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Abstract

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SOUTHEASTERN GEOLOGY

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Vol. 2, No. 3

1961

DIMENSIONS AND ATTITUDE OF THE PERIDOTITE IN CLARK HOLLOW, UNION COUNTY, TENNESSEE: AN AEROMAGNETIC STUDY *

by

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ABSTRACT

An aeromagnetic survey was made of a small area in Union County, Tennessee, that is underlain by an altered mica peridotite body, the only known occurrence of igneous rock in Tennessee west of the Blue Ridge Mountains. The areal extent of peridotite is obscure owing to poor exposures. Its position just beneath the Wallen Valley thrust fault led to the suggestion in earlier reports that the intrusive might occupy the fault plane.

Aeromagnetic data indicate that the peridotite does not dip southeastward along the Wallen Valley fault; rather, it occurs as a nearly vertical elliptical cylinder of approximate cross-sectional dimensions of 1,500 feet by 3,000 feet. The intrusive mass apparently was emplaced prior to the formation of the Wallen Valley fault, or at least before the last significant movement along that fault.

INTRODUCTION

An aeromagnetic survey was made in 1955 covering a small area in Union County, Tennessee, part of which is underlain by a poorly exposed mica peridotite body (Hall and Amick, 1944). Six traverses about 10 miles long, spaced at quarter-mile intervals, were made at a flight

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*Publication authorized by the Director, U. S. Geological Survey

altitude of 500 feet above the ground. The survey was designed to gain information about the extent of the peridotite mass and its relationship to local structures. Although the area covered in this survey is limited, the data allow some generalizations about the distribution of the intrusive rock at moderate depths.

ACKNOWLEDGEMENTS

Stuart W. Maher, Tennessee Division of Geology, offered valuable suggestions during the study and reviewed the manuscript. Berlen C. Moneymaker and John M. Kellberg, Tennessee Valley Authority, made available thin sections of peridotite and contributed toward the study through stimulating discussions. To them and to others who have offered valuable suggestions in numerous discussions, appreciation is gratefully acknowledged.

LOCATION AND GEOLOGIC SETTING

The intrusive mica peridotite body is located in central Union County, Tennessee, about 30 miles north of Knoxville, and 5 miles northwest of Maynardville (figs. 1 and 3). It is exposed in a small valley known locally as Clark Hollow and is more than 75 percent covered by Norris Lake when the reservoir stands at normal pool level (1,020 feet).

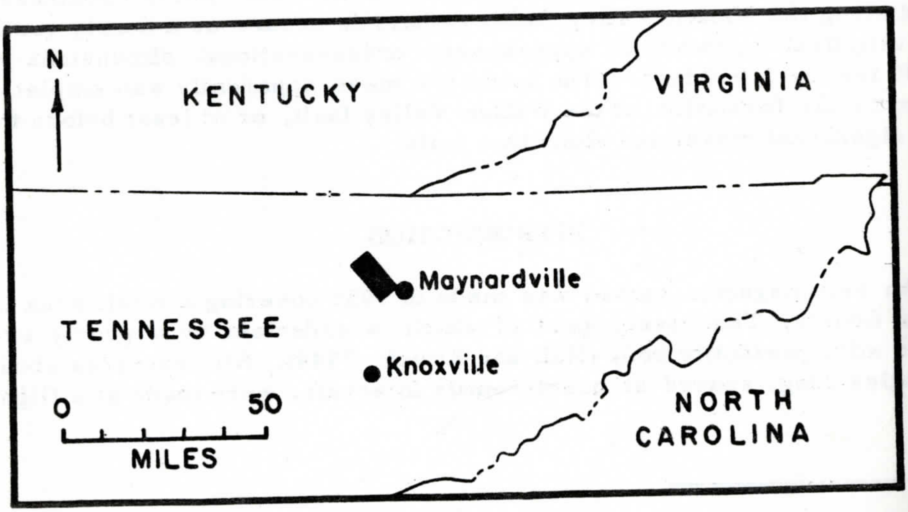

Figure 1. Index map showing the location of the Maynardville survey area.

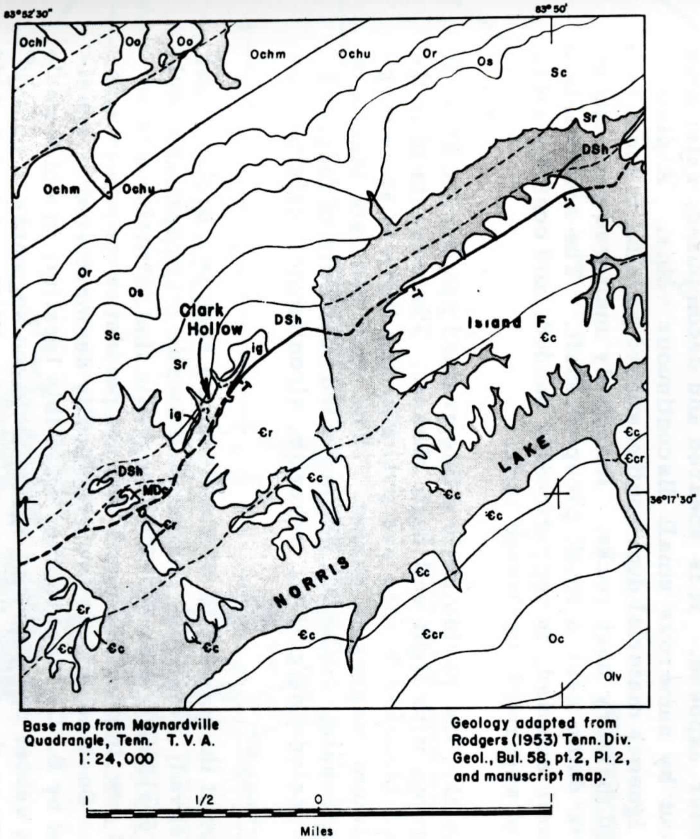

FIGURE 2 GEOLOGIC MAP OF THE CLARK HOLLOW VICINITY, UNION CO., TENN.

EXPLANATION

BEDS BELOW WALLEN VALLEY FAULT

- ig — Peridotite in Clark Hollow — Post Mississippian (?)
- MDc — Chattanooga shale — Mississippian
- DSh — Hancock dolomite — Devonian
- Sr — Rockwood formation
- Sc — Clinch sandstone — Silurian
- Os — Sequatchie formation
- Or — Reedsville shale
- Ochu — Upper part of Chickamauga limestone
- Ochm — Middle part of Chickamauga limestone
- Oo — Ottosee shale
- Ochl — Lower part of Chickamauga limestone — Ordovician

BEDS ABOVE WALLEN VALLEY FAULT

- Olv — Longview dolomite
- Oc — Chepultepec dolomite — Ordovician
- Ꞓcr — Copper Ridge dolomite
- Ꞓc — Conasauga group
- Ꞓr — Rome formation — Cambrian

Wallen Valley fault

The geology of the folded Appalachians in east Tennessee is complex; it has been summarized in several recent papers (Rodgers, 1953a, 1953b). A succession of carbonate rocks, shales, and sandstones ranging in age from Cambrian through Mississippian comprise the stratigraphic section. Several widespread unconformities have been recognized. The dominant structural feature in east Tennessee is imbricate thrust faulting.

GEOLOGY OF THE PERIDOTITE

The peridotite in Clark Hollow is the only known intrusive rock exposed in east Tennessee west of the Great Smoky Mountains. It is adjacent to and just northwest of the Wallen Valley thrust fault, which dips southeastward at a low angle ($20^{\circ} \pm$) and has a stratigraphic throw of about 7,500 feet. Cambrian shale (Rome) rests on Silurian, Devonian, and Mississippian units. Where the contact is exposed, peridotite intrudes dolomite thought to be of Hancock (Silurian and Devonian) age.

As mapped by Hall and Amick (1944) the intrusive consists of two plugs separated by approximately 1,100 feet (fig. 2). The northeastern plug is the better exposed. It is sheared and decomposed, extremely friable, and cut by numerous small discontinuous veins. A distinct banding in the igneous material dips southeastward parallel to local bedding in the sedimentary host rocks. Relatively unaltered rock can be found only on a dump near a small prospect shaft. The southwestern plug is less well exposed, is not noticeably banded, and contains more large masses of apparently unaltered rock.

Megascopically, the peridotite is a fine grained prophyritic rock; it is dull gray-green with light and dark phases. Phenocrysts of well-crystallized but bleached biotite are present, and there is some magnesian and calcium-magnesian garnet. The rock consists mainly of serpentine, carbonate, and small disseminated octahedra of magnetite. Vein minerals include magnetite, ankerite, strontianite, calcite, and deweylite.

The contact of the peridotite with the country rock is a breccia zone wherever observed; relatively unaltered dolomite fragments and boulders lie in a peridotitic matrix. This suggests that intrusion was accomplished at low temperature and that the peridotite mass was relatively plastic. Such conditions are graphically demonstrated by specimens collected by B. C. Moneymaker from this locality, in which peridotite fills the center openings and spaces between segments of crinoid stems. The stems themselves show no alteration (Hall and Amick, 1944, p. 428).

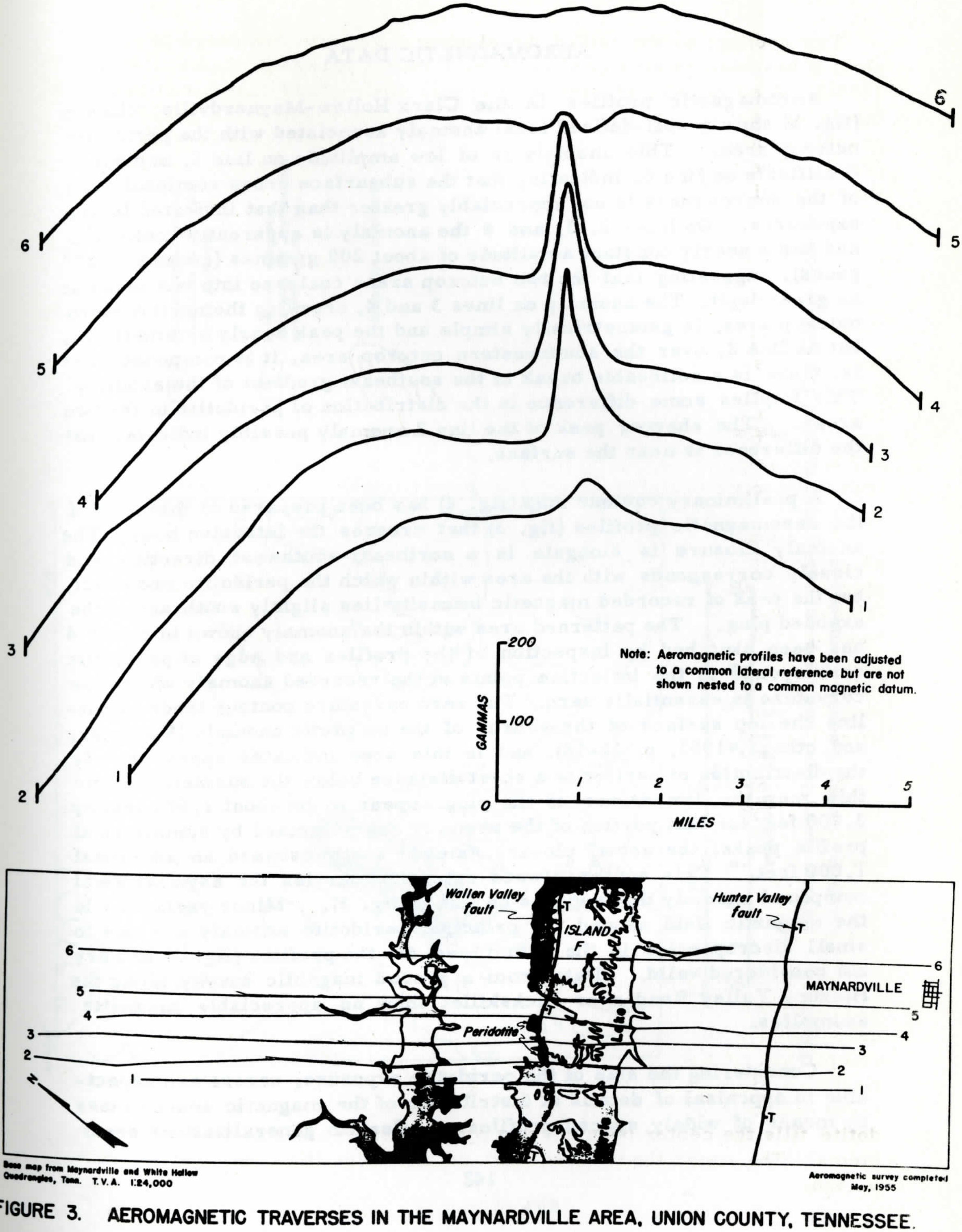

FIGURE 3. AEROMAGNETIC TRAVERSES IN THE MAYNARDVILLE AREA, UNION COUNTY, TENNESSEE.

AEROMAGNETIC DATA

Aeromagnetic profiles in the Clark Hollow-Maynardville vicinity (fig. 3) show a well-defined local anomaly associated with the peridotite outcrop area. This anomaly is of low amplitude on line 1, and not identifiable on line 6, indicating that the subsurface cross sectional area of the source mass is not appreciably greater than that indicated by the exposures. On lines 2, 3, and 4 the anomaly is apparently continuous and has a nearly constant amplitude of about 200 gammas (gamma = 10^{-5} gauss), suggesting that the two outcrop areas coalesce into one mass at no great depth. The anomaly on lines 3 and 4, crossing the northeastern outcrop area, is geometrically simple and the peak nearly symmetrical, but on line 2, over the southwestern outcrop area, it is compound; that is, there is a noticeable break in the southeast gradient of the anomaly. This implies some difference in the distribution of peridotite in the two areas. The sharper peak of the line 2 anomaly possibly indicates that the difference is near the surface.

A preliminary contour map (fig. 4) has been prepared of that part of the aeromagnetic profiles (fig. 3) that crosses the intrusive body. The anomaly closure is elongate in a northeast-southwest direction and closely corresponds with the area within which the peridotite crops out, but the peak of recorded magnetic intensity lies slightly southeast of the exposed plug. The patterned area within the anomaly shown in figure 4 has been sketched by inspection of the profiles and edge of peridotite corresponds to the inflection points of the recorded anomaly where the curvature is essentially zero. The zero curvature contour tends to outline the top surface of the source of the magnetic anomaly (Vacquier, and others, 1951, p. 16-18), and in this area indicates approximately the distribution of peridotite a short distance below the surface. From this map the dimensions of the plug appear to be about 1,500 feet by 3,000 feet for that portion of the anomaly characterized by symmetrical profile peaks; the actual closure extends southwestward an additional 1,000 feet. This southwestward extension carries the asymmetrical compound anomaly that appears on line 2 (fig. 3). Minor variations in the magnetic field around the principal peridotite anomaly are due to small discrepancies in the datum level for the profiles (fig. 3) and are not considered valid. Data from a ground magnetic survey along the Hickory Valley Road near Lickskillet show no appreciable magnetic anomalies.

Considering the size of the peridotite exposure, errors are expectable in appraisal of details of distribution of the magnetic source mass by means of widely spaced profiles. Certain generalizations seem

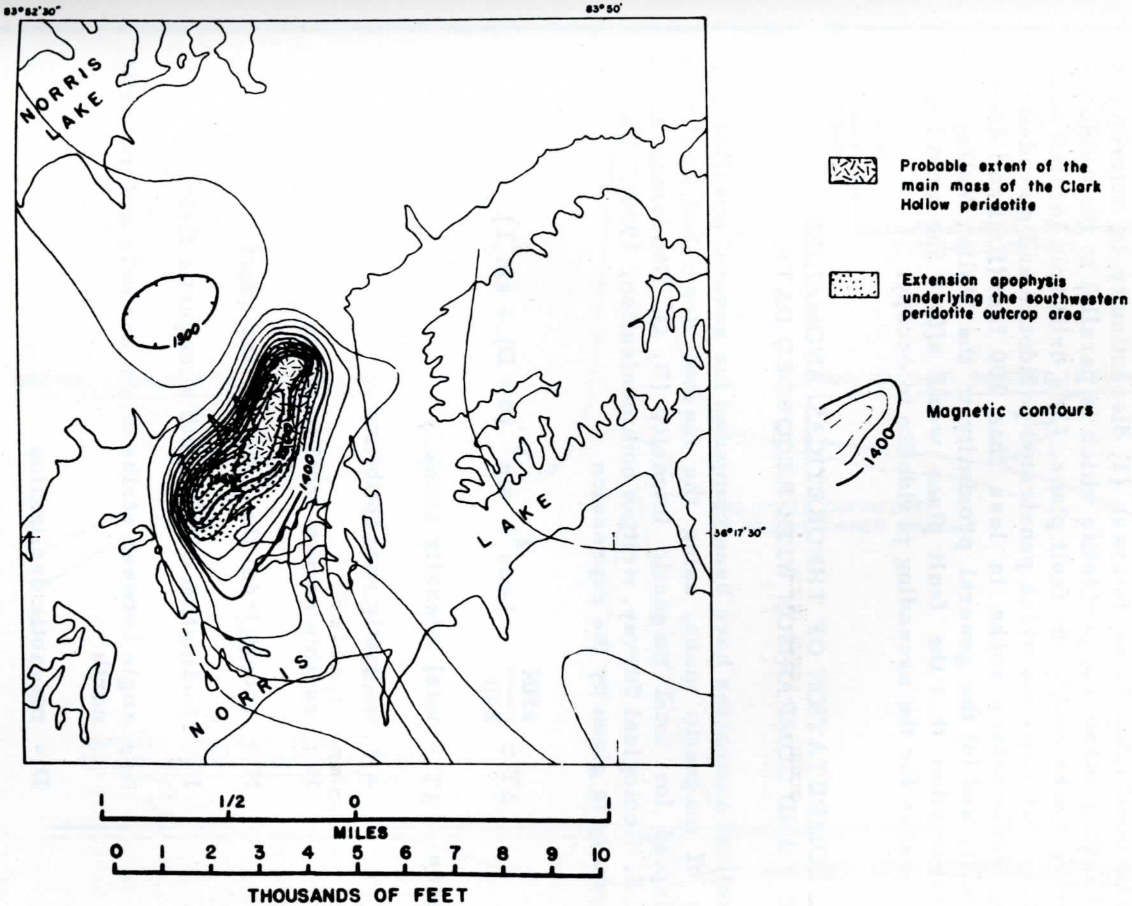

Figure 4. Preliminary total intensity aeromagnetic map of the Clark Hollow vicinity, Union County, Tennessee

valid, however, after study of the aeromagnetic date and comparison of these data with calculated anomalies given by theoretical configurations of magnetic material. Prior to the application of aeromagnetic methods in this area, it was generally thought that the intrusive rock was emplaced along the plane of the Wallen Valley fault. Field evidence supporting this conclusion is as follows: (1) discontinuity in outcrop pattern, (2) banding within the peridotite which is parallel to the bedding of the enclosing rocks and to the fault plane, (3) a drill hole located in the southwestern outcrop area which penetrated peridotite and extended into underlying sedimentary rocks in less than 100 feet (Hall and Amick, 1944, p. 427), and (4) the general proximity to the Wallen Valley fault and the assumption that the fault plane would afford the most logical zone of weakness for the ascending peridotite to occupy.

COMPUTATION OF THEORETICAL ANOMALIES AND COMPARISON WITH RECORDED DATA

Theoretical anomalies have been computed for several possible distributions of magnetic mass, using the method described by Pirson (1940) adapted for total magnetic intensity (R. G. Henderson and I. Zietz, U. S. Geological Survey, written communication, 1956). The required anomaly is given by the expression

$$\Delta T = \frac{kHN}{240} \left[\cos^2 I \ \sin^2 (\alpha + D) + \sin^2 I \right]$$

where ΔT = total intensity anomaly

k = magnetic susceptibility

H = earth's normal total intensity

N = counts from the Pirson polar chart

I = inclination of the earth's magnetic field

α = angle between strike of the anomaly and magnetic north

D = magnetic declination

For the peridotite locality, the following constants were selected by inspection of Magnetic Charts of the United States (U.S. Coast and Geodetic Survey, 1955):

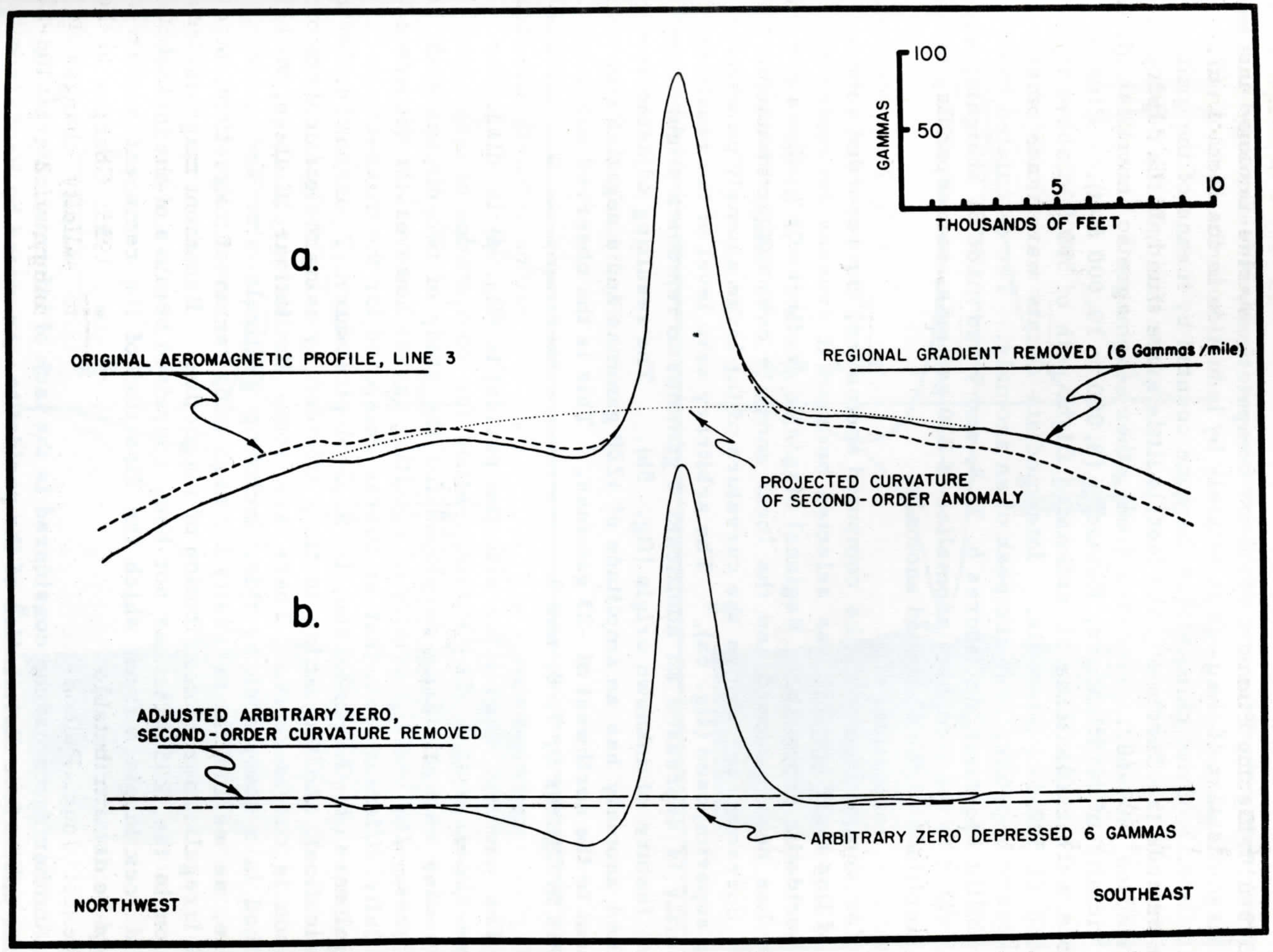

Figure 5. Partial profile of line three showing adjustment of recorded anomaly.

H = 56,000 gammas, I = 70^{o}, α = 37^{o}, and D = 0.25^{o} (negligible).

When using the Pirson method for computations, it is assumed that the magnetization of the rock is entirely by induction in the earth's magnetic field. In these calculations the zone counted by means of the graticule extends to a depth of 6,000 feet, a little more than half the depth to crystalline basement estimated from other aeromagnetic anomalies in the vicinity of Middlesboro, Kentucky (8,000 to 10,000 feet). Pirson counts were made along an estimated flight path of 500 feet above the ground at 500-foot intervals. Intermediate counts were made where necessary in proximity to the peak of an anomaly. The calculated susceptibility as shown on figures 6, 7, 8, and 9 was made by assigning a peak value to the computed anomalies of 220 gammas, corresponding to the amplitude of the observed anomaly.

For comparison with the computed anomalies, the recorded anomaly of line three (fig. 3) was selected because it crosses the center of the peridotite exposure. Regional magnetic gradient of 6 gammas per mile has been removed and the local anomaly over the peridotite has been corrected to remove the curvature of the large anomaly on which it is superimposed (fig. 5a). The arbitrary zero level of the resulting anomaly is depressed an additional 6 gammas to remove a slight negative feature of unknown origin (fig. 5b). The resulting adjusted recorded anomaly has an amplitude of +220 gammas and a negative component to the northwest of -23 gammas. This is the observed anomaly shown in figures 6, 7, 8, and 9.

The anomaly associated with the peridotite (fig. 4) is distinctly three-dimensional. The Pirson method for computation of magnetic anomalies was primarily developed for the study of two-dimensional features. The basic geometry of resulting curves however, is not essentially different from that of curves computed for the three-dimensional case (R. G. Henderson, U. S. Geological Survey, personal communication), and the saving in time afforded by using the graticule of Pirson is considerable. There are some limitations in use of the method in a study such as this, including graticule size and model scale, as well as the necessity for neglecting remanent magnetization and irregularities in distribution of magnetite. Remanent magnetization in the peridotite has not been appraised because of the lack of solid rock in place from which the direction of the remanent vector could be determined.

Another factor to be considered is the lack of information relating to the subsurface distribution of the peridotite. As stated by Henderson

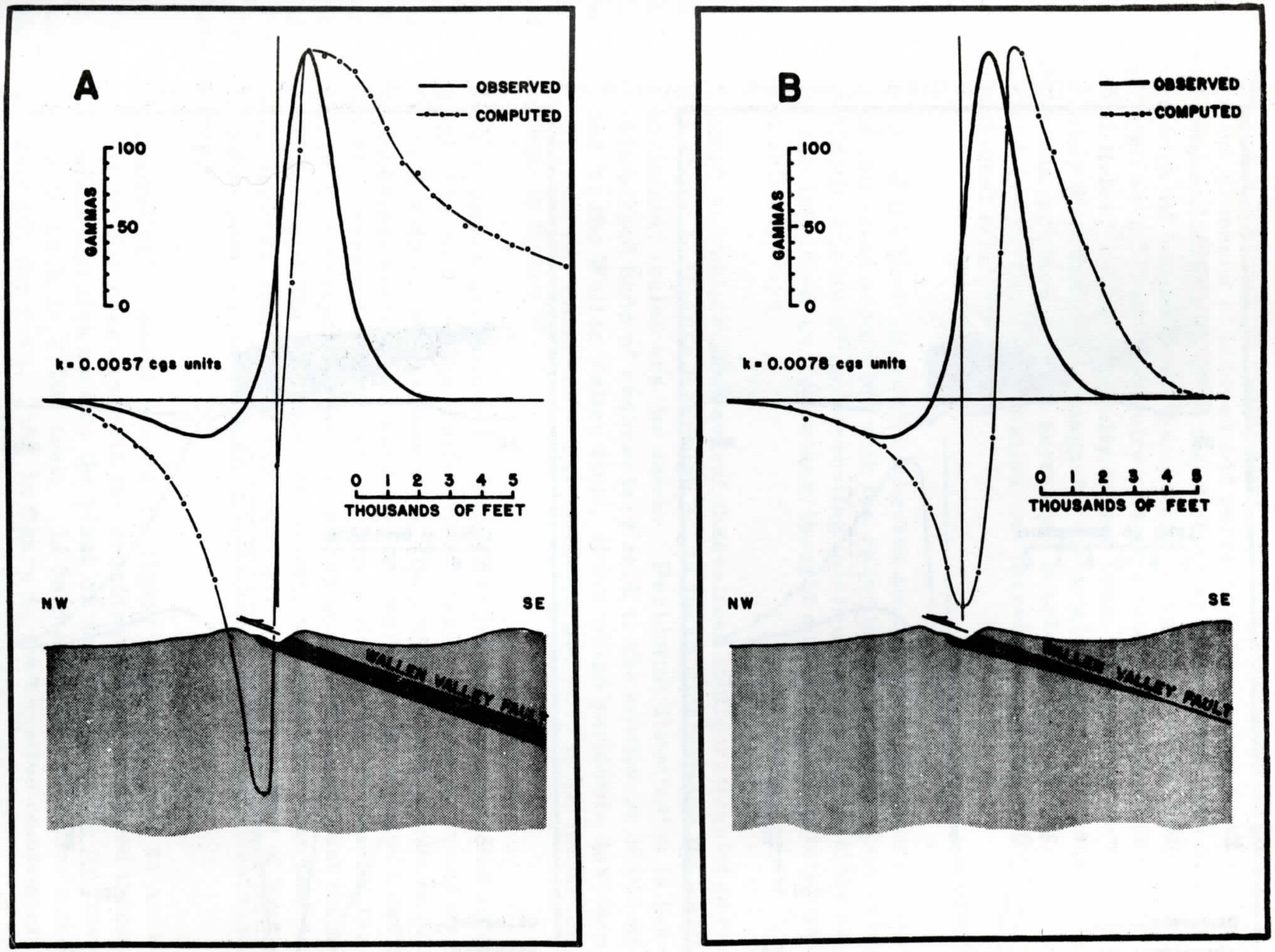

Figure 6. Computed anomalies for peridotite masses lying in the plane of the Wallen Valley fault.

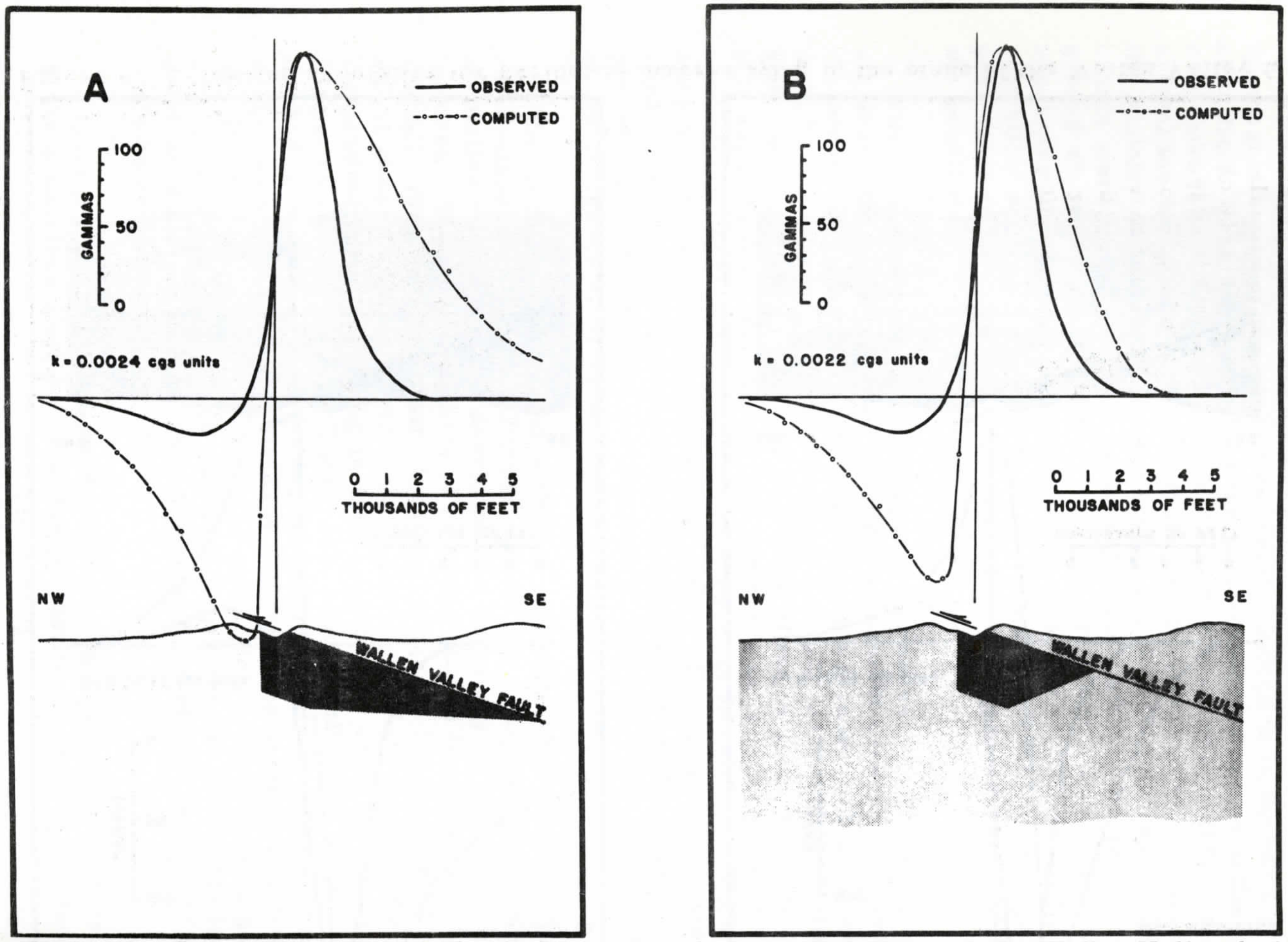

Figure 7. Computed anomalies for irregular peridotite masses beneath the Wallen Valley fault.

and Zietz (1958, p. 160),

> "The complications (of quantitative interpretation) stem largely from the presence of induced and permanent (sometimes called remanent) magnetism in the disturbing body, from lack of knowledge of magnetic and geometric parameters of the body, and from an inherent ambiguity affecting interpretation of potential fields. The ambiguity arises from the fact that there are many distributions of magnetic material at various depths which can produce a given anomaly. Supplementary geological and geophysical information is therefore necessary for unequivocal solutions."

In spite of the limitations and inherent ambiguities, however, comparison of computed anomalies with the recorded aeromagnetic anomaly of the peridotite yields some interesting information on the possible attitude of the intrusive and provokes thought concerning structural and historical relationships.

Computed anomalies for several theoretical configurations of peridotite are shown in figures 6 through 9. In these illustrations the vertical and horizontal scales are the same. Peridotite distribution is limited by undisturbed beds of sedimentary rock to the northwest of the exposure and by the Wallen Valley fault, above which peridotite has been neither reported nor observed. The observed anomaly in all instances is that shown in figure 5b.

Figure 6 shows anomalies for two distributions of magnetic rock lying within the plane of the Wallen Valley fault. In 6a the mass extends to depth with constant thickness. The computed anomaly is in all respects incompatible with the observed anomaly. The magnetic rock in figure 6b corresponds to a slice or horse of transported peridotite. The peak of this computed anomaly is displaced to the southeast more than 1,000 feet and the negative component, whereas less than that of figure 6a, exceeds that of the observed anomaly by a factor of four. The computed anomaly in both 6a and 6b has a strong northwestward asymmetry.

The theoretical masses shown in figure 7 correspond to an intrusive body in the rocks beneath the overthrust fault emplaced through a small conduit that lies outside the plane of the section. The thickness of the mass in each is 2,000 feet. In 7a the mass extends for a mile down dip beneath the fault. As in figure 6, the negative component is greatly in excess and the northwestward asymmetry persists. In figure 7b, the mass is shortened in the down dip dimension. The agreement in the positive component of the two curves is slightly improved, but the negative component remains in excess.

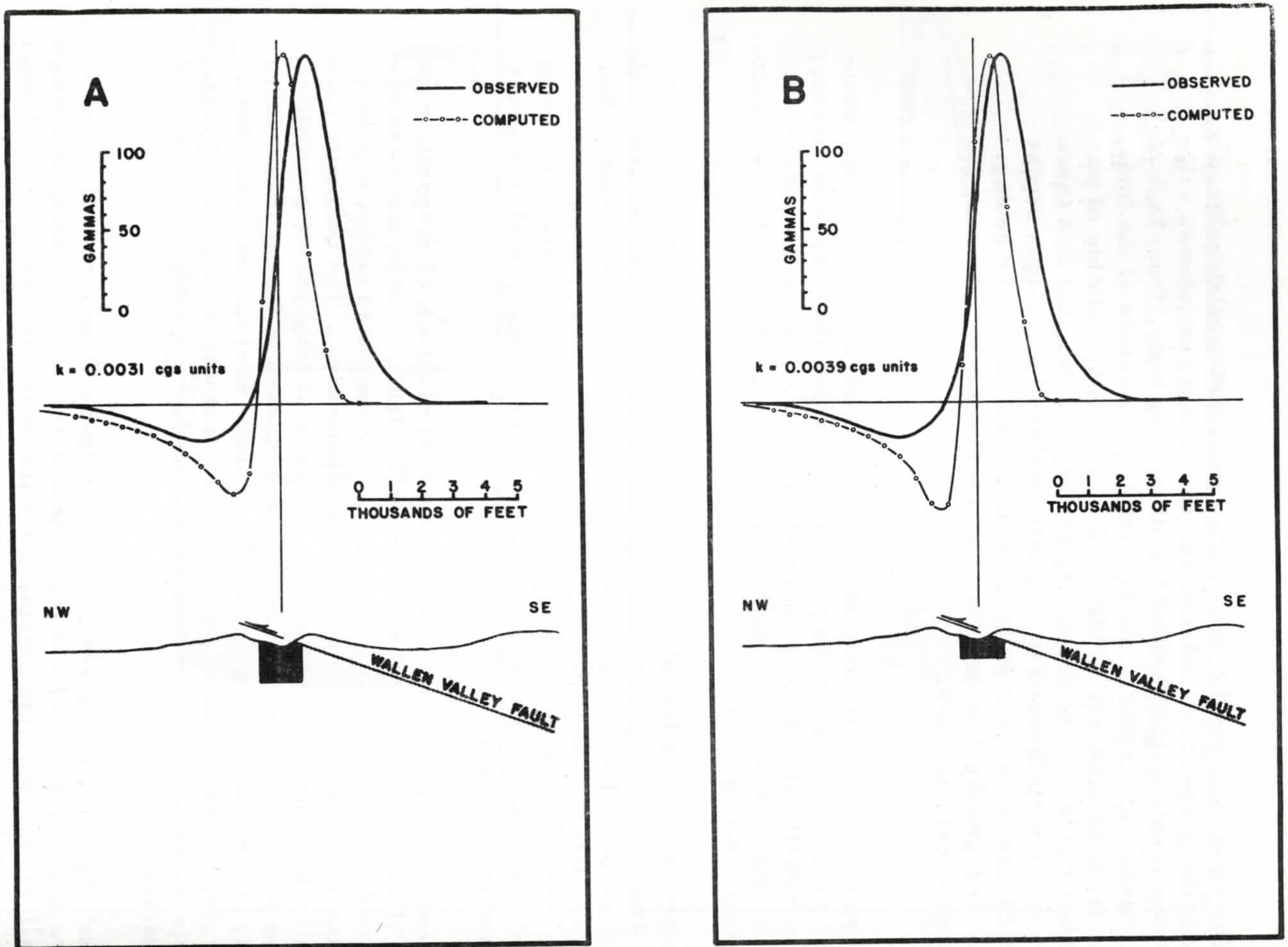

Figure 8. Computed anomalies for rectangular prisms of peridotite immediately below exposure area.

A horizontal prism is shown in figure 8 in which the longest dimension would be in a NE-SW direction, or perpendicular to the plane of drawing. In 8a the prism is of square cross section 1,200 feet on each side. The peak of the computed anomaly is displaced northwestward by 600 feet, its width at the half-maximum point is 0.6 times that of the observed anomaly, and the negative component is 2.5 times that of the observed anomaly. In 8b, the thickness of the prism is halved. No substantial change in the computed anomaly over that in 8a is present. The depth of the negative component is increased by 10 gammas.

The computed anomaly for a vertical plug is shown in figure 9a. The positive components of the computed and observed curves more nearly coincide, although there remains a slight northwestward asymmetry in the computed anomaly. The computed negative component is broadened but still exceeds that of the observed anomaly. In figure 9b, the plug dips 70° to the northwest (parallel to the inclination of the earth's magnetic field). The computed anomaly is displaced to the northwest about 400 feet, but the geometrical agreement between the computed and observed curves is greatly improved. The excess computed negative component is favorably reduced.

Other models using more complex configurations of magnetic mass were computed, but the results in general did not improve the conformity of the computed curves to that of the observed anomaly.

Considering the limitations of the method and inherent ambiguities in the interpretation of magnetic anomalies, further refinement of model geometry for a better fit between the computed and observed anomalies is not considered feasible. Quantitative geologic data relating to the actual surface and near-subsurface distribution of peridotite are lacking, as are other detailed geophysical data. The closest agreement, or "best fit" in the calculations discussed occurs with the model in which the peridotite is represented as a plug dipping steeply to the northwest (fig. 9b). If the peak displacement (400 feet) is corrected, the positive component of the two curves exactly coincide and the negative compoent of the computed anomaly exceeds that of the observed by only 12 gammas. The peak displacement may be due in part to error in airplane position. It could also be due to the contribution of remanent magnetization.

CONCLUSIONS

Until additional information is available, it is inferred from the aeromagnetic data that the peridotite body in Clark Hollow does not

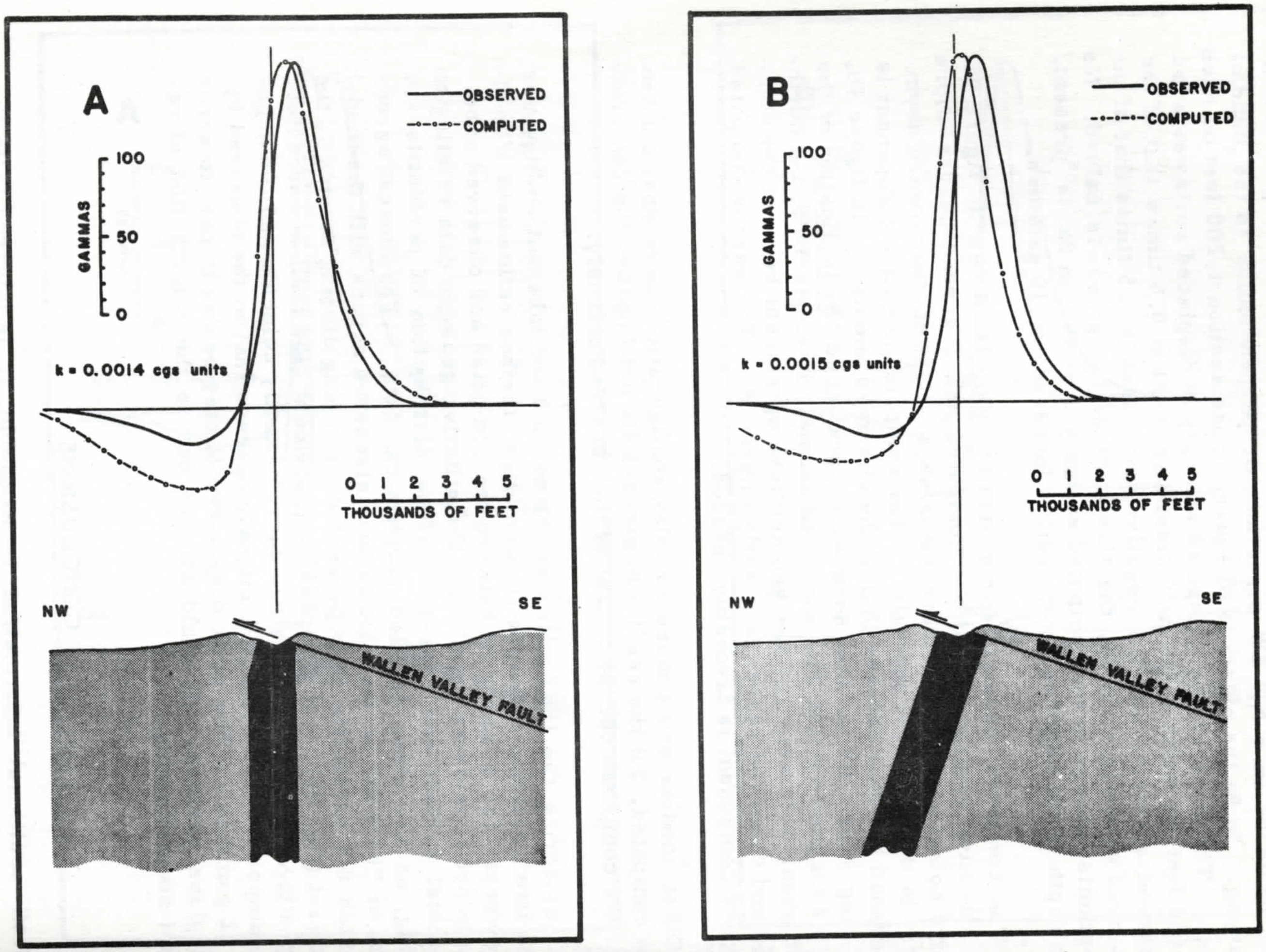

Figure 9. Computed anomalies for peridotite as vertical and inclined plug.

extend to depth along the Wallen Valley fault. It appears to be an elliptical cylindrical plug inclined steeply to the northwest and has the approximate cross-sectional dimensions of 1,500 feet by 3,000 feet.

The peridotite is considered not to be in a fault slice because of the discrepancies in computed anomalies for those configurations (figs. 6 and 7) and because subsidiary fault slices have not been mapped in the vicinity of the peridotite exposure. The contact relationships between peridotite and country rock are definitely of an intrusive nature, although alteration of the surrounding dolomite in proximity to the peridotite is notably absent. The plug configuration is considered the most plausible because it is the simplest geometry for the disturbing mass and because no other buried conduit for the peridotite can be demonstrated in the aeromagnetic data.

If the peridotite occurs as a steeply inclined plug, its attitude, position, deformation, and complex mineralogy are evidence of considerable complexity in sequence of events since the time of emplacement that are not generally recorded in the surrounding deformed sedimentary rocks. Because the plug lies entirely in the autochthonous block, it could have been emplaced prior to the development of the Wallen Valley fault. The distinct banding in several exposures of peridotite, parallel to both bedding in the sedimentary rocks and to the Wallen Valley fault plane, can be interpreted as fault-plane cleavage related to the Wallen Valley fault. The northwestward dip of the plug makes it nearly perpendicular to the bedding in the stratified rocks and suggests the remote possibility that the emplacement may have been accomplished at a time when the sedimentary beds were essentially flat lying. The occurrence in the peridotite of second-generation biotite and garnet as sorphyroblasts led Safford (1869) to call this a metamorphic rock, yet no metamorphism is encountered in the country rock, even at the contact, or within breccia fragments and inclusions lying completely within the peridotite. Disseminated magnetite, an expectable by-product of serpentinization, is universally present, but there is in addition a large quantity associated with the vein minerals. The vein-mineral assemblage is indicative of a late stage of hydrothermal activity.

It should be clear that the conclusions drawn here concerning the attitude of the peridotite body are made according to the theory of induction magnetization, and because of insufficient data, the effect of remanent magnetization is not considered. Remanent magnetization is dependent on the distribution of magnetic minerals within the rock, the thermal history of the rock, and the direction and strength of the ambient magnetic field at the time of each event of the thermal history. In the peridotite, three possible thermal events are indicated; one associated with the process of serpentinization, one during the development of the metamorphic minerals, and one at the time of emplacement of the vein minerals. These modifications of the petrology of the Clark Hollow plug must have had some effect on the magnetic character of the rock. Thus, the conclusions drawn should be considered as one group of possibilities, and it should be recognized that many other possibilities exist.

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PALEOECOLOGY OF THE CHOCTAWHATCHEE DEPOSITS (LATE MIOCENE) AT ALUM BLUFF, FLORIDA

by

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and
Donald W. Beardsley

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University of Houston

ABSTRACT

The Choctawhatchee (Late Miocene) deposits exposed at Alum Bluff, Liberty County, Florida are described. The development of facies within the Choctawhatchee is much more complex than indicated by Puri (1953). It is suggested that the full significance of these facies and their interrelationship will not be understood until all exposures are studied in much more detail and until more subsurface data become available.

The terminology previously applied to the Choctawhatchee deposits of western Florida is critically discussed. Classification of facies should be genetic, or where such a classification is not feasible, facies should be named according to the dominant lithology.

Comparison of fossil molluscan and foraminiferal assemblages with extant communities in the Gulf of Mexico, western Atlantic, and Caribbean offers strong evidence that the Alum Bluff Choctawhatchee sediments were deposited in the inner neritic zone in less than 8 fathoms of water. This conclusion is substantiated by stratigraphic, lithologic, and paleogeographic observations.

The lower Choctawhatchee shell bed at Alum Bluff was deposited in normal open shelf marine water during a minor transgression of the sea, and the upper beds were laid down during the succeeding regression under brackish-water and terrestrial conditions.

INTRODUCTION

Location and Description of Area

The area studied is located in Liberty County, Florida, at and near Alum Bluff, on the east side of the Apalachicola River about 2 miles north of the town of Bristol (Figure 1).

This part of the Florida Panhandle is covered by widespread continental sands of Pleistocene age which are loosely consolidated and very easily eroded. Thus, it is only along the steep bluffs of the major streams, such as Apalachicola and Ochlockonee rivers, that deposits of earlier Neogene age are exposed and accessible for study.

The areas near the major streams are highly dissected but the divides are flat and poorly drained. The average elevation of western Liberty County is about 150 feet above sea level, but the maximum elevation is 250 feet above sea level.

Purpose of Investigation

The type area for Miocene deposits of the southeastern states is western Florida, and the type section for the so-called "Ecphora facies" of the "Choctawhatchee formation" (Late Miocene) is the upper fossiliferous bed at Alum Bluff.

The primary purpose of this study is to determine by microfaunal, macrofaunal, and sedimentation analyses the depositional environments of the Choctawhatchee beds at Alum Bluff.

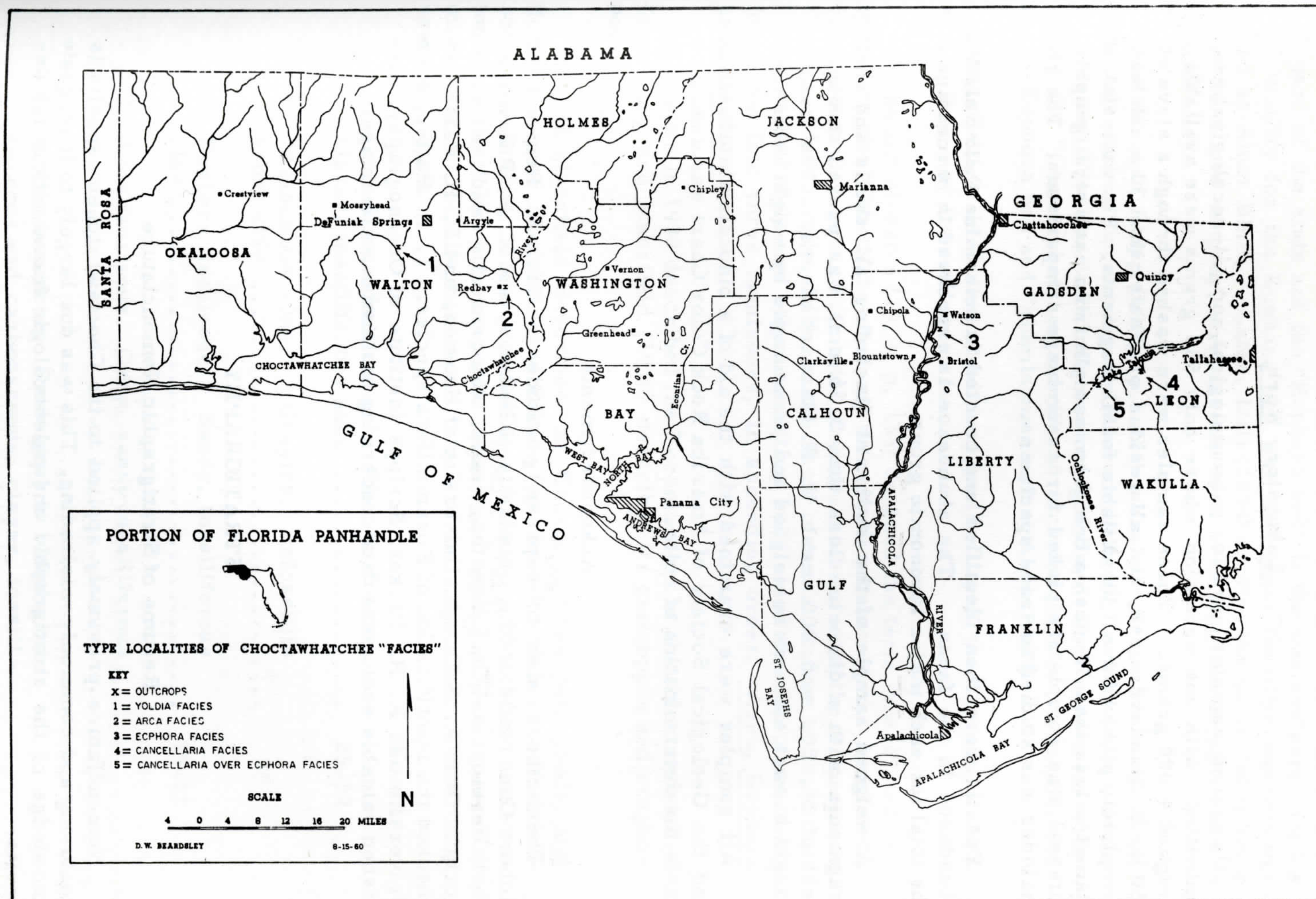
In addition, the authors suggest possible stratigraphic and paleoecologic relationships between the Choctawhatchee beds exposed at Alum Bluff and those strata which probably are equivalent in age at Jackson Bluff in Leon County, Florida.

Some of the terminology which has been applied to the various units of the Choctawhatchee formation is critically discussed.

Methods of Study

Field Work

Approximately 4 weeks were spent in the field in western Florida studying various outcrops of the Choctawhatchee beds. Sections were measured and detailed stratigraphic collecting was done along Alum Bluff, Liberty County, Florida, and at a roadcut approximately 0.5 miles southeast of the bluff. Samples, each weighing approximately 5,000 grams, were collected at 2 foot intervals in the fossiliferous



ALABAMA
GEORGIA
GULF OF MEXICO
SANTA ROSA
OKALOOSA
WALTON
HOLMES
WASHINGTON
JACKSON
BAY
CALHOUN
GULF
LIBERTY
GADSDEN
LEON
WAKULLA
FRANKLIN
Crestview
Mossyhead
DeFuniak Springs
Argyle
Redbay
Vernon
Chipley
Marianna
Greenhead
Chipola
Watson
Bristol
Clarksville
Blountstown
Chattahoochee
Quincy
Tallahassee
Lake Talquin
Panama City
Apalachicola
CHOCTAWHATCHEE BAY
Choctawhatchee
WEST BAY
NORTH BAY
ANDREWS BAY
ST JOSEPHS BAY
APALACHICOLA BAY
ST GEORGE SOUND
APALACHICOLA RIVER
Ochlockonee River
Econfina Cr.
River
PORTION OF FLORIDA PANHANDLE
TYPE LOCALITIES OF CHOCTAWHATCHEE "FACIES"
KEY
X = OUTCROPS
1 = YOLDIA FACIES
2 = ARCA FACIES
3 = ECPHORA FACIES
4 = CANCELLARIA FACIES
5 = CANCELLARIA OVER ECPHORA FACIES
SCALE
4 0 4 8 12 16 20 MILES
N
D.W. BEARDSLEY
8-15-60

Figure 1

beds, with a 4 foot maximum interval used in the nonfossiliferous beds.

Laboratory Work

Unwashed samples used for paleontological and paleoecological examination, with one exception where only 500 grams were available, weighed 4,000 grams. These samples were washed through a sieve of 150 U. S. Standard mesh, and all residue of greater than 30 mesh was completely picked for all identifiable fossil fragments. For material of diameter less than 30 mesh a one gram sample from each stratigraphic interval was completely picked for assemblage comparisons. The remainder was studied for rare specimens.

Fossils were then identified and counted to determine their relative abundance in the fauna. The abundance is expressed in percentage of the total for each major taxonomic group.

A weighed sample of the sediment (including all shells and shell fragments with a diameter less than 3.36 mm) was passed through a nest of 30, 50, and 200 mesh U. S. Standard sieves. The fractions caught in each sieve were weighed and percentages by weight determined.

All samples were examined with the aid of a binocular microscope and the Geological Society of America Rock Color Chart was used as a basis for determination of color.

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STRATIGRAPHY

Resume of Stratigraphic Nomenclature

Nomenclature previously applied to the Choctawhatchee deposits is confusing and commonly misleading. This was due largely to inadequate knowledge of the stratigraphic and paleoecologic framework of the deposits.

In 1892 Dall recognized two subdivisions of the "newer" Miocene deposits of Florida. These were the "Jacksonville limestone" in the eastern part of the state and the "Ecphora bed" in the western part. Dall's type locality for the Ecphora bed was the upper fossiliferous unit exposed at Alum Bluff. Later, Dall (1894) applied the name "aluminous clay" to a bed of gray, arenaceous clay overlying the Ecphora bed at this locality.

Matson and Clapp (1909, p. 114) were the first to use the term "Choctawhatchee" in naming the Miocene beds exposed in Walton County, western Florida, 0.75 mile east of Red Bay. They names these deposits the "Choctawhatchee marl" and included in this same division Dall's Ecphora bed and "aluminous clay" at Alum Bluff.

Mansfield in 1916 described the type locality of the Choctawhatchee at Red Bay, and its molluscan fauna.

Cooke and Mossom (1929, p. 138) dropped the term "marl" and referred to the Choctawhatchee as a formation because the marl beds constitute only a part of the total Choctawhatchee. In the same paper Cooke and Mossom (p. 140), on the basis of faunal studies by Mansfield (1916) at Red Bay and other localities subdivided the Choctawhatchee formation into three faunizones, in ascending order: Arca, Ecphora and Cancellaria.

Cushman in 1930 described the Foraminifera of the Choctawhatchee formation, and Mansfield (1930) described its gastropods and scaphopods.

In 1932 Mansfield described the Choctawhatchee pelecypods, and that same year Mansfield and Ponton (pp. 84-88) added a fourth faunizone, the Yoldia, to those of Cooke and Mossom. Mansfield and Ponton gave the following composite section of the Choctawhatchee formation (at no locality has more than 2 of these units been observed in vertical sequence):

	Feet
5. Cancellaria faunizone. Fine to coarse, clayey, fossiliferous sand	25-30
4. "Aluminous clay." Grayish, unfossiliferous clay	25
3. Ecphora faunizone. Sandy, fossiliferous clay	15-25
2. Arca faunizone. Gray, sandy fossiliferous marl	55
1. Yoldia faunizone. Dark-gray to bluish, micaceous and carbonaceous, clayey, fossiliferous sand	15

Vernon in 1942 after studying Choctawhatchee beds in Washington and Holmes counties, Florida, concluded that the Ecphora and Cancellaria faunizones were facies of the Arca and Yoldia faunizones.

Three years later, Cooke (1945) included the Arca and Yoldia faunizones in the Shoal River formation (Middle Miocene) and placed the Cancellaria and Ecphora faunizones in the Duplin marl (Late Miocene of Georgia and the Carolinas), discarding the term "Choctawhatchee."

Puri (1953) without a stated reason changed the rank of the Choctawhatchee from a formation to that of a stage which he classified as Late Miocene in age. Following Vernon (1942, p. 97) Puri concluded that the Choctawhatchee faunizones named by Cooke and Mossom (1929, p. 142) and Mansfield and Ponton (1932, p. 86) are more-or-less contemporaneous facies which he designated the Arca, Yoldia, Cancellaria and Ecphora facies. Puri did not give formal formational status to any of the Choctawhatchee deposits possibly because of the lack of certainty regarding the exact stratigraphic relationship among the four "facies." It is the authors' observation that the development of facies within the Choctawhatchee is much more complex than indicated by Puri, and that the full significance of these facies and their interrelationship will not be understood until all exposures are studied in much more detail than in the past and until more subsurface data become available.

Choctawhatchee deposits are lithologically and faunally variable so that it is difficult to trace units from one exposure to another. Moreover at any exposure any one of Puri's "facies" may be represented by several vertically superposed units each of which represents a distinct environment of deposition. In addition, Puri's "facies" do not represent the same environment of deposition at each exposure where they have been recognized. The general confusion related to the Choctawhatchee deposits seems to stem not only from lack of detailed studies, but also from the inadvisable procedure of adopting a system of nomenclature for facies which was formerly applied to divisions regarded as faunizones. In any event it seems to the authors that facies nomenclature, where possible should be genetic, being based on thorough faunal-floral and lithologic analyses. Where a genetic classification is not feasible, facies terminology should be descriptive (Teichert, 1958), referring to primary lithologic or paleontologic characteristics of the rock. Facies should not be names for fossils which occur very sparingly even though they might appear to be restricted to the facies.

In this paper the authors refer to the Late Miocene rocks of the Florida Panhandle as the "Choctawhatchee deposits," and as a matter of convenience of reference have temporarily retained Puri's facies nomenclature for all but the exposures at Alum Bluff and Jackson Bluff.

General Stratigraphy

The Choctawhatchee deposits crop out in isolated patches in western Florida. The counties in which Choctawhatchee beds are exposed include Walton, Washington, Bay, Calhoun, Liberty, Leon, Wakulla, and Franklin (Figure 1).

With the exception of work done by Vernon (1942) in Washington and Holmes counties, Florida, there has been no detailed mapping of the Choctawhatchee beds. Comprehensive descriptions of "facies" are confined to rocks in the immediate vicinity of the type locality of each "facies."

"Yoldia Facies"

Mansfield and Ponton (1932, p. 86) first used the term "Yoldia faunizone" (from Yoldia waltonensis Mansfield) in naming about 15 feet of dark gray, micaceous sandy sediments exposed southeast of the De Funiak Springs in Central Walton County, Florida (SE-1/4 Sec 18 T2N R19W). Puri (1953) discarded the term "faunizone" and named the unit the "Yoldia facies."

Mansfield and Ponton (1932, p. 84-88) stated that the Yoldia faunizone was the basal member of the Choctawhatchee formation. They thought that it disconformably overlay the Shoal River formation and was overlain by the Arca faunizone of the Choctawhatchee formation. However, neither the upper nor the lower limit of the Yoldia faunizone has ever been certainly recognized. Mansfield and Ponton separated the Yoldia faunizone from the supposedly overlying Arca faunizone because of the abundant specimens of the pelecypod Yoldia, a genus which is generally thought to indicate rather cold water.

An auger hole was drilled at the type locality of the Yoldia facies in order to determine the exact thickness of the facies. The Yoldia facies was penetrated at a depth of 10 feet, and the drill bit was still in the Yoldia facies at a depth of 85 feet, where the hole was completed (Puri, 1953, p. 29). Thus, the thickness of the facies was determined to be at least 75 feet.

Lithologically, the Yoldia facies consists primarily of greenish-gray micaceous clays with some interbedded sands.

According to Puri (1953, p. 48) the microfauna of the Yoldia facies seems to point to an inner neritic environment of deposition, (p. 40) representing the western-most shallow-water marine sediments of the "Choctawhatchee Stage" deposited in western Florida. Puri also stated that the Yoldia facies is the up-dip equivalent of the Arca facies.

By a careful survey of all previous literature on the Choctawhatchee formation it is seen that the Yoldia facies has been recognized at only the type locality, and another outcrop located less than a mile to the east of the type at a bluff on Sconiers Mill Creek (NE-1/2 Sec 17 T2N R19W, Walton County, Florida).

"Arca Facies"

Mansfield (Cooke and Mossom, 1929, pp. 140-142) named the "Arca faunizone" for 19 feet of gray, sandy, argillaceous, shell marl containing the pelecypod Arca rubisiniana Mansfield near Red Bay, Walton County, Florida. Puri (1953) changed the "Arca faunizone" to "Arca facies." The section near Red Bay, is also the type locality for the Choctawhatchee formation, and at this locality neither the top nor the bottom of the Arca facies is exposed.

At the type locality the exposed Arca facies consists of at least 35 feet of greenish, argillaceous, shell-bearing sand in the lower part and upper unit of about 5 feet of gray to greenish unfossiliferous plastic clay.

Puri (1953, p. 40), apparently on the basis of evidence furnished by microfauna, stated that the Arca facies was deposited under outer neritic conditions. He also concluded (p. 40) that the lower part of the Arca facies is contemporaneous with the Yoldia facies, whereas the upper part is contemporaneous with the Cancellaria facies, but gives no evidence for this conclusion.

The Arca facies is more widespread than any of the other 3 "facies" of the Choctawhatchee formation. The Arca facies has been recorded from localities in western Washington County (T2N, R15W) and in the vicinity of Red Bay (the type locality) in eastern Walton County. The Arca facies also has been recognized at a locality northeast of Argyle in southwestern Holmes County, Florida (Puri, 1953) and questionably from one locality in northwestern Bay County, Florida north of Econfina Creek (Sec 22 T2N R12W).

"Ecphora Facies"

The "Ecphora bed" which had been named by Dall (1892) was changed in 1929 to "Ecphora faunizone" by Mansfield and later to "Ecphora facies" by Puri (1953). The type locality for the Ecphora facies is the upper shell bed at Alum Bluff on the east side of the Appalachicola River approximately 2 miles north of Bristol, Liberty County, Florida. The Ecphora facies was named for the large gastropod Ecphora quadricostata umbilicata Wagner which is extremely rare within the unit.

At the type locality, the Ecphora facies varies from 15 to about 25 feet in thickness and, in the authors' opinion, unconformably overlies the nonmarine Hawthorn formation. The Ecphora facies at Alum Bluff consists of greenish-gray argillaceous, arenaceous shell marl which contains abundant valves of the pelecypod Mulinia congesta (Conrad). At this locality, the shell bed is conformably (?) overlain by about 25 feet of the "aluminous clay" of Dall (1894) which grades upward into an argillaceous sand.

The Ecphora facies, (Puri 1953, p. 40) was deposited under conditions similar to those of the Arda facies (outer neritic) but the Ecphora facies has a deeper water fauna. Puri also states that the Ecphora facies is a regressive unit.

Sediments assigned by earlier workers to the Ecphora facies have been collected by various geologists from outcrops along Econfina Creek in Washington County, Florida; from the vicinity of Alum Bluff, Liberty County, Florida; north of Clarksville, Calhoun County; and from the vicinity of Jackson Bluff, Leon County, Florida. At Jackson Bluff, the Ecphora facies is overlain by the Cancellaria facies. This is one of the few known localities where two of Puri's Choctawhatchee facies are exposed in vertical sequence.

The Ecphora facies at Jackson Bluff is very different both lithologically and faunally from the Ecphora facies exposed at the type locality; and apparently is comprised at Jackson Bluff of at least two distinct members.

"Cancellaria Facies"

The "Cancellaria faunizone" was named by Mansfield (Cooke and Mossom, 1929, p. 140) for beds containing Cancellaria propevenusta Mansfield which were then exposed along the banks of Harveys Creek (SW-1/2 Sec 9 T1S R3W, Leon County, Florida). This locality is no longer accessible. Puri (1953) changed the name "Cancellaria faunizone" to "Cancellaria facies."

The Cancellaria facies is exposed at Jackson Bluff, Leon County, Florida where it apparently disconformably overlies the Ecphora facies. At this locality the Cancellaria facies consists of coarse grained sandy shell marl and is approximately 3 feet thick.

The faunas of the Cancellaria and Ecphora facies are similar, both apparently having been deposited on the open shelf. According to Puri (1953, p. 51) the lower part of the Cancellaria facies was deposited under outer neritic conditions, but the upper part (deposits overlying the

Ecphora facies at Jackson Bluff) was deposited under a shallow transgressing sea.

The "aluminous clay" which overlies the Ecphora facies at Alum Bluff, Liberty County may be stratigraphically equivalent to the Cancellaria facies at Jackson Bluff.

The Cancellaria facies has been recorded by earlier workers from numerous localities in Washington County, Florida, one locality in Bay County, two localities in Leon County, one in Franklin County and one locality in Wakulla County (Figure 1).

Local Stratigraphy

Alum Bluff, Liberty County, Florida, is the type locality for the Alum Bluff Stage (Middle Miocene) as well as for the overlying Ecphora facies of the Choctawhatchee Stage (Upper Miocene).

A generalized description of the sediments exposed at Alum Bluff is presented below (Figure 2). A detailed section of the Choctawhatchee beds exposed at this locality is presented in the Appendix. Note that the unit numbers used in the discussion below correspond to those assigned to the units in Figure 2.

"Alum Bluff State--Chipola Facies" (Middle Miocene)

Bed 1. (Equivalent to Bed 1 of Puri, 1953, p. 34). The lowermost beds exposed along Alum Bluff are those of the marine "Chipola facies" of the "Alum Bluff Stage" (Middle Miocene). The Chipola beds at this locality are as much as 10 feet in thickness and consist of tan, calcareous sands which are sparsely fossiliferous in the lower part but become very fossiliferous in the upper 5 feet. The Chipola facies is soft, but rather tough, and is a prominent ledge former along the river. The contact of the Chipola with the overlying "Hawthorn facies" is disconformable. The base of the Chipola facies is not exposed at this locality.

"Alum Bluff Stage--Hawthorn Facies" (Middle Miocene)

Bed 2. (Equivalent to Puri's Bed 2, 1953, p. 34). Approximately 20 feet of the nonmarine "Hawthorn facies" (Middle Miocene) is exposed at Alum Bluff. The contact of the Hawthorn facies with the underlying Chipola facies is irregular, and the lower one foot of the Hawthorn facies is made up of a limonitic sandstone with numerous large quartz pebbles up to one inch in diameter. The remainder of the Hawthorn is composed of argillaceous, gray, yellow and white, variegated, cross-bedded and laminated sands, and contains wood fragments, leaves and carbonized logs.

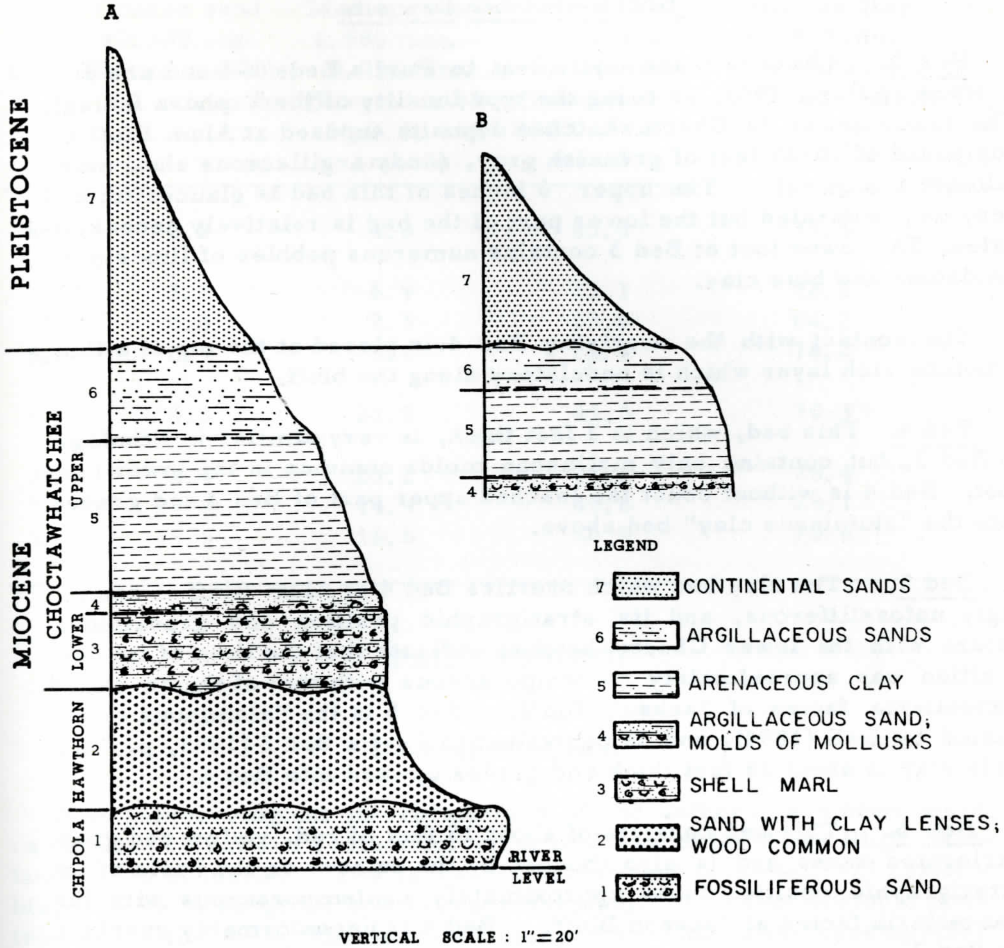

Figure 2. (A) Section exposed at Fort Preston, Alum Bluff, Liberty County, Florida. (B) Section exposed south of dam, SW 1/4 NW 1/4 Sec. 30 T1N R7W, Liberty Co., Florida.

The contact with the overlying Choctawhatchee is very irregular, and the top foot of the Hawthorn is bored by organisms and filled with the overlying Choctawhatchee shell marl.

Choctawhatchee Deposits

Bed 3. (Beds 3-6 are equivalent to Puri's Beds 3-6 and are described by Puri, 1953, as being the type locality of the Ecphora facies). The lower bed of the Choctawhatchee deposits exposed at Alum Bluff is composed of 10-20 feet of greenish gray, sandy argillaceous shell marl (almost a coquina). The upper 6 inches of this bed is glauconitic and very well indurated but the lower part of the bed is relatively unconsolidated. The lower foot of Bed 3 contains numerous pebbles of limestone, sandstone and blue clay.

The contact with the overlying Bed 4 is placed at the top of a thin limonitic rich layer which is undulatory along the bluff.

Bed 4. This bed, which is 3 feet thick, is very similar in lithology to Bed 3, but contains only molluscan molds common in the lower one foot. Bed 4 is without doubt the leached upper part of Bed 3 and grades into the "aluminous clay" bed above.

Bed 5. The clay bed which overlies Bed 4 at Alum Bluff is seemingly unfossiliferous, and its stratigraphic position and gradational nature with the lower Choctawhatchee indicate that the time of its deposition was approximately contemporaneous with that of the so-called Cancellaria facies of Jackson Bluff. Bed 5 is the "aluminous clay" named by Dall (1894), and is equivalent to Puri's Bed 5 (1953, p. 34). This clay is about 25 feet thick and grades upward into Bed 6.

Bed 6. This bed consists of about 15 feet of red, yellow and gray variegated sands and is also thought by the authors on the basis of its stratigraphic position to be approximately contemporaneous with the Cancellaria facies at Jackson Bluff. Bed 6 is unconformably overlain by Bed 7.

Pleistocene Series--"Coharie Formation"

Bed 7. (Includes Beds 7-12 of Puri 1953, p. 33). Approximately 50 feet of primarily variegated sands with some clays, assigned by earlier workers to the "Coharie formation" of Pleistocene age, overlie the Choctawhatchee beds, at Alum Bluff. The lower contact is placed below a zone containing scattered quartz and kaolinite pebbles which apparently represents a disconformity. The Coharie beds are the highest deposits exposed at Alum Bluff.

Table 1. Grain Size Analysis Chart of Alum Bluff Choctawhatchee Deposits.

Bed	Coarse sand >0.589 mm. (% residue 30) U.S. std. mesh	Medium sand 0.589 mm. - 0.295 mm. (% residue 30 50 U.S. std. mesh)	Fine sand 0.295 mm. - 0.074 mm. (% residue 50 200 U.S. std. mesh)	Silt and clay <0.074 mm. % residue 200 U.S. std. mesh)
6	0.8	4.8	83.0	11.4
5C	3.8	6.9	73.1	16.2
5B	0.5	2.3	13.0	84.2
5A	0.5	5.9	15.4	78.2
4	4.3	23.9	41.5	30.3
3C	8.4	23.2	42.2	26.4
3B	11.4	14.9	49.6	24.1
3A	15.5	16.6	40.9	26.6

PALEOECOLOGY

General Discussion

The paleoecological interpretations of the authors have been based on detailed faunal and sedimentological analyses of the Alum Bluff Choctawhatchee deposits. The large molluscan and foraminiferal assemblages have been given special consideration. Excellent ecologic control was afforded by the fact that many of the Choctawhatchee species still live in the Gulf of Mexico, and many of the extinct forms differ morphologically only slightly from their present day descendants.

Recently much data has been published concerning the ecology of the faunas, the sedimentation and oceanography of the northern Gulf of Mexico (Bandy, 1954, 1956; Curtis, 1960; Hulings, 1955; Ladd, 1951, 1957; F. L. Parker, 1954; R. H. Parker, 1955, 1956, 1959; Phleger, 1951, 1954, 1955; Post, 1951). This information was especially useful to the authors in the interpretation of the Choctawhatchee depositional environments. It must be pointed out, however, that each assemblage and sedimentary suite is the reflection of a complex of physical, chemical and biological factors, the intricacies of which are never fully understood even in the most thoroughly studied recent marine environments. It is, for example, very difficult to determine which factor, (depth, salinity, bottom conditions, nutrients, etc.) if any single one, represents the chief control in the local distribution of a species. Thus, it can be seen that even with the best fossil assemblages detailed paleoecologic analysis becomes precarious. In addition, although overall environmental conditions in a region such as the Gulf of Mexico have apparently remained rather uniform for millions of years it is certain that during that time the environment fluctuated at least slightly and that at no time in the past were conditions exactly the same as those of the present.

It would seem to the authors that we should not be completely literal in our application of ecologic knowledge of recent environments to interpretation of ancient environments. Differences in the Late Miocene paleogeography, source of sediments, rate of runoff, ocean currents, bottom configuration, temperature, etc. might result in the development of local or even regional communities which would differ appreciable in composition from any now known to exist. Fossil assemblages similar to present day communities might have occupied slightly different ecologic niches in the Miocene (i.e. deeper or shallower water). Further, physiological evolution, especially among the forams, without detectable morphological evolution seems a definite possibility. This is not to suggest that the honored axiom "The Present is the Key to the Past" cannot be applied successfully to paleoecological studies, on the contrary as with all other geological investigation it is, when properly applied, our guiding light and chief hope for accurate interpretation of the geologic past.

Faunas

Microfauna

Foraminifera. The Choctawhatchee shell bed at Alum Bluff contains an abundant fairly well preserved foraminiferal fauna of more than 50 species (Faunal Check List 1, Appendix). The fauna is dominated by the extant species Buliminella elegantissima d'Oribigny which comprises up to 74.4 per cent of the individuals in the samples studied by the authors.

Puri (1953, p. 34) lists the following foraminifer species as occurring only in the Ecphora facies:

Quinqueloculina contorta d'Orbigny
Spiroloculina depressa d'Orbigny
Marginulina dubia Neugeboren
Virgulina (Virgulinella) gunteri curtata
  Cushman and Ponton
Uvigerina parkeri Karrer
Massilina sp.

None of the above species were found by the authors to be present in the type deposits of the Ecphora facies at Alum Bluff.

Ostracoda. The ostracode fauna of the Choctawhatchee deposits at Alum Bluff is extremely sparse and only a very few specimens were observed during this study. Puri (1953) recorded only 3 species of ostracodes from the Choctawhatchee deposits at Alum Bluff.

Macrofauna

The lower Choctawhatchee deposits at Alum Bluff (Beds 3 and 4) contain a rich macrofauna, composed primarily of mollusks (Faunal Check Lists 2 and 3, Appendix).

Though many specimens are soft and chalky due to ground water action, there is no evidence of wear caused by current or wave action. In addition, there is no apparent orientation by currents although all the shells seem to have been at least slightly disturbed as none now occupy a life orientation.

Mollusca. Pelecypods are by far the most abundant mollusks in number of specimens in Bed 3 at Alum Bluff. However, 38 species of gastropods and only 34 species of pelecypods were recorded from Bed 3 by the authors.

The most abundant molluscan species of the Choctawhatchee shell bed at Alum Bluff are listed below:

Pelecypoda
- Mulinia congesta (Conrad)
- Nuculana trochilia Dall
- Phacoides crenulatus pemphigus Dall

Gastropoda
- Turritella alumensis Mansfield

Scaphopoda
- Cadulus floridanus Dall
- Dentalium carolinense Conrad

Other macrofossils. Macrofossils other than mollusks occur sparsely throughout the Choctawhatchee shell bed at Alum Bluff.

Large colonial corals (?*Astrangia* sp.) are present in the lower one foot of bed 3, and broken echinoid spines and plates occur throughout the bed.

Barnacle fragments (*Balanus* sp.) were found throughout Bed 3 at Alum Bluff, but are not common in the upper part of the unit.

Small, scattered fragments of Bryozoa were found throughout the Choctawhatchee shell bed.

Depositional Environments

General Statement

Previous work concerning the depositional environment of the Choctawhatchee deposits (Puri, 1953, p. 49-51 and Bandy, 1956, p. 190) has resulted in the hypothesis that the Ecphora facies of the Choctawhatchee formation was deposited under outer neritic conditions. Puri (1953 p. 58) postulated a maximum depth of 100 meters for the deposition of the Ecphora facies, and Bandy (1956 p. 190) indicated that the Ecphora facies was deposited in 250 to 600 feet of water.

Several factors lead the authors to disagree with the conclusions of Puri and Bandy, at least for the Choctawhatchee beds exposed at Alum Bluff, the type locality for Puri's Ecphora facies.

Past interpretations of the paleoecology of the Choctawhatchee deposits have been based primarily on the occurrence of certain foraminiferal species without regard to the relative abundance of each species or to other faunal elements. Also, these interpretations were based on composite lists of foraminifers from several localities representing more than one depositional environment within the Ecphora facies. In addition, stratigraphic, paleogeographic and sedimentological evidence has been disregarded in the earlier studies.

The evidence from the present study indicates that the Choctawhatchee deposits at Alum Bluff were deposited very near to shore, and that during Choctawhatchee time the water at this locality was never more than 50 feet deep.

Beds 3 and 4

The faunal, stratigraphical, sedimentological and paleogeographical evidence leads the authors to the following conclusions concerning the depositional environments of Beds 3 and 4 (Figure 2) at Alum Bluff:

1. The beds were deposited in an open sea, inner neritic environment.

2. Deposition occurred during a minor transgression-regression cycle.

3. At maximum transgression (represented by the upper part of Bed 3) the water was probably not more than 50 feet at this locality.

4. The Early Choctawhatchee shoreline probably was not more than 5 miles inland from Alum Bluff.

5. During deposition of Units 3 and 4, the water salinity was normal for the open shelf.

6. The water was at least periodically turbid at this locality during Early Choctawhatchee time.

7. The temperature of the Early Choctawhatchee Gulf of Mexico was possibly slightly lower than that of the modern Gulf.

The lowermost Choctawhatchee bed (Bed 3) is, primarily because of its abundant fauna, the key to the paleocology of the entire Choctawhatchee section exposed at Alum Bluff.

Bed 4, which contains molluscan molds, is undoubtedly the upper part of Bed 3 which has been leached of shell material along the bluff. At a locality 0.5 mile northeast of Alum Bluff, (Figure 2) an unleached, richly fossiliferous argillaceous sand (Bed 3 equivalent) grades vertically into a unit judged to be equivalent to Bed 5 (the "aluminous clay") at Alum Bluff.

The molluscan fauna of Bed 3 offers strong evidence for a nearshore depositional environment. All of the molluscan species from Bed 3 are closely related (morphologically) to forms which live today in shallow, nearshore marine environment. Many are similar to species most characteristic of the inner neritic zone.

The more common pelecypod species from Bed 3 are listed below:

TABLE 2. DISTRIBUTION OF MOST COMMON SPECIES FROM BED 3 AT ALUM BLUFF

SPECIES	% (P=<1%)	LIVING	CLOSELY RELATED MODERN SPECIES	GEOGRAPHIC DISTRIBUTION	DEPTH RANGE (FATHOMS)	OTHER ECOLOGIC DATA
FORAMINIFERA	100					
Bulimina marginata d'Orbigny	P	x		Atlantic and Gulf cont'l shelf and slope.	Common to 200	
Buliminella elegantissima (d'Orbigny)	41.2-74.4	x		Atlantic and Gulf cont'l shelf and slope.	0-192	Common near-shore
Buccella mansfieldi Cushman	4.6-17.1		Buccella hannai (Phleger and Parker)	Gulf of Mexico.	0-50	
Cancris sagra D'Orbigny	P	x		Florida to Brazil.	1-50	
Cassidulina crassa d'Orbigny	P	x		Atlantic and Gulf cont'l shelf and slope.	25-2150	
Cassidulina laevigata d'Orbigny	P	x		W. Indian area north to 34 N lat.	50-306	
Cibicides floridanus Cushman	1.0-4.1	x		W. Indian area north to 34 N lat.	9-1550	
Discorbis floridana Cushman	1.5	x		Florida, Cuba, Rio de Janeiro Harbor.	0-45	
Discorbis floridensis Cushman	P	x		South of Cape Hatteras.	47-200	
Elphidium incertum (Williamson)	P-3.6	x		Gulf of Mexico.	0-50	
Elphidium poeyanum (d'Orbigny)	2.4-15.3	x		Gulf of Mexico.	0-73	
Hanzawaia concentrica (Cushman)	1.0-2.4	x		Gulf of Mexico.	0-75	
Nonionella grateloupi (d'Orbigny)	3.1-6.3			Atlantic and Gulf of Mexico.	Common to 50	
Virgulina fusiformis (Cushman)	0.0-4.2		Virgulina pontoni	Atlantic and Gulf of Mexico.	0-62	

SPECIES	% (P= 1%)	LIVING	CLOSELY RELATED MODERN SPECIES	GEOGRAPHIC DISTRIBUTION	DEPTH RANGE (FATHOMS)	OTHER ECOLOGIC DATA
PELECYPODA	100					
Caryocorbula inequalis Say	2.7-5.7		Corbula dietziana C. B. Adams	Mass. to W. Indies.	Shallow	Common in Aransas Bay, Tex. (2 fathoms).
Mulinia congesta (Conrad)	11.4-47.9		Mulinia lateralis (Say)	Canada to Mexico.	0-8	Can withstand abnormal salinities.
Nuculana trochilia Dall	12.6-23.9		Nuculana acuta Conrad	Cape Cod to W. Indies.	Shallow	Common in Aransas Bay.
Phacoides crenulatus pemphigus Dall	28.4-51.9		Phacoides multilineatus Toumey and Holmes	N. Carolina to Florida.	0-120	Abundant in passes and on Cont'l shelf.
GASTROPODA AND SCAPHOPODA	100					
Crucibulum auriculum imbricatum Sowerby	P		Crucibulum auriculum Gmelin	W. Florida to W. Indies.	Shallow	Uncommon.
Marginella minuta Pfeiffer	0-5.1	x		S. Florida and W. Indies	Common to 40	
Nassarius alumensis (Olsson)	0-15.8		Nassarius actus Say	W. Florida to Texas.	Shallow	Abundant in polyhaline bays and open Gulf.
Olivella mutica (Say) Dall	0-7.6	x		N. Carolina to Florida, Texas and W. Indies.	Shallow	Abundant in inlets.
Retusa canaliculata (Say)	P	x		Nova Scotia to Florida, Texas, and W. Indies.	Shallow	Common in polyhaline bays, passes.
Tectonatica pusilla (Say)	P	x		Cape Cod to Florida, Gulf states and W. Indies.	0-18	
Turritella alumensis Mansfield	27.3		Turritella exoleta Linne'	S. Florida and W. Indies.	1-100	Genus abundant in quiet water
Cadulus floridanus Dall	7.1-50.5		Cadulus carolinensis Bush	N. Carolina to Florida and Texas.	3-100	
Dentalium carolinense Conrad	21.4-42.1		Dentalium texasianum Phillipi	N. Carolina to Gulf states.	3-10	

Species	Percentage of Pelecypod Fauna
Mulinia congesta (Conrad)	11.4-47.9
Phacoides crenulatus pemphigus Dall	28.4-51.9
Nuculana trochilia Dall	12.6-23.9

Modern relatives of the above species are Mulina lateralis (Say), Phacoides multilineatus Toumey and Holmes and Nuculana acuta Conrad. All three species are shallow water forms (Table 2) occurring today in the open waters of the inner neritic zone as well as high salinity, enclosed environments such as bays and lagoons.

Though gastropods and scaphopods are relatively uncommon in the Choctawhatchee deposits at Alum Bluff, the most abundant species offer evidence of nearshore deposition. The Recent scaphopod, Dentalium texasanium Phillip, a form similar to Dentalium carolinense Conrad that occurs in Bed 3, is a common species occurring in the modern Gulf of Mexico at depths to 10 fathoms.

The concentration of Turritella alumensis Mansfield in the upper part of Bed 3 at a locality 0.5 mile southeast of Alum Bluff probably represents deposition in a shallow nearshore depression where wave and current action were reduced and plant detritus was plentiful. Such an environment, according to Merriam (1941, p. 18) is very favorable for the development of Turritella colonies.

According to Parker (1960, p. 320) Olivella mutica is a characteristic species of the sandy surf zone throughout the Northern Gulf. Retusa canaliculata, rare at Alum Bluff, is considered by Parker (1960, p. 315) as a characteristic species of the open lagoon or open sound center, where along the Northern Gulf recorded salinities range from 20 to 39%, temperatures range from 8 to 36°C and the substrate is somewhat argillaceous. According to Abbott (1954) Tectonatica pusilla is common from Cape Cod to the West Indies in shallow water to depths of 18 fathoms.

The large and varied fauna and the presence of such genera as Eucrassatella, Mitra, and Crucibulum, the absence of beach forms such as Donax and the lack of brackish water species such as those of the genera Rangia and Ostrea all point to open marine conditions.

Bed 3 at Alum Bluff contains a foraminiferal fauna of more than 50 species. however, most of the species are represented by relatively few individuals. The following 9 species each comprise more than 1 per cent of the total foraminiferal fauna or most samples:

Species	Percentage
Buliminella elegantissima (d'Orbigny)	41.2-74.4
Buccella mansfieldi Cushman	4.6-17.1
Cibicides floridanus Cushman	1.0- 4.1
Discorbis floridana Cushman	0.0- 1.5
Elphidium incertum (Williamson)	1.0- 3.6
Elphidium poeyanum (d'Orbigny)	2.4-15.3
Hanzawaia concentrica (Cushman)	1.0- 2.4
Nonionella grateloupi d'Orbigny	3.1- 6.3
Virgulina fusiformis (Cushman)	0.0- 4.2

Most of the extant species (12 in number) from Bed 3 are reported to live today in depths of water much greater than suggested by the molluscan fauna of Bed 3. However, one living species, Buliminella elegantissima d'Orbigny, comprises up to 74.4 per cent of the total foraminiferal fauna of Bed 3. According to R. H. Parker (1960, personal communication) the high percentage of Buliminella elegantissima indicates a near shore turbulent zone. Parker further states that the species is a particularly characteristic inhabitant of the outer surf zone and depths to 30 feet, where it comprises 70 to 80 per cent of some modern foraminiferal faunas.

Tests of deeper water species might have been washed shoreward although this seems unlikely for the benthonic forms. It is more probable that ecologic conditions peculiar to the Choctawhatchee Sea (such as colder water) caused displacement of the living benthonic communities shoreward into shallower water than that in which they live today.

The relatively high percentage (5 per cent) of planktonic Foraminifera indicates that the area was not restricted from marine influence during Lower Choctawhatchee deposition. The absence of miliolids, the presence of only a few bryozoans and corals in Beds 3 and 4 is probably due in part at least to turbidity of the water as indicated by the high percentage of clay in the beds (See Grain Size Analysis Chart).

Some large colonial corals (?Astrangia sp.) occur at the base of Bed 3. These corals are worn and may represent the remnants of a near shore, shallow water deposit which was virtually obliterated by the surf in the transgressing Early Choctawhatchee Sea.

The fauna and lithology of Bed 3 is vertically uniform in composition throughout the bed and thus represents essentially constant environmental conditions during deposition of the entire unit. The authors think that this strongly indicates that the sea never reached a very great depth at Alum Bluff. It is highly improbable that outer neritic deep water conditions could have been established in such a short time that deposits of the inner neritic zone would not have been laid down in the vicinity of Alum Bluff. A relatively thin brackish water bed could conceivably be reworked and destroyed by the surf zone of an advancing sea, but it would seem improbable that initially deposited neritic sediments would be so destroyed under later outer neritic conditions.

The presence of large quartz grains, poor sorting of the sediments (Table 1, Grain Size Analysis Chart) and angularity of the sand grains strongly indicates that the sediments of Bed 3 were deposited near to shore in shallow turbulent water.

Paleogeographic evidence further substantiates the authors' conclusion of a nearshore environment of deposition for Beds 3 and 4. Choctawhatchee beds have not been mapped more than 2 miles north of Alum Bluff. Surely, if the marine Choctawhatchee deposits at Alum Bluff had been lain down in an outer neritic environment, the shoreline would have extended far enough inland for marine Choctawhatchee beds to be deposited many miles north of Alum Bluff, and some erosional remnants of these deposits would remain today.

Lower Choctawhatchee deposits judged to be equivalent to Bed 3 at Alum Bluff, are exposed at Jackson Bluff, Leon County, Florida (Locality 5, Figure 1) approximately 22 miles southeast of Alum Bluff. Preliminary study of these deposits indicates that they contain an inner neritic fauna. Cooke (1945, p. 112) places the Late Miocene shoreline a greater distance from Jackson Bluff than from Alum Bluff. If Cooke is correct, then the Lower Choctawhatchee fauna from Jackson Bluff probably would have lived in slightly deeper water than that at Alum Bluff.

The Choctawhatchee Sea probably had reached its maximum transgression during the time in which Bed 3 was deposited, and was regressing during the deposition of Bed 4. Regressive conditions possibly are indicated by the paucity of fossils in Unit 4 and the presence of gypsum crystals in the upper part of the bed. The gypsum crystals become more common in the overlying aluminous clay bed (Bed 5) which is gradational with Bed 4.

Bed 5

The "aluminous clay" bed which overlies Bed 4 at Alum Bluff is probably a lateral facies of the Upper Choctawhatchee shell bed (Cancellaria facies) at Jackson Bluff, Leon County, Florida.

Bed 5 was deposited under stagnant conditions, possibly in a lagoon which was drying up after the withdrawal of the Lower Choctawhatchee Sea. The shallow sea under which the Cancellaria facies at Jackson Bluff was deposited evidently did not reach Alum Bluff.

Several factors indicate a stagnant dessicating depositional environment for Bed 5. Some of the more important criteria are the absence of marine fossils, the gypsiferous and limonitic nodules which occur commonly throughout the bed, and the sulphurous odor and the carbonaceous nature of the sediments.

Bed 5 becomes less carbonaceous and more sandy near the top where it grades into Bed 6.

Bed 6

The variegated sands (Bed 6) which overlie Bed 5 are the youngest deposits of Choctawhatchee age exposed at Alum Bluff.

Due to the absence of fossils, paleoecological interpretation of the depositional environment of Bed 6 is difficult. The unit is comprised of cross-bedded, well sorted, subrounded, fine to medium quartz sand and probably is partly of dune origin, having been deposited near to shore during regression of the Late Choctawhatchee (Cancellaria) Sea.

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APPENDIX

Section at Fort Preston, Alum Bluff, Liberty County, Florida (See Figure 2).

Description	Thickness in feet
Pleistocene Series	
Coharie formation	
7. Sand, yellow, white, brown variegated. Composed of loosely consolidated, fine to medium subrounded, frosted quartz grains. Contains some cross-bedded sand beds and blocky arenaceous clay beds up to 2 feet thick. Scattered quartz and kaolinite pebbles are present at the base of Bed 7, indicating an unconformable contact with Bed 6	48.0
Miocene Series	
Upper Choctawhatchee Deposits (Late Miocene)	
6. Sand, red, yellow, gray variegated. Argillaceous, micaceous, composed of loosely consolidated fine to medium, frosted sub-angular quartz grains. Bed 6 becomes more argillaceous downward and is gradational with Bed 5 below......................................	15.0
5. C (Top) Sand, dark gray weathers to brown. Very argillaceous, micaceous, gypsiferous. Composed of poorly consolidated, fine subangular quartz grains.	
5. B (15 feet from base) Clay, dark greenish gray, yellowish brown when weathered. Moderately consolidated, micaceous, arenaceous, containing fine subangular quartz grains, limonitic, nodules and crusts of gypsum.	

5. A (Base) Clay, dark olive gray, light gray on weathered surfaces. Moderately consolidated slightly arenaceous, micaceous, with subangular quartz grains, crusts of gypsum and limonitic nodules. Gradational with Bed 4. Total thickness of Bed 5.................. 25.0

4. Sand, dark greenish gray, unctuous clay matrix. Fossil molds common in lower foot..... 3.0

3. C (Top) Shell marl, dark olive gray, weathers to yellowish brown. Well indurated and glauconitic in upper 6 inches with a thin limonitic layer at the contact with Bed 4. Mulinia common.

3. B (6 feet from base) Shell marl (almost a coquina). Olive gray, loosely consolidated, argillaceous, arenaceous with poorly sorted fine to coarse subangular quartz grains. Mulinia, Phacoides, Caryocorbula abundant.

3. A (Base) Shell marl (almost a coquina). Olive to bluish gray, argillaceous, arenaceous, with fine to very coarse subangular quartz fragments. Mulinia abundant. Contains pebbles of bluish clay, gray sandstone and limestone in lower foot. Contact with Bed 2 very irregular. Bed 2 contains animal borings filled with the shell marl of Bed 3. Total thickness of Bed 3............................... 12.0

Hawthorn Facies (Medical Miocene)

2. Sand, yellow, gray, white variegated, crossbedded and laminated. Frosted fine to medium quartz grains. Brown and blue clay lenses in upper 5 feet. Leaf impressions and wood fragments common in lower 5 feet. Lower foot is a basal conglomerate composed of coarse quartz sand, clay and sandstone pebbles and boulders. The base of Bed 2 is a thin limonitic sandstone...................... 19.5

Chipola Facies (Medical Miocene)

2. Sand, tan to tannish-gray, calcareous, fine to medium grained, very fossiliferous in upper 5 feet, sparsely fossiliferous in lower 5 feet. Base not exposed..............................	10.0
Total section exposed	132.5

Faunal Check List 1. Foraminifera from Bed 3 at Alum Bluff

(See Figure 2, and Alum Bluff Section, Appendix)

	Percentage (P = <1%)		
Horizon	A	B	C
Specimens per 1 gm residue (30-150 mesh)	334	1739	57
Species			
Angulogerina occidentalis (Cushman)	1.2	P	P
Angulogerina sp.	-	P	P
Astrononion glabrella (Cushman)	-	P	-
Bolivina marginata Cushman	P	1.4	-
Bolivina plicatella Cushman	P	P	1.2
Bolivina sp.	-	P	-
Buccella mansfieldi (Cushman)	8.7	4.6	17.1
Bulimina inflata Seguenza	-	P	-
Bulimina marginata d'Orbigny	P	P	P
Bulimina sp. a	-	P	-
Bulimina sp. b	-	P	-
Buliminella elegantissima (d'Orbigny)	43.7	74.4	41.2
Cancris sagra (d'Orbigny)	P	P	P
Cassidulina crassa d'Orbigny	P	P	-
Cassidulina laevigata d'Orbigny	P	P	P
Cassidulinoides bradyi (Norman)	P	P	P
Cibicides floridanus (Cushman)	1.2	P	4.1
Cibicides sp.	-	P	P
Discorbis consobrina (d'Orbigny)	P	P	-
Discorbis floridana Cushman	1.5	P	-
Discorbis floridensis Cushman	-	P	P
Discorbis mira Cushman	-	P	-
Discorbis rosacea (d'Orbigny)	-	P	-
Discorbis sp.	P	P	-
Elphidium incertum (Williamson)	3.6	P	2.4
Elphidium peoyanum (d'Orbigny)	7.1	2.4	15.3
Elphidium discoidale (d'Orbigny)	-	-	P
Epistominella pontoni (Cushman)	-	P	-
Eponides repandus (Fichtel and Moll)	-	-	1.8
Globigerinidae	8.9	4.8	4.1
Globorotalia menardii (d'Orbigny)	-	P	-
Globulina lactea (Walker and Jacob)	-	P	-
Hanzawaia concentrica (Cushman)	2.4	P	1.8
Lagena costata amphora (Williamson) Reuss	P	P	P

Faunal Check List 1. (Continued)

	Percentage (P = <1%)		
Horizon	A	B	C
Species			
Lagena substriata Williamson	-	P	-
Nonionella auris (d'Orbigny)	2.7	-	-
Nonionella grateloupi (d'Orbigny)	6.3	3.1	3.5
Nonionella opima Cushman	-	P	-
Nonionella sp.	P	P	-
Oolina hexagona scalariformis (Williamson)	P	P	-
Planulina depressa (d'Orbigny)	P	-	-
Textularia floridana Cushman	-	P	-
Uvigerina sp. cf. U. pigmea d'Orbigny	P	P	-
Uvigerina sp.	-	-	-
Valvulineria floridana Cushman	-	P	-
Virgulina fusiformis Cushman	4.2	1.4	-

Faunal Check List 2. Pelecypods from Bed 3 at Alum Bluff

(See Figure 2, and Alum Bluff Section, Appendix)

	Percentage (P = <1%)		
Horizon	A	B	C
Specimens per 4000 gm unwashed sample	4230	3147	712
Species			
Anadara idonea alumensis Mansfield	P	-	-
Anadara sp. a	-	-	P
Anadara sp. b	-	-	P
Cardita granulata Say	-	P	P
Cardita scituloides (Olsson)	P	P	-
Cardium (Cerastoderma) virginianum Conrad	P	-	-
Chama striata Emmons	-	P	-
Chione (Lirophora) ulocyma Dall	P	P	P
Caryocorbula inequalis Say	2.7	5.7	2.9
Caryocorbula nucleata Dall	P	2.5	5.1
Caryocorbula sp.	P	P	P
Diplodonta acclinis Conrad	-	-	P
Dosinia (Dosinida) acetabulum obliqua Dall	P	P	-
Eucrassatella meridionalis Dall	P	P	P
Ensis sp.	-	-	P
Glycymeris subovata (Say)	P	-	-
Gouldia metastriatum (Conrad)	P	-	-
Macoma alumensis Dall	P	P	-
Macoma (Psammacoma) hosfordensis Mansfield	-	P	-
Macoma sp. cf. M. virginianum coensis Mansfield	-	-	P
Mercenaria tridacnoides rileyi Conrad	P	-	P
Mulinia congesta (Conrad)	30.1	47.9	11.4
Nuculana trochilia Dall	22.0	12.6	23.9
Ostrea disparilis Conrad	P	P	-
Pandora (Clidiophora) crassidens Conrad	P	P	P
Pecten sp.	P	-	-
Phacoides (Lucinoma) contractus Say	P	-	-
Phacoides (Lucinisca) cribrarius Say	P	P	-
Phacoides (Parvilucina) crenulatus pemphigus Dall	42.3	28.4	51.9
Semele alumensis Dall	P	P	P

Faunal Check List 2. (Continued)

Horizon	Percentage (P = <1%) A	B	C
Species			
Semele alumensis leonensis Mansfield	P	-	P
Tellina aequistrata Say	P	-	P
Tellina alternata Say	-	P	-
Transenella carolinensis Dall	P	-	-
Yoldia tarpaeia Dall	P	P	2.8

Faunal Check List 3. Gastropoda and Scaphopoda from Bed 3 at Alum Bluff
(See Figure 2, and Alum Bluff Section, Appendix)

	Percentage (P = <1%)		
Horizon	A	B	C
Specimens per 4000 gm unwashed sample	155	95	156
Species			
Gastropoda			
Busycon maximum alumense Mansfield	-	P	-
Busycon maximum rapum (Heilprin)	-	-	P
Busycon pyrum aepynotum (Dall)	-	P	-
Calliostoma aluminium Dall	-	P	-
Cancellaria tabulata Gardner and Aldrich	P	-	-
Cancellaria coensis Mansfield	-	-	P
Clathrodrillia emmonsi (Olsson)	-	-	P
Clathrodrillia gracilina (Dall, MS) Mansfield	-	P	1.3
Crucibulum auriculum imbricatum Sowerby	-	P	-
Crucibulum sp.	-	P	-
Cymatosyrinx lunulata (H. C. Lea)	-	P	-
Cymatosyrinx propaepynota libertiensis Mansfield	-	P	-
"Drillia" sp.	-	1.1	1.3
Epitomium alumensis Mansfield	-	P	-
Fasciolaria sp.	-	P	-
Fusinus dalli Mansfield	P	P	-
Fusinus sp.	-	P	-
Glyphosoma watsoni leonensis Mansfield	-	P	-
Mangilia gardnerae Mansfield	-	P	-
Marginella denticulata clarksvillensis Mansfield	-	-	P
Marginella minuta Pfeiffer	-	2.2	5.1
Marginella sp. a	-	4.4	-
Marginella sp. b	-	P	-
Mitra hosfordensis libertiensis Mansfield	-	7.2	-
Muricacea sp.	-	P	-
Nassarius alumensis Olsson	-	15.8	3.9
Olivella mutica (Say) Dall	-	7.4	7.6
Peristernia filicata (Conrad)	P	1.1	-

Faunal Check List 3. (Continued)

	Percentage (P = <1%)		
Horizon	A	B	C
Species			
Retusa canaliculata (Say)	-	-	P
Tectonatica pusilla Say	P	P	-
Turbonilla sp. a	-	P	P
Turbonilla sp. b	-	P	-
Terebra binodosa Mansfield	-	P	-
Turritella alumensis Mansfield	27.3	5.5	2.1
Turritella duplinensis Gardner and Aldrich	-	-	P
Scaphopoda			
Cadulus floridanus Dall	50.5	7.1	22.7
Dentalium carolinense Conrad	21.4	42.1	34.9
Dentalium disparile leonense Mansfield	P	-	-