disappear and the member loses its identity, merging with the Keel. This is believed to be the explanation for its irregular distribution.

Maxwell attributed the earthy brown appearance of this rock to the presence of argillaceous material, but the writer has calculated several insoluble residues and all show less than 2 percent. It seems likely that the color is due at least in part to the presence of iron. The residues commonly show considerable limonite (?); they also show minor amounts of glauconite.

Thickness and distribution: The thickest section observed is 5 feet on Chimneyhill Creek; commonly it is 3 feet or less and at several places is unrecognized. This member is well developed on the Lawrence uplift, and in the area around old Hunton townsite. It is known to be present in the vicinity of Wapanucka and near Mill Creek; in most other areas it has not been observed.

Fossils and age: It is difficult to get satisfactory specimens out of this rock; however, the writer has been able to collect a small fauna. The fossils have not yet been carefully studied, but the following species have been tentatively identified: *Clorinda*

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* All color terms herein used are from the *Rock Color Chart* prepared by Goddard and authors under the auspices of the National Research Council and distributed by the Geological Society of America.

**The term bioclastic is herein used for those limestones with a clastic or fragmental texture, the particles being composed largely of recognizeable fossil material. Such rocks have been called microcoquinas, or encrinites if the organic material is made up largely of pelmatozoan plates (Pettijohn 1957, p. 402). Some of the Hunton calcarenites are true encrinites, but more commonly they include many brachiopod shells, trilobite tests and other organisms.

cf. *C. thebesensis* Savage, *Dictyonella* sp., *Modiolopsis*? sp. and a few gastropods.

The age of these strata is uncertain although it seems reasonably certain that the Ideal Quarry and Keel members are closely related in time. Both Reeds and Maxwell assigned these basal Chimneyhill beds to the Alexandrian. The general stratigraphic relations make this correlation appear to be reasonable, and such fossils as the writer has observed would fit in with this interpretation.

KEEL MEMBER. The term Keel was proposed by Maxwell (1936), this being the name of the "allottee who originally owned the land where the limestone exhibits best the oolitic texture". The type locality was given as the NW¼ NE¼ NE¼ sec. 36, T. 3 N., R. 5 E., which is the site of the present quarries of the Ideal Cement Company. There are excellent exposures of the member in the quarries, and it is also well exposed at the type locality of the Chimneyhill formation. The Keel and the underlying Ideal Quarry member compose the Oolitic member of Reeds (1911, p. 259).

Lithology: The Keel is an oolitic limestone, the oolites ranging in diameter from less than 0.1 mm to over 2 mm (pisolites). The writer has measured individual ooids almost 4 mm in diameter and Maxwell reports them up to 5 mm. These ooids are commonly packed close together and constitute the major part of the rock. In places they are graded as to size and the bedding is clearly defined by marked changes in the size of the ooids. Most are nearly spherical, but some are ellipsoidal or even irregular, this being especially true of the smaller ones. In thin-sections or peels many ooids show a nucleus which is commonly a fossil fragment. Reeds (1914, p. 76) stated that "A few oolites possess primary nuclei, many none at all, the remainder having secondary nuclei". Thin-sections or peels of well preserved ooids show both a concentric and a radial structure in ordinary light. The ooids are silicified in many places, this being especially true of the upper part of the Keel. Where this silicification is strongly developed it grades into nodules and small lenses of oolitic chert.

Fossils are present in this rock and locally become abundant. Commonly the fossils are coated with a layer of material, variable in thickness, that appears to be identical in composition and texture to that composing the ooids. Near old Hunton townsite the Keel is especially fossiliferous and acetic acid residues yield an abundance of pelmatozoan fragments.

The Keel member, excluding the strongly silicified portions, has a low insoluble content; all samples tested yielded less than 3 percent and some less than 1 percent residues. Much of this residue consists of fragments of silicified fossils and centers or "knots" of silicification. One specimen from Chimneyhill Creek which was analysed* for calcium-magnesium content gave the following results: insoluble residue — 0.8 percent; $CaCO_3$ — 98.6 percent; $MgCO_3$ — 1.0 percent.

The Keel-Cochrane relationship is discussed at the close of the section on *Thickness and distribution.*

Subdivisions of the Keel member: Locally the middle portion of the Keel loses its oolitic character, becoming a fine-grained, argillaceous calcilutite. Most of this rock is finely laminated, the individual laminae being less than ¼ inch in thickness. The development of laminated limestone in the middle of the Keel produces a three-fold division (fig. 5), here informally designated the lower oolite, middle laminated calcilutite and upper oolite. The middle unit is generally sharply marked off from the overlying and underlying oolitic beds, but is believed to be only a facies of the oolite because the beds above and below have the typical Keel lithology, and the combined thickness of all three is comparable to that of the Keel where it is oolitic throughout. Locally the middle laminated calcilutite becomes slightly oolitic.

One specimen of the middle laminated calcilutite tested for insoluble residue content yielded 7.8 percent, the residues being almost entirely silt and clay. A peel of the typical laminated lithology shows a fine-textured rock (most grains below 0.05 mm) with little fossil material.

* All chemical analyses prepared for this report are of rock specimens (no channel samples), and were prepared in the chemical laboratories of the Oklahoma Geological Survey.

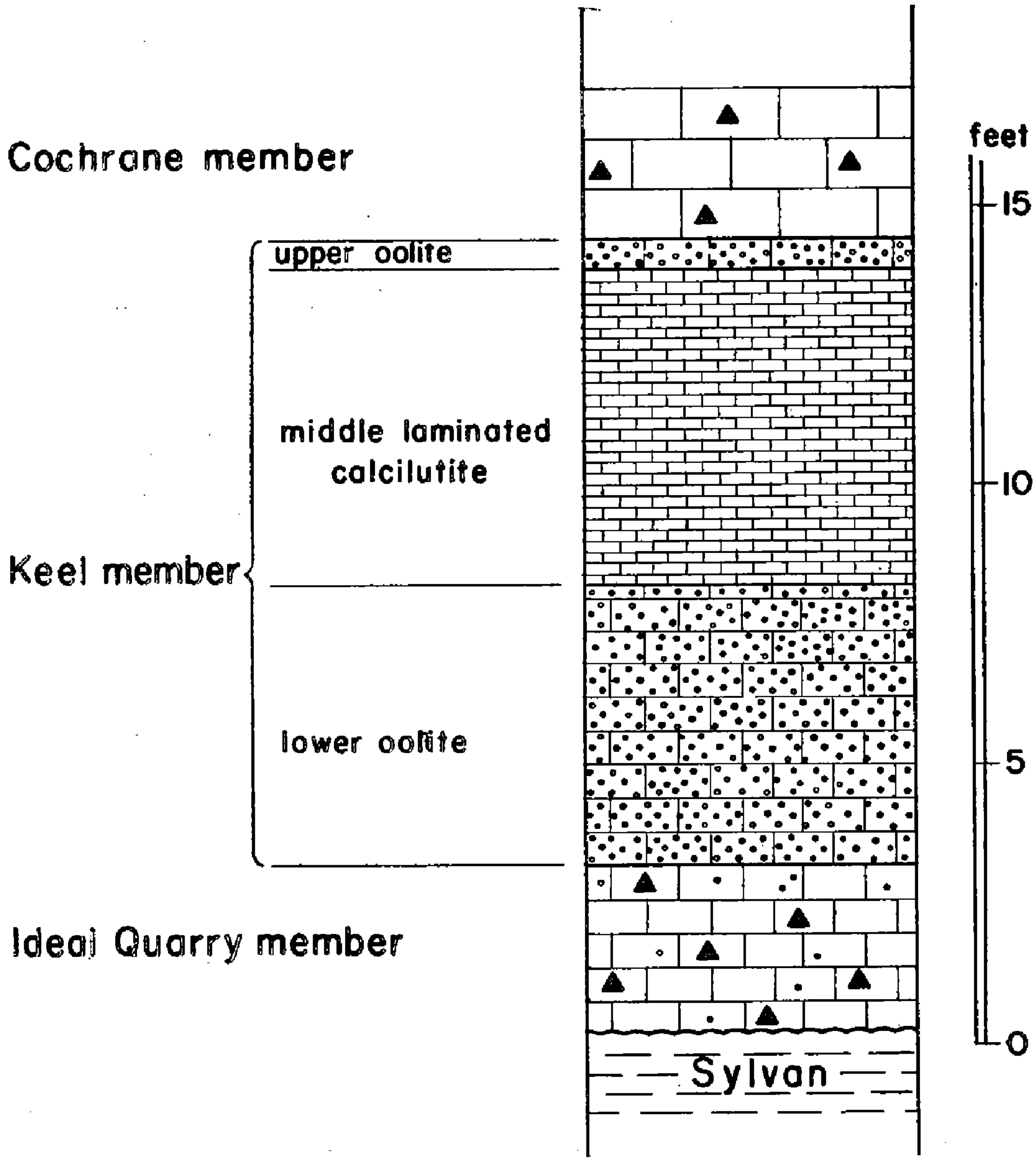


Figure 5. Section showing the three fold division of the Keel member, Chimneyhill formation. Near Coal Creek, NW¼, sec. 22, T. 1 N., R. 7 E.

The writer has thus far observed this laminated Keel lithology at only three localities, all in the eastern part of the Arbuckle complex. It is well represented in the area near Coal Creek, as shown in figure 5. These three divisions are also present about 3 miles northwest of Coal Creek (SE¼ sec. 7, T. 1 N., R. 7 E.) where the following Keel section was measured:

	feet
upper oolite	1.0
middle laminated calcilutite	2.5
lower oolite	6.5

The only other locality at which the Keel units have been seen is in the area southwest of Wapanucka (SE¼ sec. 27, T. 2 S., R. 8 E.), where the section is of special interest because parts of the midde laminated unit are conglomeratic, with flattish limestone pebbles up to ½ inch in length. A peel of this conglomeratic lithology shows the presence of scattered oolites, some of which are broken. This coarse phase appears to be only a local, intraformational conglomerate. These divisions have the following thicknesses:

	feet
upper oolite	2.5
middle laminated calcilutite in part conglomeratic	6.0
lower oolite	4.0

The only fossils collected from the middle laminated calcilutite are a few tetracorals from the Coal Creek section.

Thickness and distribution: Maxwell (1936, p. 52) reported a maximum thickness of 15 feet for the Keel member, and Reeds a maximum thickness of 12 feet for the combined Keel and Ideal Quarry members (his Oolitic member). The thickest section of Keel measured by the writer is 12½ feet, but at most places it is thinner than this. This member is well developed on the Lawrence uplift, and in the Hunton belt extending to old Hunton townsite and onward to the area around Wapanucka. The Keel appears to be absent southwest of Wapanucka (sec. 9, T. 3 S., R. 9 E.); the Cochrane is present, but no trace of any oolite was observed, and presumably the Cochrane rests directly upon the Sylvan. All of the Chimneyhill seems to be absent north of Reagan, in sections 18 and 19, T. 2 S., R. 6 E., and the Bois d'Arc formation probably rests directly upon the Sylvan. The Keel is present in the area just west of Mill Creek although it is only 1½ feet thick. It is absent in a section measured by the writer 2 miles west of Ravia, and has not been seen in the area around White Mound or in the section studied on Vines Dome. There is, however, one foot of oolitic limestone exposed on Henryhouse Creek.

This irregular distribution and variable thickness of the Keel is believed to be the result of an unconformity separating this member from the overlying Cochrane. The writer has never observed any oolites in the Cochrane, nor other evidence indicating that the Keel lithology is a facies of the Cochrane. Some of the HCl residues from the Keel show traces of glauconite, but this mineral is present in minor amounts throughout most of the Hunton (see *Fossils and age*).

Maxwell believed the Keel and Cochrane to be conformable. He postulated that as the Chimneyhill sea advanced over the irregular Sylvan surface the Ideal Quarry (Hawkins) and Keel members were deposited in the depressions; over low islands not submerged until late in Keel time only the upper part of that member was deposited. As evidence he stated that the Keel is at a maximum thickness on the Lawrence uplift where the Ideal Quarry member is present, whereas in the southern areas where the Keel is much thinner the Ideal Quarry member is absent. This explanation does not fit the stratigraphic relations observed by the writer. In the southeastern area (SW¼ sec. 18, T. 2 S., R. 8 E.) the Keel is only one foot thick, but it is still underlain by 1.5 feet of typical Ideal Quarry. Furthermore, even on Lawrence uplift the Keel is locally thin, as on Chimneyhill Creek where there is only 3½ feet of oolite underlain by 5 feet of the Ideal Quarry member. This thickness variation, along with the lithologic and faunal characters mentioned elsewhere indicates there is an unconformity separating the Keel from the Cochrane.

Fossils and age: The Keel member is fossiliferous, but it is difficult to extract satisfactory specimens from the rock. The writer has been able to collect a small fauna from the quarries of the Ideal Cement Company. These fossils have not been carefully studied; however, a preliminary check shows the following species: *Cyclonema*? sp., *Modiolopsis*? sp., *Pterinea*? sp., *Dictyonella* sp., *Clorinda* cf. *C. thebesensis* Savage, *Leptaena* sp., *Parmorthis*? sp., *Rhynchotreta*? cf. *R. thebesensis multistriata* Savage, *Halysites* sp.

Reeds (1911, p. 261) listed 4 species from his Oolitic member and Maxwell a total of 9 species from his Keel limestone; both authors correlated this member with the Alexandrian. The writer has not studied the Keel fossils in sufficient detail to justify any definite statement concerning its age, but its stratigraphic position and the general character of its fauna make such a correlation seem reasonable. The Keel fauna appears to be distinct from that of the Cochrane.

COCHRANE MEMBER. The name Cochrane was applied by Maxwell (1936, p. 134) to the rocks which Reeds (1911, p. 260) called the Glauconitic member. This name is that of the allottee who originally owned the land upon which the type locality is situated (SE¼ sec. 5, T. 2 N., R. 6 E.). This is the same as the type locality of the Chimneyhill formation, and is an excellent type section as the Cochrane is well exposed along the banks of a small tributary entering Chimneyhill Creek. One of the thickest sections known is southwest of Wapanucka, SE¼ sec. 27, T. 2 S., R. 8 E., where the Cochrane is 57 feet thick; but in that area the stratigraphic relations with the Clarita member are complicated (see CLARITA MEMBER *Clarita-Cochrane contact*).

Lithology: The Cochrane is a richly fossiliferous calcarenite with scattered grains of glauconite. On a fresh surface it is a light gray (N 8) to pale orange (10YR 8/2) or pale olive (10YR 6/2), weathering to a medium gray (N6 to N7). Typically the bedding is irregular, ranging from 6 inches to 2 feet or more in thickness, but in many places the bedding planes are obscure (pl. I, A). Commonly the rock is a fine to medium calcarenite, but there are finer phases in which the texture is definitely within the range of a calcilutite, and also coarser phases ranging into a calcirudite.

The writer has examined a number of peels and a thin section which clearly show that a large part of this rock is composed of fossil debris. The typical Cochrane lithology is thus a bioclastic calcarenite, a conservative estimate placing the fossil content of most beds at 50 to 60 percent or more.

Glauconite is almost universally present in the form of small grains, generally rounded, ranging up to a millimeter or so in diameter. The proportion of glauconite is highly variable, being conspicuous in some strata and obscure in others; it is estimated to range as high as 3 to 4 percent, although generally much less. The insoluble residues are composed largely of glauconite in the form of rounded, irregular nodules. Some of the glauconite has the form of small fossils such as snails and ostracods, and appears to represent the filling of the internal cavity of such shells. It is also present in the form of sponge spicules, which may also be steinkerns, or may represent replacement.

Chert is common on the Lawrence uplift and the Hunton belt extending down to Coal Creek. Elsewhere it is not so abundant and in several areas no chert has been seen in this member. Where present it is a vitreous chert in nodules or slighlty elongate lenses. It is generally a light color, but a few nodules of almost black chert have been observed.

A number of HCl insoluble residues have been calculated, most of these ranging from 0.8 to 2.5 percent; one specimen yielded 3.5 percent and another slightly over 6 percent, but these are unusual and the average is less than 3 percent. Much of the residue is in the form of glauconite with a very small amount of clear, subangular quartz. Acetic acid residues are rich in pelmatozoan plates and also contain conodonts.

The Cochrane contains little dolomite. Several rock specimens have been analysed for calcium and magnesium; the $CaCO_3$ ranges from 95.8 to 98.9 percent, and the $MgCO_3$ from 1.0 to 1.6 percent.

Cochrane-Keel contact: The Cochrane is easily distinguished from the oolitic limestone of the Keel in all sections studied by the writer. An unconformity is believed to separate these two members, the evidence for this being discussed under the KEEL MEMBER (see close of the section on *Thickness and distribution*).

Cochrane-Clarita contact: In many areas this member can be distinguished from the overlying Clarita with little difficulty (pl. I, A), the Cochrane being characterized by: (1) abundant glauconite, (2) presence of chert, (3) thick, irregular beds, (4) lack of pink pelmatozoan plates. Unfortunately, there are places where it is difficult to separate the Clarita from the Cochrane.

The latter is everywhere rich in pelmatozoan plates, and locally these have a pink color; if in the same strata the glauconite and chert content are reduced, the rock closely resembles the Clarita. The writer has encountered such areas where it is difficult to distinguish these two members; however, a discussion of this problem will be deferred to the section on the CLARITA MEMBER (*Clarita-Cochrane-contact*).

The Cochrane is separated from the Clarita by an unconformity. This relationship can be best established in areas, such as the Lawrence uplift, where these two members are lithologically distinct, thus simplifying the study of the stratigraphic relations. The Cochrane-Clarita contact is well exposed for a hundred feet or so in a small quarry located in the NE¼ SE¼ sec. 30, T. 3 N., R. 6 E. In this quarry the Clarita strata are lithologically distinct and appear to truncate Cochrane beds, as is shown in plate 1, A. Further evidence for this unconformity is the Cochrane thickness variation. In those areas where the Cochrane is directly overlain by either Henryhouse or Devonian (figure 4) this thickness variation may be due to either the post-Clarita, or the post-Henryhouse unconformity. The Cochrane, however, varies in thickness even in those areas where it is overlain by Clarita; for example, in the vicinity of Coal Creek (NW¼ sec. 22, T. 1 N., R. 7 E.) the thickness ranges from 11 to 20 feet in a distance of 200 feet. Finally, the faunas are distinct and probably represent different epochs, the age of the Cochrane being Lower (?) and that of the Clarita Middle (?) Silurian. See under CLARITA MEMBER, *Fossils and age*.

Thickness and distribution: The sections thus far measured by the writer show a thickness ranging from 4 feet to 57 feet. As noted above, some of this thickness variation is believed to be due to post-Cochrane unconformities, but a part may be a primary, depositional feature.

The Cochrane is the most widely distributed of the Chimneyhill members. It appears to be absent in the belt just north of Reagan, all of the Chimneyhill being absent here. In the section studied on Vines Dome only the upper part of the Clarita was observed, the base of this member being covered, as well as any older

Chimneyhill strata that might be present. In all other sections investigated (fig. 1) the Cochrane is present.

Fossils and age: The Cochrane is richly fossiliferous, but it is difficult to break out satisfactory specimens. The writer has collected some trilobites, mollusks, corals and brachiopods, but most of these are fragmentary. The best collection was made on Henryhouse Creek, where a number of specimens of *Triplesia* were broken out of a bed near the base of the Cochrane; a preliminary check indicates that it is a species similar to *T. alata* Ulrich and Cooper from the Brassfield near Batesville, Arkansas. Some conodonts have been recovered from acetic acid residues.

Reeds (1911, p. 261) listed 11 species from this member, and Maxwell recorded 24 species, both correlating it with the Alexandrian. The writer has not studied the Cochrane fauna in any detail, but the general character of the fauna suggests an early Silurian age.

CLARITA MEMBER. The name Clarita is here proposed to replace Maxwell's name of Dillard (1936, p. 134) which is preoccupied, having been used for a Cretaceous "series" in Oregon, a Jurassic formation in Oregon and for a subsurface Pennsylvanian sand in Oklahoma. This member was first recognized by Reeds (1911, p. 260) who called it the Pink-crinoidal member. Reeds did not indicate any type locality, although he noted that typical exposures were to be found on the Lawrence uplift and on the Hunton belt extending down to Bromide. The writer's name is taken from the town of Clarita, Coal County (fig. 1), but the type section is located about 3 miles west, in the vicinity of old Hunton townsite (NW¼ sec. 8, T. 1 S., R. 8 E.)*. There are also excellent exposures of the Clarita at the type locality of the Chimneyhill formation along the banks of Chimneyhill Creek.

* Maxwell designated the E½ W½ SW¼ sec. 8, T. 1 S., R. 8 E. as the type locality of his Dillard member.

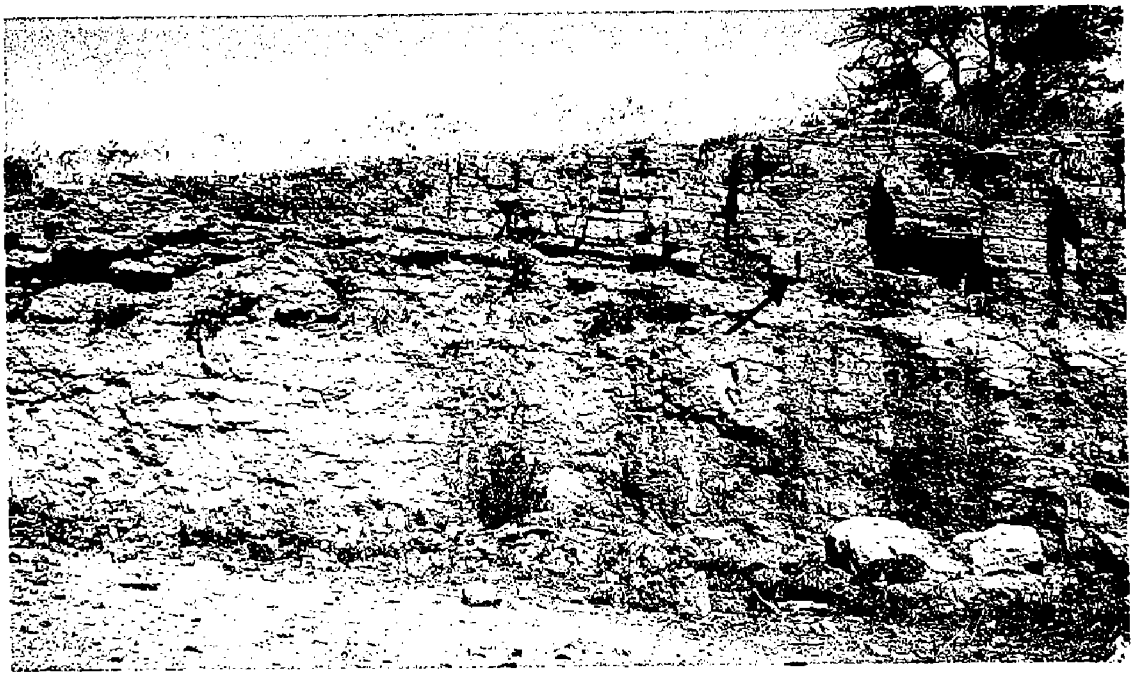
Lithology: The Clarita is a richly fossiliferous limestone, ranging from a fine calcilutite to a coarse calcarenite. Pelmatozoan plates* are abundant and many of these have an orange-pink color. It is generally an even-bedded rock, the beds ranging up to 6 or 8 inches (pl. 1, A). The color on a fresh surface of the calcilutite commonly ranges from a yellowish gray (5Y 7/2) to a pale olive (10Y 6/2) with scattered pelmatozoan plates of an orange pink (10Y 7/4 to 10R 7/4). Where the rock is a coarse-grained calcarenite with many pelmatozoan plates the overall color is orange pink.

The Clarita exhibits rather extreme textural variations. Perhaps the most common facies is a calcilutite with scattered orange-pink pelmatozoan plates. Less common, but still widely distributed, is a calcarenite facies, locally becoming very coarse and grading into a calcirudite. Both the fine and the coarse phases are present in the Clarita on Chimneyhill Creek and in the vicinity of old Hunton townsite. This member is almost exclusively in the calcilutite facies on Henryhouse Creek, Vines Dome, and near White Mound.

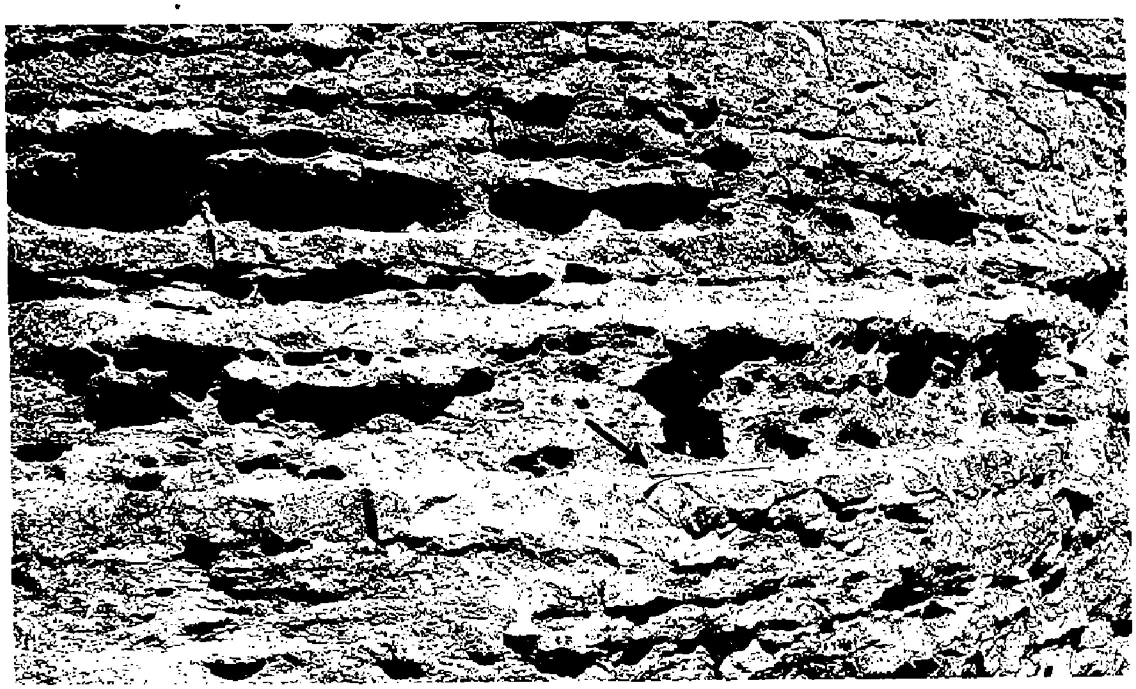
The writer has examined a number of peels and thin-sections and these show a richly fossiliferous matrix, commonly over half of the rock being composed of recognizable fossil debris. Even the fine-grained portions are seen to be highly fossiliferous when viewed under high magnification. Pelmatozoans are especially abundant, but trilobites, brachiopods, mollusks and other groups are common. In addition this member has a substantial microfauna of Foraminifera and conodonts.

A number of insoluble residues have been calculated for rock specimens of the Clarita with most of these falling between 1 and 6 percent, the average being about 3 percent. On Vines Dome and on Henryhouse Creek these strata have an unusually high insoluble

* These plates have commonly been identified as crinoidal, and undoubtedly most do represent this class. It is, however, generally impossible to determine the precise biologic affinities of such disarticulated fragments. Thin-sections and peels clearly show these plates to have the typical porous texture of the Echinodermata skeleton or test, but more exact identification is generally not feasible. Since most Silurian and Devonian echinoderms were stalked, the term pelmatozoan is herein used, although this probably includes some rare plates of free living types.



A. Clarita and Cochrane members, Chimneyhill formation. Arrow points to geologic pick resting head down on the contact. Small quarry, NE¼, SE¼, sec. 30, T. 3 N., R. 6 E., Pontotoc County.



B. Haragan and Bois d'Arc formations. Arrow points to pencil resting on the lowest chert bed of the Bois d'Arc formation. North bank, Bois d'Arc Creek, NW¼, sec. 11, T. 2 N., R. 6 E., Pontotoc County.

content, ranging from 7 to 11 percent. The residues consist almost entirely of silt and finer material, only a few sand-size particles have been observed. Washed residues are composed largely of silt-size, clear, subangular quartz with minor glauconite and other dark minerals. Arenaceous Foraminifera are common to abundant* in most of these residues. Conodonts are fairly numerous in most acetic acid residues.

The Clarita member has a low dolomite content. Several calcium-magnesium analyses have been prepared and these show a $MgCO_3$ content ranging from 0.6 to 1.2 percent; the $CaCO_3$ from 93.8 to 99.4 percent.

Clarita-Cochrane contact: The Clarita rests unconformably upon the Cochrane (pl. I, A), the base of the Clarita being marked by a few inches of shale or shaly limestone. This basal argillaceous zone, which was first noted by Maxwell, appears to be widely developed. It is not commonly exposed, but even where the contact does not crop out its position is generally marked by a small covered interval, accompanied by a break in slope. This is useful in locating the Clarita-Cochrane contact, being especially helpful in those areas where it is difficult to separate the two. As noted before (COCHRANE MEMBER, *Cochrane-Clarita contact*) these two members can be lithologically distinguished in most areas, but there are places where the Cochrane loses its conspicuous glauconitic character and contains many pink pelmatozoan plates so that it closely resembles the Clarita. There is an example of this southwest of Wapanucka, in the belt of Hunton extending northwest across sec. 27 into the southwest corner of sec. 22, T. 2 S., R. 8 E. At the southwestern end of this belt the Cochrane is thick (57 feet) and is directly overlain by marlstone. In this area the Cochrane retains its characteristic lithology, but towards the north, in the NW¼ of section 27 and the SW¼ of section 22, it tends to lose its glauconitic character and many of the pelmatozoan plates are pink, in these respects resembling the Clarita member. This change takes place somewhat irregularly, but at

* The writer has checked all HCl residues for arenaceous Forminifera. These fossils have been observed in different parts of the Hunton, but appear to be common only in the Clarita member.

places a considerable portion of the Cochrane develops a "pink-crinoidal" type of lithology. The stratigraphic relations in the northwestern part of this belt are further complicated by the fact that true Clarita appears to wedge in along an unconformity. Although this region shows the greatest stratigraphic complexity it is not the only place where the Cochrane has been observed to resemble the Clarita. The upper Cochrane strata on Henryhouse Creek show a similar lithology, and it is locally developed in the Bromide-Hunton townsite belt. As a general rule the Cochrane member retains its thick, somewhat obscure bedding even where it has lost its characteristic glauconitic (and cherty) lithology. This bedding character combined with the basal shaly zone of the Clarita is of great help in separating these two members. Moreover, there is some evidence that the microfaunas are distinctive and can be used to distinguish the upper Chimneyhill members. The writer has made a preliminary examination of the Clarita and Cochrane conodont faunas and the work suggests that there is a distinct faunal break between the two. A study of the HCl residues shows a prolific arenaceous foraminifera fauna in the Clarita, whereas that of the Cochrane appears to be meager. At the present time not enough work has been done on these microfaunas to justify any conclusions. A study of them is being carried on by William Gregware, a University of Oklahoma graduate student, and it is hoped some stratigraphically useful data will be forthcoming.

Upper Clarita contact: The Clarita is unconformably overlain by the Hunton marlstone*. At some places it is the Henryhouse which rests on the Clarita and at other places it is the Haragan. In either case this member is generally easily distinguished from the overlying Silurian or Devonian strata, the relatively pure limestones of the Clarita standing in marked contrast to the more argillaceous beds of the Henryhouse or Haragan. The insoluble content of the Hunton marlstones averages 18 to 22 percent, whereas in the Clarita the average is below 5 percent. The content

* The writer has not observed the Bois d'Arc formation in contact with the Clarita, but at some places only a small stratigraphic interval separates the two and it is quite possible that further field work will reveal a locality where they come together.

of the acetic and HCl residues is also distinctive, those of the marlstones having a meager microfauna of Foraminifera and conodonts, whereas these fossils are common in the Clarita. The Clarita has thicker, more evenly-bedded strata and the beds of marlstone are thinner and weather to give a "nodular" appearance. There are a few areas where the Clarita has a relatively high insoluble content, up to 10 or 11 percent (e. g. Vines Dome), thus ranging into an argillaceous calcilutite that is similar in appearance to the overlying marlstones. In most areas studied the contact can be located in the field with a reasonable degree of precision. The writer has found that if some doubt exists on the accuracy of the contact as drawn in the field, an examination of the acetic and HCl residues will commonly reveal the characteristically abundant microfauna of the Clarita standing in contrast to the sparse fauna of the marlstone.

Thickness and distribution: The Clarita is highly irregular in its distribution, being absent at many places. It is everywhere present on the Lawrence uplift and in the Hunton belt extending to old Hunton townsite. From Bromide south into Atoka County its development is erratic, but it is generally absent. It is also absent in the region around Reagan and Mill Creek, but is present to the south in the area just west of Ravia. It is present in the vicinity of White Mound, on Vines Dome and along Henryhouse Creek.

The maximum Clarita thickness measured by the writer is 45 feet on the Lawrence uplift. It is 40 feet at old Hunton townsite, but elsewhere is much thinner, commonly less than 20 feet.

Fossils and age: The Clarita member is richly fossiliferous, although it is generally difficult to extract good specimens. Locally the coarse calcarenite facies develops a somewhat friable character which permits moderately good specimens to be recovered. The writer has made several collections from the Clarita, and a preliminary check of this fauna reveals many trilobites and a fair number of mollusks and some brachiopods. One of the most common brachiopods is an *Eospirifer* which is similar to, perhaps identical with, an undescribed St. Clair species.

In addition to the megafauna the Clarita carries a large fauna of conodonts and arenaceous Foraminifera; Moreman and Ireland have described about 60 species of arenaceous Foraminifera from the Chimneyhill formation (see Amsden 1956 for a complete list). Neither of these authors indicated the member from which their specimens came, but it is probable that most, if not all, are Clarita species since this is the member which carries a prolific fauna.

Reeds listed about 20 species from his Pink-crinoidal member (Clarita) which he assigned to the Alexandrian. Some years later E. O. Ulrich (1927, p. 32) removed this member to the Niagaran, stating "Only the lower members, the "Oolitic" and the "Glauconitic", are properly referable to the Alexandrian group of the Medinan series, whereas the upper, "Pink-crinoidal", member contains an excellent representation of the Clinton St. Clair limestone of Arkansas". Maxwell (1936, p. 136) followed Ulrich's age assignment; he recorded 15 species from this member.

In 1956 Miller (p. 1353; table 1) assigned the Chimneyhill to the Albion on the basis of its arenaceous Foraminifera. Most of the Chimneyhill species listed in his faunal chart are species described by Moreman or Ireland and it seems likely that many, perhaps all, of these are from the Clarita; however, this cannot be regarded as a certainty until such time as the Foraminifera from the different Chimneyhill members have been restudied and compared to the type specimens. In any event, it should be emphasized that the Chimneyhill formation appears to include at least three different faunas: Keel, including the Ideal Quarry; Cochrane; Clarita. Each member is separated from the other by an unconformity, and the Chimneyhill formation probably represents a considerable time span. (see CHIMNEYHILL FORMATION).

At the present time the writer has no new evidence bearing on the age of the Clarita. A preliminary check of the fauna seems to support Ulrich's correlation with the St. Clair, a formation generally assigned to the Middle Silurian. Both the megafauna and the microfauna seem to be distinct from that of the underlying Cochrane.

HUNTON MARLSTONE. The middle portion of the Hunton group in most areas consists of a sequence of marlstones* extending from the Chimneyhill formation to the basal cherty beds of the Bois d'Arc formation. This sequence commonly includes both Silurian and Devonian strata, although locally the Silurian is absent, bringing the Devonian portion directly against the Chimneyhill limestone (fig. 4). Reeds recognized this age relationship and proposed two divisions, a lower Henryhouse shale for those beds containing a Silurian fauna, and an upper Haragan shale for those strata with a Helderbergian fauna. This author (1911, p. 257) realized the lithologic similiarity of these two units, stating "The writer's classification is based on both faunal and lithologic grounds but primarily on the faunal evidence. In localities where the Haragan shale rests on the Henryhouse shale, as in the exposures about Dougherty, it will be difficult, without a knowledge of the fossils, to separate one formation from the other". Some years later Maxwell (1936, p. 134) proposed to change the names to Henryhouse and Haragan formations, pointing out, quite correctly, that there is little (if any) true shale present. There is, however, a question as to the propriety of designating these units formations. The writer's study, based upon both field and laboratory work, indicates that the Henryhouse and Haragan have very similar, if not identical lithologies. Certainly there appears to be no practical means for making a field separation of the two (pl. II, A, B). If a formation is defined as a lithologic unit, and certainly many stratigraphers so define it, then these are not formations. Actually the combined Henryhouse-Haragan would make a good lithologic unit, and the writer thought seriously of including these strata in a single formation, with the Henryhouse and Haragan being treated as faunal units (or zones) within it. However, since the Henryhouse and Haragan are separated from one another by a

* The term marlstone is discussed in the introduction. For a detailed description of this lithology, including insoluble residues and chemical analyses, see the sections on *Lithology* for the HENRYHOUSE FORMATION and the HARAGAN FORMATION.

considerable unconformity, and since each belongs in a different geologic system, they are here retained as formations. This marlstone sequence between the limestones of the Chimneyhill and the basal cherty beds of the Bois d'Arc formation is here informally designated the Hunton marlstone, a stratigraphic unit that will at places include both the Henryhouse and Haragan formations, at other places only the Haragan (fig. 4).

The Hunton marlstone makes a lithologic unit which is easily mapped, the writer having mapped it on the Lawrence uplift and in the area around White Mound. The Haragan part of this sequence is believed to be a facies of at least a part, quite probably all, of the Bois d'Arc formation (see under CRAVATT MEMBER, *Cravatt-Haragan contact*). This facies relationship causes the Hunton marlstone-Bois d'Arc contact to transgress the stratigraphic section (as shown in figure 4), but in any particular area this transgression is gradual and probably introduces little if any structural distortion to a geologic map.

It should be emphasized that the Henryhouse and Haragan portions of the Hunton marlstone can only be distinguished by the fossils. In recent years there has been an attempt to separate these two formations on the basis of color, the Henryhouse supposedly characterized by a red color (away from the Lawrence uplift) in contrast to the yellowish grays of the Haragan, but this is not a reliable criterion as red beds are present in the Haragan, and even in the Bois d'Arc formation.

The thickness of the Hunton marlstone ranges from 0 to about 240 feet. This great variation is due in part to the removal of Silurian beds on the post-Henryhouse, pre-Haragan unconformity, and in part to the facies changes into the cherty marlstones of the Bois d'Arc. There may also be a regional thinning of some parts of the Hunton.

HENRYHOUSE FORMATION. The Henryhouse was named by Reeds (1911, p. 261)* for exposures on Henryhouse

* Reeds first used the name Henryhouse (as Henry House) formation in figure 10 of Oklahoma Geological Survey Bulletin No. 3 (1910). No lithologic description or other information was given and this publication is therefore of historic significance only.

Creek, about 3 miles east of Woodford (SE¼ sec. 30, T. 2 S., R. 1 E.). Reeds called this the Henryhouse shale, but Maxwell (1936, p. 133) changed this to Henryhouse formation, pointing out, quite correctly, that these beds include little (if any) true shale (see HUNTON MARLSTONE). The formation is well exposed at the type section on Henryhouse Creek where it has a thickness of about 185 feet, the precise thickness being difficult to determine because of a paucity of fossils (see *Henryhouse-Haragan contact*). The thickest section known to the writer is on the Lawrence uplift where this formation is about 230 feet thick. This area is also significant because some of the most fossiliferous Henryhouse strata are found here.

Lithology: The typical Henryhouse lithology is a fossiliferous, argillaceous and silty calcilutite, commonly referred to as a marlstone (see INTRODUCTION). It is thinly bedded, the beds ranging up to 3 inches and commonly weathering with an irregular or "nodular" appearance (pl. II, B). Chert is absent or at least extremely rare; the writer has never observed any chert nodules in this formation. On the Lawrence uplift the characteristic color (fresh surface) is some shade of yellowish gray (5Y 7/2 to 5Y 8/4), with a few beds having a greenish cast (10Y 8/2). South of the uplift this color prevails, but reddish brown (10R 5/4) to reddish gray (10R 4/2) strata are also present. At the type locality these red beds are scattered all through the Henryhouse, about 10 percent of the section having a red or mottled red and gray color. This red color is not confined to the Henryhouse, being present in the Haragan and Bois d'Arc formations (see HUNTON MARLSTONE).

The marlstones of the Henryhouse and overlying Haragan generally disintegrate to produce rubble covered slopes which are relatively free of vegetation, bearing only scattered clumps of grass and a few cedar trees. At intervals these slopes are broken by outcrops of "nodular"-bedded, argillaceous calcilutites. In western Tennessee similar, bare, weathered zones formed on marlstones are called glades, a rather convenient term to use in describing the typical Henryhouse and Haragan outcrops. The fossils may weather out free on the glade surface, in places being common, but only rarely are the Henryhouse fossils as abundant as those from the Haragan.

The writer has examined a number of peels and thin-sections which show that most of the Henryhouse is a fine-textured rock with fossils scattered through it. Excluding the fossils, the fragments composing the matrix rarely exceed 0.05 mm in diameter and most are much smaller. The matrix is composed largely of carbonate and quartz fragments; examination under a binocular magnification of 112 diameters reveals little evidence of any interlocking texture, most of the rock appearing to be composed of discrete fragments. The fossils commonly appear to be scattered through this matrix more or less at random, exhibiting only moderate to slight evidence of having been concentrated into beds. Furthermore, the long dimensions of some fossils do not lie in the bedding plane. The percentage of fossil material is extremely variable, but for the most part appears to be well below 50 percent. A few rock specimens have been observed in which fossils are extremely abundant, making up more than 50 percent of the rock, and such beds locally grade into a calcarenite. This is, however, rare and it is estimated that most strata carry less than 25 percent recognizable fossil debris.

The writer has prepared a number of insoluble residues, which range from 8 to 36 percent, the average being about 20 percent. These residues are almost entirely in the silt and clay size, there being little sand-size debris present. Residues which have been washed to remove the fines are composed mainly of silt-size, subangular, quartz fragments. Some mica is generally present, but other minerals are represented in only minor quantities. Arenaceous Foraminifera are rare or absent; only a few specimens were observed from strata which are referred with question to the uppermost Henryhouse. No conodonts have been observed in the acetic acid residues, but they could presumably be recovered by the use of heavy liquids.

One nearly complete chemical analysis of the Henryhouse has been prepared by A. L. Burwell (1955). This was of a 40 foot channel sample of the formation collected near the center of the SE¼ sec. 4, T. 2 N., R. 6 E., Pontotoc County. The acid insolubles amounted to 21.2 percent (cold 1:5 HCl), and the calculated $CaCO_3$ was 66.7 percent, the $MgCO_3$ was 9.5 percent. A complete analysis is given in table 1 of this publication.

The writer has also had a number of Henryhouse rock specimens analysed for their calcium-magnesium content. Fifteen specimens from the writer's stratigraphic section on Chimneyhill Creek were tested; these specimens were collected throughout the 230 feet of Henryhouse exposed in this area, beginning with the oldest and extending to the youngest. Stratigraphically this section shows no progressive chemical change from top to bottom, the uppermost strata exhibiting about the same variation as do those from the middle and lower portions. The insoluble residues range from 8.0 to 33.7 percent, averaging 17.7 percent; the $CaCO_3$ ranges from 52.4 to 88.4 percent, averaging 75.9 percent; the $MgCO_3$ from 1.1 to 11.3 percent, averaging 5.3 percent. Four Henryhouse specimens from the writer's section on Vines Dome were analysed; the insoluble residues range from 8.1 to 29.0 percent, averaging 22.4 percent: the $CaCO_3$ ranges from 70.2 to 89.2 percent, averaging 75.8 percent: the $MgCO_3$ from 0.3 to 1.1 percent, averaging 0.75 percent. A single specimen was analysed from the type locality on Henryhouse Creek: insoluble residue—30.7 percent: $CaCO_3$—60.5 percent: $MgCO_3$—3.7 percent. Additional analyses are being prepared to determine if there is a geographic relationship in the calcium-magnesium distribution.

The analyses obtained from the Haragan formation are quite similar to those given above (see HARAGAN FORMATION, *Lithology*), but those from the underlying Clarita differ sharply. For example on the Chimneyhill Creek section 3 rock specimens from the Clarita ranged from 94.6 to 99.4 percent $CaCO_3$, the average being 96.5, whereas the Henryhouse strata from this same section averaged only 75.9 percent $CaCO_3$. A Clarita specimen from Vines Dome had 93.8 percent $CaCO_3$ while the Henryhouse from this same section averaged 75.8 percent $CaCO_3$. The Clarita insoluble residues are correspondingly lower than are those from the Henryhouse formation as pointed out in the section on CLARITA MEMBER.

Henryhouse-Haragan contact: The Henryhouse and Haragan strata have been studied at a number of different places and thus far no reliable field criterion, other than fauna, has been found for separating the two; in lithology, bedding, color and weathering characteristics they are alike. Furthermore, a laboratory examination of rock specimens collected from each reveals no significant difference; peels, thin-sections, insoluble residues and chemical analyses all indicate that the Henryhouse and Haragan are lithologically similar. The Haragan may be somewhat less argillaceous (see HARAGAN FORMATION, *Lithology*), but this difference, if it exists, is slight and the two formations must represent nearly identical conditions of deposition.

The separation of these two formations is made even more difficult by the fact that at most places there is little evidence for a physical break between them. This contact has been studied in a number of different areas, but on most stratigraphic sections the exposures are not sufficiently complete to make it absolutely certain that the precise boundary is not covered. It is, however, completely exposed at (1) the type locality on Henryhouse Creek, (2) near the top of Cedar Hill (SE¼ sec. 4, T. 2 N., R. 6 E.), and (3) along the north bank of Bois d'Arc Creek (NW¼ sec. 11, T. 2 N., R. 6 E.). At the first two of these localities there is little evidence of any break at the contact (as located by means of the fossils). The exposures on Bois d'Arc Creek are therefore of special interest and significance because here there is stratigraphic evidence for an unconformity* (fig. 6; pl. II). As shown in figure 6 the strata have a component of dip to the east so that the Henryhouse-Haragan contact passes below the stream level, reappearing a hundred feet or so farther east. At the west end of this exposure there is little physical evidence of an unconformity at the boundary (located by means of the fossils) as is shown in Plate II, A, however, a short distance east the contact reappears

* The writer wishes to thank E. A. Frederickson and R. D. Alexander for information regarding this outcrop.

along a boundary that cuts across the bedding as shown in Plate II, B.

The juxtaposition of two "formations" with nearly identical lithology but carrying different faunas is not unique although it is troublesome to the stratigrapher, especially when it involves a systemic boundary. Much more puzzling is the obscure nature of the contact at most places where it can be carefully studied. This contact represents an erosional unconformity of some magnitude

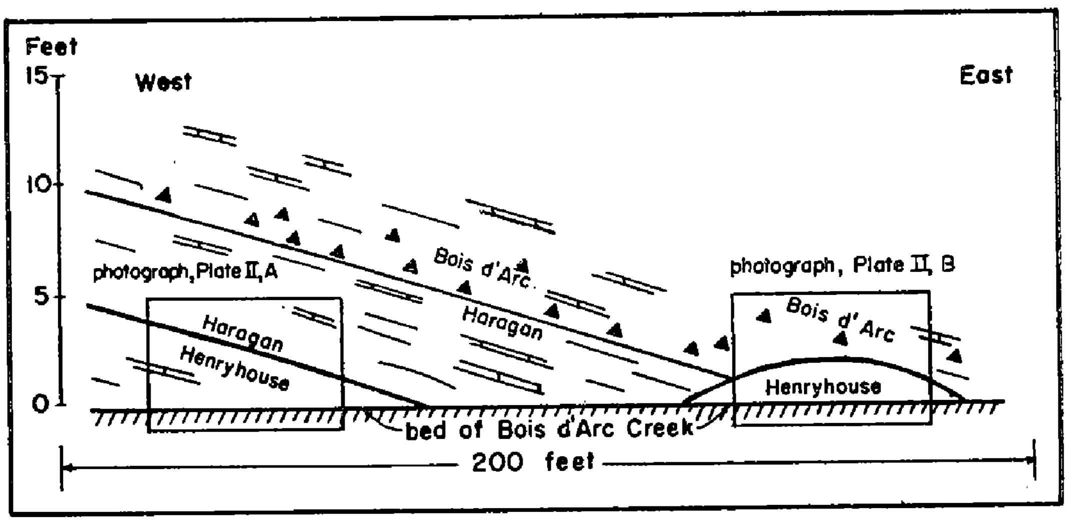


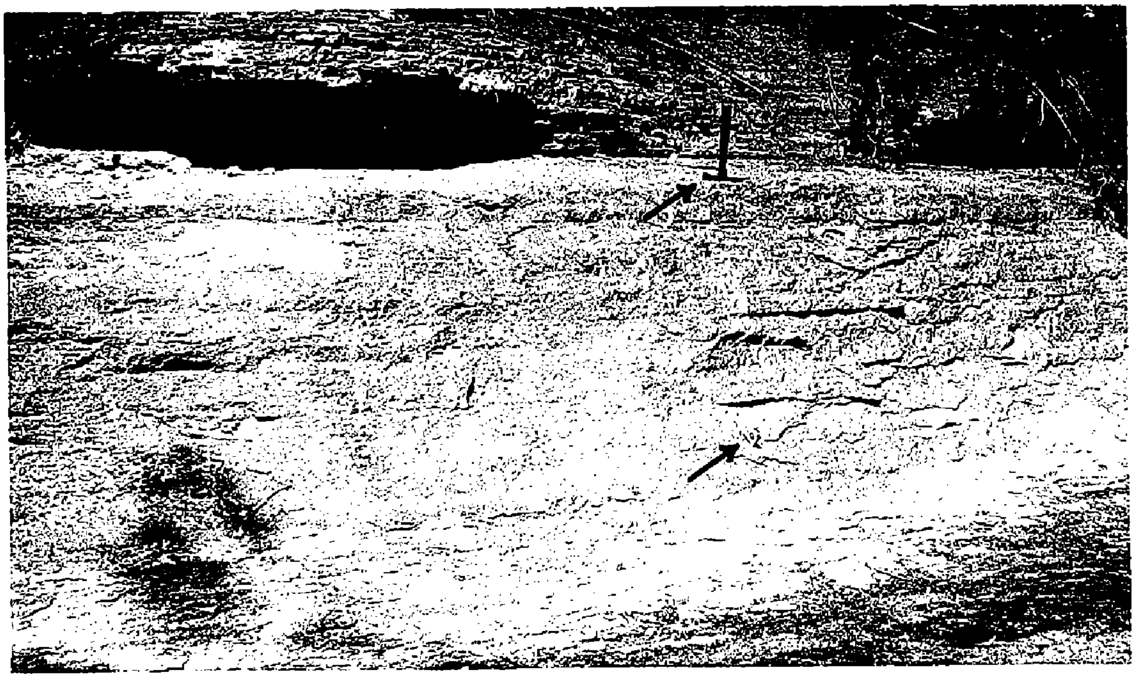
Figure 6. Geologic section showing the Henryhouse-Haragan unconformity along Bois d'Arc Creek, NW¼, sec. 11, T. 2 N., R. 6 E. The two photographs indicated on the section are shown on plate II.

as indicated in figure 4, yet the stratigraphic evidence for this is meager. While it is true that the evidence for this unconformity is based on paleontological data, nevertheless this faunal evidence is unambiguous and conclusive (see *Fossils and age*). Fortunately the Bois d'Arc Creek exposures described above give some physical evidence for a break in sedimentation, correlating with, and supporting that, furnished by the fossils.

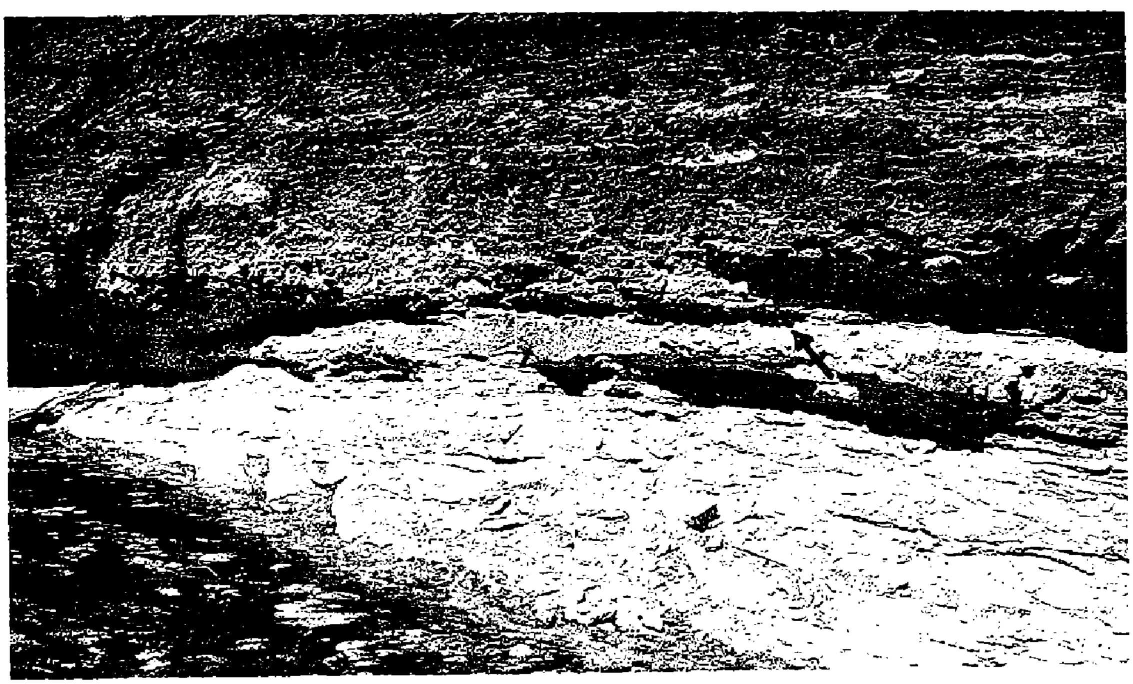
Thickness and distribution: The Henryhouse reaches its maximum thickness on the Lawrence uplift, where it is about 230 feet. South of here it thins rapidly, and is absent at Coal Creek, the Haragan resting directly upon the Chimneyhill. From Coal Creek south and east into Atoka County it is thin or absent; this is also true of the Henryhouse in the Hunton belt extending west to Mill Creek. The formation is again present near White Mound and on Vines Dome; at Henryhouse Creek, the westernmost section which has been studied by the writer, it is well developed, reaching a thickness of about 180 feet.

The maximum Henryhouse thickness measured by the writer on the Lawrence uplift is similar to that given by Reeds (1911, p. 257). In contrast, Maxwell reports only 47 feet in this area, and Decker and Ruedemann (1935, p. 434) measured only 76 feet of Henryhouse at the type locality on Henryhouse Creek. There can be little doubt that these authors included considerable Henryhouse in their Haragan. This is quite evident in Maxwell's paper (1936, p. 134) because he gives the Haragan a thickness of from 124 feet to 175 feet on the Lawrence uplift in contrast to the writer's 4 to 8 feet, and on Henryhouse Creek this same author measured 151 feet whereas the writer found 50 feet or less.

Fossils and age: The Henryhouse formation is fossiliferous, although the fossil content is variable, some beds having much more organic material than others. To the collector the irregular distribution of Henryhouse fossils is conspicuous, some areas appearing to be highly fossiliferous whereas other places seem to be almost barren. This variability is also apparent in a study of peels and thin-sections, but here it is not so striking. The writer has examined a number of these and has never seen a specimen without some fossil material and as a rule even those strata which appear barren to the collector will reveal substantial amounts of fossil debris. The collector generally judges the fossil content by the number of specimens which can be readily collected, but this only partially reflects the concentration of fossils in the rocks. To a large extent this factor is controlled by the lithologic character of the matrix, the highly argillaceous marlstones breaking down more readily and thus permitting the more resistant fossils to weather out. The best collecting is found on the Lawrence uplift and it is probably significant that in this area the Henryhouse formation is relatively thick and has a gentle dip, thus giving maximum exposure and therefore a better opportunity for the more fossiliferous *and more shaly* strata to be exposed to weathering. Although such factors as lithology have an important effect on the



A. Henryhouse and Haragan formations. Upper arrow points to hammer resting on a bed carrying Haragan fossils; lower arrow points to tape resting on a bed carrying Henryhouse fossils. Text figure 6 shows the relationship of this outcrop to the one shown in B, below. North bank of Bois d'Arc Creek, NW¼, sec. 11, T. 2 N., R. 6 E., Pontotoc County.



B. Henryhouse and Bois d'Arc formations. Arrow points to hammer resting head down on the contact. Text figure 6 shows the relationship of this outcrop to the one shown in A, above. North bank of Bois d'Arc Creek, about 150 feet east of the outcrop shown in A.

number of free specimens available to the collector, the fact still remains that some beds have more fossils than others. This erratic distribution is in part primary, reflecting the original faunal distribution in Henryhouse seas, and in part secondary, being a result of concentration by currents, and other transporting agents. The movement of organisms after death was probably slight, because they are well preserved and show little evidence of abrasion. Moreover, the sediments exhibit almost no trace of ripple marks, channelling or other evidence of current or wave action.

On the Lawrence uplift, where the upper Henryhouse and overlying Haragan strata yield many fossils the contact can be located with some precision. In other areas, such as the type section on Henryhouse Creek, where the collecting is unsatisfactory this contact is much more difficult to locate and there may be as much as 15 feet of beds whose age is in question.

The Henryhouse fauna is a large one which is dominated by the brachiopods, although there are also a substantial number of corals and Bryozoa, along with some Mollusca, trilobites and other groups. Maxwell listed slightly over 100 species from this formation, and in 1951 the writer described 41 species of brachiopods (for a complete list of species which have been described and illustrated see Amsden 1956). The Henryhouse fauna appears to be closely related in age to the Brownsport of western Tennessee (Amsden 1951, pp. 70-72), but its position in terms of eastern Silurian faunas is in question. The Brownsportian fauna has generally been assigned to the Niagaran, but more recent work indicates it is early Upper Silurian, presumably representing some part of the Ludlovian. Present information indicates a time break between the Henryhouse and Haragan formations covering the latter part of the Upper Silurian. Regardless of the age assigned to the Henryhouse its fauna is distinctly different from that of the Haragan, the writer having found no evidence of any transitional or gradational faunal elements in the upper Henryhouse or lower Haragan beds.

All of the fossils used in the present study have been collected from carefully measured sections. In making this collection great care has been used to locate precisely the stratigraphic position of all fossils; each collection was made from a narrow stratigraphic zone, thus greatly reducing the danger of uniting Henryhouse and Haragan fossils in the same lot. Using this method the writer has found no evidence of mingling of Henryhouse and Haragan species. Where such has been reported it is believed to be either the result of improper identification, or to be caused by mixing of fossils from different beds.*

There appears to be little doubt that past investigators have mixed Henryhouse and Haragan fossils. This is apparent in the table given by Reeds (1911, p. 267) listing the species supposed to be common to the Henryhouse and Haragan; for example, he records 14 species of brachiopods found in both formations, whereas the writer's study does not reveal a single species in common. In part this may be due to the fact that Reeds used a more broadly defined species concept, but a careful study of his list clearly indicates some mixing, a fact which is substantiated by an examination of the collections at Peabody Museum, Yale University. The relative thickness which Maxwell obtained from the Henryhouse and Haragan indicates the inclusion of some Henryhouse within the Haragan, an observation confirmed by this author's statement (1936, p. 133), "These figures [for thickness] differ from those given by Reeds who credits the Henryhouse with a thickness of 223 feet [on the Lawrence uplift] because of a different assignment of formational boundaries. The upper part of the shale, formerly assigned to the Henryhouse, has a characteristic Devonian fauna, and that part is now included in the Haragan formation". Finally the writer's examination of the older collections at the University of Oklahoma and elsewhere shows evidence of a mixing of the Silurian and Devonian fossils from the Hunton marlstone. This is not surprising in view of the lithologic similarity of the Henryhouse and the Haragan, and the writer strongly recommends that great care be exercised by

* Maxwell reported the incorporation of Henryhouse fossils in the basal part of the Haragan. The writer has not observed this, but it seems reasonable to expect some reworking of upper Henryhouse in very early Haragan time; however, if it does exist it should be confined to a narrow zone at the base of the Haragan.

anyone making a collection from the marlstone portion of the Hunton group.

HARAGAN FORMATION. The Haragan was named by Reeds (1911, p. 263), the name being taken from a small creek (named by Reeds) in the SW¼ sec. 17, T. 2 S., R. 3 E., a short distance northwest of White Mound (fig. 1). Reeds called this the Haragan shale, but Maxwell changed it to Haragan formation, a more appropriate term since there is little true shale in the Haragan (see HUNTON MARLSTONE). The region around White Mound makes an excellent type area since the formation is well exposed, having a thickness of about 100 feet. (The type section is here designated as the SE¼ NE¼ sec. 20, T. 2 S., R. 3 E.) Moreover, the Haragan at White Mound is richly fossiliferous and has gained international renown as a choice collectting ground for early Devonian fossils, a distinction which the present owner fails to appreciate. The Haragan is also well exposed in the vicinity of old Hunton townsite where it has a thickness of about 230 feet (the basal 100 feet of this interval is covered and could include some Henryhouse), an area that also yields many well-preserved fossils.

Lithology: The Haragan is a fossiliferous, argillaceous and silty calcilutite which is here called a marlstone (see INTRODUCTION). It is thin bedded, the beds ranging up to 3 or 4 inches in thickness (pl. II, A), and commonly weathering with an irregular, "nodular" appearance. Chert is rare, but a few beds with chert nodules are included in the Haragan (see BOIS D'ARC FORMATION). The color on a fresh surface is generally some shade of yellowish gray (5Y 7/2; 5Y 8/1; 5Y 8/4), in places with a greenish cast (10Y 8/2). Although the characteristic color is yellowish gray there are a number of places where Haragan beds are red or mottled red and gray (10R 6/2; 10R 7/4; 10R 5/4; 10R 4/2; see section on HUNTON MARLSTONE).

The Haragan marlstone weathers in a manner identical to that of the Henryhouse (see HENRYHOUSE FORMATION, *Lithology*). White Mound is a typical glade exposure of the Haragan, being a low hill covered with rubble and relatively free of vegetation. Such areas are the best collecting grounds as the more resistant fossils weather out of the softer matrix and can be picked up from the surface. The Haragan is, on the whole, a more fossiliferous formation than the Henryhouse, and certain localities such as White Mound are among the finest Paleozoic collecting localities known.

Most peels and thin-sections of the Haragan are indistinguishable from those of the Henryhouse. Excluding the fossils, the fragments making up the rock rarely exceed 0.05 mm in diameter and most are much smaller. This matrix is composed largely of discrete fragments of carbonate and quartz with fossils scattered through it. The amount of fossil material is highly variable, but commonly appears to be well below 50 percent. A few specimens have been examined with a rich fossil content, considerably above 50 percent, but these are exceptional.

A number of insoluble residues have been prepared and these show a range from 10 to 30 percent, the average being around 18 percent. These residues are almost entirely in the silt and smaller sizes, there being little sand-size debris present. Residues which have been washed to remove the fines are composed mainly of silt-size, subangular, clear quartz fragments. Arenaceous Foraminifera are rare or absent.

A number of Haragan rock specimens have been analysed for their calcium-magnesium content. One specimen from Bois d'Arc Creek yielded 12.1 percent insoluble residue, 76.8 percent $CaCO_3$, and 10.2 percent $MgCO_3$; a Henryhouse specimen from this same locality gave 17.5 percent insolubles, 68.8 percent $CaCO_3$, and 13.9 percent $MgCO_3$. Five specimens from the writer's section on Vines Dome showed insolubles ranging from 17 to 25 percent, averaging about 18 percent; $CaCO_3$ from 75.1 to 83.3, averaging 79.7 percent; $MgCO_3$ from 0.83 to 5.9, averaging 3.0 percent (on this same section the Henryhouse averaged 22.4 percent insolubles, 75.8 percent $CaCO_3$, and 0.74 percent $MgCO_3$).

Both Reeds and Maxwell believed the Haragan to be slightly more argillaceous than the Henryhouse, but the foregoing analyses suggest that it was slightly less argillaceous than the Henryhouse, although the difference, if its exists, is slight and would amount to only a few percentage points. Moreover, it would be of little diagnostic value in separating the two formations since the difference in the average insoluble content is far less than the maximum and minimum insolubles exhibited by each. Finally, it is quite possible that with the testing of additional samples this apparent difference may disappear. It is interesting to note that 15 specimens of the Henryhouse from the section on Chimneyhill Creek give an average insoluble of only 17.7 percent.

For a discussion of the Henryhouse-Haragan contact see under HENRYHOUSE FORMATION. The Haragan-Bois d'Arc relations are discussed under BOIS D'ARC FORMATION.

Thickness and distribution: The Haragan probably reaches its maximum thickness in the vicinity of old Hunton townsite where there is 230 feet of strata between the Chimneyhill and Bois d'Arc formations; however, this includes a 100 foot covered interval just above the Clarita and this could be in part Henryhouse. To the north the Haragan thins, and on the Lawrence uplift it is only a few feet thick; southeast of old Hunton townsite, in the area around Wapanucka, the Haragan is largely replaced by the Bois d'Arc cherty beds, as shown in figure 4. In the Hunton belt extending west to Reagan the Haragan is thin or absent, but near Mill Creek it begins to thicken and at White Mound is around 100 feet thick. On Henryhouse Creek, the most westerly section which has been studied by the writer, the Haragan is about 50 feet thick.

Much of the thickness variation of the Haragan is probably a result of its facies relationship with the Bois d'Arc formation. Lateral facies shifts between these two formations cause this contact to "migrate" up and down in the section over short distances (fig. 4; see BOIS D'ARC FORMATION).

Fossils and age: The Haragan carries a large fauna, which is estimated to include over a hundred species. The megafauna is dominated by the brachiopods, although there are also a fair number of trilobites, gastropods, corals and Bryozoa. In recent years a large number of ostracods have been described from this formation (see Amsden 1956).

This is a Helderbergian fauna with close affinities to the New Scotland, and at least some of the species appear to be conspecific with those from the Lower Devonian of Tennessee and New York. The Haragan fauna is distinctly different from that of the Henryhouse, but appears to be identical, or neary identical, with that of the overlying Cravatt member of the Bois d'Arc formation. The writer is now preparing a paper on the Haragan brachiopods and this will include a comparison with the faunas from the overlying and underlying formations as well as a discussion on correlation.

BOIS D'ARC FORMATION. Between the Haragan and the Frisco formations is a series of strata, variable in thickness, but locally reaching as much as 200 feet. The lower part of this sequence is marlstone, which, in many areas, grades upwards into calcarenites. The basal part is everywhere cherty, this being the characteristic used to distinguish it from the Haragan, and commonly chert is scattered through the rest of the formation in varying amounts (fig. 4). The chert in the lower part is generally a brown, porous-weathering tripolitic* type (pl. I, B), while that from the upper part is commonly a solid, vitreous type of chert. It is everywhere in the form of nodules or slightly elongate lenses; no bedded chert was observed.

Reeds applied the name Bois d'Arc limestone to these upper Hunton strata, the name being taken from the Bois d'Arc Creek on the Lawrence uplift (fig. 1). In his first publication this author (1911, p. 265) included all of the upper Hunton in this formation, although he did note that in the type area the upper 40 feet might be Oriskany in age. Some years later Reeds (1926, p. 13) removed the upper, massive-bedded limestones which carry an Oriskany fauna from the Bois d'Arc and placed them in his Frisco limestone. He designated the type locality of his Bois d'Arc formation as "along Bois d'Arc Creek, sec. 4, T. 2 N., R. 6 E.", but this must be an error since Bois d'Arc Creek is not present in section 4; however, it is well exposed on the north bank of

* The term tripolic chert is herein used for these porous-weathering cherts. There appear to be gradations between this type and the solid, vitreous chert.

this creek in sec. 11, T. 2 N., R. 6 E., and presumably this was the location to which he referred. The most complete section of the formation in this area is present in sec. 4, starting at the top of Cedar Hill and extending north along the banks of Chimneyhill Creek, and this is here designated the type section.

Reeds' descriptions are brief, but there would seem to be little doubt that his Bois d'Arc and Frisco limestones are the equivalents of the Bois d'Arc and Frisco formations of the present report. The principal addition that the writer wishes to make is to divide the Bois d'Arc formation into a lower Cravatt member (Maxwell 1936; see below) and an upper Fittstown member (new name). The Cravatt is composed largely of marlstone with varying amounts of chert, and the Fittstown of calcarenites with some calcilutites, the calcilutites commonly argillaceous; locally the Fittstown has abundant chert. There is no well-defined contact between the two, one grading into the other, as suggested in figure 4, and it seems probable that at least the lower part, perhaps all, of the Fittstown is a facies of the Cravatt.

Maxwell (1936, pp. 134-135) employed a stratigraphic classification which was different from that of either Reeds or the writer. He restricted Reeds' term Bois d'Arc limestone* to the upper calcarenite beds and proposed the name Cravatt for the lower strata. This division corresponds roughly to the writer's Cravatt and Fittstown members, although as noted below his interpretation of the stratigraphic relationship was different. Maxwell united his Cravatt and Haragan formations in a group called the Kite, stating that (1) the faunas are similar, and (2) the Haragan lithology grades into the Cravatt lithology. The Bois d'Arc limestone (restricted) was recognized as a distinct unit because "its fauna and the lithology separate it distinctly from the Cravatt".

The writer does not believe that Maxwell's grouping is a satisfactory one, being neither a usable lithologic classification, nor a suitable faunal classification. In so far as lithology is con-

* In 1931 Mildred Armor submitted a Master of Science thesis to the University of Oklahoma on the Bois d'Arc formation. The conclusions reached in this paper are similar to those of Maxwell.

cerned, the post-Chimneyhill strata fall into three stratigraphic units which can be readily distinguished in the field. These are (1) the Hunton marlstone (Haragan and Henryhouse formations), (2) Bois d'Arc formation (of Reeds and the writer), and (3) Frisco formation. The Bois d'Arc formation (of Reeds and the writer) is distinguished from the underlying Hunton marlstone by the presence of chert; furthermore, this part of the Hunton group almost everywhere makes a conspicuous topographic ridge, thus marking the position of the lowest chert bed. The Frisco differs from the upper part of the Bois d'Arc formation in its thicker beds and reduced argillaceous content (pl. III). These divisions are mappable units, as the writer can attest, having mapped them on the Lawrence uplift.

On the other hand the contact between Maxwell's Kite group and his Bois d'Arc limestone (restricted; this is the Cravatt-Fittstown contact of the present report) is a difficult one to locate in the field. It is certainly true that in many areas the upper part of Reeds' Bois d'Arc (and the writer's) grades into moderately pure calcarenites, a change which is recognized in the writer's division of this formation into members. There is, however, no well defined contact between the two, the marlstones of the lower member grading into the upper calcarenites through a considerable thickness of beds. Even where the upper Bois d'Arc calcarenites (Fittstown member) are well developed, as on the Lawrence uplift, argillaceous calcilutites are present even near the top of the formation. Conversely, beds of relatively pure calcarenites may be found low in the Bois d'Arc formation (of Reeds and the writer) in what is otherwise a typical Cravatt section.

Finally the writer would question Maxwell's statement that the fauna of his Bois d'Arc formation (restricted) is markedly different from that of his Cravatt. The evidence now available suggests that the Fittstown member (Maxwell's Bois d'Arc restricted) is at least in part a facies of the Cravatt, and of the Haragan. This is of course, a question that requires a faunal as well as a stratigraphic analysis. At the present time the writer's faunal study is not complete, but the work done thus far suggests that the Bois d'Arc formation is a facies of the Haragan, and such faunal variations as may exist within this sequence of beds are due to ecological differences rather than to time.

Thickness and distribution: The Bois d'Arc is the most widely distributed of the Hunton formations, being present in all of the sections thus far studied (fig. 1). Its known thickness ranges from 45 to 200 feet with at least a part of this variation caused by the facies gradation from the Bois d'Arc into the Haragan formations (fig. 4). The Cravatt member is present in all of the sections examined, whereas the Fittstown member is more irregular in its thickness and distribution, being absent in many areas.

Fossils and age: See under CRAVATT MEMBER and FITTSTOWN MEMBER.

CRAVATT MEMBER. The term Cravatt was introduced by Maxwell (1936, p. 135), who treated it as a formation in his Kite group (see discussion under BOIS D'ARC FORMATION). This name was taken from that of the original allotment owner, Katy Cravatt, in the NE¼ SW¼ SW¼ sec. 2, T. 2 S., R. 7 E. (fig. 1). There are quite suitable exposures of the Cravatt in this area, but the member can be best studied on the Lawrence uplift where the overlying Fittstown member is well developed, permitting an examination of the boundary between the two. There are excellent exposures on Chimneyhill Creek (E½ sec. 4, T. 2 N., R. 6 E.), and this is here designated the type section. There are also excellent exposures on Bois d'Arc Creek (N½ sec. 11, T. 2 N., R. 6 E.), this last locality being especially interesting as the Frisco is present, thus giving a complete section of the upper Hunton. There is also a thick section of the Cravatt and Fittstown members exposed along Haragan Creek in the White Mound area (fig. 1).

Lithology: The Cravatt is a fossiliferous, argillaceous and silty calcilutite in beds up to 4 inches or so in thickness. Nodules and small lenses of chert are invariably present in the lower part, this being the characteristic used to distinguish the Cravatt from the Haragan, and in most areas chert is common throughout the member. This chert is typically a brown-weathering, tripolitic type, but some solid, vitreous chert is also present. It is commonly fossiliferous. Characteristically the Cravatt is a fine-textured, argillaceous calcilutite, but it does have beds of relatively pure calcarenite, even in the lower part (see *Cravatt-Fittstown contact*).

The writer has examined several peels and thin-sections of this rock and these show a texture and composition (excluding the chert) much like those of the Haragan. Most of the rock is composed of clay- and silt-size particles with fossils scattered through the matrix. Typically the fossil content is well below 50 percent except for the beds of calcarenite, which are largely a bioclastic limestone.

A number of insoluble residues* have been prepared, most of which fall between 8 and 30 percent, the average being around 16 to 17 percent. A few of the specimens tested range much higher or much lower; one highly argillaceous rock contained 63 percent insolubles, and one of the calcarenites (near the base) had only 2.4 percent insolubles. These residues are almost entirely in the silt and smaller sizes, there being little sand-size debris present. Residues which have been washed to remove the fines are composed mainly of silt-size, clear, subangular quartz fragments. Some specimens also yield considerable silicified fossil material, but most of this is fragmentary, apparently representing incomplete silicification. The writer has found one place where the Bois d'Arc fossils are well silicified and this has furnished a moderate fauna, consisting mostly of brachiopods.

The typical color is like that of the Haragan, being some shade of yellowish gray. Locally some beds are red or mottled red and gray (10R 6/2; 10R 7/4), and these strata closely resemble the red beds present in the Haragan and the Henryhouse.

Seven Bois d'Arc rock specimens have been analysed for their calcium-magnesium content. Two from the Lawrence uplift show a $CaCO_3$ content of 31.3 and 77.7 percent; $MgCO_3$ of 5.1 and 7.8 percent. One specimen from near old Hunton townsite had 87.9 percent $CaCO_3$ and 2.3 percent $MgCO_3$; two specimens from Vines Dome averaged 86.3 percent $CaCO_3$ and 2.6 percent $MgCO_3$.

* All Cravatt specimens tested for insoluble residues were selected to exclude chert nodules; however, a binocular examination of the residues commonly shows some "spongy" silica.

Cravatt-Haragan contact: The base of the Cravatt formation is arbitrarily placed at the base of the lowest cherty bed of any appreciable thickness. The Cravatt almost everywhere forms a conspicuous topographic ridge, the Haragan being exposed in the underlying scarp face and the upper Cravatt and Fittstown forming the dip slope. In most areas the cherty character, combined with the topographic expression, make this boundary an easy one to locate. Using this system of classification, the Haragan is almost chert free, although a few cherty beds have been included where such strata are thin and show little lateral persistence. Such inclusions are rare, occurring in only two of the writer's stratigraphic sections, and in both cases this can be demonstrated to be a local development.

Except for chert, the Cravatt member is lithologically like the Haragan, the two being similar in color, bedding characteristics and lithology (pl. I, B). The Cravatt member as a whole probably has a slightly lower silt-clay content, but this difference is not conspicuous; moreover, the minimum-maximum insoluble content of each of these stratigraphic units shows such a great range that it is difficult to arrive at an average figure on which to base a comparison.

The Cravatt is believed to be a facies of the Haragan. The only basic faunal or stratigraphic difference between the two is the chert, but this is quite irregular in its development within the Cravatt. It is everywhere present in the basal part (by definition). The overlying beds may have chert abundantly distributed throughout, or may be almost chert free, the chert free portions being lithologically indistinguishable from the Haragan. Significantly, at least some of the individual cherty beds can be demonstrated to grade laterally into chert-free strata, thus strongly suggesting a facies relationship, a relationship further supported by the marked similarity of the two faunas (see *Fossils and age*). The regional distribution also indicates that the Cravatt is a facies of the Haragan. As shown in figure 4, the Haragan is well developed around old Hunton townsite where it rests directly upon the Chimneyhill. Farther south, in much of the region around Wapanucka, this stratigraphic position above the Chimneyhill is occupied by the Cravatt; those Cravatt strata which rest upon the Chimneyhill are lithologically and faunally similar to the Haragan, the only really diagnostic difference being the presence of chert.

Cravatt-Fittstown contact: The Cravatt is believed to be at least in part, probably entirely, a facies of the Fittstown. The boundary between the two is poorly defined and in most areas one member grades into the other through a relatively thick transition zone. Moreover, beds of Cravatt marlstone occur well up in the Fittstown calcarenites, and conversely beds of relatively pure calcarenite occur in what is otherwise a typical Cravatt sequence. The similarity of the two faunas also suggests a facies relationship (see *Fossils and age*).

Thickness and distribution: The Cravatt member is present in all of the Hunton sections studied (fig. 1). It is difficult to determine the exact thickness in those areas where the Fittstown is present because of the uncertainty of locating the upper boundary, but the Cravatt is believed to range from 30 to 190 feet in thickness.

Fossils and age: The Cravatt strata are fossiliferous, although it is rather difficult to collect satisfactory free specimens. The fossil content is about the same as in the Haragan, but at most places the fossils do not weather out free, the rock being more resistant and only rarely distintegrating to form a glade exposure. At places free specimens, especially silicified shells and steinkerns, can be collected from the surface of the Cravatt member. Silicification is fairly general in this member although it is commonly only a partial replacement.

A preliminary check indicates that it contains a fauna of Helderbergian age much like that of the Haragan. This examination also shows little significant difference between the Cravatt and the Fittstown fossils. There is evidence that the relative proportions of some species are changed, with certain species being much more common in the calcarenites than in the marlstones and vice versa, but this could be entirely an ecological factor, the clearer waters of calcarenite deposition being more favorable to certain organisms. Certainly there is no marked faunal break within the Bois d'Arc formation (nor in the Haragan-Bois d'Arc sequence) which is comparable to the abrupt and sharp faunal change between the Fittstown and Frisco calcarenites.

FITTSTOWN MEMBER. The Fittstown is a new name here proposed for the upper member of the Bois d'Arc formation. It corresponds to the upper part of Reed's Bois d'Arc formation and to all of Maxwell's Bois d'Arc limestone. The name is taken from the town of Fittstown, Pontotoc County (fig. 1), however, the type section is along Chimneyhill Creek (SE¼ and NE¼ sec. 4, T. 2 N., R. 6 E.). It is generally well developed on the Lawrence uplift and is also well exposed along Haragan Creek in the White Mound area.

Lithology: The characteristic Fittstown lithology is fossiliferous calcarenite with a relatively low silt-clay content. It is somewhat unevenly bedded, the beds ranging up to 6 or 8 inches in thickness (pl. III). Nodules and lenses of chert are irregularly distributed through the Fittstown, being common in places and rare or absent in others. The chert is generally a solid, vitreous type, but some tripolitic chert is present. The calcarenites may be separated by argillaceous partings, and locally beds of argillaceous calcilutite are present, at places attaining a thickness of several feet (see CRAVATT MEMBER, *Cravatt-Fittstown contact*).

The calcarenites of the Fittstown are similar in color to the argillaceous calcilutites of the underlying strata although they are generally slightly lighter in color. Typically they are some shade of yellowish gray, but there are beds with a distinct orange cast (5Y 8/1; 10YR 7/4).

Most peels of the Fittstown show a richly fossiliferous calcarenite with many beds composed of 70 percent or more recognizable fossil material. In fact, several of the rock specimens examined consist entirely of fossil debris except for a layer of clear calcite separating the fragments. A large part of this organic material is in the form of pelmatozoan fragments and some beds are typical encrinites composed almost entirely of these plates. Most strata, however, also include a substantial percentage of brachiopods, mollusks, corals and trilobites. In general the particles fall between 0.5 mm and 2 mm in diameter, but there are many larger fossil fragments and locally the rock grades into a calcirudite. Completely silicified fossils are not common, but evidence of partial replacement can be seen in most specimens.

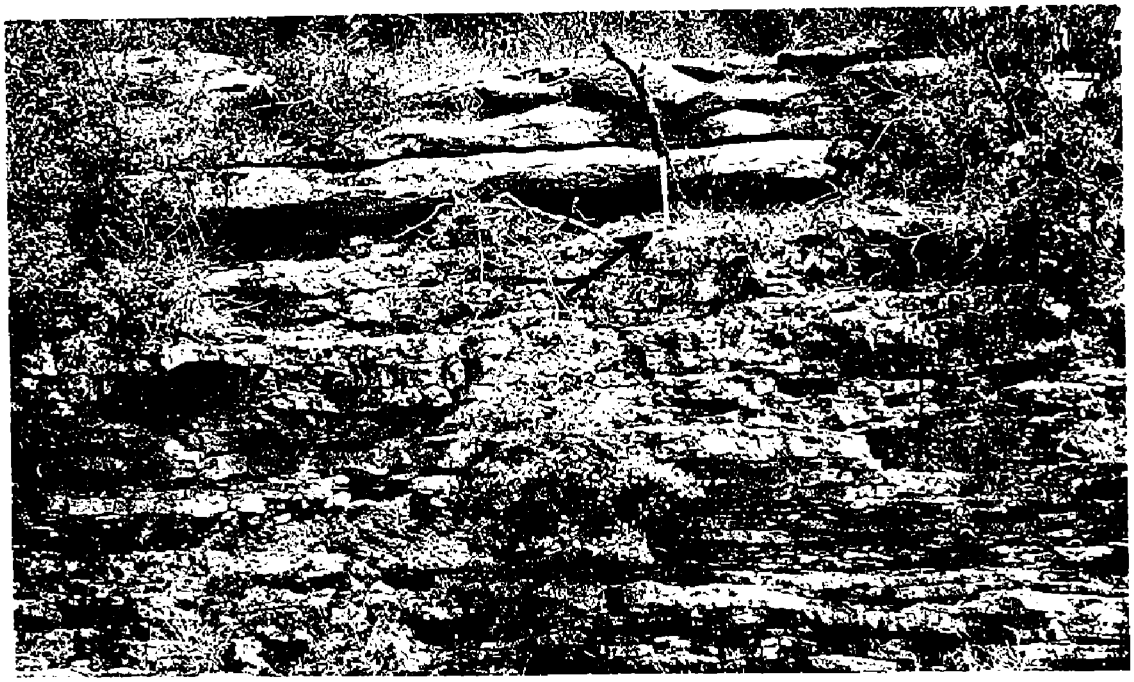
Insoluble residues of the typical Fittstown calcarenites range from 1.8 to 5.5 percent, the average being around 3.5 percent. Included within this member are a few beds and partings of argillaceous calcilutite with an insoluble content like that of the Cravatt member. A considerable part of the residues consist of silicified fossil fragments; excluding this material the residues are almost entirely in the silt and smaller sizes. Four calcium-magnesium analyses have been prepared; the $CaCO_3$ ranges from 95.8 to 97.5; the $MgCO_3$ from 0.17 to 0.88 percent.

The *Fittstown-Cravatt contact* is discussed under the CRAVATT MEMBER.

Fittstown-Frisco contact: The Fittstown can be separated from the overlying Frisco on both stratigraphic and paleontologic grounds. The most obvious difference between the two is the bedding, the Fittstown being consistently thinner bedded, as shown in plate III. In addition, the Frisco is almost entirely a high-calcium calcarenite, with little or no argillaceous calcilutite, whereas the Fittstown has some partings and even beds of marlstone. The fossils are distinct, the Fittstown carrying a Helderbergian fauna and the Frisco a Deerparkian fauna.

It should be noted that the calcarenites of the Frisco are like those from the Fittstown and where exposures are poor, with only a bed or two exposed, it is difficult to distinguish the two solely on the basis of lithology. This similarity caused Reeds to unite the two in his early work (1911, p. 265) and has undoubtedly confused some later investigators. Maxwell correctly separated the two and gave an accurate outline of the geographic distribution of the Frisco.

Thickness and distribution: This member is much more restricted in its distribution than is the Cravatt. It is well developed on the Lawrence uplift and on the Hunton belt extending



A. Bois d'Arc and Frisco formations. Arrow points to hammer resting head down on the contact. South bank of Bois d'Arc Creek, NE¼, sec. 11, T. 2 N., R. 6 E., Pontotoc County.

B. Bois d'Arc and Frisco formations. Arrow points to contact. North bank of Bois d'Arc Creek, NW¼, sec. 11, T. 2 N., R. 6 E., Pontotoc County.

to old Hunton townsite. In the area around Wapanucka and extending west towards Mill Creek it is generally absent, but just west of Mill Creek it is again present and is well represented in the vicinity of White Mound and on Henryhouse Creek. It is difficult to determine the exact thickness limits on this member because of the gradational nature of the lower boundary. On the Lawrence uplift it ranges from 25 to 60 feet; the greatest thickness known to the writer is the 75 feet exposed on Haragan Creek.

Fossils and age: This member if richly fossiliferous, although it is somewhat difficult to collect satisfactory specimens because the matrix and the fossils have about the same hardness. The writer has been able to collect a moderately large fauna from some of the coarser-grained beds. Some rather nice specimens can be broken out of those coarse-grained parts which have been weathered to the point where they are slightly friable.

FRISCO FORMATION. These strata were included by Reeds (1911) in the Bois d'Arc limestone, but in 1926 he placed them in his Frisco limestone, the name being taken from the town of Frisco, Pontotoc County (fig. 1). There is no Hunton exposed at Frisco, and no type section was designated, although Reeds stated that the best exposures were along Bois d'Arc Creek and near Coal Creek. Reeds illustrated a Frisco outcrop on Bois d'Arc Creek (1926, fig. 10) and since there are excellent exposures along this creek it can be used as the type section (NE¼ sec. 11, T. 2 N., R. 6 E.). There are also fine exposures where the Hunton belt is crossed by Coal Creek (NW¼ sec. 22, T. 1 N., R. 7 E.).

Lithology: The Frisco is a fossiliferous calcarenite with almost no argillaceous calcilutite. The bedding is fairly even, generally ranging from 6 inches to 2 feet in thickness (pl. III). Small lenses and nodules of chert are present, and locally become abundant. It is mostly a vitreous, light-colored chert.

Much of the rock is a medium to coarse calcarenite, at places grading into a calcirudite. Peels reveal much fossil debris, but also show a considerable amount of clear calcite, at least some of which appears to be the result of recrystallization.

Four insoluble residues have been calculated for Frisco rock specimens from the Lawrence uplift. Three of these range from 0.51 to 0.87 percent, averaging 0.65 percent; the fourth had a residue of 3. 5 percent. The washed residues consist of silificied fossil fragments with some clear subangular quartz fragments in the silt and fine sand sizes. These four specimens were also analysed for their calcium-magnesium content: the $CaCO_3$ ranged from 97 percent to over 99 percent; the $MgCO_3$ from 0.38 to 0.57 percent.

The *Fittstown-Frisco* contact is discussed under the FITTSTOWN MEMBER.

Thickness and distribution: This formation has a restricted distribution. On the Lawrence uplift it is present only in the southeastern part, being confined to parts of secs. 2, 10, 11, 12 (T. 2 N., R. 6 E.). It is also present in the Hunton belt extending from Lawrence uplift to old Hunton townsite. Between old Hunton and the southern end of this belt of outcrops (sec. 33, T. 1 S., R. 8 E.) the Frisco disappears and in so far as known is absent in all other parts of the Arbuckle region.

The Frisco probably reaches its maximum thickness along Bois d'Arc Creek, but the writer has not yet made an exact measurement in this area. Maxwell reported a thickness of 41.5 feet along this creek, this being his maximum for the formation.

Fossils and age: This formation is richly fossiliferous and in some beds specimens can be broken out of the coarse calcarenites. It is, however, difficut to recover complete specimens as they commonly break in being extracted. Even complete specimens have a preservation which leaves much to be desired, the ornamentation and other external and internal details being generally obscure. The fauna obtained by the writer has not been studied in detail, but a preliminary check indicates that it is Deerparkian in age, probably rather close to that of the Oriskany sandstone. These fossils are distinctly different from those of the underlying Bois d'Arc formation and the two faunas can easily be distinguished.

POST-HUNTON STRATA. Throughout the Arbuckle region the Hunton is unconformably overlain by the Woodford shale. The erosional interval separating the Woodford from the Hunton is considerable, so this shale may be in contact with any of the Hunton formations or members, and there are places where the Woodford rests directly upon the Sylvan shale (Ham 1954). The Woodford is everywhere a fissile shale which is easily distinguished from any of the Hunton units.

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