October 18, 1971

To the Graduate Council:

I am submitting herewith a dissertation written by Mansour Kashfi entitled "Structure, Stratigraphy and Environmental Sedimentology of the Middle Ordovician Chickamauga Group of a Segment of Monroe County, Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Geology.

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Major Professor

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Harry J. Klepser

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Vice Chancellor for
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STRUCTURE, STRATIGRAPHY AND ENVIRONMENTAL SEDIMENTOLOGY OF THE MIDDLE ORDOVICIAN CHICKAMAUGA GROUP OF A SEGMENT OF MONROE COUNTY, TENNESSEE

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

Mansour Kashfi

December 1971

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ABSTRACT

The purpose of this study was to analyze the structure, stratigraphy and environmental sedimentology of the southeasternmost Middle Ordovician outcrop belt in East Tennessee. Structurally, the area contains a plunging syncline trending parallel to the strike of the Great Smoky fault near the center of Monroe County. Five major stratigraphic units and their subdivisions were mapped in this region. These units are the Knox Group of Late Cambrian and Early Ordovician age, and the Athens Formation, the Tellico Formation including the Notchy Creek facies (new), and the Ottosee and Bays Formations, all of Middle Ordovician age. Within this area the type section of the Notchy Creek facies of the Tellico Formation and a standard section of the Tellico Formation (Keith, 1896) were established. Because of the wide differences in opinion on both the correlation and the classification of the lower and middle portion of the Chickamauga Group, special emphasis was placed on resolving these differences in the area of study. The Athens and Ottosee Formations contain fossils; a number of thin sections were made and the fossil content was studied. The facies relationship of the Notchy Creek facies of the Tellico and standard Tellico Formation was established. During the field work of this study, an effort was made to describe any primary or secondary sedimentary features in the rocks of this area in order to form a basis for interpretation of the environment of deposition of each formation. Generally, shallow marine water and deltaic deposits are characteristic of the major portion of these units. Structural features of various scales were observed and

described during the course of this work. The joints and slaty cleavage are basically of compressive type and usually trend parallel with regional strike. The Athens and Ottosee erode to flat terrain and the Notchy Creek facies and Bays Formation form higher ridges. A range of soil forming processes has produced widely different characteristics in soils in the area under study.

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CHAPTER I

INTRODUCTION

Statement of the Problem

The stratigraphy of the lower and middle portions of the Chickamauga Group of Middle Ordovician age in East Tennessee has been subject to debate for a long time. Differences of opinion regarding Chickamauga subdivisions and nomenclature have been well summarized by Rodgers (1953).

The present report describes an 8750 foot thick sequence of Middle Ordovician rocks in Monroe County, eastern Tennessee, which is in the southeasternmost belt of the Valley and Ridge Province. The Middle Ordovician rocks in this belt occur in an asymmetrical syncline which plunges northeastward. This syncline is the southwestern extremity of the Bays Mountain synclinorium and is located immediately northwest of the trace of the Great Smoky fault. This southeast dipping, low angle thrust fault serves as the boundary between resistant Lower Cambrian and Precambrian metamorphosed sedimentary rocks of the Blue Ridge Province and the less resistant overthrust Paleozoic sedimentary rocks of the Valley and Ridge Province to the west. Within the syncline, several small scale northeast-southwest trending folds and faults are present.

The primary problem with which this writer was concerned was the mapping of the Middle Ordovician rocks in this area, and the comparison of stratigraphic relationships of these rocks with those of an area mapped by Neuman (1955) in adjacent Blount County.

The following questions concerning the structural patterns along this belt have also been considered: What is the structural nature of the Sink, Hicks, Mahan, Cedar faults and the Bays Mountain syncline? What are the orientations of the cleavage and joints in these units, and lastly, what was the environment of deposition of these rocks?

Location and Extent of the Area Studied

The study area (Figure 1) in Monroe County lies within four Tennessee Valley Authority 7 1/2 minute quadrangles. The main portion of the area mapped is in the Mount Vernon (132-NE) quadrangle and the area includes parts of Madisonville (131-SE), Rafter (140-NW) and Vonore (139-SW) quadrangles (Figure 2). The area embraces approximately 84 square miles. It is located about 50 miles southwest of Knoxville near Madisonville in Monroe County. Only one major highway, State 68, traverses the southwestern portion of the area.

Previous Investigations

The general geology of East Tennessee has long been known from the works of Safford (1856), Keith (1896), and Ulrich (1911). Although the remarkable works of Safford and Keith show the major stratigraphic (Figure 3) and structural relationships, they lack detail concerning both subdivision and correlation. Much of this has been modified by Rodgers (1953). No other studies have considered the area covered by the present investigation.

Present Investigation

The present work is based on detailed areal mapping. The measured

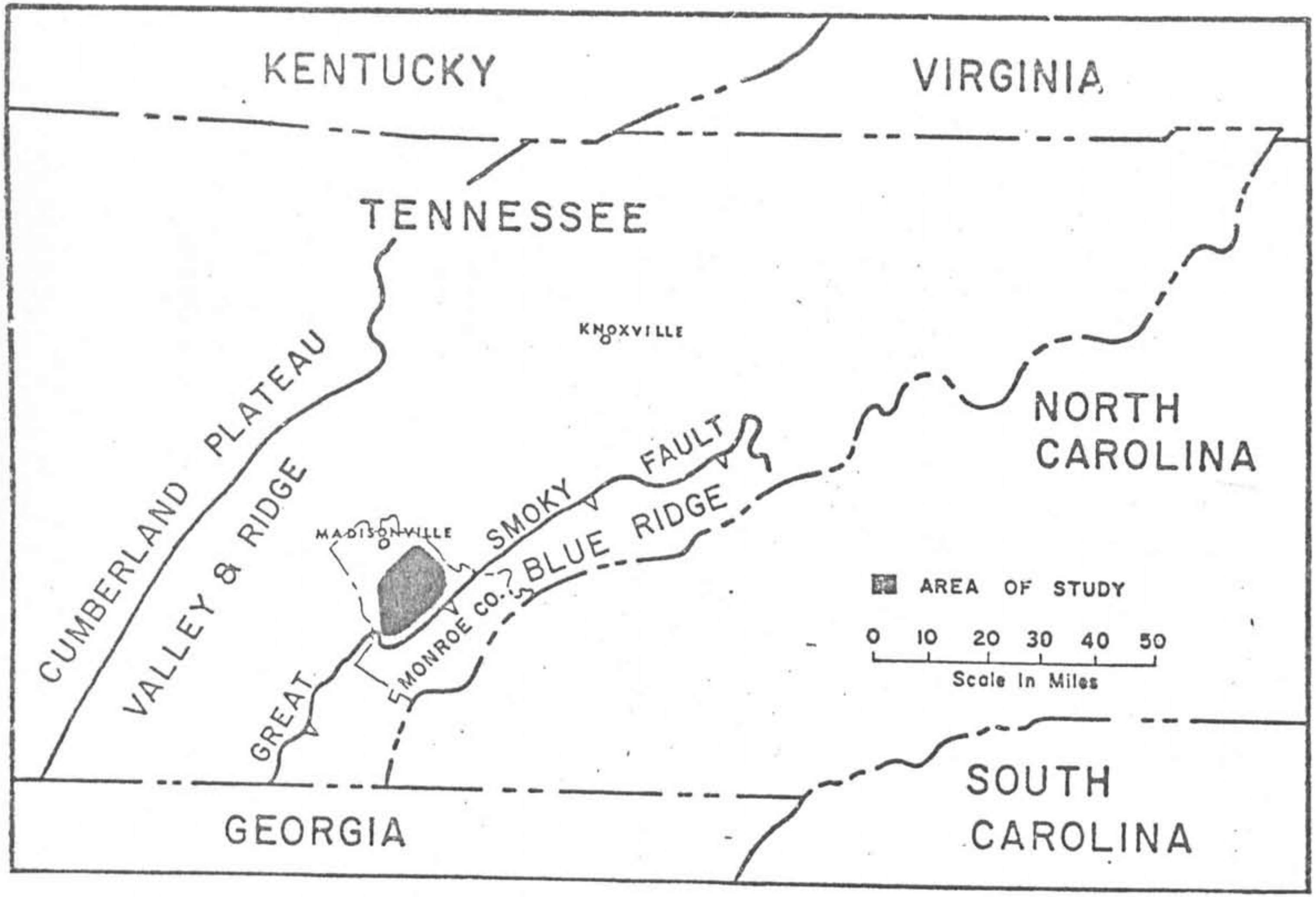


Figure 1. Index map to location of study area.

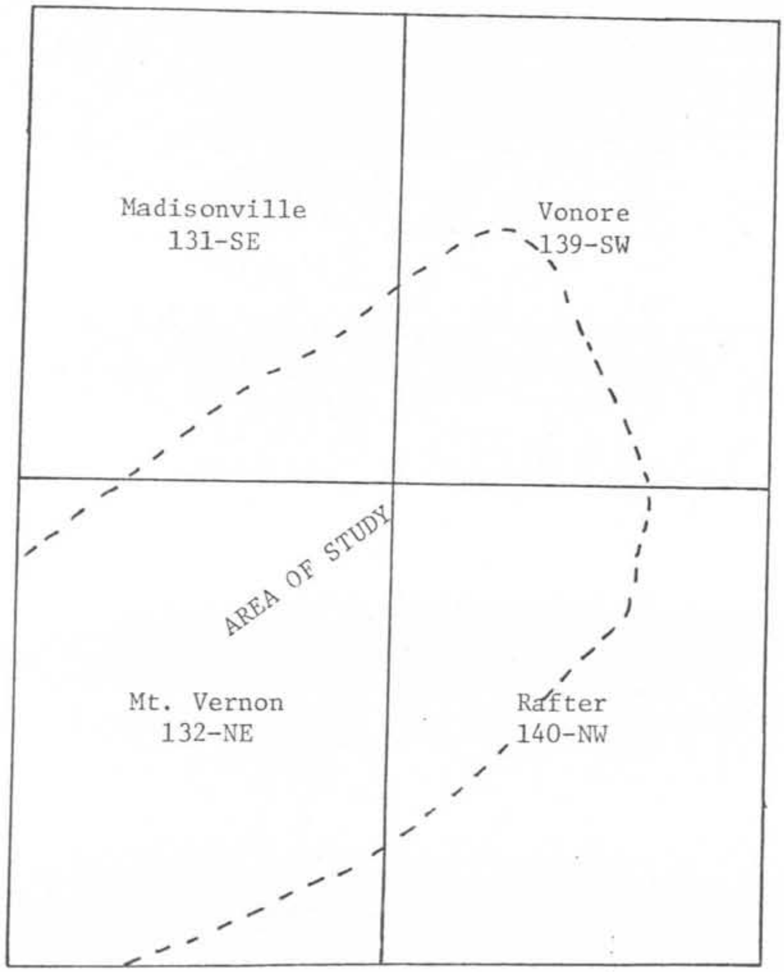


Figure 2. Index map to location of study area with regard to four quadrangles.

		Safford, 1869	Campbell, 1894	Hayes, 1895	Keith, 1895	Ulrich, 1911
ORDOVICIAN	M		Bays Sandstone	Bays Sandstone	Bays Sandstone	Bays Sandstone
			Sevier Shale	Sevier Shale	Sevier Shale	Sevier Shale Ottosee Shale
		Trenton and Nashville Series		Tellico Ss	Tellico Ss	Tellico Ss Holston Ls Athens Sh
				Athens Shale	Athens Shale	
		Lenoir Limestone	Chickamauga Lime- stone	Chickamauga Lime- stone	Chickamauga Lime- stone	Lenoir Limestone
	L	Knox Dolomite	Knox Dolomite	Knox Dolomite	Knox Dolomite	Knox Dolomite

Figure 3. Early classification of Lower and Middle Orodvician rocks by various workers in Eastern Tennessee.

geologic features were plotted on topographic base maps with a scale of one inch to two thousand feet.

Field work, using conventional techniques, primarily involved the study of lithographic types and structural attitudes. Where field conditions permitted, units and structural features were "walked out" and the contacts of the rock units were chosen largely by making traverses perpendicular to the strike of the strata. Four cross-sections and two columnar sections were constructed to illustrate the writer's interpretation of the stratigraphy and structure. Structural study was undertaken and an attempt was made to present an accurate description of the structural features present in this area. A number of thin sections were made and the fossil content was studied. Correlations were made by using selected and standard geologic methods based primarily on available paleontological data, comparison of measured sections, general stratigraphic positions, similarity of lithologic composition, and structural relations. The field studies started in the fall of 1968 and were concluded in the summer of 1970.

CHAPTER II

ROCK UNITS AND STRATIGRAPHY

General Statement

The Appalachian Highlands, one of the eight major physiographic divisions of the United States, extends from the Gulf Coast to the St. Lawrence River and from the Atlantic Coastal plain to the Central Lowland. The Appalachian Highlands division is divided into six provinces. This report is mainly concerned with a small part of one of these six provinces--the Valley and Ridge.

The Valley and Ridge consists chiefly of sedimentary rocks of Paleozoic age. In the Tennessee section of the Valley and Ridge, faulting is dominant with but few unbroken folds. Topographically, the Valley and Ridge is a succession of valleys and ridges which trend northeast-southwest with an extreme width of 40 miles locally.

Fenneman (1938) believed that morphologically the Valley and Ridge Province consists of folded mountains in their second cycle of erosion, in which more resistant rocks make ridges and weaker strata form lowlands or valleys.

The stratigraphy and classification of the Chickamauga Group and equivalent rocks has produced more controversy than any other major Paleozoic unit in the southern Appalachians. Because of the wide difference in opinion on both the correlation and the classification of the lower and middle Chickamauga Group, Rodgers (1953) described the rocks themselves, belt by belt along the strike. Rodgers established a standard belt in the middle of the Valley as a reference and worked first southeastward and then northwestward. The largest area of Middle Ordovician rocks in East Tennessee is the belt called the Gray Belt by Safford (1869). This belt extends from the Bays Mountain synclinorium southwestward along the east side of the Valley to Etowah and the edge of Polk County (Rodgers, 1953). The area studied lies within the southwest part of this belt.

Rodgers (1953) described the stratigraphic column in Monroe County and presumably he traced these units northeastward along axis from the plunging syncline toward Bays Mountain. In the main body of this belt, in Monroe County, Rodgers recognized four units. These units are the Athens Shale, Holston Formation, Ottosee Shale, and Bays Formation. He considered the stratigraphy of these units in this general area primarily from a lithologic viewpoint.

As previously mentioned, one of the objectives of the present work is to correlate these units, if possible, with those of the adjacent area in Blount County mapped by Neuman (1955) (Plate III, pocket). The work of Neuman in Blount County is more or less in harmony with that of Rodgers (Figure 4). Neuman subdivided the Athens Shale of Rodgers into Whitesburg Limestone Member, Toqua Sandstone Member and Dark Shale Member; he also called Rodgers' upper Athens the Tellico Formation in Blount County. Neuman proposed Chota and used Sevier (earlier proposed by Keith, 1895) formations, respectively, for the Holston and Ottosee formations adopted by Rodgers.

Where it is possible the present writer has used the older terms which tend to be the current standard classification for these strata.

			Rodgers, 1953	Neuman, 1955
ORDOVICIAN	Middle	Chickamauga	Bays Formation	Bays Formation
ORDOVICIAN	Middle	Chickamauga	Ottosee Shale	Sevier Formation
ORDOVICIAN	Middle	Chickamauga	Holston Formation	Chota Formation
ORDOVICIAN	Middle	Chickamauga	Athens Shale	Tellico Formation
ORDOVICIAN	Middle	Chickamauga	Sandstone layers near Etowah, Tennessee	Blockhouse Shale: Dark Shale Member Toqua Sandstone Member Whitesburg Limestone Member
ORDOVICIAN	Middle	Chickamauga	Lenoir Limestone in other belts	Lenoir Limestone
ORDOVICIAN	Lower		Knox Group	Knox Group

Figure 4. A comparison of classifications of Middle Ordovician rocks in the northeastern portion of the study area.

He considers a part of Keith's classification (1895), in which he referred to a "Sandstone lentil in the Sevier Shale" which, later, Neuman called "Chota," Rodgers called "Holston Formation," and this writer calls it "Hawkins Member" of the Ottosee Formation.
The writer's findings with respect to the stratigraphy of some of the units in a part of the study area do not conform with those of Rodgers and Neuman. The new stratigraphic conclusions that are offered in the following pages are mainly derived from studies in the Vonore quadrangle in the northeast segment of the area studied. Observations by the writer are in harmony, however, with those of Rodgers in the Mount Vernon quadrangle in the southwest portion of the area of study (Figure 5) except that he maps the "Holston" of Rodgers as the Notchy Creek facies of the Tellico. Through detailed areal mapping, study of lithology and available paleontologic data, this writer has attempted to resolve the stratigraphic relationships in the study area.

Four major stratigraphic units are involved in this study. These units are (in ascending order): the Athens, the Tellico including the Notchy Creek facies, Ottosee, and Bays formations all of the Chickamauga Group of Middle Ordovician age. The underlying Knox Dolomite was observed in the course of geologic mapping but was not studied in detail.

Six stratigraphic sections were measured during the field investigation of this study. The grain size terms used in this report are adopted from the Wentworth Grade Scale (1922). This writer uses terms "thin bedded" for beds less than one foot and "thick bedded" for beds thicker than one foot throughout this text. Rock colors were determined

SOUTHWEST		EXTREME NORTHEAST	
Rodgers	Present Report	Rodgers	Present Report
Bays	Bays: U. Member, M. Member, L. Member	Bays	Bays: U. Member, M. Member, L. Member
Ottosee	Ottosee	Ottosee	Ottosee
		Holston	Hawkins Member (Ottosee)
Holston	Tellico (Notchy Creek Facies)	Athens	Tellico
Athens	Athens: U. Member, M. Member, L. Member		Athens: U. Member, M. Member, L. Member
Knox	Knox	Knox	Knox

Figure 5. A comparison of classifications of Middle Ordovician rocks across study area.

by comparing dry specimens with the Geological Society of American Rock-Color Chart (Goddard, et al., 1963).

Knox Group

Although the stratigraphy of the Knox Group is not a primary concern of this work, because of the surface of unconformity between this sequence and the overlying Athens Formation, a very brief discussion will be given.

The Knox Dolomite was named by Safford in 1869 for exposures in Knoxville and Knox County. It is exposed areally more in East Tennessee than any other major unit (Rodgers, 1953, p. 53). This unit is chiefly cherty dolostone in the northwestern portion of the Valley. In the southeastern part (including the area of this study) the unit is mainly limestone with little chert.

The terms Conococheague Limestone and Jonesboro Limestone, which were proposed respectively by Stose (1908) and Ulrich (1911), are subdivisions of the Knox Group in the southeastern phase (Rodgers, 1953). Only a portion of the uppermost part of the Jonesboro Limestone (possibly equal to the Mascot Dolomite and part of the Kingsport Formation in the northwest phase) is present in the study area.

The diagnostic lithology of this rock is commonly massively-bedded, yellowish-gray (5Y 7/2), finely crystalline, dense limestone, with occasional thin beds of dolostone. The individual limestone beds are generally one to two feet thick. The dolostone weathers a dusky yellow (5Y 6/4), whereas the limestone weathers a grayish-yellow (5Y 8/4). Pebble to boulder sized float blocks of very pale orange (10YR 8/2) to white (N9) sandy chert are present in the soil. These float blocks, along with the peculiar color of the residual soil and rounded appearance of weathered outcrops, are the diagnostic features of the Knox in the area. The contact between Knox and the Athens above is not exposed in the area under study, thus, the unconformity cannot be observed. However, the Knox unconformity has been reported widely in various locations northeastward, especially around Douglas Lake (Rodgers, 1953).

Lower and Middle Chickamauga Group

In ascending order, the subdivisions of this group, recognized in Monroe County, are the Athens, Tellico (including the Notchy Creek facies), Ottosee and Bays formations. The characteristics of these units and their subdivisions are shown in Table I. The thickness of the Middle Ordovician rocks in this belt is about 8750 feet. All units discussed in the present chapter are calcareous with the exception of a rather thin, clean sandstone at the top of the section. They are claystones, shales, siltstones, sandstones--all calcareous--, and various types of limestone. Contacts are usually gradational in the sequence with the exception of the Ottosee-Bays contact which is rather sharp.

Athens Formation

This formation, 3100-3300 feet thick, consists chiefly of calcareous shale but contains a 300-500 foot unit of calcareous sandstone in the lower third. For this reason, the writer has subdivided it into three members; they are best exposed along State Highway 68 in the southwestern part of the Mount Vernon quadrangle. Because of highly deformed and weathered outcrops, there is no conventional

TABLE I

PRESENT CLASSIFICATION AND A SUMMARIZED DESCRIPTION OF ROCK UNITS

Classification of Present Report	Thickness (in feet)	Description
Bays:		
U. Member	370-390	sandstone, grayish-orange pink (5YR 7/2); coarse-grained, well sorted, well rounded quartz grains toward the top, thick bedded; irregularly fractured.
M. Member	630-650	mudstone, calcareous, moderate brown (5YR 3/4); clay aggregates, interbedded with siltstone beds; cleavage and joints are present.
L. Member	110-140	siltstone to medium-grained sandstone., grayish-red (5R 4/2); thin bedded, fine muscovite flakes; usually fractured.
Ottosee	2500-3500 (total)	shale, calcareous, medium yellow brown (10R 5/4); commonly contains even laminae, irregularly fractured; common fossils are graptolites and bryozoans. Minor amounts of siltstones, sandstone, marble, and limestone are present.
Hawkins Member	(650-750)	sandstone arkose, calcareous, dark reddish-brown (10R 3/4); medium to coarse-grained, massive, thick bedded, poorly rounded; locally cross bedded.
	(220-240)	shale, as main body of Ottosee.
Notchy Creek facies of the Tellico Formation	(1300-1500)	sandstone arkose, calcareous, dark reddish-brown (10R 3/4); fine to very coarse, angular grains, poorly sorted and rounded; cemented by calcite, massive, thick bedded, cross bedded, some shale beds interbedded. This unit changes along strike to Tellico Formation of Neuman. Sandstone, light brownish-gray (5YR 6/1); medium-grained, interbedded with thin bedded siltstone.

TABLE I (continued)

Classification of Present Report	Thickness (in feet)	Description
Athens		
U. Member	2200-2400	shale, calcareous, olive gray (5Y 3/2); finely laminated, graptolites.
M. Member	300-500	sandstone, calcareous medium-grained, yellowish-gray (5Y 7/2); occasionally cross bedded; jointed.
L. Member	400-600	shale, calcareous, olive gray (5Y 3/2); finely laminated.

way to accurately measure the thickness of the Athens Formation in the area of study. However, the writer believes that more than 3200 feet of Athens are present in this area.

The name Athens Shale was proposed by Hayes in the Kingston folio in 1894 for Upper Ordovician Shale. In the Cleveland folio (1895), Hayes used it for middle Ordovician shales between the Chickamauga Limestone (Lenoir of Rodgers) and the red Tellico (Holston marble of Rodgers) (Rodgers, 1953, p. 73).

Lithology

Lower Member. The Lower Member is mainly calcareous shale, olive gray (5Y 3/2) to grayish-blue (5PB 5/2) where fresh and pale olive (10Y 6/2) where weathered. It is locally finely laminated and weathers to small soft chips. This member is from 400 to 600 feet thick and except for a greater calcareous content is similar to the Upper Member.

Middle Member. This member is about 300-500 feet thick and is composed of fine to medium-grained calcareous sandstones. It is yellowish-gray (5Y 7/2) where fresh but dark yellowish-brown (10YR 4/2) on weathered surfaces. Coarse to very coarse quartz grains are scattered throughout this member; they decrease in abundance upward. Small scale truncated planar cross bedding is occasionally present within this member. Joints are normal to the bedding planes, with a few irregular fractures filled with calcite. The beds have a maximum thickness of about two feet and are in places separated by thin beds of shale. Figure 6 shows the contact between the Lower and Middle members.

Figure 6. Exposure of Athens and fossils identified within this formation.

A. Contact (at hammer) between Lower and Middle Members of Athens Formation. The location is about 3 1/3 miles north of Mount Vernon, State Highway 68.

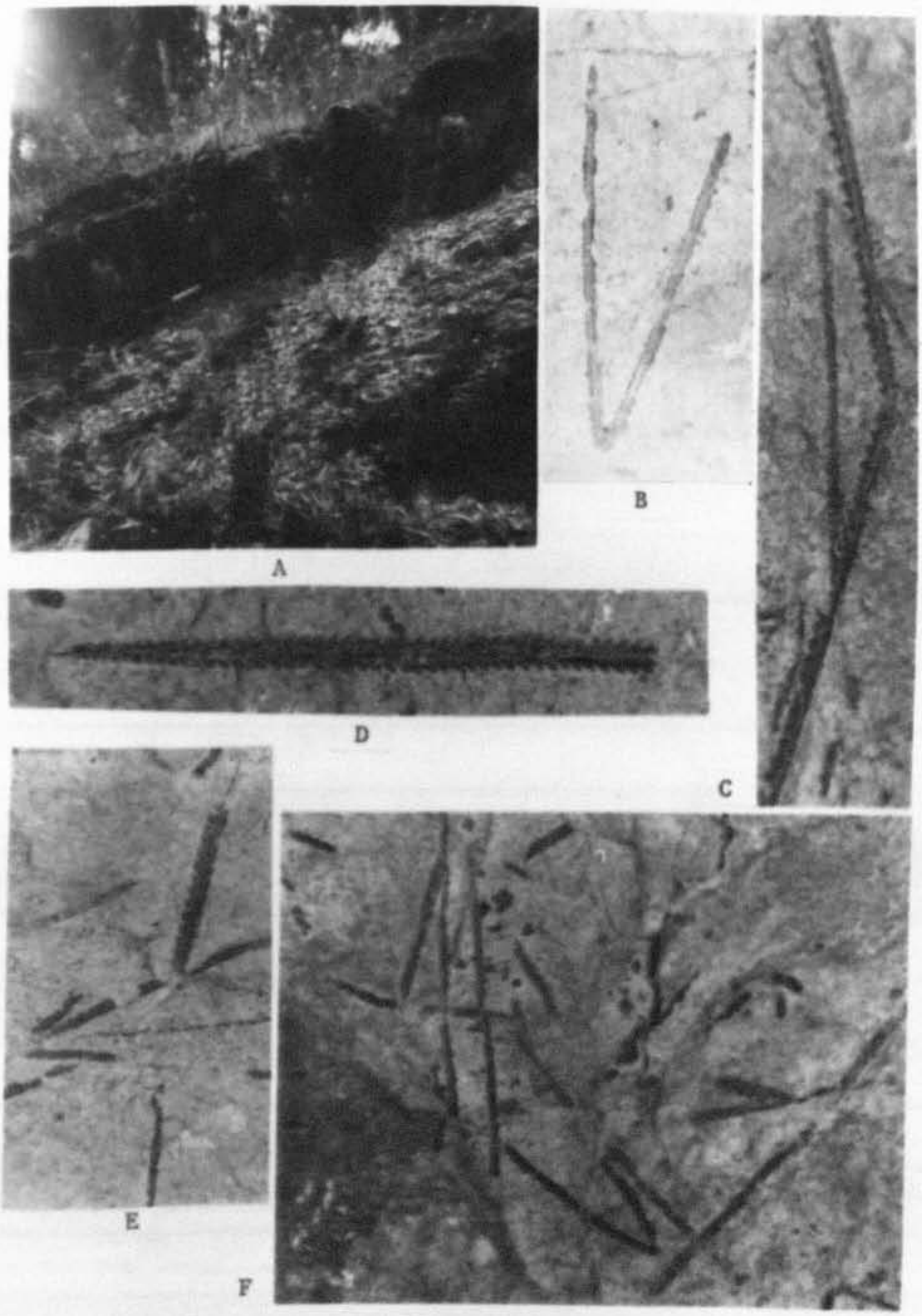
B. Dicellograptus (cf. D. moffatensis alabamensis), natural size. Athens Shale; three miles southeast of Mount Vernon, State Highway 68.

C. Nemagraptus (N. gracilis), natural size. Athens Shale; three miles southeast of Mount Vernon, State Highway 68.

D. Diplograptus (D. foliaceus), natural size. Athens Shale; three miles southeast of Mount Vernon, State Highway 68.

E. Climacograptus (cf. C. shcarenbergi), natural size. Athens Shale; three miles southeast of Mount Vernon, State Highway 68.

F. Dicellograptus (cf. D. smithi), natural size. Athens Shale; three miles southeast of Mount Vernon, State Highway 68.



A B C D E F

Figure 6

Upper Member. This member makes up the major portion of the Athens Formation. It consists of 2200-2400 feet of calcareous shale, olive gray (5Y 3/2) to medium bluish-gray (5B 5/1) where fresh and light olive gray (5Y 5/2) and pinkish-gray (5YR 8/1) where weathered; locally thin moderate olive brown (5Y 4/4) beds are present. Some thin silty shale beds are interbedded within this unit. Shale beds, for the most part, are finely laminated and weather to very small soft chips. Bedding can be recognized even in weathered outcrops if deformation has not disturbed the attitude of the rocks. Graptolites are the chief fossils in the middle part of the Upper Member of the Athens Formation. The following fossils were identified (Figure 6):

Dicellograptus (cf. _D. moffatensis alabamensis_).

Dicellograptus (cf. _D. smithi_)

Climacograptus (cf. _C. scharenbergi_)

Nemagraptus (_N. gracilis_)

Diplograptus (_D. foliaceus_)

Stratigraphic Relations

The Athens is the lowest unit of the Chickamauga Group and lies unconformably on the Knox Group. The carbonate facies of the Athens in part is known as Lenoir Limestone in various more westerly strike belts in East Tennessee (Rodgers, 1953).

It is possible that the Middle Sandstone Member of this report is equivalent to the Toqua Sandstone Member of the Blockhouse Shale of Neuman and the sandstone layers that Rodgers recognized near Etowah, Tennessee, within the Athens in his classification of units. The Upper Member of the present classification is probably equivalent to the Dark Shale Member of the Blockhouse Shale of Neuman.

The Athens Formation conformably underlies the Tellico Formation. The contact is rather sharp in the southwest, gradually becoming gradational toward the northeast in the Vonore quadrangle.

Tellico Formation

The Tellico Formation, 1330-3900 feet thick, consists chiefly of calcareous sandstone, arkose sandstone, siltstone and shale. In the area, it changes laterally from sandstone and shale to arkose sandstone southwestward along strike. The term "type Tellico" is applied to facies at the northeast extremity of the area and the term "Notchy Creek facies of the Tellico Formation" (arkose sandstone) southwestward in Monroe County.

Type Tellico

The term type Tellico is here applied to a light brownish-gray (5YR 6/1) calcareous sandstone, interbedded with thin brownish-gray (5YR 4/1) siltstone layers and occasional shale beds. The sandstone beds are medium-grained and the particles are better sorted and rounded than those of the arkosic facies to the southwest. The maximum thickness of the individual sand beds is not more than one foot and the beds are usually planar and uniform. Upon weathering, the surface expression of the siltstone beds becomes smooth and form depressions but the more resistant sandy beds form small ridges.

The term Tellico Sandstone was originally applied by Keith (1895), without designating a type section. Therefore, the writer has established a standard section for the Tellico Sandstone along the east bank of the Tellico River (Neuman area)(see Appendix, Table II).

Notchy Creek Facies of the Tellico Formation

The name Notchy Creek facies of the Tellico Formation is here given to a unit which is composed dominantly of massive calcareous arkose sandstone and shale approximately 1300-1500 feet in thickness. This formation is underlain by the Athens Formation and overlain by the Ottosee Formation. It is the unit mapped as the "Holston Formation" by Rodgers (1953), in the southwest part of the study area. Figure 7 illustrates a comparison of geologic maps by Rodgers and the present investigator of the area studied.

The name is taken from the Notchy Creek Knobs, Monroe County, Tennessee.

Lithology. The Notchy Creek facies of the Tellico Formation is a dark reddish-brown (10R 3/4) arkose where it is fresh and pale red (5R 6/2) where it is weathered; the chemical cement is usually fine crystalline calcite. It is normally composed chiefly of two detrital clastic minerals: quartz and feldspar. The unweathered rock is very dense and massive (Figure 8), and is composed of poorly sorted, angular, fine to very coarse sand size grains, occurring in individual beds up to six feet in thickness.

Cross bedding is a common feature of these beds (especially in lower half). Where cross bedding is present, the nature of the bedding surface is uneven; otherwise, it is chiefly planar. On weathering, the carbonate cement leaches out leaving a friable, powdery rock, which upon further weathering produces a deep red sandy soil. In some places, fractures produced by deformation could be mistaken for true bedding planes. This arkose, in some places, appears as shaly-looking

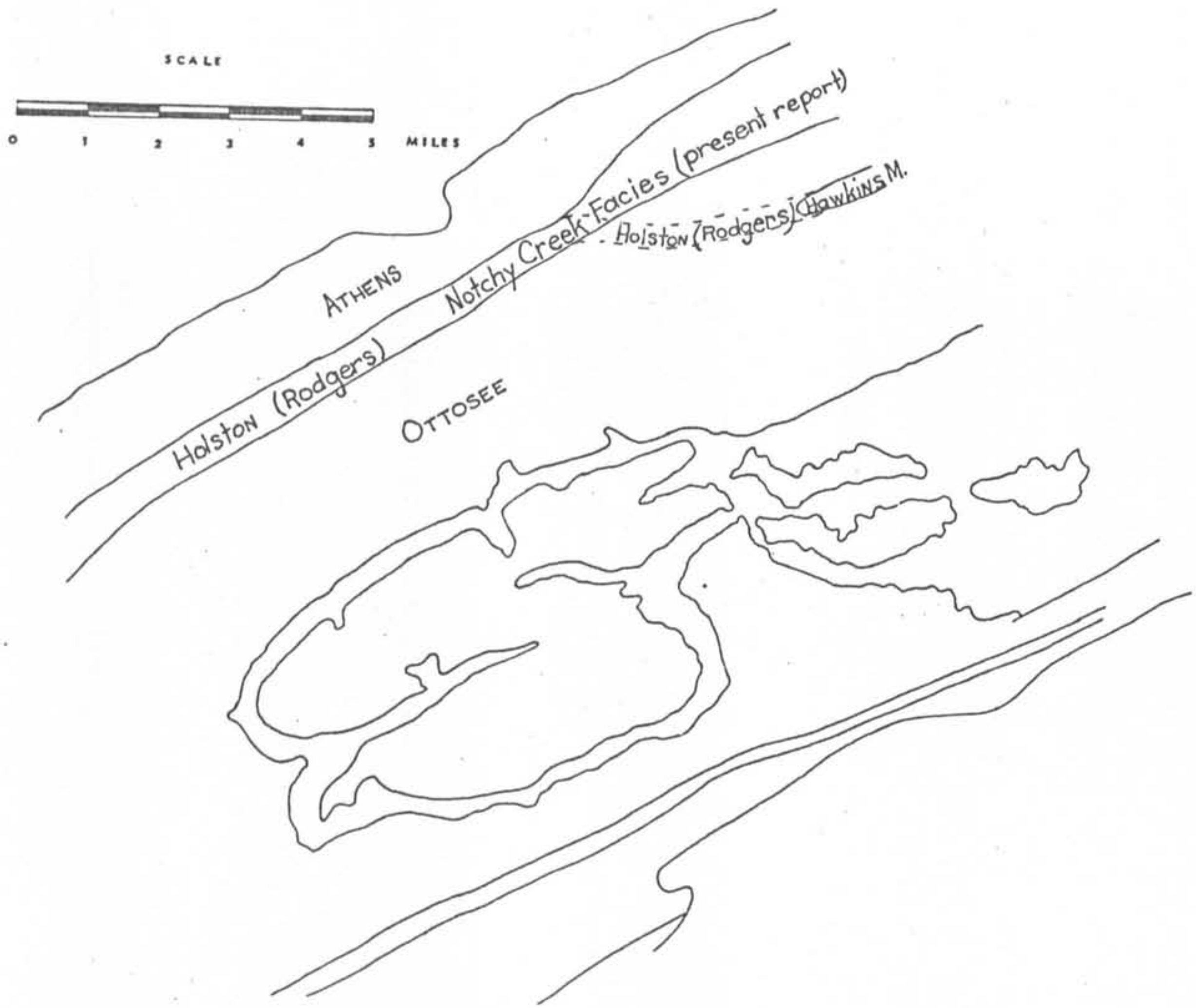
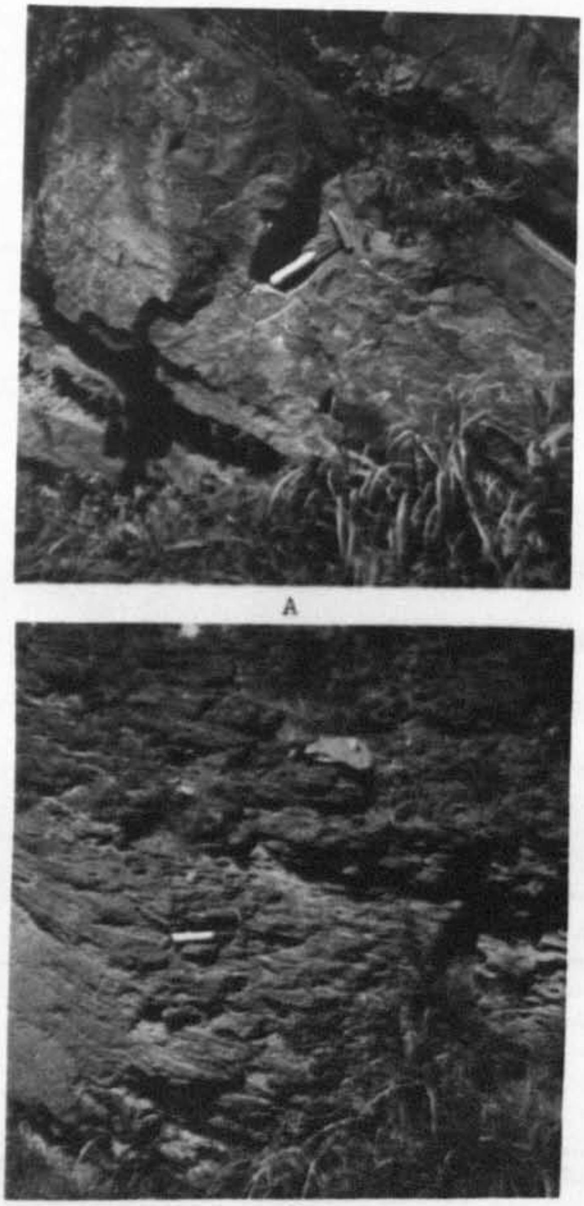


Figure 7. A comparison of geologic maps of the study area by Rodgers and the present investigator.

Figure 8. Exposures of the Notchy Creek facies of the Tellico Formation.

A. Exposure of the Notchy Creek facies of the Tellico Formation. The location is about 2 1/2 miles north of Mount Vernon, along State Highway 68.

B. Weathered Notchy Creek facies. The location is about 2 1/2 miles north of Mount Vernon, along State Highway 68.



A

B

Figure 8

units due to severe weathering (Figure 8). The weathered units have irregular fractures but bedding planes can usually be recognized; they are colored moderate orange pink (5YR 8/4).

Local shale beds in the Notchy Creek facies are predominantly quartzose shale with carbonate cement. The rock is light olive brown (5Y 5/6) where fresh and weathers to dusky yellow (5Y 6/4) chips. The beds in these units are parallel and even.

The amount of shale increases toward the northeast and the Notchy Creek facies finally interfingers with the main body of the Tellico Formation of Neuman (1955) in the vicinity of the Tellico River in the Vonore quadrangle.

The type section and two other well exposed sections (see Appendix) of the Notchy Creek facies of the Tellico Formation were measured and described along the northwestern limb of the syncline. The lateral variation of the unit is clearly demonstrated by these sections (Figure 9).

Stratigraphic relations. Rodgers (1953) mapped and referred to this unit as the Holston Formation in this area (he apparently mapped Tellico lithology as Holston, but did not use Tellico in his maps), but what the present writer has described as Notchy Creek facies of the Tellico Formation here is lithologically unlike the type Holston in the Knoxville belt. Therefore, the older name Tellico is retained for this unit.

As was mentioned previously, the lithology of the Notchy Creek facies of the Tellico Formation changes laterally from predominantly arkosic sandstone in the southwest sections to predominantly shale and

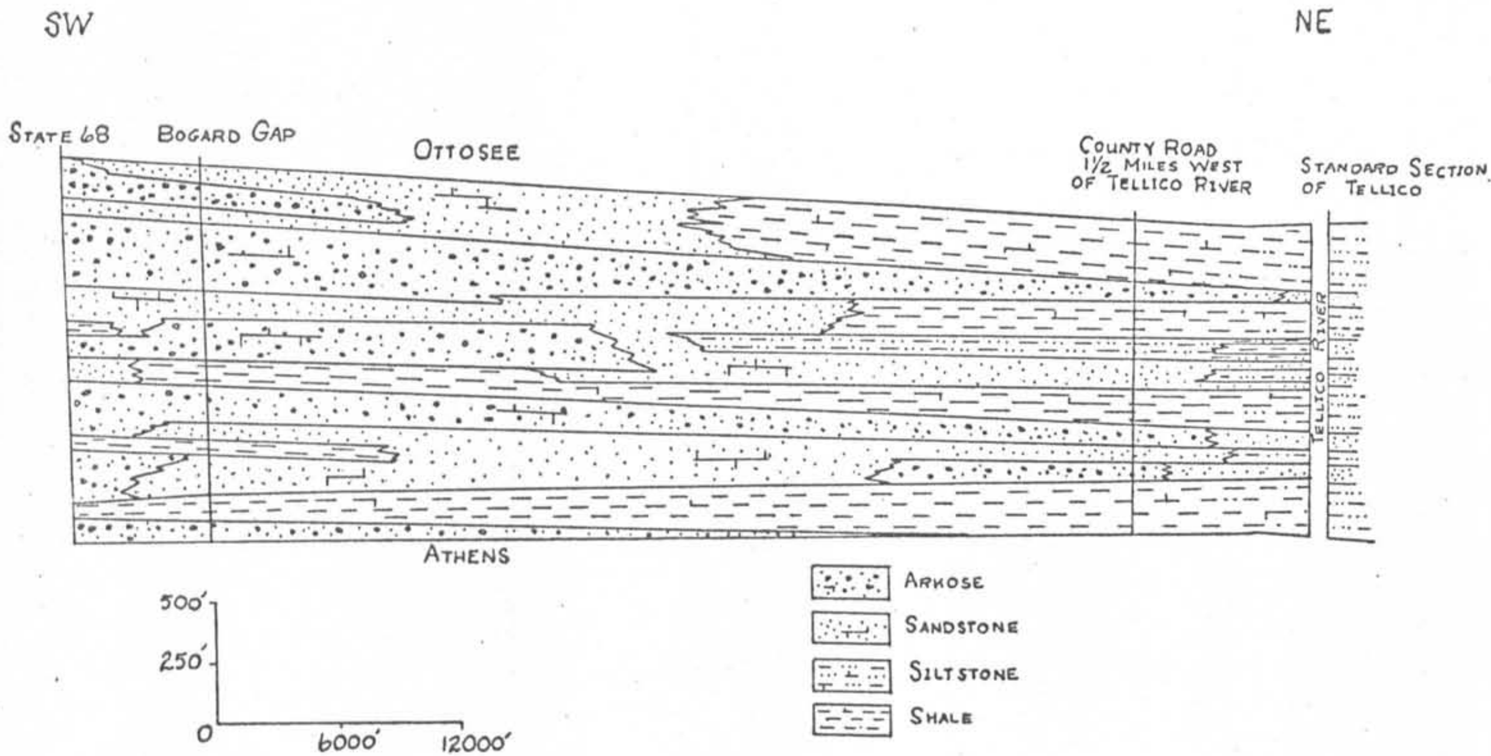


Figure 9. Diagrammatic facies relationships of the Notchy Creek facies of the Tellico on the southwest and the type Tellico Formation on the northeast in the study area.

interbedded sandstone in the northeast sections along this belt. This apparent lateral variation in composition along the strike illustrates the concept of facies very well in this unit. The contact of the Notchy Creek facies with the overlying sequence is for the most part gradational.

Given the lithologic and stratigraphic data described in the foregoing sections for the Notchy Creek facies of the Tellico Formation, the validity of the term "Holston" may be discussed. In accordance with the common usage of the term, the Holston may be defined as a coarsely crystalline marble overlying the Lenoir Limestone. A study of the literature indicates that the term Holston has been used for at least four different medium to coarsely crystalline horizons at various geologic times throughout East Tennessee (Prouty, 1946, p. 1128). A few workers have tried to avoid this confusion and coined new terms for this unit (Holston), such as the Farragut Limestone by Prouty (1946). Figures 10, 11, and 12 show different stratigraphic positions of Holston as used by different workers. The detailed work of Cattermole (1958), around Knoxville, shows the stratigraphic position of the Chapman Ridge Sandstone to be above the Holston Formation and below the Ottosee Shale. A detailed discussion of this problem is given in the next chapter.

Ottosee Formation

The Ottosee Formation was named by Ulrich in 1911 for outcrops at Lake Ottosee in Chilhowee Park in Knoxville. This formation consists of a variety of lithologies within the area of study. Rarely can any of these individual lithologic units be traced for any distance because

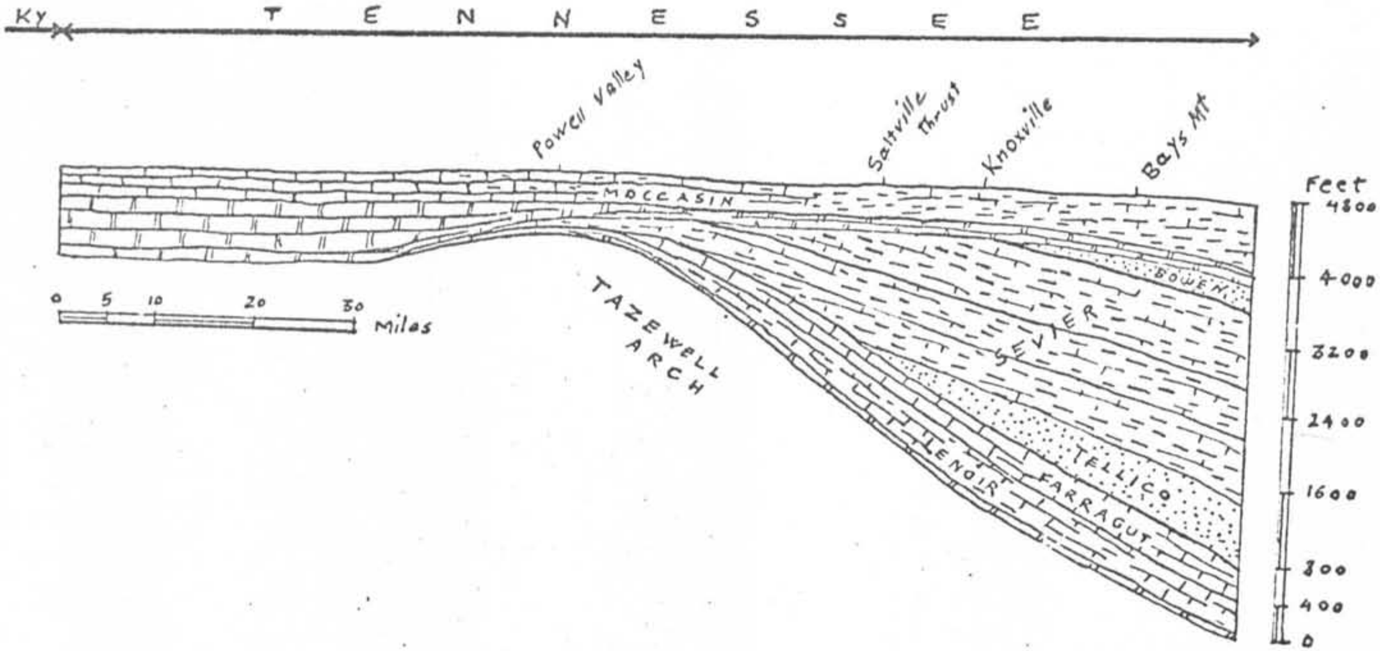


Figure 10. Facies relationship in Middle Ordovician rocks as interpreted by Prouty (1946).

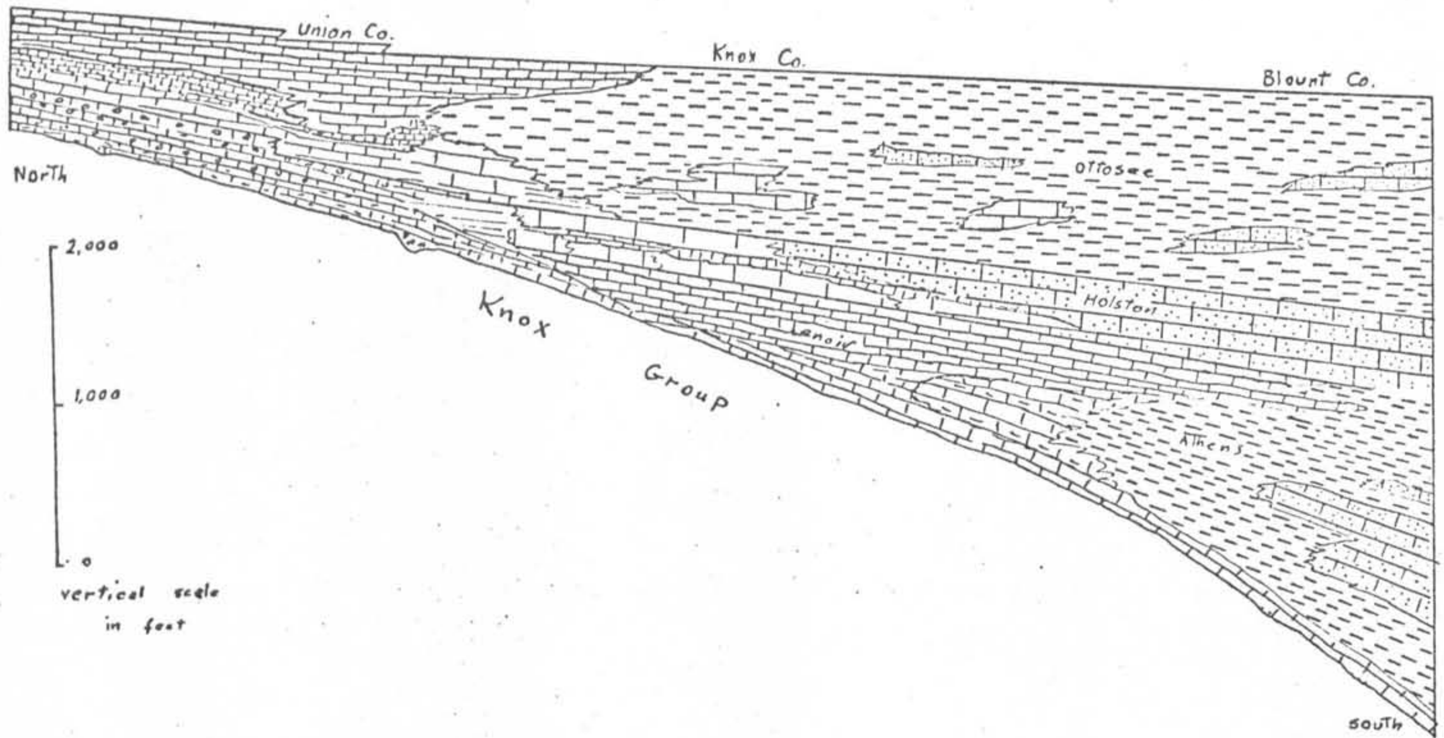


Figure 11. Facies relationships in Middle Ordovician rocks as interpreted by Rodgers (1953).

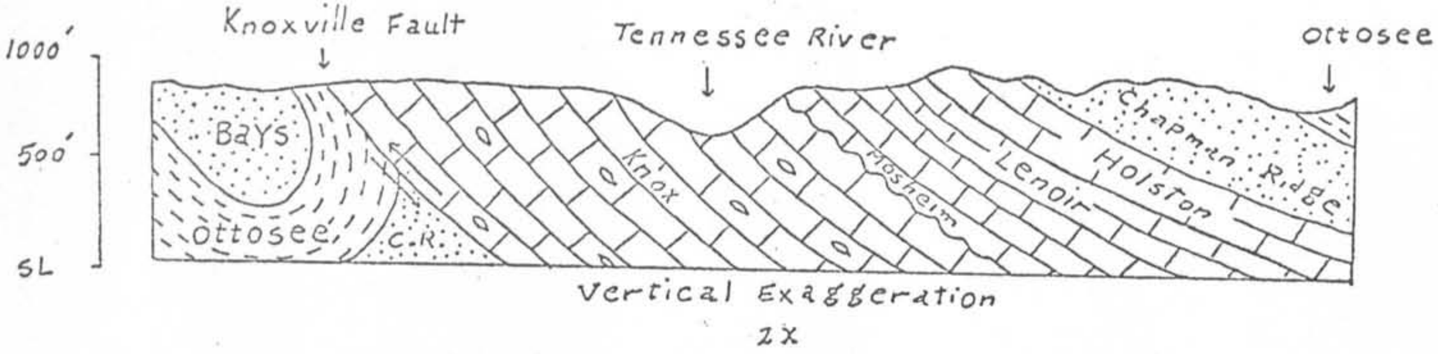


Figure 12. Structure section of Middle Ordovician rocks, Knoxville, as interpreted by Cattermole (1958).

they are patchy and irregular in distribution. However, an attempt was made to describe each of these rock units independently.

Again, because of the lack of continuous outcrops and the tight structures, it is practically impossible to measure the thickness of the Ottosee Formation. This worker estimates that about 2500 to 3500 feet of Ottosee rocks are present in this area. The contact between the Ottosee and the overlying unit (Bays) is sharp throughout the present study area.

Lithology

Calcareous shale makes up the main body of the Ottosee Formation. It is medium yellow brown (10YR 5/4) to pale brown (5YR 5/2) where fresh and weathers to a pale yellowish-orange (10YR 8/6) to a dark yellowish-orange (10YR 6/6). It commonly contains even laminae; these laminations disappear upon weathering and the result is a powdery-looking mass which is very soft and friable. Irregular fractures are characteristic of the unweathered shale. Although most of the formation is shale, the unit also contains calcareous siltstone and limestone. The siltstone is usually pale yellowish-orange (10YR 8/6) to pale yellowish-brown (10YR 6/2) nodular in appearance and easily weathered. Locally, thin-bedded sandstone units are present. These are light brown (5YR 5/6), medium-grained, and contain symmetrical ripple marks. In a few locations these sandstones grade laterally into limestone (Figure 13). The description and classification of these carbonate rocks is after Folk (1959).

Three types of limestone occur in the Ottosee Formation. The main type of limestone is Folk's "Type I," in which the allochem fraction is made of fossil fragments (bryozoans and crinoids) and the

Figure 13. Exposure of Ottosee limestone, and fossils identified within this formation.

A. Typical limestone outcrops of the Ottosee Formation, along State Highway 68, 1/2 mile south of Mount Vernon.

B. Longitudinal section of Trepostomina X25.

C. Longitudinal section of Trepostomina X25.

D. Longitudinal section of Bashkirella 10X.

E. Longitudinal section of Stigmatella X12.

F. Transverse section of Halloporina X15.

G. Transverse section of Prasopora X20.

H. Longitudinal section of Batostoma X15.

I. Transverse section of Dekayella X25.

J. Longitudinal and transverse sections of Phylloporina X45.

K. Longitudinal section of Rhinidictya X20.

L. Unidentified bryozoan and broken trilobite skeleton X65.

M. Unidentified bryozoan X32.

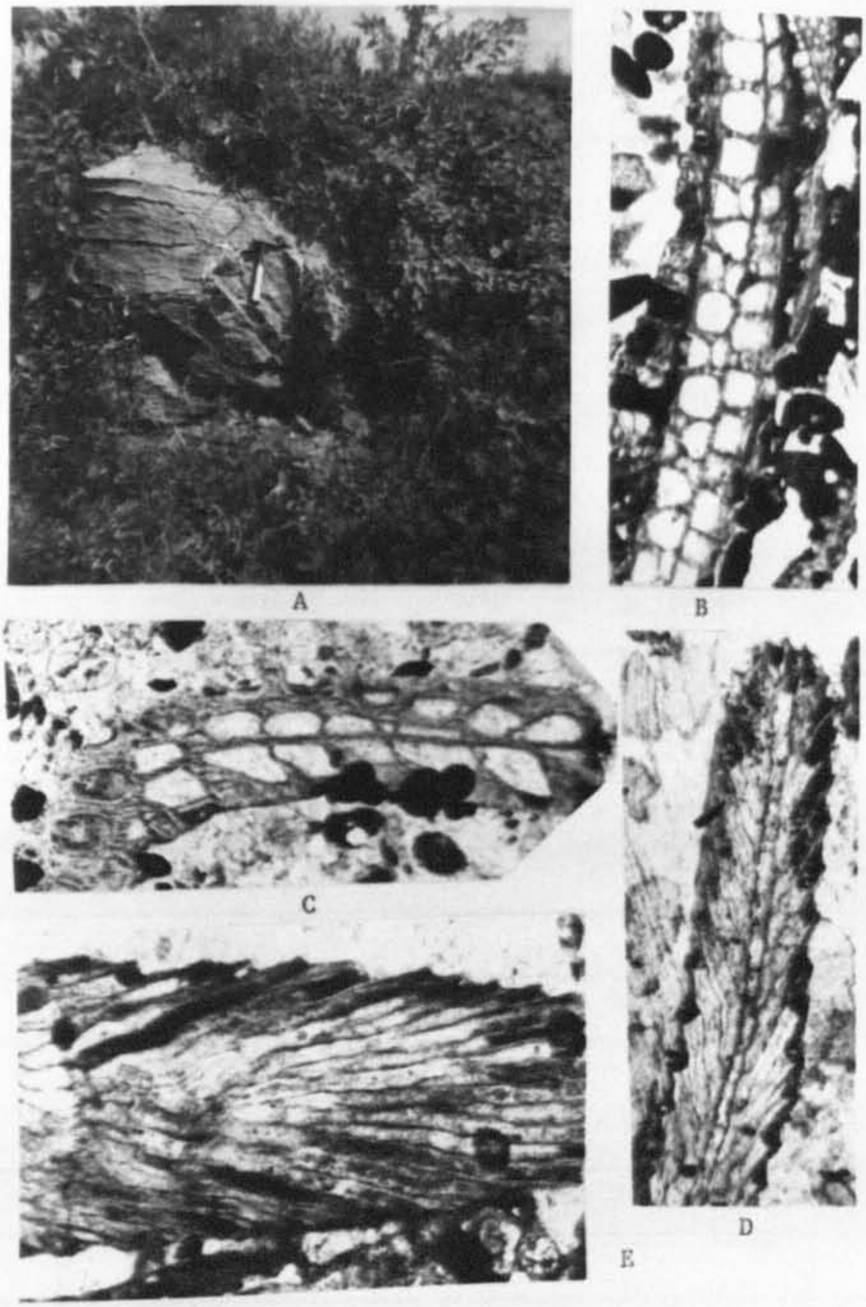


Figure 13

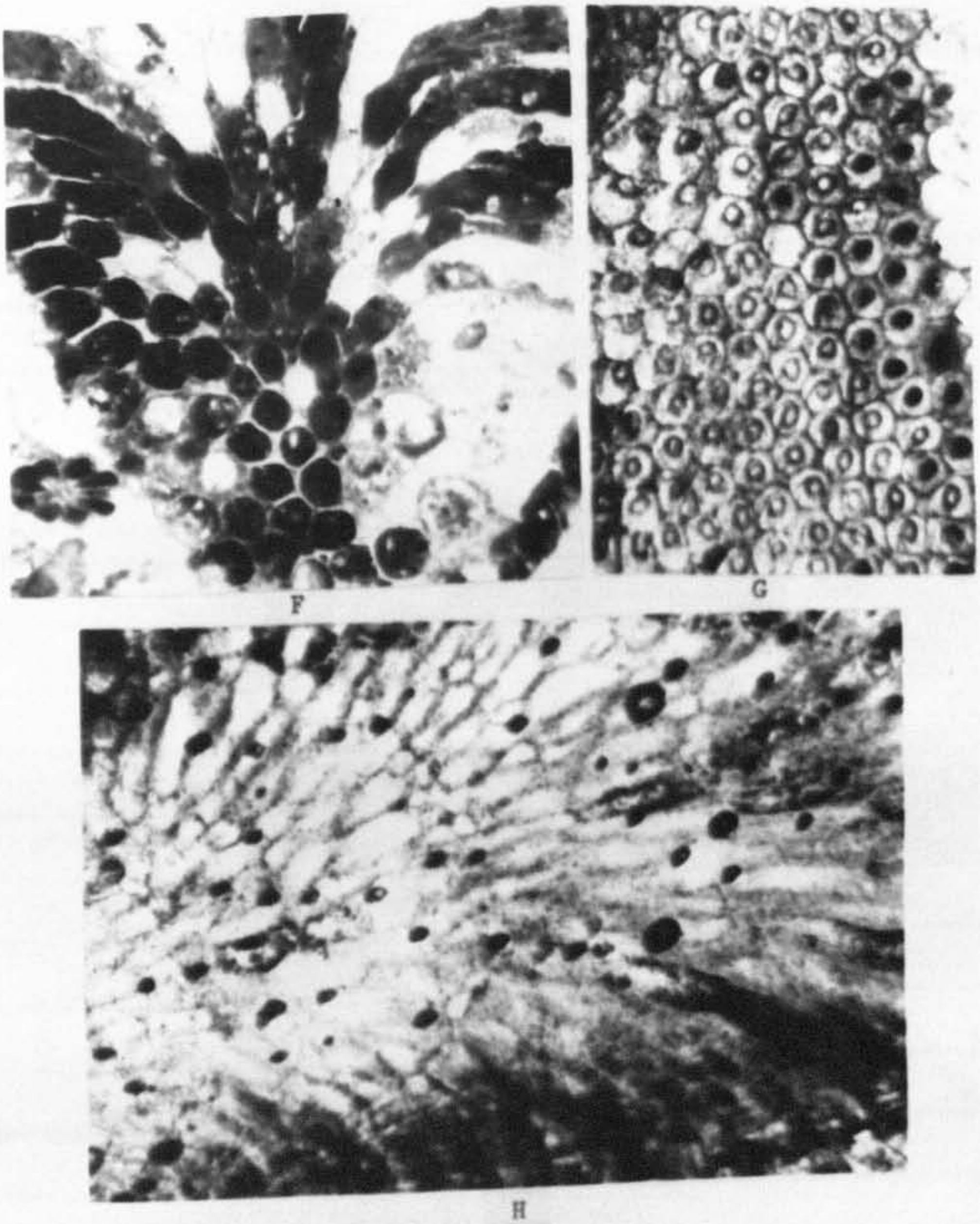


Figure 13 (continued)

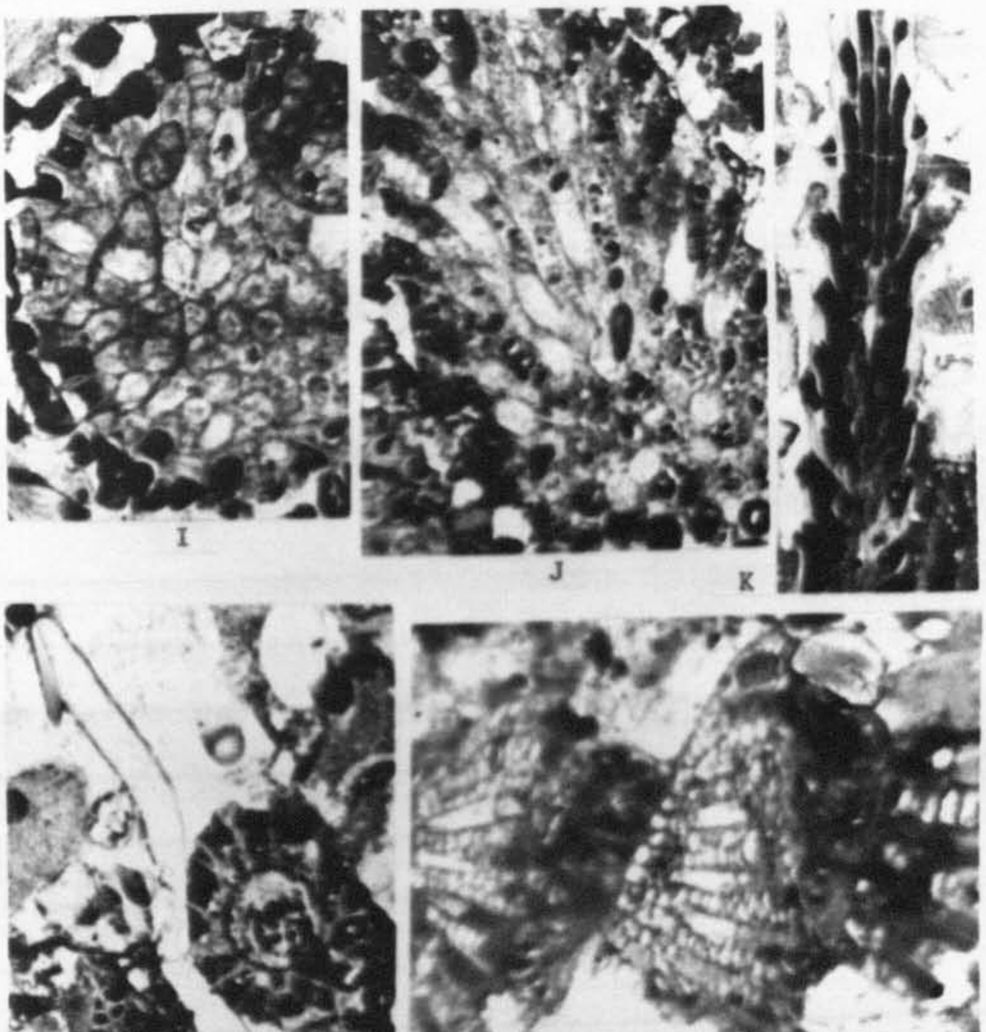


Figure 13 (continued)

matrix is spary calcite. This is very dense limestone with a few rounded quartz grains. In places, the rock is cherty and cross bedded with abundant stylolites. Another type of limestone is one in which oolites are predominant with equal amounts of spary calcite and micrite and the matrix is usually pale red (5R 6/2) to grayish-red (5R 4/2). Oolites have only a few concentric laminae and thus are of the superficial type. The third type of limestone present here is one in which micrite is predominant; Folk's "Type II." It is mainly calcareous mud and contains a low percentage of allochems. This rock, in some places, grades laterally to coarse-grained spary calcite with a low percentage of mud. Finally, there are a few outcrops of coarse-grained, moderate orange pink (5YR 8/4) marble scattered throughout the Ottosee Formation.

Fossils

Fossils were collected from eight localities within limestone units in the Ottosee Formation. Sixteen thin sections were made. Bryozoans were the most common fossil; graptolites, ostracods, algae, crinoidal debris and a few brachiopod fragments were also present.

The following fossils were identified (Figure 13):

Bryozoans:

Batostoma (cf. *B. magnopora*)

Rhinidictya

Dekayella

Prasopora

Trepostomina

Phylloporina

Halloporina

Bashkirella

Stigmatella

Stratigraphic Relations

Hawkins Member. The name Hawkins Member is here given to a unit of arkosic, calcareous sandstone approximately 700 feet thick, located in the lower part of the Ottosee Formation near the northeast edge of the area studied (Plate I, pocket).

The name is taken from Hawkins Bridge, Tellico River, Vonore quadrangle, Monroe County, Tennessee; 2,535,000 feet E 419, 750 feet N of Tennessee coordinate line (Plate I, pocket).

Lithology. The lithology of the Hawkins Member is similar to that described for the Notchy Creek facies of the Tellico Formation. It is rather massive, dark reddish-brown (10R 3/4), composed of moderately sorted, poorly rounded clastic grains of feldspar and quartz and is locally cross bedded.

Stratigraphic relations. The sandstone lentil of Keith (1895) is called the Hawkins Member of the Ottosee in the present paper. This unit is thickest at the northeastern edge of the area studied and traced to the southwest it tends to decrease in thickness and appears to rise in stratigraphic position.

In the writer's opinion, both Rodgers (1953) and Neuman (1955) mapped and referred to a sandstone member of the Ottosee Formation of this writer as the Holston and the Chota, respectively, in the Vonore quadrangle near Tellico River. The writer agrees that the lithology of this sandstone member of the Ottosee is similar to that of the Holston Formation of Rodgers in the Mount Vernon quadrangle and the Notchy Creek facies of the Tellico Formation of this report. However, there are other horizons in the Ottosee Formation where the same type of lithology can be observed. Geologic Section 5 (in appendix) represents the type section of this member.

Bays Formation

Three distinct lithologic units were recognized in the Bays Formation. The main unit, 630-650 feet thick, is calcareous mudstone and siltstone, here referred to as the Middle Member. The outcrops of Bays Formation in the area studied are numerous and in many places almost continuous along small creeks and county roads. The distinct lithology of the Bays Formation makes it easily recognized in the field. The total thickness of this formation is approximately 1140 feet in the area under study. One well exposed section of the Bays Formation was measured and described (Geologic Section 6, in appendix).

Lithology

Lower Member. This unit is composed chiefly of calcareous siltstone interbedded with a few medium-grained sandstone layers and is grayish-red (5R 4/2) where fresh and pale red (5R 6/2) where weathered. Fine muscovite flakes stained by hematite are common. Sandstone beds average one foot in thickness and are usually fractured. Upon weathering, the siltstone portion becomes very friable and the sandstone portion breaks down to rectangular blocks which produces reddish soil. The thickness of the member varies from 110 to 140 feet. The unit is best exposed along Ballplay Road, Mount Vernon quadrangle.

Middle Member. The main member in the Bays Formation is a calcareous mudstone and a few thin bedded siltstone units with a thickness from 630 to 650 feet.

It is moderate brown (5YR 3/4) where fresh and light brown (5YR 5/6) where weathered. Locally, some moderate yellowish-brown (10YR 5/4) traces of clay aggregates can be found. The amount of carbonate decreases upward and the number of sand beds and size of sand grains increase toward the top of this unit. The composition of individual beds varies sharply vertically from mudstone to siltstone in a matter of inches. The siltstone part weathers to blocks which have a shiny appearance due to the presence of small muscovite flakes. The mudstone weathers to very small pieces with conchoidal shapes. In most parts, the mudstone and siltstone show closely spaced cleavage and joints. The mud cracks and worm tubes are characteristic of this unit. Figure 14 shows the contact between this member and the Upper Member of the Bays Formation. There are many good exposures of this member in the center of the syncline.

Upper Member. The upper part of the formation is a 370-390 foot thick sandstone member. It is grayish-orange pink (5YR 7/2) to grayish-orange (10YR 7/4) and weathers to nearly white (N9). The rock is commonly coarse-grained, well sorted, and even textured, becoming exclusively well rounded quartz grains toward the top of this member. The beds are up to three feet in thickness and are locally separated by thin beds of siltstone. These rocks exhibit irregular fracture cleavage and joints. Locally, some small fractures and cavities are filled with large size quartz crystals. The Upper Member of the Bays

Figure 14. Middle and Upper Members contact (at hammer) of the Bays Formation.

The location is 1/3 mile southwest of Cedar Knob, Mount Vernon quadrangle.

Figure 14

Formation is best exposed along the county road, southwest of Cedar Knobs, Mount Vernon quadrangle.

Stratigraphic Relations

The Bays Formation was first referred to as the Bays Sandstone by Campbell in 1894. The type locality of the formation is Bays Mountain in Hawkins and Greene Counties, Tennessee (Keith, 1895).

The present writer is in full agreement with Rodgers (1953) and Neuman (1955) regarding the stratigraphic position of the Bays Formation. As is mentioned previously, three distinct members (here called Lower, Middle, and Upper members) were recognized. In Blount County, the Bays Formation is overlain by the Chattanooga Shale of Devonian-Mississippian age. This contact is the most significant disconformity in the Paleozoic rocks of the southern Appalachians. Mapping by Biery (1968) in the southeast portion of the Vonore quadrangle shows that the unconformity is developed on each of the three members mentioned above.

CHAPTER III

SEDIMENTARY FEATURES AND ENVIRONMENT OF DEPOSITION

General Statement

During the field work of this study, an attempt was made to observe, describe and identify any primary or secondary sedimentary features which exist in rocks of the area studied. Hopefully, these observations will help in environmental interpretations. The primary features, especially those of most use in environmental interpretation, are discussed in the following pages; minor sedimentary features, if any, have been discussed in the description of rock units in the previous chapter.

Worm tubes and mudcracks are characteristic of the Middle Member of the Bays Formation and cross bedding is present, especially in the Notchy Creek facies of the Tellico Formation, in the Middle Member of the Athens and in some limestones within the Ottosee Formation.

Worm Tubes

Structures similar to those formed by modern burrowing organisms are observed throughout the Middle Member of the Bays Formation.

Many infaunal animals burrow or bore tubular holes into the substratum. These burrows must remain open in order for the organisms to survive. Thus, the depth of water and the rate of sedimentation are two important factors regarding boring activities. Therefore, a particular environment is required in order to develop and preserve this type of sedimentary feature throughout geologic time. Many modern clams, inarticulate brachiopods, and especially polychaeta worms live in burrows. Many ostracods are also capable of burrowing horizontally beneath the surface of bottom sediments. Therefore, they seem to be able to escape occasional subareal exposure of the sea floor on which they live by withdrawing into the sediment (Walker, 1970), and the ancient animals may have had the same adaptation.

Usually associated with cleavage in finer-grained strata in the Middle Member of the Bays Formation are numerous concentrations of trace fossils resembling worm tubes. These are cavities averaging about 8 centimeters in length and 1/5 to 1/2 centimeter in diameter. Some of these are branched downward. They are filled with leached material similar to that in the overlying bed, sometimes with quartz and calcite. Their ends are usually at the upper bedding surface and the structures extend vertically or obliquely downward to a maximum of 14 centimeters into the bed. Horizontal or near horizontal tubes are absent in these rocks. The tubes have never been seen to start at the base of a bed and extend upward into it. Also, a few vertical displaced tubes were observed, an indication of later structural deformation.

The environment in which these vertical burrows were formed was probably high intratidal to supratidal. Details of these processes have been discussed by Walker (1970).

Mud Cracks

Another feature common in supratidal to high intratidal environments is mudcracks, a dominant characteristic in the Middle Member of the Bays Formation. Dessication and shrinkage of water-filled calcareous mud of the Middle Member produced a system of shrinkage cracks. Thus, in their typically developed form, a network is formed which divides the surface into irregular polygonal segments.

The average size of these mudcracks is about 2 centimeters across. They are rarely larger than 8 centimeters in size. Although they show considerable range in depth, laboratory experiments by Anderson (1965) and Walker (1970), show that the larger polygons form in the thicker layer than in the thin layers. Incomplete mudcracks were also observed, and indicate that shrinkage was not carried to completion or, they formed entirely below water (Walker, 1970). These cracks seem to be filled with the same material as the overlying beds, an indication of continuous sedimentation through the period of filling and burial of the mudcracks.

Usually smaller polygons are associated with thinner and finer-grained layers and large size polygons are found in thicker and coarser-grained layers. These associations also have been reported by Anderson (1965) in other localities. Apparently these mudcracks illustrate a supratidal to intertidal environment.

Cross Bedding

Current or cross bedding was observed in certain parts of the Notchy Creek facies of the Tellico Formation, on a smaller scale within the Middle Member of the Athens Formation, and in some limestone units of the Ottosee Formation.

Twenhofel (1932, p. 619) states that ". . . cross-lamination is important in structural geology, as the truncation at the top of the foresets gives a nearly unfailing means for the determination of the tops of beds." One outstanding feature of cross bedding that makes it so useful and reliable a criterion for top and bottom determination is the angular relation of beds to the underlying and overlying strata or boundary surfaces (Shrock, 1948).

The study of cross bedding within the Notchy Creek facies of the Tellico Formation yields the best evidence that beds in the southeast limb of the syncline (Plate I, pocket) are overturned. The most common type of cross bedding found in these rocks is that in which the laminae are sharply transected at the top of the bed and tangent at the base. This cross bedding is usually incomplete and rarely topset and bottomset are present together in one tabular or wedgeshaped body. Even when the angular relation appears to be similar above and below, a thin zone of heavier or larger grains may indicate the lower part of the unit.

Environment of Deposition

Each formation of the Middle Ordovician sequence possesses certain characteristics that permit an approximation of the environment of deposition.

The unconformity at the base of these units records a period of subaerial erosion that produced a surface of considerable relief. According to Rodgers (1953), the lithology above the disconformity is everywhere mainly limestone which indicates clear seas. Of course, in the area of study, the Athens Formation which overlies the irregular surface is chiefly shale with some carbonate content, suggesting that seas carried largely terrigenous sediments in this area. These clastics are mainly clay with minor silt and sand which are incorporated into the basal layers of sediment.

It seems reasonable to postulate that the terrigeneous muds that form the Athens Shale, and the carbonates of the Lenoir Formation are simultaneous deposits in the same transgressing sea. If, as is believed by the writer, the Lenoir Limestone and the Athens Shale are in part of the same age, the two formations would be expected to show differences because of the distance from terrigenous source areas. Lenoir represents carbonate bank deposits while Athens may represent a slightly deeper basin between carbonate bank and terrigenous source. The even laminae in the upper and lower units of the Athens Formation suggests that it was not disturbed by wave turbulence; also, the dark shales likely represent a reducing environment that might be expected in the deeper, slightly restricted sea floor. The occurrence of small scale cross bedding in the Middle Member of the Athens suggests that probably it was deposited in a shallower, higher energy environment.

The slight increase in the thickness and grain size of this unit toward the southeast limb of the Bays Mountain syncline indicates that the source was from the southeast. Almost immediately after the invasion of the sea the area started to rise quickly and distributed a large amount of terrigenous sediment to the subsiding basin. Perhaps the maximum relief between the source area and the sedimentary basin was reached at the time the Notchy Creek facies sediments were being deposited. A detailed discussion of these processes are given in the following pages.

The overlying Ottosee Formation with various compositions shows a departure from this condition. The interbedded shale and siltstone with different types of limestone, together with the lack of coarse-grained terrigenous material suggest that the source area underwent severe weathering or that the source had become more distant from the study area.

Perhaps the basin configuration relative to the source area was similar to that of Athens time except that the depth of the water in which the rocks of the Ottosee Formation were deposited was more likely less than during Athens deposition, as evidenced by a number of crinoid and bryozoan colonies and remains of other animals found throughout the formation. It is possible these colonies formed mounds or reef-like buildups which may have affected the distribution and pattern of currents and, therefore, sedimentation.

The writer believes that the rate of subsidence decreased during Ottosee sedimentation and the source area reached its lowest relief.

Following this episode, red or maroon clay (Bays Formation) began to replace the Ottosee Formation on the sea floor. There is no doubt that the climate in the source area had changed considerably. Most workers believe that the source for this red clay was also from the southeast, and suggest that the sea became shallower or even a tidal flat, so that the bottom was later oxidized (Rodgers, 1953). The source area probably was a terrain covered with red soils produced by chemical weathering under humid conditions, which allowed iron-bearing minerals to be completely oxidized (Krynine, 1950). The mud-cracks and vertical burrows found in this red clay suggest a supratidal to high intertidal environment for the depositional site of these rocks.

Finally, white coarse to very coarse sand, perhaps representing beach deposits, invaded the sea and covered the red mud flats.

Environmental Sedimentology

Sedimentalogical analyses of various processes are an integral part of environmental and stratigraphic studies. Thus, a detailed discussion concerning the nature of the source area and configuration of the depositional basin of the clastic facies is appropriate at this time.

The prominent and relatively resistant arkosic unit of the Notchy Creek facies yields reliable data concerning the provenance, process of sedimentation and the environment of deposition.

Bedding Features of the Notchy Creek Facies

Field investigations reveal that most of the bedding features observed in this unit are of a directional nature; in other words, they exhibit energy directions. Cross bedding is one of the most important sedimentary features to be found in the Notchy Creek facies of the Tellico Formation. Although, in the field, this feature can not be observed and measured in three dimensions it yields information about the direction of currents and the nature of the source area. The mode of formation of these beds is obviously by water currents that build the deposit forward by successive addition of sediments on the down-current side. The general direction of the cross bedding indicates that the source area for these sediments was to the south-southeast. Insignificant directional variation occurs in several places, but these changes can be attributed to local conditions.

Source Rocks and Petrology of the Notchy Creek

Grant (1956) reported the occurrence of coarse-grained sandstone layers in the Sevier Formation to the northeast in the Bays Mountain synclinorium area. These coarse-grained sandstones are an indication of an orogeny which affected the area of the southern part of the Appalachian geosyncline during Middle Ordovician time (Grant, 1956). The disturbance was named "Blountain" by Kay (1942) and Blountain phase of the Taconian orogeny by Rodgers (1953). According to Grant these coarse-grained sandstone layers contain grains of Early Cambrian and probably Precambrian rocks, and he concluded that the Sevier Formation was derived from a source area in the south-southeast. The study of the mineralogy of the Notchy Creek facies also leads to certain inferences regarding the nature and lithologic character of the source area. Through a quantitative study of the mineral particles of the Notchy Creek facies, it is clear that relatively unstable feldspar particles dominate the Notchy Creek facies; these particles also retained their angularity and crystal facies, an indication of rapid weathering and deposition. The possibility that these feldspar particles were reworked and still kept their original shapes is very poor. If erosion was taking place in the areas from which the Notchy Creek sediments were derived, it would be conceivable to reach a point where the crystalline complex would be exposed and eroded. Therefore, during part of Middle Ordovician time, there was an upwelling of the crystalling rocks which caused an erosion of part of the rocks from the Cambrian and Precambrian crystalline complex.

Deltaic Model

A deltaic model and its components (Figure 15) can easily be constructed in view of both time and space limitation (Van Andel, 1967).

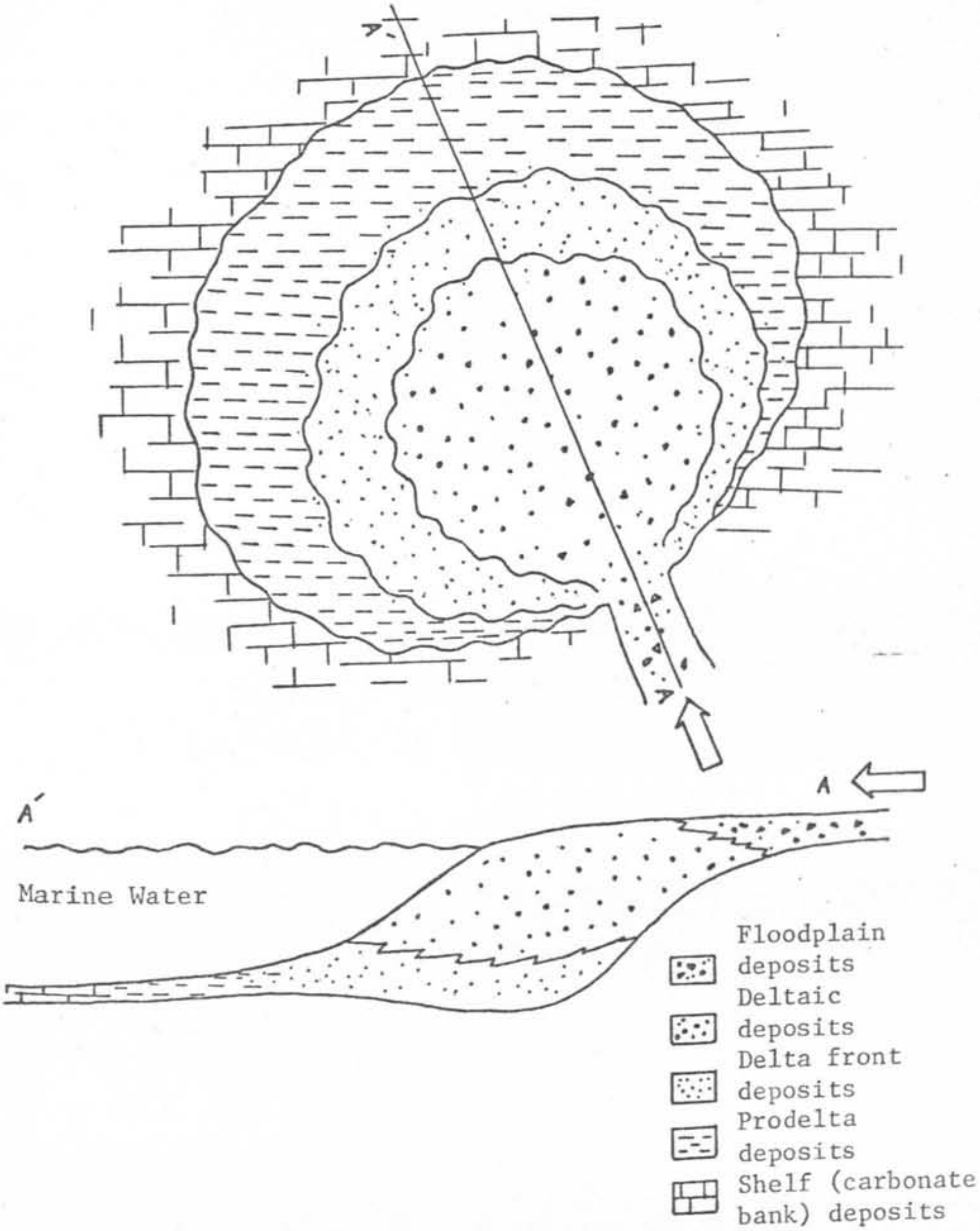


Figure 15. Model of a delta and its components.

The thick shaly units below and above the Notchy Creek facies of the Tellico Formation suggest a seaward prodelta environment; whereas, the thick arkosic unit indicates a landward deltaic and fluviomarine or fluvial environment. The principal rock type of this unit is reddish-detrital arkosic-sandstone of deltaic deposits in nature and finally changes laterally into shaly units of offshore to deep sea environment. This situation prevailed during deposition of the Notchy Creek facies and reflects episodes of rapid sediment introduction during high velocity of transporting agents. Field observation shows that the lower part of this unit has relatively large scale cross bedding which grades gradually upward to smaller ones and, in a few locations, to ripples in the upper part. Apparently the basin was filling and there was no powerful current to redistribute these tremendous amounts of freshly eroded materials. It is generally agreed that these detrital materials are of a northward progradation from a south-southeast source which grades seaward into finer grained offshore sediments.

Lateral migration of the basin of accumulation occurs when deposition has raised the delta surface sufficiently to favor shifting of the stream channel to a lower part of the delta (Van Andel, 1967). Apparently this migration was toward the northeast. Changes in the loci of deposition along radial lines has effect in the overall grain size distribution of the delta. Probably the stream channel has remained near the mountain front during the formation of the delta; hence, a general decrease in particle size toward the northern direction is observed. As the stream flowed into the sea from the southeast, the velocity and transporting power of it was being gradually checked. Accordingly, the larger sized particles would be deposited when the currents of the stream could no longer transport them. Of course, this occurs when a stream terminates in a delta, weakening the velocity sufficiently for the bulk of the sediment load to be deposited. However, since the running water was not brought to a complete standstill, the finer materials in suspension were carried across the delta in a northward direction.

Implication of the Sedimentalogical Studies: Chapman Ridge-Tellico Problem

The author prefers to discuss this subject here rather than in the stratigraphic chapter simply because he has chosen a new approach to attack this old and complicated problem. Previously, many workers tried to break through this problem stratigraphically and none have presented any satisfactory solution. The new sedimentalogical treatment which is applied in this paper suggests a simple and less complex approach to the study of this problem. The conclusion derived from these discussions may be a possible solution to the problem.

The data for this work were obtained both in the field and laboratory. Well developed cross bedding and reddish color of the rocks can be distinguished in Notchy Creek facies, Chota and Chapman Ridge units. The laboratory procedure consisted of making thin sections of the above units and then carrying out the quantitative studies under the microscope.

The Chapman Ridge (Cattermole, 1955)-Tellico (Keith, 1895) problem has been subject to debate for many years. As is revealed from the literature, there are many unanswered questions regarding this difficulty. Anyone who is familiar with stratigraphy of East Tennessee appreciates this problem and recognizes its importance. One might ask the following questions regarding Chapman Ridge-Tellico units.

What is the stratigraphic position of Chapman Ridge with respect to the Tellico Formation? Are these two units of the same age? If not, which one is younger? How does Notchy Creek facies of Tellico relate to these questions? What is the age relation of Notchy Creek with regard to Chapman Ridge? If not of the same age, which one is younger? Did these sediments derive from a common source area? Finally, how does the Chota Formation (Neuman, 1955) fit into this picture? These are some of the unanswered questions that this author tries to answer in the following pages.

The answers to these questions simply lies within the sedimentary features recorded in these rocks. We start to investigate this problem by first reviewing the known facts which we observe in these rocks. A careful examination of these rocks shows that internal and external sedimentary features which were observed and described for the Notchy Creek facies in the previous pages are of different magnitude also characteristic of Chota and Chapman Ridge formations. Petrographic similarities (Figure 16) with a decrease in grain size and thickness of beds northward, rock color and presence of cross bedding furnish enough clues to establish the same type depositional environment for these units. The deltaic concept which was discussed for the Notchy Creek unit would also be applied to the above mentioned units.

We shall continue our discussion concerning the deltaic model. As it was mentioned before, distributaries of the delta prograde when a stream establishes a shorter and steeper route to the ultimate base level. As a rule, this occurs when the stream breaks through its own levees into an adjacent bay (Allen, 1965, pp. 569 and 585). According to Allen, a typical deltaic distributary before breaking or crevassing

Figure 16. Petrographic photographs of Notchy Creek facies of Tellico, Chota, and Chapman Ridge formations.

The specimens in this figure illustrate a comparison of grain sizes. Note the cross bedding in A.

A. Notchy Creek facies of the Tellico Formation.

B. Chota Formation (Neuman), Hawkins Member of the Ottosee Formation (present report).

C. Chapman Ridge Formation.

D. Notchy Creek facies of the Tellico Formation.

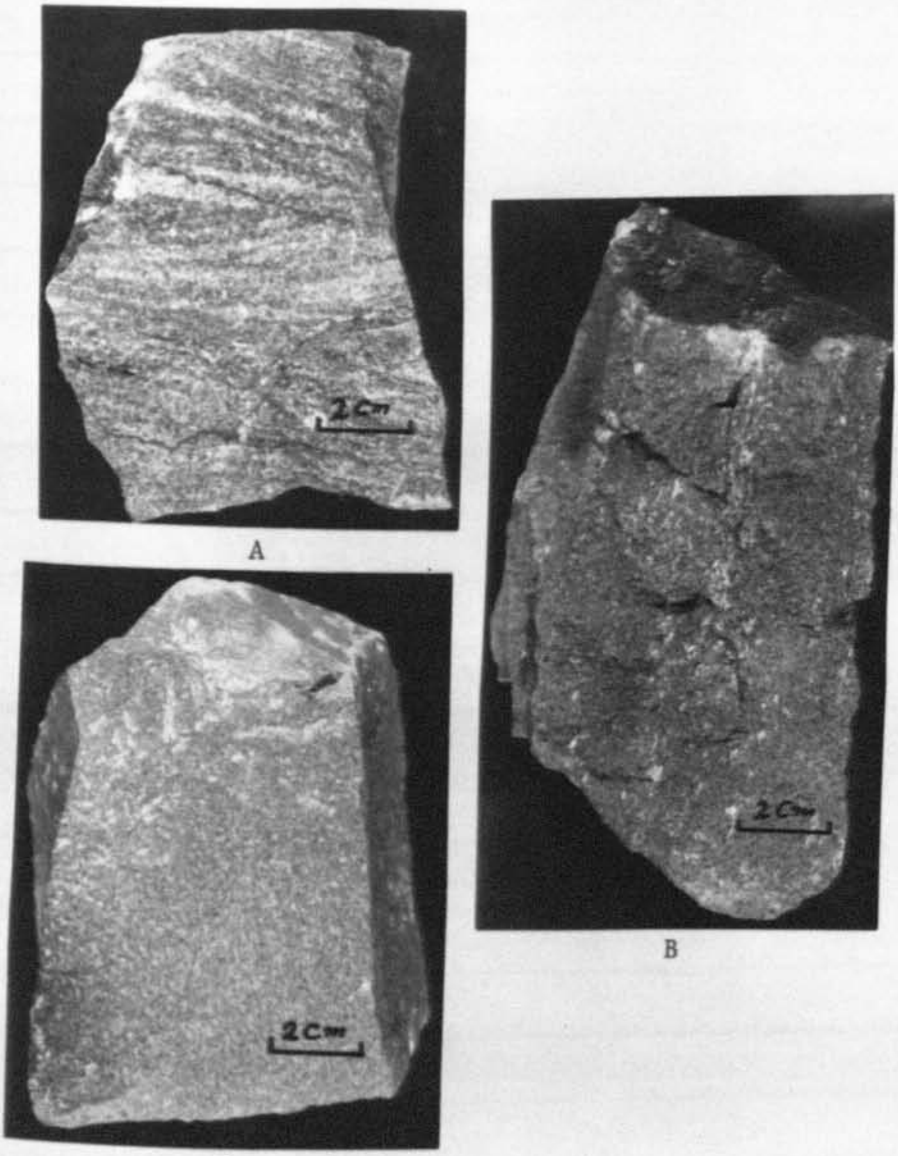
E. Chota Formation (Neuman), Hawkins Member of the Ottosee Formation (present report).

F. Chapman Ridge Formation.

G. Notchy Creek facies of the Tellico Formation.

H. Chota Formation (Neuman), Hawkins Member of the Ottosee Formation (present report).

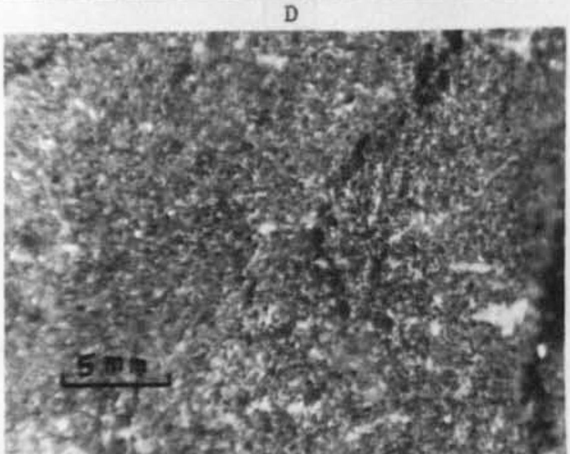
I. Chapman Ridge Formation.



A B C

Figure 16

D



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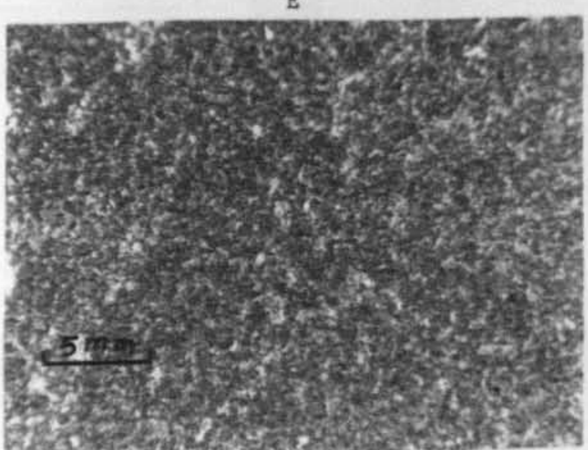

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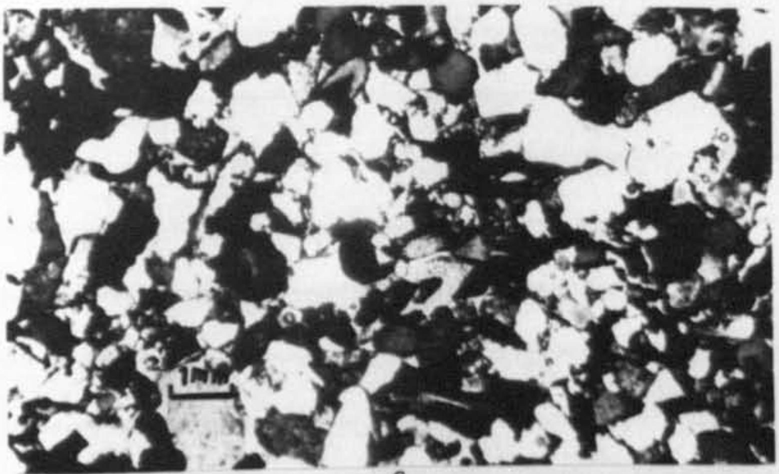
Figure 16 (continued)



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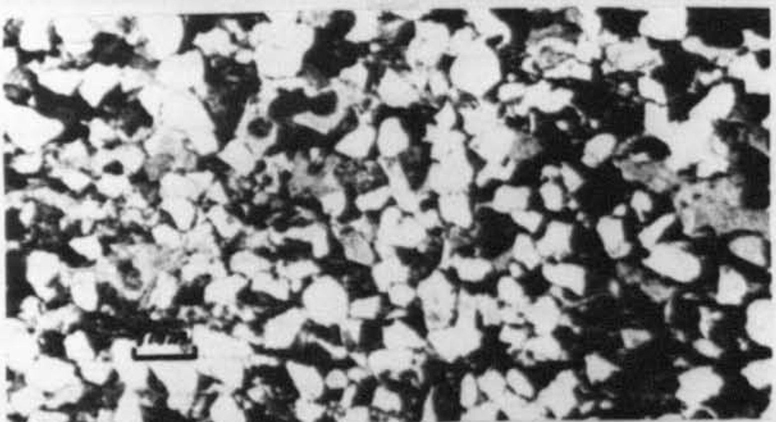

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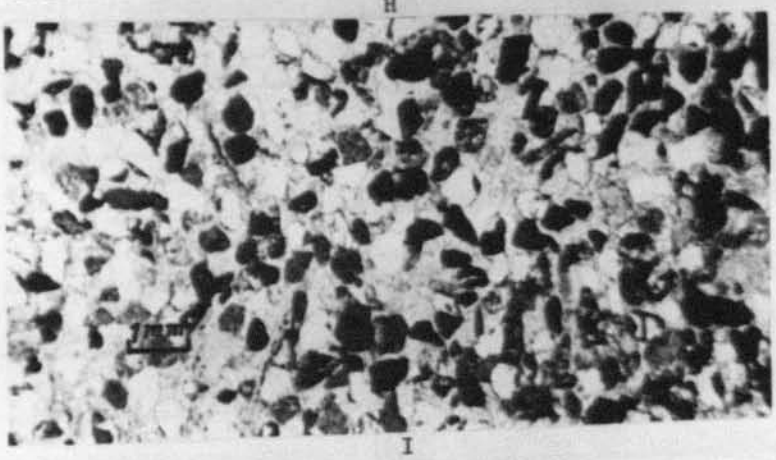

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Figure 16 (continued)

may have a longitudinal gradient of two inches per mile. When the breaks take place gradient usually would be of five feet per mile. Consequently high water velocity occurs, resulting in sediments being carried into the still waters of the adjacent bay. Several subdeltas of the modern Mississippi River serve as classic illustrations of "breaks" that have filled shallow bays near main distributaries (Fisk and McFarlan, 1955; McFarlan, 1961; Scruton, 1956, and Shepard, 1956). In the process of progradation, branching of tributaries is the typical mode of delta extension. Levees gradually built to water surface if they were submarine, and continue to develop as subarial levees by overbank flow during floods (Van Andel, 1967, p. 305). Gradually, the interdistributary basins will be the accumulation site of fine-grained sediments from the stream and within a short time a broad platform of a new deltaic land has filled in an area which previously was water. Details of this process have been discussed by Van Andel (1967) and Allen (1965). Progradation ceases when the gradients of minor distributaries approaches that of the main channel; simultaneously the rate of sediment transporting and depositing diminish rapidly. While the supply of sediments stop, the process of subsidence, because of the weight of the sediments, also diminishes (Fisk, 1954). Then probably a new cycle of delta building starts again.

Figure 17 illustrates the generalized sequence of the deltaic cycle in the area under study as interpreted by this writer. The first stage of delta formation is what was described for Notchy Creek facies in previous pages. It appears that the first deltaic cycle progradation was of such magnitude that the "deltaic" deposits did not reach the area in the extreme northeast portion of the mapped area and Blount County

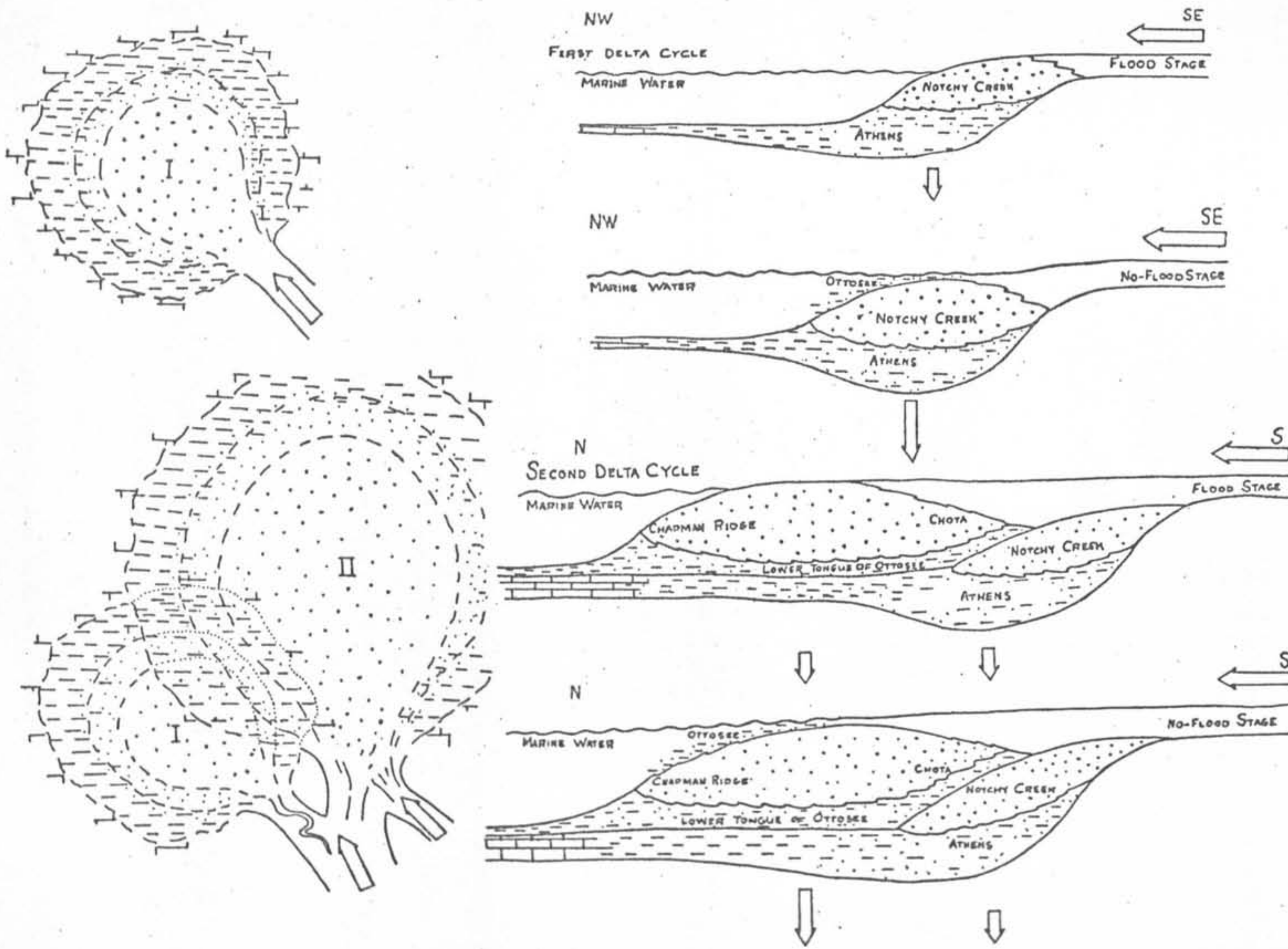


Figure 17. Chronology of the delta cycles in the area under study.

where the Tellico was deposited in a "delta front" and "prodelta" environment and in the same manner farther north-northeast where the Chapman Ridge is reported. Therefore, relatively finer grained materials were being deposited in less energetic marine water to form the Tellico Formation in the extreme northeast portion of the area under study and in Neuman's area within Blount County.

Now, we examine the environment which dominated the area around Knoxville (Chapman Ridge) at the time of the first delta cycle. It seems that this area had been a carbonate bank (shelf) since the transgressive sea covered the highly uneven post-Knox erosional surface. Away from any energetic environment, covered with warm and quiet sea almost free of terrigenous materials, to permit deposition of carbonate lime. Also, at the same time, many organisms started to inhabit this sea. The Lenoir carbonate was deposited mixed with some clay-silt impurity which probably was left behind by the advancing sea. Yet, the better carbonate bank environment was established when the last clay particle of Lenoir was deposited. This was the Holston sea, paradise for varieties of organisms to enjoy the desirable ecology. What is left today of this environment is known as the reef or bioherm structures of Holston.

This carbonate bank was disturbed when the first terrigenous particles, which originated several miles south, reached it. At this time the first deltaic cycle was near completion and its final product being fine clay suspended in water and traveled several miles to the north-northeast direction to invade the Holston sea and originate shaly layers which formed the lower tongue of the Ottosee Formation (Figure 18). But this condition was rapidly interrupted because in the south, near the

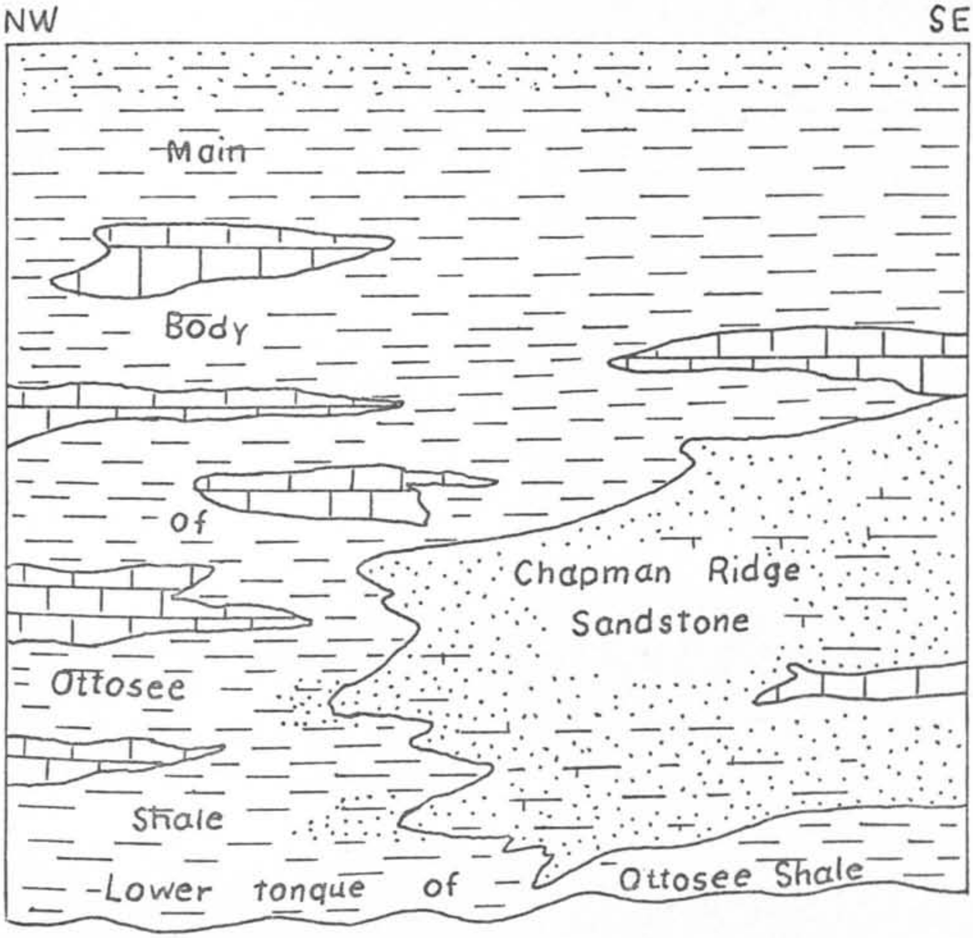


Figure 18. Generalized facies relationships between the Chapman Ridge Sandstone and the Ottosee Shale (after Cattermole, 1960).

source area, the second deltaic cycle was being born (Figure 17, p. 60). The initial delta gradually started to subside and the interdistributary basins were being filled with fine-grained sediments and these processes were accompanied by the advancement of the marine environment across the delta which may very well have resulted in the deposition of the Ottosee shale. The second cycle of delta formation started with rejuvenation of fluvial activities, then the progradational phase of this cycle transferred materials farther away from the first deltaic site. The second cycle of delta building was mechanically similar to that of the first cycle, accompanied by regression of the marine environment, but was shifting northeastward with respect to the position of the first delta (this phenomena is clearly illustrated in the modern Mississippi delta, McFarlan, 1961). As is shown in Figure 17, the second cycle delta prograted northeastward, probably in the direction of long shore currents. This cycle was apparently more extensive than the first cycle and far spreading; the coarse-grained terrigenous materials reached several miles north-northeast to form another massive rock body which is known as Chapman Ridge. The southwestern extension of this cycle in Blount County consisted of deltaic type materials which deposited the Chota Formation (Hawkins Member of Ottosee) and the extreme southwestern corner of this delta system was filled with prodelta materials and some carbonate reefs to form the Ottosee Formation. This cycle of deltaic activity also diminished and again the final product in the Knoxville area was prodelta materials which overlie Chapman Ridge (Figure 18).

The following conclusions were derived with regard to the above discussions. Notchy Creek facies of Tellico and Tellico Formation are of the same age and are the product of the first deltaic cycle. Chota (Hawkins Member of the Ottosee) is the same age as the Chapman Ridge Formation and they are produced by second delta cycle (Figure 19). The source area was a crystalline complex for all of them and was located to the south-southeast.

Topographic Expression and Soil

The topography and drainage patterns in this area are largely dependent upon the structure and stratigraphy of the region. In the Valley and Ridge Province, the alternations of ridges and lowlands illustrate this concept very well, and are known as a classic example of topography formed through differential erosion of different lithologies. The area of study stands in noticeable contrast to the high mountainous terrain of the adjacent Blue Ridge Province to the southeast. A northeast-southwest trending series of parallel alternating valleys and ridges is clearly marked in this area, with the Athens and the Ottosee forming valleys, and the more resistant Notchy Creek facies of the Tellico and the Bays forming ridges. These topographic expressions are helpful in mapping. Residual soils, formed from underlying parent material, in most cases give a clue as to the nature of the bedrock. The highest elevation in this area is about 1400 feet and the lowest is about 800 feet. Below is a brief description of topographic expression and soil association of rock units.

The Knox is not a ridge former in this area. The limestone of the southeastern phase of the Knox Group weathers to a residual clay and a very small amount of chert; it produces an orange-red soil.

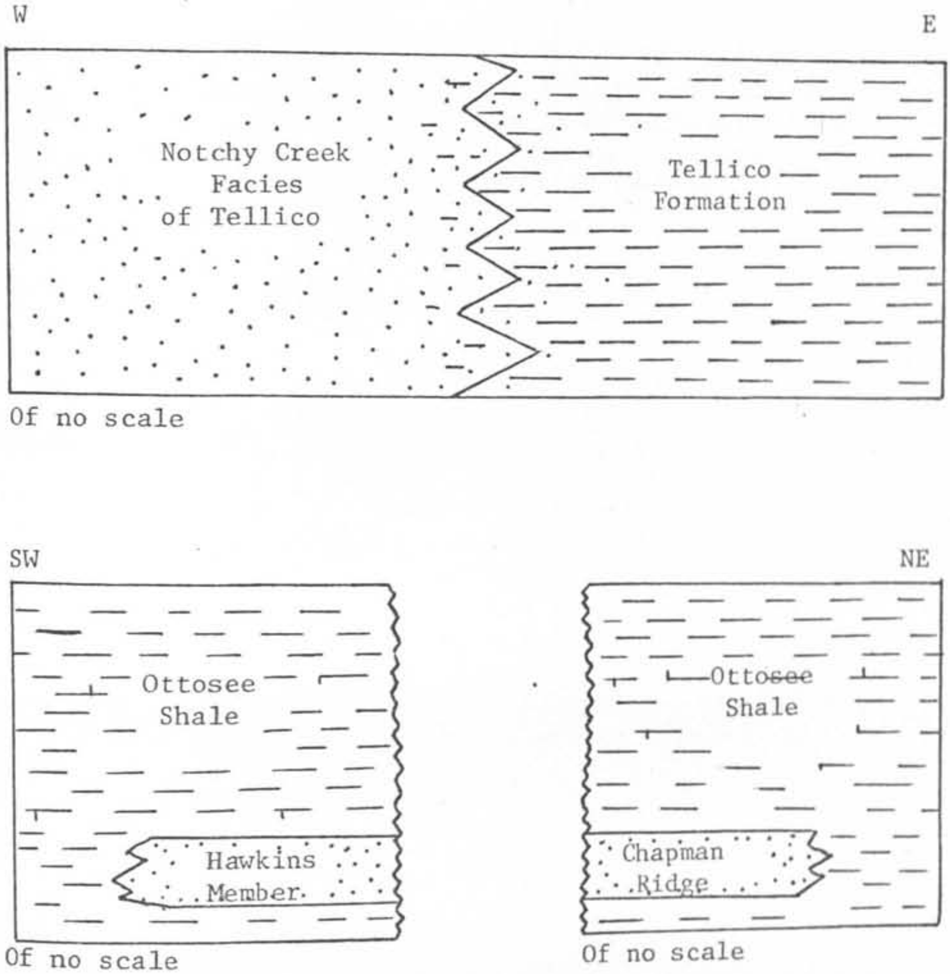


Figure 19. Interpretation of deltaic cycles.

(Above) A generalized facies change across mapped area (first deltaic cycle). (Below) A generalized cross section of Ottosee Formation, as presented by this worker and Cattermole (second deltaic cycle).

The Athens Formation is very much susceptible to erosion, except for silty carbonate beds of the Upper Member and Sandy Middle Member which form rather low ridges. The Athens Formation usually represents a flat terrain with scattered shale chips. The soil is clayey, light gray in color, and of low permeability. Thus, running water does not penetrate but runs off and removes the weathered material leaving the soil thin. Soil produced by the Middle Member is sandy loam, light gray to light brown, thick and relatively permeable.

The resistant sandstone beds of the Notchy Creek facies of the Tellico Formation underlie prominent ridges which are of great help in tracing this unit. This unit weathers very deeply, producing a dark red residuum high in iron oxide. According to Rodgers (1953), this residuum was directly mined as iron ore near Sweetwater. The soil produced by the Notchy Creek facies is a deep red silty clay. Because these soils have developed on ridges, they have crept downslope into the valleys underlain by shale, covering the shale in many areas. Locally, where the Notchy Creek facies is weathered, the carbonate content leaches out and clastic material appears as a powdery mass, light in color and friable. The shale, where present, forms chips. Soil formed from the shaley facies is usually light brown to yellow and is not well developed.

The Ottosee Formation forms topography lower than that formed by the adjacent formations. Few lines of linearly oriented elliptical knobs are underlain by limestone beds of this formation. Soils developed from rocks of the Ottosee are variable, show different characters and are patchy in distribution. The shale of the Ottosee Formation weathers to a fairly light to dark brown, clayey soil in which chips of weathered shale and siltstone are abundant. Locally limestone outcrops appear throughout this weathered shale and siltstone. The limestone outcrops weather to light red, compact soil.

The Bays Formation weathers to rather small dissected ridges and has very minor topographic expression. The soil produced by the Lower and Middle members of the Bays Formation is shallow silty clay, reddish-maroon in color, and is easily removed by running water. The Upper Member weathers white and produces pebble sized particles. The fresh float blocks form a scattered mass at the surface near the bedrock. Upon further weathering, the sand loses its cohesiveness and becomes dispersed in the residuum.

In summary, this general area is under a variety of soil forming processes. The main Great Soil Groups in this region are the red-yellow Podzolic or Paleudults and Hapludults and Lithosols or Dystrochrepts.

Soils in this area differ very much in color, texture, structure and relief conditions. The soils textures vary from loam to clay. The colors of the surface soils range from dark red or dark brown to light brown or light gray.

The Sequoia and Litz soils are produced from shaly units. Erosion is relatively rapid, so the soil-forming processes can not act upon the regolith for a sufficient length of time to produce thick soils. Tellico soils which are much sandier, deeper and redder are formed on the sandy units.

Areas in which limestone outcrops are abundant produce soils which are either shallow in depth or high in clay content and as a consequence dry out after rains in warm weather.

CHAPTER IV

STRUCTURE

Regional Setting

The Appalachian Highlands occupy the eastern part of North America for more than 3000 miles, from Gaspe, Canada, southward until the Appalachian folds disappear beneath younger sedimentary rocks in Alabama.

The nature of the Appalachian geosyncline has been known since the time of James Hall (1840 to 1860); however, it was not until about 1920 that concepts were widely held regarding the Appalachian geosyncline. This geosyncline subsided most in the site of the present Blue Ridge Province where more than 30,000 feet of sediments accumulated in places. It appears now that the Blue Ridge Province marks approximately the boundary between a western miogeosyncline and an eastern eugeosyncline in early Paleozoic time.

Generally, the western half of the miogeosyncline or shelf area is undeformed or deformed only into very gentle folds which include the Cumberland Plateau and the Allegheny synclinorium. The eastern half of the miogeosyncline is the folded and thrust-faulted Valley and Ridge Province.

The Valley and Ridge is known as the newer Appalachians (Thornbury, 1962) in contrast to the older Appalachians which includes the Blue Ridge and Piedmont Provinces. The newer Appalachians have been subject to debate for sometime as to whether the folds and faults of this province reach to the basement or whether they are not controlled by the crystalline basement. The basement concept is called the "thick skinned" theory, and the no-basement concept is known as the "thin skinned" theory (Rodgers, 1949). Further discussion about these ideas is not the subject of this paper.

About ten major southeast dipping thrust faults and many large scale folds trending northeast-southwest divide the Valley of East Tennessee into several strike belts. The southeasternmost of these strike belts is composed of a syncline bounded by the Great Smoky fault on the southeast and the Dumplin Valley fault on the northeast. The Great Smoky fault serves as an approximate boundary between the sedimentary rocks of the Valley and Ridge and the Precambrian and Early Cambrian, intensely deformed and metamorphosed, sedimentary rocks of the Blue Ridge Province. It is with a segment of this syncline that this work is concerned.

Description of Structural Features

Middle Ordovician rocks with an irregular outcrop pattern occupy the center of the regularly patterned syncline and serve as the footwall of the Great Smoky fault. This fault and the syncline trend southwest-northeast. On the southeast limb of the syncline, three minor faults are present: two trend southwest-northeast while the third one is a tear fault which cuts diagonally across a part of the southeastern limb. Also a small thrust fault, which approximately coincides with the axis of the syncline, is present. Near the center of the syncline and toward its southeastern flank are several small scale folds. Consideration of these structures is helpful in determining the sequence of events involved in the deformation of these rocks (Figure 20 is an illustration of structural features of the area studied).

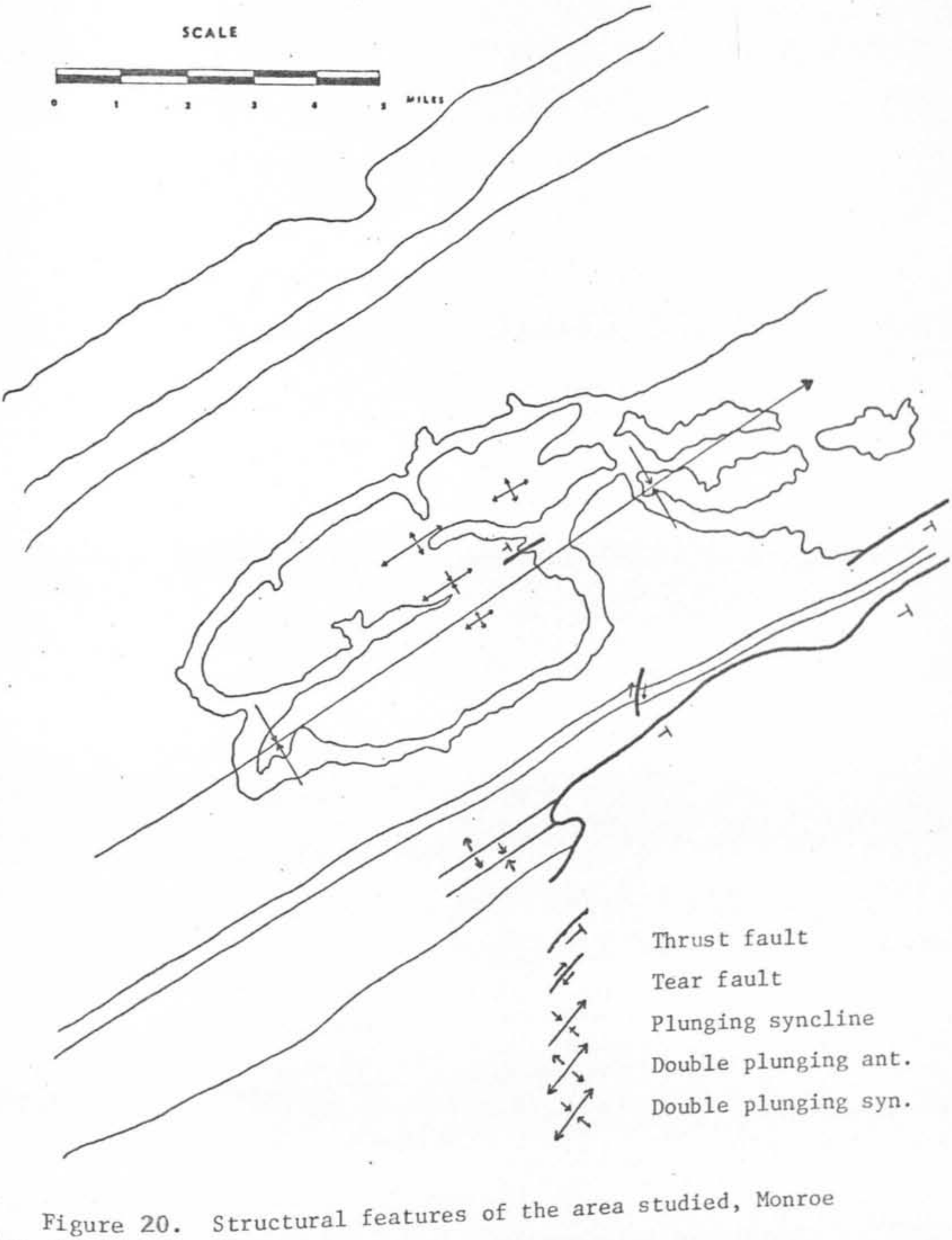


Figure 20. Structural features of the area studied, Monroe County, Tennessee.

Folds

Bays Mountain Syncline

The entire area studied is within a large asymmetrical syncline that plunges approximately N50°E (Plate I, pocket). The axis of this fold is nearly parallel to the Great Smoky fault. This structure disappears under a thrust fault a few miles southwest of the studied area. The rocks exposed in this syncline range from Middle Cambrian to Middle Ordovician in age with a patch of Lower Mississippian rocks in its southeast limb. The southeast limb dips steeply toward the northwest in the southwest portion of the studied area, gradually becoming vertical and finally becoming overturned in the northeast part of the mapped area. The southeastern limb is structurally more complex (Figure 21): overturned beds and a number of faults contribute to this complexity. The Knox and Athens rocks are folded in the southeast portion of this limb. These consist of small scale synclines and anticlines, striking parallel with regional structures. They disappear northeastward under the Sink fault near the Tellico River. The northwestern limb dips less steeply to the southeast exposing more complete sections. In the center of the syncline the beds of the Bays Formation are horizontal.

The northeastern part of the syncline was studied by Neuman (1955) and Biery (1968). Marie (1963) mapped further northeast where the syncline widens and becomes structurally more complex. The Bays Mountain syncline was completed at the end of the Paleozoic Era as a result of regional stresses.

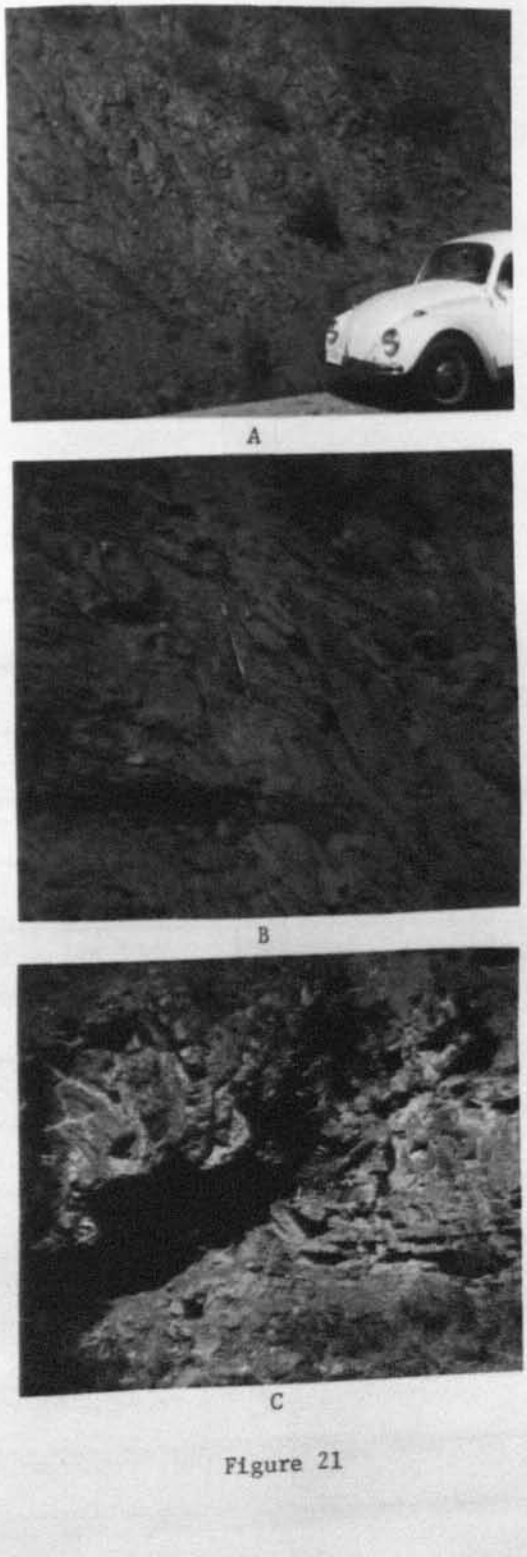
The name Bays Mountain syncline is taken from Bays Mountain in Sullivan, Hawkins and Green Counties, Tennessee.

Figure 21. Deformation and structure within Notchy Creek facies and Bays Formation.

A. Highly deformed Notchy Creek facies rocks on the southeast limb of the Bays Mountain syncline, along Ballplay Road.

B. Small scale folds and faults in highly deformed Notchy Creek facies. Location, a closer shot of A.

C. Cedar fault. The location is southwest of Cedar Knob, along the county road.



A

B

C

Figure 21

Ballplay Synclinorium

Approximately in the center of the Bays Mountain syncline, rocks of Bays Formation wrinkle to form a small synclinorium, with a width of about three miles. The trend of this structure is parallel to the axis of the Bays Mountain syncline, and rocks of the Ottosee Formation are exposed in the middle of this synclinorium. The dips of the beds are variable, but folds are seldom seen in the field.

The name Ballplay synclinorium is taken from Ballplay Road, Mount Vernon quadrangle, Monroe County, Tennessee.

Faults

Sink Thrust Fault

The name Sink fault is here given to the largest fault recognized during the course of this study. The name is taken from Sink Road, Mount Vernon quadrangle, Monroe County, Tennessee.

The Sink fault, as indicated by its sinuous trace and a window (Plate I, pocket), has a low dip. The Athens Formation comprises the footwall of the Sink fault along all of the nine-mile segment of the fault trace mapped in the area studied. There is little stratigraphic displacement; the Knox Group is thrust on the incompetent Upper Member of the Athens Formation. The minimum amount of horizontal movement along the plane of the fault is approximately 3/4 mile.

Although the fault is seldom exposed, closely spaced outcrops in most places are sufficient to define its position within 30 feet. The fault plane dips approximately 12° to 18° southeast as determined from its topographic trace. The fault strikes nearly parallel with the axis of the Bays Mountain syncline. Except for a small portion, the fault strikes generally parallel to its trace. Because the trace of the fault parallels the strike of the rocks on either side, it is assumed that movement has been generally perpendicular to the strike. In the area near Oak Grove Church, south of Red Mountain, where the fault crosses the county road, drag folds and slickensides are present in the Athens Formation. Elsewhere on the footwall, the Athens Formation exhibits widely varying attitudes.

Everywhere, the Sink fault truncates the southeastern limb of the Bays Mountain syncline. This limb dips progressively steeper northeastward and becomes overturned in the southeast part of the study area (Structure Section, Plate II, pocket).

Hicks Fault

Parallel to the Sink fault, in the extreme southeast portion of the mapped area (Plate I, pocket), is another subsidiary thrust fault. The Hicks fault probably diverges from the Guess Creek fault (Plate I) for two miles, eventually dieing out in the Ottosee Formation.

Where the fault is exposed, on the county road along the East Fork Hicks Creek, small scale slickensides and drag folds may be observed in the Middle Member of the Bays Formation. Actual displacement along the fault plane cannot be determined because of the steep dip of the fault plane.

The name Hicks fault is taken from the East Fork Hicks Creek, Rafter quadrangle, Monroe County, Tennessee.

Mahan Fault

A nearly vertical right handed (dextral) tear fault that strikes north-south (Plate I) was mapped in the southeastern limb of the Bays

Mountain syncline. It crosses the Notchy Creek facies of the Tellico Formation and disappears within incompetent rocks of the Athens and Ottosee Formations. Probably the same compressive force which caused overturning of beds in this area simultaneously produced this fault. The fault is not exposed at the surface, but topographic expressions indicate its existence (Plate I, pocket).

Cedar Fault

Approximately coinciding with the axis of the Bays Mountain syncline and parallel to the Sink fault is another thrust fault (Plate I) that extends for a short distance through the Upper Member of Bays Formation with the fault plane dipping about 32° northwest. This fault, which is exposed in the road cut (Figure 21, p. 73), shows only two or three feet of displacement. The Cedar fault is one of the few faults in the entire Valley and Ridge in which the fault plane dips northwestward.

The name Cedar fault is taken from the Cedar Knob, Mount Vernon quadrangle, Monroe County, Tennessee.

Minor Structures

Cleavage

Within the Middle Member of Bays Formation, two sets of cleavage are present. Measurements indicate that the strike of the more prominent cleavage planes is approximately N40°E, nearly parallel to the regional structure. The second set of planes strikes roughly perpendicular to the first set (N50°W).

Within the area of this study these two sets of cleavage are best developed locally on the limb of minor folds of the Middle Member of the Bays Formation. This writer believes that the cleavage associated with the folds is of slaty type, as is evidenced by their parallelism with the axial plane of the folds. However, where the bedding plane is hard to determine, the nature of cleavage is uncertain. Cleavage is also developed in the Ottosee Formation and the Upper and Lower members of the Athens Formation. The orientations of these cleavages are more or less in harmony with those of Bays Formation (Middle Member), mentioned above (Figure 22 is an illustration of cleavages and their orientations of the area studied).

Some of the cylindrical worm tubes which were discussed earlier occur in close association with these cleavages. There is no apparent parallel orientation of mineral constituents on the cleavage faces. However, the horizontal striations and micaceous mineral orientation on the cleavage surfaces are reported by Biery (1968) farther northeast of the studied area. Apparently, these striations show movement subsequent to formation of the cleavage.

Joints

Compressional joints may be observed in all of the rock units. These joints are generally normal to the bedding plane.

The compressive joints are more numerous in shales and siltstone, and their strike is approximately parallel with the general strike of the rocks. They cross the strike of the rock at various angles in massive sandstones. Upon weathering, shale units form blocky shale fragments as a result of closely spaced joint sets.

The compressive joints which genetically are shear joints developed in highly competent sandstones of the Notchy Creek facies of the Tellico Formation and the Upper Member of the Bays Formation

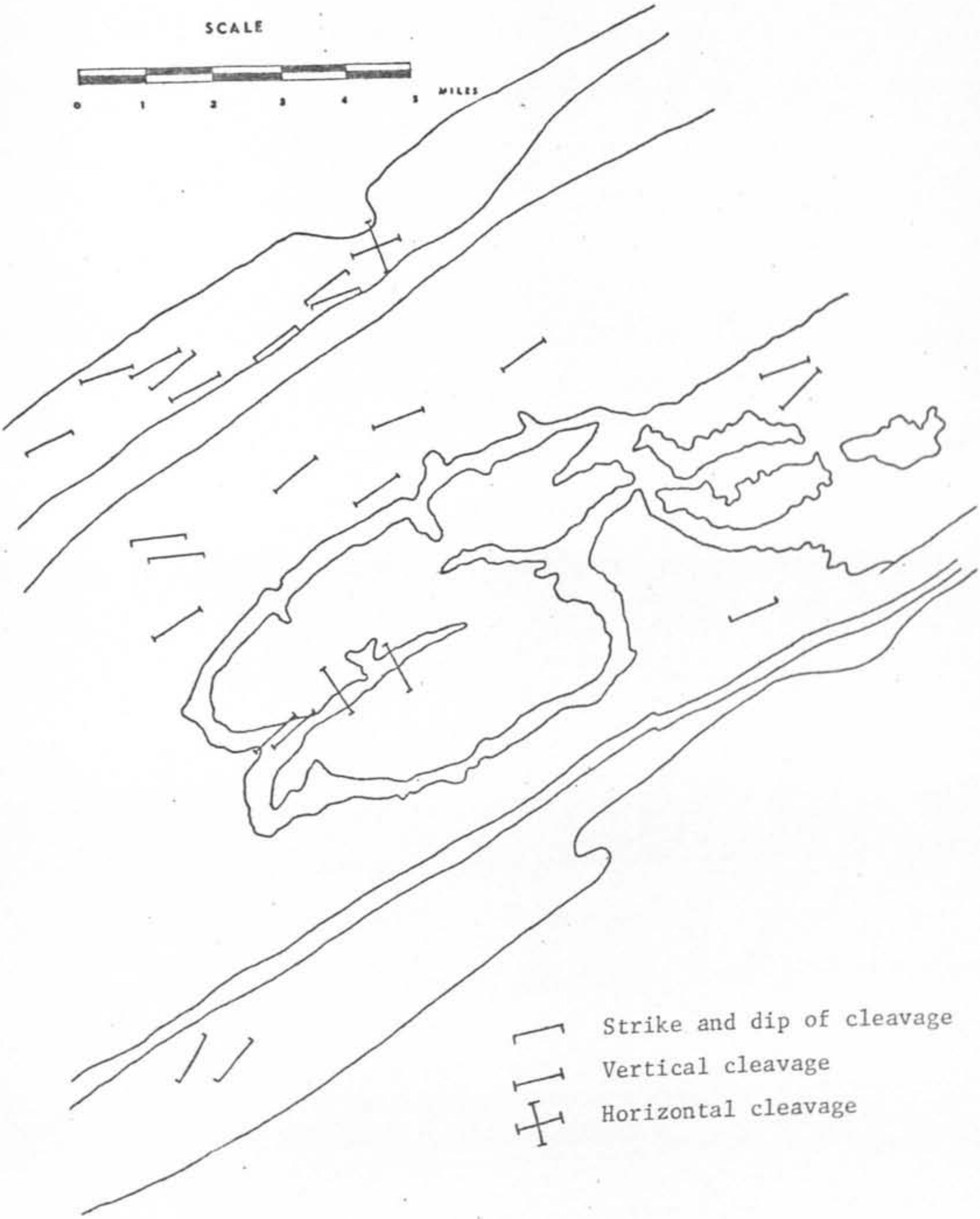


Figure 22. Slaty type cleavage of the area studied, Monroe County, Tennessee.

form in two sets joining at acute angles. In incompetent shales of Athens and Ottosee formations, the angle is more obtuse. Joints are also present in the limestone units of the Ottosee Formation. They are relatively widely spaced and show considerable enlargement because of solution (Figure 23 is an illustration of joint system at the different locations of the area studied).

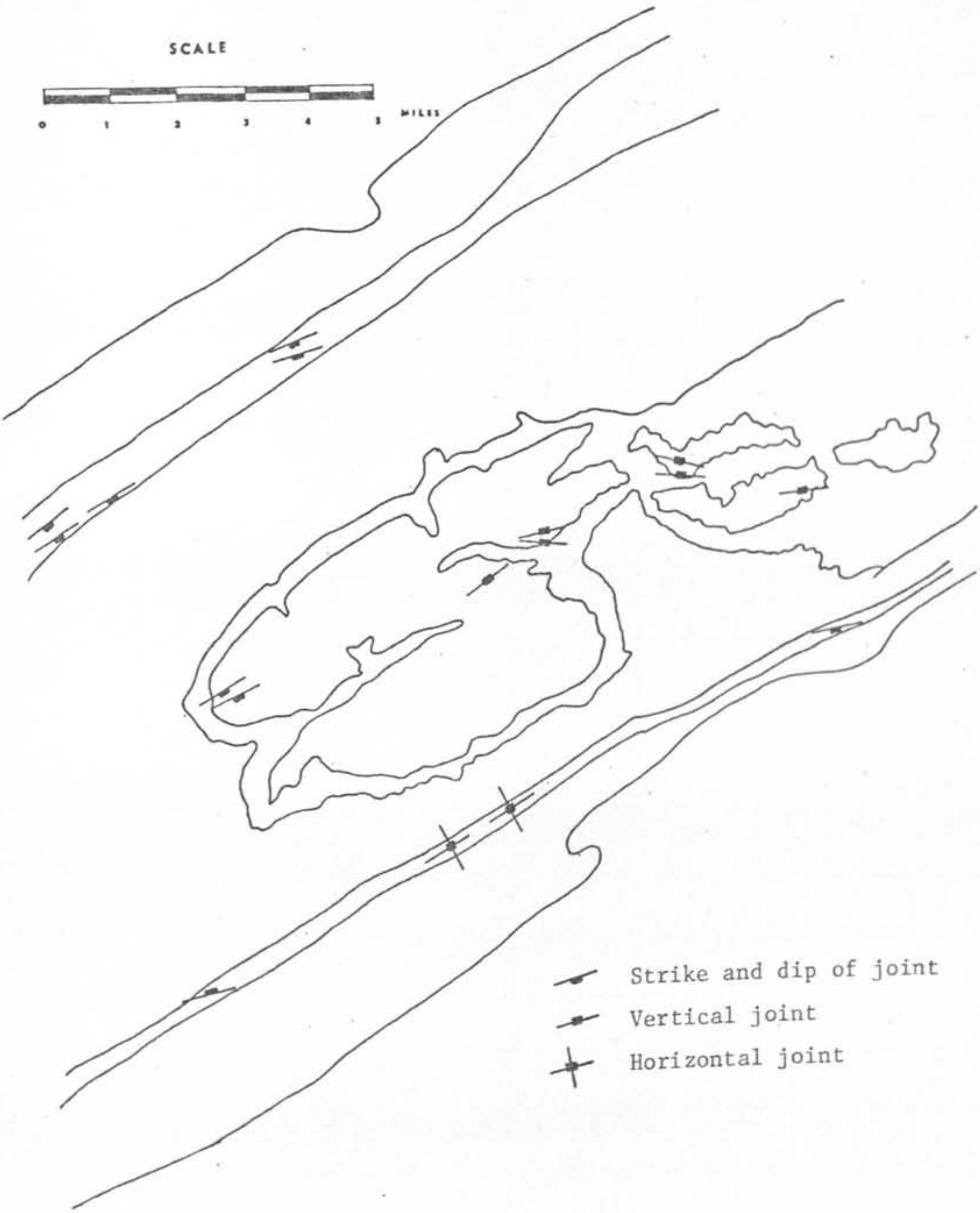


Figure 23. Joint sets of the area studied, Monroe County, Tennessee.

CHAPTER V

SUMMARY AND CONCLUSIONS

For more than a century, since the pioneering works of geologists like Safford and Killebrew (1876), the geology of East Tennessee has proved to be an unlimited source for understanding the structure, stratigraphy, and sedimentation of the early and middle Paleozoic Era in the southern Appalachian area. For many years, however, there was little realization that many of the individual stratigraphic units in fact expressed the lateral relationships of the formations. It is perhaps not surprising that early workers interpreted each of the major facies as a separate time-stratigraphic lithologic unit or formation. However, from detailed field examination, the present writer has attempted to demonstrate that some of these formations are in fact time-transgressive and interfinger laterally with each other, as has been shown by some previous workers.

Thus, given the stratigraphic interpretation proposed in this paper for the lower and middle Chickamauga Group, it appears feasible to study the environmental relationship of those units which are laterally equivalent to each other. An attempt was made to provide a rudimentary environmental interpretation for the lower and middle Chickamauga Group. By reasoning from particular stratigraphic and sedimentological observations, it should be possible to infer that the stratigraphic interpretation of a few units by some previous workers is invalidated by their inadequate correlation. Various structural features of different scale were observed and described during the course of this work.

The following conclusions are presented from the study of the time relations and spatial position of the faults and folds of the area under investigation.

1. A previously unrecognized major thrust fault (Sink fault) was mapped. The minimum horizontal displacement along Sink fault is 3/4 mile.

2. The dip of the Sink fault in this area is low angle as suggested from the intersection of its trace with the topography.

3. Faults to the southeast are probably older than those toward the northwest in the area under study, and the intensity of deformation increases progressively toward the southeast.

4. Compressive forces from the southeast causing downwarping of the Bays Mountain syncline concluded in Late Paleozoic.

5. As folding of the Bays Mountain syncline continued and it became more closed, its southeastern flank was broken by a thrust fault (Sink fault). Movement along this flank resulted in overturning of the southeastern flank of the Bays Mountain syncline.

6. There is no evidence of unconformities within these sequences, except at the top of the Knox, as has been recognized by previous workers. This unconformable relationship is, however, not exposed in the study area.

7. The Chickamauga Group has been completely subdivided into mapable units in the area of this investigation.

8. The so-called "Holston Formation" has no significance as a definite stratigraphic term; it exhibits lateral variation, as has been described by previous workers.

9. The "type section" of the Notchy Creek facies of the Tellico Formation and the "standard section" of the Tellico Formation were established.

10. The facies relation of Notchy Creek facies of this study and Tellico Formation of Neuman was established.

11. The Hawkins Member of the Ottosee (Chota of Neuman) and Chapman Ridge (Cattermole) are of the same age and younger than Notchy Creek facies and the Tellico Formation.

12. The Bays Formation presents three definite lithologic members. The thickness of the Upper Member has been reduced an indeterminate amount by post Bays erosion.

13. The thickness of the formations within the Gray Belt usually decreases toward the northeast and northwest.

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APPENDIX

TABLE II

Geologic Section 1--Standard Section of the Tellico Formation, Along East Bank of the Tellico River, Vonore Quadrangle, Monroe County, Tennessee. Section Measured of Exposures on the Northeast of the Notchy Creek Knobs

Description	Thickness in Feet Of Unit	Thickness in Feet From Top of Formation
Ottosee Formation		
Tellico Formation		
Covered	195	195
Siltstone, calcareous, medium dark gray (N4), thin-bedded, nodules and concretion, fossilferous, brachiopods (<u>Cyrtonotella</u>, <u>Strophomena</u>, <u>Paurorthis</u>)	180	375
Siltstone, weathered chips, blocks are exposed	280	655
Sandstone, calcareous, medium gray (N5) and massive where fresh, grayish-red purple (5RP 4/2) and powdery where weathered, medium to fine-grained, quartz particles are rather rounded and cemented with calcium carbonate, occasional pebbles interbedded with this sandstone, this exposure weathers to thin bedded shaly looking rock	175	830
Sandstone, as above, except coarser grained	185	1015
Covered	250	1265
Siltstone, calcareous, interbedded with sandstone beds	65	1330
Covered	125	1455
Siltstone, calcareous, massive, pale red (10R 6/2) where fresh, dark reddish-brown (10R 3/4) where weathered, interbedded with thin beds of sandstone	55	1510
Covered	410	1920
Sandstone, calcareous, thin bedded, for most part weathered chips are exposed	460	2380
Covered	420	2800
Siltstone, calcareous, highly weathered	90	2890
Covered	530	3420
Siltstone, calcareous, grayish-red (5R 4/2) where fresh, pale red (5R 6/2) where weathered, usually weathers to small size chips and blocks	75	3495
Covered	425	3920
Athens Formation		

TABLE III

Geologic Section 2--Type Section of the Notchy Creek Facies of the Tellico Formation, 2 1/2 Miles North of Mount Vernon, Mount Vernon Quadrangle, Monroe County, Tennessee. Section Measured Along Highway, Tennessee 68

Description	Thickness in Feet: Of Unit	Thickness in Feet: From Top of Formation
Ottosee Formation		
Notchy Creek facies of the Tellico Formation		
Covered	24	24
Arkose, highly weathered to small blocks	29	53
Covered	57	110
Sandstone, calcareous, moderate orange pink (5YR 8/2), fine-grained, irregular bedding	9	119
Covered	123	242
Arkose, highly weathered	33	275
Covered	26	301
Arkose, massive, dark reddish-brown (10R 3/4), coarse-grained, thick-bedded, irregularly fractured, locally concentrated quartz particles, in elongated bodies, parallel to bedding, white in color (N9)	151	452
Arkose, weathered, friable	10	462
Covered	15	477
Sandstone, calcareous, moderate orange pink (5YR 8/4), medium-grained, thin-bedded, occasionally thin beds of corase arkose	121	598
Shale, silty, light olive brown (5Y 5/6), nodules, muscovite flakes, locally oxidized	64	662
Covered	63	725
Sandstone, calcareous, light olive brown (5Y 5/6), medium to coarse-grained, cross bedded, changes laterally to weathered-looking shale	45	770
Arkose, massive, dark reddish-brown (10R 3/4), dense, coarse-grained, pale red (5R 6/2) where weathered, slickenside, small fractures, filled with calcite, beds average thickness of 4 feet, cross bedded, spotty weathering	72	842
Arkose, as above, except few thin beds of shale	31	873
Shale, highly weathered	73	946
Arkose, massive, calcareous, dark reddish-brown (10R 3/4), coarse-grained, cross bedded	102	1048
Covered	58	1106

TABLE III (continued)

Description	Thickness in Feet Of Unit	Thickness in Feet From Top of Formation
Arkose, calcareous, dark reddish-brown (10R 3/4), coarse-grained, cross bedded, some thin beds of calcareous shale with interbedded siltstone	64	1170
Covered, with some shale chips and occasional arkosic pebbles	149	1319
Shale, calcareous, highly weathered	58	1377
Covered	8	1385
Athens Formation		

TABLE IV

Geologic Section 3--Section Measured of the Notchy Creek Facies of the Tellico Formation Along Road Through Bogard Gap, Mount Vernon Quadrangle

Description	Thickness in Feet Of Unit	Thickness in Feet From Top of Formation
Ottosee Formation		
Notchy Creek facies of the Tellico Formation		
Shale, light brown (5YR 5/6), highly weathered, breaks to small chips	99	99
Arkose, grayish-red (5R 4/2) to very dark red (5R 2/6), medium to coarse-grained, massive, small cross beds	58	157
Shale, highly weathered, yellow chips	85	242
Covered, reddish soil	130	372
Arkose, grayish-red (5R 4/2), medium-grained, weathers to friable rock	39	411
Covered	81	492
Arkose, grayish-red, medium-grained, massive, small cross beds	30	522
Covered	82	604
Arkose, highly weathered, coarse to medium-grained, powdery and friable	44	777
Arkose, grayish-red (5R 4/2), medium-grained	40	817
Shale, highly weathered	19	836
Covered	31	867
Arkose, grayish-red (5R 4/2) to very dark red (5R 2/6), medium-grained, massive, weathers to shaly-looking rock	52	919
Arkose, highly weathered, dusky red (5R 3/4), friable, irregular bedding plane	80	999
Covered	177	1176
Sandstone, silty, calcareous, shales interbedded	15	1191
Covered	36	1227
Sandstone, calcareous, grayish-red (5R 4/2), where fresh, moderate red (5R 5/4), where weathered, fine-grained, uneven fractures and joints, few thin shaly beds	28	1255
Sandstone, calcareous, pale red (5R 6/2), fine-grained, silty, weathers to small blocks	51	1306
Shale, calcareous, pale red (5R 6/2), interbedded with fine-grained sandstone, grayish-red (5R 4/2),	70	1376
Covered	122	1498
Athens Formation		

TABLE V

Geologic Section 4--Section Measured of the Notchy Creek Facies of the Tellico Formation; 1 1/2 Miles West of the Tellico River, in Area of Intertonguing of Tellico and Notchy Creek Facies on Plate I

Description	Thickness in Feet: Of Unit	Thickness in Feet: From Top of Formation
Ottosee Formation		
Notchy Creek facies of the Tellico Formation		
Shale, calcareous, weathered, medium-grained sandstone, interbedded	112	112
Covered	53	165
Arkose, calcareous, moderate brown (5YR 4/4), coarse-grained, weathers to powdery mass, friable, with thin beds of shale	72	237
Covered	71	308
Shale, calcareous, pale yellowish-brown (10YR 6/2), fine lamination, interbedded medium-grained sandstone	49	357
Covered	420	777
Siltstone, interbedded with shale and sandstone weathers to shale chips	53	830
Sandstone, coarse-grained, interbedded with silt and shale	31	861
Covered	72	933
Shale, calcareous, pale yellowish-brown (10YR 6/2), finely laminated	44	977
Covered	42	1019
Arkose, calcareous, pale red (5R 6/2), coarse-grained, cross bedded	36	1055
Sandstone, calcareous, grayish-red (10R 4/2), fine-grained, dense	30	1085
Arkose, grayish-red (10R 4/2), medium-grained, interbedded with coarse-grained sandstone	32	1117
Covered	116	1233
Shale, calcareous, interbedded with silt	30	1263
Shale, light brown (5YR 5/6), to pale brown (5YR 5/2) in color	42	1305
Covered	32	1337
Athens Formation		

TABLE VI

Geologic Section 5--Type Section of the Hawkins Member of the Ottosee Formation, Near Hawkins Bridge, Vonore Quadrangle, Monroe County, Tennessee. Section Measured South of Hawkins Bridge, East of the Tellico River

Description	Thickness in Feet: Of Unit	Thickness in Feet: From Top of Formation
Ottosee Formation		
Hawkins Member of Ottosee Formation		
Sandstone, poorly exposed, calcareous, grayish-brown (5YR 3/2) to dusky brown (5YR 2/2), medium-grained, thin bedded	207	207
Covered	106	313
Arkose, grayish-brown (5YR 3/2), massive, coarse grained, cross bedded, becomes thin bedded upward, fractures filled with red soil	392	705
Main Portion of Ottosee		

TABLE VII

Geologic Section 6--Section Measured of the Bays Formation, Northeast of Laurel Mountain

Description	Thickness in Feet Of Unit	Thickness in Feet From Top of Formation
Bays Formation		
Erosional Surface		
Upper Member		
Quartzite, white (N9)	102	102
Covered	30	132
Quartzite, white (N9), medium-grained, occasionally red siltstone interbedded	59	191
Covered, with weathered blocks of quartzite	139	330
Sandstone, reddish-brown (10R 3/4), coarse-grained	40	370
Quartzite, white (N9)	8	378
Middle Member		
Mudstone, alternation of siltstone and sandstone	208	586
Covered	7	593
Mudstone, calcareous, dark reddish-brown (10R 3/4), some silt interbedded, close spaced fractures	8	601
Covered	206	807
Mudstone, dark reddish-brown (10R 3/4), rather dense, fractures are not developed well	6	813
Covered	204	1017
Lower Member		
Siltstone, calcareous, grayish-red (5R 4/2), medium-grained	120	1137
Ottosee Formation		

VITA

Mansour Kashfi was born on May 21, 1939 at Tehran, Iran. He obtained his B.S. degree in geology from the University of Tehran in 1962. Following two years of military service, he came to the United States, where he obtained his M.S. degree in geology from Michigan State University in 1967. He enrolled at the University of Tennessee where he received a Ph.D. in geology in 1971. During his stay at the University of Tennessee he was a teaching assistant.

Currently he is with the National Iranian Oil Company.

PLATE I

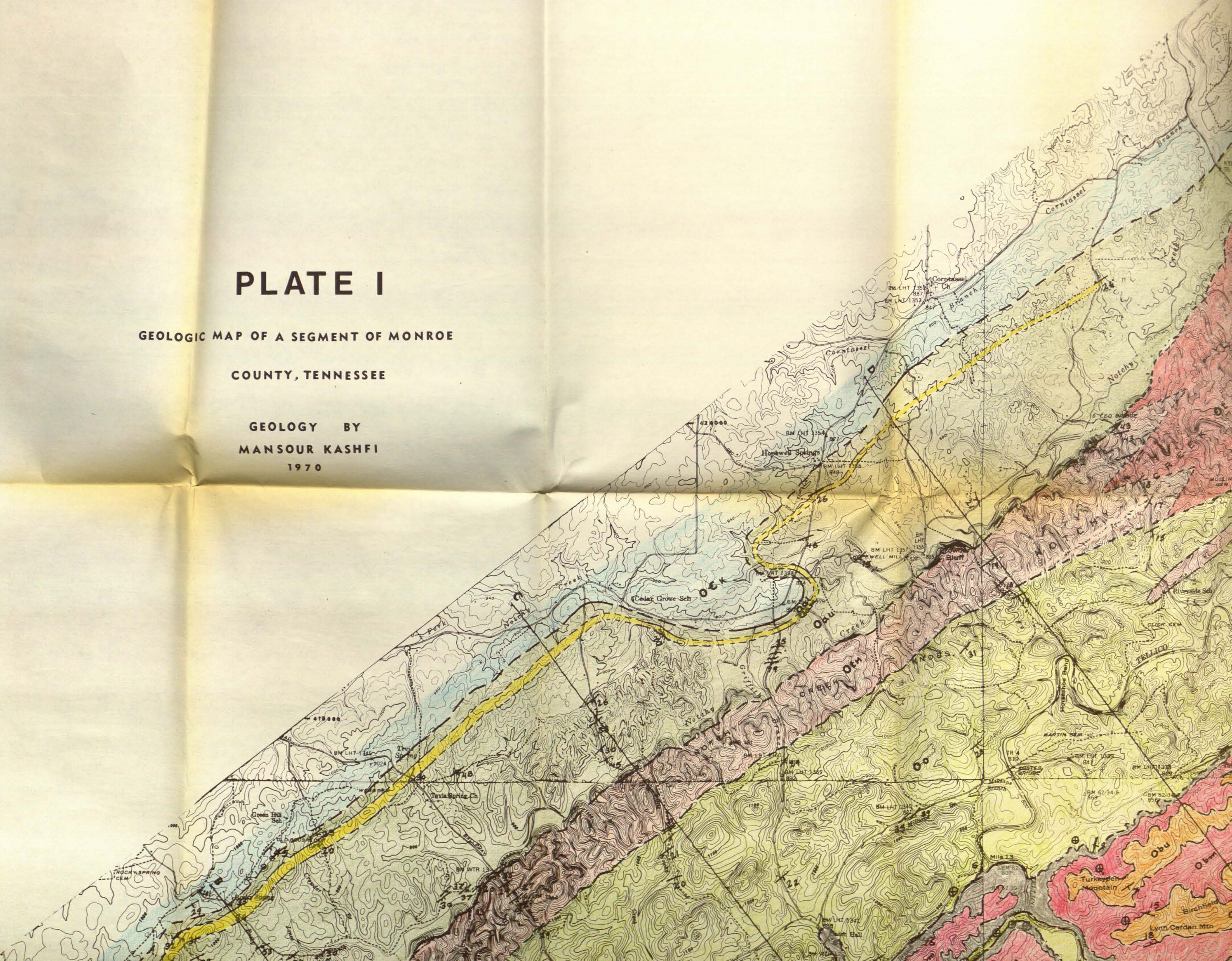
GEOLOGIC MAP OF A SEGMENT OF MONROE

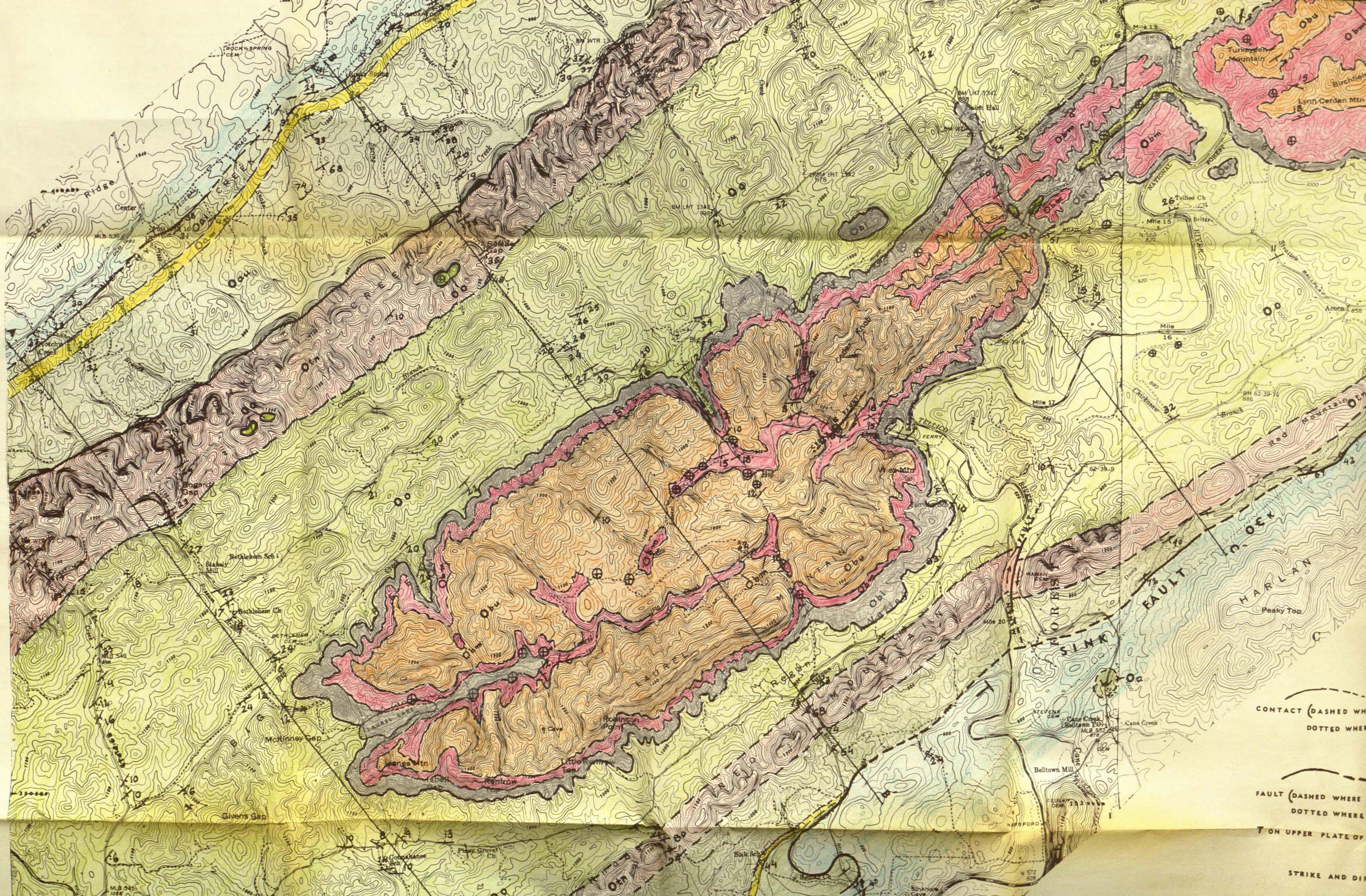
COUNTY, TENNESSEE

GEOLOGY BY

MANSOUR KASHFI

1970





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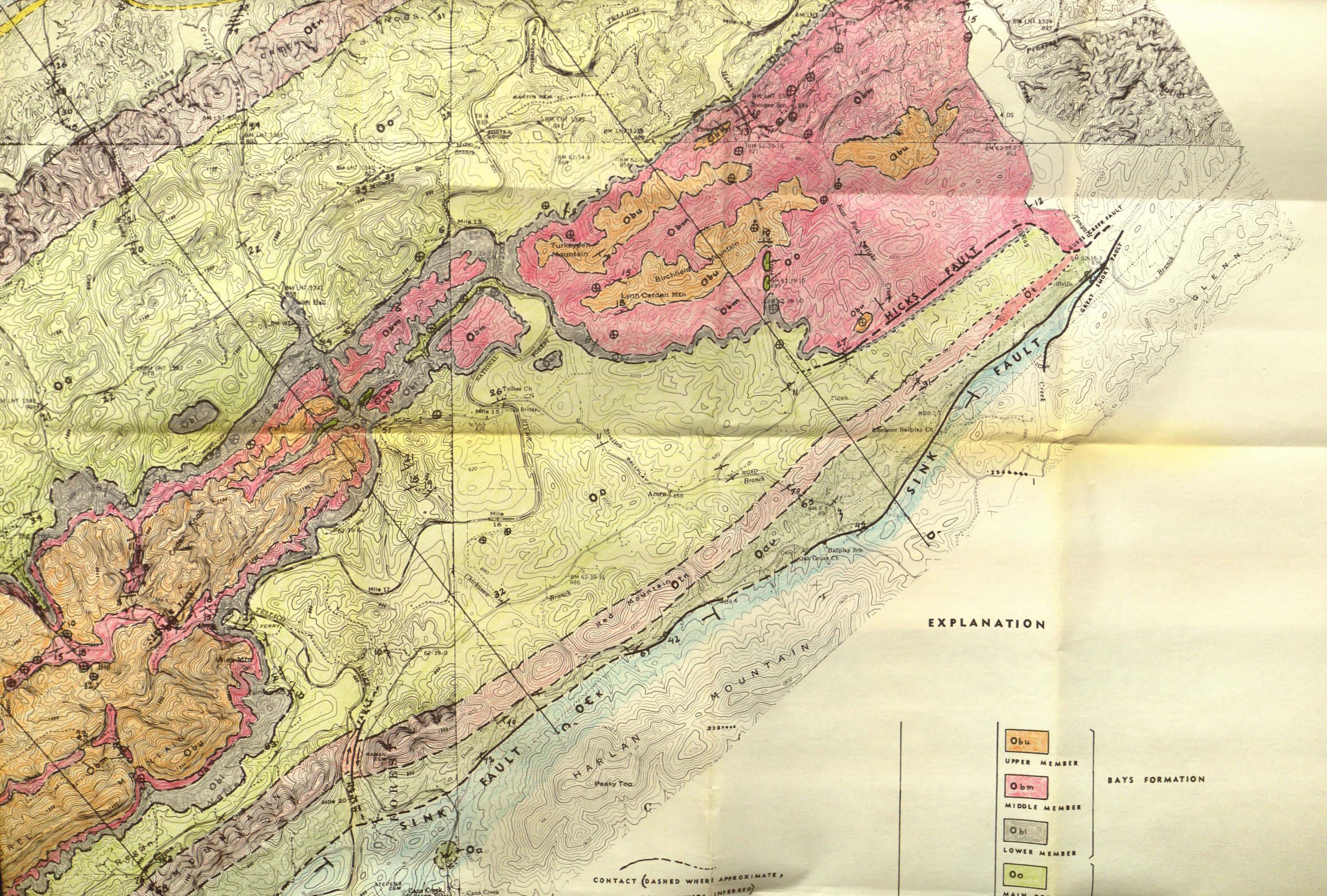

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A — A′ GEOLOGIC SECTION LINE

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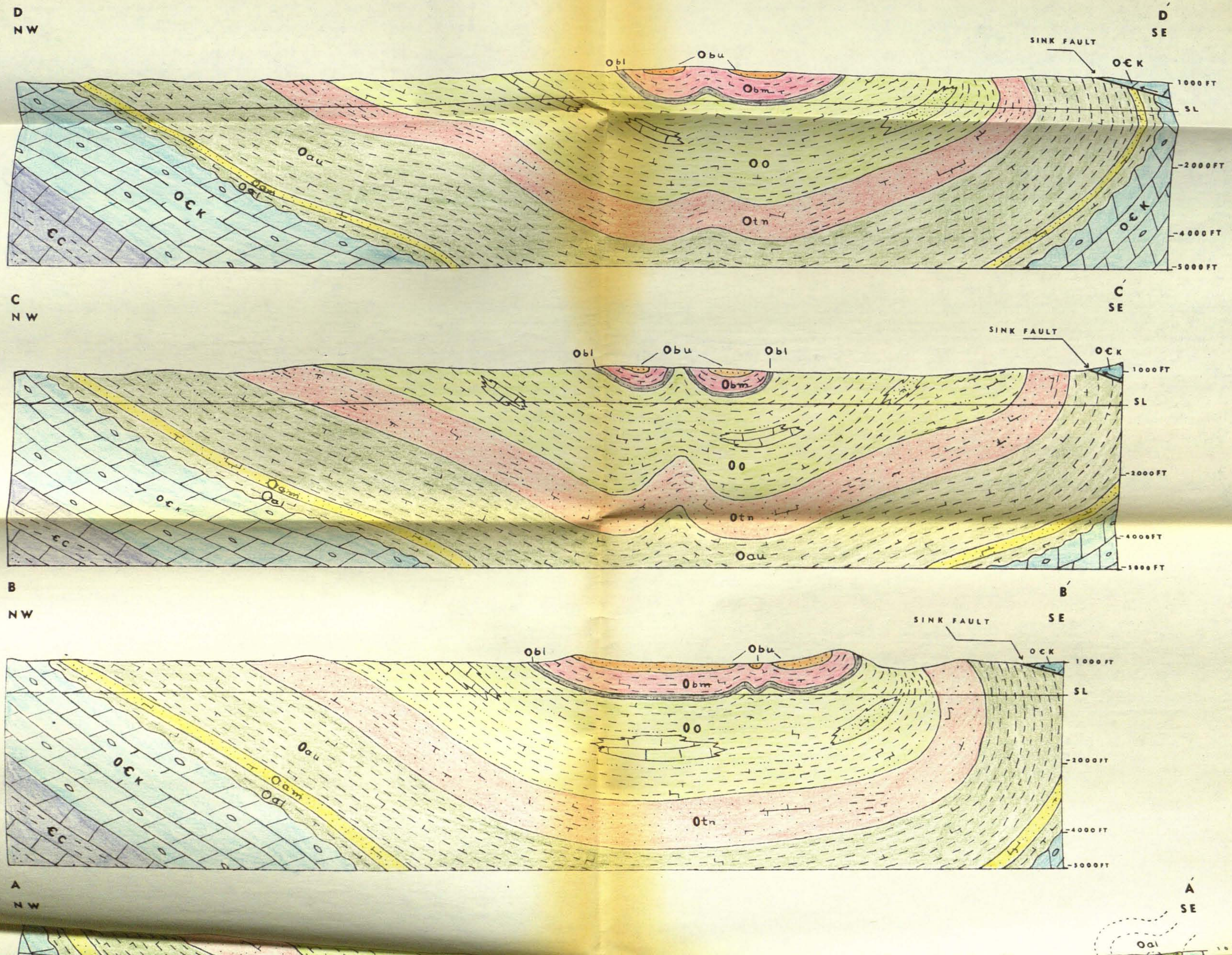
- MIDDLE MEMBER
- Obl — LOWER MEMBER
- Oo — MAIN BODY — OTTOSEE FORMATION
- Ooh — HAWKINS MEMBER
- Ot — TELLICO
- Otn — NOTCHY CREEK FACIES OF TELLICO FORMATION
- Oau — UPPER MEMBER — ATHENS FORMATION
- Oam — MIDDLE MEMBER
- Oal — LOWER MEMBER

OЄk — KNOX GROUP

CAMBRIAN

Єc — CONASAUGA GROUP

PLATE II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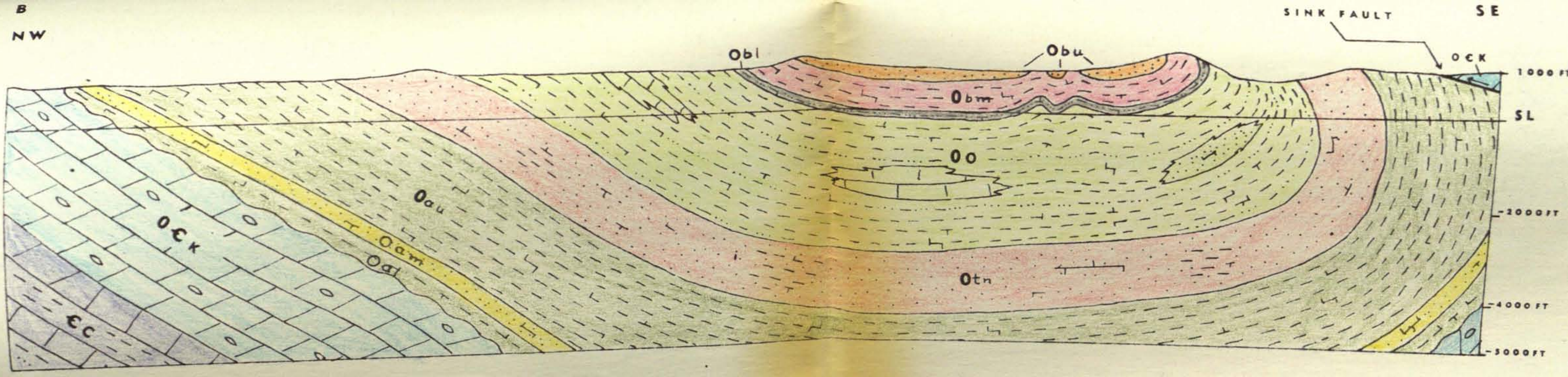
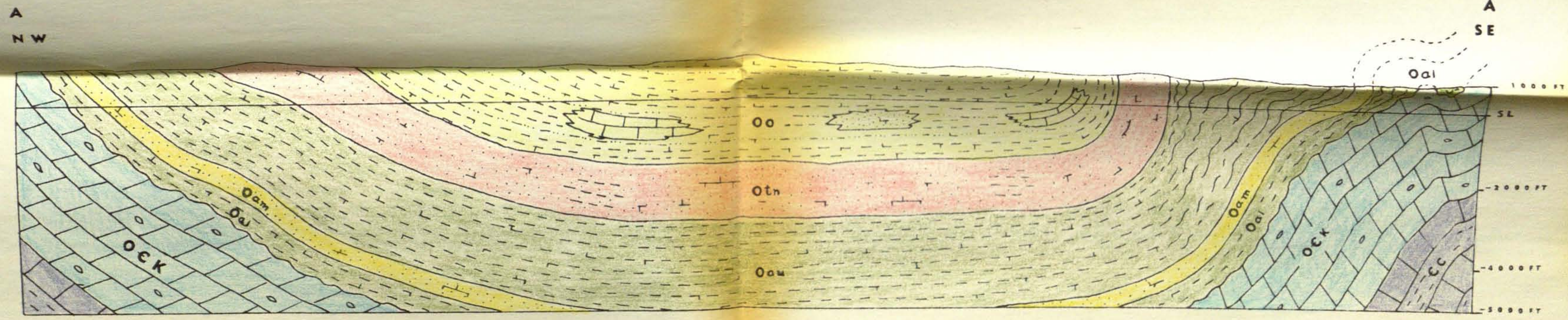
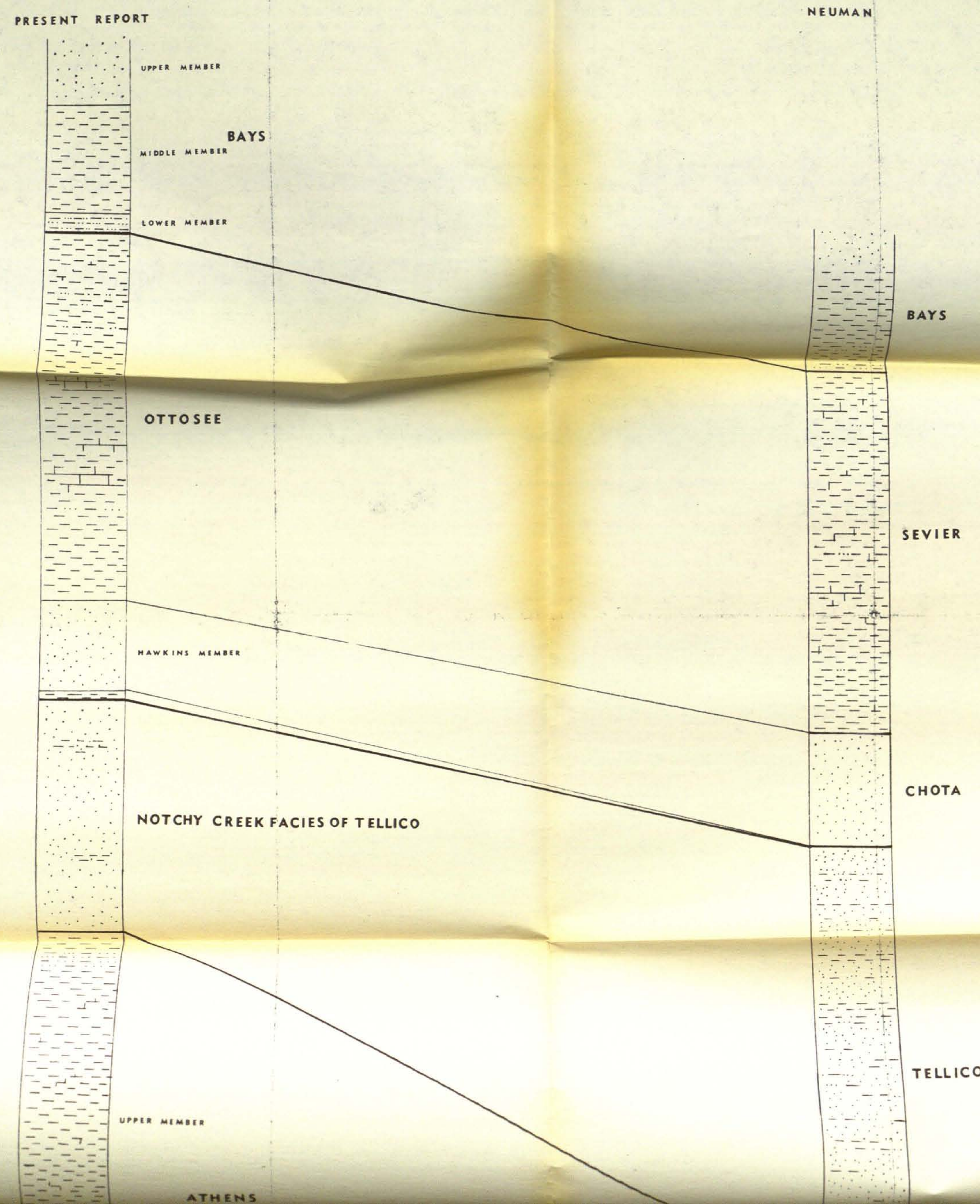




GEOLOGIC CROSS SECTIONS

SCALE 1" = 2000'

FOR EXPLANATION SEE PLATE I



PRESENT REPORT
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MIDDLE MEMBER
LOWER MEMBER
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UPPER MEMBER
ATHENS
NEUMAN
BAYS
SEVIER
CHOTA
TELLICO

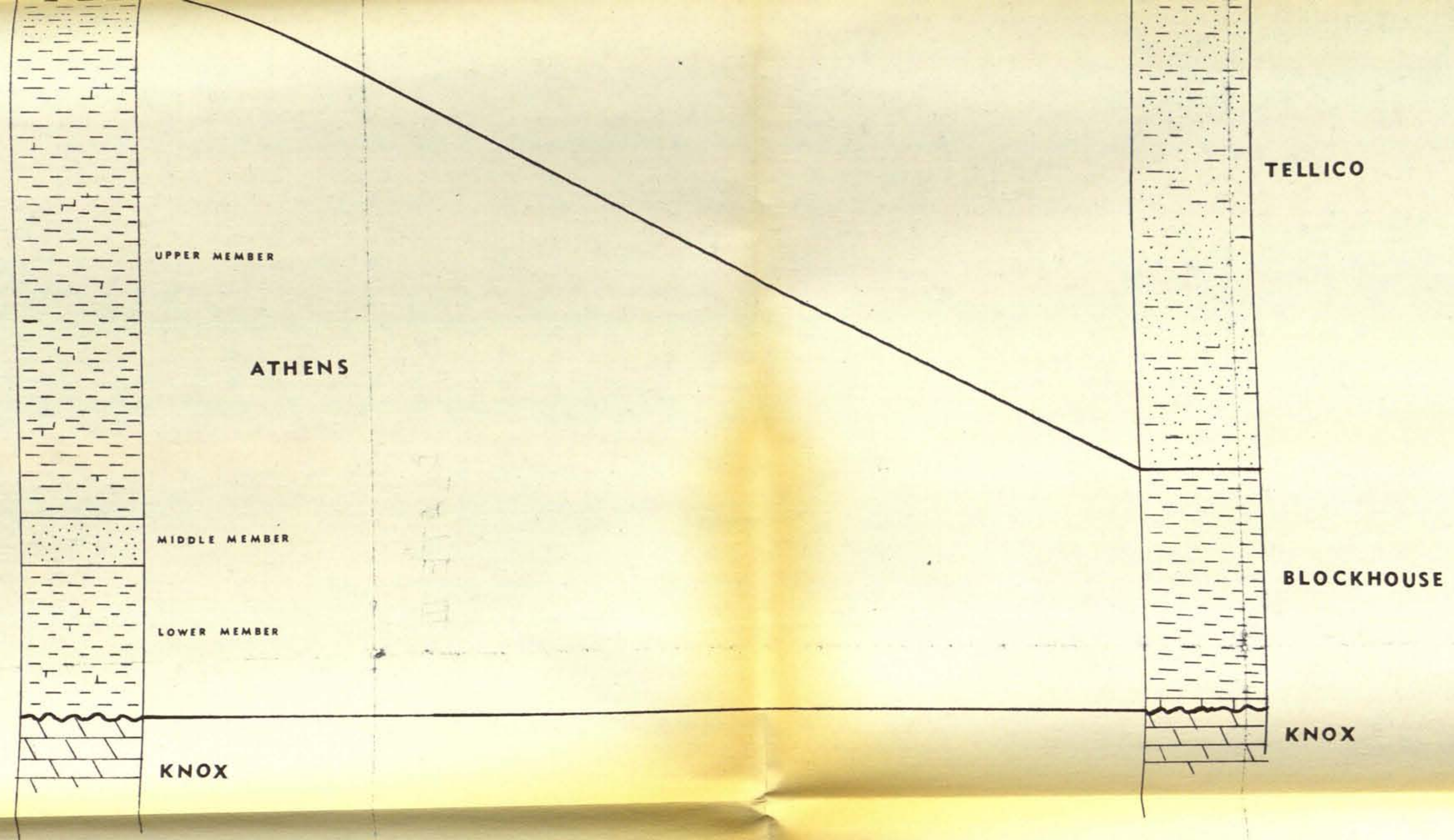

PLATE III

CORRELATION BETWEEN AREA UNDER STUDY AND THAT OF NEUMAN

VERTICAL SCALE 1" = 500'