GRAVITY INVESTIGATION OF BASEMENT STRUCTURE IN NORTHWEST PENINSULAR FLORIDA

by

Neil M. Coleman

of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Geology in the University of South Florida

December, 1979

Major Professor: Mark T. Stewart

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CERTIFICATE OF APPROVAL

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An Abstract

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Major Professor: Mark T. Stewart

ABSTRACT

A gravity study has been completed in northwest peninsular Florida. The investigation covered an area of 5700 km^2 which extends northwest to Levy County to Taylor County. Two-hundred and sixteen gravity stations were established and correlated with the International Gravity Standardization Net. Standard corrections were applied to reduce the raw gravity data to Bouguer anomaly values. The Synagraphic Mapping System (SYMAP) was used to generate a Bouguer anomaly map with a contour interval of one milligal.

Using trend surface analyses, an attempt was made to separate regional and residual gravity components from the data set. A simple regional trend was not found to exist on the scale of the study area. Profiles were drawn perpendicular to contours in areas with high gravity gradients. Geologic cross-sections based on available well data, neutron density logs and core samples were prepared for each profile. The gravity effect for each cross-section was calculated using the method of polygons. Basement offsets were adjusted until close agreement was achieved between calculated and observed gravity profiles.

The resulting geologic sections show that thicknesses of the Paleozoic Erathem have a minimum range of 0.5 to 2.5

km. Normal faulting probably produced the corresponding minimum basement offset of 2.0 km. Zones of high gravity gradient are strongly linear, suggestive of subcrop fault traces. The more prominent zones trend northeast and parallel the proposed trend of major normal faults in the Southwest Georgia Embayment. Basalt flows or diabase dikes have been penetrated in wells drilled in eastern Taylor County. The proximity of these flows and/or dikes to the study area conforms with a hypothetical zone of rifting in early Mesozoic time.

Two long, linear basins are inferred from the gravity data. One trends northeast from southern Taylor County to Hamilton County and the other trends northeast from southern Dixie County to Baker County. These basins and the Southwest Georgia Embayment may have developed in response to the same regional stress field in early Mesozoic time.

Results of the gravimetric investigation, in combination with other geologic information, suggest that basement offsets produced by normal faulting are the sources of observed regional gravity and magnetic anomalies. A series of parallel fault-block basins and uplifts are proposed as the dominant basement structures.

Abstract approved: Mark T. Stewart
Major Professor

11/21/79
Date of Approval

INTRODUCTION

An understanding of the geologic history of Florida is crucial to the application of plate tectonics theory to the region which includes the Gulf of Mexico, Florida and the Bahama Platform. Northern Florida, considered to be underlain by continental crust, is of central importance since it probably is bordered on three sides by oceanic crust.

Cores taken from widely scattered drillholes show that most of the northern peninsular Florida is probably underlain by Paleozoic rocks. The relation of these rocks to Paleozoic strata in west Africa has been suggested by, among others, Grasty and Wilson (1967) and Cramer (1971). Rifting of Pangaea and creation of the Atlantic Ocean and the Gulf of Mexico must have profoundly affected the structure of these rocks. Unfortunately, Paleozoic rocks do not outcrop anywhere in Florida. Gradual subsidence of the Florida Platform and deposition of the Zuni and Tejas Sequences prevent direct mapping of Paleozoic structures. Therefore, geophysical methods provide the only means of examining large-scale structures in the Paleozoic Erathem and the underlying basement.

The goal of this study is to identify the sources of regional gravity and magnetic anomalies in northwest peninsular Florida (Figures 1 and 2). The project includes the

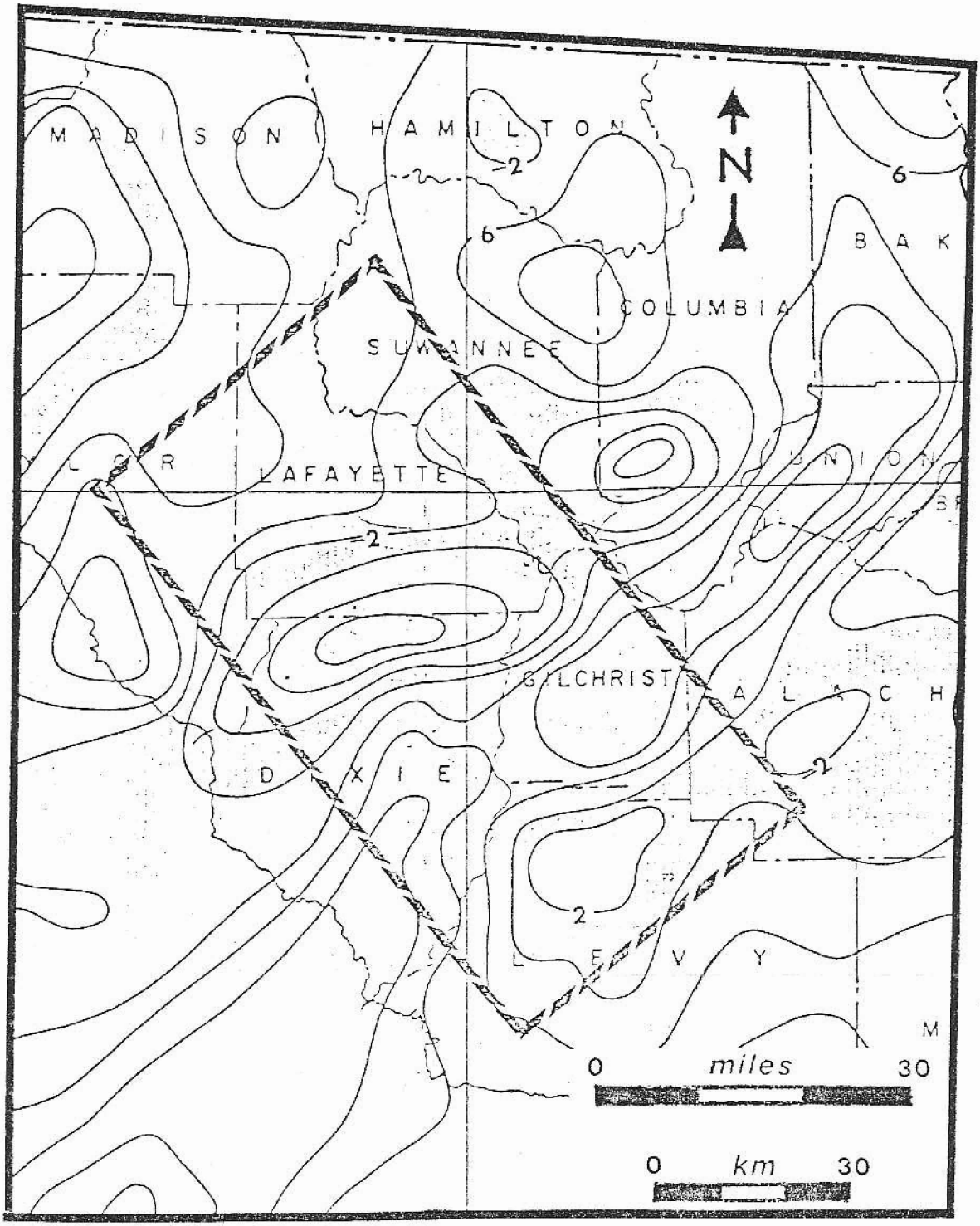


Figure 1. Regional Bouguer anomaly map of northwest peninsular Florida with 4 milligal contour interval. Study area outlined (from Oglesby, Ball and Chaki, 1973).

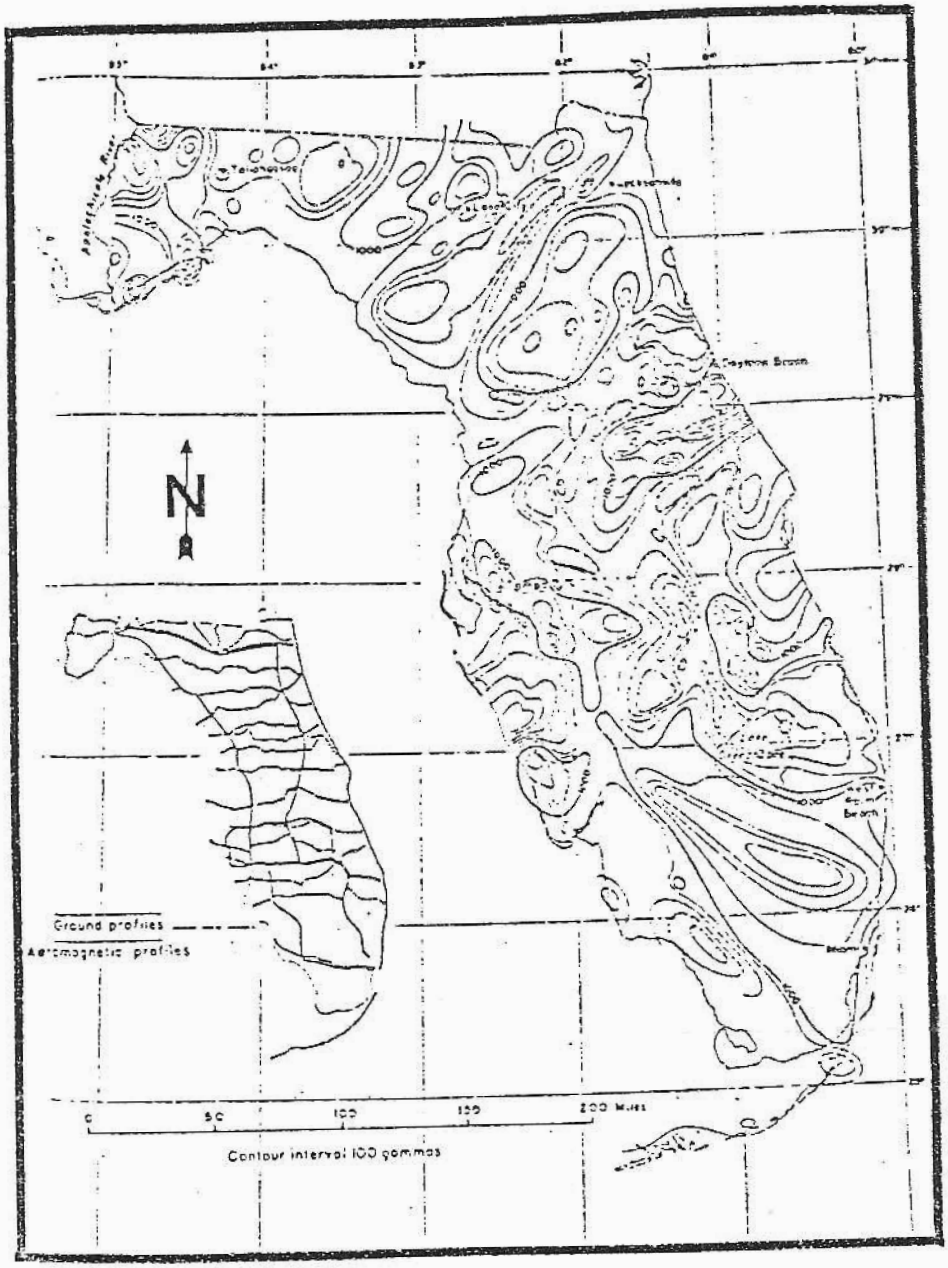


Figure 2. Regional magnetic map of the Florida peninsula (from King, 1959).

preparation of a Bouguer anomaly map and polynomial trend surface analyses of regional trends. Gravity profiles for assumed geologic cross-sections are fitted to observed gravity profiles using the method of polygons (Talwani, and others, 1959) in order to determine which possible structures conform to observed Bouguer anomalies.

Description of Study Area

Gravity stations were established within a rectangular area of 5700 km^2 which extends northwest from Levy County to Taylor County, Florida (Figure 3).

The study area is a coastal region of low relief and sub-tropical climate. Nearly all of the land surface is less than 30 m above sea level and most is less than 15 m. More than 50% of the terrain consists of densely vegetated swamps and hammocks, the largest of which are Mallory and Warrior Swamps and San Pedro Bay.

Major watercourses include the Suwannee, Santa Fe and Steinhatchee Rivers. Bridges cross the Suwannee River only along major highways, making it a serious barrier to ground-based surveys.

Regional Geology

Stratigraphy

Outcroppings in the study area include some of the oldest rocks exposed in Florida. Surface and near-surface rocks are limestones and dolostones of the Alachua, Crystal River, Williston and Inglis Formations and the Avon Park

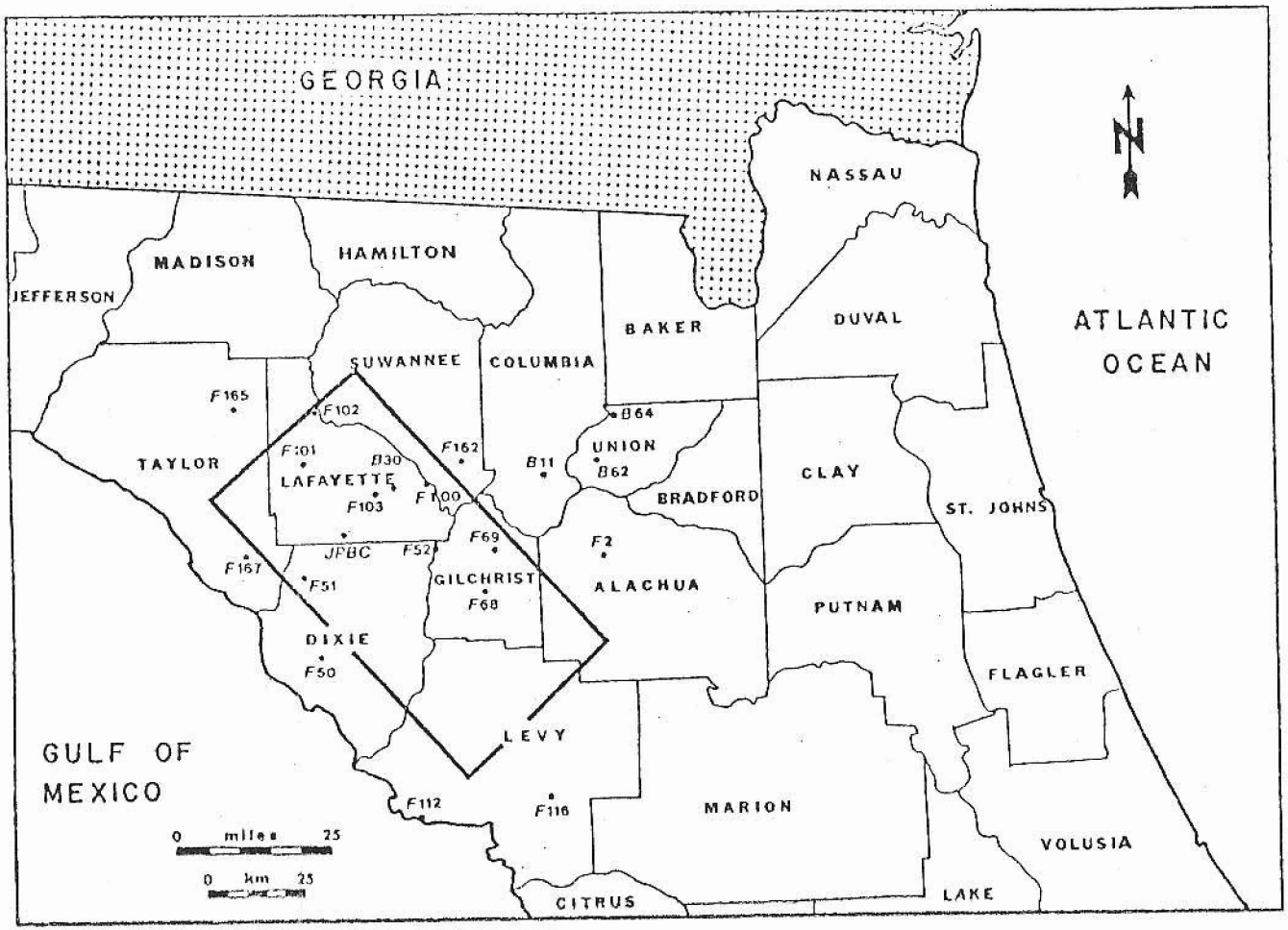


Figure 3. Location map of study area with drillhole locations (well names refer to data tabulated in Appendix 1).

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Limestone.

Thorough descriptions of the Cretaceous System in Florida are given by Applin and Applin (1965 and 1967). Rocks of the Gulfian Group (Upper Cretaceous) have a relatively uniform thickness underlying the study area. In northern Florida these rocks include light-colored chalky limestones and dolostones, medium- to fine-grained calcareous sandstones and dark to gray shales. Most of these rocks have a shallow-water marine origin. The Comanchean Group (Middle Cretaceous) rocks include vari-colored shales and fine- to coarse-grained sandstones and comprise a marginal clastic facies. Rocks of this group are absent over much of northeast Florida and southeast Georgia.

A remarkably uniform unconformity underlies the Cretaceous Group in northern and central Florida (Applin, 1951). Barnett (1975) describes it as the sub-Zuni erosional surface. This surface consists of a wide range of rock types which range in age from Precambrian (?) to Middle Jurassic. Sub-Zuni rocks penetrated by wells in the study area are sandstones and shales of probable Ordovician to Devonian age (Carroll, 1963).

Wells in eastern Taylor County encountered basalt or diabase overlain by clastic rocks. Barnett (1975) proposes that a graben underlies eastern Taylor County and he correlates its sediments with the Eagle Mills Formation. Barnett, in agreement with previous investigators (Applin and Applin, 1965), considers these and similar deposits in

the Southwest Georgia Embayment to be a continuation of the Newark Group of the Atlantic coastal region.

Structure

Peninsular arch. The sub-Zuni rocks comprise the Peninsular arch, the largest known structural feature underlying the Florida peninsula (Figure 4). Its main axis is over 400 km long and trends S35°E from southern Georgia to the vicinity of Lake Okeechobee. Barnett (1975) describes the arch as a Precambrian (?) block of continental crust which was covered by Paleozoic sediments and later deformed by early Mesozoic uplift. Extensive erosion planed these rocks and provided a relatively smooth platform for the subsequent deposition of Cretaceous and Cenozoic sediments.

Ocala uplift. Since the mid-1950's petroleum geologists have used the term "Ocala uplift" to include the Peninsular arch. It is emphasized here that the structures are independent of each other. Vernon (1951) gives a definitive description of the Ocala uplift. This term refers to structural features in Tertiary units of central and northern Florida. The dominant structure is a flexure 370 km long which trends northwest through Levy and Citrus Counties. Structures of the uplift are mainly confined to the shallow Tertiary rocks.

Basement

Geologists in Florida commonly refer to the sub-Zuni rocks as representing "basement". The term basement in this report is defined as massive metamorphic and/or igneous rocks

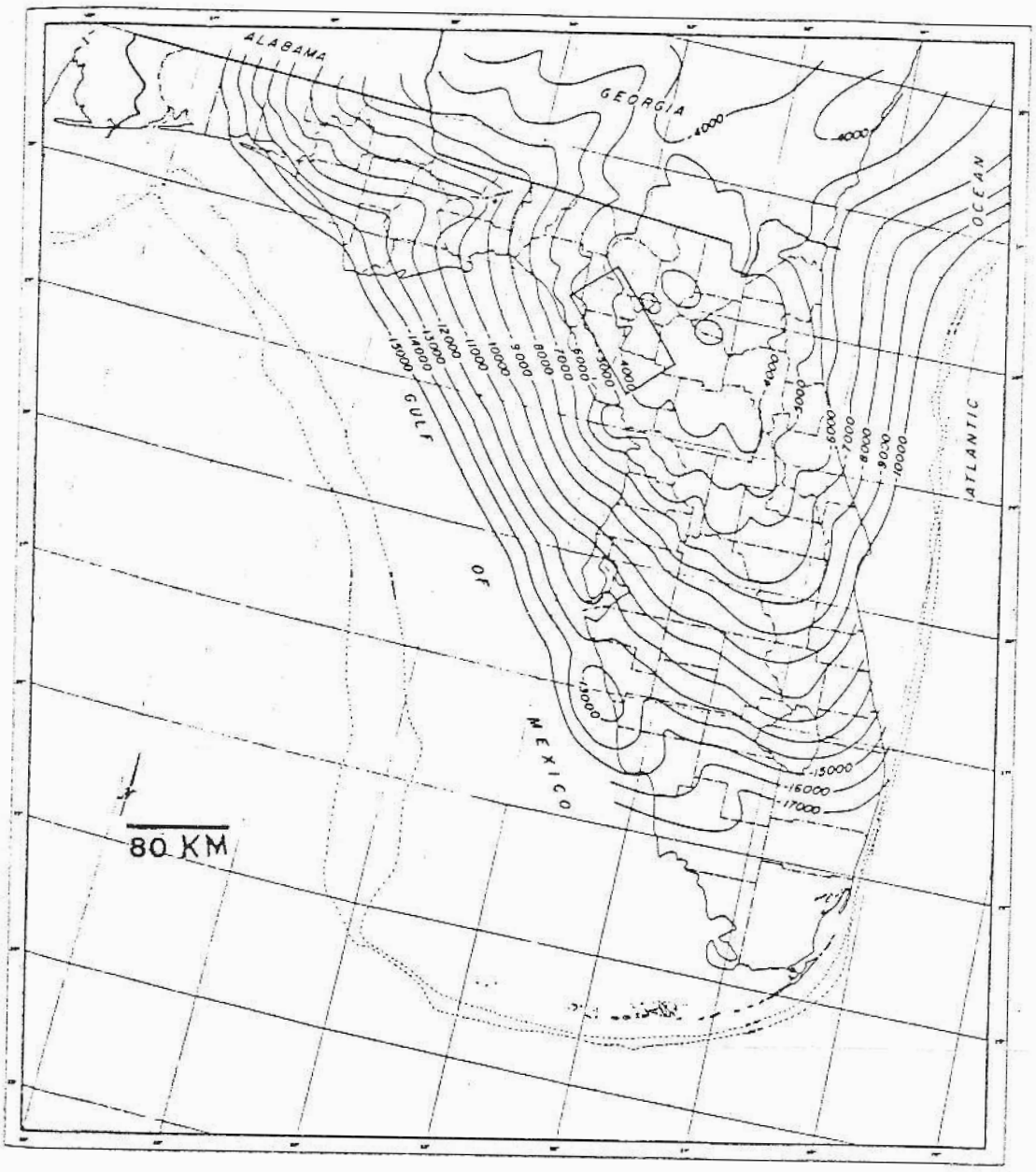


Figure 4. Structure contour map of sub-Zuni unconformity in Florida and southern Georgia (from Barnett, 1975).

at the base of the sedimentary section. Wells in northwest peninsular Florida have not been drilled deep enough to encounter basement as defined here. The deepest rocks penetrated consist of Paleozoic sandstones and shales which comprise much of the westward-dipping flank of the Peninsular arch.

Milton (1972) tabulated radiometric ages for volcanic rocks obtained from drillholes in Florida and Georgia. At least two different periods of volcanic activity can be identified. Diabases, basalts and rhyolites of Mesozoic age are found from northern Florida southward to Lake Okeechobee. These igneous rocks are apparently a southward continuation of rocks penetrated in the coastal plain of Georgia (Milton and Hurst, 1965).

An older group of igneous rocks is located between Glades and Flagler Counties. Milton (1972) describes these highly altered rocks as "granites", "diorite", "Alaskites", and "metabasalts", dated from 226 $\pm$ 6 m.y. to 480 $\pm$ 100 m.y. Barnett (1975) proposes a Precambrian (?) age for rhyolitic tuffs penetrated in Marion County. He states that these tuffs are overlain by 100 m of Ordovician sandstone and that rhyolitic tuffs underlying Flagler, Putnam and Volusia Counties are of similar Precambrian (?) age.

Banks (1976) refers to this older group of rocks in central Florida as the Avalon Complex. This correlation is apparently based on age determination of 527 m.y. for feldspar taken from a well in Osceola County (Bass, 1969). King (1969)

originally proposed the existence of Avalonian rocks in central Florida. However, he inferred that northwest Florida, including the study area, was underlain by rocks of the Grenville province. It should be emphasized that the oldest rocks known in the Florida basement are Middle Cambrian (?) in age. Until more reliable radiometric data are gathered, inferences about the ages of basement rocks in Florida are only speculation.

Previous Investigation

Vernon (1951) described the geology, structure and stratigraphy of Citrus and Levy Counties, Florida. A report on the geology, stratigraphy and structure of Dixie and Gilchrist Counties was prepared by Puri, Yon and Oglesby (1967). Applin and Applin (1967) described the stratigraphy, structure and facies relationships of the Gulfian Series in northern Florida and adjacent states.

Applin (1951) catalogued available information on wells which penetrated sub-Zuni rocks in Florida. He presented the first map which showed the known subsurface distribution of these rocks in the state. Barnett (1975) tabulated new well information and, with his access to recent geophysical data, greatly refined Applin's map. Barnett's conclusions are the most comprehensive to date regarding Florida's pre-Mesozoic rocks. The petrology and radiometric ages of sub-Zuni igneous and metamorphic rocks in Florida were reported by Milton (1972).

Regional gravity maps of Florida and its adjoining

continental shelves were prepared by Chaki and Oglesby (1972) and Oglesby, Ball and Chaki (1973). Regional magnetic maps of the Florida peninsula and the eastern Gulf of Mexico were presented by King (1959) and Gough (1967), respectively.

Seismic investigations in the northeastern Gulf of Mexico were reported by Antoine, Bryant and Jones (1967), Antoine and Harding (1963), Antoine and Harding (1965) and Eggleston (1979). Arden (1974) interpreted geophysical profiles in the western part of the Southwest Georgia Embayment.

Recent geophysical surveys completed by members of the Geology Department of the University of Florida are particularly relevant to this study. Gravity and magnetic maps of Alachua County have been prepared by Taylor (1975) and Bennett (1979), respectively. Their works contribute local details to the regional gravity and magnetic maps of Oglesby and others (1973) and King (1959). Wicker and Smith (1978) used two-dimensional gravity modeling techniques to present a generalized interpretation of subsurface rocks in peninsular Florida, based on the regional gravity data of Oglesby and others (1973).

DATA ACQUISITION AND REDUCTION

Data Acquisition

Ground-based geophysical surveys in Florida face the hardships of swampy terrain, frequent rains and biting insects. Most of the roads in the sparsely populated study area are unimproved or light-duty allowing only limited access during wetter periods. Complicating this situation, most of the U. S. Geological Survey topographic maps of the region were published in 1954 and have not been revised. Although many roads have been greatly improved since that time, others are represented by barely perceptible gaps in roadside foliage. Aerial photographs obtained from the U. S. Soil Conservation Service in Cross City were useful in updating access routes.

Accurate elevation data are essential for a gravity survey. Benchmarks and photogrammetric methods are accurate to ± 3 cm and $\pm$ 30 cm, respectively. However, twenty-five years of road maintenance lend some unreliability to photogrammetric reference points such as bridges and road intersections. Published elevation data for these points can sometimes be refined by making careful field observations.

Gravity stations were established on a grid pattern. Because state and local roads frequently parallel section

boundaries, a survey limited to stations accessible by road will have a grid spacing with units of miles. As in Figure 1 the target anomalies have widths of 12 to 15 miles (19 to 24 km). A grid spacing of 4 miles (6.4 km) would be sufficient to examine these features. A 3-mile (4.8 km) spacing was chosen after consideration of terrain conditions.

A worden gravity meter (Master model no. 1022) was used in this survey. Gravity measurements were completed between July and October, 1978. Two-hundred and sixteen (216) stations were established and later referenced to the International Gravity Standardization Net. The base station used is located 2.2 km southwest of Bronson, Levy County (BM W-12 1932 USCGS; g-979288.50; from Smith and Taylor, 1977). Base stations were reoccupied at average intervals of 3.2 hours.

The Iranian earthquake of September 16, 1978 interrupted gravity measurements for two hours. The quake was rated 7.7 on the Richter Scale by the National Earthquake Information Service and caused the gravimeter's light beam to vibrate with a periodicity of 20-30 seconds. Although the earthquake occurred at 11:38 a.m. EDT, a gravimetric reading obtained at 11:43 was stable. Early seismic wave arrivals were not noted until the next reading at 12:08.

Data Reduction

Observed instrument readings were multiplied by the gravimeter's calibration constant (0.0874 milligals/division). Latitude, drift, free-air and Bouguer corrections

were applied and the data correlated with the International Gravity Standardization Net. The average instrument drift between base station readings was 0.08 milligals. Latitude corrections were based on a reference latitude of 29° 15' 00" and elevations were corrected to sea level. The free-air gradient was measured and did not significantly differ from the theoretical value of 0.308 milligals/m. Due to shallow bedrock over much of the study area, Bouguer corrections were made assuming a formation density for near-surface materials of 2.2 g/cm^3. Terrain corrections were unnecessary due to the low relief of the coastal plain topography.

Bouguer anomaly values were obtained by subtracting theoretical values derived from the International Formula (Dobrin, 1976) from observed gravity readings. The data were analyzed with an IBM 360/75 computer utilizing the Synagraphic Mapping System (SYMAP) created by the Laboratory for Computer Graphics and Spatial Analysis, Harvard University (1975). A map of desired size was generated with a contour interval of one milligal (Figure 5).

Residual Separation

The separation of regional trends and residual anomalies is a problem faced in many studies of potential fields. Two techniques commonly used are Fourier and polynomial trend surface analyses because these analytical methods preclude personal bias in their operations. Available SYMAP options include polynomial trend surface analyses. Trend surface and residual maps up to the sixth order can be

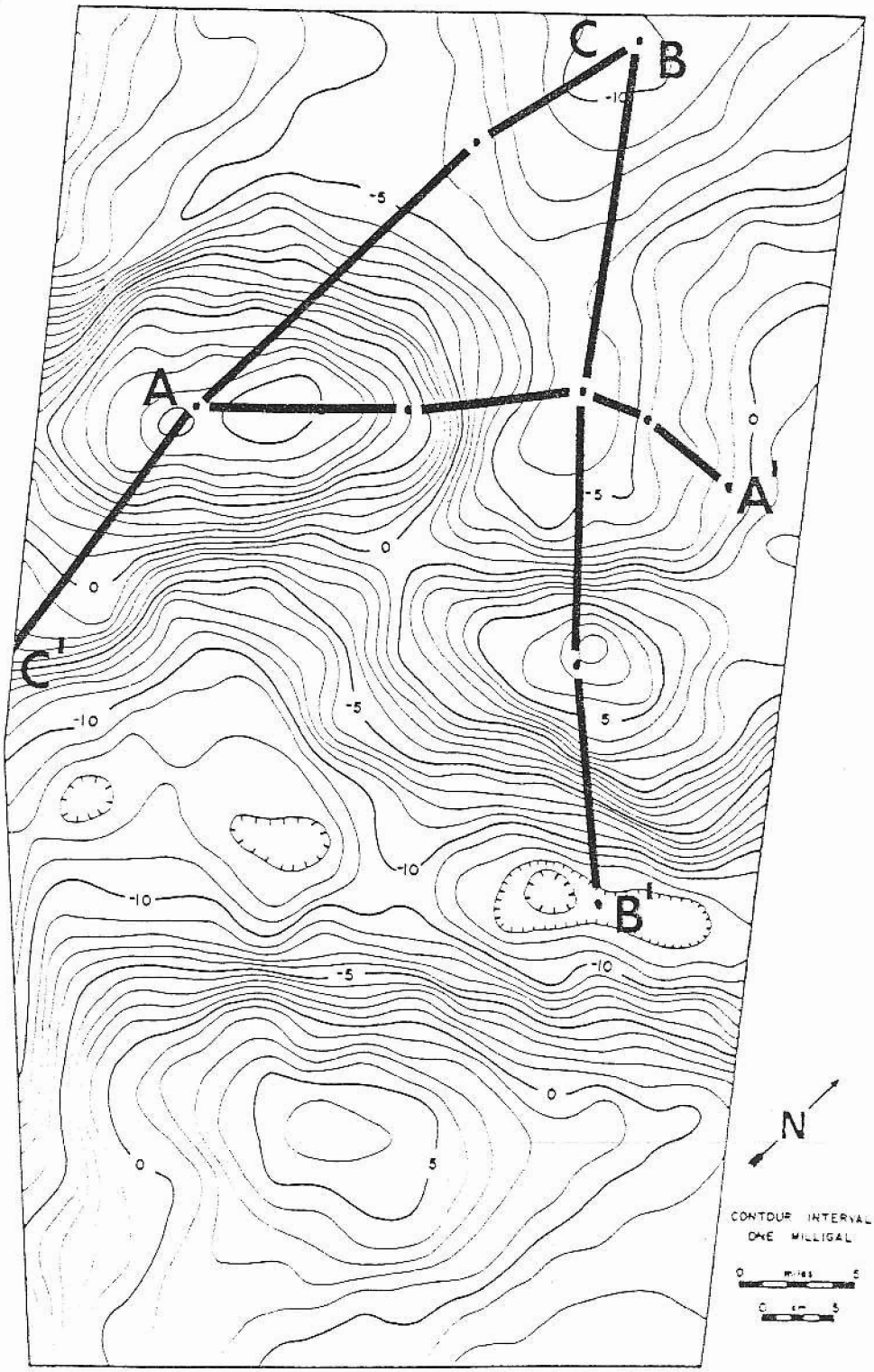


Figure 5. Bouguer anomaly map of study area with profile locations (gravity data tabulated in Appendix 2).

produced.

A polynomial trend surface is a function of the (x,y,z) coordinates of a data set. The surface is fitted through the data points in a way which minimizes the squared deviations from the specified order of trend surface. The order of the surface determines the number of inflections permitted. Any existing regional trend of a data set can be approximated by the trend surface of lowest order which accounts for a significant fraction of the data variance. Subtraction of this surface from the original data values gives a set of residuals which may enhance the resolution of local anomalies. Residual separation cannot give a unique solution. The investigator must rely on experience and intuition to select the order of trend surface which best represents a regional trend.

As shown in Table 1 an attempt has been made to separate a regional gravity component from the data set. Less than half of the gravity data variability is explained by a sixth order trend surface. Clearly a simple regional trend does not exist on the scale of the study area. This conclusion is supported by the strong closure of contours in the Bouguer anomaly map (Figure 5). For these reasons the Bouguer anomaly map was selected as the basis for constructing observed gravity profiles.

Table 1

Numerical results of polynomial trend surface analyses

Order of Trend Surface	Correlation Coefficient	% Variation Explained By Surface
1	0.18	3.4%
2	0.24	5.9%
3	0.36	13.0%
4	0.42	17.8%
5	0.65	42.9%
6	0.68	46.4%

GEOLOGIC INTERPRETATIONS

Gravity Computations

The use of a computer to calculate the gravity effect of hypothetical geologic cross-sections is the interpretive method used in this study. The program used is POLYGON V (1973), created at the Princeton University Department of Civil and Geological Engineering, with modifications by James Robertson of the University of Wisconsin. The program uses the method of polygons of Talwani, and others, (1959). Subsurface structures or layers are approximated in cross-section by polygonal forms. Using densities and shapes defined for each layer, the program calculates the gravity field along a line of discrete points. A curve constructed through these calculated gravity points is compared to a curve of observed Bouguer anomaly values. Residual differences are reconciled by altering the shapes and/or assigned densities of the polygons. Using a fault model as an example, for each density distribution the iterative procedure involves the generation of families of calculated gravity curves representing increasing fault displacements.

Preparation of Geologic Cross-Sections

To investigate the possible geologic structures, three interconnecting profiles were drawn roughly perpendicular

to Bouguer anomaly contours in areas with high gravity gradients (Figure 5). Using the data in Appendix 1, geologic cross-sections were drawn for each profile dividing the units into layers of uniform density. As shown in the geologic sections (Figures 6-8), thicknesses of Tertiary and Upper Cretaceous (Gulfian Group) rocks are relatively uniform throughout the study area. Lower Cretaceous (Comanchean Group) rocks thin gradually from west to east, pinching out along the western flank of the Peninsular arch. The thickness range of the underlying Paleozoic Erathem is unknown since basement rocks have not been penetrated by drillholes in the study area.

Drillhole data establish that the depth to basement rocks underlying well JPBC on profile A'A- must exceed 2 km below sea level (Figure 6 and Appendix 1). This minimum depth is held constant on all cross-sections of A-A'. Basement depths in profiles B-B' and C-C' are constrained by their planes of intersection with profile A-A'.

Density Determinations

The densities of the basement and overlying Paleozoic rocks are unknown. However, values can be selected which maximize the density contrast between the Paleozoic and basement rocks. Using the largest reasonable density contrast produces geologic sections which have the smallest possible offsets or relief.

Neutron density logs establish a formation density of approximately 2.40 b/cm^3 for Upper Cretaceous rocks in

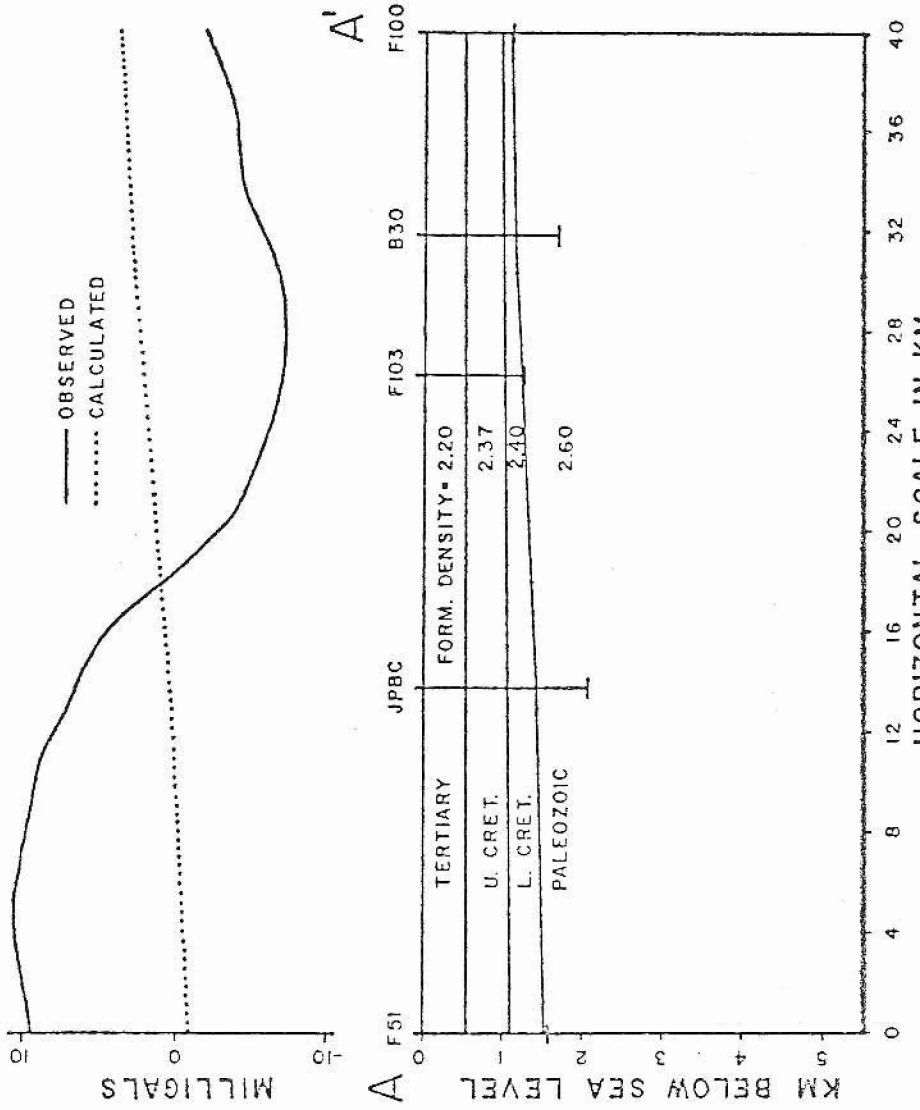


Figure 6. Profile A-A' - Comparison of observed Bouguer anomaly curve to gravity curve calculated on basis of known stratigraphy.

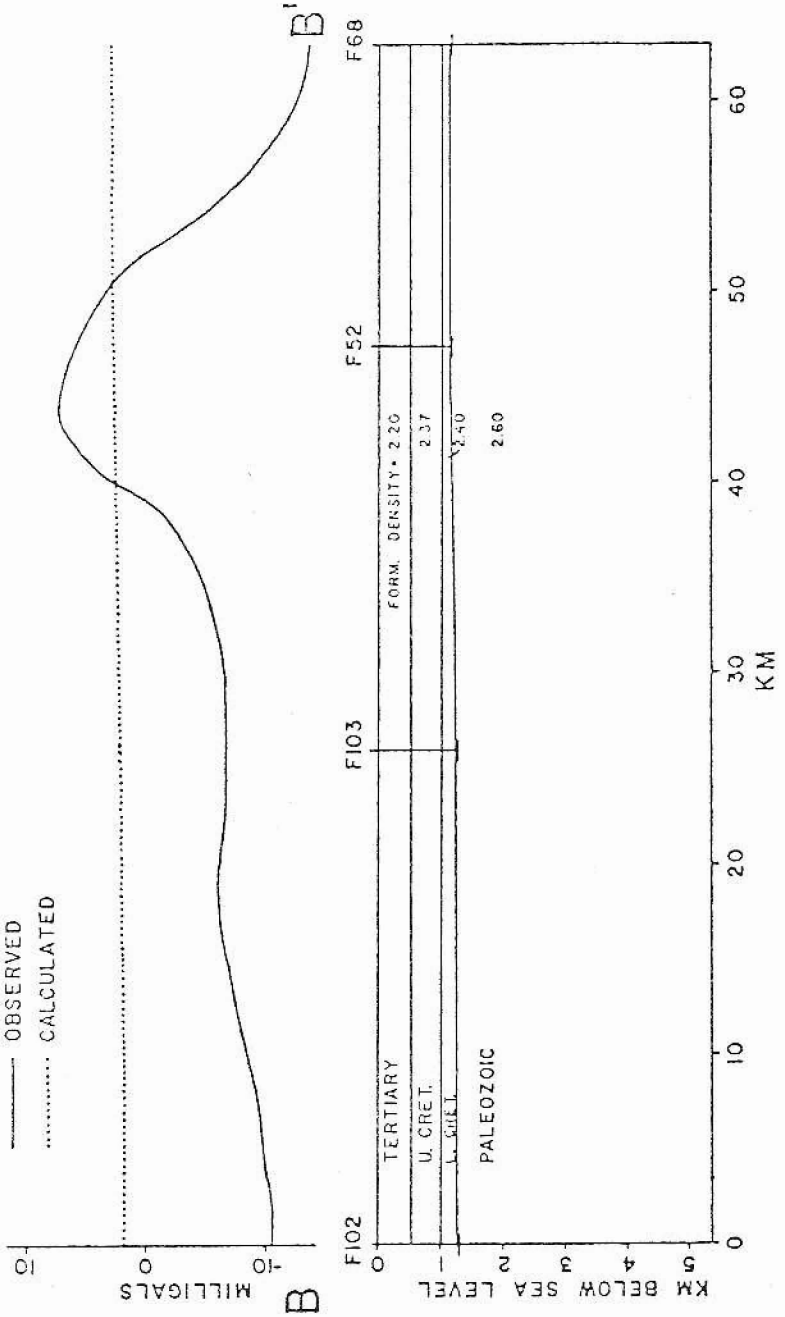


Figure 7. Profile B-B' - Comparison of observed Bouguer anomaly curve to gravity curve calculated on basis of known stratigraphy.

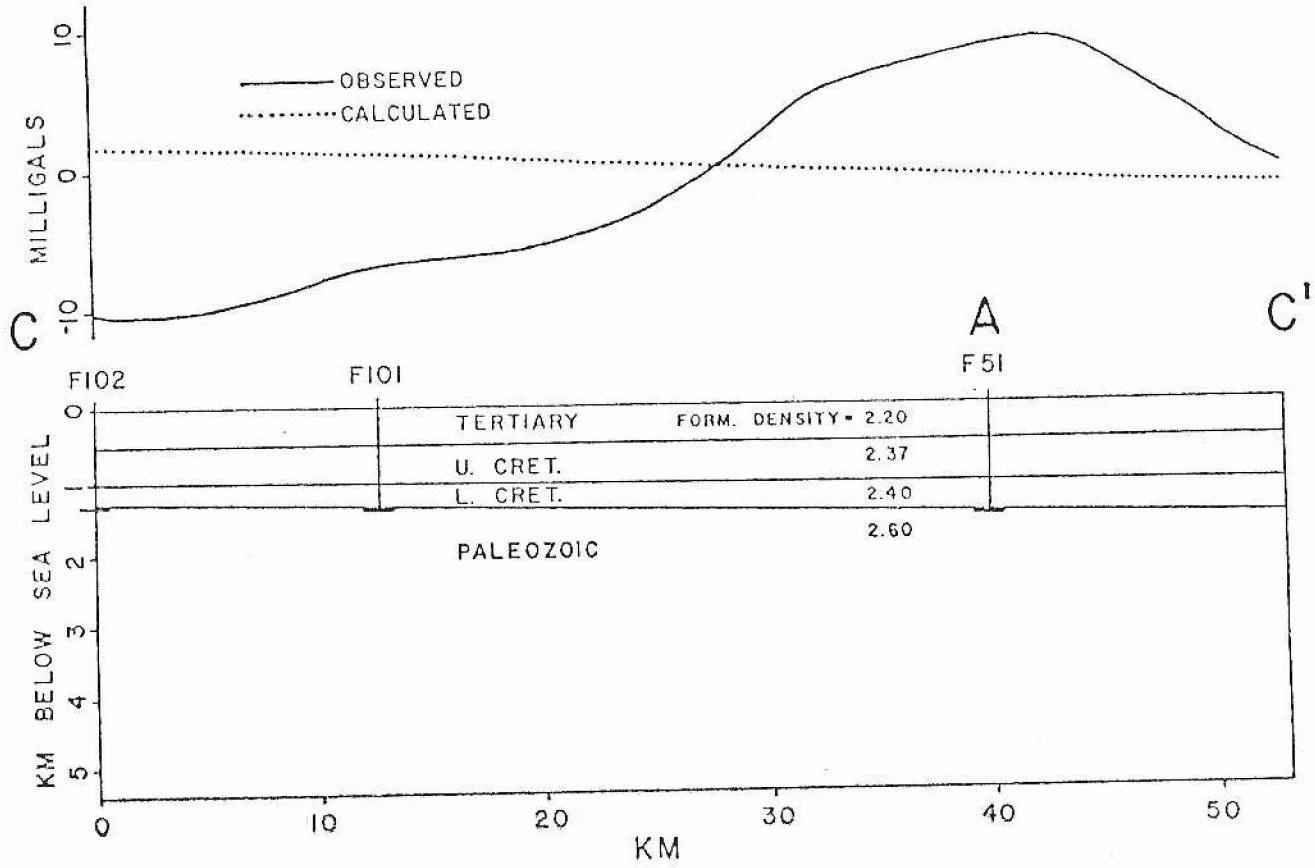


Figure 8. Profile C-C' - Comparison of observed Bouguer anomaly curve to gravity curve calculated on basis of known stratigraphy.

northern Florida (Table 2). It is unlikely that the deeper Paleozoic rocks are less dense, establishing a lower limit on their density range. Mericle (1979) presents strong evidence that a transition zone in central Florida separates continental crust in northern Florida from oceanic crust in southern Florida. Mericle's work is supported by the earlier gravity calculations of Wicker and Smith (1978). The gross lithology of continental crust is granitic in nature. Considering the density range of granitic materials (Dobrin, 1976) it is unlikely that such continental crust would have an average density greater than 2.80 g/cm^3.

Development of Conceptual Basement Models

Figures 6-8 show comparative plots of observed gravity and gravity calculated on the basis of known stratigraphy. Large discrepancies between observed and calculated curves are caused by anomalous masses at depths greater than the deepest well penetration of 2 km (well JPBC, Figure 6 and Appendix 1).

Observed Bouguer anomalies (Figure 5) may result from the effects of lateral density variations in the basement, relief on the basement subcrop, or a combination of these effects. Relative to a granitic basement and assuming zero basement relief, lateral density contrasts could arise in the following ways: juxtaposition of continental and oceanic crustal blocks by wrench faulting; intrusion of high concentrations of diabase dikes and sills; emplacement of mafic or ultra-mafic plutons. Relief on the basement subcrop could

Table 2

Sources of formation densities

Geologic Density Units	Formation Densities g/cm^3	Source
Tertiary	2.20	Maximum value for Tertiary strata; value is mean obtained from 3 neutron density logs in N. Florida Columbia Co. Richard C. Bradley #1 - Brunswick Pulp and Paper Union Co. Getty Oil Co. 1-R Bielling 4-1 Getty Oil Co. 1-KO Dicks
Upper Cretaceous	2.37	Mean value obtained from neutron logging of wells listed above
Lower Cretaceous	2.40	Minimum assumed value relative to Upper Cretaceous density
Paleozoic	2.40	Same as above
Basement	2.80	Maximum value based on gross granitic composition of continental crust

have been produced by faulting; igneous intrusions, or differential erosion prior to deposition of the Paleozoic sedimentary column.

It is very unlikely that the strongly closed, rectilinear anomalies in the study area have any relation to oceanic crust. Basalt flows, diabase dikes and associated clastic sediments of Triassic and Jurassic ages are common in eastern North America (Triassic Subcommittee, 1957; May, 1971; Marine and Siple, 1974; DeBoer and Snider, 1977). Gravity calculations show that sheets of basalt overlying the Paleozoic Erathem could account for the observed positive anomalies. However, well data disprove this interpretation. Three wells were drilled in areas characterized by positive Bouguer anomalies (wells F51, JPBC and F52; Figures 5, 6 and 7; Appendix 1). All three wells terminated in Paleozoic rocks without encountering igneous bodies. Well JPBC penetrated more than 1 km of the Paleozoic Erathem. Diabase dikes or basalt flows have been penetrated by wells in eastern Taylor County, but they occur in areas characterized by negative Bouguer anomalies.

Although differential erosion in Precambrian (?) to Cambrian (?) time could account for the magnitude of observed anomalies, it cannot account for the strong northeast trends of anomalies in the study area and other parts of northern Florida. Therefore, igneous plutons and faults are the only reasonable geologic interpretations for the observed anomalies. No evidence for or against plutons can

be offered. However, other geologic investigations in northern Florida favor interpretations which invoke block faulting.

In the study area, zones of high gravity gradients are strongly linear, suggestive of subcrop fault traces. The more prominent zones trend northeast and parallel the proposed trend of major normal faults in the Southwest Georgia Embayment (Arden, 1974; Barnett, 1975). This northeast trend also parallels the general trend of Triassic normal faulting in the Atlantic Coast region. Diabase (?) samples from Lowndes County, Georgia have been dated at 180 and 200 million years before present (Milton and Grasty, 1969). Therefore, intrusive activity and normal faulting probably occurred in the region of the southwest Georgia Embayment during Triassic time.

The work of Eggleston (1979) provides additional evidence of block faulting in the region of the study area. He has interpreted the results of a seismic reflection study on the continental shelf in the northeastern Gulf of Mexico. He proposes a Pre-Jurassic horizon which exhibits tensional rifting. The dominant trend of the proposed faults is northwest, but the largest fault mapped trends northeast. Eggleston's project area is located only 32 km west of the study area.

Multiple Working Hopotheses

All of the gravity calculations in this report are based on the important assumption that the density of the basement

is laterally uniform throughout the study area. Given this constraint, observed gravity anomalies are assumed to be caused by relief on the basement subcrop.

Using profile A-A' (Figure 5) as an example, Figure 9 shows four geologic interpretations which can account for observed gravity anomalies. Figure 9A presents a "master fault" interpretation in which crustal blocks are displaced along a narrow, high-angle shear zone. Diagram 9B shows displacements occurring along a series of parallel step faults. Calculated gravity profiles displacement does not vary.

Figure 9C depicts either an irregular Precambrian topographic surface buried by Paleozoic sediments or igneous emplacement. Figure 9D represents one of many possibilities which combine the features of 9A and 9C. A modern analog of figure 9D is the western flank of the Wasatch Range in Utah.

Profile Descriptions

Proposed geologic cross-sections which account for the observed gravity profiles were prepared for each profile. All cross-sections have a vertical exaggeration of 3.2. Sources of formation densities assigned to the geologic layers are tabulated in Table 2. The density contrast between basement and Paleozoic rocks is critical for each profile.

Profile A-A'

Figures 10-15 show various geologic interpretations for

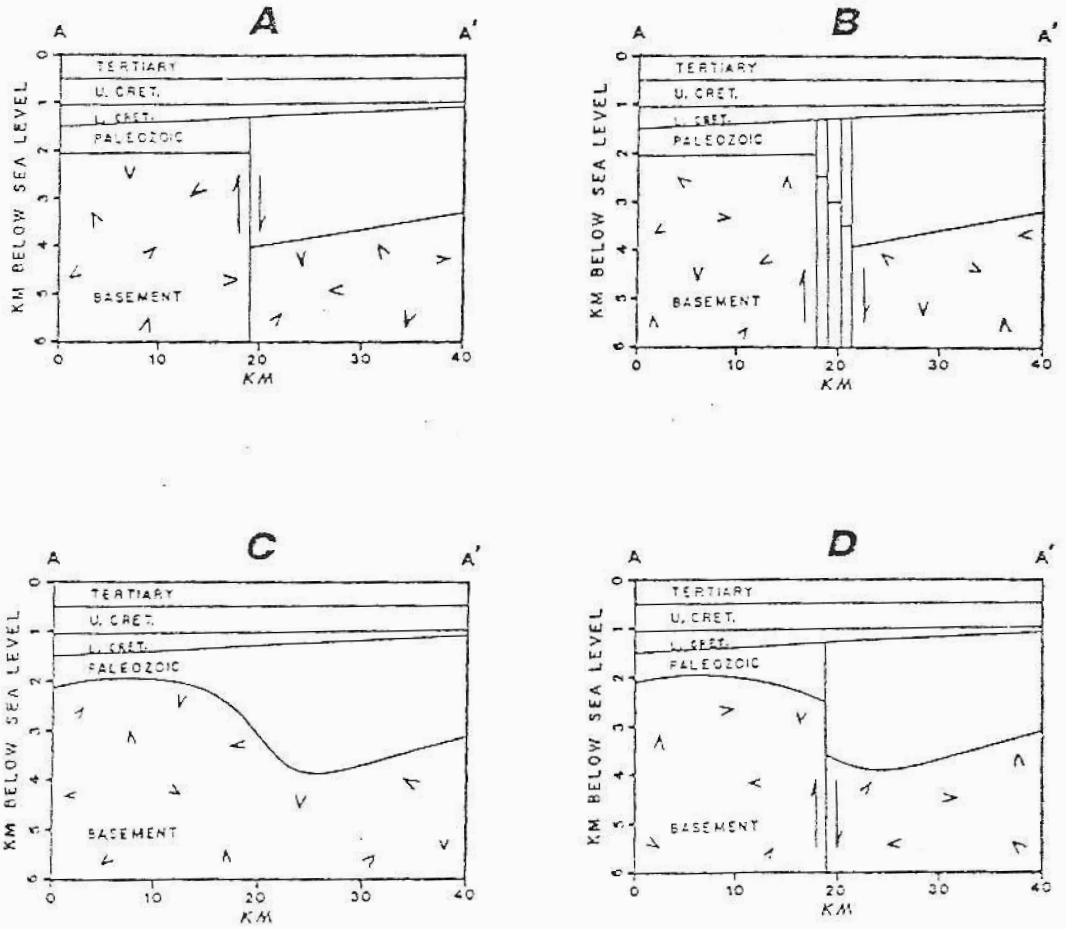


Figure 9. Multiple working hypotheses: A - "master" fault; B - step faulting; C - intrusion or buried relief; D - combination of A and C.

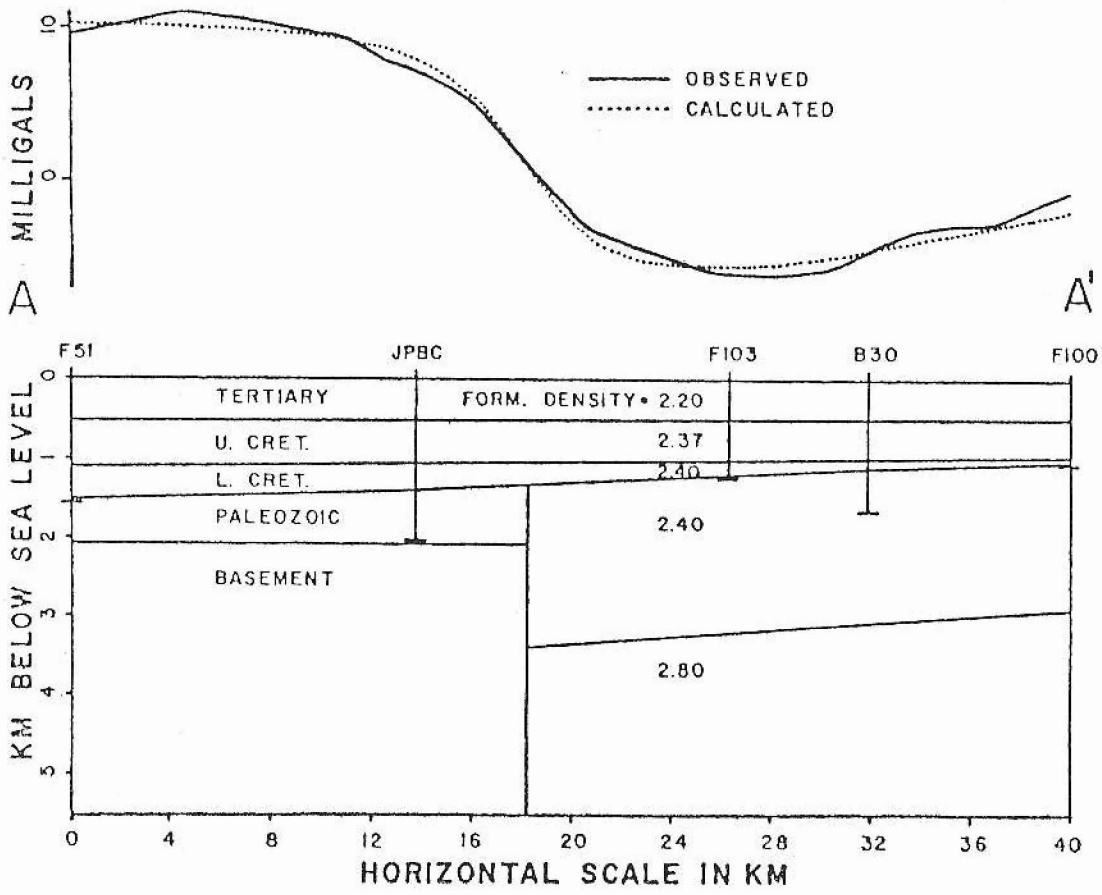


Figure 10. Profile A-A' - Block-fault interpretation with minimum possible offset.

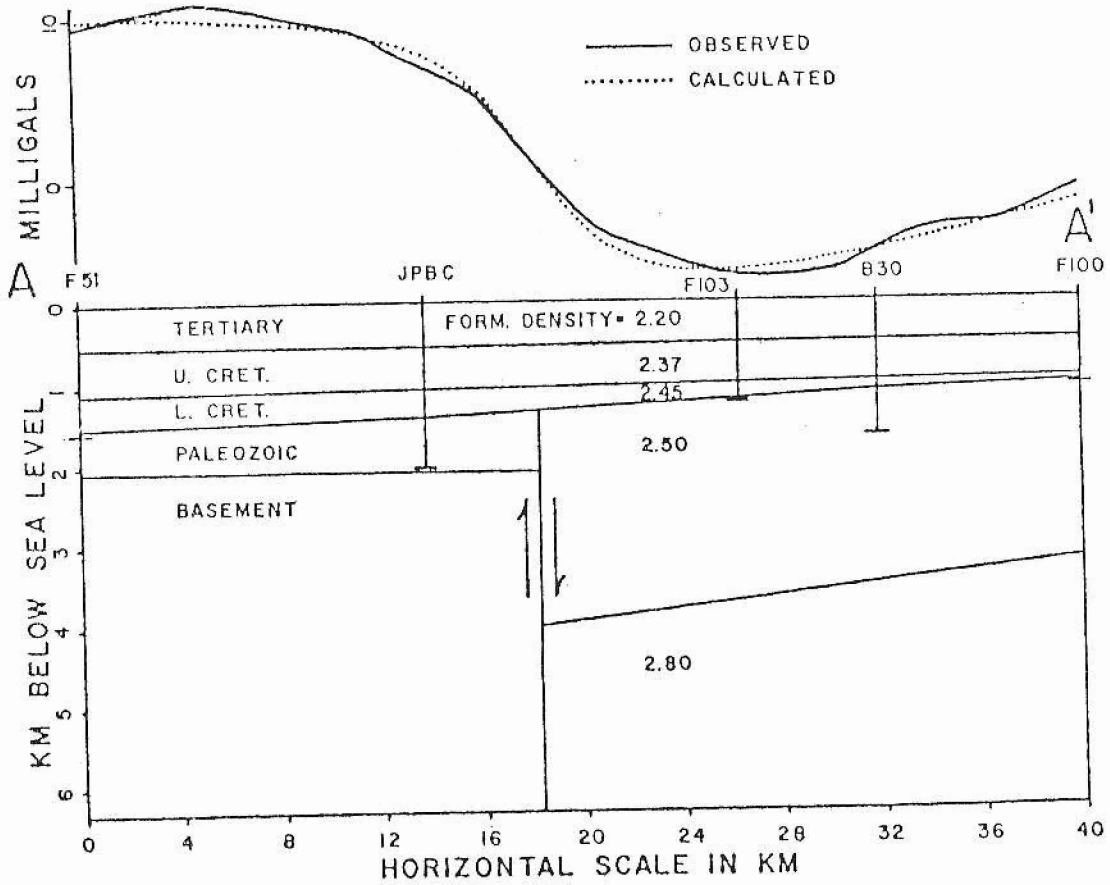


Figure 11. Profile A-A' - Block-fault interpretation with intermediate offset.

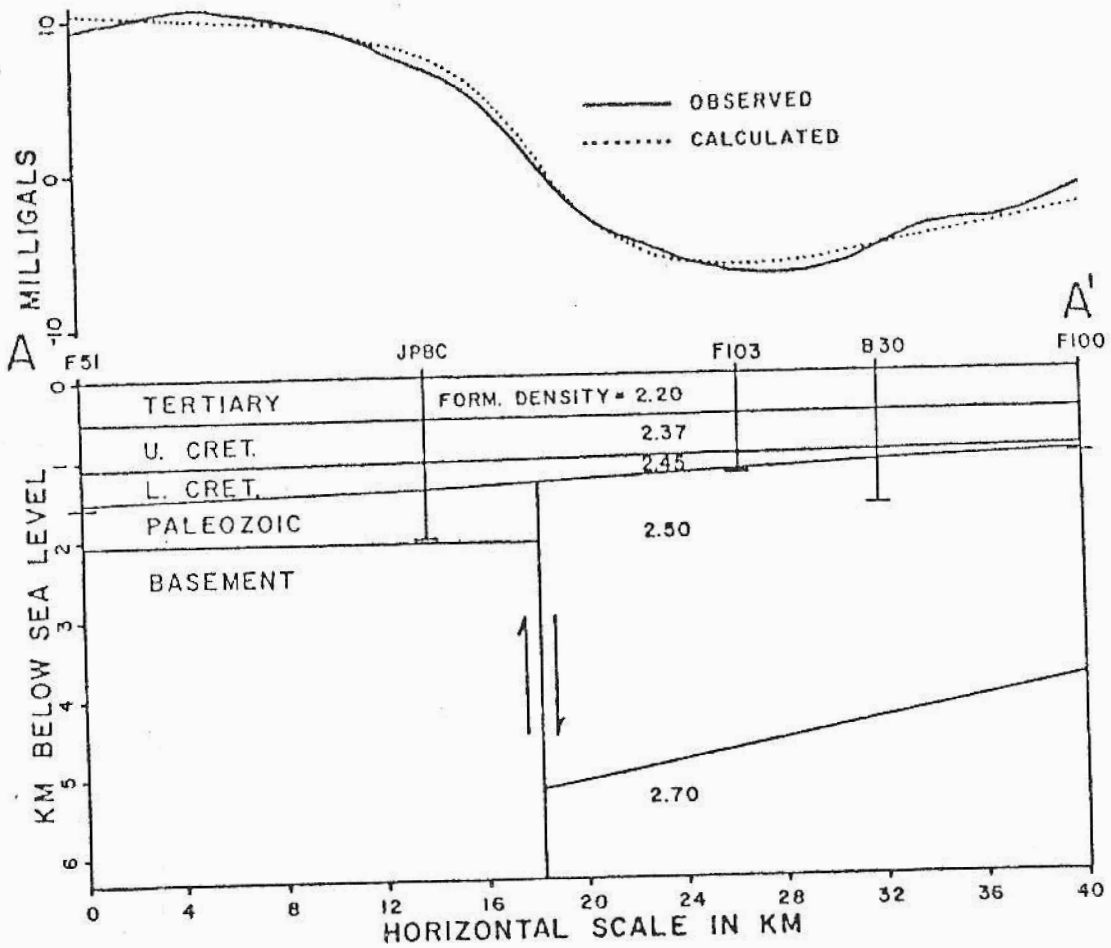


Figure 12. Profile A-A' - Block-fault interpretation with high offset.

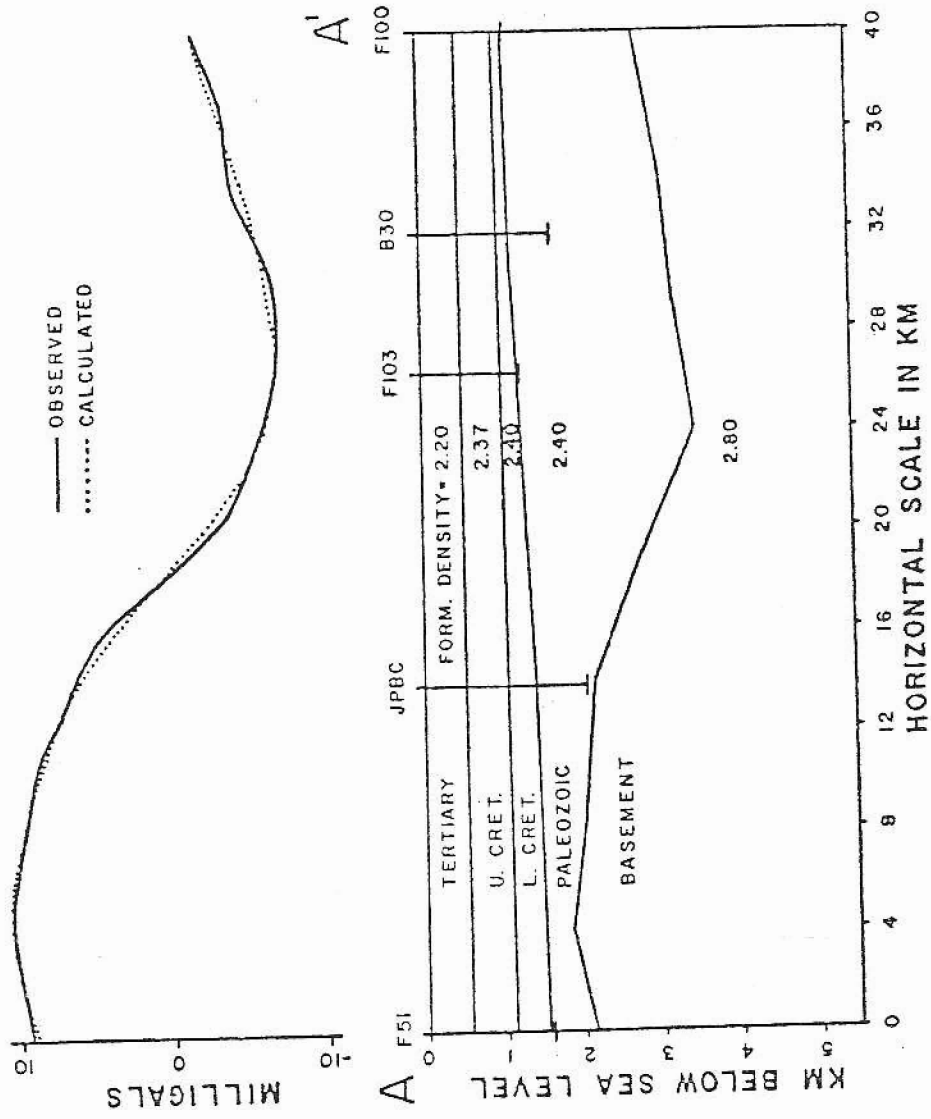


Figure 13. Profile A-A' - Buried topography interpretation with minimum possible relief.

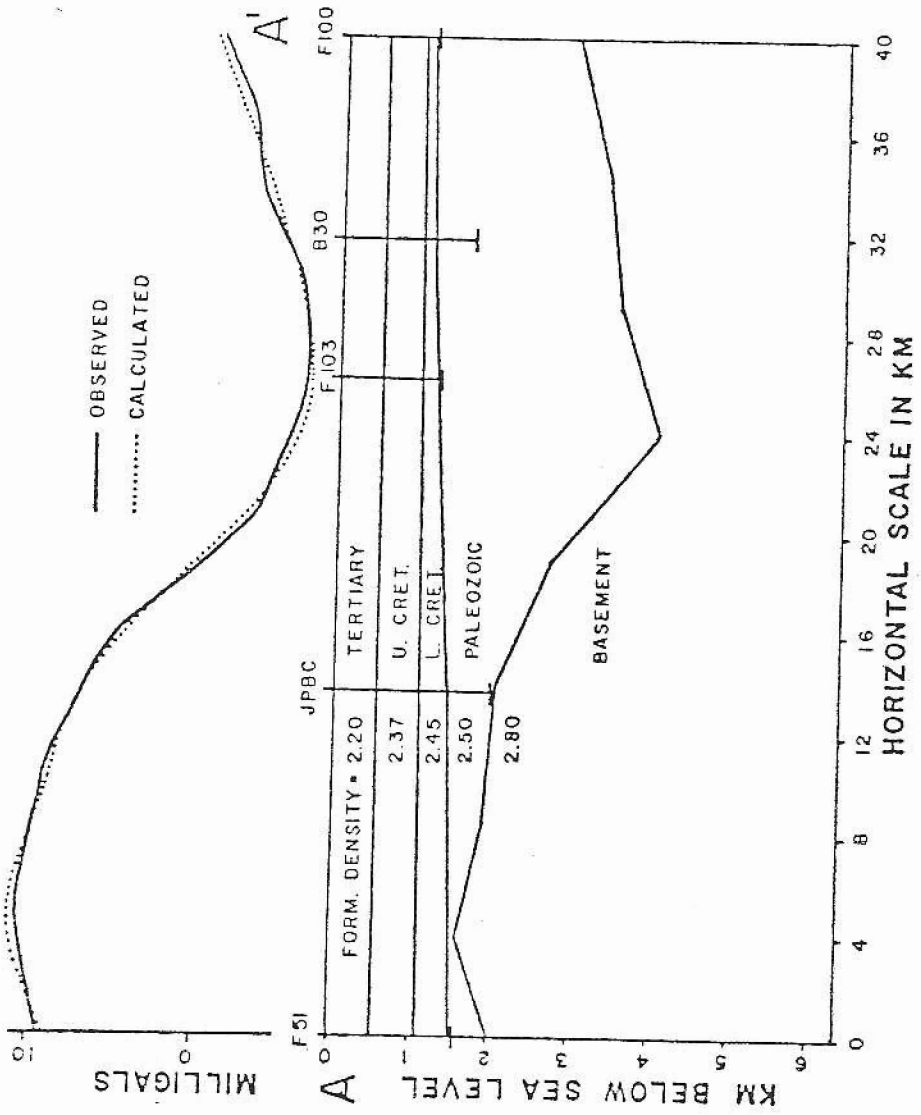


Figure 14. Profile A-A' - Buried topography interpretation with intermediate relief.

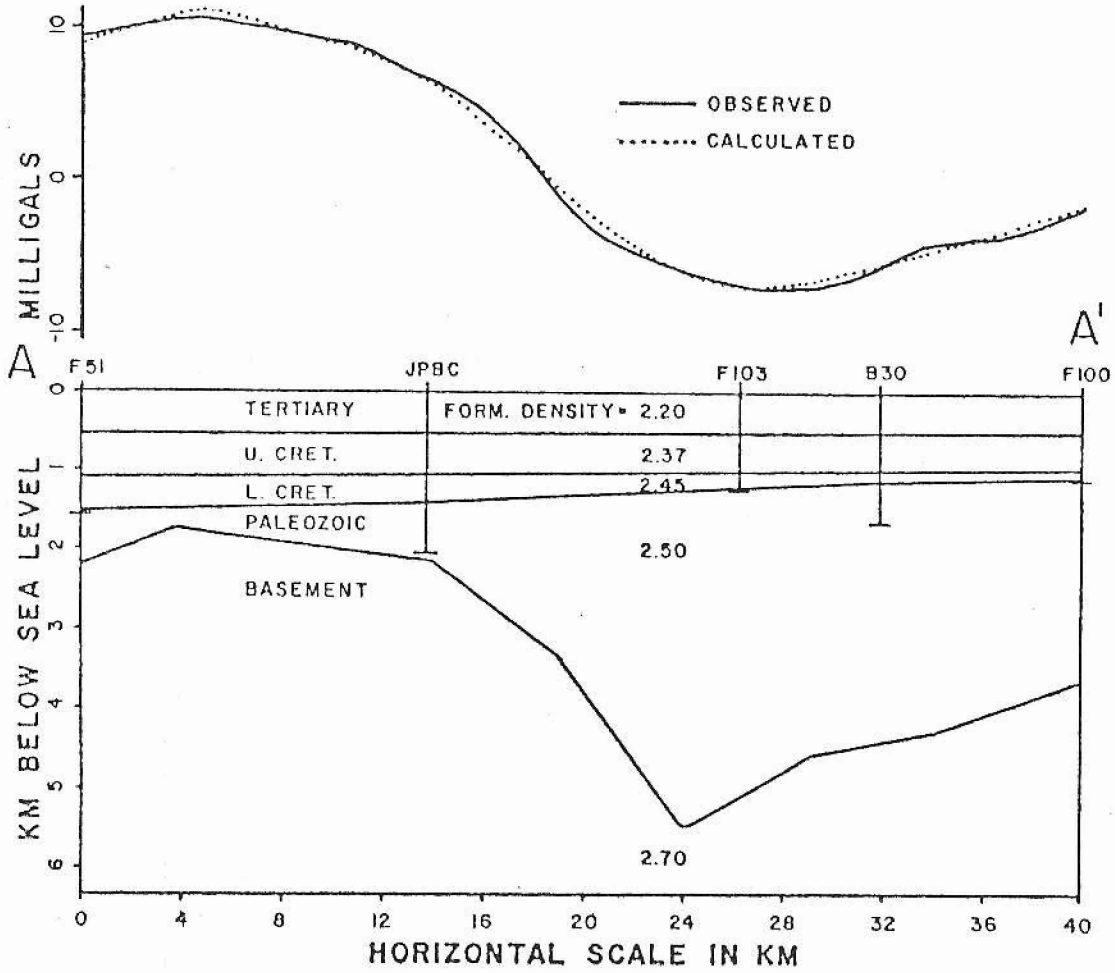


Figure 15. Profile A-A' - Buried topography interpretation with high relief.

profile A-A'. Basement depths beneath well JPBC are held constant in all sections. Figures 10-12 give very simple fault interpretations. One fault and two crustal blocks tilted with respect to each other easily account for the observed gravity field. The minimum possible throw of 1.2 km is given in Figure 10 where the density contrast between Paleozoic and basement rocks has the maximum value of 0.4 g/cm^3. As Figures 11 and 12 show, the observed gravity field can also be approximated by reducing the density contrast and increasing fault throw. In Figure 11 a contrast of 0.3 g/cm^3 requires a fault throw of 1.8 km. In Figure 12, fault throw in excess of 3 km is required in conjunction with a density contrast of 0.2 g/cm^3.

Figures 13-15 show interpretations of basement relief without faulting. The smallest possible slope of the basement surface is 5° (Figure 13). In Figures 14 and 15, basement slopes of 10° and 15°, respectively, are required.

Profile B-B'

The smallest possible throw of faults which border the proposed horst beneath well F52 is 1.2 km (Figure 16). Figure 17 illustrates a density contrast of 0.3 g/cm^3 and throws of 1.8 km. Figure 18 shows that throws of 3.3 km are required for a density contrast of 0.2 g/cm^3.

Profile C-C'

Only three crustal blocks and two faults are necessary to account for the observed gravity field along profile C-C'.

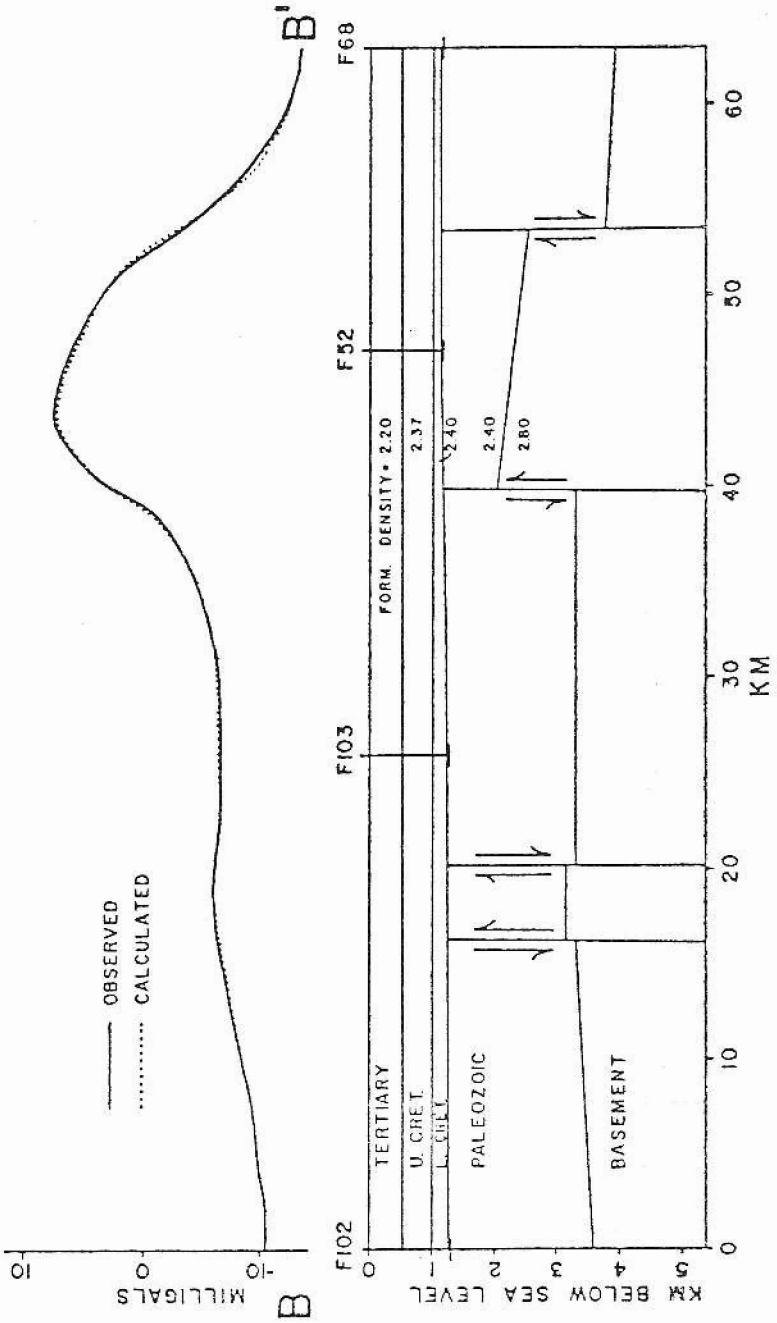


Figure 16. Profile B-B' - Block-faulting interpretation with minimum possible offsets.

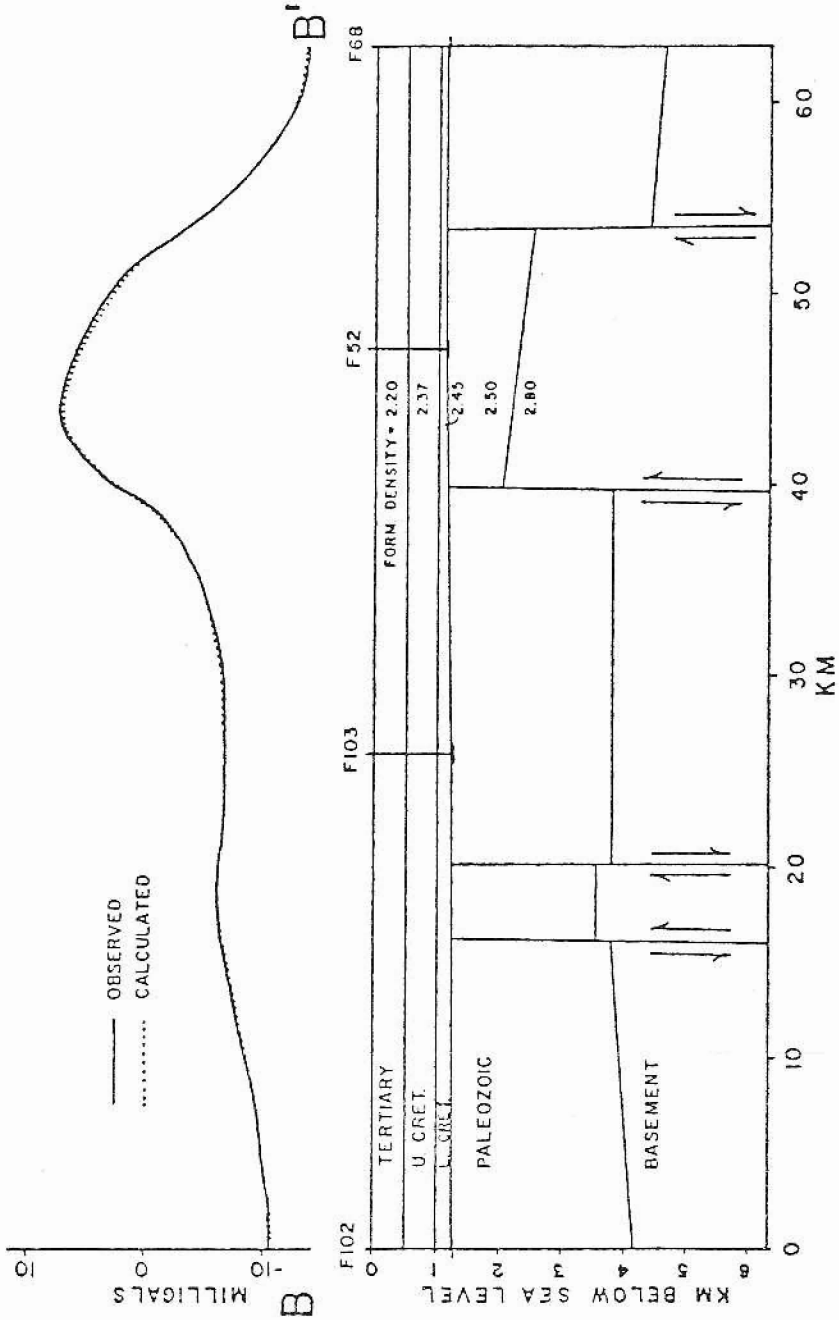


Figure 17. Profile B-B' - Block-faulting interpretation with intermediate offsets.

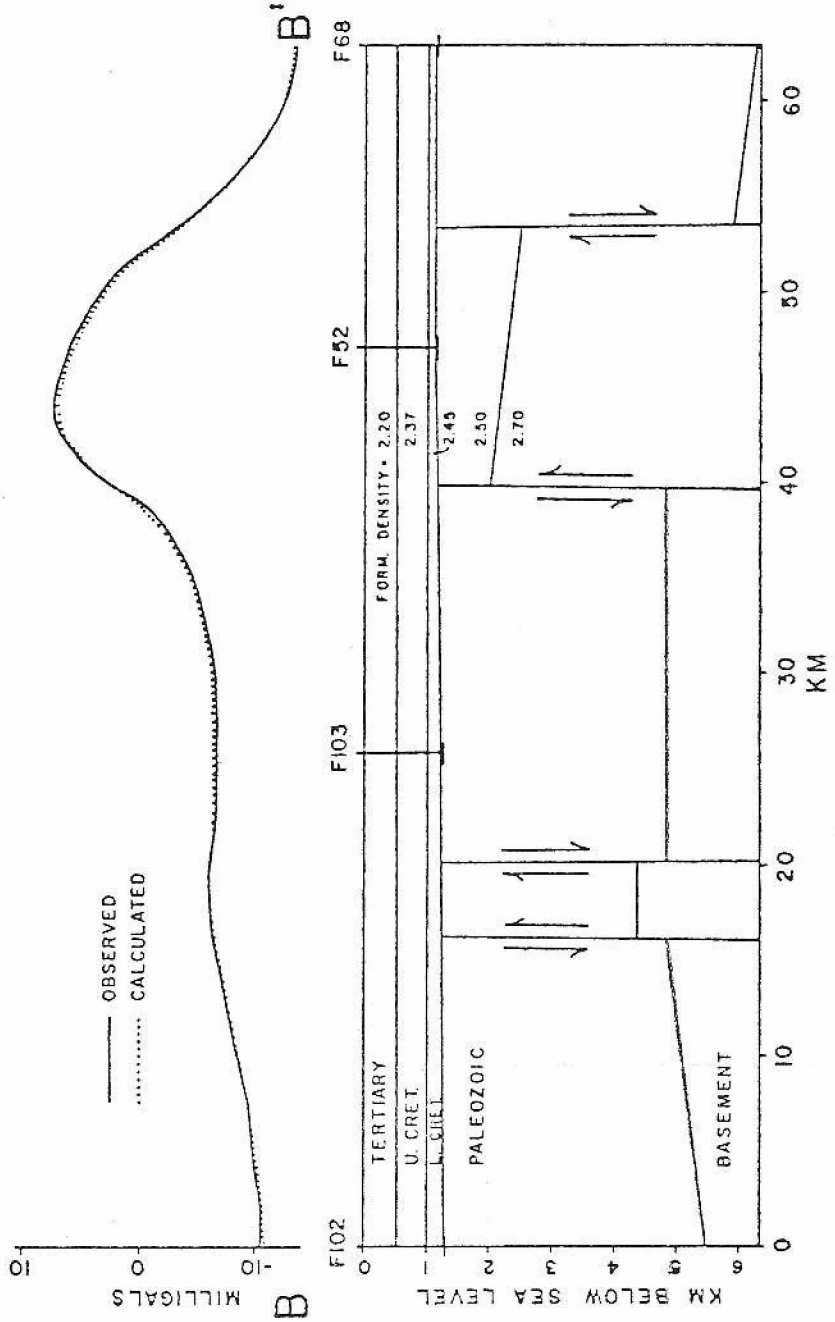


Figure 18. Profile B-B' - Block-faulting interpretation with high offsets.

Note that the southern end of profile C-C' (Figure 5) is tied to a well which lies outside the study area (well F50, Figure 5 and Appendix 1). Figure 19 shows that the Paleozoic Erathem thickens north of a horst proposed under well F51. The minimum basement depth beneath well F102 is 3.5 km below sea level. Figure 20 illustrates that fault throws of 1 km correspond to a density contrast of 0.3 g/cm^3. In Figure 21, a density contrast of 0.2 g/cm^3 requires throws of 2.3 km or more.

Summary of Results

In Figure 22 subcrop locations of proposed fault traces are superimposed on the Bouguer anomaly map. Major anomalies are lettered to facilitate discussion. Anomalies A, B and C are probably produced by upthrown blocks bounded by northeast trending faults with minimum displacements ranging from 0.7 to 1.3 km. Downthrown blocks probably produce anomalies D, E and F. Anomalies D and F are the central portions of long linear troughs which trend northeast from the continental shelf across Florida. Anomaly E represents a local basin which is probably bounded on three or more sides by major upthrown blocks.

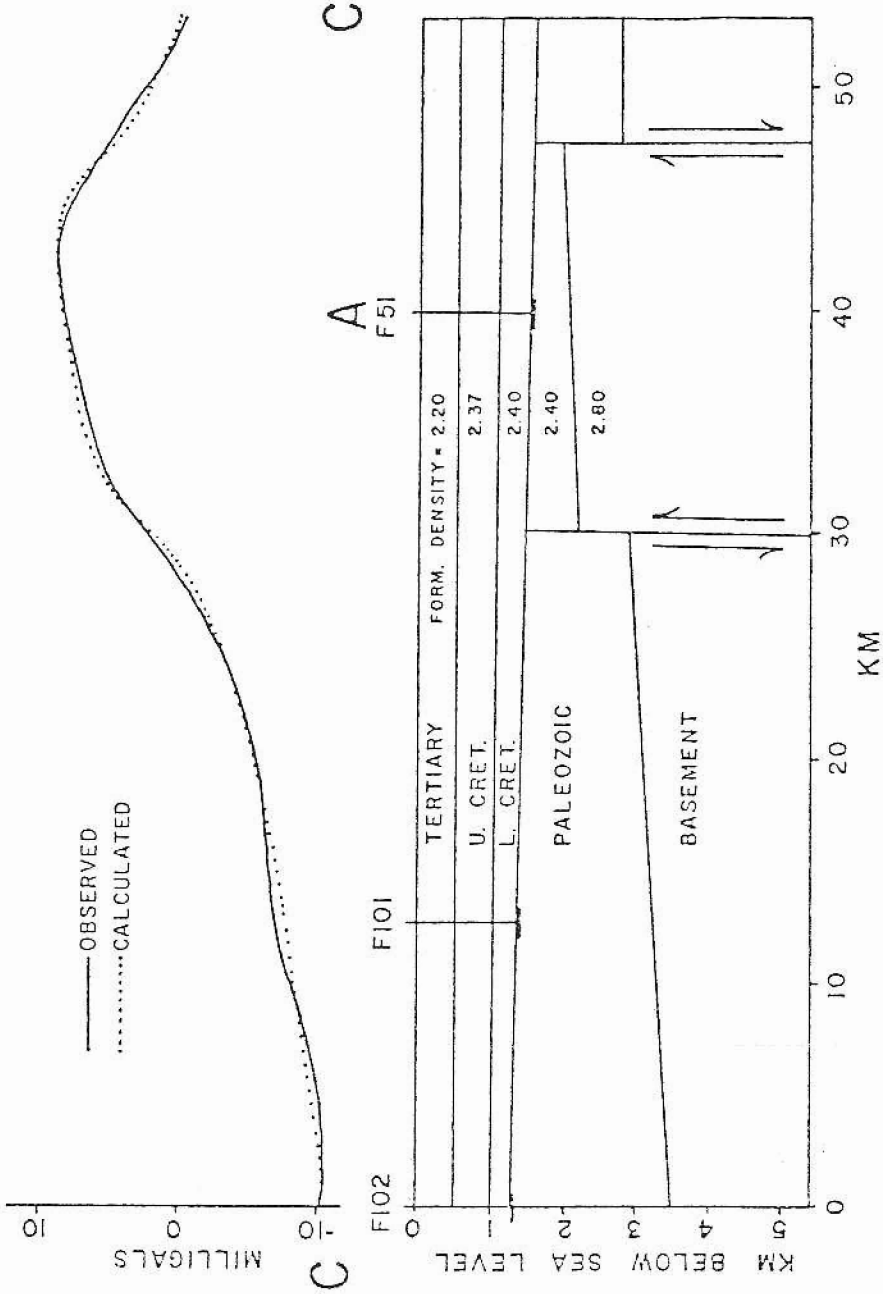


Figure 19. Profile C-C' - Block-faulting interpretation with minimum possible offsets.

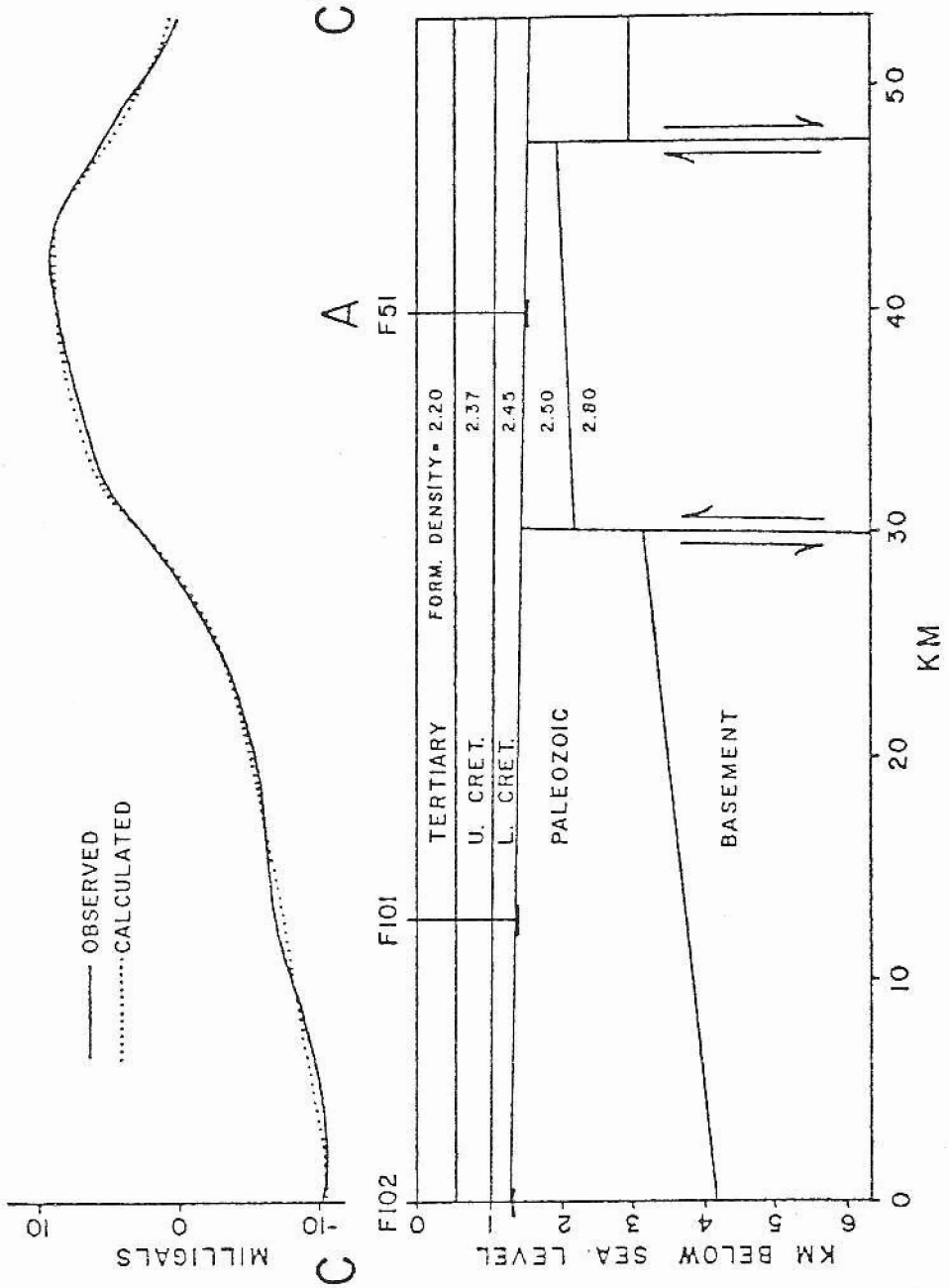


Figure 20. Profile C-C' - Block-faulting interpretation with intermediate offsets.

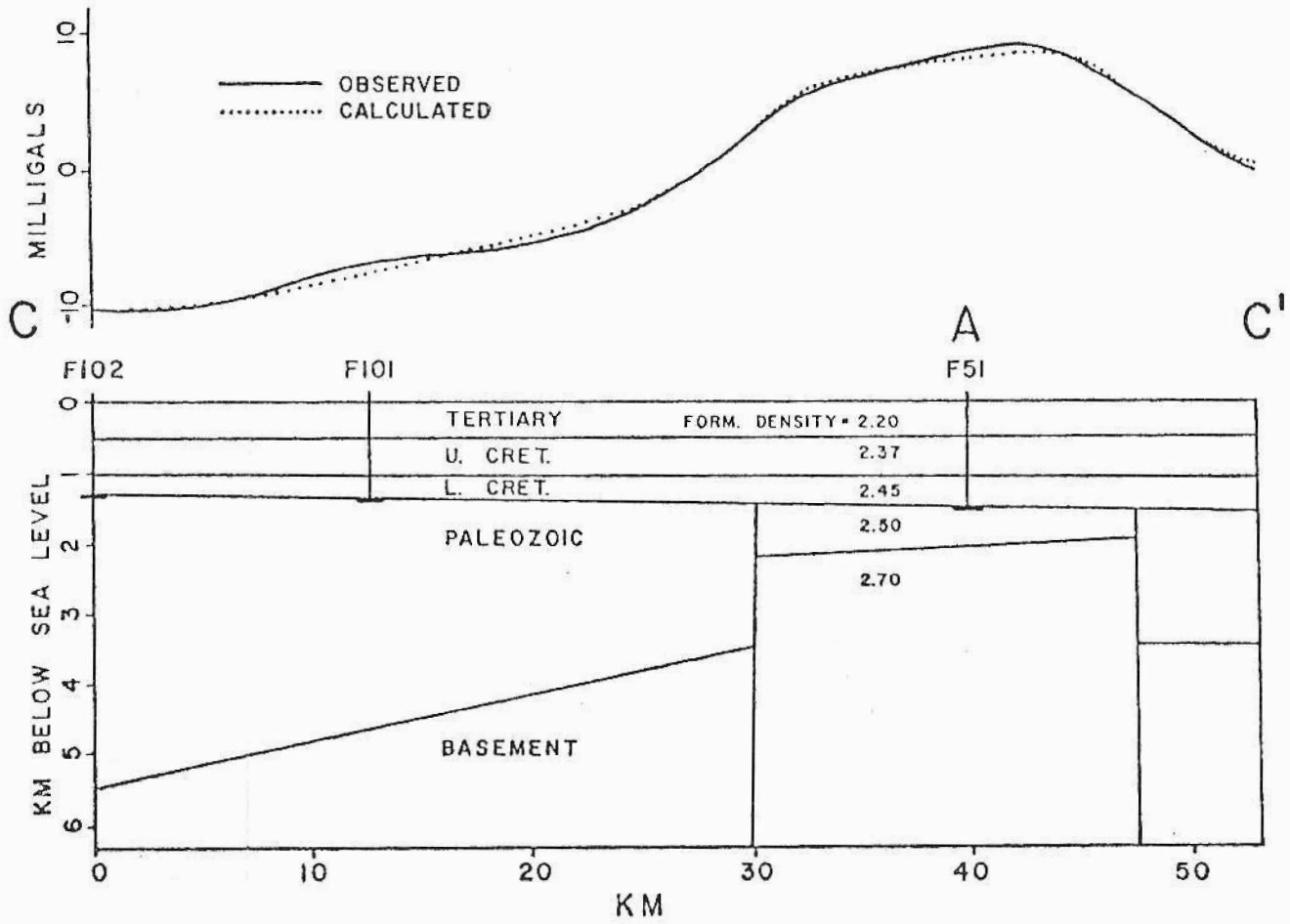


Figure 21. Profile C-C' - Block-faulting interpretation with high offsets.

CONCLUSIONS

The Bouguer anomaly map (Figure 5) adds additional detail to the regional gravity map of Florida (Oglesby and others, 1973). The anomaly located on the boundary between Lafayette and Dixie Counties (Figure 1) is resolved into two discrete features in Figure 5.

The geologic cross sections show that thicknesses of the Paleozoic Erathem have a minimum range of 0.5 to 2.5 km. Block faulting probably produced the corresponding minimum basement offset of 2.0 km. Subcrop locations of calculated and inferred faults are shown in Figure 22. The more prominent faults parallel Barnett's (1975) proposed northeast trend of major normal faults in the Southwest Georgia Embayment. Basalt flows or diabase dikes have been penetrated in wells drilled in eastern Taylor County. The proximity of these flows and/or dikes to the study area conforms with a hypothetical zone of rifting in early Mesozoic time.

Two long, linear basins are inferred from the gravity data. One trends northeast from southern Taylor County to Hamilton County and the other trends northeast from southern Dixie County to Baker County. An isolated, local basin apparently underlies southeastern Lafayette County. On Barnett's (1975) structure map (Figure 23) the more southerly linear

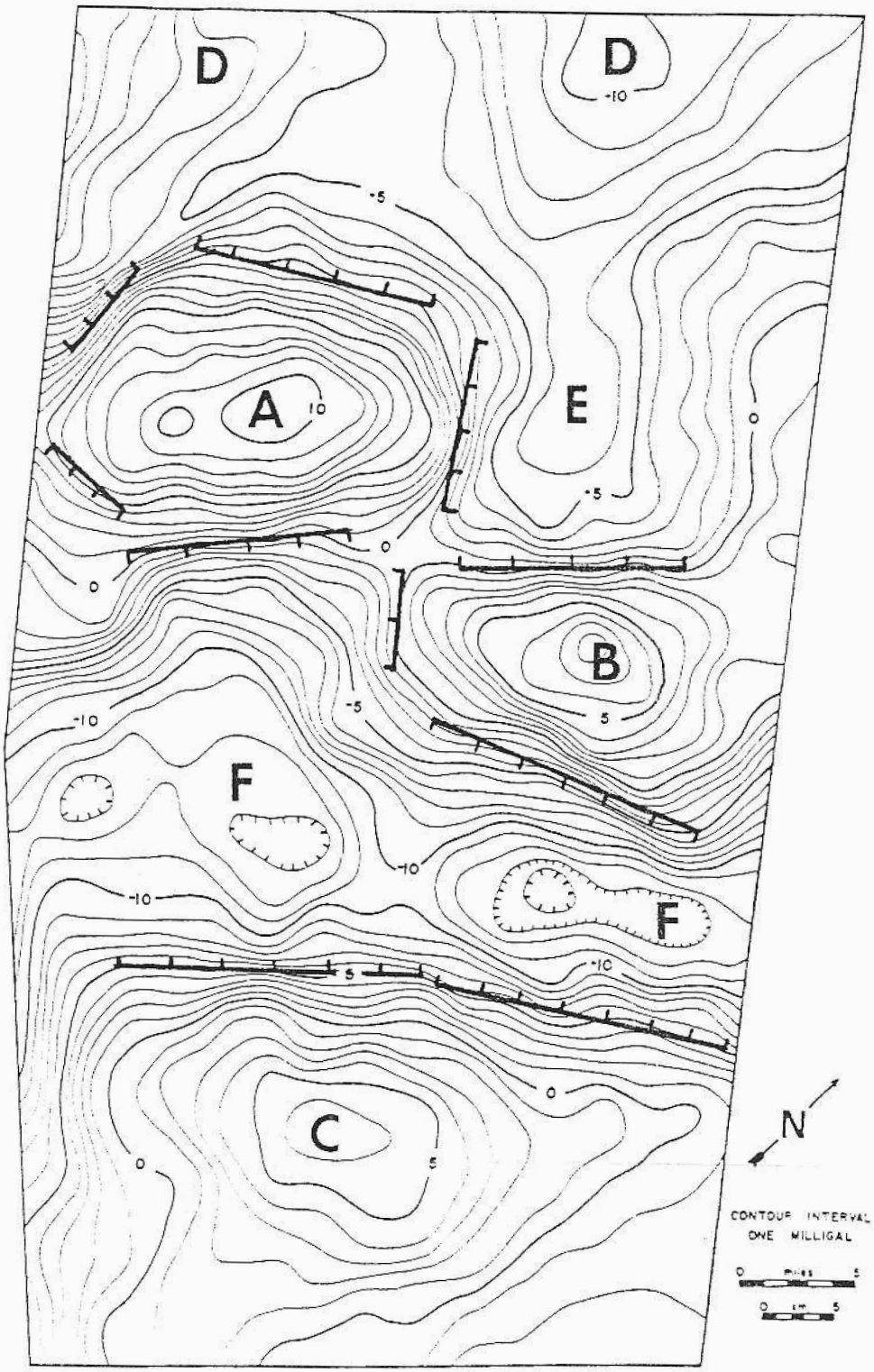


Figure 22. Bouguer anomaly map of study area showing locations of proposed subcrop fault traces (letters refer to discussion in text).

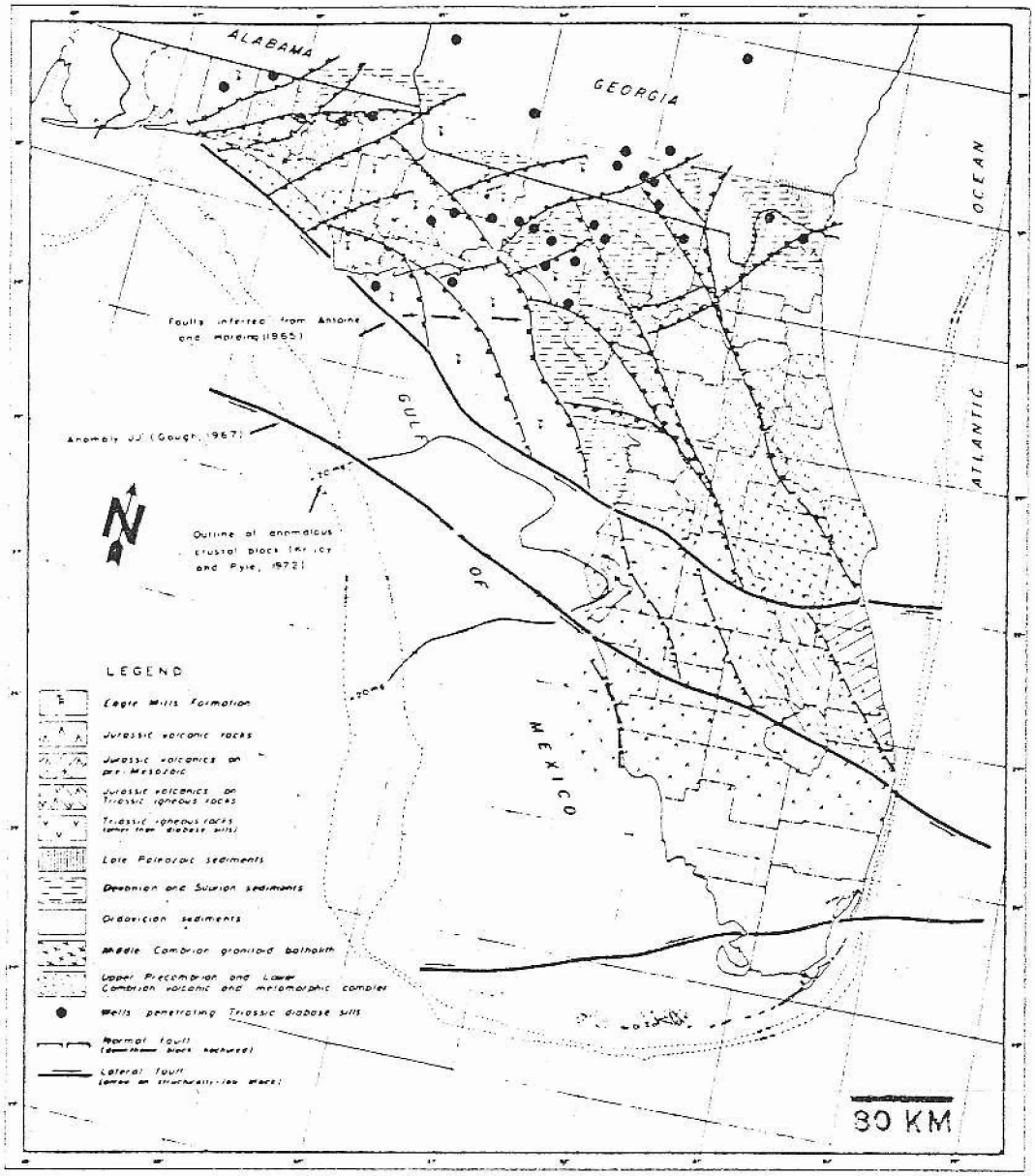


Figure 23. Subcrop structure map of sub-Zuni unconformity in Florida and southern Georgia. (from Barnett, 1975).

basin is terminated in Gilchrist County by a northwest trending graben. This gravity study supports the view that the basin is structurally continuous from the continental shelf across Florida to Baker County.

Results of the gravity investigation, in combination with other geologic information, suggest that basement offsets produced by block faulting are the sources of observed regional gravity and magnetic anomalies in northwest peninsular Florida. A series of parallel fault-block basins and uplifts are proposed as the dominant basement structures (Figure 24). These structures and the Southwest Georgia Embayment may have developed in response to the same regional stress field in early Mesozoic time.

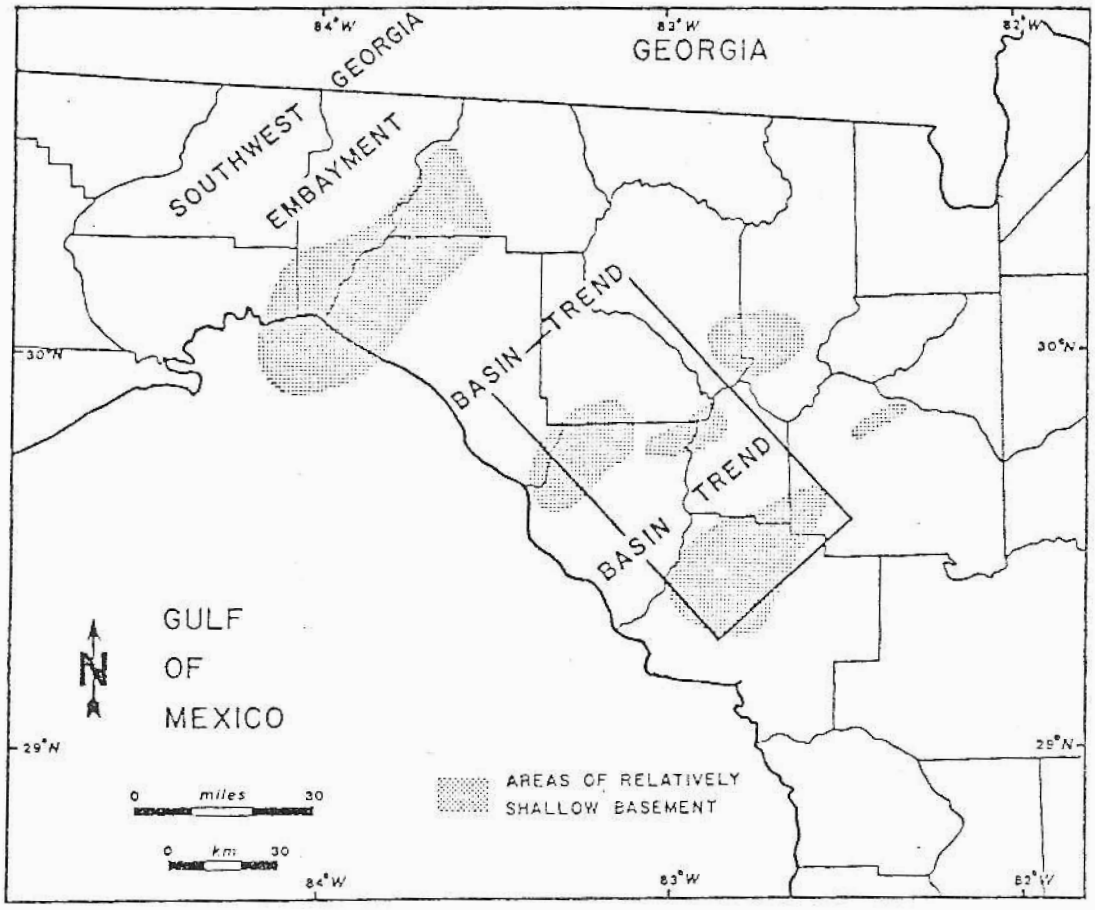


Figure 24. Locations of proposed fault-block basins and uplifts in northwest peninsular Florida.

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APPENDICES

Appendix 1. Data on wells penetrating sub-Zuni rocks in northern Florida.

Well #**	County	Operator and Well Name	Depths in feet below sea level: Top Gulfian Group	Top Comanchean Group	Top Paleozoic Erathem	Total Depth
JPBC	Lafayette	Jet Phillips - Buckeye Cellulose 1	?	?	4594	6717
B11	Columbia	Richard C. Bradley - Brunswick Pulp & Paper Co.	?	___	2987	3000
B12	Columbia	Richard C. Bradley - J. M. Carter 1	?	?	3023	3034
B30	Lafayette	Hunt Oil Co. - P. C. Crapps 1A	?	?	3641	5426
B62	Union	Getty Oil Co. - R. Bielling 4-1 1	?	?	?	2894
B64	Union	Getty Oil Co. - K. O. Dicks 1	?	___	2890	2896
F2	Alachua	Tidewater Assoc. Oil Co. - R. H. Cat 1	1808	___	3023	3038
F50	Dixie	Standard Oil & Gas Co. & Sun Oil Co. - Perpetual Forest, Inc. 1	1832	3732	5195	7477

Appendix 1. (continued)

Well #**	County	Operator and Well Name	Depths in feet below sea level: Top Gulfian Group	Top Comanchean Group	Top Paleozoic Erathem	Total Depth
F51	Dixie	Sun Oil Co. - P. C. Crapps 1A	1739	3561	4975	5063
F52	Dixie	Sun Oil Co. - Hazel Langston 1	1677	3206	3612	3638
F68	Gilchrist	Sun Oil Co. - Alto Adams 1	1687	3267	3495	3660
F69	Gilchrist	Sun Oil Co. - Williams Brothers 1	1703	3131	3271	3289
F100	Lafayette	Coastal Petro. Co. - Ronald Sapp 1	1575	3169	3435	3462
F101	Lafayette	Gulf Oil Corp. - Brooks-Scanlon, Inc. Block 49 1	1617	3468	4418	4425
F102	Lafayette	Humble Oil & Ref. Co. - R. L. Henderson 1	1618	3353	4153	4183
F103	Lafayette	Sun Oil Co. - P. C. Crapps et al. 1	1550	3307	3960	4063

Appendix 1 (continued)

Well #**	County	Operator and Well Name	Depths in feet below sea level: Top Gulfian Group	Top Comanchean Group	Top Paleozoic Erathem	Total Depth
F112	Levy	Coastal Petro. Co. - J. B. and J. P. Ragland 1	2266	4348	5796	5836
F116	Levy	Sun Oil Co. - J. T. Goethe 1	2156	3860	3926	3963
F162	Suwannee	Sun Oil Co. - Earl Odom et al. 1	1492	___	2967	3084
F165	Taylor	Gulf Oil Corp. - Brooks-Scanlon, Inc. Block 33 1	1874	3499	5104*	5147
F167	Taylor	Gulf Oil Corp. - Brooks-Scanlon, Inc. Block 42 1	1959	3679	5397*	5476

* Depth to top of basalt flow or diabase dike; underlies clastic rocks of Pre-Cretaceous age.

** Well #'s preceeded by B - catalogued by Barnett (1975).
Well #'s preceeded by F - catalogued by Applin and Applin (1967).

APPENDIX 2. Observed gravity values and gravity station locations.

STATION NUMBER	STATION* ELEVATION	LATITUDE†	LONGITUDE†	READING**
1	63.2	292557	823934	979288.50
2	61	292652	823834	289.14
3	36	292828	825322	299.92
4	29	291913	824759	284.64
5	42	295442	831727	324.04
6	24	294640	831934	324.91
7	40	293828	830839	296.74
8	25	293342	825920	289.32
9	30	293527	825525	293.90
10	74	301024	830851	338.67
11	49	300512	830818	333.89
12	38	295700	825644	329.67
13	53	294o37	825312	298.96
14	44	293106	825023	302.35
15	93	293633	823824	301.27
16	84	293843	823853	304.84
17	31	292552	825321	295.94
18	30	292550	825622	294.23
19	16	292554	825919	292.35
20	28	292314	825320	288.41
21	26	292313	825620	288.86
22	30	292022	825318	283.55
23	26	291852	825348	280.88
24	30	292312	825021	290.46
25	35	292556	824958	296.60
26	36	292354	824722	290.79
27	41	292553	824730	294.80
28	30	292048	824649	286.19
29	24	292834	825623	297.70
30	41	292828	825022	301.25
31	43	292829	824723	300.10
32	51	292831	824423	298.64
33	50	292835	824123	295.47
34	73	292607	823753	286.48
35	48	292557	824122	290.95

* Elevation in feet
** International observed gravity at station in milligals
† 292557 = 29°25'57" and 823934 = 82°39' 34"

Appendix 2 (continued)

STATION NUMBER	STATION* ELEVATION	LATITUDE	LONGITUDE	READING**
36	43	292332	824134	979287.49
37	30	292044	824433	284.76
38	56	293106	824723	302.73
39	55	293113	824422	301.13
40	53	293112	824116	298.49
41	58	293311	824144	300.88
42	58	293254	824412	301.75
43	55	293344	824723	302.67
44	49	293343	825024	300.94
45	70	293637	823525	301.73
46	72	293358	823625	297.84
47	85	293359	823225	296.77
48	74	293122	823225	293.13
49	78	292912	823526	290.34
50	61	292837	823824	291.77
51	85	293110	823824	293.83
52	70	293357	823824	299.18
53	91	293906	824124	302.99
54	83	294147	824127	302.24
55	89	293847	824420	299.55
56	76	293626	824342	301.81
57	95	293626	824127	302.86
58	31	292037	824947	286.79
59	21	291807	824712	283.40
60	20	291726	825002	282.22
61	40	293342	825324	296.99
62	32	293342	825550	294.17
63	41	293105	825323	298.23
64	39	293620	825355	295.03
65	56	293647	825025	296.62
66	61	293623	824725	300.26
67	65	293858	824718	295.79
68	48	293903	825023	294.20
69	43	293858	825256	295.33
70	25	293830	825625	297.35
71	29	293642	825610	294.66
72	21	294201	825555	305.85
73	40	294413	825544	311.80
74	59	294401	825328	306.40
75	54	294652	825331	21.44
76	89	294654	825028	315.76
77	74	294421	825045	304.00
78	57	294127	825026	295.11
79	92	294350	824804	298.00
80	82	294238	824358	297.26
81	88	294424	824157	299.54
82	79	294400	824436	297.63
83	69	294657	824427	305.23
84	74	294715	824732	312.19

Appendix 2 (continued)

STATION NUMBER	STATION* ELEVATION	LATITUDE	LONGITUDE	READING**
85	16	292538	830218	979287.19
86	15	292851	825918	292.50
87	21	293049	825958	290.07
88	47	295452	825705	325.05
89	63	295438	825930	321.35
90	63	295223	825932	320.47
91	43	295204	825635	327.68
92	20	295212	825333	330.05
93	57	294931	825852	325.06
94	31	294927	825633	330.22
95	55	294652	825950	322.64
96	26	294636	825702	324.53
97	32	294928	825333	328.58
98	66	294930	825116	322.54
99	46	295708	825355	332.74
100	43	295445	825339	329.31
101	34	295432	825022	329.31
102	65	295155	825046	323.09
103	45	300010	825638	335.98
104	45	300220	825943	338.13
105	43	300510	830346	339.28
106	51	295732	825910	327.61
107	48	295949	825943	332.82
108	59	295932	830213	329.27
109	71	295734	830530	322.86
110	74	295943	830556	326.86
111	56	300747	830549	338.02
112	80	301025	830520	339.31
113	95	301302	830852	340.31
114	85	301301	831154	339.46
115	73	301023	831153	336.17
116	45	300737	830850	336.17
117	52	300718	831150	333.26
118	60	300508	831154	330.40
119	71	300501	831455	328.79
120	84	300507	831738	329.79
121	85	300744	831734	331.91
122	63	300745	831457	332.34
123	75	300957	831450	336.72
124	47	300441	830547	336.07
125	56	300232	830546	333.46
126	45	300207	830245	335.40
127	84	300243	830916	328.23
128	84	295959	830904	328.66
129	75	295953	831143	324.60
130	66	295730	831435	324.87
131	79	300258	831152	327.16
132	79	300224	831353	326.85
133	22	293612	825928	291.81

Appendix 2 (continued)

STATION NUMBER	STATION* ELEVATION	LATITUDE	LONGITUDE	READING**
134	26	293901	825921	979298.56
135	36	294203	825935	308.36
136	44	294416	825905	315.18
137	37	293635	830454	292.78
138	31	293615	830202	292.07
139	29	293436	830158	289.73
140	25	293111	830145	288.88
141	36	293620	830809	293.34
142	22	293313	830608	289.59
143	14	293103	830503	288.16
144	19	292828	830455	286.21
145	24	293352	830843	290.08
146	16	293123	830810	285.67
147	27	293338	831045	292.17
148	30	293632	831111	297.73
149	35	293644	831332	304.58
150	38	293857	831107	299.91
151	36	293733	831421	306.28
152	31	293845	831638	309.87
153	16	294054	832011	318.13
154	29	294138	831751	320.33
155	41	294153	831401	315.03
156	42	294102	831131	306.24
157	51	294126	830510	302.84
158	55	294402	830530	309.69
159	46	294135	830205	306.00
160	52	294403	830205	314.23
161	41	293828	830558	295.52
162	50	294150	830908	304.48
163	57	294432	830850	312.35
164	58	294626	830835	318.26
165	54	294622	831139	325.17
166	41	294644	831412	328.61
167	40	294421	831413	323.61
168	42	294352	831204	318.66
169	33	295159	831828	325.31
170	28	294924	831756	327.91
171	28	294645	831811	326.93
172	27	294412	831915	323.68
173	32	294408	831733	325.28
174	27	294917	832006	324.11
175	33	295159	832001	323.12
176	66	295146	830150	316.98
177	65	294945	830206	318.81
178	58	294625	830254	318.98
179	61	294728	830457	316.75
180	65	295010	830430	316.68
181	65	295155	830417	317.15
182	66	295444	830418	319.44

Appendix 2 (continued)

STATION NUMBER	STATION* ELEVATION	LATITUDE	LONGITUDE	READING**
183	50	295343	831450	979325.52
184	46	295138	831433	328.20
185	43	294922	831406	330.87
186	53	294939	831146	330.04
187	59	294947	830851	325.89
188	60	295200	831155	329.01
189	62	295418	831111	325.55
190	71	295754	831122	324.66
191	72	295654	830738	322.63
192	65	295458	830829	323.97
193	50	295637	832858	322.31
194	58	295740	832648	322.57
195	61	295852	832611	324.53
196	36	295151	832333	318.93
197	38	295215	832639	316.84
198	32	294941	832534	314.35
199	35	295140	832900	314.13
200	46	295442	832620	318.66
201	47	295434	832912	318.05
202	44	295428	833156	316.21
203	44	295713	833217	320.49
204	56	295920	832948	324.91
205	74	295859	831517	325.17
206	42	295507	831943	323.38
207	56	295642	832011	324.13
208	64	295653	831735	323.95
209	55	295642	832307	323.61
210	44	295401	832403	320.49
211	82	300257	831605	327.49
212	81	300051	831704	327.12
213	86	300153	831945	328.36
214	81	300014	832018	326.66
215	73	300008	832333	326.53
216	73	300117	832558	331.86