FLORIDA STATE UNIVERSITY

COLLEGE OF ARTS AND SCIENCES

THE NEOGENE STRATIGRAPHY OF THE CENTRAL FLORIDA PANHANDLE

by

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ABSTRACT

Two groups, ten formations, and one member are formally recognized and described in this redefinition of the marine deposits of the central Florida panhandle. The Alum Bluff Group is redefined on the basis of lithology and includes the following formations and members: The Chipola Formation, the Oak Grove Sand, the Shoal River Formation, the Whites Creek Member of the Shoal River Formation, the Choctawhatchee Formation, and the Jackson Bluff Formation. The Hawthorn-type deposits, including the Torreya Formation, are excluded from the Alum Bluff Group. The Coastal Group is recognized and includes the following formations: the Bruce Creek Limestone, the St. Joe Limestone, and the Intracoastal Limestone. The Citronelle Formation is not included in either group.

Portions of three structural elements are present in the central Florida panhandle. The Gulf Coast Basin is restricted to the region west of the Choctawhatchee River, the Apalachicola Embayment extends east of the Chipola-Apalachicola River area, and the Chattahoochee Arch lies between. The stratigraphy is related to these structural elements. The main mass of the Alum Bluff Group is restricted to the eastern margin of the Gulf Coast Basin and

to the vicinity of the Chattahoochee Arch whereas the Hawthorn-type deposits are restricted to the Apalachicola Embayment area. The Coastal Group consists of a mass of offshore, downdip Neogene limestones.

At least seven periods of deposition and at least seven periods of nondeposition are recognized. The periods of deposition include the following biostratigraphically equivalent formations from older to younger: (1) undifferentiated Chickasawhayan deposits - "Suwannee Limestone" - Chattahoochee Formation, of Late Oligocene, Chattian age; (2) Chipola Formation - Chipola equivalent sands - Chipola equivalent limestone of Early Miocene, Burdigalian Age; (3) Bruce Creek Limestone - Oak Grove Sand of Middle Miocene, Langhian Age; (4) Whites Creek Member - St. Joe Limestone of Middle Miocene, late Langhian and early Serravalian Age; (5) middle and upper Shoal River Formation - St. Joe Limestone of Middle Miocene, Serravalian Age; (6) Choctawhatchee Formation of Late Miocene, probably late Tortonian Age; and (7) Intracoastal Limestone - Jackson Bluff Formation - phosphoritic sand unit of Pliocene, late Zanclian to Piacenzian Age. There is some evidence that an eighth, Late Pleistocene period of deposition is present.

Regional hiatuses exist between the various regional deposits. These discontinuities vary in time length from the scale of relatively major hiatuses, as between the Chickasawhayan deposits and the Chipola Formation (approximately 15 million years), to discontinuities that are little more than diastems, such as between the lower and middle Shoal River Formation.

Three parameters of the environment are postulated to have a predominant influence on the sedimentary regime in the west Florida Neogene: (1) Epeirogenic movements with long periods of tectonic stability are punctuated by shorter periods of mild instability and subsidence. (2) The periods of epeirogenic stability coincide with periods of sedimentational dynamic equilibrium on the inner continental shelf whereas the brief periods of subsidence coincide with periods of sedimentational disequilibrium. (3) Two sources of sediment are recognized, one being terrigenous clastics from the continent that are supplied from local sources and/or from a possible western source via the longshore drift system, and the other being biogenic debris, either from shallow-water shelly biota or from smaller foraminifera.

INTRODUCTION

General Statement

The Neogene deposits of western Florida have been known for almost a century at the time of this writing. They have been of academic and economic interest throughout this century and periodically have received intensive studies. Yet, in spite of the fact that these deposits have been known to the geological world since the 1890's, the stratigraphic succession and the lateral stratigraphic relationships are still not well understood nor adequately documented.

The reasons for the confusion and uncertainties are clear. The deposits that contain rich and diverse fossil assemblages have few and sporadic unweathered exposures. As a result, only rough biostratigraphic successions have been constructed. Strict lithostratigraphic studies have been hampered because the lithologies of the deposits of various ages are not particularly distinctive or characteristic. In the fullers earth region in Gadsden County, on the other hand, where there have been many large excavations, the sediments are rarely fossiliferous. Where they are fossiliferous, the faunas are dominated by a few shallow-water species that suggest a restricted brackish, hypersaline, or schizohaline marine environment. Biostratigraphic successions have not been satisfactorily worked out in this area. Physical correlation has not been successful with areas to the south and west due to poor outcrop control, severe lithofacies and biofacies change, and possibly pinch-out of stratigraphic units.

Two erroneous assumptions have been made in the past regarding the geometry and structural attitudes of the Miocene deposits of western Florida. The assumed direction of strike and dip based on inadequate evidence, and the assumption that these deposits without exception are all simple, blanket, layer cake deposits have led to miscorrelations and therefore to stratigraphic confusion.

The Neogene deposits of western Florida are a mass of terrigenous detrital sediments and limestones that are not easily adapted to standard North American stratigraphic terminology practices. The lithofacies and even some entire stratigraphic units are disposed in narrow belts paralleling the ancient shoreline. Except along the strike of these belts, lithologies are not laterally persistent.

There appear to be several dominant lithology types that persist through various units from approximately the uppermost Lower Miocene to the Upper Pliocene. Within these lithology types, clay, sand, shell bed, "marl", or limestone, the lithologic range of variation is small. As a result, only a few of the units described in this study have particularly distinctive lithologies.

The writer has attempted to conform as closely as he feels it is possible to established or ideal North American stratigraphic practices. He recognizes that there are points where he has deviated from recommended lithostratigraphic practices but he does not feel the need to offer apologies for it. The deviations from recommended lithostratigraphic practices are justified by allowing greater insight into the geologic framework of the area. It is the writer's intention to use stratigraphic terminology that approximates as closely as possible the natural geologic subdivisions of the study area. It is his experience that adherence to very strict lithostratigraphic treatment of the Neogene deposits in the southeast produces an artificial and unwieldy classification system.

Although this study is based on both outcrops and cores, the greater emphasis has been placed on the study of the cores. Field studies have been far from exhaustive. The writer has only examined and sampled a sufficient number of outcrops in the study area to be certain of correlation with the shallow subsurface in the cores.

Thirty-eight cores taken by the Florida Bureau of Geology over a period of about 10 years have been used in this study (Figures 2 and 3). The core spacing in the study area is irregular due to differing objectives in the coring program. Twenty-eight cores are located in Walton County, 26 of them having been taken for a study of the economic minerals and ground-water geology of the county. Five of the cores are located in the Alum Bluff area in Calhoun and Liberty Counties. Two are from the coastal area of the Apalachicola Embayment in Gulf and Franklin Counties. Four additional cores were taken for added stratigraphic control in Okaloosa, Walton, and Washington Counties. One core is located at Hosford, Liberty County, between Alum Bluff and Jackson Bluff. These cores have been examined, partially logged, and sampled for foraminifera.

Planktonic foraminifera are the primary source of biostratigraphic correlation in this study. The Neogene deposits of the study area are commonly abundantly microfossiliferous, and may even consist of an unconsolidated foraminiferal coquina in places. In addition, these west Florida marine deposits are phenominally rich in planktonic foraminifera for being shallow-water shelf deposits. It is not uncommon that planktonic foraminifera constitute more than 50% of the foraminifera in a given sample.

Eighty-four species, subspecies, and varieties of planktonic foraminifera have been identified in the Miocene through Pliocene deposits of western Florida. Almost all of the described tropical species and their varieties are present in these deposits. Evolutionary bioseries, evolutionary first occurrences, irreversible assemblage changes, and species associations are the critical agents of correlation. In some instances, extremely precise correlations with the tropical planktonic foraminiferal zones and with the stratotype sections in Europe are allowed.

The precise regional correlation allowed by planktonic foraminifera within the study area in conjunction with the tight core control in Walton County, permit regional correlations, stratigraphic definitions, structural contour maps, and isopach maps to be constructed. As a result stratigraphic definition is attained in this study that places the stratigraphic succession of the classical west Florida, type Alum Bluff deposits on a new stratigraphic foundation.

Study Area

The area under study in western Florida extends east to west from Jackson Bluff on the Ochlockonee River in Leon County, to the type area of the Oak Grove Sand near the old community of Oak Grove on the Yellow River in Okaloosa County. In Walton County the area under study extends

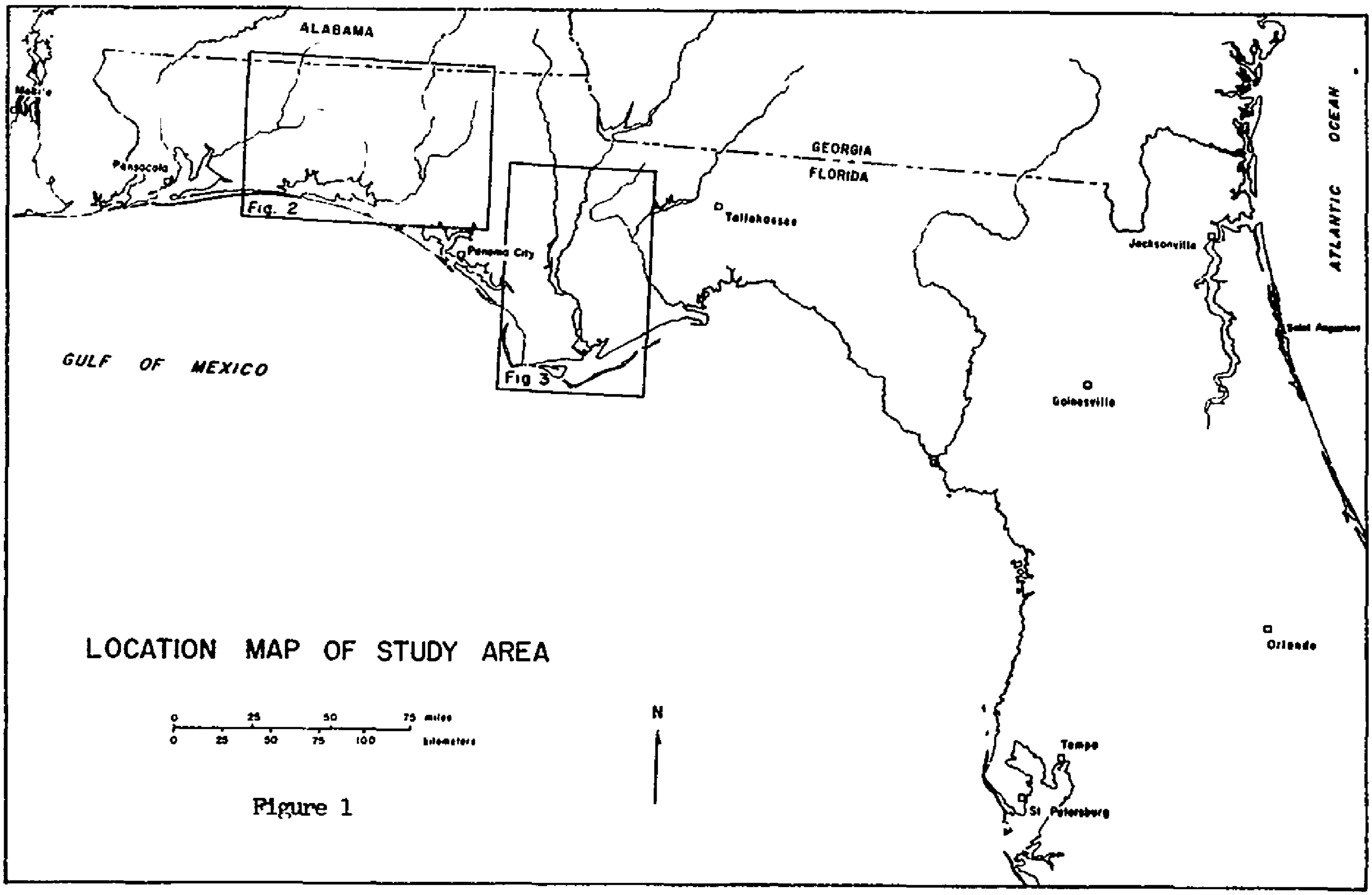

ALABAMA
GEORGIA
FLORIDA
ATLANTIC OCEAN
GULF OF MEXICO
Mobile
Pensacola
Panama City
Tallahassee
Jacksonville
Saint Augustine
Gainesville
Orlando
Tampa
St Petersburg
Fig. 2
Fig 3
LOCATION MAP OF STUDY AREA
0 25 50 75 miles
0 25 50 75 100 kilometers
N

Figure 1

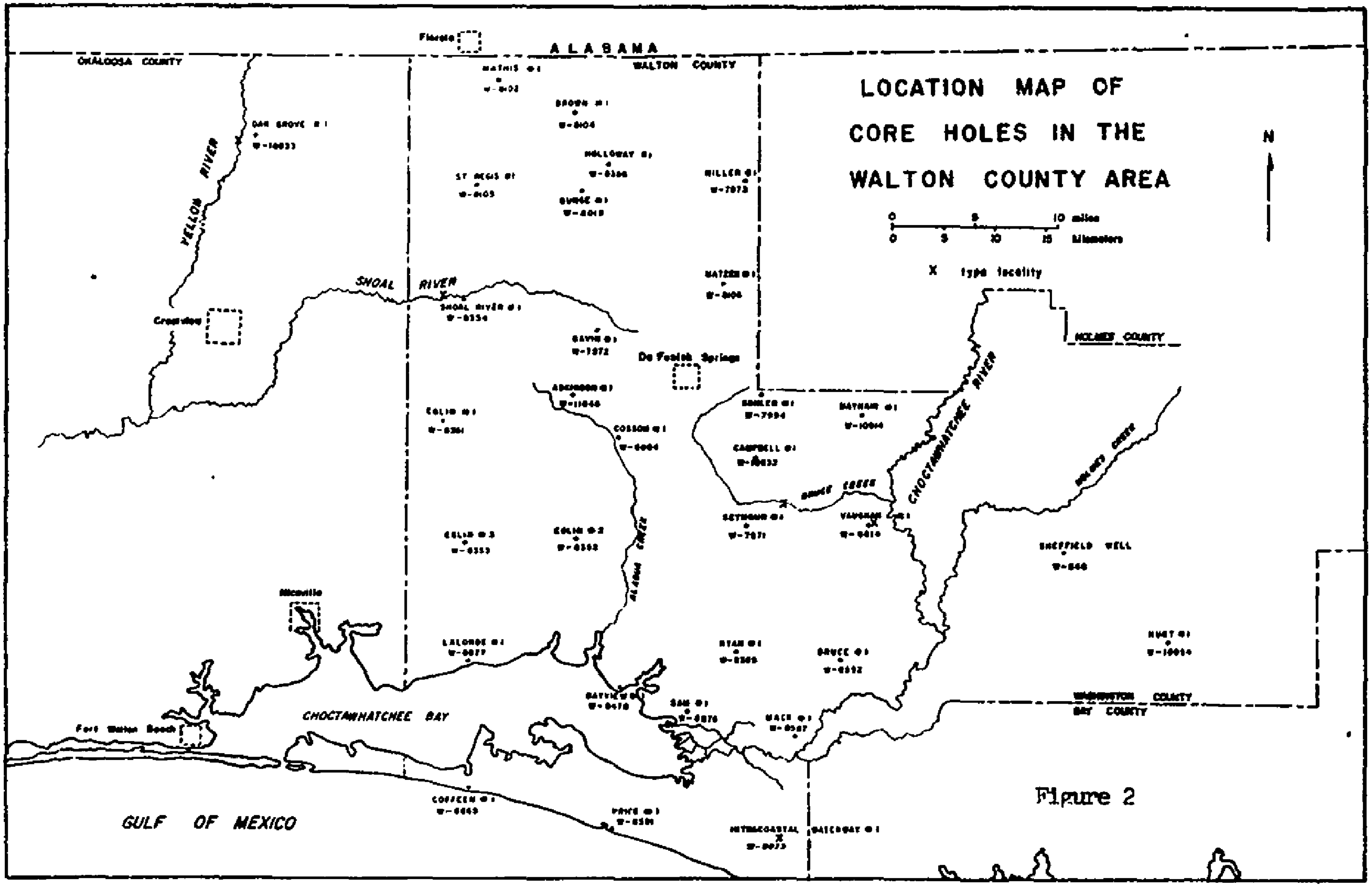

LOCATION MAP OF
CORE HOLES IN THE
WALTON COUNTY AREA
10 miles
kilometers
X type locality
N
ALABAMA
OKALOOSA COUNTY
WALTON COUNTY
HOLMES COUNTY
WASHINGTON COUNTY
BAY COUNTY
YELLOW RIVER
SHOAL RIVER
CHOCTAWHATCHEE RIVER
CHOCTAWHATCHEE BAY
GULF OF MEXICO
Fort Walton Beach
DeFuniak Springs
SHEFFIELD WELL

Figure 2

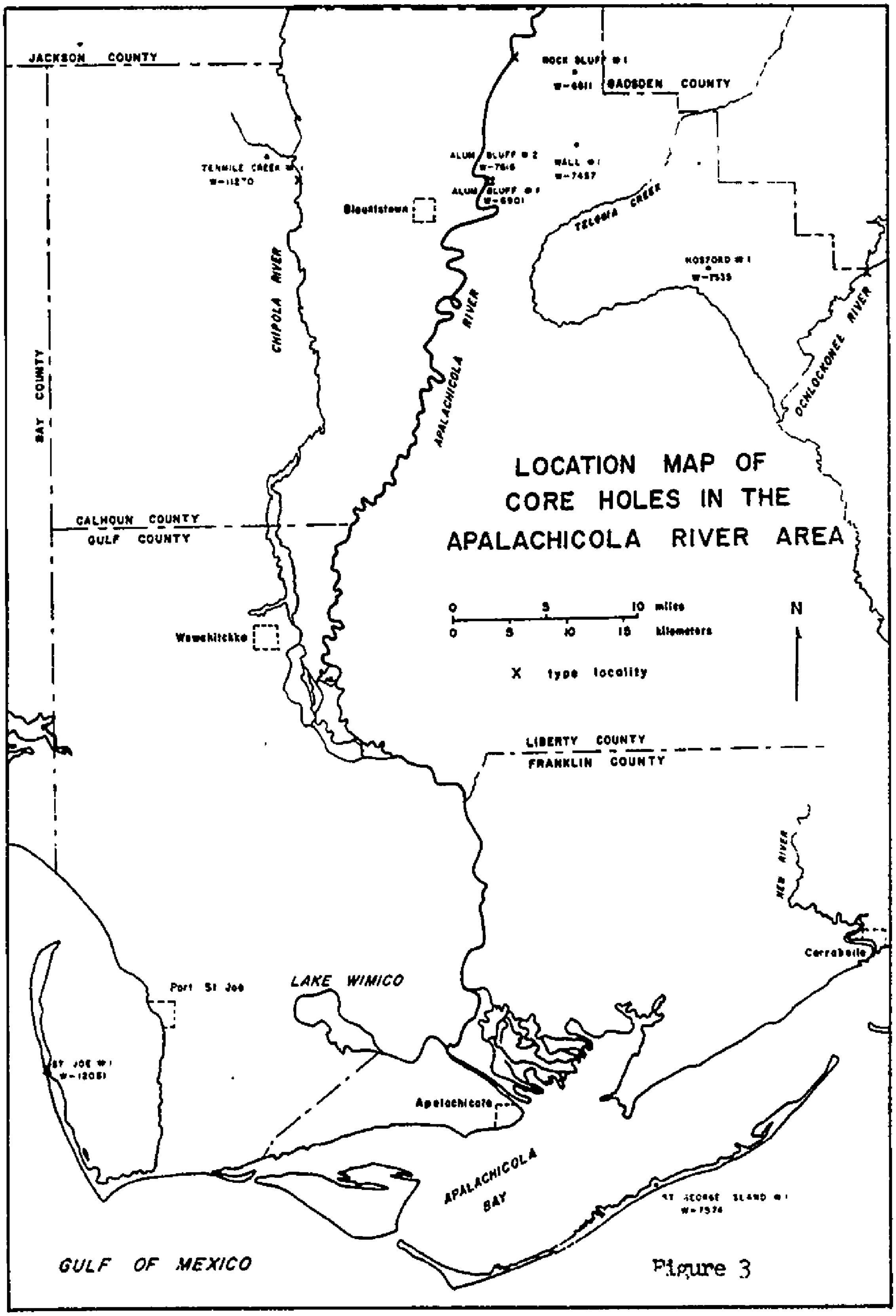

LOCATION MAP OF CORE HOLES IN THE APALACHICOLA RIVER AREA
JACKSON COUNTY
GADSDEN COUNTY
BAY COUNTY
CALHOUN COUNTY
GULF COUNTY
LIBERTY COUNTY
FRANKLIN COUNTY
ROCK BLUFF # 1
ALUM BLUFF # 2
ALUM BLUFF # 1
W-6901
WALL # 1
W-7457
TENMILE CREEK # 1
W-11270
HOSFORD # 1
Blountstown
Wewahitchka
CHIPOLA RIVER
APALACHICOLA RIVER
TELOGIA CREEK
OCHLOCKONEE RIVER
NEW RIVER
Carrabelle
0 5 10 miles
0 5 10 15 kilometers
N
X type locality
Port St Joe
LAKE WIMICO
ST JOE # 1
Apalachicola
APALACHICOLA BAY
GULF OF MEXICO

Figure 3

in the north from near the Alabama - Florida state line to the shore of the Gulf of Mexico. In the Apalachicola River area it extends from Rock Bluff on the Apalachicola River in Liberty County to St. George Island and St. Joseph spit on the coast. The Walton County area has received the most intensive study because the Florida Bureau of Geology has taken a total of 28 cores in that county. Elsewhere both core control and outcrop control is spotty in western Florida. Seven cores and numerous outcrops were examined and sampled in the vicinity of the Chipola and Apalachicola Rivers.

The following exposures were examined and sampled for microfossils in the study area:

LEON COUNTY: Jackson Bluff and Larkins Bluff on the Ochlockonee River and Dismal Sink in southern Leon County have been examined and sampled at various times. Samples collected from Harveys Creek by personnel of the Florida Bureau of Geology were also examined by the writer.

WAKULLA COUNTY: Exposures of the Sopchoppy Limestone along the Sopchoppy River in NW 1/4, Sec. 24, T4S, R3W, and the Torreya Formation in the Taff Pit southwest of Crawfordville have been examined and sampled. Samples collected by Mr. Joseph Banks and Ms. Muriel Hunter from the Jackson Bluff Formation dredged up and heaped in spoil piles at Shell Point on the coast were examined for planktonic foraminifera.

FRANKLIN COUNTY: Borrow pits exposing the Intracoastal Limestone were examined and sampled in the vicinity of New River, 5 miles northwest of Carrabelle.

LIBERTY COUNTY: The entire section at Alum Bluff exposing the Chipola Formation, Jackson Bluff Formation, and overlying sands of the "terrace" deposits were examined and sampled at various times by the writer. The Torreya Formation exposed in the bluff at the old plantation house in Torreya State Park was examined and sampled by the writer.

CALHOUN COUNTY: The writer has traversed the Chipola River from Darling Slide, where the Jackson Bluff Formation is exposed, to the mouth of Ten Mile Creek where only the Chattahoochee Formation is exposed. All fossiliferous outcrops along that stretch of river were examined and sampled for microfossils. The outcrops of the Chipola Formation along Farley Creek and Ten Mile Creek, and the Jackson Bluff Formation outcropping on Four Mile Creek about three quarters of a mile north of Clarksville were also examined and sampled.

BAY COUNTY: An exposure of the Intracoastal Limestone was examined by the writer on Econfina Creek, 1.5 miles west of Bennett. Samples were also examined that were collected by members of the staff of the Florida Bureau of Geology from the Choctawhatchee Formation at Taylor Branch in SW 1/4, SW 1/4, Sec. 22, T2N, R12W.

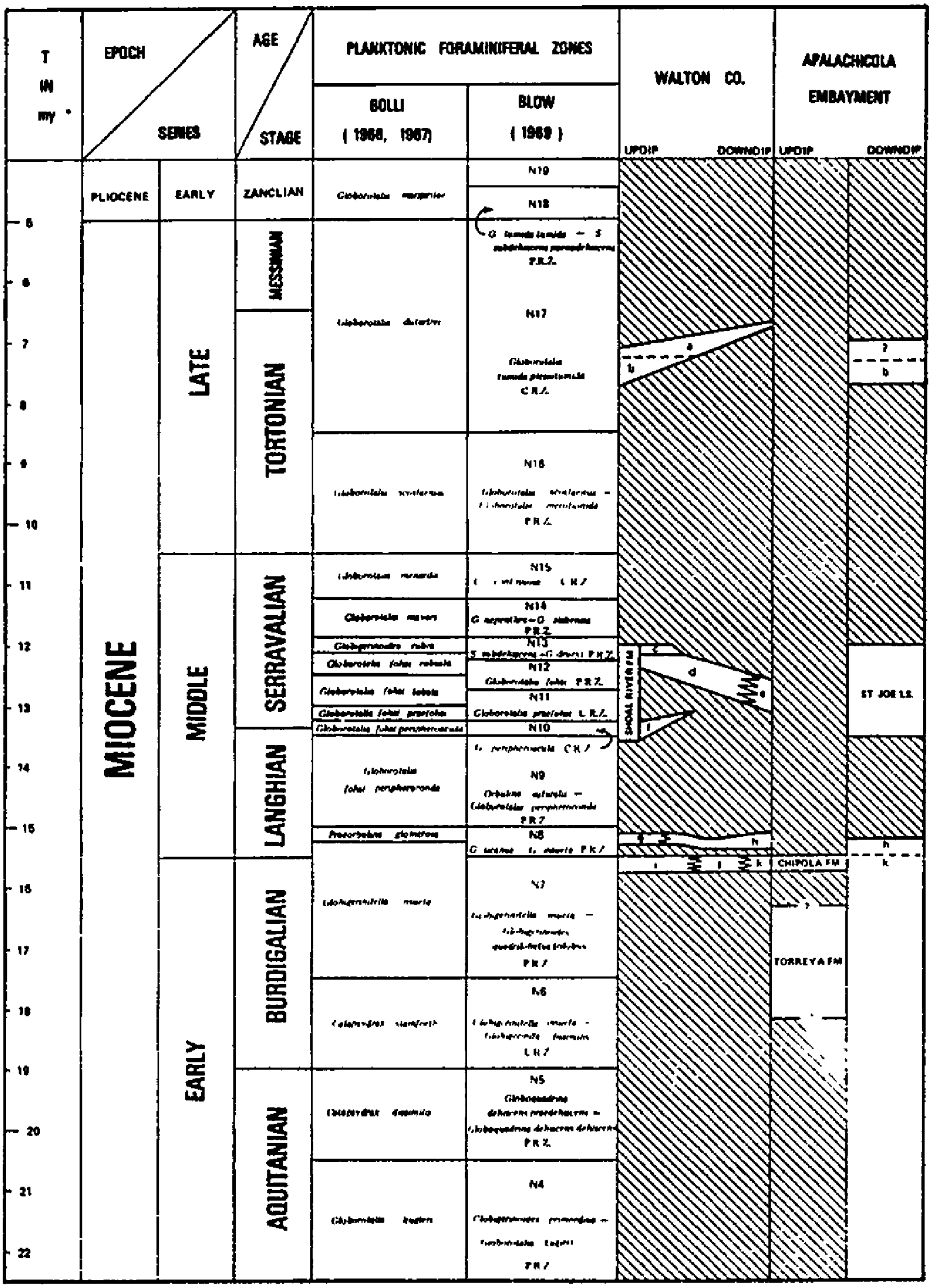
WALTON COUNTY: The writer has examined and sampled the section of the Shoal River Formation exposed near the type locality in NW 1/4, Sec. 4, T3N, R21W, on the Shoal River; the type locality of the *Yoldia* Zone in SE 1/4, SE 1/4, Sec. 18, T2N, R19W; the type locality of the Choctawhatchee Formation at Red Bay; the type locality of the Bruce Creek Limestone in N 1/2, Sec. 2, T2N, R18W; and he has examined numerous road cut exposures of the Shoal River Formation and exposures of the Citronelle Formation in borrow pits. Samples collected by the staff of the Florida Bureau of Geology from the Choctawhatchee Formation exposed on Blounts Creek in Sec. 28, T2N, R19W, were examined for foraminifera.

OKALOOSA COUNTY: Although the writer has visited the Oak Grove type locality on numerous occasions, he has never had the good fortune of finding the river at sufficiently low water stage to sample the outcrop. However, several samples collected by past members of the staff of the Florida Bureau of Geology were examined by the writer for foraminifera.

Methods

The methods employed by the writer in executing this study are as follows: Type localities and other exposures were examined and sampled for foraminiferal analysis. The planktonic foraminiferal assemblages were assigned as closely as possible to the various published planktonic foraminiferal zonations. The cores taken by the Florida Bureau of Geology were then lithologically described, logged, and sampled for foraminiferal analysis. When all the cores were processed in this way, biostratigraphic and lithostratigraphic boundaries were determined. Once the biostratigraphic and lithostratigraphic units were defined, stratigraphic cross-sections, structural contour maps, and isopach maps were constructed for the study area. Finally a regional stratigraphic synthesis was achieved from the various cross-sections and maps.

Microfossil processing consisted of washing the samples in a dilute solution of Calgon and distilled water (136 grams of Calgon per 50 liters of water). The samples were first weighed dry to determine the weight loss of the fine fraction due to washing. The samples were then immersed in Calgon solution and allowed to simmer on a hot plate for about 15 minutes. After cooling, the samples were washed in a 62 micron sieve to remove the silt and clay fraction of the sample. After washing, the samples were dried in an oven overnight at approximately 125°



a UPPER CHOCTAWHATCHEE
b LOWER CHOCTAWHATCHEE
c UPPER SHOAL RIVER
d MIDDLE SHOAL RIVER
e ST JOE
f LOWER SHOAL RIVER
g OAK GROVE
h BRUCE CREEK
i CHIPOLA EQUIV SAND
k CHIPOLA EQUIV LIMESTONE
l CHIPOLA

Figure 4

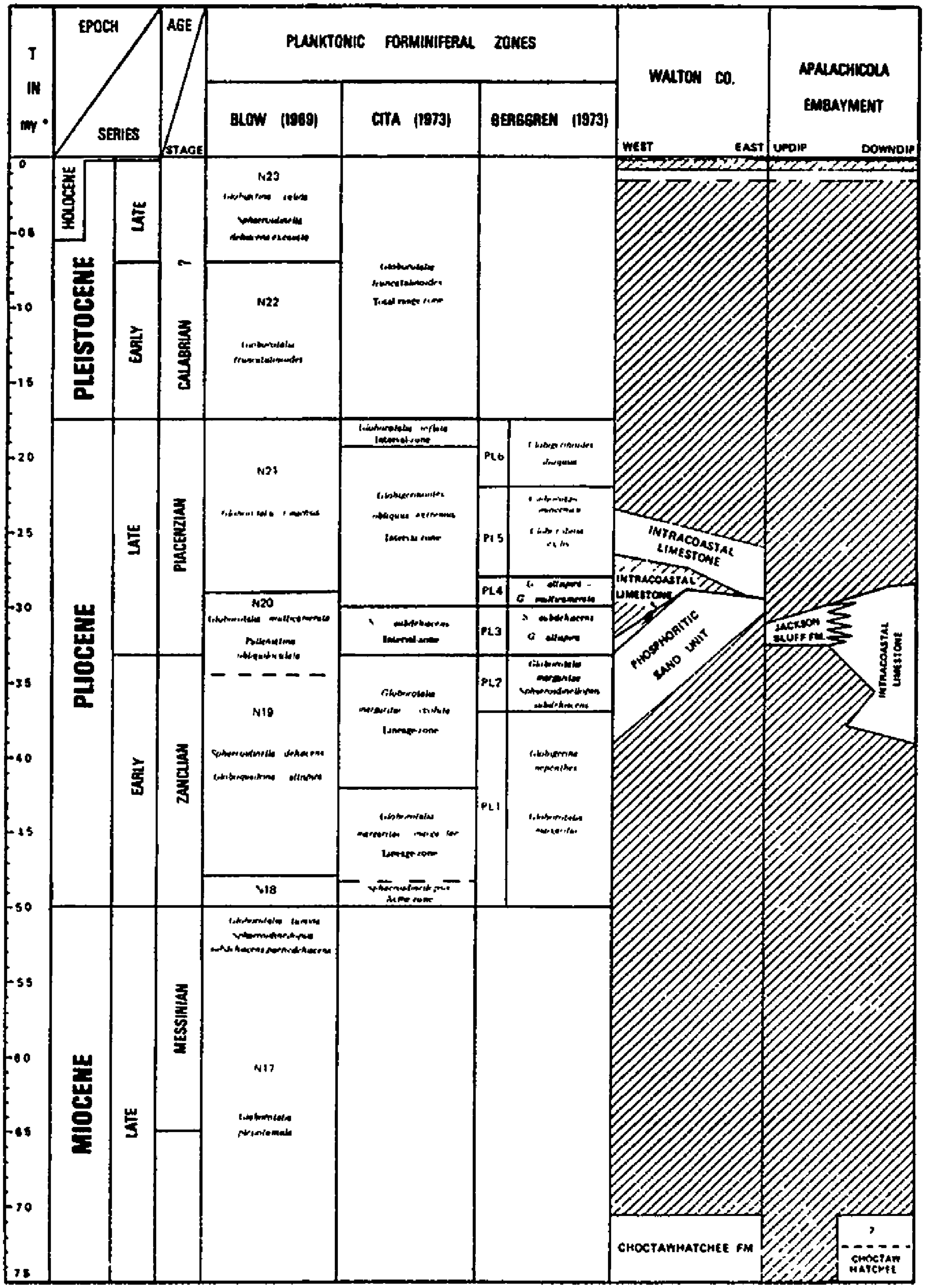


Figure 5

* time scale after Berggren (1969, 1973).

Fahrenheit. This process was conducted three or more times, thus removing all the clay minerals from the samples and from the interior chambers of the foraminifera. The samples were then weighed again to find the weight after washing. The foraminifera were then concentrated by flotation in perchlorethelene or carbontetrachloride. The remainder of the samples were then stored for future reference while the concentrated foraminifera were examined and identified.

No foraminiferal analysis was attempted where the sediments were lithified. In a few samples where there was minor induration or cementation, mineral spirits or in a few extreme situations, Quaternary O was employed in breaking down the sample.

Some thin-sectioning of Miogypsina tests was done. This consisted of finding megalospheric individuals and cementing them to a glass slide with "Lakeside 70". When one side of the specimen was sufficiently ground down, the "Lakeside 70" was heated and melted, the specimen turned over, and grinding continued. This process was repeated until the section was sufficiently thin for identification purposes.

STRUCTURAL SETTING

The entire study area was a region of general subsidence during the geologic time involved in this study. There are two slightly to moderately unstable areas that have a greater tendency for subsidence. These are a small part of the Gulf Coast Basin in the west and part of the Apalachicola Embayment in the east. These two basins are separated by a more stable area, the Chattahoochee Arch. The Chattahoochee Arch may not be a discrete structural feature (see Patterson and Herrick, 1971), rather it may mark the eastern extent of the Gulf Coast Basin. It is likely that if it were not for the Apalachicola Embayment-Gulf Trough of Georgia[1] to the east and northeast, the Chattahoochee Arch as such would not exist.

As would be expected, the geologic sections in any one core are the most complete in the deepest parts of the basins covered in the study area, i.e., in the Coffeen #1 (W-8865) in the Gulf Coast Basin and in the St. Joe #1 (W-12051) in the Apalachicola Embayment. Conversely they are thinnest and most abbreviated on the Chattahoochee Arch, with some units pinching out on its flanks.

The two basins have had differing histories of subsidence in the study area. There was much greater subsidence in the Apalachicola Em-

1 The Gulf Trough (Herrick and Vorhis, 1963) a narrow, linear structure in southern Georgia, is recognized as a structural extension to the northeast of the Apalachicola Embayment. The two structures together make up what has been referred to as the Southwest Georgia Embayment.

bayment during the Late Oligocene and Early Miocene. Even in Walton County, on the eastern edge of the Gulf Coast Basin, the Chipola Formation appears to thicken to the southeast, in the direction of the Apalachicola Embayment rather than to the south or southwest as most of the younger units do (Fig. 10).

There was relatively much greater subsidence in the Gulf Coast Basin during the Middle Miocene through Late Pliocene than there was in the Apalachicola Embayment. In Walton County, these deposits thicken toward the depocenter of the basin to the west and southwest. Although sediments of Middle Miocene to early, Late Pliocene age are present under the present coast of the Apalachicola Embayment, they are not present updip in the outcrop area in the vicinity of the Chipola and Apalachicola Rivers. Nor is that interval present to the east in western Leon County at Jackson Bluff or in the Lake Talquin #1 (W-6890). Unfortunately there is no shallow subsurface control between this area and the coast at the present time, and as a result, the updip extent of the Middle Miocene through Lower Pliocene deposits is not known.

The lithologies and stratigraphic intervals represented in the coastal area of the Apalachicola Embayment are much the same as those under coastal Walton County. These lithologies and stratigraphic intervals are thought to be representative of the Gulf Coast Basin and not of the Hawthorn-Torreya lithologies and stratigraphic intervals of the Apalachicola Embayment. If this is true, then there may be a structural relationship between the Gulf Coast Basin of the northern Gulf Coast to the west and the Apalachicola Embayment to the east. The two basins may merge in the offshore area south of Panama City, Bay County.

There is insufficient core control to define clearly the areal limits of the Apalachicola Embayment and the Chattahoochee Arch or to come to a clear understanding of the stratigraphy and facies relations associated with the structural elements. There is also insufficient core control immediately east of the Choctawhatchee River to define clearly the boundaries and stratigraphic relationships on the western flanks of the Chattahoochee Arch. There is at least sufficient control on the eastern margins of the Gulf Coast Basin to recognize various structural features and to relate some of the aspects of the stratigraphy to the basin structure.

The structural strike of the contact between the Oligocene and Miocene Series in the Walton County area varies between N 55° W and N 65° W, and the dip varies between S 25-30° W with an inclination of roughly 15 feet per mile (Fig. 6). In southwestern Washington County (Fig. 6) the structural strike swings to a more east-west direction whereas in coastal Walton County the strike appears to be more uniformly in a N 70° W direction.

In general, the structural strike of the successively younger Miocene deposits gradually swings to a more east-west direction. The strike of the Bruce Creek - Shoal River contact is about N 65° W (Fig. 7) whereas the strike on the top of the middle Shoal River is about N 70° W (Fig. 8). On the other hand, the approximate direction of the assumed depositional strike has less of a northwest-southeast trend. The updip limit of the calcareous marine Chipola in Walton

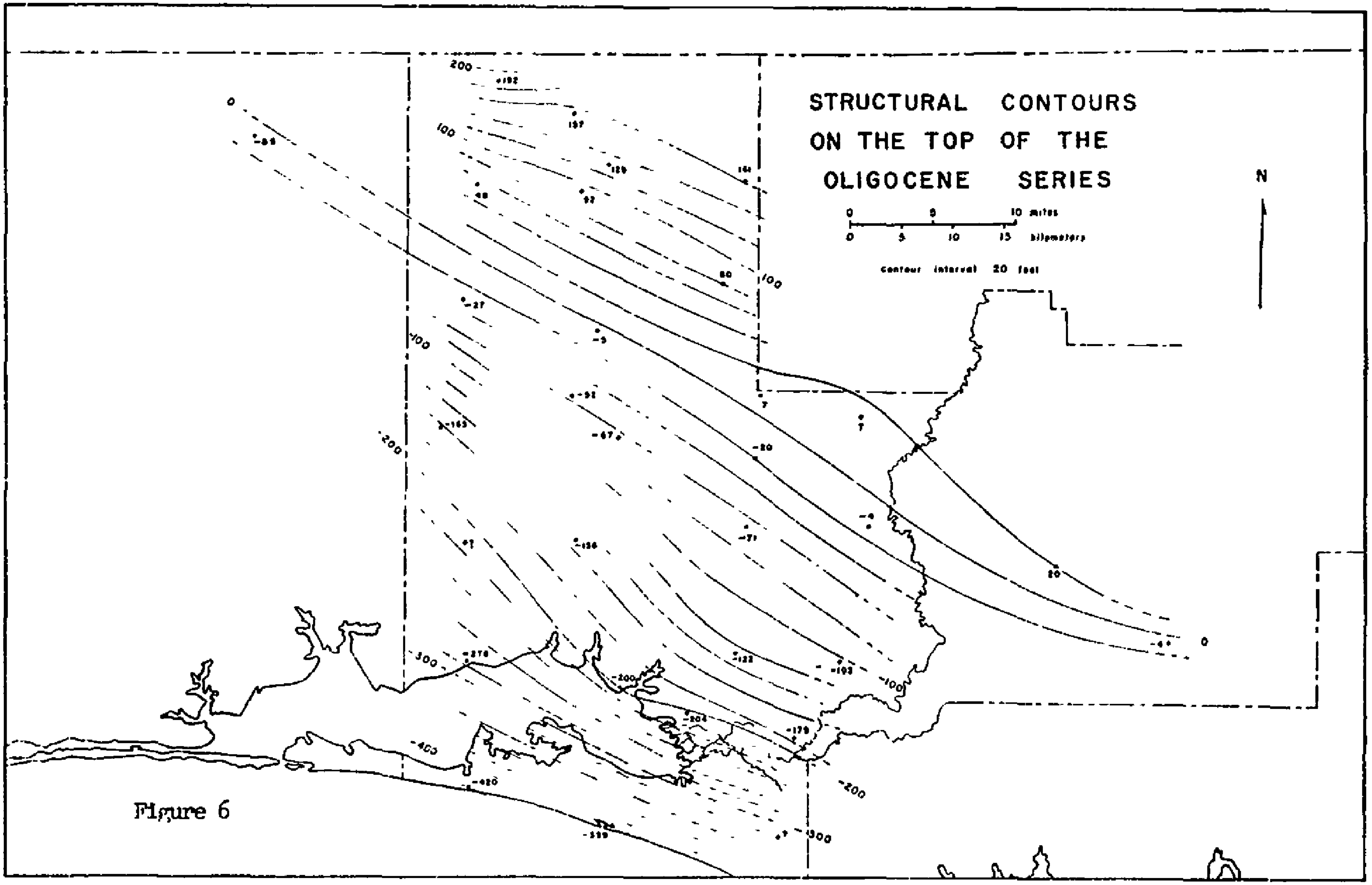

STRUCTURAL CONTOURS
ON THE TOP OF THE
OLIGOCENE SERIES
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
N

Figure 6

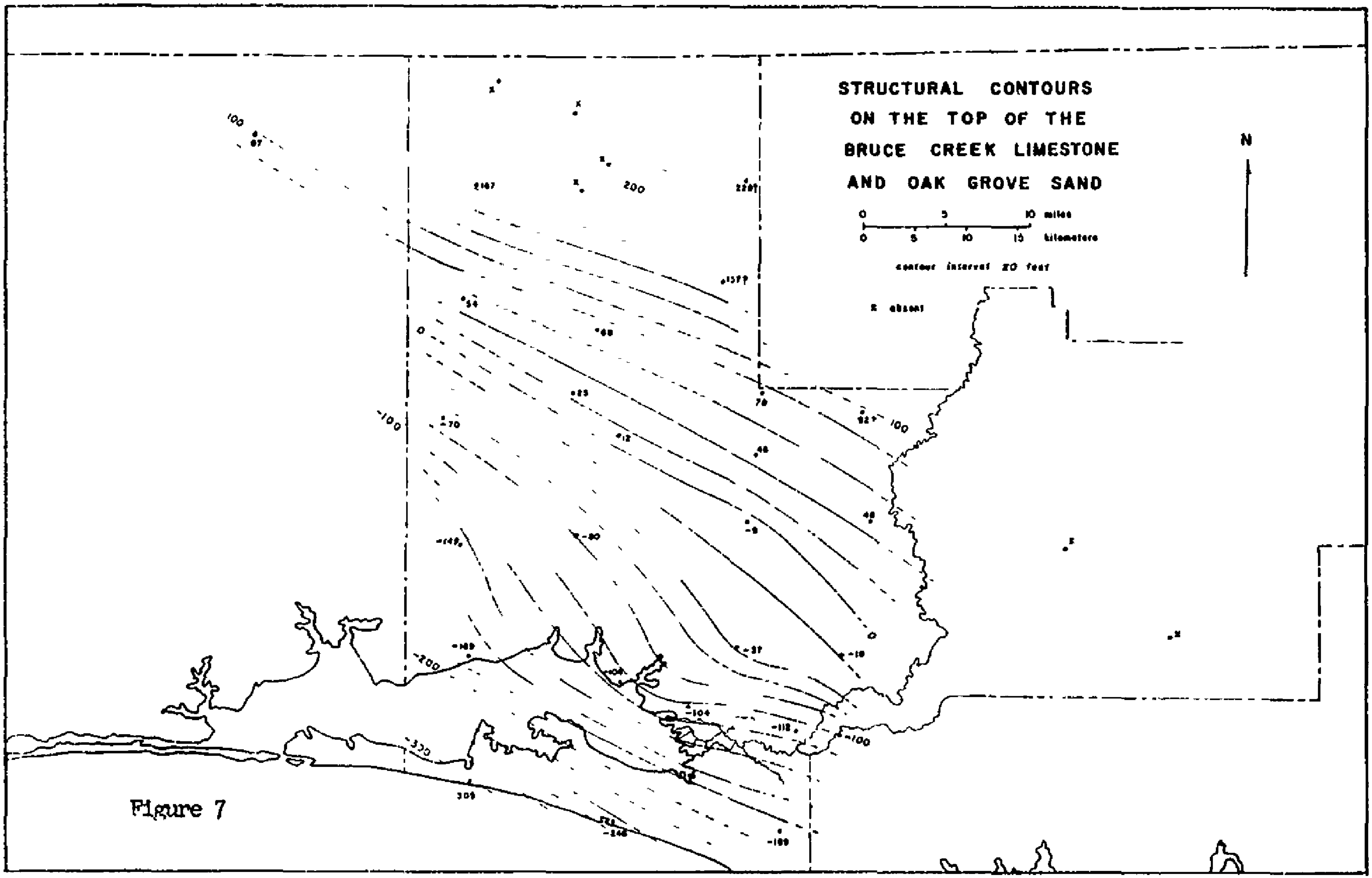

STRUCTURAL CONTOURS
ON THE TOP OF THE
BRUCE CREEK LIMESTONE
AND OAK GROVE SAND
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
x absent
N
100
200
0
-100
-200
-300

Figure 7

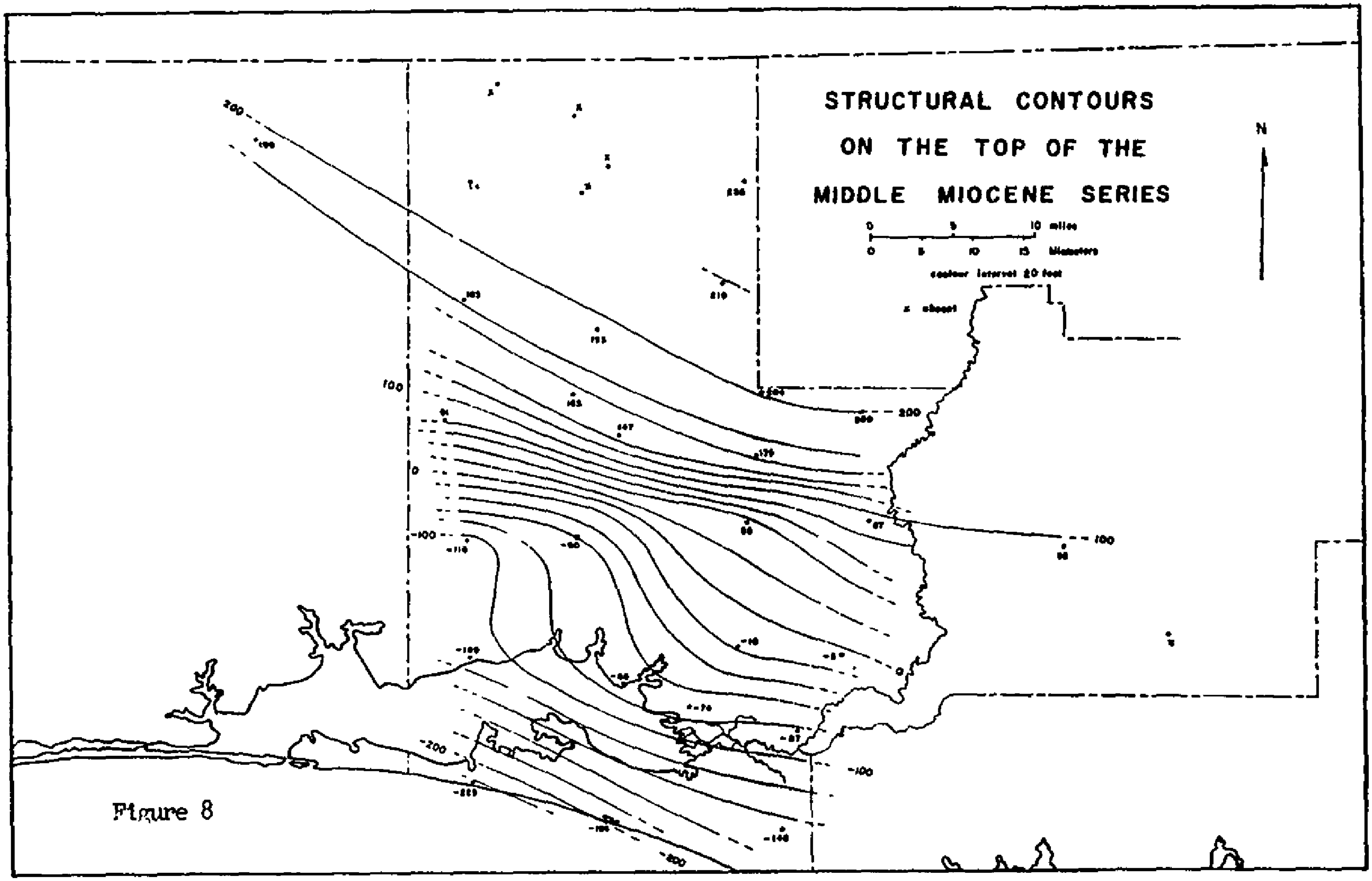

STRUCTURAL CONTOURS
ON THE TOP OF THE
MIDDLE MIOCENE SERIES
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
x absent
N
200
100
0
-100
-200

Figure 8

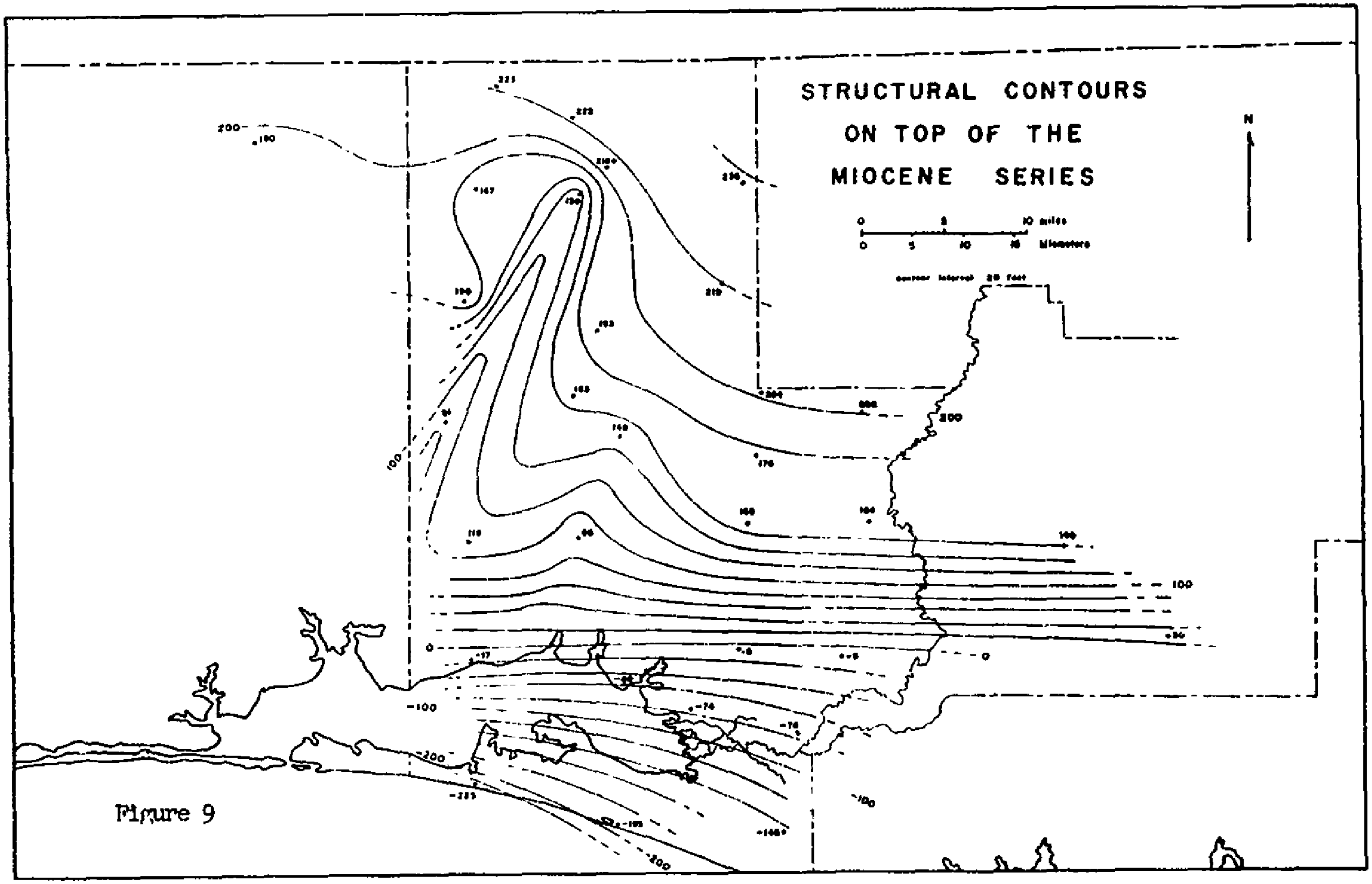

STRUCTURAL CONTOURS
ON TOP OF THE
MIOCENE SERIES
0 5 10 miles
0 5 10 15 kilometers
contour interval 25 feet
N
200
100
0
-100
-200

Figure 9

County trends about N 72° W but it too swings to a more nearly east-west direction east of the Choctawhatchee River (Fig. 10). The updip limit of the Bruce Creek - Oak Grove trends approximately N 70° W (Fig. 16) as does the clay bed within the Bruce Creek (Fig. 17), strongly suggesting that the Bruce Creek - Oak Grove shoreline trended in the same direction across northern Walton County. However, the facies strike and the strike of the updip limit of the formation swings to a more southeastern trend in eastern Walton County. Again the updip limits of the marine, fossiliferous, lower Shoal River strike N 72° W across northern Walton County but there is a sudden depositional strike change within the Shoal River. The middle Shoal River strikes vaguely east-west (Fig. 2) but the upper Shoal River (Fig. 13), Choctawhatchee (Fig. 15), and marine Pliocene very definitely strikes east-west across the Walton - Washington Counties area.

The change in depositional strike at the end of early Shoal River time suggests that a good part of the nearshore, Gulf Coast Basin in the northern Gulf of Mexico was silted up during Chipola, Bruce Creek, and especially early Shoal River time. Subsequent to early Shoal River time, land was built outward in more nearly east-west trending increments in western Florida.

The dip of the various datums into the Gulf Coast Basin is clearly not regular, but is interrupted by step-like irregularities. This is especially pronounced in a structural "terrace" that underlies the Choctawhatchee Formation in the Walton County area (Figs. 8, 21, 22, and 23). It appears that there is a direct relationship between the thick, clastic prisms and the step-like structural "terraces". Such a "terrace" underlying the upper Shoal River, if present, is rather vague, but it appears that one may also be present under the marine Pliocene wedge under the present coastline.

The origin of these terrace-like steps is speculative. There is one of two possibilities for their origin in the writer's opinion: either sedimentation initiated the subsidence or the subsidence initiated the sedimentation. It is difficult to understand how a clastic prism, no more than 150 feet thick can cause an isostatic downwarping of 50 feet displacement as is clearly the case in Figure 22, where the Choctawhatchee Formation overlies the Shoal River Formation. As a consequence, this writer favors subsidence initiating sedimentation for these structures. This of course, raises the problem of the nature of the structures because they are clearly long and narrow, extending for at least 30 miles along the strike in Walton County and narrowing from approximately 15 miles across in western Walton County to about 5 miles across in eastern Walton and Washington Counties (Fig. 8). The most apparent explanation for the origin of these terrace-like structures is that they originate from down-to-basin faulting in the basement and that the soft, unconsolidated Coastal Plain sediments are draped over the lines of dislocation, essentially producing gentle flexures in the near-surface materials.

Although it is difficult to understand how a clastic prism, no more than 150 feet thick, can cause isostatic downwarping of 50 feet, it is also difficult to understand how subsidence of as much as 50 feet can result in the deposition of 150 feet of sediments. It is possible that subsidence during sedimentation within a depositional episode, plus marine erosion during the preceding nondepositional interval is sufficient to explain the terrace-like features. Clearly nearshore marine erosion during the Shoal River-Choctawhatchee nondepositional interval could not cause a down-flexing of pre-Shoal River contacts as is evident in Figures 21, 22, and 23. Whatever the cause or causes may be of these subsurface, terrace-like features in Walton County, all the available evidence does not point clearly to one single explanation.

STRATIGRAPHY

Torreya Formation

The Torreya Formation was recently proposed by Banks and Hunter (1973) for sands, clays, dolomitic limestones, and sandy limestones exposed in SW 1/4, Sec. 17, T2N, R7W at Rock Bluff on the Apalachicola River, Torreya State Park, Liberty County, Florida. The lower part of the Torreya Formation at the type locality is a sandy limestone that is exposed to about 10 feet above the river. This limestone has been consistently placed in the Chattahoochee Formation or Tampa Limestone by earlier authors. The overlying sands of the Torreya, on the other hand, have been considered to be either Alum Bluff Formation (Dall, 1893) or Hawthorn Formation (Cooke and Mossom, 1929; Cooke, 1945). As recognized by Banks and Hunter (1973), the entire section exposed at Rock Bluff is Torreya Formation.

The top of the Oligocene[1] Chattahoochee Formation (St. Marks of Banks and Hunter, 1973; Tampa in part of earlier authors) in the nearby Rock Bluff #1 (W-6611), 3 1/2 miles to the east, occurs at approximately 7 feet above sea level. Unless the strata in this area dips at a rate of at least 10 feet per mile to the east, the Chattahoochee Formation, as understood in this study, should not be exposed in outcrop at Rock Bluff. The fact that the sandy limestone exposed at the base of the type locality at Rock Bluff is an integral part of the Miocene

1 For discussion of age criteria, see page 180.

Torreya Formation and is distinct from the Oligocene Chattahoochee Formation may account for the repeated claims that the "Tampa Limestone" and "Hawthorn Formation" are conformable and gradational in this area. This is in contrast to the clear lithologic and biostratigraphic discontinuity between the so-called "Tampa" (Chattahoochee Formation) and the Chipola Formation in the rest of the study area, and their abrupt and often dramatic change in lithology. It is the observation of this writer that the Oligocene/Miocene contact passes into the "Tampa Limestone" of earlier authors east and north of the Alum Bluff area on the Apalachicola River. The Oligocene/Miocene boundary and the time-stratigraphic and lithologic distinction between the two carbonate units, i.e., the Chattahoochee Formation and the lower part of the Torreya Formation, have hitherto not been discriminated.

The Torreya Formation is peripheral to this study area and consequently no full evaluation can be given to it at this time. However, it is possible to make some observations on the Torreya and to consider it in the stratigraphic framework of the rest of this study. Unfortunately the Torreya Formation is almost devoid of planktonic foraminifera and its stratigraphic relationship with the other units covered in this study remains in doubt.

Lithology

As proposed by Banks and Hunter (1973), the Torreya Formation is a lithologically heterogeneous unit that currently is identified by the fauna and stratigraphic position. Within the area of the present study, the Torreya Formation is most typically a quartz sand and the absence of sand is exceptional. Limestone and dolomite are commonly present in the lower part of the formation. Elsewhere varying proportions of limestone, dolomite, shells, and clay mineral may be present. The lower part of the formation at the type locality is a sandy limestone with scattered intervals of calcareous sandstone. Commonly the limestone is very fine grained to pasty calcilutite and contains suspended quartz grains. In the nearby Rock Bluff #1 (W-6611) the various lithologic components of the Torreya Formation are greenish clayey sand to sandy clay; dolomitic fine sand; calcareous, shelly sand; clayey sandstone; calcareous sandstone; claystone; calcilutite with angular clay clasts; white, fine-grained, lutitic limestone; dolomite; white, sandy limestone; and partially indurated calcareous sand to sandy limestone.

Although the core recovery was very poor in the Torreya interval of the Rock Bluff #1 (W-6611) and it is therefore hazardous to make too many generalizations about the Torreya lithology and sedimentary characteristics in that core, it is noted that bioturbation is present and there appears to be more indication of discrete bedding than in the cores to the south.

Farther to the south and southwest the recognizable Torreya Formation thins drastically and the lithology changes. In this area, in the Wall #1 (W-7457), Alum Bluff #1 and #2 (W-6901 and W-7616), the lithology is essentially indistinguishable from Alum Bluff Group lithology. The Torreya Formation here consists of an unconsolidated, massive-bedded, slightly micaceous and very slightly argillaceous, shelly, calcareous, medium to coarse quartz sand. Intervals of indurated, calcareous sand or sandy limestone and noncalcareous, micaceous sand also occur.

Underlying and Overlying Units

The Torreya Formation paraconformably and with abrupt change in lithology overlies the Chattahoochee Formation (Tampa Limestone in part) of Chickasawhayan age in the Alum Bluff-Rock Bluff area along the Apalachicola River. At Taff pit in Wakulla County, the Torreya Formation overlies the St. Marks Limestone with a very sharp contact and dramatic change in lithology.

At Alum Bluff the Torreya Formation is overlain abruptly and with apparent discontinuity by the Chipola Formation. Farther east in the Wall #1 (W-7457) the core recovery between recognizable Torreya Formation and Jackson Bluff Formation is very poor, and as a consequence, the upper limit of the Torreya and its relation with the overlying sandy limestone is in doubt. Nor is it clear whether the poorly recovered shelly, sandy limestone/shelly calcareous sandstone that overlies the Torreya in that core is a facies of the Chipola, whether it is a facies of the Torreya, or whether it is both.

In the vicinity of Torreya State Park, the Torreya Formation is overlain by finely laminated sands and clays, lensy-bedded clay and sand, and poorly sorted sands and phosphatic sands. By physical correlation these deposits appear to be an updip, nearshore, marginal marine facies of the Jackson Bluff Formation but the lithology type and stratigraphic position suggests assignment to the Miccosukee Formation.

It should be pointed out that it was not the intention of Banks and Hunter (1973, p. 361) to extend the name Torreya to the fullers earth deposits of Gadsden County. They preferred to retain the name Hawthorn for the dominantly clay deposits in that area. The Torreya lithologies are mainly restricted, therefore, to carbonates and sands with minor amounts of clay whereas the Hawthorn lithology, in their usage, is restricted to the dominantly clay deposits. Because the top bed of the section exposed at Rock Bluff has been described as fullers earth and therefore correlated with the fullers earth deposits of Gadsden County, the Torreya may be said to be overlain by Hawthorn at the type locality. The stratigraphic relationships between the two units , however, have not been examined at the present time.

Distinction Between Adjacent Units

The type Torreya can be distinguished from the other units in this study in that the carbonate phases are very rarely fossiliferous or bioclastic but tend to be much finer grained, sandy, and brecciated in some intervals while the terrigenous clastic phases are very sparsely fossiliferous, and rarely calcareous or dolomitic. In the Chipola Formation and the younger deposits of the Alum Bluff Group, the clays are dominantly gray or black whereas the Torreya clays are lighter in color. Alum Bluff Group clays are dominated by montmorillonite and contain minor kaolinite and illite whereas the Torreya clays contain appreciable amounts of palygorskite (attapulgite) and sepiolite. The sands in the type Torreya commonly have a characteristic pale yellowish-green color that is completely lacking in typical Alum Bluff Group sands.

In the vicinity of Alum Bluff the lithologic distinction between the Chipola and Torreya is subtle. The Chipola can be characterized as being a shelly, calcarenitic sand whereas the Torreya is a less shelly, coarser grained, quartz sand that does not contain the fine to medium-textured bioarenite. In the Alum Bluff #2 (W-7616) the Torreya grades upward into a noncalcareous, nonfossiliferous, tan to brown, slightly argillaceous sand that is overlain abruptly by the Chipola Formation.

Elsewhere in the eastern panhandle of Florida, the stratigraphic relationships within the Hawthorn lithosome are obscure with the present information and the recognition of the Torreya Formation is based mostly on the recognition of the Torreya fauna.

Within the main part of the study area east of the Apalachicola River, the distinction between the lower limestone and shelly phases of the Torreya Formation and the underlying Chattahoochee Formation (and St. Marks Formation) is clear. The underlying Oligocene carbonates contain very little quartz sand, if any, while the Miocene sediments are either very sandy or coarsely fossiliferous. To the north and east, however, the distinction becomes more subtle in that the lower, limestone phase of the Torreya and the underlying Chattahoochee Formation become very similar lithologically. The principal distinctions between the two formations in the study area is that the Torreya is always sandy and limestone appears to dominate over dolomite whereas in the Chattahoochee Formation, quartz sand is rare to lacking and the carbonate is dominantly dolomite.

Areal Distribution

In the study area, the Torreya Formation is restricted to the region east of the Apalachicola River. It is not present in outcrop along the Chipola River and it is not present in the continuously fossiliferous marine, sedimentary sections in Walton County.

Age

The age of the Torreya Formation in west Florida is based on the following criteria cited by Banks and Hunter (1973): (1) geologic range of Miogypsina globulina, (2) stratigraphic position of the Torreya Formation in the Alum Bluff #1 and #2 (W-6901 and W-7616), (3) presence of two bird fossils known from deposits in Europe no younger than Aquitanian Age, (4) Arikareean age reported by Olsen (1962) for the mammal fauna like that in the Thomas farm beds that also contain a Torreya molluscan suite. The conclusion of Banks and Hunter (1973) is that the age of the Torreya Formation is older than the Chipola Formation and is probably either late Aquitanian or early Burdigalian in age (N5 or N6 of Blow, 1969).

As cited by Banks and Hunter, according to various authors (R. W. Barker, 1972, fide Banks and Hunter; Akers, 1972, p. 10; Akers and Drooger, 1957, p. 665) the presence of Miogypsina globulina (Michelotti) indicates an age greater than that of the Chipola, being most probably equated with the Catapsydrax dissimilis Zone of the Catapsydrax stainforthi Zone of Bolli (1957) (= N5 and N6 of Blow, 1969) (see Figure 4). However, Clarke and Blow (1969) report the range of M. globulina to extend from upper N6 through lower N8, considerably younger than the range postulated by previous authors. This is consistent with Barker (personal comminication, Hunter, 1975) having found a late-type nepionic apparatus grading into that shown by older forms of Miogypsina intermedia Drooger from M. globulina populations.

This writer has identified multispiral Miogypsina, Miogypsina cf. globulina, from the interval 233-231 feet in the Cosson #1 (W-8004) in Walton County. Miogypsina in this core occurred with a typical Chipola planktonic foraminiferal fauna in the basal, Chipola shelly sand. The

Chipola age of transitional N7/N8 is consistent with the range of M. globulina given by Clarke and Blow (1969) but is not consistent with that given by previous authors. Therefore, the presence of Miogypsina globulina in the Torreya Formation is not necessarily diagnostic of a pre-Chipola age for that formation and it certainly suggests a post-Aquitanian age of the Torreya.

The conclusion of this writer on the age of the Torreya Formation for the localities cited by Banks and Hunter (1973) is that it is at the youngest, equivalent in age to that of the Chipola Formation and therefore transitional from Burdigalian to Langhian. It is at the oldest, Aquitanian in age as suggested by the two Avian special (Avian biostratigraphy is not well developed in the Coastal Plain at this time) and the Thomas farm fauna. It is possible that the Torreya Formation may represent more than one depositional unit. This could account in part for some of the diversity in ages and in lithologies attributed to the formation.

Stratigraphic Correlatives

Until the Torreya Formation can be placed with confidence in a regional biostratigraphic framework, nothing firm can be said of its stratigraphic equivalents outside of the type area. It must certainly be correlatable with at least part of the Hawthorn Formation of Georgia and peninsular Florida.

The Torreya Formation present at Alum Bluff and in the Taff pit in Wakulla County may result from intergradation of "Hawthorn clastics" lithosome with the offshore, carbonate lithosome. It is to be noted that the limestone interval below 350 feet in the St. George Island #1

(W-7574) contains only palygorskite (attapulgite) as a clay mineral constituent (personal communication, C. E. Weaver, 1975) and palygorskite is restricted to the pre-Chipola deposits in the study area. Therefore, the limestone interval in question may be equivalent to the Torreya Formation.

Alum Bluff Group

The concept of the Alum Bluff is changed in this study from past usage. It is treated on a strict lithostratigraphic basis. The group is restricted to those units that were originally assigned to the Alum Bluff formation by Matson and Clapp (1909, p. 91) and that bear the typical Alum Bluff lithology, i.e., the Chipola Formation, the Oak Grove Sand, and the Shoal River Formation. The lithologies of these units, however, are not restricted to those formations in the type area of the Alum Bluff Group in western Florida. Consequently the writer is compelled to add the Choctawhatchee Formation and the Jackson Bluff Formation to the Alum Bluff Group. This is a logical outcome of treating the Alum Bluff Group in a lithostratigraphic sense because the Jackson Bluff Formation is also exposed at Alum Bluff and at that locality the Jackson Bluff Formation is more typical of the lithology of the Alum Bluff Group in Walton County than is the underlying Chipola Formation.

The Alum Bluff lithologies are characteristically argillaceous sands and sandy clays that are commonly calcareous and fossiliferous. Mica is commonly present but carbonaceous material, such as lignitic flecks, and glauconite and phosphorite have scattered occurrences. Some beds in the Alum Bluff Group may consist of relatively pure sand or pure clay but this situation is rare. The units are typically sandy with quartz sand rarely being entirely absent from the sediments. It is only in beds of clay or thin beds or lenses of limestone that sand or silt may be absent. Elsewhere the clay or limestone is sandy. The clay mineral assemblage of the Alum Bluff Group is dominated by montmorillonite, but contains minor amounts of kaolinite and illite. The clays are generally gray in color, but may be dark gray to black, especially in the upper Shoal River. Limestone is a very minor component of the Alum Bluff lithology, except where it occurs in discontinuous lenses or thin beds. Alum Bluff deposits are most commonly noncalcareous and nonfossiliferous where the lithology is strongly dominated by dark-gray to black clays, or in the updip extremities of the units.

Shell beds with excellently preserved shells are characteristic of the Alum Bluff deposits but they actually are a minor component of the mass of sediments. The shells and tests of calcareous organisms, where they are present, are rarely altered or leached, except in the Shoal River Formation and in some limestone lenses in other units, and the preservation is commonly superb. In the nearshore, updip areas of the various units (Chipola, Oak Grove, Shoal River, Choctawhatchee, and Jackson Bluff) shell beds and shelly sands predominate. In the far updip areas, however, the deposits are rarely calcareous and fossiliferous. Offshore the units either grade into richly microfossiliferous clastic deposits and fossiliferous limestones, or they pinch out.

It is clear from the above description that the Hawthorn Formation of Florida and Georgia cannot be placed in the Alum Bluff Group. Although the Hawthorn is also dominantly sandy and clayey, the carbonate in the formation is concentrated in the lower part of the unit and the main body of Hawthorn sediments are not particularly calcareous as the Alum Bluff deposits commonly are. The Hawthorn deposits are more dolomitic than calcareous, and they are rarely fossiliferous. Where there are fossiliferous beds in the Hawthorn, the aragonitic shells are typically leached, leaving only the molds of shells and calcitic shells such as the oysters, pectenids, Wakullina, and Pododesmus.

The Hawthorn further differs from the Alum Bluff in containing appreciable palygorskite (attapulgite) and sepiolite among the clay minerals whereas the Alum Bluff Group deposits do not contain these minerals. The Hawthorn may contain extensive beds or lenses of chert and is commonly phosphoritic, especially in eastern Florida and Georgia. Alum Bluff Group deposits are not known to contain chert beds, chert lenses, or chert concretions, and phosphorite is a very minor constituent of the typical deposits, when it is present at all.

It could be argued that the Torreya Formation should also be a part of the Alum Bluff Group because in the subsurface at Alum Bluff, the Torreya has essentially an Alum Bluff, shelly sand lithology. In addition, the lithology of the Torreya that is exposed near Crawfordville in Wakulla County could with little difficulty be compared to Alum Bluff lithology. However, as described by Banks and Hunter (1973), the Torreya contains a very heterogeneous lithology, and at the type locality, it is distinct from the Alum Bluff as recognized in this study. At this time, much too little is known of the stratigraphic relationships of the Miocene deposits in western Florida east of the Apalachicola River.

As a result of the exclusion of the Hawthorn and Torreya Formations from the Alum Bluff Group, the Alum Bluff Group is now restricted for the most part to the area west of the Apalachicola River in western Florida. It is not present in Georgia or in Peninsular Florida. At this time, only the Jackson Bluff Formation is known to occur any distance east of the Apalachicola River.

Chipola Formation

It has been found in this study that the type lithology of the Chipola Formation is atypical for the formation as a whole, and as a result, the Chipola is treated here on an expanded lithologic basis. Within the area of study, the Chipola is lithologically varied and heterogeneous. Broadly speaking, the Chipola Formation is a sand and the main lithology type is a gray to cream, calcareous sand that is more or less argillaceous and micaceous. Three lithofacies are present that can be clearly demonstrated to be lateral facies within the same depositional unit. These are the shelly sand facies of the typical Chipola, a nonshelly, calcareous, clayey sand facies, and a sandy limestone facies. These lithofacies are lateral equivalents and they intergrade and intertongue with each other. Their areal distribution is systematic in that the shell-bed facies is characteristic of the updip and eastern part of the Chipola, the nonshelly, calcareous sand facies is found downdip from the shell bed facies, and the sandy limestone is found downdip, or seaward, of the nonshelly, calcareous sand.

In Walton County a nonfossiliferous, noncalcareous, medium-to coarse-grained sand gradationally overlies the basal Chipola shelly facies. This sand appears to displace the shell-bed facies westward from Calhoun, or Washington Counties. In most of northern Walton County, however, the stratigraphic relationships of this sand deposit are uncertain due to their typical unfossiliferous nature. These beds do contain a few fossiliferous intervals in some basal beds however, but the precise age relationships remain uncertain due to the small molluscan fauna obtainable from cores and to the very low frequencies of planktonic foraminifera. The little evidence does suggest that the basal beds of these updip sands do not contain a significantly different planktonic foraminiferal fauna from the Chipola, and therefore are, or may be, closely related in age to the Chipola. Consequently, these typically unfossiliferous sands of northern Walton County are, for practical purposes in this study, considered a part of the Chipola depositional phase. It will be noted, however, that in some areas, the upper part of these unfossiliferous deposits (Fig. 23) may best be correlated with the Shoal River Formation.

Shelly Sand Facies

The typical Chipola lithology is a shell bed that appears to be restricted to a westnorthwest-eastsoutheast trending band between the Choctawhatchee River and the Apalachicola River. Alum Bluff, in Liberty County, on the Apalachicola River, is near the updip or northern limit of the Formation. It is possible that this facies of the Chipola may form a blanket deposit in the Chipola-Apalachiaola River area but it is more likely, in the writer's opinion, that this facies is a narrow band broadening slightly to the east and pinching out to the west.

Within this facies belt, the Chipola lithology consists of an unconsolidated, massive-bedded to thick-bedded, quartz or calcarenitic sand that contains abundant, well preserved shells and is subordinately micaceous and argillaceous. Chipola sediments are generally unconsolidated but there are some layers where the sand is partially cemented with calcium carbonate, or where thin-bedded, sandy limestone beds occur. With the exception of these thin-bedded limestone layers and occasional finely bedded sands and clayey sands, bedding is rarely apparent. The sediments are characteristically well mixed but in some cases the sands and clays are poorly mixed and bioturbated. Sand size varies from fine to very coarse but is mainly medium grained. In places shells dominate the other components of the lithology and, with the exception of the burrowing bivalves, are typically randomly oriented. The typical Chipola shelly fauna is a mollusc-rich assemblage that is impoverished in coral species, echinoderms, and in oysters and pectinids. In general, this facies of the Chipola represents a shallow-water, near shore, lower shoreface, open marine environment.

There is too little core control east of the Choctawhatchee River to determine precisely the type of facies change seaward of the typical Chipola shell bed. The one downdip core in this area, however, (Hunt #1 (W-10954)), shows that the shell bed of the Chipola does not exist in the Gully Ponds region of Washington County. The lithology of the Chipola in this core is the gray, microfossiliferous, argillaceous sand typical of much of the marine Chipola in Walton County.

From both outcrop and core information from the Chipola Formation in the type area, the coarse interbedding of shelly sands and nonshelly, microfossiliferous beds suggest that at least in this area, the typical shell bed passes downdip into nonshelly, calcareous sands by interfingering rather than by simple gradation.

Nonshelly Sand Facies

The nonshelly, microfossiliferous, calcareous sand facies of the Chipola consists of unconsolidated to moderately indurated massive-bedded to fine-bedded, calcareous, argillaceous, micaceous quartz sand; calcareous, micaceous, sandy or silty clays; argillaceous sandy limestone; and in some cases sandy, clayey, abundantly microfossiliferous, even-textured, fine to medium grained, unconsolidated calcarenite. There is somewhat better bedding in this facies than in the shell bed facies, but fine scale bedding is only rarely encountered. Bioturbation is commonly evident in finer grained deposits. Sand size varies from fine to very coarse but is usually fine to medium grained. Gypsum bloom is noted in some places on the dessicated cores.

This facies is well developed in the southern part of Walton County and is present in southern Washington County. Sediments of this facies are present in the type area along the Chipola River, suggesting that the facies is developed in the shallow subsurface of southern Calhoun County.

In Washington County and probably in Calhoun County, this lithofacies is developed downdip or seaward of the Chipola shell bed. However, in Walton County where the shell bed facies pinches out, the nonshelly facies grades updip directly into a noncalcareous, nonfossiliferous, soft, clean, sporadically gravelly sand, or clayey sand. Whatever the ancient environment was in this area during Chipola time, it was clearly not conducive to the development of a prolific shelly fauna.

Limestone Facies

The nonshelly, calcareous sand facies of the Chipola Formation passes downdip, or seaward, both by gradational facies change and by interfingering, into a limestone facies. In the areas of facies change, the intergradations are not clearly defined. The sand appears to grade into the limestone by both increase in calcium carbonate content and decrease in quartz sand. As a result, in its updip limits, the sandy limestone beds pass into a very calcareous sand and to calcareous sandstone. Seaward of this area the quartz sand component of the limestone steadily decreases, both downdip and upward in the section. Only in coastal, southwestern Walton County does the sand component drop out of the lower part of the Chipola interval altogether. Characteristically in this limestone facies, only the lower part of the Chipola section in each core contains a relatively pure limestone (Coffeen #1(8865), Price #1 (W-8591), Bayview #1 (W-8478)). The upper part of the Chipola section in these cores may contain either a regressive, nonshelly, sand facies of the Chipola or a more sandy limestone interval.

Typically the limestone facies of the Chipola Formation consists of a moderately indurated to hard, indurated, massive-bedded, slightly micaceous and argillaceous, sandy, fossiliferous, calcarenite limestone. It has a fine to coarse, even, granular texture that is only rarely coarsely bioclastic. In many of the cores near the coast there is a dark speckling in the limestone that appears to be concentrations of finely disseminated pyrite. As mentioned earlier, the lower part of the limestone section in downdip cores has only a small amount of impurities, generally clay mineral and mica. In the updip area of this facies, the limestone is very sandy, argillaceous, and micaceous and commonly has a rubbly texture.

There is a thick sequence of limestone in the St. George Island #1 (W-7574) in Franklin County that will be discussed more fully in the section dealing with the Bruce Creek Limestone. Within that limestone section the writer tentatively assigns the interval between 201 and 350 feet to the Chipola equivalent. If that assignment is correct, this limestone lithology in the St. George Island #1 (W-7574) differs from the equivalent limestone in Walton County in being a more indurated, pure, coarsely fossiliferous, moldic limestone that is calcarenitic in the lower part, and which contains sporadically abundant *Sorites* and algae.

In a strict sense the limestone facies of the Chipola cannot be considered Chipola Formation or a part of the Alum Bluff Group since it consists of a distinctly different lithology and mineralogy from both the broadly conceived Chipola of this study and the Alum Bluff Group. There is too little stratigraphic control on this unit both inside and outside of Walton County at this time and consequently the lithologic variation to be expected within the unit is unknown. As a result the writer considers it imprudent to attempt formal subdivision of this limestone from the Chipola at the present time.

Underlying and Overlying Units

In northern Walton and Okaloosa Counties the assumed Chipola equivalent sands overlie undifferentiated calcareous deposits of Late Oligocene, Chickasawhayan Age, and in southern Walton County the Chipola Formation overlies paraconformably "Suwannee Limestone" of probable Late Oligocene age. In northeastern Walton County on the other hand, the Chipola Formation and Chipola equivalent sands overlie calcareous deposits of Chickasawhayan Age that appear to be lithologically intermediate to the undifferentiated Chickasawhayan deposits and the Chattahoochee Formation (previously referred to as Tampa Formation in this area). In Washington County and in Calhoun County along the Chipola River, the Chipola Formation paraconformably overlies the Chattahoochee Formation of Late Oligocene age. However, at Alum Bluff on the Apalachicola River, the Chipola abruptly overlies the Torreya Formation of Miocene age (Banks and Hunter, 1973).

In Walton County and possibly in southwestern Washington County, the Chipola Formation is overlain paraconformably by the Bruce Creek Limestone. Only in northwestern Walton and in northern Okaloosa Counties are deposits of suggested Chipola age overlain without obvious break by the Oak Grove Sand. Elsewhere, the areal occurrences of the Chipola Formation, in the strict sense, and Oak Grove Sand are exclusive and do not occur together in the same section. According to Vernon (1942), the Chipola Formation is overlain by the Shoal River Formation in western Washington County. To the southeast of this, in southcentral and southeastern Washington County, Bay County, Calhoun County, and at Alum Bluff in Liberty County, the Chipola is overlain paraconformably by the Jackson Bluff Formation of Late Pliocene age.

Lithologic Distinction Between Adjacent Units

The Chipola Formation is distinguished from the underlying "Suwannee Limestone" or Chattahoochee Formation in that the Chipola is an argillaceous, sandy, and sometimes shelly unit whereas the other two are generally pure limestones or dolomites. Where the Chipola and Chattahoochee occur together in the same section, the Chattahoochee is typically a limestone or dolomite but it may have clayey intervals.

The updip, Chipola equivalent sands are distinguished from the underlying Oligocene deposits in that they are rarely calcareous whereas the underlying Oligocene deposits are either relatively pure limestones or dolomites, or are very calcareous, or dolomitic, sediments.

The Chipola Formation is distinguished from the Torreya Formation, where they occur together, in being more finely calcarenitic and containing proportionally less quartz sand.

The Chipola Formation is readily separated from the Bruce Creek Limestone in that the Bruce Creek is either a relatively pure limestone or is a sandy limestone whereas the underlying Chipola consists of either a noncalcareous sand or calcareous sands and clays. The distinction between the Chipola equivalent limestone and the Bruce Creek limestone is more subtle. Where they occur in the same section the Bruce Creek is almost always a relatively pure limestone whereas the Chipola equivalent limestone is sandy, argillaceous, and less calcarenitic. In that area, the writer arbitrarily places the boundary between the Chipola limestone and the Bruce Creek Limestone at the topmost occurrence of quartz sand in the underlying limestone. It must be pointed out, however, that the lower beds of the Bruce Creek farther updip generally consist of a sandy limestone, and this criterion that distinguishes between the two units, may not be precise.

North of the latitude of the Shoal River valley in Walton County, there is no useful way of separating the updip Chipola sands from any possible overlying noncalcareous Oak Grove equivalent deposits or sandy Shoal River deposits. In that area the mass of weathered sands may best be considered as undifferentiated Miocene. To the west, however, the

Oak Grove is clearly distinguished from the underlying updip Chipola sands in being a shell bed. To the east the base of the noncalcareous Shoal River is arbitrarily defined as the first massive, gray, silty clay above the sands (Fig. 23). The Citronelle is differentiated from these deposits in being consistently coarser textured, gravelly, and in typically lacking mica.

The lithologic distinction between the Chipola Formation and the Jackson Bluff Formation is subtle. In the western part of the area of their mutual occurrence, the Chipola Formation is essentially nonmacrofossiliferous whereas the Jackson Bluff Formation is both more calcareous and shelly. To the east, in the type area of the Chipola Formation, the Chipola is more sandy and is typically lighter in color. The Jackson Bluff Formation in that area is much more argillaceous and micaceous and is distinctly darker in color, commonly being a gray to a dark gray sand or clay.

Areal Distribution, Geometry, and Thickness

The Chipola Formation occurs south of a line that runs just north of west from the vicinity of Alum Bluff in the east to the Choctawhatchee River in the west. From the Choctawhatchee River, the strike of the updip limit of the formation changes to a more westnorthwest direction and it apparently holds to this trend through northern Okaloosa County since it is not found as far north as the type area of the Oak Grove.

It is not known at this time whether the Chipola Formation extends appreciably east of the Apalachicola River since the core control in that area is very poor. It does not, however, occur in western Leon

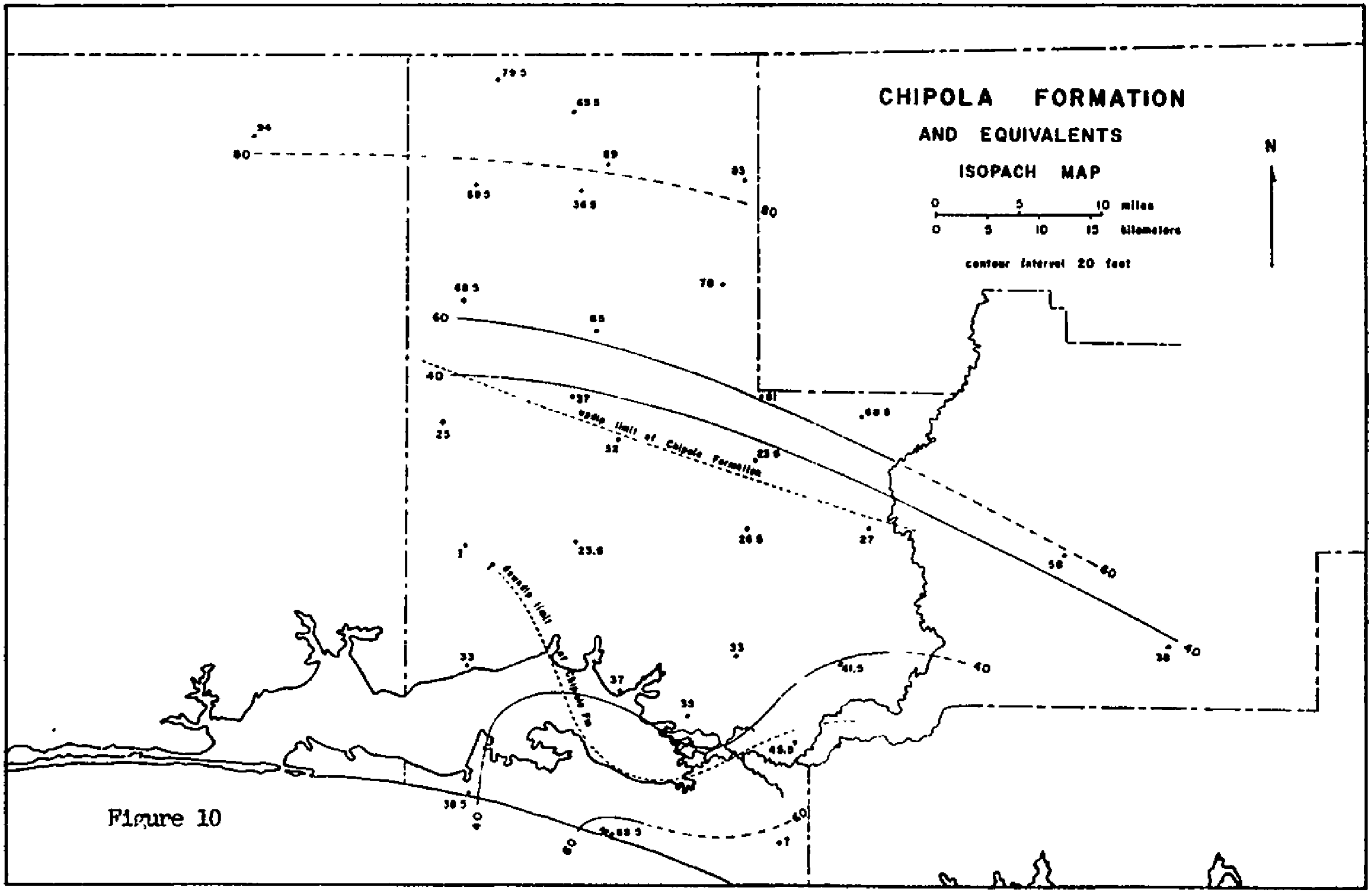

CHIPOLA FORMATION
AND EQUIVALENTS
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
N
updip limit of Chipola Formation

Figure 10

County in the Jackson Bluff #1 (W-6999) or in the Lake Talquin #1 (W-6890).

It is to be stressed that the Chipola Formation does not extend very far north or northeast of Alum Bluff. It is not present in the Wall #1 (W-7457) about 5 1/2 miles slightly north of east of Alum Bluff, it is not present in northern Liberty County in the Rock Bluff #1 (W-6611), and it is not present in the Wall #2 (W-7458) in southwestern Gadsden County. The various earlier reports of the Chipola Formation occurring east of the Apalachicola River and in Georgia cannot be substantiated (MacNeil, 1947; Siever, 1966, 1969).

The Chipola Formation (including the limestone facies in this study) is a thin, blanket-type deposit that reaches its greatest known thickness in the type area. It does not appear to thicken toward the west or southwest as many of the deposits do in the study area. Rather, the Chipola thickens toward the southeast and reaches its greatest thickness in the Apalachicola Embayment. The proposed Chipola equivalent limestone in the St. George Island #1 (W-7574) is 149 feet thick. Although the Chipola horizon was not reached in the St. Joe #1 (W-12051), it is presumably much thicker there since most of the other Neogene units penetrated in that core are relatively quite thick. The combined thickness of the shell bed and the overlying sparsely fossiliferous sands in the Alum Bluff #1 and #2 (W-6901 and W-7616) are 96 feet and 71 feet respectively. In the Ten Mile Creek #1 (W-11270) near the type locality, the Chipola is 71 feet thick.

In Walton County the Chipola Formation ranges in thickness from about 40 feet to 25 feet with a thickening to 60 feet in the downdip, limestone facies (Fig. 10). There appears to be a subtle thinning of the unit in an east-west band across the center of the county. Across this area, the Chipola thins typically from over 40 feet in the north to about 25 feet, beyond which it thickens to over 40 feet again. There is very meager control on the Chipola in Washington County. However, the thickness of the Chipola in the Sheffield well (Vernon, 1942, p. 35) of 58 feet and the thickness of 38 feet in the Hunt #1 (W-10954) is consistent with the general trend of Chipola thickness.

The Chipola - updip Chipola sand sequence thickens very gradually in a south to north direction from around 25 feet in the center of Walton County to more than 80 feet in the far northern part of Walton County. The thickness of the unit in that part of the county, however, is very irregular due apparently to errosion and truncation prior to the deposition of the Citronelle Formation.

Stratigraphic Correlatives

It has long been held that the Chipola Formation or a lateral facies of it in the Hawthorn Formation was present in the eastern part of the panhandle of Florida, in peninsular Florida, and in Georgia (Vaughan and Cooke, 1914; Cooke and Mossom, 1929; Cooke, 1945; MacNeil, 1947; Siever, 1966). Likewise it has been believed that at least a part of the Calvert Formation of Maryland is equivalent to the Chipola. To the knowledge of this writer, the precise correlation of the Chipola Formation with units outside the area of its occurrence has not been rigorously established.

This writer has identified a Chipola planktonic foraminiferal assemblage from the basal limestone beds of the Miocene in the vicinity of Savannah, Georgia. At the present time, the writer considers this limestone bed to be a lower, carbonate facies of the overlying "Hawthorn Formation" of Furlow (1969). The writer has found (study in progress) that the "Hawthorn Formation" of Furlow is a downdip, shallow subsurface equivalent of the Marks Head Marl of Sloan (1905). Unfortunately this particular unit is very rarely fossiliferous. In the few places that it is microfossiliferous, the fauna is dominated by *Ammonia beccarii*. The molluscan fauna was described by Vaughan (1910) and Gardner (1925) and is dominated at the type locality by mussels, *Wakullina floridana*, *Chlamys* cf. *acanikos*, and by one species of benthonic foraminifer *Ammonia beccarii*. There is some evidence then that the Marks Head (Hawthorn of Cooke, 1934, 1943) is equivalent to the Chipola, (Gardner, 1925), but more evidence is needed to make this correlation convincing.

Age

The following planktonic foraminifera have been identified from the Chipola Formation:

Globigerinoides sacculifera trans. *sicana*
G. sacculifera quadrilobata
G. sacculifera sacculifera
G. aff. *altiapertura*
Globorotalia mayori
Globigerina praebulloides praebulloides
G. praebulloides pseudociperoensis
G. foliata
G. obesa
G. eamesi
G. quinqueloba
G. cf. *bulloides*
G. cf. *falconensis*
Globigerinita glutinata
G. uvula
Globorotaloides hexagona variabilis
Globoquadrina altispira
Cassigerinella chipolensis

There are no species of planktonic foraminifera that are restricted to the Chipola Formation.

Based on forms transitional between the planktonic foraminiferal species Globigerinoides sacculifera and Globigerinoides sicana, the Chipola Formation is placed at the very top of the Globigerinitella insueta - Globigerinoides quadrilobata triloba Partial-range zone (N.7), or transitional between that zone and the Globigerinoides sicana - Globigerinitella insueta Partial-range zone (N.8) of Blow (1969). The Chipola Formation occurs in the Globigerinitella insueta Zone of Bolli (1966). This age assignment is consistent with the presence of typical G. sicana in the Bruce Creek limestone and the paraconformable relationship between the two formations.

According to Cita and Blow (1969), the lower part of the stratotype Langhian section in Italy contains G. sicana and as a result, they place the base of the Langhian Stage, for convenience, at the first evolutionary occurrence of that species. The Chipola contains forms transitional between Globigerinoides sacculifera and G. sicana, therefore the Chipola appears to transcend the boundary between the Burdigalian Stage and the Langhian Stage of Europe.

Whether the Chipola Formation is Early or Middle Miocene in age depends upon whether the earliest Langhian Stage is considered to be Early or Middle Miocene in age. If, as some authors suggest, the first evolutionary occurrence of the genus Orbulina is taken as the base of the Middle Miocene (Bandy, 1964; Berggren and van Couvering, 1974), then the Chipola, Bruce Creek, and Oak Grove are Early Miocene in age and only the Shoal River Formation and St. Joe Limestone are Middle Miocene in age in western Florida. Since there is no uniformity of opinion on this point, for the purposes of this paper, the writer considers the top of the Burdigalian Stage to be the top of the Lower Miocene, and therefore considers the Chipola to be transitional in age between the early and Middle Miocene.

Oak Grove Sand

The Oak Grove Sand is a little understood unit that has been variously considered as a member, formation, faunizone, and lithofacies. It has been considered in the past as one integral unit, the Oak Grove Sand, (Gardner, 1926; Cooke and Mossom, 1929; Smith, 1941), it has been placed entirely in the Shoal River Formation (Cooke, 1945), and it has been split between Oak Grove Sand and Shoal River Formation (Matson and Clapp, 1909). As recognized in this study, the shelly sand deposits occurring in the vicinity of the type locality of the Oak Grove Sand in Okaloosa County, Florida, are separated into two distinct formations in the same way as that of Matson and Clapp (1909). The shell bed exposed in the Yellow River near the old community of Oak Grove, i.e., the type locality of the formation, is considered to be a valid lithostratigraphic unit although it is known to occur in outcrop only in the immediate vicinity of the type locality. The fossiliferous sand exposed a few miles away at the old site of Senterfeits Mill on Mill Creek, which in the past has been the source of controversy, is here placed in the Whites Creek Member of the Shoal River Formation. This subdivision is based both on lithology and biostratigraphic correlation.

Type Locality and Lithology

The type locality of the Oak Grove Sand is near the old community of Oak Grove on the Yellow River in Okaloosa County, Florida. The formation is exposed at low water a few hundred feet south of the bridge where Florida highway 2 crosses the river in NE 1/2, Sec. 20, T5N, R23W.

The Oak Grove consists principally of an unconsolidated, massive bedded, shelly, calcareous, slightly argillaceous and micaceous quartz sand. The grain size of the sand varies from medium fine to medium coarse.

Areal Distribution and Thickness

The Oak Grove Sand is an updip, shallow-water, open marine, near-shore terrigenous clastic facies of the much more widely occurring Bruce Creek Limestone. It has been identified in only two cores in the study area, the Oak Grove #1 (W-10833) in Okaloosa County, and the St. Regis #1 (W-8103) in Walton County. It appears from the very limited core control in northern Okaloosa and northwestern Walton Counties, that the Oak Grove occurs in a roughly northwest-southeast trending band paralleling the updip limits of the Bruce Creek Limestone. The band apparently either pinches out west of the north-central part of Walton County or it becomes so narrow that the core spacing in that part of the county is insufficiently close to delineate the unit.

Little can be said at this time about the thickness distribution of the Oak Grove Sand. The shell bed (and type lithology) in the Oak Grove #1 (W-10833) is only 12 feet thick, but a lower, nonfossiliferous to very sparsely microfossiliferous interval immediately underlying the shell bed may also belong properly to the Oak Grove-Bruce Creek depositional interval. The shell bed in the St. Regis #1 (W-8103) is 23 feet thick but the overlying noncalcareous sand interval in that core may be an upper facies of the Oak Grove. The combined thickness of the shell bed and the overlying sand in that core is 48.5 feet thick.

Overlying and Underlying Units

In the study area, the Oak Grove Sand overlies with apparent gradation, the updip Chipola equivalent sands.

In the type area of the Oak Grove Sand and in the Oak Grove #1 (W-10833), the Oak Grove Sand is overlain paraconformably, and with very subtle change in lithology, by the Whites Creek Member of the Shoal River Formation. However, as discussed above, in the St. Regis #1 (W-8103) the shell bed of the Oak Grove grades upward into noncalcareous sands. If the Shoal River or Shoal River equivalent is present in this sand section, it cannot be distinguished as such. This sand section is in turn overlain disconformably by the Citronelle Formation.

Lithologic Distinction Between Adjacent Units

The only way the Oak Grove Sand can be identified at this time is in its being a shell bed with a particular fauna (in this case, planktonic foraminifera). As such it can be readily differentiated from the underlying sediments since they are characteristically noncalcareous and therefore lack any shelly faunas. In the type area of the Oak Grove Sand, however, the lithologic distinction between it and the overlying Shoal River Formation is subtle and the criteria used in separating the two units is mainly paleontological. Lithologically the Whites Creek Member of the Shoal River in that area is more argillaceous, micaceous, and microfossiliferous than the Oak Grove.

In the writer's opinion, the Oak Grove Sand could be a formation separate from the Shoal River and the Bruce Creek, or it could be classified as a member of the Shoal River Formation. The relationship between the Shoal River Formation and the Bruce Creek Limestone is close since they are related in part by lithofacies change, as will be discussed in a later section. Since the Oak Grove Sand is an updip, sandy facies of the Bruce Creek Limestone, and since the lithologic distinction between the Shoal River and the Oak Grove in the vicinity of the Yellow River is subtle, it would be reasonable to include the Oak Grove as the oldest part of the Shoal River. However, there is a regional hiatus, as will be discussed later, below which is "typical" Bruce Creek Limestone/Shoal River Formation, and above which occurs the Shoal River equivalent Bruce Creek Limestone/Shoal River Formation.

For the purposes of this study, the writer prefers to distinguish the Oak Grove Sand from both the Shoal River Formation and the Bruce Creek Limestone, recognizing however that future studies may make it imperative to include the Oak Grove Sand in the Shoal River Formation.

Stratigraphic Correlatives

The only stratigraphic units in the Coastal Plain that can be clearly correlated with the Oak Grove Sand, at this time, are the upper part of the typical Bruce Creek Limestone and bed 10 in the upper part of the Calvert Formation in Maryland (Gibson, 1967). The upper part of the Bruce Creek can only be distinguished paleontologically from the rest of the Bruce Creek in the study area in southwestern Walton County, in the Coffeen #1 (W-8865) and in the Price #1 (W-8591).

Age

The following species of planktonic foraminifera have been identified from the type locality of the Oak Grove Sand and from the equivalent interval in the Oak Grove #1 (W-10833):

Praeorbulina glomerosa curva
P. glomerosa glomerosa
P. glomerosa glomerosa trans. circularis
Globorotalia mayori
Globigerina praebulloides praebulloides
G. praebulloides pseudociperoensis
G. falconensis
G. bulloides
G. quinqueloba
Globigerinoides sacculifera quadrilobata
G. sacculifera sacculifera
G. sicana trans. sacculifera quadrilobata
G. subquadrata
Globoquadrina altispira
Globigerinita glutinata
G. uvula
Cassigerinella chipolensis

The presence of Praeorbulina in the Oak Grove allows correlation with the type Langhian section in northern Italy (Cita and Blow, 1969). In addition, the presence of Praeorbulina occurs only in the upper part of the Globigerinitella insueta-Globigerinoides sicana Partial-range zone (N. 8) of Blow (1965, 1969) and in the Praeorbulina glomerosa Zone of Bolli (1966) (Fig. 4).

Shoal River Formation

The Shoal River Formation is a terrigenous clastic unit consisting of sand, silt, and clay. In the type area along the Shoal River in Walton County, Florida, it varies principally from a micaceous, slightly argillaceous, silty, fine quartz sand to a micaceous, medium quartz sand. Some beds are calcareous and the sand is packed with mollusc shells. The principal shell bed along the Shoal River contains a profusion of excellently preserved shells whereas other beds in the area contain only molds and impressions of the shells.

In general, the Shoal River Formation is characteristically much more argillaceous than it is in its type area along the Shoal River valley and the type lithology is not representative for the formation as a whole. Gray, calcareous clay; black sulphurous clay; micaceous silty clay; and micaceous, clayey silt lithologies are more typical of the formation than the sand or shelly sand that occurs along the Shoal River. However, the sand and shelly, calcareous sand distribution within the formation is systematic in that it is restricted mainly to the lower, Whites Creek Member, and to the updip, nearshore open marine facies of the formation.

Sandy Facies

The Shoal River sands are unconsolidated, thin-bedded to massive-bedded, slightly argillaceous and micaceous, and in places calcareous and fossiliferous. The calcareous, fossiliferous sands are invariably massive-bedded. The sand size varies from fine grained to coarse grained and sporadically gravelly. Molluscan shells where present are typically randomly oriented and robust, and double-valved bivalves with very small gape at the hinge-line are common. In some places the molluscs are abundant enough to be closely packed in the sand. Calcareous sandstone concretions have been noted in the shell bed in the Gavin #1 (W-7972).

Noncalcareous sands may be either massive bedded or show fine-scale bedding with clay, very coarse sand, or gravel layers. Commonly, discrete beds are less than one foot thick and may be less than one inch thick. This type of deposit is characteristically unfossiliferous and was probably more marginal to the marine environment than the massive bedded, shelly sand.

The uppermost beds of the Shoal River Formation are dominated by a massive-bedded, very slightly argillaceous, micaceous, pale colored, fine to medium grained, quartz sand. This sand is commonly encountered in outcrop because of its relatively high elevation. Apparently, in updip areas, all time-horizons grade into this type of sand deposit since it physically and gradationally overlies the entire formation.

There are three persistent shell beds in the Shoal River Formation. The stratigraphically lowest bed is exposed at White Creek in Walton County, and is referred to a distinct, lower member of the formation in this study. The middle shell bed is exposed in the type area along the Shoal River and is included in the type locality of the formation. The upper shell bed is the youngest identifiable part of the Shoal River Formation and has been referred to informally as the Cardium bed in the past. The lower and middle shell beds pinch out in an eastward direction about five miles east of DeFuniak Springs, whereas the upper shell bed appears to be restricted to the western half of the county. All the shell beds thicken to the west.

Clayey Silty Sand Facies

The Shoal River sands (excluding the lower member, which appears to either pinch out downdip or grade downdip into the upper part of the Bruce Creek Limestone) and shell beds grade downdip into much finer grained clastics. These unconsolidated sediments are ordinarily micaceous and calcareous, even if slightly so. The deposits are less homogeneous lithologically and consist of alternating beds of silt and clay. The individual beds may be as little as one or two feet thick but are typically thicker. They are strongly gradational but in places have abrupt lithologic changes. These silty, argillaceous sediments are commonly very finely bedded or laminated. Apparent massive-bedded intervals, when the cores are dessicated, commonly prove to be finely laminated with silt and mica causing the core to fall apart along stratification planes. In addition, very fine, delicate shells or shell fragments and/or flecks of lignitic, carbonaceous material may be disseminated through the core or concentrated along stratification planes. Incomplete bioturbation commonly imparts a mottled or marbled texture to the sediment without completely destroying the original fine stratification. Gypsum bloom is common on the walls of the dessicated cores in this facies, especially in the more argillaceous intervals.

Clay Facies

In the downdip extremities of the Shoal River Formation, the unit consists almost entirely of clay. The clay may be either gray or black or any shade between. Yellow sulpho-salts commonly crystallize on the dessicated cores in the black clay intervals. Quartz silt and mica are very minor mineral components in this facies and are typically concentrated along stratification planes. The clays are typically noncalcareous and contain no fossils with calcareous shells or tests except in the western part of the county where thin stringers of slightly calcareous, microfossiliferous clay are interspersed in the generally noncalcareous clay. The clay appears to be massive-bedded, but the dessication of the cores reveal the very finely laminated nature of the clay.

Subdivisions of the Shoal River Formtaion

The writer recognizes three parts of the Shoal River Formation. The lower, oldest part is formally recognized here as a separate member and will be discussed fully in a later section. The middle and upper parts of the formation have subtle lithologic differences and differences in the geometries of the deposits. The lithologic distinctions do not appear clear enough at this time to warrant formal subdivision of the middle and upper parts of the formation.

Middle Shoal River

Both the lower and middle Shoal River is exposed in the type area along the Shoal River. However, because the middle Shoal River contains the main shell bed, it has been the principal concept of the formation. Its only known exposure is in the valley of the Shoal River but it may also crop out downdip in the tributaries of the upper part of the White Creek drainage basin (Cook and Mossom, 1929, p. 113, 114; Cooke, 1945, p. 177). The middle Shoal River is consistently more calcareous, more persistently microfossiliferous, and slightly more silty and sandy than the upper Shoal River. It is also more of a blanket-type deposit than the upper Shoal River (Fig. 16). The middle Shoal River can be distinguished from the lower member of the Shoal River in being more argillaceous and micaceous, and in being more finely sandy whereas the lower Shoal River is typically more coarsely sandy.

Upper Shoal River

The upper Shoal River consists of the Cardium bed and the Yoldia zone (or facies) of earlier authors plus an extensive interval of underlying typically noncalcareous clay and silt. This interval is consistently more argillaceous than the middle Shoal River and is dominated by gray or black, noncalcareous clay that may or may not be silty. The most distinctive lithology in this stratigraphic interval is black, sulphurous clay. The black clay is not restricted to this part of the

Shoal River, but it is most common and conspicuous there. The base of the upper Shoal River, as recognized in this study, is defined lithologically in most of the cores containing this stratigraphic interval by a two to four feet thick bed of black, noncalcareous clay. Both the upper and lower boundaries of this bed appear to be gradational.

In the western part of Walton County, where there is a well developed section of upper Shoal River (Eglin #1 (W-8351); Adkinson #1 (W-11045); Cosson #1 (W-8004)), there appear to be three persistent fossiliferous, calcareous beds in the upper Shoal River. The uppermost bed is the main shell bed of the upper Shoal River (*Cardium* bed-*Yoldia* zone). The lower two horizons may or may not be macrofossiliferous, and the molluscan shells, where present, do not achieve the robustness of those in the *Cardium* bed. It is the lateral persistence of these three calcareous, microfossiliferous horizons in the same stratigraphic position in the upper Shoal River, that suggest the physical correlation between the *Cardium* bed and the *Yoldia* zone (Figures 19, 21 and 22).

Julia Gardner (1926) first used the name "*Cardium* bed" in an informal sense and its subsequent usage has been consistent with her original use of the name. The *Cardium* bed is the name given to a consistently occurring shell bed exposed in gullies and "steep heads" in the upper drainage basin of Alaqua Creek. This shell bed, in the updip sandy facies of the upper Shoal River, appears to be confined to a narrow band. It is not present in the Cosson #1 (W-8004) but is present in an exposure slightly more than a mile north and northeast of that core (Cushman and Ponton, 1932, p. 9-12). At one locality (ibid.) Cushman and Ponton report that the *Yoldia* zone directly overlies the

Cardium bed apparently with an abrupt change in lithology.

Yoldia Zone

The *Yoldia* Zone was named by Mansfield and Ponton (1932) for what they considered to be the basal faunizone of the Choctawhatchee Formation. Vernon (1942, p. 99) and later Puri (1953, p. 48) referred to the "zone" as a facies or lithofacies. Subsequently Puri and Vernon (1964, p. 115, 116) recommended that the *Yoldia* faunizone be placed both in their newly suggested Red Bay Formation (ibid., p. 115) and Yellow River Formation (ibid., p. 116, 200-202). The type locality of the *Yoldia* Zone, or Yellow River Formation, is in a steep-sided tributary on the north side of Alaqua Creek in SE 1/4, Sec. 18, T2N, R19W. The lithology of the type *Yoldia* Zone is a stiff, blocky, slightly micaceous, calcareous, microfossiliferous clay in which there is a profusion of large specimens of the deposit-feeding bivalve, *Yoldia frater*.

None of the cores in Walton County contained type *Yoldia* Zone lithology, nor were sediments containing the characteristic, large *Yoldia frater* or planktonic foraminiferal-rich assemblages observed in that stratigraphic position. This includes the Cosson #1 (W-8004), the core being taken about 500 feet from the type locality at the top of the hill. In that core, micaceous, argillaceous, calcareous, silty, fine sand occurred at the same elevation as that at the type exposure, a few hundred feet away. Furthermore, the writer could not find typical *Yoldia* Zone lithology or faunas in adjacent gullies and tributaries. The only lithology found in the adjacent tributaries was either calcareous or noncalcareous, micaceous, argillaceous silty sand, such as occurs in the same stratigraphic position of the type locality in the Cosson #1 (W-8004).

The Yoldia Zone and its lateral equivalents in the type area appears to occur in the same stratigraphic position as the Cardium bed, as discussed above. Since neither the Cardium bed nor the Yoldia Zone is present in the Cosson #1 (W-8004), and since the Yoldia Zone is also not present in any other core in Walton County, but does occur in outcrop at the type locality in the stratigraphic position of the Cardium bed, the only reasonable conclusion that the writer can make at this time is that the Cardium bed and the Yoldia Zone are facies of each other. The Cardium bed appears to occur in the updip, sand facies and the Yoldia Zone appears to be a component of the downdip clayey sand facies. Where neither sand nor clay are present, as in the Cosson #1 (W-8004), neither "zone" is present.

The planktonic foraminiferal assemblages in the upper shell bed (Cardium bed) and in the type Yoldia Zone supports this conclusion. The planktonic foraminifera in any part of the upper Shoal River can not be distinguished in any way from those of the type Yoldia Zone.

The writer therefore proposes that the name Yoldia Zone be discontinued in its original biostratigraphic and lithostratigraphic sense because it cannot be demonstrated that the faunizone or lithofacies has any lateral continuity. In spite of the fact that the name Yellow River Formation has never been formally proposed, it has been used in a formal sense (Puri and Vernon, 1964; Akers, 1972). Furthermore, the Yellow River does not flow through Walton County and if the upper Shoal River were found to be systematically distinguishable from the middle Shoal River. the use of that name for the upper Shoal

River would be inappropriate.

Overlying and Underlying Units

Except in the vicinity of Oak Grove in Okaloosa County, Florida, where the Shoal River Formation paraconformably overlies the Oak Grove Sand, the Shoal River Formation in Walton County overlies the Bruce Creek Limestone with abrupt change in lithology. Eastward in Washington County, Florida, the Shoal River Formation was reported to directly overlie the Chipola Formation (Vernon, 1942, p. 83).

At the time of writing, there is insufficient core control north of the Shoal River valley in Walton County to be certain of the stratigraphic relations between the far updip Shoal River Formation and the underlying Bruce Creek-Oak Grove or updip Chipola equivalents.

In the northern part of its area of occurrence, the Shoal River is overlain disconformably by the Citronelle Formation. Farther south, however, it is overlain paraconformably and with very inconspicuous change in lithology by the Choctawhatchee Formation of Late Miocene age.

Lithologic Distinction Between Adjacent Units

The Shoal River Formation is easily distinguished from the underlying Bruce Creek Limestone in being a gray to black, in places calcareous and fossiliferous, micaceous, sand or clay. Its distinction from the Oak Grove Sand is much more subtle but in the Oak Grove #1 (W-10833), the Shoal River is more argillaceous, micaceous, and microfossiliferous. The Oak Grove in general seems to be a cleaner sand.

The Shoal River Formation is more argillaceous and less sandy than the overlying Choctawhatchee Formation. The lower, calcareous member of the Choctawhatchee is both more laterally persistent and lithologically distinctive than any similar calcareous bed in the Shoal River. However, the basal sand and clay of the overlying Choctawhatchee has essentially the same lithology as the top-most beds of the Shoal River where they are in contact. Where this stratigraphic interval is continuously, or almost continuously, fossiliferous as in the Eglin #2 (W-8352) and Eglin #3 (W-8353), the stratigraphic horizon of the hiatus can be pinpointed in the cores and the Choctawhatchee clays and silty clays can be separated biostratigraphically from the underlying Shoal River. Where the interval is not continuously microfossiliferous as in the Vaughan #1 (W-8014) and Seymour #1 (W-7971). the contact between the Shoal River and Choctawhatchee is placed arbitrarily at the base of the lowest calcareous sediments that grade upward into the lower, calcareous member of the Choctawhatchee.

The upper, pale-colored, massive-bedded, micaceous, fine sand that overlies all the Shoal River Formation (see page 54) cannot at this time be separated lithologically from similar sands that occur in the same stratigraphic position in the Choctawhatchee Formation. These massive-bedded, fine, micaceous sands are, however, easily distinguished, even when weathered, from the overlying Citronelle Formation. The Citronelle sands are typically much coarser, intermittently gravelly, poorly to well sorted, and often contain clay beds that are abruptly bounded above and below, by coarse sands. Also the Citronelle is very rarely micaceous, whereas the Alum Bluff Group sands commonly are.

Areal Distribution

The Shoal River Formation strikes east-west across the central half of Walton County (Fig. 11). It is not known to exist in the northern quarter of the county and it grades into the St. Joe Limestone and the upper part of the Bruce Creek Limestone in the southern part of the County (Figures 21-24). It does occur in Okaloosa County but has been reported only in the northeastern part of the county in the vicinity of Crestview (Gardner, 1926), and near Oak Grove. Vernon (1942) reported its presence in the western part of Washington County but noted that it thins rapidly eastward. The formation is not known east of the western part of Washington County, Florida.

Thickness and Geometry

The Shoal River Formation is a prism-shaped mass of sands and clays that was apparently deposited parallel to the old shoreline (Figures 11, 12, 13 and 14). This mass of sediments thins and narrows in a roughly westnorthwest/eastsoutheast direction across the center of Walton County. In the narrow belt across Walton County where it has long been known to be exposed, the Shoal River averages about 130 feet thick (Fig. 11). Its greatest known thickness is in the Eglin #1 (W-8351) in western Walton County where it is 160 feet thick. The formation thins rapidly both north and south of the axis of greatest thickness across the central part of the county. To the north the thinning may be due to truncation by the Citronelle Formation. To the south the thinning probably represents a real thinning of the deposit but could conceivably be in part due to subsequent removal of some of the youngest Shoal River prior to deposition of the Choctawhatchee. The Shoal River Formation grades into the St. Joe Limestone in the southern part of Walton County.

The geometries and thickness distributions of the lower, middle,

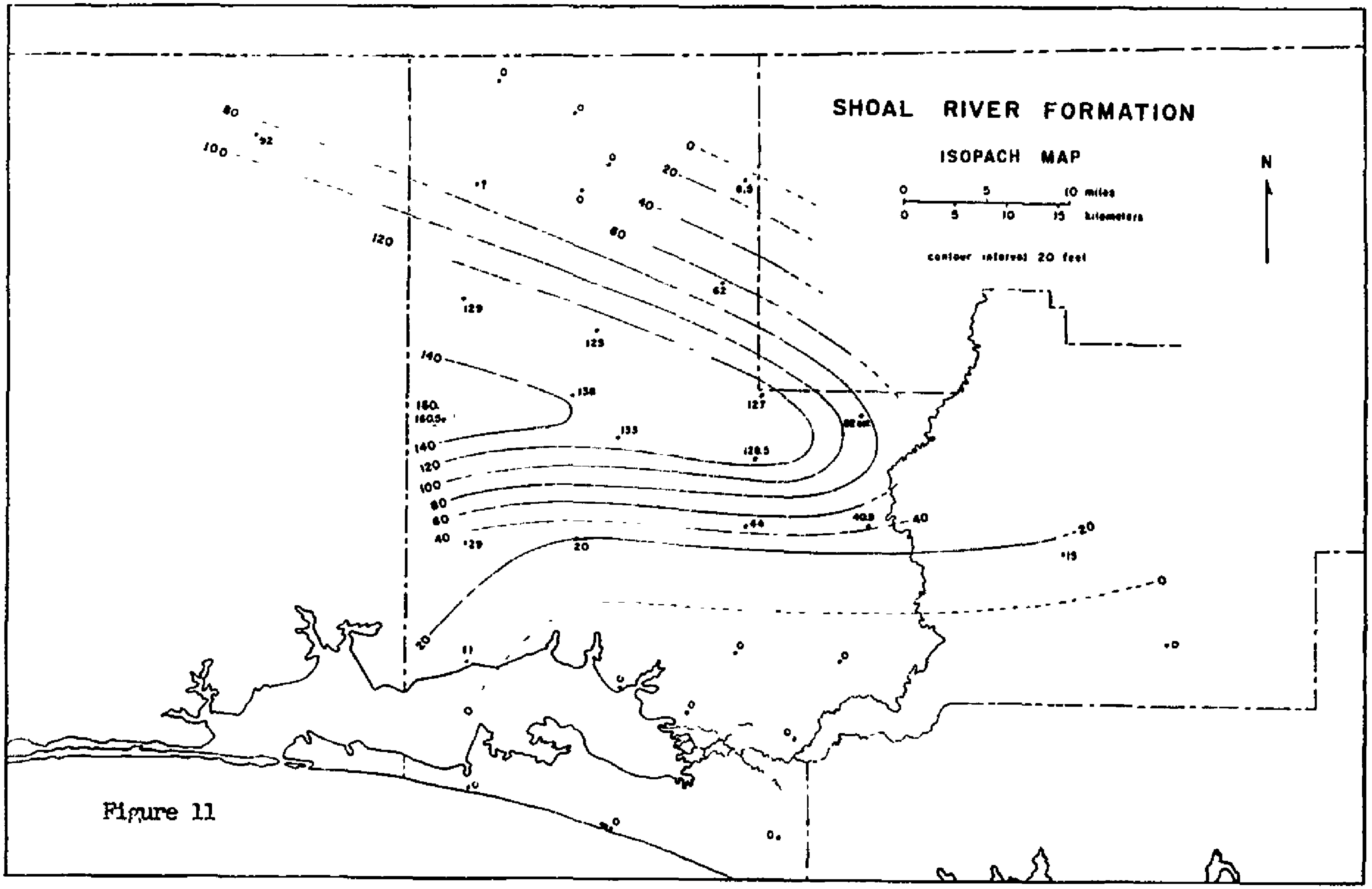

SHOAL RIVER FORMATION
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
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Figure 11

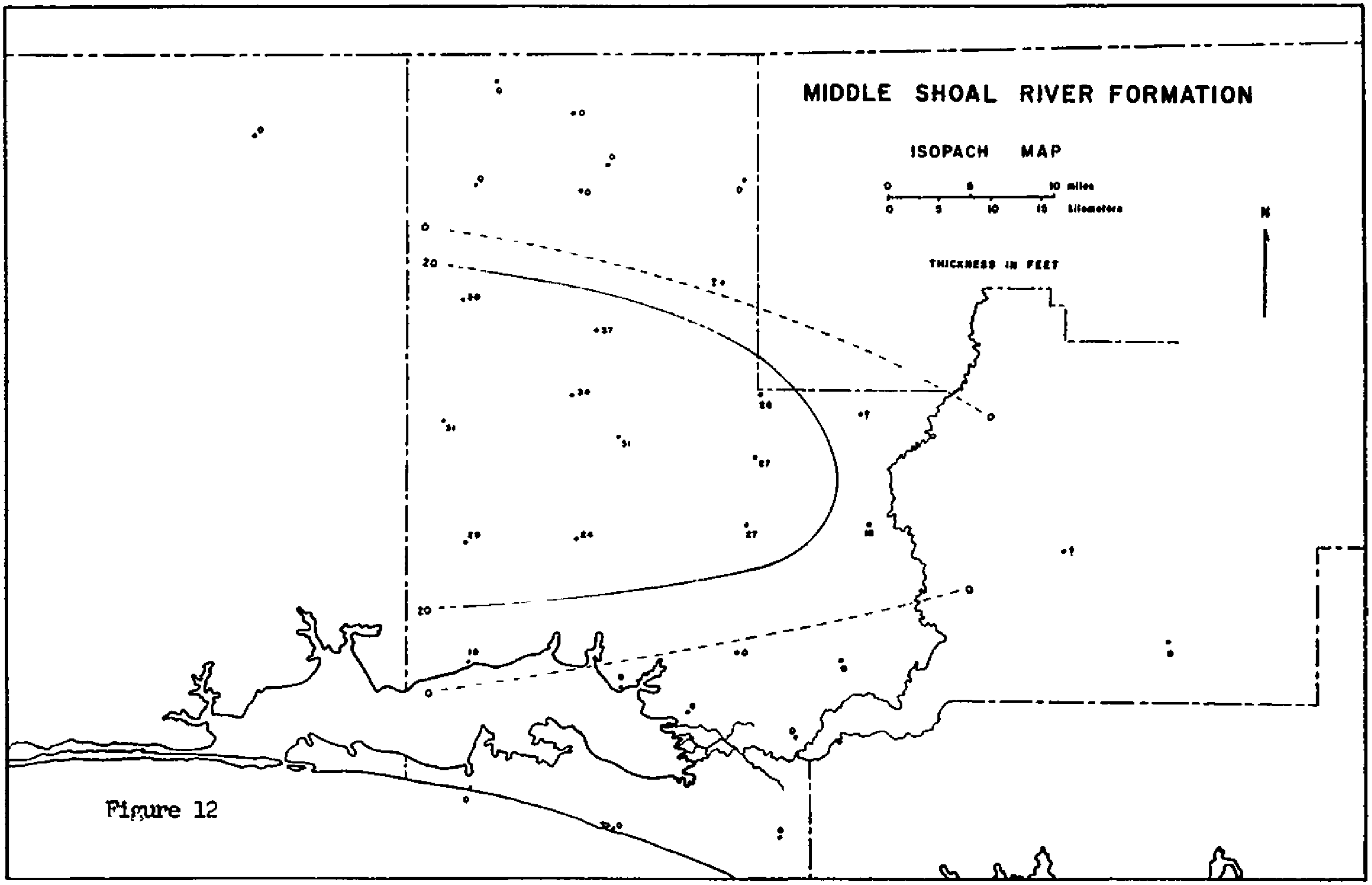
MIDDLE SHOAL RIVER FORMATION
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
THICKNESS IN FEET
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Figure 12

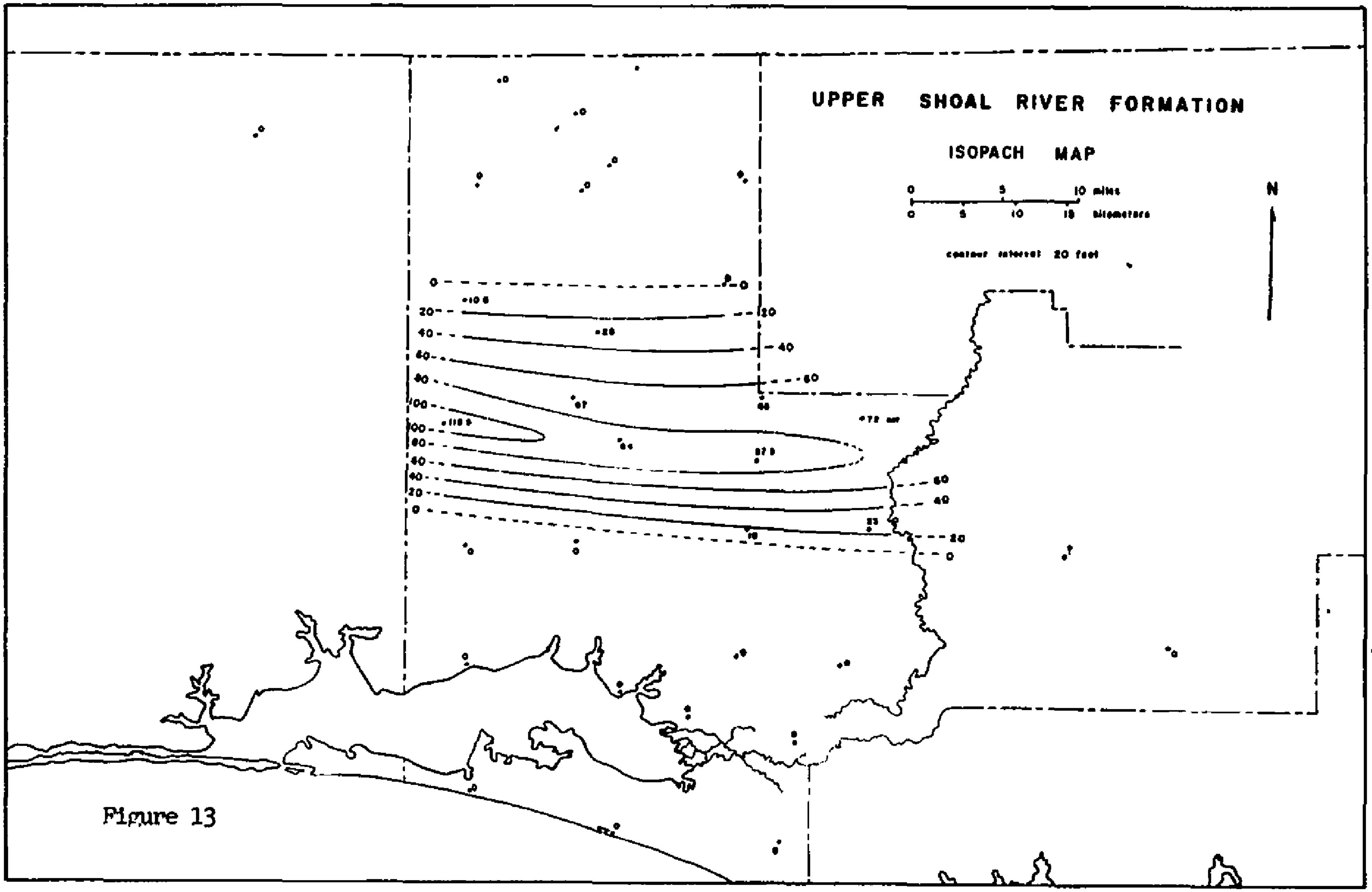
UPPER SHOAL RIVER FORMATION
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
N

Figure 13

and upper Shoal River are distinctive. The lower, Whites Creek Member of the Shoal River, is a wedge-shaped mass of sands found in an east-west belt across the center of the county (Fig. 14). Its greatest thickness occurs in its most western and/or updip, recognizable extremities, and it progressively thins to the south and west. North of the valley of the Shoal River the lower member thins rapidly by truncation by the Citronelle and also passes lithologically into undifferentiated Shoal River sediments (Fig. 23). It either pinches out or grades downdip into Bruce Creek lithology since it is not found in the southern half of the county. Its greatest known thickness is 80 feet in the Shoal River #1 (W-8354) but it may be as much as 92 feet in the Oak Grove #1 (W-10833).

The middle Shoal River is a vaguely elongate, thin, blanket-type deposit that occurs over the central half of Walton County. It ranges in thickness from 18 to 37 feet (Fig. 12).

The deposits of the upper Shoal River occur in a narrow, east-west band across the center of Walton County (Fig. 13). In the thickest part of the prism, the deposits are more than 80 feet thick, reaching almost 120 feet in the Eglin #1 (W-8351). The upper Shoal River thins rapidly both north and south of the depoaxis and is not found either in the northern or southern 1/3 of the county. The maximum width of the deposit is no more than 15 miles.

Stratigraphic Correlatives

It has long been assumed that part of the Hawthorn Formation of Florida, Georgia, and South Carolina, and part of the Chesapeake Group of Maryland are time-equivalents of the Shoal River Formation. This assumption, however, has neither been carefully documented nor demonstrated beyond reasonable doubt. This writer, however, has examined planktonic foraminiferal assemblages from the Choptank Formation exposed at Calvert Cliffs, Maryland, and has identified *Globorotalia fohsi peripheroronda* and forms intermediate to *G. fohsi peripheroacuta*, suggesting correlations with the Bruce Creek or more likely, in the writer's opinion, with the lower Shoal River.

Miocene deposits exposed along the lower Savannah River in Effingham County, Georgia, do in fact contain a characteristic Shoal River planktonic foraminiferal association. The writer has identified *Orbulina suturalis*, *Globorotalia fohsi peripheroacuta*, *G. fohsi praefohsi*, *G. mayori* (*G. siakensis* of authors), *Globigerinoides subquadrata*, and *Globigerina druryi* from these beds. Based on the relatively high frequencies of *G. subquadrata* and the typical development of *G. druryi*, the correlation is probably with the early part of the typical, middle Shoal River. This unit has been variously referred to as Marks Head Marl (Sloan, 1905; Veatch and Stephenson, 1911) and Hawthorn (Cooke, 1934, 1943; MacNeil, 1947), and Coosawhatchie Formation (Abbott, 1974; personal communication, 1975).

Age

The following planktonic foraminifera have been identified from the Shoal River Formation:

Globorotalia fohsi peripheroronda
G. fohsi peripheroacuta
G. fohsi praefohsi
G. fohsi lobata (sensu Bolli, 1957)
G. fohsi robusta (sensu Bolli, 1957)
G. praemenardii archeomenardii
G. praemenardii praemenardii

G. menardii s. l.
G. mayori (includes G. siakensis of authors)
G. scitula praescitula
G. lenguaensis (includes G. minima of Akers)
G. cf. minutissima
Globigerina praebulloides praebulloides
G. praebulloides pseudociperoensis
G. foliata
G. obesa
G. falconensis
G. druryi
G. bulloides
G. quinqueloba
G. eamesi
Globigerinopsis aguasayensis
Globigerinoides sacculifera quadrilobata
G. sacculifera sacculifera
G. obliqua obliqua
G. subquadrata
G. aff. Globigerinopsis aguasayensis
Globoquadrina dehiscens
Globoquadrina altispira
Sphaeroidinellopsis seminulina
S. subdehiscens
Globigerinita glutinata
G. uvula
Cassigerinella chipolensis
Globorotaloides hexagona variabilis
Orbulina suturalis

The following planktonic foraminifera are restricted to the Shoal River Formation:

Globorotalia fohsi peripheroacuta
G. fohsi praefohsi
G. fohsi lobata (sensu Bolli, 1957)
G. fohsi robusta (sensu Bolli, 1957)
G. praemenardii praemenardii
G. scitula praescitula
Globigerina druryi
Globigerinopsis aguasayensis

Excluding those species that are restricted to the Shoal River Formation, the following species have their first local occurrence in the Shoal River:

Globorotalia menardii s. l.
G. lenguaensis (includes G. minima of Akers)
Orbulina suturalis
Sphaeroidinellopsis subdehiscens

Excluding those species that are restricted to the Shoal River Formation, the following species have their last local occurrence in the Shoal River:

Globorotalia mayori (includes *G. siakensis* of authors)
G. cf. *minutissima*
G. fohsi peripheroronda
Globigerina falconensis
G. foliata
Globigerinoides subquadrata
Cassigerinella chipolensis

The planktonic foraminiferal species that characterize the lower, Whites Creek Member of the Shoal River Formation will be listed separately under the section describing that unit. The following planktonic foraminifera are characteristic and restricted to the middle Shoal River:

Globorotalia fohsi lobata
G. fohsi robusta

The following species have their last local occurrence in the middle Shoal River:

Globorotalia fohsi s. l.
G. scitula praescitula
Globigerinopsis aguasayensis
Cassigerinella chipolensis

In addition, *Globigerinoides subquadrata* is very severly reduced in abundance along with the termination of the above species at the top of the middle Shoal River. It is, however, present but extremely rare in the upper part of the Shoal River.

The following species make their first local appearance in the upper Shoal River:

Globorotalia lenguaensis (includes *G. minima* of Akers)
Globigerinoides aff. *Globigerinopsis aguasayensis*

The following species have their last local occurrence in the upper Shoal River:

> Globorotalia mayori (G. siakensis of authors)
> Globigerina druryi
> Globigerinoides subquadrata

Accepting the writer's preliminary conclusions that the Oak Grove Sand should be considered separate from the Shoal River Formation, the Shoal River therefore is included entirely in the uppermost Langhian Stage and lower Serravalian Stage of Italy (Cita and Blow, 1969) (Helvetian of older authors, see Mansfield, 1935).

Although Bolli (1957, 1966, 1967), Blow and Banner (1965), and Blow (1969) have offered planktonic foraminiferal zonation schemes for the Miocene, their zonations are similar but they differ in details. The writer has adopted, for the purposes of this paper, the zonation of Blow because it has received more general acceptance and usage than that of Bolli. However, it must be pointed out that the zonation of Bolli is in part more applicable to the sequence of planktonic foraminiferal populations in the Middle Miocene deposits of western Florida. As a result the writer will refer to the zonations of both Bolli and Blow (Fig. 4).

Within the zonation scheme of Blow (1969), the Shoal River Formation includes the Orbulina suturalis-Globorotalia (Turborotalia) peripheroronda Partial-range zone (Zone N.9), the Globorotalia (Turborotalia) peripheroacuta Consecutive-range zone (Zone N.10), the Globorotalia (G.) praefohsi Consecutive-range zone (Zone N.11), the Globorotalia (G.) fohsi Partial-range zone (N.12), and the Sphaeroidinellopsis subdehiscens subdehiscens-Globigerina druryi Partial-range zone (N.13).

In the zonation scheme of Bolli (1967), the Shoal River includes the Globorotalia fohsi peripheroronda Zone (= G. peripheroronda of Blow), the Globorotalia fohsi peripheroacuta Zone (= G. peripheroacuta + G. praefohsi of Blow), the Globorotalia fohsi lobata Zone (includes G. praefohsi and G. fohsi of Blow), the Globorotalia fohsi robusta Zone (includes G. fohsi of Blow), and the Globigerinoides ruber Zone (= G. subquadrata).

The lower, Whites Creek Member of the Shoal River includes latest zones N9, N10, and earliest N11 (G. peripheroronda. G. peripheroacuta, and G. praefohsi Zones). The middle Shoal River includes N12 and earliest N13 (G. fohsi lobata and G. fohsi robuta Zones. The upper Shoal River is entirely within N13 (G. ruber Zone).

Akers (1972) placed the Yoldia Zone (Yellow River Formation) in N14 on the abundant occurrence of the coccolithophorid? Catinaster coalitus. Akers did not recognize the presence of G. subquadrata in the type Yoldia Zone deposits although it does occur there in extremely low frequencies. Globigerinoides subquadrata does not extend to the top of N13 according to the range chart published by Blow (1969, p. 268, 327) and it defines the upper boundary of the Globigerinoides ruber Zone of Bolli (Fig. 4). Therefore, unless both of the above authors are in error on the upper range of G. subquadrata (which includes the Early and Middle Miocene G. ruber of Bolli), the upper Shoal River must be included in N13 by definition.

Shoal River Formation

Whites Creek Member (amended name)

The exposure of the shell bed in a gully immediately south of the road from Knoxhill to Eucheeana at White Creek in Walton County, has long been a classic Shoal River fossil collecting locality. Authors previous to Cushman and Ponton (1932), however, did not consider the age of the shell bed exposed at White Creek distinct from that of the rest of the Shoal River Formation. Cushman and Ponton (1932 p. 16) were of the opinion that these beds were "perhaps" slightly younger than the type Shoal River. Smith (1941), on the other hand, came to the conclusion that they were as old or older than the type beds on the Shoal River. In addition he (Smith, 1941, p. 275) proposed "the term Whites Creek beds to designate a member of the Shoal River formation either older than, or in part equivalent to, the typical Shoal River as exposed at Shell Bluff on Shoal River".

The present writer recognizes the beds exposed at White Creek as an integral but distinct part of the Shoal River Formation and amends the name Whites Creek Member for the member proposed by Smith (1941).

<u>Type Locality and Lithology</u>

The type locality of the Whites Creek Member of the Shoal River Formation is in a gully, 200 feet south of the road from Knoxhill to Eucheeana, on the east side of White Creek in SE 1/4, SW 1/4, Sec. 23, T2N, R18W, in Walton County, Florida.

The lithology of the type exposure is an unconsolidated, shell-bearing, slightly argillaceous and micaceous, medium to coarse sand. Smith (1941, p. 275) gave the following section exposed at the type locality:

Type section of Whites Creek beds

		thickness in feet
5.	Brown sand with some casts of mollusks.	2
4.	Lense of compact gray shell marl containing abundant Chione cymaina and Conus waltonensis anodosus. Glycymeris waltonensis is comparatively rare in this lens which is exposed upstream from 5.	0-2
3.	Below and in part equivalent to 4 is a bed of brown and yellow sand with abundant Chione ceromata, Glycymeris waltonensis, and Crassatellites densus.	4-5
2.	Gray shell marl in places indurated to form hard lumps. Fewer mollusks than the overlying beds but contains an excellent microfauna.	2
1.	Blue shell marl, the unweathered equivalent of the above. Penetrated by a short bore hold. Contains a good microfauna.	2

Due to physical deterioration of the outcrop at the type locality, little more can be added today to the type description by Smith. However, a core, the Campbell #1 (W-10832), was taken 1.4 miles west of the Whites Creek type locality in SE 1/4, SE 1/4, Sec. 21, T2N, R18W, to determine the stratigraphic sequence in that area and to determine the thickness, lithology, and stratigraphic position of the type Whites Creek Member. In that core the thickness of the member was no more than 14 feet and probably less than 11 feet. The core in the upper part of the unit was not recovered in the coring operation due to its being an unconsolidated, shelly sand. The lower part of the unit, however, is a microfossiliferous, clayey, calcarenitic, fine sand. The lithology and thickness of the Whites Creek Member in the Campbell #1 (W-10832) is consistent with the lithology and thickness given by Smith (ibid.). The outcrop, then, of the member at Whites Creek exposes most of the unit. There are two lithologies present, a lower microfossiliferous, clayey, calcarenitic, fine sand, and an upper unconsolidated, shelly, medium to coarse sand.

In the study area, the Whites Creek Member is characteristically a quartz sand with varying amounts of silt, mica, clay, shells, and bioclastic debris. The particular lithologies within the unit vary in a systematic way. The typical shell bed lithology of the Whites Creek Member is restricted to the lower part of the unit and to its downdip extremities, as at the type locality. In the updip part of the recognizable Whites Creek Member, i.e., along a line from the vicinity of Oak Grove through the upper valley of the Shoal River to the vicinity of Argyle, the upper part of the Whites Creek consists of a noncalcareous sand that contains clayey and gravelly horizons. Finally, in the downdip extremities, the lower part of the unit consists of a microfossiliferous, calcarenitic fine sand to a calcarenitic, microfossiliferous limestone reminiscent of the farther downdip, St. Joe lithology.

The lithology of the Whites Creek shell bed is characteristic of the other shell beds in the Alum Bluff Group. It is typically an unconsolidated, massive-bedded to very coarse-bedded, shelly, calcareous, slightly argillaceous, commonly medium grained quartz sand. Strata within the shell bed may be more or less shelly with the lithologies varying from a closely packed shelly sand to an argillaceous, calcareous sand with shells scattered throughout. It is clear from the evolutionary development of Globorotalia fohsi peripheroacuta within the member that the downdip shell bed, as at the type locality, is younger than that farther updip. This relationship suggests that the shell bed becomes younger in a downdip or seaward direction. However, in the one core that contains an intermediate facies within the Whites

Creek Member, the Adkinson #1 (W-11045), there is no shell bed present. This, on the other hand, suggests that there may be two shell beds within the Whites Creek Member, a lower one whose only known exposure is the old Senterfeit's Mill locality on Mill Creek near Oak Grove, and an upper one that is exposed at the type locality and is present in the Campbell #1 (W-10832) and in the Cosson #1 (W-8004).

In the updip area, the shell bed grades upward into an unconsolidated, noncalcareous, micaceous, very slightly argillaceous, fine to medium-grained sand. This sand is massive-bedded to coarsely-bedded and contains stringers of clay and gravel. The upper part of this section may consist of rather clean, well sorted, coarse quartz sand, clayey sand, or sandy clay. It is possible that this coarse sand - clayey section may prove to be more properly referable to the middle Shoal River whereas the underlying massive-bedded, fine to medium sand is properly a part of the Whites Creek Member.

The Adkinson #1 (W-11045) is located in an intermediate dip position for the Whites Creek Member, and the lithology of the unit in the core is distinctive. In that core the Whites Creek consists mainly of a massive-bedded, unconsolidated but tough, bioturbated, micaceous, calcareous, clayey, silty, fine sand and micaceous, calcareous, silty clay. Neither a shell bed nor an upper, noncalcareous sand interval is developed in this section. The lithology of the entire Shoal River Formation in this core is quite uniform and varies little between lower, middle, and upper parts, demonstrating the lithologic continuity of the formation as a whole.

As mentioned earlier, the lower part of the downdip Whites

Creek Member consists of a microfossiliferous, clayey, calcarenitic, fine-grained, quartz sand. In the Cosson #1 (W-8004) the basal bed of the member is a slightly indurated, argillaceous, very microfossiliferous, even-textured, calcarenitic limestone that is very similar to St. Joe lithology.

The lithology of the Whites Creek Member in the vicinity of Oak Grove differs slightly from the equivalent shell bed horizons in Walton County in being rather more argillaceous, micaceous, finer grained, and less shelly. There is, however, too little core control in that area to be certain whether this variation represents a systematic trend in the lithology of the unit.

Overlying and Underlying Units

The Whites Creek Member overlies the Bruce Creek Limestone abruptly and with hiatus in all cores where it is present in Walton County. At Oak Grove in northern Okaloosa County, on the other hand, the Whites Creek Member overlies the updip, nearshore equivalent of the Bruce Creek Limestone, the Oak Grove Sand.

At Oak Grove, in the vicinity of the Yellow River, the Whites Creek Member is overlain disconformably by the Citronelle Formation. In all cores in Walton County, however, the recognizable Whites Creek Member is overlain paraconformably, or with apparent gradation, by the middle Shoal River.

Lithologic Distinction Between Adjacent Units

The Whites Creek Member is distinguished from the rest of the Shoal River Formation by its being dominantly a quartz sand, whereas the rest of the formation is characteristically much more clayey. In updip areas where the upper part of the Whites Creek is a noncalcareous sand, the contact between the Whites Creek Member and the overlying middle Shoal River is arbitrarily drawn at the base of the first calcareous, fossiliferous bed. In the downdip cores the contact is more subtle since the basal bed of the middle Shoal River is typically sandy. The lithologies on both sides of the paraconformity separating the lower and middle Shoal River therefore are commonly quite similar. In this case, paleontological data (identification of *Globorotalia fohsi*) is needed to pinpoint the contact with certainty.

The differentiation between the Bruce Creek Limestone and the Whites Creek Member presents no problems in that the Bruce Creek is typically an indurated calcarenitic limestone or sandy limestone whereas the Whites Creek Member is a slightly argillaceous, shelly, gray sand.

Areal Distribution

The Whites Creek Member is exposed at the surface and is present in the subsurface in a belt across the middle of Walton County (Fig. 14). There are three known areas of exposure of the member at this time. It is exposed in the type area around White Creek in eastern Walton County, it crops out in the bed of the Shoal River in the type area of the formation (Godwin bridge beds of Smith, 1941, p. 279), and it crops out at the old site of Senterfeit's mill near the Yellow River in Okaloosa County.

Although the precise areal distribution of the member is not clear at this time, it appears to become thicker and broader in the western part of its area of occurrence (Fig. 14 and 19). Its eastern

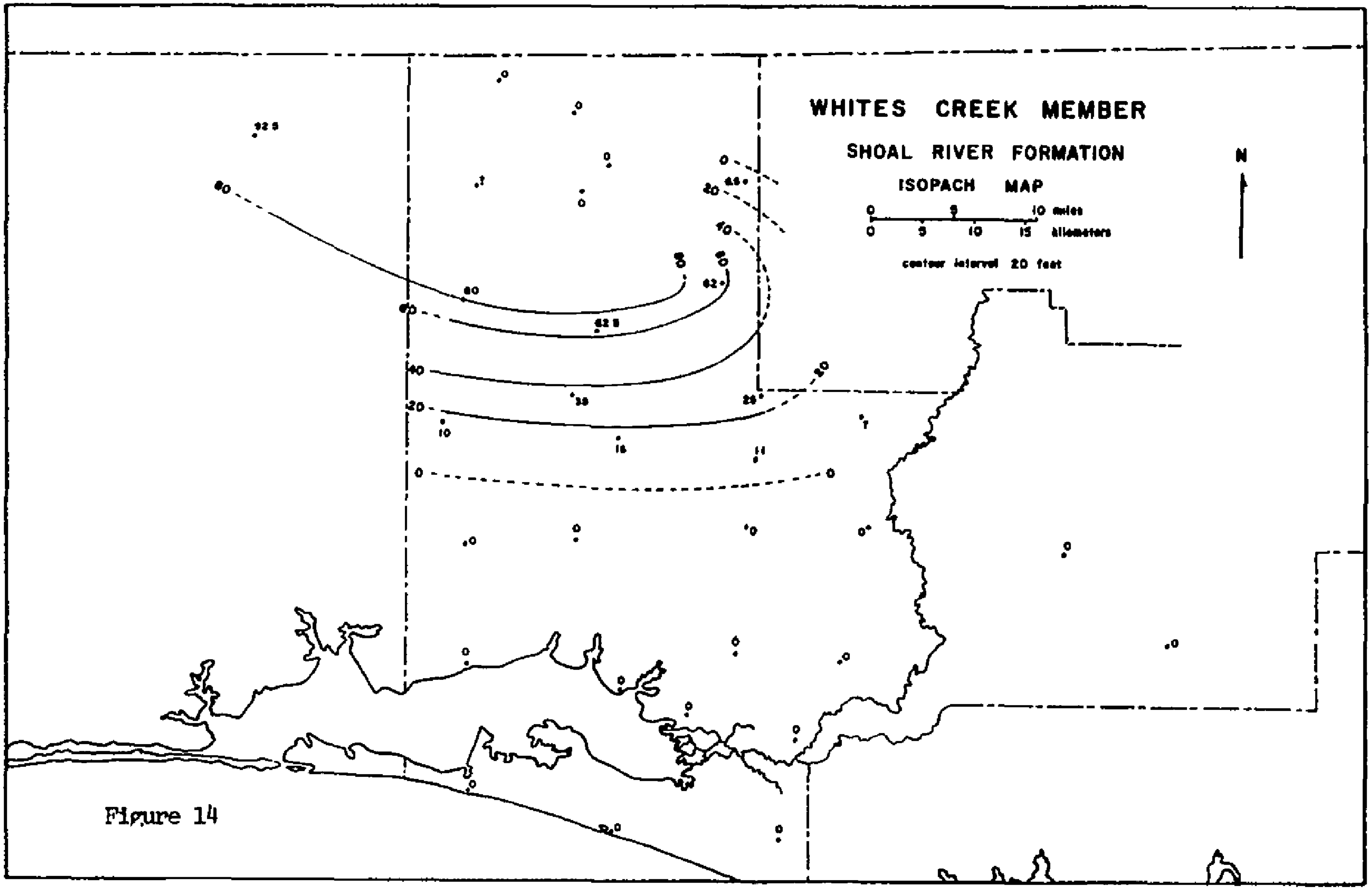
WHITES CREEK MEMBER
SHOAL RIVER FORMATION
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
N

Figure 14

extent is not known yet but it has not been identified east of the type locality near White Creek. From the isopach map (Fig. 15) it almost certainly extends into southwestern Holmes County. On the other hand there is no evidence that it extends as far east as the Choctawhatchee River.

The updip limit of the member cannot be clearly defined at this time due to insufficient core control in the northern part of Walton County and in northeastern Okaloosa County; to the ubiquitous deep weathering of the unconsolidated, near-surface sediments; and its apparent loss of lithologic distinction as it grades updip into undifferentiated Shoal River lithology.

The downdip, or southern, limit of the member however is essentially an east-west line across the center of Walton County. The unit either pinches out along this line due to nondeposition (as will be discussed in greater detail in a later section) or grades downdip into Bruce Creek lithology.

Thickness and Geometry

The Whites Creek Member is an elongate sandy wedge that thickens to the west and to the north (Fig. 14 and 19). It appears to thin abruptly on its northern side due to truncation by the Citronelle Formation but it thins gradually on its southern side before pinching out. It apparently has an axis of greatest thickness that trends approximately in a westnorthwest-eastsoutheast direction but due to poor control on the north, this axis cannot be delineated.

The maximum known thickness of the Whites Creek Member is 92 feet in the Oak Grove #1 (W-10833). It thins to the east and to the south at a constant rate, reaching no more than 14 feet at the type locality in eastern Walton County. Its rate of thinning from north to south in Walton County is about 5 feet per mile.

Stratigraphic Correlatives

The lower part of the St. Joe Limestone that underlies the coastal area of the Apalachicola Embayment and one interval in the Bruce Creek Limestone in southeastern Walton County (Mack #1 (W-8587)) are the only known stratigraphic equivalents in the Coastal Plain south of Maryland. The writer has identified Globorotalia fohsi peripheroronda and G. fohsi peripheroronda trans. G. fohsi peripheroacuta from the shell bed in the Choptank Formation exposed at Calvert Cliffs, Maryland. The presence of these planktonic foraminifera suggests correlation either with the Bruce Creek, or more likely in the writer's opinion, with the Whites Creek Member. Unfortunately neither Globigerinoides sicana nor Orbulina were found in this exposure, which would have allowed greater precision in correlation.

Age

The following planktonic foraminifera have been identified from the Whites Creek Member of the Shoal River Formation:

Globorotalia fohsi peripheroronda
G. fohsi peripheroacuta
G. fohsi praefohsi
G. mayori (includes G. siakensis of authors)
G. praemenardii archeomenardii
G. praemenardii praemenardii
G. cf. minutissima
Globigerina praebulloides praebulloides
G. praebulloides pseudociperoensis
G. foliata
G. obesa
G. bulloides
G. falconensis

G. druryi
G. quinqueloba
G. eamesi
Globigerinoides sacculifera quadrilobata
G. sacculifera sacculifera
G. obliqua obliqua
G. subquadrata
Globoquadrina dehiscens
G. altispira
Sphaeroidinellopsis seminulina
Globigerinita glutinata
G. uvula
Cassigerinella chipolensis
Globorotaloides hexagona variabilis
Orbulina suturalis

The following species are restricted to the Whites Creek Member and its equivalents in the study area:

Globorotalia fohsi peripheroacuta
G. fohsi praefohsi

Excluding the species that are restricted to the unit, the following species make their earliest local appearance in the Whites Creek Member:

Orbulina suturalis
Globigerina druryi

The following species makes its last or latest local appearance in the Whites Creek Member:

Globorotalia praemenardii archeomenardii

The age of the Whites Creek Member of the Shoal River Formation is defined by the presence of the planktonic foraminifera Orbulina suturalis in association with the evolutionary bioseries of Globorotalia fohsi peripheroronda, G. fohsi peripheroacuta, and G. fohsi praefohsi. Within the zonation scheme of Blow (1969), the Whites Creek Member contains the Orbulina suturalis-Globorotalia (Turborotalia) peripheroronda Partial-range zone (Zone N.9), the Globorotalia (Turborotalia) peripheroacuta Consecutive-range zone (N. 10), and the earliest part of the Globorotalia (G.) praefohsi Consecutive-range zone (N. 11).

In the zonation scheme of Bolli (1967), the Whites Creek Member includes the Globorotalia fohsi peripheroronda Zone, the G. fohsi peripheroacuta Zone, and the G. fohsi praefohsi Zone.

The Whites Creek Member is in the uppermost Langhian Stage and lowermost Serravalian Stage of Italy (Cita and Blow, 1969) and is early, Middle Miocene in age (Fig. 4).

Choctawhatchee Formation

Type Locality and Lithology

The writer recognizes the Choctawhatchee Formation as a distinct lithostratigraphic unit. The Choctawhatchee Formation is the Arca Zone of Mansfield (1930, 1932) plus the Permenter's Farm beds of Smith (1941, p. 269-274). Two informal members of the Choctawhatchee Formation are recognized: the lower member is the typical fossiliferous, calcareous sand exposed at the type locality, and the upper member is the sandy Permenter's Farm beds of Smith (1941). Both members are exposed at the type locality at Red Bay.

The type locality of the Choctawhatchee Formation is 0.75 miles southeast of Red Bay, Walton County, in NW 1/4, NW 1/4, Sec. 15, T2N, R17W (not 900 feet west of center of Sec. 19, T2N, R17W as given by Puri and Vernon, 1964, p. 197). The type locality is in a spring-head in a ravine on the western slope of the valley of the Choctawhatchee River.

The lithology of the lower member is distinctive and presents the standard concept of the lithology of the "Arca Zone". It consists of nonindurated but firm to tough, massive-bedded, fossiliferous, slightly phosphatic, slightly micaceous, argillaceous, calcarenitic fine sand to sandy calcarenite. There appears to be a systematic trend in the lithologic variation of the unit. In the outcropping, updip part of the prism of Choctawhatchee sediments in Walton County, and at the type locality, the lithology of the unit is essentially a calcarenitic fine sand. The amount of quartz sand in the Choctawhatchee prism in Walton County diminishes in a downdip, offshore direction. As a result, the lithology of the downdip part of the lower member of the Choctawhatchee varies from a sandy, very microfossiliferous calcarenitic limestone to a foraminiferal, coquinoid limestone that resembles the older St. Joe Limestone.

The downdip, foraminiferal limestone facies of the lower member of the Choctawhatchee Formation should properly, and for the sake of consistency, be given a separate formation name and assigned to the Coastal Group. This would result in the typical, calcarenitic sand facies of the lower member being restricted to the updip side of the Choctawhatchee wedge (Fig. 17) whereas the foraminiferal limestone facies would be restricted to the central and downdip side of the wedge. However, it is not the intention of the writer to proliferate lithostratigraphic names. Because the formation is already very restricted in geographic extent and because the physical appearance and texture of the sediments of the two facies of the lower member are very similar, the writer considers it prudent and practical at this time to refrain from further informal subdivisions of the formation. It is inescapable, however, that the foraminiferal limestone facies of the lower member be recognized as a shoreward extension or tongue of the carbonate lithosome during Choctawhatchee time.

The upper member is typically a micaceous, argillaceous sand. Like the lower member, there is an apparent lithologic pattern along the east-west belt of the occurrence of the upper member. In the western part of the county the lower part of the unit is mainly a calcareous, fossiliferous sand. Eastward the amount of clay increases and the calcium carbonate and fossils decrease so that in the eastern part of the county, the entire member is typically argillaceous and noncalcareous. At the type locality of the Choctawhatchee, the upper member (which in the past has been called the Ecphora bed or Zone) is mainly sandy clay with some argillaceous sand.

The upper member is typically massive-bedded to very coarsely-bedded in the sandy facies. It is only in the more clayey beds in the sandy facies, or in the eastern, argillaceous facies that bedding becomes distinct. Within these argillaceous intervals the beds may be thick, thin (a few inches thick), or finely laminated.

There is a distinct difference between the accessory minerals of the two members of the Choctawhatchee Formation. Fine sand-size, black, phosphorite grains are consistently present in the lower member. The phosphorite grains, however, are more abundant in the sandier phases of the member and are therefore present in greater abundance in the eastern part of the country, where the formation crops out, and in the basal beds of the unit. Phosphorite is present as a very minor trace constituent in the foraminiferal coquinoid limestone facies of of the member.

Very little if any granular phosphorite is present in the upper member. Where it is found, it is present only in the very basal part of the unit. The upper member does contain abundant heavy minerals and biotite. The heavy minerals are typically quite angular or prism-shaped. No heavy minerals have been noted in the lower member and they begin to appear in the cores only in the transitional interval between the two members or at the base of the upper member.

In the downdip, southwestern part of Walton County, the lithology of the Choctawhatchee Formation is different from that in any other core or locality. In the Lalonde #1 (W-8877) the formation consists of a phosphoritic sand with some rounded heavy minerals and is calcareous only in the basal 8 feet. The sand in that core appears to have been slightly oxidized, is very massive-bedded and shows no bedding or sedimentary structures, and is partially indurated to unconsolidated. In addition, many sand grains at certain horizons are frosted and rounded, an exceptional condition for sands in the Alum Bluff Group.

Underlying and Overlying Units

The Choctawhatchee Formation in Walton County paraconformably overlies the Shoal River Formation and the St. Joe Limestone. There are no known localities where the contact between the Choctawhatchee and the Shoal River is exposed at the surface. It would appear from the stratigraphic cross-sections, however, (Figures 19, 21, 22, and 23), that in the updip, outcrop belt, the Choctawhatchee Formation should directly overlie the upper Shoal River. It evidently does in the Vaughan #1 (W-8014) and in the Seymour #1 (W-7971) (Figures 19, 23, and 24) but farther to the west and slightly downdip in the Eglin #2 (W-8352) and Eglin #3 (W-8353), the Choctawhatchee Formation directly overlies the middle Shoal River (Figures 21 and 22). In all the downdip areas of its occurrence in Walton County, the Choctawhatchee paraconformably overlies the middle Shoal River or the St. Joe Limestone. In the Apalachicola Embayment, the Choctawhatchee paraconformably overlies the St. Joe Limestone.

The Choctawhatchee Formation is overlain disconformably by the Citronelle Formation in the northern part of its area of occurrence in Walton County, and by undifferentiated Pliocene deposits in the coastal area in southwestern Walton County (Figures 21 and 23). In the Apalachicola Embayment in the St. Joe #1 (W-12051), the Choctawhatchee equivalent limestone is overlain by the Intracoastal Limestone of Jackson Bluff age.

Lithologic Distinction Between Adjacent Units

There is no one, simple, lithologic criterion that is invariably useful in distinguishing between the Choctawhatchee and the Shoal River. In a general way, the Choctawhatchee Formation is more sandy and less argillaceous than the Shoal River but this is due to the relatively great thickness of the sandy, upper member. In Walton County, at any rate, there is no stratigraphic interval in the Choctawhatchee that has a comparable clay interval to that in the Shoal River Formation and among the various formations of the Alum Bluff Group, the Choctawhatchee Formation has the least developed shell bed lithology.

There is a special problem in the study area in distinguishing the basal Choctawhatchee Formation from either the underlying Shoal

River Formation or the St. Joe Limestone. In spite of the fact that there are three, and possibly four planktonic foraminiferal zones missing in the hiatus between the two formations, the lithologies on either side of the paraconformity are typically very similar and commonly are virtually the same. The primary criterion involved in discriminating between the two units is paleontology. Once the zonal boundaries are identified in continuously fossiliferous sections, it is possible also to identify a subtle lithologic change at the biostratigraphic boundary. In this study, these subtle lithologic changes between the Choctawhatchee and the Shoal River depositional units are taken as formational contacts although the clear and obvious lithologic changes in the sections may occur at various other stratigraphic horizons.

The basal phase of the Choctawhatchee Formation in the updip cores Vaughan #1 (W-8014) and Seymour #1 (W-7971), and in the outcrop in the vicinity of Alaqua Creek south of DeFuniak Springs, is a micaceous, calcareous, microfossiliferous, sandy clay or clayey sand that grades downward into Shoal River lithology through diminution and disappearance of the calcareous and microfossil component of the lithology. In this study, the distinction between upper Shoal River and the Choctawhatchee is arbitrarily placed at the first occurrence of calcareous, fossiliferous horizons beneath the typical calcareous sand of the lower member. In western Walton County, in the Eglin #3 (W-8353), the Shoal River-Choctawhatchee interval is continuously fossiliferous. In that core the only lithologic distinction between the two units is that the overlying Choctawhatchee clays are slightly more calcareous and have more common stringers or lenses of clayey, foraminiferal calcarenite than the underlying Shoal River clays.

Above this basal, transitional, sequence between the Shoal River and the Choctawhatchee, the Choctawhatchee lithologies are more distinctive and more readily separable from Shoal River lithology. There is no comparable, relatively thick, widespread, massive-bedded, very calcareous sand or sandy, foraminiferal calcarenite in the Shoal River Formation. Nor is there such a thick section of sand or clayey sand in the Shoal River. The uppermost, regressive, noncalcareous, micaceous sands of both the Shoal River and the Choctawhatchee are virtually identical lithologically and cannot be distinguished except by stratigraphic position.

The lithology of the lower, foraminiferal limestone member of the Choctawhatchee is similar to that of the St. Joe Limestone. As a result, in the Ryan #1 (W-8355) where the lower member of the Choctawhatchee directly overlies the St. Joe Limestone, the lithologic distinction between the two units is subtle. The underlying St. Joe is more calcareous and is a more coarsely foraminiferal coquinoid limestone whereas the Choctawhatchee is a relatively more sandy and argillaceous, more fine-textured, microfossiliferous limestone. The main criterion useful in identifying the paraconformity and formational boundaries is again paleontological. Although the core recovery was poor at the top of the St. Joe Limestone and the base of the Choctawhatchee Formation in the St. Joe #1 (W-12051), the formational boundary in the Apalachicola Embayment area appears to be distinctive. The top of the St. Joe Limestone in that core is a calcareous, microfossiliferous, olive-colored clay whereas the overlying Choctawhatchee is a

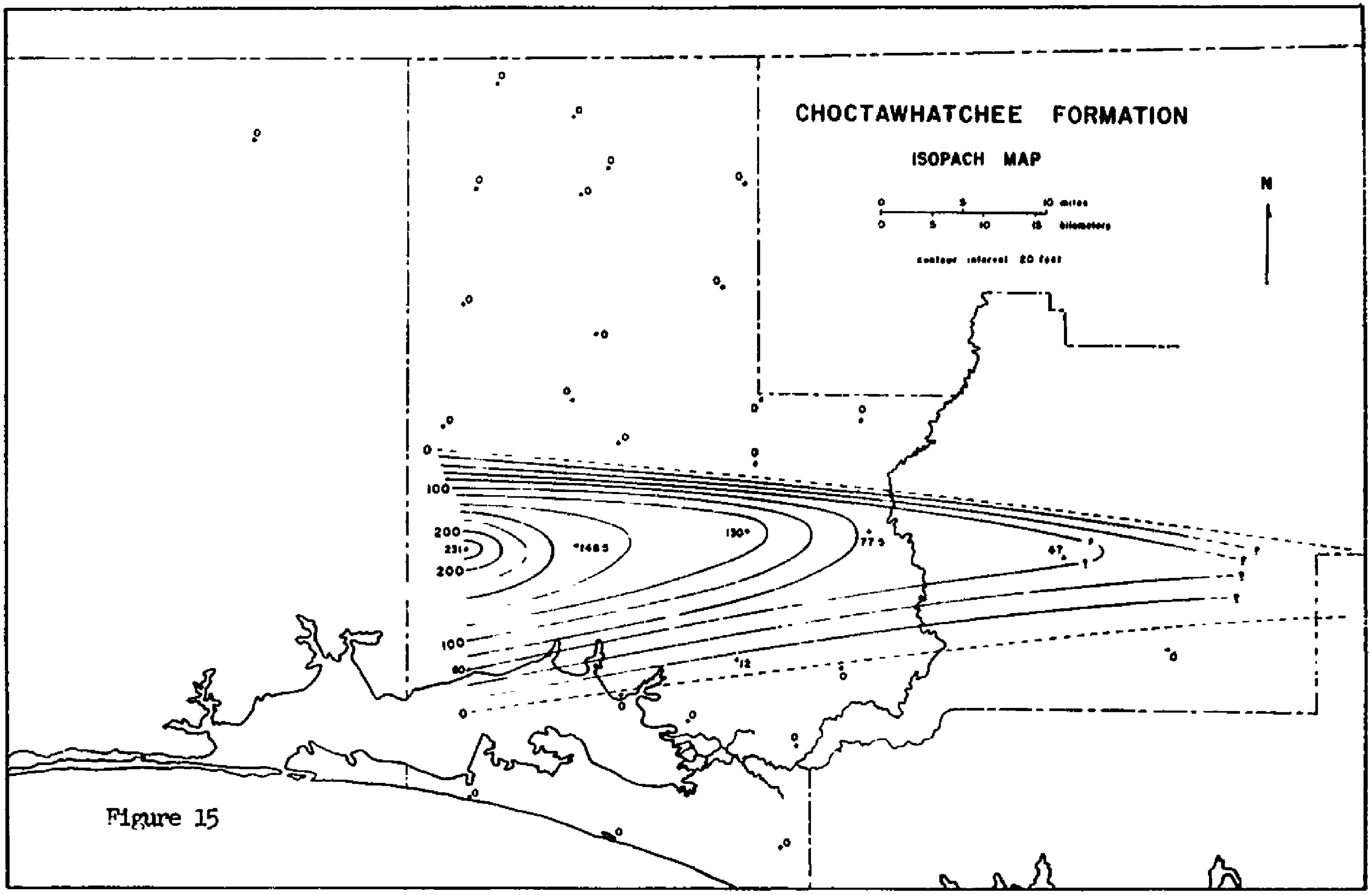
CHOCTAWHATCHEE FORMATION
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
N
0
100
200
231
200
100
80
0
148.5
130
77.5
67
12

Figure 15

moderately indurated to nonindurated, finely foraminiferal limestone.

It is only in the Lalonde #1 (W-8877) that there is a clear lithological break between the underlying Shoal River Formation and the Choctawhatchee Formation. There, however, both the Shoal River and the Choctawhatchee are atypical lithologically, the top of the Shoal River Formation consisting of a limestone and the Choctawhatchee Formation being a calcareous, phosphoritic sand.

The distinction between the Citronelle Formation and the Choctawhatchee Formation is essentially the same as that between the Shoal River and the Citronelle (see page 62).

Areal Distribution, Geometry, and Thickness

The Choctawhatchee Formation is an east-west trending wedge of sands (Fig. 15). It occurs only in the southern half of Walton County but is not present in the shallow subsurface of coastal or southeasternmost Walton County. It also occurs in a narrow east-west band across the center of Washington County and into the northern part of Bay County in the vicinity of Econfina Creek (Vernon, 1942).

The subsurface band of Choctawhatchee sediments narrows from a width of approximately 15 to 20 miles near the Walton-Okaloosa county line on the west to about 10 miles in the vicinity of the Choctawhatchee River. Its subsurface width in Washington County is not known but probably continues to narrow until it pinches out somewhere east of Econfina Creek in northern Bay County. It is not present as far east as the Chipola or Apalachicola Rivers.

The greatest known thickness of the Choctawhatchee Formation in Walton County is 231 feet in the Eglin #3 (W-8353) in the western part of the county. It progressively thins eastward in the Walton County cores to 77 feet in the Vaughan #1 (W-8014) at Red Bay near the type locality (Fig. 15). According to the figures of Vernon, (1942), the Choctawhatchee continues to thin eastward in Washington County to 67 feet in the Sheffield well.

The Choctawhatchee in the St. Joe #1 (W-12051) in the Apalachicola Embayment is 101 feet thick. Based on present data, the Choctawhatchee thickens from 0 feet on the updip side of the wedge in Walton County at a minimum rate of 20 to 30 feet per mile. After reaching maximum thickness, it thins in a downdip direction at the rate of 10 to 20 feet per mile. The writer believes, however, that the depoaxis of the wedge is a more east-west trending line than is evident in Figure 18, and that it passes south of the type locality at Red Bay. The thickness of the unit at Red Bay may not, therefore, be the greatest thickness of the unit in eastern Walton County.

An outlier of the Choctawhatchee Formation occurs in the Apalachicola Embayment in the St. Joe #1 (W-12051). Since the Choctawhatchee does not underlie coastal Walton County, the relationship of this outlier to the main mass of Choctawhatchee sediments is speculative. The deposits may be continuous in the present offshore area, or the Apalachicola Embayment Choctawhatchee may in fact be isolated geographically from the western Florida wedge.

Stratigraphic Correlatives

The Choctawhatchee Formation and its biostratigraphic equivalent in the limestone section (327-302 feet) in the St. Joe #1 (W-12051) are the only Upper Miocene deposits in the study area of western Florida.

Outside of the study area, there are no known deposits that have been satisfactorily demonstrated to be of equivalent age to the presently understood Choctawhatchee Formation. The several units that have been suggested as equivalent of the Arca Faunizone are the Charlton Formation of northeastern Florida and southeastern Georgia (Waller, 1969), and the Murdock Station Member of the Tamiami Formation in southern Florida (Hunter, 1968).

Age

The following planktonic foraminifera have been identified from the Choctawhatchee Formation in western Florida:

Globorotalia acostaensis
G. acostaensis humerosa
G. cf. *continuosa*
G. menardii s.l.
G. lenguaensis
G. cibaoensis
G. tumida plesiotumida
G. scitula scitula
Globigerina bulloides
G. parabulloides
G. cf. *praebulloides*
G. foliata
G. obesa
G. nepenthes
G. apertura
G. quinqueloba
G. eamesi
Globigerinoides sacculifera quadrilobata
G. sacculifera sacculifera
G. rubra
G. obliqua obliqua
G. obliqua extrema
G. mitra
G. aff. *Globigerinopsis aguasayensis*
G. conglobatus canamarensis
Globoquadrina dehiscens
G. altispira
G. cf. *venezuelana*
Sphaeroidinellopsis seminulina
S. subdehiscens
Hastigerina siphonifera siphonifera

H. siphonifera praesiphonifera
Globigerinita glutinata
G. uvula
Candeina nitida nitida
Globorotaloides hexagona variabilis
Orbulina suturalis
O. universa

The following species have their earliest local occurrence in the Choctawhatchee Formation:

Globorotalia acostaensis acostaensis
G. acostaensis humerosa
G. cf. continuosa
G. cibaoensis
G. tumida plesiotumida
G. scitula scitula
Globigerina parabulloides
G. nepenthes
G. apertura
Globigerinoides rubra
G. obliqua extrema
G. conglobata canimarensis
G. mitra
Globoquadrina cf. venezuelana
Hastigerina siphonifera siphonifera
H. siphonifera praesiphonifera
Candeina nitida nitida

The following species have their latest local occurrence in the Choctawhatchee Formation:

Globorotalia cf. continuosa
G. lenguaensis
G. cibaoensis
G. tumida plesiotumida
Globigerina foliata
G. eamesi
G. cf. praebulloides
Globigerinoides mitra
G. aff. Globigerinopsis aguasayensis
Globoquadrina dehiscens

The following species are restricted to the Choctawhatchee Formation:

Globorotalia cibaoensis
G. cf. continuosa

G. tumida plesiotumida
Globigerinoides mitra

The Choctawhatchee Formation contains the Globorotalia tumida plesiotumida Consecutive-range zone (N.17) of Blow (1969) or the Globorotalia dutertrei/Globigerinoides obliqua extrema Zone of Bolli (1966). It is therefore in the Tortonian/Messinian Stage of Europe (Cita and Blow, 1969; Berggren and van Couvering, 1974) and is Late Miocene in age.

Age Relationships Within the Choctawhatchee Formation

The age relationships within the Choctawhatchee wedge are not clear at this time because there are no clear or locally useful evolutionary first occurrences, extinctions, or documented faunal progressions. In the updip part of the wedge in Eglin #2 (W-8352) and Eglin #3 (W-8353), there is a very distinct foraminiferal faunal change, both among the benthonic and planktonic foraminifera, between the lower and upper members of the formation. The change in the planktonic foraminiferal assemblage requires at least a watermass change on the ancient shelf. Because the planktonic foraminiferal assemblage is also more advanced, or modern in appearance in the upper member. the change is also suggestive of a hiatus between the members. However, the change in lithology between the members is often fairly abrupt but gradational and there is no clear physical evidence of a paraconformity in the cores or in the outcrop. Finally, the foraminiferal assemblage change is also gradational where the lithologies are most gradational.

In the updip part of the wedge, the planktonic foraminiferal assemblage of the lower member of the Choctawhatchee Formation is characterized by rarely occurring, small, primitive appearing, predominantly left coiled Globorotalia acostaensis acostaensis and G. cf. continuosa, trace occurrences of G. lenguaensis, rare occurrences of Globigerinoides aff. Globigerinopsis aguasayensis, and moderate frequencies of Globoquadrina dehiscens. The planktonic foraminiferal assemblage of the upper member in the updip part of the wedge is characterized by commonly occurring, relatively large, well developed, randomly coiled to left coiled Globorotalia acostaensis humerosa and G. acostaensis acostaensis, by the only occurrence of Globigerinoides mitra in the study area, by local first occurrence of Hastigerina siphonifera siphonifera, Globigerinoides conglobata canimarensis, and Candeina nitida nitida, by the very rare occurrence of Globoquadrina dehiscens, and the absence of Globorotalia lenguaensis and Globigerinoides aff. Globigerinopsis aguasayensis.

The outcropping lower member in Blount Creek and its tributaries contains essentially a typical lower Choctawhatchee planktonic foraminiferal assemblage except the Globorotalia acostaensis species complex contains larger individuals and forms a larger percentage of the planktonic foraminiferal assemblage than is typical for the lower member. It is characteristic of the rest of the member in the updip area in its rather commonly occurring Globoquadrina dehiscens, the presence of Globorotalia lenguaensis and Globigerinoides aff. Globigerinopsis aguasayensis, and the typical absence of Hastigerina siphonifera siphonifera.

The planktonic foraminiferal assemblage of the Choctawhatchee Formation in the downdip part of the wedge in the Ryan #1 (W-8355) is entirely consistent with a late, upper Choctawhatchee, age. However, the lithology of the formation in that core is essentially identical to the lithology of the lower member in the Eglin #2 and #3 (W-8352 and W-8353). This situation suggests that the downdip, lower member is equivalent in time to the updip, upper member, that the updip sands of the upper member grade laterally and downdip into lower member, foraminiferal limestone lithology, and that the wedge must, therefore, be prograding seaward (see facies interpretation in Fig. 23 as opposed to alternate interpretation in Figures 21 and 22). The evidence for the seaward prograding wedge is even more convincing in the Late Miocene planktonic foraminiferal fauna of the Lalonde #1 (W-8877). In that core, the planktonic foraminiferal fauna of the basal strata of the Choctawhatchee Formation is consistent with that of the upper member. However, the strata above the basal one or two feet contains a planktonic foraminiferal assemblage decidedly younger than any other Choctawhatchee assemblage. This fauna is characterized by morphologically advanced *Globorotalia menardii*, with a consistently occurring right-coiling component in the assemblage, *G. tumida plesiotumida*, *G. cibaoensis*, abundant, well-developed *G. acostaensis acostaensis* and *G. acostaensis humerosa*, and commonly occurring, well-developed *Globigerigerinoides conglobata canimarensis*. This association is distinctly younger than any other Late Miocene planktonic foraminiferal assemblage in the study area.

The writer tentatively recognizes three planktonic foraminiferal faunal components in the Choctawhatchee Formation. The oldest is characteristic of the updip, lower member; the next younger association is characteristic of the updip, upper member; and the youngest association is found in one core in the downdip facies of the prism. The time-lines in the Choctawhatchee Formation in Figure 21 approximately represent the divisions between these three planktonic foraminiferal assemblages.

Jackson Bluff Formation

Type Locality and Lithology

The type locality of the Jackson Bluff Formation is at Jackson Bluff on the east bank of the Ochlockonee River. The bluff is immediately below the dam and power plant and is 0.6 miles upstream from the Fla. 20 bridge in NW 1/4, NW 1/4, NW 1/4, Sec. 21, T1S, R4W, Leon County, Florida.

The Jackson Bluff Formation at the type locality consists of three distinct shell beds. The lowest bed is a very coarsely fossiliferous shell bed that is 3 feet thick. No bedding structures are apparent. The matrix material of the bed is a tough, very slightly indurated, dense, sandy, calcareous, blue-green clay when freshly exposed. It quickly loses its intense blue-green color on exposure to air and turns to a flat gray or buff color. Brief weathering will further change the color to the characteristic orange that is found on the weathering surface.

The shells in the bed are characteristically large, robust, and disposed in random orientation. Many species of pelecypods are found with both valves together and with very small gape, if any, at the margin, suggestive of being "dumped in". The basal 6 inches of the bed is almost devoid of mollusc shells. It consists of a granular, even-textured, calcareous, phosphatic sand that contains small, articulate brachiopods.

The lower bed is gradational with the overlying bed, which is referred to informally as the Pecten-barnacle bed. The pecten-barnacle bed is 4 to 5 feet thick and consists of a shelly, sandy, very calcareous clay to clayey sand. The weathering surface is generally partially indurated but fresh exposures lack this induration. Large oysters, pectens, and barnacles are characteristic of this bed. As with the other beds of the formation at Jackson Bluff, bedding structures are rare and there is no indication of bioturbation. These lower two beds in the past have been referred to as the Ecphora Zone.

Along the face of the exposure at the Jackson Bluff type locality, the middle bed, or Pecten-barnacle bed, both grades upward over an interval of one foot into the overlying bed and is also overlain abruptly by the overlying bed. Where the gradation is abrupt, fine scale bedding is apparent. The upper bed is at least 9 feet thick at Jackson Bluff and contains the Cancellaria Zone molluscan assemblage. It con-consists of a massive-bedded, loose but firm, medium textured, shelly, quartz sand. Shells are less abundant than in the lowest bed and are not as large or as robust as those in either of the two underlying beds. The preservation is however, exquisite, some shells even showing traces of original color patterns.

There are three broad lithofacies of the Jackson Bluff Formation, a shell bed facies, a shelly sand and clay facies, and a limestone facies. The shell bed facies and sand and clay facies are exposed in the type area, one, the shell bed facies at Jackson Bluff, the type locality, and the other, the sand and clay facies at Alum Bluff. In outcrop, the type Jackson Bluff lithology, i.e., the shell bed lithology, is the most widely distributed of the three lithofacies of the formation. Typically it varies from a light colored, very slightly argillaceous, shelly, well sorted, medium grained quartz sand; to a shelly, clayey, sand; to a clayey, sandy shell bed. It is found in a narrow belt on either side of the Chipola-Apalachicola River area. Its known outcrop distribution in the west extends from the Gully Ponds area in south-central Washington County to the Econfina Creek area in Bay County. It is found again in the tributaries of Telogia Creek north of Hosford in Liberty County, and on the Ochlockonee River and its tributaries in Leon County. The outcrop belt from there bends to the south where it is exposed again in south-central Leon County, about 7 miles south-southwest of Tallahassee, in Dismal Sink in NW 1/4, Sec. 17, T2S, R1W. It is also known to crop out in the vicinity of Crawfordville, Wakulla County (Banks and Hunter, personal communication, 1973) while a more calcareous and shelly sand phase of the shell bed has been dredged up from shallow depths at Shell Point, on the coast in Wakulla County, Florida.

The shelly sand and clay facies is found only in the vicinity of the Apalachicola and Chipola Rivers and differs appreciably from the type lithology exposed at Jackson Bluff on the Ochlockonee River. This sand and clay lithofacies is much more reminiscent of the lithologies of the Shoal River and Choctawhatchee Formations. The dominant lithologies in this lithofacies consist of a lower, unconsolidated, massive-bedded, micaceous, calcareous, argillaceous to clayey, shelly, fine to medium to coarse, quartz sand, and an upper, noncalcareous, micaceous,, silty to sandy clay (aluminous clay of Dall at Alum Bluff). There is a similar clay facies of the Jackson Bluff Formation exposed at Larkins Bluff on the Ochlockonee River, 6 miles south of Jackson Bluff, that differs from the lithology just described. It is a massive, blocky, sticky, plastic, dark gray clay that contains impressions of molluscs along some bedding planes and some small lenses of broken shells and shell hash.

Of the three discernible lithofacies of the Jackson Bluff Formation, the sand and clay lithofacies is the most abundantly terrigenous clastic and the least calcareous. Its general lithology and its areal distribution (in the vicinity of the Apalachicola and Chipola Rivers) suggests that it may be a prodeltaic facies of an ancestral Apalachicola River.

The third lithofacies of the formation is a limestone facies that is properly referred to the Intracoastal Limestone of this study. It is exposed in relatively downdip areas on both sides of the Apalachicola-Chipola River area in western Florida and will be discussed in more detail on pages 140 to 150.

Underlying and Overlying Units

The Jackson Bluff Formation paraconformably overlies various formations in its area of occurrence. In the western half of its outcrop area, i.e., from the Gully Ponds-Deadening Lakes area of Washington County to the Chipola River, the Jackson Bluff Formation paraconformably overlies the Chipola Formation. At Alum Bluff and in the Wall #1 (W-7457), it unconformably and paraconformably overlies a sand, clayey sand, and sandy limestone unit that has been referred to variously as the Alum Bluff Formation (Dall and Stanley-Brown, 1893), Alum

Bluff Group (?) (Cooke and Mossom, 1929), and Fort Preston Formation (Puri and Vernon, 1964). This writer regards these beds as a regressive, intertidal, lower shoreface facies of the Chipola Formation, with which it is gradational and conformable. At Jackson Bluff and in the vicinity of the Ochlockonee River, the Jackson Bluff Formation paraconformably overlies the Hawthorn Formation. At Dismal Sink in southern Leon County it paraconformably overlies what has been called "St. Marks Formation" and farther south in the vicinity of Crawfordville, Wakulla County, it overlies the Torreya Formation.

The stratigraphic relationships between the Jackson Bluff Formation and the overlying sands are not clear. According to Hendry and Sproul (1966, p. 75) and Hendry and Yon (1967) the Miccosukee Formation unconformably overlies the Jackson Bluff Formation in western Leon County. Sediments of similar lithology to the Miccosukee and occurring stratigraphically higher than the Jackson Bluff are known to crop out at Hosford in Liberty County, and near Farley Creek in Calhoun County. However, the sediments overlying the Jackson Bluff Formation at Alum Bluff and in the Wall #1 (W-7457) consist generally of loose sand that is crossbedded and gravelly in places. The overlying sediments in the Ten Mile Creek #1 (W-11270) are intermediate to the above lithologies and the Miccosukee lithology in being a gravelly, very coarse sand with some thin clay layers. In the Hunt #1 (W-10954), there is a facies break between the underlying Jackson Bluff sediments and the overlying sands but no obvious paraconformity. The overlying sands in that core consist of well sorted, medium to coarse, micaceous sands and cannot be referred to the Miccosukee Formation.

No firm conclusions can be reached concerning the unit or units overlying the Jackson Bluff Formation or on the nature of the contact. It is clear that more than one type of sand lithology is present in the overlying sediments and it is also clear that in some locations the contact appears gradational and in others there appears to be a discontinuity. The only pattern that seems to emerge is that the more different the sediment and environment types between the Jackson Bluff and the overlying sands, the more abrupt the lithology change.

Lithologic Distinction Between Adjacent Units

The shell bed facies of the Chipola Formation strikes north of west whereas the Jackson Bluff shell bed strikes more nearly east-west. The shell beds of the two formations occur together in the vicinity of the Chipola and Apalachicola Rivers but farther west they diverge. As a result, in Washington County, the Jackson Bluff shell bed directly overlies the downdip, nonshelly sand facies of the Chipola Formation and here the two formations may be distinguished easily by the paucity of shells in the Chipola, and their abundance in the Jackson Bluff. Because the Jackson Bluff Formation is restricted to the southern part of the county, the two formations are not in contact farther north in Washington County where the Chipola shell bed is supposed to occur.

In the vicinity of the Chipola and Apalachicola Rivers, however, the two shelly units may be distinguished in that the Chipola is characteristically a more coarsely fossiliferous, cream-colored to gray, fine to medium sand. The overlying Jackson Bluff Formation is typically much more argillaceous and is always a darker gray color. The Jackson Bluff is, in addition, more micaceous and contains more carbonaceous and lignitic material, commonly causing the exposure to have a "gunpowder" odor.

The Jackson Bluff Formation can be differentiated readily from the underlying Hawthorn Formation in being coarsely fossiliferous and with the original shell structures intact, in being consistently calcareous, and in being less indurated. The Hawthorn commonly contains palygorskite (attapulgite) and may contain dolomite. The Jackson Bluff does not contain palygorskite clay but only montmorillonite and a trace of kaolinite or illite. The Hawthorn is very sparsely fossiliferous, but where fossiliferous beds occur, the fossils generally consist of molds or impressions.

At Dismal Sink in Leon County, the Jackson Bluff overlies a limestone that has been referred to as the St. Marks Limestone (Hendry and Sproul, 1966). The "St. Marks" at this location is a massive-bedded, soft to slightly indurated, very sparingly fossiliferous to nonfossiliferous, slightly sandy limestone. The overlying Jackson Bluff is a shell bed in a matrix of weathered, clayey sand.

In the Taff pit near Crawfordville, Wakulla County, the Jackson Bluff Formation is preserved in pinnacles above the Torreya Formation (Banks and Hunter, personal communication, 1973). The Torreya here consists of an unconsolidated to moderately indurated, calcarenitic, quartz sand to a sandy limestone that contains abundant oysters, pectenids and other fossils. The overlying Jackson Bluff is a weathered remnant of shelly, argillaceous sand only 3 inches thick.

Areal Distribution

The known geographic extent of the Jackson Bluff Formation is from south-central Washington County in the west, to south-central Leon County in the east. It is exposed along major stream courses and their tributaries and in the walls of sink-holes in Washington, Bay, Calhoun, Liberty, Leon, Wakulla, and Franklin Counties. In the western part of its area of exposure, the updip limit of the unit strikes almost straight east-west from the Deadening Lakes area to the Alum Bluff area. In the eastern part of its area of exposure, however, it strikes south of east from Alum Bluff to Dismal Sink, and then almost straight south to the coast. It has not been reported in northern Florida from east of the longitude of Dismal Sink or Shell Point.

Mansfield (1932) and Cushman and Ponton (1932) have reported the Ecphora Zone from Walton County. As Smith (1941) and Puri (1953) have pointed out, the Permenter's farm beds are not Ecphora Zone but a younger unit of the Arca Zone (upper member of the Choctawhatchee Formation of this study). Also, the writer recognizes the upper, noncalcareous, sandy clay bed at the type locality of the Choctawhatchee Formation at Red Bay as the upper member of the Choctawhatchee, and not the Ecphora Zone. Despite the close core control in Walton County, the writer has not identified the Jackson Bluff Formation in that area. Jackson Bluff equivalent sediments are present in the subsurface of the coastal area but the lithologies are not those of the Jackson Bluff Formation.

Geometry and Thickness

The Jackson Bluff Formation is a thin, blanket type deposit in the eastern half of the Florida panhandle. Its greatest known thickness occurs in the Alum Bluff area where the clayey sand-sandy clay facies of the formation is developed. It is 63 feet and 60 feet thick respectively in the Alum Bluff #2 (W-7616) and Wall #1 (W-7457). It is 17 feet thick at the type locality but the top of the formation is either not exposed there or has been truncated by terrace deposits. Elsewhere (Hunt #1 (W-10954), Ten Mile Creek #1 (W-11270), and Hosford #1 (W-7535) the Jackson Bluff is between 20 and 30 feet thick.

Stratigraphic Correlatives

The Jackson Bluff Formation is stratigraphically equivalent to the type Yorktown Formation (exposed on the York Peninsula in Virginia) of the central Atlantic Coastal Plain, to the Duplin Formation of the southern Atlantic Coastal Plain, and to the Pinecrest Sand Member, the Ochopee Limestone Member, and the Buckingham Limestone Member of the Tamiami Formation of southern Florida (Hunter, 1968). It is equivalent to the upper part of the phosphoritic sand unit in coastal Walton County, and to part of the Intracoastal limestone of this study.

Age

The following planktonic foraminifera have been identified from the outcropping Jackson Bluff Formation:

Globorotalia menardii (right coiling)
G. menardii cf. *multicamerata*
G. acostaensis acostaensis
G. acostaensis humerosa
G. acostaensis pseudopima
G. puncticulata
G. crassula viola
G. hirsuta
G. crassula trans. *hirsuta*
G. scitula scitula
Globigerina parabulloides
G. bulloides
G. apertura
G. cf. *decoraperta*
G. quinqueloba
Globigerinoides rubra
G. sacculifera quadrilobata

G. sacculifera sacculifera
G. obliqua obliqua
G. obliqua extrema
G. cf. conglobata
Globoquadrina altispira
Sphaeroidinellopsis seminulina
S. subdehiscens
Sphaeroidinella dehiscens
Hastigerina siphonifera
Globigerinita glutinata
G. uvula
Globorotaloides hexagona
Orbulina universa
Candeina nitida

In addition, the following planktonic foraminifera have been identified from downdip, Jackson Bluff equivalent units in Walton County:

Globorotalia menardii multicamerata
G. crassaformis
Globoquadrina venezuelana

The following species have their first local occurrence in outcropping Jackson Bluff deposits:

Globorotalia menardii (right coiling)
G. acostaensis pseudopima
G. puncticulata puncticulata
G. crassula viola
G. hirsuta
G. scitula scitula
Globigerina cf. decoraperta
Globigerinoides cf. conglobata
Sphaeroidinella dehiscens

Although the presence of Sphaeroidinella dehiscens, Globorotalia puncticulata puncticulata, G. crassula viola, G. acostaensis pseudopima, and G. hirsuta unquestionably define these deposits as Pliocene in age, it is the biostratigraphic succession in the coastal Walton County cores that allows the Jackson Bluff Formation to be zones and correlated with precision. It is the zone that overlies the Globorotalia margaritae Zone (Zones PL1 and PL2 of Berggren, 1973), in coastal

Walton County, that contains the Jackson Bluff planktonic foraminiferal association. In the study area the upper part of the Globorotalia margaritae Zone (PL2 of Berggren, ibid.) is characterized by the persistent presence of Globorotalia menardii tumida, the sporadic presence of G. margaritae, the common occurrence of G. crassaformis sensu G. crassacrotenensis of Lamb and Beard, 1972; and G. crassula conomiozea of Blow, (1969), and the very rare and sporadic occurrence of G. puncticulata puncticulata.

The faunal association of the next younger zone (Zone PL3 of Berggren, ibid.), i.e., the zone that contains the typical part of the Jackson Bluff Formation, differs from the Globorotalia margaritae Zone association in the absence of Globorotalia menardii tumida and in the presence of morphologically generalized, right-coiling G. menardii, the persistent presence of G. puncticulata in frequencies of a few percent or less, the persistent presence of G. crassula crassula and G. crassula viola, the common occurrence of typical G. crassaformis, the first occurrence of G. acostaensis pseudopima, the first consistent common occurrence of Globigerinoides rubra in frequencies greater than 5%, and the very rare occurrence and trace frequencies of Sphaeroidinella dehiscens.

The next younger zone of Berggren (ibid.), PL4, is defined on the first evolutionary occurrence of Sphaeroidinella dehiscens with flanges around the apertures, and the extinction of Sphaeroidinellopsis spp. This evolutionary development of Sphaeroidinella is supposed to coincide with the second Sphaeroidinella datum of Saito (in Hays et al., 1969) (Berggren, 1973; Berggren and van Couvering, 1974), i.e., the time at which the genus Sphaeroidinella became the dominant form in the Sphaeroidinellopsis-Sphaeroidinella complex. The PL3/PL4 boundary, or datum, is a clearly recognizable datum in the study area. Although the writer has not found Sphaeroidinellopsis spp. to become extinct concurrently with the abrupt increase in relative abundance of Sphaeroidinella, it does become extinct within Zone PL4 in the study area. On the other hand, the writer has observed an abrupt phenotypic change at the PL3/PL4 boundary between G. crassula and G. hirsuta. Globorotalia hirsuta is not present in the study area in Zone PL3 but G. crassula grades abruptly into G. hirsuta by changing from a plano-convex form to a biconvex form. The G. crassula phenotype continues through the Pliocene section but only as a trace constituent of the planktonic foraminiferal population.

The writer has observed this same zonal sequence in the Bowden Formation of Jamaica. In the Bowden, these zonal intervals have been referred to zones N18 and N19 of Blow (Robinson, 1966).

The PL3/PL4 boundary, or second Sphaeroidinella datum, is present in the youngest strata of the Jackson Bluff Formation. The exposures of the Cancellaria Zone in the Gully Ponds area of Washington County are basal PL4 in age and contain both common S. dehiscens and rare G. hirsuta. Forms transitional to G. hirsuta from G. crassula (identified as G. margaritae by Akers, 1972, p. 102, pl. 32) are present in the Jackson Bluff Formation at Darling Slide on the Chipola River. It is likely, in the writer's opinion, that the Darling Slide locality is intermediate in age between that of the type locality and Gully Ponds, and is youngest PL3 in age. This is consistent with the time-space relations of a prograding deposit.

The general planktonic foraminiferal faunal composition of the typical Jackson Bluff Formation is consistent with the Zone PL3 fauna from the shallow subsurface of coastal Walton County. The presence of morphologically generalized, right-coiling G. menardii, G. crassula viola, G. puncticulata, G. acostaensis pseudopima, common Globigerinoides rubra, and very rare S. dehiscens along with the absence of G. menardii tumida and G. margaritae requires assignment to Zone PL3.

Because Globorotalia tosaensis is seen to evolve from G. crassaformis at a younger biostratigraphic horizon in Zone PL4 in the coastal Walton County cores, and because the Jackson Bluff Formation contains the subspecies, G. acostaensis pseudopima, the formation is contained in the zone N20 of Blow (1969).

In the zonal scheme of Cita (1973) for the western Mediterranean Sea, the Jackson Bluff Formation is contained in the Sphaeroidinellopsis subdehiscens Interval-zone. This zone is equivalent to the Globorotalia hirsuta aemiliana Zone of Italian authors (see Bertolino et al., 1967).

In the Pliocene of Italy, the top of the Lower Pliocene is marked by the extinction of Globorotalia margaritae (= G. hirsuta in part of Bertolino et al., 1967). Because G. margaritae became extinct prior to Jackson Bluff time, the Jackson Bluff Formation is earliest Late Pliocene in age and is in the Placenzian Stage of Italy.

Phosphoritic Sand Unit

The phosphoritic sand unit is a name informally used in this paper to facilitate discussion of a distinctive Pliocene, marine, phosphoritic and glauconitic sand that underlies coastal Walton County. This unit appears to be a part of a more widely occurring phosphoritic sand facies. The stratigraphic relationships between the more generally occurring phosphoritic sand facies and the Pliocene phosphoritic sand unit are not clearly understood at this time. There are three reasons for this uncertainty. (1) The phosphoritic sand facies quite clearly, based on the planktonic foraminiferal assemblages, contains stratigraphic intervals of diverse ages ranging from Late Miocene to Late Pliocene. (2) This facies is not uniformly calcareous and fossiliferous, therefore impeding correlation between cores. (3) A convincing isopach map cannot be constructed on this lithology alone since the contours are highly irregular. As a result, the Upper Miocene part of the phosphoritic sands in the Lalonde #1 (W-8877) (most of that section being nonfossiliferous) is included in the biostratigraphically equivalent Choctawhatchee Formation. The unfossiliferous phosphoritic sand in the Sam #1 (W-8876) is included in the Pliocene phosphoritic sand unit because the physical position of this interval in cross-sections (Fig. 23) suggests this correlation.

The fossiliferous Pliocene phosphoritic sand unit in the coastal cores Coffeen #1 (W-8865), Price #1 (W-8591), and Intracoastal Waterway #1 (W-8873) contains the central concept of this Pliocene unit and its lithology in the study.

In these cores the unit is biostratigraphically complex. Sedimentation must have occurred irregularly but deposition clearly transgressed eastward through time. The phosphoritic sand must represent an offshore environment where sedimentation was rare and sporadic. The environment of deposition and the lithology are unique in the study area and consequently the unit is only tentatively placed in the Alum Bluff Group as an informal formation.

The lithology of this unit is typically an unconsolidated to indurated, massive-bedded, calcareous, microfossiliferous, slightly argillaceous, glauconitic, phosphoritic sand or sandstone. The phosphate grains are typically pelletal, rounded to irregular in shape, and range in color from black to brown and orange. Fine, boney, bioclastic debris of vertebrate origin is commonly evident. Characteristically the cores give the appearance of having been partially oxidized, due to the common occurrence of brown and orange glauconite and phosphorite pellets and grains.

The phosphoritic sand unit in the Sam #1 (W-8876) is consistent with the above lithology except that it is noncalcareous, and radiating wavellite crystals have been found in the unit only in this core. Internal molds (either black phosphorite or glauconite) of planktonic foraminifera are present but none have been found that are biostratigraphically definitive.

Underlying and Overlying Units

The phosphoritic sand unit paraconformably overlies the St. Joe Limestone of Middle Miocene age. In turn it is gradationally and conformably overlain by the Intracoastal Limestone, or in the Sam #1 (W-8876) by questionable Citronelle Formation.

Lithologic Distinction Between Adjacent Units

The phosphoritic sand unit can be distinguished easily from both overlying and underlying limestone units in being a dark, weathered-looking, phosphoritic sand or sandstone. The phosphoritic sand unit, however, cannot be distinguished lithologically from the similar phosphoritic sand of Late Miocene age. The Miocene and Pliocene phosphoritic sands are separated for convenience of discussion.

Areal Distribution and Thickness

The phosphoritic sand unit is restricted to the coastal area of Walton County. It thins to the east and probably pinches out near the Walton and Bay county lines. The extent of the unit to the west is not known but its characteristic lithology was not reported by Smith (1941) in the Niceville well in Okaloosa County.

The unit thins systematically from 56 feet in the Coffeen #1 (W-8865) to 21 feet in the Price #1 (W-8591) to 8 feet in the Intracoastal Waterway #1 (W-8873). It is 47 feet thick in the relatively updip Sam #1 (W-8876) but it is not present in any of the surrounding cores.

Age

The following planktonic foraminifera have been identified from the basal phosphoritic sand unit in the Coffeen #1 (W-8865). This association is the earliest Pliocene planktonic foraminiferal assemblage in the study area:

Globorotalia menardii s.l. (random coiling direction)
G. menardii multicamerata
G. menardii tumida (left coiling)
G. menardii tumida flexuosa
G. margaritae
G. puncticulata
G. crassula
G. crassaformis s.l.
G. acostaensis acostaensis (dominantly left coiling)
G. acostaensis humerosa (dominantly left coiling)
Globigerina bulloides
G. apertura
G. nepenthes

G. parabulloides
G. quinqueloba
Globigerinoides sacculifera quadrilobata
G. sacculifera sacculifera
G. rubra
G. obliqua obliqua
G. obliqua extrema
G. conglobata
G. cf. conglobata
Sphaeroidinellopsis seminulina
S. subdehiscens
Globoquadrina altispira
G. venezuelana
Hastigerina siphonifera siphonifera
Globorotaloides hexagona
Globigerinita glutinata
G. uvula
Candeina nitida
Orbulina universa

This association is consistent with zone PL1 of Berggren (1973), with the Globorotalia margaritae evoluta Lineage-zone of Cita (1973), and with the Pulleniatina primalis subzone of the Globorotalia margaritae zone of Lamb and Beard (1972). Without Sphaeroidinella dehiscens, whose first occurrence defines the base of N19 of Blow (1969), the interval in question would be properly placed in N18. However, the writer considers the absence of S. dehiscens in this part of the Pliocene in west Florida to be biostratigraphically insignificant, and he considers these beds to be properly N19 in age according to Blow's (1969) zonation.

This oldest stratigraphic interval of the phosphoritic sand unit is Early Pliocene in age and is in the Zanclian Stage of Europe.

The basal stratum of the next core to the east, the Price #1 (W-8591), contains a younger Pliocene planktonic foraminiferal assemblage. The biostratigraphic position of these beds is based on the occurrence of the following planktonic foraminifera:

Globorotalia menardii s.l. (right coiling)
G. acostaensis s.l. (right coiling)
G. margaritae margaritae
G. margaritae evoluta (very rare)
G. crassacrotenensis (sensu Lamb and Beard, 1972)
Sphaeroidinella dehiscens

The evolutionary development of the fauna (including irreversible coiling changes) plus the lack of Globigerina nepenthes suggests assignment to zone PL2 of Berggren (1973, 1974). The presence of S. dehiscens undeniably places the assemblage in N19 of Blow (1969). This assemblage in the same zones of both Cita (1973) and Lamb and Beard (1972) as the earlier occurring assemblage.

The base of the phosphoritic sand unit in the Intracoastal Waterway #1 (W-8873) includes the planktonic foraminifera:

Globorotalia menardii s.l. (right coiling)
G. menardii multicamerata
G. crassula crassula
G. crassula viola
G. crassaformis s.l.
G. puncticulata
G. acostaensis acostaensis
G. acostaensis humerosa
Globigerina bulloides
G. parabulloides
G. apertura
G. calida praecalida
G. quinqueloba
Globigerinoides rubra (common)
G. sacculifera quadrilobata
G. sacculifera sacculifera
G. obliqua s.l.
G. cf. conglobata
Candeina nitida
Hastigerina siphonifera
Globoquadrina altispira
G. venezuelana
Globorotaloides hexagona
Globigerinita glutinata
G. uvula
Orbulina universa
Sphaeroidinellopsis seminulina
S. subdehiscens

Sphaeroidinella dehiscens

The continued evolutionary development of the fauna plus the lack of G. margaritae suggests assignment to zone PL3 of Berggren (1973), to the Sphaeroidinellopsis subdehiscens Interval-zone of Cita (1973), and to the Pulleniatina obliquiloculata Zone of Lamb and Beard (1972). The presence of Globorotalia acostaensis pseudopima, the first occurrence of which defines the base of N20, requires assignment to this zone of Blow (1969).

This basal horizon in the easternmost occurrence of the phosphoritic sand unit is Late Pliocene in age and is in the Piacenzian Stage of Europe.

The top of the phosphoritic sand unit is likewise diachronous, but there seems to be no systematic pattern as with the base of the unit. The top of the phosphoritic sand unit is in zone PL3 of Berggren (1973), in the Coffeen #1 (W-8865), PL4 in the Price #1 (W-8591), and PL4 in the Intracoastal Waterway #1 (W-8873).

Stratigraphic Correlatives

The upper, latest part of the phosphoritic sand unit, PL3 to basal PL4 in age, contains the same planktonic foraminifera association as the Jackson Bluff Formation farther to the east in Florida. That part of the phosphoritic sand unit is therefore judged to be equivalent to the Jackson Bluff Formation, and therefore also to the type Yorktown of the central Atlantic Coastal Plain, to the Duplin of the southern Atlantic Coastal Plain, and to the Pinecrest Member of the Tamiami Formation in southern Florida. The basal part of the phosphoritic sand unit is equivalent to at least the 116 to 123 foot interval in the limestone sequence in the St. George Island #1 (W-7574). The Upper Pliocene part of the phosphoritic sand unit (PL3-PL4) on the other hand is equivalent to that part of the limestone sequence in the St. Joe #1 (W-12051) above 284 feet in the core. That interval in the St. Joe #1 (W-12051) is assigned to the Intracoastal Limestone in this study.

No marine equivalents are known of the Lower Pliocene part of the phosphoritic sand unit from either the outcrop or from the shallow subsurface in the Coastal Plain to the east of western Florida.

Undifferentiated Pliocene Deposits

Under the Pamlico terrace deposits along the north coast of Choctawhatchee Bay and the low lands to the east of it is a rather thin sequence of typically noncalcareous, nonfossiliferous sands. These sands are considered to be Pliocene in age and for the most part, equivalent to the phosphoritic sand unit and the Intracoastal Limestone. The reasons for this correlation are as follows: (1) These sands occur in the same stratigraphic position as the downdip, marine Pliocene units. They overlie with apparent discontinuity limestones of Middle and Late Miocene age. (2) The upper part of the Intracoastal Limestone in the Intracoastal Waterway #1 (W-8873) is at a physically higher elevation than the lower part of the noncalcareous sands immediately updip in the Mack #1 (W-8587). Because there is no stratigraphic indication for reversal of dip due to folding or faulting, the simplest explanation for the lateral juxtapositions in the two cores is facies change and not structural dislocation. (3) The basal 5.5 feet of these sands in the Bruce #1 (W-8592) is fossiliferous and contains an excellent planktonic foraminiferal fauna. The age of this bed is Early Pliocene, late

Zanclian age based on the following foraminifera:

Globorotalia menardii (right coiling
G. margaritae margaritae
G. puncticulata
G. acostaensis s.l. (random coiling)
Pulleniatina primalis
Globigerina nepenthes

The age of this bed is intermediate between that of the basal phosphoritic sand unit in the Coffeen #1 (W-8865) and the basal phosphoritic sand unit in the Price #1 (W-8591). It is therefore entirely equivalent to the phosphoritic sand unit.

Typically this deposit consists of sand but it may be gravelly, clayey, peaty or carbonaceous, or even altered to humate. It is commonly well sorted and consists of fine to medium to coarse sand. Intervals occur, however, in which the sands are poorly sorted and consist of clayey coarse sand. Bedding is commonly evident in the cores and in places the bedding is inclined, suggesting crossbedding. In the more organic-rich intervals, a yellow sulpho-salt generally crystallizes on the dessicated surface of the cores.

Lithologically these Pliocene sands cannot be distinguished from other sands along the coast on the south side of Choctawhatchee Bay that are probably Pleistocene in age. As discussed above, the principal reasons for believing these sands to be Pliocene in age rather than Pleistocene is their stratigraphic position and their physical position in the eastern part of the county. It is possible that what appear to be equivalent deposits in the western part of the county may in fact be Pleistocene in age, but the lithologic similarity and the lack of fossils makes differentation at this time impossible.

At elevations higher than the Pamlico surface (about 25 feet) and near the north shore of Choctawhatchee Bay are weathered red and orange sands that may be Citronelle Formation. The only difference between these exposed, low elevation red sands and the Citronelle Formation is the near lack of clay and gravel beds in these coastal deposits. Weathered red, gravelly sands are present, however, in the upper part of the Sam #1 (W-8876). These gravelly sands abruptly overlie the phosphoritic sand unit in that core.

Citronelle Formation

The Citronelle Formation blankets the upland areas of Walton County. It consists principally of a sand that is medium to coarse to very coarse in texture. It is commonly well sorted but also may be poorly sorted. Gravel and gravelly sand beds and beds and lenses of relatively pure clay are typical and characteristic secondary lithologies in the Citronelle in Walton County. The clay beds are typically underlain and overlain abruptly and with very sharp contact by sands and gravels. The Citronelle, generally but not invariably, is deeply weathered with colors ranging from brown and purple to red, orange and yellow. The formation is variable in thickness due both to an undulating pre-Citronelle topography and to present day dissection. As a result the Citronelle varies in thickness from 0 feet in river valleys and creek bottoms to as much as 144 feet in the Eglin #1 (W-8351).

There has been controversy on the age of the Citronelle Formation. Berry (1920) considered the Citronelle to be Pliocene in age on the basis of leaf fossils found in clay lenses in the Citronelle Formation in the type area. Doering (1956, 1958, 1960) presented mainly nonpaleontological evidence for a Calabrian, "pre-glacial Pleistocene" age. On the other hand, Ishphording and Lamb (1971) described a fossil vertebrate assemblage from near the type locality of the Citronelle and they concluded that the assemblage was most consistent with a Hemphillian land-mammal age (Upper Miocene-Lower Pliocene, Berggren, 1972; Berggren and van Couvering, 1974).

The results of the present stratigraphic study are significant in terms of the correlation of the Citronelle Formation with marine equivalents and, therefore, to the age of the formation. Unfortunately the stratigraphic correlation is not unambiguous because marine, fossiliferous beds do not interfinger with typical Citronelle lithology. The difficulty is in correlating nonfossiliferous sediments across a severe facies change; from open marine fossiliferous deposits, through coastal, shore-line deposits, to bay, estuarine, and fluvial deposits. As a result, both stratigraphic position and physical position of the deposits in the cores and in exposures are critical in correlation of this sort. In near-shore coastal plain deposits, correlation of this kind is at best approximate, and may be spurious.

There are scattered exposures of what appear to be Citronelle Formation over much of southern Walton County north of Choctawhatchee Bay and the Choctawhatchee River Valley. These exposures indicate that the base of the formation drops rather rapidly in elevation between the uplands (above 150 feet above sealevel) and the coast. In most of the cores along Choctawhatchee Bay the Citronelle lithology is exceptional (see section on Undifferentiated Pliocene Deposits, p. 117-119). The Citronelle Formation (or Citronelle lithofacies) has been identified in only the Sam #1 (W-8876) and possibly in the Bruce #1 (W-8592). In the rest of the coastal cores (Lalonde #1 (W-8877), Bayview #1 (W-8478), Ryan #1 (W-8355), Mack #1 (W-8587), Coffeen #1 (W-8865), Price #1 (W-8591), and Intracoastal Waterway #1 (W-8873) the Citronelle lithology is not present. Rather, the typically unweathered, noncalcareous, nonfossiliferous sands of probable Pliocene age and marine Pliocene deposits are found in the stratigraphic position occupied by the Citronelle Formation farther updip. In the Sam #1 (W-8876), the Citronelle lithology overlies with abrupt contact a section of the noncalcareous, nonfossiliferous, phosphoritic sand unit. In the Bruce #1 (W-8592) the possible Citronelle consists of unweathered sand and gravel that abruptly overlies a thin fossiliferous bed of Early Pliocene age. It must be pointed out that the abrupt basal contacts in these two cores may be insignificant as a measure of geologic time and that they may only represent an invasion of an open marine facies by a prograding shoreline facies.

There are several possible stratigraphic interpretations of the relationships just described. The one favored here is that the fluvial-deltaic/estuarine, Citronelle Formation interfingers with shoreline, beach and lagoon sands and muds in the vicinity of the north shore of Choctawhatchee Bay. These shoreline deposits in turn grade into marine sediments of Pliocene age in a downdip direction. If this interpretation is correct, then the Citronelle Formation in Walton County is Pliocene in age and is consistent with the conclusions of Berry (1920) and Ishphording and Lamb (1971). The present core control is not sufficient to suggest any more precise correlation with the marine Pliocene sediments. It may be significant that the Citronelle sediments in the two earlier mentioned cores overlie phosphoritic sands that physically correlate with the phosphoritic sand unit of Early Pliocene age, or directly overlays a demonstrable Early Pliocene bed. Certainly, however, the Citronelle is a diachronous unit and the oldest parts of the unit may be of Early Pliocene age whereas the youngest Citronelle may be Late Pliocene in age.

The results of this study are more consistent with a Pliocene age for the Citronelle than with an Early Pleistocene, Calabrian age. Fossiliferous deposits of that age, though present elsewhere in the Coastal Plain of the southeast (Bender, 1973; Akers, 1972), are not present in the study area of western Florida.

Coastal Group, (new group)

The Coastal Group is a new name for Alum Bluff equivalent carbonate units underlying the coastal area of the panhandle of Florida. This group includes three formally defined formations in this study and probably includes as many as four additional units that are not clearly definable with the present core control. The defined units are, in ascending order, the Bruce Creek Limestone, the St. Joe Limestone, and the Intracoastal Limestone.

The less clearly definable units includes the limestone facies of the Chipola Formation in Walton County. This limestone is lithologically distinguishable from the overlying Bruce Creek Limestone in Walton County but there is too little core control to be certain of the range of lithologic variation of the unit. The Chipola equivalent limestone appears to be present in the Apalachicola Embayment area but with a somewhat different lithology than in Walton County. There is also some evidence that the Torreya Formation grades downdip into a limestone facies (Sopchoppy Limestone?) that is consistent with the Coastal Group lithology except that the clay mineral present in the limestone is palygorskite (attapulgite) rather than montmorillonite.

The downdip, offshore facies of the lower member of the Choctawhatchee Formation is a fine-textured, granular, foraminiferal limestone that is entirely consistent with Coastal Group lithology and not with Alum Bluff lithology. However, the areal distribution of the Choctawhatchee Formation is very limited in extent and the limestone facies is even more limited in extent. The writer chooses to refrain from subdivision of the Choctawhatchee, therefore, until the stratigraphic relations of the lithofacies within that unit are clearly definable.

It is possible that the Intracoastal Limestone will eventually be formationally subdivided into the typical western part, characteristic of the Gulf Coast Basin, and an eastern part that is characteristic of the Apalachicola Embayment.

The limestones of the Coastal Group are characteristically unconsolicated to moderately indurated (rarely thoroughly indurated and crystalline), massive-bedded, and impure. The impurities consist of quartz sand, clay mineral, mica, glauconite, pelletal apatite, and pyrite. Gypsum bloom is commonly found on the dessicated cores. The limestones are typically granular and even-textured but in some places they may be coarsely bioclastic and rubbly. The units are commonly extremely microfossiliferous, even consisting of a foraminiferal coquina. Rarely beds of calcareous clay or sand occur in the limestone.

The writer recognizes two broad lithology types within the currently understood Coastal Group. One lithology type is found in the Bruce Creek Limestone, Chipola equivalent limestone, and in the earlier limestones. These limestones are typically more indurated, more coarsely calcarenitic, lighter colored, and much less microfossiliferous. The other lithology type is found in all of the younger units of the group. This limestone is unconsolidated to moderately indurated, extremely microfossiliferous; less coarsely calcarenitic; more impure with clay, glauconite, and phosphorite dominating the impurities; and with colors ranging from olive to yellowish gray.

The Coastal Group differs from the underlying "Suwannee Limestone" in that the "Suwannee Limestone" is hard and well indurated, not obviously macro- or microfossiliferous, is a quite pure carbonate that invariably contains tan to brown, sugary dolomite beds or dolomitic limestone beds that appear to be randomly situated and rarely correlatable from core to core.

At this time the Coastal Group is recognized as far west as Niceville in Okaloosa County (based on the geologic log of Smith, 1941) and as far east as Carrabelle in Franklin County. It underlies the southern quarter of Walton County but it extends in a thin tongue (Bruce Creek Limestone) into the northern part of the county. Elsewhere in the study area the core control is insufficient to delineate its updip limits, except possibly along Econfina Creek in Bay County. It is not present in southern Washington County or at Alum Bluff.

<u>Bruce Creek Limestone</u>, (new formation)

This formation has been referred to previously as a limestone facies of the Chipola Formation (Cooke and Mossom, 1929, p. 104). It is for the most part a subsurface unit. The only exposure of this formation known with certainty at this time is the type locality on Bruce Creek. Similar limestone is reported by Cooke and Mossom (1929, p. 104) in White Creek in NW 1/4, Sec. 26, T2N, R18W, in Walton County, and in southwestern Washington County in the vicinity of the Choctawhatchee River (Sellards and Gunter, 1918, p. 92; Cooke and Mossom, 1929, p. 104, 106; Vernon, 1942).

The type locality of the Bruce Creek Limestone is several hundred feet downstream from the county road bridge over Bruce Creek in N 1/2, Sec. 2, T1N, R18W, Walton County, Florida. At this locality, 1 to 2 feet of pale bluish-green, unconsolidated, soft, slightly argillaceous, sandy, slightly macrofossiliferous limestone is exposed.

Typically in the shallow subsurface, the Bruce Creek Limestone consists of massive-bedded, weakly to well indurated, friable but brittle, rather even-grained, medium to coarse textured, shelly to moldic, bioclastic, calcarenite limestone. Minor lithologies within the main body of the formation consist of unconsolidated calcarenite with fine-grained carbonate matrix; algal limestone; hard, dense, crystalline limestone; fine-grained to lutitic limestone; clayey limestone, and microfossiliferous, calcareous clay.

Updip in the outcrop area and at the type locality, quartz sand is an important constituent of the lithology. Here the formation consists of either massive-bedded, indurated, sandy, moldic limestone or of sandy, macrofossiliferous limestone interbedded with soft, slightly argillaceous, macrofossiliferous, very calcareous quartz sand.

A persistent clay bed occurs immediately downdip from the sandy limestone facies of the Bruce Creek. The clay is pale brown in color, is highly calcareous and microfossiliferous, and is sparsely sandy. It overlies gradationally a lower, sandy phase of the limestone and, in downdip areas, grades upward into typical Bruce Creek limestone. The clay bed (or beds, since there are two present in the Cosson #1 (W-8004)) occurs in a very narrow belt no more than 5 miles wide that parallels the strike of the formation and is located near the updip limits of the formation. The clay bed is in the lower part of the Bruce Creek and it is mainly this bed that contains the rich assemblage of foraminifera that defines the age of the Bruce Creek Limestone.

Underlying and Overlying Units

The Bruce Creek Limestone overlies, with apparent conformity in the cores, the updip, Chipola equivalent sands, and it overlies paraconformably, the Chipola formation and the Chipola equivalent limestone. In updip areas it is overlain abruptly by the Shoal River Formation either conformably or with hiatus. It is overlain in the coastal area paraconformably by the St. Joe Limestone.

Lithologic Distinction Between Adjacent Units

The Bruce Creek Limestone is distinguished from both the underlying Chipola Formation and the overlying Shoal River Formation in being a pure, calcarenitic limestone or sandy limestone, whereas the other two formations are dominantly sands and clays. Where the Bruce Creek Limestone directly overlies the Chipola limestone, the Chipola limestone is sandy and impure while the Bruce Creek is almost devoid of terrigenous impurities.

<u>Areal Distribution, Geometry, and Thickness</u>

At this time the Bruce Creek Limestone has been identified in two areas of western Florida. It underlies the southern two thirds of Walton County and it underlies the present coastal area of the Apalachicola Embayment in Gulf and Franklin Counties. It probably underlies the coastal areas of Gulf and Bay Counties but there is no firm shallow subsurface control in that area. Its extent to the west of Walton County is unknown.

The trend of the updip limit of the formation in Walton County is westnorthwest-eastsoutheast (N 70° W) (Fig. 16). Considering that the Oak Grove Sand is a sandy, lower foreshore facies of the Bruce Creek Limestone, the same westnorthwest-eastsoutheast trend appears to continue through northeastern Okaloosa County. The updip trend of the limestone bends abruptly to the southeast in the vicinity of the Choctawhatchee River. The Bruce Creek Limestone is believed to underlie West Bay and East Bay in the Panama City area.

The Bruce Creek Limestone is a thin, blanket-type deposit that thickens gradually in a downdip, south-southwest direction, apparently normal to the ancient shoreline (Fig. 16). The average thickness of the unit in Walton County is 50 feet. It thins to at least 9 feet near its updip limit in the Kohler #1 (W-7994), and is 86 feet thick in one core under the coast (Price #1 (W-8591)). It is possible that the thinning in the updip extremity of the formation may result from facies change in the lower part of the unit, from downdip or offshore limestone into updip or nearshore noncalcareous sands and clays. If so, these sands and clays would be considered, in this study, a part of the noncalcareous

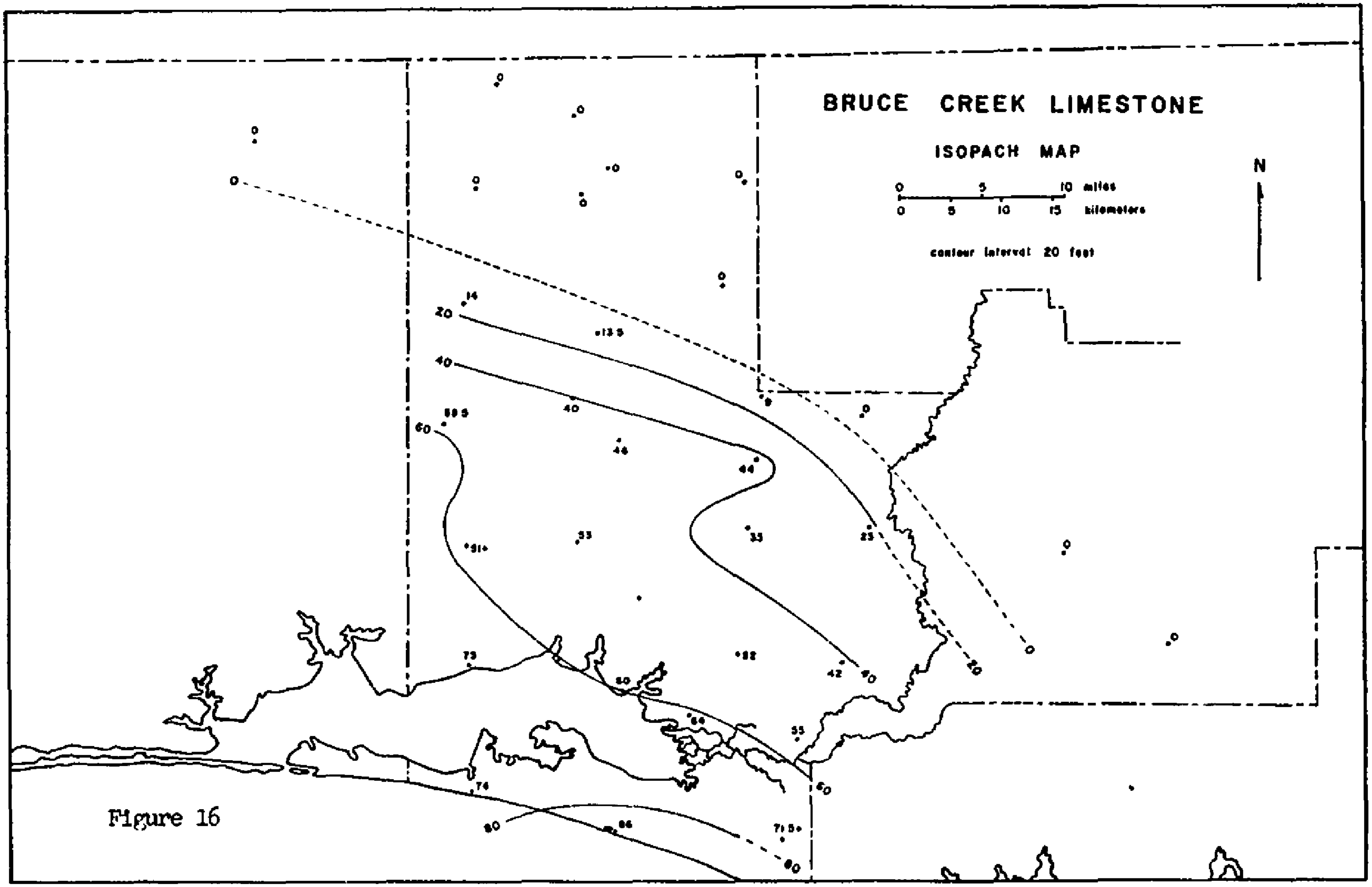
BRUCE CREEK LIMESTONE
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
N

Figure 16

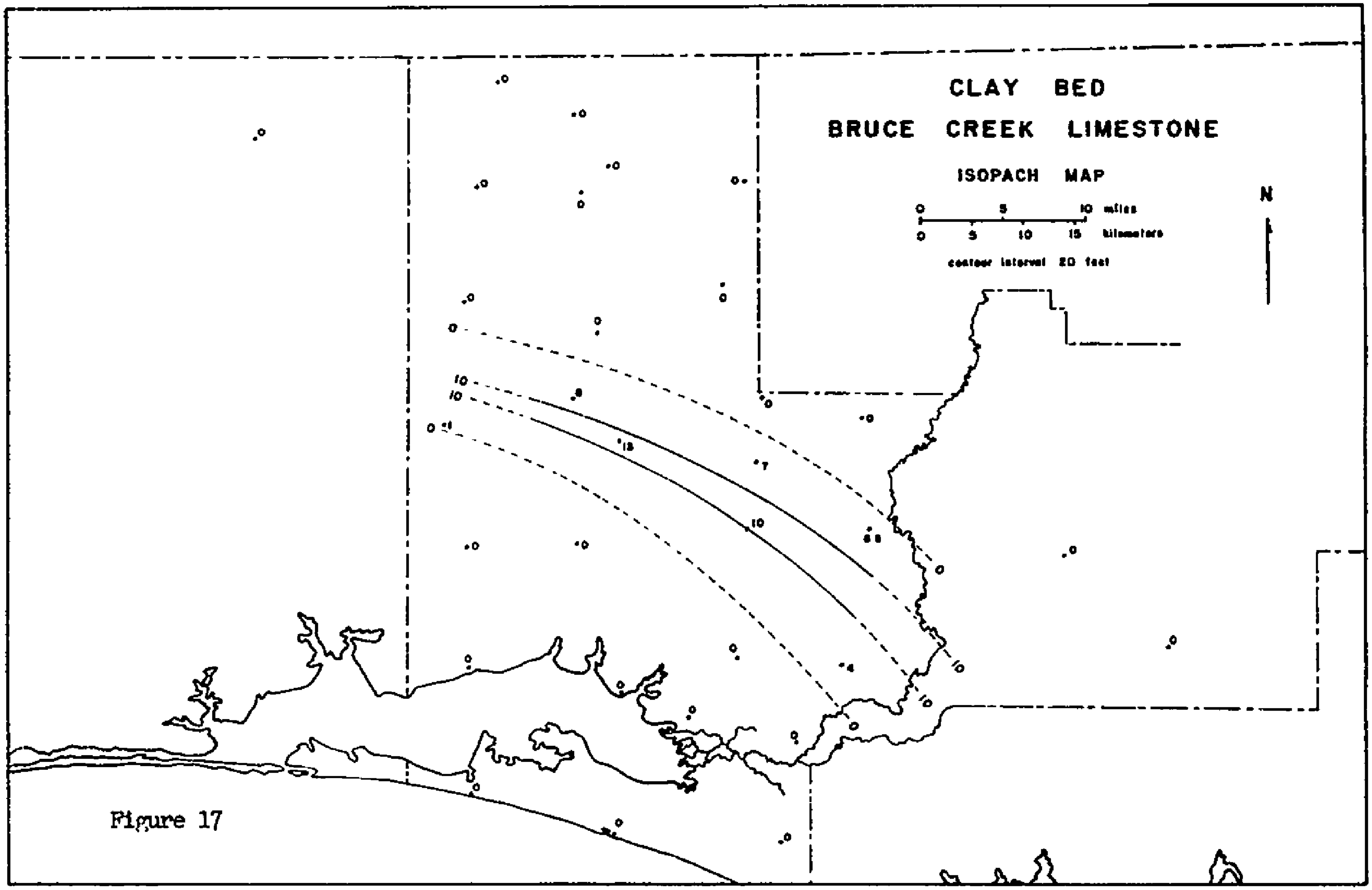
CLAY BED
BRUCE CREEK LIMESTONE
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
N

Figure 17

sands of probable Chipola age. The writer considers this a possibility since the combined thicknesses of the downdip Chipola and Bruce Creek - updip Chipola sands and Oak Grove stratigraphic interval are approximately the same. The lower, Chipola-noncalcareous Chipola sands interval thickens updip whereas the upper, Bruce Creek Oak Grove interval thins (Figures 21-24).

There is too little core control in the Apalachicola Embayment area to discern the thickness distribution of the Bruce Creek. There is at least 36 feet of Bruce Creek in the St. Joe #1 (W-12051) but the identity of the thick sequence of limestones in the St. George Island #1 (W-7574) is at this time problematical. The upper 24.5 feet of the limestone sequence in that core is an algal limestone that contains a Bruce Creek planktonic foraminiferal association. The underlying 149 feet of limestone is hard and dense but has a Bruce Creek-like lithology. The lowermost 90 feet of limestone is a calcarenitic, calcilutitic limestone whose sole clay mineral component is palygorskite (attapulgite), which according to Dr. Charles Weaver (personal communication, 1975) is characteristic of the Hawthorn of Florida and Georgia, the Torreya Formation of Banks and Hunter (1973), and the Sopchoppy Limestone in Wakulla County, Florida. This writer tentatively considers the uppermost algal limestone to be Bruce Creek, the underlying limestone to be possibly Chipola equivalent, and the lowest limestone containing palygorskite (attapulgite) to be Torreya or Sopchoppy equivalent.

Stratigraphic Correlatives

The only stratigraphic equivalents of the Bruce Creek Limestone known to the writer are its updip, sandy, nearshore equivalent, the Oak

Grove Sand; the Pungo River Formation of North Carolina (Gibson, 1967); the Calvert Formation exposed at Plum Point in Maryland; and bed 10 in the upper part of the Calvert Formation (Gibson, ibid.).

Age

The following planktonic Foraminifera have been identified from the Bruce Creek Limestone:

Globorotalia fohsi peripheroronda
G. praemenardii archeomenardii
G. mayori (in part G. siakensis of Blow, 1969)
G. cf. minutissima
Globigerina praebulloides praebulloides
G. praebulloides pseudociperoensis
G. foliata
G. bulbosa
G. falconensis
G. eamesi
G. quinqueloba
G. bulloides
Globigerinoides sicana
G. sacculifera quadrilobata
G. sacculifera sacculifera
G. obliqua obliqua
G. subquadrata
Globigerinitella insueta
Globoquadrina dehiscens
G. altispira
Sphaeroidinellopsis seminulina
Globigerinita glutinata
G. uvula
Cassigerinella chipolensis
Globorotaloides hexagona variablis
Praeorbulina glomerosa curva
P. glomerosa glomerosa

The following species are restricted to the Bruce Creek Limestone or to its equivalent in the study area:

Globigerinoides sicana
Globigerinitella insueta
Praeorbulina glomerosa curva
P. glomerosa glomerosa
Globigerina bulbosa

Excluding the above species, the following species have their first local occurrence in the Bruce Creek Limestone:

Globorotalia fohsi peripheroronda
G. praemenardii archeomenardii
G. cf. minutissima
G. obliqua obliqua
Globoquadrina dehiscens
Sphaeroidinellopsis seminulina

The Bruce Creek Limestone contains the Globigerinoides sicanus - Globigerinitella insueta Partial-range zone (N. 8) of Blow (1969). In the zonation system of Bolli (1966), the Bruce Creek contains the upper part of the Globigerinitella insueta Zone and the Praeorbulina glomerosa Zone. The Bruce Creek Limestone is contained, therefore, in the Langhian Stage of Europe (Cita and Blow, 1969) (Fig. 4).

There is an east-west trending band across the southern part of Walton County where the upper part of the Bruce Creek lithology is not restricted to the zones and age described above. In the following cores, the upper part of the Bruce Creek limestone interval contains a Shoal River planktonic Foraminiferal association: Eglin #3 (W-8353), Eglin #2 (W-8352), Sam #1 (W-8876), and Mack #1 (W-8587). In addition, the basal Shoal River in the Vaughan #1 (W-8014) is interlayered with a limestone that is Bruce Creek in lithology and, lower in the core, contains a typical Bruce Creek planktonic foraminiferal fauna.

The conclusion is inescapable that Bruce Creek conditions prevailed across this band in Walton County during lower and through much of middle Shoal River time. Since there are few lithology breaks within the limestone sequence that one can ascribe to an apparent paraconformity, it seems unlikely that there were any marine withdrawals during the time interval in question. This part of the Bruce Creek must grade both laterally updip into the Shoal River Formation (which may be the situation in the Vaughan #1 (W-8014)) and laterally downdip into the

St. Joe Limestone.

The following planktonic foraminifera are diagnostic of the Middle Miocene, Shoal River age of this youngest Bruce Creek Limestone:

Globorotalia fohsi peripheroacuta
G. fohsi praefohsi
G. fohsi lobata (sensu Bolli, 1957)
Orbulina suturalis
Globigerina druryi

Since *Globigerinoides sicana* occurs near the top of the Bruce Creek Limestone in cores from other areas of Walton County and from the Apalachicola Embayment, it can be inferred at this time that this Shoal River equivalent-Bruce Creek Limestone is exceptional and need not be treated as typical Bruce Creek.

St. Joe Limestone, new formation

The St. Joe Limestone is a new name for a limestone deposit that underlies much of the coastal area of the panhandle of Florida. It is entirely a subsurface unit and is not known to occur above sea level anywhere in the study area.

The type core of the formation is the St. Joe #1 (W-12051). The location of the corehole is on St. Joseph Spit in St. Joe State Park, Sec. 14, T8S, R12W. The following is a lithologic log of the St. Joe Limestone interval in the type core:

Lithologic Description	Interval	Thickness
Core Gap, "Clay, same as 412 feet."	403-412 feet	9 feet
Clay, calcareous, gypsiferous; nonbedded; tough, compact; foraminiferal-rich, a few bits of phosphatic vertebrate debris, burrowed, especially from 412-413 feet, burrow-fillings more calcareous and foraminiferal-rich; color of nonburrowed clay, light olive gray (5 Y 5/2), burrowed clay, yellowish gray (5 Y 7/2); merges very gradually into:	412-417 feet	5 feet

Foraminiferal-coquinoid limestone, argillaceous, glauconitic, slightly gypsiferous, somewhat pyritic and phosphatic in lower part; massive-bedded, even textured. medium grained; soft and unconsolidated to brittle and very slightly indurated; rare echinoid spines, some delicate pectenid shells, rare thin, chalky bivalve shells, amount of phosphatic vertebrate debris increases along with amount of pelletal apatite in lower part of interval, many foraminiferal tests void of sediment filling; color varies from light olive gray (5 Y 6/1) to very light olive gray (5 Y 6/2); merges downward very graaually into:	417-442 feet	25 feet
Foraminiferal-coquinoid limestone, slightly to moderately argillaceous with clay content increasing upward in core, glauconitic, slightly phosphatic, sporadically pyritic and gypsiferous; massive-bedded to thick-bedded; even textured, medium-grained, well mixed; soft and unconsolidated to variably coherent with some tough, hard layers alternating with softer layers of varying thicknesses, some incipient recrystallization; scattered macrofossil remains, small fish bones, chalky shell molds, echinoid plates and spines; bryozoans rare, scattered pectenids in horizontal orientation; some slight concentrations of glauconite; color light olive gray (t Y 6/1) to very light olive gray (5 Y 6/2) to yellowish gray (5 Y 7/2); grades downward into:	442-499 feet	57 feet
Foraminiferal-coquinoid limestone, slightly argillaceous, glauconitic, slightly phosphatic and pyritic; medium grained, even-textured, moderately to lightly indurated, some molds and impressions of macrofossils in upper part; (very poor core recovery); color yellowish gray (5 Y 8/1); grades downward into:	449-526 feet	27 feet
Clay and calcarenite, thinly interlayered clay and argillaceous, foraminiferal-coquinoid calcarenite, somewhat glauconitic and phosphatic; color moderate olive gray (5 Y 5/1) to light olive gray (5 Y 6/1); abruptly but gradationally overlies:	526-527 feet	1 foot
Foraminiferal calcarenite limestone, sandy	527-531.5 feet	4.5 feet

slightly argillaceous, somewhat glauconitic, scattered black apetite pellets; massive-bedded, well mixed, even-textured; slightly to moderately consolidated, medium grained; some scattered, finely disseminated pyrite; some dark gray to black, very fine-grained, phosphatic dolomite fragments at base of interval, concoidal fracture, heavily bored by Toredo clams? so that fragments have a frothy appearance; some scattered pectenid shells and a few chalky bivalve fragments; color light olive gray (5 Y 6/1) to yellowish gray (5 Y 7/2); abruptly overlies the Bruce Creek Limestone.

Total thickness 128.5 feet

In Walton County the St. Joe Limestone is a lightly indurated to unconsolidated, massive-bedded, commonly glauconitic, very slightly argillaceous, even-textured, granular, foraminiferal-coquinoid limestone. In the downdip cores under the coastline of Walton County, the formation tends to be more indurated and glauconitic. Near its updip limits it is softer, almost unconsolidated, argillaceous, and does not contain glauconite.

Underlying and Overlying Units

In all the cores that contain the St. Joe Limestone, it paraconformably overlies the Bruce Creek Limestone.

Various units are known to overlie the St. Joe Limestone. In Walton County it is overlain gradationally and conformably by the Shoal River Formation in the Lalonde #1 (W-8877). In the Ryan #1 (W-8355) it is overlain paraconformably and with subtle lithologic change by the foraminiferal limestone facies of the lower member of the Choctawhatchee Formation. Noncalcareous sands of probable Pliocene age (see Figures 22 and 23) abruptly overlie the St. Joe Limestone in the Bayview #1 (W-8478) and Sam #1 (W-8876). In the Coffeen #1 (W-8855), Price #1

(W-8591), and Intracoastal Waterway #1 (W-8873), it is overlain paraconformably by the phosphoritic sand unit of Pliocene age. The St. Joe Limestone is overlain by the lower member of the Choctawhatchee Formation (St. Joe #1, W-12051) and by the Intracoastal Limestone (St. George Island #1, W-7574) in the Apalachicola Embayment.

Lithologic Distinction Between Adjacent Units

The St. Joe Limestone differs from the Bruce Creek Limestone in being relatively unconsolidated, slightly argillaceous, and extremely microfossiliferous whereas the Bruce Creek is moderately indurated, calcarenitic limestone that is irregularly microfossiliferous. The Shoal River differs in being mainly a clay, sandy clay, or calcareous clayey sand. The various overlying Pliocene deposits in Walton County are invariably sands with varying amounts of clay mineral, calcite, granular phosphorite, and shells. Only the foraminiferal limestone facies of the lower member of the Choctawhatchee Formation is difficult to distinguish from the St. Joe Limestone. That unit, however, is typically a more fine-textured foraminiferal limestone and in Walton County is slightly more sandy and argillaceous. Where it overlies the St. Joe Limestone in the St. George Island #1 (W-7574), the Intracoastal Limestone is slightly sandy and, except for the basal bed, is much more indurated.

Areal Distribution, Geometry, and Thickness

The St. Joe Limestone is areally widespread under the coastal area of the panhandle of Florida (Fig. 18). It underlies the southern quarter of Walton County and is apparently present at least as far west as Niceville in Okaloosa County based on the published log of the Niceville well by Smith (1941, p. 266, 267). It underlies the Apalachicola

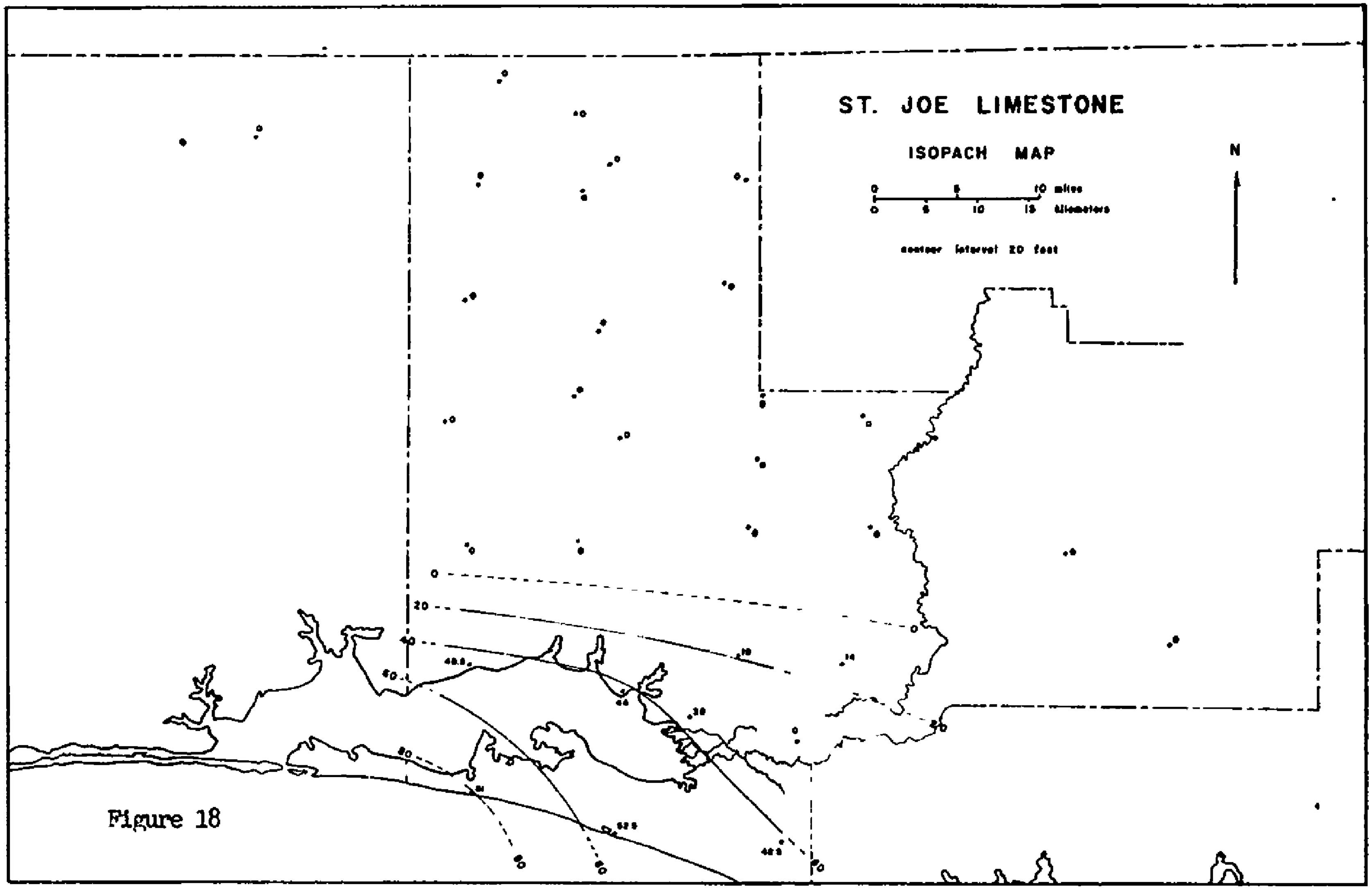
ST. JOE LIMESTONE
ISOPACH MAP
0 5 10 miles
0 5 10 15 kilometers
contour interval 20 feet
N

Figure 18

Embayment in coastal Gulf and Franklin Counties and, therefore, presumably underlies the intervening coastal area of Bay County. The St. Joe is unusually thick in the coastal area of the embayment, suggesting that it may underlie an extensive area inland.

Although the St. Joe Limestone is an east-west trending unit in Walton County, it thickens mainly to the southwest, reaching a thickness under the southwestern corner of the county in the Coffeen #1 (W-8865) of 79 feet. The formation is exceptionally thick and well-developed in the Apalachicola Embayment where it is 128 feet thick in the St. Joe #1 (W-12051). It thins eastward to 84 feet in the St. George Island #1 (W-7574).

Stratigraphic Correlatives

In Walton County, the St. Joe Limestone is intermediate in age to the outcropping lower and middle Shoal River Formation. Actually it is a slightly earlier, downdip phase of the transgression that culminated in the deposition of the middle Shoal River shell bed that is exposed in the valley of the Shoal River. In the St. Joe #1 (W-12051) in the Apalachicola Embayment, the St. Joe Limestone is equivalent to the entire Shoal River Formation in Walton County. The core recovery in the St. George Island #1 (W-7574) was too poor to be certain of the complete time span of the formation in that core. The known St. Joe Limestone in the St. George Island #1 (W-7574) is equivalent to only the lower, Whites Creek Member of the Shoal River.

Age

The following planktonic foraminifera have been identified from the St. Joe Limestone in Gulf, Franklin, and Walton Counties, Florida:

Globorotalia fohsi peripheroronda
G. fohsi peripheroacuta
G. fohsi praefohsi
G. fohsi lobata (sensu Bolli, 1957)
G. fohsi robusta (sensu Bolli, 1957)
G. praemenardii archeomenardii
G. praemenardii praemenardii
G. menardii s.l.
G. mayori (includes G. siakensis of Blow, 1969)
G. scitula praescitula
G. cf. minutissima
Globigerina praebulloides praebulloides
G. praebulloides pseudociperoensis
G. foliata
G. obesa
G. falconensis
G. druryi
G. bulloides
G. quinqueloba
G. eamesi
Globigerinopsis aguasayensis
Globigerinoides sacculifera quadrilobata
G. sacculifera sacculifera
G. obliqua obliqua
G. subquadrata
G. aff. Globigerinopsis aguasayensis
Globoquadrina dehiscens
G. altispira
Sphaeroidinellopsis seminulina
S. subdehiscens
Globigerinita glutinata
G. uvula
Cassigerinella chipolensis
Globorotaloides hexagona variabilis
Orbulina suturalis

In the Apalachicola Embayment, the St. Joe Limestone in the St. Joe #1 (W-12051) includes the following zones of Blow (1969): the Globorotalia (Turborotalia) peripheroacuta Consecutive-range zone (Zone N. 10), the Globorotalia (G.) praefohsi Consecutive-range zone (Zone N. 11), the Globorotalia (G.) fohsi Partial-range zone (N. 12), and the Sphaeroidinellopsis subdehiscens subdehiscens-Globigerina druryi Partial-range zone (N. 13).

In the zonation scheme of Bolli (1967), the St. Joe Limestone in the type core includes the Globorotalia fohsi peripheroacuta Zone, the Globorotalia fohsi praefohsi Zone, the G. fohsi lobata Zone, the G. fohsi robusta Zone, and the Globigerinoides rubra Zone (= G. subquadrata).

In Walton County the St. Joe Limestone varies in age from N. 11 in the southeastern part of the county to N. 12 for the main body of the formation. It is almost entirely restricted to the Globorotalia fohsi lobata Zone of Bolli (1967).

The St. Joe Limestone is included in the uppermost Langhian Stage and the lower Serravalian Stage of Italy (Cita and Blow, 1969).

Intracoastal Limestone, (new formation)

The Intracoastal Limestone is a new name for a soft, sandy limestone of Pliocene age that underlies the coastal area of western Florida. The name is taken from the Intracoastal Waterway #1 (W-8873). The location of this core is near the Intracoastal Waterway in NE 1/4, SW 1/4, Sec. 11, T3S, R18W in Walton County, Florida. The interval in which this formation occurs in that core is between 67 feet and 180 feet. The following is a log of the formation in the type core:

Lithologic Description[1]	Interval	Thickness
Sandy calcarenite to calcareous sand, quartz sand and calcarenite medium to coarse grained; massive-bedded, sediment thoroughly mixed, structureless; unconsolidated to slightly indurated; quartz sand increases upward in the section to the point that above 75.5 feet, the sediment becomes a calcarenitic	67-83 feet	16 feet

1 Characteristically the vertical changes in lithology in the Intracoastal Limestone, and in the type core, are very broadly gradational so that it is generally inaccurate to speak of distinct beds.

quartz sand; above 69-70 feet, the sediment becomes somewhat shelly, medium to coarse quartz sand that contains common Cerithium; small aragonitic shells rare at base, become more common upward in section; color varies from medium light gray to yellowish gray (N 6 - N 5 - 5 Y 8/1); abruptly but conformably overlain by noncalcareous and with some humate, upper contact appears to be an alteration contact; grades downward over a one foot interval into:

Limestone, calcarenitic, very finely sandy, more sandy at base of bed but quartz sand diminishes upward, some gypsum crystals observed on the dessicated core; massive-bedded, sediment thoroughly mixed; lower part of interval slightly indurated, becomes gradually more consolidated and indurated upward in section, above 106 feet the sediment becomes moderately well-indurated; shells increase in abundance upward in section, calcitic shells (oysters and pectinids) present throughout the interval, molds of aragonitic shells become more conspicuous above 106 feet, also above 106 feet pectenid shells become common; as a result of the increasing induration of the limestone plus the abundance of pectinid shells and molds of shells, the limestone takes on a rubbly, bioclastic texture with calcarenite forming the matrix of the bioclastic limestone; color very light olive gray to yellowish gray (5 Y 7/1 - 5 Y 8/1); grades downward into:	83-121.5 feet	37.5 feet
Limestone, slightly sandy to sandy, very slightly argillaceous, slightly micaceous, glauconitic, somewhat phosphatic; massive-bedded, sediment thoroughly mixed, structureless; fine-grained, even-textured; unconsolidated to weakly consolidated, coherent, more consolidated intervals occur in layers; some rare, chalky shell molds and oyster shells; more phosphatic with coarse, rounded quartz grains and disseminated pyrite in basal part of interval; becomes less glauconitic, more argillaceous and micaceous above 162 feet; fine sand component increases up-	121.5-180 feet	58.5 feet

ward in section, mainly calcarenite below approximately 150 feet, calcareous sand interval from 150-147 feet, above which the lithology is a very finely sandy calcarenite; color very light olive gray to yellowish gray (5 Y 7/1 - 5 Y 8/1); grades downward very gradually over an interval of about 2 feet into underlying phosphoritic sand unit.
(no core recovery from 132 feet to 147 feet).

Total thickness 112 feet

For the purposes of this study, the Intracoastal Limestone may be loosely divided into a younger, western, typical part that appears to be characteristic of the Gulf Coast Basin, and an older, eastern part that appears to be characteristic of the Apalachicola Embayment area. In addition to a temporal difference between the two parts of the formation, there also appears to be a lithologic difference as well. However, the core control, especially in the Apalachicola Embayment, is insufficient to be certain that the differences are systematic, and if so, what the ranges in lithologic variation are.

Lithology

In coastal Walton County, the type area of the formation, the Intracoastal Limestone is typically a soft, unconsolidated to slightly recrystallized, fossiliferous, sandy limestone. Calcite is the dominant mineral of the formation. Quartz sand is generally present and clay mineral, mica, and glauconite may be present. The basal part of the formation, where it gradationally overlies the phosphoritic sand unit, is phosphatic. Shells may be present in the section, but the aragonitic shells in the Walton County area are either chalky or leached. Oyster and pectenid shells are generally unaltered. Texturally the sediment varies from unconsolidated, granular, and even-textured to friable, brittle, and shaley-textured; and where macrofossils are present, to coarse-textured, rubbly, and bioclastic. Beds of calcareous sand, calcareous clay, and organic-rich, clayey coarse sand are present locally in the formation. The Intracoastal Limestone ordinarily is massive-bedded to thick-bedded, but scattered thin beds may be present.

The Intracoastal Limestone in the subsurface of the Apalachicola Embayment area appears to differ from the Walton County Intracoastal Limestone in being less sandy, less argillaceous, and less micaceous. Glauconite is less conspicuous except in the basal beds. The formation also tends to be more consolidated or indurated with some beds of hard, dense, fossiliferous, crystalline limestone in the upper part.

There are two known areas of outcrop of the eastern Intracoastal Limestone: one along the lower, Econfina Creek in Bay County, and the other in the vicinity of Carrabelle in Franklin County. The limestone in both these areas have, in the past, been referred to the Cancellaria Zone (Cooke and Mossom, 1929; Cooke, 1945; Puri, 1953). On Econfina Creek, where Fla. 388 crosses Econfina Creek 1.5 miles west of Bennett, Bay County, the outcropping Intracoastal Limestone consists of an indurated to partially indurated, sandy, shelly limestone; to a very calcareous, shelly sandstone. A similar lithology is exposed farther east in the vicinity of Carrabelle. The formation is exposed on New River about 5 miles northwest of Carrabelle, and in borrow pits in the vicinity of New River. The lithology here varies from a very calcareous, shelly soft and unconsolidated to partially indurated, sandy calcarenite; to a shelly, granular, even-textured, slightly indurated, soft limestone.

The principle differences between the outcropping and subsurface Intracoastal Limestone in the Apalachicola Embayment area is the sandiness and shelliness of the outcropping limestone.

Underlying and Overlying Units

In Walton County the Intracoastal Limestone conformably and gradationally overlies the phosphoritic sand unit. In the Apalachicola Embayment it paraconformably overlies the St. Joe Limestone in the St. George Island #1 (W-7574) and the Choctawhatchee equivalent limestone in the St. Joe #1 (W-12051). The formation probably overlies several other units in the subsurface of the Apalachicola Embayment area, such as the Chipola Formation, the Chipola equivalent limestone, the Torreya Formation, and the "Sopchoppy Limestone". With the present limited stratigraphic and subsurface control in the area, however, this cannot be documented.

Lithologic Distinction Between Adjacent Units

The Intracoastal Limestone is distinguished from the underlying phosphoritic sand unit in being a sandy, nonphosphatic limestone whereas the phosphoritic sand unit is a calcareous, coarsely glauconitic and phosphoritic, weathered-looking, sand or sandstone. The Intracoastal Limestone can be distinguished from the other limestones in the Walton County area by being typically a more argillaceous, micaceous, sandy, calcarenitic limestone that contains more coarsely fossiliferous intervals than the underlying limestones of the Coastal Group.

In the Apalachicola Embayment area the distinction between the eastern Intracoastal Limestone and the underlying limestones is not clear at this time due to lack of sufficient subsurface stratigraphic control. In general the Intracoastal Limestone is very similar to the lower member of the Choctawhatchee Formation and the Choctawhatchee equivalent limestone in the St. Joe #1 (W-12051). Both the Upper Miocene and Pliocene limestone sequences in that core begin with an unconsolidated to lightly indurated, granular, foraminiferal calcarenite limestone at the bases of the sections and grade upward into moderately indurated, coarse-textured, calcarenite limestone. The St. Joe Limestone interval in the St. George Island #1 (W-7574) is atypical in being much less coarsely foraminiferal than is generally found for that unit. On the other hand, the recovered part of the section is typical in being poorly consolidated whereas the Intracoastal Limestone in that area tends to be moderately indurated.

Areal Distribution and Thickness

The typical Intracoastal Limestone is restricted to the immediate coastal area of the subsurface of Walton County and it is not found north of Choctawhatchee Bay. There is insufficient subsurface control in adjacent coastal Okaloosa and Bay Counties to be certain of the extent of its occurrence there. The eastern part of the Intracoastal Limestone is found as far west and as far updip as Econfina Creek in Bay County. It is known to underlie the coastal area of the Apalachicola Embayment and it crops out in the vicinity of Carrabelle. The formation lies close to the surface under Carrabelle since chunks of impure limestone containing fossils of Jackson Bluff age are found on spoil heaps along the channel leading from the village to the Gulf. Numerous submerged, hard-bottom, limestone outcrops in the Gulf of Mexico off the coast of Franklin County may be Intracoastal Limestone.

The Intracoastal Limestone is uneven in thickness in Walton County. In the Coffeen #1 (W-8865) and Intracoastal Waterway #1 (W-8873) it is 103 feet and 112 feet respectively. In the Price #1 (W-8591), however, it is only 64 feet thick. There is too little core control in the Apalachicola Embayment area to discern any but the most general thickness patterns. In the St. Joe #1 (W-12051), near the depoaxis of the embayment, the Intracoastal Limestone is 149 feet thick. On the eastern flanks of the embayment, in the St. George Island #1 (W-7574), it is 63 feet thick.

Age

The following planktonic foraminifera have been identified from the Intracoastal Limestone in Walton County:

Globorotalia menardii s. l. (right coiling)
G. menardii multicamerata
G. menardii miocenica
G. menardii exilis
G. crassaformis s. l.
G. puncticulata
G. crassula crassula
G. crassula viola
G. tosaensis
G. hirsuta
G. acostaensis acostaensis
G. acostaensis humerosa
G. acostaensis pseudopima
Neogloboquadrina dutertrei
Globoquadrina altispira
G. venezuelana
Globigerina bulloides
G. apertura
G. rubescens
G. cf. *decoraperta*
G. parabulloides
G. calida praecalida
G. quinqueloba
Globigerinoides rubra
G. sacculifera quadrilobata
G. sacculifera sacculifera
G. sacculifera fistulosa

G. *obliqua* s. l.
G. *conglobata*
G. cf. *conglobata*
Sphaeroidinellopsis subdehiscens
S. *seminulina*
Sphaeroidinella dehiscens
Hastigerina siphonifera
Globigerinita glutinata
G. *uvula*
Orbulina universa
Pulleniatina obliquiloculata
Globorotaloides hexagona

The above list is misleading in that a number of species are restricted to the lower part of the unit, and other especially diagnostic forms are found in the middle to upper parts of the formation. The following species either become extinct or have their last local occurrence in the lower to middle part of the formation in Walton County:

Globoquadrina altispira
G. *venezuelana*
Sphaeroidinellopsis subdehiscens
S. *seminulina*
Globorotalia menardii s. l.
G. *menardii multicamerata*
G. *acostaensis acostaensis*
Globigerinoides cf. *conglobata*

The following species have been found only in the lower to middle part of the Intracoastal Limestone in Walton County:

Globorotalia tosaensis
Globigerinoides sacculifera fistulosa

The following species are characteristic and found only in the upper part of the formation in Walton County:

Globorotalia menardii miocenica
G. *menardii exilis*
Neogloboquadrina dutertrei
Pulleniatina obliquiloculata

The following species of planktonic foraminifera have been identified from the Intracoastal Limestone in the Apalachicola Embayment area:

- Globorotalia menardii s. l. (right- and random-coiling)
- G. menardii multicamerata
- G. crassaformis s. l.
- G. puncticulata
- G. margaritae
- G. crassula crassula
- G. crassula viola
- G. hirsuta
- G. acostaensis acostaensis (random-coiling and right-coiling)
- G. acostaensis humerosa (random-coiling and right-coiling)
- Globoquadrina altispira
- Globigerina bulloides
- G. parabulloides
- G. apertura
- G. nepenthes
- G. cf. decoraperta
- G. quinqueloba
- Globigerinoides rubra
- G. sacculifera sacculifera
- G. sacculifera quadrilobata
- G. obliqua s. l.
- G. cf. conglobata
- Sphaeroidinellopsis subdehiscens
- S. seminulina
- Sphaeroidinella dehiscens
- Hastigerina siphonifera
- Globigerinita glutinata
- G. uvula
- Orbulina universa
- Globorotaloides hexagona

Only the basal Intracoastal Limestone in the St. George Island #1 (W-7574) contains an assemblage with Globigerina nepenthes, Globorotalia margaritae, random-coiled G. menardii, and random-coiled G. acostaensis s.l. The rest of the known formation in the Apalachicola Embayment area contains essentially a Jackson Bluff to immediately post-Jackson Bluff planktonic foraminiferal association that is characterized by the presence of Globoquadrina altispira, Globorotalia crassula s. l., Globorotalia hirsuta, and Sphaeroidinellopsis spp. (see discussion of Jackson Bluff planktonic foraminiferal assemblage on p. 107-110).

In the zonation scheme of Berggren (1973), the Intracoastal Limestone ranges from zones PL1 to PL5 (PL2 has not yet been identified in the formation). The Intracoastal Limestone includes the Globorotalia margaritae evoluta Lineage-zone, the Sphaeroidinellopsis subdehiscens Interval-zone, and the Globigerinoides obliquus extremus Interval-zone of Cita (1973) zones N19 to N21 of Blow (1969); and the Pulleniatina primalis Subzone of the Globorotalia margaritae Zone, the Pulleniatina obliquiloculata Zone, and the Globorotalia tosaensis Zone of Lamb and Beard (1972).

The Intracoastal Limestone ranges from late, Early Pliocene to Late Pliocene in age as is in the upper Zanclian and Piacenzian Stages of Europe.

As noted near the beginning of this section, there is an apparent time distinction, with the present information, as well as a lithologic distinction between the western and eastern parts of the Intracoastal Limestone. The western, typical part of the Intracoastal Limestone is entirely Late Pliocene in age (PL3 - PL5). The oldest beds in the Intracoastal Limestone of Walton County are Jackson Bluff in age (PL3 - PL4). On the other hand, Intracoastal sedimentation began in the Apalachicola Embayment in Early Pliocene, pre-Jackson Bluff time (PL1) and the youngest beds currently recognized are Jackson Bluff or slightly post-Jackson Bluff in age (PL4). In terms of time, the common denominator between the western and eastern Intracoastal Limestone is the Jackson Bluff sedimentational episode (PL3 to earliest PL4).

The present evidence suggests that the eastern Intracoastal Limestone is fully equivalent to the phosphoritic sand unit of Walton

County (see discussion of age of the phosphoritic sand unit on p. 113-116) whereas the time equivalent of much of the typical Intracoastal Limestone of Walton County is not present in the Apalachicola Embayment.

DISCUSSION

Depositional Units and Depositional Intervals

There are a number of small scale, quasi-chronostratigraphic units in the study area that for convenience are referred to in this study as depositional units (similar to depositional sequences of Frazier, 1969). Depositional units differ in only two significant ways from chronostratigraphic units, (1) they are necessarily bounded above and below by stratigraphic discontinuities that represent intervals of nondeposition to erosion, and (2) the time intervals of nondeposition or erosion are of equal significance in this stratigraphic system to material deposits in the geologic record. The formal recognition of both the material deposits and the intervening absence of deposits in the geologic record. The formal recognition of both the material deposits and the intervening absence of deposits in the geologic record, and the placing of both in a time framework, produces subtle changes in the kinds of information derived from application of this system as opposed to the standard chronostratigraphic system (Am. Comm. Strat. Nom., 1970; Intern. Subcomm. Strat. Class., Rept. 7, 1972). The depositional units in this study emerge as a sort of tectono-stratigraphic unit in that they were formed during discrete basin filling events that resulted from epeirogenic subsidence of the continental margin. They are, like chronostratigraphic units, material deposits of diverse lithologies that cut across facies change from one formation to another. They are, however, more like lithostratigraphic units in that they are of local to regional extent and are probably not of continental or world-wide extent.

Depositional intervals are the intervals of time over which sedimentation of the various depositional units took place (depositional episode of Frazier, 1969). Although the depositional units in the study area are bounded rather precisely in time, they are diachronous in that the time span of a depositional unit in any one section is less than the total time span of the unit based on accumulated sections.

At least six depositional intervals are recognized in this study. These include (1) the Chipola interval, (2) the Bruce Creek/Oak Grove interval, (3) the lower Shoal River/St. Joe interval, (4) the middle and upper Shoal River/St. Joe interval, (5) the Choctawhatchee interval, and (6) the phosphoritic sand unit/Intracoastal/Jackson Bluff interval. In addition there is some evidence that the upper Pleistocene may represent a discrete depositional interval. A hiatus that is not present in the Intracoastal Waterway #1 (W-8873) opens up to the west, resulting in the separation of the phosphoritic sand unit from the Intracoastal Limestone in the Coffeen #1 (W-8865). Although there is too little core control to be confident of this particular hiatus, it does suggest that the lower Pliocene and upper Pliocene represent two distinct depositional intervals farther west.

Nondepositional Intervals

The time intervals of nondeposition (lacunae in part) are as laterally persistent as the depositional intervals in the study area. Six nondepositional intervals, or hiatuses, have been traced in the study area and at least two more subtle hiatuses may be present. These nondepositional intervals include the following from older to younger: (1) the late Oligocene through early Miocene hiatus, (2) a subtle but consistent hiatus between the Chipola and Bruce Creek, (3) the hiatus separating the Bruce Creek/Oak Grove from the Shoal River, (4) the hiatus or depositional minimum between the lower and middle Shoal River, (5) the hiatus between the middle and late Miocene, and (6) the hiatus between the Miocene and Pliocene.

There is almost certainly a hiatus between the Pliocene depositional interval and the late Pleistocene-Holocene sands under the present coast. However, these sands are fossiliferous only in the Apalachicola Embayment, and even there, the lower part of the interval is nonfossiliferous. Because the Pliocene sediments grade upward into the "Pleistocene" sand lithology and there are no clear physical breaks within the sand sequence, the nature of the Pliocene-Pleistocene transition is not clear in the study area. Since the Pleistocene sands are almost all nonfossiliferous coastal deposits overlying nonfossiliferous, regressive sands, this particular hiatus differs as a consequence from those in the older deposits. Any open marine, fossiliferous Pleistocene sediments, if present, must lie offshore and therefore the Pliocene-Pleistocene nondepositional interval cannot be evaluated in this study.

As with the depositional intervals present in the study area, the nondepositional intervals also (and necessarily) are bounded rather precisely by time. Their slight diachroneity is reciprocal to that of the depositional units.

The physical and temporal nature of the contacts between the depositional units is critical in evaluating the nature of the paraconformities and the environment and physical conditions that may have prevailed during the nondepositional phase. It is consequently useful at this point to give an account of the physical characteristics of the various contacts between the depositional units in the study area.

For convenience of discussion, the paraconformities may be divided into three kinds, (1) paraconformities with no significant lithology change across the contact, (2) paraconformities with abrupt lithology change and with no mineralogical alterations or concentrations, and (3) paraconformities with abrupt lithology change and with mineralogical alterations and/or concentrations present above or below the contact. These three "kinds" of paraconformities are not exclusive but form a continuum so that it is often difficult to categorize them. It is self evident that the paraconformities with no lithology change are restricted to those paraconformities within a lithosome. The paraconformities where there is abrupt lithology change may occur within a lithosome or between lithosomes.

It is significant that most of the definite paraconformities in the study area includes local examples where there is no lithology change across the contact between depositional units. In this kind of paraconformity, the lithologies on either side of the contact are essentially the same. There is no alteration of the underlying deposit and there are no concentrations of unconformity sediments such as lag deposits, glauconite, phosphorite, or pebbles or clasts of the underlying unit. The contact can be identified with certainty only by paleontological means. It appears from examination of the cores that sedimentation simply ceased, and after some interval of time that may have been as much as 5 million years, sedimentation began again with no apparent change in conditions. Commonly planktonic foraminifera from the underlying unit are reworked into the basal few feet of overlying sediments. The preservation of the reworked foraminifera generally is no different than that of the in situ foraminifera and is almost always excellent. On the other hand the writer has not observed any foraminifera from the overlying unit reworked into the underlying deposit. This suggests that burrowing and mixing of the upper-most horizons of the underlying deposits by burrowing organisms has not been extensive, and that only very gentle and local reworking of the underlying deposits occurred upon initiation of sedimentation.

Paraconformities with abrupt lithology change but with no apparent mineralogical alterations or concentrations in the overlying or underlying beds are the most common type in the study area. In this type of paraconformity there is no evidence of chemical or physical alterations in the upper-most horizons of the underlying deposits. There is no evidence for solution, oxidation, dolomitization, or mineralization. Similarly there are no concentrations of lag deposits, glauconite, phosphorite, or reworking of the underlying sediments in the basal beds or the overlying units. This is the kind of contact that exists between the Miocene and the Oligocene in west Florida and has been referred to as "unconformable" in the past (Matson and Clapp, 1909).

There is a "twilight" zone between the paraconformities with evidence of alteration or concentrations and those paraconformities without evidence of alteration or concentrations. As a result it is sometimes difficult to judge by simple examination of a core if alteration in fact exists. The alteration in an underlying limestone may consist of dolomitization or more subtly, of induration of the limestone. In the Hunt #1 (W-10954) the topmost clays of the Chipola Formation, underlying the Jackson Bluff Formation, have been indurated to claystone while the upper ten feet of the limestone of the Chattahoochee Formation has been dolomitized and contains manganese dendrites immediately below the top of the formation. It is commonly difficult to determine whether induration of limestone under a paraconformity is a result of physical conditions during the development of the paraconformity or whether induration preceded the paraconformity. The Oligocene carbonates in the study area are typically indurated and often contain dolomite, and the presence of indurated limestone or dolomite underlying the Oligocene/Miocene paraconformity is not necessarily a function of physical conditions during the development of that paraconformity.

It is stressed that evidence of solution or scour in the underlying deposits has not been observed in association with paraconformities or diastems in the study area.

Basal deposits of units overlying paraconformities commonly contain sediments that differ markedly from the lithologies of the rest of the overlying units. These basal deposits are no more than a few feet thick and are often loose and unconsolidated. They are arenaceous in texture with the principal component of the lithology being either quartz sand or calcarenite. Generally these basal sediments are somewhat phosphoritic and/or glauconitic and small shells and shell fragments are common (especially of the pectens). Irregular shaped, heavily bored, phosphatic dolomite pebbles that may have a shiny, black glaze are locally common. These dolomite pebbles appear to be present only where limestone underlies the paraconformity. They are especially common at the Bruce Creek/Chipola paraconformity, and at the Shoal River-St. Joe/Bruce Creek paraconformity. Finally, it is common that the basal sediments of this paraconformity type contain more quartz sand than both the underlying and overlying deposits.

There is clear evidence of only one disconformity in the study area. This is the stratigraphic discontinuity that underlies the Citronelle Formation. The Citronelle/Miocene disconformity is distinctive in that the basal Citronelle sediments typically are gravelly and appear to be channel deposits. The topmost beds of the Miocene underlying the Citronelle Formation are invariably oxidized, and the Miocene surface on which the Citronelle was deposited is quite irregular in the western half of Walton County. The oxidation of the underlying Miocene sediments may not necessarily be related to the disconformity in view of the fact that alteration could be a relatively recent result of watertable lowering and ground water activity. On the other hand the irregular surface on top of the Miocene must almost certainly be due to pre-Citronelle erosion and dissection because there is reciprocal thickening and thinning of the Citronelle Formation on the Miocene surface.

The paraconformity at the base of the Jackson Bluff Formation is distinctive in the study area in that it contains clasts of the underlying "Hawthorn Formation" and exhibits truncation of foreset beds as at Alum Bluff. It does, therefore, show signs of active erosion prior to sedimentation.

Dynamic Equilibrium and Base Level

The sedimentational model adopted in this study is consistent with the theories of sedimentation developed by Barrell (1917) and refined by Dunbar and Rodgers (1957) and Wheeler (1964). The principal factors controlling sedimentation in this scheme are equilibrium, sediment influx, and subsidence. Dynamic equilibrium exists on the sea floor when the current regime (oscillatory wave motion, long shore currents, and other local bottom currents) and the sediment input are in delicate equilibrium at the sediment/water interface. This state may be said to exist when for every particle of detritus generated at or carried into an epeirogenically stable site, whether it be terrigenous clastic, biogenic debris, glauconite, or phosphorite grain, another particle is removed to another site. The equilibrium is directly related to the amount of wave and current energy, volume of sediment input, and size of the sedimentary particles. For example the greater the influx of sediment, the greater the energy level or competence of the currents required to maintain the balance of input and output. The sea floor in this kind of equilibrium may be envisaged as not only being a region of sedimentary bypass, it is also a region of nonaccumulation of sediments. Biogenic debris, glauconite, phosphorite grains and mica could well leave the system by physical attrition.

Sedimentational dynamic equilibrium of this kind is a state that can be achieved and maintained only in a stable environment. Frequently changing current velocities, frequent changes in relative sea level, whether the cause be epeirogenesis or eustatic changes, and changing volumes of sediment influx are not conducive to equilibrium. In order to maintain dynamic equilibrium on a sea floor where there are no frequent or abrupt changes in at least one of the parameters of sedimentation, there must be precisely equal or compensatory changes in at least one of the other parameters. It would seem that such a degree of offsetting change would be an improbable event. For example, to maintain dynamic equilibrium over broad areas of the continental shelf during or after an abrupt relative rise in sea level would require a general increase in current velocities and/or a general decrease in sediment input. Current velocities are a function of climate and wind. On the other hand, sediment input is complex in that there are four general sources of sediment on the shelf: the erosion of the continent, marine biological activity, chemically derived or altered sediments that are generated in situ such as phosphorite, and possibly erosion of the continental shelf. Therefore a relative rise in sea level, which would be interpreted as a marine transgression, would require a climatic change, and/or a tectonic change plus a reduction in biological production on the shelf for dynamic equilibrium to be maintained. As a result of equilibrium, the marine transgression, which would be accompanied by a series of changes that would qualify as a geological event, would go unnoticed in the geologic record. It is doubtful whether such a series of changes could be effected without at least a temporary loss of equilibrium.

Barrell (1917) extended Powell's (1875) concept of base level to the marine environment. He considered base level to represent a plane of equilibrium. Any area of the sea floor that exists above the plane of equilibrium, i.e., above base level, would undergo erosion. The area of the sea floor that lies beneath base level would be subject to sedimentation. Periods of equilibrium are essential to the formation of diastems in the geologic record, diastems being temporally immeasurable breaks in the stratigraphic record. Barrell did not relate the periods of equilibrium to hiatuses in the stratigraphic record of greater magnitude than diastem.

Dunbar and Rodgers (1957) referred to the equilibrium condition as the baselevel of aggradation. However, they believed that "no such condition exists in nature" (1957, p. 130) in that equilibrium "varies from day to day with the passing storms, and from season to season as the prevailing weather changes. . . . Thus the baselevel of aggradation constantly fluctuates, so that perfect equilibrium is never attained over any considerable area or maintained for any considerable length of time."

Wheeler (1964) envisaged base level "generally as an intensely active surface, and with the lithosphere surface in virtually all areas lying within the field of amplitude of its incessant "vibrations"." It is only where the base level surface intersects the lithosphere that a state of equilibrium exists. Apparently Wheeler was also of the opinion that the condition of equilibrium for all practical purposes does not exist in nature since he referred to the line of intersection of the lithosphere surface and the base level surface as a baselevel transit contour. Since the base level surface is always migrating upward or downward, the baselevel transit contour must also be constantly moving across the lithosphere surface.

It is the contention of the present writer that broad areas of the sea floor, perhaps as much as several thousand square miles of shelf in the study area, may have been in a state of dynamic equilibrium for extended periods of time. Certainly the point raised by Dunbar and Rodgers (1957, p. 130) that base level must vary from day to day, storm to storm, and season to season cannot be denied. However, the effects of the vertical, oscillatory base level migrations may be viewed from both a short term perspective (days, years, centuries, etc.) and from the long term perspective of geologic time. The amplitude of base level migration or oscillation through geologic time may be referred to as the zone of base level migration. The zone of base level migration is that range of oscillation of base level between the low energy, calm periods and the high energy, violent storm periods at a given site. During the periods of low energy, base level would stand well above the sea floor and conditions of sedimentation would prevail. During the more violent storms or periods of vigorous current activity, base level would extend below the sediment/water interface and marine erosion would temporarily set in. The depth of the sea floor relative to sea level would depend on the cumulative positions of base level for the area and would always be within the zone of base level migration. Within this zone the sediments would be alternately deposited and reworked. The depth of reworking should depend on the extremes of the energy expended on the sea floor at that site, on the grain size of the sediments, the degree of compaction and/or recrystallization, and to some extent on the amount of sediment being bypassed over the site. If the zone of base level migration were stable relative to sea level, the sea floor would silt up to some stable level within the zone and should remain at that depth relative to sea level if all other parameters of the sedimentational system remain unchanged. Since the bottom reworking would occur monthly, seasonally, or over some longer time intervals, all fossils would be destroyed in the reworked zone from physical attrition. As a result, when sedimentation is again established, the reworked zone would be incorporated into the overlying deposit and there would be no indication of fossils of intermediate age between the underlying deposit and the basal reworked zone of the overlying deposit.

Evidence of periods of dynamic equilibrium in the geologic record are necessarily subtle and elusive since the condition of dynamic equilibrium must result in absence of record. The recognition or postulation of equilibrium therefore must be a probability and cannot be a certainty. It must be based on various lines of evidence of a regional and local nature, such as absence of evidence of erosion in the underlying deposits or clasts of the underlying deposit reworked into the basal sediments of the overlying deposit, regional thickness distributions, and the interpretation of the physical nature of the paraconformities.

Corollary to the concept of equilibrium are two states of disequilibrium. In one case of disequilibrium (sedimentational phase) the sediment influx is greater than the current energy required to keep the sediment in active transport. This phase of disequilibrium may be brought about by several different processes. Tectonic subsidence or eustatic rise in sea level may cause a deepening of the water and a consequent decrease in current energy impinging on the sediment/water interface. Daily, seasonal, or long term climatic changes which effect the current velocities and directions on the continental shelf may result in less current activity. On the other hand current velocities may remain relatively constant but an increase in sediment influx will result in sedimentation.

In the erosion or degradation phase of disequilibrium the current energy is greater than that needed to keep the incoming sediment in active transport and as a result, some of the energy is expended in removing previously deposited sediments. Tectonic uplift or eustatic fall in sea level could result in an increase in current energy on the seafloor. Decrease in sediment influx should likewise result in more current energy available to erode the previously deposited sediments.

The state of disequilibrium reflects instability in the environment. Disequilibrium results from the change in at least one of the parameters of sedimentation without compensatory change in the other parameters. If the disruptional changes were episodic rather than continual, the sedimentation system should readjust itself in time to reattain the state of dynamic equilibrium.

It must be stressed that the conditions favoring dynamic equilibrium on the continental shelf are variable. It is clear that the sedimentational regime on the topset beds of a delta or a prograding wedge of sediments is going to be different from that on the foreset beds or on the bottomset beds. In the far offshore, deeper water areas of the shelf, dynamic equilibrium may be attained locally under conditions of low current velocities and low input of terrigenous detritus and biogenic debris. In the shallow water, nearshore area, equilibrium can be attained under conditions of higher current velocities and greater influx of terrigenous clastics and biogenic debris. On carbonate banks or reefs, biological activity may be so intense that the upper limit of sedimentation is the intertidal zone and conditions of sedimentational equilibrium or disequilibrium do not pertain, except that sedimentation overwhelms all other parameters of the sedimentational system.

The principles described above are less clear cut and simple when considered in terms of the zone of base level migration. If the region of the continental shelf under consideration is subsiding very slowly, then the sediment/water interface should always remain within the zone of base level migration. The evidence of this condition in the geologic record should be similar to the condition of dynamic equilibrium except there would be a slow net accumulation of sediments. Conversely it is conceivable that a very gradual lowering of the zone of base level migration would also leave the sediment/water interface within the zone of base level migration. In that case the condition of degradation of the underlying deposit could hardly be distinguished at the paraconformity from the condition of equilibrium if the underlying deposits were relatively unconsolidated. The presence of reworked foraminifera in the basal bed of the overlying deposit would not necessarily be sufficient evidence for degradation because there may still be some pavement of the older deposit exposed during the inception of sedimentation of the younger deposit. Still, however, presence of gently reworked planktonic foraminifera in the basal bed of the overlying deposit would be more suggestive of very gradual degradation of the underlying deposit within the zone of base level migration.

It is apparent that within this relatively stable area of the Coastal Plain in western Florida that there must have been only a slight, but real, distinction between conditions of sedimentation equilibrium and conditions of sedimentational disequilibrium. In the two cores that contain all three parts of the Shoal River age deposits, the Adkinson #1 (W-11045) and the St. Joe #1 (W-12051), the average rates of sedimentation calculated on the basis of the time scale of Berggren and van Couvering (1974) are 2.8 cm/1000 years and 2.6 cm/1000 years respectively. Furthermore, based on the same time scale, the average rate of sedimentation for the middle and upper Shoal River in the Eglin #1 (W-8351) which contains the thickest Shoal River section in the study area is only 8.9 cm/1000 years. These values are very low and compare with sedimentation rates of the bathyal and abyssal zones of the world oceans. These rates are especially significant since the Shoal River sections contain mainly sand and clay with a very low concentration of foraminifera while the St. Joe sections contain essentially a foraminiferal coquina. Obviously the type of sediments deposited had little influence on the rates of sedimentation.

Chemical Equilibrium

Chemical equilibrium may be another factor involved in the indistinctness of some of the paraconformities in the study area. If the sediments on the sea floor were not in chemical equilibrium with the overlying watermass, then solution or recrystallization of some previously existing minerals, or precipitation of new minerals would be expected to occur in the sediments on the ancient sea floor. This must certainly be the origin of the heavily bored, pyritic, phosphatic dolomite pebbles that appear to be concentrated at the Bruce Creek/Chipola equivalent limestone contact and at the Shoal River/Bruce Creek contact.

Since there is rarely evidence for chemical activity at some of the paraconformities, notably the Shoal River/Choctawhatchee contact, this is regarded as evidence that chemical equilibrium prevailed during some of the nondepositional phases.

Sediment Sources

There are two sources for the greater part of the Neogene sediment mass of western Florida. These are the continent which supplied the terrigenous clastics, and biological activity which supplied the biogenic debris. Chemically precipitated or altered sediments such as dolomite, palygorskite (attapulgite), sepiolite, glauconite, and apatite are quantitatively minor lithologic components.

It is apparent from the geometry of the terrigenous clastic deposits after an examination of Figures 14, 15, 16, and 18 that the great bulk of the sands and clays were derived either from a western source via the long shore drift system, or that they were derived from a local source and were trapped in narrow, subsiding east-west blocks. It is important to note that the principal direction of the longshore drift during at least the depositional phases of the Miocene in the first case would have to have been reversed from that of the present direction and would have to have been from west to east. In addition to a postulated western source of clastics there would certainly have been a local source. This source includes the rivers that discharged into the Gulf of Mexico in the study area. However, from the perspective of this study it is impossible to evaluate the relative sediment contributions from either a local source or a postulated western source. Only in the Apalachicola and Chipola River area can the locally distinctive sand

and clay facies of the Jackson Bluff Formation be certainly ascribed to a local source because the lithology is found neither to the east nor to the west of that area.

The source of the calcium carbonate in the limestones and calcareous sediments of the study area is almost wholly biogenic debris. It is possible that some of the limestone beds in the updip Chipola equivalent sands may have resulted from direct precipitation, but in the normal marine sections there is no evidence, from simple examination of the cores, for this source of calcium carbonate.

There are two discrete sources of biogenic debris. One source consists of mainly a shallow water, benthic biota such as molluscs, echinoderms, ostracods, bryozoans, and corals with a smaller component of both larger and smaller benthonic foraminifera and planktonic foraminifera and possibly calcareous nannoplankton. The two sources of bioclastic debris are not exclusive and there is almost always at least a small component of one of the sources present in the calcareous sediments.

The calcareous sediments constructed with the remains of the shallow water biota are generally coarser textured and less well sorted. The source of this biogenic debris was the skeletal material of organisms that inhabited the ancient sea floor. After death however, the skeletal debris was usually disarticulated and abraded due to current activity and the vertical reworking due to base level oscillations. Some of the calcareous material was broken down further from comminution by other organisms. As a result, coarsely bioclastic, rudaceous limestones are not common in these deposits. Typically the limestones and calcareous sediments are coarse, moderate to poorly sorted calcarenites.

The foraminiferal limestones consist mainly of smaller benthonic foraminifera, planktonic foraminifera, and possibly calcareous nannoplankton. Commonly the foraminiferal assemblage is dominated by planktonic foraminifera to the extent that the sediments resemble coarse textured Globigerina ooze of the deep sea. The distinction in the sources of the two limestone types is that one is composed mainly of skeletal debris of organisms that lived on the sea floor, and the other is composed mainly of minute, skeletal debris much of which rained down on the sea floor from the overlying watermass.

Epeirogenesis and Eustatic Sea Level Changes

It is clear from the earlier discussion that sedimentation was periodic during the Neogene in western Florida. What is not clear at this point is whether the depositional intervals were punctuated by intervals of tectonic stability with a delicate balance between current energy and sediment input, or whether they were punctuated by intervals of relative uplift and degradation, thus removing at least part of the deposits of intervening age from the paraconformities (Lacunae in the strict sense). It is the objective in this section to examine the evidence bearing on these alternatives, and finally to examine the possible causes of the local periodic sedimentation.

It is apparent from the literature that most stratigraphers consciously or subconsciously lean toward the premise that either sedimentation or erosion must prevail at any given site on the lithosphere over any extended period of time. If that is the case we should expect to find evidence of (1) erosion and degradation at the various paraconformities, or (2) we should, perhaps, expect to find Miocene marine sedimentary deposits at elevations too high to be attributable to simple eustatic lowering of sea level, thus giving evidence of epeiroganic uplift, or (3) we should expect to find Miocene deposits wedging out on the flanks of positive structures due to erosion and truncation.

It is clear from the discussion on paraconformities that there is little consistent evidence of active erosion at the paraconformities. The evidence for degradation is subtle. If it exists, the paraconformity most likely would be located within the zone of base level migration. This being the case the only positive evidence for degradation would be the presence of reworked planktonic foraminifera from the underlying deposit and the presence of the bored, phosphatic dolomite pebbles concentrated near several of the paraconformities.

These bored pebbles are especially curious in that commonly they have been so heavily bored by organisms (probably by members of the pelecypod Superfamily Pholadacea) that they appear frothy. They are generally covered with a black glaze of unknown composition and therefore may resemble pumice. Chemical analyses of five of these pebbles show that they are mainly pyritic, very phosphatic, dolomite or dolomitic limestone. The mineralogies of these pebbles differ significantly from the mineralogies of the underlying, overlying, and adjacent deposits. There are no older formations or beds in the study area that contain this particular lithology. These pebbles are, therefore, mineralogically exotic.

It is postulated that these pebbles formed on the sea floor as a sort of pavement during a period of time when the sediments and the overlying watermasses were not in chemical equilibrium and when the sedimentational system was either in a state of dynamic equilibrium or very mild degradational disequilibrium. If the pebbles lay exposed to the watermass for any significant period of time, then even the zone of base level migration must have been very narrow and little, if any, reworking of the underlying deposits was likely.

Epeirogenic uplift, and therefore indirect evidence supporting degradation, can be demonstrated only if the marine deposits occur at an elevation too high for the difference in their elevation and present sea level to have resulted from simple eustatic lowering of sea level. Epeirogenic uplift also can be inferred if the bathymetric interpretation of the benthonic faunas in the marine deposits likewise require an ancient sea level stand to have occurred at an elevation too high for the differences in elevation between the ancient sea level and present sea level to be attributable to eustatic lowering of sea level.

In Walton County the highest marine Miocene deposits are the updip Chipola equivalent sands that are found at elevations up to 235 feet above sea level. The highest occurring Shoal River deposits are around 220 feet above sea level whereas the Choctawhatchee Formation is 165 feet. The highest occurring Jackson Bluff Formation is 135 feet in the vicinity of Alum Bluff. The elevations of all the deposits listed above include the very shallow water regressive phases and probably do not vary appreciably from sea level at the time of deposition of the units. All of these deposits are thin and are of shallow water origin. The Choctawhatchee Formation is the thickest terrigenous clastic unit in the study area and ranges in thickness from 67 feet to 231 feet. Even if penecontemporaneous subsidence did not occur during sedimentation of the

Choctawhatchee, and its basal beds were deposited in water depths between 200 and 250 feet deep, the benthonic foraminiferal fauna is not inconsistent with a middle neritic environment (see Cushman, 1931; Cushman and Ponton, 1932). It is not consistent however, with an outer neritic environment postulated by Bandy (1956) and by Puri (1953).

The amount of sea water locked up in glacial ice in Greenland and Antarctica is sufficient to have caused a lowering of about 400 feet in the sea level of the world. Therefore the elevations of marine deposits do not offer unequivocal evidence supporting epeirogenic uplift. In addition, none of the shallow water, clastic deposits in western Florida were deposited in water of sufficient depth to demand a sea level stand greater than the highest occurring Miocene deposit at 235 feet above sea level.

Demonstrated truncation or even nonexistence of units on the flanks or crest of the Chattahoochee Arch could suggest, but not prove, that at least subtle, local epeirogenic uplift occurred. A positive feature such as an "arch" would be the most likely place to seek evidence of uplift. Vernon (1942) reported the Shoal River from the western flanks of the arch in western Washington County and the Choctawhatchee from the western flanks and the crest in northern Bay County. The Chipola passes over the arch without thinning whereas the Jackson Bluff overlaps the arch from the east and grades into noncalcareous sands on the western flanks of the arch (Fig. 20). The arch evidently had little or no influence on either Chipola or Jackson Bluff sedimentation and the presence of the other two important Miocene depositional units on the flanks and crest of the arch require there to have been little if any erosion subsequent to deposition of the units. It is concluded, therefore, that the Chattahoochee Arch was not involved in epeirogenic uplift in the study area during the Neogene. It appears, rather, that the area of the arch has the general aspect and features of a stable sedimentary shelf.

Since it must be concluded that there is no evidence of uplift within the area under study in western Florida, we are left with two possible explanations for the formation of the nondepositional intervals or hiatuses. Either the hiatuses formed during periods of tectonic stability as a result of sedimentational equilibrium on the sea floor, or they resulted from degradation and erosion on the sea floor due to eustatic lowering of sea level. If the hiatuses were formed as a result of eustatic lowering of sea level, then there is no apparent reason for a concomitant reduction in sediment influx on the continental shelf. At each low sea level stand, one would expect to find nearshore, sandy shell beds or beach deposits developed in the shallow subsurface sandwiched between deeper water, microfossiliferous deposits. This however is not the case. Based on both the absence of very nearshore and beach sedimentary associations and very shallow water benthonic foraminiferal associations, there are no nearshore-type deposits in the downdip sections in the west Florida subsurface. All of the shallow water, shelly clastic wedges with the very shallow water, brackish marine benthonic foraminiferal faunas are found in the updip areas. As a result there is also no unequivocal evidence supporting periodic eustatic lowering of sea level as an explanation for the formation of the various hiatuses. In the one hiatus where there is evidence of erosion in the updip area, i.e., the disconformity underlving the Citronelle Formation, there is no evidence of dissection below present sealevel. And with one possible exception in the Bruce #1 (W-8592), there is also no evidence of a shallow water shell bed associated with this interval.

It is concluded that there is in west Florida neither definite evidence for epeirogenic uplift nor evidence for recurrent eustatic lowering of sea level before the end of the Miocene or during the Pliocene depositional interval. There is, however, evidence that sea level has gradually dropped through Miocene and Pliocene time (see Page 169) but this lowering of sea level was not evidently of a recurring nature and consequently would not show the extreme variations in sea level such as are known to exist in the Pleistocene. As a result the paraconformities cannot be related to repeated lowering of relative sea level.

It may be suggested that the depositional intervals are. on the other hand, effects of eustatic lowering of sea level and that the sediments deposited during the intervening nondepositional intervals were updip deposits that have long been stripped off due to erosion and degradation. Little can be said of this alternative explanation because there is little evidence to either support it or reject it. The disconformity and paraconformity between the Miocene and Pliocene deposits may be sited as evidence for either case because it would take a very significant lowering of sea level from the very high stand to cause the dissection of the Miocene "offshore" deposits. Yet it would take relatively little lowering of sea level from those levels postulated in the earlier pages to cause the dissection at the end of the Miocene.

According to the Tertiary time scale presented by Berggren (1972) and Berggren and van Couvering (1974) (see also Figs. 4 and 5) the Oligocene/Miocene hiatus includes a time interval of approximately 15 million years in the study area, the middle/late Miocene hiatus includes an interval of approximately 5 million years, and the Miocene/Pliocene hiatus includes about 3 million years. It can be seen from Figures 4 and 5 that each of the depositional intervals probably does not exceed 1.5 million years in duration and is generally less. Therefore, assuming that simple eustatic sea level changes alone could not alter the volume of sediment influx into the study area, a much greater volume of sediments would have to have been removed from the study area than there is present there today. Certainly the removal and bypassing of so much terrigenous clastic sediment should have left some imprint on the paraconformities in the form of scour and lag deposits. That these geological features are either very rare or not apparent in the study area is further evidence against the depositional units being results of eustatic lowering of sea level.

Without recurrent high and low stands of sea level or epeirogenic uplifts, the only controls of sedimentation left that are possible factors of deposition in the west Florida Neogene are subsidence, stability, and fluctuations in sediment influx.

The evidence for subsidence in the study area is both elementary and clear. Shallow water limestones containing common algal balls, molluscan molds and impressions, and palygorskite clay (Apalachicola Embayment only) now occur at outer neritic to upper bathyal depths relative to present sea level in both the Apalachicola Embayment and the Gulf Coast Basin. In addition, the benthonic foraminiferal faunas in the downdip Chipola limestone and the Bruce Creek Limestone are relatively shallow water assemblages that indicate water depths no greater than shallow middle neritic.

By the simple existence of the depositional units in western Florida it must be accepted that sedimentation was periodic. And since there is no evidence for epeirogenic uplift or recurring high and low sea level stands during the Miocene and Pliocene, it must be concluded that the nondepositional intervals must represent intervals of time when the sea floor was roughly in a state of sedimentational dynamic equilibrium. That being accepted, it follows that the depositional intervals represent periods of sediment accumulation due to the state of sedimentary disequilibrium. Therefore, the intervals of time when there was accumulation of sediments on the inner continental shelf of western Florida were periods of subsidence or downwarping on the continental margins of the northeastern Gulf of Mexico. Similarly the intervening intervals of time represent periods of stability on the continental margin.

The concept of sedimentational dynamic equilibrium, sedimentational disequilibrium, and general tectonic stability punctuated by brief periods of tectonic instability and subsidence is sufficient for explaining many of the west Florida Neogene characteristics of sedimentation. It also explains well enough the sudden, simultaneous inception of both terrigenous clastic sedimentation in the updip, nearshore areas, and carbonate sedimentation in the downdip, offshore areas. It also can explain the abrupt termination of offshore, bioclastic sedimentation. It does not, however, explain the apparent termination of nearshore terrigenous clastic sedimentation at the end of Chipola, Shoal River. and

Choctawhatchee times. This problem is especially acute with the termination of upper Shoal River and Choctawhatchee sedimentation in that these deposits thin and pinch out downdip, leaving a paraconformity between the St. Joe Limestone of middle Shoal River age and deposits of early and late Pliocene age.

Two possible explanations for this aspect of the problem are suggested, (1) all terrigenous clastic sediments were bypassed over the sea floor, and (2) the terrigenous clastic influx was either terminated or severely reduced during the periods of nondeposition. In the first case, dynamic equilibrium caused the terrigenous clastics to be bypassed while in the second case dynamic equilibrium was caused by a real reduction in terrigenous clastic influx. Yet a real reduction in the terrigenous clastic influx prior to the establishment of sedimentational dynamic equilibrium should have resulted in an upward increase in bioclastic sedimentation during the depositional periods. This is not the case. On the other hand there is only scant evidence that sand was being bypassed during the nondepositional intervals because the basal beds of the depositional units, interpreted in this study as being equilibrium deposits of the zone of base level migration "trapped" at the inception of subsidence, are only slightly and occasionally quartzose sandy. It may be that both explanations are in part correct, that there was both a real reduction in terrigenous clastic influx and the terrigenous clastic sediments that were still being supplied to the shelf were being bypassed.

There are two possible causes for the reduction in the terrigenous clastic input in the study area. The first is a real reduction in the terrigenous debris supplied to the continental shelf in the northern

Gulf of Mexico while the other possible cause is a change in the current regime resulting in either a net cessation or reversal of the long shore drift.

If, as Barrell (1917, p. 787) suggested, basin subsidence is coupled with "geanticlinical" or continental uplift, then the depositional intervals in the study area should be coupled with epeirogenic uplift in the continent rather than alternating with uplift as examined earlier in this paper. This may be the case since it is only during the subsiding depositional intervals that there has been any terrigenous clastic sedimentation in the study area. To follow this possibility further, it could be argued that the greatest amount of terrigenous debris would be carried into a basin immediately after an uplift in the interior and before the incising drainage systems had achieved equilibrium, during which the drainage systems would be incising into the soft saprolite formed during the preceding stable period. If the uplift were periodic the amount of detritus brought into the basin by rivers should diminish until either dissection and lateral erosion cease or until the erosion cycle is terminated by another uplift.

In the study area there should be evidence of declining sedimentation during a depositional interval with the youngest terrigenous clastic sediments being dominated by clays and silts. There is, however, no evidence of diminishing sedimentation during the Miocene depositional intervals and there is certainly no tendency for the size of the clastic particles to diminish. If anything, the particle size appears to increase with time in that the upper part of each of the Miocene depositional units is sand whereas clay is most common in the lower parts.

The general impression is that sedimentation and terrigenous clastic influx builds up to a climax, and then simply ceases. What compounds the problem is that the deposition of the offshore plankton-rich foraminiferal limestones ceases concurrently.

It may be that sedimentation continues to the west, farther into the Gulf Coast Basin, at a diminishing rate. And it must be stressed that the westernmost part of the area under study is only the easternmost fringe of the basin. It is dangerous to draw too many conclusions about the tectonics and sedimentational characteristics of the Gulf Coast Basin from such a small area on its periphery.

It is possible that the terrigenous clastic deposits in the western part of the study area were dominantly transported from the west (see Figures 13, 14, and 15). If so, the diminution, cessation, or reversal of the long shore drift system in the northeastern Gulf of Mexico should have a profound impact on the nearshore sediments. With the drift being directed from the Gulf Coast Basin depocenter in Louisiana, sand and clay would be transported to the study area. The stronger the drift currents, the greater the influx of sand and clay onto the west Florida shelf. If the velocity of the drift currents were reduced, or if the net drift direction declined, ceased, or was reversed from eastward to westward as at present, the influx of clastics from the west should have been either reduced or terminated. Certainly the Florida peninsula or archipelago would have been a very poor source for terrigenous clastic sediments. Such a reduction or cessation of terrigenous clastic influx would be conducive to sedimentational dynamic equilibrium or erosional disequilibrium in that the current system would cease to be overwhelmed with an inundation of sediments.

Although a change in the long shore drift system could severely alter the amount of terrigenous clastics being transported into the study area, it is not at all clear that it could cause a simultaneous cessation of carbonate sedimentation both nearshore and offshore in the study area. Nor is it clear why a subsequent reversal or net change in drift direction should cause a recurrence of carbonate sedimentation. As a result, at the present time the writer prefers a tectonic origin coupled with a diminishing supply of terrigenous clastic sediments to explain both the inception and termination of sedimentation in the study area.

The writer wishes to emphasize that the standard concepts of transgression and regression are not employed in this model. Such transgressions as that documented for the late Cambrian of the Midcontinent or the oscillatory transgressions and regressions of the cyclothems during the Pennsylvanian in the Midcontinent cannot be demonstrated in this area of the Coastal Plain. Rather, the ancient shorelines were relatively stable in position, prograding outward gradually through geologic time. Subsidence may have altered the position of the ancient shorelines only slightly, but the outbuilding, prograding mass of coastal sediments was probably more effective in displacing the shorelines seaward and therefore giving the deposits a regressive aspect.

STRATIGRAPHIC SYNTHESIS

The various concepts discussed above allow a preliminary geologic history to be constructed for the study area in western Florida. This geologic history is based on the probable validity of the roles and effects of (1) general tectonic stability punctuated by periods of mild instability and subsidence, (2) of dynamic equilibrium and disequilibrium on the floor of the continental shelf, and (3) periodic influxes of terrigenous clastic sediments during intervals of subsidence.

The Chickasawhay depositional interval in the study area consists of limestones, dolomites, and dominantly calcareous sediments referred to in this study as Chickasawhay-equivalent deposits, "Suwannee Limestone", and Chattahoochee Formation (Tampa Limestone in part of earlier authors). The foraminifera that establish the age of these deposits are *Globigerina angulisuturalis*, *G. tripartita*, *G. galavisi*, and *Cheilogumbelina cubensis* among the planktonic foraminifera; *Pararotalia mexicana*, *Discorinopsis* sp., and *Valvulina* sp. among the benthonic foraminifera. Only *G. angulisuturalis* ranges into the Miocene according to Blow (1969), all other species and *Discorinopsis* and *Valvulina* are restricted to Oligocene time or older in the Coastal Plain of the Southeastern United States.

The sediments of late Oligocene age in Alabama, Florida, Georgia, and South Carolina are either dominantly calcareous or are entirely limestones with some dolomite. Evidently then, if epeirogenic uplift in the eastern part of the continent accompanied subsidence of the continental margins in the Southeast, it was minimal and resulted in only an increase in clay deposition with some sand in the nearshore areas. The offshore sediments of Chickasawhayan age are almost pure, shallow water, limestones and dolomites.

In the study area west of the Apalachicola River (possibly excluding the coastal area of Gulf and Franklin Counties due to insufficient control), much of the Chattian, all of the Aquitanian, and much of the Burdigalian Stages are missing in the hiatus between the Chickasawhay depositional unit and the Chipola depositional unit. In the area of western Florida from the Apalachicola River to Okaloosa County, the ancient sea floor on the continental shelf must have been in a state close to that of dynamic equilibrium for an extended period of time. Deposits of intermediate, early Aquitanian age are known in eastern Georgia underlying the southern Atlantic Coastal Plain (Huddlestun, 1973) and they may extend south into eastern Florida. Although other contemporaneous depositional units in eastern Georgia appear to be in step with the Chipola, Shoal River, and Pliocene depositional units, the absence of Aquitanian in western Florida and the absence of a recognizable Choctawhatchee depositional interval in eastern Georgia suggests that there may be subtle differences in the regional tectonics between the continental margins of the Gulf of Mexico and the Atlantic Ocean.

The Chattian-Burdigalian period of stability ended in west Florida with a general subsidence that resulted in the first terrigenous clastic coastal plain deposits over much of the area, the Chipola Formation and its equivalents. Because the Chipola planktonic foraminiferal assemblage is dominated by long-ranging species, the diachroneity of the formation boundaries cannot be demonstrated. However, the Chipola Formation must be viewed as a regressive, prograding mass of terrigenous clastics and carbonates. In Walton County it is invariably more calcareous and contains a much more diverse fauna in its basal beds whereas it is less calcareous in its uppermost beds and contains a more restricted foraminiferal fauna characterized by the brackish-water, benthonic foraminifera species, Ammonia beccarii. The prograding clastic tongue of the Chipola extends to the present coast under central Walton County.

The updip Chipola-equivalent sands in Walton County is believed by this writer to constitute a vast semi-sound or lagoon complex that developed during the Chipola depositional interval. It may have been separated from the open ocean environment by a barrier island chain that trended approximately westnorthwest-eastsoutheast across central Walton County, or it may have had direct access to the open ocean but with restricted watermass access due to a very low ramp angle on the continental shelf. Within this area of restricted marine conditions is the sound facies of the Chipola, the Chipola equivalent sands. Seaward is the Chipola Formation that grades downdip into the offshore, Chipola-equivalent limestone.

It appears likely from examination of Figures 21-23 that some of the upper deposits here included in the Chipola equivalent sands may in fact be both Bruce Creek/Oak Grove-equivalent and Shoal River-equivalent. If that is the case, then the nearshore, semi-sound or lagoon facies may have persisted into a later, middle Miocene time.

The updip limit of the marine Chipola (which is believed to approximately parallel the ancient shoreline trend of the Chipola) changed to that of a more east-west direction in the vicinity of the Choctawhatchee River during the Chipola depositional interval. This east-west trend is maintained as far east as Alum Bluff, east of which the Chipola Formation has not yet been identified.

The Chipola-Bruce Creek contact is interpreted as a paraconformity in this study although in all cores the formations have the appearance of being conformable and gradational. There are two sets of criteria used in judging the presence of a hiatus, (1) the apparent evolutionary jump from forms transitional from Globigerinoides sacculifera quadrilobata to G. sicanus in the Chipola Formation to well developed and typical G. sicanus in the basal sediments of the Bruce Creek Limestone. The time interval involved in the hiatus is as little as a few hundred thousand years (see Figure 4); and (2) the heavily bored, phosphatic dolomite pebbles that are always associated with either paraconformities or biostratigraphic breaks are commonly found at or immediately above the contact between the Chipola-equivalent limestone and the Bruce Creek Limestone.

There was a tectonic change during the Chipola/Bruce Creek nondepositional interval. The stratigraphic relations between the Chipola Formation and Bruce Creek Limestone west of the Choctawhatchee River is one of overlap while east of the river it is offlap. In addition, in the Walton County area the Bruce Creek is characterized as a minimum in terrigenous clastic influx. In general it appears that there was a brief period of sedimentational dynamic equilibrium on the inner shelf immediately following Chipola deposition. The equilibrium condition was interrupted rather abruptly in the western part of the study area with a subsidence but with only a feeble influx of terrigenous clastics. This subsidence affected only the coastal areas of west Florida west of the Choctawhatchee River. Apparently the region east of the Choctawhatchee River, i.e., the area of the Chattahoochee Arch, was not involved significantly in the Bruce Creek subsidence since the updip clay bed of the Bruce Creek Limestone (Figure 12) trends in a more southeasterly direction in the vicinity of the Choctawhatchee River and the benthonic foraminiferal fauna of the clay bed exposed at Boynton Landing on the Choctawhatchee River is very strongly dominated by Ammonia beccarii.

Bruce Creek deposition ceased slightly diachronously in the study area with sedimentation lingering the longest only in the western-most part of the study area in western Walton County and Okaloosa County. Subsequent to Bruce Creek deposition there occurred a period of equilibrium that lasted from one to two million years according to the time scale of Berggren and van Couvering (1974). Sedimentation in the study area was reinitiated with subsidence and deposition of foraminiferal limestone in the Apalachicola Embayment and with an influx of nearshore terrigenous clastics in northern Walton and Okaloosa Counties. This sedimentation resulted in the beginning of St. Joe and Shoal River deposition respectively. In Walton and Okaloosa Counties, the clastic wedge of the lower, Whites Creek Member of the Shoal River Formation prograded both in an eastern direction as a possible result of sediment transport in the long shore drift system, and in a southerly, offshore direction which probably resulted from basin filling. In addition, sedimentation began in an irregular diachronous manner near the updip limits of the lower Shoal River in that the age of the base of the unit varies unsystematically between the zones N9 and N10 of Blow (1969) suggesting local sources of sediment. The Whites Creek depositional unit thins and pinches out downdip and this depositional unit has been recognized in the study area west of the Apalachicola Embayment only in southeastern Walton County. This would suggest that at least in Walton County, sedimentation was not due so much to subsidence as it was to a disruption in equilibrium due to an abrupt increase in terrigenous clastic influx.

In the Apalachicola Embayment, on the other hand, foraminiferal sedimentation of the St. Joe Limestone began almost at the beginning of the Whites Creek depositional interval. This requires the origin of the St. Joe sedimentation in the Apalachicola Embayment to be in subsidence, not in increased rate of sedimentation.

It is clear from the planktonic foraminifera content of the Bruce Creek Limestone that the upper part of the Bruce Creek lithology is Shoal River in age in an irregular east-west band across the south-central part of Walton County. Only one nonindurated interval from the Bruce Creek Limestone in the Mack #1 (W-8587) contains a Whites Creek fauna. This is sufficient to show that the Whites Creek depositional unit may contain Bruce Creek lithology before it pinches out under coastal Walton County, and that the Whites Creek depositional unit may be more widespread in Walton County than is currently demonstrable.

The Whites Creek depositional interval was terminated by a sedimentational minimum in the downdip, offshore area and by a hiatus in the updip, nearshore area of Walton County. It would appear that regional dynamic equilibrium was almost achieved before being disrupted by another period of subsidence and sedimentation.

The areal and temporal distributions of the ensuing middle and upper Shoal River depositional unit does not fit with ease any simple sedimentational model. Based on the evolutionary bioseries of Globorotalia fohsi s.l., the earliest sediments of the Shoal River depositional unit in the Walton County area are contained in the St. Joe Limestone in the southeastern corner of Walton County. From there the transgression progressed northward and westward in an updip direction. This diachroneity continues up the dip to the type area of the Shoal River Formation along the valley of the Shoal River where the middle Shoal River transgression is climaxed with the deposition of a relatively nearshore shell bed.

What makes this Shoal River transgression difficult to understand is that in the coastal area, there are significantly greater time differences in the unit between the cores than there are within the unit in any one core. The base of the unit is strongly diachronous in the coastal area and the top of the unit is equally diachronous. Surprisingly, terrigenous clastic sedimentation in the updip area was not initiated until the transgressive "wave" of foraminiferal sediments passed a line just north of Choctawhatchee Bay that parallels the present coast. This line also marks the area of the facies change within the depositional unit between the offshore foraminiferal limestone and the nearshore sands and clays. By the time foraminiferal and biogenic sedimentation reached the vicinity of this line, all downdip St. Joe sedimentation ceased. According to the sedimentary model employed in this study, the most offshore area had reached approximately a state of dynamic equilibrium while foraminiferal and biogenic sedimentation commenced in a more shoreward area. This was due either to high biological productivity and/or a subsidence which resulted in a place to bury the debris.

It is curious that in Walton County almost all of the middle part of the Shoal River Formation is younger than any of the St. Joe Limestone which constitutes the early part of the transgression. Two factors must be pointed out in discussing the stratigraphic relationships between the two lithosomes in this particular transgression. First the source of sediment between the two facies was vastly different. The source of sediment for the foraminiferal limestone was essentially microfossiliferous debris that formed either in situ or rained down from the overlying watermass. On the other hand the source for the terrigenous clastic facies was either local or possibly from the long shore drift system from the west. Secondly the "line" mentioned in the above paragraph not only is a facies boundary but is also a sort of temporal hinge line in that the depositional unit is strongly diachronous south of the "line" but is only slightly diachronous north of the "line". In spite of the rapidly evolving Globorotalia fohsi lineage, no diachroneity can be distinguished in the middle and upper Shoal River Formation parallel to the depositional strike. This is unlike both the earlier, diachronous Whites Creek Member and the downdip, offshore St. Joe Limestone. What little diachroneity can be distinguished occurs in an updip-downdip direction. This diachroneity is not that of a prograding clastic wedge but that of a transgressing deposit. It can only be concluded therefore that the main mass of the middle and upper Shoal River Formation must have been deposited relatively rapidly. It was probably the sudden overwhelming influx of terrigenous clastics (an average rate of sedimentation that may not have been much more than 10 cm/1000 years) that terminated the transgression of the foraminiferal limestone. Possibly the long shore drift currents may have been unusually vigorous and competent during this period. But why middle Shoal River clastic sedimentation began so suddenly and why dynamic equilibrium was maintained in the nearshore area after it was disrupted in the offshore area is a puzzle. If sedimentation were strictly related to subsidence and if subsidence were epeirogenic, then it is difficult to understand why clastic sedimentation did not begin in the nearshore area at the beginning of the middle and upper Shoal River depositional interval. It is also difficult to understand why, if subsidence continued slowly through the middle and upper Shoal River depositional interval, the sedimentation did not continue in the downdip, offshore area throughout middle and upper Shoal River time.

Part of the problem may be involved in the recognition of lower and middle Shoal River in the far updip areas where the deposits are discontinuously fossiliferous or are nonfossiliferous. For convenience in this study, the base of the middle Shoal River in the type area of the Shoal River valley is arbitrarily defined as the base of the shell bed. However the shell bed appears to be gradational with the underlying noncalcareous sands. It is possible then that the upper part of these noncalcareous sands that are arbitrarily referred to as Whites Creek Member in this study may indeed be middle Shoal River in age and a part of the middle Shoal River depositional unit.

In this study the middle and upper Shoal River is considered to be one depositional unit. The lack of a lithologic discontinuity plus the paleontological gradation within this interval (460-430 feet) in the St. Joe #1 (W-12051) in the Apalachicola Embayment supports this contention. However, in Walton County the contact between the two parts of the Shoal River Formation is significant from both a paleontological and sedimentological point of view and will therefore be discussed in some detail.

In Walton County there is a clear break in fossiliferous, calcareous sedimentation at the top of the middle Shoal River. In all cores where fossiliferous middle Shoal River is overlain by upper Shoal River that contains fossiliferous beds, there is a black, sulphurous clay immediately above the topmost fossiliferous bed of the middle Shoal River. In only one core (Cosson #1, W-8004) is there a fossiliferous bed immediately above the black clay, and this bed contains an upper Shoal River planktonic foraminiferal assemblage and not a middle Shoal River assemblage.

The nature of the change from middle to upper Shoal River is not clear at this time due to the fact that the stratigraphic interval containing the middle/upper Shoal River transition is not continuously fossiliferous in Walton County. The upper and lower contacts of the black clay bed are everywhere gradational with the overlying and underlying sediments but from the earlier discussions, it is clear that the presence of apparent stratigraphic continuity may be quite misleading in these west Florida deposits. However, in the Cosson #1 (W-8004) the clay separating fossiliferous middle Shoal River from fossiliferous upper Shoal River is only 3 feet thick. Because the clay is gradational with the two fossiliferous beds over an interval of approximately 6 inches, the writer concludes that this is evidence supporting a gradational and conformable contact between the middle and upper Shoal River, and therefore of continuous sedimentation through middle and upper Shoal River time.

As discussed in the section on the description of the Shoal River Formation, the geometries of the middle and upper Shoal River differ from each other. The middle Shoal River is a thin deposit, its greatest known thickness being 37 feet in the Gavin #1 (W-7972). It is intermediate in shape between a wedge or prism, and a blanket (Figure 15). The upper Shoal River is a clastic wedge that has an east-west axis and is no more than about 12 to 15 miles across (Figure 16). In Walton County its greatest thickness is about 120 feet.

There is, finally, a paleontological discontinuity between the middle and upper Shoal River. Four species of planktonic foraminifera, including Globorotalia fohsi robusta, became extinct in the study area and one species, Globigerinoides subquadrata, was very severely reduced in numbers (see page 69). One species, or form, had its evolutionary first occurrence. This faunal discontinuity is also present in the equivalent section of the St. Joe Limestone in the St. Joe #1 (W-12051) in the Apalachicola Embayment. This interval in that core is continuously and abundantly rich in planktonic foraminifera. The discontinuity is not abrupt as it is in Walton County but takes place over an interval of about 2 feet. The species that disappear do not vanish but appear to fade out.

In Walton County the upper Shoal River thins and pinches out downdip, passing into the paraconformity between the earlier middle Miocene and the upper Miocene and Pliocene. The upper part of the middle Shoal River also pinches out downdip, but in the southwestern corner of Walton County this interval penetrates almost to the coast before it pinches out.

The contact between the middle and upper Shoal River depositional unit and the Choctawhatchee depositional unit presents the typical case in western Florida where there is only a very vague lithology change across a paraconformity. In spite of the hiatus that includes three and probably four planktonic foraminiferal zones (Figure 4), the change in lithology across the paraconformity is extremely subtle. For whatever reasons then, the terrigenous clastic sedimentation that prevailed during Shoal River time in the nearshore area of Walton County was rather abruptly terminated and a condition approaching equilibrium that had already become established in the offshore area, was extended to the nearshore area. This condition of dynamic equilibrium lasted for about 5 million years in the ancient nearshore area of Walton County and for approximately 10 million years in the offshore area (Figures 4 and 5).

When the condition of dynamic equilibrium was again disrupted in the late Miocene and the condition of sedimentational disequilibrium reinitiated, the physical conditions in the nearshore area were essentially identical to those that prevailed when sedimentation ceased in the middle Miocene. As a result, the basal sediments of the Choctawhatchee depositional unit are for practical purposes the same as the underlying

Shoal River.

The Choctawhatchee depositional unit in the Walton County area is a large clastic wedge that thins, narrows, and pinches out to the east. As with the older clastic wedges in the study area, the source of the Choctawhatchee terrigenous clastics was apparently either from the west, via the long shore drift system, or from local sources (Figure 15).

The general structure of the middle and upper Shoal River wedge and the Choctawhatchee wedge are rather similar in that there is an upper and lower part to both. In the Choctawhatchee wedge, a lower, calcareous fossiliferous bed is analogous to the middle Shoal River whereas the upper Choctawhatchee (Permenters Farm beds of Smith, 1941) is analogous to the upper Shoal River. The principal deviation from the analogy is a basal Shoal River type Choctawhatchee lithology that has no analogies that are known with certainty in the Shoal River depositional unit. The possibility of such a basal middle Shoal River deposit was discussed, however, on page 76 .

The diachroneity of the Choctawhatchee Formation is both similar to and different from that in the middle and upper Shoal River. It is similar in that no diachroneity can be detected along the depositional strike of the unit. It should be pointed out, however, that there were no rapidly evolving lineages of planktonic foraminifera during much of Choctawhatchee time. In this way the main part of the Choctawhatchee planktonic foraminiferal assemblage is like that of the Chipola and the measurement of diachroneity must be viewed as relative to the measuring system. The diachroneity of the Choctawhatchee Formation differs from that of the middle and upper Shoal River in distinctly prograding seaward. The youngest Choctawhatchee deposits immediately north and northeast of Choctawhatchee Bay are measurably younger than the basal deposits in the outcrop area.

There is also a similar planktonic foraminiferal assemblage change between the lower and upper Choctawhatchee Formation, carrying the analogy between the middle and upper Shoal River and Choctawhatchee depositional units a step further. The Choctawhatchee assemblage change differs in that there are no extinctions or evolutionary first appearances, although there are local first appearances (see pages 94-97). The principal changes are in increases and decreases of assemblage proportions by several of the species and in evolutionary development among other species. In general the faunal change between the lower and upper Choctawhatchee is more subtle than between the middle and upper Shoal River but none-the-less it does exist and is about the only paleontological means at this time of correlating within the Choctawhatchee depositional unit.

As with the upper Shoal River, sedimentation ceased abruptly at the end of Choctawhatchee time over much of Walton County. It appears to have lingered longest in the southwestern corner of the county where a phosphoritic sand was deposited relatively slowly. The Choctawhatchee depositional unit thins and pinches out downdip, passing into the paraconformity between the middle Miocene and the Pliocene Series. There is no indication in the downdip Walton County area that sediments of Choctawhatchee age had ever been deposited. It appears, therefore, that the sea floor in the offshore Walton County area had remained essentially in a state of dynamic equilibrium during deposition of the relatively thick

Choctawhatchee wedge in the nearshore area. It is curious that a pattern emerges that suggests that periods of relatively thick, nearshore clastic wedge sedimentation are also periods of nondeposition offshore.

The nondepositional interval following Choctawhatchee sedimentation and preceding Citronelle sedimentation in the updip area and marine Pliocene sedimentation in the downdip area, apparently does contain an interval of lowered sea level. Since there is no evidence for epeirogenic uplift in the study area, the most likely explanation for the lowering of sea level is eustacy. Indeed there is evidence elsewhere in the world for a climatic cooling event and worldwide lowering of sea level near the end of the Miocene. The Messinian evaporites in the western Mediterranean basin have been linked to a eustatic lowering of sea level due to Antarctic glaciation (Bandy, 1969; see discussion by Berggren and van Couvering, 1974). There is a sharp increase in ice rafted clastics recorded from the Southern Ocean (Margolis and Kennett, 1971) near the end of the Miocene and this ice rafting event has been correlated with the Kapitean Stage of New Zealand. The Kapitean Stage has long been recognized as a cool interval both on the basis of the Mollusca and planktonic foraminifera (Kennett, 1966, 1967). Kennett and Watkins (1974) have presented evidence that the Kapitean Stage of New Zealand is related to the Gilbert C paleomagnetic events that have been dated at approximately 4.5 million years. This according to recent Neogene time scales (Berggren, 1972, 1973; Berggren and van Couvering, 1974) would be early Pliocene in age because the presently accepted age for the Miocene/Pliocene boundary is approximately 5 million years, near the Gilbert/Epoch 5 paleomagnetic boundary. Whatever the cause of the discrepancy between the postulated ages of the cooling event near the Miocene/Pliocene boundary may be, the cooling event or events along with the eustatic lowering of sea level is still contained in the nondepositional interval between the Miocene and Pliocene deposits in western Florida.

In the diachroneity of its lithofacies and hiatuses, the variability of lithofacies and biofacies, the low predictability of physical stratigraphic relationships without recourse to sophisticated stratigraphic analysis, and the variability and flux of the planktonic foraminiferal assemblages, the Pliocene depositional unit is by far the most complex Neogene depositional unit in western Florida.

Marine sedimentation was not resumed in the study area until near the end of the early Pliocene when dynamic equilibrium was again disrupted due probably both to an inundation of terrigenous clastics directly from the Appalachian and Piedmont provinces and to subsidence. This inundation buried previously formed topography in the onshore area of western Florida and spilled over into the Gulf of Mexico immediately north of the present north shore of Choctawhatchee Bay. It is clear that his thin blanket of nearshore sand prograded seaward because in southeastern Walton County, older Pliocene sediments occur at the base of the updip section than occur at the base of the updip section (Figure 24). Concurrently, however, subsidence progressed offshore with the greatest subsidence occurring to the west and not in a presumed downdip direction to the south. This combination of subsidence and sedimentation resulted in a progradation of shallow water sands from north to south, and a deeper water, offshore phosphoritic sand transgressing concurrently from west to east. Consequently the earliest currently datable marine Pliocene sediments are found either in the southwesternmost part of the occurrence of marine Pliocene sediments or sporadically in the most updip part in the Walton County area. Conversely the youngest basal Pliocene sediments in the Walton County area occur in the southeastern corner of the county.

With only two cores from the downdip Apalachicola Embayment, it would appear that the distribution of early Pliocene sediments is just as complex in the carbonate lithosome in that basin. It is curious that the early Pliocene interval is not presently recognized in the thicker, more unstable part of the Apalachicola Embayment in the St. Joe #1 (W-12051) but is present on its eastern flanks in the St. George Island #1 (W-7574).

An environmental change that resulted in both a regional lithofacies and biofacies change occurred throughout the study area in the early part of the late Pliocene, immediately subsequent to and during Jackson Bluff sedimentation and the maximum phase of the Pliocene transgression. This environmental change was irregularly diachronous as reflected in the sediments. In some places it occurred, at the earliest, during the time of Jackson Bluff deposition. This has resulted in the recognition of an Ecphora Zone or facies, and a Cancellaria Zone or facies. In other places, such as in the Price #1 (W-8591), the change occurred slightly later, during an advanced stage of the Jackson Bluff regression.

The lithofacies and biofacies of the early part of the Pliocene depositional unit, prior to the environmental change, are characteristic and restricted in areal distribution. The phosphoritic sand unit of this study is restricted to the Gulf Coast Basin and is not known at this time to occur east of the Choctawhatchee River. The sands and clays of the Ecphora zone in the outcrop area of the Chipola and Apalachicola Rivers are a prodeltaic deposit found only in that area. These lithofacies are lithology types that are characteristic of the Miocene and early Pliocene of western Florida and to some extent of the Miocene and early late Pliocene of the Atlantic Coastal Plain. Subsequent to this environmental change, these lithology types do not occur again in the outcropping or shallow subsurface coastal Plain from west Florida to North Carolina.

The marine Pliocene sediments deposited after the environmental change are all calcareous and consist of impure limestones with occasional beds of calcareous clay or calcareous sand in the shallow subsurface. Representative deposits in the outcrop area have been called the Cancellaria Zone or facies. This upper part of the Pliocene depositional unit is very well developed both in the Gulf Coast Basin and the Apalachicola Embayment where it is called the Intracoastal Limestone in this study.

Because the principal part of the marine, Pliocene depositional unit is found, in the study area, only under the present coast of western Florida, the full geometry of the unit remains unknown due to insufficient core control. It is clear, however, that the unit thickens very abruptly from north to south across Choctawhatchee Bay in Walton County. This suggests that the downdip, open marine part of the depositional unit is a wedge, similar to the Whites Creek wedge, the middle and upper Shoal River wedge, and the Choctawhatchee wedge. The Pliocene wedge differs from those earlier wedges in that the Pliocene wedge is relatively starved from lack of terrigenous clastics. The geometry of the depositional unit, therefore, cannot be ascribed to an influx of terrigenous clastics. It is rather more apparent then that Pliocene sedimentation in the offshore area was due to subsidence and a disruption of dynamic equilibrium.

There are two aspects of the Pliocene depositional unit that are distinctive. The first is the presence of a cooling event that occurred just subsequent to the environmental change. This cooling event is recognized from the great increase in abundance of the temperate planktonic foraminiferal species *Globorotalia puncticulata* and the concomitant reduction in purely tropical species such as *Globorotalia menardii* and the extinction of other tropical species such as *Globoquadrina venezuelana*, *G. altispira*, and *Sphaeroidinellopsis subdehiscens*. In addition the tropical to warm temperate species *Globorotalia tosaensis* evolved at this time from its immediate ancestor *G. crassaformis*.

Based on planktonic foraminiferal correlation, this cooling event is the same as that referred to the "Nebraskan" glaciation by Akers (1965), Akers and Holk, (1957), Akers and Dorman (1964), Beard and Lamb (1968), Beard (1969), Lamb and Beard (1972), Poag (1971), Sachs (1970), and Sachs and Skinner (1973). According to these authors, then, the main mass of the Intracoastal Limestone in the upper part of the Pliocene depositional unit would be "Aftonian" in age. Berggren (1972) recognized the same cooling event in the North Atlantic Ocean as the first major northern hemisphere, continental glaciation. He placed the age of this event at approximately 3 million years and correlated it approximately with the Mammoth magnetic event in the Gauss magnetic epoch. Although he originally correlated this cooling event with the Nebraskan glaciation (Berggren, 1972), he later rejected this correlation (Berggren and van Couvering, 1974) and placed the Nebraskan at a much younger date.

The other distinctive aspect of this depositional unit is the presence of a definite hiatus within it that is restricted to the western part of the Walton County subsurface. This hiatus is not present in the southeastern corner of Walton County but it opens up westward and includes the greatest interval of time in the southwestern corner of the county. The hiatus is approximately related to the cooling event in that the base of the hiatus occurs within the upper part of the cool interval in the Price #1 (W-8591) but completely includes the cool interval in the Coffeen #1 (W-8865). In the Louisiana subsurface, the so-called "Nebraskan" has been associated with a eustatic lowering of sea level (see for example Akers and Holk, 1957). If the hiatus discussed above is due to eustatic lowering of sea level, it is not obvious from the benthonic foraminiferal assemblage in the Intracoastal Waterway #1 (W-8873) where sedimentation was apparently continuous through the cooling event. Unfortunately there is too little core control to be certain of the relationship of this hiatus with the cooling event.

Dynamic equilibrium was apparently regained before the end of the Pliocene and it is suggested that no more subsidence occurred in the study area until sometime in the late Pleistocene. This, however, is not clear since all Pleistocene deposits in the study area are either noncalcareous and nonfossiliferous or as in the Apalachicola Embayment, consist of very shallow water, nearshore shell beds that are almost devoid of planktonic foraminifera. If a discrete, Pleistocene depositional unit exists in western Florida, it occurs off the coast of Florida where it has not yet been identified.

One characteristic of the coastal Plio-Pleistocene sands must be stressed. The late Pliocene, calcareous marine deposits all grade upward into noncalcareous, nonfossiliferous sands. These noncalcareous, nonfossiliferous sands on the other hand are not overlain either gradationally or with sharp physical break by any other deposits in the coastal area. The top of these sands is the soil zone or grass roots. Certainly the sands under the present shoreline are either late Pleistocene or Holocene in age and therefore there may be numerous diastems in the section that are not detectable on the basis of lithology change. The almost continuously shelly, fossiliferous Pleistocene section in the St. Joe #1 (W-12051) suggests that most of the stratigraphically equivalent sands in other coastal cores are of one age and therefore there may be only one break present in the sections. This paraconformity (or disconformity) would separate the late Pliocene depositional interval from a possible late Pleistocene depositional interval. If older Pleistocene coastal sands are, in fact, present in the study area, they cannot be identified as such in this study.

A paraconformity between the late Pliocene and the late Pleistocene would differ from other paraconformities in the study area in that this paraconformity would not represent a nondepositional interval due to a state of sedimentational dynamic equilibrium. Due to the Pleistocene glaciations, there has been one or perhaps numerous eustatic sea level falls affecting the present coastal area of west Florida. Therefore the surface of the paraconformity or diastems would have been exposed to subaerial erosion and perhaps dissection. There is, however, no evidence of subaerial erosion or weathering in the Plio-Pleistocene sands under the coastal area, suggesting that subaerial exposure resulted in neither erosion nor in oxidation of the surficial sands. The contact between the sands is of the type where there is no physical indication of a break.

This situation would appear to have serious consequences for the hypothesis that such breaks in the marine sections of the study area represent a state of dynamic equilibrium on the sea floor. Obviously the same sort of ambiguous discontinuity can occur without having to resort to the equilibrium concept. However, the Pliocene/Pleistocene discontinuity is a different situation from that of the other paraconformities in that shoreline deposits overlie shoreline deposits paraconformably or disconformably. These deposits being noncalcareous cannot be analyzed paleontologically by the writer and the exact nature of the break or breaks remains unknown.

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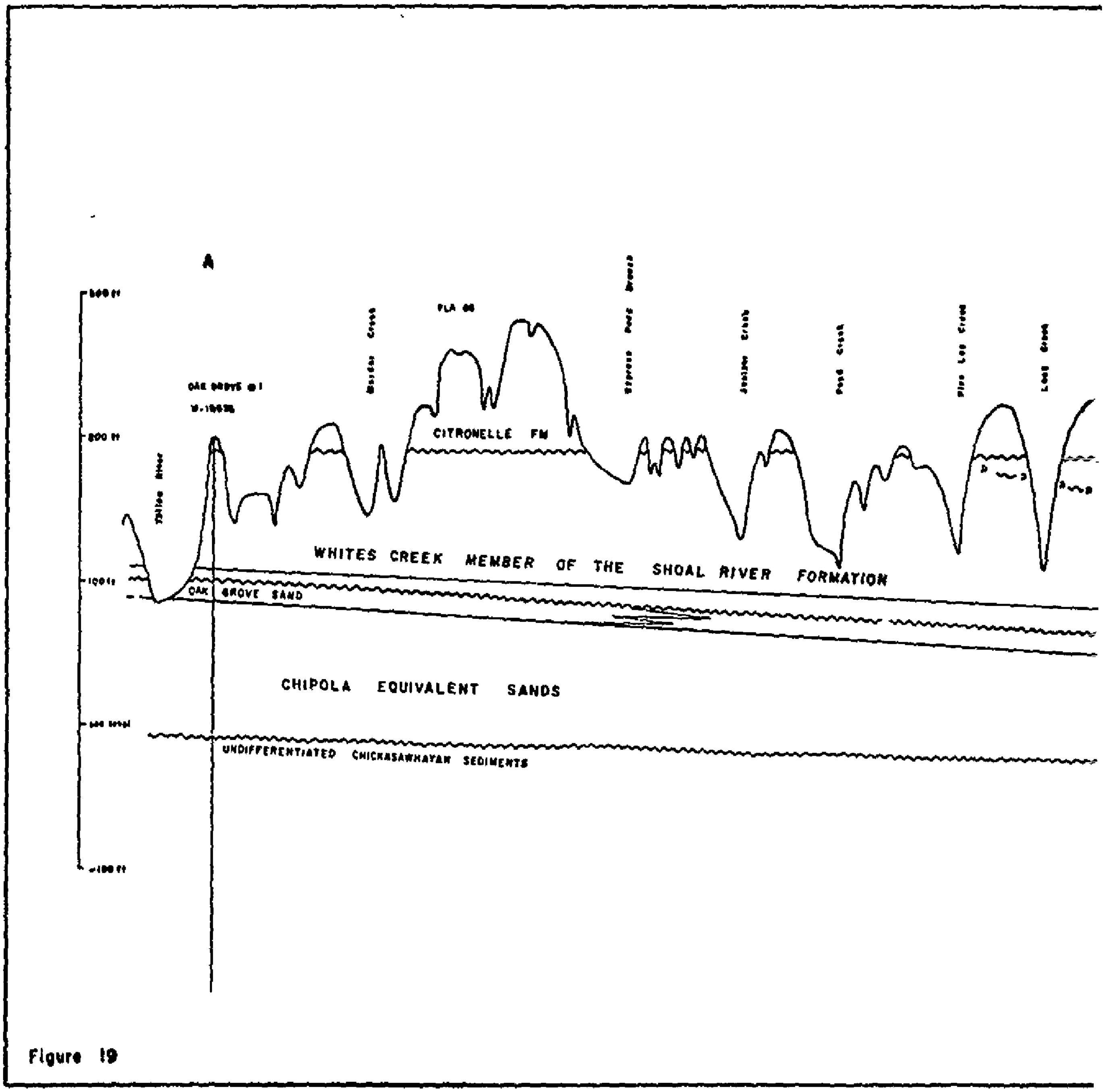
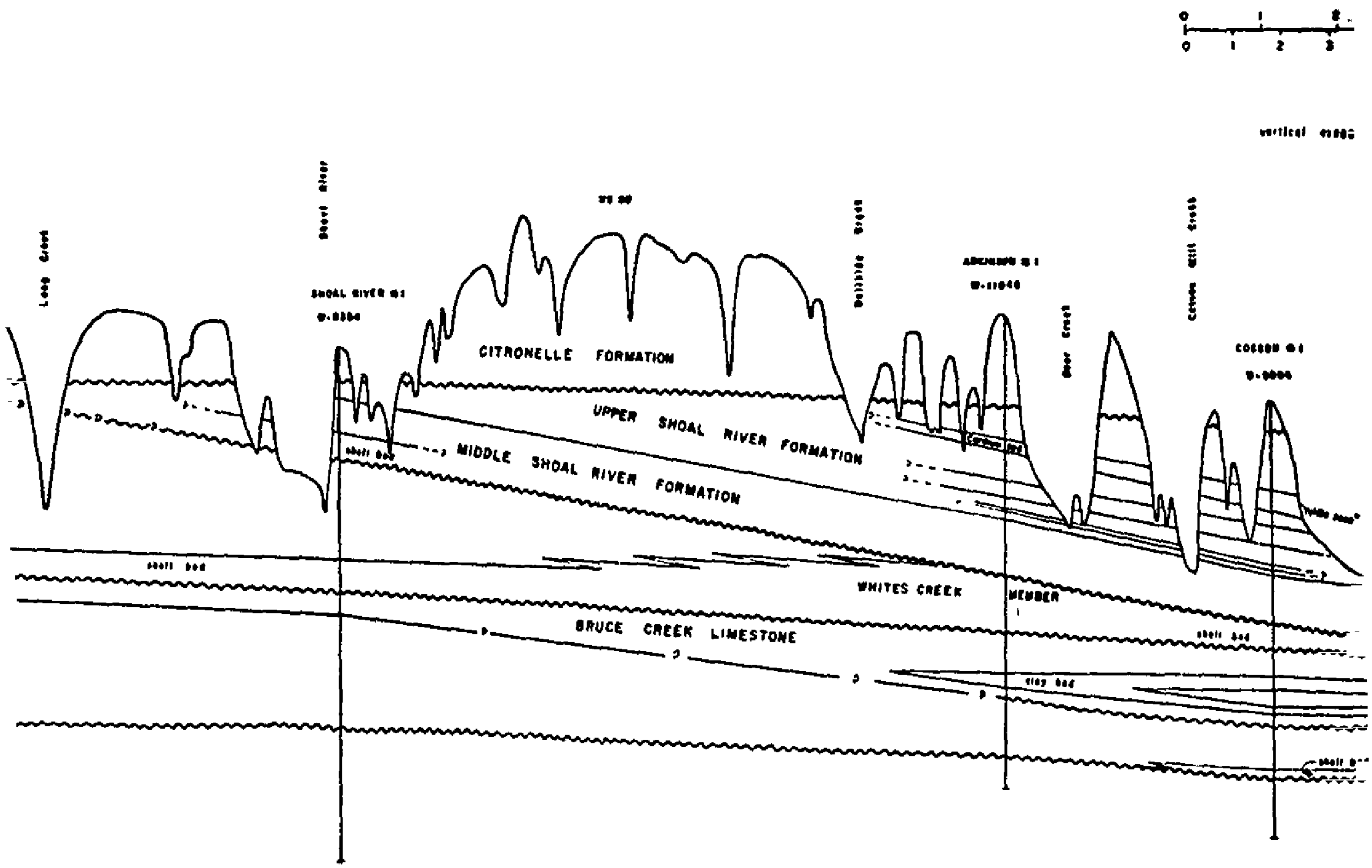

A
CITRONELLE FM
WHITES CREEK MEMBER OF THE SHOAL RIVER FORMATION
OAK GROVE SAND
CHIPOLA EQUIVALENT SANDS
UNDIFFERENTIATED CHICKASAWHAYAN SEDIMENTS

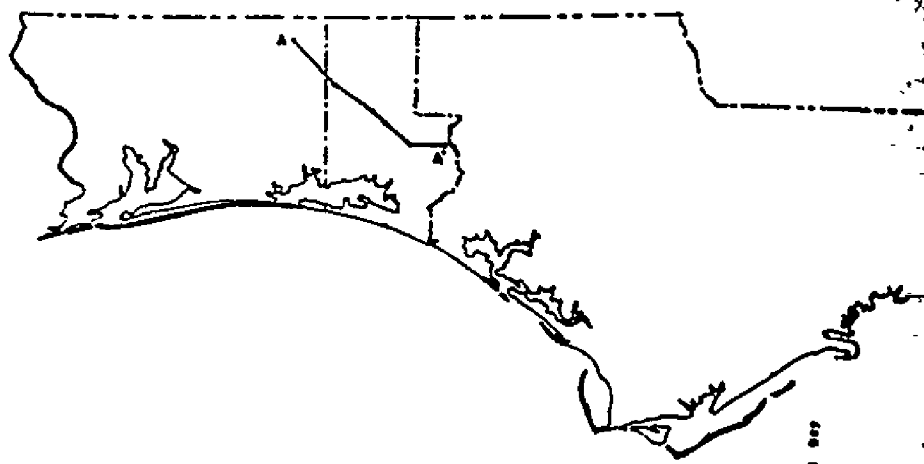
Figure 19

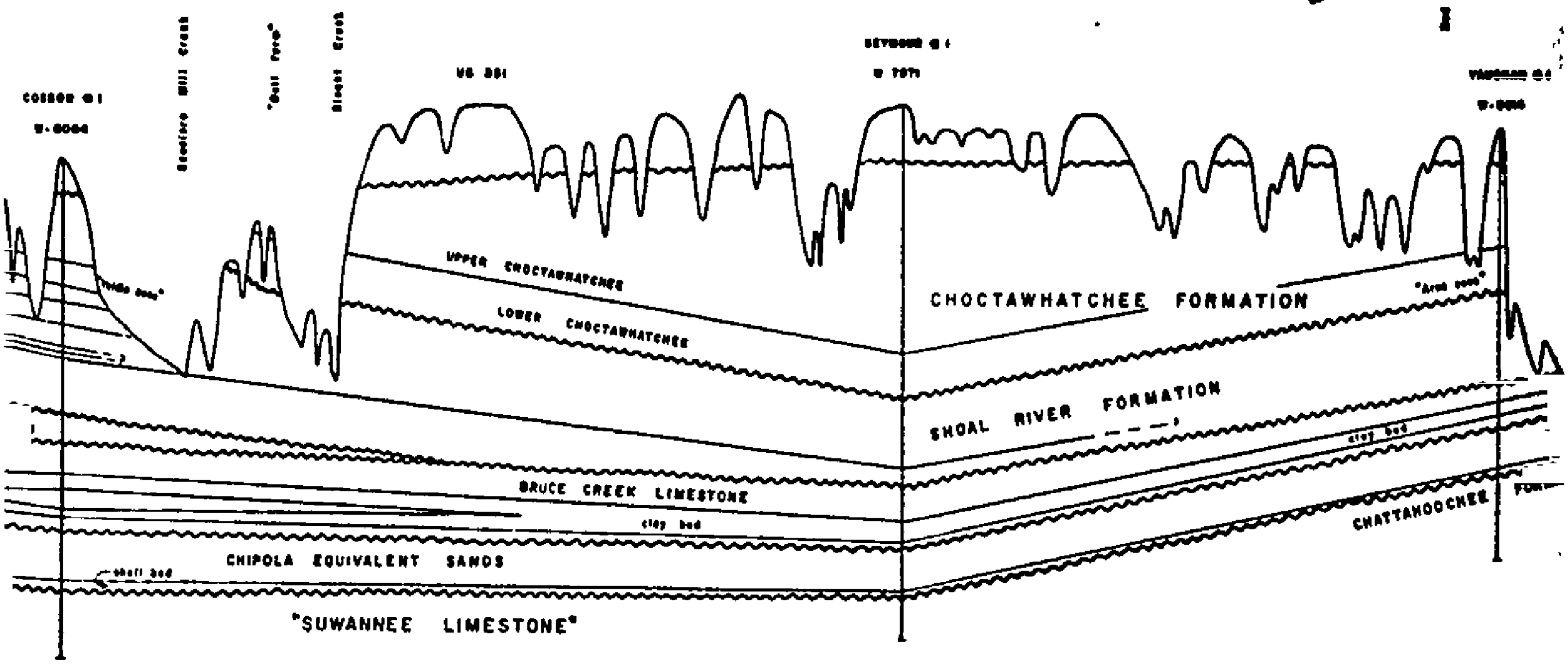
CROSS S

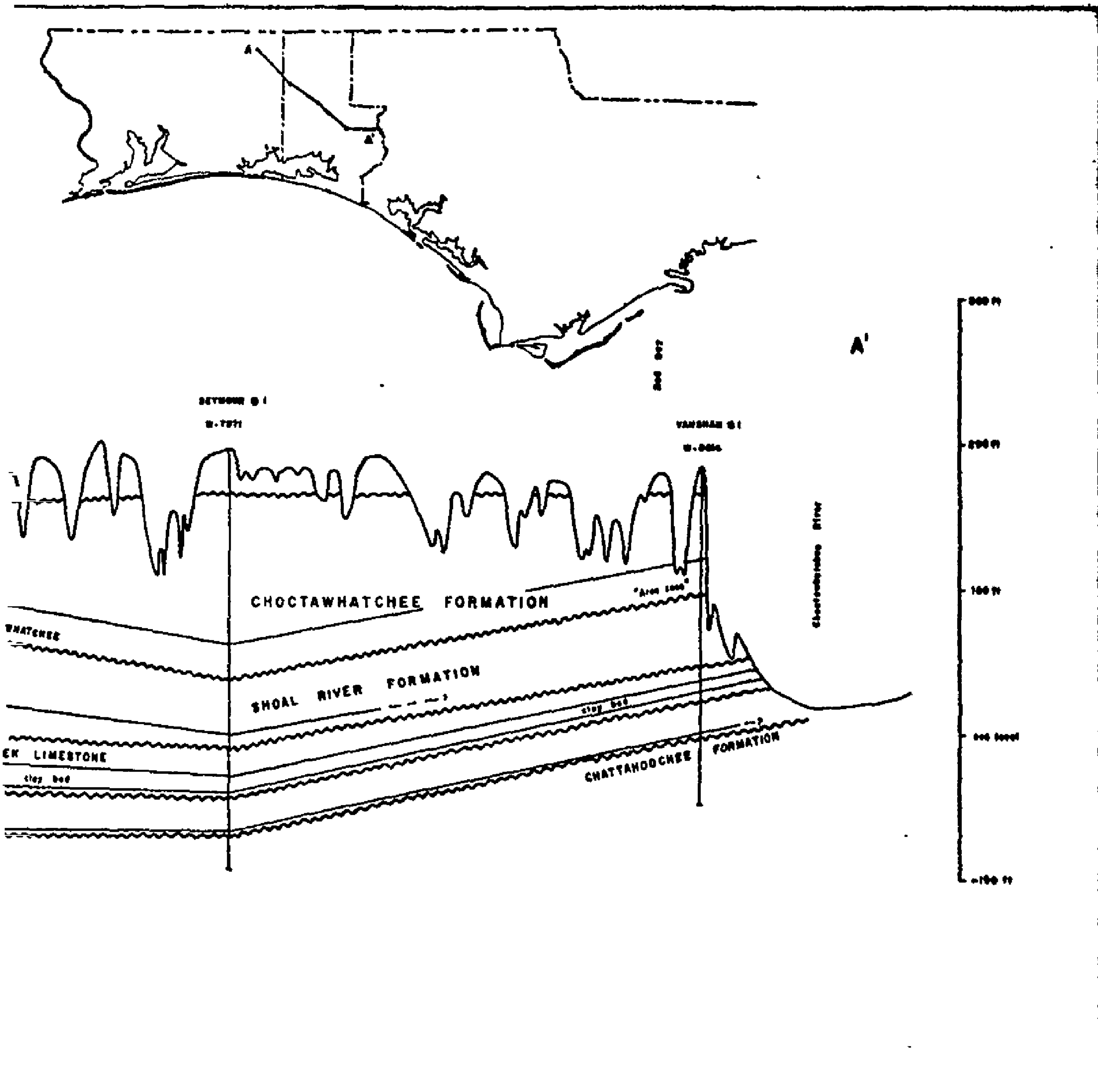


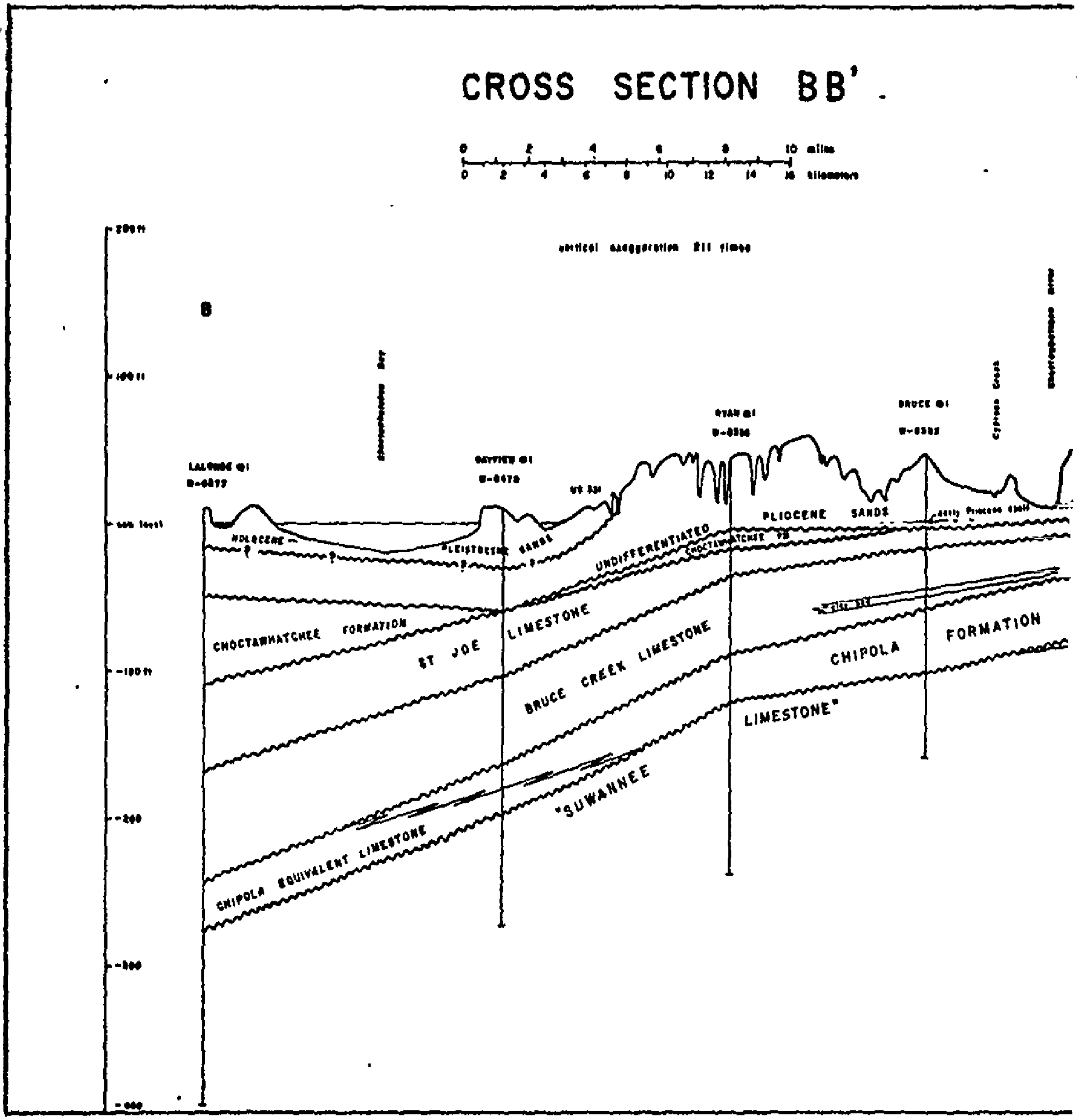
SHOAL RIVER #1
CITRONELLE FORMATION
UPPER SHOAL RIVER FORMATION
MIDDLE SHOAL RIVER FORMATION
shell bed
WHITES CREEK MEMBER
BRUCE CREEK LIMESTONE
clay bed
COSSON #1

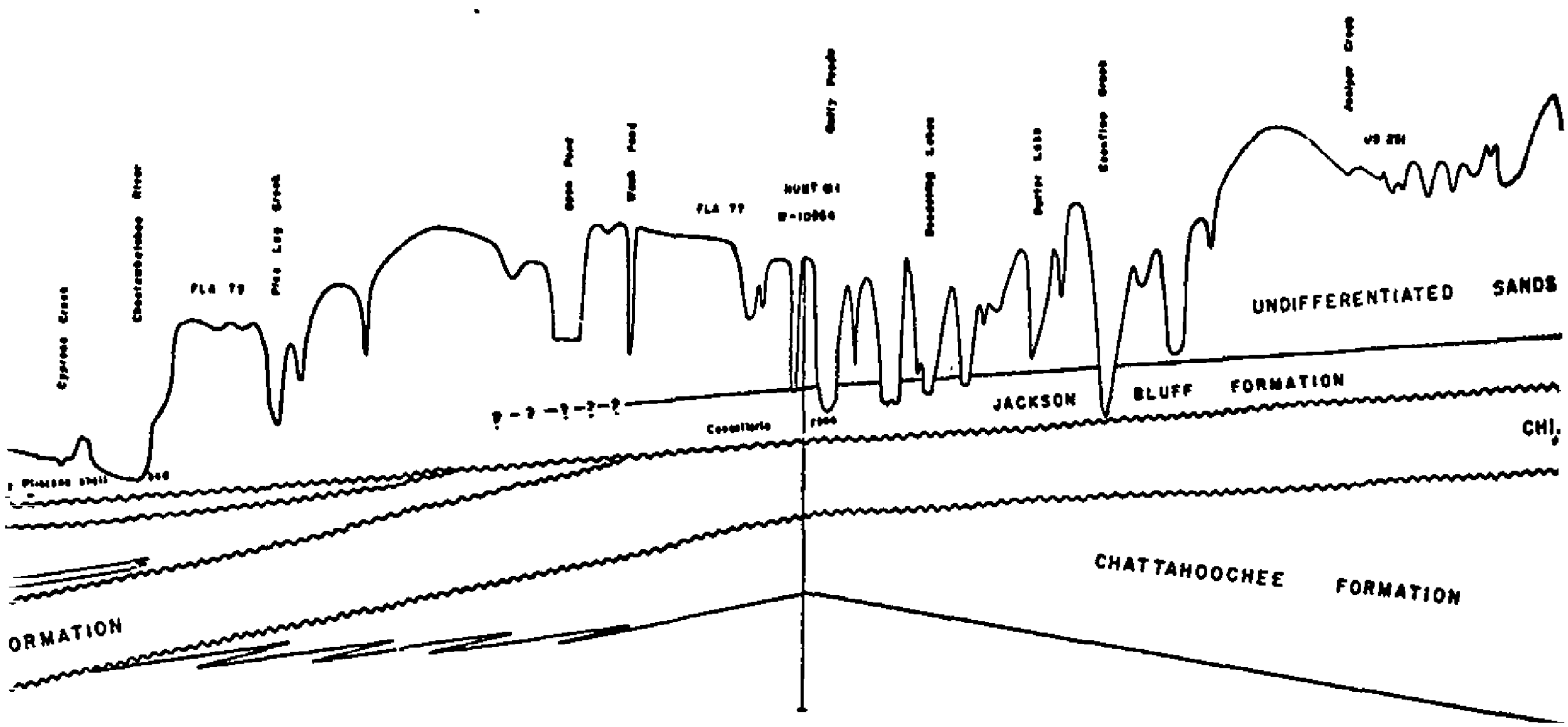
SS SECTION AA'






A
A'
A'
CHOCTAWHATCHEE FORMATION
WHATCHEE
SHOAL RIVER FORMATION
clay bed
EK LIMESTONE
clay bed
CHATTAHOOCHEE FORMATION


CROSS SECTION BB'
0 2 4 6 8 10 miles
0 2 4 6 8 10 12 14 16 kilometers
B
HOLOCENE
PLEISTOCENE SANDS
PLIOCENE SANDS
UNDIFFERENTIATED
CHOCTAWHATCHEE FORMATION
ST JOE LIMESTONE
BRUCE CREEK LIMESTONE
CHIPOLA FORMATION
"SUWANNEE LIMESTONE"
CHIPOLA EQUIVALENT LIMESTONE


FLA 79
FLA 77
UNDIFFERENTIATED SANDS
JACKSON BLUFF FORMATION
CHI.
CHATTAHOOCHEE FORMATION
ORMATION

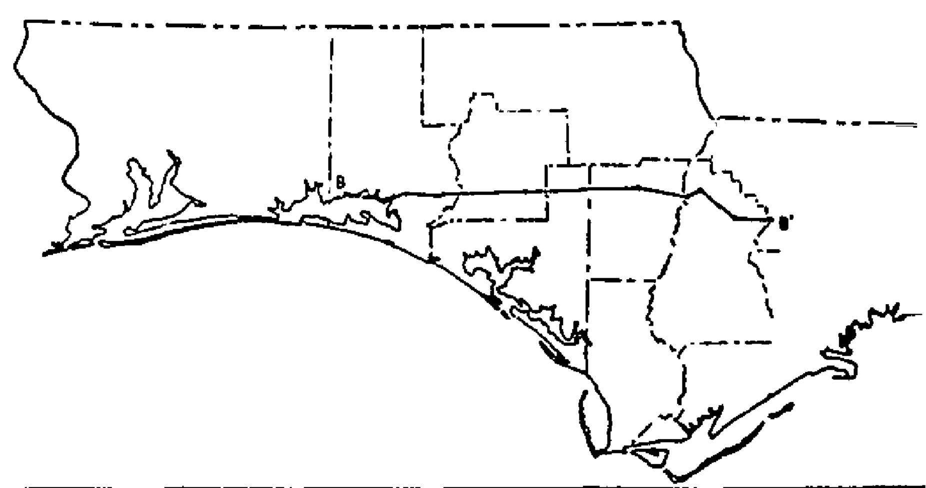
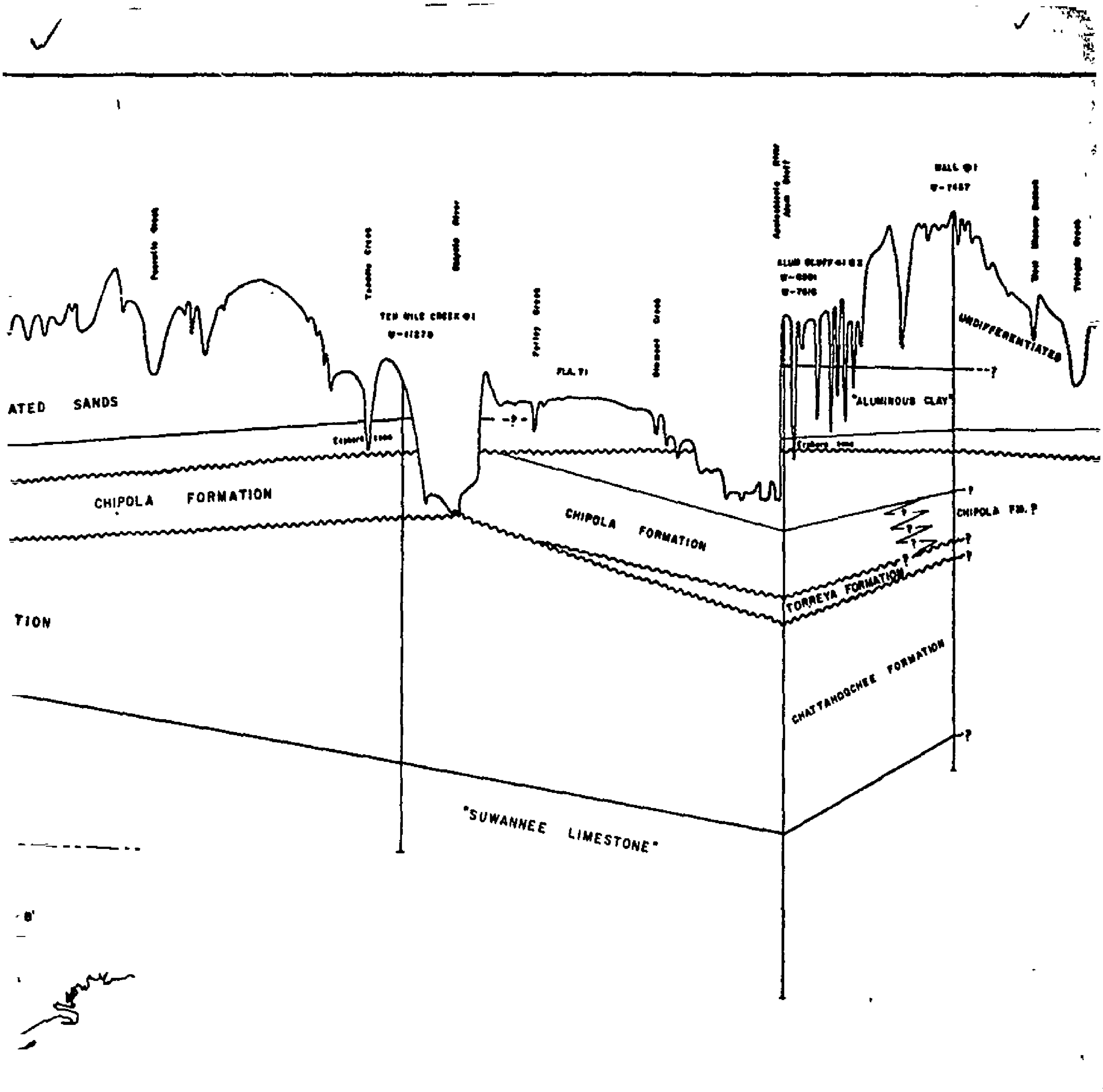
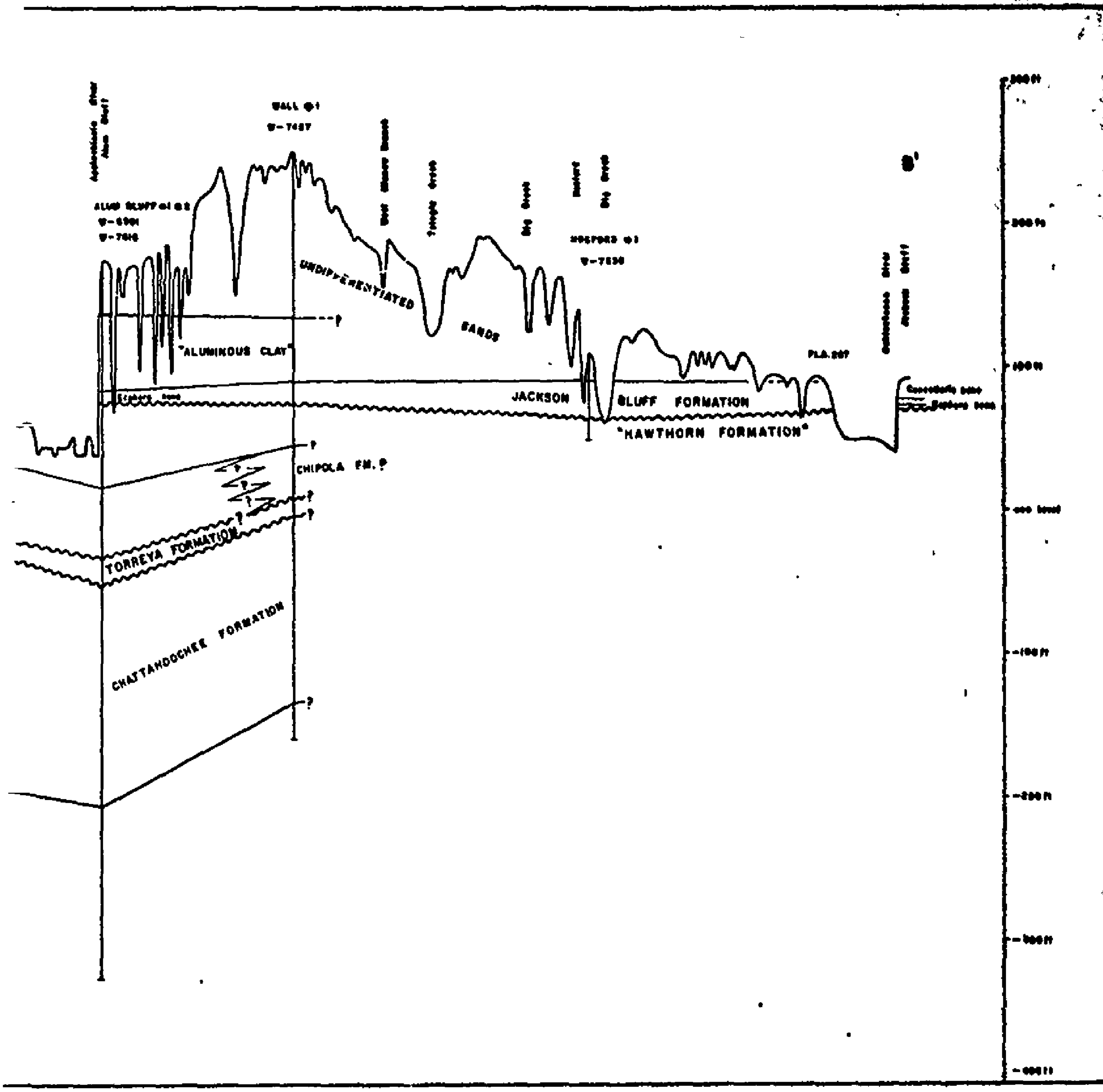

B
B'

Figure 20



ATED SANDS
CHIPOLA FORMATION
TION
TEN MILE CREEK #1
FLA. 71
ALUM BLUFF #1 & 2
HALL #1
UNDIFFERENTIATED
"ALUMINOUS CLAY"
CHIPOLA FORMATION
CHIPOLA FM. ?
TORREYA FORMATION
CHATTAHOOCHEE FORMATION
"SUWANNEE LIMESTONE"



WALL #1
UNDIFFERENTIATED SANDS
"ALUMINOUS CLAY"
JACKSON BLUFF FORMATION
"HAWTHORN FORMATION"
CHIPOLA FM.?
TORREYA FORMATION
CHATTAHOOCHEE FORMATION
sea level

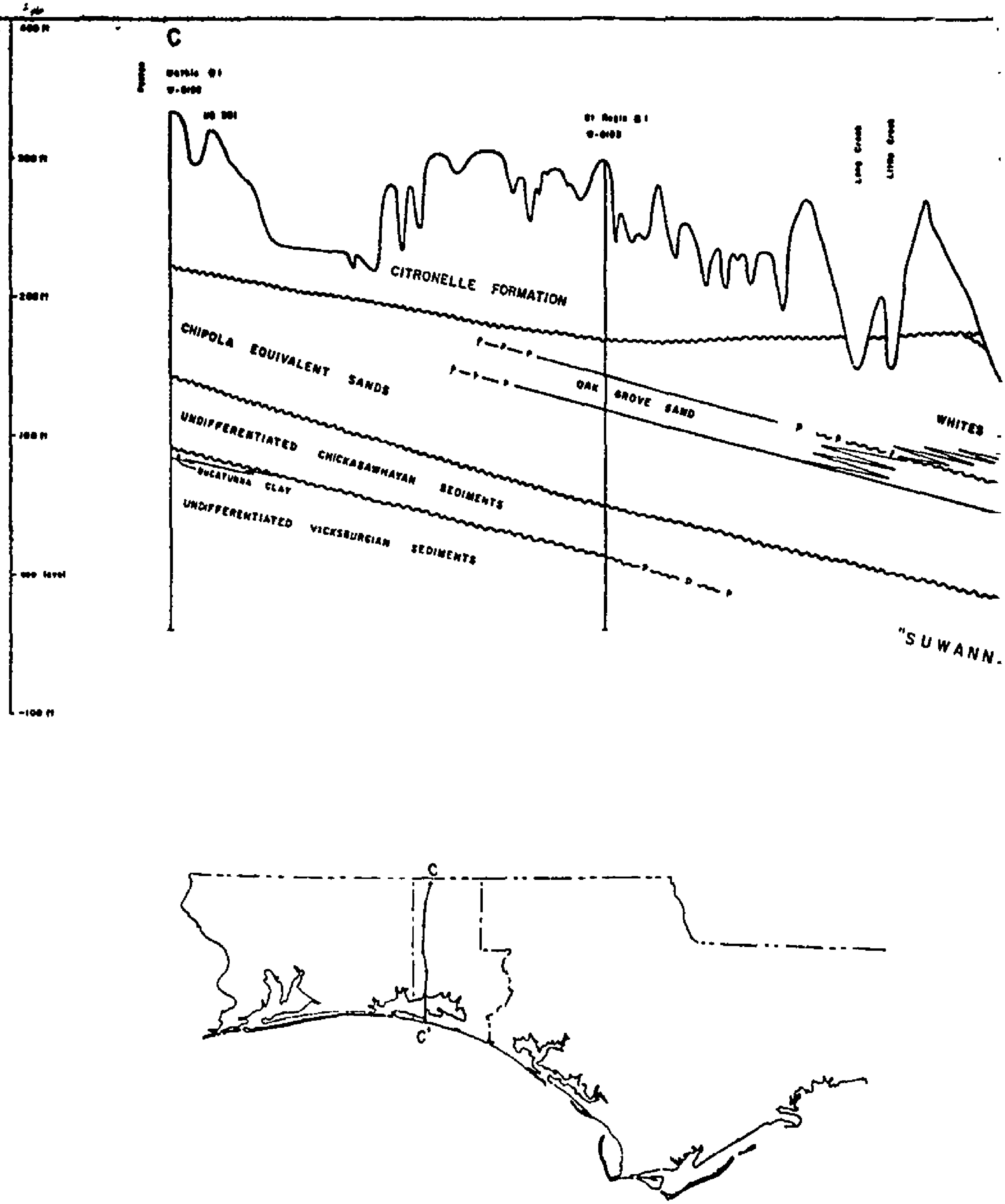
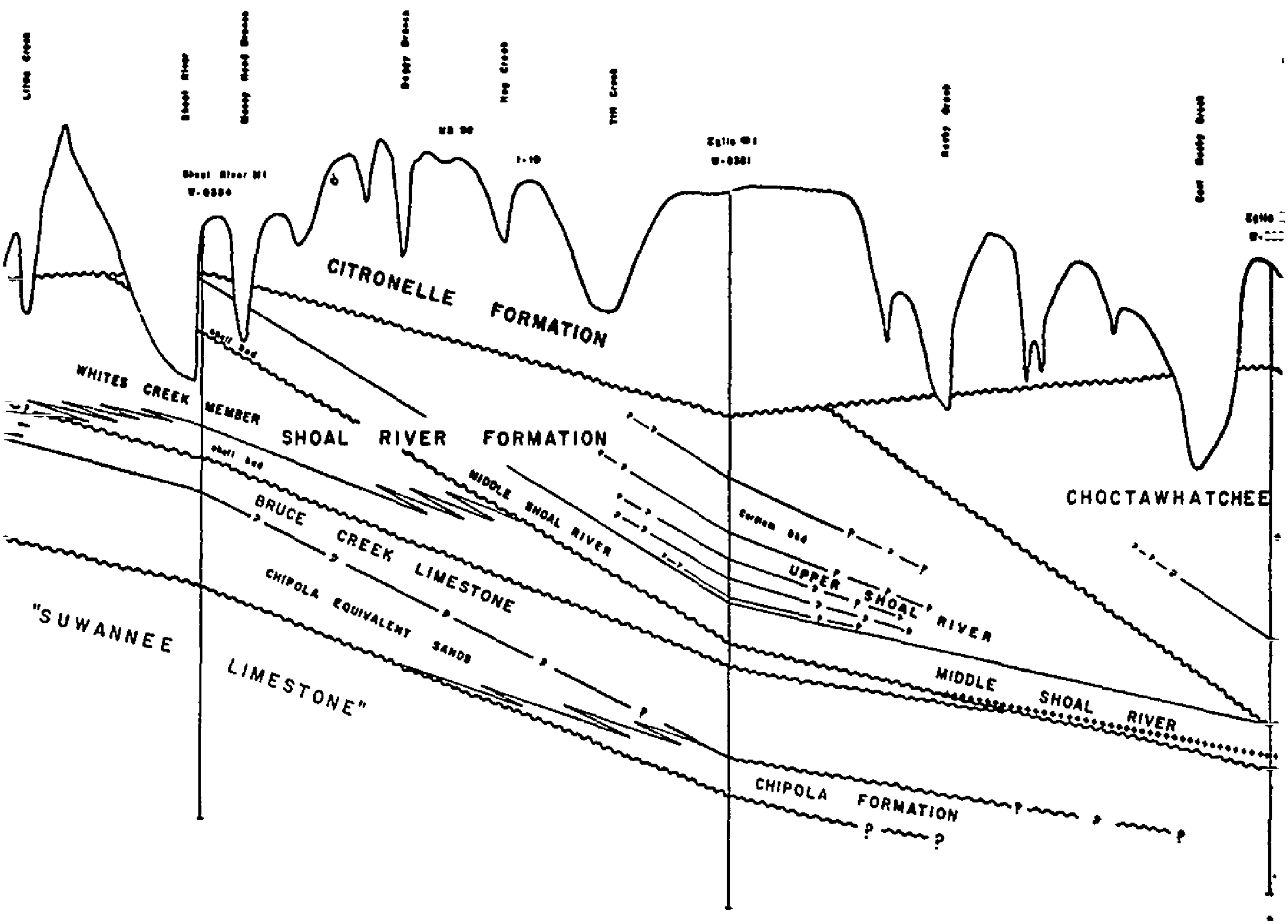
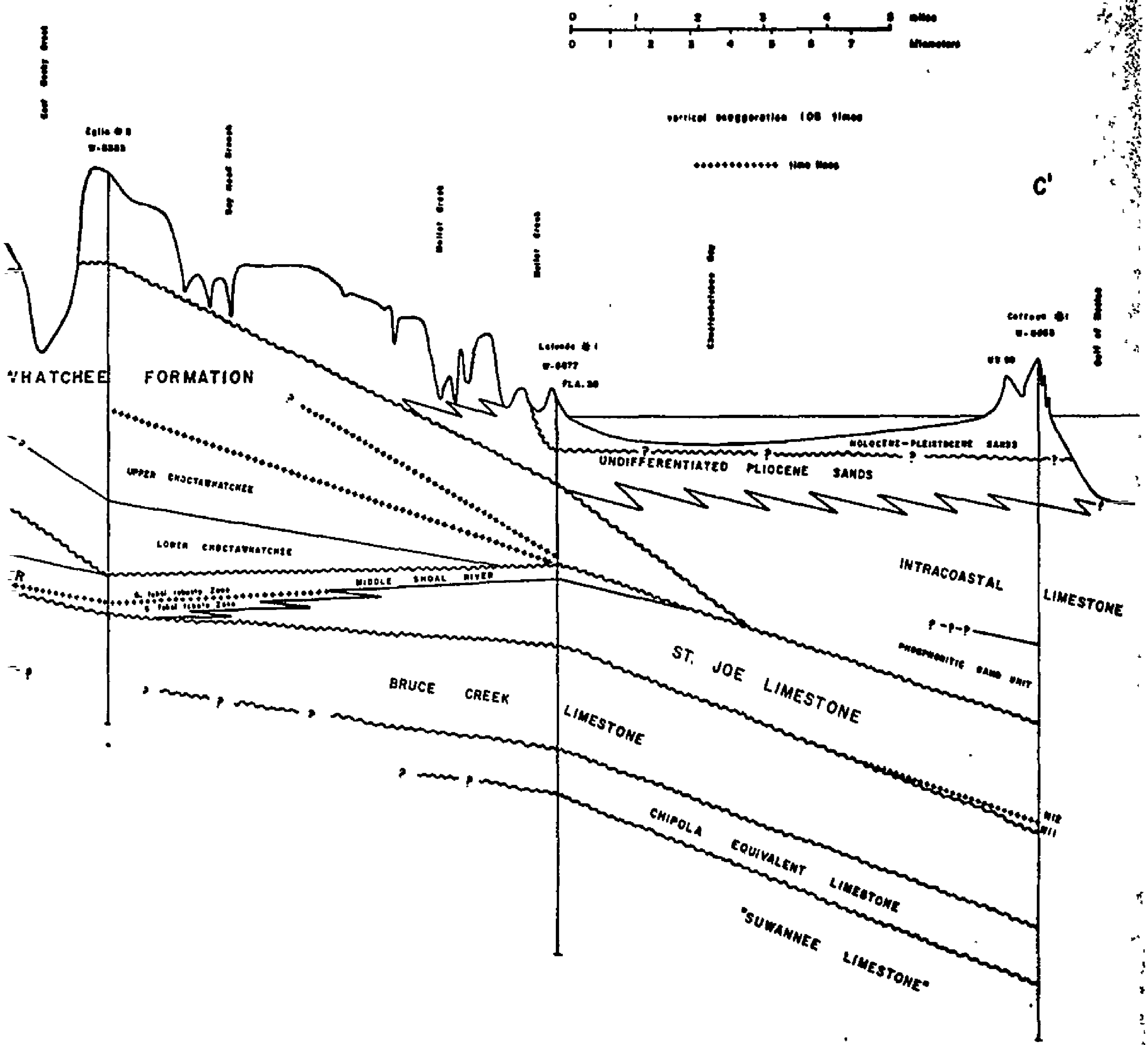

C
300 ft
200 ft
100 ft
sea level
-100 ft
CITRONELLE FORMATION
CHIPOLA EQUIVALENT SANDS
OAK GROVE SAND
WHITES
UNDIFFERENTIATED CHICKASAWHAYAN SEDIMENTS
BUCATUNNA CLAY
UNDIFFERENTIATED VICKSBURGIAN SEDIMENTS
"SUWANN
C
C'

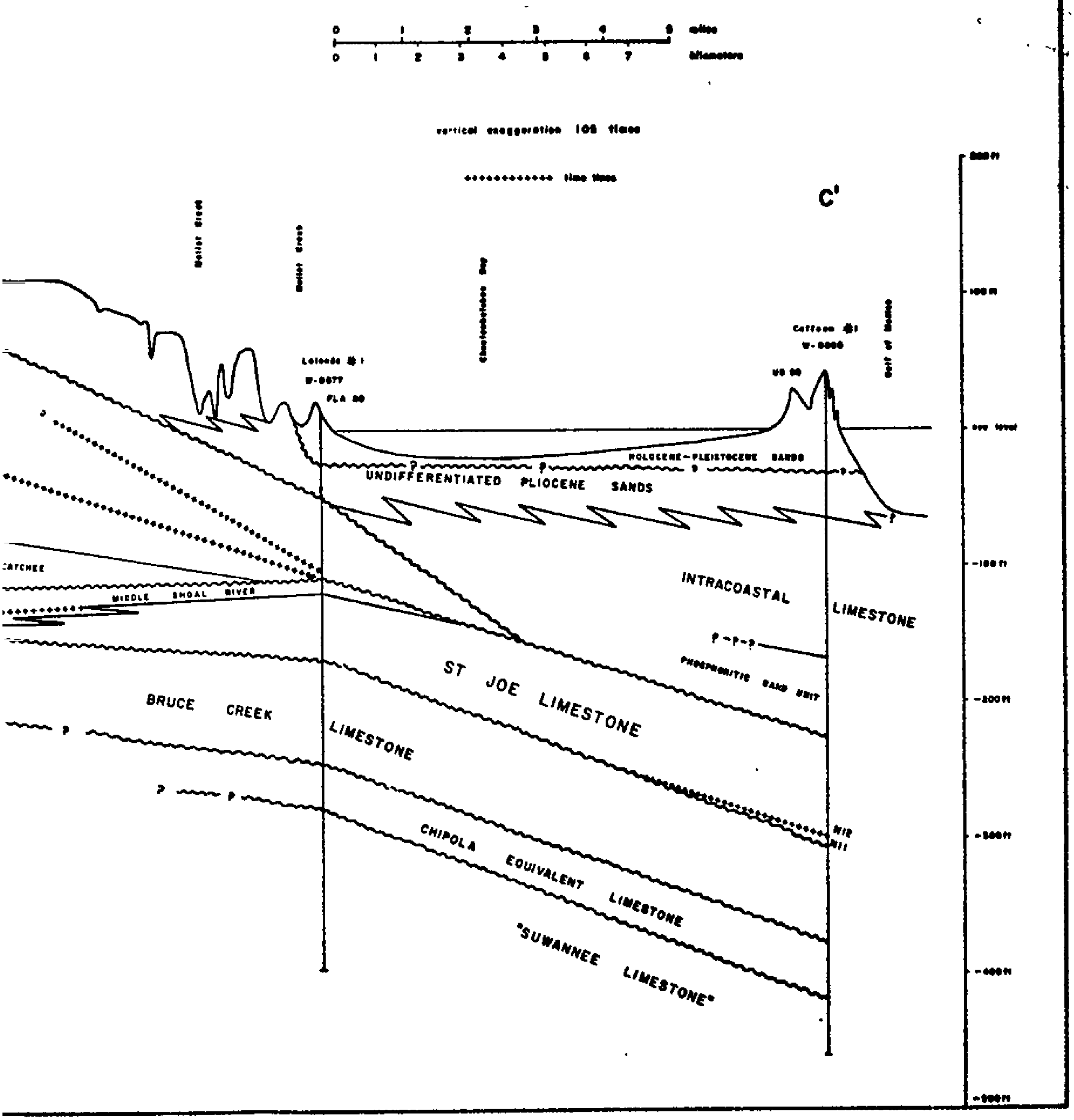
Figure 21


CITRONELLE FORMATION
WHITES CREEK MEMBER
SHOAL RIVER FORMATION
MIDDLE SHOAL RIVER
CHOCTAWHATCHEE
BRUCE CREEK LIMESTONE
CHIPOLA EQUIVALENT SANDS
UPPER SHOAL RIVER
"SUWANNEE LIMESTONE"
MIDDLE SHOAL RIVER
CHIPOLA FORMATION

CROSS SECTION CC'



CROSS SECTION CC'



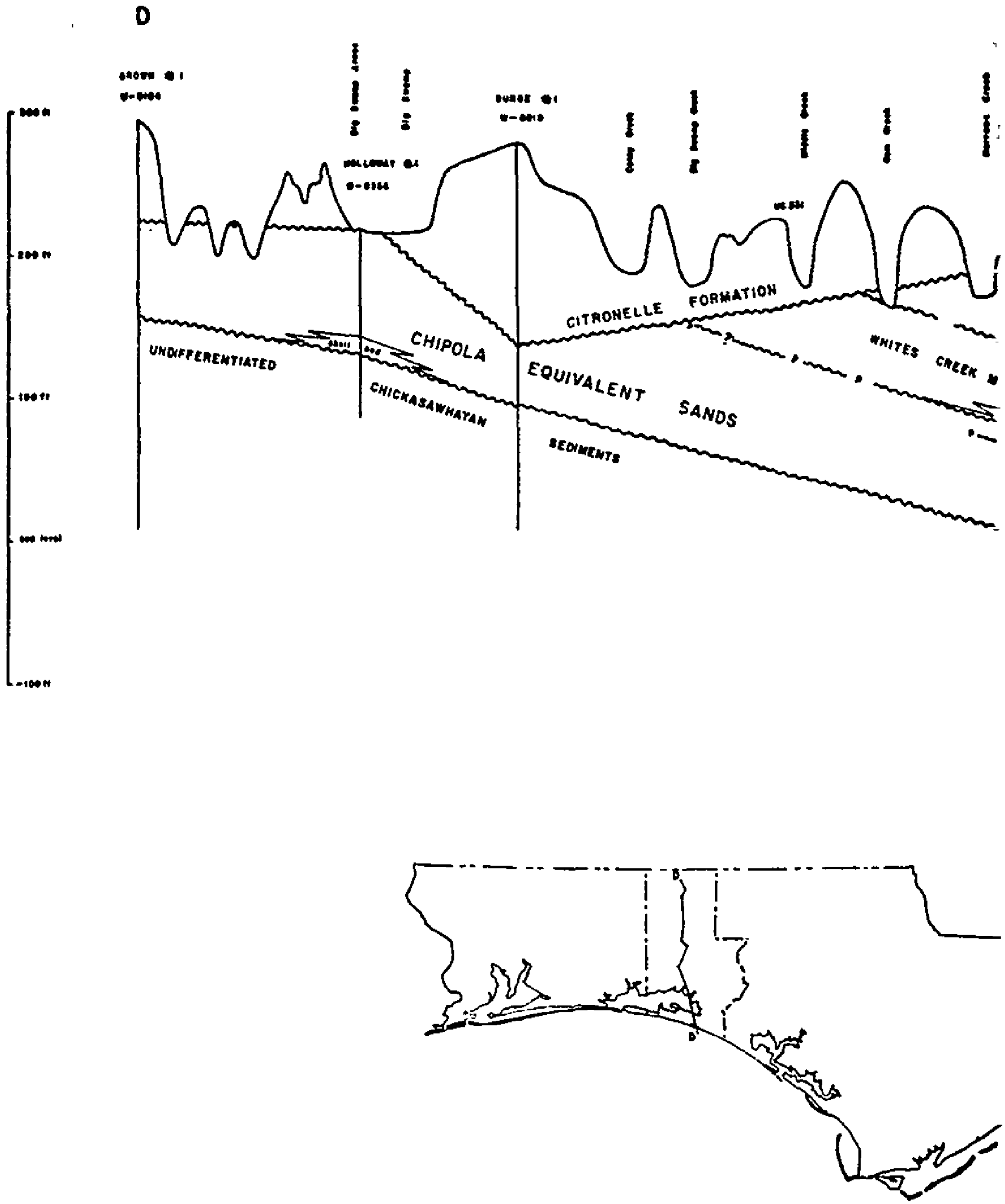
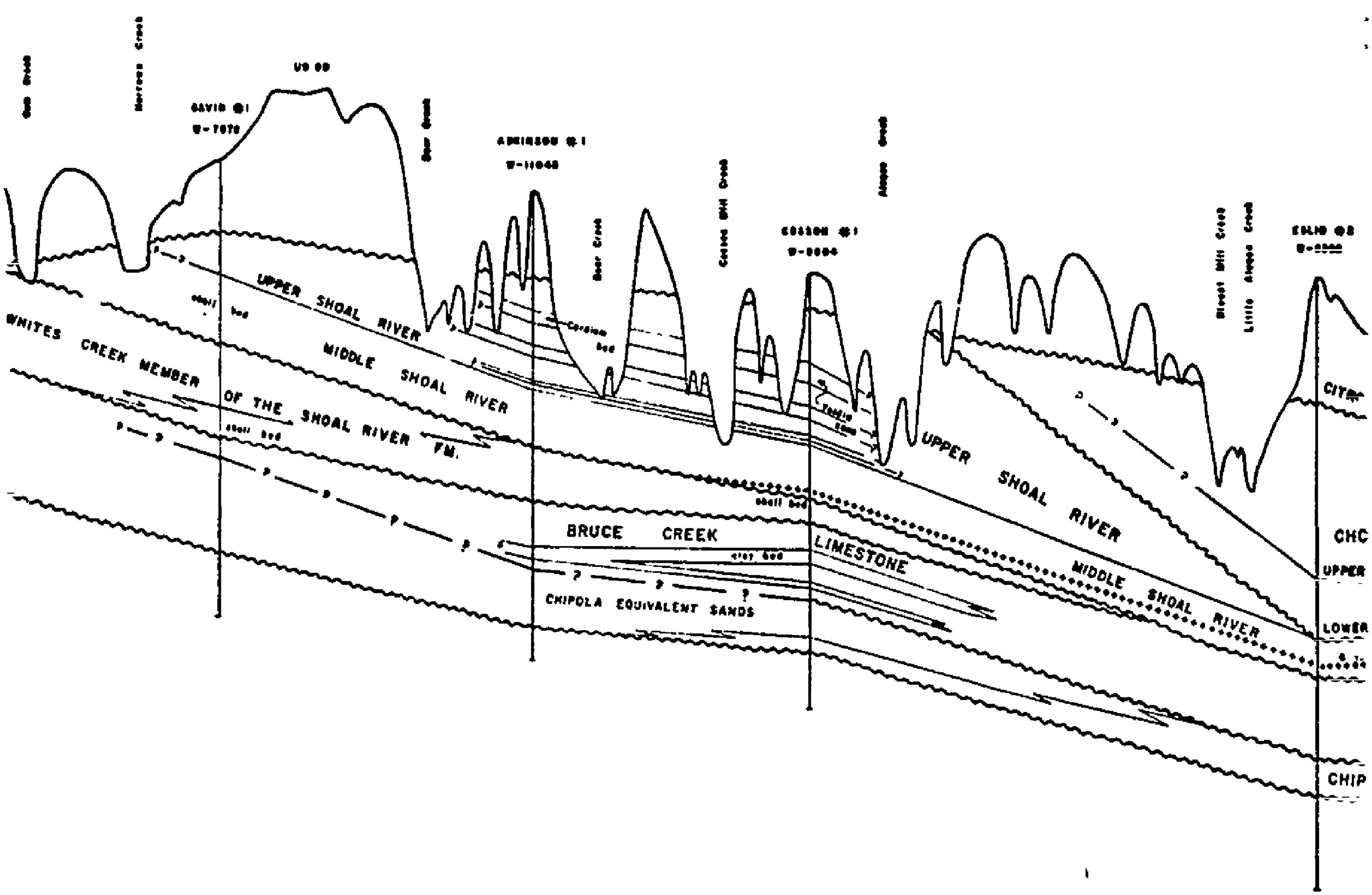
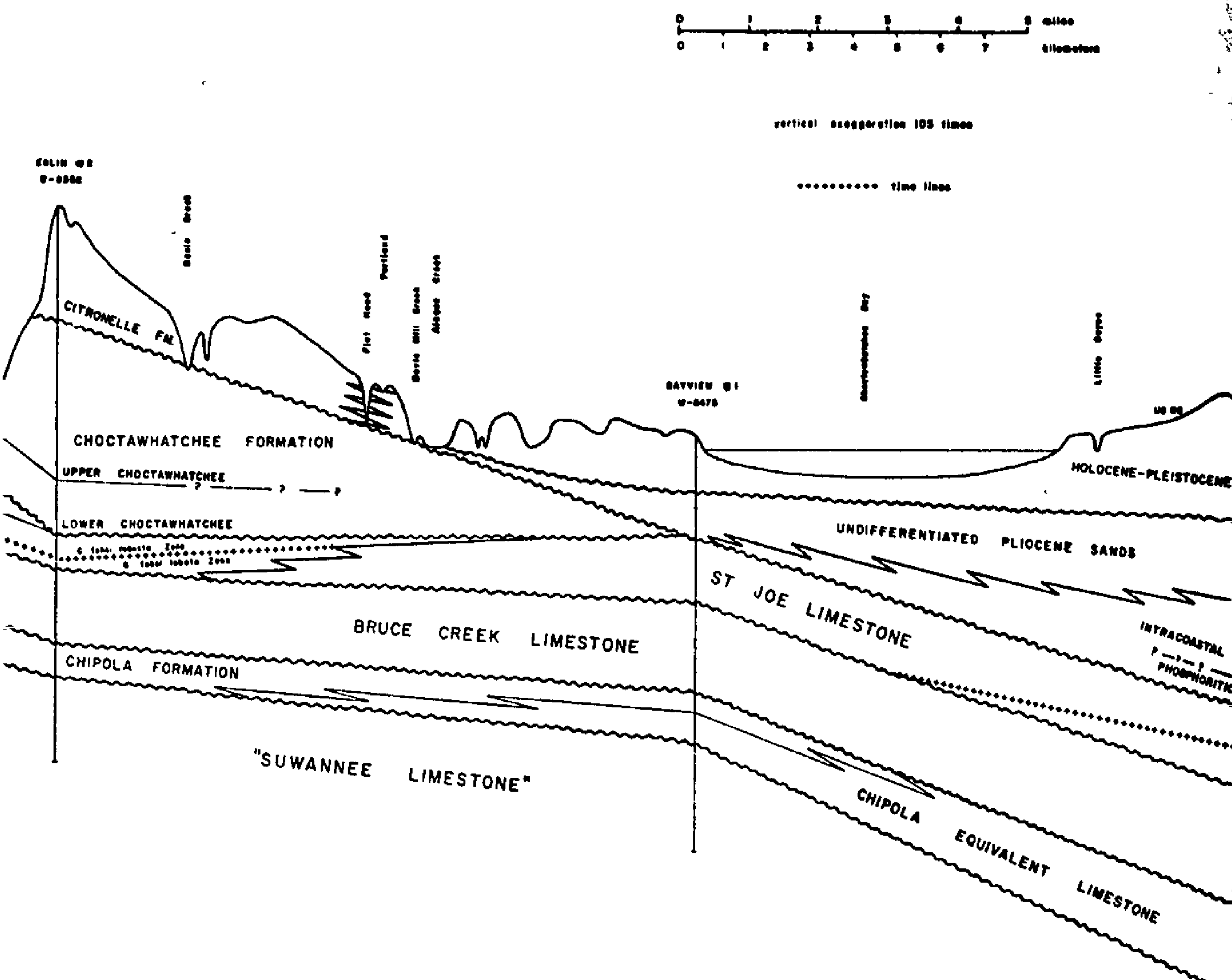

D
CITRONELLE FORMATION
CHIPOLA
EQUIVALENT SANDS
UNDIFFERENTIATED
CHICKASAWHAYAN
SEDIMENTS
WHITES CREEK

Figure 22


UPPER SHOAL RIVER
WHITES CREEK MEMBER OF THE SHOAL RIVER FM.
MIDDLE SHOAL RIVER
BRUCE CREEK LIMESTONE
CHIPOLA EQUIVALENT SANDS
UPPER SHOAL RIVER
MIDDLE SHOAL RIVER
CHC
UPPER
LOWER
CHIP

CROSS SECTION DD'



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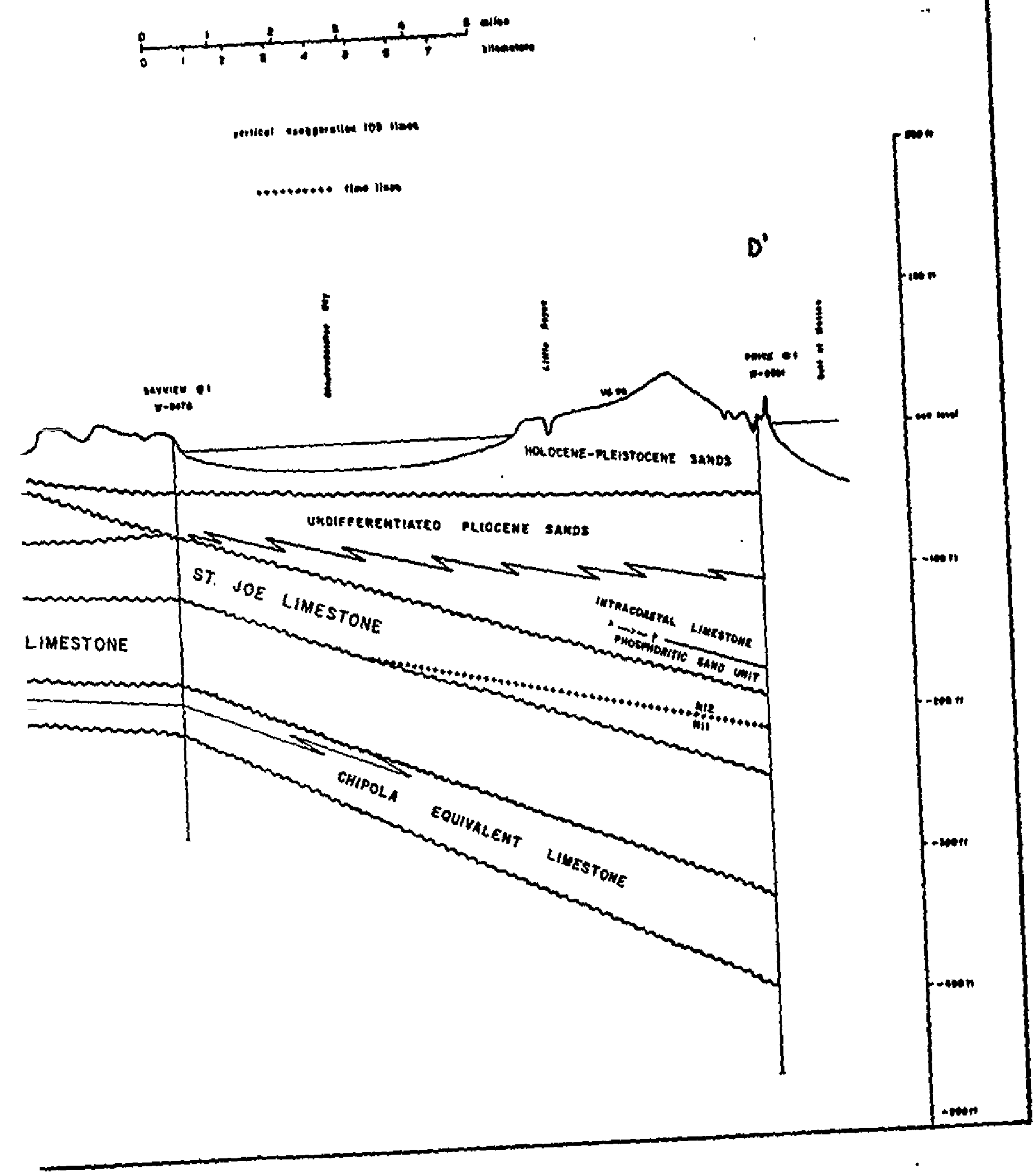


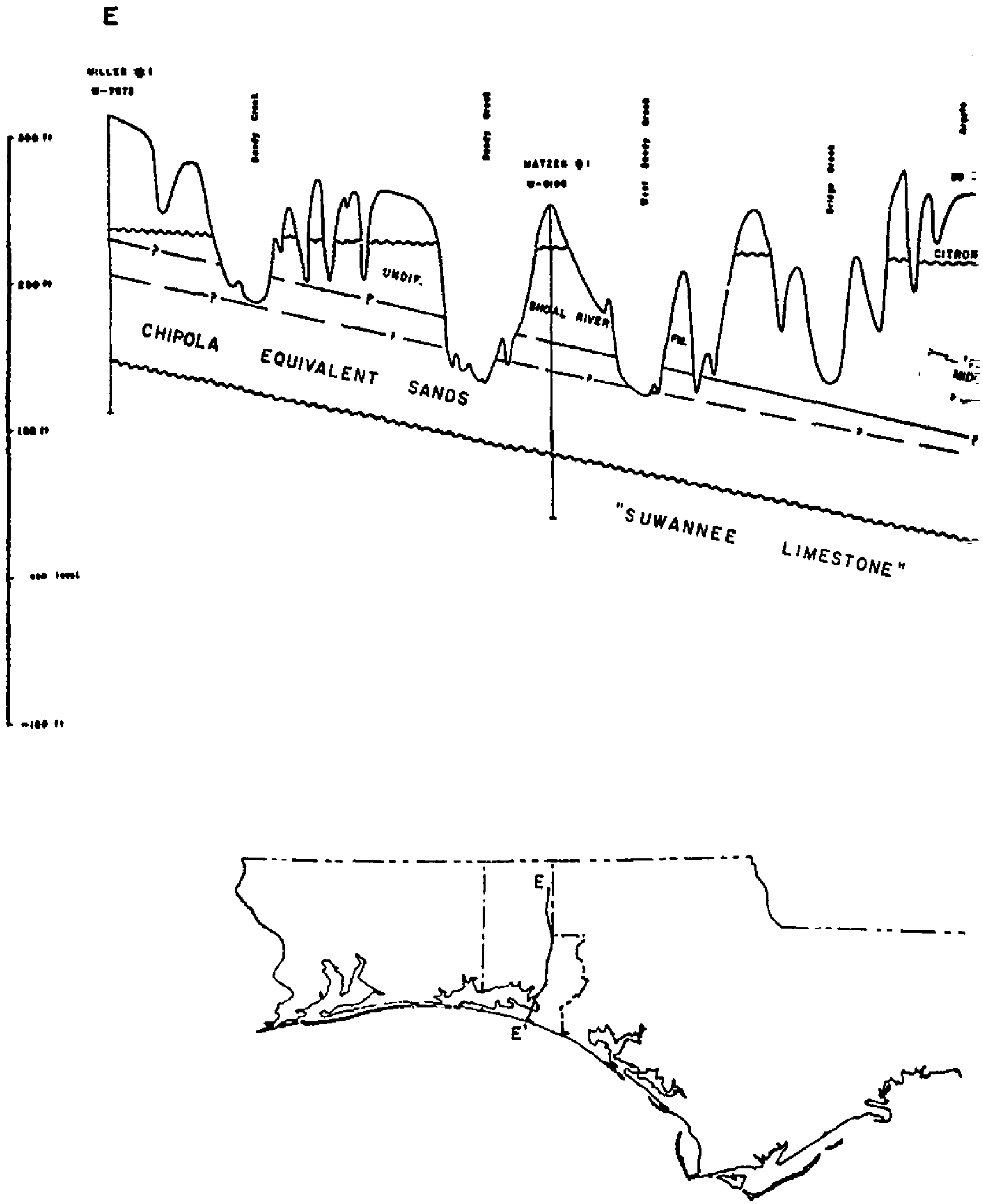
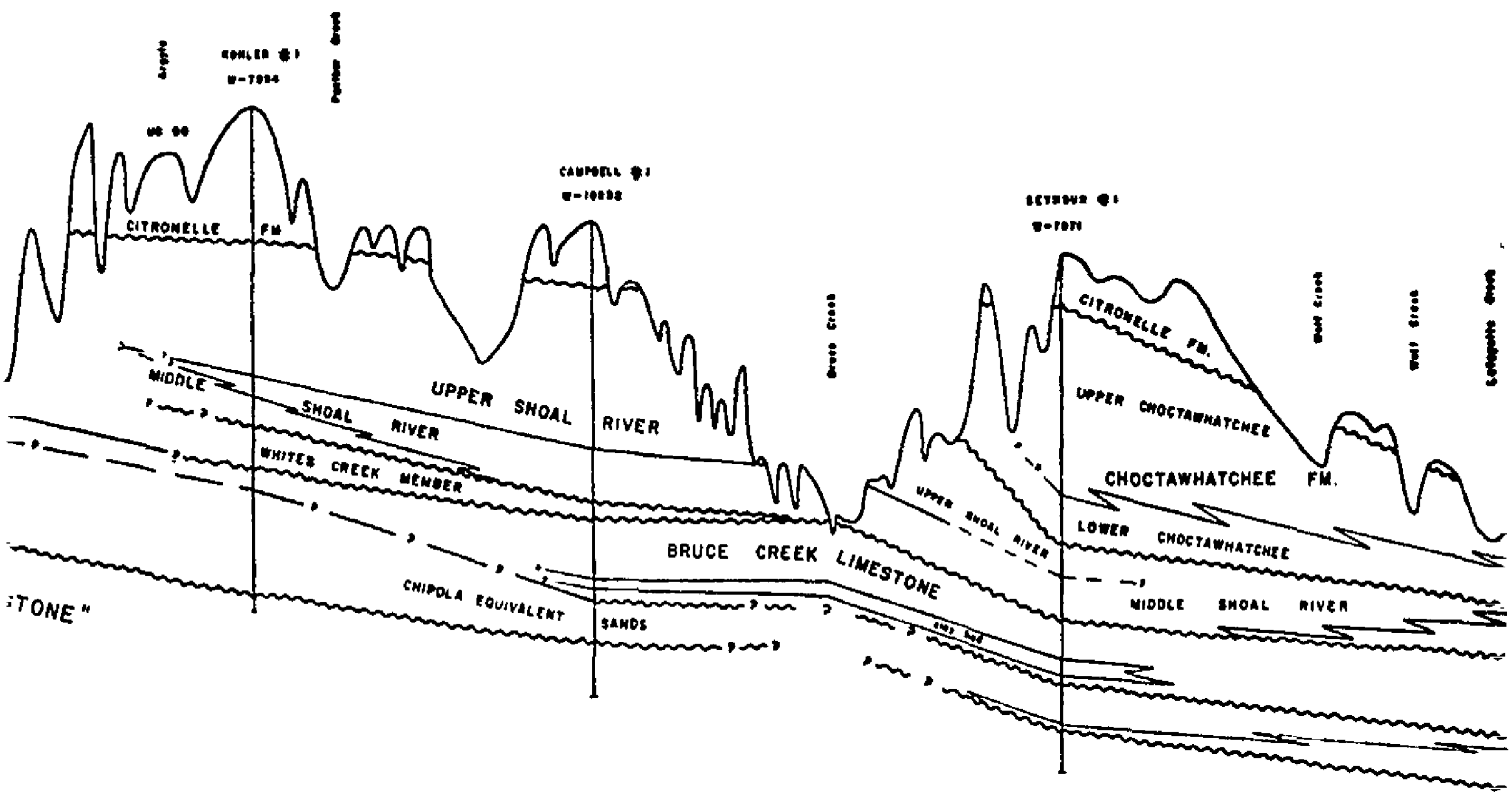
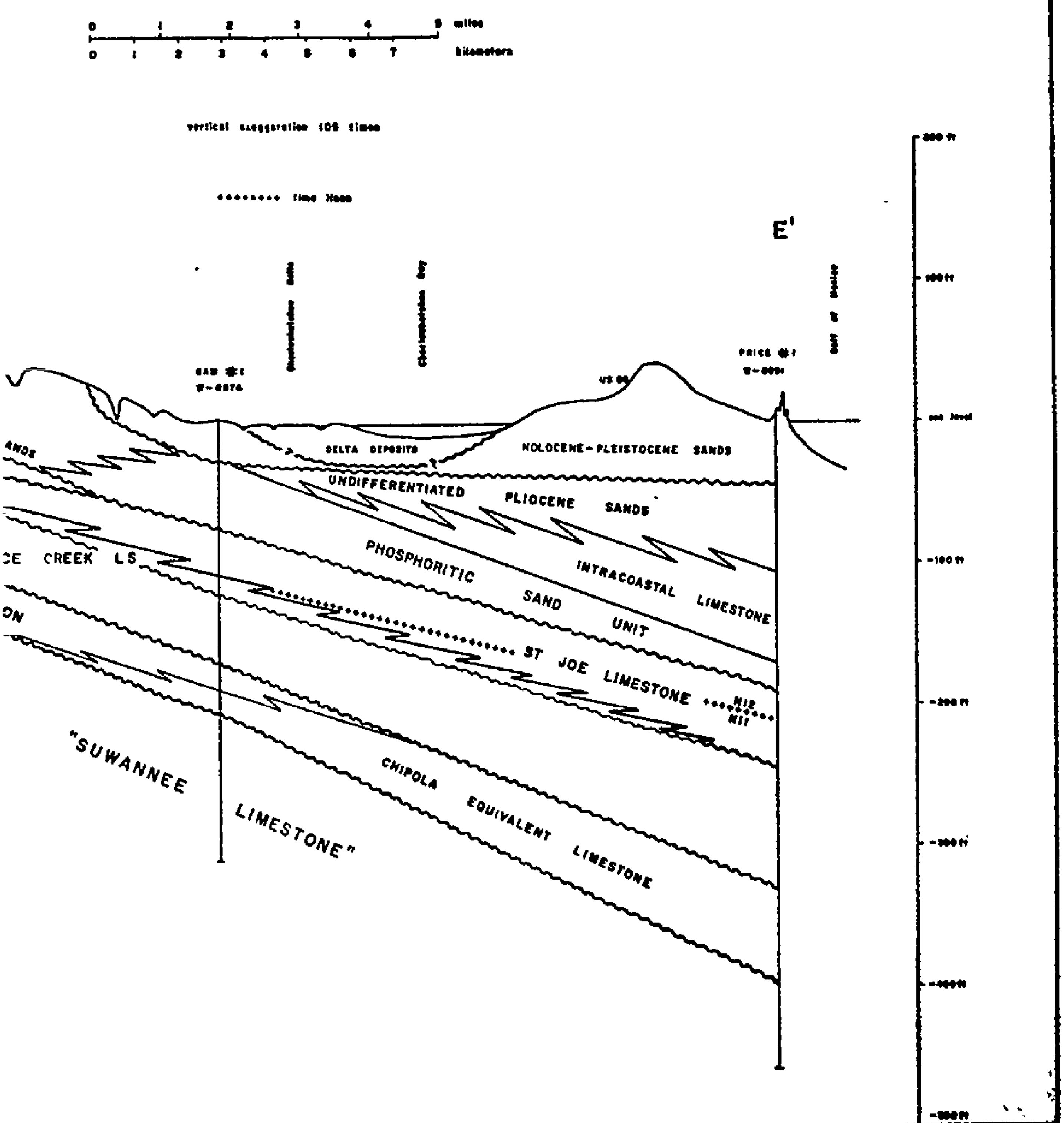

E
UNDIF.
SHOAL RIVER
FM.
CITRON
CHIPOLA
EQUIVALENT
SANDS
"SUWANNEE
LIMESTONE"
E
E'

Figure 23



US 90
CITRONELLE FM
MIDDLE
SHOAL RIVER
UPPER SHOAL RIVER
WHITES CREEK MEMBER
BRUCE CREEK LIMESTONE
CHIPOLA EQUIVALENT SANDS
TONE"
CITRONELLE FM.
UPPER CHOCTAWHATCHEE
CHOCTAWHATCHEE FM.
UPPER SHOAL RIVER
LOWER CHOCTAWHATCHEE
MIDDLE SHOAL RIVER

CROSS SECTION EE'



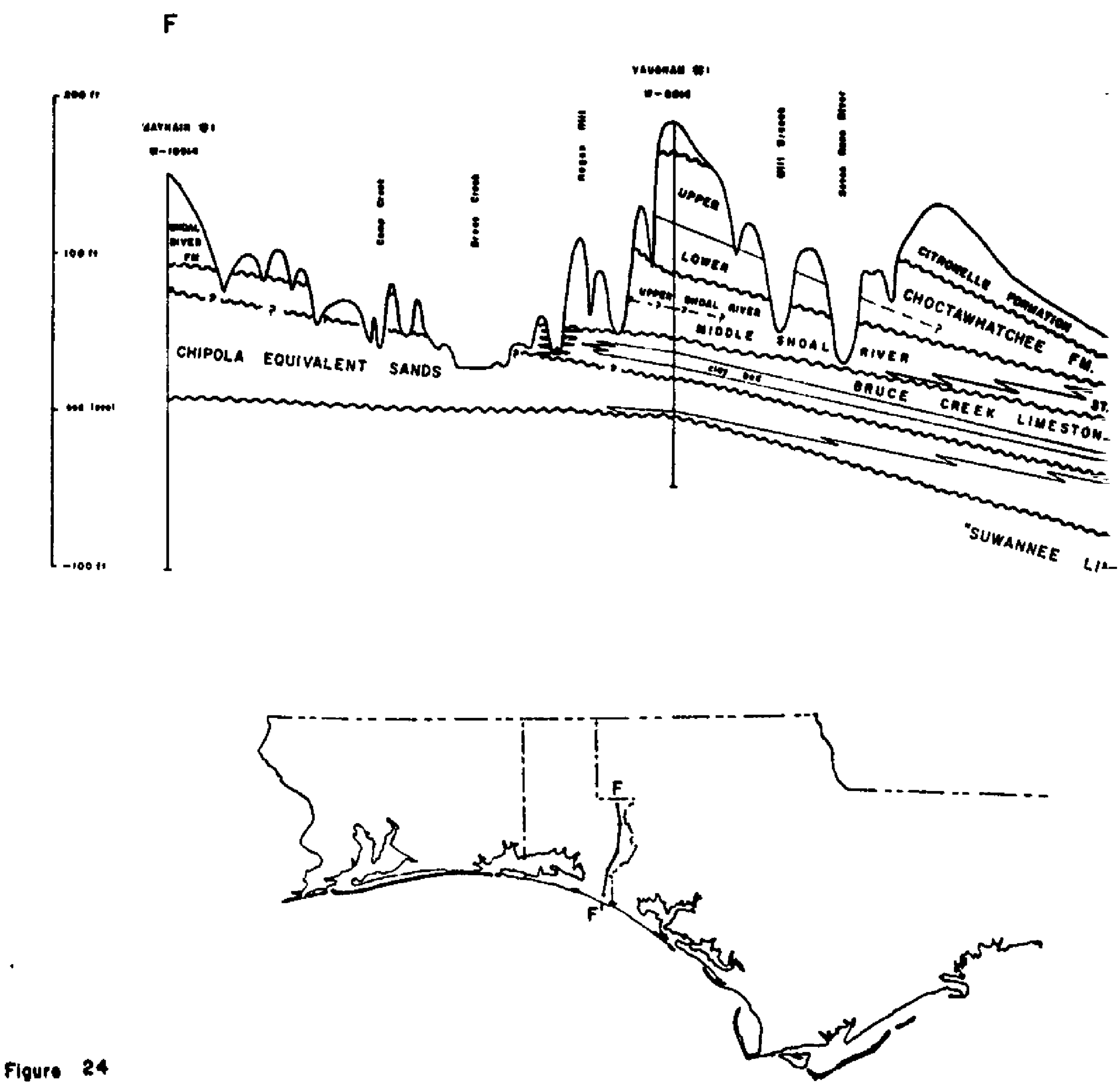

F
VAUGHAN #1
100 ft
sea level
-100 ft
SHOAL RIVER FM
CHIPOLA EQUIVALENT SANDS
UPPER
LOWER
UPPER SHOAL RIVER
MIDDLE SHOAL RIVER
CITRONELLE FORMATION
CHOCTAWHATCHEE FM.
clay bed
BRUCE CREEK LIMESTON
ST.
"SUWANNEE LI
F
F'

Figure 24

CROSS SECTION FF'