OKLAHOMA GEOLOGICAL SURVEY
CARL C. BRANSON, *Director*

BULLETIN 90

STRATIGRAPHY OF THE FRISCO AND SALLISAW FORMATIONS (DEVONIAN) OF OKLAHOMA

by

THOMAS W. AMSDEN

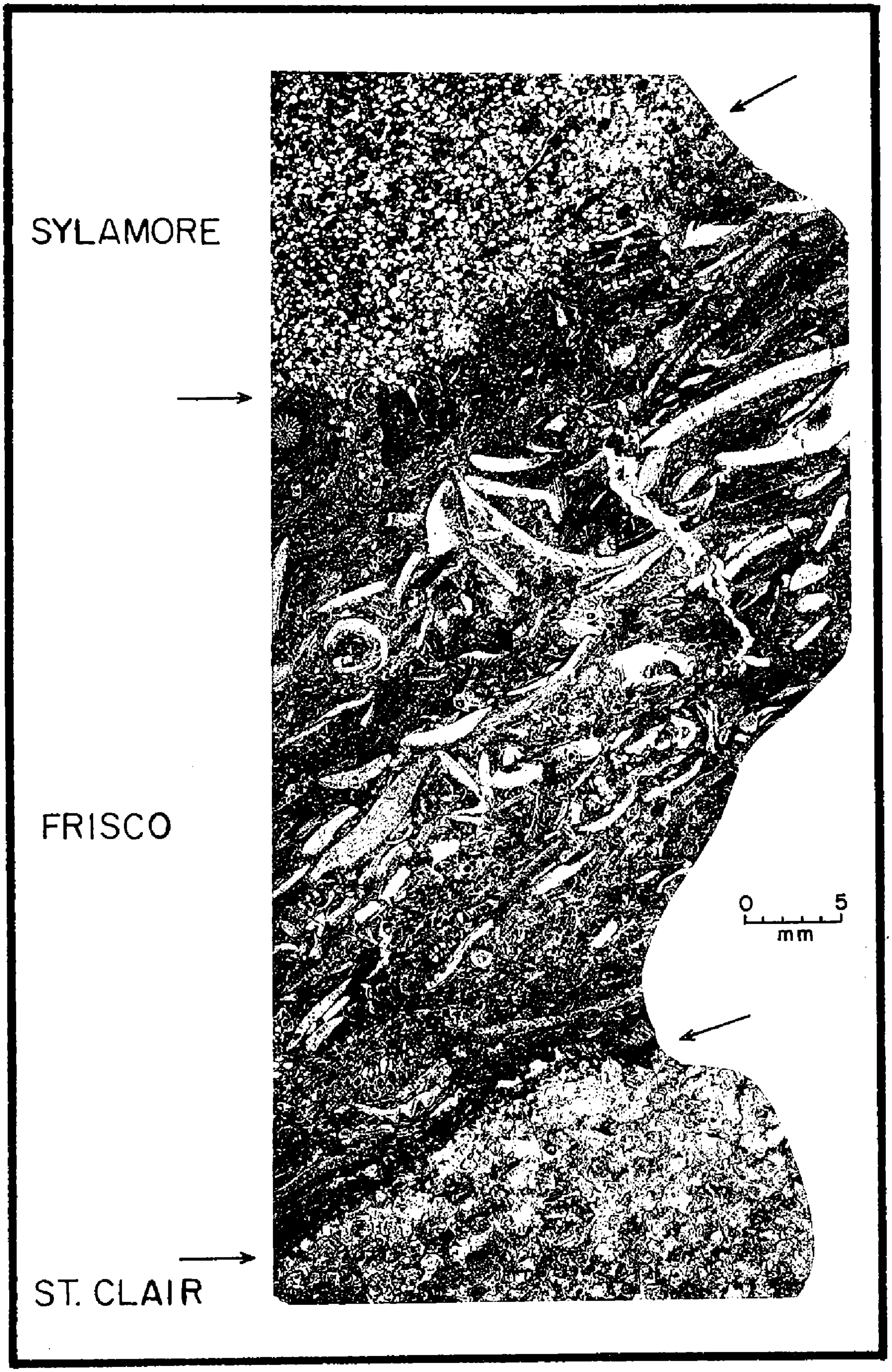
The University of Oklahoma
Norman
June 1961

CONTENTS

ILLUSTRATIONS

TEXT-FIGURES

PLATES



Photomicrograph of a thick thin-section showing the St. Clair (Silurian), Frisco (Lower Devonian) and Sylamore (Upper Devonian) formations. Stratigraphic section S7 (see discussion under Frisco Formation and Appendix).

STRATIGRAPHY OF THE FRISCO AND SALLISAW FORMATIONS (DEVONIAN) OF OKLAHOMA

THOMAS W. AMSDEN

ABSTRACT

This report describes the physical stratigraphy of the Frisco and Sallisaw formations. It is based on a field study of the stratigraphic relationships, and a laboratory study of the lithologic characteristics by means of thin sections, paralodion peels, insoluble residues, and chemical analyses.

The Frisco and Sallisaw formations are Early Devonian in age, the Frisco representing a part of the Deerparkian stage and the Sallisaw a part of the Onesquethawan stage. The Frisco crops out in the Arbuckle Mountain region, south-central Oklahoma, and in Sequoyah County, northeastern Oklahoma; the Sallisaw crops out only in Sequoyah County. In the Arbuckle Mountain region the Frisco rests unconformably upon the Bois d'Arc formation (Helderbergian) and is unconformably overlain by the Woodford formation (Upper Devonian). In Sequoyah County the Frisco is unconformably underlain by the St. Clair formation (Silurian) and is unconformably overlain by the Sallisaw formation, which is in turn unconformably overlain by the Sylamore member of the Chattanooga formation (Upper Devonian).

The Frisco is a bioclastic limestone, much of it being a moderately coarse shell coquina which appears to represent a high-energy deposit; its acid-insoluable content and $MgCO_3$ content are low. It is 60 feet thick at the type locality, but much thinner elsewhere in the Arbuckle Mountain region and in Sequoyah County. The Sallisaw is an arenaceous limestone locally grading into an arenaceous calcitic dolomite; in places there is an arenaceous chert facies. The acid insolubles average 9.5 percent and the $MgCO_3$ averages 11.5 percent. In most places the Sallisaw is less than 20 feet thick; it also appears to represent a high-energy deposit.

All the formation boundaries are exposed at one place or another in Sequoyah County, but the St. Clair-Frisco (Silurian-Devonian) contact is especially well exposed, both on the surface and in the underground workings of the St. Clair Lime Company mine. At several places the Frisco limestone is welded to the St. Clair limestone and it has been possible to collect specimens which span the boundary between the two formations. Thin sections cut from these specimens have made it possible to study this unconformity microscopically as well as megascopically. The present report includes several photomicrographs of this unconformity; the Frisco-Sallisaw and Frisco-Sylamore contacts are also illustrated.

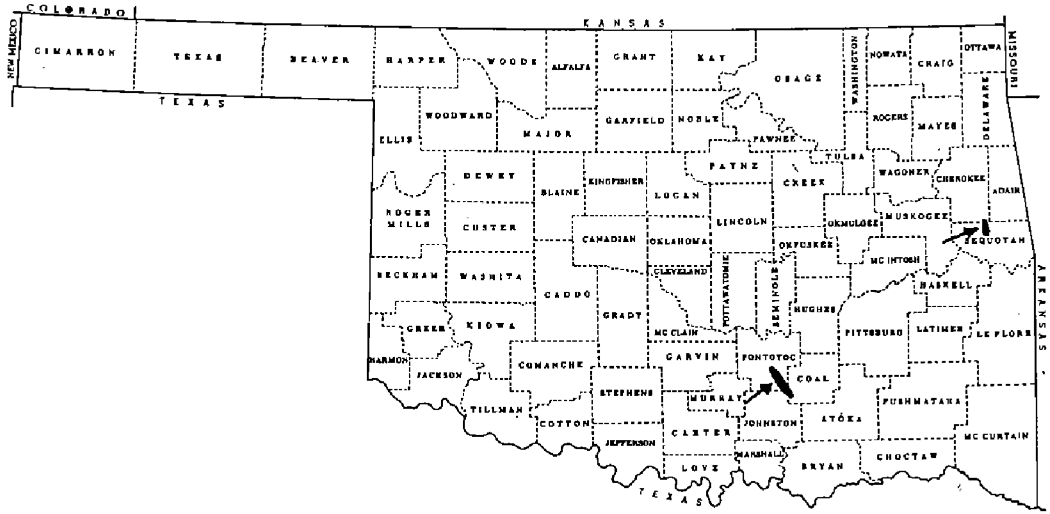
This report includes a brief description of the upper part of the St. Clair formation and of the Sylamore sandstone member of the Chattanooga formation.

The stratigraphic distribution of dolomite in the St. Clair, Frisco, and Sallisaw formations is discussed and it is concluded that the $MgCO_3$ in these units was probably introduced at the time of deposition.

Large fossil collections have been made from the St. Clair, Frisco, and Sallisaw formations. This report gives a brief summary of the fauna from each of these formations, but it does not include any descriptive paleontology.

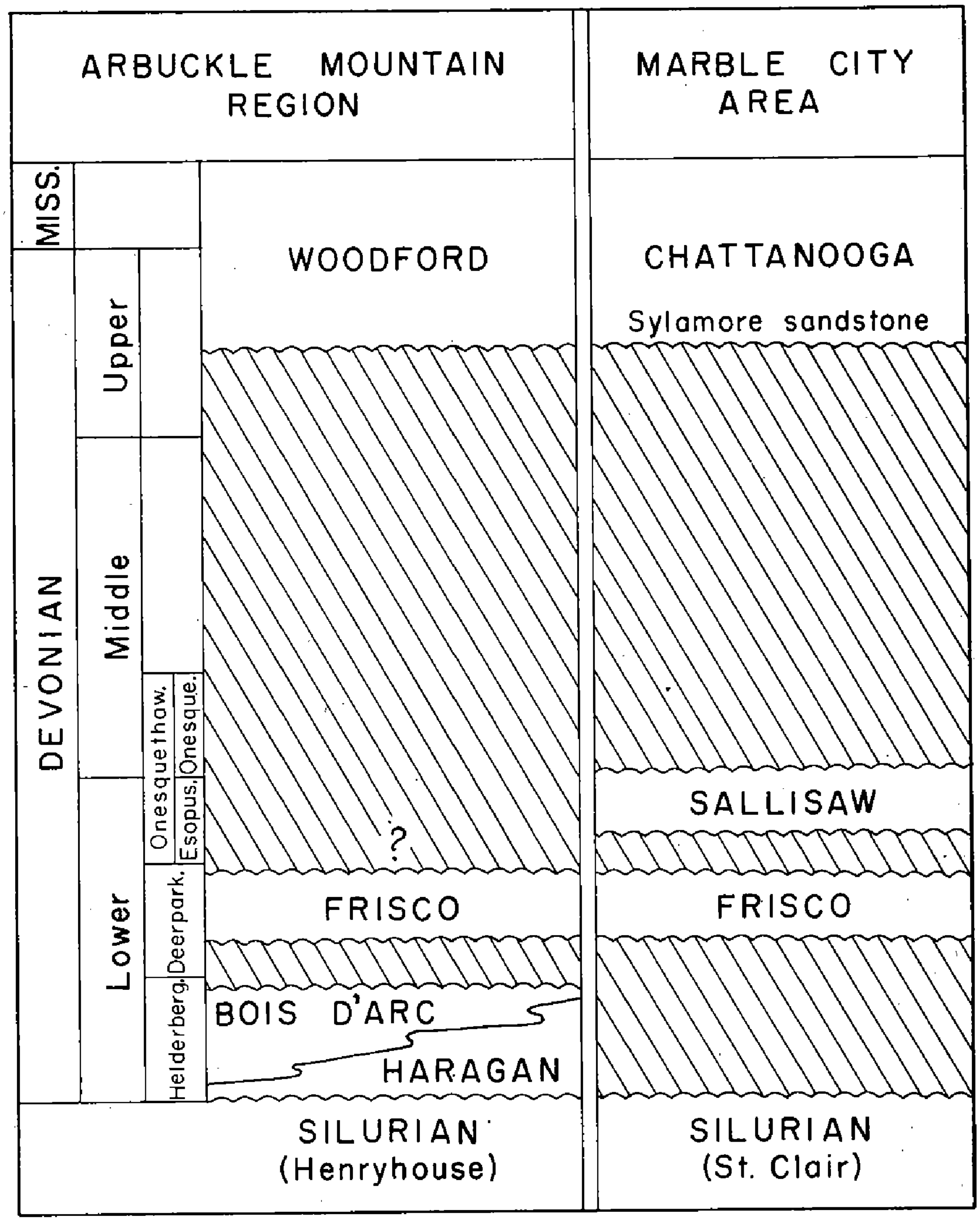
INTRODUCTION

The Frisco and Sallisaw are thin carbonate formations of Early Devonian (Ulsterian) age, the Frisco representing the Deerparkian stage and the Sallisaw the early part of the Onesquethawan stage (text-fig. 2). The Frisco crops out in two areas: (1) in south-central Oklahoma, in parts of Pontotoc, Johnston, and Coal Counties, and (2) in the Marble City area of Sequoyah County, northeastern Oklahoma. The outcrop area of the Sallisaw formation is confined to Sequoyah County. The regional geographic setting is shown in text-figure 1; additional details are given in text-figures 4, 10, and 25. Plate I is a geologic map of the Marble City area, Sequoyah County.



TEXT-FIGURE 1. Map showing the outcrop areas of the Frisco and Sallisaw formations. The Frisco crops out both in south-central and in northeastern Oklahoma, whereas the Sallisaw is present only in the northeastern area. See also plate I and text-figures 4, 10, and 25.

The Frisco formation is primarily a bioclastic limestone having low acid-insoluble and low $MgCO_3$ content (text-fig. 3). Its type locality is on Bois d'Arc Creek in Pontotoc County (Amsden, 1957, p. 47). Here and throughout its outcrop area in the Arbuckle Mountain region it is regarded as the uppermost formation in the Hunton group. In this region it rests upon the Bois d'Arc formation of Helderbergian age, and is overlain by the Woodford formation of Late Devonian age (Amsden, 1960, panels II, III). The Frisco is also present in Sequoyah County, but here it rests upon the St. Clair formation of Silurian age, and is overlain by the Salli-

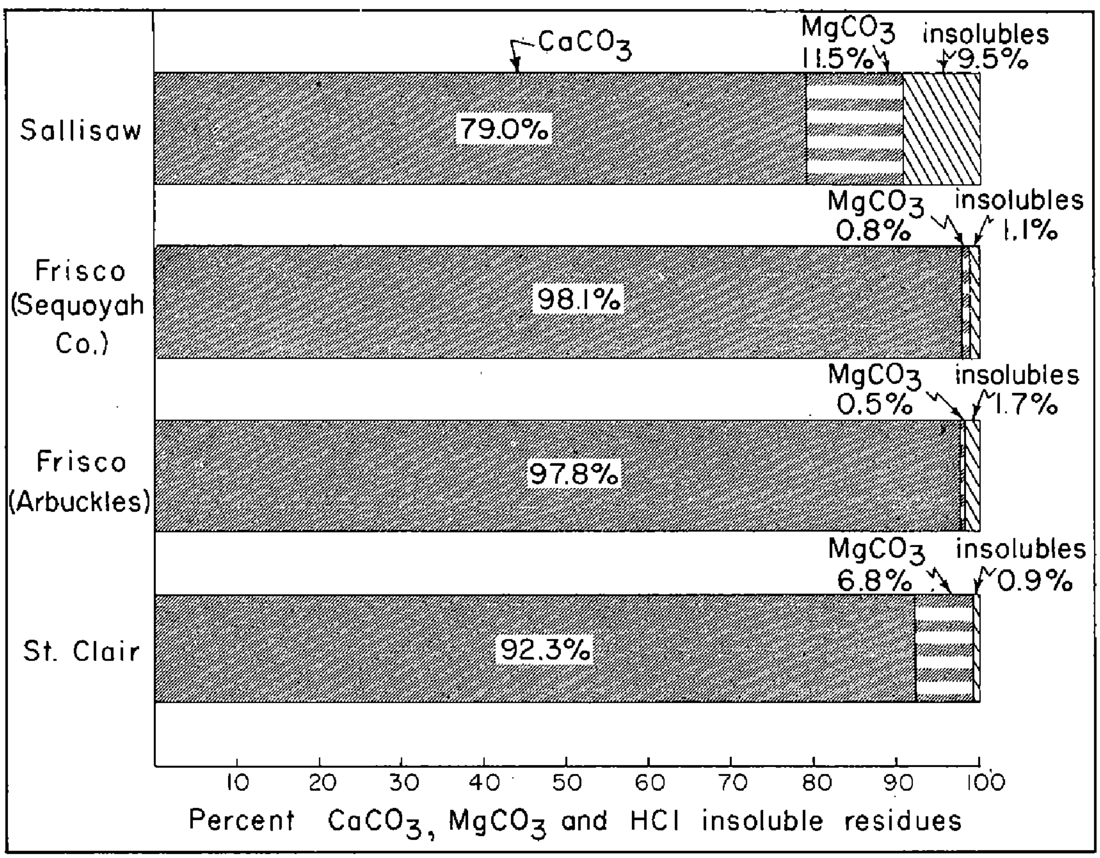


TEXT-FIGURE 2. Chart showing the Devonian formations present in the Arbuckle Mountain region of south-central Oklahoma, and in the Marble City area, Sequoyah County, Oklahoma. The division of the Onesquethawan stage into an Esopus stage and Onesquethawan stage (restricted) is based on a recent study by Boucot (1959, p. 738); this is discussed in the section on *Fossils and age* of the Sallisaw formation. The dividing line between the Lower Devonian and Middle Devonian is placed between the Esopus and Onesquethawan (restricted) stages, but this is merely for convenience as the present report does not deal with this boundary; on the Devonian correlation chart (Cooper et al., 1942, chart 4) the Onesquethawan stage (unrestricted) is classed as Lower or Middle Devonian. The age of the Woodford and Chattanooga formations is that given by Hass (1956) and has not been investigated by me. Strata exposed in a small inlier on Turkey Creek, Marshall County, may represent some part of the Onesquethawan (unrestricted) stage (see Amsden, 1960, p. 151-159). The formations underlying the Devonian are shown but this chart does not attempt to give the relative ages or correlatives of these Silurian strata.

saw formation, or, where that formation has been removed by erosion, by the Chattanooga formation (text-fig. 2, pl. I).

The Sallisaw formation is a calcarenite with varying amounts of subangular, sand-size quartz detritus. It is locally dolomitic, the average $MgCO_3$ content being 11.5 percent with some beds having as much as 26 percent (text-fig. 3). Its type locality is on Sallisaw Creek in Sequoyah County where it rests upon the Frisco formation, but at some places the Frisco has been removed by pre-Sallisaw erosion and the Sallisaw rests upon the St. Clair formation. The Sallisaw is everywhere overlain by the Chattanooga formation (text-fig. 2, pl. I).

The geology of the Marble City area is of special interest because of the excellent opportunity it offers for the study of the



TEXT-FIGURE 3. Bar graph comparing the average $CaCO_3$, $MgCO_3$, and HCl-insoluble residue content of the St. Clair, Frisco, and Sallisaw formations. All of the data for the Sallisaw and Frisco formations are given in the Appendix. The data for the St. Clair represents a combined average of the 20 rock-specimen analyses given in the Appendix ($CaCO_3$ — 92.9%, $MgCO_3$ — 6.6%) and the channel sample analyses given in Oklahoma Geological Survey Mineral Report 16 (Ham, et al., 1943) ($CaCO_3$—92.6%, $MgCO_3$—6.8%); note that these figures are averages, and in places the St. Clair is a high-calcium stone of exceptional purity. A further discussion on composition is given in the sections on the lithologic character of the formations.

contact relationships between the various Silurian and Devonian formations. Of particular interest is the boundary between the Frisco and St. Clair formations, formations which are separated by an unconformity of some magnitude. These formations are lithologically and faunally distinct so that their boundary can be easily located in the field. They are well exposed at a number of places by natural outcrops and these are supplemented by the workings of the St. Clair Lime Company mine. The Frisco is commonly welded to the St. Clair so that specimens spanning the contact may be obtained, and thin sections cut from these specimens make it possible to study the boundary microscopically as well as megascopically. Several photomicrographs illustrating this contact are shown in the frontispiece and in plates IV, V, and VIII.

Previous investigations: The Frisco formation was named by Reeds (1926, p. 10, 13) for exposures in Pontotoc County in the Arbuckle Mountain region of south-central Oklahoma. A discussion of the nomenclatorial history of this formation, which constitutes the uppermost unit in the Hunton group, is given in my 1957 paper (p. 47). Maxwell (1936, p. 99-105), in his study of the Hunton group, gave additional information on the Frisco, including a lengthy faunal list. In 1958 Ventress presented a Master of Science thesis to the University of Oklahoma on the stratigraphy and megafossils of the Frisco formation in the Arbuckle Mountain region, and in 1960 I described this formation at some length, including a discussion of its geographic distribution, thickness, and lithologic characteristics (Amsden, 1960; p. 125-135; panel II, pls. A, B; panel III, pls. A, C). Strata equivalent to the Frisco formation of the Arbuckle Mountain region were first recognized in Sequoyah County by Schuchert (1922, p. 667-670), who described them as the "upper Oriskanian white limestone" and gave a short faunal list. A few years later Cram (1930, p. 550) applied the name Frisco to this formation in the Marble City area.

The Sallisaw formation was named by Cram (1930, p. 550-551) for exposures on Sallisaw Creek in Sequoyah County. This formation and the underlying Frisco are briefly discussed in a paper by Ham et al. (1943, p. 4-5) dealing with the chemical composition of the St. Clair limestone in the Marble City area. In 1953 Christian presented a Master of Science thesis to the University of Oklahoma on the geology of the Marble City area, Sequoyah County, and included a description of the Sallisaw and Frisco formations with a faunal list for each. Christian made a geologic map of this area, and a modification of his map is given on plate I of the present report. Huffman (1958, p. 33-38) also described these formations in a bulletin which presented five geologic maps showing the regional distribution of the Silurian and Devonian strata in northeastern Oklahoma.

Present investigation: The present study is concerned with the physical stratigraphy, or lithostratigraphy, of the Frisco and Sallisaw formations. I have included a brief section on fossils and age, although the major biostratigraphic aspects of these formations will be treated in a later paper. The primary basis for this report is a field investigation which includes some detailed geologic mapping as well as descriptions of a number of stratigraphic sections; numerous fossils and lithologic specimens were collected from these sections. The Frisco formation has been mapped throughout most of its outcrop area in the Arbuckle Mountain region by myself, Styron Douthit, and William Ventress; the northern and southern parts of this map were published in my 1960 paper on Hunton stratigraphy (panel II, pls. A, B), and a small, simplified outcrop map of this entire area is shown in text-figure 10 of the present report. In 1953 H. Christian presented an excellent geologic map showing all of the formations in the Marble City area and a part of this is included on plate I. Christian's map has been modified in two ways: (1) only the St. Clair, Frisco, and Sallisaw formations are shown, the later Paleozoic formations being undifferentiated, and (2) some changes have been made in the outcrop pattern of the Frisco and Sallisaw formations. In this connection it should be noted that the distribution of these two formations as shown on the map undoubtedly represents some simplification. Both the Frisco and Sallisaw are thin and they are separated from each other, and from the formations above and below, by unconformities so that their actual outcrop pattern is in all probability more complicated than that shown on plate I.

William Ventress and I have described a number of stratigraphic sections in the Arbuckle Mountain region. Those done by me may be found in the Appendix of my 1960 paper on Hunton stratigraphy, and those by Ventress are given in the Appendix of the present report; the locations of the Arbuckle

Mountain sections are shown in text-figure 10. I have also described a number of stratigraphic sections in the Marble City area and these are given in the Appendix of the present report; the locations of these sections are shown on plate I. The numbering system and other information pertaining to these sections is given in the introductory remarks accompanying the part on Stratigraphic Sections (Appendix).

The field work has been supplemented by a laboratory investigation of selected rock specimens. The primary goal for this part of the study has been to obtain a more precise description of the lithologic character of these formations, and to try to get a better insight into their environment of deposition. The principal laboratory techniques employed are discussed below.

A number of thin sections and a few paralodion peels have been used to study the textures of the limestones. For the most part, peels have not been extensively used as some of the rocks, notably the upper part of the St. Clair, do not yield satisfactory results. I have found that the textures of the limestones generally show up best in petrographic sections cut to approximately twice the thickness of a conventional thin section, whereas the more arenaceous parts of the Sallisaw and the Sylamore are best studied in standard petrographic thin sections. A study of the microtextures by means of sections and peels has proved to be of value in differentiating the formations of the Marble City area. The finer-textured facies of these formations may be difficult to distinguish in the field, whereas in thin section they are easily distinguished. For example, the calcilutite facies of the Frisco has a megascopic resemblance to those parts of the Sallisaw having a low content of acid insolubles, but the microtextures of these two facies are quite different. This subject is discussed in detail under the Sallisaw Formation, *Sallisaw-Frisco relationships,* and under the Frisco Formation, *Frisco-St. Clair relationships.*

A number of specimens have been analyzed for their acid-insoluble, $CaCO_3$, and $MgCO_3$ contents by John Schleicher in the geochemical laboratory of the Oklahoma Geological Survey. All of these analyses were made from chert-free rock samples (no channel samples) collected from described stratigraphic sections. These data are tabulated in the section on Chemical Analyses in the Appendix, and are discussed and illustrated graphically under the section on *Lithologic character* for each of the formations.

The average $CaCO_3$, $MgCO_3$, and insoluble-residue contents of the St. Clair, Frisco, and Sallisaw formations are shown in text-figure 3.

I have studied the composition of the HCl-insoluble residues, mostly by means of a binocular microscope at magnifications up to 112 diameters. Material to be examined in this way was prepared by crushing (not pulverizing) a sample to about pea-size and smaller, and digesting it in warm, dilute HCl. The residue was then washed and the silt and coarser fraction examined under the microscope. This method has the disadvantage of removing the clay-size debris, but is necessary as I have no way to study the fines (the clay content of the rocks under study is low). In this study I have been especially concerned with the detrital portion of the insolubles as this represents material derived from outside the basin of deposition.

The descriptive terminology applied to the limestones in this report is essentially the same as that used in my paper on Hunton stratigraphy (1960, p. 178-180). I use the term bioclastic as a general term for those rocks in which fossil material makes up more than half the total volume.* The grain size of the rocks under study generally falls within the range of a calcarenite, but some are coarse enough to be classed as calcirudites and some are fine enough to be classed as calcilutites; these may be termed biocalcarenites, biocalcirudites, and biocalcilutites (Carozzi, 1960, p. 221, 225, 260). Some of the bioclastic limestones have a matrix of sparry calcite (biosparites of Folk, 1959) and some have a matrix of finely divided carbonate (biomicrites of Folk) a few beds, notably the pelmatozoan limestones, have a combination of the two types.

The Frisco and St. Clair limestones have a low acid-insoluble content, and therefore the quality of detrital or terrestrial material is negligible, at least where lithologic terminology is concerned. In contrast, certain parts of the Sallisaw have a substantial insoluble content which is mostly in the form of sand-size quartz detritus. In

* In a recent article Thomas (1960, p. 1833-1834) pointed out that Grabau originally defined bioclastic in a quite different sense, applying it to "rocks made up of fragments which originated through the breaking action of organisms." Rocks of this kind are uncommon and the term has rarely been used in this way; however, many authors have used the term bioclastic for the common rock type in which the allochems or clasts are composed predominantly of fossils (see references in Thomas, 1960; and Amsden, 1960, p. 13; see also supplement to the Glossary of Geology, Amer. Geol. Institute, 1960). Defined in this way, bioclastic is a valuable term and in the present report it is so used.

the present report the following descriptive terms will be applied to rocks of this type:

Term	Percent insolubles	Illustrated
Low-arenaceous limestone	5 to 10	pl. XI, fig. 1 (see below)
Arenaceous limestone	10 to 50	pl. XI, fig. 2
Calcareous sandstone	more than 50	pl. XI, fig. 3 approaches this category (45.3%)

In parts of the Sallisaw the carbonate is partly in the form of $MgCO_3$, in which case the word dolomite may be substituted for limestone (Pettijohn, 1957, p. 418); the Sallisaw part of the specimen illustrated on plate XI, figure 1 is a *low arenaceous calcitic dolomite* (HCl insolubles — 5.1 percent; $MgCO_3$ — 24.5 percent). My term arenaceous limestone thus belongs in the impure allochemical category of Folk (1959, p. 4), and arenaceous dolomite presumably belongs to his impure orthochemical group. In places the Sallisaw carbonate has been replaced by finely crystalline quartz, producing a rock which I call an *arenaceous chert* (pl. XII, fig. 6; see under *Lithologic character,* Sallisaw Formation).

Acknowledgments: The works of earlier investigators have been consulted freely in the course of this study, but I am especially indebted to William Ventress and to H. E. Christian. Ventress presented a fine study of the Frisco formation in the Arbuckle Mountain region to The University of Oklahoma as a Master of Science thesis, and in the near future he and I plan to describe the brachiopods from this formation. Christian's work, which was also a University of Oklahoma Master of Science thesis, represented a detailed study of the strata in the Marble City area, and a part of his geologic map has been incorporated into the present report.

Rodger E. Denison prepared a number of the photomicrographs illustrated in this paper, and he also helped me in determining the petrographic character of some of the sandstones. The thin section illustrated in the frontispiece was photographed by Neville M. Curtis, Jr.

I wish to acknowledge the generous help of William E. Ham with whom I have consulted at length on the various field and laboratory problems encountered in this study. I also thank Mr. Homer H. Dunlap, Jr., general manager of the St. Clair Lime

Company, and Mr. Tom L. Rowland, geologist of this company, for extending every courtesy and aid to me during the course of this investigation.

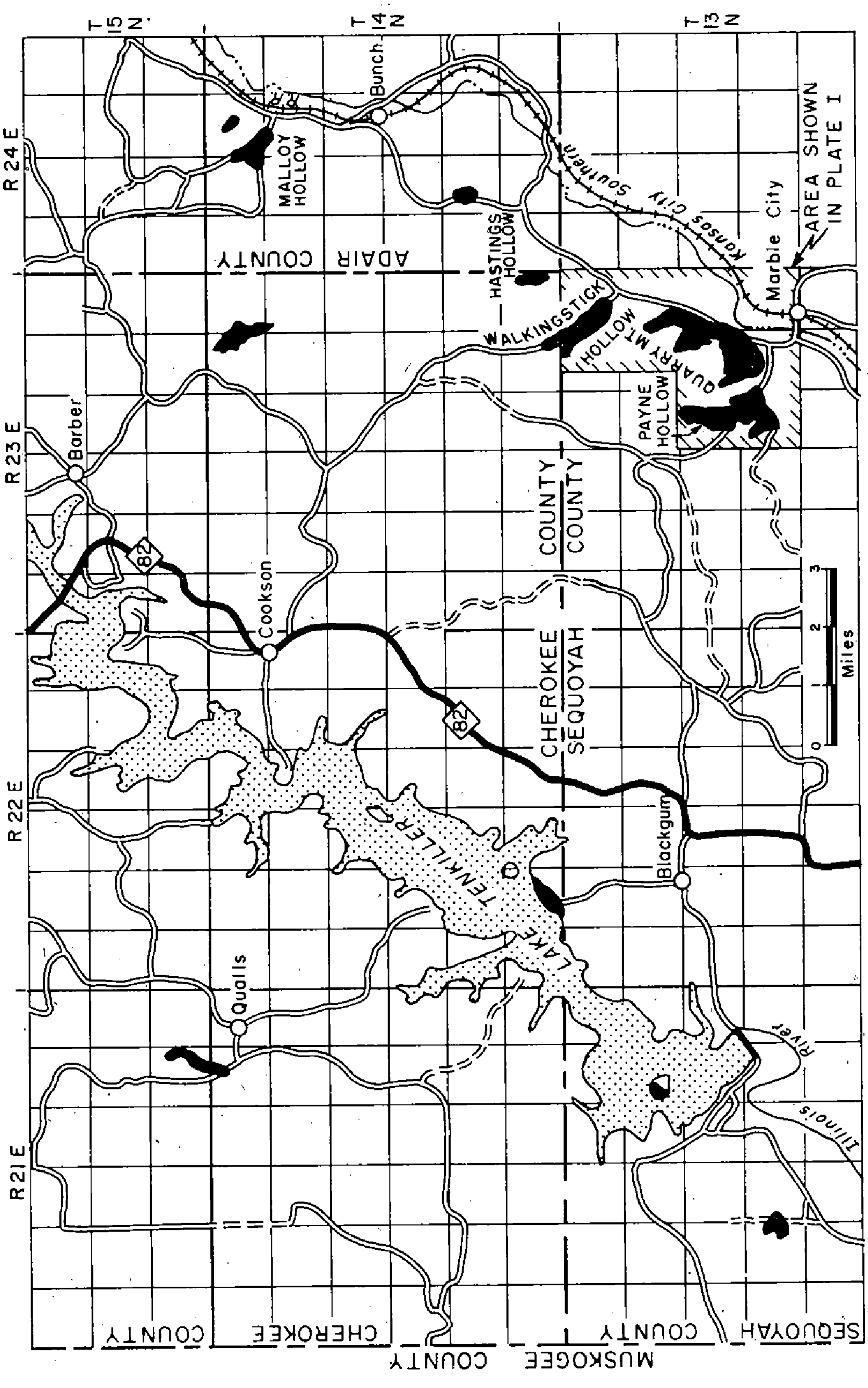
ST. CLAIR FORMATION

Work on the St. Clair formation is not a basic part of this study and a detailed examination of its lithostratigraphy will be deferred to a later report. I will, however, try to describe the composition and texture in enough detail so that a reasonably accurate comparison can be made with the overlying formations. The data given here were obtained entirely from an examination of the formation in the Marble City area (pl. I), mostly of the upper 20 to 30 feet.

The St. Clair was named for exposures at St. Clair Springs near Batesville, Independence County, Arkansas. This name was later extended into northeastern Oklahoma where it has been applied to all of the Silurian limestones which crop out in parts of Sequoyah, Cherokee, and Adair Counties (text-fig. 4). In the Marble City area (pl. I) only the upper part of the formation is exposed, the lower portion and underlying formations being covered.* There is reason to question whether this upper part of the St. Clair is equivalent to the St. Clair of Arkansas, and even more reason to question whether all of the northeastern Oklahoma strata which have been referred to this formation are correlative with the strata in the type area. The name St. Clair is retained in this report although future investigations will almost certainly show the need for some modification or revision. This question is discussed further in the section on *Fossils and age*.

The St. Clair formation has a low acid-insoluble content (text-fig. 5) and in those areas where the magnesium content is also low it is a stone of exceptionally high purity. Beds of 98 to 99 percent $CaCO_3$ (text-fig. 6; Appendix) are not uncommon and this formation has been extensively quarried as a source of lime. The largest workings are those of the St. Clair Lime Company, which consist of a quarry and an underground mine. This mine, the outline of which is shown on plate I, is located in the upper

* The basal part of the St. Clair formation in Oklahoma is exposed at Blackgum Landing on the south shore of Lake Tenkiller, and near Qualls, northwest of the lake (Huffman, 1958, p. 30).



TEXT-FIGURE 4. Map showing the distribution of the St. Clair formation (solid black) in northeastern Oklahoma; outcrop width exaggerated. A geologic map of the Marble City area is shown in plate I. Compiled from Huffman, 1958, plates IV, V.

part of the St. Clair, just beneath the Devonian contact; other prospect pits and quarries are also shown on the geologic map, plate I. An excellent discussion of the chemical composition and physical properties of the St. Clair limestone is in Oklahoma Geological Survey Mineral Report 16, by W. E. Ham, R. H. Dott, A. L. Burwell, and M. C. Oakes (1934).

Lithologic character: The St. Clair formation is a pale-gray to pinkish-gray limestone which generally weathers to a darker gray. The more dolomitic parts have a fine texture and weather to a dark gray. It is commonly rather thick bedded, the thicker beds being 18 to 24 inches thick (pl. II; pl. VI, fig. 2). This formation is well exposed in the Marble City area in natural outcrops as well as in the numerous prospect pits and quarries.

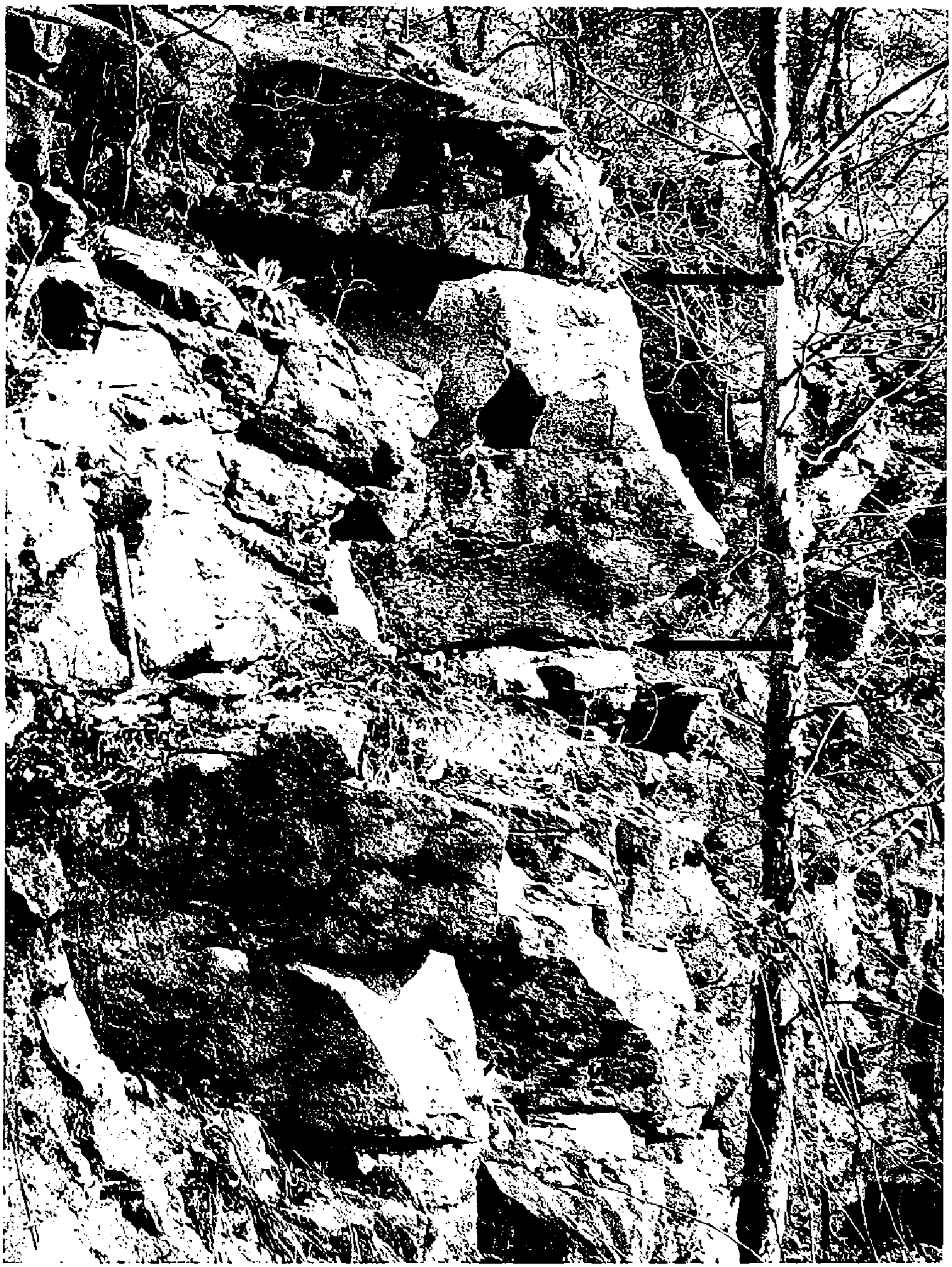
The St. Clair beds of the Marble City area have a distinctive texture. Typically they are calcarenites which are composed in large part of pelmatozoan plates set in a matrix of sparry calcite. These plates, most of which must represent crinoids, may have a pink color, and it is these plates which give much of the reddish color to the St. Clair. It is common for the individual plate to be enclosed in a single crystal as shown in figures 1-3 of plate VII. These pelmatozoan plates do not show up well in peels or in petrographic thin sections of standard thickness, and are best studied in thin sections cut to approximately twice the conventional thickness. The sparry calcite matrix imparts a crystalline texture to the rock and the St. Clair is often described as a marble. Other megafossils, such as brachiopods and bryozoans, are present and may contribute substantially to the rock (pl. VII, fig. 4). In general the preservation of the fossils is good and many of the brachiopod shells have the two valves articulated. Photomicrographs of the St. Clair are shown on the frontispiece, and on plates IV; V; VII; VIII, fig. 2; and XIII, fig. 3. It should be noted that small patches of the St. Clair have been altered to finely crystalline calcite. Such areas are gray to bluish-gray and somewhat resemble the dolomitic parts of the St. Clair. Thin sections show that the typical bioclastic texture is largely obscured in these areas.

Solution cavities or vugs are common in parts of the St. Clair. These are generally lined or filled with coarse, sparry calcite which in some of the larger openings are in the form of large, well-formed crystals. Some of the vugs contain bituminous material and

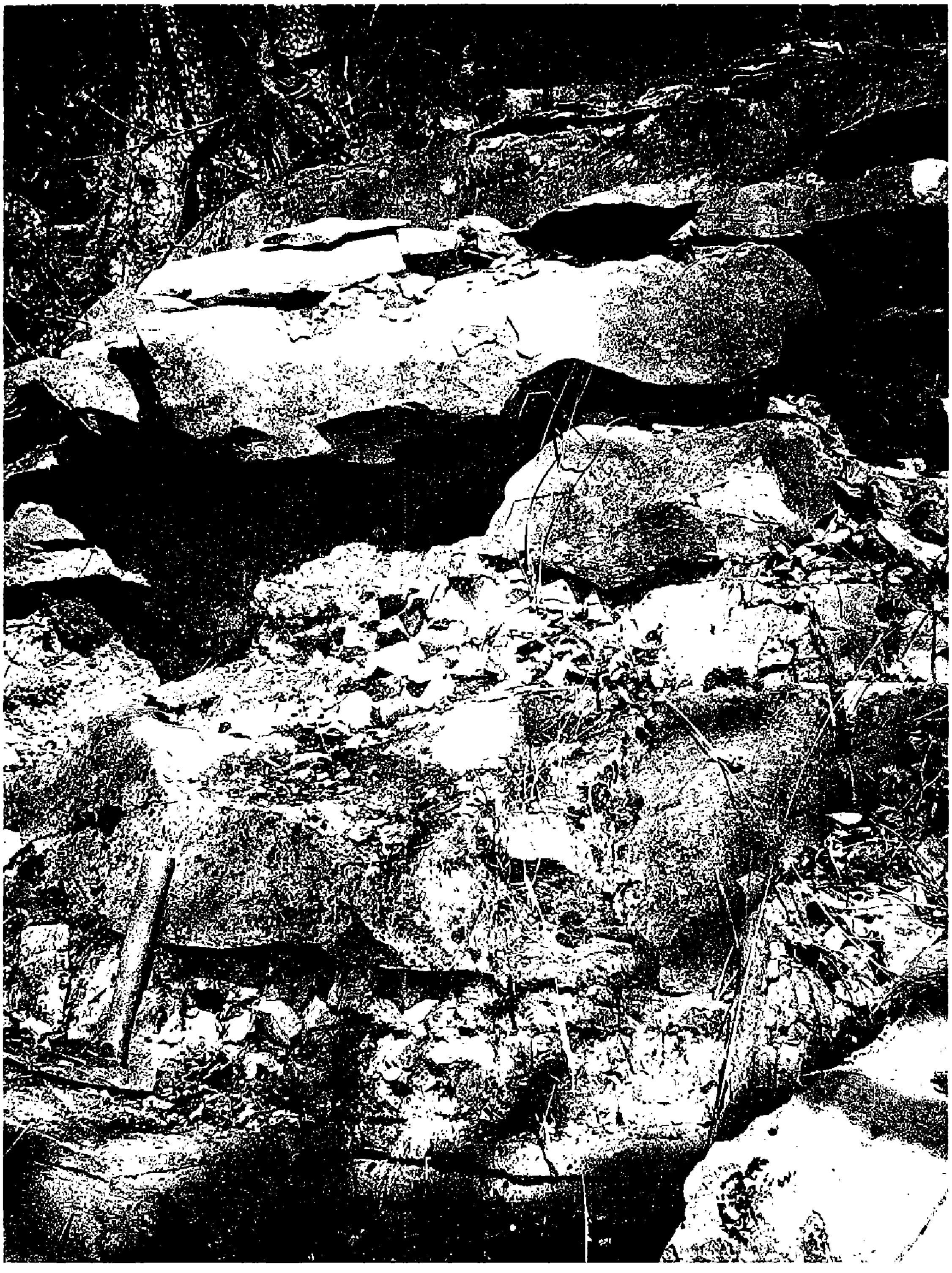
Christian (1953, p. 18) reported that some contain light oil; he also mentioned pockets of sphalerite and galena. Scattered through the St. Clair are pockets of gray, finely laminated carbonate, some of which have a slightly higher insoluble-residue content than does the surrounding rock. In places this laminated material is separated from the enclosing rock by a zone of sparry calcite, suggesting that it represents the filling of calcite-lined cavities. Some of this material in the upper part of the formation appears to represent debris from the overlying formations which was introduced along fissures. There are, however, pockets of finely laminate carbonate as much as 90 feet below the top of the formation and these do not seem to be connected with the overlying strata; the origin of these is not clear, although they may possibly represent some kind of internal sediment.

The St. Clair formation is a remarkably pure carbonate rock. Excluding the laminated material and sandstone-filled fissures discussed elsewhere, the acid insolubles from 19 rock samples average only 0.28 percent, and the maximum is less than 0.5 percent (text-fig. 5; Appendix). Two specimens of the laminated carbonate which were tested for HCl-insoluble residues did yield significantly higher percentages (3.4 and 3.1 percent), but both were from the upper 20 feet of the formation and probably represent debris from the overlying formations which was brought in along solution fissures. The channel samples studied by Ham et al. (1943, p. 16-19) had very little insoluble material, with all but one having in excess of 99 percent carbonate ($CaCO_3$ plus $MgCO_3$; text-fig. 6).

Most of the HCl-insoluble residues contain a substantial amount of quartz. Some of this is in the form of subangular to subrounded detrital grains up to 0.1 mm in diameter, and some is in well-formed, doubly terminated quartz crystals up to approximately 0.25 mm in length. The latter may represent secondary overgrowths on detrital grains although this fact has not been clearly demonstrated. In addition to quartz, some samples yielded a small amount of a light-green glauconite; some also have considerable amounts of dark, bituminous material, and others have much pyrite and limonite, and possibly some sphalerite. I have observed two residues with a pale, yellowish-brown material, possibly some form of clay.



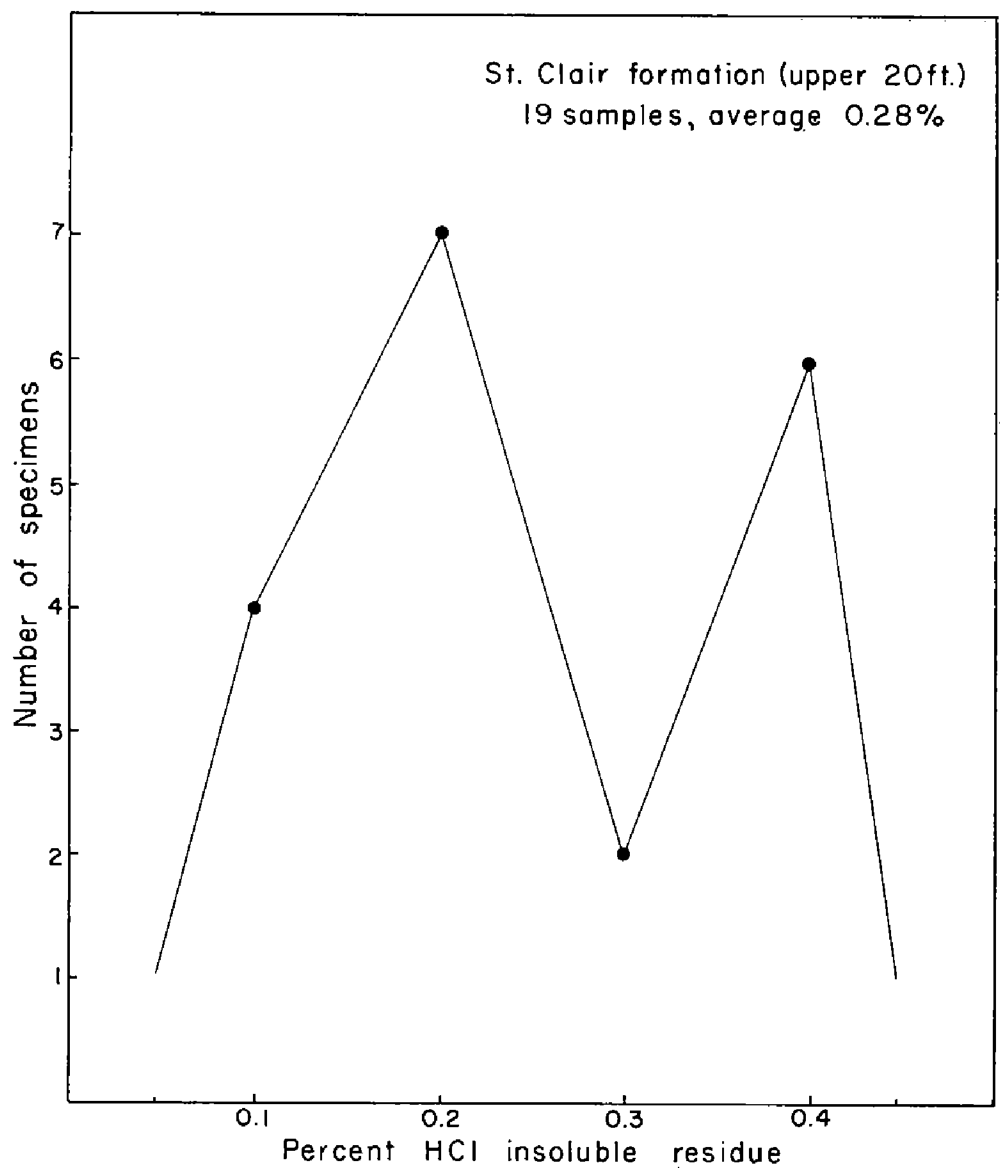
St. Clair, Frisco and Sallisaw formations at stratigraphic section S1 on the northwest bank of Sallisaw Creek (see Appendix). The lower arrow points to the St. Clair-Frisco contact and the upper arrow to the Frisco-Sallisaw contact.



Sallisaw formation at stratigraphic section S5, south of the St. Clair Lime Company quarry (see Appendix). There are two chert beds present in this outcrop, one just above the hammer head and the other in about the middle of the picture.

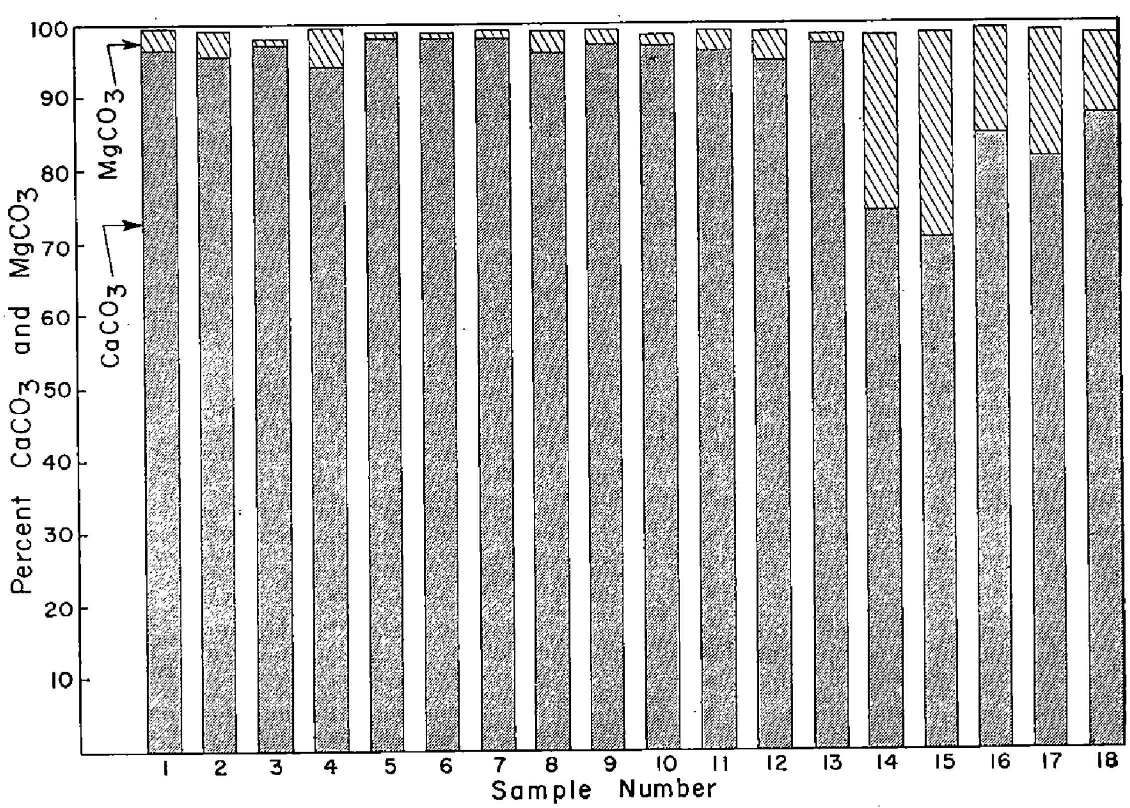
Several rock samples were digested in acetic acid and the residues examined for microfossils. I did not observe any conodonts, arenaceous Foraminifera, or other fossils, although a more extensive sampling may yield a small microfauna.

Analyses of rock and channel samples (text-figs. 5, 6, 7; Appendix) show that the St. Clair formation ranges from a high-purity limestone with more than 99 percent $CaCO_3$ to a calcitic dolomite (Pettijohn, 1957, p. 418) with as much as 36 percent $MgCO_3$. My study in the Marble City area has been, up to the



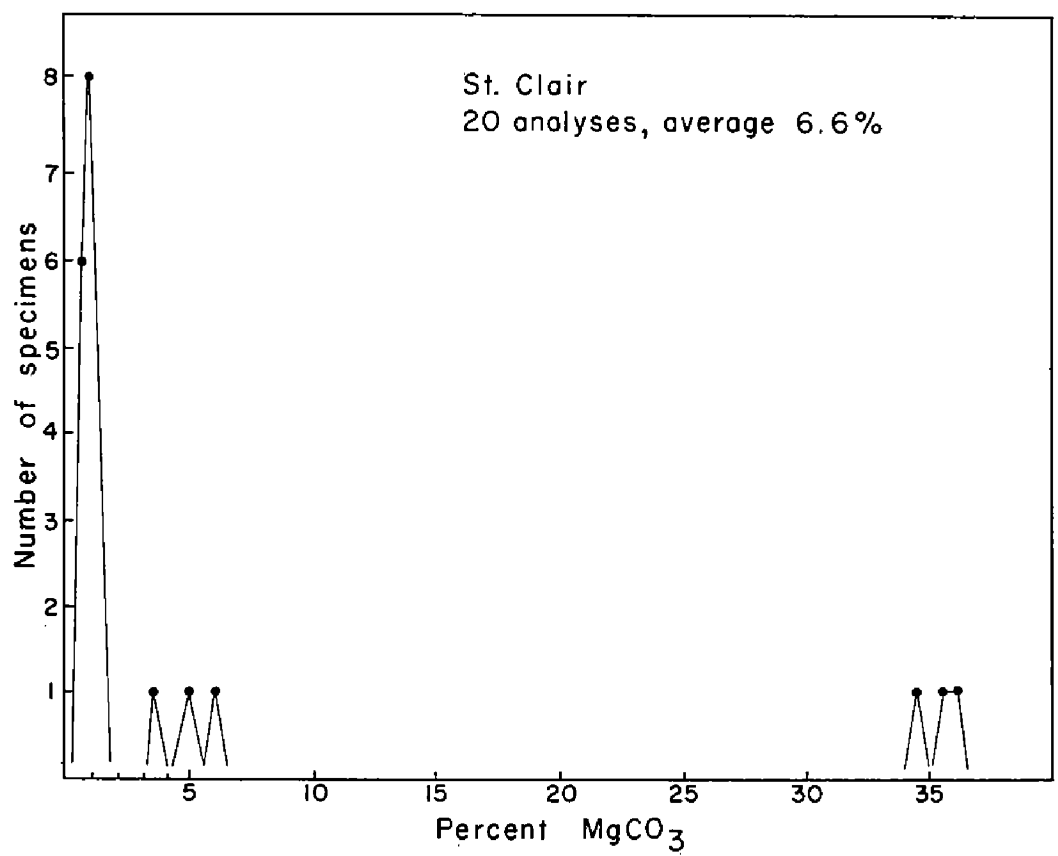
TEXT-FIGURE 5. Frequency diagram showing the distribution of HCl-insoluble residues in the St. Clair formation. All of these analyses are of rock samples collected from the upper 20 feet of the formation in the Marble City area (Appendix, Chemical Analyses). Two residues of the laminated material at S1-A (3.49% and 8.1%) are omitted; see discusssion of this rock type in the section on lithologic character of the formation.

present, largely concerned with the Devonian strata and only the uppermost St. Clair has been investigated in any detail so that the precise distribution of $MgCO_3$ in this formation has not been determined. Ham et al. (1943, p. 9-10) in their study of the St. Clair formation recognized three zones: (1) an upper "blue-gray, dense, and uniformly crystalline limestone that ranges from 5 to 12 feet thick. Locally it contains abundant fossil remains and chert nodules." The dolomite content was reported as variable, but in places with as much as 11.6 percent MgO. It seems probable that this upper zone included, at least locally, some Frisco and Sallisaw; chert is common only in the Sallisaw formation and the high fossil content suggests the Frisco formation. (2) "A middle zone, ranging from 55 to about 100 feet thick, a high-calcium limestone comparatively free from dolomite, is composed largely of crinoid fragments." (3) "The lowest exposed zone is a light gray dolomitic limestone containing as a general rule from 30 to 50 percent dolimite."



TEXT-FIGURE 6. Graph showing the distribution of $CaCO_3$ and $MgCO_3$ in 18 samples collected from the St. Clair formation in the Marble City area. These data are compiled from Mineral Report 16 (Ham et al., 1934); the location and stratigraphic position of each sample are listed on pages 16 to 18 of their report. These are analyses of channel samples, a total of 331 feet being represented in the 18 analyses given above (see also text-figs. 3, 5, 6)

The more recent mining operations in the St. Clair formation show that dolomitic bodies are present in the upper 30 feet or more of the St. Clair. These bodies appear to be quite irregular in their stratigraphic and geographic distribution and this makes it difficult to state with any degree of precision just how much of the St. Clair is dolomitic, a point which should be kept in mind when examining the analytical data shown in text-figures 6 and 7. Only a detailed stratigraphic investigation of all of the beds exposed in the Marble City area will give the complete answer, but enough work has been done to permit certain observations: (1) The uppermost St. Clair beds, those lying just beneath the Devonian strata, are in some places high-purity limestone having in excess of 99 percent $CaCO_3$, and in other places they are strongly dolomitic with up to 35 percent $MgCO_3$. (2) The composition of the overlying Frisco is unrelated to the distribution of calcium and magnesium in the St. Clair, this formation having a uniformly low magnesium content. (3) The dolomitic beds, at least those in the



TEXT-FIGURE 7. Frequency diagram showing the distribution of $MgCO_3$ in the St. Clair formation. These are analyses of rock specimens collected from the upper 20 feet of the formation (see Appendix). Analyses of channel samples are shown in text-figure 6.

upper 30 feet or so of the St. Clair, are not distributed according to any well-defined zone (or zones), but lens in and out, in places quite abruptly. This topic is discussed further in the section, Stratigraphic Distribution of Dolomite.

Fissures filled with Sylamore sandstone are relatively common in the St. Clair (pl. XIII, fig. 3) and some of these extend down into the formation for a distance of 20 feet or more. Fissures filled with debris from the Frisco are also common, but as a rule these are considerably shorter. These are discussed in the sections on the Frisco Formation and Sylamore Sandstone.

Strata overlying the St. Clair formation: The St. Clair is unconformably overlain by various Devonian strata; in places it is directly overlain by the Frisco formation, in other areas by the Sallisaw formation, and in still others by the Sylamore member of the Chattanooga formation. These relationships are shown on the map and stratigraphic cross section (pl. I). A detailed discussion of this topic is given in the sections on Frisco Formation, Sallisaw Formation, and Sylamore Sandstone.

Thickness and distribution: The St. Clair formation crops out in parts of Sequoyah, Cherokee, and Adair Counties (text-fig. 4); however, only its lithostratigraphic aspects in the Marble City area (pl. I) are discussed in this report. Within this area it is exposed in three outcrop belts: (1) A western belt extending for about a mile along Payne Hollow; (2) A large area extending from the big bend of Sallisaw Creek north into section 12 (this includes the St. Clair Lime Co. mine and quarry); (3) A northern belt along Walkingstick Hollow, extending a short distance into Cherokee County. The formation is well exposed at many places within these areas, but probably the best place to examine it is in the quarries of the St. Clair Lime Company in the eastern half of section 14 (pl. VI, fig. 2) where approximately 95 feet of St. Clair beds is exposed.

The total thickness of the St. Clair formation cannot be determined on the surface as the base is nowhere exposed in the Marble City area. In the latter part of 1960 the St. Clair Lime Company drilled a hole to the Sylvan shale and the core was generously given to the Oklahoma Geological Survey. This hole is near the bottom of the St. Clair Lime Quarry (SE¼ NE¼ sec. 14, T. 13 N.,

R. 23 E.), approximately 90 feet below the St. Clair-Frisco contact, and it reached the Sylvan shale at 97 feet. The strata in this area are nearly horizontal so that the total thickness of the St. Clair is very close to 187 feet. A detailed description of this core will be given in a later report.

Fossils and age: In discussing the age of the St. Clair formation of Oklahoma it should be kept in mind that this formation includes all of the Silurian rocks exposed in this general area (text-fig. 4). The lower part of these strata, which is exposed at Blackgum Landing and near Qualls, is lithologically and faunally quite distinct from the beds exposed near Marble City and there is no reason, stratigraphic or faunal, for combining all of these strata into a single formation. In the present report I am concerned only with the upper part of the St. Clair, and the following brief review on fossils and age is restricted to those strata exposed in the Marble City area (pl. I). It should, however, be noted that earlier investigators have generally failed to distinguish between these different stratigraphic units within the "St. Clair," thus introducing further complications into the problem of age and correlation.

Several investigators (Taff, 1905; Powell, 1951; Christian, 1953) have given lists of fossils from the upper St. Clair beds, but most of their identifications were queried, and as none was accompanied by any description or illustrations it is impossible to evaluate them. I have recently made large collections from the upper 95 feet of the St. Clair in the Marble City area. This fauna is strongly dominated by the brachiopods, but it also includes a substantial number of bryozoans and trilobites, along with some corals and mollusks. This appears to represent a Niagaran or "Middle Silurian"* fauna but its precise age and correlatives are uncertain. Ulrich (in Taff, 1905, p. 2) first correlated the upper part of the Oklahoma St. Clair with the type St. Clair of northern Arkansas, assigning both a Middle Silurian (i.e. Niagaran) age,

*Most American stratigraphers have used Niagaran and Middle Silurian as synonymous, assuming these strata to be equivalent to the Wenlock (i.e. Middle Silurian) of Great Britain. In a recent article Boucot (1958, p. 1029-1030) pointed out that the basal part of the American Niagaran or "Middle Silurian" series carries fossils of late Llandoverian age (i.e. Lower Silurian of European usage) and the upper part carries fossils of early Ludlovian age (i.e. Upper Silurian of European usage).

but later he (Ulrich, 1911, p. 559) stated that this part of the Oklahoma St. Clair was younger than the Arkansas strata. Most subsequent authors (Gould and Decker, 1925; Swartz et. al., 1942, chart No. 3) have correlated the St. Clair of Oklahoma with the St. Clair of Arkansas, but I suspect that Ulrich was correct in assigning the St. Clair strata at Marble City to a somewhat younger age than that of the type St. Clair.* I plan to describe the Marble City-St. Clair fossils and at that time will discuss the age and correlatives in some detail.

FRISCO FORMATION

The Frisco formation was named by Reeds (1926, p. 13) for those limestone strata bearing an Oriskany fauna (Deerparkian) which crop out near Frisco in the northeastern part of the Arbuckle Mountain region. Reeds treated the Frisco as the youngest formation in the Hunton group and this usage has been followed by all subsequent investigators.** Recently I (1957, p. 47) reviewed the nomenclatorial history of this formation and designated the exposures along Bois d'Arc Creek in NE¼ sec. 11, T. 2 N., R. 6 E., as the type section (Amsden, 1960, p. 283-284, stratigraphic section P11). In 1958 Ventress presented a biostratigraphic study of the Frisco in the Arbuckle region as a Master of Science thesis to the University of Oklahoma, and in 1960 I described the formation at some length in a report which included geologic maps, chemical analyses, and photomicrographs.

*I have recently collected a large number of fossils from the St. Clair formation in its type area near Batesville, Arkansas.

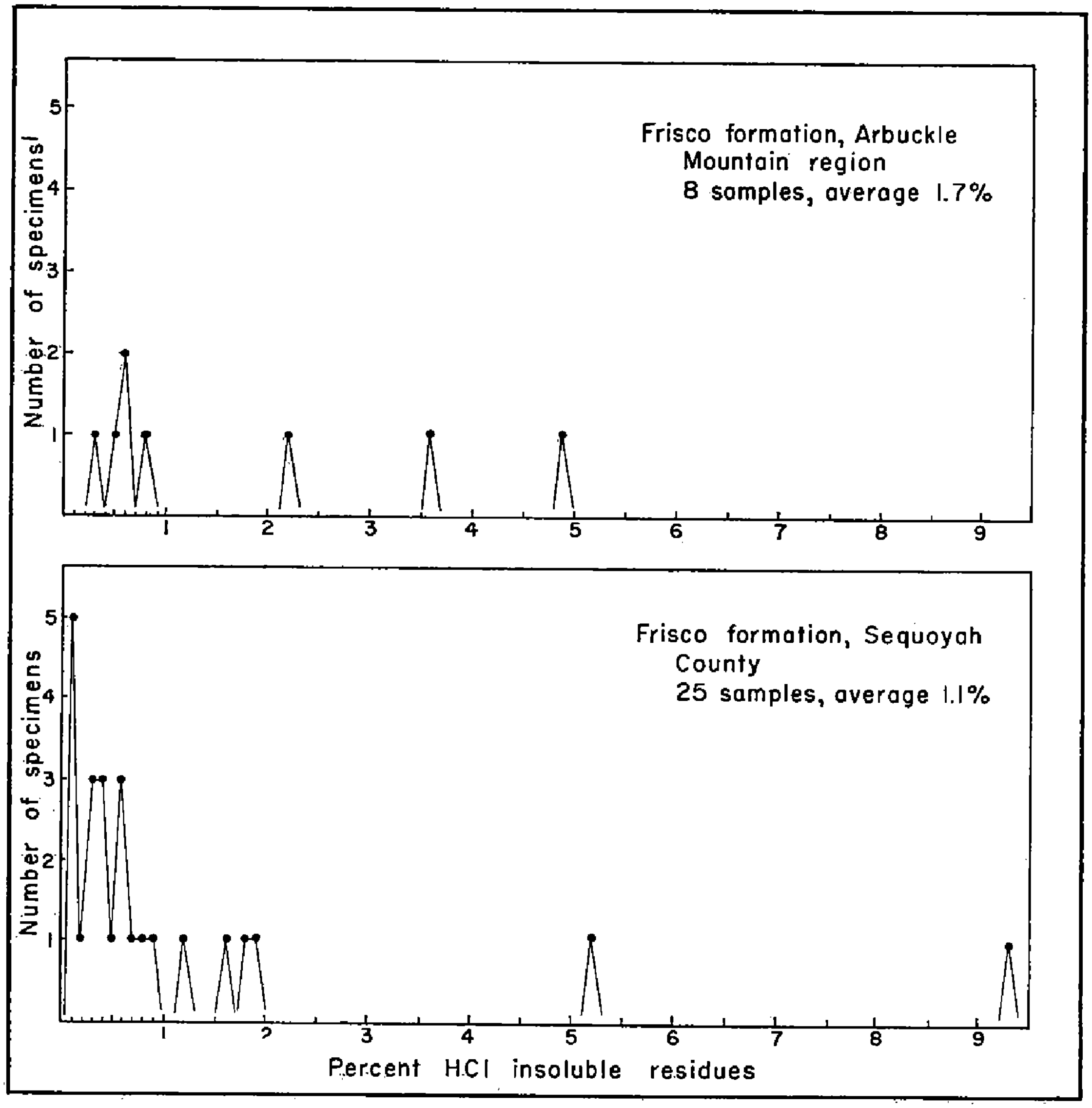
**The term Hunton has been used by surface stratigraphers for those stratigraphic units extending from the base of the Ideal Quarry member (Early Silurian) to the top of the Frisco formation (Early Devonian); its use has been confined to the type area in the Arbuckle Mountain region and Criner Hills of south-central Oklahoma (Taff, 1904; Reeds, 1911; Maxwell, 1936; Ham et al., 1954; Amsden 1960). The Hunton group has been much more widely used by subsurface stratigraphers for the sequence of strata, largely carbonates and cherts, between the Sylvan shale and the Woodford-Chattanooga shale; it has been applied over a large geographic area in the mid-continent region and unquestionably includes stratigraphic units which are both older and younger than those present in the type area. Recently Swann and Willman (1961) have proposed to formalize this usage by recognizing a Hunton Limestone Megagroup, a lithostratigraphic unit which, in southern Illinois, includes some 1800 feet of strata, ranging in age from Early Silurian (possibly Late Ordovician) to Upper Devonian. Whatever may be the the merits of using "megagroups" in subsurface work, such a broadly defined lithostratigraphic group would appear to serve little purpose in a detailed surface investigation. I do not think there is any need to combine the Silurian and Devonian strata of northeastern Oklahoma into a group or "megagroup."

Oriskany strata were first recognized in the Marble City area of northeastern Oklahoma by Schuchert (1922, p. 666-667), and in 1930 Cram (p. 550) applied Reeds' name Frisco to these beds. My own biostratigraphic investigation of the Frisco in both outcrop areas, combined with the study of Ventress in the Arbuckles, shows that the Frisco strata of Sequoyah County are remarkably similar in lithology and fauna to the Frisco strata in the type region, and I believe Cram was justified in extending this name to northeastern Oklahoma. Most of the present report will be devoted to discussing the Sequoyah County Frisco as I have already described the strata from the type region in considerable detail (1960, p. 125-135; pl. VIII; pl. XIV, figs. 1-4; panels II, III). For convenience a short resume of the Arbuckle Mountain Frisco is given on the following pages.

FRISCO FORMATION (HUNTON GROUP) — ARBUCKLE MOUNTAIN REGION

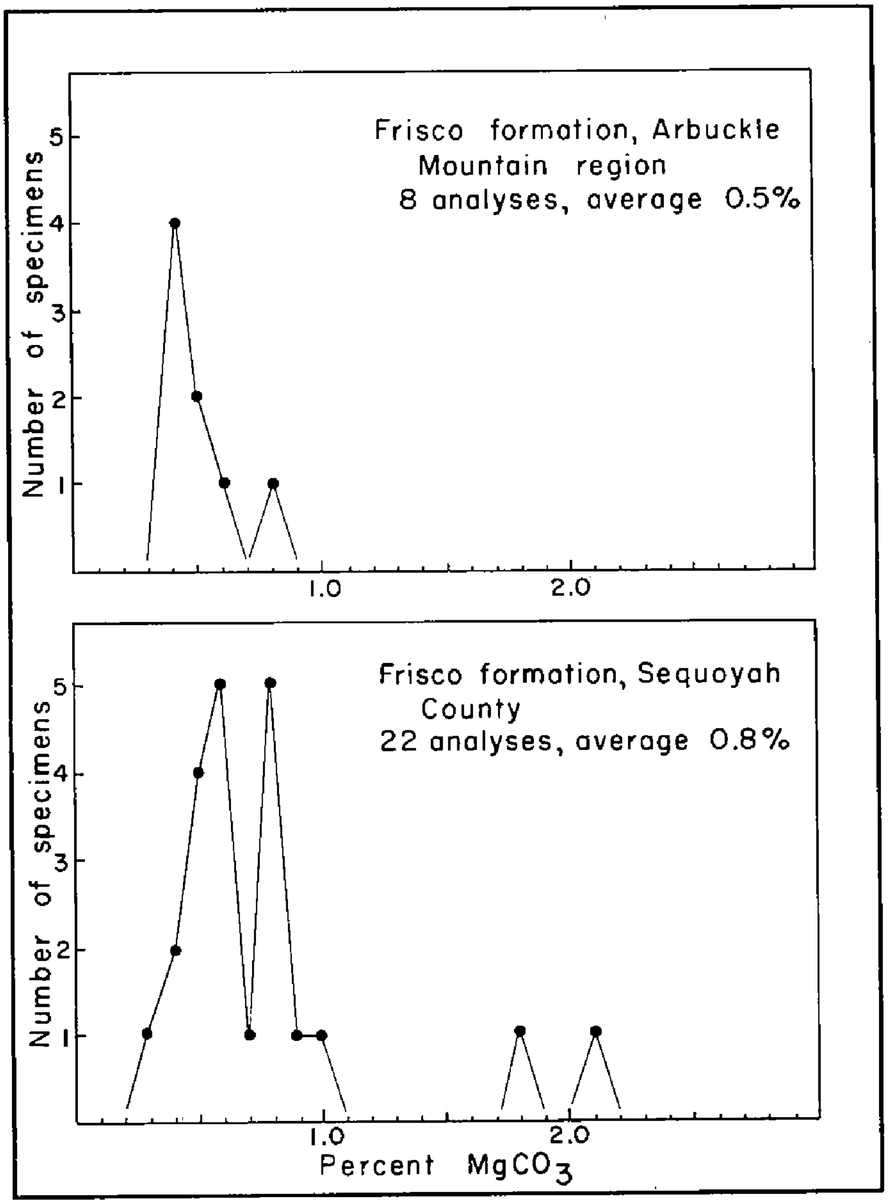
The Frisco formation in the Arbuckle Mountain region is a fossiliferous calcarenite, generally in beds two or three feet thick, but locally it is massive with individual beds as much as 10 feet thick. The beds are somewhat irregular and tend to weather with a pitted or "pot-holed" surface (Amsden, 1957, pl. III; 1960, pl. VIII). Chert is locally present, mostly in the form of small, light-colored, vitreous nodules, but with some elongate bands up to one foot thick.

The Frisco in the type area is mainly a bioclastic calcarenite composed in large part of fossil debris set in a matrix of clear calcite (Amsden, 1960, pl. XIV, figs. 1-4; this report, pl. X). Its texture is variable with some beds being relatively fine grained (pl. X, fig. 3) and others coarse enough to approach a calcirudite. The fossils are mainly brachiopod and snail shells along with some corals, bryozoans, and, locally, abundant pelmatozoan plates. I have not observed any reef-like structures, nor have I seen any calcareous algae. There is considerable evidence of breakage and most of the brachiopod shells are disarticulated. An interesting rock type is illustrated on plate X, figure 1; most of the matrix in this specimen is clear calcite, but beneath the larger fossil fragments are dark areas or "shadows," which are produced by a concentration of finely divided calcite matrix. The specimen illustrated in figure 2 of plate X has a relatively large proportion of pelmatozoan debris, although other fossil groups such as the corals and brachiopods are present. The clear calcite surrounding a pelmatozoan plate is commonly in optical continuity with the plate and both may show a common cleavage (Amsden, 1960, pl. XIV, figs. 3, 4), but aside from this there is little evidence of "recrystallization." The boundaries of the individual fossil fragments are almost everywhere sharp, showing little or no evidence of any "corrosion" and I suspect that most of the sparry calcite matrix is a primary feature of the rock texture (Amsden, 1960, p. 130).

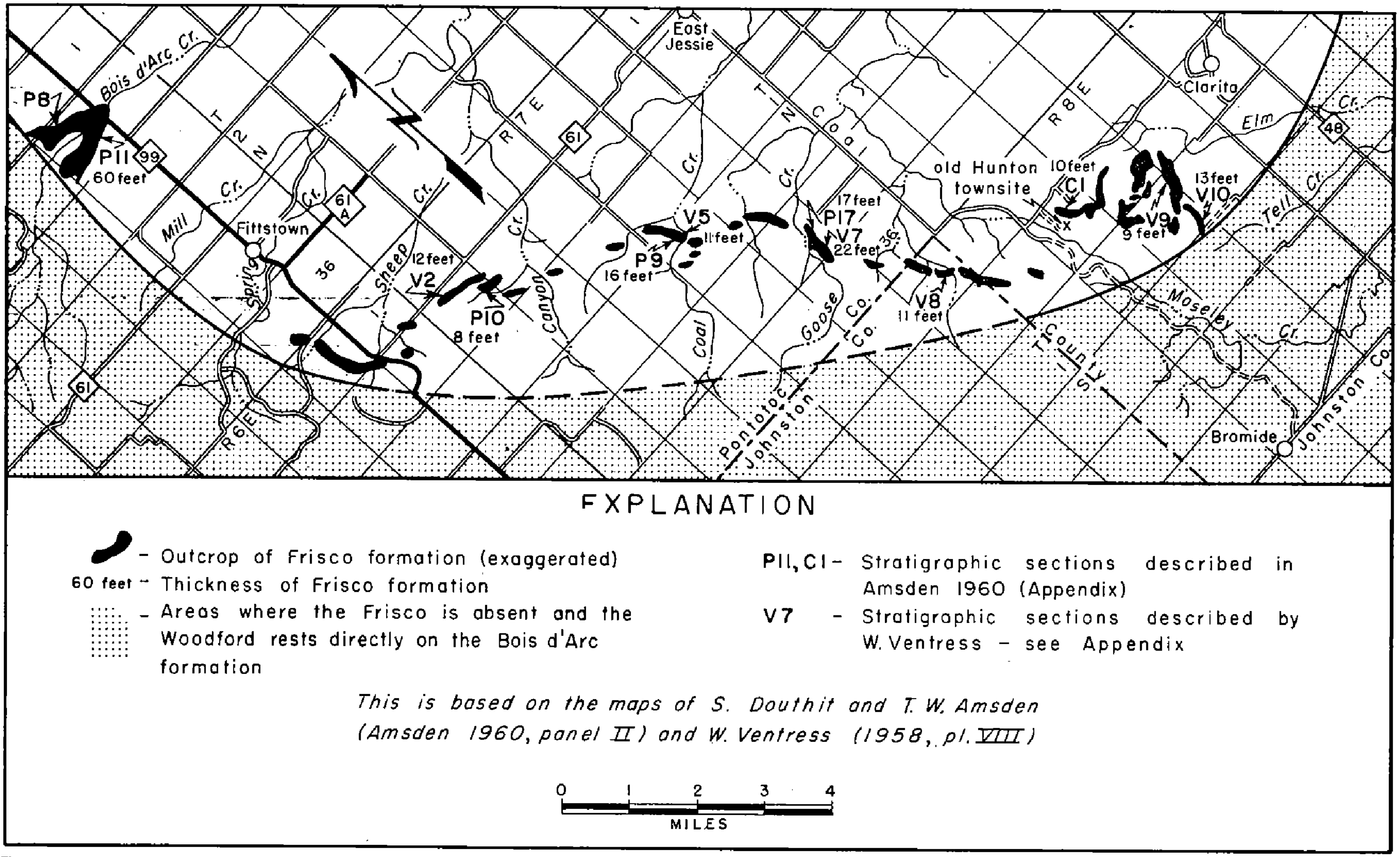


TEXT-FIGURE 8. Frequency diagram showing the range of HCl-insoluble residues in the Frisco formation of the Arbuckle Mountain region (above) and of Sequoyah County (below). The data for this range are given in the Appendix.

The Frisco formation of the Arbuckle region, like that of Sequoyah County, has a low acid-insoluble content (excluding chert). The average of eight rock specimens tested is only 1.7 percent, with a maximum of about 5 percent (text-fig. 8). A considerable part of the residue consists of subrounded to subangular, clear quartz grains, few of which exceed 0.2 mm in diameter. Some of the insoluble material, however, is in the form of small quartz crystals, a few of which are doubly terminated; a few small aggregates of quartz crystals are also present. These quartz crystals commonly show little evidence of abrasion and some may repre-



TEXT-FIGURE 9. Frequency diagram showing the range of $MgCO_3$ in the Frisco formation of the Arbuckle Mountain region (above) and of Sequoyah County (below). The data for this range are given in the Appendix.



TEXT FIGURE 10. Outcrop map of the Frisco formation in the Arbuckle Mountain region showing the location and thickness of the described stratigraphic sections. Those sections with the letter prefix P or C are described in the Appendix of my 1960 paper on Hunton stratigraphy; those with the letter prefix V were measured by William Ventress and are described in the Appendix of the present report. All thicknesses were determined by Ventress. The stippled areas indicate those places where the Frisco was removed by pre-Woodford post-Hunton erosion, allowing the Woodford to be deposited upon the Bois d'Arc formation (Helderbergian). The Frisco type section is at P11 on Bois d'Arc Creek.

sent secondary overgrowths on detrital grains. Fragments of silicified fossils are generally present and may be abundant. Most residues have some glauconite and locally it is the dominant constituent; the specimen illustrated in plate X, figure 3 has a substantial amount of glauconite, most of which is present as an infiltration into pelmatozoan plates. Elsewhere the glauconite is in the form of polylobate grains or as a filling of various hollow fossils (Amsden, 1960, p. 129).

The Frisco formation has an extremely low magnesium content. Of eight specimens tested, all had less than one percent $MgCO_3$ (text-fig. 9).

Frisco outcrops in the Arbuckle region are confined to a narrow belt extending along the northeastern margin of the area, from central Pontotoc County southward to old Hunton townsite in Coal County (text-fig. 10). In the northern exposures, along Bois d'Arc Creek, the formation reaches its maximum thickness of 60 feet; from here southward it thins rapidly and is generally less than 20 feet thick. Throughout its outcrop belt in the Arbuckle Mountain region the Frisco rests upon the Bois d'Arc formation of Helderbergian age and is overlain by the Woodford formation (text-fig. 2).

The Frisco fauna is discussed under Frisco Formation—Sequoyah County, *Fossils and age*.

FRISCO FORMATION — SEQUOYAH COUNTY

Lithologic character: The Frisco formation in Sequoyah County is a highly fossiliferous limestone in beds up to 18 inches or two feet in thickness (pl. II). Its color is light to medium gray, generally weathering to a pale gray. Chert is rare, but some beds do include small nodules up to 2 or 3 inches long.

The Frisco is a bioclastic limestone, composed in large part of fossil debris (frontispiece; pls. IV; V; VIII; IX; XII, fig. 1). The grain size ranges from a coarse calcilutite (pl. XII, fig. 1) to a fine calcirudite (pls. IV; VIII, fig. 2), although most of the formation has a calcarenite texture. The matrix is also variable, some parts having sparry calcite (pls. V; IX, figs. 2, 3) and other parts finely divided calcite (frontispiece; pls. IV; VIII; IX, fig. 1), or a mixture of the two (pl. IX, figs. 5, 6). Three major rock types or lithofacies can be recognized in this variable sequence: (1) a relatively coarse calcarenite or coquina; (2) a calcilutite (grading into a fine calcarenite) composed of broken fossil debris, and (3) a pelmatozoan limestone. All three types grade into one another and these actually represent end members in a continuous series.

(1). The coarse, shell-rich limestone or coquina is perhaps the most common, and certainly the most distinctive, rock type in the Frisco formation (frontispiece; pls. IV; V; VIII, fig. 2; IX, fig. 1). Typically it is a rather heterogeneous mixture of fossil material, mostly brachiopod shells, with some snail shells, bryozoans, corals, and remains of other groups.* It is poorly sorted as to size and fragments range in size from microscopic fossil debris up to brachiopod shells as much as two inches long. Characteristically it is a calcarenite, although not uncommonly some parts are coarse enough to be classed as calcirudites (pl. VIII, fig. 2). This rock type generally displays some orientation and most fossils have their long dimensions alined in the plane of the bedding (frontispiece), although in places this alinement is quite crude (pl. IV). The matrix is in places clear, sparry calcite (biosparite) (see pls. V; IX, figs. 2-4; XII, fig. 1), and in other places it is finely divided calcite (biomicrite) (see frontispiece; pls. IV; VIII; IX, fig. 1); less commonly it is a mixture of sparry calcite and

*I have not observed any reef-like structures in any part of the Frisco; no calcareous algae have been observed.

finely divided calcite (pl. XI, fig. 1). In places this rock has undergone considerable solution and many of the fossils are cut off by stylolite seams (pl. VIII, fig. 2). Both the megascopic field examination of the formation and the microscopic study of it in thin sections show that extensive breakage of the hard parts of fossils took place either before or during deposition. Much of the finer debris which is mixed in with the larger shell fragments appears to have been derived by comminution of the organic material. This shell coquina facies is unique in the Marble City area and not likely to be confused with any of the rock types in the underlying St. Clair or overlying Sallisaw formations. A similar rock type is also the dominant facies in the Frisco of the Arbuckle region (pl. X).

(2). The second type, which is fairly common in the Marble City area, is a light-gray, fine-grained limestone that appears, at least in a field examination, to be poorly fossiliferous. However, a microscopic examination in thin section shows that it is a biosparite composed of fossil fragments set in a matrix of clear calcite (pls. IX, figs. 2-4; XII, fig. 1). Individual fossil fragments are as much as 0.5 mm or more in length so that in part the rock falls within the range of a fine calcarenite, but for the sake of convenience it is termed the Frisco biocalcilutite. Most of the debris is clearly composed of the broken pieces of larger fossils (pl. IX, fig. 4) and presumably represents the finer fragments which were flushed out of the shell facies discussed above. This rock type is concentrated into beds, or, locally, it makes up most of the Frisco (stratigraphic section S4), but small patches are also intimately associated with the other two facies and there can be little doubt that it represents a part of Frisco deposition. A nearly identical facies is present in the Frisco formation of the Arbuckle Mountain region (pl. X, fig. 3). Past investigators have confused this rock type with parts of the Sallisaw and with parts of the St. Clair; it has a close resemblance to the more calcareous facies of the Sallisaw, and has a superficial resemblance to the dolomitic parts of the St. Clair (see *Strata underlying the Frisco formation* and *Strata overlying the Frisco formation*).

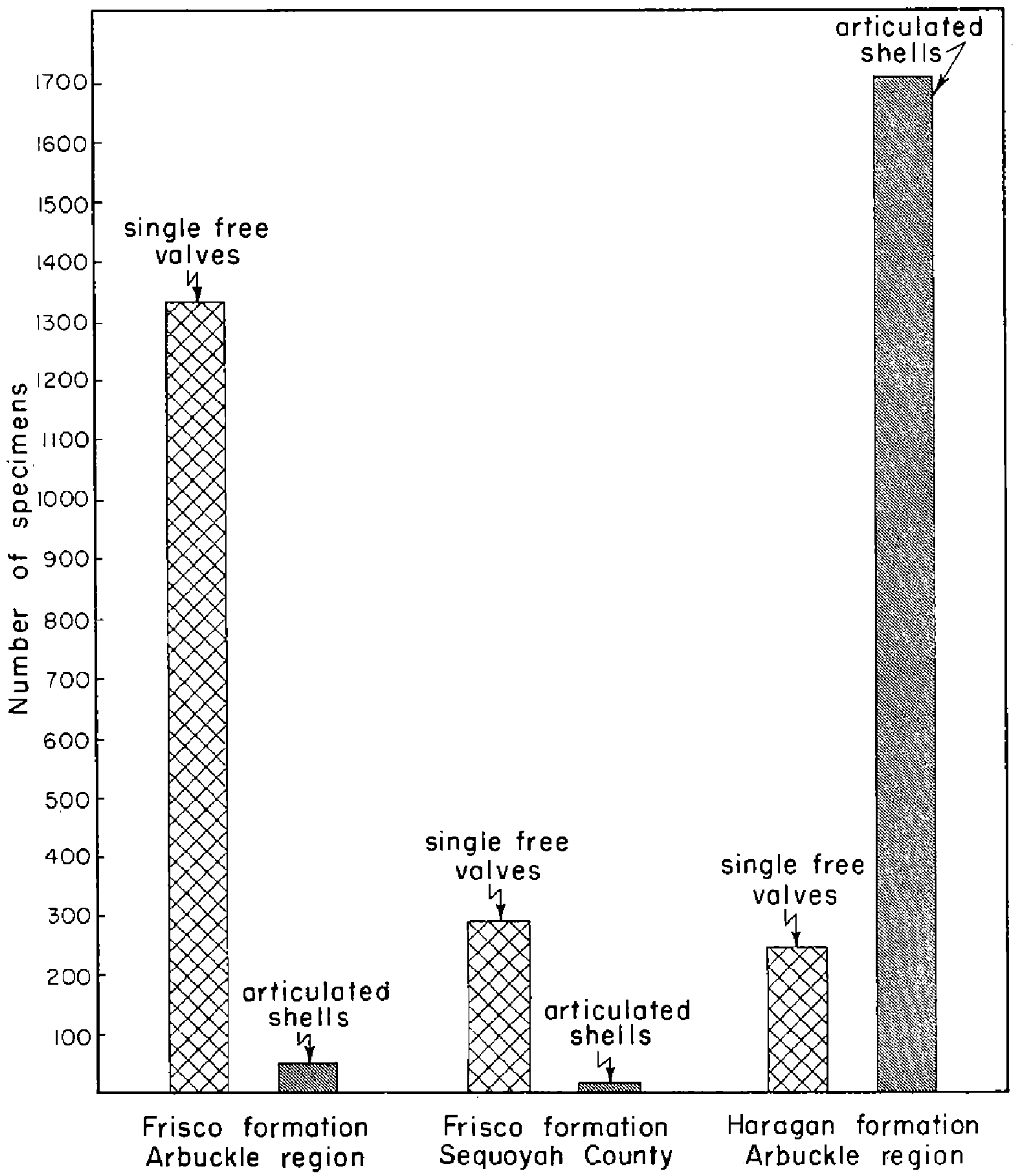
(3). The third rock type covers that portion of the Frisco formation in which pelmatozoan plates are the dominant part of the fossil debris (pl. IX, figs. 5, 6). The matrix may be either clear, sparry calcite, or microcrystalline calcite, although in the latter case there is generally at least a rim of clear calcite around the individual plates. This type is in no case entirely composed of pelmatozoan plates, and as the other fossil groups become proportionately greater it grades into the shell coquina of type (1). The pelmatozoan facies of the Frisco has some resemblance to the St. Clair formation although the latter rarely has a micrite matrix.

Many of the Frisco fossils are broken in such a way that it is difficult for the collector to obtain good specimens. Of course a considerable amount of breakage takes place in the process of extracting the shells from the rock, but there is also excellent evidence pointing to extensive fragmentation either before or during deposition. At the time this organic debris was being shifted about on the sea floor most of the brachiopod valves were separated, and this took place to such an extent that articulated shells are unknown for some species. This process of disarticulation was equally active in the Arbuckle Mountain region and in Sequoyah County (text-fig. 11). Although the total number of specimens collected from the Frisco formation in the Arbuckle region is considerably greater than that from the Sequoyah County outcrops, the articulated-shell/free-valve ratio is almost identical (0.04).

It is interesting to compare the degree of disarticulation in a bioclastic limestone like the Frisco with that found in a marlstone deposit such as the Haragan formation of the Arbuckle Mountain region (Amsden, 1960, p. 86-99). A survey of ten Haragan species (out of a total of 38) shows an almost complete reversal of conditions from those of the Frisco, with articulated shells strongly predominating over the free valves (text-fig. 11); the articulated-shell/free-valve ratio is 7 in the Haragan, and 0.04 in the Frisco. Precisely the same results are obtained when a comparison is made of selected genera* that are represented in both the Frisco and Haragan formations (the species are different). The comparison is shown graphically in text-figure 12 where the free valves, obtained by counting the total number of isolated pedicle and brachial valves, are plotted as a percentage of the total number of specimens in that

* Three of the groups compared in text-figure 12 are genera, whereas the fourth is based on the Terebratulacea and includes all of the genera and species of that superfamily which are present in the Frisco and Haragan formations.

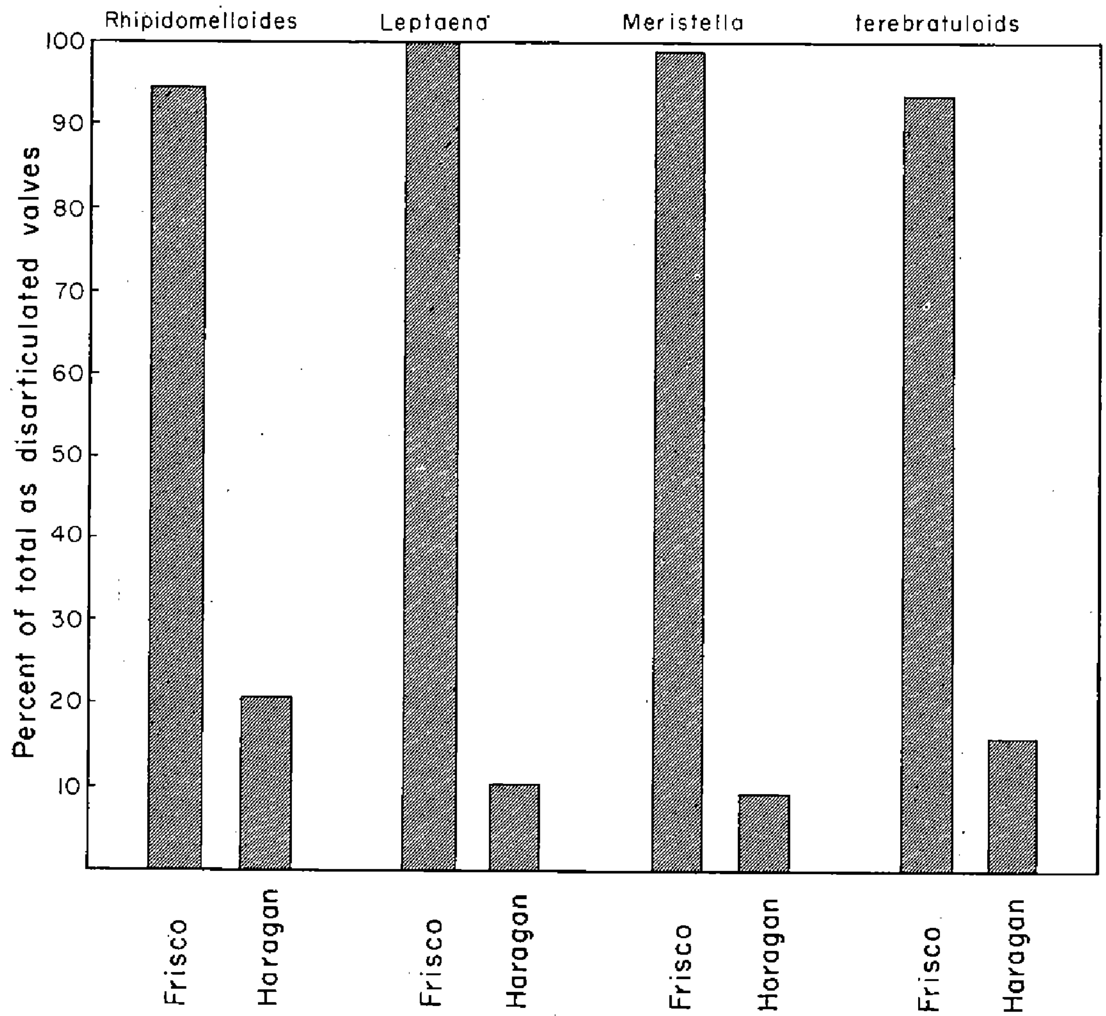
particular group, obtained by counting the articulated shells, pedicle valves, and brachial valves. This fully supports the other lines of evidence pointing to a quiet, nonturbulent type of deposition for the Haragan, well removed from the zone of effective wave action (Amsden, 1960, p. 93). The Frisco, on the other hand, must represent a relatively high-energy deposit laid down in much more



TEXT-FIGURE 11. Graph showing the proportion of articulated brachiopod shells in the collections from the Frisco formation of the Arbuckle Mountain region, the Frisco formation of Sequoyah County, and the Haragan formation (Helderbergian) of the Arbuckle Mountain region. The bar on the right shows the number of complete shells (both valves in conjunction), and the bar on the left shows the combined number of separate pedicle and brachial valves. The data for the Frisco formation of both areas represent a nearly complete count of all the species represented, whereas those for the Haragan are based on a count of only 10 brachiopod species (out of a total of 38 species).

turbulent waters. These facts are discussed further in the section on Geologic History (see also Amsden, 1960, p. 131).

I find little evidence of "recrystallization" or alteration in the Frisco formation. Some of the clear calcite appears to be optically continuous with the pelmatozoan plates, but aside from this the fossil boundaries are sharp, both where embedded in sparry calcite as well as in the finely divided calcite. There is some vein calcite which may indicate replacement (frontispiece), but, excluding this material, both kinds of matrix are thought to be largely a primary feature of the rock texture formed at the time of deposition (Ams-



TEXT-FIGURE 12. Graph comparing the percentage of disarticulation in selected brachiopod groups from the Haragan formation and the Frisco formation (the Arbuckle Mountain and Sequoyah County Frisco collections combined). The height of the bar indicates the percentage of free valves (pedicles plus brachials) in the total number of specimens (free valves plus articulated shells) for each group. The first three groups represent genera which are present in both the Frisco and Haragan formations (in each case the species are different). The last group is based on all of the terebratuloid brachiopods (Terebratulacea); only a single species, *Rensselaerina haraganana*, is present in the Haragan, but there are six species (asssigned to five genera) in the Frisco and the data from all of these have been combined.

den, 1960, p. 130). Note the sparry calcite rims on some of the fossils in plate IX, figure 1; this appears to resemble the structure which Bathurst (1958, p. 21) called rim cementation.

For the most part, the Frisco formation in Sequoyah County has an extremely low acid-insoluble content. The average of 25 rock specimens is 1.1 percent, with most of the analyses falling below 2.0 percent (text-fig. 8). Only two of the specimens have insolubles significantly above the average (5.2 and 9.5 percent), and these appear to represent small, local concentrations of quartz grains.

The acid residues from most specimens are composed predominantly of clear to slightly cloudy quartz grains. Commonly these grains are angular to subangular, and many have well-defined crystal faces. In fact, well-formed doubly terminated quartz crystals are present in most residues, and may make up most of the sample; for example the residues from the two specimens having the highest percentage (text-fig. 8) are made up in large part of doubly terminated crystals. Only a few moderately well-rounded quartz grains have been observed. At least some of the crystals appear to have originated as overgrowths on detrital grains; however, this aspect needs further investigation. The grains range in size from coarse silt to fine sand, with some of the larger crystals being as much as 0.5 mm long; however, these larger grains are few and most are less than 0.3 mm long. The size range differs somewhat from bed to bed and locality to locality, and some of the samples studied have residues in which the maximum diameter of the grains is 0.1 mm. In general, the larger grains have well-formed crystal faces.

The quantitative distribution of acid insolubles in the Frisco formation of Sequoyah County is similar to that of the Frisco in the Arbuckle region (text-fig. 8), and well-formed quartz crystals are present in the residues from both areas, although probably more abundantly in the northeastern Oklahoma beds. In 1958 Huffman and I (p. 74) described a fossiliferous Frisco core from Pottawatomie County which had 30 percent insoluble residues; most of this was in the form of sand-size quartz grains, many with crystal faces and a few in the form of doubly terminated crystals. The quantity of insolubles in this core is unusually high; however, the fossil evidence for correlating it with the surface Frisco is excellent.

In addition to quartz, most residues contain some glauconite in grains ranging up to 0.3 mm. Typically this has a pale-green, less commonly a brownish-green to olive, color. In some of the residues the glauconite is in the form of fossil steinkerns, and several thin sections show glauconite filling the hollow spaces of corals, bryozoans, and other fossils (frontispiece; many of the dark areas in the Frisco part of the section are glauconite). Glauconite in this form is also common in parts of the Frisco formation in the Arbuckle region (pl. X, fig. 3). I do not know if the glauconite anywhere actually replaces some of the fossil shells or other skeletal parts. In so far as I can tell the glauconite does not seem to be concentrated in the basal part of the formation; it is highly variable in quantity, making up a substantial part of the residue in some beds and only a trace in others, but this variation does not appear to be related to stratigraphic position (e. g., at stratigraphic section S4-E the upper two feet has a considerable amount of glauconite).

Limonite is common in some samples and locally there is a considerable amount of a dark, carbonaceous material. Other minerals, which are present in small quantities, have not been investigated.

The Frisco formation has a low magnesium content and this, combined with its equally low acid-insoluble content, produces a high-calcium stone (text-fig. 3); most specimens tested have over 98 percent $CaCO_3$ (Appendix). The average of 22 specimens analyzed for $MgCO_3$ is 0.8 percent (text-fig. 3), with only two of these having more than 1.0 percent (text-fig. 9); one specimen from stratigraphic section S9-C yielded 1.79 percent $MgCO_3$, and one from the lower two inches of the Frisco in the St. Clair Lime Company mine (stratigraphic section S13) tested 2.12 percent (Appendix). At stratigraphic section S11-CD(d) the basal two inches of the strata provisionally referred to the Sallisaw have 40.6 percent $MgCO_3$, and as the insolubles are only 0.94 percent this could be dolomitized Frisco, but I am inclined to think it is Sallisaw because dolomite is common in that formation (see Sallisaw Formation, *Lithologic character*).

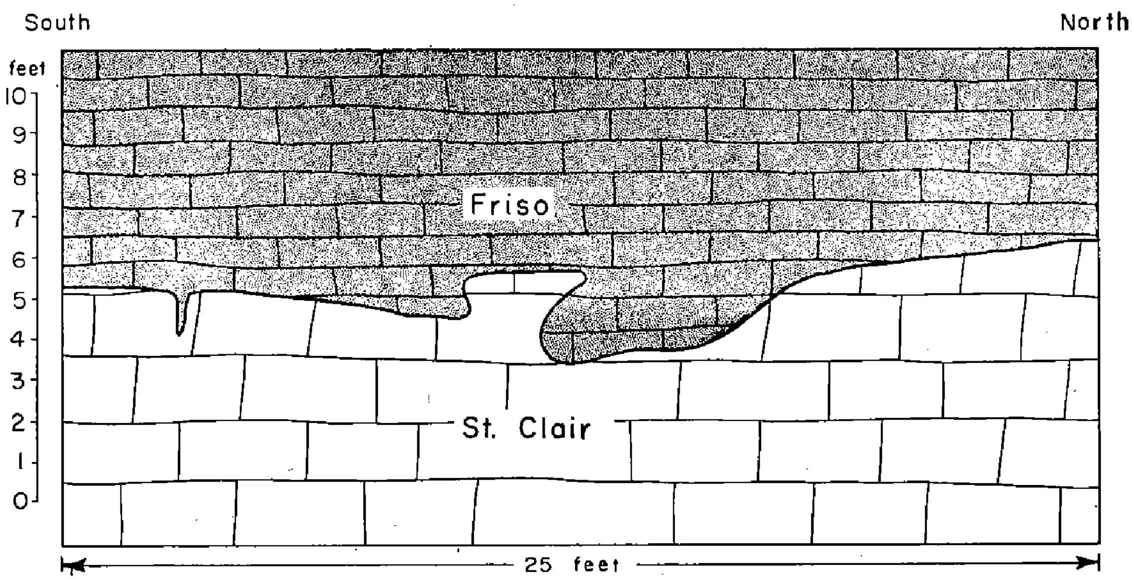
The stratigraphic distribution of $MgCO_3$ in the St. Clair, Frisco, and Sallisaw formations is interesting and significant. Both the St. Clair, including its uppermost beds, and the Sallisaw are locally strongly dolomitic with some strata having 35 percent or more $MgCO_3$ (text-figs. 7, 18). In contrast, the Frisco, which at few places exceeds 4 or 5 feet in thickness, has a universally low magnesium content (text-figs. 9, 24). For example, at stratigraphic section S9 the uppermost St. Clair has 35.5 percent $MgCO_3$, and the lower Sallisaw has 26.4 percent $MgCO_3$, whereas the Frisco has less than two percent $MgCO_3$ (three Frisco specimens tested 0.61, 0.30, and 1.79 percent $MgCO_3$; Appendix). This certainly suggests that the dolomite of the St. Clair and Sallisaw is genetically related to the deposition of these units, and is not a late-stage, "secondary" dolomite introduced at some time after all of the Silurian and Devonian beds had been laid down. This subject is discussed at greater length in the section on Stratigraphic Distribution of Dolomite.

Strata underlying the Frisco: The Frisco formation in the Arbuckle Mountain region is unconformably underlain by the Bois d'Arc formation of Helderbergian age (text-fig. 2). The stratigraphic and lithologic relationships of these two formations are discussed at some length in my paper on Hunton stratigraphy and will not be repeated here (Amsden, 1960, p. 85, 133, figs. 28, 35, panels II, III; the Bois d'Arc-Frisco contact is illustrated in Amsden, 1957, pl. III, figs. A, B). In Sequoyah County the Frisco formation is underlain by the St. Clair formation which is provisionally referred to the Middle Silurian (see St. Clair formation, *Fossils and age*). There is thus a considerable time gap separating the Frisco from the St. Clair, an interval which covers most, if not all of the Late Silurian and a part of the Early Devonian (Ludlovian, Downtonian, and Gedinnian).

Frisco-St. Clair relationships: The Frisco-St. Clair contact is well exposed at a number of places in the Marble City area, and as these formations are lithologically and faunally distinct this is an excellent place to study an unconformity. Moreover, both formations have a low argillaceous content with almost no shaly partings, so that the contact is commonly welded, making it possible to collect lithologic specimens spanning the boundary. Thus the Frisco-St. Clair boundary can be studied megascopically in the field and microscopically in the laboratory.

The Frisco is separated from the St. Clair by a long period of time during which there was uplift and erosion of the exposed St.

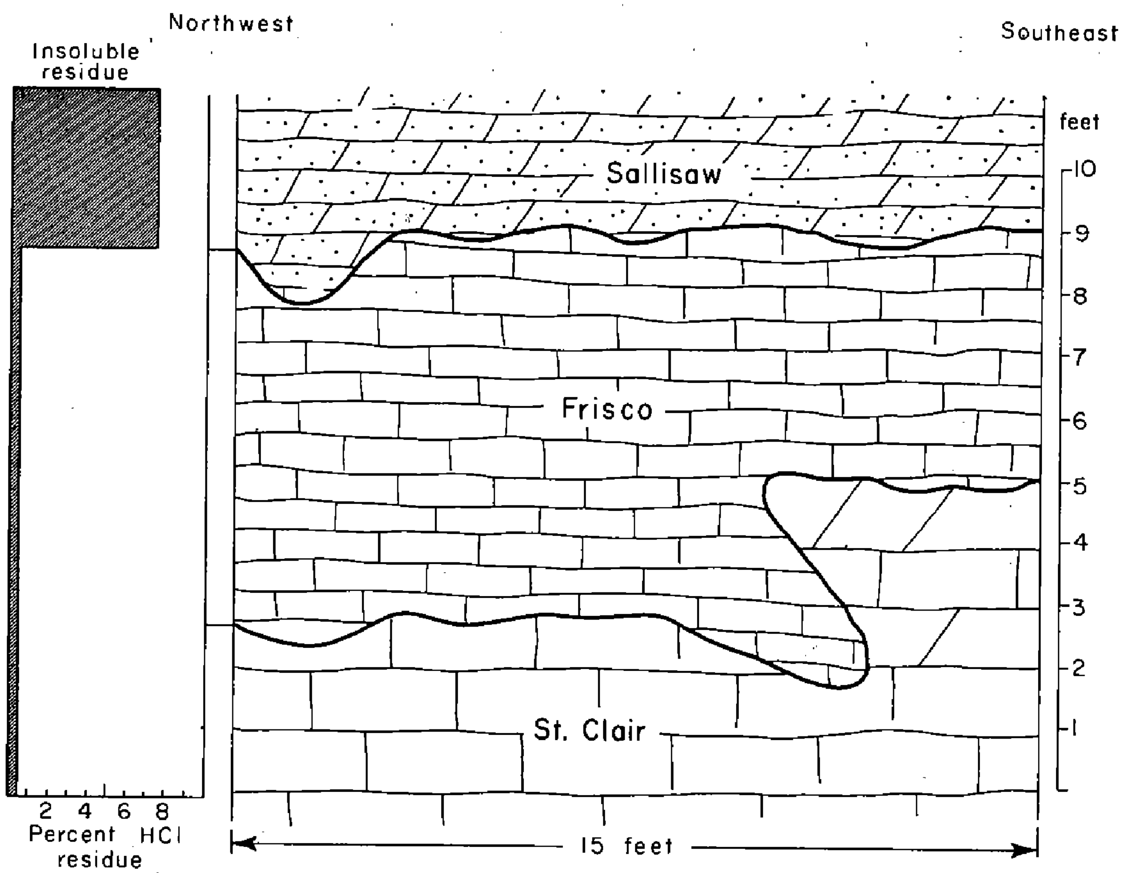
Clair strata. Just how much of the St. Clair was removed is uncertain as the Frisco is present only in the vicinity of Marble City, and within this small area no reliable stratigraphic markers have been found in the upper part of the St. Clair. That considerable pre-Frisco erosion did occur is amply demonstrated at several outcrops in which the St. Clair-Frisco contact is exposed. One of the best of these is in the southern part of the St. Clair Lime Company mine (S13A; pl. I) where the boundary is exposed in the west face for a distance of approximately 60 feet. This exposure, a detail of which is illustrated in text-figure 13, shows that several feet of relief was



TEXT-FIGURE 13. Sketch showing the St. Clair-Frisco contact in the southern part of the St. Clair Lime Company mine, near S13A (pl. I). This drawing was made from a photograph.

developed on the old St. Clair surface by channeling and solution. Narrow tongues of Frisco may be seen to extend down into the St. Clair for a distance of 12 to 18 inches, indicating that fissures were developed on the exposed surface of the Silurian rocks which were later filled with debris laid down by the advancing Frisco sea. Another excellent place at which to see the Frisco formation truncating St. Clair strata is at stratigraphic section S1 where the contact is completely exposed for 30 or 40 feet (pl. II; a photomicrograph of the contact is illustrated in pl. IV). At stratigraphic section S10 irregular bodies and pockets of Frisco extend down into the St. Clair, indicating the development of cavities two to three feet deep on the old St. Clair surface (text-fig. 14; Appendix).

These and other exposures (see S7, S8, S11) show that considerable erosion took place prior to the deposition of the Frisco beds.



TEXT-FIGURE 14. Sketch showing the stratigraphic relations of the St. Clair, Frisco, and Sallisaw formations at stratigraphic section S10. The insoluble residues shown in the graph on the left-hand side are averages of the analyses given in the Appendix. The upper part of the St. Clair is irregularly dolomitic, and the lower part of the Sallisaw is strongly dolomitic, whereas the Frisco strata have a low $MgCO_3$ content. A photomicrograph of the Sallisaw-Frisco contact is shown on plate XI, figure 1.

The Frisco formation is, with the exceptions noted below, lithologically distinct from the underlying St. Clair, although the two do have similar chemical compositions. Each formation has a low content of acid insolubles (text-figs. 5, 8), and where the magnesium content of the St. Clair is also low (text-fig. 7) it is a high-calcium stone similar to the Frisco. Texturally, however, the formations are almost everywhere quite different. The Frisco is a gray-weathering, bioclastic limestone, commonly in a coarse, shell-coquina facies which is unlike other strata in this area. In contrast, the St. Clair is generally a light-gray to pink, crinoidal limestone. There are places where the Frisco grades into a pelmatozoan limestone somewhat like the St. Clair, although it almost everywhere has a darker color, due at least in part to a micrite matrix; furthermore, this pelmatozoan facies is generally restricted in its development, and in most places can be seen to grade laterally into the more distinctive Frisco rock types. The lithologic contrast between these formations is well shown in the photomicrographs in the frontispiece and plates IV, V, VIII; compare also the illustrations on plate VII with those on plate IX.

It is only in those areas where dolomitized St. Clair comes in contact with the calcilutite facies of the Frisco that there is any problem in distinguishing the two formations. As the $MgCO_3$ content of the St. Clair increases it tends to lose its pink color and coarse texture, and becomes darker and finer grained (pl. VII, fig. 5), finally grading into a dense, dark-gray dolomite (pl. VII, fig. 6) which superficially resembles the calcilutite facies of the Frisco. An excellent sample of this may be seen at stratigraphic section S8 where the uppermost St. Clair beds are dolomitic (pl. VII, fig. 5) and have a marked megascopic resemblance to the overlying fine-grained facies of the Frisco. The stratigraphic relationships at S8 are further complicated by the fact that the dolomitic St. Clair beds are not sharply marked off from the underlying pink crinoidal facies, but grade into them through transitional beds. The Frisco thus appears to grade into the underlying St. Clair; however, a microscopic study of the contact relationships by means of thin sections shows a well-defined lithologic break between the Frisco biocalcilutite, composed of broken fossils set in sparry calcite, and the dolomitic St. Clair crinoidal limestone (pl. VII, fig. 5). Analyses of rock specimens from these beds also show a marked difference in the $MgCO_3$ content, the St. Clair having about five percent $MgCO_3$ and the Frisco less than one percent (Appendix). This relationship undoubtedly explains one of the stratigraphic problems that puzzled earlier investigators. Both Ham (Ham et al., 1943, p. 4) and Christian (1953, p. 27-28) commented on the fact that the St. Clair, which they believed to be unconformably overlain by the Frisco, locally appeared to grade into the Frisco through transitional beds. It should be noted that the uppermost St. Clair is dolomitized at several places although this usually creates no particular problem as it is generally overlain by the coarse shell coquina of the Frisco.

One of the interesting features of the Frisco-St. Clair boundary is the absence of any basal conglomerate or breccia in the Frisco. The unconformable nature of this contact is clearly defined and has been noted by all previous investigators (Cram, 1930, p. 550; Christian, 1953, p. 20; Huffman, 1958, p. 34). There is abundant lithostratigraphic evidence to show that the Silurian strata were uplifted and subjected to considerable erosion prior to Frisco time; the solution cavities and fissures developed during this period of time were later filled with Frisco sediments. The paleontological evidence fully supports the stratigraphic evidence; the time separating the uppermost Silurian strata from the Frisco strata is considerable, encompassing most, if not all, of the Upper Silurian (Ludlovian) and a part of the Early Devonian (Helderbergian). It is therefore somewhat surprising to find so little evidence that any kind of regolith was developed during this period of erosion. At no place have I seen a well-marked basal conglomerate or breccia in the Frisco formation. This contact is well exposed at a number of places in the Marble City area and can be easily located as the Frisco and St. Clair formations are lithologically distinct* (see discussion, p. 39). At none of these exposures are there any argillaceous or arenaceous beds separating the two formations, nor have I see unmistakable evidence that pieces of St. Clair were incorporated into the basal Frisco; typical Frisco bioclastic limestone rests directly on the pelmatozoan limestone or dolomitic limestone of the St. Clair, and the contact is tightly welded as is to be expected where little or no argillaceous material is present.

This information on the St. Clair-Frisco contact is not only based on a megascopic examination in the field, but is supplemented by a microscopic examination of the contact in thin section. I have thin sections bridging the Frisco-St. Clair boundary at stratigraphic sections S1, S6, S7, S8, and S13, and none of these show any argillaceous zone at the top of the St. Clair, or basal breccia in the Frisco; several of these thin sections are illustrated in the frontispiece, and in plates IV, V, and VIII. There does not appear to be any special concentration of glauconite near the contact. If any quantity of debris was developed on the St. Clair

*This boundary is equally well defined faunally; I have numerous Silurian fossils collected in situ from the upper two or three feet of the St. Clair, and many Devonian fossils collected in situ from the basal foot or so of the Frisco.

surface in pre-Frisco time it must have been largely swept away before the Frisco sediments were deposited, at least in the area now exposed for study. Not even those parts of the Frisco which fill fissures and cavities in the St. Clair show any concentration of coarse debris; I have a thin section from the fissure illustrated in figure 13 and this looks like the typical Frisco lithology seen in other thin sections. This absence of erosional debris may be only a local phenomenon, and perhaps more extensive exposures of the contact would give a different picture, but my own study of such contacts in other areas suggests that the Paleozoic limestone terranes (in the absence of chert) did not yield much of a regolith* (see section on Geologic History).

Strata overlying the Frisco formation: The Frisco formation is overlain by the Sallisaw or, where that formation has been removed by pre-Chattanooga post-Sallisaw erosion, by the Sylamore sandstone member of the Chattanooga formation (see the stratigraphic cross section, pl. 1). These lithostratigraphic relations are discussed under the sections on Sallisaw formation and Sylamore sandstone, but I would here call attention to the remarkable lithologic specimen illustrated in the frontispiece. In the area northwest of the St. Clair Lime Company mine, at stratigraphic section S7, pre-Chattanooga erosion has removed the Sallisaw and almost all of the Frisco, leaving only a feather edge of that formation between the St. Clair and the Sylamore (text-fig. 26). At section S7 I was able to collect a lithologic specimen which included the top of the St. Clair formation, the Frisco formation (about 1.5 inches thick), and the bottom of the Sylamore sandstone, all welded together. A thick thin-section prepared from this specimen includes all of the Frisco formation, with both the upper and lower contacts, on a single oversize slide; a photomicrograph showing almost the entire thin section is illustrated in the frontispiece, and enlarged details are shown on plate VIII. The orientation of the contacts on this section is fortuitous, being related to the way in which the specimen was cut.

---

* In this connection it is interesting to note the nature of the Woodford-Hunton contact in the Arbuckle Mountain region (Amsden, 1960, p. 136-140); where the Woodford rests upon the chert-bearing Frisco and Bois d'Arc formations it commonly has a thin, basal conglomerate, mostly chert pebbles, but where it rests upon the non-cherty Haragan and Henryhouse marlstones it generally has little or no basal conglomerate.

Photomicrograph of a thick thin-section showing the St. Clair-Frisco contact (arrows) at stratigraphic section S1 (see Appendix). The Frisco matrix is largely finely divided calcite; compare with plate V. Bar is 1 mm long.

Photomicrograph of a thick thin-section showing the St. Clair-Frisco contact (arrows) at stratigraphic section S6(A). The Frisco matrix is mostly sparry calcite; compare with plate IV. Bar is 1 mm long.

Thickness and distribution: The Frisco formation crops out in the Arbuckle Mountain region and in northeastern Oklahoma. In the Arbuckles it is confined to the northeastern margin, where it is exposed in a series of linear, disconnected outcrops extending from Pontotoc County through the northeastern tip of Johnston County and into western Coal County (text-fig. 10). There are many excellent exposures of the formation in this area, one of the best being the type section along Bois d'Arc Creek (Amsden, 1960, stratigraphic section P11, p. 283-285); another excellent place to see the Frisco formation is at stratigraphic section P9 near Coal Creek (Amsden, 1960, p. 279). In northeastern Oklahoma the Frisco is confined to a small outcrop belt in northern Sequoyah County, just north of Marble City (pl. I). The formation is well exposed at a number of places in this area, one of the best exposures being at stratigraphic section S1 on Sallisaw Creek (Appendix); other good outcrops are present just south of the St. Clair Lime Company mine (S5), and along the eastern side of Payne Hollow (S9, S10, S11).

The exposed Frisco is thickest along Bois d'Arc Creek in the Arbuckle Mountain region, where Ventress measured a total thickness of 60 feet. The formation thins rapidly to the southeast, and throughout most of the central and southern parts of the area it is generally less than 20 feet thick (text-fig. 10). In Sequoyah County the formation is less than 10 feet thick; at stratigraphic sections S9 and S10 it is about 7 feet thick, and at the other sections where the Frisco is present it ranges from 4 to 6 feet in thickness (Appendix).

This paper does not deal with the subsurface distribution of the stratigraphic units herein described, but it is interesting to note that the Frisco formation is known to be present in the subsurface of Pottawatomie County (Amsden and Huffman, 1958, p. 73), suggesting that it may have a rather widespread distribution in central and eastern Oklahoma (Amsden, 1960, p. 134).

Fossils and age: The Frisco formation in both the Arbuckle Mountain region and Sequoyah County is richly fossiliferous although the preservation leaves something to be desired. Its megafauna is dominated by the brachiopods, but other groups such as the snails, corals, and bryozoans are present.* Reeds (1926, p. 10) listed 5 species, all brachiopods, from the Frisco of the Arbuckle region, and in 1958 Ventress described 33 species from this region, of which there are 22 brachiopods, 6 snails, 4 corals, and 1 pelecypod. The first discussion of Frisco fossils from northeastern Oklahoma was by Schuchert (1922, p. 669-670), who listed 17 species, including 13 brachiopods, 1 coral, 1 bryozoan, 1 snail, and 1 trilobite. In 1953 Christian recorded a total of 39 Frisco species from this area with 3 corals, 24 brachiopods, 9 snails, 2 trilobites, and 1 species of *Tentaculites*. Recently I have made large collections from the Frisco formation in Sequoyah County. The brachiopods are by far the best represented group, both in number of specimens and number of species, and a preliminary check indicates a total of 23 species; in addition to the brachiopods, my collections include a number of corals and bryozoans, along with some snails and a few trilobites. Ventress and I plan to describe jointly the Frisco brachiopods from Sequoyah County and the Arbuckle Mountain region.

Reeds (1926, p. 13) correlated the Frisco formation of the Arbuckle Mountain region with the Oriskany sandstone of New York, and Ventress (1958, p. 26-27), in his detailed study of this formation in the type area, also found a marked similarity between the Frisco and Oriskany faunas. Schuchert (1922, p. 665, 669) was the first to recognize Oriskany equivalents in Sequoyah Coutny, and the fossils later collected by Christian (1953, p. 31-32) support this age assignment. My own study of the Frisco formation, based on fossils collected from both the Arbuckle region and Sequoyah County, shows a marked similarity in the faunas from these two areas and it would seem reasonably certain that deposition was nearly, if not precisely, synchronous. I have recently had an opportunity to compare the Oklahoma Frisco fossils with collections from the Oriskany sandstone of New York and other eastern states, and my comparison fully confirms the correlation made by earlier authors. The Frisco fauna is also similar to that of the Harriman and Quall formations of western Tennessee (Dunbar, 1919, p. 69-77; Wilson, 1949, p. 306-309), and to that of the Little Saline limestone of Missouri.

*Ostracods and conodonts are present in parts of the Frisco formation (Amsden, 1960, p. 131).

The age of the Frisco formation and its relationship to the overlying Sallisaw is summarized in the chart, text-figure 2. For a further discussion of this matter see under Sallisaw Formation, *Fossils and age*.

SALLISAW FORMATION

The Sallisaw formation was named (as Sallisaw sandstone) by Cram (1930, p. 550-551) for exposures of a "calcareous sandstone of earliest Middle Devonian age which occur in the vicinity of Marble [City]." These are the strata which Schuchert (1922, p. 668-669) correctly recognized as bearing an Ulsterian fauna, although he confused this formation with the Sylamore sandstone, failing to recognize that the Sallisaw and Sylamore represent distinct stratigraphic units of quite different age (text-fig. 2). Cram did not designate a type section although he did state that the formation derived its name from exposures on Sallisaw Creek, and, as there is only one small outcrop on this creek, this may be taken as the type section (stratigraphic section S1; SW¼ SW¼ SW¼ sec. 13, T. 13 N., R. 23 E.; pl. I). The lower part of the Sallisaw formation is well exposed at this locality, including its contact with the underlying Frisco formation (pls. II; VI, fig. 1); however, the upper part of the Sallisaw and the overlying Sylamore have been removed by erosion.

The Sallisaw outcrops are largely confined to the vicinity of Marble City (pl. I). In this small area the formation is thin, nowhere exceeding 20 feet in thickness, but exposures are excellent and some beds are moderately fossiliferous. Fossiliferous Sallisaw float is also present in a small belt located about three miles west of Tenkiller Dam, along the west side of a small creek in SE¼ NE¼ sec. 20, T. 13 N., R. 21 E. (text-fig. 4). This is the arenaceous chert facies of the Sallisaw, and whereas I did not observe any of this rock in situ, the sizes of the blocks (up to 2 feet in diameter) and their abundance leaves little doubt that the formation is present. Moreover, the basal breccia of the Sylamore, which is well developed in this area, contains many pebbles of fossiliferous Sallisaw chert (including *Amphigenia* sp.) suggesting the close proximity of Sallisaw beds. Siemens (1950, p. 15, map), who mapped this general area, reported Sallisaw from sections 2 and 11

(T. 13 N., R. 21 E.) as well as from section 20. The outcrops in section 2 are now covered by Lake Tenkiller and those of section 11 are located on an island and have not been examined by me. Siemens described the Sallisaw as follows: "The basal zone, two or three inches in thickness, is made up of light tan to colorless chert blocks surrounded by brown sandstone. Above the cherty zone, the sandstone is brown, slightly calcareous, and composed of subangular grains of quartz sand." From this description it would appear that Siemens confused the basal breccia of the Sylamore with the Sallisaw; however, as noted above, Sallisaw beds are known to be present in section 20.

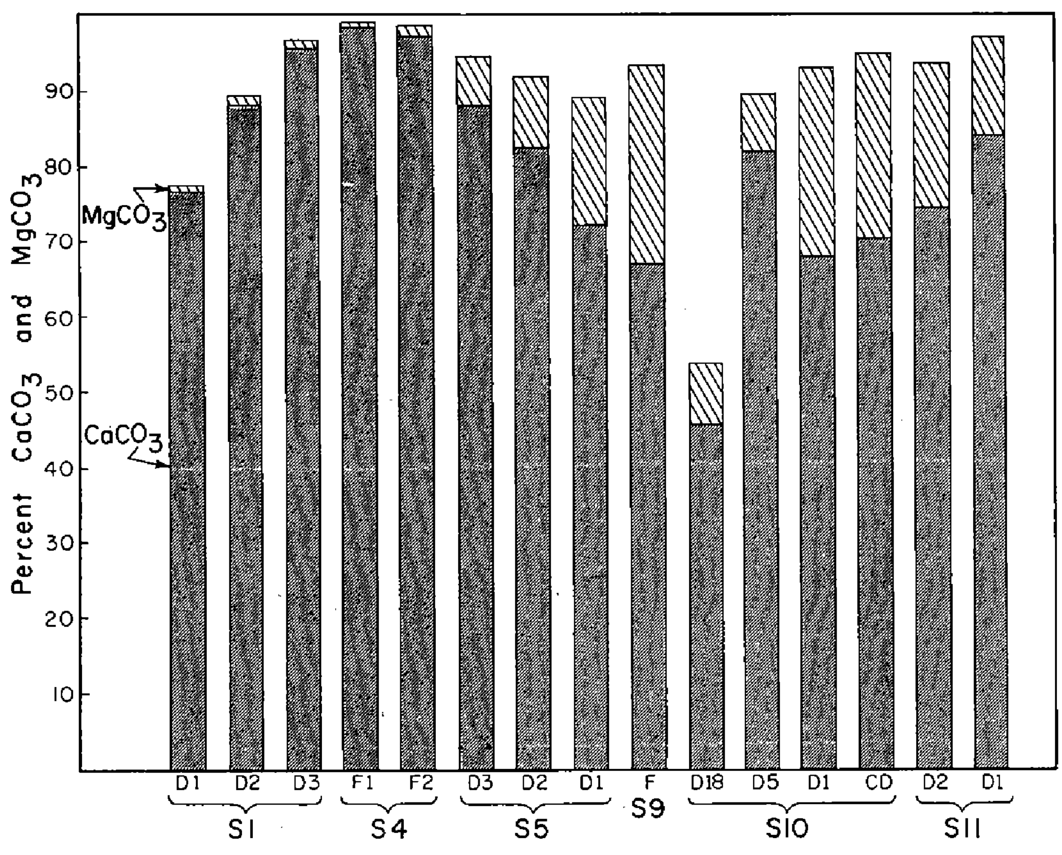
Powell (1951, p. 18, fig. 1) reported a thin bed of questionable Sallisaw in the outcrop belt about two miles southwest of Bunch (NE¼ sec. 29, T. 14 N., R. 24 E.) (text-fig. 4). This was described as a 10-inch bed of unfossiliferous, pearl-gray chert, underlain by the St. Clair formation and overlain by the Sylamore sandstone. The St. Clair in this area is a pinkish-gray, crinoidal limestone similar to that of the Marble City area; at the outcrop which I examined (located in the stream bed on the west side of the road) the St. Clair is directly overlain by Sylamore sandstone. I have not seen the chert bed mentioned by Powell, but from his description it seems possible this could be a part of the Sylamore rather than part of the Sallisaw. Some faunal evidence is needed to establish firmly the presence of Sallisaw in this area.

In the area near Qualls, on the north side of Lake Tenkiller (text-fig. 4), Beckwith (1950, p. 25, fig. 13) and Mondy (1950, p. 26-27, fig. 10) found a thin, brown to yellowish-brown, calcareous sandstone which they tentatively referred to the Sallisaw. This sandstone, which is generally less than a foot thick, is said to rest unconformably upon the St. Clair and to be unconformably overlain by the Sylamore sandstone. In this area the St. Clair is thin (Beckwith records a maximum of 5 feet) and consists of a basal oolite, partly silicified, and an overlying impure, glauconitic limestone.* These strata are quite unlike those exposed in the Marble City area and presumably represent only the basal part of the St. Clair (beds which do not come to the surface in the Marble City

*The HCl-insoluble residues from this rock consist mostly of medium- to dark-green glauconite. Much of this has a polylobate shape, but some is in the form of fossil steinkerns (compare to Amsden, 1960, pl. XVII, figs. 5, 6).

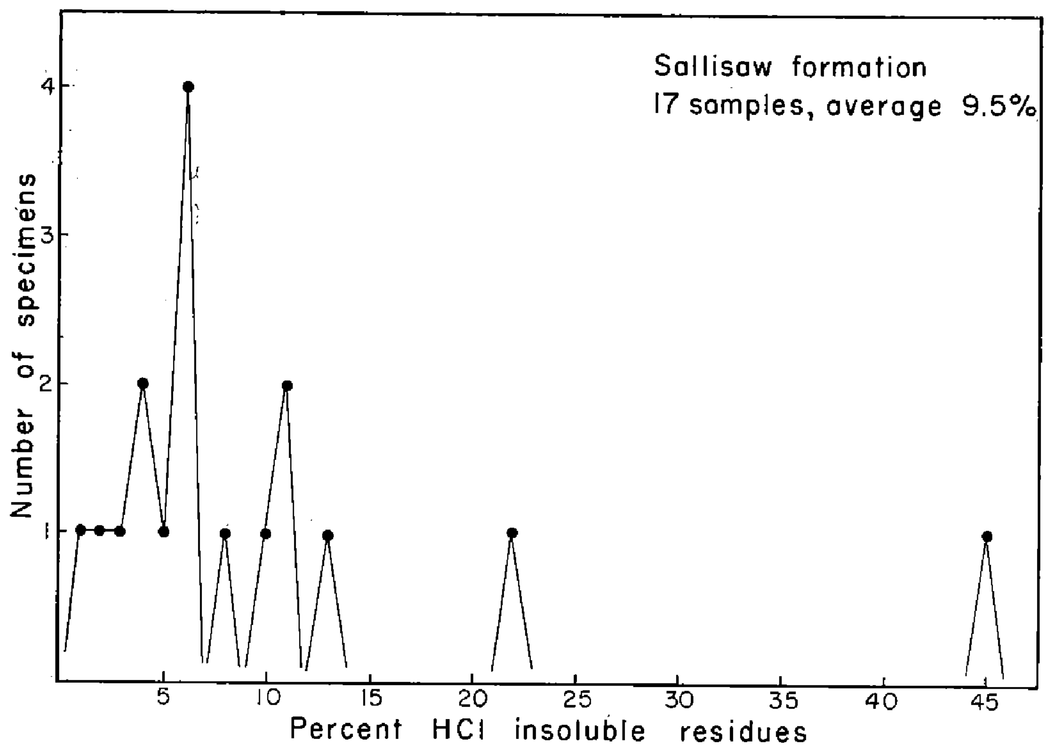
area). The reference of this sandstone to the Sallisaw is based upon its lithologic character and stratigraphic position as neither Mondy nor Beckwith found fossils. I have examined the St. Clair in this area, but have not seen the sandstone in question and am therefore not in a position to comment on its lithology or stratigraphic relationships. If the Sallisaw is present in this area it is most interesting because it shows that pre-Sallisaw erosion (includes both post St. Clair-pre Frisco and post Frisco-pre Sallisaw erosion) has removed nearly all of the Silurian.

Lithologic character: The Sallisaw formation is a light- to medium-gray, arenaceous limestone, locally grading into an arenaceous calcitic dolomite, in irregular beds up to a foot or so in thickness (pls. II, III). Past investigators have described this unit as a calcareous sandstone (Cram, 1930, p. 550; Christian, 1953, p. 33-34); however, the acid insolubles average only 9.5 percent (text-fig. 3) and few, if any, individual beds (text-fig. 16) have enough detritus to be classed as a sandstone. Locally the carbonate has been



TEXT-FIGURE 15. Graph showing the percentage of $CaCO_3$ and $MgCO_3$ in 15 rock specimens from the Sallisaw formation. The data for these graphs are given in the Appendix.

replaced by finely divided quartz, but, excluding this rock type, the Sallisaw is generally composed of more than 50 percent carbonate. With the possible exception of pelmatozoans, megafossils are sparingly represented, although there are exceptions as at stratigraphic section S14 where the uppermost Sallisaw carries a substantial amount of fossil debris (pl. XII, figs. 3, 4). Nodules and elongate lenses of light-colored, vitreous chert are present (pl. III).



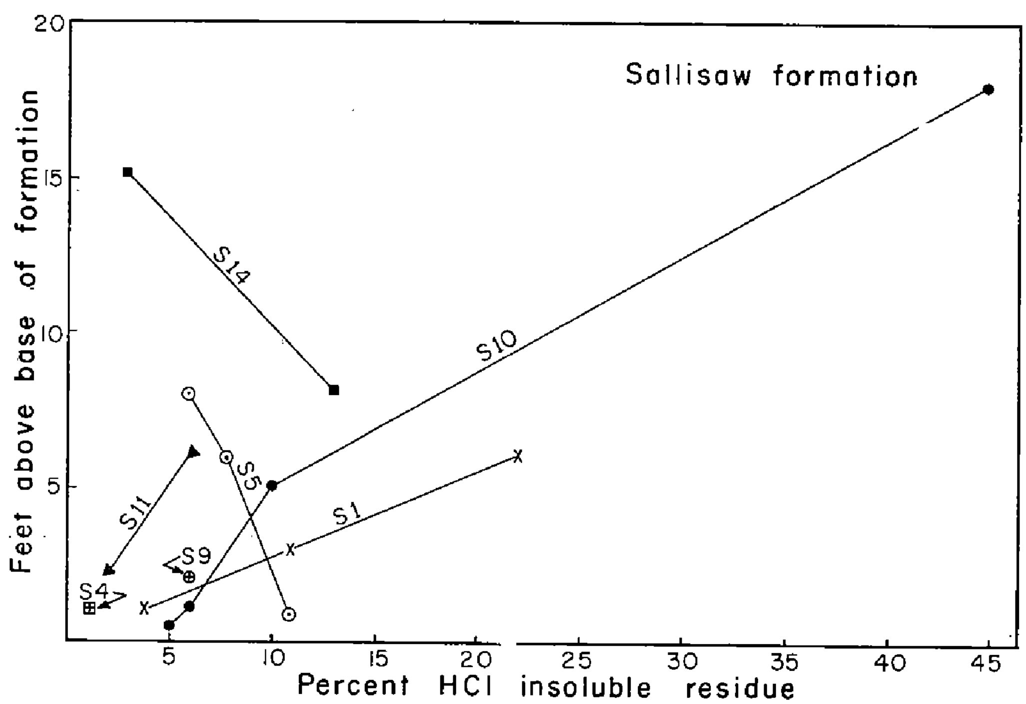
TEXT-FIGURE 16. Frequency diagram showing the range of HCl-insoluble residues in the Sallisaw formation. These were made from rock specimens and exclude the nodules of vitreous chert and the arenaceous-chert facies of the Sallisaw. The data for this chart are given in the Appendix.

Characteristically the Sallisaw is a carbonate with scattered quartz grains (pl. XI, figs. 1-3; pl. XII, figs. 2-5). Its average grain size falls within the range of a fine calcarenite. The limestone facies (exclusive of insolubles) varies somewhat in texture, but is mostly composed of calcium carbonate grains up to 0.3 mm in diameter. In thick thin-section the calcium carbonate bodies commonly appear as granular to cloudy bodies with an irregular outer rim of clear, sparry calcite. Some of these bodies appear to have the shape of pelmatozoan plates, and although none has been observed with the internal porous structure of this group, I strongly suspect that many, perhaps the greater number, of the grains with cloudy centers represent crinoid plates. If this is true, then much of the Sallisaw is a bioclastic calcarenite. There seems to have been considerable breakage of the plates before or during deposition because many appear to be incomplete; moreover, the absence of larger plates suggests fragmentation (the grain size of the Sallisaw in few instances exceeds 0.3 mm). These fragments may have been somewhat further altered by "recrystallization" as the boundary between the cloudy and sparry calcite is not everywhere sharp. In this connection, however, it should be noted that the larger fossils, such as brachiopod shells, show little evidence of alteration (see below). There are parts of the Sallisaw in which the calcium carbonate is more finely divided, but I have not observed any microcrystalline calcite (micrite matrix).

The Sallisaw acid insolubles range from less than one percent up to 45 percent (text-fig. 16), this information being based on the analyses of 17 specimens collected from various parts of the formation throughout the Marble City outcrop area (Appendix). All analyses were made from chert-free rock specimens and do not include any from the arenaceous chert facies of the Sallisaw; the latter would, I am sure, yield almost no carbonate. The average is about 9.5 percent and would thus be classified as a low arenaceous limestone or low arenaceous dolomitic limestone, and for many of the beds the insoluble content is so low (less than 5 percent) that they would be classified as limestone or dolomitic limestone. A more intensive sampling of the Sallisaw might introduce minor changes in the distribution pattern shown in the frequency diagram (text-fig. 16), but it seems fairly certain that only rarely, if ever, does the Sallisaw grade into a calcareous sandstone.

The specimens analyzed for insoluble residues were collected from all parts of the Sallisaw formation. Those collected from stratigraphic sections S1, S10, and S11 show an increase in acid insolubles toward the upper part of the formation; however, this condition is not universal because at stratigraphic sections S5 and S14 the residues decrease upwards. This is illustrated in text-figure 17 where the insoluble residues are plotted against their stratigraphic position within the formation.

The insoluble residues are mostly clear, detrital quartz grains. Other minerals such as glauconite and limonite are present, but only in minor amounts, and the variation in quantity of insolubles discussed above is almost entirely due to a variation in the amount of detrital quartz. This is well shown by the photomicrographs on plates XI (figs. 2, 3) and XII (fig. 2) illustrating thin sections of specimens with different percentages of insolubles (1.5 to 45 percent). The quartz grains do not show a great range in size and most fall into the category of fine sand. Only a few grains attain a diameter of as much as 0.4 mm, and a few are fine enough to be classified as coarse silt (0.04 to 0.05 mm), but most range between 0.15 and 0.2 mm. It might also be noted that the carbonate particles, both the calcite bodies and the dolomite rhombs, have approximately the same size as the quartz grains (pls. XI, XII).



TEXT-FIGURE 17. Graph showing the stratigraphic distribution of Sallisaw rock specimens tested for HCl-insoluble residues. The lines connect analyses of specimens collected from the same stratigraphic section. Stratigraphic section S9 is represented by a single rock analysis; S4 is represented by two analyses, but these are similar and therefore are shown as a single point. The data for these analyses are given in the Appendix.

The quartz grains are mostly angular to subangular although a few subrounded grains are present in most residues, and at stratigraphic section S4 many are subrounded. Much of the angularity is due to the presence of crystal faces which appear to be overgrowths on the detrital grains. Many of the crystal faces are incomplete; well-formed terminations and double terminations are few.

Most of the grains have a pitted or "corroded" surface and this pitting even affects some of the crystal faces. In thin section many of the quartz boundaries are highly irregular (pl. XII, fig. 5), and in many cases there is an outer rim or zone with "dusty" inclusions, most of which appear to be carbonate. On at least some grains this outer irregular and pitted surface can be seen to be an overgrowth on a more rounded detrital grain, and presumably most of these result from the secondary addition of quartz after the grains were enclosed in the carbonate matrix. Unfortunately, on most grains the boundary between the primary detrital body and the secondary overgrowth is not well defined so that it is difficult to determine the shape of the original grain. The character of the insoluble material from those beds where overgrowths are poorly developed (e. g. S4-F) suggests that the original detritus ranged from subangular to subrounded (classification of Pettijohn, 1957, fig. 28). Where megafossils such as brachiopods or *Tentaculites* are present (pl. XII, figs. 3, 4) the quartz grains penetrate into the shell, presumably representing a pressure-solution phenomenon. I am unable to detect any geographic pattern in the distribution of detrital quartz in the Sallisaw; however, the area sampled is too small to give much of a trend.

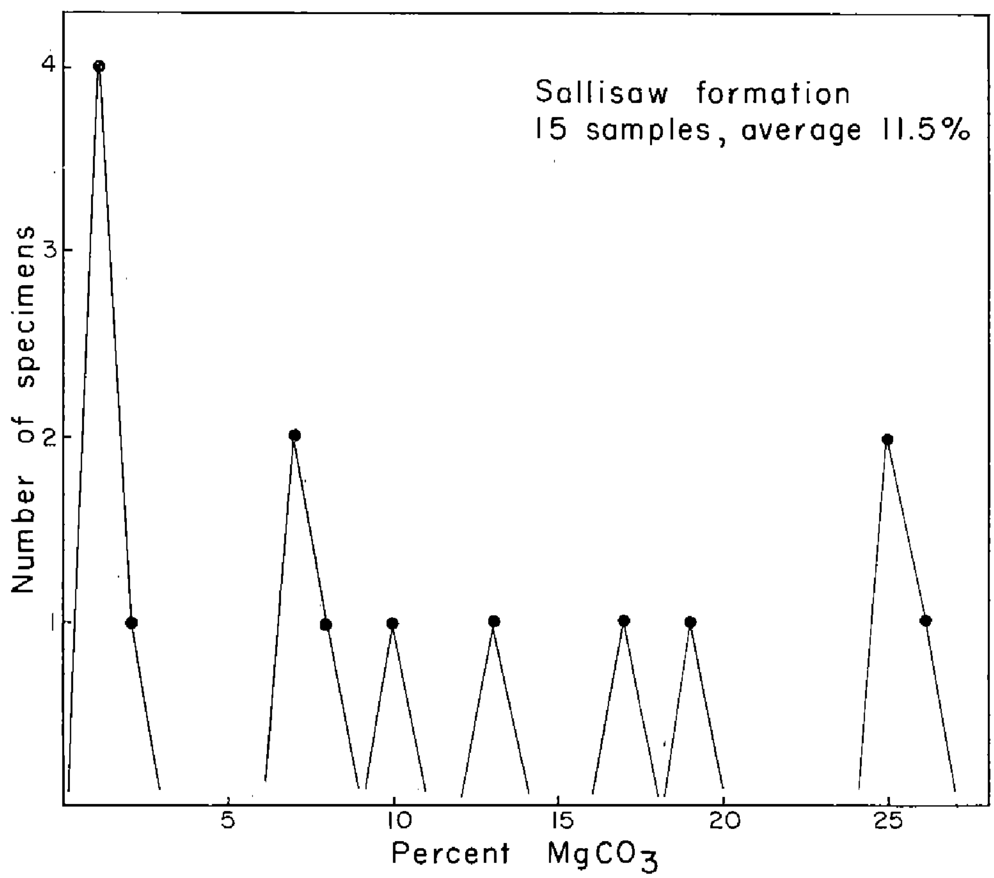
Most residues contain traces of glauconite, generally as small, pale-green, rounded to subangular bodies. Some residues also contain a small quantity of limonite and of a dark, carbonaceous material. A few thin sections show a brown, translucent mineral which is probably some phosphatic material, possibly collophane. Other minerals that are represented in small quantities have not been investigated.

Megafossils* are, on the whole, rather uncommon in the Sallisaw. The fauna is overwhelmingly dominated by the brachiopods; in fact, the only fossils which I have collected are brachiopods and *Tentaculites*. At most outcrops I have been able to find a few brachiopod-bearing strata, but, with few exceptions, even in these beds the fossils are widely scattered. Almost 100 percent of the brachiopod shells are disarticulated, and some of the individual valves are broken, showing that some fragmentation

* In the discussion which follows pelmatozoan plates are not considered; these are discussed above.

took place either before or during deposition. Thin sections of the brachiopod-bearing beds generally show the fossils to be sparsely distributed through the matrix of carbonate and quartz detritus (pl. XI, fig. 2). Some of the Sallisaw chert nodules are highly fossiliferous; the brachiopods are preserved as internal and external molds and they appear to have undergone less fragmentation.

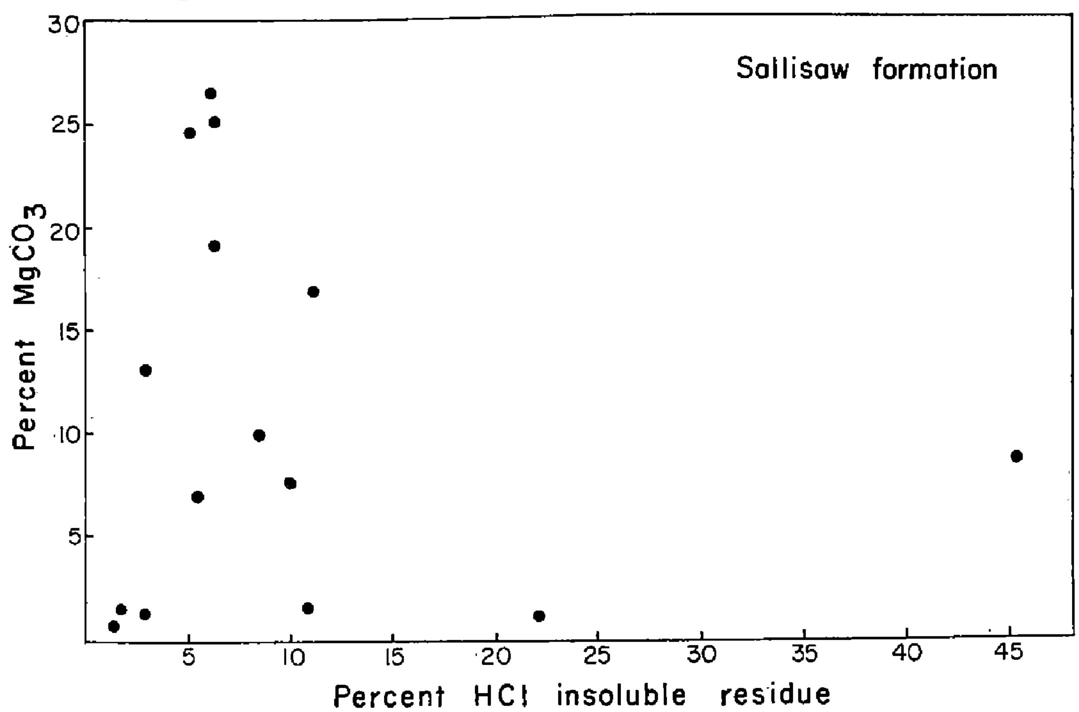
At a few localities the Sallisaw formation includes some fairly fossiliferous beds. The best example is at stratigraphic section S14 where the upper 3 or 4 feet of the Sallisaw contains some beds with a high concentration of brachiopods and *Tentaculites* (pl. XII, figs. 3, 4). This rock, which is one of the more interesting in the Marble City area, has a matrix of quartz detritus (3.6 percent insolubles), dolomite rhombs, and calcite grains (the latter with cloudy centers suggesting pelmatozoan plates); all of this material is in approximately the same grain size. The fossil debris is scattered through this matrix, in places sufficiently concentrated to make a bioclastic



TEXT-FIGURE 18. Frequency diagram showing the range of $MgCO_3$ in the Sallisaw formation. One specimen with 40.6% $MgCO_3$ (S11-CD[d]), which is doubtfully referred to the Sallisaw, is not shown (Appendix). See also text-figure 15.

calcarenite. The fossils show some breakage and almost all the brachiopod shells are disarticulated.

The Sallisaw formation has a highly variable $MgCO_3$ content; the analyses of 15 rock specimens show a range of from less than one percent to slightly over 25 percent (text-figs. 3, 15, 18). The average is 11.5 percent ($CaCO_3$ averages 79.1 percent; HC1 insolubles average 9.5 percent) so that much of the Sallisaw can be termed an arenaceous dolomitic limestone (see under Introduction). At stratigraphic sections S1 on Sallisaw Creek and S4 on Walkingstick Hollow the $MgCO_3$ content is low, less than three percent, but at all of the other stratigraphic sections for which I have data it is more than seven percent (text-fig. 15). As the magnesium content of the rock increases, dolomite rhombs become conspicuous and these, mixed in with the detrital quartz grains, give the rock a distinctive texture (pl. XI, fig. 1). It is interesting to note that these dolomite rhombs are about the same size as the quartz grains (and calcite grains). This equigranular texture is conspicuous in the matrix of the highly fossiliferous strata from the upper part of the formation at S14 (pl. XII, figs. 3, 4). I do not detect any relationship between the $MgCO_3$ content and the acid insolubles (see text-figs. 15, 19).



TEXT-FIGURE 19. Graph on which the $MgCO_3$ content has been plotted against the HCl-insoluble residues. Each point represents the analysis of a single rock specimen from the Sallisaw formation (see also text-fig. 15). The data for this graph are given in the Appendix.

At several places the lowermost Sallisaw beds have a high $MgCO_3$ content, whereas the underlying Frisco is everywhere a high-calcium stone. This fact is well shown at stratigraphic section S10 (Appendix) where the basal Sallisaw contains almost 25 percent $MgCO_3$ and the underlying Frisco less than one percent (pl. XI, fig. 1). This distribution suggests that the Sallisaw dolomite is genetically related to the deposition of the Sallisaw strata, and not a late-stage, "secondary" dolomite.

The Sallisaw formation has small nodules and lenses of light-colored, vitreous chert (pl. III), in places rather heavily iron-stained. The nodules are generally fractured and in places they have a brecciated appearance. Locally the chert is highly fossiliferous, the fossils being preserved as internal and external molds. Thin sections made from the nodules at stratigraphic section S1 show an interesting texture. The subangular, sand-size detrital quartz grains, which form such an integral part of the Sallisaw carbonate facies, are easily distinguished in the chert. The surrounding matrix is mostly finely crystalline quartz, in part chalcedony, which retains in places the dim outlines of fossils; scattered through this matrix are rhomboidal bodies which probably represent the outlines of dolomite crystals that have been replaced by quartz. The only carbonate present is in the form of tiny, dust-like inclusions. This texture suggests that these chert nodules originated by the local silicification of the Sallisaw arenaceous carbonate. The time at which such silicification took place is discussed below.

In the Marble City area the typical Sallisaw rock type grades laterally into an arenaceous chert facies. This facies, which is well developed at stratigraphic section S3, is similar in composition to the vitreous chert described above, but has a somewhat different appearance, both megascopically and microscopically. At section S3 the entire Sallisaw is a fine-textured, gray to reddish- or brownish-gray rock in beds up to approximately a foot thick. Some of the beds are moderately fossiliferous, containing mostly the brachiopod *Amphigenia* sp., although the original shell has been completely removed leaving only the external and internal molds; furthermore the rock itself is porous, the individual holes being very small but quite abundant. In thin section this rock has a distinctive texture (pl. XII, fig. 6). The detrital quartz grains are easily distinguished and have the same size and shape as do those in the carbonate facies. The surrounding matrix is mostly finely crystalline quartz, with only traces of carbonate in the form of minute, dust-like bodies. There are many voids or holes in the thin section and some of these have a rhomboid outline suggesting that they were originally occupied by dolomite crystals. The history of this rock is believed to be as follows: At some time after the deposition of the Sallisaw arenaceous carbonate (and after the introduction of the dolomite), the carbonate parts were largely replaced by finely crystalline quartz. This replacement was not complete as the brachiopod shells and some carbonate grains, which were at least in part dolomite, were left unaltered. Even in the parts replaced by silica some tiny carbonate particles were left behind. At some time after silicification the entire rock was leached and most of the carbonate, including the brachiopod shells, was removed, leaving only the minute traces of carbonate behind.

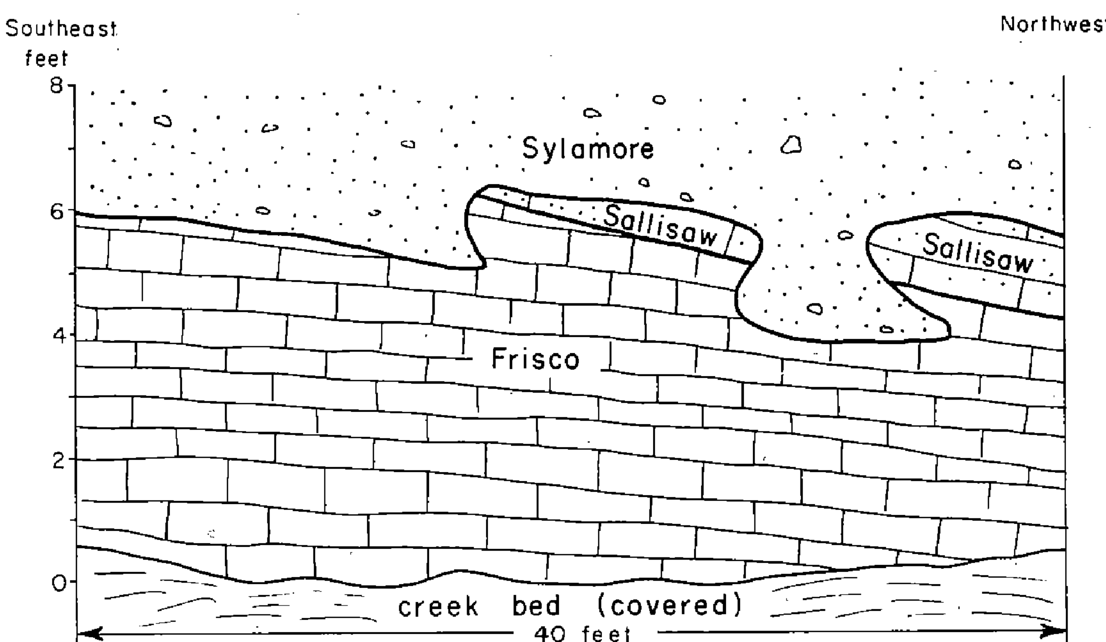
The arenaceous chert facies is similar to the chert nodules although the two do show some differences: (1) Megascopically the chert nodules generally have a vitreous or porcellaneous texture whereas the arenaceous chert is porous. (2) In thin section the chert nodules show considerable spherulitic chaledony whereas the arenaceous chert does not, the replacing silica being in the form of small quartz crystals. It is, however, probable that both originated in much the same manner and they may be genetically closely related.

The time of silicification can be fixed within certain well-defined limits. It must have followed the deposition of the Sallisaw arenaceous carbonate, including the introduction of dolomite, because the basic texture of this rock is retained, and it must have preceded the deposition of the Sylamore because blocks of both the vitreous and arenaceous cherts are present in the basal conglomerate of that member. I have found fairly large fragments of both types with identifiable Sallisaw fossils incorporated in the lower part of the Sylamore, indicating that silicification took place prior to Chattanooga time (text-fig. 22). A photomicrograph of a Sallisaw arenaceous chert block from the basal Sylamore conglomerate is illustrated on plate XIII, figure 6.

Strata underlying the Sallisaw formation: The Sallisaw formation is separated from the underlying beds by an erosional unconformity (disconformity of Dunbar and Rodgers, 1957, p. 119).

The total amount of relief developed on the pre-Sallisaw surface cannot be determined, but it was sufficient to remove locally all of the Frisco, allowing the Sallisaw to rest directly upon the St. Clair. These relationships are shown on plate I.

Sallisaw-Frisco relationships: The Sallisaw and Frisco formations, in their characteristic lithologic expression, are different from one another and the boundary between them is easily located in the field (pls. II; VI, fig. 1). In most places the Sallisaw is an arenaceous calcarenite with widely scattered fossils, whereas the Frisco is a highly fossiliferous, bioclastic calcarenite. The shell coquina facies of the Frisco, with its heterogeneous assortment of fossil debris (frontispiece; pls. IV; V; VIII; X; IX, fig. 1) is quite unlike the finer-grained, arenaceous limestone of the Sallisaw (pl. XI). These two formations also differ markedly in their acid-insoluble contents (text-figs. 3, 8, 16), the Frisco averaging only one percent in contrast to the 9.5 percent of the Sallisaw. Parts of the Sallisaw, however, have a much lower insoluble content, approaching that of the Frisco, and where Sallisaw rock of this type is in contact with the calcilutite facies of the Frisco, as it is at stratigraphic section S4, the boundary between the two formations is difficult



TEXT-FIGURE 20. Sketch showing the stratigraphic relationships of the Frisco, Sallisaw, and Sylamore formations at stratigraphic section S4 on the southwest side of Walkingstick Hollow (pl. I). Photomicrographs of Frisco and Sallisaw thin sections from this locality are shown on plate XII, figures 1, 2; photomicrographs of a Sylamore thin section are shown on plate XIII, figures 1, 2. Stratigraphic and chemical data for this section are given in the Appendix.

to see in the field.* The Sallisaw at this locality has a maximum thickness of only two feet. At the southeast end of the outcrop it is absent, and the Sylamore rests directly upon the Frisco (text-fig. 20).

At section S4 both the Sallisaw and Frisco formations are high-calcium stones, the Frisco averaging 99.01 percent $CaCO_3$ and the Sallisaw 97.2 percent $CaCO_3$ (Appendix), and, as both are fine-grained, it is difficult to tell them apart megascopically. In thin section, however, they are easily distinguished as shown in the photomicrographs, figures 1 and 2, plate XII. The Frisco is a biosparite composed of broken fossils set in a matrix of clear calcite; its insoluble debris consists mostly of angular quartz grains, some of which are doubly terminated crystals, along with considerable glauconite. In contrast, the Sallisaw is composed of widely scattered detrital quartz grains set in a matrix of granular calcite; some of the calcite grains have cloudy centers and may represent pelmatozoan plates, but other than this there is little fossil material. The Sallisaw residues are mostly subangular to subrounded quartz grains with only traces of glauconite (at this locality the Sallisaw quartz grains show fewer overgrowths than normal; see discussion under *Lithologic character*). I might digress here to point out that most Frisco insoluble residues contain some doubly terminated quartz crystals, and in some samples these make up most of the residue. On the other hand, the Sallisaw quartz detritus generally shows some crystal overgrowths, but these are mostly imperfect, and doubly terminated crystals are rare. The Sallisaw has considerably less glauconite than does the Frisco. Not all of the Frisco at section S4 is fine grained, and a few of the beds are moderately coarse biocalcarenites, approaching the more typical Frisco rock type.

The Sallisaw formation has, for the most part, a much higher magnesium content than does the Frisco formation (text-figs. 3, 9, 15, 18). The latter averages less than one percent $MgCO_3$, with the maximum amount determined being only slightly more than two percent, whereas much of the Sallisaw is a dolomitic limestone, averaging about 9.5 percent; however, some Sallisaw beds,

* Christian (1953, p. 38, pl. II) did not recognize Sallisaw at this outcrop (my section S4), and in his sketch of the stratigraphic relationships he shows the Sylamore resting directly upon the Frisco; compare his plate II with my text-figure 20.

such as those at stratigraphic sections S1 and S4, have a low magnesium content similar to that of the Frisco (text-fig. 15; Appendix). At some localities, such as stratigraphic section S10 (Appendix), the basal beds of the Sallisaw are dolomitic (24.5 percent $MgCO_3$) whereas the underlying Frisco has only traces of $MgCO_3$ (text-fig. 14; a photomicrograph of the contact is illustrated on pl. XI, fig. 1). This relationship, which can be observed at several localities, suggests that the Sallisaw dolomite was introduced at the time the rock was deposited; for a discussion of this topic see the section on Stratigraphic Distribution of Dolomite.

Sallisaw-St. Clair relationships: In several places the Sallisaw formation rests directly upon the St. Clair formation. This condition may be observed in parts of sec. 22, T. 13 N., R. 23 E. (pl. I). It is also the relationship in the southern part of sec. 12 and the northern part of sec. 13, T. 13 N., R. 23 E.; at stratigraphic section S3 the arenaceous chert facies of the Sallisaw rests upon the St. Clair.

The St. Clair has, for the most part, a lithologic character entirely different from that of the Sallisaw and the two are easily distinguished. The only possibility for confusion would be where strongly dolomitic St. Clair is in contact with dolomitic Sallisaw.

Strata overlying the Sallisaw formation: Throughout the Marble City area the Sallisaw is overlain by the Sylamore sandstone member of the Chattanooga formation. This relationship is discussed under the section on Sylamore Sandstone.

Thickness and distribution: The Sallisaw is widely distributed throughout the southern part of the Marble City area; in the northern part, along Walkingstick Hollow, it is generally absent (pl. I). This formation is also present in a small outcrop belt situated about three miles west of Tenkiller Dam (text-fig. 4; SE¼ NE¼ sec. 20, T. 13 N., R. 21 E.). Thin unfossiliferous Sallisaw beds have also been reported in small outcrops southwest of Bunch and northwest of Qualls, but these have not been verified by me (see pages 45, 46).

The Sallisaw formation is thin throughout its outcrop area. It is eight feet thick at the type section (S1) on Sallisaw Creek (incomplete section), and 10 feet thick at S5, south of the St. Clair Lime Company mine. It attains its greatest thickness in sec. 15,

Figure 1. Frisco-Sallisaw contact at stratigraphic section S1 (see Appendix). The coin (quarter) is just below the contact.

Figure 2. View of the upper part of the St. Clair formation in the quarry of the St. Clair Lime Company. The contact with the Frisco formation is a short distance above the mine opening.

T. 13 N., R. 23 E.; at stratigraphic section S10 I measured 18 feet and at S14 there is 20 feet with the base not exposed (Appendix).

Fossils and age: The Sallisaw formation has a small megafauna consisting almost entirely of brachiopods. My own collections from this formation are composed of brachiopods except for some specimens of *Tentaculites* sp. from stratigraphic section S14. The total brachiopod fauna, which I plan to describe in a future publication, comprises about 10 species. This brachiopod fauna appears to be similar to one recently described by Boucot (1959, p. 734) from the Woodbury Creek member of the Esopus formation in southeastern New York. In this publication Boucot divided the Esopus into three members, an upper Woodbury Creek member, middle member, and a lower Highland Mills member, the latter containing a fauna different from that of the Woodbury Creek. In southeastern New York the Esopus is underlain by the Connelly conglomerate of Oriskanian age (Deerparkian) and overlain by the Kanouse sandstone of Onondagan age (Onesquethawan). According to Boucot, "The discovery of the Highland Mills and Woodbury Creek member faunas makes it clear that Esopus time, if one is to judge by the nature and diversity of the fauna, is of the same order as either Deerpark or Onesquethaw time. Therefore, it is proposed that an Esopus stage be recognized in eastern North America." If the correlation of the Sallisaw formation with the Woodbury Creek member is correct, this formation is of late Esopus age and should be separated from the Frisco, which is an Oriskany (Deerparkian) equivalent, by an interval representing Highland Mills time (the middle member has no diagnostic fauna). This accords quite well with the biostratigraphic relations in northeastern Oklahoma, the Sallisaw being separated from the Frisco by a time interval of sufficient duration to allow for uplift and enough erosion to remove locally all of the Frisco. These age relations are summarized in the chart on text-figure 2.

The Sallisaw also appears to be correlative with the Camden formation of western Tennessee, and the Clear Creek formation of Illinois.

CHATTANOOGA FORMATION

The Lower Devonian formations in Sequoyah County are overlain by the Chattanooga formation. The stratigraphy of the Chattanooga is not a basic part of this report and it has been studied only to the extent necessary to determine its relationships to the underlying strata. In the Marble City area the Chattanooga formation is divisible into two parts, an upper dark to black shale, and a lower sandstone, which is in part conglomeratic. For many years it has been common practice to call these the Chattanooga black shale and the Sylamore sandstone (Christian, 1953, p. 39-42), but recently Huffman and Starke (1960, p. 159-163) have proposed the application of the term Noel to the shale part of this sequence, thus dividing the Chattanooga formation into an upper Noel black shale member and a lower Sylamore sandstone member. The term Noel was first used many years ago for the dark shales of McDonald County in southwestern Missouri.

The latest information on the age of the Chattanooga is based on the conodont studies of Hass (1956, p. 1, 2, 21, 25), who assigned the lower part of the Chattanooga dark shales to the Upper Devonian and the upper part to the Lower Mississippian. To my knowledge no diagnostic fossils have been described from the Sylamore sandstone, but the stratigraphic relations in the Marble City area and elsewhere indicate that it is closely related to the overlying shales.

The Chattanooga formation is separated from the underlying strata by a marked erosional unconformity so that in the Marble City area the Sylamore sandstone may rest on the Sallisaw, the Frisco, or the St. Clair.

SYLAMORE SANDSTONE

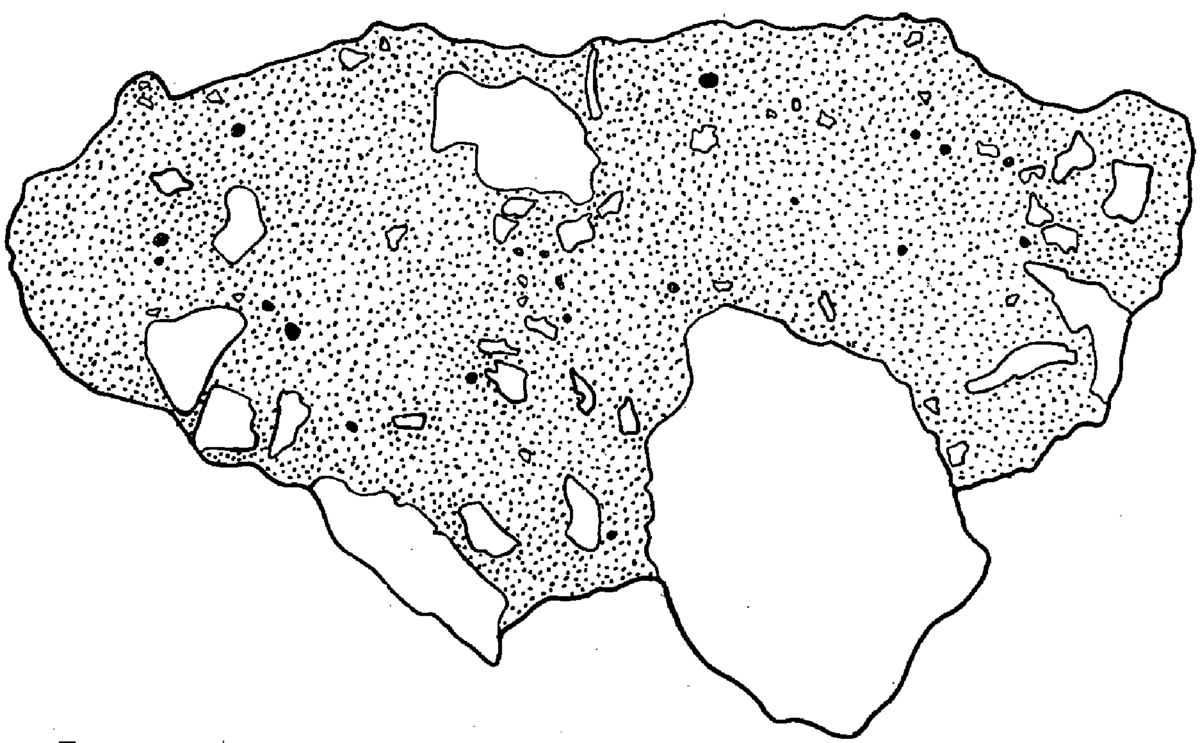
The Sylamore sandstone was named for exposures on Sylamore Creek in Stone County, north-central Arkansas. According to Wilmarth, there is some question concerning the stratigraphic relationships in the type area, but the name has come to be widely used for the basal sandstone member of the Chattanooga formation in Arkansas, Missouri, and Oklahoma. Christian (1953, geologic map) mapped it as a separate stratigraphic unit in the Marble City area.

Lithologic character: In the Marble City area the Sylamore sandstone is a light-gray to brownish-gray sandstone in fairly uniform beds up to two or three feet thick. I have not observed any well-defined cross-bedding and if this is present it must be on a subdued scale. Typically the Sylamore is a medium- to coarse-grained sandstone, generally friable, and composed largely of quartz. In hand specimen or under low-power magnification the quartz grains appear subangular to angular, but this angularity is largely the product of secondary overgrowths. Scattered among the quartz grains are dark-gray to dark-brown phosphatic pebbles which are commonly well rounded. For the most part these are somewhat coarser than the quartz detritus and some grains are as much as 3 or 4 mm in diameter. I have not made a study of their mineralogical composition but many appear to be organic material, probably some kind of bone; conodonts are also present. This phosphatic material is darker than the surrounding quartz and gives the rock a rather distinctive speckled appearance which is helpful in distinguishing the Sylamore from the Sallisaw.

In thin section the Sylamore sandstone has a distinctive texture. It is composed in large part of well-rounded, detrital quartz grains with distinct secondary overgrowths; these overgrowths have extended the boundaries of the detrital grains outward and they fill the interstices to a large extent. This relationship is shown in the photomicrographs on plate XIII, figures 1 and 2. The Sylamore is thus largely composed of quartz, although other minerals do contribute to the detritus. The junction between adjacent crystal overgrowths is generally not a firm bond so that much of the Sylamore is friable; most of the individual quartz grains broken out of this rock are angular because the separation is between adjoining crystal faces and not between the detrital grain and its overgrowth. Some Sylamore beds have a fairly uniform grain size (pl. XIII, fig. 5), but others, notably the basal breccia facies (text-fig. 21), show great size range.

Most of the Sylamore sandstone has a low carbonate content. The vein material discussed below, as well as some of the basal beds (stratigraphic section S7; Appendix), may have a lime cement, but other than this the rock has little carbonate. In addition to the quartz and phosphatic material, most thin sections have some pale-green glauconite. Other minor mineral components have not been investigated.

Sylamore breccia: Throughout most of the Marble City area the basal foot or two of the Sylamore is a sedimentary breccia; this breccia is also present in a small outcrop belt about three miles west of Lake Tenkiller dam (text-fig. 4), SE¼ NE¼ sec. 20, T. 13 N., R. 21 E. (Siemens, 1950, p. 15, assigned this rock to the Sallisaw; see discussion under Sallisaw Formation, *Thickness and distribution*). This rock is composed of irregular pebbles and blocks set in a quartz-sand matrix like that described above (text-



TEXT-FIGURE 21. Sketch of a lithologic specimen of the Sylamore basal breccia; stratigraphic section S5-E, approximately natural size. The unshaded, angular fragments are chert; the black, well-rounded bodies are phosphatic pebbles. The drawing was made from a photograph.

fig. 21). The fragments are commonly angular to subangular and range from a fraction of an inch up to more than two feet in diameter. In large part they are composed of light-colored chert fragments, including both a vitreous and an arenaceous chert; the latter is illustrated on plate XIII, figure 6 (compare with pl. XII, fig. 6). These chert fragments are identical in texture to the arenaceous chert in the Sallisaw, and pebbles of both types bearing identifiable Sallisaw fossils have been found in the basal Sylamore. It is certain, therefore, that at least some of the fragments were derived from the underlying Sallisaw, and I suspect that in large part they had a local origin.

The origin of this breccia seems to have puzzled past investigators (Christian, 1953, p. 35, 40; Huffman, 1958, p. 36; Siemens, 1950, p. 15), but they have generally assigned it to the upper Sallisaw, interpreting it as an old regolith cemented in situ by the Sylamore. In my opinion, however, it is a part of the Sylamore, being nothing more than a lower facies produced by the incorporation of loose surface debris into the initial deposits. It is true that a considerable part was locally derived, much being chert from the underlying Sallisaw, but the matrix which completely engulfs and, for the most part, far outweighs the fragments (text-fig. 21) is typical Sylamore, identical in all respects with the overlying sandstone with which it is connected by gradational strata. In my experience, most basal breccias or conglomerates are made up of fragments which were not transported any great distance. There is a similar (although considerably thinner) conglomeratic bed at the base of the Woodford formation in the Arbuckle Mountain region (Amsden, 1960, p. 139) and much of this seems to be of local origin (see footnote, p. 42).

The presence of Sallisaw chert fragments in the basal Sylamore shows that both the vitreous and the arenaceous types were formed before the beginning of Chattanooga time.

Fissures in the underlying strata which have been filled with Sylamore sandstone: Irregular fissures filled with Sylamore sandstone extend down into the underlying beds. These are fairly common in the Marble City area and some are rather long; Christian (1953, p. 23) cites one locality (NE¼ SE¼ NE¼ sec. 2, T. 13 N., R. 23 E.) where the Sylamore penetrates to at least 37 feet below the top of the St. Clair. I have observed such sandstone-filled fissures at a number of places and, although I have not seen any as long as the one mentioned by Christian, it is not uncommon to find them extending downward 10 feet or so into the St. Clair. At stratigraphic section S2 a stringer of Sylamore sandstone penetrates six to eight feet into the St. Clair. The main trunk of this fissure is approximately an inch wide, but it is highly irregular and there are many branches leading into small veinlets (pl. XIII, fig 3). In parts of this system small pieces of St. Clair limestone are engulfed in the Sylamore matrix. The Sylamore filling in this fissure is composed predominantly of rounded quartz detritus with well-defined quartz overgrowths, up to 0.8 mm in diameter; some rounded phosphatic pebbles are present. The matrix enclosing this detritus is mostly finely divided carbonate.

One of the better places to study the Sylamore fissure fillings is in the underground workings of the St. Clair Lime Company mine (pl. I). In this mine the upper part of the St. Clair is cut by numerous fissures and some of these extend to the floor of the working face (the roof of this mine is generally at, or near, the St. Clair-Frisco contact). Some of this Sylamore material is in the form of irregular bodies ranging up to several feet in width, and must represent the filling of small caverns rather than of narrow fissures. A few of the larger pockets include much limestone debris that was derived from the walls of the St. Clair cavities. This car-

TEXT-FIGURE 22. Sketch of a rock specimen of Sylamore sandstone from the filling in a fissure in the St. Clair formation; stratigraphic section S13-(5), approximately natural size. The unshaded, angular fragments are pieces of pink crinoidal limestone from the St. Clair; the shaded areas represent the Sylamore matrix consisting of a mixture of rounded detrital quartz and carbonate fragments. A photomicrograph of the matrix is shown on plate XIII, figure 4. This drawing was made from a photograph.

bonate detritus ranges from microscopic particles up to blocks several inches across; the fine-grained portion of one of these pockets is illustrated on plate XIII, figure 4, and the coarse-grained part in text-figure 22. The limestone fragments, especially the larger pieces, are angular and in places so closely packed that there is only room for enough Sylamore matrix to bind them together. The Sylamore matrix consists of well-rounded detrital quartz grains mixed with finely divided carbonate (pl. XIII, fig. 4); some phosphatic pebbles are present and glauconite is locally common.

For the most part these fissures and pockets pinch or swell, and branch or anastomose in a most irregular fashion, and if they could be viewed in three dimensions would undoubtedly present a complex distribution pattern. On any exposed surface of the host rock (which gives a view that is largely two dimensional) these may appear as linear bodies having the pattern of connected fissures, or they may appear as isolated bodies which seem to be completely surrounded by the enclosing formation.

All of the sandstone-filled fissures which I have examined can be assigned to the Sylamore with considerable certainty, even where they cannot be traced directly to that member (as in the mine). Lithologically, the large, rounded quartz grains with well-developed overgrowths, and the rounded phosphatic pebbles, are identical to those found in the Sylamore proper. Of course there are many places where these veins can be traced directly to the Sylamore. An excellent outcrop showing this relationship may be seen at the northern end of Walkingstick Hollow, just north of the Sequoyah County line, in Cherokee County (a short distance north of the map area shown in pl. I). Here the St. Clair-Sylamore contact is well exposed in the creek bed, and veins of Sylamore may be seen to extend into the underlying St. Clair (see also text-fig. 20). I have also observed fissures filled with Frisco limestone extending down into the St. Clair (text-fig. 13), but I have not seen any Sallisaw-filled fissures in either the Frisco or the St. Clair. As the Sallisaw generally has a fairly high carbonate content it would be difficult to distinguish such veins from the enclosing Frisco or St. Clair limestones, assuming they are present.

The pre-Sylamore land surface must have undergone a moderate amount of solution prior to Chattanoogan time. For the most part, this appears to have been confined to the development of narrow fissures by solution acting along joint planes or fractures, but in places it produced cavities several feet across and may even have developed a few small caverns. Some collapse breccia (founder breccia) was produced at this time, at least judging from the coarse, angular limestone fragments found in the larger pockets (text-fig. 22). The Sylamore sand which was laid down on this old surface filled these cavities, being fine enough to penetrate into the small crevices. The Sylamore sandstone which fills these cavities is generally cemented with carbonate, whereas in the main body of this member there is little carbonate present.

Strata underlying the Sylamore sandstone: The Chattanooga formation, with its basal member the Sylamore sandstone, is separated from the underlying beds by an erosional unconformity. Within the Marble City area the Sylamore rests in places upon the Sallisaw, in other places on the Frisco, and in still others on the St. Clair (pl. I). North of this area, in Mayes and Delaware Counties, the entire Silurian and most of the Ordovician were removed by pre-Chattanooga erosion and the Sylamore rests upon the Cotter dolomite (Huffman, 1958, p. 16). The uplift which accompanied this period of erosion may have been accompanied by some folding, but if so it must have been in the nature of a gentle warping as the strata appear to be nearly conformable, at least in the region I have studied. It is difficult to determine the amount of relief developed on the pre-Sylamore land surface; however, in the Marble City area at least 25 feet of Lower Devonian plus an unknown amount of Silurian were removed.

The Sylamore sandstone rests upon the Sallisaw formation throughout most of the southern half of the Marble City area (pl. I). The distinction between these two stratigraphic units has given past investigators some trouble and the units have frequently been confused with each other. Not only has the Sylamore basal breccia been referred to the Sallisaw, but a perusal of the lithologic descriptions and maps of past publications shows that the Sylamore sandstone itself has been in places identified as Sallisaw and vice versa. This is somewhat surprising because the two formations are actually quite different from each other. Probably a part of the confusion stems from the fact that the Sallisaw formation has been described generally as a calcareous sandstone, whereas it is in reality a low arenaceous limestone with average insoluble content of less than 10 percent. The typical Sallisaw texture consists of subangular quartz detritus, mostly in grains less than 0.2 mm in diameter, scattered through a carbonate matrix (pl. XI). On the other hand the Sylamore, excluding the vein material, is a quartz sandstone made up largely of rounded quartz grains with prominent overgrowths which largely fill the interstices (pl. XIII, figs. 1, 2); carbonate is rare except in the fissure fillings where it is associated with much fragmental limestone debris quite unlike anything in the Sallisaw. The quartz grains in the Sylamore tend to be larger and better rounded than those in the Sallisaw; another distinctive feature of the Sylamore is the presence of well-rounded, dark-colored phosphatic pebbles. The arenaceous chert facies of the Sallisaw is a high-silica rock like the Sylamore, but its texture is quite unlike any part of the latter (compare pl. XIII, figs. 5, 6). With a few exceptions fossils are not especially common in the Sallisaw, although most outcrops include some brachiopod-bearing beds; in contrast, the only megafossils I have found in the Sylamore are rare linguloid brachiopods (the phosphatic nodules may be organic).

Where the Sylamore sandstone rests upon the Frisco formation there is no problem in distinguishing the two as the sandstone and sandy breccia of the Sylamore is entirely different from the bioclastic limestone of the Frisco; a photomicrograph showing this contact is illustrated in the frontispiece. In the thin-section shown in the frontispiece, the basal Sylamore does not have pebbles, but other specimens from this same stratigraphic section (S7) include chert fragments up to an inch in length, along with some small pieces of Frisco limestone. Of special interest is the fact that one specimen from S7 includes fragments of arenaceous Sallisaw limestone, a formation which is not present in the immediate vicinity. The Sallisaw does, however, crop out a short distance to the south (pl. I).

Throughout most of the outcrop belt along Walkingstick Hollow, in the northern part of the Marble City area (pl. I), the Sylamore sandstone rests directly upon the St. Clair formation. Both the pink crinoidal limestone facies and the dolomite facies of the St. Clair are easily distinguished from the Sylamore sandstone and sandy breccia.

Thickness and distribution: The Sylamore member has a widespread, although somewhat erratic, distribution in northeastern Oklahoma (Huffman, 1958, p. 38). It is present throughout most of the Marble City area; Christian's geologic map shows the Sylamore to be absent in several places, but it must be kept in mind that he included the basal breccia in the Sallisaw formation. The Sylamore sandstone is apparently everywhere thin; the thickest section measured by me is 20 feet at stratigraphic section S14 where the top is not exposed.

Fossils and age: The only Sylamore fossils which I have observed are linguloid brachiopods and a few conodonts. Christian (1953, p. 43) and Huffman (1958, p. 39) mention fragments of spirifers, but these probably came from Sallisaw chert fragments incorporated into the basal breccia. The stratigraphic relations indicate that the Sylamore is closely related in age to the Chattanooga black shale, the lower part of which has been assigned to the Upper Devonian.

WOODFORD FORMATION

In the Arbuckle Mountain region of south-central Oklahoma the Frisco formation is overlain by the Woodford formation. The Woodford shale is lithologically similar to the Chattanooga shale of northeastern Oklahoma, and these two formations are generally considered to be nearly exact correlatives (text-fig. 2). In places the Woodford has a basal conglomerate or breccia, but this is thin and nowhere attains the proportions of the Sylamore sandstone (and sandy breccia) member of the Chattanooga. The Woodford-Frisco stratigraphic relations will not be taken up in the present report as I have already discussed this topic in my report on Hunton stratigraphy (1960, p. 135-140, panels II, III).

STRATIGRAPHIC DISTRIBUTION OF DOLOMITE

A detailed study of the dolomites in the Silurian and Devonian rocks of Sequoyah County is beyond the scope of the present report. Here, as elsewhere, the genesis of the $MgCO_3$ presents a complex problem the investigation of which would, among other things, require a more detailed petrographic analysis than has been made. I have, however, assembled a considerable amount of information on the stratigraphic distribution of dolomite in the upper part of the St. Clair, in the Frisco, and in the Sallisaw formations, and, as this appears to have a bearing on the time at which the magnesium was introduced, it is summarized below. Further details on the dolomite content are given under the section on *Lithologic character* for each of these formations. For a discussion of dolomite in the Frisco formation of the Arbuckle Mountain region see my 1960 paper on Hunton stratigraphy (p. 18-20, 129).

There is a marked stratigraphic control to the distribution of dolomite in the Silurian and Devonian strata of the Marble City area. The St. Clair and Sallisaw have a wide range in $MgCO_3$ content, both formations ranging from high-calcium limestones to calcitic dolomites. In contrast, the intervening Frisco formation is everywhere a high-calcium limestone the maximum $MgCO_3$ content of which is only two percent. The range of $MgCO_3$ in each of these formations is compared in text-figure 23, and their averages are compared in text-figure 3. The chemical analyses are given in the appendix. The stratigraphic control is especially conspicuous in those areas where the uppermost St. Clair strata and the lowermost Sallisaw strata are strongly dolomitic. This is the relationship at stratigraphic section S9 where Frisco high-calcium limestone, with a thickness of only seven feet, is sandwiched between dolomitic St. Clair and dolomitic Sallisaw; the distribution of $MgCO_3$ and acid insolubles at S9 is shown in text-figure 24. Another example may be seen at stratigraphic section S10 where the lowermost Sallisaw bed has 24.5 percent $MgCO_3$ whereas the uppermost Frisco has less than one percent; a photomicrograph of this contact is illustrated on plate XI, figure 1. Still another example of the abrupt decline in dolomite content at the Frisco contact may be seen at stratigraphic section S8; here the uppermost St. Clair is dolomitic, with four to five percent $MgCO_3$ whereas the lowermost Frisco has only one percent. I have a thin section cut from a specimen which spans the contact, and this shows dolo-

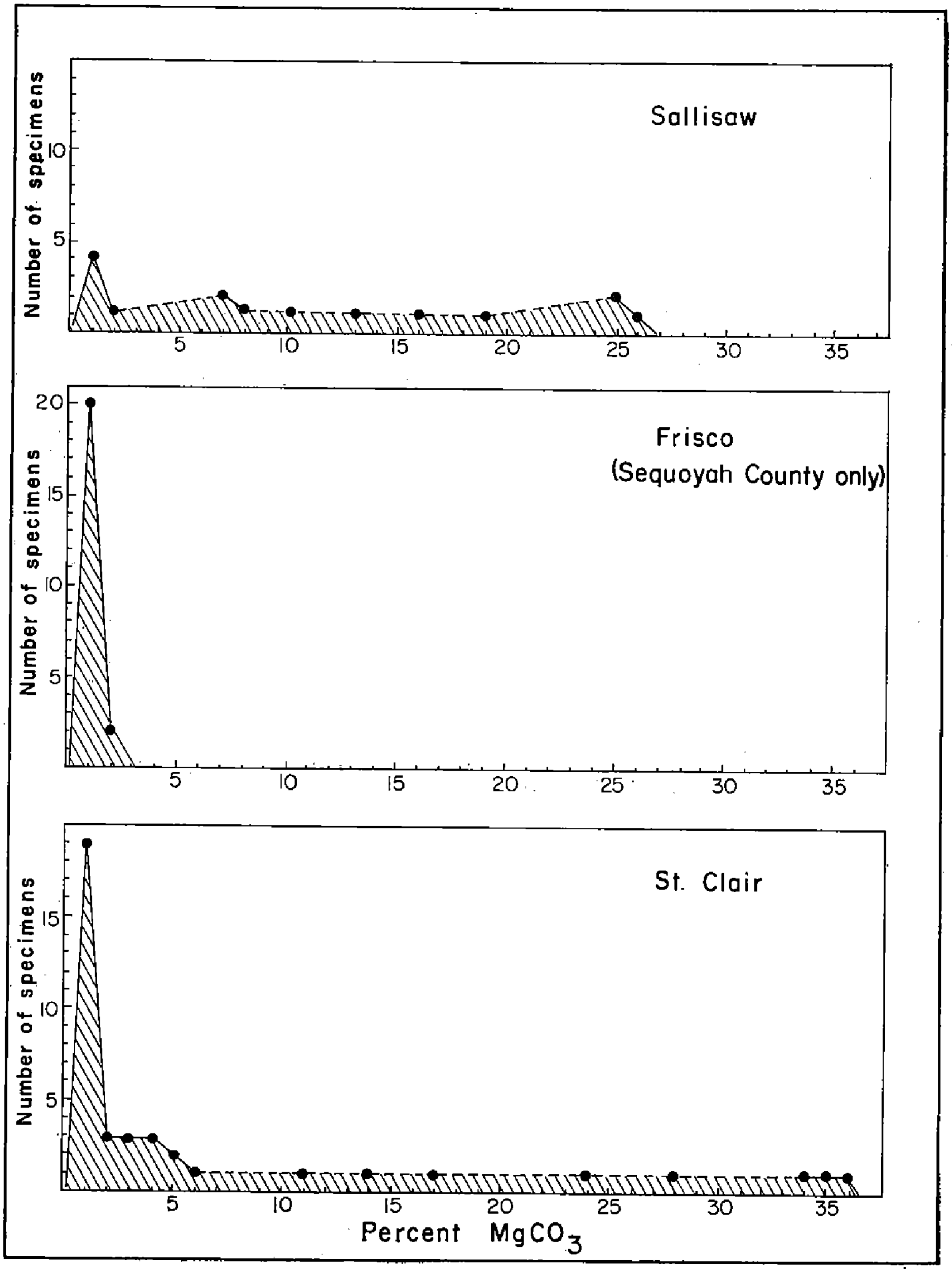


FIGURE 23. Frequency diagrams comparing the $MgCO_3$ content of the Sallisaw, Frisco, and St. Clair formations in the Marble City area, Sequoyah County. The Sallisaw and Frisco data are based on the rock-specimen analyses given in the Appendix (see text-figs. 9, 18); the St. Clair data include the rock-specimen analyses given in the Appendix (text-fig. 7) and the channel sample analyses given in Mineral Report 16 of the Oklahoma Geological Survey (Ham et al., 1943) (text-fig. 6). See also text-figure 3.

mitic St. Clair sharply truncated by the bioclastic limestone of the Frisco.

There are places in the Marble City area where all of the Silurian* and Devonian strata have a low magnesium content. This is the condition at stratigraphic section S1 where none of the St. Clair (upper 20 feet), Frisco or Sallisaw strata has more than 1.5 percent $MgCO_3$. As a matter of fact the distribution of dolomite in the upper St. Clair and throughout the Sallisaw is most irregular and does not seem to follow any predictable stratigraphic pattern. The erratic distribution of dolomite in the upper part of the St. Clair is well displayed in the mine of the St. Clair Lime Company. At the entrance to this mine the St. Clair is a high calcium stone, whereas at the face, near S13A (pl. I) dolomitic beds are common; as the strata in this area are essentially flat lying and the mine workings are nearly horizontal, the beds exposed in the face must occupy about the same stratigraphic position as do those near the opening. This shows that the dolomite is in the form of lenses, i.e., the high-magnesium-bearing strata are a facies of the high-calcium beds. It should also be noted that the Frisco-St. Clair contact is completely exposed for a distance of 100 feet or so in the mine face near S13A, and non-dolomitic Frisco beds clearly can be seen to truncate both the dolomitic and the non-dolomitic (pink-crinoidal) beds of the St. Clair.

The lensing character of the dolomitic beds can be seen at various places on the surface. For example, at stratigraphic section S8 beds of dolomite can be traced laterally into the typical, pink-crinoidal limestone facies of the St. Clair. This same condition is present in the Sallisaw, although it is not so obvious in this formation as the dolomitic and calcitic facies are not megascopically as distinct as they are in the St. Clair; however, in thin section the textures are quite distinct (compare figs. 1 and 2, pl. XI). It might also be added that there does not appear to be any relationship between the distribution of dolomite in the St. Clair and in the Sallisaw. In places (e.g. S9) the uppermost St. Clair and lowermost Sallisaw are high in $MgCO_3$, but in other places (S4) the uppermost St. Clair is high in $MgCO_3$ and the Sallisaw is low in $MgCO_3$.

* In the present study only the upper 25 to 30 feet of the St. Clair have been studied in detail.

The stratigraphic distribution of dolomite cited above suggests that the $MgCO_3$ in these strata is closely related to the time of deposition. If it represented a "secondary" or late-stage dolomitization, introduced after all of these formations were laid down, it should be present in the Frisco formation as well as in the St. Clair and Sallisaw formations. Its paucity in the Frisco would therefore indicate that the St. Clair dolomite was already present before the Frisco was deposited. The St. Clair $MgCO_3$ could, of

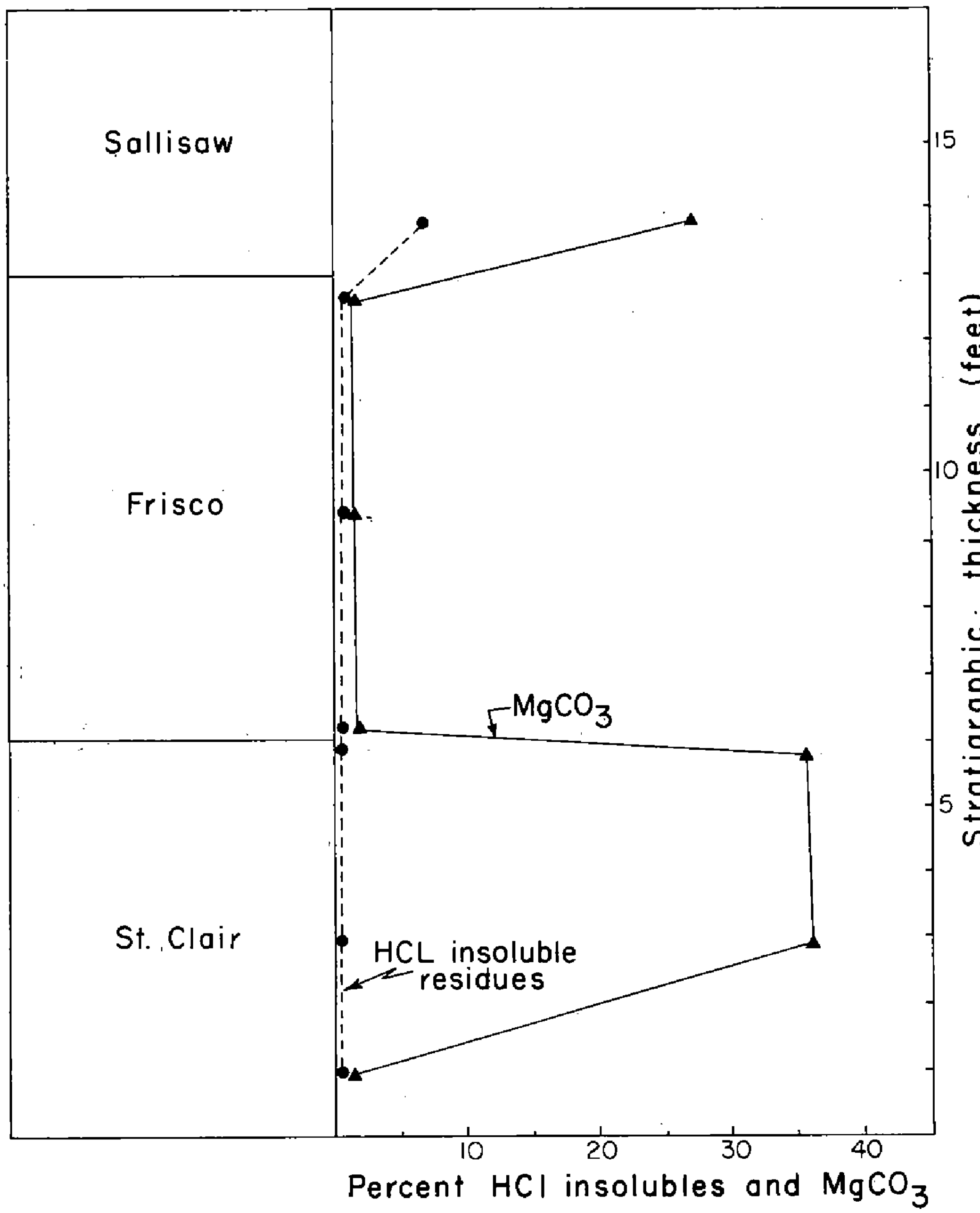


FIGURE 24. Diagram showing the range of HCl-insoluble residues and $MgCO_3$ in the rock samples collected from stratigraphic section S9. Each point represents the analysis of a single rock specimen. The data for this diagram are given in the Appendix.

course, represent a "secondary" dolomitization which took place at some time after deposition of the limestone and before deposition of the Frisco. Although this might be the correct explanation, there is no evidence relating the St. Clair dolomites to the pre-Frisco land surface; in places the uppermost St. Clair beds are dolomitic (e. g. stratigraphic section S9; text-fig. 24), but in other places the uppermost strata are high-calcium stone (e.g. S1; pl. IV) and the dolomite beds are situated some distance below the top. In any event, the Sallisaw dolomite would not appear to be a "secondary" type, because any magnesium-bearing waters circulating through the rocks would have penetrated into the Frisco.* It would therefore seem more reasonable to interpret the $MgCO_3$ in the St. Clair, Frisco, and Sallisaw as "primary," used in the sense that it was introduced at the same time the limestones were laid down, either as a precipitate or as a penecontemporaneous replacement.

* It might be postulated that there is something in the Frisco composition and/or texture which inhibited dolomitization by magnesium-bearing waters; however, the rock is sufficiently similar to the St. Clair in chemical composition and texture to make such an explanation appear unlikely.

GEOLOGIC HISTORY

This section contains a summary of the events, depositional and erosional, which took place in the Marble City area* during Silurian and Early Devonian times. The observations made herein are, of course, entirely inferential, representing an interpretation based on the field and laboratory data given in the preceding pages. All of the remarks concerning the St. Clair formation are based on a study which was restricted to the Marble City area, and largely concentrated on the upper 25 to 30 feet of the formation.

The St. Clair formation is an evenly bedded, pelmatozoan limestone showing little or no cross-bedding or channeling. The pelmatozoan debris which makes up a large part of the rock is mostly in the form of discrete plates, but, except for the disarticulation of the skeletal elements, there is little evidence of breakage or abrasion. On the whole the megafossils are well preserved and many of the free brachiopod specimens consist of complete, articulated shells. All of this points to a low-energy deposit well removed from the zone of strong wave or current action. A deposit of this type would seem to be most reasonably associated with an offshore environment, possibly the outer neritic zone of modern ecologists (e.g., Hedgpeth, 1957, p. 18). Terrestrial detritus is extremely sparse in the St. Clair, indicating that either the source of such material was far removed or that some barrier separated the site of deposition from the source area. In all probability the St. Clair seas had a fairly high magnesium content which locally became sufficiently concentrated to produce beds of dolomitic limestone or dolomite.

The deposition of the St. Clair formation was succeeded by a long period of emergence which appears to have occupied most of Upper Silurian and Early Devonian time. If any strata were deposited during this time they were removed by erosion which took place prior to the invasion of the Frisco sea. In this connection it is interesting to note the widespread distribution of Helderbergian strata in the central part of the United States; beds of this age are present in south-central Oklahoma, southwestern Illinois, southeastern Missouri, western Tennessee, and southern Mississippi,

* For a discussion of the geologic history of the Frisco formation in the Arbuckle Mountain region see Amsden, 1960, p. 131-132, 159-165.

and it is possible they were also deposited in northeastern Oklahoma and subsequently removed by pre-Deerparkian erosion. The amount of strata removed by post-St.Clair and pre-Frisco erosion in the Marble City area is not known, but the surface upon which the Frisco was deposited probably had only moderate relief. This period of emergence does not seem to have developed much of a regolith, or if it did the debris was largely swept away by the advancing Frisco sea. The absence of a mantle may well be related to the paucity of insoluble material, such as chert and terrigenous clastics, in the St. Clair. It is somewhat surprising that so little limestone rubble was produced at this time, although this could be explained by assuming that erosion was largely by chemical solution rather than mechanical abrasion. St. Clair strata have clearly been subjected to considerable solution in the past and at least some of this can be related to pre-Frisco time. Probably the pre-Frisco land surface was low lying and well removed from any source of land-derived clastics.

The Frisco formation appears to have been deposited in a much higher energy environment than was the St. Clair. It is composed in large part of organic debris, mostly brachiopods, snails, corals, bryozoans, and crinoids, mixed together to make a poorly sorted coquina. Much of this organic material is broken and the bivalve shells are largely disarticulated. The finer debris produced by this breakage was in places flushed out of the coquina and concentrated into beds or bars. In general the bedding is irregular and the various lithologic types grade laterally and vertically into one another. All of this evidence indicates shallow water deposition where wave and/or current action was strong. It could represent a littoral or beach deposit although its extensive geographic distribution might militate against such an interpretation. Perhaps it is more reasonably interpreted as the product of deposition in the inner neritic zone.* In any event the organic material was shifted about on the sea floor to such an extent that much of it was broken and most of the bivalve shells were disarticulated. Although the Frisco

* The Frisco includes little terrigenous detritus, but this does not appear to be of any particular significance in so far as indicating whether it is, or is not, a beach deposit; if no terrigenous material was available, and certainly the old St. Clair terrane would not have supplied much, then none would be present in the deposit regardless of where it was laid down.

would seem to be a thanatocoenose I do not believe the organic material has moved far from its original habitat. The Frisco seas appear to have had a low magnesium content.

The foregoing remarks apply to the Frisco formation in both the Arbuckle Mountain region and Sequoyah County. Although this formation cannot now be continuously traced from one area to the other, the similarities in lithology and fauna between the rocks of the two regions suggest that they were laid down in the same sea as a more or less continuous deposit which subsequent pre-Chattanooga (pre-Woodford) erosion has reduced to discontinuous patches.

Frisco deposition was terminated by a period of emergence and erosion. At this time, as in the post-St. Clair and pre-Frisco period of emergence, little or no regolith appears to have been developed. In Sequoyah County the post-Frisco erosion was of sufficient magnitude to remove locally all of the Frisco and an unknown amount of St. Clair, allowing the Sallisaw to rest directly upon the Silurian strata. Nothing is known about this period of emergence in the Arbuckle Mountain region because Sallisaw beds are absent and the Woodford rests directly upon the Frisco.

The environment of deposition during Sallisaw time would seem to have been similar to that of the Frisco in spite of the fact that the two formations are lithologically different. Organic material, with the possible exception of pelmatozoan debris, was not as abundant as in Frisco time whereas the supply of terrestrial detritus greatly increased. The Frisco and St. Clair have only traces of quartz detritus whereas the Sallisaw averages 9.5 percent, and some beds have as much as 45 percent. Nothing is known about the source of this material; the small outcrop area gives no clue as to the direction or proximity of the land supplying this detritus. The Sallisaw strata appear to have been laid down in a relatively high energy environment. The bedding is irregular and the fossil material is broken up with almost all of the bivalve shells being disarticulated. Like the Frisco, the Sallisaw would appear to have been deposited in a zone of rather strong wave action, possibly a littoral or inner neritic environment. The increase in the quantity of quartz sand over that found in the Frisco could be entirely related to an increase in the supply furnished to the basin of deposition, and would not necessarily have any significance concerning proximity to shore.

The Sallisaw sea probably had a fairly high magnesium content, locally becoming sufficiently concentrated to produce dolomitic beds. The origin of the silica in the vitreous and arenaceous cherts of this formation presents a problem. These cherts clearly seem to be replacement bodies which developed after the Sallisaw carbonate, including dolomite, was formed, and before the basal breccia of the Sylamore was laid down. They could have developed by silica in the sea water replacing the carbonate during the period of deposition, or they could have been produced by silica-charged waters circulating through the rocks at some time after deposition, and before Chattanooga time. In the latter case the detrital quartz could have been the source of the silica, although it should be noted that the quartz grains in the arenaceous chert do not appear to have undergone solution; in fact they commonly appear to have secondary overgrowths. There is little silica of any kind in the underlying Frisco and Sallisaw formations.

Sallisaw deposition was succeeded by a period of uplift and erosion. Within the Marble City area all of the Lower Devonian strata and a part of the Silurian beds were locally removed, and farther north all of the Silurian and most of the Ordovician were stripped away. In the Marble City area some coarse debris was produced by pre-Chattanooga weathering and this was later incorporated into the basal Sylamore. Much of this material is of local origin, mostly pieces of chert which were weathered out of the underlying strata. For further information on the pre-Chattanooga (and pre-Woodford) unconformity see the following: Amsden, 1960, p. 136; Huffman, 1958, p. 16; Maxwell, 1959, p. 101-126; Tarr, 1955, p. 1852-1853.*

* The depositional history of the Frisco formation given in this section differs slightly from that of my 1960 report; additional lithostratigraphic evidence suggests that these strata were laid down in a somewhat more turbulent environment that previously inferred.

REFERENCES

Amsden, T. W., 1957, Stratigraphy and paleontology of the Hunton group in the Arbuckle Mountain region, Part I — Introduction to stratigraphy: Okla. Geol. Survey, Circ. 44, 57 p., 3 pls., text-figs.

——— 1960, Stratigraphy and paleontology of the Hunton group in the Arbuckle Mountain region, Part IV — Hunton stratigraphy: Okla. Geol. Survey, Bull. 84, 311 p., 3 panels, 17 pls., text-figs.

Amsden, T. W., and Huffman, G. G., 1958, Frisco brachiopod from a Hunton core, Pottawatomie County: Okla. Geol. Survey, Okla. Geology Notes, vol. 18, p. 73-76.

Bathurst, R. G. C., 1958, Diagenetic fabrics in some British Dinantian limestones: Liverpool and Manchester Geol. Jour., vol. 2, p. 11-36, 1 pl., text-figs.

Beckwith, C. G., Jr., 1950, The geology of the Fort Gibson area, Cherokee and Muskogee Counties, Oklahoma: Master of Science thesis, University of Oklahoma, 74 p., map.

Boucot, A. J., 1958, Age of the Bainbridge limestone, Jour. Paleontology, vol. 32, p. 1029-1030.

——— 1959, Brachiopods of the Lower Devonian rocks at Highland Mills, New York: Jour. Paleontology, vol. 33, p. 727-769, pls. 90-103.

Carozzi, A., 1960, Microscopic petrology: New York, John Wiley and Sons, Inc., 485 p., illust.

Christian, H. E., 1953, Geology of the Marble City area, Sequoyah County, Oklahoma: Master of Science thesis, University of Oklahoma, 160 p., map, illust.

Cooper, G. A., et al., 1942, Correlation of the Devonian sedimentary formations of North America: Geol. Soc. America, Bull., vol. 53, p. 1729-1794, 1 pl., 1 fig.

Cram, I. H., 1930, Cherokee and Adair Counties, *in* Oil and Gas in Oklahoma: Okla. Geol. Survey, Bull. 40, vol. 3, p. 531-582.

Dunbar, C. O., 1919, Stratigraphy and correlation of the Devonian of western Tennessee: Tenn. Geol. Survey, Bull. 21, 127 p., 3 pls., text-figs.

Dunbar, C. O., and Rodgers, J., 1957, Principles of stratigraphy: New York, John Wiley & Sons, Inc., 356 p., illust.

Folk, R. L., 1959, Practical classification of limestones: Amer. Assoc. Petroleum Geologists, Bull., vol. 43, p. 1-38, text-figs.

Gould, C. N., and Decker, C. E., 1925, Index to the stratigraphy of Oklahoma: Okla. Geol. Survey, Bull. 35, 113 p.

Ham, W. E., Dott, R. H., Burwell, A. L., and Oakes, M. C., 1943, Geology and chemical composition of the St. Clair limestone near Marble City, Oklahoma: Okla. Geol. Survey, Mineral Report 16, 24 p.

Ham, W. E., et al., 1954, Geologic map and sections of the Arbuckle Mountains of Oklahoma: Okla. Geol. Survey, Map A-2.

Hass, W. H., 1956, Age and correlation of the Chattanooga shale and the Maury formation: U. S. Geol. Survey, Prof. Paper 286, p. 1-47, 5 pls.

Hedgpeth, J. H., 1957, Classification of marine environments, *in* Treatise on marine ecology and paleoecology, vol. 1; Geol. Soc. America, Memoir 67, p. 17-29, text-figs.

Huffman, G. G., 1958, Geology of the [south and west] flanks of the Ozark uplift: Okla. Geol. Survey, Bull. 77, 281 p., 6 pls., text-figs.

Huffman, G. G., and Starke, J. M., Jr., 1960, Noel shale in northeastern Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 20, p. 159-163.

Maxwell, Robert W., 1959, Post-Hunton pre-Woodford unconformity in southern Oklahoma, *in* Petroleum geology of southern Oklahoma, vol. 2: Amer. Assoc. Petroleum Geologists, p. 101-126, text-figs.

Maxwell, Ross A., 1936, The stratigraphy and areal distribution of the "Hunton formation," Oklahoma: Ph.D. dissertation, Northwestern University, 120 p., illust., maps and sections. An abstract of this dissertation was published in *Summaries of Doctoral Dissertations,* vol. 4, Northwestern University, 1936, p. 131-136.

Mondy, H. H., 1950, The areal geology of the Greenleaf area, Cherokee and Muskogee Counties, Oklahoma: Master of Science thesis, University of Oklahoma, 72 p., map and illust.

Pettijohn, F. J., 1957, Sedimentary rocks, 2nd ed.: New York, Harper & Brothers, 718 p., illust.

Powell, C. C., 1951, The geology of the Bunch area, Adair and Sequoyah Counties, Oklahoma: Master of Science thesis, University of Oklahoma, 80 p., map and text-figs.

Reeds, C. A., 1911, The Hunton formation of Oklahoma: Amer. Jour. Science, vol. 182, p. 256-268.

Reeds, C. A., 1926, The Arbuckle Mountains, Oklahoma: Okla. Geol. Survey, Circ. 14, 15 p., illust. This paper also appeared in the Amer. Museum Nat. History, Jour., vol. 26, p. 463-474, illust.

Schuchert, C., 1922, Devonian of Oklahoma with special reference to the Oriskany and Camden formations: Geol. Soc. America, Bull., vol. 33, p. 665-670.

Siemens, A. G., 1950, The areal geology of the Tenkiller Ferry area, Sequoyah and Muskogee Counties, Oklahoma: Master of Science thesis, University of Oklahoma, 57 p., map and text-figs.

Snider, L. C., 1915, Part I — Geology of a portion of northeastern Oklahoma: Okla. Geol. Survey, Bull. 24, 65 p., illust.

Swann, D. H., and Willman, H. B., 1961, Megagroups in Illinois: Amer. Assn. Petroleum Geologists, Bull., vol. 45, p. 471-483.

Swartz, C. K., et al., 1942, Correlation of the Silurian formations of North America: Geol. Soc. America, Bull., vol. 53, p. 533-538, 1 pl.

Taff J. A., 1904, Geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma: U. S. Geol. Survey, Prof. Paper 31, 111 p.

Taff, J. A., 1905, Description of the Tahlequah quadrangle [Indian Territory-Arkansas]: U. S. Geol. Survey, Geol. Atlas, Folio 122, 7 p., maps.

Tarr, R. S., 1955, Paleogeologic map at base of Woodford and Hunton isopachous map of Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 39, p. 1851-1858, maps.

Thomas, H. D., 1960, Misuse of "bioclastic limestone": Amer. Assoc. Petroleum Geologists, Bull., vol. 44, p. 1833-1834.

Ulrich, E. O., 1911, Revision of the Paleozoic systems: Geol. Soc. America, Bull., vol. 22, p. 281-680, pls. 25-29.

Ventress, W. P. S., 1958, Stratigraphy and megafossils of the Frisco formation: Master of Science thesis, University of Oklahoma, 144 p., 7 pls., map.

Wilson, C. W., Jr., 1949, Pre-Chattanooga stratigraphy in central Tennessee: Tenn. Dept. Conservation, Division Geology, Bull. 56, 405 p., maps and pls.

PLATES VII TO XIII

Plate VII

Figures 1-6. St. Clair formation. All of these are illustrations of thick thin-sections. Bar is 0.5 mm long.

1, 2. Photomicrographs showing the typical St. Clair texture consisting of pelmatozoan plates set in a matrix of sparry calcite. Stratigraphic section S1-A.

3. Enlarged view of a pelmatozoan stem plate which is almost completely embedded in sparry calcite. Stratigraphic section S1-A.

4. Photomicrograph of a specimen with scattered bryozoan fragments in addition to the pelmatozoan debris. This specimen was collected from the upper 30 feet of the St. Clair, just north of the St. Clair Lime Company quarry; NE¼ SE¼ NE¼ sec. 14, T. 13 N., R. 23 E.

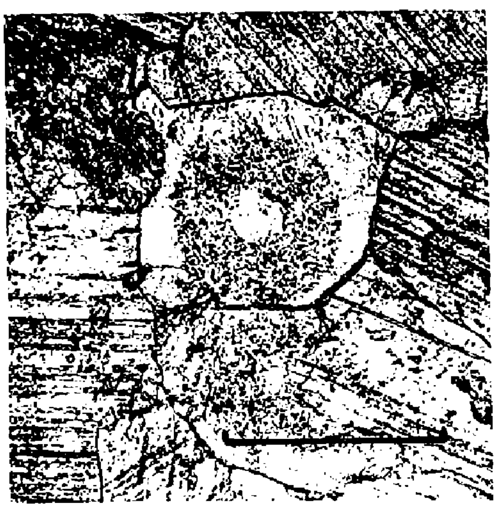
5. Photomicrograph of a dolomitic limestone bed in the St. Clair. The darker, finer-grained areas are partly dolomite. Stratigraphic section S8; upper two feet of the St. Clair formation.

6. Photomicrograph of a St. Clair dolomite bed ($MgCO_3$ about 35 percent). Stratigraphic section S9-B.

Other photomicrographs of the St. Clair are illustrated on the frontispiece and on plates IV, V, VIII, XIII.

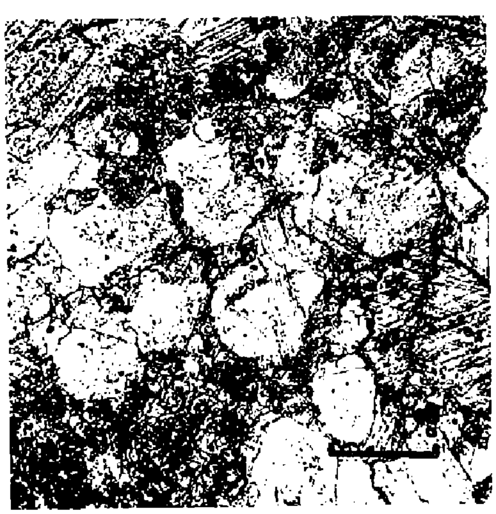
1

2

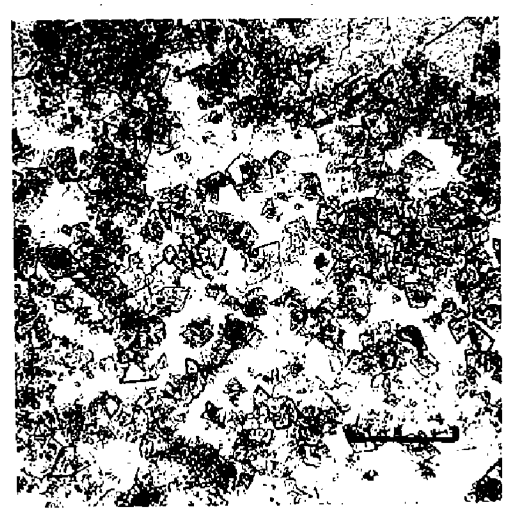


3

4



5



6

1

2

PLATE VIII

FIGURE 1. Thick thin-section of the Frisco formation showing a mixture of coarse and fine fossil debris. The finer material in the upper part of the picture is composed largely of broken fossils. Note that some of the shells have a rim of sparry calcite. Bar is 1 mm long.

FIGURE 2. Thick thin-section of the St. Clair-Frisco contact (arrow). Note the stylolite in the Frisco. Bar is 1 mm long.
Both of these photomicrographs are enlarged views of the thin section illustrated in the frontispiece (stratigraphic section S7).

Plate IX

FIGURES 1-6. Frisco formation, Sequoyah County. All of these illustrations are of thick thin-sections. Bar is 0.5 mm long.

1. Photomicrograph of the shell coquina facies. The matrix is mostly finely divided carbonate (micrite). Note the rim of sparry calcite on the larger fossils. Stratigraphic section S7; this is a much enlarged view of part of the thin section shown in the frontispiece.

2. Photomicrograph of the biocalcilutite-biocalcarenite facies. The matrix is mostly sparry calcite. Stratigraphic section S9-C.

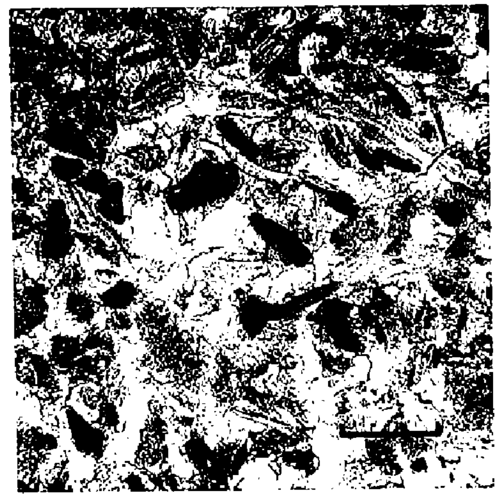
3, 4. Photomicrographs showing the biocalcilutite-biocalcarenite facies; figure 4 is an enlarged view of figure 3. Stratigraphic section S11-B.

5. Photomicrograph of the biocalcarenite facies which is made up in large part of pelmatozoan debris (gray, stippled-appearing bodies). The matrix is partly sparry calcite (clear areas). This specimen was collected from the rim of the St. Clair Lime Company quarry, NE¼ sec. 14, T. 13 N., R. 23 E. (pl. I).

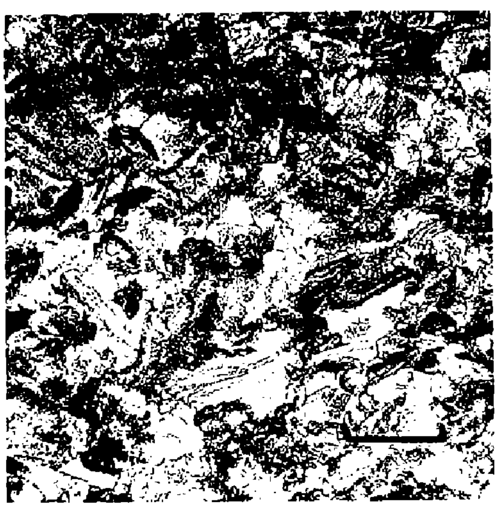
6. View of a Frisco specimen which is a mixture of pelmatozoan plates and shell debris, including much bryozoan material. The matrix is partly sparry calcite (clear areas) and partly finely divided carbonate or micrite (dark areas). Stratigraphic section S9-D.

Other photomicrographs of the Frisco formation are shown on the frontispiece and plates IV, V, VIII, X, XII.

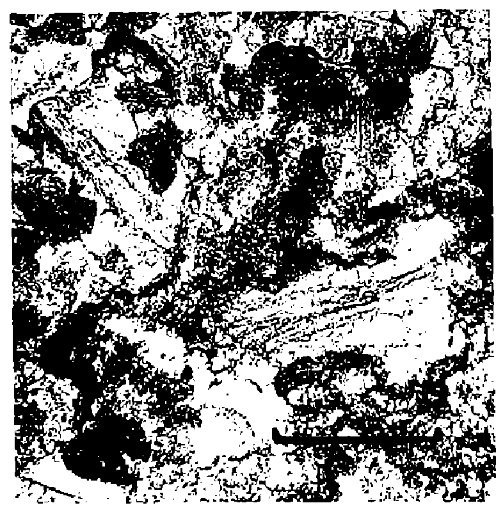
1



2



3



4

5

6

Plate XI

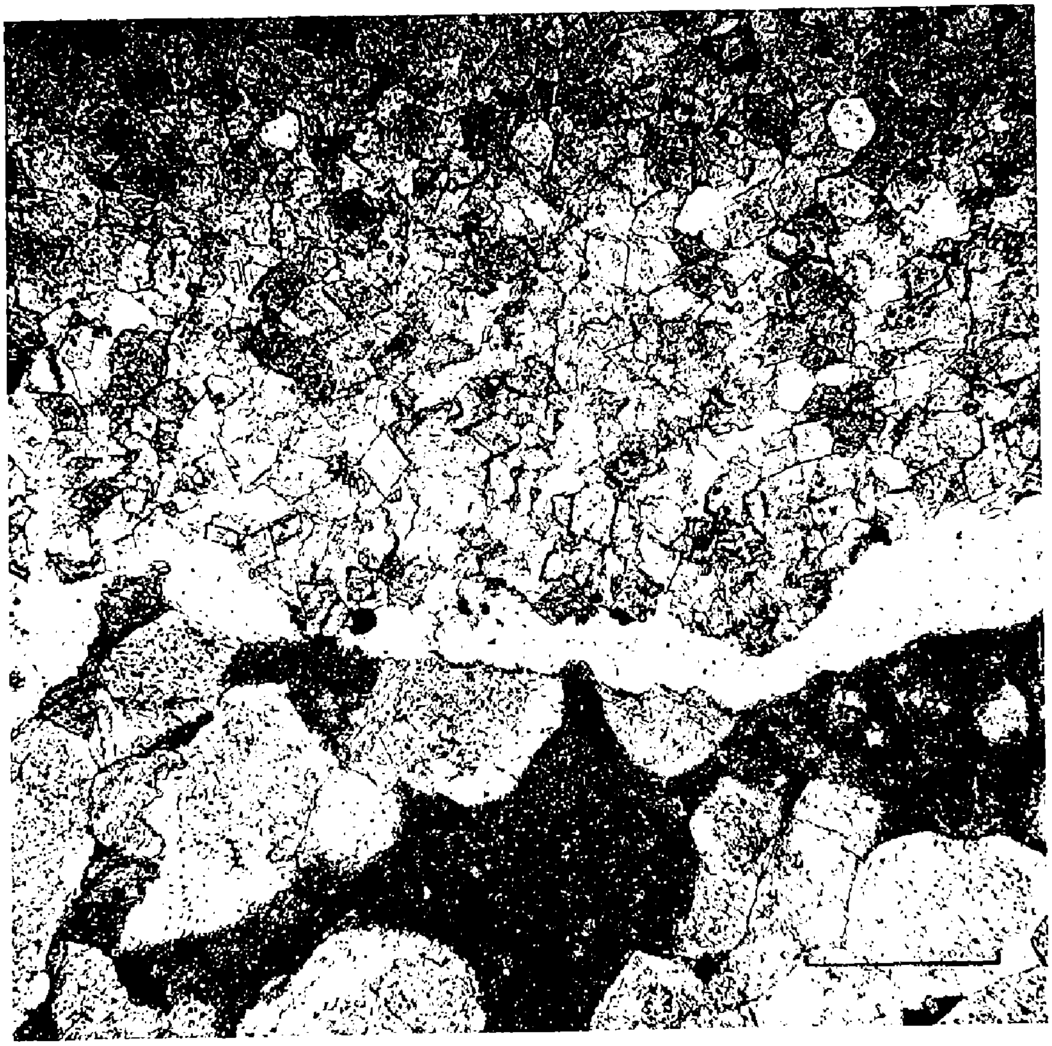
Figures 1-3. Sallisaw formation (fig. 1 includes Frisco in the lower part). Bar is 0.5 mm long.

1. Photomicrograph of the Frisco-Sallisaw contact at stratigraphic section S10-DC (thin section of conventional thickness). During preparation of this section the Sallisaw separated slightly from the Frisco, leaving a clear area (balsam) between the two formations. The Frisco consists largely of pelmatozoan plates (commonly with a rim of sparry calcite) set in a matrix of finely divided calcite (dark areas). The Sallisaw is calcitic dolomite ($MgCO_3$—24.6%) with scattered quartz grains (HCl-insoluble residue—5.1%); the quartz grains appear in the photograph as clear areas.

2. Photomicrograph of a thick thin-section from stratigraphic section S1-D (specimen No. 3 collected 5 to 7 feet above the base of the Sallisaw). The granular-appearing areas are carbonate, mostly calcite ($CaCO_3$—76.8%; $MgCO_3$—1.0%) and the clear areas are detrital quartz (HCl-insoluble residue—22.1%). The large fragments are brachiopod shells.

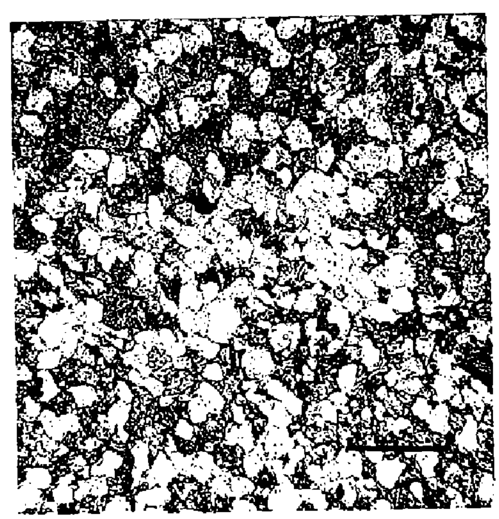
3. Photomicrograph of a thin section (conventional thickness) from stratigraphic section S10-D (specimen collected 18 feet above the base of the Sallisaw). This rock has an unusually high percentage of detrital quartz (clear areas), the insoluble residues being 45.4% ($MgCO_3$— 8.5%).

Other photomicrographs of the Sallisaw formation are illustrated on plate XII.



1

2



3

PLATE XIII

FIGURES 1-6. Sylamore member of the Chattanooga formation. In figures 3 to 6 the bar is 1 mm long. The Sylamore sandstone is also illustrated in the frontispiece.

1, 2. Photomicrographs of a thin section (conventional thickness) of the Sylamore at stratigraphic section S4-G (2 feet above base). Figure 1 was taken with crossed nicols and figure 2 in ordinary light. Note the well-rounded quartz grains with secondary enlargements that largely fill the interstices. Both enlarged about 90 times.

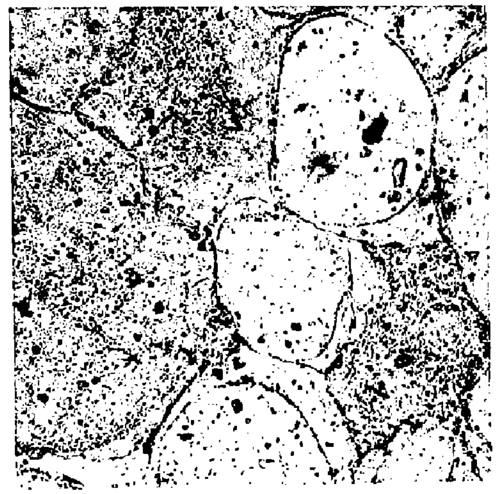
3. Thick thin-section showing Sallisaw sandstone filling a fissure in the St. Clair limestone; stratigraphic section S2. The St. Clair is composed largely of pelmatozoan plates set in a matrix of clear, sparry calcite. The Sylamore quartz grains are generally well rounded and commonly have secondary overgrowths. Ordinary light.

4. Photomicrograph of a thick thin-section showing the Sylamore sandstone which fills a fissure in the St. Clair limestone (not shown) in the St. Clair Lime Company mine; stratigraphic section S13-(5). The clear areas are rounded quartz grains (some with overgrowths) and the darker material is mostly carbonate fragments ranging in size from extremely fine pieces up to relatively large blocks (some are several inches in length; see text-fig. 22). Much of this carbonate detritus was derived from the St. Clair formation. Some of the very dark bodies are glauconite. Ordinary light.

5. Photomicograph of a thin section (standard thickness) from stratigraphic section S5-F. Crossed nicols.

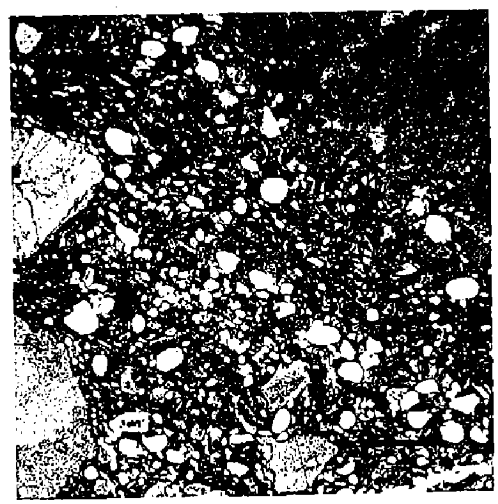
6. Photomicrograph of a block of Sallisaw arenaceous chert which is enclosed in the basal breccia of the Sylamore sandstone at stratigraphic section S5-E. The larger fragments are detrital quartz grains set in a matrix of finely-crystalline quartz. Compare with the Sallisaw specimen illustrated on Plate XII, figure 6. This rock is porous and the very dark areas are mostlv holes in the rock. Crossed nicols.

1

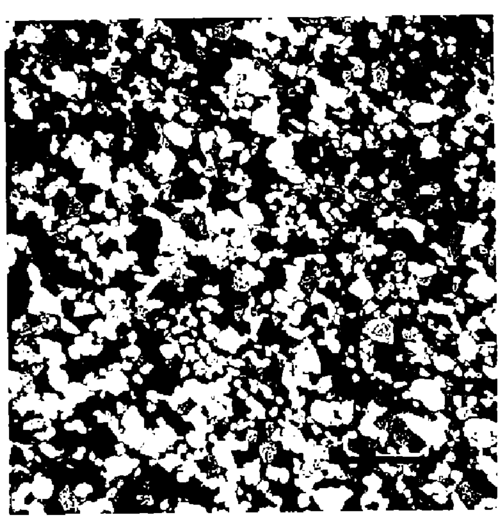


2

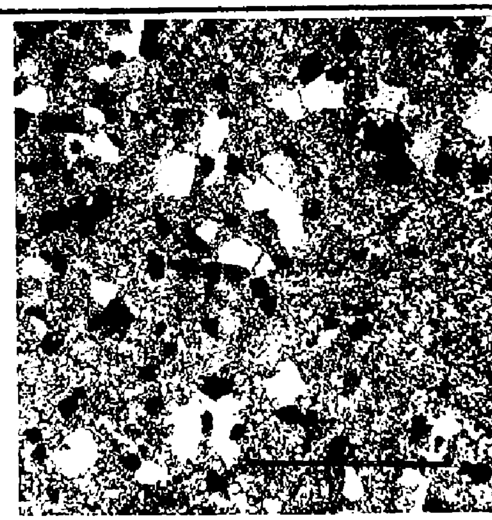
3



4



5



6

S8*—Payne Hollow
S9*—Payne Hollow
S10*—Payne Hollow
S11*—Payne Hollow
S12—north of St. Clair Lime Co. quarry
S13*—St. Clair Lime Co. mine
S14—Payne Hollow

The stratigraphic divisions recognized in each section are designated with a letter. For example, at stratigraphic section P8 the lower part of the Frisco is indicated with the letter H, as P8-H (Amsden, 1960, p. 277); or, for stratigraphic section S9 the letter D in S9-D marks the lower 3 feet of the Sallisaw (p. 102 of this report).

The stratigraphic sections for this report (as well as for those of my 1960 paper) were prepared as follows: A preliminary description was made in the field at the same time the thickness and other stratigraphic data were recorded. Rock specimens from each of the lithologic units recognized were collected at this time and these were later studied in the laboratory by means of thin sections, paralodion peels, HCl-insoluble residues, and chemical analyses. After the laboratory work was completed my field descriptions were revised to accord with any new information acquired. In the course of this investigation a great many photomicrographs were made, some of which are illustrated in this report, and these have proved to be most helpful in preparing the descriptions of textures. A discussion of the laboratory techniques and lithologic terminology used in this report is given in the introduction.

Throughout the Marble City area (which includes all stratigraphic sections with the letter prefix S) the dip of the strata is gentle, generally less than 10 degrees.

STRATIGRAPHIC SECTION S1

Big bend of the Sallisaw Creek

Section described and collected by T. W. Amsden, April 1, 2, 1959; an earlier collection was made by T. W. Amsden, C. C. Branson, and W. E. Ham on Oct. 8, 1958. This section is on the northwest side of Sallisaw Creek, at a big bend in the creek, about 0.75 mile north of Marble City; SW¼ SW¼ SW¼ sec. 13, T. 13 N., R. 23 E., Sequoyah County, Oklahoma (pl. I). The upper St. Clair, Frisco, and Sallisaw formations are present; about 20 feet of the upper St. Clair is exposed in an old quarry, followed by the Frisco and the lower part of the Sallisaw, all completely exposed. The Sallisaw caps a small knob, and the overlying beds, as well as an unknown thickness of the Sallisaw, have been removed by erosion.

The beds have a gentle dip to the southeast; the bedding planes are irregular, making it difficult to get a precise reading, but the dip is probably around 5 degrees.

Rock analyses from this section are listed under Chemical Analyses. Outcrop pictures of the St. Clair, Frisco, and Sallisaw formations are shown on plates II and VI. A photomicrograph of the St. Clair-Frisco contact is illustrated on plate IV; other photomicrographs are on plate VII, figures 1-3; plate XI, figure 2; plate XII, figure 5.

This is the type section of the Sallisaw formation.

SALLISAW FORMATION

(7 feet exposed to top of hill)

D. *Lithology*: Arenaceous limestone in irregular beds up to .... 7 feet
6 or 8 inches thick (pl. II). Chert sparingly present in the lower part, becoming more abundant towards the top where there are lenses 2 or 3 feet long and 8 inches or so thick; this is a light-colored, vitreous to porcellaneous chert which appears to represent a silicified arenaceous carbonate (2 thin sections). The texture of D is fairly uniform throughout. It is only sparingly fossiliferous, but one bed yielded specimens of *Amphigenia* sp.

Peels and thin sections show that this rock is primarily a calcarenite with quartz grains scattered through it (pl. XI, fig. 2; pl. XII, fig. 5). Quartz grains rather uniform in size, ranging up to 0.3 mm in diameter; a few are silt size, but most are fine sand. Grains are angular to subangular, with many having well-formed crystal faces (a few as doubly terminated crystals) some of which appear to represent secondary overgrowths on detrital grains; some grains are quite irregular (pls. XI, fig. 2; XII, fig. 5). The quantity of quartz ranges widely, the acid insolubles (3 specimens) ranging from 3.8 to 22.1 percent (Chemical Analyses). Carbonate mostly in sand-size grains similar to the quartz; some are clear calcite but many of the grains have a cloudy core, some of which may represent pelmatozoan plates.

$MgCO_3$ content low; 3 specimens tested had less than 2 percent (Chemical Analyses).

Remarks: The Sallisaw at this locality is entirely an arenaceous calcarenite and probably no part of it even approaches a sandstone. Its contact with the underlying Frisco is well exposed (pls. II; VI, fig 1) and easily located. The Frisco has a much greater amount of fossil material, and for the most part, much less quartz.

Fossils: This rock is sparingly fossiliferous; a few fragmentary conodonts recovered from acetic-acid residues.

FRISCO FORMATION

(total 4 feet)

C. *Lithology*: Light-gray, pelmatozoan limestone; uniform .... 2 feet
texture. Few chert nodules up to 2 or 3 inches in diameter. Peels and thin sections show this rock to be mostly pelmatozoan debris set in a micrite matrix; many of the pelmatozoan plates have a thin rim of sparry calcite. This is a high-calcium rock; four chemical analyses (Chemical Analyses) range from 98 to 99 percent $CaCO_3$

Remarks: The contact between this rock and the overlying Sallisaw is easily located in the field (pls. II; VI, fig. 1). One thin section cut from a rock specimen bridging the Frisco-Sallisaw contact shows an abrupt change in the microtexture, the coarse pelmatozoan limestone of the Frisco being in marked contrast to the arenaceous calcarenite of the Sallisaw.

Unit C represents the pelmatozoan facies of the Frisco, whereas the underlying unit B is the shell coquina (see text, Introduction); the boundary between these two is not everywhere well defined and there is vertical and lateral gradation from one to the other.

One HCl-insoluble residue from a specimen six inches below the contact had an unusually high percentage of insolubles (5%), most of the residue consisting of doubly terminated quartz crystals; only minor glauconite.

Fossils: Highly fossiliferous; no collection made.

B. *Lithology*: Gray, bioclastic calcarenite grading into .... 2 feet
a calcirudite. Peels and thin sections show that this rock is composed in large part of fossil debris, mostly broken and

poorly sorted, set in a matrix that is largely finely divided calcite (micrite; pl. IV) but with some clear sparry calcite, the latter generally associated with pelmatozoan plates.

This is a high-calcium rock, two analyses testing over 98 percent $CaCO_3$ (Chemical Analyses). HCl residues are mostly small quartz crystals less than 0.5 mm, many of which are doubly terminated; some pale-green glauconite, most abundant in the lower few inches.

Remarks: The Frisco is easily distinguished in the field from the underlying pinkish-gray crinoidal limestone of the St. Clair (pl. II). The contact is even more sharply defined in thin section (pl. IV); no pebbles of St. Clair have been observed in the basal Frisco at this locality, and the upper St. Clair shows no clear evidence of pre-Frisco weathering.

Fossils: This unit carries a large megafauna, mostly brachiopods with some corals, bryozoans, and snails. A great many fossils have been collected from here; it is a varied fauna although the preservation is not good because many of the shells are broken and the brachiopod shells are mostly disarticulated.

ST. CLAIR FORMATION

A. *Lithology*: Pinkish-gray to light-gray, pelmatozoan .... limestone in beds to a foot or so in thickness. Cavities present, many of these being filled or lined with coarse sparry calcite; some filled with a gray, thinly-laminated carbonate which has a higher HCl-insoluble content (3.4% and 8.1%) than the surrounding limestone; some sparry calcite associated with the laminations; range up to a foot in length although most are smaller.

Peels and thin sections show this rock is made up largely of pelmatozoan plates set in a matrix of sparry calcite (pls. IV; VII, figs. 1-3).

This is a high-calcium limestone; three analyses range from 98 to more than 99 percent $CaCO_3$. HCl-insoluble residues mostly tiny quartz crystals (less than 0.5 mm) and crystal aggregates; well-formed, doubly terminated crystals are common; also a few grains of subangular, detrital quartz. Some pyrite and limonite, and possibly sphalerite in tiny crystals.

Remarks: The upper 20 feet or so of the St. Clair is completely exposed in an abandoned quarry. The St. Clair-Frisco contact is well exposed for a distance of 50 feet or so; see pl. II and remarks under S1-B.

Fossils: Mostly pelmatazoans but there are some other megafossils present; small collection of brachiopods made from the upper 15 feet of the St. Clair.

STRATIGRAPHIC SECTION S2

North of St. Clair Lime Co. Quarry

This section described and collected by T. W. Amsden, April 2, 1959. It is in a small gully about 0.5 mile north of the St. Clair Lime Company Quarry (pl. I); SW¼ SW¼ SW¼ sec. 12, T. 13 N., R. 23 E., Sequoyah County. This is near Christian's fossil collecting locality #10 (1953, p. 31) which he recorded as Frisco and from which he collected specimens recorded as Favosites shriveri. *I did not, however, observe any Frisco in this area although it is quite possible that there are small pockets of this formation between the Sallisaw and the St. Clair. The St. Clair is locally dolomitized, but mostly it is pinkish-gray pelmatozoan limestone. A photomicrograph of a Sylamore sandstone filling in a fissure in the St. Clair is illustrated on plate XIII, fig. 3.*

SALLISAW FORMATION

Lithology: Light-gray, arenaceous, dolomitic limestone;........ peels and thin sections show this rock is finely divided carbonate (grains rarely exceed 0.5 mm) with scattered quartz grains; the carbonate includes dolomite rhombs but very little recognizable fossil material (there may be some pelmatozoan debris). The quartz grains are angular to subangular, ranging up to 0.6 mm in diameter with most falling between 0.1 and 0.5 mm; many of the grains have well-formed crystal faces, probably representing secondary growths on detrital grains. Some nodules of fossiliferous, white, vitreous chert.

One HCl residue, 21 percent; mostly sand-size quartz with some limonite and glauconite.

Remarks: Only the lower couple of feet of sallisaw exposed; much Sylamore sandstone float but this rock was not seen in place and the thickness of the Sallisaw was not determined. One rock specimen was collected which included the Sallisaw-St. Clair contact; a thin section of this contact shows a well-marked textural break between the arenaceous carbonate of the Sallisaw and the St. Clair crinoidal limestone. No recognizable fragments of St. Clair seen in the basal Sallisaw. No Frisco seen in this area.

Fossils: There are a few pieces of fossiliferous chert in the vicinity of this section but no megafossils were observed in the arenaceous carbonate.

ST. CLAIR FORMATION

Lithology: Pinkish-gray to light-gray limestone. Peels .... and thin sections show this rock is mostly composed of pelmatozoan plates set in a matrix of sparry calcite; some beds also include other fossils such as bryozoans and brachiopods.

The acid-insoluble content of this rock is low; residues mostly clear quartz in grains to 0.5 mm; much of this quartz is in small crystals, some doubly terminated, and aggregates of crystals; also some glauconite and some dark, reddish-brown mineral (possibly sphalerite).

Remarks: The upper part of the St. Clair is well exposed in the vicinity of this section. No Frisco was observed and in several places the Sallisaw may be observed directly in contact with the St. Clair. Thin "veins" of Sylamore sandstone extend down into the St. Clair for several feet (pl. XIII, fig. 3).

Fossils: A few fossils, mostly brachiopods, collected from the upper 2 or 3 feet.

STRATIGRAPHIC SECTION S3

Northeast of the St. Clair Lime Co. Quarry

This section described and collected by T. W. Amsden, April 2, 1 the fall of 1958 T. W. Amsden, C. C. Branson, and W. E. Ham visit locality and collected some fossils from the upper part of the St. Cl mation. It is on the north rim of a large, abandoned quarry in the NE¼ NW¼ sec. 13, T. 13 N., R. 23 E., Sequoyah County (pl. I). locality there is a complete exposure of the upper 30 to 40 feet of .... Clair in the north wall of the quarry. This formation is directly overlain by the Sallisaw formation, there being no Frisco present in the immediate vicinity of S3. The Sallisaw is of special interest because it is entirely in the arenaceous chert facies. A photomicrograph of the Sallisaw is illustrated on plate XII, figure 6.

SALLISAW FORMATION

Lithology: Fine-textured, light-gray, arenaceous chert .... weathering to a brownish- to reddish-gray. The rock is porous with many tiny holes; also the brachiopod shells have been almost entirely removed leaving only a hole between the outer and inner molds. Nodules of vitreous chert.

A thin section (pl. XII, fig. 6) shows this rock to be composed of subangular detrital quartz grains ranging up to 0.5 mm set in a matrix which is largely finely crystalline quartz; some dusty inclusions of carbonate remain but this is only a small fraction of the total rock. There are numerous voids in

the rock, some of these appearing to have a rhomb-shaped outline. See discussion Sallisaw Formation, *Lithologic character*.
Remarks: All of the Sallisaw in this area appears to be in this cherty facies; none of the typical Sallisaw arenaceous carbonate observed. The upper part of the Sallisaw is poorly exposed and I did not observe any Sylamore in place; thickness of the Sallisaw not determined.
Fossils: Some beds carry numerous brachiopods, most of which are *Amphigenia* sp.; all have had the shell leached away leaving only internal and external molds.

ST. CLAIR FORMATION

Lithology: Light-gray to pinkish-gray crinoidal .... limestone. Some dolomitic beds.
Remarks: No thin sections or analyses. The St. Clair in this area is much like that in the quarry of the St. Clair Lime Co.
Fossils: A small collection, mostly brachiopods, from the upper 30 feet of the St. Clair.

STRATIGRAPHIC SECTION S4

Walkingstick Hollow

Stratigraphic section S4 was first described and collected by T. W. Amsden on April 2, 3, 1959; it was re-examined on Oct. 15, 1959, and on Jan. 20, 1960. This section is on a small stream which flows northeastward into Walkingstick Hollow, about 0.25 mile southwest of the main creek in the hollow; SW¼ SW¼ SW¼ sec. 1, T. 13 N., R. 23 E., Sequoyah County (pl. I). The Frisco, Sallisaw, and Sylamore make a prominent ledge across the creek, resulting in a small waterfall. The stratigraphic relations are shown in text-figure 20, and photomicrographs of the Frisco and Sallisaw are illustrated on plate XII, figures 1, 2; the Sylamore is illustrated on plate XIII, figures 1, 2. Analyses of selected rock specimens from this section are given in the second part of the Appendix, Chemical Analyses.

This is an interesting outcrop and one which has given some trouble in interpretation. The Frisco at this locality is mostly in a calcilutite facies (see, Frisco formation Lithologic character), and the Sallisaw has an unusually low quartz-sand content. Thus the two formations have, at least megascopically, a close resemblance to one another. Christian, who first described this locality, correctly interpreted the highly irregular nature of the lower Sylamore contact, but failed to recognize any Sallisaw (1953. pl. II; compare to text fig. 20 of the present report). However, a detailed field examination, aided by a study of thin sections cut from rock specimens the stratigraphic position of which were carefully determined, clearly shows that the Sallisaw is present. See the description given below and compare figures 1, 2 of plate XII.

This is an excellent locality at which to see the transgressing character of the Sylamore sandstone.

SYLAMORE SANDSTONE

(about 10 feet exposed)

G *Lithology*: Gray to brownish-gray, quartz sandstone and...... conglomeratic sandstone; beds to 2 or 3 feet thick. many dark-brown to dark-gray, well-rounded phosphatic pebbles up to 3 or 4 mm in diameter. A thin section shows this rock is made up largely of well-rounded quartz grains, most of which are less than 0.5 mm in diameter, with prominent quartz overgrowths which extend out and fill the interstices (pl. XIII, figs. 1, 2). Little or no carbonate present. 10 feet
Remarks: The Sylamore makes a conspicuous ledge across the stream bed; about 10 feet is exposed with the upper contact covered. The lower contact is completely exposed and shows irregular pockets and veins of Sylamore sandstone extending down into the underlying beds; on the southwest side of the stream the Sylamore rests on the Sallisaw formation, but on the northeast side this formation has been removed by

pre-Chattanooga erosion and the Sylamore rests on the Frisco (text-fig. 20).
Fossils: None observed.

SALLISAW FORMATION
(0 to 18 inches thick)

F. *Lithology*: Medium-gray, low-arenaceous calcilutite. .... 0 to 18 in.
Two thin sections show this rock is largely granular calcite, most grains being less than 0.3 mm in diameter, with widely scattered detrital quartz grains (pl. XII, fig. 2). The granular calite may be in part, perhaps in large part, broken pelmatozoan plates; other megafossils rare; minor amounts of clear, sparry calcite. Insoluble residues low; two specimens tested 1.27 and 1.58 percent; most of the residue is clear, subangular to subrounded quartz detritus; few grains are as large as 0.4 mm in diameter, but most fall between 0.05 and 0.2 mm; minor, pale-green glauconite. $MgCO_3$ content low; two specimens tested 0.45 and 1.40 percent.
Remarks: The Sallisaw is present only on the southwest side of the outcrop, being truncated by the Sylamore on the northeast side (text-fig. 20). At this locality the Sallisaw has an unusually low percentage of insoluble quartz detritus and as it rests on the calcilutite facies of the Frisco there is some problem in locating the contact. However, the microtexture of the Sallisaw is quite distinct from that of the Frisco. The Frisco is a bioclastic limestone composed of broken, easily recognized, fossil debris; its insolubles are extremely low, four specimens tested all had less than 0.7 percent. In contrast the Sallisaw has little clearly recognizable fossil material, being made up largely of granular calcite (some of which may represent broken pelmatozoan debris); the quartz detritus is scattered but easily distinguished in thin section (compare figs. 1, 2 of pl. XII).

The Sallisaw quartz detritus is somewhat better rounded at S4 than is the case at most localities.
Fossils: Megafossils, with the possible exception of pelmatozoan plates, are few. I found one specimen of the brachiopod *Leptocoelia* sp.

FRISCO FORMATION
(about 5 feet exposed)

E. *Lithology*: Medium-gray biocalcilutite in somewhat .... 5 feet
irregular beds up to 4 or 5 inches thick. Peels and thin sections (pl. XIII, fig. 1) show this rock to be made up largely of fossil fragments set in a matrix of clear, sparry calcite. Most of the fossil debris is fine, well under 0.5 mm, but there are some coarser beds, locally grading into a shell coquina. Insoluble content is extremely low, four specimens testing 0.6 percent or less, most of the insoluble detritus is fine (less than 0.2 mm), subangular quartz grains, some of which have well-formed crystal faces; some pale-green glauconite (especially in the upper 2 feet), and some limonite (?). The $MgCO_3$ content is low; four specimens all tested less than one percent.
Remarks: About 5 feet of Frisco is exposed with the base covered; the upper contact with the Sallisaw and Sylamore is completely exposed for a distance of 40 feet or so; see text-figure 20.
Fossils: A small collection of brachiopods and one specimen of *Tentaculites* sp. made from the lower part of S4-E.

ST. CLAIR FORMATION and/or FRISCO FORMATION

D. *Lithology*: Covered .... 5 feet

ST. CLAIR FORMATION

C. *Lithology*: Pale-gray to pinkish-gray, fine-grained .... 2 feet
dolomite in beds to 3 or 4 inches thick. One specimen analyzed: 34.40 percent $MgCO_3$ and 0.99 percent insolubles.

Remarks: This is dolomitized St. Clair.
Fossils: None observed.

B. *Lithology*: Covered .... 2 feet

A. *Lithology*: Pinkish-gray, fossiliferous limestone. .... 3 feet
One specimen tested 0.61 percent $MgCO_3$ and 0.38 percent insolubles.
Remarks: This ledge has the typical St. Clair lithology. Below is a small covered interval and then numerous other outcrops of St. Clair extending back to Walkingstick Hollow.
Fossils: A small fauna, mostly brachiopods, collected from S4-A. No conodonts were observed in the acetic acid residues, nor were any arenaceous Foraminifera seen in the HCl residues.

Covered.

STRATIGRAPHIC SECTION S5

South of the St. Clair Lime Company Quarry

Section described and collected by T. W. Amsden, April 13, 14, 1959. It is about 600 feet southwest of the entrance to the St. Clair Lime Co. mine; SW¼ NE ¼ SE¼ sec. 14, T. 13 N., R. 23 E., Sequoyah County. This section describes the upper part of the St. Clair, Frisco, and Sallisaw formations, and the lower part of the Sylamore sandstone. The strata have a gentle dip and are, for the most part, well exposed. Fossils were collected from the upper part of the St. Clair, and from the Frisco and Sallisaw formations.

An outcrop of the Sallisaw is shown on plate III. Photomicrographs of the Sylamore sandstone, and of a Sallisaw pebble incorporated into the basal Sylamore, are illustrated on plate XIII, figures 5, 6; a piece of the basal Sylamore breccia is shown in text-figure 21. Analyses of selected rock specimens from the St. Clair, Frisco, and Sallisaw formations are given in the section on Chemical Analyses.

SYLAMORE SANDSTONE

(about 4 feet exposed)

F. *Lithology*: Brown, somewhat friable sandstone with .... 2 feet
rounded phosphatic pebbles. A thin section (pl. XIII, fig. 5) shows this rock is largely made up of well-rounded detrital quartz with prominent quartz overgrowths which extend out and largely fill the interstices. Very little carbonate present.
Remarks: The top of unit F is covered. The Sylamore sandstone is easily distinguished from the underlying Sallisaw which is an arenaceous limestone the insolubles of which do not exceed 15 percent.
Fossils: Conodonts are present in the Sylamore.

E. *Lithology*: Brown quartz sandstone as above with .... 2 feet
subangular pebbles and blocks of chert ranging up to 6 to 8 inches in diameter (text-fig. 21). Some blocks are vitreous chert and some are arenaceous chert the latter lithologically identical with the arenaceous chert in the Sallisaw. The thin section illustrated on plate XIII, figure 6, is cut from one of these chert blocks; compare with the specimen illustrated on plate XII, figure 6.
Remarks: This is undoubtedly the rock which earlier investigators assigned to the upper Sallisaw, interpreting it as an old regolith cemented in situ. It is, however, only the basal breccia of the Sylamore sandstone, with which it is completely gradational. Although many of the chert blocks were derived from the underlying Sallisaw, the sandstone matrix which completely encloses them is identical with that of the overlying Sylamore sandstone, and quite unlike the underlying Sallisaw limestone. Some of the chert blocks in this breccia are fossiliferous, but no fossils were observed in the sandstone matrix. The fossils in the chert represent brachiopods, but are not well enough preserved to permit a more exact identification.

SALLISAW FORMATION
(about 10 feet thick)

D. *Lithology*: Medium-gray, arenaceous and dolomitic .... 10 feet
limestone in beds up to 8 or 10 inches thick; nodules and lenses of white, vitreous chert (pl. III). The insoluble-residue content ranges from 5 to 11 percent (3 analyses). Most of the residue is clear subangular detrital quartz up to 0.4 mm in diameter; many of the quartz grains have crystal faces indicating some secondary overgrowths. Residues also include a small amount of pale-green glauconite in small, irregular grains. $MgCO_3$ content ranges from 6 to 17 percent (3 analyses).
Remarks: The upper part of this unit is not well exposed so that it was difficult to make a precise thickness measurement.
Fossils: Fossils are sparse but there are some rather widely scattered brachiopods; most of these are specimens of *Amphigenia* sp.

FRISCO FORMATION
(total 7 feet)

C. *Lithology*: Medium-gray, bioclastic calcarenite. .... 3 feet
Peel shows this rock is composed mostly of pelmatozoan plates set in a matrix which is partly clear, sparry calcite and partly finely divided, granular calcite; fragments of other fossils fairly common. This is a high-calcium limestone; one specimen analyzed 99.07 percent $CaCO_3$.
Remarks: The Frisco at this locality has two moderately distinct facies: An upper unit (S5-C), which is predominantly a pelmatozoan limestone, and lower unit (S5-B), which is mostly a shell coquina. The boundary between these two is not distinct and there is lateral as well as vertical gradation from one type to the other.
Fossils: This unit contains well over 50 percent fossil debris but most of this is pelmatozoan plates and no collection was made.

B. *Lithology*: Medium-gray, bioclastic calcarenite .... 4 feet
grading into a calcirudite in beds to 6 or 8 inches thick. Predominantly a shell coquina composed mostly of brachiopod and snail shells with some bryozoans, corals, and pelmatozoans. Brachiopod shells largely disarticulated and all fossils show considerable evidence of breakage; fossils fairly well oriented with long dimensions in the plane of the bedding. This is a high-calcium stone; one specimen analyzed 98.52 percent $CaCO_3$.
Remarks: This is gradational with the overlying unit.
The Frisco-St. Clair contact is well exposed and easily located in the field; the pinkish-gray limestone of the St. Clair is quite different from the gray, shell coquina of the Frisco.
Fossils: I have a large collection from here; mostly brachiopods with some snails, bryozoans, and corals.

ST. CLAIR FORMATION

A. *Lithology*: Light-gray to pinkish-gray calcarenite. ....
Beds fairly thick, somewhat obscure, giving the rock a massive appearance. This is largely a pelmatozoan sand, but some beds do carry other megafossils such as brachiopods, snails, and bryozoans.
At the place where this section was measured the St. Clair is a high-calcium stone; 4 specimens range from 98 to 99 percent $CaCO_3$. However, just south of here beds of dolomite do appear and in one place the upper 2 feet of the St. Clair is a dolomite (observation based on a specimen stained with Lemberg dye).
Remarks: The upper 30 feet or so of the St. Clair is well

area seems to be the typical pink crinoidal rock type of the St. Clair with very little dolomite; however, south of here beds of dolomite appear. In this connection it is interesting to note that stratigraphic section S5 is near the southwestern face of the underground workings of the St. Clair Lime Company (see pl. I).

Fossils: A moderately large megafauna, mostly brachiopods, collected from the upper 20 feet of the St. Clair. No conodonts or arenaceous Foraminifera observed in the acetic acid residues.

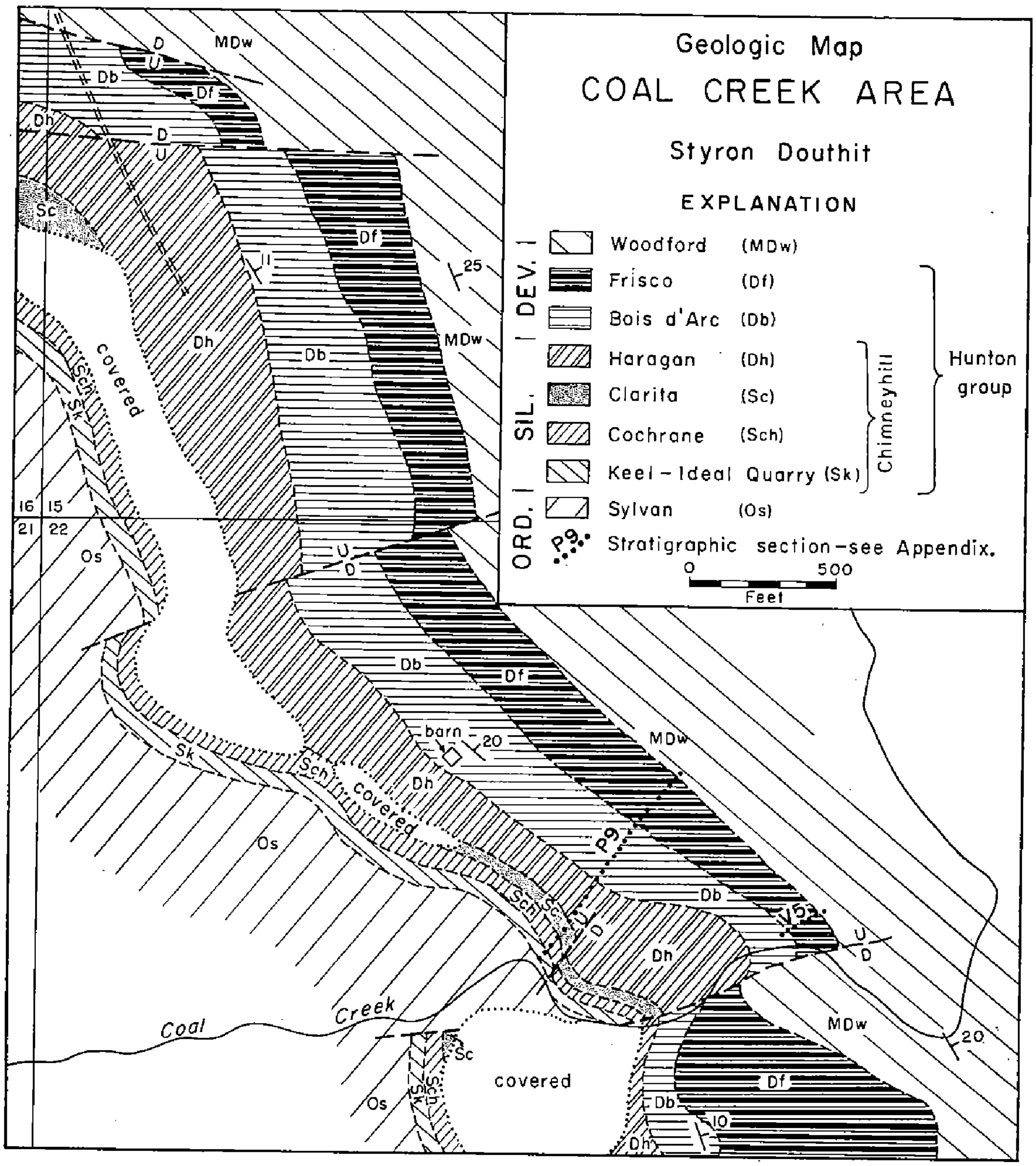


FIGURE 25. Geologic map of the Coal Creek area showing the location of stratigraphic sections P9 and V5. The regional setting of this area is shown in text-figure 10. Compare the Silurian-Devonian relationship in this area with that near Marble City (pl. I); note that the Haragan formation truncates the Clarita, locally resting upon the Cochrane.

STRATIGRAPHIC SECTION S6

Southwest of the St. Clair Lime Company Quarry

This is actually a collecting locality in the Frisco formation rather than a described stratigraphic section. It is about 600 feet southwest of stratigraphic section S5, SE¼ NW¼ SE¼ sec. 14, T. 13 N., R. 23 E., Sequoyah County (pl. I). The stratigraphic succession and lithologic characteristics of the St. Clair, Frisco, and Sallisaw are similar to those at S5. The Frisco at S6 is highly fossiliferous and on April 14, 1959, I collected a large fauna from here, predominantly brachiopods, but including some snails, corals, and bryozoans.

STRATIGRAPHIC SECTION S6(A)

Southwest of St. Clair Lime Company Quarry

This is about halfway between S5 and S6, in the SW¼ NE¼ SE¼ sec. 14, T. 13 N., R. 23 E., Sequoyah County (pl. I). It is primarily a Frisco collecting locality rather than a described stratigraphic section; the lithologic and stratigraphic characteristics of the St. Clair, Frisco, and Sallisaw at S6(A) are similar to those at S5. The St. Clair-Frisco contact is well exposed and I was able to collect a large lithologic specimen spanning the contact between these two formations; a thin section cut from this block is illustrated on plate V. The basal Frisco is a coarse, shell coquina set in a matrix of clear, sparry calcite and the upper St. Clair is predominantly a pelmatozoan limestone; compare the Frisco texture shown on plate V to that shown on plate IV.

On Oct. 16, 1959, I made a large collection of fossils from the lower 6 inches of the Frisco formation at S6(A). This was mostly brachiopods, but also included some snails, corals, and bryozoans.

STRATIGRAPHIC SECTION S7

Northwest of the St. Clair Lime Company Quarry

Section described by T. W. Amsden, April 15, 1959. It is in the bed of a small stream, SE¼ NW¼ NE¼ sec. 14, T. 13 N., R. 23 E., Sequoyah County (pl. I). The stratigraphic relations at this locality are most interesting. The Sylamore sandstone is almost in contact with the St. Clair, with only a thin featheredge of Frisco separating them; the Sallisaw is represented by only a few pebbles of arenaceous limestone in the basal Sylamore. The Frisco limestone may have a thickness of 4 to 5 inches in some pockets, but mostly

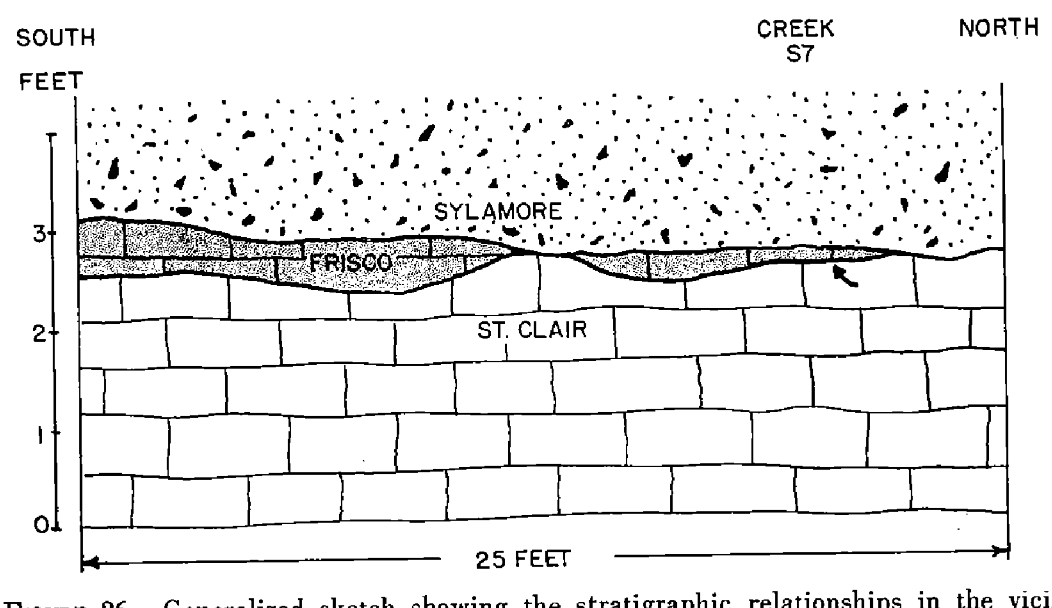


FIGURE 26. Generalized sketch showing the stratigraphic relationships in the vicinity of stratigraphic section S7. Arrow indicates the location of the lithologic specimen from which the thin section illustrated in the frontispiece and in plate VIII was cut.

it is only an inch or so thick and in places is absent. I was able to collect an excellent lithologic specimen which included uppermost St. Clair, all of the Frisco (about 1.5 inches thick) and the lowermost Sylamore; a thin section cut from this specimen is illustrated in the frontispiece and on plate VIII. These stratigraphic relations are shown in text-figure 26.

The exposures in the creek bed where this section is located are excellent, but from here south to the quarry there are only scattered outcrops. There is, however, enough bed rock exposed to show that the Sallisaw is present only a short distance south of S7; see plate I.

SYLAMORE SANDSTONE
(about 2 feet exposed)

C. *Lithology*: Medium-gray to brown, conglomeratic quartz .... 2 feet sandstone with dark-brown, well-rounded phosphatic pebbles. A thin section (illustrated in the frontispiece) shows this rock is composed mostly of rounded quartz grains up to about 0.5 mm in diameter with some phosphatic pebbles; this detritus is enclosed in a carbonate matrix. Scattered through the sandstone are subangular to subrounded pebbles up to a couple of inches in diameter; these are mostly chert, but there are some fragments of arenaceous limestone which is identical to that found in the Sallisaw, and some fossil fragments which almost certainly represent pieces of the underlying Frisco.

Remarks: Only the lower 2 feet of the Sylamore is exposed; above is a covered interval of about 5 feet, followed by 6 inches of dark sandstone and then dark shale.

The Sylamore, at least in the lower few inches, has a carbonate matrix which is somewhat unusual because the cementing material of this member is generally formed by the quartz overgrowths on the detrital grains. It is interesting to note the presence of both Frisco and Sallisaw fragments in the basal part of the Sylamore; these do not show on the thin sections illustrated in the frontispiece, but polished surfaces and peels of larger areas show this material quite clearly.

Fossils: None observed.

FRISCO FORMATION
(maximum thickness about 5 inches)

B. *Lithology*: Gray, bioclastic calcarenite grading into a .... 0 to 5 inches calcirudite. Peels and a thin section (frontispiece and pl. VIII) show this to be the typical Frisco shell coquina composed of fragmented fossils packed close together; matrix is predominantly micrite, but does include some sparry calcite (pl. VIII, fig. 1); some parts have undergone considerable solution (pl. VIII, fig. 2).

Remarks: The Frisco at this locality is represented by only a thin featheredge, and in places is absent (text-fig. 26). The St. Clair-Frisco contact is lithologically well defined (frontispieces and pl. VIII, fig. 2); there is no evidence of any St. Clair pebbles in the basal Frisco.

Fossils: I have a small collection from here; this consists mostly of brachiopods and appears to be a typical Frisco fauna.

ST. CLAIR FORMATION

A. *Lithology*: Gray to pinkish-gray, pelmatozoan limestone. .... Peels and a thin section (frontispiece, pl. VIII, fig. 2) show this rock is composed largely of pelmatozoan plates set in a matrix of clear, sparry calcite.

Remarks: The upper part of the St. Clair is well exposed in this stream bed. For a discussion of the St. Clair-Frisco contact see above.

Fossils: None collected.

STRATIGRAPHIC SECTION S8

Payne Hollow

Section described and collected by T. W. Amsden, April 16, 20, 1959. It is on a hillside near the southern end of Payne Hollow; NW¼ SW¼ NE¼ sec. 22, T. 13 N., R. 23 E., Sequoyah County (pl. I). At this locality there are excellent exposures of the upper St. Clair and of the Frisco; the overlying strata are mostly covered, but there is some fossiliferous, arenaceous chert float indicating the presence of Sallisaw. The St. Clair-Frisco relationship is interesting because this is one of the places where the contact superficially appears to be gradational; the lower Frisco is in a fine, calcilutite facies and the upper part of the St. Clair is in a fine dolomitic facies, thus producing a contact that is not readily located in the field. I have, however, collected a number of lithologic specimens from this part of the section, and the peels and thin sections prepared from these show the exact position of the contact.

A photomicrograph of a specimen from the upper St. Clair is illustrated on plate VII, figure. 5. Analyses of selected rock specimens from the upper St. Clair and Frisco are given in the section on Chemical Analyses. I have a fairly large collection of fossils from the Frisco formation.

SALLISAW FORMATION

Lithology: Covered. Loose blocks of fossiliferous, arenaceous chert.

FRISCO FORMATION

(6 feet exposed)

D. *Lithology*: Medium-gray, bioclastic calcarenite. Most .... 2 feet
of the fossil material is pelmatozoan debris; minor shell material. HCl-insolubles low; residues mostly limonite (?) and clear quartz; the latter is partly subangular to subrounded quartz detritus and partly doubly terminated quartz crystals; grains up to 0.4 mm long.

Remarks: Unit D is largely composed of pelmatozoan debris whereas the underlying unit C is mostly a shell coquina; the boundary between the two is not sharp and there are lateral and vertical gradation from one rock to the other.

Fossils: No collection made from unit D.

C. *Lithology*: Gray, bioclastic calcarenite grading .... 3 feet
into a calcirudite. This is largely a shell coquina made up of brachiopods and snails, along with some bryozoans, corals, and pelmatozoans; brachiopod shells mostly disarticulated and all fossils show considerable breakage. HCl residue extremely low; insolubles consist mainly of clear quartz grains up to 0.4 mm or so in diameter; some of these are subrounded to subangular quartz detritus, but most are in the form of small, doubly terminated quartz crystals; some limonite (?) and dark, carbonaceous material; also minor pale-green glauconite.

Remarks: Unit C represents the shell-coqnina facies of the Frisco; it is not sharply marked off from the overlying pelmatozoan facies (unit D) nor from the underlying calcilutite facies (unit B), and there is considerable lateral as well as vertical gradation from one rock type to the other.

One rock specimen from this interval was chemically analyzed: S8-AB(10), collected 2 feet above the base of the Frisco formation and one foot above the base of unit C.

Fossils: A large collection made from C; predominantly brachiopods, but with some snails, corals, and bryozoans.

B. *Lithology*: Medium-gray (N6 to N7) biocalcilutite. A .... 1 foot
peel and a thin section show this rock is composed in large part of fossil fragments, most of which are less than 0.5 mm in largest dimension, although there are a few larger pieces: many are fragments of shells, somewhat elongate, and oriented with their long axis in the bedding plane; matrix mostly sparry calcite. The HCl-insoluble residue is low, about 1 percent, and

consists mainly of small, doubly terminated quartz crystals, most of which are less than 0.3 mm long, there is also a considerable quantity of pale-green glauconite, much of it with a polylobate shape (compare Amsden, 1960, pl. XVII, fig. 6); also minor limonite (?) and carbonaceous material.

Remarks: I have termed this lithologic type the calcilutite facies of the Frisco although a considerable part is actually a fine calcarenite (see Introduction). The insoluble-residue content is low, although probably somewhat greater than that of C; the residues have a much higher percentage of doubly terminated quartz crystals and of glauconite than do those of unit C. At the point where the section was measured unit B is separated from unit C by a stylolite seam, but elsewhere the two facies grade into one another.

Two rock specimens from this interval were chemically analyzed: S8-AB(1) collected 6 inches above the base, and S8-AB(8), from 1 foot above the base.

The St. Clair-Frisco contact is discussed below.

Fossils: No collection made.

ST. CLAIR FORMATION

A. *Lithology*: Light-gray to pinkish-gray pelmatozoan limestone locally dolomitic. The HCl-insoluble residues are low (less than 0.5 percent in the upper 2 feet), and consist mostly of subangular quartz including some doubly terminated crystals; the grain size rarely exceeds 0.2 mm; also minor limonite (?). The upper 2 feet has about 6 percent $MgCO_3$.

Remarks: The upper 30 feet or so of the St. Clair is almost completely exposed on this hillside and mostly it is typical, pink crinoidal limestone. However, in the upper part beds and lenses of dolomitic limestone are irregularly distributed through the formation. Along the line of section, where the upper St. Clair and Frisco beds are completely exposed, the upper 2 to 3 feet of the St. Clair grades into a dense, medium-gray, dolomitic limestone, some parts of which have as much as 5.8 percent $MgCO_3$; a photomicrograph of this rock is illustrated on pl. VII, fig. 5. Megascopically this rock resembles the gray, dense calcilutite facies of the overlying Frisco, and superficially the St. Clair appears to grade into the Frisco. However, a study of peels and thin sections shows a sharply defined contact between the dolomitic pelmatozoan limestone of the St. Clair and the bioclastic Frisco which is made up of small fossil fragments set in a clear calcite matrix (and with little $MgCO_3$). This relationship is undoubtedly the same as that cited by earlier authors who found a gradational contact in some places between the St. Clair and the Frisco.

Four rock specimens were chemically analyzed. In the section on Chemical Analyses these are designated as follows:

S8-AB(5) — 3 inches below top of the St. Clair formation.
S8-AB(4) — 6 inches below top of the St. Clair formation
S8-AB(2) — 12 inches below top of the St. Clair formation
S8-AB(1) — 18 inches below top of the St. Clair formation

Fossils: No collection made.

STRATIGRAPHIC SECTION S9

Payne Hollow

Section measured and collected by T. W. Amsden, April 20, 1959. It is on the east side of Payne Hollow, about 100 feet east of an abandoned quarry, NE¼ NW¼ NE¼ sec. 22, T. 13 N., R. 23 E., Sequoyah County (pl. I). This section covers the upper part of the St. Clair, all of the Frisco and the lower part of the Sallisaw. The stratigraphic distribution of dolomite in this section is of special interest; the upper St. Clair and lower Sallisaw beds are strongly dolomitic, whereas the intervening Frisco has less than 2 percent $MgCO_3$ (text-fig. 24).

Photomicrographs of the Frisco are illustrated on plate IX, figures 2, 6; the St. Clair is illustrated on plate VII, figure 6. Analyses of rock specimens from the St. Clair, Frisco, and Sallisaw are given in the section on Chemical Analyses.

SALLISAW FORMATION
(3 feet exposed)

F. *Lithology*: Light-gray, arenaceous dolomitic limestone. .... 3 feet
One specimen analyzed 26.5 percent $MgCO_3$ and 6.3 percent HCl-insoluble residues. The insolubles are mostly silt- and sand-size quartz detritus ranging up to 0.2 mm in diameter; grains angular to subangular, some with well-developed crystal faces; small amount of pale-green glauconite.
Remarks: Only the lower 3 feet of the Sallisaw is exposed; upper part covered.
Fossils: No fossils observed at this locality.

FRISCO FORMATION
(total 7 feet)

E. *Lithology*: Light-gray bioclastic calcarenite. Peel .... 1 foot
shows this rock is composed mainly of pelmatozoan plates set in a micrite matrix; also considerable other fossil material. It is a high-calcium stone; one specimen analyzed 99.6 percent $CaCO_3$. Another tested 1 percent HCl-insoluble residues (this sample crushed, not pulverized). Residues mostly small, doubly terminated quartz crystals up to approximately 0.2 mm in length; also some dark carbonaceous material and a few grains of pale-green glauconite.
Remarks: This unit is much like the underlying beds, differing only in its higher proportion of pelmatozoan debris. It is easily distinguished from the overlying Sallisaw which is an arenaceous, dolomitic limestone; unit E has only 0.61 percent $MgCO_3$.
Fossils: None collected.

D. *Lithology*: Light-gray, biocalcarenite grading into .... 5½ feet
a shell coquina. Peel and thin section (pl. IX, fig. 6) show this rock is a mixture of pelmatozoan plates and shell fragments, including considerable bryozoan debris; matrix partly micrite, partly clear sparry calcite; fossil debris shows much breakage. One rock specimen analyzed 99.3 percent $CaCO_3$, 0.30 percent $MgCO_3$, and only 0.01 percent HCl insolubles (this sample pulverized with mortar and pestle; another specimen yielded about 2 percent acid insolubles, but this was not pulverized). Residues are mostly subangular to angular quartz grains, some of which are doubly terminated quartz crystals, up to 0.15 mm in length; also a little pale-green glauconite and a dark, carbonaceous material.
Remarks: This unit is not sharply marked off from the overlying beds (E), differing mainly in its having a greater proportion of shell debris.
Fossils: No collection made.

C. *Lithology*: Medium-gray, biocalcilutite. Peel and .... ½ foot
thin section (pl. IX, fig 2). show this rock is composed of broken fossil fragments ranging up to, but only rarely exceeding, 0.5 mm in greatest dimension; enclosing matrix is largely clear, sparry calcite; well over 50 percent of this rock is fossil debris. One specimen analyzed 97.72 percent $CaCO_3$, 1.79 percent $MgCO_3$ and 0.37 percent HCl-insoluble residue (sample pulverized with mortar and pestle); another specimen (not pulverized) tested 2 percent acid insolubles. Residues mostly quartz grains, the great majority being doubly terminated crystals (up to 0.5 mm long), also a moderate amount of pale-green glauconite.
Remarks: This is the Frisco rock type which I have termed the calcilutite facies although it is in part a fine calcarenite (see Introduction). It differs from the overlying beds, with

which it is gradational, primarily in its finer texture; it also has a somewhat greater proportion of glauconite. For a comparison with the underlying strata see *Remarks* under St. Clair Formation.
Fossils: None collected.

ST. CLAIR FORMATION

B. *Lithology*: Pale-gray, to pinkish-gray, calcitic dolomite............ 4 feet
Peels and thin sections (pl. VII, fig. 6) show this rock is mostly crystalline dolomite with small areas of clear calcite; no fossil debris observed. Two specimens analyzed 35.5 percent and 36.0 percent $MgCO_3$; both had 0.39 percent acid insolubles.
Remarks: This rock is easily distinguished from the overlying Frisco by its dolomitic character. It would seem almost certainly to be dolomitic St. Clair rather than dolomitized Frisco, because it has the typical St. Clair color and appears to grade into the underlying strata. Moreover, throughout this area the upper part of the St. Clair has dolomitic beds, many of which can be traced laterally into the typical pink-crinoidal facies; at no place have I observed dolomitic beds in undoubted Frisco. The transition from the highly dolomitic St. Clair to the high-calcium Frisco and back to dolomitic Sallisaw is illustrated in text-figure 24; notice that the insoluble content shows almost no change between the St. Clair and the Frisco.

A. *Lithology*: Pale-gray to pinkish-gray pelmatozoan .... limestone. Locally some beds have brachiopods and other megafossils. Matrix mostly clear, sparry calcite. One specimen analyzed 99.05 percent $CaCO_3$. Acid residues mostly a reddish-brown mineral, possibly limonite, and some subangular quartz grains. No conodonts or other fossils seen in the acetic-acid residues.
Remarks: The upper 30 feet or so of the St. Clair is well exposed in this area. Most of this is the typical, pinkish pelmatozoan limestone. Some beds are moderately fossiliferous.
Fossils: Some megafossils, mostly brachiopods, collected from the upper 30 feet of the St. Clair in this area.

STRATIGRAPHIC SECTION S10

Payne Hollow

Section described and collected by T. W. Amsden, April 22, 1959. It is on the east side of Payne Hollow, east of a small stream leading southwest into Payne Hollow Creek; SW¼ SE¼ SE¼ sec. 15, T. 13 N., R. 23 E., Sequoyah County (pl. I). This section covers the upper part of the St. Clair, the Frisco, and the Sallisaw formations. It is one of the thickest sections of the Sallisaw that I have examined (see also S14). Both the Sallisaw and Frisco are fossiliferous and I have collected a number of megafossils from each.

A photomicrograph of the Sallisaw is illustrated on plate XI, figure 3; the Sallisaw-Frisco contact is illustrated on plate XI, figure 1. The stratigraphic relations at this locality are shown in text-figure 14; the stratigraphic distribution of HCl-insoluble residues in the Sallisaw is shown in text-figure 17. Analyses of rock specimens are given in the section on Chemical Analyses.

SALLISAW FORMATION

(18 feet exposed)

D. *Lithology*: Light- to medium-gray, arenaceous and dolo- .... 18 feet
mitic limestone. No chert observed in situ but there is much chert float on the ground, some of which carries well-preserved Sallisaw brachiopods (preserved as internal and external molds). Much of the arenaceous carbonate has few or no fossils, but there are beds with a substantial number of brachiopods.

The acid-insoluble content of this rock has a wide range from 5.1 to 45.4 percent. Most of the residues are composed of subangular quartz grains up to about 0.4 mm in diameter; many of these show crystal faces but double terminations are few or absent; a small amount of pale-green glauconite is present. Peels and thin sections (pl. XI, figs. 1, 3) show that this insoluble debris is set in a carbonate matrix; a part of this is crystalline dolomite (pl. XI, fig. 1), but much is in the form of granular calcite bodies (pl. XI, fig. 3), some of which might be fragments of pelmatozoan plates. The quartz grains, calcite grains, and dolomite crystals are approximately the same size.

The acid insolubles and $MgCO_3$ content vary greatly as shown below. The amount of insolubles appears to increase upwards (text-fig. 17), at least judging from the four specimens tested, and the uppermost beds (pl. XI, fig. 3) have the greatest quartz-sand content of any of the Sallisaw beds that I have examined.

S10-D

	HCl-insolubles (percent)	$MgCO_3$ (percent)
18 feet above base	45.43	8.48
5 feet above base	9.86	7.52
1 foot above base	6.33	25.05
1 inch above base	5.11	24.58

Remarks: A part of this unit is covered, but the lower beds and upper beds are well exposed and there are scattered ledges of the intervening strata. The Frisco-Sallisaw contact is well exposed and easily distinguished as the dolomitic and arenaceous Sallisaw limestone is quite different from the high-calcium Frisco bioclastic limestone; a photomicrograph of this contact is illustrated on plate XI, fig. 1. There are few doubly terminated quartz grains in the Sallisaw whereas these are common in the Frisco.

Fossils: The megafauna from unit D consists almost entirely of brachiopods. I have collected a number of specimens from a bed about 5 feet above the base, and from beds 10 to 20 feet above the base. The uppermost exposed strata carry a few brachiopods but none were collected. Some well-preserved brachiopods were obtained from loose chert blocks.

FRISCO FORMATION

(total 7 feet)

C. *Lithology*: Light- to medium-gray, bioclastic limestone .... 6 feet

grading into a shell coquina. Beds somewhat irregular, up to 6 or 8 inches thick. Much of this unit is typical Frisco shell coquina although most beds have a substantial amount of pelmatozoan debris, locally grading into a pelmatozoan limestone; fossil debris shows much breakage. Matrix largely micrite although there is some sparry calcite; commonly the pelmatozoan plates have a rim of clear calcite (pl. XI, fig. 1). This is a high-calcium limestone; one specimen analyzed 99.17 percent $CaCO_3$.

Remarks: Most of this unit is the typical shell-coquina facies, composed in large part of disarticulated brachiopod shells along with some snails, bryozoans, and corals; also a substantial amount of pelmatozoan debris. The upper surface of the Frisco has a moderate amount of relief as shown in text-figure 14.

Fossils: A fairly large collection made from unit C; mostly brachiopods with some snails and bryozoans, and a few corals.

B. *Lithology*: Medium-gray, biocalcilutite. Peel shows .... 1 foot

this rock is composed largely of small fossil fragments set in a matrix of clear, sparry calcite; most of the fossil debris in the form of elongate shell fragments, commonly well oriented in the plane of the bedding; most fragments less than 0.5 mm long. This is a high-calcium stone; one specimen analyzed 98.7 percent $CaCO_3$.

Remarks: This is the biocalcilutite facies of the Frisco (actually, much of it is a fine calcarenite; see discussion of the lithologic character of the Frisco formation). It is, for the most part, lithologically distinct from the overlying shell coquina, but in this area these two rock types grade into one another, vertically and laterally.
Fossils: None collected.

ST. CLAIR FORMATION

A. *Lithology*: Light-gray to pinkish-gray pelmatozoan .... limestone locally grading into dolomitic limestone. The pelmatazoan imestone is a high-calcium stone; one specimen analyzed 98.7 percent $CaCO_3$. Acid insolubles mostly a finely crystalline, dark-brown mineral (limonite?), and subangular to angular quartz grains, some of which are doubly terminated.
Remarks: The upper 20 feet or so of the St. Clair is well exposed in this area. Most of the rock is in the pinkish-gray pelmatozoan facies, but there are dolomitic beds present.

The upper surface of the St. Clair, just beneath the Frisco, has a fair amount of relief as shown in text-figure 14; cavities filled with Frisco extend down into the St. Clair for 3 feet or so.
Fossils: None collected.

STRATIGRAPHIC SECTION S11

Payne Hollow

Section described and collected by T. W. Amsden, April 21, 1959. It is on the east side of Payne Hollow, on the rim of an abandoned quarry in the St. Clair formation; NW¼ SW¼ SE¼ sec. 15, T. 13 N., R. 23 E., Sequoyah County (pl. I). This section covers the upper St. Clair, Frisco, and lower Sallisaw formations. A number of megafossils were collected from the lower 6 feet of the Sallisaw.

A photomicrograph of the Frisco is illustrated on plate IX, figures, 3, 4. The stratigraphic distribution of HCl-insoluble residues from the Sallisaw are shown in text-figure 17. Analyses of rock specimens from the St. Clair, Frisco, and Sallisaw are given in the section on Chemical Analyses.

SALLISAW FORMATION

(6 feet exposed)

D(2). *Lithology*: Light-gray to pale brownish-gray, arenaceous ...... 2 feet
and dolomitic limestone. Peel shows this rock is composed of subangular quartz grains set in a matrix of dolomite crystals and irregular calcite grains; the individual particles (quartz detritus, dolomite rhombs, and calcite grains) rarely exceed 0.4 mm in diameter. Scattered through this rock are megafossils, most of which are brachiopods. One rock specimen analyzed 6.3 percent HCl-insoluble residues, 19.0 percent $MgCO_3$ and 74.5 percent $CaCo_3$.
Remarks: This unit is similar to the underlying beds, S11-D(1), from which it is separated by a small covered interval; S11-D(2) carries megafossils whereas fossils are few or absent in S11-D(1).

The top of the Sallisaw is covered in the vicinity of this section. This formation is known to be relatively thick to the south (18 feet at S10) and to the north (20 feet at S14).
Fossils: A number of brachiopods were collected from these beds; no other megafossils observed.

Covered .... 2 feet

D(1). *Lithology*: Light-gray, arenaceous and dolomitic lime- .... 2 feet
stone. One specimen analyzed 2.75 percent HCl-insoluble residue, 83.69 percent $CaCO_3$ and 12.98 percent $MgCO_3$. Acid residues mostly subangular to angular quartz detritus ranging up to 0.3 mm in diameter; many grains with crystal faces, but doubly terminated crystals few or absent.
Remarks: This rock is similar to unit D(2), differing mainly

in its lower insoluble content; also D(1) has few or no megafossils.

The Sallisaw-Frisco contact is well exposed here and I have collected rock specimens spanning the contact. The basal inch or so of rock which is assigned to the Sallisaw is strongly dolomitic, 40.65 percent $MgCO_3$, but has only 0.94 percent HCl insolubles; this could be dolomitized Frisco, although it is unlikely because undoubted Frisco here (and elsewhere) has only minor amounts of $MgCO_3$.

Fossils: No megafossils observed in these beds.

FRISCO FORMATION
(total thickness 4 feet)

C. *Lithology*: Medium-gray, bioclastic limestone. This is .... 3 feet
predominantly a pelmatozoan limestone but some parts grade into a fine, biocalcilutite and other parts approach a shell coquina. One specimen of typical pelmatozoan limestone analyzed 98.80 percent $CaCO_3$, 0.85 percent $MgCO_3$, and 0.37 percent HCl residues. The insolubles are mostly subangular to angular quartz grains, many of which have crystal faces (double terminations are present but not common); grains range up to 0.3 mm in diameter. Also considerable pale-green glauconite and a brown mineral, possibly limonite.

Remarks: Most of this interval is in the pelmatozoan facies but there is considerable variety and all of the common Frisco rock types are represented. One specimen which spans the contact between the Frisco and the Sallisaw shows the calcilutite facies against the Sallisaw.

Fossils: No fossils collected from this interval.

B. *Lithology*: Dark-gray, biocalcilutite. Peels and a thin .... 1 foot
section (pl. IX, figs. 3, 4) show this rock is largely composed of small, fossil fragments set in a matrix of clear, sparry calcite; few fragments exceed 0.5 mm in length although there are a few relatively large shell fragments. One specimen analyzed 97.84 percent $CaCO_3$, 0.65 percent $MgCO_3$ and 1.58 percent insolubles.

Remarks: This is the characteristic biocalcilutite facies of the Frisco. In most places a stylolite seam separates unit B from unit C, but there are patches of calcilutite within the overlying strata.

Fossils: None collected.

ST. CLAIR FORMATION

A. *Lithology*: Light-gray to pinkish-gray pelmatozoan ....
limestone. Two specimens analyzed, one from the upper 6 inches and the other 4 feet below the top; both are high-calcium stones with more than 99 percent $CaCO_3$.

Remarks: The upper 30 feet or so of the St. Clair is exposed in old quarry. Most of this appears to be the characteristic pelmatozoan limestone, but I did not examine it carefully for dolomitic beds.

Fossils: No fossils collected.

STRATIGRAPHIC SECTION S12
North of the St. Clair Lime Company Quarry

This is actually a collecting locality in the St. Clair rather than a described stratigraphic section. It is approximately one mile north of the St. Clair Lime Company Quarry. SE¼ NW¼ SW¼ sec. 12, T. 13 N., R. 23 E., Sequoyah County (pl. I). In this area the St. Clair pelmatozoan limestone is directly overlain by the Sylamore sandstone. I collected a small fauna, mostly brachiopods, from a loose block of St. Clair limestone about 20 feet below the St. Clair-Sylamore contact; collection made Oct. 16, 1959.

STRATIGRAPHIC SECTION S13
St. Clair Lime Company Mine

Stratigraphic section S13 is the designation given to the underground workings of the St. Clair Lime Company. The entrance to this mine (pl. VI, fig. 2) is in the NE¼ NE¼ SE¼ sec. 14, T. 13 N., R. 23 E. Almost the entire mine is in the NE¼ SE¼ and in the SE¼ NE¼ of sec. 14, (the outline of the mine workings is shown in plate I).

I first examined the stratigraphic relationships in this mine with W. E. Ham and T. L. Rowland on January 20, 21, 1960; on June 14 and October 18 I again visited the mine with T. L. Rowland. At the time I examined the mine all of the workings were on single level and the area mined was, for all practical purposes, horizontal (a second, deeper level is being worked in 1961). The beds in the area have only a gentle dip and most of the workings are in the upper part of the St. Clair formation (pl. VI, fig. 2); in places the Frisco is exposed in the roof, and at S13A (see below), in the southwestern part of the mine, the upper St. Clair, Frisco, and lower Sallisaw formations are exposed in the face.

The southern part of the mine is an excellent place to examine the St. Clair-Frisco contact (at the locality designated S13A; pl. I). In this area the contact is exposed in the face for some distance, and when the walls have been washed down, the boundary between these two formations, is clearly defined, the darker Frisco standing in marked contrast to the much lighter St. Clair. The upper surface of the St. Clair has several feet of relief and numerous veins of Frisco extend down into the St. Clair. A sketch of this contact is shown in text-figure 13; note that this is a drawing made from a photograph taken in the mine. At one of the faces in this part of the mine (end of the tunnel almost due west of the entrance) the St. Clair, Frisco, and lowermost Sallisaw are exposed.

Near locality 13A I have collected several lithologic specimens which span the St. Clair-Frisco contact. Thin sections cut from these specimens show that the upper St. Clair is a pelmatozoan limestone, the individual plates being set in clear, sparry calcite (in places the St. Clair is dolomitic). The lower Frisco is mostly a coarse shell coquina, although locally it grades into a biocalcilutite facies. One Frisco specimen analyzed 2.12 percent MgCO . Here, as elsewhere, there is little or no evidence of basal conglomerate in the Frisco.

Sylamore-filled fissures and pockets are common in the St. Clair and some of these extend to the floor of the mine. These are especially numerous in the northern part of the mine. Some of the larger pockets of Sylamore contain angular pieces of St. Clair limestone which are packed so closely together that they suggest a collapse or founder breccia; a specimen of this is illustrated in text-figure 22. The matrix enclosing these angular fragments is made up in large part of well-rounded quartz grains; see the photomicrograph on plate XIII, figure 4.

STRATIGRAPHIC SECTION S14
Payne Hollow

Section first described and collected by T. W. Amsden and Fred Manley on April 2, 1960; it was later re-examined and additional fossils collected by T. W. Amsden and T. L. Rowland on June 13, 1960. It is about 300 feet northeast of stratigraphic section S11, on a small stream flowing southwest into Payne Hollow; NW¼ SW¼ SE¼ sec. 15, T. 13 N., R. 23 E., Sequoyah County (pl. 1). The Frisco is not exposed at S14, there being covered interval between the highest exposures of St. Clair and the lowest exposures of Sallisaw, but this formation is believed to be present as it crops out a couple of hundred feet to the south (see S11); the Frisco is also known to crop out further north, along Payne Hollow.

The Sallisaw at this locality is unusual because it includes some highly fossiliferous beds in the upper few feet (pl. XII, figs. 3, 4). This is Christian's Sallisaw collecting locality #5 (1953, p. 38).

SYLAMORE SANDSTONE

Exposed in contact with the Sallisaw ....

SALLISAW SANDSTONE
(20 feet, base covered)

C. *Lithology*: Medium-gray to brownish-gray, arenaceous .... 8 feet
and dolomitic limestone with a few beds of highly fossiliferous biocalcarenite. Most is typical Salisaw arenaceous carbonate with only widely scattered megafossils (with the possible exception of pelmatozoan debris; see below). Upper 2 or 3 feet include irregular beds, up to 8 or 10 inches thick, of bioclastic carbonate having more than 50 percent fossil material. Fossils consist almost entirely of brachiopod shells and tests of *Tentaculites* sp. Peels and thin sections (pl. XII, figs. 3, 4) show the fossil debris is set in a matrix composed of a mixture of quartz detritus and carbonate grains. Carbonate includes both dolomite crystals and grains of calcite, most of the latter consisting of an outer rim of clear calcite and an inner core of granular calcite (suggesting that the core is a piece of a pelmatozoan plate). One specimen tested 3.6 percent HCl-insoluble residue (sample not pulverized). Acid residues largely subangular to angular quartz detritus, most grains having crystal faces (few double terminations); these are up to about 0.3 mm long. Residues also include some pale-green glauconite. The quartz detritus, dolomite crystals, and calcite grains are all about the same size range (pl. XII, fig. 3). No chemical analyses was made of this rock, but thin sections and stained specimens show it is dolomitic. Many of the dolomite crystals and quartz grains penetrate into the fossils (pl. XII, fig. 4), probably representing a pressure-solution phenomenon, at least in so far as the detrital quartz is concerned.
Remarks: The upper 3 or 4 feet of the Sallisaw and the lower 2 or 3 feet of the Sylamore form a ledge which is approximately 50 feet long; the lower part of unit C is partly covered. Most of unit C is fairly typical Sallisaw rock, but the highly fossiliferous brachiopod-*Tentaculites* beds are different and, in so far as I am aware, unique for this formation; compare the Sallisaw photomicrographs on plate XI with those on plate XII, figures 3, 4.
Fossils: A number of brachiopods and *Tentaculites* sp. collected from the upper 2 or 3 feet; the brachiopod fauna is similar to that collected from the Sallisaw at other localities, but this is the only place where I have found *Tentaculites*.

B. *Lithology*: Light-gray, arenaceous and dolomitic .... 12 feet
limestone. Peel shows this rock consists of subangular quartz detritus set in a matrix of dolomitic crystals and calcite grains. One specimen tested 13.3 percent HCl insolubles. Most residues are subangular to angular quartz grains, many with well-developed crystal faces; a few with double terminations; most of this detritus is a fine sand, ranging from 0.1 to 0.3 mm in diameter. No magnesium analyses were run on this rock, but a peel and a specimen stained with Lemberg dye show a substantial amount of dolomite. Dolomite crystals are in approximately the same size range as are the quartz grains. Some brachiopods scattered through the rock.
Remarks: This unit is moderately well exposed. The thickness given above may be affected slightly by slump, but it is probably reasonably accurate.
Fossils: A few brachiopods collected.

Covered. Probably includes the Frisco formation; see above. .... 10 feet

ST. CLAIR FORMATION

Lithology: Pinkish-gray, crinoidal limestone. ....

STRATIGRAPHIC SECTION V2

Southeast of Fittstown

Section described by W. Ventress (1958, p. 139). It is about 2.5 miles southeast of Fittstown, and a half mile south of Oklahoma Highway 61; NE¼ NW¼ sec. 7, T. 1 N., R. 7 E., Pontotoc County (text-fig. 10).

WOODFORD FORMATION

Base covered

FRISCO FORMATION
(11.5 feet exposed)

Lithology: Light-gray, fine- to coarse-grained, dense calcarenite; fossil remains fragmentary, especially crinoid stems; scattered nodules of vitreous chert and a one-inch-thick bed of chert along a bedding plane; beds 2 to 4 feet thick. .... 11.5 feet

BOIS D'ARC FORMATION — FITTSTOWN MEMBER

Lithology: Yellowish-gray, argillaceous calcilutite with beds of calcarenite. ....

STRATIGRAPHIC SECTION V5

Coal Creek

Section described by W. Ventress (1958, p. 141). It is on the north side of Coal Creek, 500 feet or so southeast of stratigraphic section P9 (Amsden, 1960, p. 279-282); center N½ sec. 22, T. 1 N., R. 7 E., Pontotoc County (text-figs. 10, 25; see page 98).

WOODFORD FORMATION

Base covered

FRISCO FORMATION
(10.9 feet exposed)

Lithology: Light-gray, medium-grained biocalcarenite; cavernous fragmental; vitreous chert in irregular beds up to 6 inches thick; also angular nodules of chert; bedding massive, obscure. .... 10.9 feet

BOIS D'ARC FORMATION — FITTSTOWN MEMBER

Top covered

STRATIGRAPHIC SECTION V7

Goose Creek

Section described by W. Ventress (1958, p. 142). It is on the east side of Goose Creek a short distance south of section P17 (Amsden, 1960, p. 286), Ryan Ranch, center SE¼ sec. 26, T. 1 N., R. 7 E., Pontotoc County (text-fig. 10).

WOODFORD FORMATION

Base covered

FRISCO FORMATION
(22 feet exposed)

Lithology: Light-gray, coarsely crystalline, dense to friable biocalcarenite basal five feet with many gastropods and brachiopods; *Leptostrophia magnifica* common; chert nodules few; beds to 2 or 3 feet thick. .... 22 feet

BOIS D'ARC FORMATION — FITTSTOWN MEMBER

Lithology: Light-green to light-gray, friable coarse-grained biocalcarenite streaked with yellow marlstone; beds 2 to 4 inches thick.

STRATIGRAPHIC SECTION V8

Northeastern Johnston County

Section described by W. Ventress (1958, p. 143). It is on the Ryan Ranch in the extreme northeastern corner of Johnston County, NW¼ SE¼ sec. 1, T. 1 S., R. 7 E. (text-fig. 10).

WOODFORD FORMATION

Lithology: Two beds of white, viterous chert, 5 to 6 inches thick; shale covered. ....

FRISCO FORMATION

(11 feet exposed)

Lithology: Light-gray, medium-grained calcarenite; cavernous weathering; fossils not apparent; beds 2 to 3 feet thick. .... 11 feet

BOIS D'ARC FORMATION

Top covered

STRATIGRAPHIC SECTION V9

Southeast of old Hunton Townsite

Section described by W. Ventress (1958, p. 143). It is about a mile southeast of old Hunton Townsite and a couple of miles southwest of Clarita, NE¼ NE¼ sec. 16, T. 1 S., R. 8 E., Coal County (text-fig. 10). This is the same location as Amsden's (1960, p. 190) collection C3 from the uppermost Fittstown.

WOODFORD FORMATION

Lithology: Yellow to brown, fissile shale; some evidence of bedded chert in the base. ....

FRISCO FORMATION

(total thickness 9 feet)

Lithology: Yellowish-brown to olive-gray, fine grained biocalcarenite; cavernous weathering; scattered nodules of vitreous chert; bedding indistinct, probably around 2 feet thick. .... 9 feet

BOIS D'ARC FORMATION — FITTSTOWN MEMBER

Lithology: Gray, fossiliferous calcarenite with numerous chert lenses. Amsden (1960, p. 190) recorded the following brachiopods: *Sphaerirhynchia lindenensis, Howellella cycloptera, Cyrtina dalmani,* and *Kozlowskiellina (M.) velata.*

STRATIGRAPHIC SECTION V10

Southeast of Old Hunton Townsite

Section described by W. Fentress (1958, p. 144). It is about a mile and a half southeast of old Hunton Townsite and a couple of miles southwest of Clarita; SE¼ SE¼ sec. 16, T. 1 S., R. 8 E., Coal County (text-fig. 10). This is near southeastern margin of the Frisco in the Arbuckle Mountain region; a few hundred feet south of this location the Frisco is absent and the Woodford rests directly upon the Bois d'Arc formation (See Amsden, 1960, panel II, pl. B).

WOODFORD FORMATION

Lithology: Bedded. white, vitreous chert; beds up to 1 foot thick. ....

FRISCO FORMATION

(total thickness 13 feet)

Lithology: Yellowish-brown to olive-gray, fine grained biocalcarenite; cavernous weathering; some silicified fossils; bedding 1 to 2 feet thick. .... 13 feet

BOIS D'ARC FORMATION — FITTSTOWN MEMBER

Lithology: Light-gray, medium-grained calcarenite; beds up to 6 inches thick.

CHEMICAL ANALYSES

The analyses tabulated on the following pages were prepared in the geochemical laboratory of the Oklahoma Geological Survey by John A. Schleicher. All were made from chert-free rock specimens collected by me from described stratigraphic sections. Those designated by the letter S cover the Sallisaw and Frisco formations and the upper part of the St. Clair formation in the Marble City area of Sequoyah County; the stratigraphic sections from which these were collected are described in the preceding section of the Appendix. Those designated by the letter P cover the Frisco formation in the Arbuckle Mountain region, Pontotoc County; the stratigraphic sections from which these were collected are described in the Appendix of my 1960 paper on Hunton stratigraphy.

These specimens were prepared as follows: The rock was first pulverized and then digested in warm (not boiling), dilute HCl. The insoluble residue was calculated and the amount of CaO and MgO determined for the acid-soluble part; these data were then converted to equivalents of $CaCO_3$ and $MgCO_3$. It should be noted that pulverizing the sample with mortar and pestle seems to give maximum solubility. I have found that samples which are crushed to only about pea size and smaller yield an insoluble residue that is slightly higher than that of powdered specimens.

A few HCl-insoluble residues prepared by me are not listed below. These include one specimen of the laminated rock from the St. Clair formation at S1-A (8.1 percent), and five from the Frisco formation at S1 (1 percent and 2 percent) and S9 (1 percent, 2 percent, and 2 percent). All of these were prepared by crushing the specimen to about pea size.

The analyses of 65 rock specimens from the St. Clair (upper part only), Frisco, and Sallisaw are given below. These data are arranged stratigraphically under the appropriate section. The Sequoyah County sections represented are: S1, S4, S5, S8, S9, S10, S11, and S13; those from Pontotoc County are P8, P9, and P11.

These analyses are discussed and illustrated graphically in the text under the appropriate formation. A discussion of the stratigraphic distribution of $MgCO_3$ and its possible significance is given in the section, Stratigraphic Distribution of Dolomite. Additional chemical analyses of the St. Clair limestone may be found in Ham et al. (1943), *Geology and chemical composition of the St. Clair limestone near Marble City, Oklahoma.*

Note: All of the following data are expressed as percentages.

Stratigraphic Section	Location	Rock Sample	Formation	Insoluble Residue	$CaCO_3$	$MgCO_3$	Total	Remarks
P8	North side of Bois d'Arc Creek, Pontotoc Co.	P8-H(2) P8-H(1)	Frisco	0.59 0.51	100.64 99.62	0.51 0.38	101.74 100.51	From Amsden, 1960, p. 277.
P9	Coal Creek, Pontotoc County	P9-R	Frisco	0.26	99.18	0.79	100.23	From Amsden, 1960, p. 279.
P11	Bois d'Arc Creek, Pontotoc County	P11-C	Frisco	0.86	101.23	0.54	102.63	From Amsden, 1960, p. 284.
Miscellaneous	Pontotoc County (see remarks)		Frisco	3.56	97.48	0.39	101.43	NE¼ SE¼ sec. 10, T. 2 N., R. 6 E.
			Frisco	4.94 2.20	94.54 96.72	0.45 0.41	99.93 99.33	NE¼ NE¼ sec. 16, T. 1 S., R. 8 E.
			Frisco	0.61	99.18	0.60	100.39	SE¼ SW¼ sec. 9, T. 1 S., R. 8 E.
S1	Big bend of Sallisaw Creek, Sequoyah Co.	S1-D(3) S1-D(2) S1-D(1)	Sallisaw	22.13 11.03 3.81	76.78 87.44 95.20	1.03 1.57 1.10	99.94 100.04 100.11	5 to 7 feet above base. 2 to 5 feet above base. 0 to 1 feet above base.
		S1-C(1) S1-C(2)	Frisco	0.69 0.29	98.45 99.20	0.84 0.81	99.98 100.30	Samples from unit C.
		S1-B(1) S1-B(2)		0.65 0.03	98.78 99.36	0.38 0.55	99.81 99.94	Samples from unit B.
		S1-A(1) S1-A(2) S1-A(3) S1-A*	St. Clair	0.06 0.42 0.07 3.42	99.40 98.99 99.82 95.30	0.76 0.82 0.42 1.26	100.22 100.23 100.31 99.98	Samples from upper 20 feet.

*Specimen containing laminated material.

S4	Walkingstick Hollow, Sequoyah County	S4-F(1)	Sallisaw	1.27	97.78	0.45	99.50	Samples from unit F.
		S4-F(2)		1.58	96.69	1.40	99.67	
		S4-E(4)	Frisco	0.32	99.47	0.51	100.30	Upper 3 inches.
		S4-E(3)		0.24	99.27	0.65	100.16	2 feet below top.
		S4-E(2)		0.65	98.63	0.71	99.99	4 feet below top.
		S4-E(1)		0.63	98.77	0.51	99.91	5 feet below top.
		S4-C	St. Clair	0.99	64.07	34.40	99.46	5 feet below unit E.
		S4-A		0.38	99.03	0.61	100.02	7 feet below unit E.
S5	South of St. Clair Lime Company Quarry, Sequoyah County	S5-D(3)	Sallisaw	5.65	87.98	6.80	100.43	8 feet above base.
		S5-D(2)		8.42	82.00	9.89	100.31	6 feet above base.
		S5-D(1)		11.19	71.80	16.96	99.95	Lower 1 foot.
		S5-C	Frisco	0.03	99.07	0.46	99.56	
		S5-B		0.32	98.52	0.57	99.41	
		S5-A(4)	St. Clair	0.45	98.28	1.22	99.95	Upper 2 feet.
		S5-A(3)		0.19	99.00	0.63	99.82	5 feet below top.
		S5-A(2)		0.07	99.09	0.52	99.68	10 feet below top.
		S5-A(1)		0.07	99.09	1.12	100.28	15 feet below top.
S8	Payne Hollow, Sequoyah County	S8-AB(10)	Frisco	0.41	98.89	0.63	99.93	2 feet above base.
		S8-AB(8)		0.54	98.45	0.92	99.91	1 foot above base.
		S8-AB(7)		0.95	97.87	1.00	99.82	6 inches above base.
		S8-AB(5)	St. Clair (upper 2 feet)	0.38	96.03	3.75	100.16	3 inches below top.
		S8-AB(4)		0.17	94.69	5.21	100.07	6 inches below top.
		S8-AB(2)		0.23	98.72	0.97	99.92	12 inches below top.
		S8-AB(1)		0.23	94.09	5.88	100.20	18 inches below top.
S9	Payne Hollow, Sequoyah County	S9-F	Sallisaw	6.26	67.29	26.49	100.04	
		S9-E	Frisco	0.14	99.61	0.61	100.36	
		S9-D		0.01	99.30	0.30	99.61	
		S9-C		0.37	97.72	1.79	99.88	
		S9-B(2)	St. Clair	0.39	64.01	35.52	99.92	Upper 2 feet.
		S9-B(1)		0.39	63.32	36.05	99.76	2 to 4 feet below top.
		S9-A		0.25	99.05	0.48	99.78	5 feet below top.

Stratigraphic Section	Location	Rock Sample	Formation	Insoluble Residue	$CaCO_3$	$MgCO_3$	Total	Remarks
S10	Payne Hollow, Sequoyah County	S10-D(18)	Sallisaw	45.43	45.72	8.48	99.63	18 feet above base.
		S10-D(5)		9.86	82.71	7.52	100.09	5 feet above base.
		S10-D(1)		6.33	67.88	25.05	99.26	1 foot above base.
		S10-CD(d)		5.11	70.23	24.58	99.92	Lower 1 inch.
		S10-C	Frisco	0.00	99.17	0.77	99.94	
		S10-B		0.80	98.65	0.39	99.84	
		S10-A	St. Clair	0.36	98.74	0.97	100.07	
S11	Payne Hollow, Sequoyah County	S11-D(2)	Sallisaw	6.30	74.50	19.01	99.81	6 feet above base.
		S11-D(1)		2.75	83.69	12.98	99.42	2 feet above base.
		S11-CD(d)	Sallisaw ? (see remarks)	0.94	57.87	40.65	99.46	Lower 2 inches. May be dolomitic Frisco.
		S11-CD(c)	Frisco	1.84	96.83	0.85	99.52	Upper 2 inches.
		S11-C		0.37	98.80	0.85	100.02	
		S11-B		1.58	97.84	0.65	100.07	
		S11-A(2)	St. Clair	0.19	99.21	0.71	100.11	Upper 6 inches.
		S11-A(1)		0.22	99.15	0.67	100.04	1 to 4 feet below top.
S13A	St. Clair Lime Co. Mine, tunnel J north of 17	S13-J	Frisco	—	88.53	2.12	—	Basal 2 inches.

INDEX

An asterisk (*) indicates the page where a subject is discussed or described.