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Abstract

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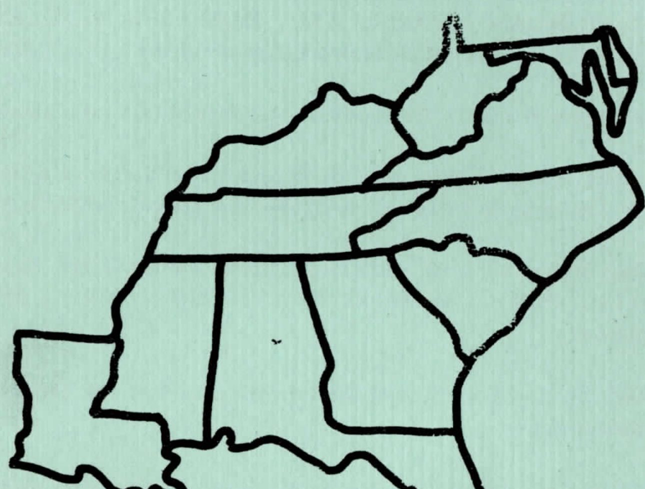
Southeastern Geology



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SOUTHEASTERN GEOLOGY

Table of Contents

Vol. 2, No. 4
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GRAVITY FEATURES OF THE DEEP RIVER-WADESBORO TRIASSIC BASIN OF NORTH CAROLINA

by

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ABSTRACT

Over 1200 gravity stations have been located in the Deep River-Wadesboro Triassic basin of North Carolina. Simple Bouguer anomaly maps suggest that the basin is not a significant or sharp anomaly in the gravitational field of this state. To outline the basin, one must resort to gravity profiles. A study of detailed profiles normal to the axis of the basin suggests that the basin locally reaches a depth of at least 8,000 feet, and in places has graben like features. The basin was traced under the Coastal Plain overlap by locating the easily recognized discontinuity in the profile where it represents the Jonesboro fault. In the future, specific rock types in the Piedmont may possibly be outlined by the gravity profile technique.

INTRODUCTION

General Statement

In 1957, a program to establish the earth's gravitational field in North Carolina was started at the University of North Carolina. During the course of this regional investigation, it became apparent to the authors that the gravity field over certain rock types was so unique, it might be used to outline, or possibly identify specific lithologies. As the Deep River-Wadesboro Triassic basin is one of the most easily recognizable units in the state, a program of detailed gravity studies was inaugurated to establish the gravitational patterns over the basin. By this study, the present authors hoped to: 1) locate the geologic boundaries of the Triassic basin, 2) establish the boundaries along the northwestern and southwestern borders of the basin where they are covered by post-Triassic overlap, 3) locate any concealed structures within the basin, and 4) establish at least the approximate thickness of the sediments within the basin.

Acknowledgements

The writers wish to acknowledge the assistance given the project by the University of North Carolina, the University of Wisconsin, and the National Science Foundation. The University of North Carolina furnished the meter, and the automobile. The University of Wisconsin Geophysics Department completed the calculations for each station. The National Science Foundation financed the undertaking with Grant #NSF-G5042.

GEOGRAPHY

Location

The Deep River-Wadesboro Triassic basin of North Carolina extends from a point southeast of Oxford, Granville County southwestward to the South Carolina boundary near Wadesboro, Anson County. This basin is one of a discontinuous chain of fault troughs of Triassic age distributed in eastern North America for a distance of approximately 1,000 miles. In North Carolina, Triassic basins occupy two areas which trend northeast. The western belt is the Dan River basin which lies in the northwestern part of the state and extends northward into Virginia. The eastern belt, the area under study for this report, has a northern limit near Oxford, and a southern terminus near Pageland, South Carolina. This report is confined to that portion of the eastern basin which lies in North Carolina.

The Deep River-Wadesboro basin lies along the eastern edge of the

Piedmont Plateau, and is partly covered by younger sediments of the Coastal Plain. (See Geologic Map of North Carolina, 1958). In North Carolina, this basin is approximately 120 miles long, and it varies between five and twenty miles wide (Fig. 1). An overlap of Coastal Plain sediments from the east across the eastern belt separates the exposures in the Deep River basin to the northeast from those of the Wadesboro basin to the southwest. The dashed lines on the index map (Fig. 1) between Glendon and Mount Gilead on the west and Sanford and Rockingham on the east indicate the wedgelike overlap remnant of the younger sediments across the eastern Triassic basin.

Subdivisions of the Basin

Five names are used in this report to locate regions within the large basin. From north to south, the regions are: 1) Durham basin, 2) Colon cross structure, 3) Sanford basin, 4) Coastal plain overlap, 5) Wadesboro basin. (See Fig. 2)

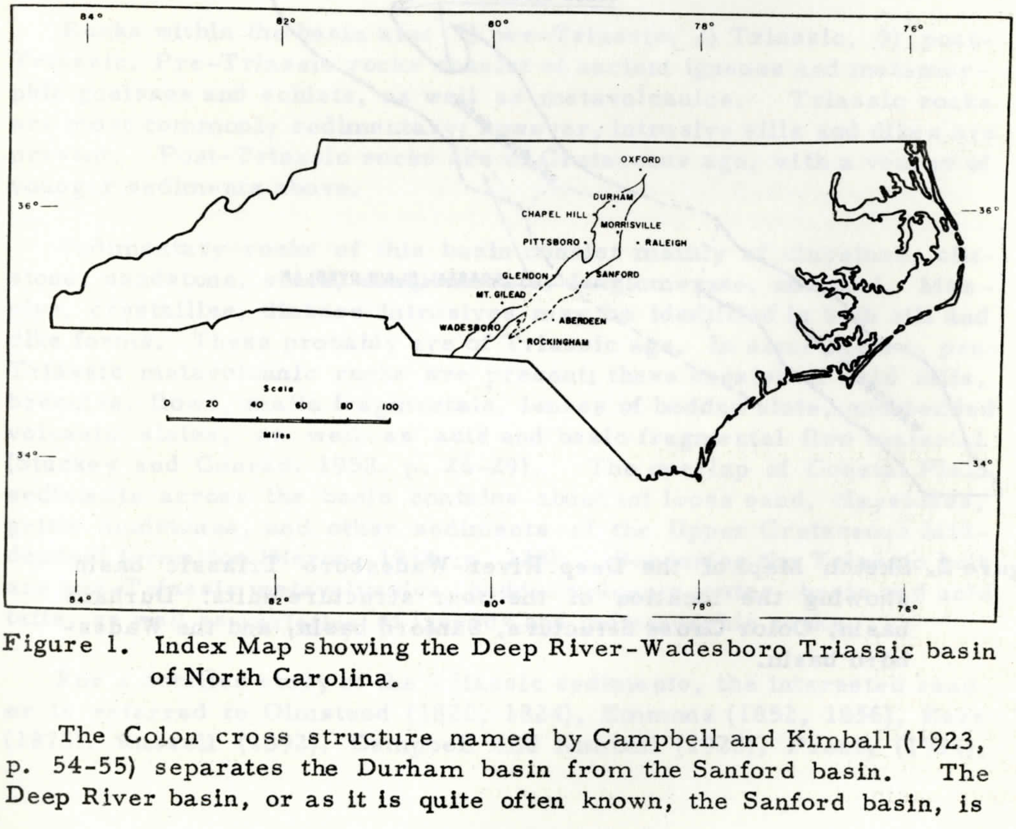

Figure 1. Index Map showing the Deep River-Wadesboro Triassic basin of North Carolina.

The Colon cross structure named by Campbell and Kimball (1923, p. 54-55) separates the Durham basin from the Sanford basin. The Deep River basin, or as it is quite often known, the Sanford basin, is separated from the Wadesboro basin by the Coastal Plain overlap. Where possible, locations will be described in terms of these five area names.

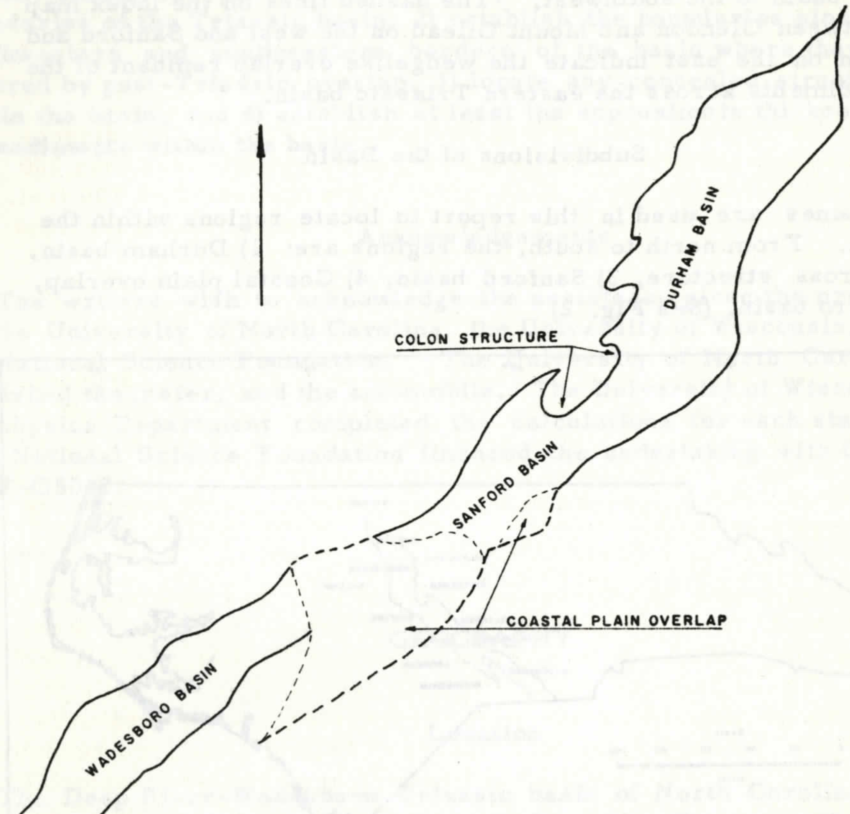

Figure 2. Sketch Map of the Deep River-Wadesboro Triassic basin showing the location of the four structure units: Durham basin, Color Cross Structure, Sanford basin, and the Wadesboro basin.

GEOLOGY

Topography

The Deep River-Wadesboro Triassic basin is a topographic lowland in the Piedmont province. The basin is surrounded by igneous and metamorphic rocks of the Piedmont upland, except where covered by the Coastal Plain overlap.

The Triassic basin has a rolling surface that is intricately dissected. Although elevations in the basin vary from slightly less than 200 feet MSL to over 500 feet MSL, local relief is usually less than 100 feet. The fault line scarps bordering the basin vary in relief from a few tens of feet to a maximum of 250 feet (Reinemund, 1955, p. 15).

Stratigraphy

Rocks within the basin are: 1) pre-Triassic, 2) Triassic, 3) post-Triassic. Pre-Triassic rocks consist of ancient igneous and metamorphic gneisses and schists, as well as metavolcanics. Triassic rocks are most commonly sedimentary; however, intrusive sills and dikes are present. Post-Triassic rocks are of Cretaceous age, with a veneer of younger sediments above.

Sedimentary rocks of this basin consist mainly of claystone, siltstone, sandstone, shale, conglomerate, fanglomerate, and coal. Massive, crystalline, diabase intrusives may be identified in both sill and dike forms. These probably are of Triassic age. In some layers, pre-Triassic metavolcanic rocks are present; these consist of acid tuffs, breccias, flows, mafic fragmentals, lenses of bedded slate, and bedded volcanic slates, as well as acid and basic fragmental flow material (Stuckey and Conrad, 1958, p. 26-29). The overlap of Coastal Plain sediments across the basin contains abundant loose sand, claystones, gritty mudstones, and other sediments of the Upper Cretaceous Middendorf formation (Heron, 1958, p. 128). Bordering the Triassic belt are pre-Triassic metavolcanics, bedded volcanic slates, basic and acid tuffs, as well as varieties of igneous and metamorphic rocks.

For a detailed study of the Triassic sediments, the interested reader is referred to Olmstead (1820, 1824), Emmons (1852, 1856), Kerr (1875), Russell (1892), Campbell and Kimball (1923), Prouty (1931), Harrington (1948), Reinemund (1949, 1955), and Stuckey and Conrad (1958).

Structure

The Deep River-Wadesboro basin is a northeast trending wedge-like block of sediments, bordered on the southeast by a normal fault named the Jonesboro by Campbell and Kimball (1923, p. 55). On the northwest, the basin is bordered by a series of normal faults and pre-Triassic rocks (Harrington, 1948). Generally, the sediments within this wedge-shaped block dip to the southeast at an average angle of 15 degrees. Reinemund (1955, p. 67) calculated that the Jonesboro fault has a vertical displacement of between 6,000 and 10,000 feet. He concluded that longitudinal and cross-faults divide the Triassic into rectangular sub-blocks in the Deep River basin. Prouty (1931, p. 484) estimated that the maximum thickness of the Triassic sediments in the Durham basin was about 10,000 feet.

Harrington (1948, p. 83) best summed up the structural picture of the Triassic basin as follows:

> "It is evident that the movement along the great eastern border fault has had its counterpart on this (the western) side. Displacement on the west was not along a single great plane. The basin is not a simple graben structure with two similar sides. The movement along the west border was a slumping action with minor displacement on many faults and perhaps major displacement on a few. Some faults were parallel to the length of the basin. Others were cross faults. The result has been that the west border converges on the east border in a series of en echelon strike changes."

The four apparent large structural units of the Deep River-Wadesboro basin are: 1) the Durham basin, 2) the Colon cross-structure, 3) the Deep River (Sanford) basin, and 4) the Wadesboro basin.

GRAVITY

General Statement

During the course of two years, approximately 1,200 gravity stations were established in the Triassic basin. An early gridwork was set up by Woollard prior to 1957, and a later gridwork set up by Mann with Worden meter #14. During the summer of 1958, Zablocki (1959) located 1,200 stations, each placed approximately one mile apart along all paved roads in the 1,400 square mile area of the Triassic basin. These stations were established by Worden gravimeter #121, which has a sensitivity of 0.3187 miligals per scale division. Regional stations which had not already been established by Mann or Woollard were located by Zablocki during the summer of 1958.

Elevations of most of the stations were established by a Paulin altimeter. All traverses were tied into benchmarks at least once each hour. Most elevations were taken by the Paulin altimeter twice on each traverse; readings were taken with gravimeter values on the way out, and a fast altimeter run was made on the way back. All values whose elevations exceeded a plus or minus five-foot variation were considered as tares and not used.

All gravity stations were tied into the station established by Woollard and Mann in 1956 at Chapel Hill. This Chapel Hill station is part of the international system. Observed gravity was calculated to an absolute value, and a series of Bouguer values, as well as free air values, was established on IBM cards by the Geophysics Department of the University of Wisconsin. In order that a uniform pattern be developed, the Bouguer values of rocks of a specific gravity of 2.67 was used for making all simple corrections. No terrain corrections were made; hence all anomalies are simple Bouguer.

Construction of Maps and Profiles

Plotted Bouguer anomalies are illustrated by two methods: a) as a Bouguer anomaly gravity map with an isomilligal interval of five milligals (Fig. 3) and b) as gravity profiles from specific traverse lines (Figs. 5 to 12). Attempts to establish residual anomalay gravity maps were made; however, the deepseated features so masked the surface features, that they showed nothing more than the simple Bouguer map.

The Bouguer map (Fig. 3) was constructed by plotting each station on a base map mosaic of the AMS series v501 sheets, and contouring station values at five milligal intervals. Gravity profiles (Figs. 5 to 12) were plotted from traverse lines across the Deep River-Wadesboro basin (Fig. 4). On the profiles, the resultant residual anomalies were obtained by subtracting the regional gradients from the Bouguer anomaly curve. Lithologic boundaries are indicated below the residual anomalies for each profile.

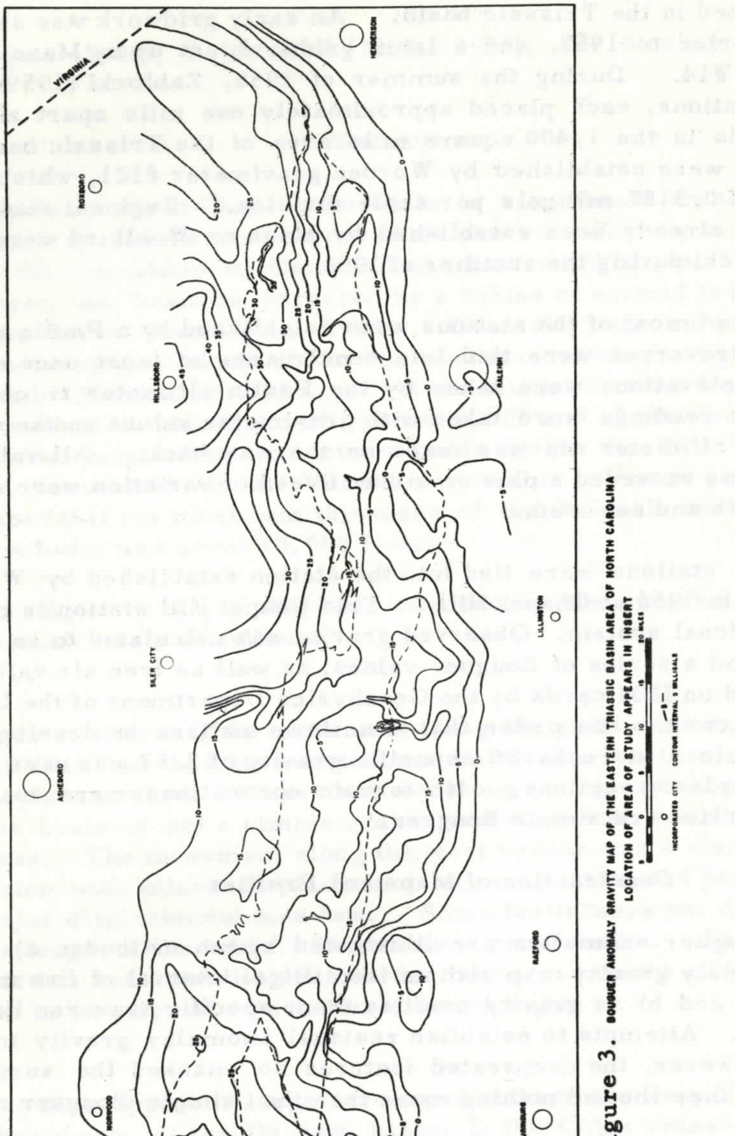

Figure 3. BOUGUER ANOMALY GRAVITY MAP OF THE EASTERN TRIASSIC BASIN AREA OF NORTH CAROLINA
LOCATION OF AREA OF STUDY APPEARS IN INSERT

The profile method, and smooth contour method (Jakosky, 1950, p. 420-424; Woollard, 1943, p. 810; Vajk, 1951, p. 129-143), was used to remove the regional effect caused by deepseated, and unexplained features. In order that true regional be established, some of the regional lines were extended to nearly 100 miles away from the end of the detailed traverse used in the profiles.

Interpretation of Gravity Maps

The attempts to evaluate the maps of the simple Bouguer anomalies were disappointing. Because of the potential error of one-half a milligal caused by an uncertain elevation for some of the stations, an attempt was made to contour the map on a two milligal, five milligal, and ten milligal interval. Maps of the regionals were drawn up and were applied to each of the preceding simple Bouguer maps. All six of these maps, three simple Bouguer, and three residual maps, failed to outline the basin, establish the fault boundaries, or locate significant features within the basin. It was only when profiles plotted normal to the trend of the basin were examined, that the boundaries of the basin became apparent. For this reason, the following discussion concerns the simple Bouguer anomaly map contoured on a five milligal interval, followed by a series of profiles arranged normal to the basin.

Bouguer Anomaly Gravity Map

Figure 3 is the Bouguer anomaly gravity map of the Deep River-Wadesboro basin, contoured with an interval of five milligals. The Triassic area is outlined by dashed lines. As one may readily see, the outlines of the basin are not established by the gravity of contour lines. Even so, some existing patterns or trends may be pointed out.

Two gravity "highs" border the basin: one on the northwestern side of the Durham basin, the other on the southeastern side of the Wadesboro basin. Relative gravity "lows" exist in the Wadesboro, Sanford, and Durham sub-basins. The only negative gravity area is in the southeastern part of the Durham basin; the value is -5 milligals. In the southern part of the Durham basin, the isanomaly lines cross the Jonesboro fault at right angles; but north and northwest of this area, the isanomaly lines cross the fault obliquely. Variations in the intra-basement and near-surface lithology surrounding the basement are believed to be part of the cause for the fault to be masked in the gravity map.

The contour lines surrounding the Colon cross structure, an anticlinal warp trending northwest, have a saddle-like appearance. This same saddle-like form in the gravity map existing in the Colon area also may be seen in the Pekin area. Therefore, we suggest there probably is a similar type constriction at the north end of the Wadesboro basin, and designate it as the Pekin cross structure.

Finger-like features in the isanomaly lines in the Sanford basin may be correlated with longitudinal faults, cross-faults, and diabase dikes. Similar features in the Wadesboro, and Durham basins, more than likely originate from the same structural features.

Residual Anomaly Gravity Maps

In the residual maps drawn, only two features are more apparent than in the simple Bouguer map. First, there is a suggestion that the Sanford basin continues beneath the Coastal Plain overlap into the Wadesboro basin. It appears to be separated by a northwest trending anticlinal warp. Such merely confirms what was already apparent in the simple Bouguer map.

Secondly, the negatives resulting from the removal of regional appeared to be located in areas which had previously been designated as the deepest portion of the basin. As gravity values are not amenable to unique solution, the map in plan view offers little new that was not apparent in the Bouguer map.

As these two geologic features are more easily seen, described, and interpreted by profiles, they will be discussed in the succeeding section.

Interpretation of Gravity Profiles

General Statement:

The location of the profiles to be described in this report are to be found in Figure 4. All profiles have been drawn so as to show a plan map at the top, a Bouguer curve upon which is superimposed the regional curve, the residual anomaly, and the geology related to all of the features.

Inasmuch as the regional anomaly was established for distances as far as 100 miles away from the detailed area, the smooth curve of the residual is as close to the absolute value as can be allowed by this method. Therefore, we assume that the residual represents the shape of the basement rocks upon which the Triassic sediments rest. Although the absolute value of depth and width cannot be established, we believe the configuration of the basement, as well as the approximate depth, is as accurately done as is possible by the straight gravity technique.

No density determinations of the varied lithology in the basin has been made by the present writers; further, no density determinations

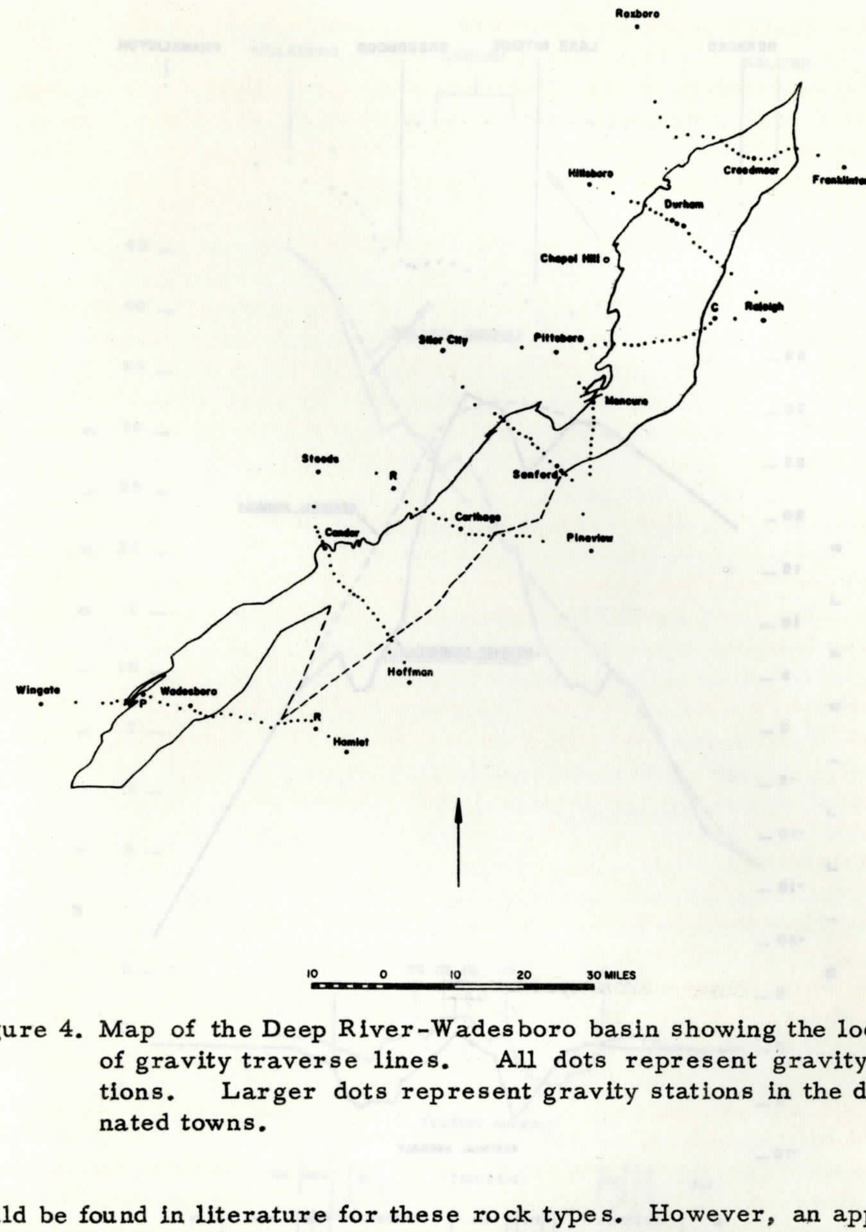

Figure 4. Map of the Deep River-Wadesboro basin showing the location of gravity traverse lines. All dots represent gravity stations. Larger dots represent gravity stations in the designated towns.

could be found in literature for these rock types. However, an approximation of the maximum thickness of sediments in the deepest parts of the profiles, can be made for different densities. For the purpose of the present report, a density differential of 0.1 was used for the calculations. By using the formula $T = A \div 0.013S$ milligals, with S as 0.1, the values of the thickness of sediments have been estimated. T is the thickness of sediments in feet. As is the local anomaly relative to bedrock areas surrounding the basement, and S is the difference in specific gravity. (Thompson and Sandberg, 1958, p. 1272.)

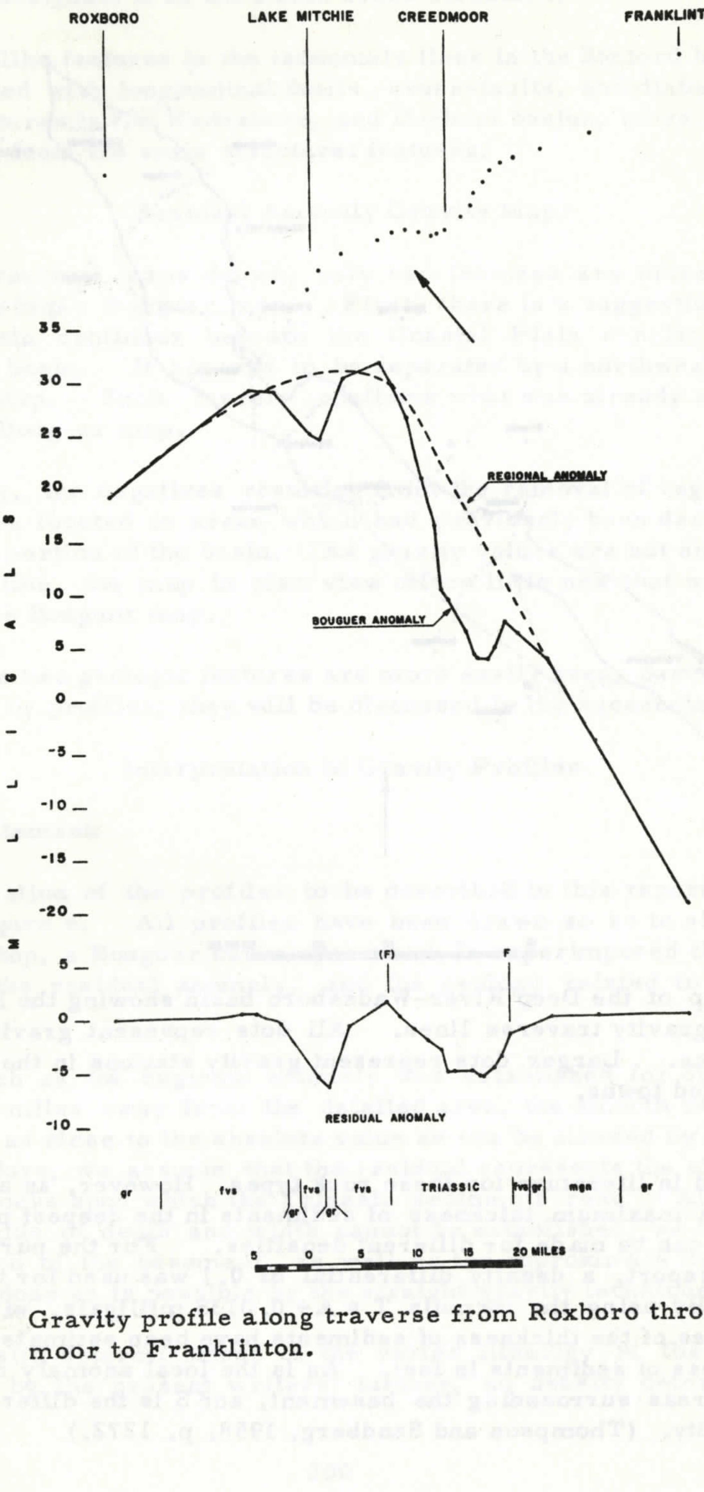

Figure 5. Gravity profile along traverse from Roxboro through Creedmoor to Franklinton.

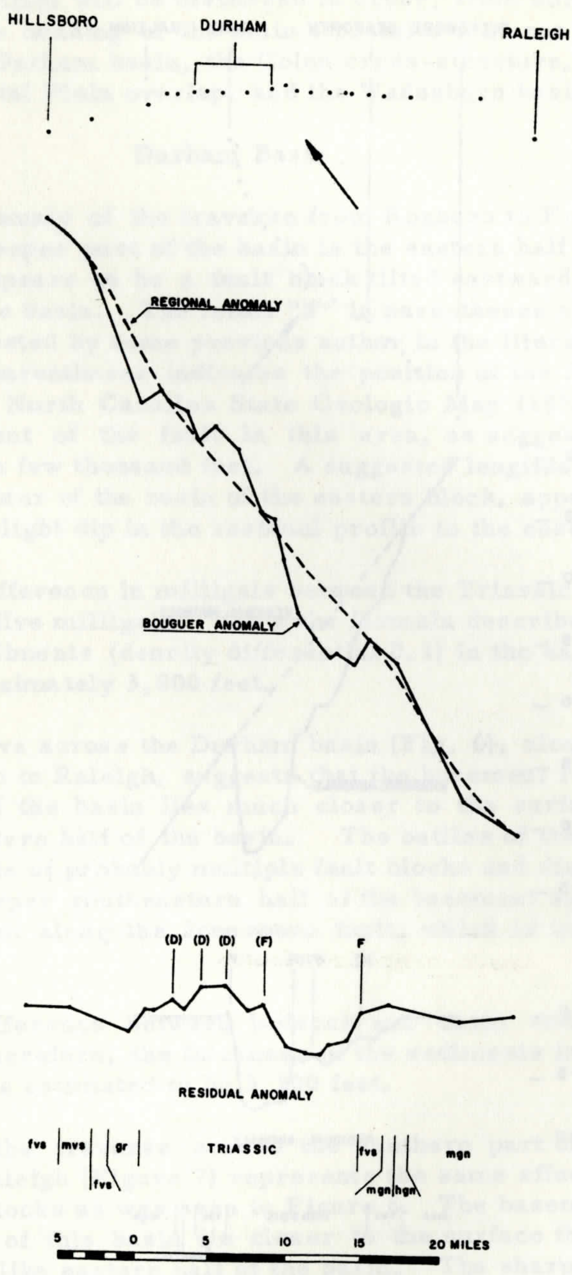

Figure 6. Gravity profile along traverse from Hillsboro through Durham to Raleigh

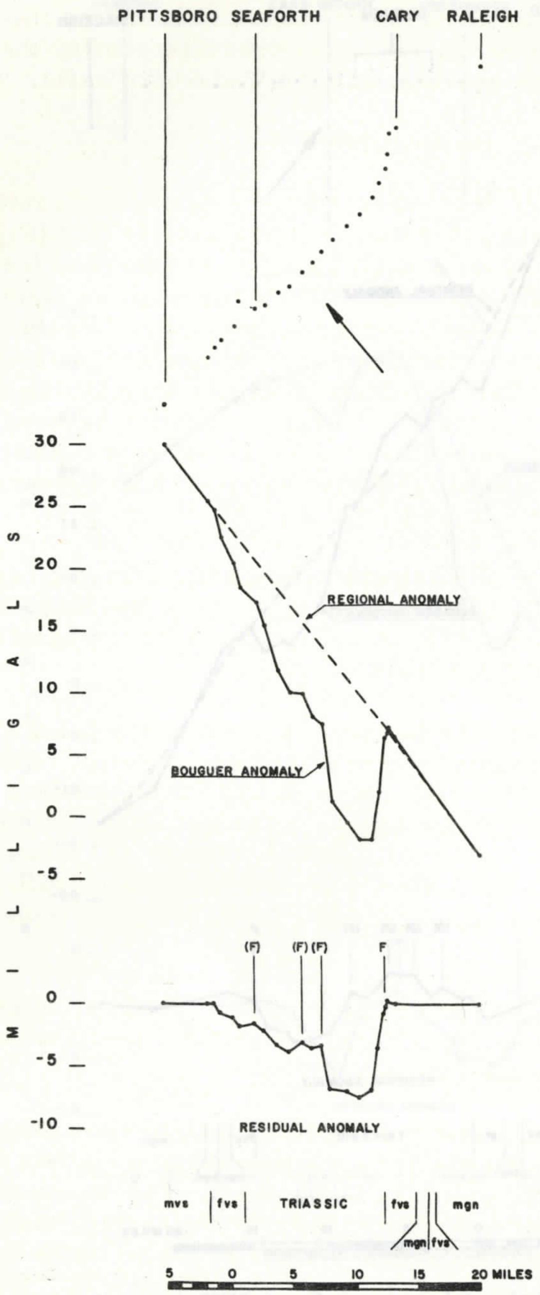

Figure 7. Gravity profile along traverse from Pittsboro through Cary to Raleigh

Eight gravity profiles will be discussed in order, from northeast to southwest, under the heading of the main structural features they traverse; namely, the Durham basin, the Colon cross-structure, the Sanford basin, the Coastal Plain overlap, and the Wadesboro basin.

Durham Basin

The residual anomaly of the traverse from Roxboro to Franklinton indicates that the deeper part of the basin is the eastern half (Fig. 5). The western half appears to be a fault block tilted eastward from the western border of the basin. The letter "F" in parentheses signifies a probable fault suggested by some previous author in the literature; the letter "F" without parentheses indicates the position of the Jonesboro fault as found on the North Carolina State Geologic Map (1958). The probable displacement of the fault in this area, as suggested by the gravity profiles, is a few thousand feet. A suggested longitudinal fault, occurring in the center of the basin of the eastern block, appears to be responsible for the slight dip in the residual profile to the east.

The measured difference in milligals between the Triassic basin and adjacent bedrock is five milligals. Using the formula described before, the thickness of sediments (density differential 0.1) in the eastern half of the basin is approximately 3,800 feet.

The residual curve across the Durham basin (Fig. 6), along the traverse from Hillsboro to Raleigh, suggests that the basement rock in the northwestern half of the basin lies much closer to the surface than it does in the southeastern half of the basin. The outline of the anomaly represents the effects of probably multiple fault blocks and diabase intrusives (D). The deeper southeastern half of the basement suffered the greatest displacement along the Jonesboro fault, which is indicated by the letter "F".

The anomaly difference between bedrock and basin sediments is 4-1/2 milligals. Therefore, the thickness of the sediments in the basin at its deepest point is estimated to be 3,100 feet.

The profile of the traverse across the southern part of the basin from Pittsboro to Raleigh (Figure 7) represents the same effect of probable multiple fault blocks as was seen in Figure 6. The basement rocks of the western half of this basin lie closer to the surface than do the rocks in the graben-like eastern half of the basin. The sharp displacement of the Jonesboro fault is illustrated well in this profile. The western half of the basin is not sharply outlined; there are a number of indistinct minor faults labelled (F).

Along the Jonesboro fault, the measured anomaly difference is 8-1/2 milligals; this should result from the difference between basement and

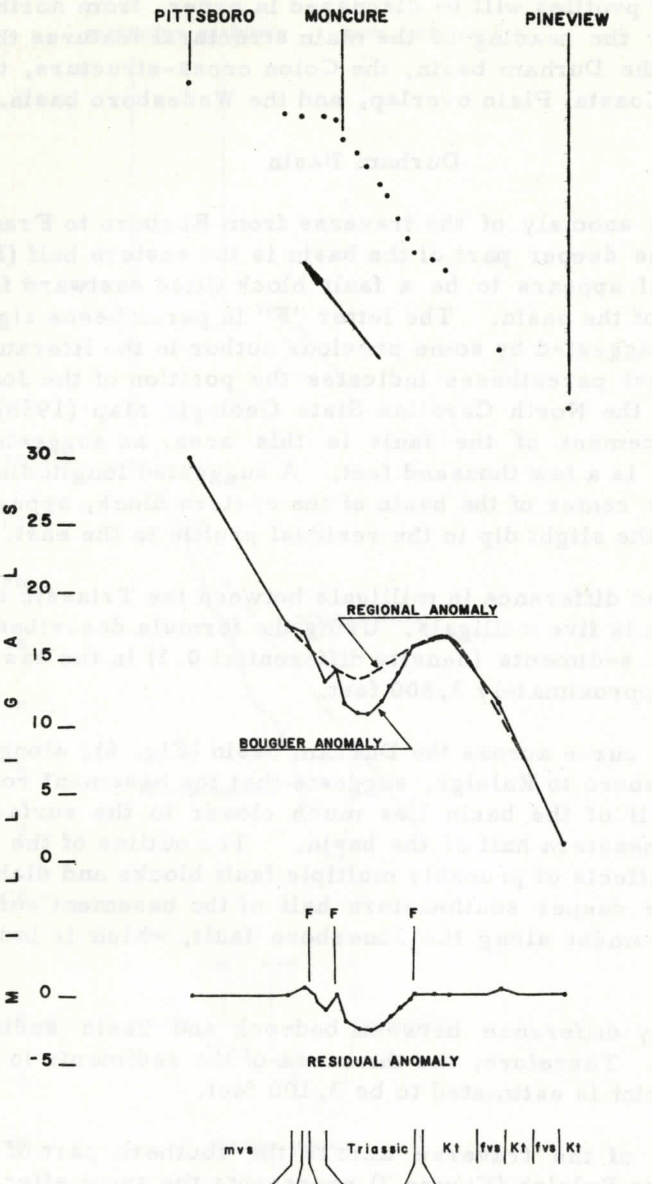

Figure 8. Gravity profile along traverse from Pittsboro through Moncure to Pineview.

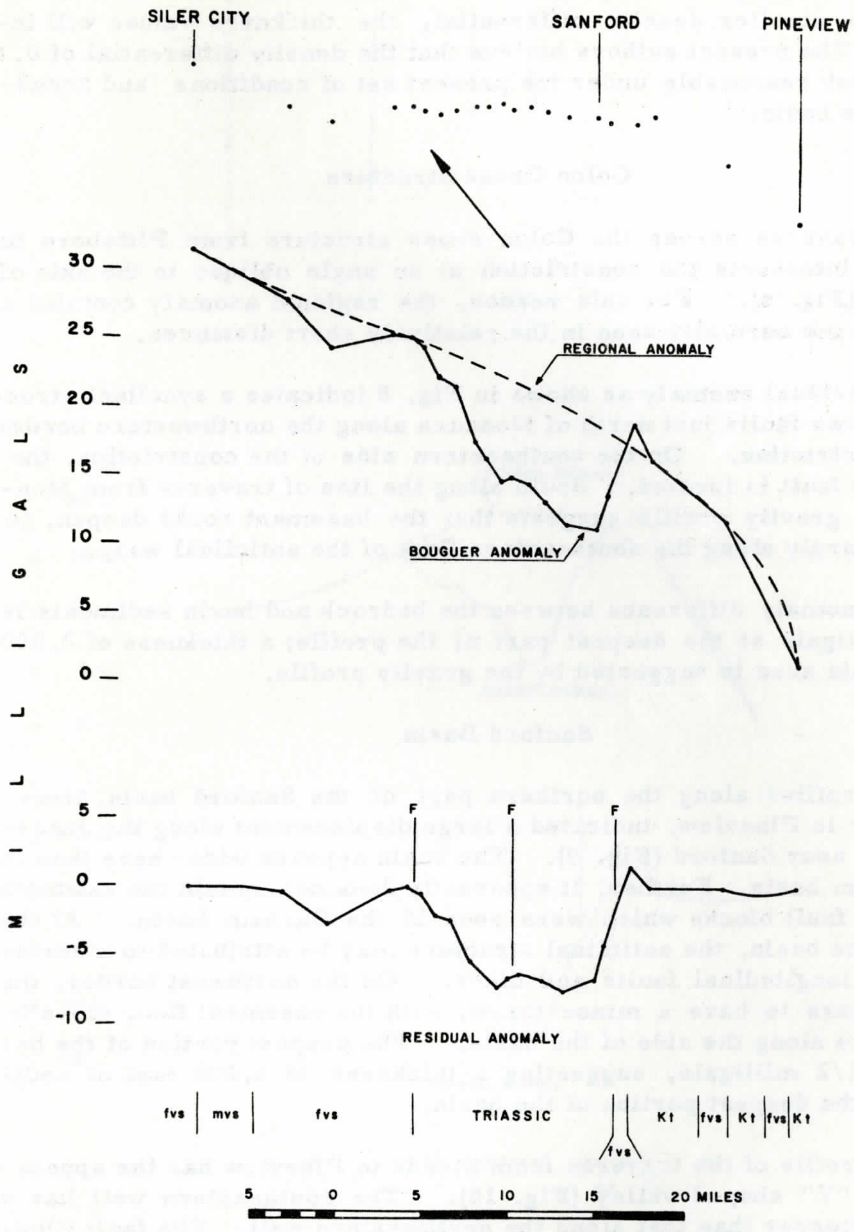

Figure 9. Gravity profile along traverse from Siler City through Sanford to Pineview.

sediments in the basin. Thus, a thickness of 6,500 feet is calculated for the sediments at this point. The reader should note that if one chooses a smaller density differential, the thickness values will increase. The present authors believe that the density differential of 0.1 is the most reasonable under the present set of conditions and knowledge of the basin.

Colon Cross Structure

The traverse across the Colon cross structure from Pittsboro to Pineview intersects the constriction at an angle oblique to the axis of the basin (Fig. 4). For this reason, the regional anomaly contains a contortion not normally seen in the relatively short distances.

The residual anomaly as shown in Fig. 8 indicates a synclinal structure with two faults just north of Moncure along the northwestern border of the constriction. On the southeastern side of the constriction, the Jonesboro fault is located. South along the line of traverse from Moncure, the gravity profile suggests that the basement rocks deepen, to ascend sharply along the southeastern flank of the anticlinal warp.

The anomaly difference between the bedrock and basin sediments is 2-1/2 milligals at the deepest part of the profile; a thickness of 2,000 feet for this area is suggested by the gravity profile.

Sanford Basin

The profiles along the northern part of the Sanford basin, from Siler City to Pineview, indicated a large displacement along the Jonesboro fault near Sanford (Fig. 9). The basin appears wider here than in the Durham basin. Further, it apparently does not contain the sawtooth pattern of fault blocks which were seen in the Durham basin. At the base of the basin, the anticlinal structure may be attributed to a series of known longitudinal faults and dikes. On the northwest border, the fault appears to have a minor throw, with the basement floor close to the surface along the side of the basin. The deepest portion of the basin is 7-1/2 milligals, suggesting a thickness of 5,800 feet of sediments in the deepest portion of the basin.

The profile of the traverse from Steeds to Pineview has the appearance of a "V" shaped valley (Fig. 10). The southeastern wall has a gradient steeper than that along the northwestern wall. The fault illustrated on the southeast is the Jonesboro fault; the fault on the northwestern side is a border fault mapped by Reinemund (1955). The anomaly difference between the adjacent bedrock and basin sediments is eight milligals. A thickness for the sediments in the deepest part of the basin therefore is estimated as 6,100 feet.

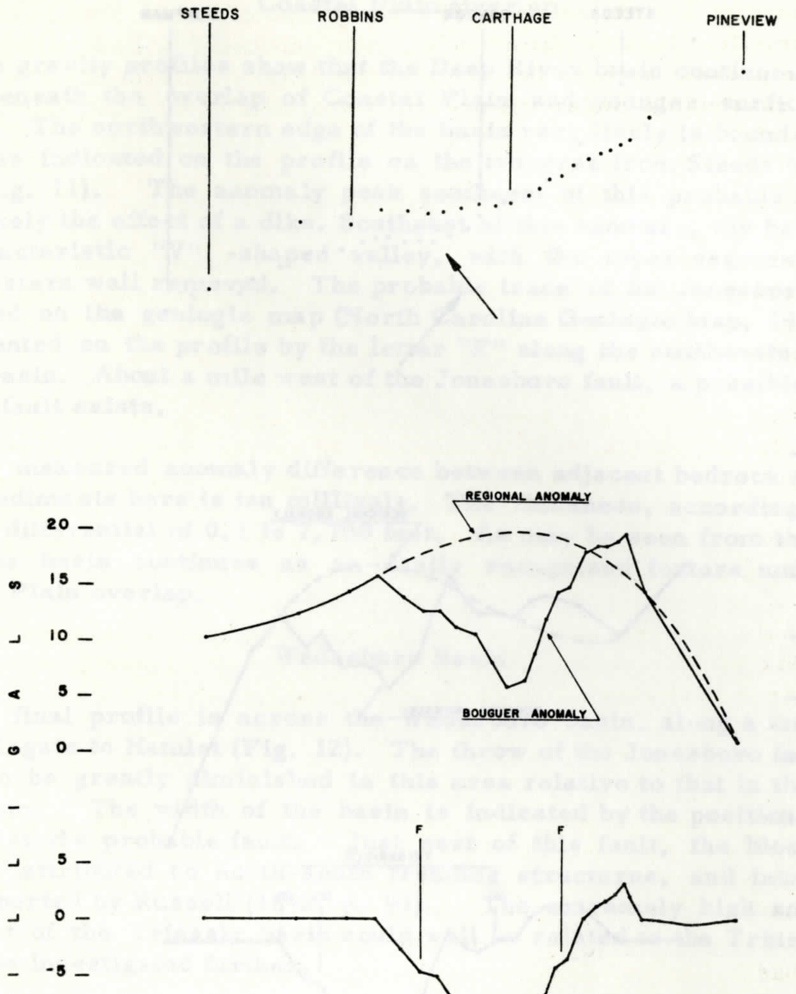

Figure 10. Gravity profile along traverse from Steeds through Carthage to Pineview.

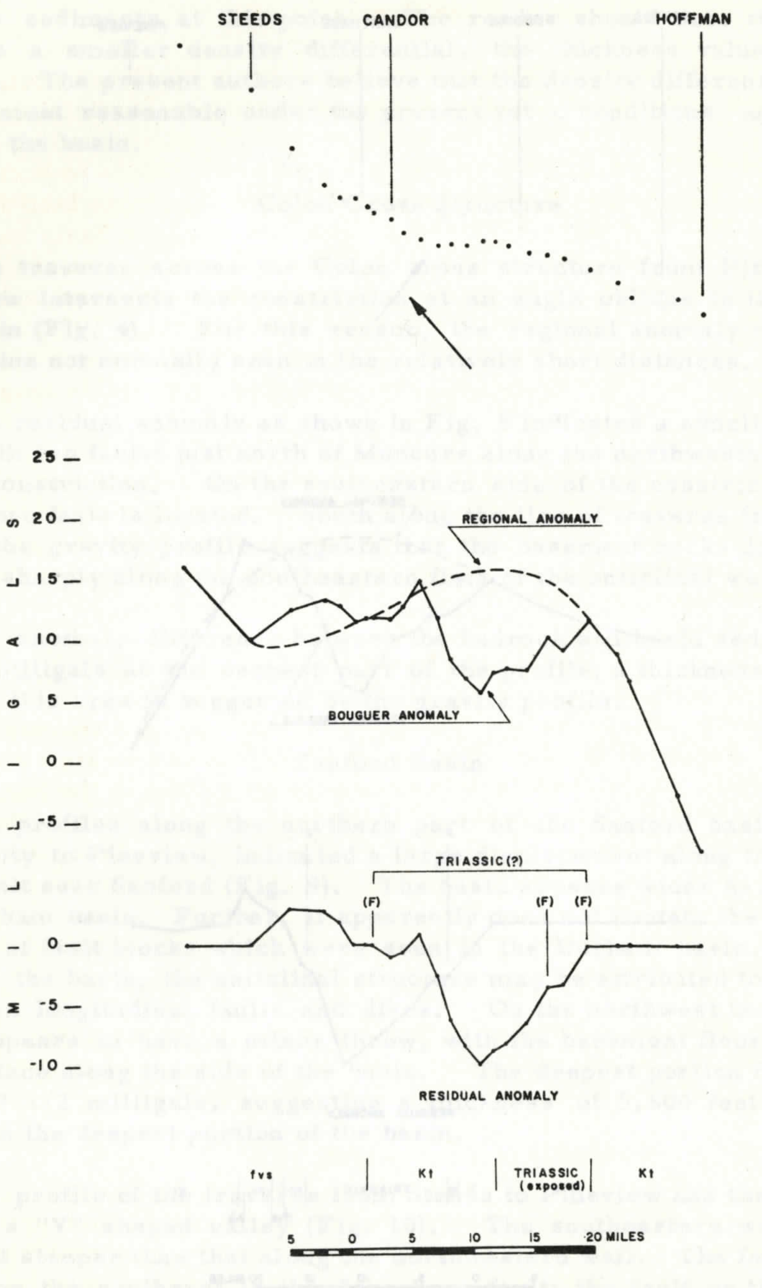

Figure 11. Gravity profile along traverse from Steeds through Candor to Hoffman.

Coastal Plain Overlap

The gravity profiles show that the Deep River basin continues southward beneath the overlap of Coastal Plain and younger surficial deposits. The northwestern edge of the basin very likely is bounded by a fault, as indicated on the profile on the traverse from Steeds to Hoffman (Fig. 11). The anomaly peak southeast of this probable fault is very likely the effect of a dike. Southeast of this anomaly, the basin has a characteristic "V" -shaped valley, with the upper segment of the southeastern wall removed. The probable trace of the Jonesboro fault indicated on the geologic map (North Carolina Geologic Map, 1958) is represented on the profile by the letter "F" along the southeastern side of the basin. About a mile west of the Jonesboro fault, a possible longitudinal fault exists.

The measured anomaly difference between adjacent bedrock and the basin sediments here is ten milligals. The thickness, according to the density differential of 0.1 is 7,700 feet. As may be seen from the profile, the basin continues as an easily recognized feature under the Coastal Plain overlap.

Wadesboro Basin

The final profile is across the Wadesboro basin, along a traverse from Wingate to Hamlet (Fig. 12). The throw of the Jonesboro fault appears to be greatly diminished in this area relative to that in the Sanford basin. The width of the basin is indicated by the position of the most westerly probable fault. Just east of this fault, the block-like mass is attributed to north-south trending structures, and intrusives first reported by Russell (1892, p. 95). The extremely high anomaly just east of the Triassic basin could well be related to the Triassic; it should be investigated further.

The anomaly difference between sediments of the basin and adjacent bedrock in this profile is five milligals. Hence, the thickness of sediments for this part of the basin is calculated to be 3,800 feet.

Summary of Profile Data

A comparison of the values obtained by the gravitational interpretation and the geologic interpretation, show that the two agree within reason. In all cases our values are less than those estimated by earlier geologists. Prouty (1931, p. 484) estimated the maximum thickness of the Triassic sediments in the Durham basin to be 10,000 feet. The maximum value which we have been able to calculate with a density differential of 0.1 is 6,500 feet. Reinemund (1955, p. 74), suggested that the thickness of sediments in the Colon Cross Structure would be

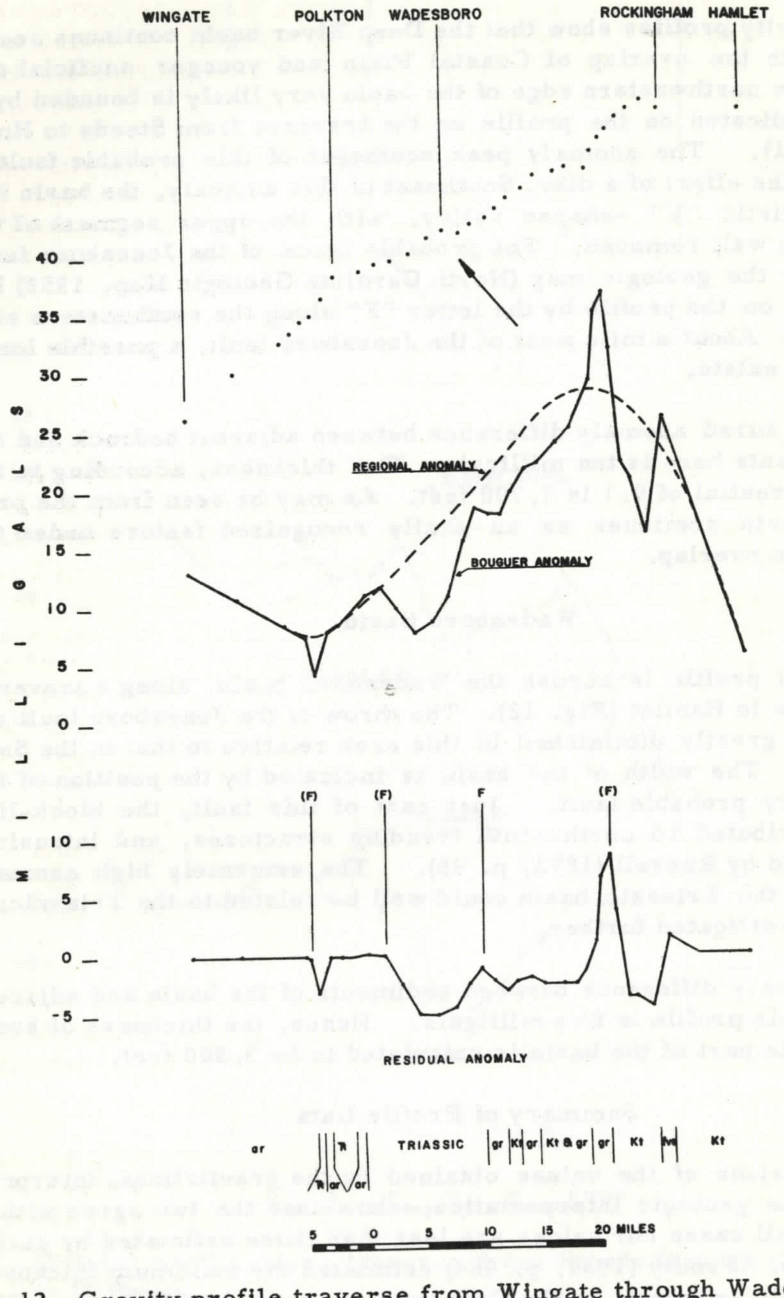

Figure 12. Gravity profile traverse from Wingate through Wadesboro to Hamlet.

between 4,000 and 5,000 feet. Our calculations show the thickness to be near 2,000 feet. Reinemund estimated (1955, p. 67), the combined thickness for sediments in the Sanford basin between 6,000 and 8,000 feet. Our values vary between 6,100 and 7,700 feet. No value for the depth of sediments in the Wadesboro basin has been published. Hence, we cannot compare our value of 3,800 feet with an earlier estimate.

Thus, if the geologic data is right, the density differential between granite on one hand, and sediments on the other is less than 0.1. However, if the gravity data is more nearly correct, the Triassic subbasins are not quite as deep as earlier workers have suggested.

CONCLUSIONS

Gravity studies made over the Deep River-Wadesboro Triassic basin suggest that this basin is not a significant gravitational feature. The basin may be outlined by profile maps, which are aligned normal to the axis of the structure. Simple Bouguer (d = 2.67) and Bouguer residual maps do not adequately outline the basin. Considerable variation and experimentation must be made with different densities in order to establish the proper differential between the basin sediments and surrounding rocks. There is considerable evidence that the difference in density between the rocks in the basin, and those outside of the basin, is either 0.1 or less than that value. Most of the interpretations must come from the profiles.

From a study of the profiles, the deepest parts of the basin appear to be in the northeastern and southeastern parts of the Durham basin, the central part of the Sanford basin, and the southern part of the Wadesboro basin.

The Sanford basin continues beneath the Coastal Plain overlap to the south, where it is constricted in a manner similar to the Colon constriction between the Durham and Sanford basins. This anticlinal warp is the Pekin constriction.

Gravity profiles were capable of delineating boundaries, intrusives, some faults, and the basement configuration of the Deep River-Wadesboro basin. The residual anomaly, if properly obtained, represents the shape of the basement rocks upon which the Triassic sediments rest. From such profiles, the northwestern half of the Durham basin exhibits a saw-toothed pattern of fault blocks, while the southeastern half is a graben-like trough which suffered the greatest displacement along the Jonesboro fault. The greatest displacement of the Jonesboro fault is clearly shown in the profiles across the Sanford basin.

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MIDDLE ORDOVICIAN STRATIGRAPHY

OF THE RED MOUNTAIN AREA, ALABAMA

by

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ABSTRACT

The Chickamauga "limestone" (Middle Ordovician) in Alabama may be divided into four units which correlate well with sections previously studied in adjacent states. Detailed stratigraphic and lithologic studies of the existing outcrops in the Red Mountain area have been made.

That section of predominantly Middle Ordovician strata in Alabama and southern Tennessee lying between the uppermost members of the Knox group and the base of the Red Mountain formation should be called the Chickamauga group rather than the Chickamauga "limestone." The group is composed of the lithostratigraphic units herein designated as Unit I, Unit II, Unit III, and Unit IV, in ascending order. Gross correlation of these units is suggested with units 1, 2, 3, and 4 as erected by John Rodgers in eastern Tennessee. Unit I is Chazy in age and is correlated with the Five Oaks and Lenoir limestones of Virginia and Tennessee and the Lenoir limestone of Cahaba Valley, Alabama. Units II and III are Black River in age and correlate with the Stones River group of the Central Basin of Tennessee and the Little Oak limestone-Athens shale sequence of Cahaba Valley, Alabama. Unit IV correlates with the Hermitage formation of the Central Basin of Tennessee and with the Martinsburg shale of Tennessee and Virginia, and is of Trenton age.

In the area investigated, the Chickamauga group lies directly on representatives of the Knox group or is separated from these representatives by the Attalla chert conglomerate. In many areas, the basal strata of the Chicamauga group is a dense, fine-grained limestone.

In others, progressively toward the northeastern extent of the area, the limestone is replaced by red to tan shale. In most areas, the lower contact is readily determinable.

The upper contact of the Chickamauga group is generally well-marked by the presence of the Red Mountain formation. In general, in the area studied, from northeast to southwest, the Red Mountain formation lies on progressively older sections of the Chickamauga group. This upper contact relationship is variously the result of thrust faulting and (or) erosion.

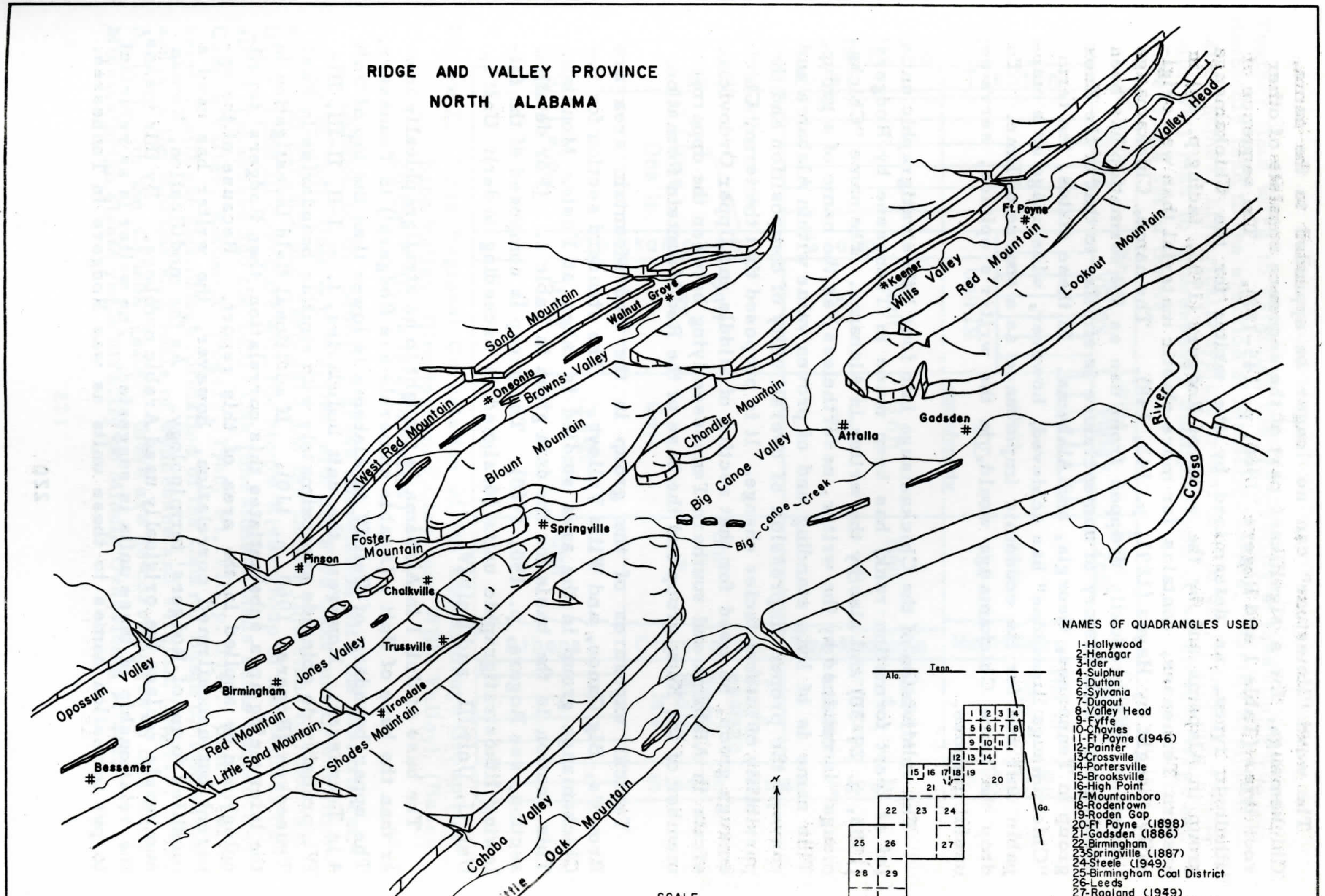
The Chickamauga group in Alabama lies within the Tennessee "basin" which includes an area from Gadsden, Alabama, to a point just north of Staunton, Virginia; Western extension of this "basin" includes the Central Basin portion of central Tennessee. A positive area (the Blount Mountains) existed in western North Carolina during a major portion of the epoch. The resulting clastic wedge, called Blount Delta by others, is recognized in Alabama. The incursion of the clastic wedge into the basin resulted in a gradual westward replacement of limestones by shales. Thus, the Chickamauga group, as exposed in Jones Valley and its northern extensions, is composed of two major lithofacies, a southwestern non-clastic facies and a northeastern clastic facies. Strata in Cahaba Valley, of lower Middle Ordovician age, are continuations of the northeastern clastic facies.

INTRODUCTION

This paper represents an excerpt from a doctoral dissertation presented to the faculty of the University of North Carolina. Many measured sections, faunal lists and other detailed information considered too lengthy for this report may be found in the dissertation (Rogers, 1960).

The area studied lies within the Ridge and Valley province. The Ridge and Valley province, as it is expressed in Alabama, is depicted schematically in Figure 1. An inset map in Figure 1 serves as a key to the quadrangles covered in this report.

Figure 1. Ridge and Valley Province, North Alabama. The map is drawn in such a way that structures are indicated by the diagrammatic topographic expression. Jones Valley and Opossum Valley, shown in the lower left hand side of the map are generally referred to as the Birmingham Valley or as the Birmingham Valley anticline.


RIDGE AND VALLEY PROVINCE
NORTH ALABAMA
Sand Mountain
Walnut Grove
West Red Mountain
Oneonta
Browns' Valley
Blount Mountain
Chandler Mountain
Big Canoe Valley
Big Canoe Creek
Attalla
Gadsden
Keener
Wills Valley
Red Mountain
Ft Payne
Lookout Mountain
Valley Head
Coosa River
Springville
Foster Mountain
Pinson
Chalkville
Trussville
Opossum Valley
Birmingham
Jones Valley
Irondale
Red Mountain
Little Sand Mountain
Shades Mountain
Bessemer
Cahaba Valley
Little Oak Mountain
SCALE
0 5 10 15 20 Miles
NAMES OF QUADRANGLES USED
1-Hollywood
2-Henagar
3-Ider
4-Sulphur
5-Dutton
6-Sylvania
7-Dugout
8-Valley Head
9-Fyffe
10-Chavies
11-Ft Payne (1946)
12-Painter
13-Crossville
14-Portersville
15-Brooksville
16-High Point
17-Mountainboro
18-Rodentown
19-Roden Gap
20-Ft Payne (1898)
21-Gadsden (1886)
22-Birmingham
23-Springville (1887)
24-Steele (1949)
25-Birmingham Coal District
26-Leeds
27-Ragland (1949)
28-Bessemer Iron District
29-Vandiver
30-Montevallo
31-Columbiana
Ala.
Tenn.
Ga.

The word "limestone" can no longer be appended to the name, Chickamauga, for a significant part of the sequence consists of other rock types (Table 1 and Rogers, 1960, p. 145-182). The sequence of lithologic types, as determined by the writer for the Chickamauga group in Alabama and by the work of Rodgers (1953, facing p. 66) in eastern Tennessee, contains far more clastic material than was originally thought by Hayes (1891, p. 143, 148). The name, Chickamauga limestone, has gradually dropped from use as the formation has been subdivided. This history of nomenclature is similar to that of the Knox group in Tennessee, Georgia, and Alabama. In these states, the term "Chickamauga limestone" has achieved, however, wide usage as a mappable unit and for its economic importance as a source of lime. To drop the name Chickamauga would, in the writer's opinion, serve no useful purpose.

The subdivision of the Chickamauga into four lithostratigraphic units (of at least formation rank) has been made in Tennessee by Rodgers (1953, p. 29-30) and also by the writer in Alabama. The name "Chickamauga" is retained by the writer, nevertheless, as the name of a group. This name is of long standing and of proven value within Alabama and conveys the proper impression of overall unity of composition and the possibility of lateral facies change. It is proposed that the term, Chickamauga group, be used for that section of Middle and Upper Ordovician strata in Alabama and southern Tennessee lying between the uppermost member of the Knox group and the base of the Red Mountain formation.

Typical exposures of the group in the Red Mountain area are Brown's, Big Canoe, and Wills Valleys. The standard section for the Chickamauga group in the area studied is taken at Foster Mountain. This section is the basis for the data given in Table 1. (For detailed section, see Rogers, p. 150, 1960). The group is composed of the following lithostratigraphic units (designed in ascending order): Unit I, Unit II, Unit III, and Unit IV.

The base of Unit I in Alabama is thought to be stratigraphically lower than the base of Unit 1 (Arabic numerals are Rodgers') in Tennessee. The upper boundary of Unit IV in Alabama is lower than the top of Unit 4 in Tennessee. However, the unit boundaries, i. e. I-II, II-III, III-IV, probably do coincide approximately with similar boundaries in East Tennessee (Rogers, 1960, p. 110). If additional field investigation in the intervening area substantiates this correlation, then Rodgers' terminology can be applied in the area of this report. Because of the apparent but unconfirmed correlation, however, the writer has used a modified form of Rodgers' terminology. As the modification, Roman numberals replace the originally used Arabic numbers. By this means, the relationship of these units is suggested. The writer is as reluctant to put formation names to these units as was Rodgers in Tennessee.

Further field work to establish the mappability of these units will undoubtedly lead to the erection of formation names. Hastily applied formation names, historically typical or workers in the Ordovician strata, could well lead to unnecessary multiplication of an already large and cumbersome set of terms.

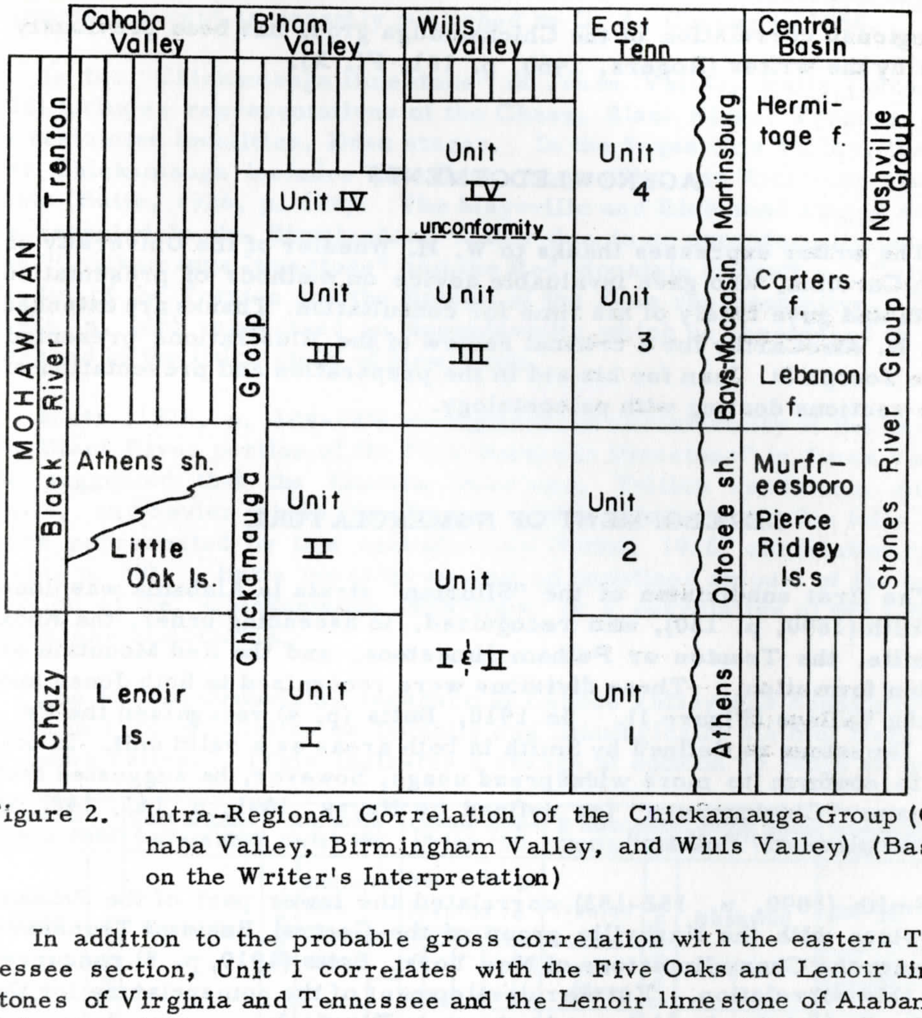


Figure 2. Intra-Regional Correlation of the Chickamauga Group (Cahaba Valley, Birmingham Valley, and Wills Valley) (Based on the Writer's Interpretation)

In addition to the probable gross correlation with the eastern Tennessee section, Unit I correlates with the Five Oaks and Lenoir limestones of Virginia and Tennessee and the Lenoir limestone of Alabama. Units II and III correlate with the Stones River group of the Central Basin of Tennessee and the Little Oak limestone-Athens shale sequence of Cahaba Valley, Alabama (Rogers, 1960, Pl. VII, p. 110). Unit IV correlates with the Hermitage formation of the Central Basin of Tennessee and with the Martinsburg shale of Tennessee and Virginia (Rogers, 1960, p. 128). In the Cahaba Valley, there are no correlatives of this unit; Mississippian strata rests directly on Middle Ordovician strata.

The Chickamauga group is composed of two parts: a calcareous and a clastic facies (Plate I and Figure 4). The latter was probably derived from the erosion of mountains produced by the Blountain phase of the Taconic Orogeny. They may also be considered to represent a more distant-from-shore facies of the section described in the Central Basin of Tennessee by Wilson (1949, p. 334-342).

Regional correlation of the Chickamauga group has been previously shown by the writer (Rogers, 1960, p. 101, Pl. X).

ACKNOWLEDGEMENTS

The writer expresses thanks to W. H. Wheeler of the University of North Carolina, who gave invaluable advice on methods of presentation of data and gave freely of his time for consultation. Thanks are extended to G. R. MacCarthy for a critical review of the illustrations presented and to Joseph St. Jean for his aid in the preparation and presentation of those sections dealing with paleontology.

DEVELOPMENT OF NOMENCLATURE

The first subdivision of the "Silurian" strata in Alabama was done by Smith (1890, p. 150), who recognized, in ascending order, the Knox dolomite, the Trenton or Pelham limestone, and the Red Mountain or Clinton formation. These divisions were recognized in both Jones and Cahaba Valleys (Figure 1). In 1910, Butts (p. 4) recognized the Pelham limestone as defined by Smith in both areas as a valid unit. In order to conform to more widespread usage, however, he suggested that the name "Chickamauga" (as defined by Hayes, 1891, p. 143, 148) be used in place of "Pelham".

Smith (1890, p. 152-153) correlated the lower part of the Pelham limestone with the Nashville group of the Central Basin of Tennessee and with the Chazy limestone of New York. Butts (1910, p. 5) concurred with this correlation. Further development of the nomenclature for the Middle Ordovician in Alabama is shown in Figure 3.

PREVIOUS WORK

Field work in the Paleozoic section of Alabama may be separated into two periods. The first period extended from 1890 to 1926, the second from 1956 to the present. The first period, initiated by E. A.

Smith, State Geologist for Alabama in 1890 saw the subdivision of the "Silurian" strata into the Knox dolomite, Pelham limestone, and Clinton formation. Inter-regional correlations were accomplished through the efforts of J. M. Safford, C. W. Hayes, E. O. Ulrich, and Charles Butts. With the completion of mapping of the Paleozoic region by Charles Butts and its publication in 1926, the first of these two periods was brought to a close. The second period has been static, with no addition of new information except as recently published by G. A. Cooper in 1956.

In the "Chickamauga limestone" of Jones Valley, Butts (1926, p. 128) includes representatives of the Chazy, Black River, Trenton, and in restricted localities, Eden stages. In the Sequatchie Valley, the upper Chickamauga includes also Eden, Maysville, and Richmond equivalents (Butts, 1926, p. 128). The Maysville and Richmond stages are not represented in the Birmingham Valley due to an unconformity between the "Chickamauga limestone" and the Red Mountain formation. Between the top of the Trenton and the Bottom of the Eden representatives, Butts (1926, p. 126) recognized an unconformity which he considered to correspond to the Utica shale of New York.

Butts (1926, p. 124-125) recognized an unconformity at the base of the Black River portion of the "Chickamauga limestone" in Jones Valley. He suggested that the Holston limestone, Tellico sandstone, Athens shale, and Sevier shale (the Blount group) of the Knoxville folio area were represented by this unconformity (Butts, 1926, correlation table facing p. 80). Butts considered that an undefined amount of the lower portion of the "Chickamauga limestone" is a correlative of the Lenoir limestone of Alabama.

The Middle Ordovician sequence in Cahaba Valley was considered by Butts in 1926 (p. 118) to be faunally and lithologically distinct from that of Jones Valley. (This indicates a change of opinion by Butts as to the

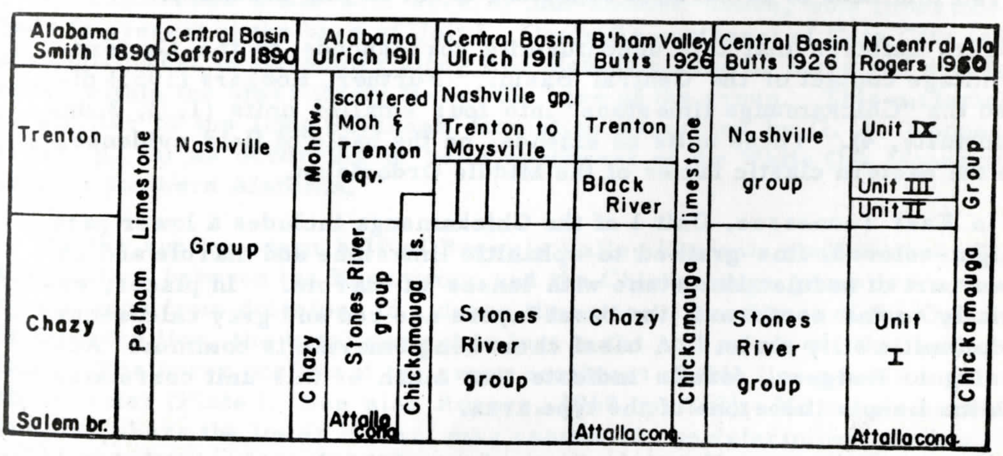


Figure 3. Development of Chickamauga Nomenclature.

application of the concept of lateral facies change. See Butts, 1910, p. 4.) The possibility of partial contemporaneity of deposition between Jones Valley and Cahaba Valley (considered by Butts, 1926, p, 118, as two structurally separated basins) was accepted.

G. A. Cooper (1956) refers to sections at Attalla and Gate City, Alabama, in Jones Valley and its northern extension. In the Cahaba Valley area, Cooper (1956) recognized the Christiania beds (Upper Lenoir, also Arline formation of G. A. Cooper, 1956) as being the lowest member of the Little Oak limestone. The Pratt Ferry formation (B. N. Cooper and G. A. Cooper in G. A. Cooper, 1956, p. 85) and the Columbiana shale (Athens shale, as widely recognized by workers in Alabama) overlying the Christiania member, G. A. Cooper considered to be correlatives of the Little Oak limestone (B. N. Cooper and G. A. Cooper in G. A. Cooper, 1956, p. 57). This correlation has been previously recognized by the writer (Rogers, 1960). Correlation of the Little Oak limestone - Athens shale (Columbiana shale) sequence to Unit II of the Chickamauga group of Jones Valley is shown in Figure 2.

The work of John Rodgers (1953, p. 66-67) in East Tennessee has furnished a guide for the subdivision of the Chickamauga group in Alabama, as previously mentioned. He writes:

> "It is apparently possible everywhere in East Tennessee to divide the Chickamauga limestone and its equivalents into two major units by means of a combination of persistent key beds somewhat above the middle of the limestone where most extended. The boundary chosen marks a break between generally fine-grained and fairly light-colored, slightly silty limestone with scattered though locally abundant fossils below, and medium-grained dark crystalline limestone packed with brachiopod shells of the groups Resserella ("Dalmanella"), Sowerbyella and Rafinesquina above . . . . In many areas one or two thin beds of calcareous sandstone occur at this boundary."

Rodgers believes that this unconformity corresponds to the Carters-Hermitage contact of the Central Basin. Further, Rodgers (1953) divided the "Chickamauga limestone" into four smaller units (1, 2, 3, unconformity, 4). These units he extends, on the basis of field evidence, into the eastern clastic facies of the Middle Ordovician.

In East Tennessee, Unit 1 of the Chickamauga includes a lower part of light-colored, fine-grained to aphanitic limestone and marble and an upper part of nodular limestone with lenses of marble. In places, especially to the northwest, the basal layers are red and gray calcareous or dolomitic silty shale. A basal chert conglomerate is common. According to Rodgers, fossils indicate that much of this unit correlates with the Lenois limestone of the type area.

The upper part of Unit 1 has a variety of lithologies: mottled red and pink limestone; coarsely crystalline red, pink, and white limestone; dark limestone; and cherty limestone. Rodgers suggests a possible correlation of this upper part of Unit 1 with the Holston limestone (Rodgers, 1953, p. 91).

Unit 2 includes several types of shaly and argillaceous limestone and limey shale with interbedded layers of pure dense limestone and marble. The pure limestone is most persistent below the middle of the unit. The total thickness of the unit is from 800-1,000 feet and in part correlates with the Sevier formation. Stromatocerium and Hesperorthis are common in the uppermost part of the unit. The upper portion probably correlates with the Ottosee shale (Rodgers, 1953, p. 88-89).

Unit 3 is more consistent, having a sequence of pure to silty limestone interbedded with siltstone and shale. Bentonite occurs in the upper strata of this unit. This unit correlates roughly with parts of the Moccasin and Bay formations (Rodgers, 1953, p. 89, 91).

Unit 4 consists of fairly dark, blue to gray, well-bedded or platy or nodular limestone, generally medium-grained and commonly interbedded with thin shale partings. This unit is correlated with the Martinsburg shale. (Rodgers, 1953, p. 95-97).

DESCRIPTION OF BOUNDARIES

Basal Contact

In several areas where the base of the Chickamauga is exposed, no Attalla chert conglomerate is found. At Foster Mountain, for instance, a red calcareous shale with several thin-bedded, dense, blue limestone beds is present at the base of Unit I. One mile northeast of Gate City and also northwest of Bessemer along Red Mountain, one or more red shales occur within the lower thirty feet of the base of the group. This material is similar to the Long Savannah formation described by G. A. Cooper (1956, p. 76) as occurring in belts northwest of the White Oak Mountain fault in southern Alabama.

In the southwestern half of Brown's Valley (Oneonta southwestward), the contact between the Knox group and the Chickamauga group is marked by a change from dolostone to a dense limestone. Northeast of the Oneonta-Gadsden line, the basal contact is lost in the soil cover of the valley floor. The lower portion of the group northeast of this line passes into a shale facies (Plate I, See also Rogers, 1960, p. 262). No conglomerate is noted where the lower contact may reasonably be determined nor has it been observed by the writer in the clastic facies of Unit I.

Upper Contact

In the Birmingham area, the upper contact of the Chickamauga group is generally well-marked, although the exact contact may be obscured by faulting and (or) the presence of a thick covering of float material derived from the Red Mountain formation (Rogers, 1960, p. 262). In the northeastern extension of Jones Valley the clastic facies of the Chickamauga group grades, maintaining an apparent conformable relation, into the Red Mountain formation. It seems probable that in this northeastern extension and in the parallel areas (northeastern Brown's Valley) that the Sequatchie formation will eventually be recognized. The relationships of the contact between the Red Mountain and the Chickamauga group is obscured along the face of Red Mountain in Jones Valley by a low angle thrust fault (the Birmingham thrust fault) (Rogers, 1960, p. 14).

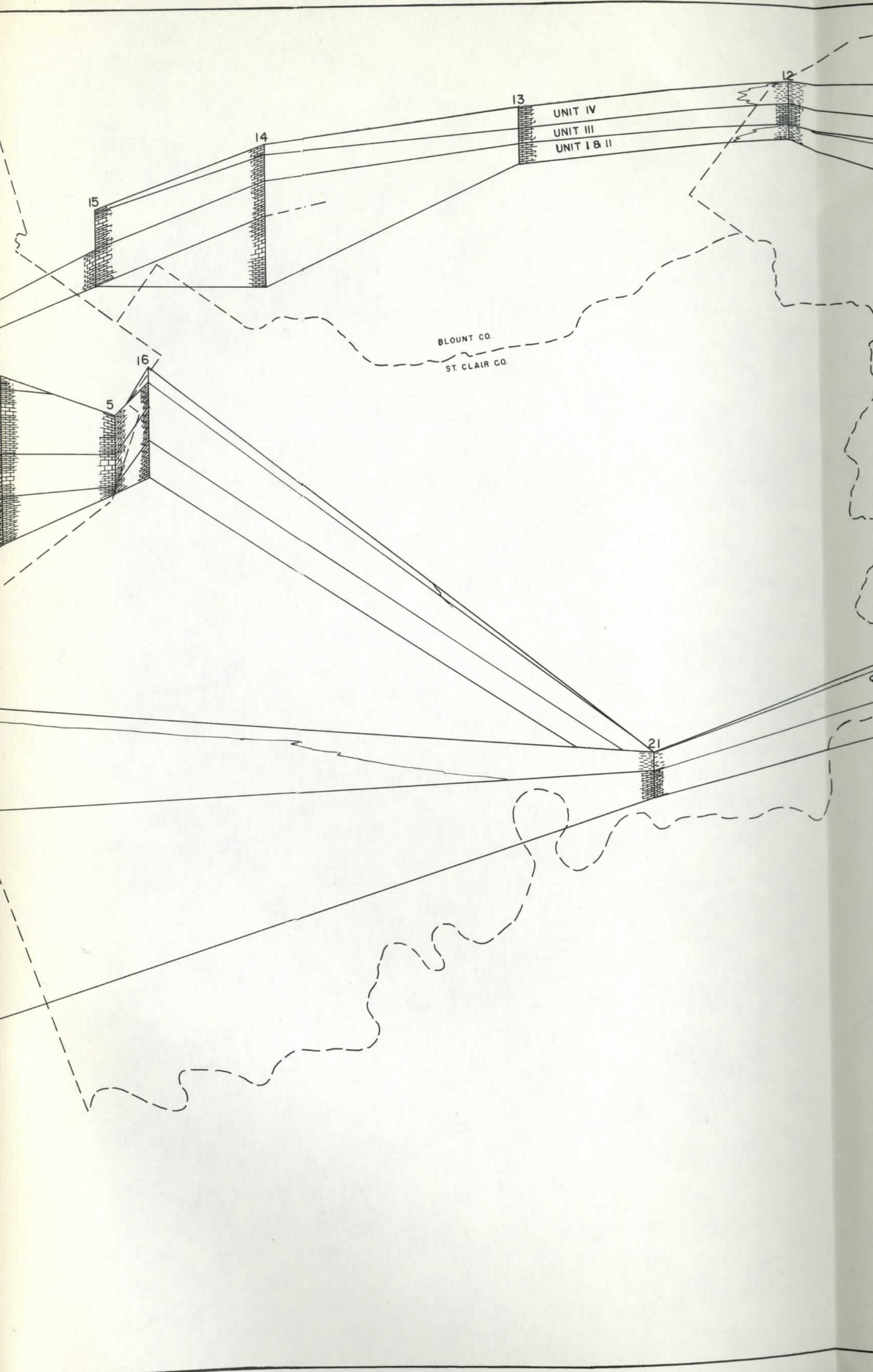
The thrust fault extends from Bessemer, Alabama, to the vicinity of Chalkville, Alabama, where it dies out in an assymmetrical anticline, Cahaba Mountain. The thrust plane, rather than erosion, accounts for the absence of the Chickamauga group in some area (intersection of U. S. Highway 31 with Red Mountain) or a reduced thickness of other areas. In certain places some of the lower part of the section has been cut out (Sections 3 and 7); in other areas, the upper part of the section has been cut out (New U. S. Highway 78). The thrust plane is apparently undulatory.

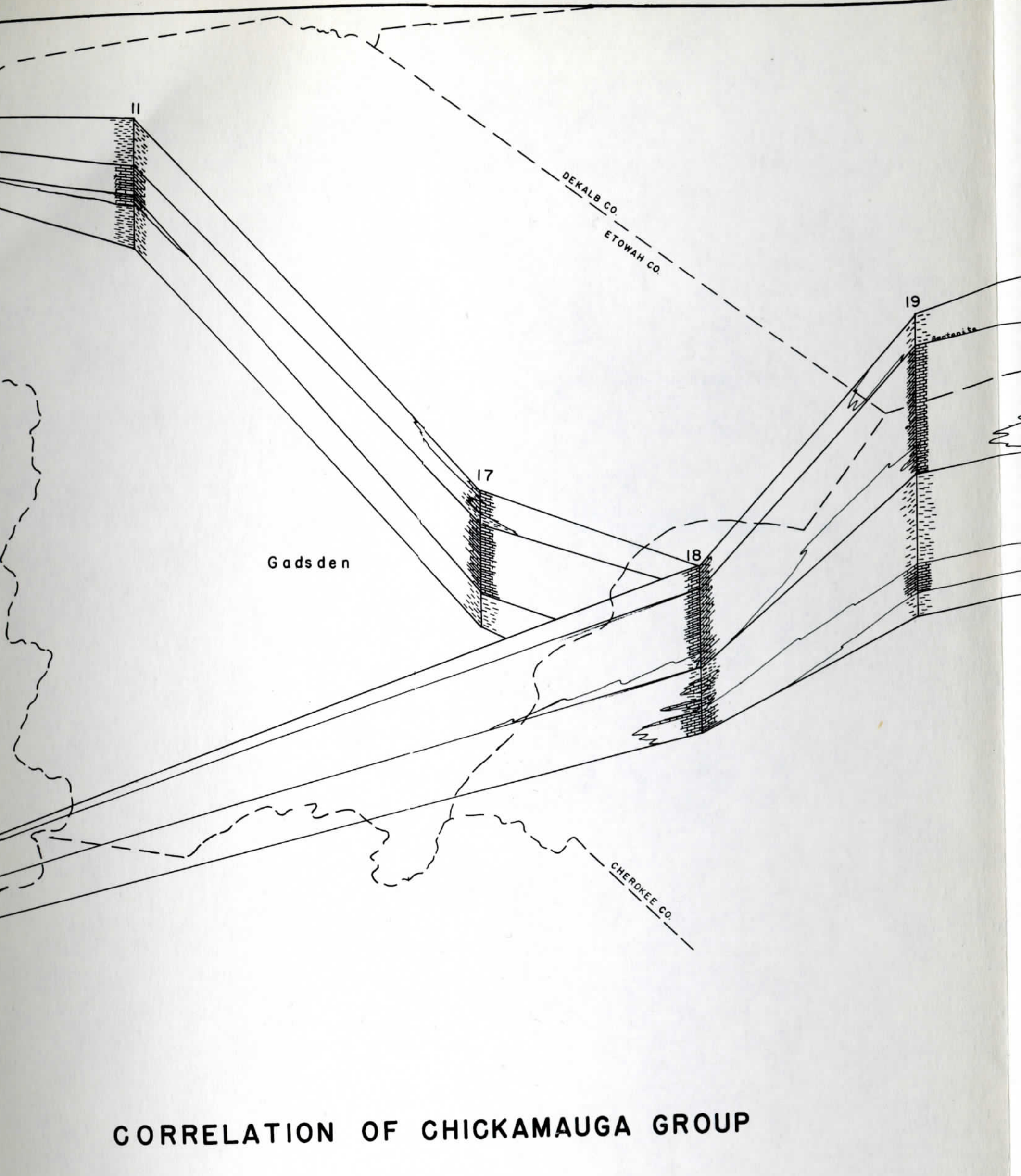
The northwestern side of Brown's Valley, the southeastern side of Wills Valley, and at the southwestern end of Blount Mountain, does not present structural difficulties. Complete sections of the Chickamauga group are found in these areas (Rogers, 1960, Pl. V, p. 42).

The southeastern side of Brown's Valley southwest of the Jefferson County-St. Clair County line and the northwestern side of Big Canoe Valley and Wills Valley are largely lacking in suitable sections of the Chickamauga group with the exception of the region in and around the southwestern end of Blount Mountain. Faulting has placed the shale and (or) the limestone facies of the Conasauga formation in contact with the Pennsylvanian, Pottsville formation.

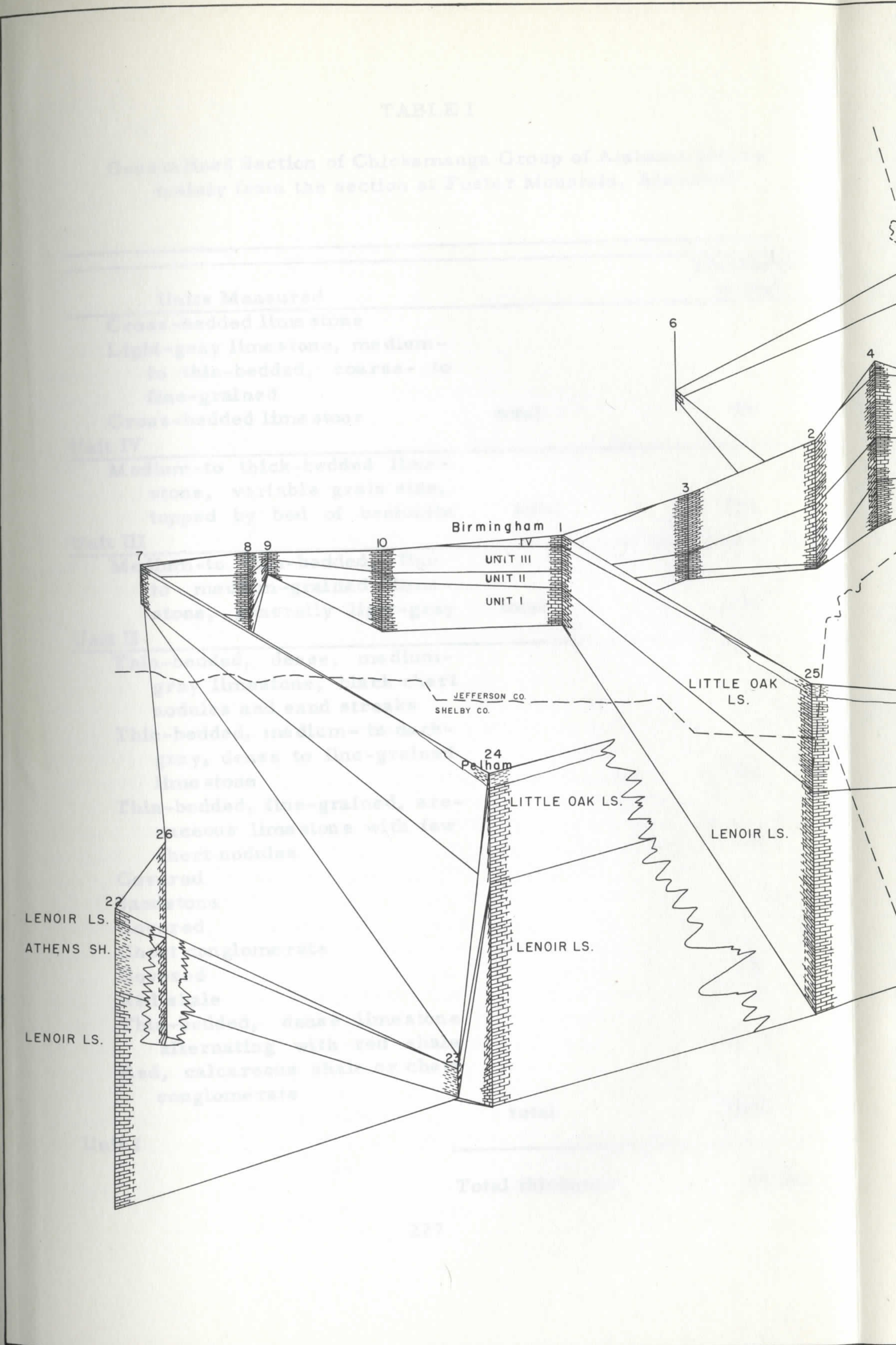
SUBDIVISION OF THE CHICKAMAUGA GROUP

The Chickamauga group, as previously stated, is subdivided in Ala-


12
13
UNIT IV
UNIT III
UNIT I & II
14
15
BLOUNT CO.
ST. CLAIR CO.
16
5
21



CORRELATION OF CHICKAMAUGA GROUP



6
4
2
3
Birmingham 1
IV
UNIT III
UNIT II
UNIT I
7
8
9
10
25
LITTLE OAK LS.
JEFFERSON CO.
SHELBY CO.
24
Pelham
LITTLE OAK LS.
LENOIR LS.
LENOIR LS.
26
22
LENOIR LS.
ATHENS SH.
LENOIR LS.
23

PLATE I

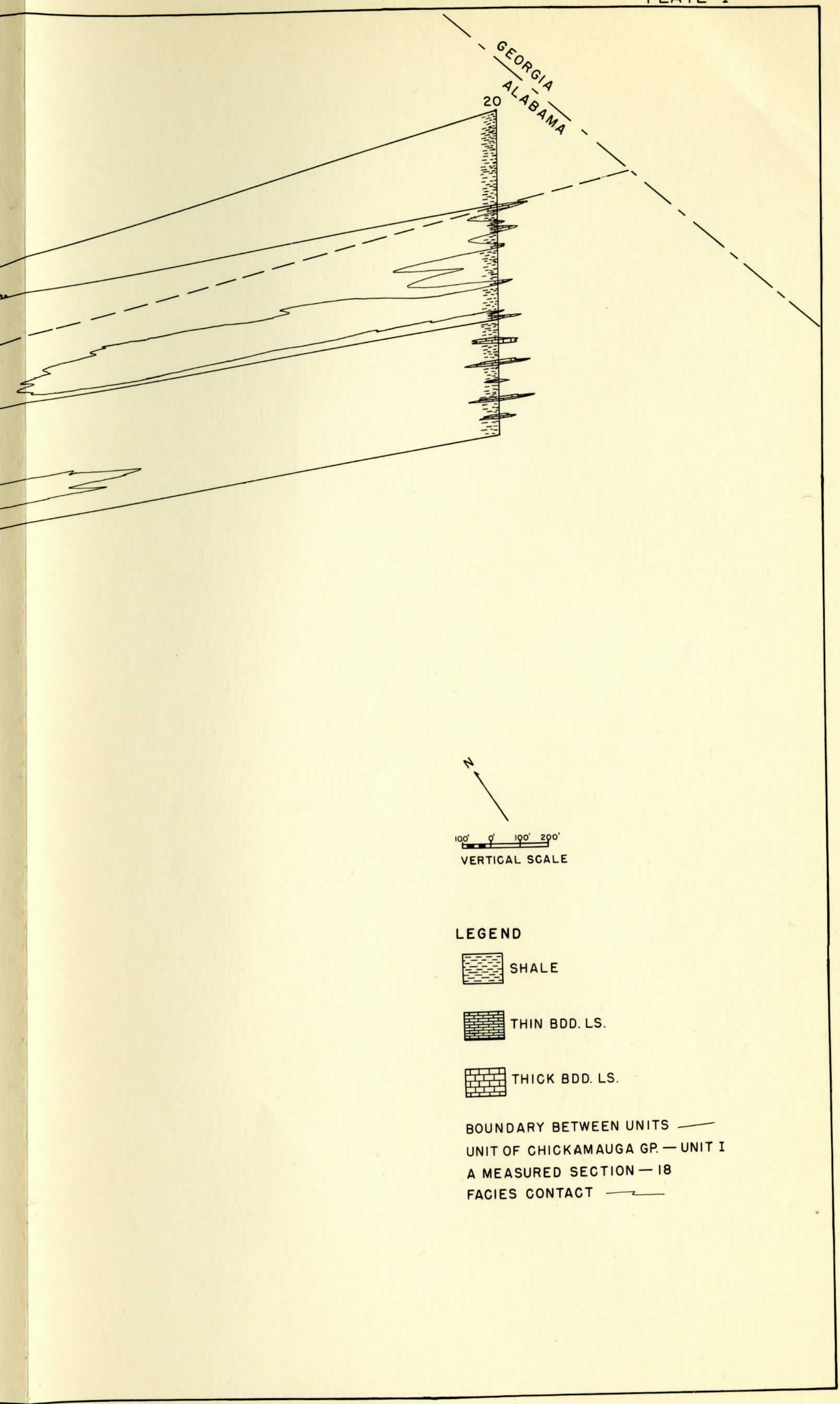

GEORGIA
ALABAMA
20
N
100' 0' 100' 200'
VERTICAL SCALE
LEGEND
SHALE
THIN BDD. LS.
THICK BDD. LS.
BOUNDARY BETWEEN UNITS
UNIT OF CHICKAMAUGA GP. — UNIT I
A MEASURED SECTION — 18
FACIES CONTACT

TABLE I

Generalized Section of Chickamauga Group of Alabama (drawn mainly from the section at Foster Mountain, Alabama)

Units Measured		Thickness in feet
Cross-bedded lime stone		
Light-gray limestone, medium- to thin-bedded, coarse- to fine-grained		
Cross-bedded lime stone	total	43
Unit IV		
Medium-to thick-bedded lime-stone, variable grain size, topped by bed of bentonite	total	235
Unit III		
Medium-to thin-bedded, fine- to medium-grained lime-stone, generally light-gray	total	237
Unit II		
Thin-bedded, dense, medium-gray limestone, black chert nodules and sand streaks		5
Thin-bedded, medium- to dark-gray, dense to fine-grained lime stone		160
Thin-bedded, fine-grained, are-naceous lime stone with few chert nodules		6
Covered		4
Sandstone		1
Covered		4
Chert conglomerate		1
Covered		29
Red shale		6
Thin-bedded, dense limestone alternating with red shale		6
Red, calcareous shale or chert conglomerate		3
	total	225
Unit I		
	Total thickness	740 feet

bama by the writer into four distinct lithostratigraphic units. These entities are referred to as Unit I, Unit II, Unit III, and Unit IV. Unit I is Chazy in age, Units II and III Black River in age, and Unit IV Trenton and perhaps lower Eden in age. Units I and II lose their distinction in the shaly facies of the group in the northeastern portion of the area studied (Plate I and Figure 4).

Criteria for the separation of the Chickamauga group into distinguishable units are the presence in the section of: cherty limestone, cross-bedded limestone (several occur within the sections), and an upper bentonite bed. Insoluble residue analyses, while not of aid in unit correlation, indicate a progressive increase of clastic material from southwest to northeast.

Though of a variable lithology, the Chickamauga group has two major facies in Alabama. The shale facies of the group in Alabama is located to the northeast of a line drawn from a point just north of Oneonta, Alabama, to Gadsden, Alabama. (Pl. I). To the southwest of this line, the dominant aspect of the group is limestone. In either region, no one section contains all lithologic variations of the group (Rogers, 1960, Pl. V, p. 42).

In north Alabama, there are two areas with a high clastic ratio (Rogers, 1960). The area with the greatest increase in clastic material begins in the Gadsden area. This clastic facies of the Chickamauga group continues into northwest Georgia and East Tennessee. This clastic facies probably includes representatives of the Blount group with the Athens shale at the base, and perhaps extends upward to include equivalents of the Martinsburg formation. Formation names such as Ottosee, Tellico, Sevier, and Athens have been inconsistently used by workers in this region. While representatives of these named formations probably occur in this clastic facies, it seems preferable, because of inconsistent usage, not to use these names.

In the southwestern part of the area studied, the Foster Mountain section (Rogers, 1960, p. 150) is considered by the writer to be a standard section. All important sections are shown in detail in Plate V (Rogers, 1960, p. 42) and are generalized in Plate I of this report. All sections measured are given in an earlier report by the writer (Rogers, 1960, Appendix A). For the northeast region, no typical section can be selected due to the rapidly changing character of the group in that direction.

LITHOLOGIC DESCRIPTION

Unit I

Unit I lies unconformably upon the Knox group. (The Knox group in the Birmingham Valley is terminated by the last massive dolostone in the section.) In Cahaba Valley, three dolostone beds, two to four feet thick, are recognized in the limestones which are upper Knox equivalent. Unit I is initiated by either the Attalla chert conglomerate as in the Red Mountain area, red calcareous shale as at Foster Mountain, argillaceous limestone as in southwestern Brown's Valley, or buff-colored shale as in northeastern Brown's and Wills Valleys. The top of Unit I is determined by the presence of a thin- to medium-bedded, sandy limestone with chert nodules. The cherty to arenaceous and argillaceous character of the upper contact in the southern area is a fairly persistent feature. The intervening strata are generally thin- to medium-bedded limes with varying amounts of chert. In general, the lower portions of the Unit have a dense texture and are dove-gray in color, while the upper portion becomes argillaceous and nodular. The lower portion may be mottled-red, pink, or green in the more southwestern areas of Jones Valley. The mottled character is not present in Units I and II in the northeastern portion of the area. Section 11 (Rogers, 1960, p. 162) shows an integration of these two units in that area.

Birmingham Valley Belt. Unit I at section 7, if present, is obscured by a heavy cover of float material composed of boulders and soil derived from the overlying Chickamauga group and Red Mountain formation. The first exposure below the lowermost exposure of the Chickamauga group (assigned to Unit II on the basis of fauna) is a fine-grained, cherty dolostone belonging to the Knox group (probably Copper Ridge). The vertical thickness of the covered interval is about 20 feet. If present, Unit I must lie within this 20 foot interval. There is no lithologic or faunal evidence in the float material that Unit I is present. One of three possibilities may explain this situation: (1) Unit I has been faulted out as a result of movement along the Birmingham thrust fault; (2) Unit I is not present here because of non-deposition; (3) Unit I was removed by erosion prior to the deposition of Unit II. On the basis of the known existence of the Red Mountain thrust fault in the area, possibility No. 1 is considered by the writer to be the most likely.

Several miles northwest of section 7 at the Tennessee Coal and Iron Company mines (section 8) (Rogers, 1960, p. 157), the lower portion of Unit I is exposed. The remainder of the section is covered by Red Mountain float or is obscured by deep chemical weathering.

That portion of Unit I present at section 8 has a thickness of approximately 114 feet. The first 60 feet is composed of mottled-red to yellowish-gray limestone, including several thin beds of a fine-grained red limestone. The entire lithologic character of the lower portion of Unit I in section 8 is similar to that of the Lenoir limestone of the Cahaba Valley and the Lenoir limestone of northwest Georgia. The upper 40 feet of this exposure is composed of medium-bedded, light-gray, dense limestone which is very similar in appearance to vaughanite (Butts, 1926, p. 101). The lower portion of the unit is thin-bedded. Calcite veins are common throughout the extent of the exposure.

At section 9 (located approximately 1 mile northwest of section 8), while Unit I is known to be present from evidence in the float material, it is not exposed. The Birmingham thrust fault is thought by the writer to be present in that portion of section 9 below Unit II.

The first relatively complete exposure of Unit I is found in section 10. Section 10 is located approximately 1 mile southwest of section 1. In this exposure, the contact between the Knox group and the Chickamauga group is covered. The writer estimates that the lower 9 feet of Unit I is thus hidden. Almost the entire exposure of the limestone in this section assigned to Unit I is dense and medium- to thin-bedded. A few shale partings and calcite veins are disseminated through the entire unit. The mottling, red and yellow, noted in section 8 is found within the first 40 feet of this exposure. Scattered green chert nodules and stringers are noted beginning 70 feet up in the section and extending upward for approximately 30 feet. The chert nodules and stringers are parallel to the bedding planes of the limestone. Above the chert horizon, the limestone changes character from that noted in the lower part of the sequence, becoming fine-grained, dark-gray, and nodular

The top of Unit I in section 10 is marked by a 15 foot sequence of fine-grained, arenaceous, cherty limestone. In section 9, only the upper contact of Unit I is exposed. Here, in section 10 as in section 9, the rock composing what has been designated as the upper contact sequence of rock is a fine-grained, arenaceous, cherty limestone. Immediately above the contact, in Unit II, there is a 1 inch thick coquina composed of shell fragments of <u>Sowerbyella</u>.

Section 1, located 1/4 mile north of old U. S. Highway 78 at Irondale, Alabama (Gate City section), has only a partial exposure of Unit I. The lower beds of Unit I exposed here lie on conglomerate composed of chert pebbles cemented with chert. The conglomerate is about 3 feet thick. This conglomerate represents the Attalla chert conglomerate. Overlying the conglomerate is a 4 foot sequence of red, calcareous shale similar to that found at the base of section 4 (Foster Mountain)

(Rogers, 1960, p. 150). The remainder of the lower portion and the upper 21 feet of Unit I are not exposed in this section.

The middle sequence of Unit I in section 1 is composed of thin- to thick-bedded, fine-grained limestones which have a few calcite veins. Several small green chert nodules are noted. Field evidence (great variation in strike of beds, presence of breccia) indicates that the Birmingham thrust fault is located in and accounts for the poorly exposed portion of the lower part of Unit I. Three quarters of a mile southwest of this section, on new U. S. Highway 78, the contact between the Knox group and the Chickamauga group is occupied by a chert breccia which has been formed as a result of thrust faulting. Here Units I-III are missing. Unit IV separates the Knox group from the Red Mountain formation.

Section 2 (Camp Crosby), located approximately 15 miles northwest of section 1 on Red Mountain, has an attenuated exposure of Unit I. The lower sequence of beds of Unit I are somewhat obscured by soil cover. The unit at this exposure is composed of fine-grained to dense, thin- to medium-bedded, light-gray limestone. Calcite veins and shale partings are common. Here, the upper contact of Unit I is marked by a sequence of cherty, nodular limestone.

Section 4 (Rogers, 1960, p. 150) is the most complete section of the Chickamauga group present in the Birmingham Valley. The base of the section is marked by a thin-bedded, mottled-red limestone which grades upward into a section 15 feet thick of red, fissile shale beds separated irregularly by thin beds (2-3 inches thick) of dense, light-gray limestone. The basal sequence of Unit I rests on the upper cherty members of the Knox group. Forty-one feet above the base of the Unit there occurs a chert conglomerate one foot thick.

The middle sequence of Unit I in section 4 is composed of fine-grained to dense, sandy limestones which have scattered, small chert nodules. The top of Unit I is marked by fine-grained, medium- to thin-bedded, arenaceous limestone with black chert nodules.

Section 5 is located on Cahaba Mountain. (Cahaba Mountain is the northwestern extremity of Red Mountain.) Due to the fortuitous structural circumstances of this area, a nearly complete stratigraphic sequence can be described. The lower contact between the Knox group and the Chickamauga group has been etched into relief by a combination of chemical weathering and differential erosion. While fresh material of the Knox group is not seen, the contact between the two groups is distinct. There is no measurable difference in dip between the two groups, and there is evidence of only minor erosion of the Knox group prior to the deposition of the Chickamauga group. An additional distinction of this section is that the Chickamauga group here is initiated by thin-bedded, light-gray limestone. Neither the Attalla chert conglomerate nor the red calcareous shales previously discussed are present. Lithologically, Unit I in this section is composed of a sequence of thin-bedded, dense to fine-grained limestone. The top of the unit (35 feet thick) is drawn at the top of a medium-bedded, fine-grained limestone sequence 5 feet thick which has scattered dark-gray chert nodules.

Brown's Valley Belt. Section 15 is located approximately 25 miles southwest of Oneonta, on West Red Mountain. It is not possible to determine if Unit I is present, as few fossils are found in the lower portion of the section and there are none of the distinctive lithologic characteristics usually recognized in Unit I. If Unit I is present, it should occur below the 3 inch thick bed of coarse-grained limestone located 33 feet up from the bottom of the section. This may correlate with the coarse-grained limestone described at the top of Unit I in section 5. Immediately below this coarse-grained limestone in section 15 is found a bed of crinoidal limestone 2 inches thick. In Unit II of sections 4, 7, and 9 in the Birmingham Valley, a similar crinoidal limestone is found.

From section 14, located southwest of Oneonta in Tidewell Hollow on West Red Mountain, toward the northeast (i.e. sections 11, 12, and 13), the Chickamauga group increases in thickness and clastic ratio. Unit I in this section is approximately 305 feet thick.

In addition to an increase in the overall thickness of Unit I in Brown's Valley, the thickness of the individual beds increases. The beds of light- to medium-gray limestone in this unit, are in general, medium- to thick-bedded and fine-grained. Two, one foot thick, beds of mottled-red argillaceous limestone occur at distances of 40 and 45 feet above the base of the section. These beds are similar to beds described in the lower member of Unit I in the Birmingham Valley. The middle member of Unit I in this section is medium- to thick-bedded, fine- to medium-grained limestone. The upper member is a thin- to medium-bedded, fine- to medium-grained limestone. The top of Unit I is drawn at the top of a sequence of medium-bedded, fine-grained, nodular, cherty limestone about 9 feet thick and directly beneath the first sequence of cross-bedded limestone in the sequence.

Traced northeast to section 13 (Table 2), one mile northeast of Oneonta on West Red Mountain, Unit I grades into the shale facies of the Chickamauga group. The unit is poorly exposed at this point due to slumpage of overlying materials and the rapid decomposition of the shale members into soil. In the soil on the valley floor, there are several boulders of mottled pink limestone, which is similar to the sequence described in the lower part of Unit I in section 14. A few green chert nodules are to be found in the soil covering this unit. They were probably derived by the weathering of cherty limestone belonging to the upper part of Unit I.

Table 2

Section 13. One Mile North of Oneonta, Alabama

	Strata	Thickness (in feet)
	Red Mountain Formation	
	Covered	19
	Thin-bedded, medium-grained, medium-gray limestone	1
	Covered	9
	Thin-bedded, medium-grained, medium-gray limestone	2
	Covered	9
	Thin-bedded, fine-grained, medium-gray argillaceous limestone	5
	Covered	5
	Thin-bedded, fine-grained, medium-gray argillaceous limestone	1
	Covered	4
	Thin-bedded, fine-grained, medium-gray argillaceous limestone	1
	Covered	5
	Thin-bedded, fine-grained, medium-gray argillaceous limestone	1
	Covered	6
	Thin-bedded, fine-grained, medium-gray argillaceous limestone	1
	Covered	6
Unit IV	Thin-bedded, fine-grained to dense, medium-gray limestone with shale partings	1

Table 2 (continued)

	Strata	Thickness (in feet)
	Medium-bedded, fine-grained medium-gray limestone	4
	Covered	12
	Medium- to thick-bedded, fine-grained to dense, light-gray limestone. Several very argillaceous beds near bottom of unit. Homotrypella.	17
	Thin-bedded, medium-grained, medium-gray limestone. Shale partings common.	2
	Thin-bedded, fine-grained, medium-gray limestone alternating with shale	2
	Medium- to thick-bedded, fine-grained, light-gray limestone	3
	Covered	17
Unit III	Thick-bedded, fine-grained, light-gray limestone. Streptelasma.	2
	Thin-bedded, fine-grained, light-gray arenaceous limestone Cross-bedded	2
	Covered	2
	Medium-bedded, fine-grained, medium-gray limestone	2
	Covered	3
	Thin-bedded, dense, light-gray limestone	5
	Covered	22
	Medium-bedded, dense, light-gray argillaceous limestone	12
	Covered	22
	Medium-bedded, medium grained, medium-gray to reddish limestone. Some sandy streaks. Several 6" beds of coarse-grained limestone. Eridotrypa.	10
	Covered	30
	Thin-bedded, fine-grained, dark-gray limestone. Mud cracks common. Streptelasma and chert nodules	5

Table 2 (continued)

	Strata	Thickness (in feet)
	Covered	5
	Medium-bedded, medium-grained medium-gray limestone. 6" bed of coarse-grained limestone at top	2
Unit II	Covered	7
	Medium-bedded, fine-grained medium-gray limestone with shale partings	2
Unit I	Covered. (Mostly covered) Few boulders of dovegray limestone in soil. One or two boulders of mottled-pink lime stone in lower 10'. Soil contains rounded green chert nodules.	20
	Knox Group	
	Thickness	286

At sections 11 and 12, located at the extreme northeastern end of Brown's Valley, Unit I has given over almost entirely to the shale facies of the Chickamauga group. Only in the upper member of combined Units I and II in section 11 (Aurora, Alabama) is any limestone found. The limestone contains Streptelasma. (Streptelasma is post-Chazy; hence, the limestone must belong at least to Unit II.) Here the upper 5 feet of the unit is represented by a fine-grained, dark-gray argillaceous limestone.

Big Canoe Valley. Field conditions in Big Canoe Valley make the accurate measurement of sections of the Chickamauga group in most areas difficult. The northern portion of the valley is described from drill core (Sections 18, 21, and 22). The southern portion of the valley is represented by section 16 (Table 3) taken 1.5 miles southwest of Springville, Alabama.

Table 3

Section 16. Near Springville, Alabama in Big Canoe Valley

	Strata	Thickness (in feet)
	Red Mountain Formation	
Unit IV	Thick-bedded, fine-grained, dull-red limestone, topped by 1' of conglomerate	10
	Covered	5
	Medium-bedded, medium-grained red limestone	5
	Covered	10
	Medium-bedded, medium-grained red limestone	5
Unit III	Thick-bedded, medium grained, light-gray limestone. Cross-bedded, bentonite at top	10
	Covered	12
	Medium-bedded, medium-grained, light-gray limestone. <u>Amplexopora.</u>	1
	Covered	21
	Thick-bedded, fine-grained, arenaceous limestone	10
	Medium-bedded, medium-grained, light-gray limestone. <u>Zygospira.</u>	5
	Covered	5
	Thick-bedded, medium grained, medium-gray limestone with streaks of dense, dark-gray limestone	15
	Covered	7
	Medium-bedded, fine-grained, light-gray limestone. Cross-bedded	12
	Covered	8
	Medium-bedded, fine-grained to dense, light-gray limestone	2

Table 3 (continued)

	Strata	Thickness (in feet)
	Covered	7
	Medium-bedded, fine-grained to dense, light-gray limestone	4
	Covered	6
	Thin-bedded, fine-grained to dense, light-gray limestone	16
	Thin-bedded, fine-grained, light-gray nodular limestone	15
	Covered	10
	Thin-bedded, fine-grained, light-gray limestone	1
	Covered	9
	Thick-bedded, fine-grained, dark-gray limestone. Gastropods.	5
	Covered	5
	Thin-bedded, fine-grained, light-gray limestone. Fragments of pelmatozoan stems present.	15
	Thick-bedded, fine-grained, medium-gray limestone. Mud cracks in limestone, overlain by crinoidal limestone	9
	Medium-bedded, fine-grained, medium- to dark-gray limestone	15
	Medium-bedded, fine-grained, light- to dark-gray limestone	24
	Medium- to thick-bedded, fine-grained, dark-gray arenaceous limestone. Top 5' very sandy. Fragments of pelmatozoan stems.	22
	Covered	7
Unit II	Thick-bedded, fine-grained, medium- to dark-gray argillaceous limestone	36
	Covered	5
	Medium-bedded, medium-grained, medium-gray argillaceous limestone. Green chert nodules	10

Table 3 (continued)

	Medium-bedded, fine-grained, medium-gray arenaceous limestone	6
	Medium- to thin-bedded, fine-grained, medium-gray limestone. Scattered red chert nodules	14
	Thin-bedded, fine-grained to dense, medium-gray limestone. Scattered red chert nodules. <u>Amplexopora</u>, <u>Neostrophia</u> ( )	10
Unit I	Tan shale	6
	Covered	3
	Thin-bedded, dense, dark-gray, argillaceous limestone	10
	Chert conglomerate (Attalla)	5
	Knox Group	5
	Thickness	418

Unit I in section 16 (Table 3) is initiated by the Attalla chert conglomerate. The conglomerate is exposed as residual boulders of conglomerate in a chert soil immediately below the first exposure of dense, thin-bedded, medium-gray limestones of Unit I. The sequence of limestone, 10 feet thick, is separated by a covered interval 3 feet thick from 6 feet of tan shale. The middle and upper members of this unit are composed of fine-grained, thin- to medium-bedded, medium-gray limestone. Red chert nodules are common in the limestones immediately above the tan shale sequence for a distance of about 20 feet. Above this shale, for a distance of 5 feet, green chert nodules are found. The top boundary of Unit I in this section is drawn approximately 94 feet from the base of the section at the top of a 10 foot thick sequence of medium-gray, medium-bedded, cherty limestone.

<u>Wills Valley Belt.</u> Sections 17, 19, and 20, located respectively at Kenner, Ft. Payne, and 2 miles northwest of Valley Head, in Wills Valley, have representatives of Unit I. To the northeast, as shown in the sections listed above, the limestones are progressively replaced by red

shales. Those limestones present are invariably dense, thin-bedded, and medium- to light-gray. Calcite veins are common in the lower limestones of Unit I in Brown's Valley.

Unit II

In general, Unit II may be characterized in the southwestern area as a medium- to thick-bedded, predominantly medium-grained limestone. The predominant color is medium- to dark-gray. However, several persistent coarse-grained limestones are also common in the southwestern areas. The top of Unit II is drawn at the point of change from the lithology characteristic of Unit II to that of the thick- to massive-bedded sequence of Unit III.

In the northeastern part of the area, the upper contact of Unit II is placed at the first cross-bedded limestone horizon. In this area, Units I and II become predominantly a shale unit with lenses of dense, dove-gray colored limestone.

Birmingham Valley Belt. The basal member of Unit II in section 7 (Woodward Iron Company, Bessemer, Alabama) is drawn at the base of the first exposure of limestone in the section. The first exposure is a sequence of medium-bedded, medium-grained, cherty limestones one foot thick. Lithologically, Unit II in this section is chiefly a fine-grained, medium- to dark-gray, medium-bedded limestone. A sequence of strata beginning approximately 39 feet from the base of the unit, with a thickness of approximately 30 feet, consists of medium-bedded, medium to coarse-grained, cherty limestone. The fragments of pelmatozoan stems are oriented parallel to the strike of the bed. The "crinoid" bed is underlain by a one-inch breccia composed of fragments of dense limestone surrounded by coarse-grained limestone. The top of the Unit is placed at the top of a two foot sequence of limestone. The top one foot of this sequence is cross-bedded. The bottom 6 inches is a conglomerate of coarse-grained limestone in a matrix of fine-grained limestone.

Within the first outcrop of Unit II in section 9, there is a one-inch thick coquina of shell fragments of Sowerbyella curdsvillensis. In this section, the base of Unit II is covered. The top of the unit is drawn 4 feet from the top of the exposed portion of this section. Only the top 4 feet of Unit II is exposed. The remainder of the section has been covered by soil or is missing as a result of movement along the Birmingham thrust fault.

Unit II of section 10 is approximately 5 feet thick. The lowest bed of the sequence is a medium-bedded, fine-grained, cherty limestone.

Though poorly exposed, the intervening members of the unit are apparently composed of fine- to medium-grained, medium-gray, medium-bedded limestone. The top of the unit is drawn at the top of a sequence three feet thick of medium-bedded, medium-gray limestone which contains Rostricellula pisa. This form is not found in Unit III.

The lower members of Unit II in section 3 contain Cliftonia occidentalis. Seven feet above the lower contact of Unit II there is a one and one-half foot thick sequence of coarse-grained, thin-bedded limestone. This is the first of several relatively persistent coarse-grained limestone horizons found in this unit. This horizon is followed by a sequence 3 feet thick of medium-grained limestone. Eighteen inches above this coarse-grained limestone begins the medium- to thick-bedded limestones considered, in this part of the area studied, to be characteristic of Unit III.

Unit II of section 2 is poorly exposed. The base of Unit II is placed at the top of the cherty limestone sequence of Unit I. The upper contact of Unit II is the top of an 18 inch thick bed of fine-grained, medium-gray, cross-bedded limestone. The intervening members of the Unit are fine-grained to dense, medium-gray limestone. A nodular limestone sequence is present 10 feet from the lower contact of the unit. In the nodular sequence, there are a few chert nodules.

The total thickness of Unit II at section 4 (Plate I) is 145 feet. The basal contact has been previously described in the paragraphs above on Unit I. The upper contact is drawn at the first cross-bedded limestone member of the group. The intervening members of this unit are, with the exception of a 19 feet thick sequence 63 feet from the lower contact, medium-grained, thin-to medium-bedded, light- to dark-gray limestone. Sixty-three feet up from the lower contact is a 25 feet thick sequence of thick-bedded, fine-grained, medium-gray limestone. Fifteen feet from the basal contact, there is a sequence 7 feet thick of limestone containing chert nodules. Unit II below the thick-bedded sequence contains many shale partings and, in general, has a more clastic character than the upper members of the unit.

Unit II of section 5 (Cahaba Mountain section) is 140 feet thick. This unit in section 5 compares lithologically to Unit II of sections 4 and 15 in that Unit II is also separated into three parts by a middle sequence of thick-bedded limestone. The lower member is a fine- to medium-grained, medium-bedded limestone. Within this member of Unit II there are two beds of coarse-grained limestone. Seventeen feet from the base there is a coquina of Sowerbyella curdsvillensis shells which probably correlated with those coquinas previously described. The upper member of the unit is a medium- to fine-grained, medium- to thin-bedded, medium-gray limestone. A few shale-partings are found throughout the entire unit.

Brown's Valley Belt. Lithologically, Unit II in this belt is very similar to Unit II of the Foster Mountain section and the Cahaba Mountain section. In section 15, Unit II is separated into two parts by a sequence of 5 feet of predominantly thick-bedded, fine-grained lime stone. Approximately 30 feet from the lower contact, there is a 3 inch thick bed of coarse-grained limestone. This bed may represent the top of Unit I, but, based on the Foster Mountain and Cahaba Mountain sections, it seems probable that this coarse-grained member correlates with one of the several coarse-grained members described there. The upper member of Unit II is a thin- to medium-bedded, medium-grained, shaly limestone. The top of Unit II is placed at the bottom of a one foot thick bed of cross-bedded limestones, which is, in this portion of the Red Mountain area, a persistent member of the Chickamauga group.

The base of Unit II in section 14 is placed beneath a sequence of cross-bedded, fine-grained, arenaceous limestones. The top of Unit II is drawn at the base of the second sequence of cross-bedded limestones in the section. Similar lithology to Unit II, in sections 4, 5, and 15, is illustrated in Figure 4. The "crinoidal" limestone previously described occurs in the lower portion (21 feet from the base) of this unit.

The lithologic character of Unit II in section 13 (Table 2) is not similar to Unit II in the previously described sections. Exposures are rare in Unit II of this section. The unexposed portions of the unit, based on an examination of the soil, probably represent shale or shaly limestone. The limestones present are largely fine-grained and medium- to thin-bedded. Thirty feet from the base of the unit, the soil cover contains chert nodules. Beginning 24 feet from the basal contact and extending upward into Unit III, there is a heavy concentration of Streptelasma. The top of Unit II in this section is drawn at the base of the first sequence of cross-bedded limestone.

Unit II, as exposed in section 11, is composed of an alternating sequence of red shales and thin-bedded, argillaceous limestones. A Streptelasma zone, described in Unit II of section 13 (Table 2), extends the entire length of Unit II in this section. The top of Unit II is drawn at the base of the first cross-bedded lime stone in the section.

Northwest of section 11 in Brown's Valley and in Wills Valley, Units I and II cannot be separated. The upper contact of Unit II is somewhat arbitrarily drawn. This contact is illustrated in Figure 4.

Big Canoe Valley Belt. Unit II of section 16 (Table 3) is unlike any previously described sections of Unit II found in the area. It is approximately 233 feet thick and is composed primarily of thin- to medium-bedded, fine- to medium-grained limestone. The top of the unit is placed at the top of a sequence of fine-grained, light-gray, cross-bedded limestone. One hundred and seventeen feet from the base of the section, mud cracks are found on the bedding plane of a fine-grained, medium-gray, medium-bedded limestone. The overlying two feet of limestone contains a heavy concentration of fragments of pelmatozoan stems. The occurrence of these fragments of pelmatozoan stems has been shown in descriptions of previously sections to be diagnostic of Unit II in the central and southern portions of the region.

Unit III

Unit III is traceable to the northwestern limit of the area studied. The base of this unit is as defined for the top of Unit II. The top of the Unit is usually marked by a 1/2 inch thick bentonite bed which is generally associated with a cross-bedded, coarse-grained limestone. Due to the thick soil cover common in this region, the bentonite bed is not always found. In general, however, one or the other of these two criteria will be available. If not, the thick-bedded to massive bedding of this unit in the southwestern part of the area studied generally serves as a guide to its location. Toward Georgia, the limestones of the Unit become thin-bedded.

Birmingham Valley Belt. Unit III in section 7 is largely covered by soil. The upper 16 feet of the unit is exposed. The top of Unit III in section 7 is drawn at the base of a 1/2 inch thick bed of bentonite. The limestones exposed below the bentonite are medium- to thick-bedded and fine-grained to dense. They contain black chert nodules. Three 6-inch beds of coarse-grained limestone are found in this sequence.

Units III and IV, if present, are not exposed in sections 8 and 10. Section 9, taken in the same area as section 8, does have some of the lower members of Unit III exposed. The limestones in this exposure are medium- to thick-bedded, medium-gray, and fine-grained. The top of Unit III is not exposed, and, if present, both it and Unit IV must occur within a stratigraphic distance of approximately 20 feet. Erosion prior to Red Mountain time may have removed Unit IV from this section so that the Red Mountain formation is resting directly on Unit III of the Chickamauga group, of the upper portion or the section may be missing as a result of thrust faulting.

Unit III of section 1 is well-exposed. Those exposures present indicate that the unit in this section is composed of thin- to medium-bedded limestones. The limestones of the lower 26 feet of the unit are fine-grained. The fine-grained limestone is followed by a 26 foot thick sequence, the lower and upper members of which are coarse-grained limestones. The intervening beds are medium-grained. An indeterminate thickness of strata composed of dense limestones overlies this sequence. The dense limestone is followed by approximately 30 feet of medium-grained limestone. The remainder of the section to past the Silurian-Ordovician contact is not exposed.

The lower contact of Unit III in section 2 is drawn at an occurrence of cross-bedded limestone. The unit is poorly exposed in this section but seems to be composed essentially of a fine-grained, thick-bedded to massive, dark-gray limestone. The limestone becomes medium- to thin-bedded toward the top of the unit. Eighty-six feet from the base of the unit, there is a sequence 39 feet thick of dense limestone. Few fossils are found in the unit in this section. The upper contact of Unit III cannot be determined. From the paucity of fossils, the lack of the key bentonite horizon, and the lack of distinctive outcrops, it cannot be determined if Unit IV is present in section 2.

Unit III of section 4 (Table 1) is, throughout its extent, a thick- to medium-bedded, light- to dark-gray limestone. The upper 22 feet of this unit is composed of an alternating sequence of medium- to coarse-grained limestone. The lower portion is largely fine-grained. The upper contact of this unit is placed at the base of a 5 foot sequence of coarse-grained, light-gray, cross-bedded limestone. If present, the bentonite horizon is obscured by soil cover. Little erosion is seen at the contact between Units III and IV in this section or in any of the other sections where the contact may be examined. The presence of an unconformity in the Chickamauga group at this point is based primarily on the absence of fauna in this portion of the section that would show a relationship to the Tyrone formation of the Central Basin of Tennessee.

Unit III of section 5 is composed of thin- to medium-bedded, shaly limestone. Poor exposure of the upper portion of this section makes it impossible to determine if Unit IV is present or not. An examination of the float material in this region does not reveal the presence of any typical Unit IV fossils.

<u>Brown's Valley and Wills Valley Belts.</u> Unit III is initiated in section 15 by medium- to thick-bedded, fine-grained, medium-gray limestone. Twenty-eight feet above the base of the unit there is a sequence, 10 feet thick, of arenaceous, thick-bedded limestone. The remainder of the unit is composed of a monotonous sequence of medium- to thick-bedded, fine-grained to dense limestone. Unit IV is not exposed in this section. However, a microscopic examination of several soil samples collected at the top of the last exposed limestone shows some materials present that appear to be bentonite. Therefore, the upper contact of Unit III is drawn at the top of the last exposed limestone in the section.

Unit III of section 14 is 87 feet thick and is composed of thin- to medium-bedded, medium- to fine-grained, light-gray limestone. The lower contact of the unit is described in the paragraphs above as the top contact of Unit II. The upper contact is poorly defined. The upper contact of Unit III is, for convenience, drawn at the top of the last exposed limestone in the section. The remaining 40 feet of section 14 is covered by float from the Red Mountain formation. Firm evidence to support the presence of Unit IV in this section is not available. The several boulders of limestone found in this covered interval contain no Unit IV "index" fossils.

From section 13 northeast, *i. e.* sections 11 and 12 in Brown's Valley, the limestones of Unit III become more clastic, although they never undergo a facies change to shales, as is the case in section 20 and partially so in section 19 in Wills Valley. The lithology of Unit III in those sections is much the same with the exception of the top member of section 11. The top 12 foot sequence is composed of medium-bedded, fine-grained, cherty limestone.

The top contact of Unit III in section 17, 18, and 19 is placed at the bottom of a two inch bed of bentonite. The bentonite of section 18 is mixed with pyrite and sand grains. The top of Unit III in sections 11, 12 and 13 is placed at the break in lithology from that of argillaceous limestone to red shale. As in the more southwestern sections, where Unit IV occurs, no evidence of erosion is found along the upper contact of Unit III.

In section 20, at the northeastern end of Wills Valley, Units III and IV cannot be delimited. At this section, within the interval of Units III and IV, the lower portion contains alternating beds of fine-grained to dense, thin-bedded limestone and red shale. This sequence is followed by a thick exposure of buff to tan shales.

Big Canoe Valley Belt. Unit III of section 16 (Table 3) is composed of medium- to thick-bedded, fine-grained, light-gray limestone. The upper contact of the unit is drawn, as is the case for section 4 (Table 1), at the base of the second sequence of cross-bedded limestone. This bounding sequence is approximately 10 feet thick.

Unit IV

Unit IV is bounded by the upper member of Unit III at its lower contact and the Red Mountain formation or, rarely, as at Roebuck, Alabama, by the Fort Payne formation at the top. The intervening strata are predominantly thin-bedded limestone with some lenses of medium-bedded limestone. Shale partings are common. Green chert nodules are found in the extreme southern part of the area studied.

Unit IV, as it occurs in sections 2, 3, 5, 8, 9, 10, 14, 15, and 20 in the Birmingham Valley, Brown's Valley, and Wills Valley Belts, has been described under the heading, Unit III. The following description serves primarily to establish the top contact of the Chickamauga group in the Red Mountain area.

Birmingham Valley Belt. Unit IV in section 7 has a thin bed of bentonite at the base which serves to separate it from Unit III. Unit IV in this section is four feet thick. It is composed of dense, thin-to medium-bedded, medium-gray limestone. This location is one of the few places in the Red Mountain area where the contact between the Red Mountain formation and the Chickamauga group can be seen. The lower beds of the Red Mountain formation rest disconformably upon the upper beds of Unit IV. The contact is only slightly more irregular than would be expected of a bedding plane contact. However, the time interval represented by this contact represents an undetermined portion of the upper Ordovician.

As stated in the discussion of Unit III, in the discussion of sections 8, 9, and 10, if Unit IV is present in these sections, it is not exposed. In these sections, the upper contact of the Chickamauga group is obscured by float material derived from the Red Mountain formation.

From an examination of the soils overlying Unit III of section 2, it cannot be determined if Unit IV is present in this section. This means that, assuming deposition of Unit IV, which seems probable as it occurs both northeast and southeast of this section, prior to Red Mountain times an indeterminate thickness of strata representing Unit IV was removed by erosion. The Red Mountain formation now rests on Unit III.

Unit IV of section 1 is delimited on the basis of the occurrence of float material of Iocrinus (Rogers, 1960, p. 186). The contact of the Chickamauga group with the Red Mountain formation cannot be determined due to field conditions.

Unit IV of section 4 (Table 1) (Foster Mountain) is limited at its bottom contact by cross-bedded limestone, and at its top contact by the Red Mountain formation. The intervening limestone is predominantly coarse-grained, medium-bedded, and light-gray in color. The upper contact is not well-defined, as erosion has removed the majority of the Red Mountain formation from the top of Foster Mountain. Only scattered boulders of Silurian material remain.

Brown's Valley Belt. Unit IV of section 13 (Table 2) is poorly exposed. Those exposures present are of thin-bedded, fine- to medium-grained, argillaceous limestone. These limestones weather to a cream-colored argillite. The exposures, separated by covered area, represent the beginning of the shale facies of the Chickamauga group. The upper contact

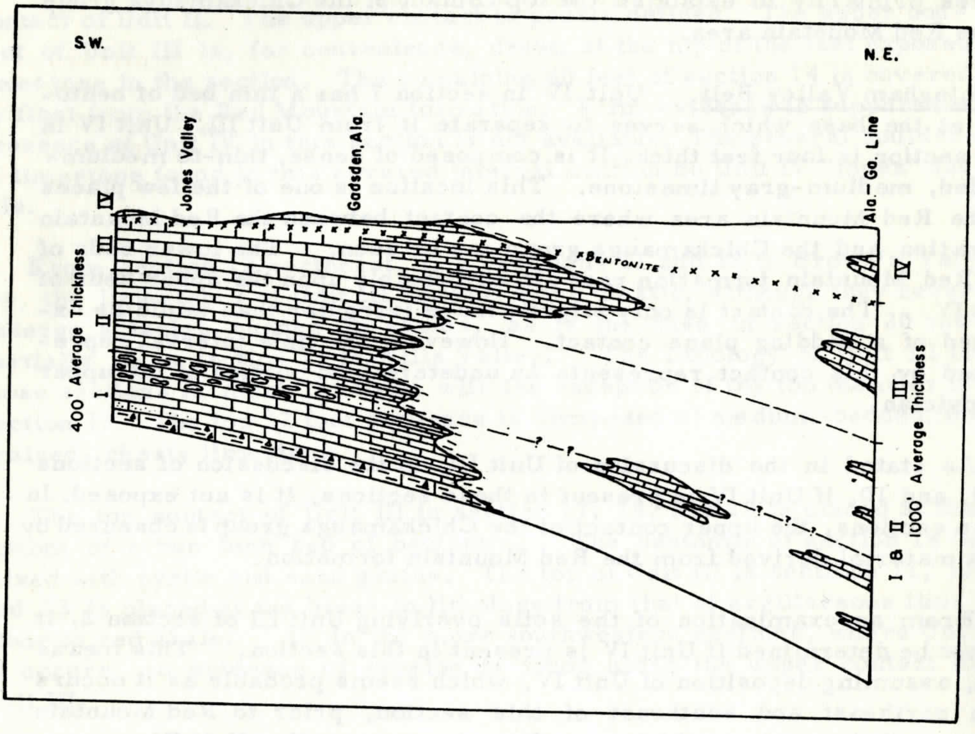


Figure 4. Facies relationships of the Chickamauga group. Lithologies are shown by standard symbols, with the exception of the shale facies, shown as white area.

of the group with the Red Mountain formation is difficult to draw in this area, as the lower member of the Red Mountain formation is a buff to tan-colored shale similar to the shales of the Chickamauga group. Where fossil evidence is absent, the upper limit of the Chickamauga group is somewhat problematical.

Unit IV in section 12 represents an advanced stage of Unit IV shown in section 13 in that the amount of limestone is greatly reduced and is replaced by tan to red shales and that the thickness of the unit increases. Unit IV in section 11 represents a complete change-over to the shale facies of the Chickamauga group.

Big Canoe Valley Belt. Unit IV in section 16 (Table 3) is composed of 45 feet of medium- to thick-bedded, fine- to medium-grained argillaceous limestone. Calcite veins, stained red from the overlying Red Mountain formation, are disseminated throughout this sequence. No chert is present. The upper contact with the Red Mountain formation is marked by a chert conglomerate that is 2 inches thick.

Wills Valley Belt. The lower contact of Unit IV in section 17 is marked by a bed of bentonite 2 inches thick. The unit is characterized by alternating thin beds of dove-gray colored argillaceous limestone and shale. Toward the top of the unit, the limestone beds are mottled-red. The upper contact is difficult to delimit due to rapid weathering of the shale and slumpage from the Red Mountain formation.

Unit IV in sections 18, 19, and 20, located progressively northwest of section 17, is in all sections much the same in lithologic character. In section 20, Unit IV is composed almost entirely of shale.

CONCLUSIONS

1. The Chickamauga limestone is raised to the rank of a group. On the basis of lithology and paleontology, the group is subdivided into four units which are, in ascending order: Unit I, Unit II, Unit III, uncomformity, Unit IV. These units are correlated with units of the same designation in the East Tennessee section of Rodgers (1953).

2. Unit I is Chazy; Units II and III are Black River; and Unit IV is Trenton in age.

3. The best guide fossils to the Chazy stage in Alabama are: Liospira and Lecanospira; to the Black River stage are Streptelasma sp., Leperditia fabulites, Hesperorthis tricenaria; and to the Trenton stage are: Zygospira recurvirostris, Rhynchotrema capax, Hebertella sinuata.*

4. Correlation of the Little Oak limestone-Athens shale sequence in Cahaba Valley to Unit II of the Chickamauga group is shown.

5. During the lower Black River times, the seas probably advanced from the south. During upper Black River times, there was no general retreat of the sea but a general lowering of sea level resulting in the formation of scattered "islands" and restricted areas of marine waters.

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* For basis of conclusions 3, 5, 6, and 7, see Rogers, 1960.

6. The Blount Delta is recognized in Alabama.

7. The southern "basin" of the Appalachian foreland area is defined with the Tennessee Basin.

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AN ALTERNATE APPROACH TO MORPHOGENETIC CLIMATES

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ABSTRACT

The relationships between climate and landform are not yet completely clear. There seem to be, however, four main climate types, as far as landforms are concerned: wet; warm dry (arid); cold dry; and temperate. The fourth of these occupies a middle position between the three extremes. In order to clarify these relationships, station data (from many parts of the world) are plotted on a chart whose coordinates are precipitation and potential evaporation. The latter is adopted, as adequate for the purpose, despite its known shortcomings. The result, like other similar charts, does not define precisely all morphogenetic regions. It is presented, however, as a basis for additional investigation.

* * *

Geomorphologists have varied widely in their willingness to use climatic indices. Some, like Lester King (1953), report more-or-less universal processes at work across many different climate types. Others profess to find genuine geomorphic differences between many climatic subdivisions.

The present writer occupies something of a middle position. He feels that, for the geomorphologist, there are four main climatic types ,

and that sub-types should be examined after these four have been firmly established. These four can be listed as: wet; warm dry (arid); cold dry; and temperate, or moderate humid. (This classification, of course, is of very little use for the climatologist, but it is not designed for him. For a climatological approach, see, for example, Trewartha, 1954.)

Important land-forms associated with these climate types include: knife-edge topography; pediment and esplanade; glacial and tundra, and "temperate." The fourth item in this list lies in between the other three, which occupy extreme positions (toward: high rainfall; high temperature; low temperature). This arrangement suggests a triangle, rather than a square, as the basic classification pattern. A square, for example, might emphasize the following combinations: hot-dry, hot-wet, cold-dry, cold-wet. However, the operational mechanics of the atmosphere are such that hot-wet and cold-wet are not readily distinguishable; there is, for all practical purposes, only "wet," with no great extremes of temperature, whether hot or cold. It is thought, then, that a three-cornered arrangement, with "temperate" in the center, is superior to a four-cornered scheme.

The parameters which have been chosen, for classification purposes, are precipitation and potential evaporation. Each of these is tentatively suggested as of greater significance, from a geomorphic point of view, than temperature. Furthermore, it is proposed that a suitable combination of these two parameters will also provide much, if not all, of the temperature information needed.

Both parameters have, however, wide variability. Potential evaporation may have any value from somewhere around one inch annually, to perhaps as much as 200 inches annually. And the annual figure for precipitation can be, apparently, anything from less than an inch to more than 1,000 inches (certain stations in India). The relative value of 10 inches, where this is the order of the annual total, on the one hand, and where the annual total averages perhaps 500 inches, on the other hand, is quite different. Hence, both parameters should be plotted on logarithmic scales.

Potential evaporation, as a climate indicator, possesses a disadvantage not shared to anything like the same degree by precipitation. It is, in effect, still an uncertain factor, despite various methods of measurement (none of which has received unqualified acceptance). Nevertheless, since a general approach rather than a precise formulation is desired, the usual corrected values for potential evaporation are thought to be acceptable.

In order to test these ideas, the author collected precipitation and potential evaporation data from many parts of the world. Data for the pre-1958 United States are easy to obtain (for summaries, see Linsley, Kohler and Paulhus, 1949). For the rest of the world potential, evaporation data are particularly hard to get. Those persons who very graciously collected information for this project included Shinjiro Mizutani, for Japan; Chester Wentworth and Jen-hu Chang, for Hawaii; Dan Yaalon, for Israel; and Arthur O. Fuller, for South Africa. Additional data were obtained from Penman (1954), for parts of Europe. It should be clear that those persons who were kind enough to collect data did so without necessarily endorsing the overall project.

The values so obtained were plotted on two charts; for most of the North American information, see Figure 1, and for a broader presentation, see Figure 2. In each case, potential evaporation (in inches per year) has been plotted against total precipitation (in inches of water per year). Figure 1 shows how little of the total chart area is utilized by the selected American states. It is obvious that, for wide variations in the two chosen parameters, one will have to range farther afield. The other 36 states (excluding Alaska and Hawaii) fall within the area outlined by the 12 which have been plotted. It has been the purpose of this chart to cover essentially the full range of both P and E for the states shown, but on the other hand, it is recognized that a few exceptional figures may

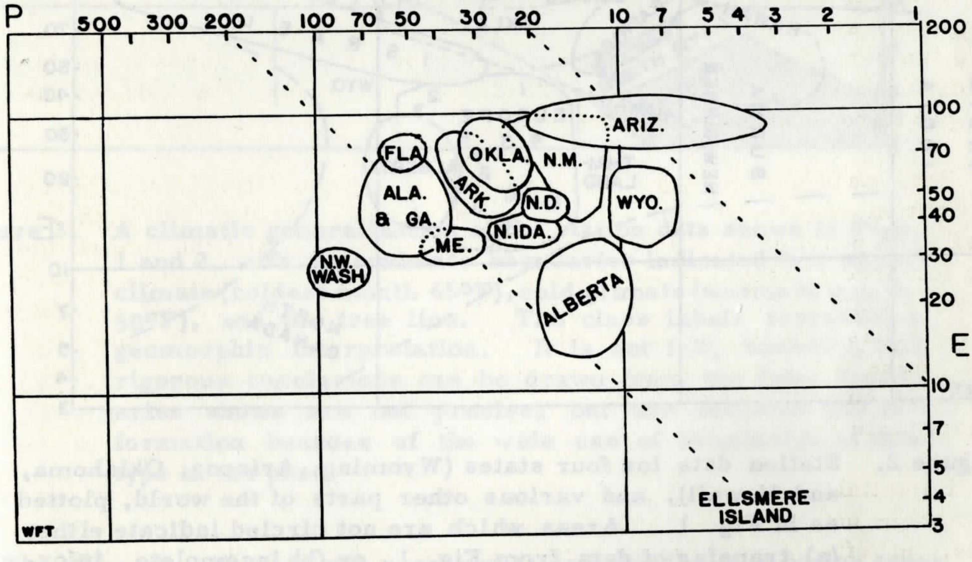

Figure 1. Station data for 12 states, and scattered parts of Canada, plotted on a chart where the coordinates are precipitation (P), in inches per year, and potential evaporation (E), in inches per year. Each state, and part of the province of Alberta, is widely, but not necessarily completely, covered. The diagonal lines are E = P, to the left, and E = 10 P, to the right. They have been used, in some instances, as boundaries between humid, semi-arid, and arid climates, and are presented here merely for information.

have been overlooked. Furthermore, the method of approach has been to emphasize the variability within each state or area (hence a patch, outlined by a black line, rather than a point representing average values). The two dashed lines represent E = P, and E = 10 P, which approximate the values used by various workers as limits for the notion of semi-aridity (for a similar concept, see Senstius, 1958).

Various parts of the world are shown on Figure 2. The circled area for India covers those stations for which both P and E were available; the uncircled area, those stations for which E had to be estimated. Obviously, not all parts of India are included. The circled area for Hawaii is based on the best (numerical) information available. The tremendous variability of the parameters, within a fairly small land area, is plain. Representative states (Arizona, Wyoming, and Oklahoma) are included, without limiting circles, for comparison. The data for Arabia north Canada, Korea, Borneo, Thailand, New Guinea, and Burma did not include figures for potential evaporation.

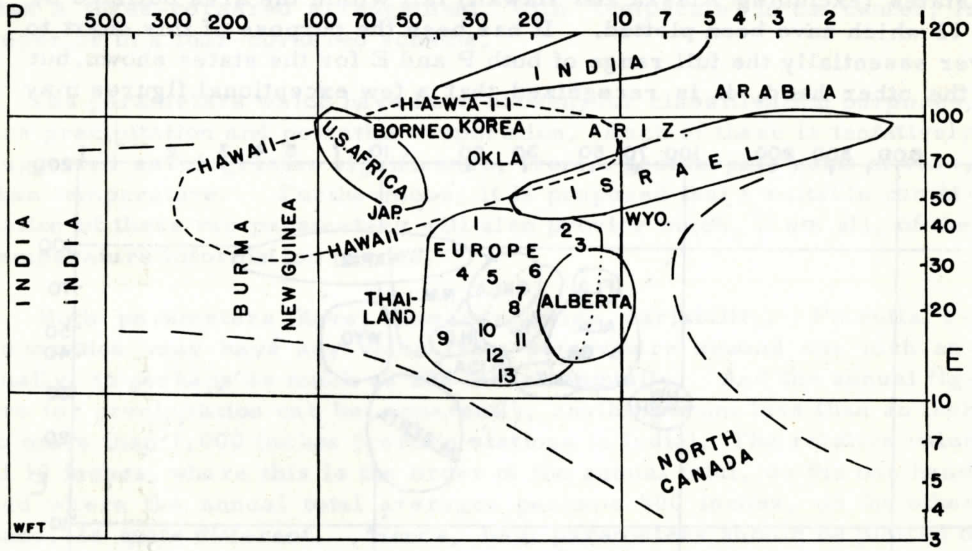

Figure 2. Station data for four states (Wyoming, Arizona, Oklahoma, and Hawaii), and various other parts of the world, plotted as in Fig. 1. Areas which are not circled indicate either (a) transfer of data from Fig. 1, or (b) incomplete information (in most cases, nocdata on potential evaporation). The numbers, in the area representing Europe, have the following meanings: 1. Lisbon, 2. Athens, 3. Madrid 4. Rome, 5. Belgrade, 6. Odessa, 7. Paris, 8. London 9. Scotland, 10. Baltic Sea, 11. Moscow, 12. Leningrad 13. southern Sweden.

The basic information conveyed by Figure 1 and Figure 2 has been simplified and redrafted as Figure 3. The external limits, taken from Figure 2, are not thought to be final, but will undoubtedly require modification. The internal boundaries are shown as broad bands, rather than as sharp lines, and are labelled in terms of temperature. There are probably quite a few exceptions to these temperature values, also. A few tentative sub-division listings are given, for purposes of illustration, but not as essential features of the chart.

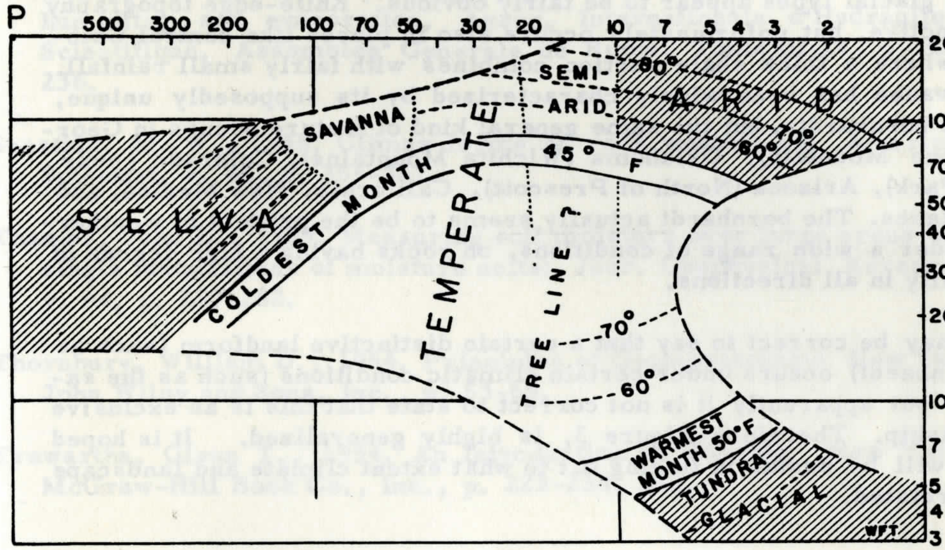

Figure 3. A climatic generalization of the station data shown in Figs. 1 and 2, with approximate boundaries indicated for: warm climate (coldest month 45°F), cold climate (warmest month 50°F), and the tree line. The class labels represent a geomorphic interpretation. It is not felt, however, that rigorous conclusions can be drawn from the data; boundaries shown are not precise, but are included for information because of the wide use of boundaries of this type in the past.

The present writer is not prepared to say that the four major types can be recognized in the field. Undoubtedly, in certain instances, recognition would be easy. In others, however, it might be much more difficult, or even impossible. This is due to the fact that climate, a complex entity in itself, is nevertheless only one of several variables in the overall picture. Any artificial scheme, where so many variables are involved, must have weaknesses. It is thought that the simplified chart given as Figure 3 will have fewer weaknesses, morphologically, than more detailed climatologic diagrams.

Arid landforms, such as the explanade (which is structurally controlled) and Kirk Bryan's pediment, should be easy enough to identify, but both also appear under semi-arid climates, as many workers have shown, and even in sub-humid to humid (i.e., temperate) climates. Tundra and glacial types appear to be fairly obvious. Knife-edge topography is distinctive, but unfortunately occurs also in places like central Colorado, where a thick shale section combines with fairly small rainfall. The savanna has been widely characterized by its supposedly unique, rounded bornhardts, but the same general kind of feature occurs in Georgia (Stone Mountain), Oklahoma (Wichita Mountains), Colorado (near Estes Park), Arizona (North of Prescott), California, New Mexico, and other places. The bornhardt actually seems to be the product of weathering, under a wide range of conditions, on rocks having a high degree of uniformity in all directions.

It may be correct to say that a certain distinctive landform (such as the bornhardt) occurs under certain climatic conditions (such as the savanna), but apparently it is not correct to state that this is an exclusive relationship. Therefore Figure 3, is highly generalized. It is hoped that it will be useful in finding out to what extent climate and landscape can be related.

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