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GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: 17 July 1973

Project Title: "Effects of Crustal Features on the Gravity Field and Isostatic Compensation"

Project No: G-35-608

Principal Investigator Dr. L. T. Long

Sponsor: U. S. Army Research Office - Durham

Agreement Period: From July 1, 1973 Until June 30, 1974

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Assigned to: Geophysical Sciences

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GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT TERMINATION

Date: March 7, 1975

Project Title: Effects of Crustal Features on the Gravity Field & Isostatic Compensation

Project No: G-35-608

Principal Investigator: Dr. L. T. Long

Sponsor: U. S. Army Research Office - Durham

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G-35-608

PROGRESS REPORT

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3. TITLE OF PROPOSAL: Effects of Crustal Features on the Gravity Field and Isostatic Compensation

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8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

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9110-EN

The primary goal of the work has been to utilize the Dorman and Lewis technique to obtain an isostatic response function for the Southeastern United States. Secondary goals were directed toward improving data coverage and isolating the major geologic features. Modifications of the Dorman-Lewis technique were required to allow application in the Southeastern U.S. since local geological features extend across the entire area and constitute an important factor in the isostatic response function. The final data set based on significant recent data acquisitions is now complete. It was derived from 10463 data points of Elevation & Bougue anomalies. Surface densities interpreted from available geologic maps have been included in the data set. Profiles perpendicular and parallel to the regional structure have been generated using a weighted average and distance weighted average technique. These will be analyzed for two-dimensional response functions. The respons function is not expected to be the same for crustal movements perpendicular or parallel to the regional structure and this analysis should give some indication of the asymetry of the isostatic response function.

The data for a detailed (0.5 to 1.0 km interval) line perpendicular to the structure is now ready for analysis. The data includes gravity, elevation, density, magnetic intensity and geologic formation. Total length of the line is over 200 kilometers.

Additional gravity data is currently being obtained in South Carolina in cooperation with the South Carolina Division of Geology and Pradeep Talwani at the University of South Carolina. The objective of this cooperative work is to allow publication (planned in July 1974) of a Bouguer Gravity Map of South Carolina similar to the Georgia Bouguer Gravity Map.

PROGRESS REPORT

1. ARO PROPOSAL NUMBER: P-9110-EN

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George H. Rothe, III (1973) Geophysical Investigation of a Diabase Dike, Masters Thesis, Georgia Institute of Technology, Atlanta, Georgia.

Long, Leland Timothy (1974) Bouguer Gravity Anomalies of Georgia, in Proceeding of the Symposium on the Petroleum Geology of the Georgia Coastal Plain, (expected June 1974) Georgia Geological Survey.

8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

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9110-EN

BRIEF OUTLINE OF RESEARCH FINDINGS

The primary goal of the work has been to utilize the Dorman and Lewis technique to obtain an isostatic response function for the southeastern United States. Secondary goals were directed toward improving gravity data coverage and understanding the anomalies from major geologic features. The 64 x 64 grid of gravity, elevation and density data with a separation of 8 km has been examined. Preliminary descriptions of this data are similar to the explanation with the Simple Bouguer Map of Georgia and will be presented in more detail in the Symposium Volume. Preliminary results from trend and correlation distance analyses indicate that crustal structures NE of a line which extends NW-SE through central Georgia differ significantly from the structures to the SW. Profiles obtained NE and SW of this line also give significantly different isostatic response functions. On the SW side smoothed free air anomalies which approximate isostatic anomalies correlate, where negative, with uplift zones in recent releveling data. While a different response was expected for profiles parallel and perpendicular to the structure, the strong variation along strike was not expected.

A 200 km NW-SE detailed profile in North Georgia indicates significant topography in the intermediate crustal layer as well as a deepening of the Moho to 45 km near Atlanta.

The data accumulation phase of preparation for a Simple Bouguer Map of South Carolina is now essentially complete. The map is expected to be ready for publication by June, 1974. This work is being performed in cooperation with the South Carolina Division of Geology and the University of South Carolina.

BRIEF OUTLINE OF RESEARCH FINDINGS

A talk presented at the "Symposium on the Petroleum Geology of the Georgia Coastal Plain" - to be published in the Proceedings.

ABSTRACT

On a broad scale, the Bouguer gravity anomalies in Georgia show patterns which correlate with the major geologic subdivisions. The Paleozoic rocks of the Valley and Ridge Province of northwest Georgia are characterized by -20 to -40 milligal anomalies. Their smoothness is a consequence of the sedimentary rocks at the surface which generally show only slight lateral variations in density. The Piedmont and Blue Ridge crystalline rocks of central and northeast Georgia are characterized by the most negative Bouguer anomlaies in Georgia. The negative values are a consequence of the elevation and total crustal thickness of these predominantly granitic rocks. Detailed gravity data obtained over crystalline rocks strongly reflect the near surface density variations and structural features. South of the fall line the Bouguer anomalies average about zero. The anomalies are related to density variations in pre-Cretaceous and crystalline basement rocks underlying the younger coastal plain sediments. The positive Bouguer anomalies are most likely due to the occurrence of dense basic rock types (like diabase, gabbro or hornblende gneiss). The negative anomalies are most likely due either to granitic rock or to increased thicknesses of sedimentary rock of pre-Cretaceous age. Detailed gravity data in the Georgia Coastal Plain can be used to delineate the boundaries of the larger structures of the pre-Cretaceous or crystalline basement rocks. Also, correlation of Bouguer anomalies with elevation often give an anomalous (e.g. $3.0 gm/cm^3$) reduction density indicating continued tectonic activity of the sediments and pre-Cretaceous crustal rocks.

GEOPHYSICAL INVESTIGATION
OF A DIABASE DIKE

A THESIS

Presented to

The Faculty of the Division of Graduate

Studies and Research

by

George Henry Rothe, III

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Geophysical Sciences

Georgia Institute of Technology

November, 1973

GEOPHYSICAL INVESTIGATION OF A DIABASE DIKE

Approved:

Chairman

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The School of Geophysical Sciences provided the computer time for the analysis of the data.

Special thanks to Mr. Roland Schenck who assisted in collecting the data. And special thanks to my wife, Donna, for her assistance in the collecting of data, and for editing and typing this manuscript.

TABLE OF CONTENTS

Table of Contents (Concluded)

LIST OF TABLES

LIST OF FIGURES

List of Figures (Concluded)

SUMMARY

Analysis of gravity, aeromagnetic, ground-level magnetic, paleomagnetic, and high altitude infrared data has revealed a complex injection zone of diabase in central Meriwether County, Georgia. This zone, which previously was considered to be a single large (30-40 meters wide) diabase dike, has been found in places to reach a width of one kilometer.

A simple Bouguer gravity map of the area shows the dikes, which compose the injection zone, to be responsible for an anomaly in the regional gravity trend of about one to two milligals. Combined results from five gravity and three total-field magnetic traverses has suggested the dikes to dip at about 70° toward N70°E. The mean of the observed ground-level magnetic anomalies for the dikes is a 1000γ positive anomaly (total field).

On the basis of observed paleomagnetic data and computed bulk susceptibilities the ratio of the remanent to induced magnetizations (Koenigsberger's ratio, Q) has been calculated to be between 0.25 and 0.5. However, the shapes of the observed ground-level magnetic anomalies suggests a Q value of 1.0 or slightly higher for the Meriwether dike.

The total-field magnetic map based on already existing aeromagnetic data has been recontoured under the assumption that the Meriwether dike is continuous, as suggested by ground-level data taken during this investigation.

On the recontoured map the dike is the most prominent magnetic

feature of the area which suggests that the spacing and direction of the aeromagnetic flight lines is inappropriate for correlating dike caused anomalies of limited extent, even though the dike anomalies are large in magnitude.

High altitude infrared photographs show a change in intensity of reflected infrared radiation from vegetation growing on diabase derived soils suggesting that such pictures can be used to map the outcrop pattern of the dike in heavily wooded, highly weathered, and other inaccessable areas. It is suggested that this technique be applied to other areas of eastern North America to determine outcrop patterns of the dikes in areas not yet geologically mapped.

CHAPTER I

INTRODUCTION

A system of diabase dike swarms outcrops throughout eastern North America from Alabama to Nova Scotia (Cohee, et al., 1962), (Stockwell, et al., 1969). Southward along the Appalachian belt from Nova Scotia through New England and into the southern Piedmont, a gradual systematic change in strike is evident (Figure 1). King (1961) commented that the pattern of diabase dikes in eastern North America is probably the result of deep-seated stresses, but that the cause of the stresses is not apparent. May (1971) noted that the systematic pattern of the dikes in eastern North America is actually part of a larger, radial, pattern of diabase dikes surrounding the North Atlantic (Figure 1) and suggested that this pattern is a result of the stress field associated with the onset of North Atlantic sea-floor spreading in Late Triassic or Early Jurassic time.

The age of the dikes in eastern North America is currently in dispute. On the basis of fossil pole positions, de Boer (1967) suggested a Jurassic age for the dikes. On the other hand, Armstrong and Besancon (1970) found whole rock K-Ar ages to fall into two clusters: one at about 200 million years (Middle Triassic) and another smaller one between 225 and 230 million years (Early Triassic). Armstrong and Besancon (1970) suggested that the older dates may represent the actual time of emplacement, while the younger group may be indicative of "burial"

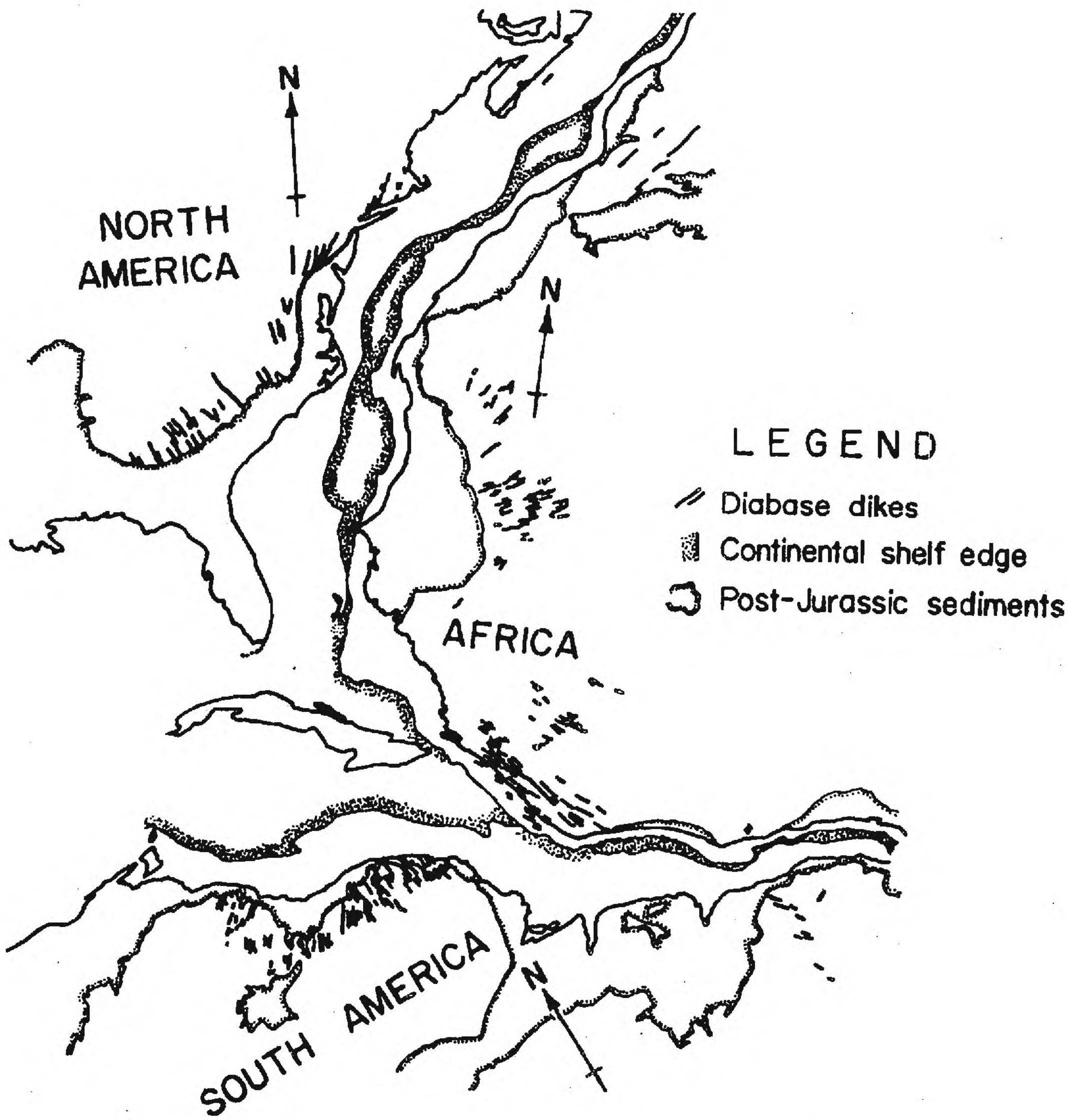

Figure 1. Map of Diabase Dikes in Eastern North America, West Africa, and Northeastern South America with the Continents Restored to Their Relative Position in the Triassic (after May, 1971). (North arrows indicate present geographic direction for each continent.)

metamorphism.

The chemistry of the diabase dikes, previously thought to be uniform (Lester and Allen, 1950) has been shown by Weigand and Ragland (1970) to vary in both major and trace element assemblages. Weigand and Ragland (1970) divided the dikes of eastern North America into several provinces based on the occurrence of three main chemical types: (1) olivine-normative, (2) high-TiO_2, quartz-normative and (3) low-TiO_2, quartz-normative.

The tracing of individual dikes along strike and the determination of thickness and dip by the usual geological field methods is inhibited in most areas of Southeastern North America by intense chemical weathering and dense vegetation. However, Johnson and Watkins (1963) noted a coincidence of dike outcrops and low-amplitude (less than 20γ at an altitude of 800 feet above ground level), positive magnetic anomalies along aeromagnetic flight lines in north-central Virginia. On the basis of linear trends in the occurrence of some of these magnetic highs, Johnson and Watkins (1963) inferred the extension of dikes into areas where no outcrops are known. The success of Johnson and Watkins (1963) suggests that geophysical methods at closer range, i.e. aeromagnetics at 500 feet, ground-level magnetics and detailed gravity, could yield detailed structural information as well as outcrop patterns. The purpose of this study was to apply these geophysical methods to a study of the structure of a diabase dike.

A portion of the long dike in central Meriwether County in west-central Georgia (hereinafter referred to as the Meriwether dike) was selected for study. The dike extends southward from an area north-east of Newnan in Coweta County, to an area south of the Towaliga fault in southern Meriwether county (Figure 2). This area of study was selected because of minimal secondary geophysical distrubances, such as gravity and magnetic anomalies associated with fault zones and basic intrusives other than the diabase dike. In addition, the roads in this area traverse the Meriwether dike at almost right angles and are spaced at approximately two miles, affording good access for a geophysical study.

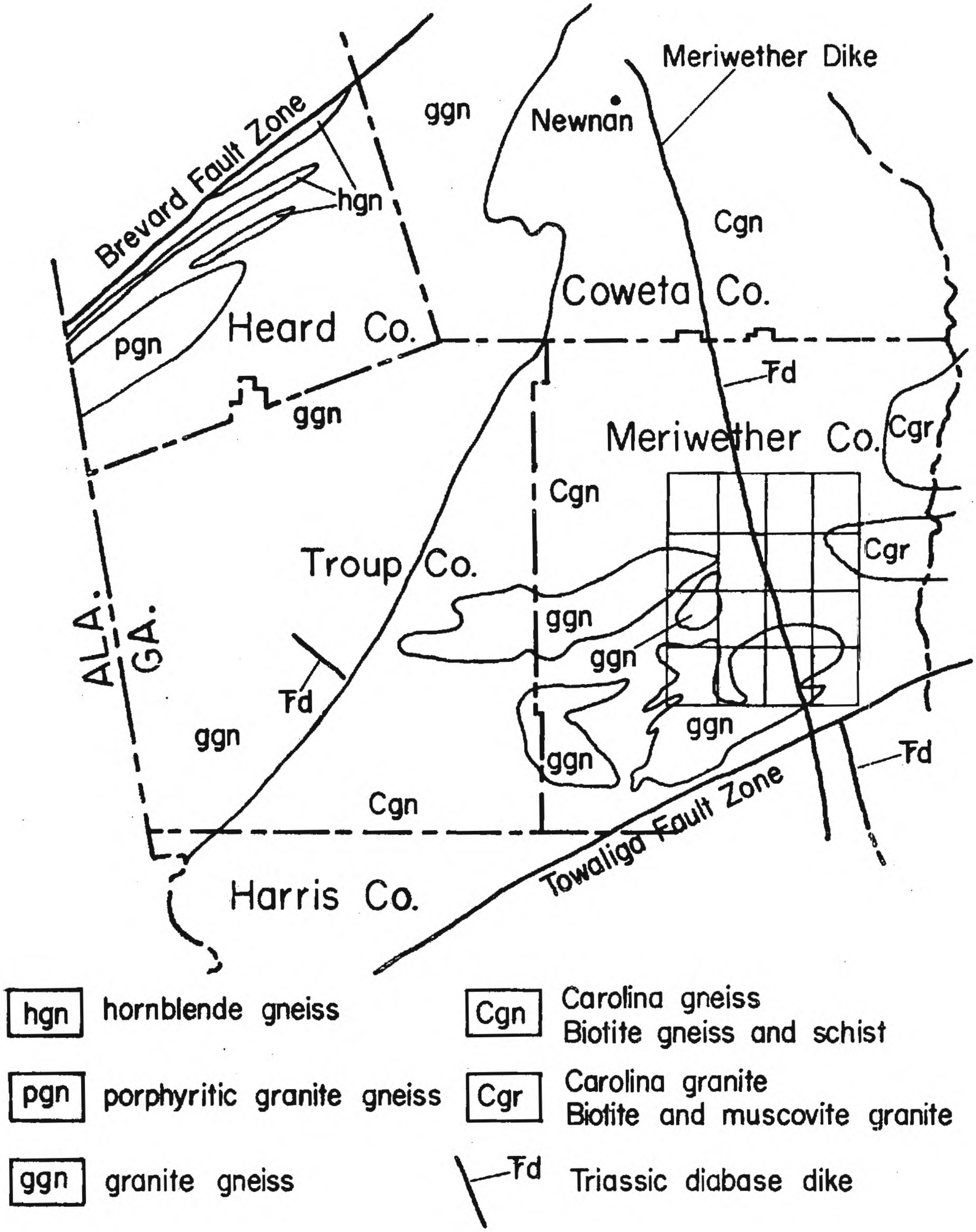

Figure 2. Geology of the Inner Piedmont of West Georgia (after the 1939 Geologic Map of Georgia). (Hatched square grid shows area of detail study.)

CHAPTER II

GEOLOGICAL SETTING AND REGIONAL GEOPHYSICS

Geologic Setting

According to the Geologic Map of the State of Georgia (Georgia Department of Mines, Mining and Geology, 1939) the geologic formations of the study area consist of granites intermingled with both biotite and granite gneisses (Figure 2). Recent reconnaissance mapping by R. D. Bentley (personal communications) has revealed the geology of the Inner Piedmont (between the Brevard and Towaliga Fault Zones) to be more complicated than suggested by the 1939 Georgia Geology Map. Bentley and Neathery (1970) renamed the rocks of the southeastern portion of the Inner Piedmont the Opelika Complex and divided it into two stratigraphic units, the Loachapoka Schist and the Auburn Gneiss-schist (Figure 3). These units were interpreted by Bentley (Bentley and Neathery, 1970) as metamorphosed sediments which are extensively intermingled with granites. The Meriwether dike strikes about N20°W through the area and intersects the rocks of the Opelika Complex at about 60°.

Regional Gravity

Based on measurements taken at 195 stations, a simple Bouguer gravity map of the area under investigation was constructed (Figure 4). The procedures used for the reduction of the data and estimating errors in the final values are given in Appendix I. Estimated error in the regional data is $\pm$0.35 milligals. Isogals trend approximately north-

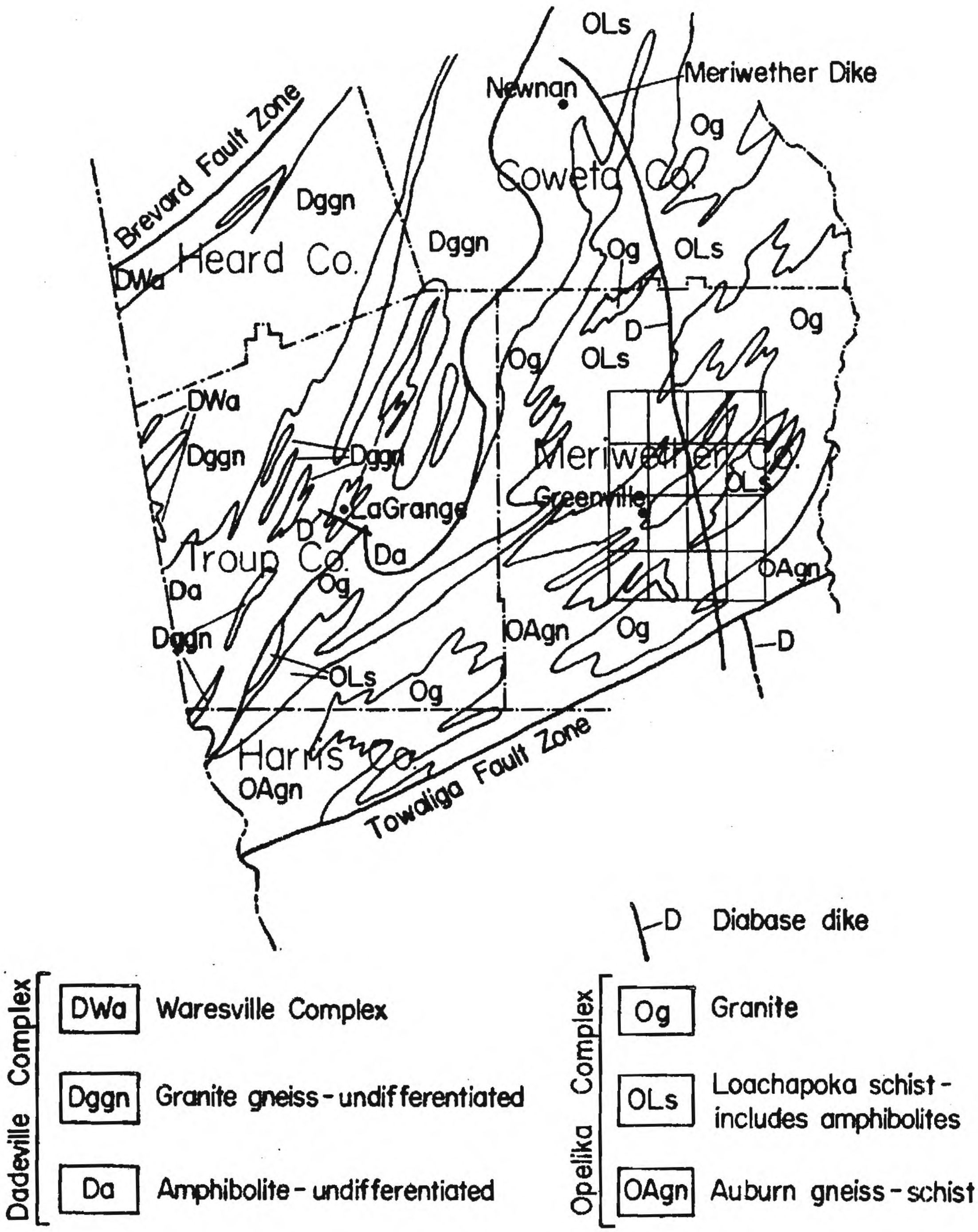

Figure 3. Geology of the Inner Piedmont of West Georgia (after Bentley Neathery, 1970). (Hatched square grid shows area of detail study.)

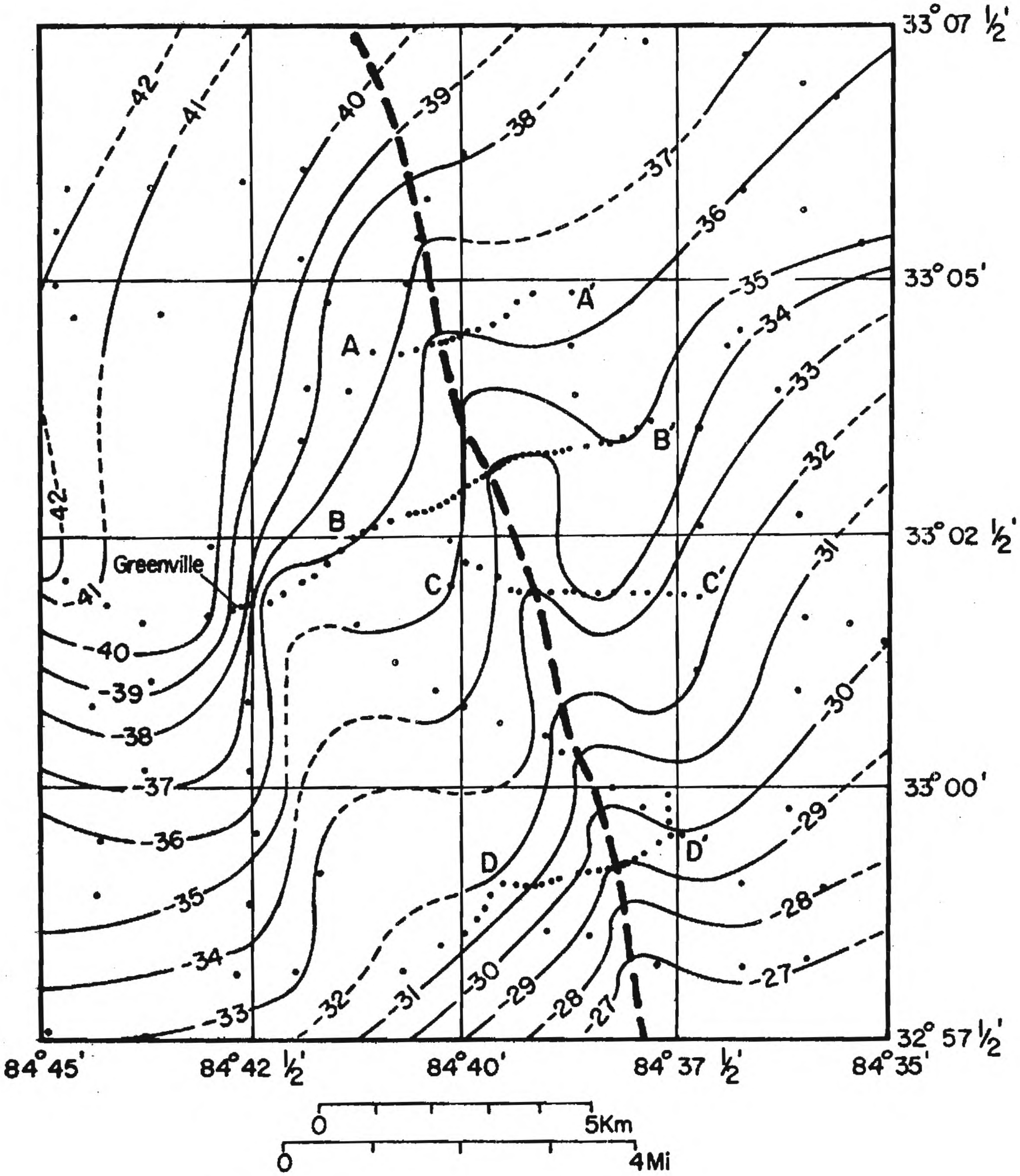

Figure 4. Simple Bouguer Gravity Map of Detail Study Area. (Dashed line gives location of Meriwether dike. Letters designate beginning and end of detailed gravity lines.)

east-southwest, and the regional gradient is about -0.8 milligals/kilometer to the northwest. The prominent features on the simple Bouguer gravity map are the steep gradient in the west-central portion of the study area and an anomaly in the regional trend of one to two milligals beginning in the southeastern part of the study area and continuing northward through the area. The steep gradient is coincidental with the contact between the Loachapoka Schist and granite west of Greenville (Figure 3). The anomaly in the regional trend is largely caused by the existence of the Meriwether dike. Too few gravity stations were taken in the extreme northern portion of the study area to warrant contouring, except by extrapolation. The anomaly probably extends northward out of the study area coincident with the dike.

Regional Magnetics

The North-Central Georgia Aeromagnetics Map (U.S. Geological Survey, open file, 1973) partially fills the gap (Figure 5) between the two previous aeromagnetic surveys of North Georgia Nuclear Laboratory (Philbin, Petrafeso and Long, 1964) and Savannah River Plant (Petty, Petrafeso and Moore, 1965). The area of this investigation (Figure 6) is part of the area covered by this latest work.

Similar to the regional gravity, magnetic features trend NE-SW. Lack of steep gradient immediately east of Greenville suggests that the units responsible for the observed steep gravity gradient in this area have a low contrast in magnetic susceptibility. The most conspicuous feature is the string of localized magnetic highs trending from north to south and having centers located at intersections of the dike and the

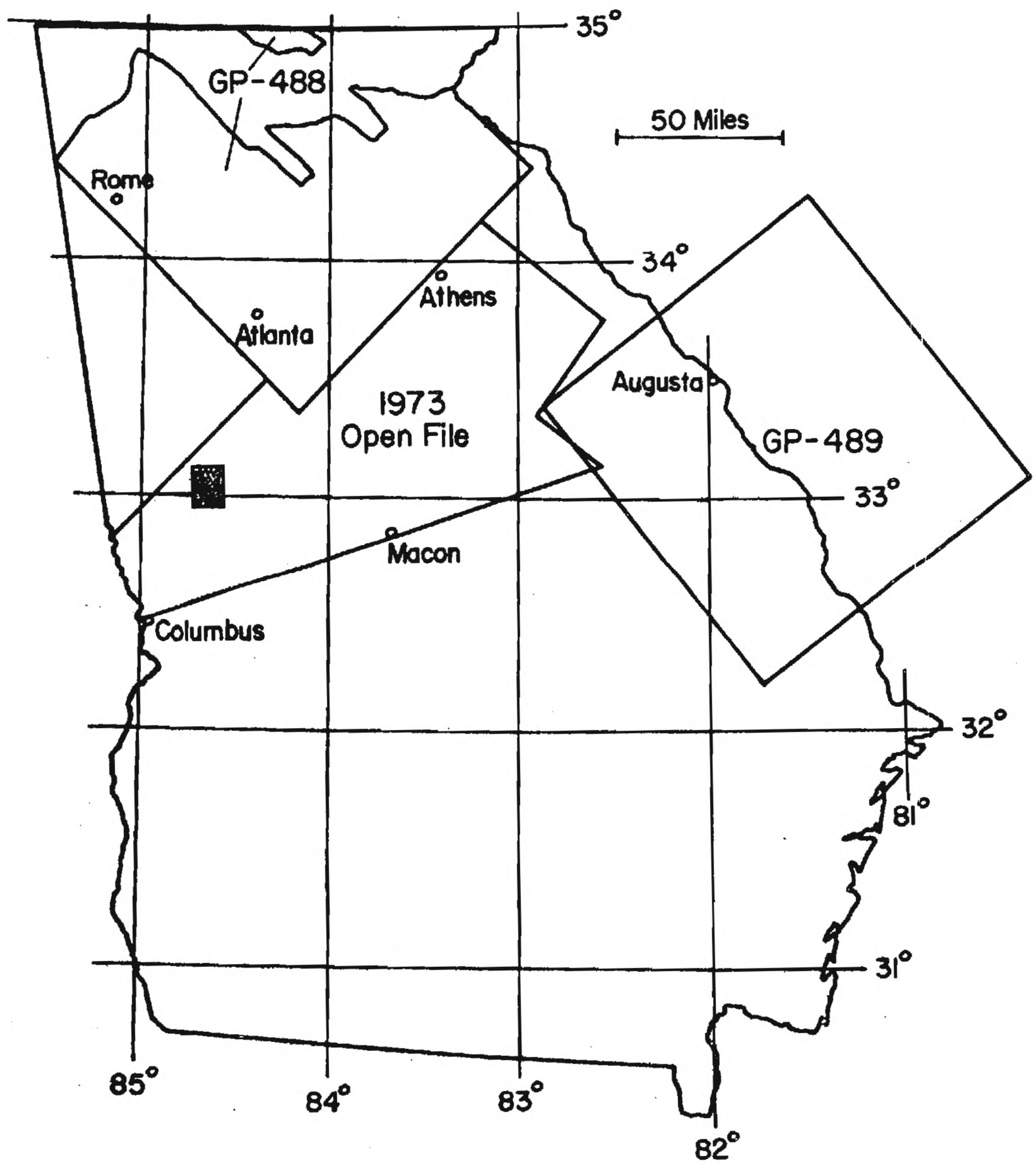

Figure 5. Index Map of Georgia Showing Location of Detail Study Area and Existing Aeromagnetic Maps. (Maps GP-488, North Georgia Nuclear Laboratory, and GP-489, Savannah River Plant, have been published by the U. S. Geological Survey. The North-Central Georgia Map is available on open file at the Georgia Geological Survey. Stipled rectangle is area of detail study.)

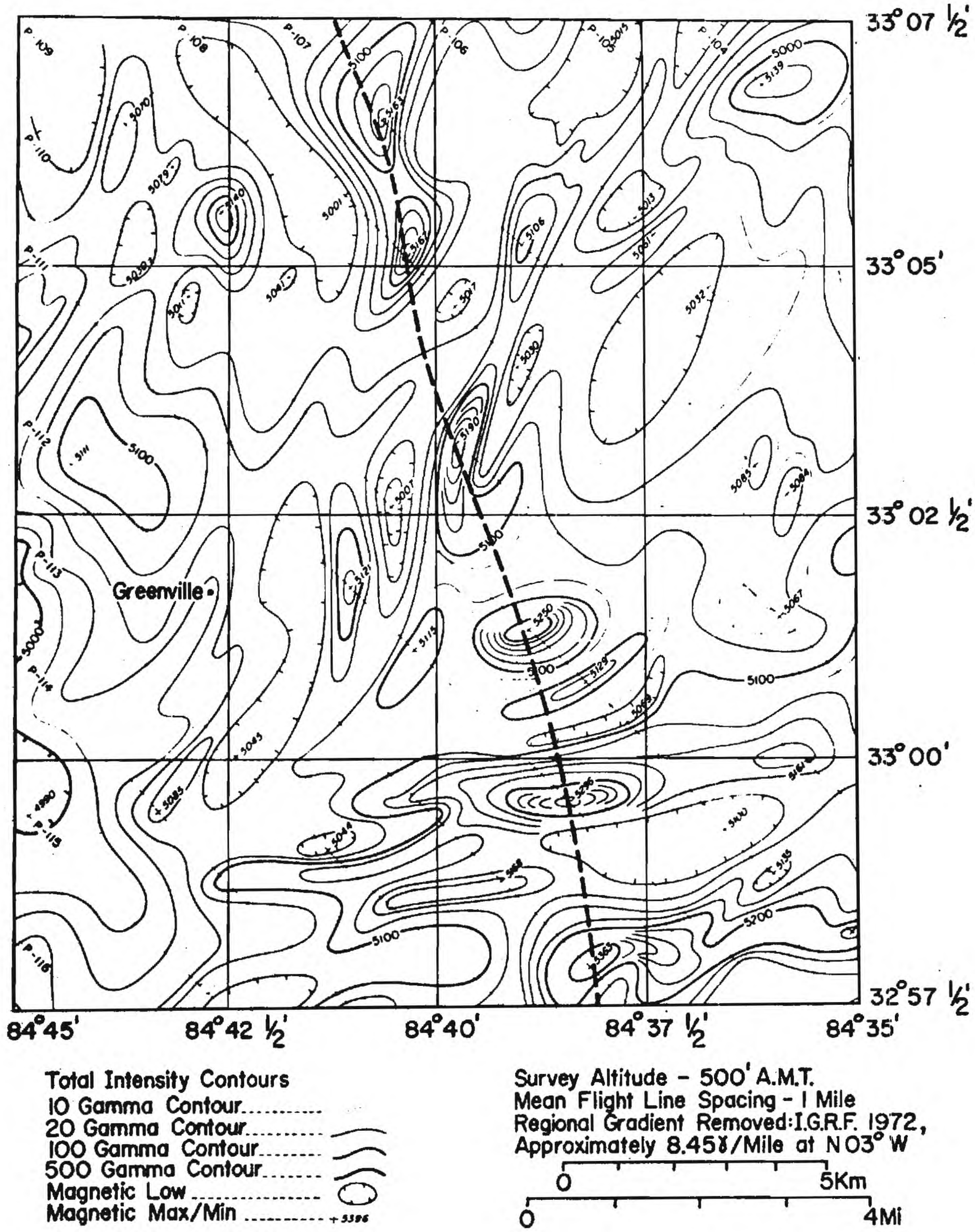

Figure 6. Portion of North-Central Georgia Aeromagnetic Map Covering Area of Detail Study. (U.S.G.S. Open File, 1973) (Dashed line gives location of Meriwether dike. Anomalies are with reference to 50,000γ datum.)

flight lines. These magnetic highs are probably a result of the presence of the Meriwether dike.

The Meriwether dike, which outcrops on roads along its entire length, is probably more continuous than suggested by the series of magnetic highs in Figure 6. Detailed ground-level magnetic traverses of the Meriwether dike at points between aeromagnetic flight lines (Figure 7) support this supposition of continuity. Prominent (1000γ) magnetic highs coinciding with observed dike outcroppings (Figure 8) suggested a recontouring of the aeromagnetic data.

Since the continuous flight line data were not available, all points where flight lines intersect contour lines were assumed to represent true values (the data were extrapolated by computer methods between flight lines). Latitude, longitude, and the total magnetic intensity were determined for each intersection and these points were plotted for recontouring. Under the assumption that the Meriwether dike is continuous along strike, straight lines were drawn connecting points of equal total magnetic intensity on adjacent flight lines in the region where the dike outcrops. In other areas contour lines were assumed to be influenced by the regional geology (after Bentley and Neathery, 1970).

Although no magnetic interpretation is unique, this one (Figure 9) does strongly suggest that the magnetic anomalies associated with the dike can be represented by a continuous linear anomaly. This interpretation is necessary for two-dimensional analysis of the dike by comparison of its observed anomalies with those of easily computed models.

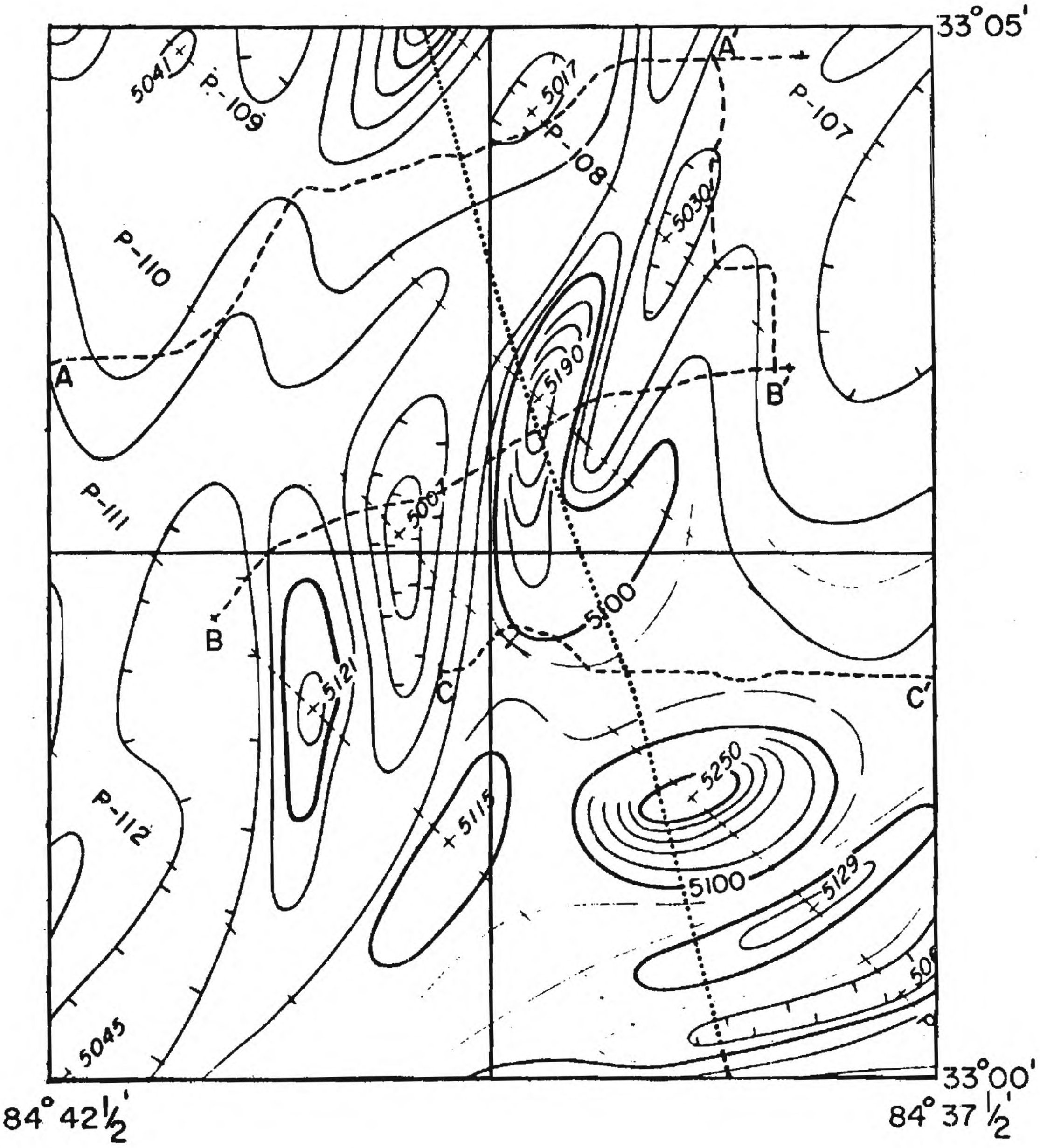

Figure 7. Index Map Showing Locations of Detailed Ground-Level Magnetic Surveys and Existing Aeromagnetic Flight Lines. (Dotted line gives location of Meriwether dike. Anomalies are with reference to 50,000γ datum.)

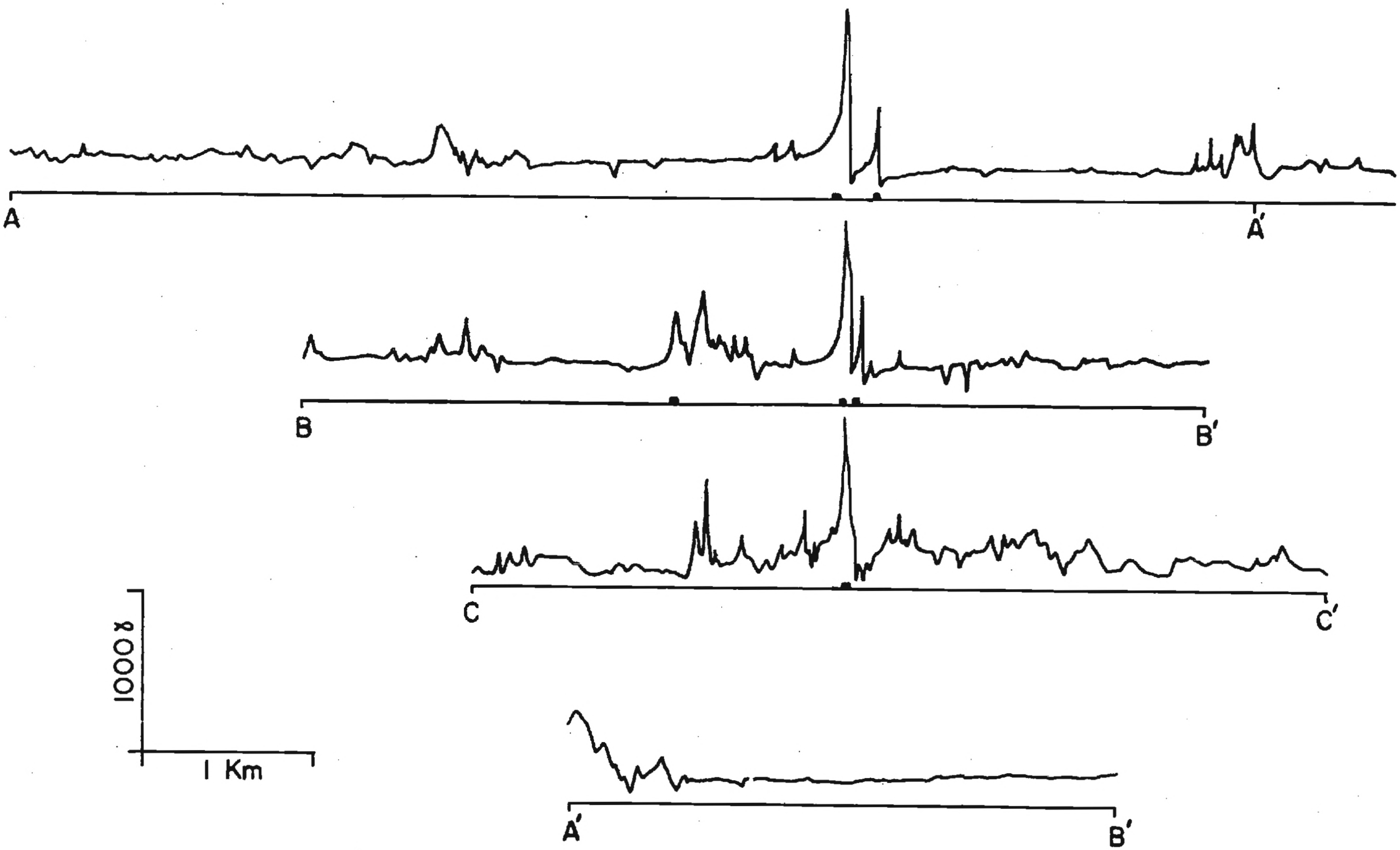

Figure 8. Ground-Level Magnetic Profiles (Total Field). (Heavy bar on profile base indicates diabase outcrop. See Figure 7 for location of profiles.)

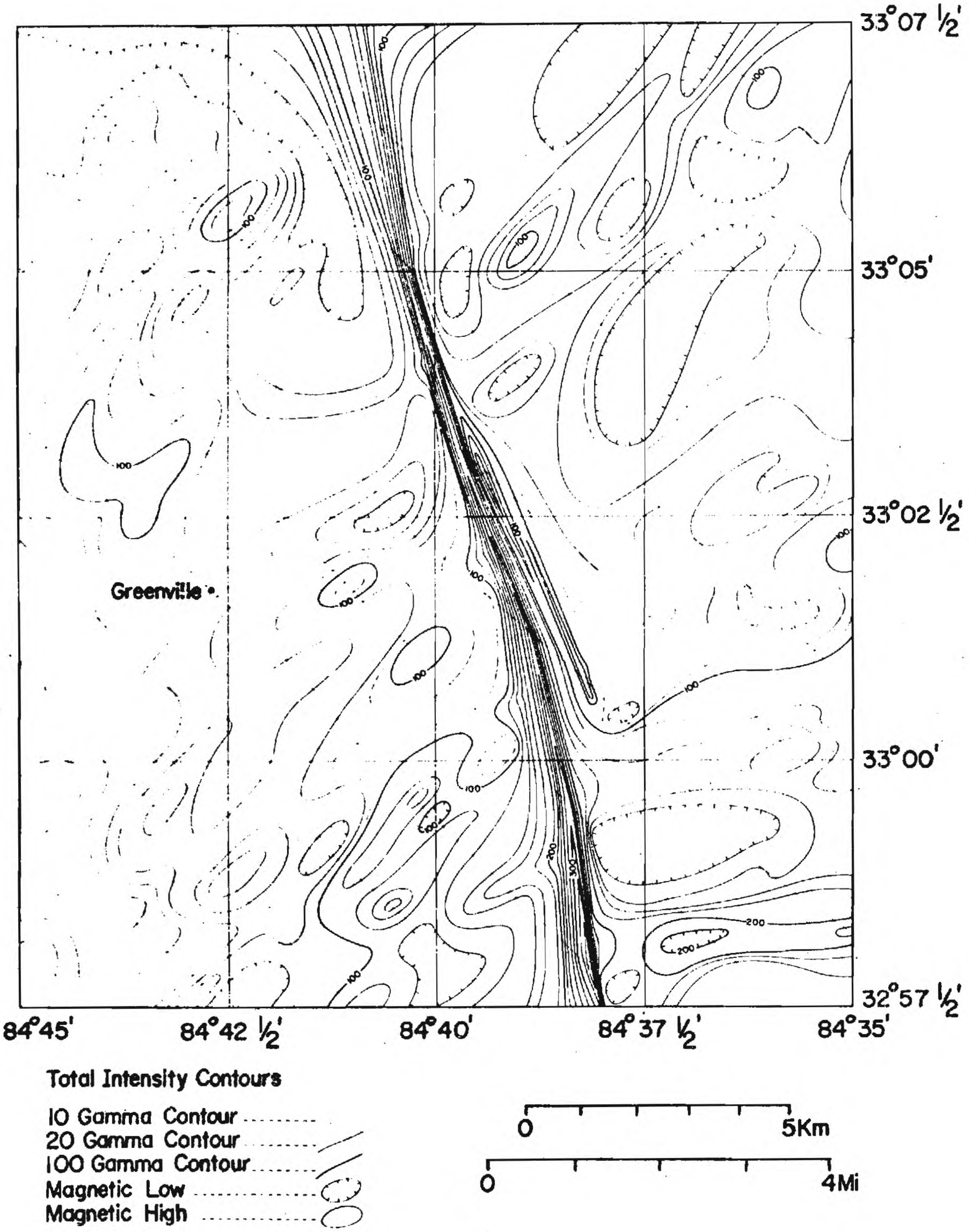

Figure 9. Aeromagnetic Map (Total Field) of the Study Area Recontoured Assuming the Meriwether Dike to be a Continuous Magnetic Feature. (Anomalies are with reference to 55,000γ datum.)

CHAPTER III

PHYSICAL PROPERTIES OF THE MERIWETHER DIKE

Density

Diabase lends itself especially well to geophysical investigation. The density of the Meriwether diabase is 3.0 ± 0.05 gm/cm^3 (as determined by gravimetric methods applied to three field samples). Watson (1902) determined the densities of the Loachapoka Schist and local granites to be 2.64 ± 0.01 gm/cm^3 and 2.70 ± 0.01 gm/cm^3 respectively. Thus, the density contrast between the diabase of the Meriwether dike and the surrounding rocks (average density 2.67 ± 0.02 gm/cm^3) is 0.33 ± 0.07 gm/cm^3. A vertical dike 30 meters wide (average observed outcrop width of the Meriwether dike) with this density contrast should yield a vertical gravity anomaly of approximately 1.5 milligals, an anomaly easily discerned with contemporary instrumentation (see Appendix I).

Magnetic Susceptibility

Several attempts have been made to statistically relate the bulk susceptibility of rocks to petrological parameters. One such attempt was that of Balsey and Buddington (1958) who related the susceptibility of some Adirondack rocks to the fractional volume of all the minerals visually identified as magnetite. This volume would generally include any Fe-Ti oxide minerals of spinel structure. Their empirical formula for the bulk susceptibility (k) in C.G.S. units is

$$k = 2.6 \times 10^{-3} V^{1.11} \tag{1}$$

where V is the volume percentage of all minerals visually identified as magnetite.

Petrographic examination of the Meriwether dike (Lee, 1971) showed that opaque grains (assumed to be Fe-Ti oxides of spinel structure) comprise 2.3 to 4.3 percent of the rock with a higher percentage occurring in the finer-grained zones near its edges. Using the empirical formula of Balsey and Buddington (1958) (Equation 1) and the range of volume percentages of opaques given by Lee (1971), the bulk susceptibility of the diabase composing the Meriwether dike was estimated to be between 0.0066 and 0.0130 cgs.

CHAPTER IV

DETERMINATION OF DIP ANGLE FROM GRAVITY AND MAGNETIC ANOMALIES

Theoretical Models

Theoretical anomalies were calculated for sets of models to examine the effects of dip angle on expected gravity and magnetic anomalies. The method of Talwani, Worzel, and Landisman (1959) was used to compute the gravity anomalies that would be expected for dikes dipping at various angles. Because the observed outcrop width would be fixed for a particular dike, anomalies were computed for models with an outcrop width of 30 meters dipping at 90, 75, 60, and 45° (Figure 10). As would be expected, the gravity anomaly caused by a vertical dike is symmetric about the center of the dike. However, as the dip angle decreases the anomaly becomes asymmetric with the peak shifting toward the direction in which the dike is dipping. The anomaly tails off more slowly on the side toward which the dike dips than the other. Even though there are obvious differences in the anomalies for various values of dip angles, a superimposed regional trend may make determination of the dip more difficult than suggested by Figure 10; in fact, unless the regional trend is simple and well defined, the determination of the dip may be impossible.

Although the dip angle has an obvious effect on the shape and asymmetry of the total-field anomaly (Figure 11), the effects of natural

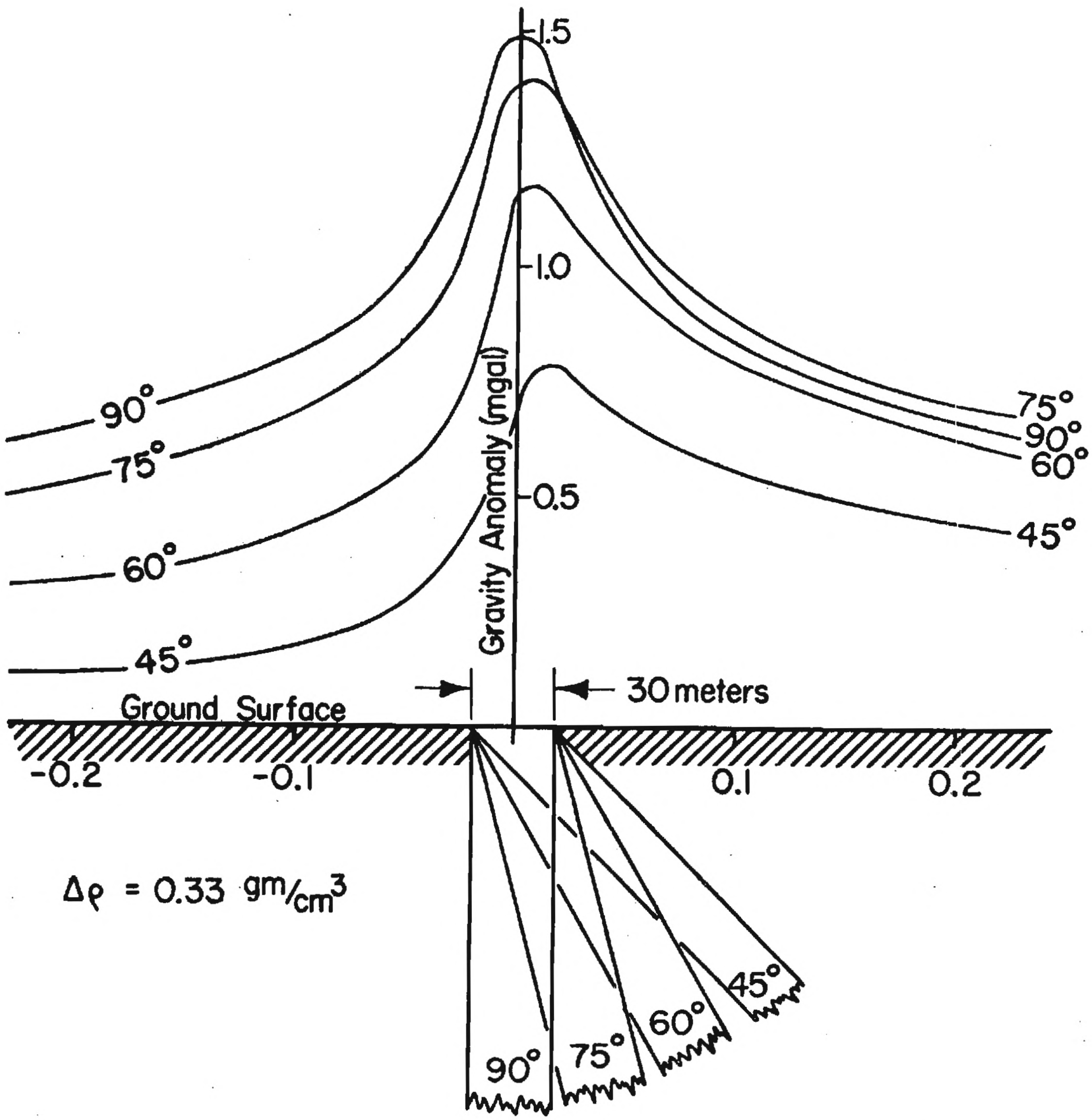

Figure 10. Calculated Curves Showing Effect of Dip Angle on Vertical Gravity Anomaly.

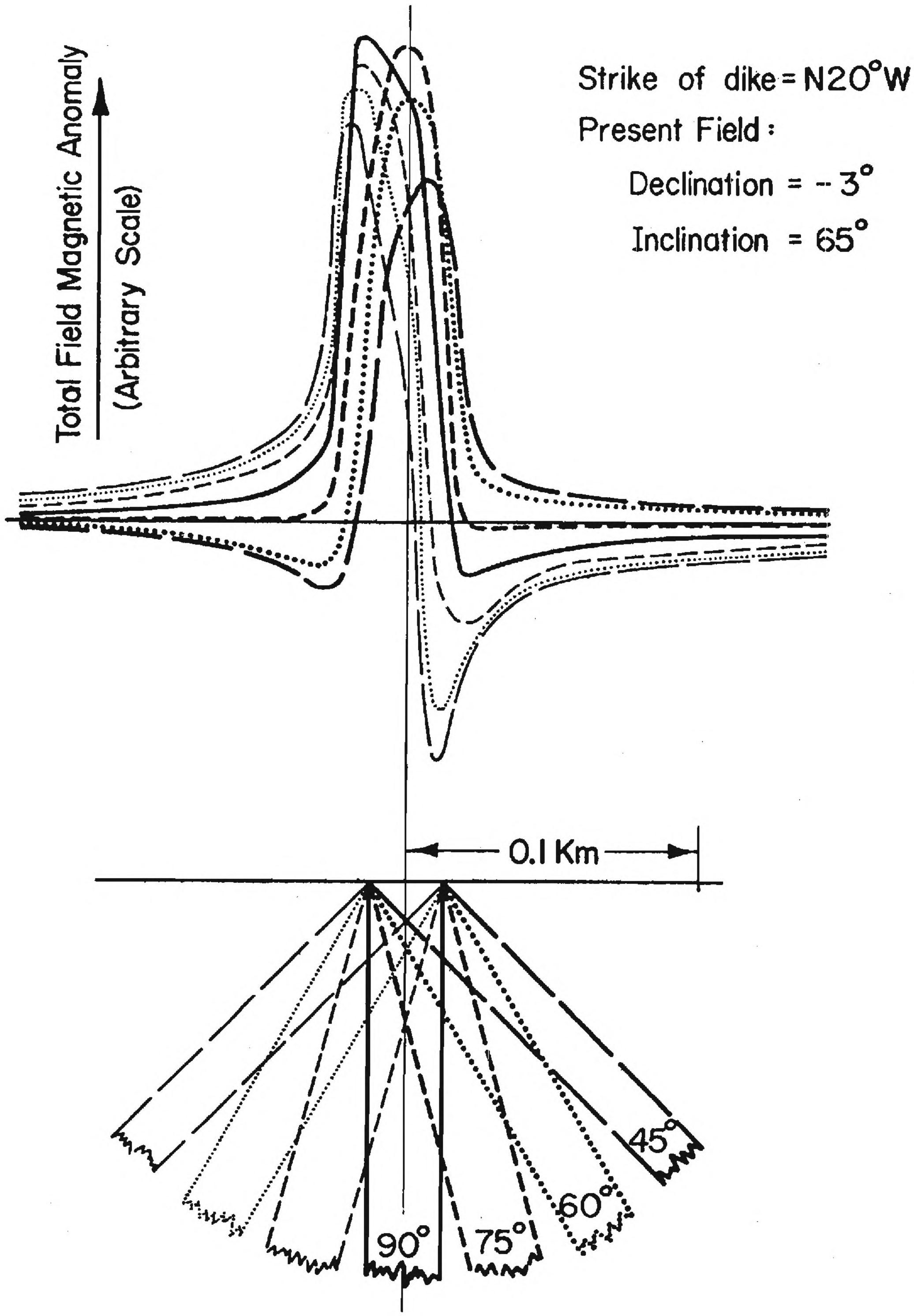

Figure 11. Calculated Curves Showing Effect of Dip Angle on Total Field Anomaly Due to Induction Magnetization Only.

remanent magnetization, when added to the induced magnetization, may complicate the determination of dip angle from the observed anomaly (Hood, 1963). For this reason, the angle of dip was determined using observed gravity anomalies only. The magnetic anomalies, because of their sharpness as compared to the gravity anomalies (Figures 8 and 10), were used only for lateral location of the dike where outcrops were nonexistent.

Detailed Gravity Profiles

Five detailed gravity lines with an average station spacing of 0.15 kilometers and a total length of 20 kilometers were obtained. Station spacing was decreased to about 0.075 kilometers in the immediate proximity of the dike. Four lines traverse the Meriwether dike in the prescribed study area (Figure 4) and the fifth traverses it along Georgia State Highway 16 southeast of Newnan and north of the study area. The observed anomalies (Figures 12 through 16), when smoothed, are about 1.0 kilometer wide at half their maximum value. This width is considerably greater than the computed anomaly width for a vertical dike 30 meters wide, approximately 0.1 kilometers at half its maximum value (Figure 10). Numerous individual peaks superimposed on the broad peaks suggest that a 0.75 kilometer wide swarm of dikes, rather than a single dike, is responsible for the observed anomaly. Such a hypothesis is further supported by the ground-level magnetic profiles, (Figure 8).

Profile A-A'.

Gravity line A-A' (Figure 4) was established along a dirt road about 3.0 kilometers north of Georgia State Highway 109. The observed

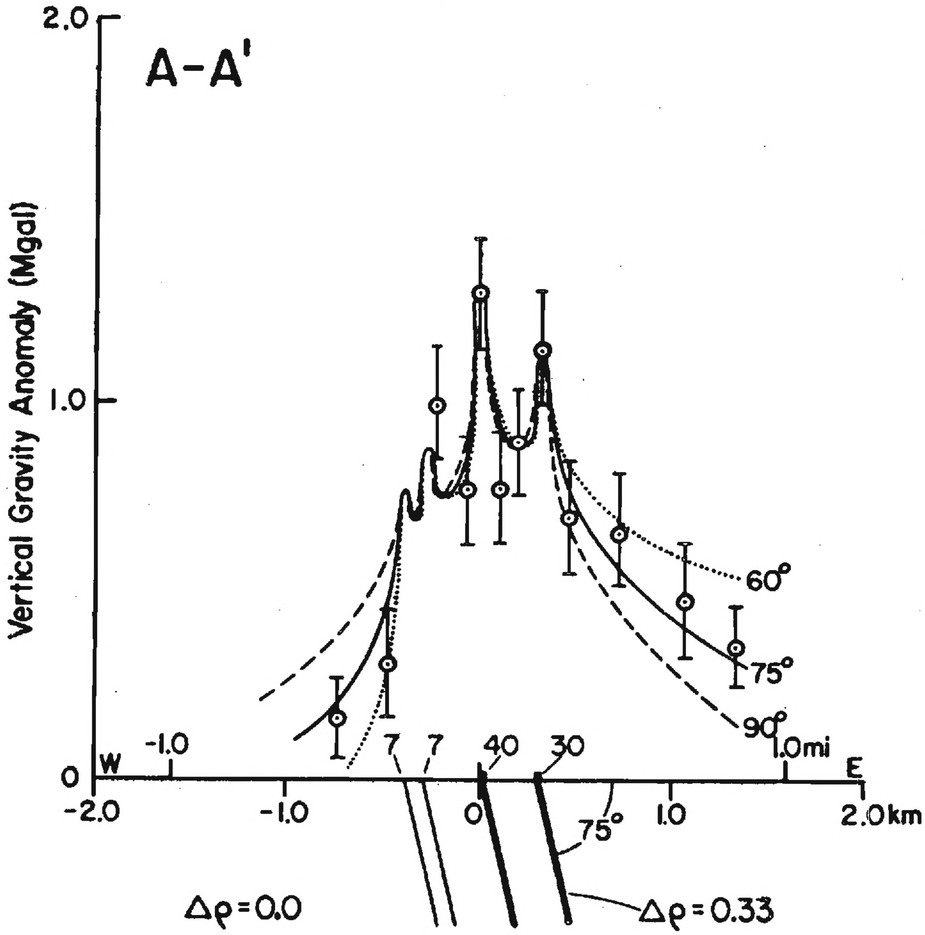

Figure 12. Detailed Gravity Profile A-A'. (Model dikes extend to infinite depth. Thickness of the modeled dike is given by the numeral above the dike. Heavy bar on profile indicates observed dike outcrop.)

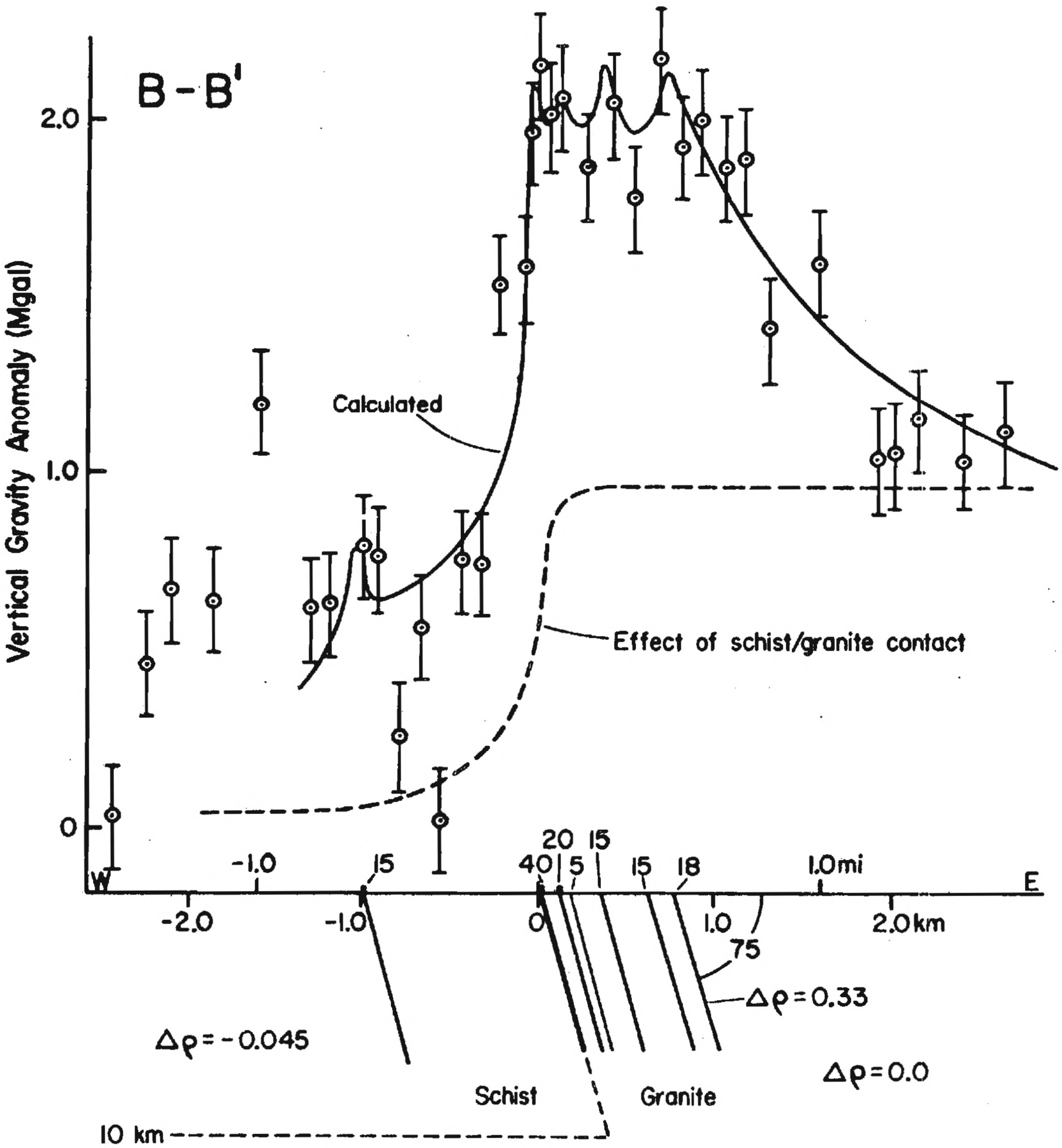

Figure 13. Detailed Gravity Profile B-B'. (Model dikes extend to infinite depth. Thickness of the modeled dike is given by the numeral above the dike. Heavy bar on profile indicates observed dike outcrop.)

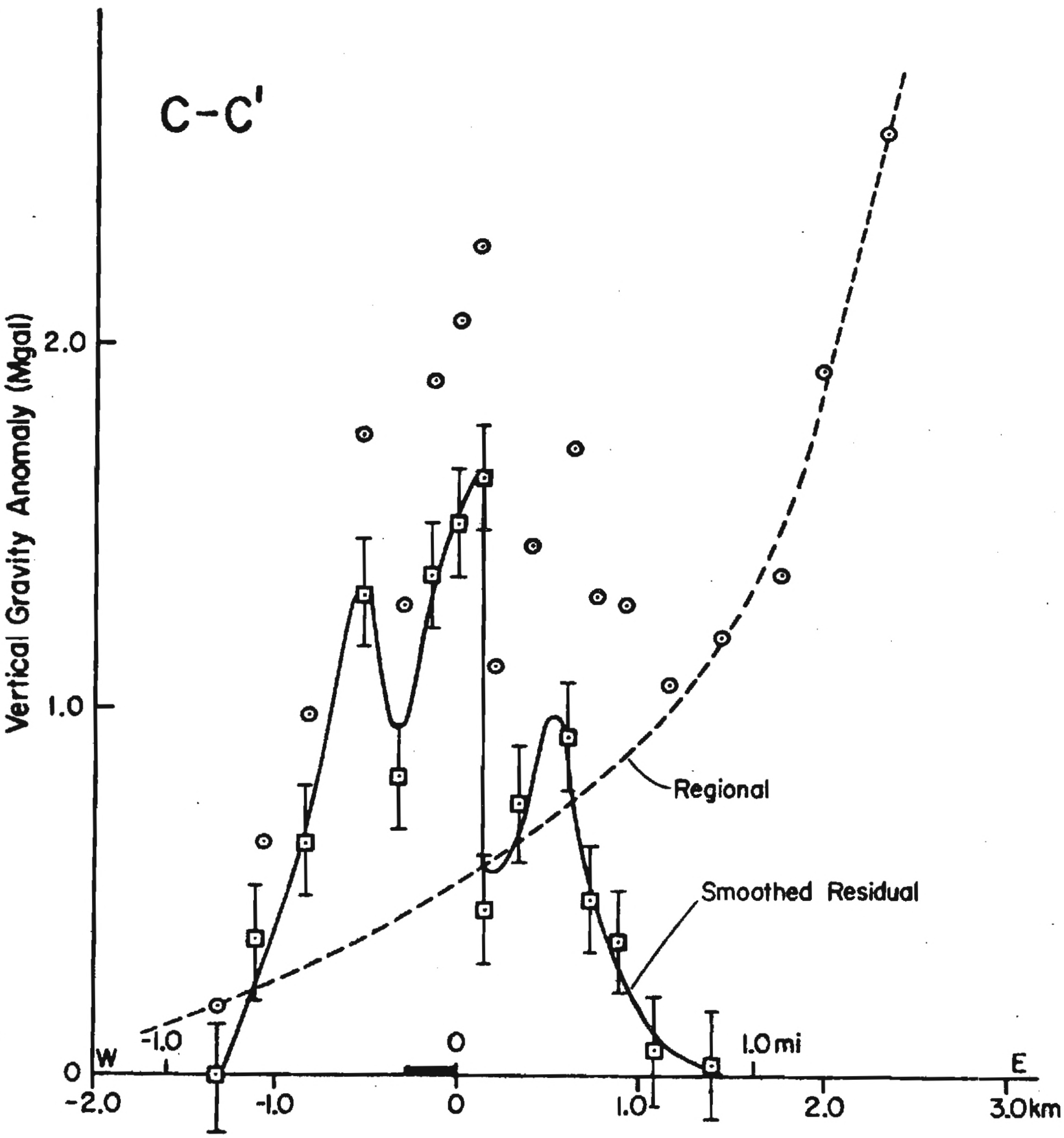

Figure 14. Detailed Gravity Profile C-C'. (Smoothed residual exhibits three definite peaks. Heavy bar on profile indicates observed dike outcrop.)

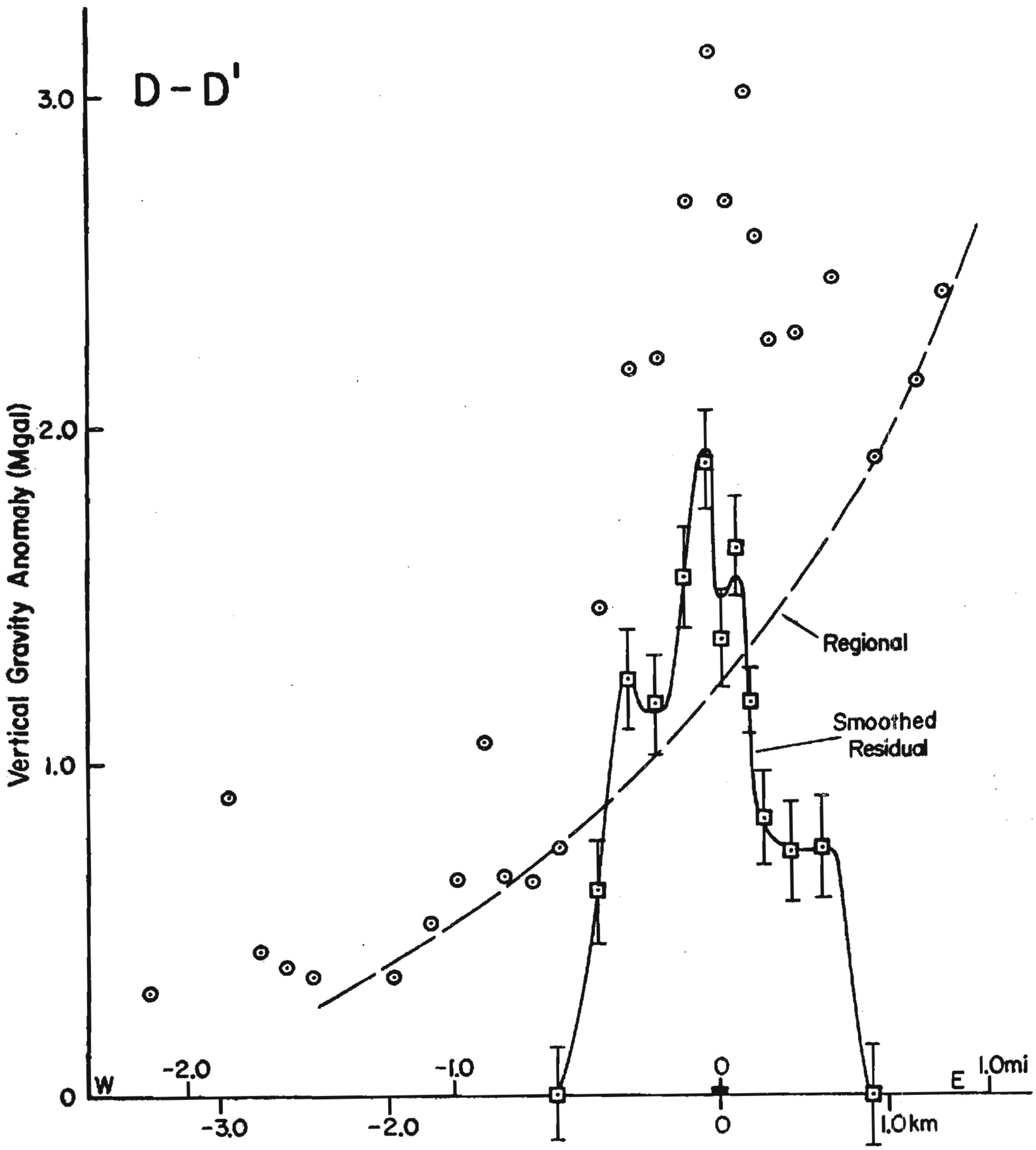

Figure 15. Detailed Gravity Profile D-D'. (Smoothed residual exhibits multiple peaks. Heavy bar on profile incidates observed dike outcrop.)

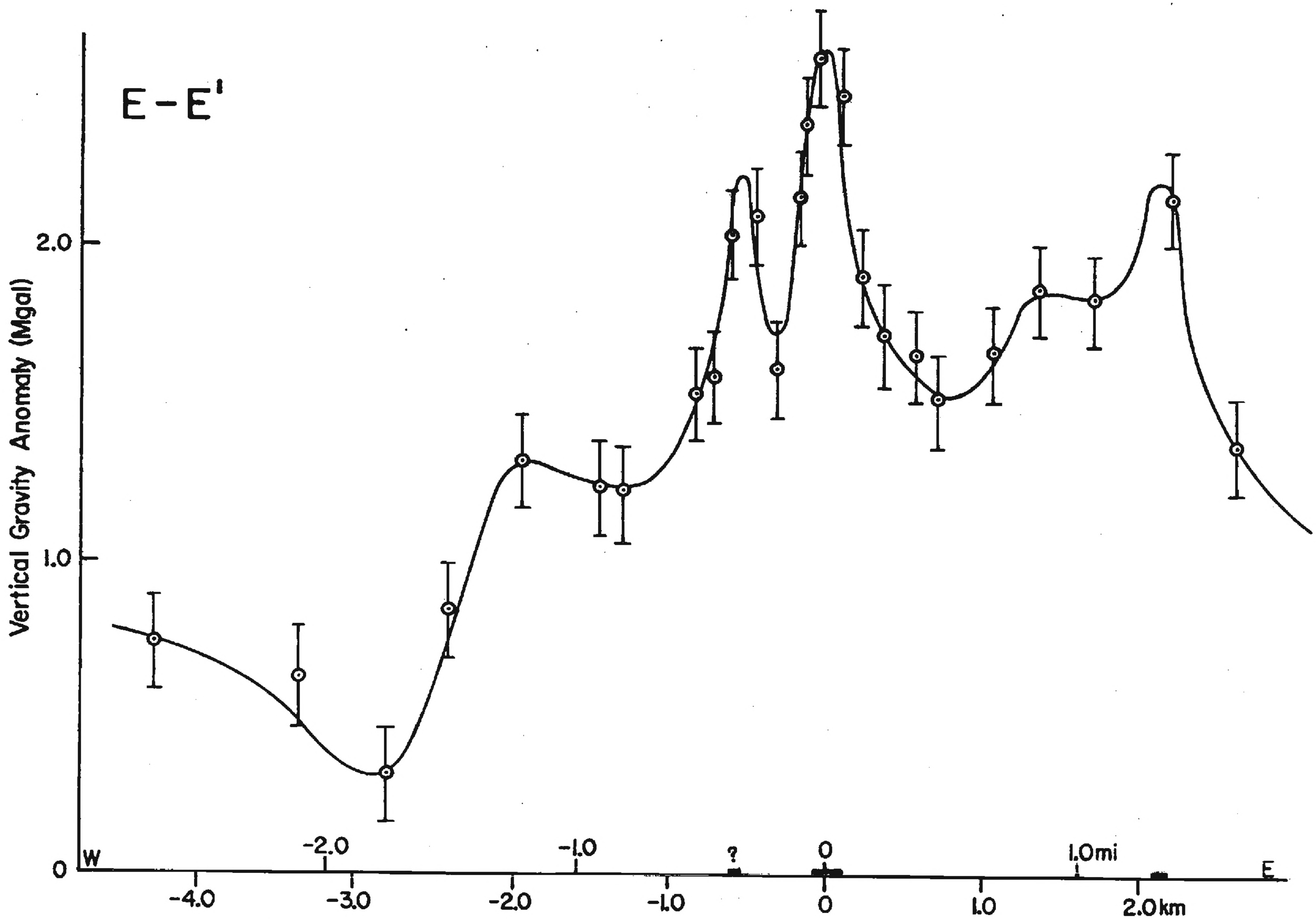

Figure 16. Detailed Gravity Profile E-E'. (Georgia Highway 16, south of Newnan. Heavy bar on profile indicates observed dike outcrops.)

gravity anomaly (Figure 12) consists of three peaks of about one milligal amplitude with the side and less prominent peaks spaced about 0.2 kilometers to either side of the main peak. Because there exist no known density anomalies, with exception of the diabase, along this profile and because the regional isogals are slightly curved in the region of this profile (Figure 4), no regional trend was removed. The three peaks and the asymmetry of the anomaly suggest that three dikes dipping to the east are necessary to account for the observed anomaly. Examination of the ground-level magnetic data for the same profile (Figure 8) suggests that the side dike to the west is actually two thin dikes. Assuming the existence of the four dikes, anomalies were computed using the observed outcrop widths for the main dike (40 meters) and the east dike (30 meters). The west dikes were not found to outcrop and because of the lesser magnitude of the associated gravity anomaly as compared to those of the main dike, they were modeled to be 7.5 meters wide.

Examination of the computed anomalies for dips of 90, 75 and 60° (Figure 12) shows the observed anomaly to fall between the computed curves for 60 and 75 with a dip angle of 70° (by interpolation) probably best satisfying the observed data.

<u>Profile B-B'.</u>

Detailed gravity line B-B' (Figure 4) was established along Georgia State Highway 109 between Greenville and Gay, Georgia. The observed anomaly consists of a "noisy" assymmetric broad peak (Figure 13). Amphibolites were found outcropping to the west of the main dike and could be responsible for the observed scatter in the data west of the dike. Diabase float was also found 1.0 kilometers west of the main dike indicating that part of the observed scatter in the data may be a result of a side dike. A corresponding magnetic anomaly was encountered during the ground-level magnetic survey of the same profile (Figure 8).

Aside from the scatter in the data to the west of the main dike, there is a difference in the base level of the observed gravity. The east side of the dike is about 1.0 milligal more positive than the west side. This offset can be accounted for by the contact (no fault is visible and the orientation of the contact is unknown) between the Loachapoka Schist to the west and the granite to the east.

After the effect of the contact was removed, the resulting asymmetric residual anomaly could be modeled by a set of six dikes dipping to the east. Only the main dike was observed to outcrop, but the ground-level magnetic data (Figure 8) indicate the existence of the others. Determination of the angle of dip was not attempted because of the uncertainty in the location and orientation of the schist-granite contact.

Profile C-C'.

Profile C-C' (Figure 4) was established along the dirt road about 1.5 kilometers south of Georgia State Highway 109. The strong eastward positive trend of the observed data (Figure 14) is probably caused by granitic rocks which dip westward (Figure 3). Because the exact location and attitude of the granite-schist contact were unknown, a regional trend was estimated (Figure 14). The residual anomaly (Figure 14) consists of a central main peak and two secondary peaks on either side of the main peak. Although the dike was found to outcrop only coincident with the central peak of the gravity anomaly, the secondary peaks of the anomaly are probably due to side dikes. A similar phenomenon was noted previously for profiles A-A' and B-B' further to the north. Because of the ambiguity created by the removal of the regional gravity trend by smoothing, and the noisy character of the ground-level magnetic data taken for the same profile (Figure 8), no attempt was made to determine the dip angle of the dikes.

Profile D-D'.

Line D-D' (Figure 4) was established along the paved county road about 8.0 kilometers southeast of Greenville and 4.5 kilometers south of detailed gravity line C-C'. As in profile C-C', there is a strong positive regional trend to the east (Figure 15), which was removed. The multiple peaks in the residual anomaly, (Figure 15) although not as well separated as in the previous profiles, again indicates that more than one dike is responsible for the observed anomaly. The only dike found to outcrop was again coincident with the main peak.

Profile E-E'.

Gravity line E-E' lies along Georgia Highway 16, southeast of Newnan. This profile, which is outside the main area of investigation, was obtained for comparison to the four previous profiles which lie within the area of detailed study 20 kilometers to the south. The observed anomaly (Figure 16) consists of three peaks all coincident with observed outcrops of dikes with the central peak corresponding to the widest outcrop. Whereas the side dikes in profiles to the south are located no more than 1.0 kilometers to the side of the main dike, the east dike on profile E-E' is located 2.1 kilometers from the main dike.

CHAPTER V

GROUND-LEVEL MAGNETICS AND THE ROLE OF NATURAL REMANENT MAGNETIZATION IN THE OBSERVED ANOMALIES

Ground-Level Magnetics

Four detailed ground-level magnetic (total field) profiles were obtained in order to examine the structure of the Meriwether dike and to provide additional data for the purpose of recontouring the aeromagnetic data previously described. Three of the profiles were obtained along the same roads as detailed gravity profiles A-A', B-B', and C-C'. The fourth was a closure profile connecting A-A' and B-B' (Figure 7). The data was obtained and reduced by standard techniques and are listed in Appendix II.

The reduced data (Figure 8) showed the main dike to be represented by an asymmetric anomaly for all three profiles. However, the calculated anomaly due to induction magnetization for a dike dipping 70° toward N70° E is a symmetric positive peak (Figure 11). This suggests that induction magnetization is not the only cause for the observed anomaly and that natural remanent magnetization (NRM) must also be considered in the analysis of magnetic anomalies (Hood, 1963).

Natural Remanent Magnetization of the Meriwether Dike

Samples from a single outcrop of the Meriwether dike were collected and analyzed for NRM by Doyle Watts (personal communications). Intensities and directions for the NRM's are given in Appendix IV. A

Schmidt stereographic projection of the NRM directions (Figure 17) shows the NRM directions to be different from today's magnetic field. Samples from the center of the dike constitute one set of directions and those from the chilled margins another set. Because it is not known what proportion of the dike has which magnetization, an average of the directions (Figure 17) and magnitudes were used for computing the anomaly due to remanent magnetization. The average direction has a declination of 28° and an inclination of 30°. The average magnitude of the NRM is 0.00175 cgs.

Theoretical Anomalies and the Determination of the Koenigsberger Ratio, Q

The ratio of remanent magnetization to induced magnetization, the Koenigsberger ratio, Q is commonly cited in paleomagnetic studies as an indication of whether or not samples have been subjected to lightning strikes. It has more recently been construed (Green, 1960) as a measure of the importance of remanent magnetization in the analysis of magnetic anomalies. Using the calculated bulk susceptibility for the diabase of the Meriwether dike and the average intensity of NRM, the probable range of Q is 0.25 to 0.50. The range of Q's is a result of the uncertainty in the bulk susceptibility.

To examine the effects of Q on the observed anomalies, several models were computed using the method of Talwani and Heirtzler (1965). For a Q of 0.25 and bulk susceptibility of 0.013 cgs, the remanent magnetization causes the anomaly to become slightly asymmetric (Figure 18) with a peak to trough ratio of about 15 to 1. For bulk suscepti-

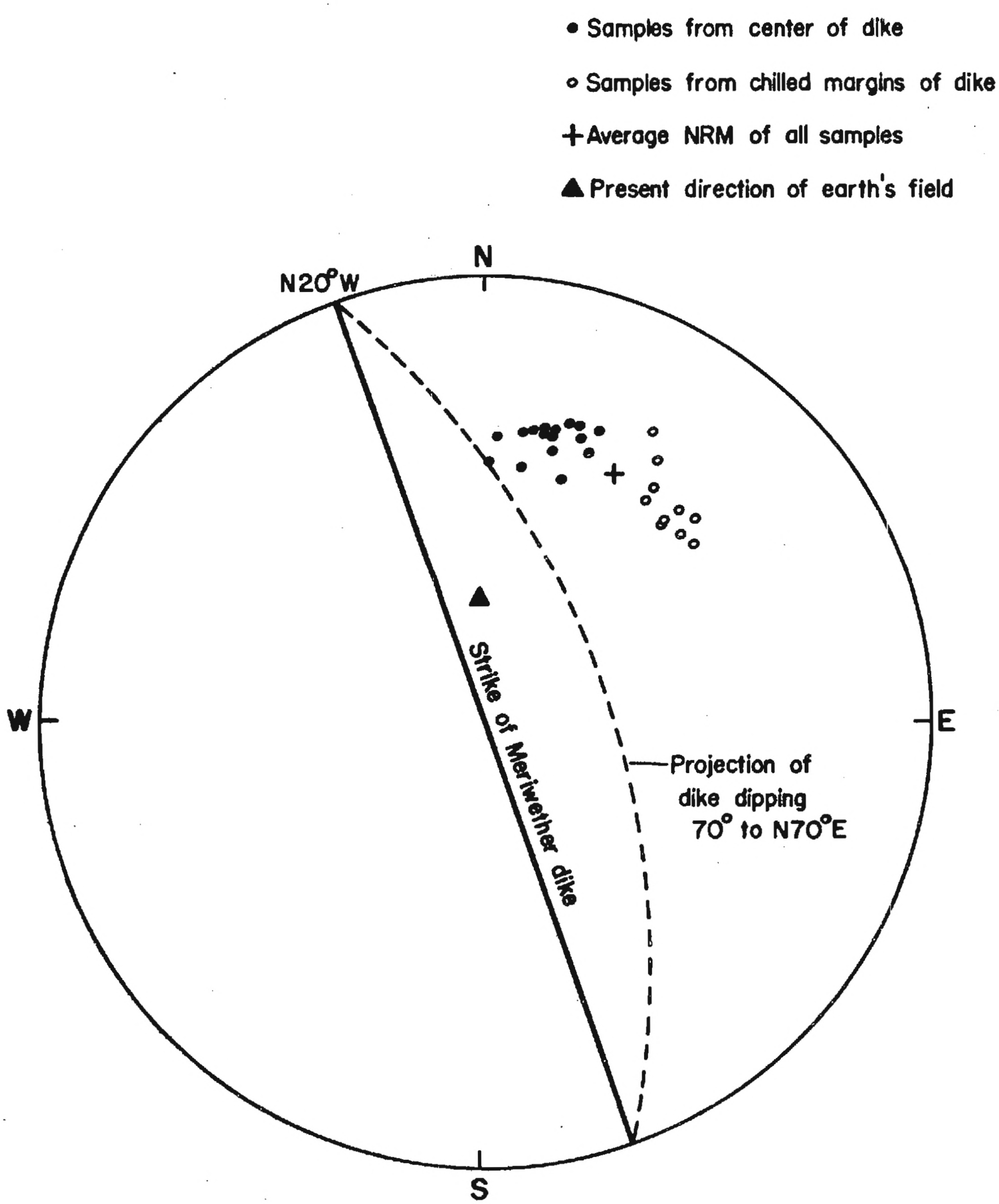

Figure 17. Stereographic Projection (Schmidt net) of Measured Natural Remanent Moments (NRM) for the Meriwether Dike.

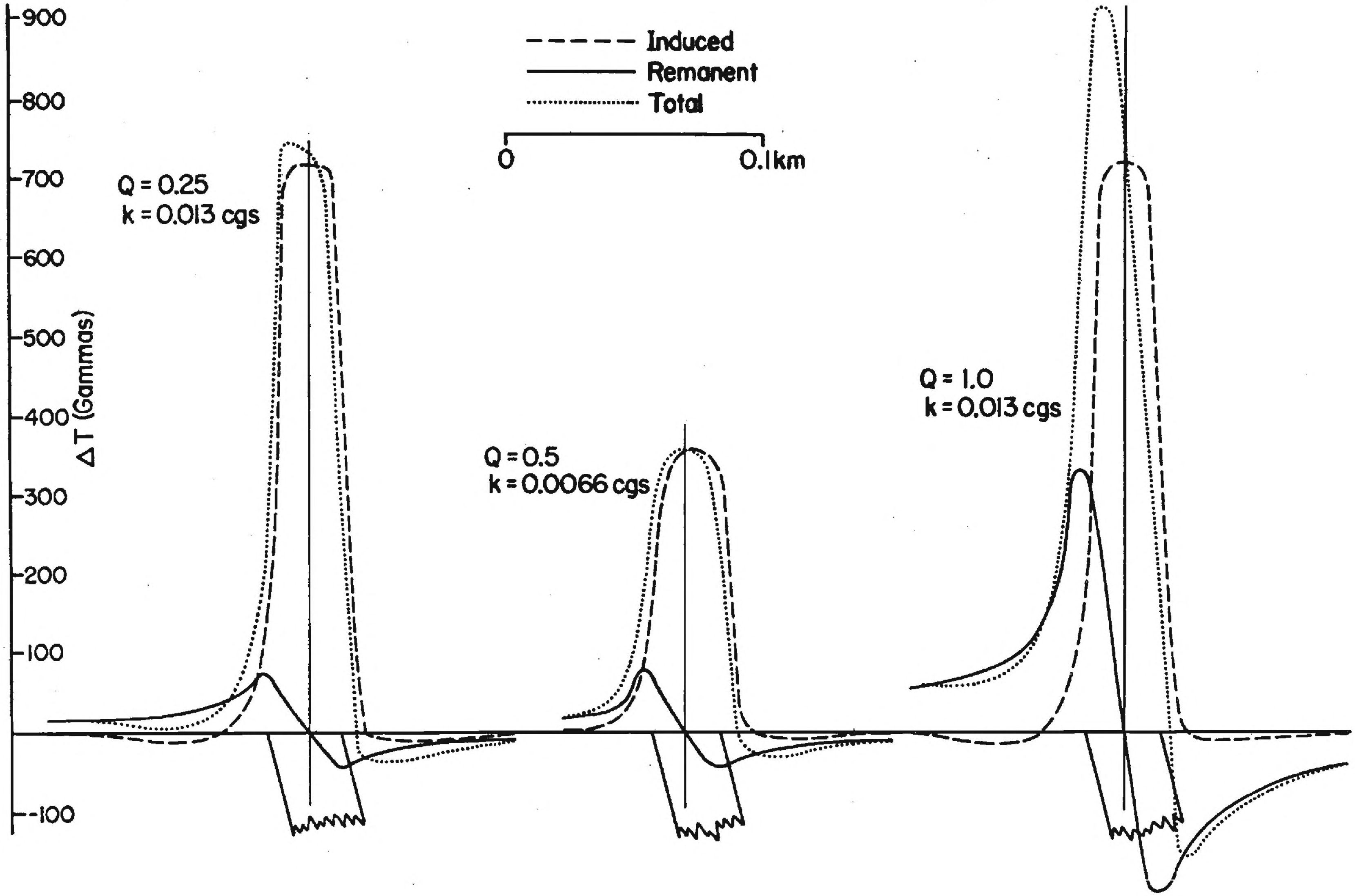

Figure 18. Calculated Curves Showing the Effect of Natural Remanent Magnetism on the Total Field Anomaly. (Dike is 30 meters wide and dips at 75°.)

bility 0.0066 cgs and corresponding Q of 0.5 the anomaly is found to be more asymmetric with a peak to trough ratio of 10 to 1.

The observed anomalies (Figure 8) however, exhibit an average peak to trough ratio of only 6. Further, the amplitude of the observed anomalies is greater than that calculated for the given range of susceptibilities and corresponding magnetizations. An increase in Q to 1.0 at a susceptibility of 0.013 cgs produced an asymmetric anomaly with a peak to trough ratio of about 6 to 1, (Figure 18) indicating that the bulk remanent magnetization was probably greater than that suggested by the surface samples.

Strangway (1965), who sampled a diabase dike at both the surface and at depth in a mine, found the ratio of remanent to induced magnetization to be greater for the underground samples. As a possible cause of this phenomenon Strangway (1965) suggests that temperature fluctuation at the surface, which was probably exposed for a considerable length of time, has accelerated the decay of the remanent magnetization. The same type of process may have occurred in the Meriwether dike and hence, the effective Q, which includes the effect of sub-surface portions of the dike, is probably closer to 1.0.

It should be noted that even if the dike actually dips as much as 80°, the magnetic anomaly due to induction would still be a symmetric peak (Figure 11), and hence the calculated Q of 1.0 would not be seriously affected.

CHAPTER VI

DISCUSSION AND CONCLUSIONS

Examination of the Meriwether dike by means of detailed gravity and magnetic profiles shows the dike to consist of an injection zone of dikes. Because the gravity anomalies of the component dikes are only partially separated, determination of whether or not the side dikes were branches of the main dike was not possible. On the basis of theoretical curves for the dike system dipping at various angles, the Meriwether dike (system) was estimated to dip at 70° toward N70°E.

The 70° dip is not as steep as noted by Lester and Allen (1950), who found several of the larger dikes in Georgia to have a constant dip toward the east of 75 to 90° and Privett (1966) who found the diabase dikes in central South Carolina to dip 80 to 90° to the NE. It is possible, however, that the Meriwether dike may actually have a dip greater than 70°, but due to the ambiguity of the regional trend it is not possible to resolve how much greater.

A simple Bouguer gravity map compiled for central Meriwether County shows the Meriwether dike to be responsible for an anomaly of one to two milligals in the regional trend. After recontouring of the available aeromagnetic data, the Meriwether dike(s) proved to be the most prominent magnetic feature of the area, and this suggests that the sharpness of the anomaly and the flight line spacing supressed the dike(s) in previous contouring. It is possible that in other areas of eastern North America covered by aeromagnetic maps, other occurrences of diabase dikes may be similarly supressed, thus reducing the probability of locating such dikes by their magnetic anomalies in areas not yet geologically mapped. Locating other dikes by this method may also be hampered by the effects of remanent magnetization.

Although not studied in detail, examination of high altitude infrared photographs (N.A.S.A., 1970) of central Meriwether County, revealed the existence of a linear anomaly coinciding with the Meriwether dike at known outcroppings in the northern third of the study area. The anomaly is probably due to a change of intensity of reflected infrared radiation from the vegetation growing in the soil derived from the diabase. It is suggested that this technique might be applied to other areas of eastern North America to determine outcrop patterns of the dikes in areas not yet geologically mapped.

Many problems currently exist concerning the diabase dikes which surround the North Atlantic Ocean such as dating, distribution and chemistry. It is hoped that more economic and efficient methods such as those suggested in this study will lead to the location of unmapped dikes, thus presenting a more complete picture of the distribution and role of these dikes in the history of the opening of the North Atlantic Ocean.

APPENDICES

APPENDIX I

GRAVITY SURVEYS AND DATA REDUCTION

Gravity data were collected and reduced by standard techniques (Dobrin, 1960). The data consist of 242 points in total including base stations - 201 gravity observations are along five detailed lines and 41 gravity observations are regional data.

The gravimeter used was the Worden Educator, Model 113. The reading precision of this meter, when read by a single operator, is approximately ± 0.1 milligals. Instrumental drift for the Worden gravimeter for an eight hour period is typically 0.2 milligals, but can be as high as 0.5 milligals for the same period. The gravimeter was stored in the field vehicle each night preceding a survey to minimize the instumental drift due to temperature change. The uncertainty in drift and reading precision combined give a gravity precision of ± 0.2 milligals. In all, three different base stations (Dorman and Ziegler, in preparation, Georgia Department of Mines, Mining and Geology) were used to correct for instrumental drift. Pertinent data concerning these base stations are given in Table 1.

The observed drifts are given in Table 2.

Table 1. Gravity Base Stations Used in this Study

Name	Base Number	Location	Gravity Value	Estimated Precision
Atlanta D	4	Georgia Tech	979527.37	±0.023
LaGrange	33	City Hall	979484.42	±0.014
Greenville	63	Meriwether County Court House	979489.58	±0.05

Table 2. Instrumental Drift for Worden Gravimeter

Station Nos.	Georgia Tech Gravity Survey No.	Drift (Mgals/hr)	Time Between Base Stations
1 - 49	36	-0.074	6.1 hours
1 - 33	46	-0.018	9.8
1 - 48	51	0.000	7.4
48 - 72	51	-0.109	3.9
72 - 95	51	0.016	2.3
4 - 20	52	-0.053	2.8
20 - 41	52	-0.121	3.8

The gravity data were corrected for latitude effect by using the international gravity formula of 1930 (as given in Dobrin, 1960, page 187) and drift corrections for the meter by assuming linear meter drift between subsequent occupations of the base station. The standard Bouguer reduction density of 2.67 gm/cm^3 was used to compute the Bouguer anomalies.

Elevation and location control were obtained from the following U. S. Geological Survey, 7½ minute topographic maps: Greenville (1971), Gay (1971), Warm Springs (1971), and Woodbury (1971). Where possible bench marks (± 1 foot) or intersection elevations (assumed ± 5 feet) were used. Elevations of stations for which bench marks or intersections were not available were obtained by interpolating between contour lines (20 foot contour interval) and confirming those interpolations with barometric altimetry data. Elevations obtained by this technique were estimated to be plus or minus five feet. The resulting uncertainty in the reduced gravity values is thus ±0.35 milligals. Because of the relatively shorter distance between stations along detail lines, and hence shorter times between gravity and barometric readings errors in drift for these measurements were considered less. This results in an estimated precision of ±0.2 milligals for the reduced gravity values for stations along detail lines.

The data, in the standard Department of Defense computer card format, are listed by individual surveys in Table 3 (Figure 19).

SOURCE NO	TITLE	CODED BY	DATE CODED

SECURITY CLASS | SECURITY CONTROL | GEOG UNITS | SIGN + = N − = S | LATITUDE | SIGN + = E − = W | LONGITUDE | TYPE ELEVATION | UNITS | SIGN | ELEVATION | SUPPLEMENTAL ELEVATION | +976000 OBSERVED GRAVITY | SIGN | FREE AIR ANOMALY | SIGN | BOUGUER ANOMALY (DENSITY 2.67) | ISO. OR T.C. | SOURCE | BASE REFERENCE STATION | BASE REF SITE | SEQUENCE | FILE MAINTENANCE | EST STD. DEV. FREE AIR | EST STD. DEV. BOUGUER

CODES USED IN ABOVE

SECURITY CLASS (Col. 1)
U - UNCLASSIFIED MATERIAL
F - FOR OFFICIAL USE ONLY
C - CONFIDENTIAL
S - SECRET

SECURITY CONTROL (Col. 2)
1 - LIMITED DISSEMINATION, TO FULL-TIME EMPLOYEES OF DEPT OF DEFENSE, CIA AND AEC
2 - NOT RELEASABLE TO FOREIGN NATIONALS
3 - LIMITED DISSEMINATION, NOT RELEASABLE TO FOREIGN NATIONALS
4 - SPECIAL RELEASE FROM ORIGINATING AGENCY REQUIRED FOR DISSEMINATION TO A 3RD PARTY
5 - MODIFIED HANDLING AUTHORIZED (INCLUDES FOREIGN "RESTRICTED", NATO, CENTO, SEATO, ETC.)

GEOGRAPHIC UNITS (Col. 3)
BLANK OR 0 - DEGREES AND MINUTES TO .01 MINUTE
1 - DEGREES, MINUTES AND SECONDS
2 - DEGREES TO .0001 DEGREE

TYPE OF ELEVATION (Col. 21)
1 - LAND
2 - SUBSURFACE
3 - OCEAN SURFACE
4 - OCEAN SUBMERGED
5 - OCEAN BOTTOM
6 - LAKE SURFACE (ABOVE SEA LEVEL)
7 - LAKE BOTTOM (ABOVE SEA LEVEL)
8 - LAKE BOTTOM (BELOW SEA LEVEL)
9 - LAKE SURFACE (ABOVE SEA LEVEL) WITH LAKE BOTTOM BELOW SEA LEVEL
A - LAKE SURFACE (BELOW SEA LEVEL)
B - LAKE BOTTOM (SURFACE BELOW SEA LEVEL)
C - ICE CAP (BOTTOM BELOW SEA LEVEL)
D - ICE CAP (BOTTOM ABOVE SEA LEVEL)
E - TRANSFER DATA GIVEN

ELEVATION UNITS (Col. 22)
BLANK OR 0 - METERS
1 - FEET
2 - FATHOMS

ELEVATION OF STATION (Col. 23-29)
NOTE: THIS FIELD WILL CONTAIN DEPTH OF OCEAN (POSITIVE DOWNWARD) IF COL 21 CONTAINS 3, 4, OR 5

SUPPLEMENTAL ELEVATION (Col. 31-35)
DEPTH OF INSTRUMENT, LAKE OR ICE; POSITIVE DOWNWARD FROM SURFACE

BOUGUER ANOMALY (Col. 50-54)
SIMPLE BOUGUER ANOMALY WITH A MEAN DENSITY OF 2.67. NO TERRAIN CORRECTION

ISO. OR T.C. CODE (Col. 56)
INDICATES IF ISOSTATIC ANOMALY OR TERRAIN CORRECTION IS GIVEN IN DOCUMENT:
0 - NO ISOSTATIC ANOM. OR T.C. IN DOCUMENT
1 - TERRAIN CORRECTION GIVEN IN DOCUMENT
2 - ISOSTATIC ANOMALY GIVEN IN DOCUMENT
3 - BOTH ARE GIVEN IN DOCUMENT

ACIC HQ FORM NOV 69 0-154 PREVIOUS EDITION OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED DoD GR

Figure 19. Standard Department of Defense Gravity Coding Form.

Table 3. Gravity Data

<u>Gravity Survey GT 36</u> (Includes Data for Profile B-B')

12345678901234567890123456789012345678901234567890123456789012345678901234567890

334640	-	842370	1	2984	3527367-	2305-	5633	GT36	GA42	1	1
332121	-	844745	1	3064	3510125-	295-	3714	GT36	GA42	2	1
33 240	-	85 180	1	2353	3484422-	2473-	5097	GT36	GA42	3	1
33 172	-	844278	1	2651	3489586-	944-	3901	GT36	GA42	4	1
33 178	-	844232	1	2426	3498070-	798-	3504	GT36	GA42	5	3
33 184	-	844217	1	2369	3498750-	913-	3556	GT36	GA42	6	3
33 197	-	844195	1	2499	3496398-	763-	3551	GT36	GA42	7	3
33 203	-	844178	1	2606	3494070-	674-	3581	GT36	GA42	8	3
33 214	-	844164	1	2554	3495086-	749-	3598	GT36	GA42	9	3
33 228	-	844147	1	2579	3494789-	721-	3598	GT36	GA42	10	3
33 244	-	844133	1	2569	3495625-	689-	3555	GT36	GA42	11	3
33 253	-	844222	1	2612	3495133-	619-	3533	GT36	GA42	12	3
33 260	-	844105	1	2566	3496102-	673-	3536	GT36	GA42	13	3
33 267	-	844086	1	2600	3496102-	579-	3479	GT36	GA42	14	3
33 272	-	844066	1	2615	3495281-	621-	3538	GT36	GA42	15	3
33 273	-	844057	1	2606	3495492-	630-	3537	GT36	GA42	16	3
33 274	-	844046	1	2591	3495961-	631-	3521	GT36	GA42	17	3
33 277	-	844037	1	2569	3496383-	658-	3524	GT36	GA42	18	3
33 280	-	844028	1	2582	3495664-	696-	3576	GT36	GA42	19	3
33 284	-	844020	1	2597	3495758-	646-	3543	GT36	GA42	20	3
33 289	-	844013	1	2572	3495758-	731-	3599	GT36	GA42	21	3
33 295	-	844004	1	2575	3496531-	653-	3525	GT36	GA42	22	3
33 300	-	843995	1	2573	3496609-	656-	3526	GT36	GA42	23	3
33 304	-	843987	1	2569	3497555-	579-	3445	GT36	GA42	24	3
33 309	-	843978	1	2544	3498188-	601-	3439	GT36	GA42	25	3
33 312	-	843975	1	2556	3498367-	550-	3401	GT36	GA42	26	3
33 314	-	843970	1	2567	3498375-	518-	3382	GT36	GA42	27	3
33 317	-	843965	1	2557	3498461-	544-	3396	GT36	GA42	28	3
33 319	-	843962	1	2545	3498766-	553-	3392	GT36	GA42	29	3
33 323	-	843951	1	2532	3498891-	587-	3411	GT36	GA42	30	3
33 326	-	843942	1	2566	3498438-	530-	3393	GT36	GA42	31	3
33 328	-	843932	1	2557	3498391-	566-	3419	GT36	GA42	32	3
33 330	-	843923	1	2552	3498898-	533-	3380	GT36	GA42	33	3
33 331	-	843913	1	2566	3498391-	542-	3405	GT36	GA42	34	3
33 332	-	843905	1	2571	3498383-	530-	3398	GT36	GA42	35	3
33 333	-	843895	1	2565	3498375-	550-	3412	GT36	GA42	36	3
33 335	-	843886	1	2536	3499016-	579-	3408	GT36	GA42	37	3
33 337	-	843877	1	2512	3499008-	656-	3458	GT36	GA42	38	3
33 339	-	843858	1	2530	3498867-	617-	3439	GT36	GA42	39	3
33 341	-	843833	1	2536	3498219-	666-	3495	GT36	GA42	40	3
33 346	-	843818	1	2472	3499664-	726-	3484	GT36	GA42	41	3
33 356	-	843801	1	2502	3499086-	704-	3496	GT36	GA42	42	3
33 363	-	843784	1	2518	3498961-	678-	3487	GT36	GA42	43	3
33 450	-	843679	1	2286	3505477-	862-	3412	GT36	GA42	44	3
33 563	-	843447	1	2536	3501578-	635-	3464	GT36	GA42	45	3
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332121	-	844745	1	3064	3510680-	239-	3658	GT36	GA42	52	1
334640	-	842370	1	2984	3527367-	2305-	5633	GT36	GA42	53	1

12345678901234567890123456789012345678901234567890123456789012345678901234567890

Table 3. (Continued)

Gravity Survey GT 46 (Includes Data for Profile E-E')

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332248	-	844802	1	3051	3510453-	480-	3883	GT46	GA	4	2	1
331998	-	844812	1	2950	3511008-	389-	3680	GT46	GA	4	3	1
331976	-	844685	1	2962	3511320-	292-	3596	GT46	GA	4	4	5
331984	-	844627	1	2936	3511828-	333-	3608	GT46	GA	4	5	5
331989	-	844591	1	2819	3513875-	494-	3639	GT46	GA	4	6	5
331992	-	844566	1	2850	3513836-	407-	3587	GT46	GA	4	7	5
331998	-	844537	1	2841	3514570-	372-	3540	GT46	GA	4	8	5
332008	-	844507	1	2743	3516547-	487-	3547	GT46	GA	4	9	3
332011	-	844498	1	2771	3516047-	458-	3549	GT46	GA	4	10	5
332016	-	844475	1	2751	3516781-	450-	3519	GT46	GA	4	11	3
332016	-	844467	1	2733	3517211-	464-	3512	GT46	GA	4	12	3
332017	-	844458	1	2719	3517945-	436-	3468	GT46	GA	4	13	3
332017	-	844448	1	2682	3518734-	469-	3461	GT46	GA	4	14	3
332017	-	844440	1	2643	3519023-	561-	3509	GT46	GA	4	15	5
332017	-	844431	1	2682	3518773-	465-	3457	GT46	GA	4	16	3
332017	-	844427	1	2686	3518969-	436-	3431	GT46	GA	4	17	5
332016	-	844423	1	2640	3520055-	466-	3411	GT46	GA	4	18	3
332015	-	844413	1	2608	3520563-	513-	3422	GT46	GA	4	19	3
332013	-	844406	1	2585	3520406-	598-	3481	GT46	GA	4	20	5
332012	-	844395	1	2560	3520695-	643-	3499	GT46	GA	4	21	5
332012	-	844383	1	2541	3521008-	671-	3506	GT46	GA	4	22	5
332012	-	844374	1	2587	3519969-	634-	3520	GT46	GA	4	23	5
332012	-	844354	1	2621	3520438-	480-	3404	GT46	GA	4	24	3
332012	-	844343	1	2545	3521133-	646-	3485	GT46	GA	4	25	5
332007	-	844310	1	2509	3521750-	690-	3488	GT46	GA	4	26	5
332001	-	844277	1	2414	3523875-	762-	3455	GT46	GA	4	27	5
331996	-	844252	1	2399	3523305-	858-	3534	GT46	GA	4	28	5
331992	-	844152	1	2649	3517711-	641-	3596	GT46	GA	4	29	5
332036	-	844107	1	2682	3519266-	443-	3435	GT46	GA	4	30	3
332013	-	844406	1	2585	3520094-	629-	3512	GT46	GA	4	31	5
332248	-	844802	1	3051	3510063-	518-	3921	GT46	GA	4	32	1
334640	-	842370	1	2984	3527367-	2305-	5633	GT46	GA	4	33	1

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Table 3. (Continued)

<u>Gravity Survey GT 51</u> (Includes Data for Profiles A-A', C-C', and D-D')

1234567890123456789012345678901234567890123456789012345678901234567890123456789

334640	-	842370	1	2984	3527367-	2305-	5633	GT51	GA63	1	1
33 172	-	844278	1	2651	3489578-	944-	3901	GT51	GA63	2	1
33 157	-	844128	1	2652	3493203-	558-	3516	GT51	GA63	3	3
33 118	-	844079	1	2432	3497875-	715-	3428	GT51	GA63	4	3
33 90	-	844033	1	2231	3501109-	974-	3463	GT51	GA63	5	3
33 63	-	843959	1	2393	3498719-	677-	3346	GT51	GA63	6	3
325952	-	843758	1	2545	3497797-	147-	2986	GT51	GA63	7	1
325904	-	843677	1	2502	3499125-	79-	2871	GT51	GA63	8	1
325813	-	844273	1	2697	3488992-	367-	3376	GT51	GA63	9	1
325814	-	844205	1	2719	3489031-	299-	3332	GT51	GA63	10	1
325817	-	844075	1	2752	3490500-	51-	3121	GT51	GA63	11	1
325840	-	844029	1	2807	3489266-	38-	3169	GT51	GA63	12	5
325851	-	844001	1	2679	3492508-	123-	3111	GT51	GA63	13	5
325860	-	843991	1	2606	3493625-	250-	3157	GT51	GA63	14	5
325869	-	843984	1	2600	3493820-	262-	3162	GT51	GA63	15	1
325880	-	843977	1	2627	3493398-	233-	3164	GT51	GA63	16	5
325894	-	843970	1	2627	3493203-	272-	3203	GT51	GA63	17	5
325904	-	843954	1	2701	3492273-	153-	3165	GT51	GA63	18	5
325902	-	843938	1	2701	3492430-	134-	3147	GT51	GA63	19	5
325901	-	843907	1	2618	3494164-	214-	3135	GT51	GA63	20	1
325902	-	843917	1	2649	3493977-	140-	3095	GT51	GA63	21	5
325901	-	843928	1	2670	3493125-	157-	3136	GT51	GA63	22	5
325906	-	843899	1	2658	3493430-	171-	3136	GT51	GA63	23	5
325909	-	843884	1	2707	3492625-	107-	3126	GT51	GA63	24	5
325913	-	843874	1	2637	3494516-	139-	3080	GT51	GA63	25	5
325923	-	843811	1	2573	3497289-	72-	2942	GT51	GA63	26	1
325915	-	843864	1	2612	3495289-	139-	3053	GT51	GA63	27	5
325916	-	843854	1	2563	3496984-	121-	2980	GT51	GA63	28	5
325917	-	843893	1	2530	3497680-	156-	2978	GT51	GA63	29	5
325918	-	843883	1	2539	3497984-	99-	2931	GT51	GA63	30	5
325919	-	843827	1	2551	3498219-	40-	2885	GT51	GA63	31	5
325922	-	843816	1	2566	3497836-	36-	2899	GT51	GA63	32	5
325920	-	843821	1	2524	3498297-	118-	2933	GT51	GA63	33	5
325952	-	843748	1	2545	3498063-	120-	2959	GT51	GA63	34	1
325943	-	843774	1	2633	3496250-	16-	2954	GT51	GA63	35	5
325934	-	843790	1	2554	3497523-	122-	2971	GT51	GA63	36	5
325929	-	843802	1	2551	3497484-	127-	2973	GT51	GA63	37	5
325957	-	843762	1	2524	3498063-	193-	3008	GT51	GA63	38	5
325974	-	843762	1	2548	3497680-	178-	3020	GT51	GA63	39	5
325993	-	843762	1	2603	3496672-	136-	3040	6T51	8A63	48	5
33 26	-	843732	1	2472	3498141-	440-	3197	GT51	GA63	41	3
33 44	-	843701	1	2478	3498219-	437-	3201	GT51	GA63	42	3
33 95	-	843612	1	2505	3499766-	268-	3063	GT51	GA63	43	3
33 146	-	843510	1	2502	3501148-	209-	3000	GT51	GA63	44	3
33 163	-	843553	1	2496	3500766-	291-	3076	GT51	GA63	45	3
33 169	-	843602	1	2240	3505859-	579-	3078	GT51	GA63	46	3
33 188	-	843727	1	2149	3506555-	818-	3215	GT51	GA63	47	1
33 172	-	844278	1	2651	3489578-	944-	3901	GT51	GA63	48	1
33 467	-	844359	1	2539	3493922-	1261-	4093	GT51	GA63	49	3
33 465	-	844460	1	2685	3490383-	1160-	4156	GT51	GA63	50	3
33 497	-	844480	1	2423	3495789-	1471-	4174	GT51	GA63	51	3
33 548	-	844479	1	2579	3492555-	1385-	4262	GT51	GA63	52	5
33 592	-	844464	1	2627	3492336-	1318-	4249	GT51	GA63	53	3
33 591	-	844370	1	2545	3495359-	1267-	4106	GT51	GA63	54	1
33 598	-	844259	1	2609	3494609-	1155-	4066	GT51	GA63	55	3
33 608	-	844187	1	2615	3495156-	1095-	4012	GT51	GA63	56	3
33 520	-	844190	1	2307	3500883-	1351-	3925	GT51	GA63	57	3
33 478	-	844162	1	2362	3500516-	1161-	3796	GT51	GA63	58	3
33 568	-	843607	1	2234	3506375-	1093-	3585	GT51	GA63	59	3
33 591	-	843676	1	2323	3504852-	1005-	3595	GT51	GA63	60	1
33 438	-	843694	1	2170	3508367-	913-	3334	GT51	GA63	61	3
33 393	-	843636	1	2365	3504055-	681-	3320	GT51	GA63	62	3
33 272	-	843611	1	2320	3504836-	577-	3165	GT51	GA63	63	3
33 357	-	843727	1	2414	3501609-	725-	3418	GT51	GA63	64	3
33 341	-	843841	1	2573	3498070-	569-	3439	GT51	GA63	65	3

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Table 3. (Continued)

Gravity Survey GT 51 (Continued)

12345678901234567890123456789012345678901234567890123456789012345678901234567890

33 390	-	843870	1	2509	3499047-	736-	3534	GT51	GA63	66	3
33 437	-	843877	1	2243	3504266-	1097-	3600	GT51	GA63	67	3
33 488	-	843875	1	2533	3499258-	773-	3599	GT51	GA63	68	3
33 488	-	843921	1	2505	3499273-	857-	3651	GT51	GA63	69	3
33 428	-	844073	1	2566	3497359-	778-	3641	GT51	GA63	70	3
33 344	-	844192	1	2643	3492906-	873-	3821	GT51	GA63	71	5
33 172	-	844278	1	2651	3489578-	944-	3901	GT51	GA63	72	1
33 272	-	844065	1	2615	3495016-	647-	3564	GT51	GA63	73	3
33 243	-	844018	1	2566	3495898-	670-	3533	GT51	GA63	74	3
33 194	-	844018	1	2502	3496789-	711-	3503	GT51	GA63	75	5
33 213	-	844000	1	2612	3495320-	545-	3459	GT51	GA63	76	5
33 216	-	843983	1	2573	3496477-	556-	3425	GT51	GA63	77	3
33 206	-	843961	1	2594	3496703-	453-	3347	GT51	GA63	78	5
33 194	-	843947	1	2539	3497164-	561-	3393	GT51	GA63	79	5
33 193	-	843936	1	2521	3498125-	520-	3331	GT51	GA63	80	5
33 193	-	843926	1	2493	3498859-	531-	3312	GT51	GA63	81	5
33 193	-	843917	1	2463	3499633-	547-	3294	GT51	GA63	82	5
33 193	-	843913	1	2454	3498625-	676-	3413	GT51	GA63	83	5
33 193	-	843900	1	2454	3499008-	638-	3375	GT51	GA63	84	5
33 193	-	843882	1	2463	3499086-	602-	3349	GT51	GA63	85	5
33 192	-	843872	1	2441	3499086-	667-	3390	GT51	GA63	86	5
33 189	-	843862	1	2441	3499008-	670-	3393	GT51	GA63	87	5
33 192	-	843846	1	2402	3499617-	735-	3414	GT51	GA63	88	5
33 192	-	843826	1	2323	3501313-	811-	3402	GT51	GA63	89	5
33 192	-	843803	1	2292	3502086-	827-	3384	GT51	GA63	90	5
33 192	-	843788	1	2335	3501813-	722-	3327	GT51	GA63	91	5
33 192	-	843762	1	2246	3504242-	753-	3259	GT51	GA63	92	5
33 191	-	843743	1	2164	3506484-	780-	3194	GT51	GA63	93	5
33 186	-	844214	1	2341	3498609-	1016-	3627	GT51	GA63	94	5
33 172	-	844278	1	2651	3489578-	944-	3901	GT51	GA63	95	1
33 233	-	844301	1	2618	3489883-	1098-	4018	GT51	GA63	96	3
33 393	-	844134	1	2627	3496133-	665-	3595	GT51	GA63	97	5
33 428	-	844073	1	2566	3497055-	808-	3671	GT51	GA63	98	3
33 433	-	844054	1	2560	3497398-	800-	3656	GT51	GA63	99	5
33 438	-	844035	1	2551	3498328-	741-	3587	GT51	GA63	100	3
33 440	-	844023	1	2573	3497711-	740-	3610	GT51	GA63	101	5
33 440	-	844019	1	2597	3497750-	662-	3559	GT51	GA63	102	5
33 442	-	844010	1	2560	3497977-	754-	3610	GT51	GA63	103	5
33 444	-	844005	1	2545	3498438-	759-	3598	GT51	GA63	104	5
33 449	-	843995	1	2545	3498750-	734-	3573	GT51	GA63	105	5
33 452	-	843985	1	2493	3499367-	836-	3618	GT51	GA63	106	5
33 458	-	843967	1	2542	3498438-	787-	3622	GT51	GA63	107	5
33 469	-	843951	1	2542	3497664-	879-	3714	GT51	GA63	108	5
33 481	-	843939	1	2548	3498664-	776-	3619	GT51	GA63	109	5
33 427	-	844106	1	2563	3496039-	918-	3777	GT51	GA63	110	5
33 497	-	844063	1	2390	3501133-	1041-	3706	GT51	GA63	111	5
33 540	-	844052	1	2280	3503750-	1177-	3720	GT51	GA63	112	5
33 579	-	844039	1	2481	3500125-	972-	3740	GT51	GA63	113	3
33 623	-	843998	1	2265	3504367-	1277-	3803	GT51	GA63	114	5
334640	-	842370	1	2984	3527367-	2305-	5633	GT51	GA63	115	1

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Table 3. (Concluded)

Gravity Survey GT 52 (Regional Data)

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1234567890123456789012345678901234567890123456789012345678901234567890
    33 172 - 844278 1      2651         3489578-  944- 3901  GT52 GA63    1   1
    33 240 - 85 180 1      2353         3484422- 2473- 5097  GT52 GA63    2   1
    33 172 - 844278 1      2651         3489578-  944- 3901  GT52 GA63    3   1
    33 164 - 844307 1      2560         3490195- 1151- 4007  GT52 GA63    4   6
    33 157 - 844387 1      2755         3485609-  997- 4071  GT52 GA63    5   3
    33 201 - 844474 1      2893         3482453-  951- 4178  GT52 GA63    6   1
    33 175 - 844427 1      2859         3483961-  868- 4057  GT52 GA63    7   3
    33 101 - 844373 1      2603         3489297- 1023- 3926  GT52 GA63    8   3
    33  76 - 844444 1      2603         3489609-  957- 3861  GT52 GA63    9   3
    33  14 - 844383 1      2691         3488273-  732- 3734  GT52 GA63   10   3
    325947 - 844436 1      2786         3486852-  491- 3599  GT52 GA63   11   3
    325893 - 844443 1      2713         3487703-  558- 3584  GT52 GA63   12   3
    325759 - 844498 1      2682         3489180-  320- 3312  GT52 GA63   13   6
    325754 - 844384 1      2792         3487102-  183- 3298  GT52 GA63   14   3
    325883 - 844260 1      2640         3490375-  504- 3448  GT52 GA63   15   3
    325949 - 844246 1      2390         3495867-  815- 3480  GT52 GA63   16   6
    325913 - 844179 1      2380         3497766-  604- 3259  GT52 GA63   17   3
    33  16 - 844258 1      2560         3491563-  811- 3667  GT52 GA63   18   6
    33  78 - 844258 1      2344         3496547- 1066- 3681  GT52 GA63   19   6
    33 172 - 844278 1      2651         3499578-  944- 3901  GT52 GA63   20   1
    33 175 - 844261 1      2621         3491000-  898- 3822  GT52 GA63   21   6
    33 174 - 844255 1      2560         3492883-  897- 3753  GT52 GA63   22   6
    33  53 - 843907 1      2377         3499430-  640- 3292  GT52 GA63   23   6
    33  33 - 843881 1      2438         3499438-  423- 3143  GT52 GA63   24   6
    325999 - 843824 1      2545         3496891-  301- 3140  GT52 GA63   25   3
    325898 - 843582 1      2420         3501367-  101- 2801  GT52 GA63   26   1
    325978 - 843619 1      2246         3504539-  429- 2935  GT52 GA63   27   3
    325821 - 843674 1      2274         3503867-  197- 2734  GT52 GA63   28   3
    325827 - 843602 1      2387         3501945-   49- 2711  GT52 GA63   29   3
    325820 - 843776 1      2499         3499727-   86- 2702  GT52 GA63   30   6
    325851 - 843852 1      2524         3497266-  127- 2942  GT52 GA63   31   3
    325861 - 843904 1      2499         3496430-  300- 3088  GT52 GA63   32   6
    325902 - 843905 1      2618         3494156-  216- 3137  GT52 GA63   33   1
    33 115 - 843730 1      2313         3502211-  644- 3224  GT52 GA63   34   3
    33 262 - 843728 1      2374         3501695-  709- 3358  GT52 GA63   35   6
    33 536 - 843542 1      2390         3503578-  849- 3515  GT52 GA63   36   3
    33 684 - 843569 1      2591         3500781-  713- 3603  GT52 GA63   37   3
    33 697 - 843604 1      2597         3500563-  733- 3630  GT52 GA63   38   3
    33 723 - 843670 1      2655         3499063-  740- 3702  GT52 GA63   39   3
    33 737 - 843791 1      2472         3503164-  913- 3671  GT52 GA63   40   3
    33 172 - 844278 1      2651         3489578-  944- 3901  GT52 GA63   41   1
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APPENDIX II

GROUND LEVEL MAGNETIC SURVEYS AND DATA REDUCTION

Measurements of the magnitude of the geomagnetic field were made using a Geometrics Model G-816 proton-precession magnetometer. The digital display has a resolution of $\pm$ 1 gamma. The sensing element of the magnetometer is held at the end of an eight foot aluminum staff to suppress the magnetic effects of iron debris, e.g., beverage cans, small underground pipes, etc.

The data were reduced using standard techniques (Dobrin, 1960). The data consist of three detailed lines along graded dirt roads and a fourth along a two lane asphalt highway (Georgia State Highway 109). Approximately 0.016 kilometer was paced off between stations. Division of the actual length of the profile line by the number of station intervals yielded the actual station spacing. Times, needed for drift corrections, were recorded every ten minutes and the stations between time readings were assigned a time by assuming a linear sampling rate.

The variation in the main field over the area of investigation has been removed by approximating a gradient of 8.45γ/mile at N3°W (Garland, 1971, Figure 17.2) by a simple latitude correction of 9.56γ/minute. Corrections for the diurnal variation were made using magnetograms of the Geomagnetic Observatory in Fredericksburg, Virginia (Figures 20 and 21) which were obtained from the World Data Center A of the National Oceanographic and Atmospheric Administration in

Boulder, Colorado.

These records were digitized and the vertical and horizontal components were added vectorily to give the magnitude of the total field. The difference between the computed total field and the value for the base line was taken to be the diurnal variation in the total field at Fredericksburg. Since the diurnal drift at any one place on the earth has been shown to be directly related to the hour angle of the sun (Matshusita and Campbell, 1965, Chapter 3) a shift of twenty-eight minutes was made in the drift curve so that it could be applied to the area of investigation. The variation of the diurnal drift with respect to latitude is negligible for the difference between Fredericksburg, Virginia and Greenville, Georgia (see Matshusita and Campbell, 1965, Figure 8, pages 321-323).

The computed latitude and longitude, time (Eastern Daylight Savings), raw magnetic value and corrected total magnetic field for each station occupied are given in Table 4.

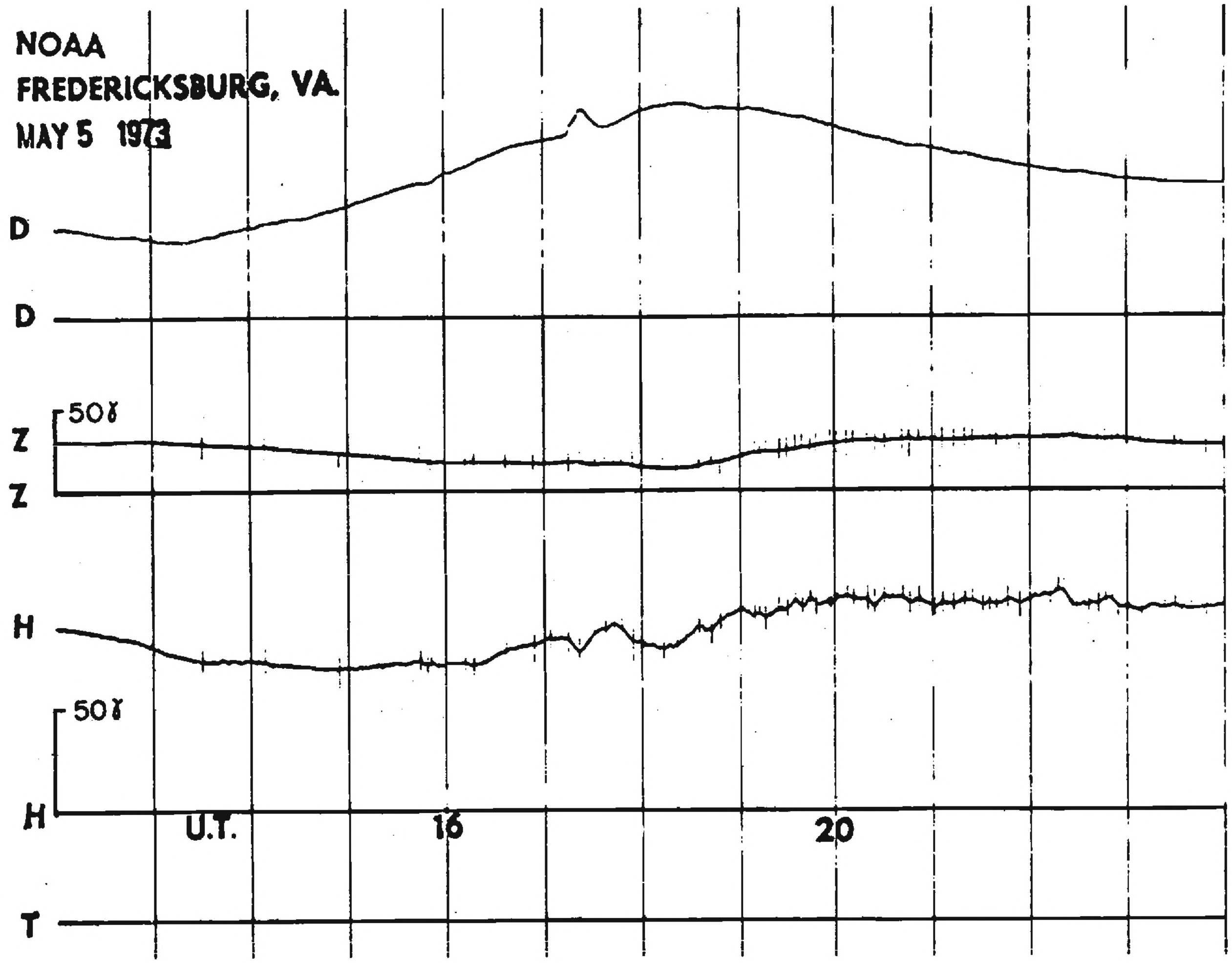

Figure 20. Magnetogram for May 5, 1973. (Courtesy National Oceanographic and Atmospheric Administration.

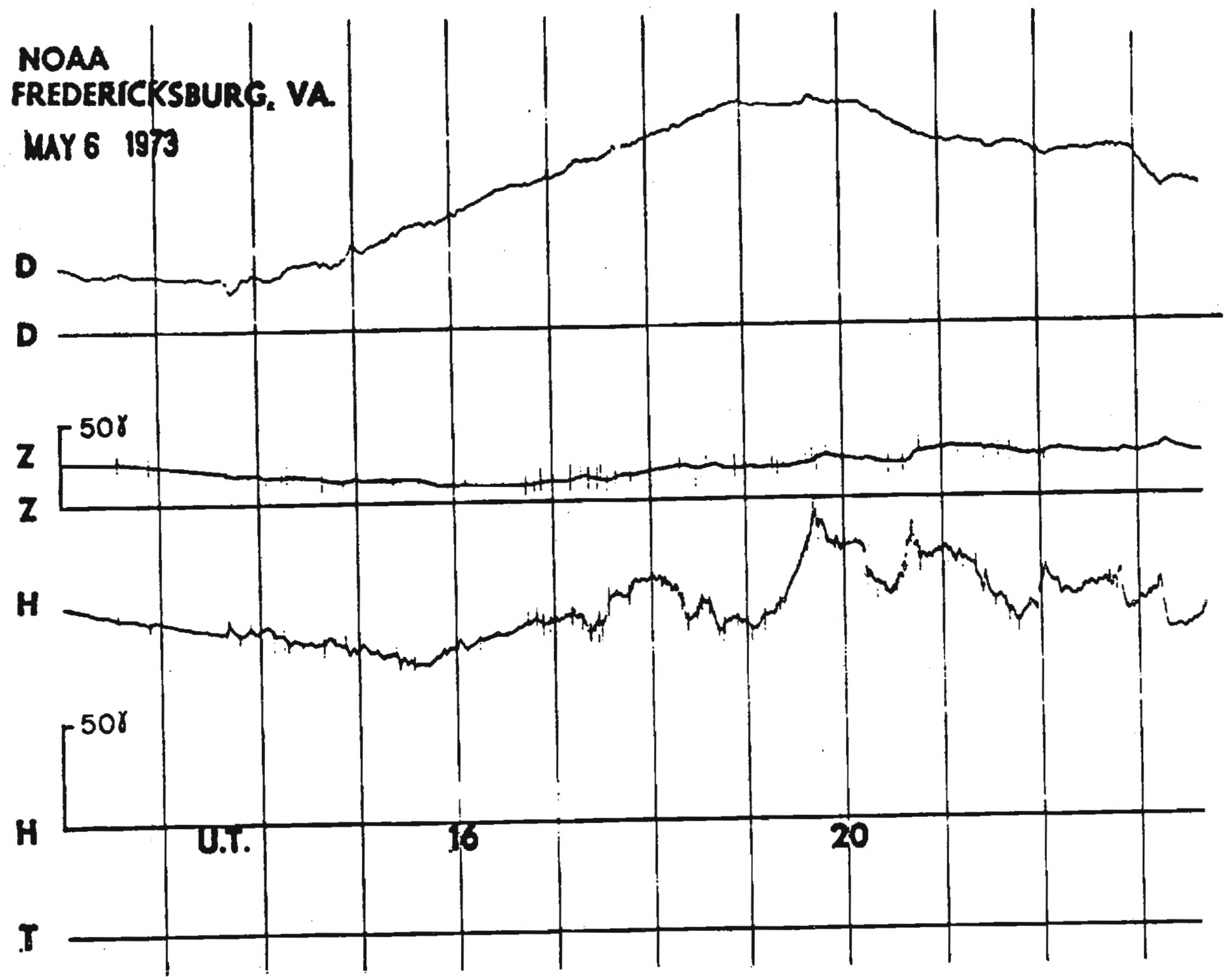

Figure 21. Magnetogram for May 6, 1973. (Courtesy National Oceanographic and Atmospheric Administration.

Table 4. Ground-Level Magnetics

<u>Profile A-A', May 5, 1973</u>

LATITUDE	LONGITUDE	TIME	RAW	REDUCED
1234567890	1234567890	1234567890	1234	567890
33 3.030	84 42.670	15.483	53594	53631
33 3.078	84 42.673	15.495	53586	53622
33 3.126	84 42.676	15.507	53584	53620
33 3.174	84 42.680	15.518	53590	53625
33 3.222	84 42.683	15.530	53598	53633
33 3.270	84 42.686	15.542	53588	53623
33 3.318	84 42.689	15.553	53609	53643
33 3.366	84 42.693	15.565	53603	53637
33 3.414	84 42.696	15.577	53618	53651
33 3.461	84 42.699	15.588	53625	53658
33 3.509	84 42.702	15.600	53632	53665
33 3.557	84 42.706	15.613	53630	53662
33 3.605	84 42.709	15.627	53636	53668
33 3.653	84 42.712	15.640	53640	53671
33 3.701	84 42.715	15.653	53586	53617
33 3.749	84 42.719	15.667	53616	53647
33 3.797	84 42.722	15.680	53617	53647
33 3.845	84 42.725	15.693	53571	53601
33 3.801	84 42.706	15.707	53594	53624
33 3.757	84 42.686	15.720	53569	53599
33 3.713	84 42.667	15.733	53595	53626
33 3.669	84 42.647	15.747	53604	53635
33 3.625	84 42.628	15.761	53606	53637
33 3.603	84 42.618	15.768	53607	53639
33 3.581	84 42.608	15.775	53802	53834
33 3.559	84 42.598	15.782	53604	53636
33 3.537	84 42.589	15.789	53612	53644
33 3.493	84 42.569	15.803	53613	53645
33 3.449	84 42.550	15.817	53635	53668
33 3.405	84 42.530	15.833	53612	53645
33 3.407	84 42.500	15.850	53618	53651
33 3.409	84 42.470	15.867	53617	53650
33 3.410	84 42.440	15.883	53617	53650
33 3.412	84 42.409	15.900	53615	53648
33 3.414	84 42.379	15.917	53624	53658
33 3.416	84 42.349	15.926	53605	53639
33 3.417	84 42.319	15.935	53608	53643
33 3.419	84 42.289	15.944	53600	53635
33 3.421	84 42.259	15.953	53605	53640
33 3.423	84 42.229	15.962	53590	53626
33 3.424	84 42.198	15.971	53608	53644
33 3.426	84 42.168	15.979	53600	53636
33 3.428	84 42.138	15.988	53593	53629
33 3.430	84 42.108	15.997	53615	53652
33 3.431	84 42.078	16.006	53607	53644
33 3.433	84 42.048	16.015	53607	53644
33 3.435	84 42.018	16.024	53607	53644
33 3.437	84 41.987	16.033	53626	53663
33 3.439	84 41.957	16.053	53636	53674
33 3.440	84 41.927	16.072	53660	53698
33 3.441	84 41.912	16.082	53655	53693
33 3.443	84 41.882	16.101	53655	53694
33 3.445	84 41.852	16.121	53644	53682
33 3.446	84 41.837	16.131	53635	53673
33 3.447	84 41.806	16.150	53629	53667
33 3.449	84 41.776	16.161	53639	53677
33 3.451	84 41.746	16.172	53619	53658
33 3.453	84 41.716	16.183	53694	53733
33 3.454	84 41.686	16.194	53617	53656
33 3.456	84 41.656	16.206	53607	53646
33 3.458	84 41.626	16.217	53603	53642
33 3.460	84 41.595	16.246	53616	53655
33 3.461	84 41.565	16.275	53601	53640
33 3.463	84 41.535	16.304	53587	53626
33 3.465	84 41.505	16.333	53604	53643
1234567890	1234567890	1234567890	1234	567890

LATITUDE	LONGITUDE	TIME	RAW	REDUCED
1234567890	1234567890	1234567890	1234	567890
33 3.477	84 41.493	16.345	53605	53644
33 3.488	84 41.481	16.357	53605	53645
33 3.500	84 41.468	16.368	53617	53657
33 3.511	84 41.456	16.380	53593	53633
33 3.523	84 41.444	16.392	53533	53573
33 3.534	84 41.432	16.403	53617	53657
33 3.546	84 41.420	16.415	53622	53662
33 3.558	84 41.408	16.427	53625	53665
33 3.569	84 41.395	16.438	53627	53667
33 3.581	84 41.383	16.450	53609	53649
33 3.592	84 41.371	16.462	53622	53662
33 3.604	84 41.359	16.473	53702	53743
33 3.610	84 41.353	16.479	53721	53762
33 3.615	84 41.347	16.485	53709	53750
33 3.621	84 41.340	16.491	53705	53746
33 3.627	84 41.334	16.497	53699	53740
33 3.638	84 41.322	16.508	53667	53708
33 3.650	84 41.310	16.520	53581	53622
33 3.657	84 41.310	16.526	53647	53687
33 3.665	84 41.310	16.532	53629	53669
33 3.680	84 41.309	16.543	53616	53656
33 3.694	84 41.309	16.555	53601	53641
33 3.709	84 41.308	16.567	53589	53629
33 3.724	84 41.308	16.576	53583	53623
33 3.739	84 41.307	16.586	53587	53627
33 3.753	84 41.307	16.595	53579	53619
33 3.768	84 41.306	16.605	53584	53623
33 3.783	84 41.306	16.614	53602	53641
33 3.798	84 41.305	16.624	53593	53632
33 3.812	84 41.305	16.633	53620	53659
33 3.827	84 41.305	16.647	53656	53695
33 3.835	84 41.304	16.653	53741	53779
33 3.842	84 41.304	16.660	53821	53859
33 3.849	84 41.304	16.667	53825	53863
33 3.857	84 41.304	16.673	53840	53878
33 3.864	84 41.303	16.680	53786	53824
33 3.872	84 41.303	16.687	53760	53798
33 3.879	84 41.303	16.693	53710	53748
33 3.886	84 41.303	16.700	53633	53671
33 3.894	84 41.303	16.707	53679	53717
33 3.901	84 41.302	16.714	53594	53632
33 3.909	84 41.302	16.722	53644	53681
33 3.916	84 41.302	16.729	53640	53677
33 3.923	84 41.302	16.736	53574	53611
33 3.931	84 41.301	16.743	53495	53532
33 3.938	84 41.301	16.750	53588	53625
33 3.945	84 41.301	16.758	53635	53672
33 3.953	84 41.301	16.765	53682	53719
33 3.960	84 41.300	16.772	53604	53641
33 3.968	84 41.300	16.779	53603	53640
33 3.975	84 41.300	16.786	53620	53656
33 3.982	84 41.294	16.794	53581	53617
33 3.988	84 41.289	16.801	53587	53623
33 4.002	84 41.277	16.815	53593	53629
33 4.015	84 41.266	16.830	53574	53610
33 4.029	84 41.255	16.844	53633	53668
33 4.042	84 41.243	16.858	53625	53660
33 4.055	84 41.232	16.873	53666	53701
33 4.069	84 41.220	16.887	53637	53672
33 4.082	84 41.209	16.902	53601	53636
33 4.096	84 41.198	16.916	53564	53599
33 4.109	84 41.186	16.930	53565	53601
33 4.122	84 41.175	16.945	53567	53603
33 4.136	84 41.164	16.959	53576	53612
33 4.149	84 41.152	16.973	53343	53379
1234567890	1234567890	1234567890	1234	567890

Table 4. (Continued)

Profile A-A' (Continued)

1234567890123456789012345678901234567890

LATITUDE	LONGITUDE	TIME	RAW	REDUCED
33 4.163	84 41.141	16.988	53597	53633
33 4.176	84 41.130	17.002	53592	53628
33 4.190	84 41.118	17.017	53595	53631
33 4.203	84 41.107	17.029	53591	53627
33 4.216	84 41.095	17.042	53593	53628
33 4.230	84 41.084	17.054	53610	53645
33 4.243	84 41.073	17.067	53589	53624
33 4.257	84 41.061	17.367	53605	53639
33 4.263	84 41.056	17.372	53602	53636
33 4.270	84 41.050	17.378	53604	53638
33 4.268	84 41.030	17.389	53593	53627
33 4.266	84 41.010	17.401	53585	53619
33 4.264	84 40.990	17.412	53506	53540
33 4.262	84 40.970	17.424	53595	53629
33 4.260	84 40.950	17.435	53598	53632
33 4.258	84 40.930	17.446	53605	53639
33 4.256	84 40.910	17.458	53594	53628
33 4.254	84 40.890	17.469	53605	53639
33 4.252	84 40.870	17.481	53605	53639
33 4.250	84 40.850	17.492	53557	53591
33 4.255	84 40.832	17.504	53589	53623
33 4.260	84 40.814	17.515	53612	53646
33 4.265	84 40.796	17.526	53618	53652
33 4.270	84 40.779	17.538	53621	53655
33 4.275	84 40.761	17.549	53616	53650
33 4.280	84 40.743	17.561	53613	53647
33 4.285	84 40.725	17.572	53614	53647
33 4.290	84 40.706	17.583	53609	53642
33 4.295	84 40.687	17.596	53608	53641
33 4.301	84 40.668	17.608	53615	53648
33 4.306	84 40.649	17.621	53622	53655
33 4.311	84 40.631	17.633	53626	53659
33 4.316	84 40.612	17.646	53628	53661
33 4.321	84 40.593	17.658	53624	53657
33 4.326	84 40.574	17.671	53629	53662
33 4.332	84 40.555	17.683	53624	53657
33 4.337	84 40.536	17.696	53654	53688
33 4.342	84 40.517	17.708	53651	53685
33 4.347	84 40.498	17.721	53636	53670
33 4.352	84 40.479	17.733	53667	53701
33 4.355	84 40.470	17.741	53695	53729
33 4.357	84 40.460	17.749	53768	53802
33 4.358	84 40.449	17.757	53631	53665
33 4.360	84 40.439	17.764	53644	53678
33 4.363	84 40.418	17.780	53657	53691
33 4.367	84 40.397	17.796	53689	53723
33 4.368	84 40.387	17.803	53734	53768
33 4.370	84 40.377	17.811	53732	53766
33 4.372	84 40.366	17.819	53650	53684
33 4.373	84 40.356	17.827	53673	53707
33 4.375	84 40.346	17.834	53655	53689
33 4.377	84 40.335	17.842	53659	53693
33 4.378	84 40.325	17.850	53666	53700
33 4.382	84 40.304	17.864	53676	53710
33 4.385	84 40.283	17.877	53707	53741
33 4.388	84 40.263	17.891	53719	53753
33 4.392	84 40.242	17.905	53749	53783
33 4.393	84 40.231	17.912	53784	53818
33 4.395	84 40.221	17.919	53852	53886
33 4.397	84 40.211	17.925	53849	53883
33 4.398	84 40.200	17.932	53922	53956
33 4.400	84 40.190	17.939	53965	53999
33 4.403	84 40.181	17.946	54111	54145
33 4.407	84 40.171	17.953	54592	54626
33 4.410	84 40.162	17.960	54246	54280

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LATITUDE	LONGITUDE	TIME	RAW	REDUCED
33 4.413	84 40.153	17.967	54096	54130
33 4.416	84 40.144	17.976	53488	53522
33 4.420	84 40.134	17.985	54541	54575
33 4.423	84 40.125	17.994	53550	53584
33 4.426	84 40.116	18.003	53564	53598
33 4.429	84 40.107	18.012	53587	53621
33 4.433	84 40.097	18.021	53599	53633
33 4.436	84 40.088	18.030	53623	53657
33 4.439	84 40.079	18.039	53602	53636
33 4.443	84 40.069	18.048	53637	53671
33 4.446	84 40.060	18.058	53726	53760
33 4.449	84 40.051	18.067	53979	54013
33 4.452	84 40.042	18.072	53453	53487
33 4.456	84 40.032	18.077	53483	53517
33 4.459	84 40.023	18.083	53505	53539
33 4.462	84 40.014	18.088	53511	53545
33 4.465	84 40.005	18.093	53513	53547
33 4.469	84 39.995	18.099	53517	53551
33 4.472	84 39.986	18.104	53515	53549
33 4.479	84 39.967	18.115	53524	53558
33 4.485	84 39.949	18.126	53536	53570
33 4.492	84 39.930	18.136	53540	53574
33 4.498	84 39.912	18.147	53554	53588
33 4.505	84 39.893	18.158	53561	53595
33 4.511	84 39.875	18.168	53554	53588
33 4.518	84 39.856	18.179	53558	53592
33 4.524	84 39.838	18.190	53558	53592
33 4.531	84 39.819	18.201	53600	53634
33 4.534	84 39.810	18.206	53561	53595
33 4.541	84 39.791	18.217	53596	53629
33 4.547	84 39.773	18.227	53587	53620
33 4.554	84 39.754	18.238	53581	53614
33 4.560	84 39.736	18.249	53593	53626
33 4.567	84 39.717	18.260	53583	53615
33 4.573	84 39.699	18.270	53584	53616
33 4.580	84 39.680	18.281	53543	53575
33 4.592	84 39.665	18.292	53560	53592
33 4.605	84 39.649	18.302	53574	53605
33 4.617	84 39.634	18.313	53582	53613
33 4.629	84 39.619	18.324	53595	53626
33 4.642	84 39.604	18.335	53587	53618
33 4.654	84 39.588	18.345	53592	53623
33 4.667	84 39.573	18.356	53586	53617
33 4.679	84 39.558	18.367	53584	53615
33 4.691	84 39.543	18.377	53590	53621
33 4.704	84 39.527	18.388	53584	53615
33 4.716	84 39.512	18.399	53581	53612
33 4.728	84 39.497	18.410	53588	53619
33 4.741	84 39.482	18.420	53591	53622
33 4.753	84 39.466	18.431	53587	53618
33 4.766	84 39.451	18.442	53583	53614
33 4.778	84 39.436	18.452	53589	53620
33 4.790	84 39.421	18.463	53595	53626
33 4.803	84 39.405	18.474	53587	53618
33 4.815	84 39.390	18.485	53580	53611
33 4.821	84 39.372	18.495	53612	53643
33 4.827	84 39.354	18.506	53589	53620
33 4.833	84 39.336	18.517	53573	53604
33 4.839	84 39.318	18.537	53581	53612
33 4.845	84 39.300	18.557	53577	53608
33 4.851	84 39.282	18.578	53575	53607
33 4.857	84 39.264	18.598	53581	53613
33 4.863	84 39.246	18.619	53582	53614
33 4.869	84 39.228	18.639	53584	53616
33 4.875	84 39.210	18.659	53548	53580

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Table 4. (Continued)

Profile A-A' (Concluded)

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LATITUDE		LONGITUDE		TIME	RAW	REDUCED
33	4.875	84	39.190	18.680	53549	53581
33	4.875	84	39.170	18.700	53564	53596
33	4.875	84	39.150	18.713	53611	53644
33	4.875	84	39.130	18.725	53614	53647
33	4.875	84	39.110	18.738	53583	53616
33	4.875	84	39.090	18.750	53588	53621
33	4.875	84	39.070	18.763	53584	53617
33	4.875	84	39.050	18.776	53594	53627
33	4.875	84	39.030	18.788	53571	53603
33	4.875	84	39.010	18.801	53565	53597
33	4.875	84	38.990	18.813	53557	53589
33	4.875	84	38.980	18.820	53612	53644
33	4.875	84	38.970	18.826	53701	53732
33	4.875	84	38.960	18.832	53587	53618
33	4.875	84	38.940	18.845	53637	53668
33	4.875	84	38.930	18.851	53602	53633
33	4.875	84	38.920	18.857	53822	53853
33	4.875	84	38.910	18.864	53697	53728
33	4.875	84	38.890	18.876	53610	53640
33	4.875	84	38.870	18.889	53716	53746
33	4.875	84	38.850	18.901	53559	53589
33	4.875	84	38.830	18.914	53647	53877
33	4.875	84	38.820	18.920	53770	53800
33	4.875	84	38.810	18.927	53852	53882
33	4.875	84	38.800	18.933	53760	53790
33	4.875	84	38.780	18.946	53698	53728
33	4.875	84	38.760	18.958	53920	53950
33	4.875	84	38.740	18.971	53680	53710
33	4.875	84	38.720	18.983	53576	53605
33	4.875	84	38.700	18.994	53548	53577
33	4.875	84	38.680	19.006	53572	53601
33	4.875	84	38.660	19.017	53610	53639
33	4.875	84	38.640	19.028	53640	53669
33	4.875	84	38.620	19.039	53624	53653
33	4.875	84	38.600	19.050	53617	53646
33	4.875	84	38.580	19.061	53616	53645
33	4.875	84	38.560	19.072	53635	53664
33	4.875	84	38.540	19.083	53668	53697
33	4.875	84	38.520	19.094	53654	53683
33	4.875	84	38.500	19.106	53594	53623
33	4.875	84	38.480	19.117	53670	53699
33	4.875	84	38.460	19.131	53640	53669
33	4.875	84	38.440	19.144	53628	53657
33	4.875	84	38.420	19.158	53628	53657
33	4.875	84	38.400	19.172	53623	53652
33	4.875	84	38.380	19.186	53645	53674
33	4.875	84	38.360	19.200	53677	53706
33	4.875	84	38.340	19.212	53643	53672
33	4.875	84	38.320	19.224	53608	53637
33	4.875	84	38.300	19.236	53599	53628
33	4.875	84	38.280	19.248	53598	53627
33	4.875	84	38.260	19.260	53605	53634
33	4.875	84	38.240	19.271	53605	53634
33	4.875	84	38.220	19.283	53592	53621

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Table 4. (Continued)

Profile B-B', May 5, 1973

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
1234567890123456789012345678901234567890						
33	2.180	84	41.580	9.083	53311	53359
33	2.194	84	41.567	9.139	53590	53638
33	2.209	84	41.554	9.194	53723	53771
33	2.223	84	41.541	9.250	53614	53661
33	2.238	84	41.528	9.267	53614	53661
33	2.252	84	41.515	9.283	53565	53612
33	2.267	84	41.502	9.300	53562	53609
33	2.281	84	41.489	9.317	53573	53620
33	2.296	84	41.476	9.333	53580	53626
33	2.310	84	41.463	9.378	53575	53621
33	2.325	84	41.450	9.422	53578	53624
33	2.339	84	41.437	9.467	53586	53631
33	2.354	84	41.424	9.478	53584	53629
33	2.368	84	41.411	9.489	53601	53646
33	2.383	84	41.398	9.500	53579	53624
33	2.397	84	41.385	9.513	53578	53623
33	2.412	84	41.372	9.527	53576	53620
33	2.426	84	41.359	9.540	53595	53639
33	2.441	84	41.346	9.553	53639	53683
33	2.448	84	41.340	9.560	53581	53625
33	2.455	84	41.333	9.567	53561	53605
33	2.470	84	41.320	9.584	53599	53642
33	2.481	84	41.302	9.602	53561	53604
33	2.491	84	41.284	9.620	53574	53617
33	2.502	84	41.266	9.637	53580	53623
33	2.513	84	41.248	9.655	53548	53590
33	2.523	84	41.230	9.673	53626	53668
33	2.529	84	41.221	9.681	53616	53658
33	2.534	84	41.212	9.690	53642	53684
33	2.539	84	41.203	9.699	53744	53786
33	2.545	84	41.194	9.708	53656	53698
33	2.550	84	41.185	9.717	53626	53668
33	2.544	84	41.165	9.727	53622	53664
33	2.538	84	41.146	9.737	53611	53653
33	2.532	84	41.126	9.747	53614	53656
33	2.519	84	41.087	9.767	53617	53659
33	2.507	84	41.048	9.783	53619	53661
33	2.495	84	41.009	9.800	53845	53887
33	2.489	84	40.990	9.808	53628	53670
33	2.483	84	40.970	9.817	53609	53651
33	2.470	84	40.931	9.833	53591	53633
33	2.458	84	40.892	9.850	53673	53715
33	2.446	84	40.853	9.867	53593	53635
33	2.433	84	40.814	9.883	53581	53623
33	2.421	84	40.775	9.900	53502	53544
33	2.415	84	40.755	9.908	53588	53630
33	2.409	84	40.736	9.917	53586	53628
33	2.403	84	40.716	9.925	53560	53601
33	2.397	84	40.697	9.933	53551	53592
33	2.391	84	40.677	9.940	53550	53592
33	2.378	84	40.638	9.952	53557	53599
33	2.366	84	40.599	9.965	53556	53598
33	2.354	84	40.560	9.978	53560	53602
33	2.342	84	40.521	9.990	53553	53595
33	2.329	84	40.482	10.003	53552	53594
33	2.317	84	40.443	10.016	53553	53595
33	2.305	84	40.404	10.029	53565	53607
33	2.292	84	40.365	10.041	53576	53618
33	2.280	84	40.326	10.054	53564	53606
33	2.268	84	40.287	10.067	53560	53602
33	2.256	84	40.248	10.079	53561	53603
33	2.243	84	40.209	10.091	53561	53604
33	2.231	84	40.170	10.103	53557	53600
33	2.225	84	40.150	10.109	53556	53599
33	2.276	84	40.177	10.121	53548	53590
1234567890123456789012345678901234567890						

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
1234567890123456789012345678901234567890						
33	2.327	84	40.204	10.133	53570	53612
33	2.378	84	40.231	10.300	53546	53587
33	2.429	84	40.259	10.317	53565	53605
33	2.480	84	40.286	10.337	53553	53593
33	2.531	84	40.313	10.357	53548	53587
33	2.582	84	40.340	10.377	53551	53590
33	2.607	84	40.354	10.387	53526	53564
33	2.633	84	40.367	10.397	53275	53313
33	2.658	84	40.381	10.407	53524	53562
33	2.684	84	40.394	10.417	53542	53580
33	2.709	84	40.408	10.428	53542	53579
33	2.735	84	40.421	10.440	53534	53571
33	2.760	84	40.435	10.452	53529	53566
33	2.762	84	40.425	10.464	53532	53569
33	2.765	84	40.405	10.487	53530	53567
33	2.768	84	40.385	10.511	53541	53578
33	2.772	84	40.365	10.534	53573	53610
33	2.773	84	40.355	10.546	53572	53608
33	2.777	84	40.335	10.570	53593	53629
33	2.780	84	40.315	10.593	53675	53711
33	2.785	84	40.305	10.605	53787	53823
33	2.791	84	40.296	10.617	53893	53929
33	2.796	84	40.286	10.625	53879	53915
33	2.802	84	40.277	10.633	53694	53730
33	2.807	84	40.267	10.642	53695	53731
33	2.813	84	40.258	10.650	53713	53749
33	2.818	84	40.248	10.658	53538	53573
33	2.824	84	40.239	10.667	53608	53643
33	2.829	84	40.229	10.675	53662	53697
33	2.835	84	40.220	10.683	53763	53798
33	2.840	84	40.210	10.692	53888	53923
33	2.846	84	40.245	10.700	54061	54096
33	2.851	84	40.280	10.709	53971	54006
33	2.857	84	40.314	10.719	53941	53976
33	2.863	84	40.349	10.728	53696	53731
33	2.868	84	40.384	10.737	53677	53711
33	2.874	84	40.419	10.746	53718	53752
33	2.880	84	40.453	10.756	53666	53700
33	2.885	84	40.488	10.765	53770	53804
33	2.891	84	40.523	10.774	53708	53742
33	2.897	84	40.558	10.783	53711	53745
33	2.902	84	40.593	10.791	53621	53655
33	2.908	84	40.627	10.798	53588	53622
33	2.913	84	40.662	10.806	53570	53603
33	2.919	84	40.697	10.814	53742	53775
33	2.925	84	40.732	10.821	53659	53692
33	2.930	84	40.767	10.829	53616	53649
33	2.936	84	40.801	10.836	53600	53633
33	2.942	84	40.836	10.844	53746	53779
33	2.947	84	40.871	10.852	53667	53700
33	2.953	84	40.906	10.859	53620	53653
33	2.959	84	40.940	10.867	53635	53667
33	2.964	84	40.975	10.874	53544	53576
33	2.970	84	41.010	10.882	53457	53489
33	2.975	84	40.979	10.889	53499	53531
33	2.980	84	40.947	10.897	53539	53571
33	2.985	84	40.916	10.905	53555	53587
33	2.990	84	40.884	10.912	53554	53586
33	3.001	84	40.821	10.927	53561	53593
33	3.011	84	40.758	10.942	53567	53598
33	3.021	84	40.696	10.958	53554	53585
33	3.031	84	40.633	10.973	53558	53589
33	3.036	84	40.601	10.980	53552	53583
33	3.042	84	40.570	10.988	53664	53695
33	3.047	84	40.538	10.995	53607	53638
1234567890123456789012345678901234567890						

Page 55 is missing.

Table 4. (Continued)

Profile B-B' (Concluded)

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
1234567890123456789012345678901234567890						
33	3.052	84	40.507	11.003	53590	53621
33	3.057	84	40.475	11.011	53574	53604
33	3.062	84	40.444	11.018	53567	53597
33	3.067	84	40.413	11.026	53574	53604
33	3.072	84	40.381	11.033	53574	53604
33	3.077	84	40.350	11.067	53578	53608
33	3.082	84	40.318	11.100	53585	53614
33	3.088	84	40.287	11.133	53593	53622
33	3.093	84	40.255	11.167	53603	53632
33	3.098	84	40.224	11.200	53609	53638
33	3.103	84	40.192	11.209	53613	53641
33	3.108	84	40.161	11.219	53617	53645
33	3.113	84	40.130	11.228	53650	53678
33	3.118	84	40.098	11.237	53678	53706
33	3.123	84	40.067	11.246	53724	53752
33	3.128	84	40.035	11.256	53751	53779
33	3.134	84	40.004	11.265	53812	53840
33	3.139	84	39.972	11.274	53944	53972
33	3.144	84	39.941	11.283	54440	54467
33	3.149	84	39.909	11.294	54392	54419
33	3.154	84	39.878	11.305	54096	54123
33	3.159	84	39.847	11.315	53502	53529
33	3.164	84	39.815	11.326	53526	53553
33	3.169	84	39.784	11.337	53596	53623
33	3.174	64	39.752	11.348	53683	53710
33	3.180	84	39.721	11.358	54017	54044
33	3.185	84	39.689	11.369	53415	53441
33	3.190	84	39.658	11.380	53466	53492
33	3.195	84	39.626	11.390	53520	53546
33	3.200	84	39.595	11.401	53630	53656
33	3.203	84	39.587	11.412	53460	53486
33	3.207	84	39.578	11.423	53495	53521
33	3.210	84	39.570	11.433	53513	53539
33	3.214	84	39.561	11.445	53526	53552
33	3.217	84	39.553	11.456	53529	53555
33	3.221	84	39.544	11.467	53530	53556
33	3.227	84	39.528	11.490	53534	53560
33	3.231	84	39.519	11.502	53533	53558
33	3.234	84	39.511	11.513	53672	53697
33	3.238	84	39.502	11.524	53539	53564
33	3.241	84	39.494	11.536	53550	53575
33	3.248	84	39.477	11.559	53550	53575
33	3.255	84	39.460	11.581	53553	53578
33	3.259	84	39.440	11.604	53544	53569
33	3.264	84	39.420	11.627	53544	53569
33	3.269	84	39.400	11.650	53524	53549
33	3.273	84	39.380	11.672	53562	53586
33	3.278	84	39.360	11.695	53559	53583
33	3.280	84	39.350	11.707	53559	53583
33	3.282	84	39.340	11.718	53436	53460
33	3.284	84	39.330	11.729	53543	53567
33	3.287	84	39.320	11.741	53558	53582
33	3.289	84	39.310	11.752	53558	53582
33	3.291	84	39.300	11.763	53554	53578
33	3.296	84	39.280	11.786	53563	53587
33	3.298	84	39.270	11.798	53560	53584
33	3.300	84	39.260	11.809	53426	53450
33	3.301	84	39.249	11.820	53557	53580
33	3.303	84	39.228	11.843	53593	53616
33	3.304	84	39.217	11.854	53600	53623
33	3.305	84	39.206	11.866	53561	53584
33	3.306	84	39.195	11.877	53559	53582
33	3.308	84	39.174	11.900	53585	53608
33	3.311	84	39.152	11.918	53569	53592
33	3.312	84	39.141	11.927	53576	53599
1234567890123456789012345678901234567890						

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
1234567890123456789012345678901234567890						
33	3.313	84	39.131	11.936	53594	53617
33	3.315	84	39.109	11.953	53609	53632
33	3.316	84	39.098	11.962	53574	53597
33	3.317	84	39.087	11.971	53587	53610
33	3.318	84	39.077	11.980	53630	53653
33	3.319	84	39.066	11.989	53568	53591
33	3.320	84	39.055	11.998	53563	53586
33	3.322	84	39.044	12.007	53613	53636
33	3.324	84	39.034	12.016	53634	53656
33	3.326	84	39.023	12.024	53667	53689
33	3.327	84	39.012	12.033	53655	53677
33	3.329	84	39.002	12.048	53632	53654
33	3.331	84	38.991	12.062	53629	53651
33	3.333	84	38.980	12.076	53633	53655
33	3.335	84	38.970	12.090	53612	53634
33	3.337	84	38.959	12.105	53605	53627
33	3.338	84	38.948	12.119	53602	53624
33	3.340	84	38.938	12.133	53601	53623
33	3.342	84	38.927	12.142	53604	53626
33	3.344	84	38.916	12.150	53612	53634
33	3.346	84	38.906	12.158	53597	53619
33	3.348	84	38.895	12.167	53588	53610
33	3.349	84	38.884	12.175	53571	53593
33	3.351	84	38.874	12.183	53573	53595
33	3.353	84	38.863	12.192	53573	53594
33	3.355	84	38.853	12.200	53574	53595
33	3.359	84	38.831	12.217	53573	53594
33	3.362	84	38.810	12.231	53583	53604
33	3.366	84	38.789	12.245	53610	53630
33	3.370	84	38.767	12.260	53584	53604
33	3.373	84	38.746	12.274	53607	53627
33	3.377	84	38.725	12.288	53612	53632
33	3.381	84	38.703	12.302	53639	53659
33	3.384	84	38.682	12.317	53554	53574
33	3.388	84	38.661	12.350	53554	53574
33	3.390	84	38.650	12.367	53557	53577
33	3.392	84	38.629	12.389	53043	53063
33	3.393	84	38.608	12.411	53577	53597
33	3.395	84	38.586	12.433	53583	53603
33	3.396	84	38.565	12.456	53598	53618
33	3.398	84	38.544	12.478	53619	53639
33	3.399	84	38.523	12.500	53596	53616
33	3.401	84	38.501	12.513	53594	53614
33	3.402	84	38.480	12.527	53608	53628
33	3.404	84	38.459	12.540	53557	53577
33	3.406	84	38.437	12.553	53571	53591
33	3.407	84	38.416	12.567	53584	53604
33	3.409	84	38.395	12.580	53599	53619
33	3.410	84	38.374	12.593	53594	53614
33	3.411	84	38.363	12.600	53587	53607
33	3.412	84	38.352	12.607	53596	53616
33	3.413	84	38.342	12.613	53594	53614
33	3.413	84	38.331	12.620	53588	53608
33	3.414	84	38.321	12.627	53589	53609
33	3.415	84	38.310	12.633	53581	53601
1234567890123456789012345678901234567890						

Table 4. (Continued)

Profile C-C', May 6, 1973

1234567890123456789012345678901234567890

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
33	1.945	84	40.277	12.050	53593	53624
33	1.944	84	40.259	12.060	53595	53626
33	1.942	84	40.242	12.070	53561	53592
33	1.941	84	40.224	12.080	53548	53578
33	1.940	84	40.206	12.090	53561	53591
33	1.939	84	40.188	12.100	53709	53739
33	1.938	84	40.179	12.109	53535	53565
33	1.937	84	40.171	12.118	53594	53624
33	1.936	84	40.153	12.136	53701	53731
33	1.935	84	40.135	12.154	53620	53650
33	1.949	84	40.125	12.172	53609	53638
33	1.963	84	40.116	12.190	53705	53734
33	1.977	84	40.106	12.208	53595	53624
33	1.991	84	40.096	12.226	53659	53688
33	2.005	84	40.087	12.244	53655	53683
33	2.019	84	40.077	12.262	53669	53697
33	2.032	84	40.068	12.281	53655	53683
33	2.046	84	40.058	12.299	53661	53689
33	2.060	84	40.048	12.317	53661	53689
33	2.074	84	40.039	12.327	53657	53685
33	2.088	84	40.029	12.337	53622	53650
33	2.102	84	40.019	12.347	53632	53660
33	2.116	84	40.010	12.357	53572	53600
33	2.130	84	40.000	12.367	53535	53563
33	2.132	84	39.990	12.377	53537	53565
33	2.134	84	39.980	12.387	53541	53569
33	2.136	84	39.970	12.397	53542	53570
33	2.138	84	39.960	12.407	53554	53582
33	2.142	84	39.940	12.427	53573	53601
33	2.146	84	39.920	12.447	53554	53582
33	2.151	84	39.900	12.467	53615	53644
33	2.155	84	39.880	12.667	53624	53653
33	2.159	84	39.860	12.687	53558	53587
33	2.163	84	39.840	12.708	53614	53643
33	2.165	84	39.830	12.719	53631	53660
33	2.161	84	39.822	12.729	53609	53638
33	2.157	84	39.813	12.740	53588	53617
33	2.153	84	39.805	12.750	53599	53629
33	2.144	84	39.789	12.768	53582	53612
33	2.136	84	39.772	12.787	53585	53615
33	2.128	84	39.756	12.805	53580	53610
33	2.120	84	39.739	12.824	53563	53593
33	2.111	84	39.723	12.842	53590	53620
33	2.103	84	39.706	12.860	53540	53570
33	2.095	84	39.690	12.879	53552	53582
33	2.091	84	39.681	12.888	53545	53576
33	2.087	84	39.673	12.897	53529	53560
33	2.082	84	39.665	12.906	53520	53551
33	2.078	84	39.657	12.916	53533	53564
33	2.074	84	39.648	12.925	53605	53636
33	2.070	84	39.640	12.934	53741	53772
33	2.066	84	39.634	12.943	53826	53857
33	2.060	84	39.627	12.952	53765	53796
33	2.056	84	39.621	12.961	53667	53698
33	2.051	84	39.615	12.971	53944	53975
33	2.046	84	39.609	12.980	54188	54219
33	2.041	84	39.602	12.989	53668	53700
33	2.036	84	39.596	12.998	53621	53653
33	2.031	84	39.590	13.007	53727	53759
33	2.027	84	39.583	13.017	53609	53641
33	2.022	84	39.577	13.100	53643	53676
33	2.017	84	39.571	13.106	53613	53646
33	2.012	84	39.564	13.111	53624	53657
33	2.007	84	39.558	13.117	53618	53652
33	1.998	84	39.546	13.128	53626	53660

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LATITUDE		LONGITUDE		TIME	RAW	REDUCED
33	1.988	84	39.533	13.139	53699	53733
33	1.979	84	39.520	13.150	53809	53843
33	1.974	84	39.514	13.156	53689	53723
33	1.964	84	39.501	13.167	53680	53715
33	1.954	84	39.489	13.180	53605	53640
33	1.950	84	39.483	13.187	53577	53612
33	1.940	84	39.470	13.200	53627	53662
33	1.940	84	39.452	13.213	53650	53685
33	1.939	84	39.433	13.227	53585	53620
33	1.939	84	39.424	13.233	53654	53689
33	1.939	84	39.415	13.242	53677	53712
33	1.939	84	39.406	13.250	53743	53778
33	1.939	84	39.397	13.258	53648	53683
33	1.939	84	39.388	13.267	53671	53706
33	1.939	84	39.378	13.275	53693	53729
33	1.938	84	39.369	13.283	53710	53746
33	1.938	84	39.360	13.292	53668	53704
33	1.938	84	39.351	13.300	53694	53730
33	1.938	84	39.342	13.308	53785	53821
33	1.938	84	39.332	13.317	53871	53907
33	1.938	84	39.323	13.325	53991	54027
33	1.938	84	39.314	13.333	53704	53740
33	1.938	84	39.305	13.342	53744	53780
33	1.937	84	39.296	13.350	53641	53677
33	1.937	84	39.287	13.358	53770	53806
33	1.937	84	39.278	13.367	53650	53686
33	1.937	84	39.268	13.375	53773	53809
33	1.937	84	39.259	13.383	53781	53817
33	1.937	84	39.250	13.392	53785	53821
33	1.937	84	39.241	13.400	53795	53831
33	1.936	84	39.232	13.408	53844	53880
33	1.936	84	39.223	13.417	53863	53900
33	1.936	84	39.213	13.427	53833	53870
33	1.936	84	39.204	13.438	53931	53968
33	1.936	84	39.195	13.448	53947	53984
33	1.936	84	39.186	13.459	54494	54531
33	1.936	84	39.177	13.470	54314	54351
33	1.935	84	39.168	13.480	54259	54296
33	1.935	84	39.158	13.491	53926	53963
33	1.935	84	39.149	13.502	53849	53886
33	1.935	84	39.140	13.512	53525	53562
33	1.935	84	39.131	13.523	53609	53646
33	1.935	84	39.122	13.533	53626	53663
33	1.935	84	39.113	13.544	53545	53583
33	1.934	84	39.103	13.555	53585	53623
33	1.934	84	39.094	13.565	53635	53673
33	1.934	84	39.085	13.576	53599	53637
33	1.934	84	39.076	13.586	53600	53638
33	1.934	84	39.067	13.597	53685	53723
33	1.934	84	39.048	13.618	53729	53767
33	1.933	84	39.030	13.639	53783	53821
33	1.933	84	39.021	13.650	53831	53870
33	1.933	84	39.012	13.659	53761	53800
33	1.933	84	39.003	13.668	53770	53809
33	1.933	84	38.984	13.686	53958	53997
33	1.933	84	38.975	13.695	53773	53812
33	1.932	84	38.966	13.705	53806	53845
33	1.932	84	38.957	13.714	53748	53787
33	1.932	84	38.938	13.732	53855	53895
33	1.932	84	38.920	13.750	53732	53771
33	1.931	84	38.902	13.761	53716	53755
33	1.931	84	38.883	13.773	53707	53745
33	1.931	84	38.865	13.784	53686	53724
33	1.931	84	38.847	13.796	53647	53684
33	1.930	84	38.828	13.807	53760	53797

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Table 4. (Continued)

Profile C-C' (Concluded)

1234567890123456789012345678901234567890

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
33	1.930	84	38.810	13.819	53735	53772
33	1.925	84	38.790	13.830	53723	53760
33	1.921	84	38.770	13.842	53623	53661
33	1.916	84	38.750	13.853	53712	53750
33	1.913	84	38.740	13.859	53670	53708
33	1.909	84	38.720	13.871	53724	53762
33	1.904	84	38.700	13.882	53729	53767
33	1.899	84	38.680	13.894	53722	53760
33	1.894	84	38.660	13.905	53773	53811
33	1.892	84	38.650	13.911	53823	53861
33	1.890	84	38.640	13.917	53791	53829
33	1.885	84	38.620	13.937	53660	53698
33	1.889	84	38.602	13.957	53826	53864
33	1.890	84	38.593	13.967	53803	53842
33	1.892	84	38.584	13.977	53754	53793
33	1.894	84	38.575	13.987	53809	53849
33	1.896	84	38.566	13.997	53793	53833
33	1.899	84	38.548	14.017	53735	53776
33	1.903	84	38.530	14.027	53808	53849
33	1.906	84	38.512	14.038	53848	53889
33	1.910	84	38.494	14.049	53857	53899
33	1.913	84	38.476	14.060	53773	53815
33	1.917	84	38.458	14.071	53783	53825
33	1.920	84	38.440	14.081	53661	53703
33	1.920	84	38.421	14.092	53708	53751
33	1.920	84	38.403	14.103	53609	53652
33	1.919	84	38.384	14.114	53649	53692
33	1.919	84	38.365	14.125	53662	53705
33	1.919	84	38.347	14.135	53730	53773
33	1.919	84	38.328	14.146	53720	53764
33	1.918	84	38.309	14.157	53801	53845
33	1.918	84	38.291	14.168	53735	53779
33	1.918	84	38.272	14.178	53702	53746
33	1.918	84	38.253	14.189	53623	53667
33	1.918	84	38.235	14.200	53590	53634
33	1.917	84	38.216	14.210	53586	53631
33	1.917	84	38.197	14.221	53596	53642
33	1.917	84	38.179	14.231	53636	53682
33	1.917	84	38.160	14.241	53653	53700
33	1.916	84	38.141	14.251	53669	53716
33	1.916	84	38.123	14.262	53646	53693
33	1.916	84	38.113	14.267	53593	53640
33	1.916	84	38.095	14.277	53586	53633
33	1.916	84	38.076	14.287	53578	53625
33	1.915	84	38.057	14.297	53578	53625
33	1.915	84	38.039	14.308	53563	53610
33	1.915	84	38.020	14.318	53603	53650
33	1.915	84	38.010	14.323	53593	53640
33	1.915	84	37.991	14.333	53669	53717
33	1.915	84	37.972	14.344	53663	53711
33	1.914	84	37.953	14.355	53683	53731
33	1.914	84	37.934	14.365	53679	53727
33	1.914	84	37.915	14.376	53653	53701
33	1.914	84	37.886	14.392	53616	53664
33	1.914	84	37.867	14.403	53641	53689
33	1.914	84	37.847	14.413	53663	53712
33	1.913	84	37.828	14.424	53661	53710
33	1.913	84	37.809	14.435	53670	53719
33	1.913	84	37.790	14.445	53633	53682
33	1.913	84	37.771	14.456	53633	53682
33	1.913	84	37.751	14.467	53620	53669
33	1.913	84	37.732	14.477	53599	53648
33	1.912	84	37.713	14.488	53632	53681
33	1.912	84	37.694	14.499	53679	53729
33	1.912	84	37.675	14.509	53626	53676

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1234567890123456789012345678901234567890

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
33	1.912	84	37.656	14.520	53638	53688
33	1.912	84	37.636	14.531	53710	53760
33	1.912	84	37.617	14.541	53676	53726
33	1.911	84	37.598	14.552	53779	53829
33	1.911	84	37.579	14.563	53668	53718
33	1.911	84	37.560	14.573	53651	53701
33	1.911	84	37.540	14.584	53619	53669
33	1.911	84	37.521	14.595	53614	53663
33	1.911	84	37.512	14.600	53614	53663
33	1.910	84	37.493	14.608	53609	53658
33	1.910	84	37.473	14.617	53618	53667
33	1.910	84	37.454	14.625	53614	53663
33	1.910	84	37.435	14.633	53567	53616

1234567890123456789012345678901234567890

Table 4. (Concluded)

Profile A'-B', May 6, 1973

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
1234567890123456789012345678901234567890						
33	4.875	84	38.740	10.033	53999	54014
33	4.859	84	38.735	10.045	54025	54040
33	4.843	84	38.731	10.056	54055	54070
33	4.827	84	38.726	10.068	54026	54041
33	4.811	84	38.721	10.079	53958	53973
33	4.796	84	38.716	10.090	53807	53822
33	4.780	84	38.712	10.102	53841	53856
33	4.764	84	38.707	10.113	53865	53880
33	4.748	84	38.702	10.125	53694	53709
33	4.740	84	38.700	10.130	53722	53737
33	4.724	84	38.700	10.142	53609	53625
33	4.707	84	38.700	10.153	53622	53638
33	4.691	84	38.700	10.164	53510	53526
33	4.675	84	38.700	10.176	53679	53695
33	4.658	84	38.700	10.187	53614	53630
33	4.642	84	38.700	10.199	53625	53641
33	4.626	84	38.700	10.210	53658	53674
33	4.609	84	38.700	10.221	53681	53697
33	4.593	84	38.700	10.233	53761	53776
33	4.585	84	38.700	10.239	53644	53659
33	4.570	84	38.705	10.250	53593	53608
33	4.555	84	38.710	10.261	53526	53541
33	4.539	84	38.714	10.272	53630	53645
33	4.524	84	38.719	10.283	53589	53604
33	4.509	84	38.724	10.294	53589	53604
33	4.494	84	38.729	10.306	53589	53604
33	4.479	84	38.734	10.317	53592	53608
33	4.464	84	38.739	10.328	53595	53611
33	4.448	84	38.743	10.339	53593	53610
33	4.433	84	38.748	10.350	53590	53607
33	4.418	84	38.753	10.364	53597	53614
33	4.403	84	38.758	10.378	53582	53599
33	4.388	84	38.763	10.392	53579	53596
33	4.373	84	38.768	10.406	53559	53576
33	4.365	84	38.770	10.412	53806	53823
33	4.357	84	38.769	10.419	53599	53616
33	4.342	84	38.768	10.433	53602	53619
33	4.327	84	38.766	10.467	53613	53630
33	4.312	84	38.765	10.500	53585	53602
33	4.296	84	38.763	10.533	53592	53609
33	4.281	84	38.762	10.567	53582	53600
33	4.266	84	38.760	10.600	53585	53603
33	4.251	84	38.759	10.633	53588	53606
33	4.235	84	38.757	10.667	53580	53596
33	4.220	84	38.756	10.700	53577	53593
33	4.205	84	38.754	10.712	53591	53607
33	4.190	84	38.752	10.724	53580	53596
33	4.174	84	38.751	10.736	53582	53598
33	4.159	84	38.749	10.748	53581	53597
33	4.144	84	38.748	10.761	53571	53588
33	4.129	84	38.746	10.773	53578	53595
33	4.113	84	38.745	10.785	53580	53597
33	4.098	84	38.743	10.797	53581	53598
33	4.083	84	38.742	10.809	53577	53594
33	4.068	84	38.740	10.821	53584	53601
33	4.052	84	38.739	10.833	53577	53594
33	4.037	84	38.737	10.852	53572	53589
33	4.022	84	38.736	10.870	53573	53590
33	4.007	84	38.734	10.889	53570	53588
33	3.991	84	38.733	10.907	53569	53587
33	3.976	84	38.731	10.926	53570	53587
33	3.961	84	38.730	10.944	53568	53585
33	3.946	84	38.728	10.963	53562	53579
33	3.930	84	38.727	10.981	53564	53582
33	3.915	84	38.725	11.000	53566	53584
1234567890123456789012345678901234567890						

LATITUDE		LONGITUDE		TIME	RAW	REDUCED
1234567890123456789012345678901234567890						
33	3.914	84	38.713	11.019	53570	53587
33	3.913	84	38.701	11.037	53569	53586
33	3.912	84	38.688	11.056	53572	53589
33	3.911	84	38.676	11.075	53575	53592
33	3.910	84	38.664	11.094	53575	53592
33	3.909	84	38.652	11.112	53577	53594
33	3.908	84	38.640	11.131	53584	53601
33	3.907	84	38.627	11.150	53599	53615
33	3.906	84	38.615	11.142	53602	53619
33	3.905	84	38.603	11.133	53596	53613
33	3.904	84	38.591	11.125	53599	53616
33	3.903	84	38.579	11.117	53595	53612
33	3.902	84	38.566	11.108	53586	53604
33	3.901	84	38.554	11.100	53584	53602
33	3.900	84	38.542	11.092	53578	53596
33	3.900	84	38.536	11.087	53630	53648
33	3.899	84	38.530	11.083	53586	53605
33	3.898	84	38.518	11.075	53584	53603
33	3.897	84	38.505	11.067	53587	53606
33	3.896	84	38.493	11.088	53589	53607
33	3.895	84	38.481	11.110	53590	53608
33	3.894	84	38.469	11.132	53600	53617
33	3.893	84	38.457	11.153	53588	53604
33	3.892	84	38.444	11.175	53588	53604
33	3.891	84	38.432	11.197	53586	53601
33	3.890	84	38.420	11.218	53590	53605
33	3.863	84	38.419	11.240	53589	53604
33	3.837	84	38.419	11.262	53590	53605
33	3.810	84	38.418	11.283	53584	53599
33	3.783	84	38.418	11.293	53581	53597
33	3.757	84	38.417	11.302	53580	53596
33	3.730	84	38.417	11.311	53579	53595
33	3.703	84	38.416	11.320	53576	53592
33	3.677	84	38.416	11.330	53577	53593
33	3.650	84	38.415	11.339	53575	53591
33	3.623	84	38.414	11.348	53574	53590
33	3.597	84	38.414	11.357	53568	53585
33	3.570	84	38.413	11.367	53576	53593
33	3.543	84	38.413	11.378	53581	53599
33	3.517	84	38.412	11.389	53578	53596
33	3.490	84	38.412	11.400	53582	53601
33	3.463	84	38.411	11.411	53581	53600
33	3.450	84	38.411	11.417	53580	53599
33	3.437	84	38.411	11.433	53585	53604
33	3.423	84	38.410	11.450	53597	53617
33	3.410	84	38.410	11.467	53595	53615
1234567890123456789012345678901234567890						

APPENDIX III

COMPUTER PROGRAMS FOR GRAVITY AND MAGNETICS MODELING

A computer program was developed for computing the vertical gravity anomaly caused by a hypothetical two-dimensioned structure using the method of Talwani, Worzel, and Landisman (1959). A listing of the main program and subroutines necessary for line printer plotting is given in Table 5.

A computer program was developed for computing horizontal, vertical, and total magnetic anomalies due to induction, NRM or mixed magnetization using the method of Talwani and Heirtzler (1965). A listing of the main program and all referenced subroutines is given in Table 6.

Table 5. Two-Dimensional Gravity Modeling Program

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
C GRAVITY PROFILING FOR 2-DIMENSIONAL STRUCTURES
C GRAVITY FOR 2-DIMENSIONAL STRUCTURES(AFTER-TALWANI,WORTZEL,LANDISMAN)
C   INPUT(2I10,3F10.3)  CARD NO. ONE
C       LL=NO. OF POLYGONS, NDX=NO. OF GRAVITY VALUES, DX=SEPARATION OF
C       GRAVITY VALUES, XO=POSITION OF FIRST GRAVITY VALUE, SCALE=PLOT
C       SCALE-FOR DRAW
C IF SCALE=0. PROGRAM CALCULATES SCALE
C IF SCALE=13. NO GRAPH IS DRAWN
C   INPUT(FREE FIELD)  LL CARDS
C       NXZ=NO.+1OF CORNERS OF POLYGON TAKEN CLOCKWISE, DRHO=DENSITY
C       CONTRAST, X(I,J),Z(I,J)=CORDINATES OF CORNERS-JTH CORNER OF ITH
C       POLYGON
C   REPEAT SEQUENCE FOR ADDITIONAL PROFILES
C   BLANK CARD AT END TO TERMINATE CALCULATION
      DIMENSION DRHO(50),X(50,20),Z(50,20),NN(50),XX(20),ZZ(20),GAL(500)
      DIMENSION A(80)
   25 READ (5,900)A
  900 FORMAT(80A1)
      READ (5,500) LL,NDX,DX,XO  , SCALE
      WRITE(6,901)A
  901 FORMAT(1H1,80A1,//)
      WRITE(6,503) LL,NDX,DX,XO
  503 FORMAT(1H ,28HVERTICAL GRAVITY ANOMALY FOR,I5, 9H POLYGONS/2X,
     13HTHE,I5,16H-GRAVITY VALUES,,F10.4,19H-KM.APART, BEGIN AT,F10.4)
      IF(LL)  26,26,27
   27 DO 100 I=1,LL
  500 FORMAT (2I10,3F10.5)
      READ(5,501)  NXZ,DRHO(I),(X(I,J),Z(I,J),J=1,NXZ)
      WRITE(6,502)  NXZ,DRHO(I), (X(I,J),Z(I,J),J=1,NXZ)
  501 FORMAT( )
  502 FORMAT(16H NO OF POINTS = ,I10,22H DENSITY DIFFERENCE = /(1X,10F10
     <.3/))
  100 NN(I) = NXZ
      DO 101 I=1,LL
      NNI = NN(I)
      DO 101  J = 1,NNI
  101 X(I,J) = X(I,J) -XO
      DO 102I=1,NDX
      G=0.0
      DO 103 J=1,LL
      NNJ = NN(J)
      DO 104 K = 1,NNJ
      XX(K) =X(J,K)
  104 ZZ(K)=Z(J,K)
      CALL TWLZ(NN(J),XX,ZZ,DRHO(J),GA)
  103 G= G+GA
      GAL(I) = G
      DO 110 M=1,LL
      NNM = NN(M)
      DO 110 N = 1, NNM
  110 X(M,N) = X(M,N)-DX
  102 CONTINUE
      WRITE(6,505) (GAL(I),I=1,NDX)
 505  FORMAT(1X//24H GRAVITY ANOMALY IN MGAL,/(5F15.4))
      ISC=SCALE
      IF(ISC.EQ.13) GO TO 25
      IF(SCALE) 130,131,130
  131 CALL MXSCL(NDX,GAL,SCALE)
  130 CALL DRAW(NDX,1,GAL,SCALE)
      GO TO 25
   26 STOP
      END
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Table 5. (Concluded)

```
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
      SUBROUTINE TWLZ(K1,XX,ZZ,DRHO,GA)
C  USES METHOD OF TALWANI, WORZEL, AND LANDISMAN (JGR 1959 PP 49-59)
C  TO GIVE GRAVITY ANOMALY AT X=0,Z=0, IN MGAL FOR TWO DIMENSIONED
C BODY IN VERTICAL PLANE DESCRIBED BY A POLYGON (IN KILOMETERS
      DIMENSION XX(K1),ZZ(K1)
      PI = 3.141592654
      KK = K1-1
      GA = 0.0
      DO 100 K=1,KK
      K2 = K+1
      IF(XX(K)*ZZ(K2)-XX(K2)*ZZ(K))  30,100,30
   30 IF(XX(K)-XX(K2)) 85,20,85
   20 XZ =        ((XX(K2)**2 + ZZ(K2)**2)/(XX(K)**2 + ZZ(K)**2))
      DG = 0.5*LOG(XZ)*XX(K)
      GO TO 99
   85 IF(ZZ(K)-ZZ(K2))  235,72,235
   72 DG = ZZ(K)*(ATAN2(ZZ(K2),XX(K2))-ATAN2(ZZ(K),XX(K)))
      GO TO 99
  235 A =(XX(K2)-XX(K))/(ZZ(K2)-ZZ(K))
      B = (XX(K)*ZZ(K2) - XX(K2)*ZZ(K))/(ZZ(K2)-ZZ(K))
      IF(XX(K))  200,201,200
  201 DG = (B/(1.+A*A))*(.5*LOG((XX(K2)*XX(K2)+ZZ(K2)*ZZ(K2))/(ZZ(K)*
     1  ZZ(K))) - A*(ATAN2(ZZ(K2),XX(K2))-PI/2.))
  200 IF(XX(K2))   31,210,31
  210 DG = (B/(1.+A*A))*(.5*LOG(ZZ(K2)*ZZ(K2)/(XX(K)*XX(K)+
     1  ZZ(K)*ZZ(K))) + A*(ATAN2(ZZ(K),XX(K)) - PI/2.))
   31 DG=LOG((XX(K2)*XX(K2)+ZZ(K2)*ZZ(K2))/(XX(K)*XX(K)+ZZ(K)*ZZ(K)))
      DG=(B/(1.0+A*A))*(0.5*DG-A*(ATAN2(ZZ(K2),XX(K2))-ATAN2(ZZ(K),
     1XX(K))))
   99 GA=(13.34)    *DRHO*DG + GA
  100 CONTINUE
      RETURN
      END

      SUBROUTINE MXSCL(N,A,AMAX)
      DIMENSION A(N)
      AMAX = 0
      DO 26 I = 1,N
      IF (ABS(A(I))-AMAX) 26,26,25
   25 AMAX = ABS(A(I))
   26 CONTINUE
      AN = LOG10(AMAX)
      IF(AN) 17,18,19
   17 NN = AN - 1
      GO TO 20
   19 NN = AN
   20 IA = AMAX/(10.**NN)
      IF(IA.LE.2) GO TO 14
      IF(IA.LE.5) GO TO 15
   16 AMAX = 10.*(10.**NN)
   18 RETURN
   14 AMAX = 2.*(10.**NN)
      RETURN
   15 AMAX = 5.*(10.**NN)
      RETURN
      END
      SUBROUTINE DRAW (NTOT, INC, F, SCALE)
C     NTOT=TOTAL NUMBER OF POINTS IN F.  F IS THE DATA (ONE DIMENSIONAL)
C     TO BE PLOTTED. INC IS THE SAMPLE INTERVAL FOR PLOTTING F.
C     SCALE IS THE AMPLITUDE OF ONE FULL SCALE DEFLECTION
      DIMENSION    F(NTOT)
      DATA AA1/1H /,AA2/1H*/,AA3/1H+
      WRITE(6,1011) SCALE,(I,I=-10,10)    , (AA2,M=1,21)
 1011 FORMAT(1H1,E14.8,17H-MGALS FULL SCALE/3X,20I5/2X,22A5)
 10   DO 1501 K = 1, NTOT, INC
      FK = 50.*F(K)/SCALE
      KI = FK/50
      KK = FK - KI*50.+50.5
      WRITE (6,511) AA2, (AA1,I=1,KK),AA2
  511 FORMAT (1X,110A1)
 1501 CONTINUE
      RETURN
      END
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Table 6. Two-Dimensional Magnetics Modeling Program

```
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
C  COMPUTATION OF MAGNETIC ANOMALIES CAUSED BY THE MAGNETIZATION OF TWO
C     DIMENSIONAL,(INFINITE EXTENT IN THIRD DIRECTION).
C     THIS PROGRAM IS A MODIFICATION OF THE PROGRAM BY
C     MANIK TALWANI AND JAMES R. HEIRTZLER WHICH WAS PUBLISHED IN
C      COMPUTERS IN THE MINERAL INDUSTRIES , PART 1, STANFORD UNIVERSITY
C     PUBLICATION GEOL. SCI., VOL 9, NO. 1, PAGES 464-480.
C     THIS PROGRAM BY GEORGE RUTH
C                        SCHOOL OF GEOPHYSICAL SCIENCES
C                        GEORGIA INSTITUTE OF TECHNOLOGY
C                        ATLANTA, GA 30332
C                        SEPTEMBER 20, 1974
      DIMENSION FLDPT(200),PSUM(200),QSUM(200),VANMLY(200,10,2),
     * HANMLY(200,10,2),TANMLY(200,10,2),SUS(10),REMDEC(10),REMDIP(10),
     *REMMAG(10),VIND(200),VREM(200),HIND(200),HREM(200),
     *TIND(200),TREM(200),VTOT(200),HTOT(200),TTOT(200)
      DIMENSION Y(10,20),Z(10,20),VWORK(200),HWORK(200),TWORK(200)
      DIMENSION WORK1(200),WORK2(200)
      REAL MGTION
      INTEGER PRIND,PLINDV,PLINDH,PLINDT,VCOMPI,VCOMPR,HCOMPI,
     * HCOMPR,TCOMPI,TCOMPR,PRNTAL,PLVAL,PLHAL,PLTAL
C***********************************************************************C
C***READ RUN DESCRITION CARD
    1 READ (5,3000) NPOLY,PRIND,PLINDV,PLINDH,PLINDT,VCOMPI,VCOMPR,
     * HCOMPI,HCOMPR,TCOMPI,TCOMPR,PRNTAL,PLVAL,PLHAL,PLTAL
 3000 FORMAT (15I2)
      IF (NPOLY.EQ.0) GO TO 320
C***********************************************************************
C***NPOLY  = NUMBER OF POLYGONS
C***THE FOLLOWING ARE OUTPUT OPTION VARIABLES
C  IF VARIABLE = 0 , OPTION NOT EXERCISED
C  IF VARIABLE = 1 , OPTION IS EXERCISED
C***PRIND  = LIST ANOMALIES FOR EACH POLYGON
C***PLINDV = PLOT VERTICAL   ANOMALY FOR EACH POLYGON
C***PLINDH = PLOT HORIZONTAL ANOMALY FOR EACH POLYGON
C***PLINDT = PLOT    TOTAL   ANOMALY FOR EACH POLYGON
C***VCOMPI = COMPOSITE PLOT OF VERTICAL ANOMALY DUE TO INDUCTION ONLY
C***VCOMPR = COMPOSITE PLOT OF VERTICAL ANOMALY DUE TO REMANENCE ONLY
C***HCOMPI = COMPOSITE PLOT OF HORIZONTAL ANOMALY DUE TO INDUCTION ONLY
C***HCOMPR = COMPOSITE PLOT OF HORIZONTAL ANOMALY DUE TO REMANENCE ONLY
C***TCOMPI = COMPOSITE PLOT OF TOTAL  ANOMALY  DUE TO INDUCTION ONLY
C***TCOMPR = COMPOSITE PLOT OF TOTAL  ANOMALY  DUE TO REMANENCE ONLY
C***PRNTAL = LINE PRINTER LISTING OF ANOMLIES DUE TO ALL POLYGONS
C***PLVAL  = PLOT VERTICAL ANOMALY DUE TO ALL POLYGONS - REMANENT + INDUCED
C***PLHAL  = PLOT HORIZONTAL ANOMALY DUE TO ALL POLYGONS -REMANENT + INDUCED
C***PLTAL  = PLOT   TOTAL  ANOMALY DUE TO ALL POLYGONS - REMANENT + INDUCED
C***********************************************************************
C***READ PROFILE DESCRIPTION CARD
C***********************************************************************
    4 READ (5,1000) NFPTS,FRSTX,DELX,DECPLX,OBSVHT,HATCHM
 1000 FORMAT (I3,5F8.3)
C***********************************************************************
C***FRSTX  = X COORDINATE OF THE FIELD POINT FARTHEREST IN THE NEGATIVE
C***         DIRECTION(LEFT).
C***DELX   = INTERVAL BETWEEN FIELD POINTS.
C***NFPTS  = NUMBER OF FIELD POINTS
C***DECPLX = DECLINATION OF THE POSITIVE X AXIS OF THE PROFILE LINE,
C***         MEASURED POSITIVE CLOCKWISE FROM GEOGRAPHIC NORTH IN DEGREES.
C***OBSVHT = HEIGHT ABOVE PROFILE LINE AT WHICH ANOMALY WILL BE
C***         CALCULATED, MEASURED POSITIVE UP(SEE FOLLOWING FIGURE).
C***HATCHM = INTERVAL BETWEEN HATCHMARKS FOR PLOTS  --  MUST BE AN
C***         INTEGRAL MULTIPLE OF DELX
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
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Table 6. (Continued)

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
C*******************************************************************************
C                                                                              C
C        OBSERVATION ALTITUDE (FLIGHT LINE)         Z = -OBSVHT                C
C------------------------------------------------------------------------------C
C                         *                                                    C
C                        ***                                                   C
C                       * * *                                                  C
C                         *                                                    C
C                         *                                                    C
C                         *                                                    C
C                       OBSVHT                                                 C
C                         *                                                    C
C                         *                                                    C
C                         *                                  *                 C
C                         *                           +X      *                C
C  FIELD POINTS           *                     ***************.*              C
C   *    *                *                                   *                C
C   *    *                *                                  *                 C
C   *    *                *                                                    C
C   V    V                *             PROFILE LINE (GROUND)                  C
C---X----X----X-----X----X----X----X----X----X----X----X----X----X----X----X---C
C FRSTX                                                 DELX->*    *<-         C
C                                                                   *          C
C                    (EXX(1),ZEE(1))  *-----------------*  (EXX(2),ZEE(2))   *  C
C                                    /                 /                    *  C
C                                   /                 /                     *  C
C                                  /                 /                +Z    *  C
C                                 /                 /                       *  C
C                                /                 /                        *  C
C                               /                 /                       * * * C
C              (EXX(4),ZEE(4))  *-----------------*  (EXX(3),ZEE(3))       ***  C
C                                                                              C
C                                                                              C
C         LIMITS --200 FIELD POINTS, 10 POLYGONS, 20 SIDES PER POLYGON         C
C                                                                              C
C*******************************************************************************
C***CALCULATE THE FIELD POINTS, AND THE NUMBER OF FIELD POINTS.
      ITICKS = HATCHM/DELX
      FLOPT(1) = FRSTX
      DO 30 I = 2,NFPTS
   30 FLOPT(I) = FLOPT(I-1) + DELX
C***READ FIELD DESCRIPTION CARD*************************************************
      READ (5,2000) FLDDEC,FLDDIP,FLDINT
 2000 FORMAT (3F15.5)
C*******************************************************************************
C***FLDDEC = DECLINATION OF REGIONAL FIELD, POSITIVE CLOCKWISE IN DEGREES.
C***FLDDIP = DIP OR INCLINATION OF REGIONAL FIELD,POSITIVE IN THE
C***            NORTHERN HEMISPHERE, IN DEGREES.
C***FLDINT = TOTAL MAGNETIC REGIONAL FIELD INTENSITY, IN GAMMAS.
C*******************************************************************************
C***CALCULATE COSINE AND SINE OF THE DIP ANGLE AND THE COSINE
C***   OF THE ANGLE BETWEEN THE POSITIVE X AXIS AND THE DECLINATION
C***     OF THE EARTH'S FIELD, FOR USE LATER.
      CDIPR = COS (.0174533*FLDDIP)
      SDIPR = SIN (.0174533*FLDDIP)
      CDIFFR = COS (.0174533*(DECPLX-FLDDEC      ))
      DO 50 I = 1,NPOLY
C***READ POLYGON DESCRIPTION CARD
      READ (5,5000) NSIDES,SUS(I),REMDEC(I),REMDIP(I),REMMAG(I)
 5000 FORMAT (I2,4F10.6)
C***NSIDES = NUMBER OF SIDES FOR THIS POLYGON.
C***SUS    = SUSCEPTABILITY IN E.U FOR THIS POLYGON.
C***REMDEC = DECLINATION OF THE REMANENT MAGNETIZATION VECTOR,J,
C***            POSITIVE CLOCKWISE IN DEGREES FOR THIS POLYGON.
C***REMDIP = INCLINATION OR DIP OF THE REMANENT MAGNETIZATION VECTOR,J,
C***            POSITIVE DOWN IN DEGREES FROM HORIZONTAL FOR THIS POLYGON.
C***REMMAG = MAGNITUDE OF THE REMANENT MAGNETIZATION VECTOR,J, IN EMU
C***            FOR THIS POLYGON
C*******************************************************************************
C***CALL SUBROUTINE POLYPO TO READ IN COORDINATES OF POLYGON CORNERS AND
C***     CALCULATE THE VALUES OF PSUM AND QSUM FOR EACH FIELD POINT
12345678901234567890123456789012345678901234567890123456789012345678901234567890
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Table 6. (Continued)

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1234567890123456789012345678901234567890123456789012345678901234567890
C***      FOR THIS POLYGON.
      CALL POLYPO (NFPTS,NSIDES,FLDPT,OBSVHT,PSUM,QSUM,I,X,Z,DELX)
C***CALCULATE ANOMALY DUE TO INDUCTION FOR THIS POLYGON AT EACH FIELD POINT.****
      MGTION = SUS(I) * FLDINT
      DO 40 J = 1,NFPTS
      VANMLY(J,I,1) =-2.*MGTION*((CDIPR*CDIFFR*QSUM(J))-(SDIPR*PSUM(J)))
      HANMLY(J,I,1) =-2.*MGTION*((CDIPR*CDIFFR*PSUM(J))+(SDIPR*QSUM(J)))
C***FOR ANOMALIES SMALL IN COMPARISON TO THE EARTH'S FIELD, THE INTENSITY OF THE
C***  TOTAL ANOMALY DUE TO INDUCTION IS THE SUM OF THE PROJECTIONS OF THE
C***  VERTICAL AND HORIZONTAL ANOMALIES DUE TO INDUCTION ALONG THE DIRECTION OF
C***  THE EARTH'S FIELD.
      TANMLY(J,I,1) = HANMLY(J,I,1)*CDIPR*CDIFFR + VANMLY(J,I,1)*SDIPR
   40 CONTINUE
C***CALCULATE ANOMALY DUE TO REMANENT MAGNETIZATION FOR THIS POLYGON
 444   40 &ARH 8I8-D POINUH
      CDIP = COS (.0174533*REMDIP(I))
      SDIP = SIN (.0174533*REMDIP(I))
      CDIFF = COS (.0174533*(DECPLX-REMDEC(I)))
      MGTION = REMMAG(I) * 100000.0
      DO 50 J = 1,NFPTS
      VANMLY(J,I,2) = 2.0*MGTION*((CDIP*CDIFF*QSUM(J))-(SDIP*PSUM(J)))
      HANMLY(J,I,2) = 2.0*MGTION*((CDIP*CDIFF*PSUM(J))+(SDIP*QSUM(J)))
C***FOR ANOMALIES SMALL IN COMPARISON TO THE EARTH'S FIELD, THE INTENSITY OF
C***  THE TOTAL ANOMALY DUE TO REMANENT MAGNETIZATION IS THE SUM OF THE
C***  PROJECTIONS OF THE VERTICAL AND HORIZONTAL ANOMALIES DUE TO REMANENT
C***  MAGNETIZATION ALONG THE DIRECTION OF THE EARTH'S FIELD.
      TANMLY(J,I,2) = HANMLY(J,I,2)*CDIPR*CDIFFR + VANMLY(J,I,2)*SDIPR
   50 CONTINUE
C*************END  OF  ANOMALY  CALCULATIONS*****************************************
C*******************BEGIN INDIVIDUAL POLYGON OUTPUT SECTION**********************
C***PRINT ANOMALIES FOR THIS POLYGON AND PLOT.
      DO 130 I = 1,NPOLY
C ADD REMANENT + INDUCED FOR INDIVIDUAL POLYGONS
      DO 60 J = 1,NFPTS
      VWORK(J) = VANMLY(J,I,1) + VANMLY(J,I,2)
      HWORK(J) = HANMLY(J,I,1) + HANMLY(J,I,2)
   60 TWORK(J) = TANMLY(J,I,1) + TANMLY(J,I,2)
C*********PRINT ANOMALIES FOR INDIVIDUAL POLYGONS*******************************
      IF (PRIND) 70,120,70
   70 WRITE (6,6000)I,SUS(I)
 6000 FORMAT(1H1,'POLYGON NUMBER ',I2,/,' SUSCEPTIBILITY IS',
     1F10.6,' EMU',/,' CORNERS ARE ( X , Z )')
      DO 80 J = 1,NSIDES
   80 WRITE (6,7000) X(I,J), Z(I,J)
 7000 FORMAT(1H ,'(',F8.3,',',F8.3,')')
      M = IFIX (1000.0 * REMMAG(I))
      IF (M) 100,90,100
   90 WRITE (6,8000)
 8000 FORMAT (1H0,'MAGNETIZATION IS INDUCED ONLY.')
      GO TO 110
  100 WRITE (6,9000)REMDEC(I),REMDIP(I),REMMAG(I)
 9000 FORMAT(1H0,'MAGNETIZATION IS MIXED.',/,' REMANENT ',
     1'MAGNETIZATION VECTOR IS DEFINED BY',/,' DEC =',F8.3,', INC =',
     2F8.3,' MAGNITUDE =',F10.6,' EMU')
  110 WRITE (6,9001)
 9001 FORMAT(1H0,'ANOMALIES IN GAMMAS',/,1X,24('*****'),/,' FIELD POINT'
     1 ,12X,'INDUCED',29X,'REMANENT',29X,'TOTAL',/,17X,
     2 3('V',9X,'H',9X,'T',15X),/,24('*****'),'*')
      DO 118 J=1,NFPTS
  118 WRITE (6,9002) FLDPT(J),VANMLY(J,I,1),HANMLY(J,I,1),TANMLY(J,I,1)
     1,VANMLY(J,I,2),HANMLY(J,I,2),TANMLY(J,I,2),VWORK(J),HWORK(J),
     2TWORK(J)
 9002 FORMAT (1H ,F9.3,' ',3(3F10.3,5X))
C***PLOT VERTICAL ANOMALY FOR THIS POLYGON -- REMANENT + INDUCED
  120 IF (PLINDV) 121,123,121
  121 FSCALE = 0.0
      CALL CONARY(VANMLY,I,1,WORK1,NFPTS)
      CALL CONARY(VANMLY,I,2,WORK2,NFPTS)
      CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,WORK2,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,VWORK,FSCALE,IEXPO,MAX)
      WRITE (6,9004) I
 9004 FORMAT (1H1,40X,'VERTICAL ANOMALY FOR PLOYGON NUMBER ',I2)
1234567890123456789012345678901234567890123456789012345678901234567890
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Table 6. (Continued)

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1234567890123456789012345678901234567890123456789012345678901234567890123456789
      CALL SPLOT(NFPTS,FLDPT,WORK1,WORK2,VWORK,FSCALE,REMMAG(I),
     * MAX,IEXPO,ITICKS)
C***PLOT HORIZONTAL ANOMALY FOR THIS POLYGON -- REMANENT + INDUCED
  123 IF (PLINDH) 124,125,124
  124 FSCALE = 0.0
      CALL CONARY(HANMLY,I,1,WORK1,NFPTS)
      CALL CONARY(HANMLY,I,2,WORK2,NFPTS)
      CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,WORK2,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,HWORK,FSCALE,IEXPO,MAX)
      WRITE (6,9008) I
 9008 FORMAT (1H1,39X,'HORIZONTAL ANOMALY FOR POLYGON NUMBER ',I2)
      CALL SPLOT(NFPTS,FLDPT,WORK1,WORK2,HWORK,FSCALE,REMMAG(I),
     * MAX,IEXPO,ITICKS)
C***PLOT TOTAL ANOMALY FOR THIS POLYGON -- REMANENT + INDUCED
  125 IF (PLINDT) 126,130,126
  126 FSCALE = 0.0
      CALL CONARY(TANMLY,I,1,WORK1,NFPTS)
      CALL CONARY(TANMLY,I,2,WORK2,NFPTS)
      CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,WORK2,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,TWORK,FSCALE,IEXPO,MAX)
      WRITE (6,9009) I
 9009 FORMAT (1H1,44X,'TOTAL ANOMALY FOR POLYGON NUMBER ',I2)
      CALL SPLOT(NFPTS,FLDPT,WORK1,WORK2,TWORK,FSCALE,REMMAG(I),
     * MAX,IEXPO,ITICKS)
  130 CONTINUE
C*****************END OF INDIVIDUAL POLYGON OUTPUT SECTION***********************
C*****************BEGIN FIELD POINT SUMMATION SECTION****************************
C***ZERO ALL FIELD POINT SUMMING ARRAYS.
      DO 135 I = 1,NFPTS
      VIND(I) = 0.0
      VREM(I) = 0.0
      HIND(I) = 0.0
      HREM(I) = 0.0
      TIND(I) = 0.0
      TREM(I) = 0.0
  135 CONTINUE
      DO 140 I = 1,NFPTS
      DO 137 J = 1,NPOLY
      VIND(I) = VIND(I) + VANMLY(I,J,1)
      HIND(I) = HIND(I) + HANMLY(I,J,1)
      TIND(I) = TIND(I) + TANMLY(I,J,1)
      VREM(I) = VREM(I) + VANMLY(I,J,2)
      HREM(I) = HREM(I) + HANMLY(I,J,2)
  137 TREM(I) = TREM(I) + TANMLY(I,J,2)
      VTOT(I) = VIND(I) + VREM(I)
      HTOT(I) = HIND(I) + HREM(I)
      TTOT(I) = TIND(I) + TREM(I)
  140 CONTINUE
C************************END  FIELD  POINT  SUMMATION  SECTION*******************
C*******************BEGIN COMPOSITE OUTPUT SECTION*******************************
C***PLOT COMPOSITION FOR VERTICAL ANOMALY DUE TO INDUCTION ONLY
      IF (VCOMPI)145,153,145
  145 FSCALE = 0.0
      DO 150 I = 1,NPOLY
      CALL CONARY(VANMLY,I,1,WORK1,NFPTS)
  150 CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,VIND ,FSCALE,IEXPO,MAX)
      WRITE (6,9010)
 9010 FORMAT (1H1,40X,'VERTICAL ANOMALY DUE TO INDUCTION ONLY.')
      CALL CPLOT(NPOLY,NFPTS,FLDPT,VANMLY,1,VIND,FSCALE,1,MAX,IEXPO,
     * ITICKS)
C***PLOT COMPOSITION FOR VERTICAL ANOMALY DUE TO REMANENCE ONLY.
  153 IF (VCOMPR) 155,153,155
  155 FSCALE = 0.0
      DO 160 I = 1,NPOLY
      CALL CONARY(VANMLY,I,2,WORK1,NFPTS)
  160 CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,VREM ,FSCALE,IEXPO,MAX)
      WRITE (6,9011)
 9011 FORMAT (1H1,40X,'VERTICAL ANOMALY DUE TO REMANENCE ONLY')
      CALL CPLOT(NPOLY,NFPTS,FLDPT,VANMLY,2,VREM,FSCALE,1,MAX,IEXPO,
1234567890123456789012345678901234567890123456789012345678901234567890123456789
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Table 6. (Continued)

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12345678901234567890123456789012345678901234567890123456789012345678901234567890
     * ITICKS)
C***PLOT COMPOSITION FOR HORIZONTAL ANOMALY DUE TO INDUCTION ONLY
  163 IF (HCOMPI) 165,173,165
  165 FSCALE = 0.0
      DO 170 I = 1,NPOLY
      CALL CONARY(HANMLY,I,1,WORK1,NFPTS)
  170 CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,HIND ,FSCALE,IEXPO,MAX)
      WRITE (6,9012)
 9012 FORMAT (1H1,40X,'HORIZONTAL ANOMALY DUE TO INDUCTION ONLY')
      CALL CPLOT(NPOLY,NFPTS,FLDPT,HANMLY,1,HIND,FSCALE,2,MAX,IEXPO,
     * ITICKS)
C***PLOT COMPOSITION FOR HORIZONTAL ANOMALY DUE TO REMANENCE ONLY
  173 IF (HCOMPR) 175,183,175
  175 FSCALE = 0.0
      DO 180 I = 1,NPOLY
      CALL CONARY(HANMLY,I,2,WORK1,NFPTS)
  180 CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,HREM ,FSCALE,IEXPO,MAX)
      WRITE (6,9013)
 9013 FORMAT (1H1,40X,'HORIZONTAL ANOMALY DUE TO REMANENCE ONLY')
      CALL CPLOT(NPOLY,NFPTS,FLDPT,HANMLY,2,HREM,FSCALE,2,MAX,IEXPO,
     * ITICKS)
C***PLOT COMPOSITION FOR TOTAL ANOMALY DUE TO INDUCTION ONLY
  183 IF (TCOMPI) 185,193,185
  185 FSCALE = 0.0
      DO 190 I = 1,NPOLY
      CALL CONARY(TANMLY,I,1,WORK1,NFPTS)
  190 CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,TIND ,FSCALE,IEXPO,MAX)
      WRITE (6,9014)
 9014 FORMAT (1H1,40X,'TOTAL ANOMALY DUE TO INDUCTION ONLY')
      CALL CPLOT(NPOLY,NFPTS,FLDPT,TANMLY,1,TIND,FSCALE,3,MAX,IEXPO,
     * ITICKS)
C***PLOT COMPOSITION FOR TOTAL ANOMALY DUE TO REMANENCE ONLY
  193 IF (TCOMPR) 195,205,195
  195 FSCALE = 0.0
      DO 200 I = 1,NPOLY
      CALL CONARY(TANMLY,I,2,WORK1,NFPTS)
  200 CALL GRSCAL(NFPTS,WORK1,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,TREM ,FSCALE,IEXPO,MAX)
      WRITE (6,9015)
 9015 FORMAT (1H1,40X,'TOTAL ANOMALY DUE TO REMANENCE ONLY')
      CALL CPLOT(NPOLY,NFPTS,FLDPT,TANMLY,2,TREM,FSCALE,3,MAX,IEXPO,
     * ITICKS)
  205 CONTINUE
C*********************  END COMPOSITE OUTPUT SECTION*****************************
C***************BEGIN ANOMALIES DUE TO ALL POLYGONS OUTPUT SECTION**************
C***PRINT OUT ANOMALIES DUE TO ALL POLYGONS
      IF (PRNTAL) 206,260,206
  206 REMFLG  = 0.0
      DO 210 I = 1,NPOLY
  210 REMFLG = REMFLG + REMMAG(I)
      WRITE (6,9016) NPOLY
 9016 FORMAT (1H1,'ANOMALIES DUE TO ALL ',I2,' POLYGON(S)')
      IF (REMFLG) 230,220,230
  220 WRITE (6,8000)
      GO TO 240
  230 WRITE (6,9017)
 9017 FORMAT (1H0,'MAGNETIZATION IS MIXED.')
  240 WRITE (6,9001)
      DO 250 I = 1,NFPTS
  250 WRITE (6,9002) FLDPT(I),VIND(I),HIND(I),TIND(I),VREM(I),HREM(I),
    1      TREM(I),VTOT(I),HTOT(I),TTOT(I)
C*************PLOT VERTICAL ANOMALY DUE TO ALL POLYGONS -- REMANENT + INDUCED
  260 IF (PLVAL) 270,281,270
  270 FSCALE = 0.0
      CALL GRSCAL(NFPTS,VIND ,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,VREM ,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,VTOT ,FSCALE,IEXPO,MAX)
      WRITE (6,9018)
 9018 FORMAT (1H1,41X,'VERTICAL ANOMALY DUE TO ALL POLYGONS')
      CALL SPLOT (NFPTS,FLDPT,VIND,VREM,VTOT,FSCALE,REMFLG,MAX,IEXPO,
12345678901234567890123456789012345678901234567890123456789012345678901234567890
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Table 6. (Continued)

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123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
     * ITICKS)
C*************PLOT HORIZONTAL ANOMALY DUE TO ALL POLYGONS - REMANENT + INDUCED
  280 IF (PLHAL) 290,300,290
  290 FSCALE = 0.0
      CALL GRSCAL(NFPTS,HIND ,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,HREM ,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,HTOT ,FSCALE,IEXPO,MAX)
      WRITE (6,9019)
 9019 FORMAT (1H1,41X,'HORIZONTAL ANOMALY DUE TO ALL POLYGONS')
      CALL SPLOT (NFPTS,FLDPT,HIND,HREM,HTOT,FSCALE,REMFLG,MAX,IEXPO,
     * ITICKS)
C*************PLOT TOTAL ANOMALY DUE TO ALL POLYGONS- REMANENT + INDUCED
  300 IF (PLTAL) 310,315,310
  310 FSCALE = 0.0
      CALL GRSCAL(NFPTS,TIND ,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,TREM ,FSCALE,IEXPO,MAX)
      CALL GRSCAL(NFPTS,TTOT ,FSCALE,IEXPO,MAX)
      WRITE (6,9020)
 9020 FORMAT (1H1,45X,,'TOTAL ANOMALY DUE TO ALL POLYGONS')
      CALL SPLOT (NFPTS,FLDPT,TIND,TREM,TTOT,FSCALE,REMFLG,MAX,IEXPO,
     * ITICKS)
  315 GO TO 1
  320 CALL EXIT
      END
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
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123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
      SUBROUTINE GRSCAL(NFPTS,A,FSCALE,IEXPO,MAX)
      DIMENSION A(200)
C*******************************************************************************
C  THIS SUBROUTINE FINDS THE VARIABLE WITH THE GREATEST ABSOLUTE VALUE IN THE
C      ARRAY A WHICH HAS NFPTS ELEMENTS.
C       FSCALE  IS THEN SET EQUAL TO THE SMALLEST VALUE FOR FULL SCALE WHICH WILL
C      BEST PRESENT THE ELEMENTS OF A.
C       IEXPO  AND  MAX  ARE SUCH THAT  FSCALE  =  MAX  * 10 **  IEXPO .
C*******************************************************************************
      DO 15 I = 1,NFPTS
    5 IF (ABS(A(I))-FSCALE) 15,15,10
   10 FSCALE = ABS(A(I))
   15 CONTINUE
C*** IF ALL VALUES OF THE ARRAY ARE ZERO, SET FSCALE = 1.0 ARBITRARILY.
      IF (FSCALE) 20,20,25
   20 FSCALE = 1.0
   25 EXPO = LOG10 (FSCALE)
      IF (EXPO) 30,35,40
   30 IEXPO = EXPO + 1
      GO TO 45
   35 MAX = 1
      RETURN
   40 IEXPO = EXPO
   45 J = FSCALE/(10.0**IEXPO)
      IF (J.LT.2) GO TO 50
      IF (J.LT.5) GO TO 55
      FSCALE = 10.0 * (10.0**IEXPO)
      MAX = 10
      RETURN
   50 FSCALE = 2.0 * (10.0**IEXPO)
      MAX = 2
      RETURN
   55 FSCALE = 5.0 * (10.0**IEXPO)
      MAX = 5
      RETURN
      END
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
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Table 6. (Continued)

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12345678901234567890123456789012345678901234567890123456789012345678901234567890
      SUBROUTINE POLYPQ (NFPTS,NSIDES,FLDPT,OBSVHT,PSUM,QSUM,
     * INDEX,X,Z,DELX)
      DIMENSION EXX(21),ZEE(21),FLDPT(200),PSUM(200),QSUM(200)
      DIMENSION X(10,20),Z(10,20)
C***********************************************************************
C***READ COORDINATE CARDS FOR POLYGON CORNERS
C***ONE COORDINATE CARD FOR EACH CORNER OF THE POLYGON--CLOCKWISE ORDER.
C***EXX(I) = X COORDINATE OF THE ITH CORNER OF POLYGON
C***ZEE(I) = Z COORDINATE OF THE ITH CORNER OF POLYGON, POSITIVE DOWN.
C***********************************************************************
      DO 10 I = 1,NSIDES
      READ (5,1000) EXX(I),ZEE(I)
 1000 FORMAT( )
C***SAVE CORNER COORDINATES FOR PRINTOUT.
      X(INDEX,I) = EXX(I)
   10 Z(INDEX,I) = ZEE(I)
      NSIDP1 = NSIDES + 1
      EXX(NSIDP1) = EXX(1)
      ZEE(NSIDP1) = ZEE(1)
      DO 150 I = 1,NFPTS
      PSUM(I) = 0.0
      QSUM(I) = 0.0
      X1 = EXX(1) - FLDPT(I)
      Z1 = ZEE(1) + OBSVHT
   15 RSQ1 = (X1*X1+Z1*Z1)
C***IF X AND Z ARE BOTH ZERO, ATAN2 GIVES ERROR, SO CHANGE Z SLIGHTLY
      IF (RSQ1.NE.0.0) GO TO 17
      Z1 = .0001 * DELX
      THETD = 0.0
      GL = ALOG (.0001 * DELX * DELX)
      GO TO 15
   17 THETA = ATAN2(Z1,X1)
      J = 2
   20 X2 = EXX(J) - FLDPT(I)
      Z2 = ZEE(J) + OBSVHT
   25 RSQ2 = (X2*X2+Z2*Z2)
      IF (RSQ2.NE.0.0) GO TO 27
      Z2 = .0001 * DELX
      THETD = 0.0
      GL = ALOG (.0001 * DELX * DELX)
      GO TO 25
   27 THETB = ATAN2(Z2,X2)
      IF (Z1-Z2) 40,30,40
   30 P = 0.0
      Q = 0.0
      GO TO 120
   40 OMEGA = THETA - THETB
      IF (OMEGA) 60,50,50
   50 IF(OMEGA-3.1415927) 70,70,90
   60 IF(OMEGA+3.1415927) 80,70,70
   70 THETD = OMEGA
      GO TO 110
   80 IF(OMEGA) 90,100,100
   90 THETD = OMEGA - 6.2831853
      GO TO 110
  100 THETD = OMEGA + 6.2831853
  110 GL = 0.5 * ALOG(RSQ2/RSQ1)
  115 X12 = X1 - X2
      Z21 = Z2 - Z1
      XSQ = X12 * X12
      ZSQ = Z21 * Z21
      XZ = Z21 * X12
      P =-((ZSQ/(XSQ+ZSQ))*THETD) + ((XZ/(XSQ+ZSQ))*GL)
      Q =-(THETD*(XZ/(XSQ+ZSQ))) - (GL*(ZSQ/(XSQ+ZSQ)))
  120 PSUM(I) = PSUM(I) + P
      QSUM(I) = QSUM(I) +Q
C***RELABEL VARIABLES INVOLVING ONLY THE SECOND POLYGON CORNER AS THE
C*** VARIABLES INVOLVING ONLY THE FIRST POLYGON CORNER SO THEY DON'T
C***   HAVE TO BE CALCULATED AGAIN.
  140 X1 = X2
      Z1 = Z2
      RSQ1 = RSQ2
      THETA = THETB
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Table 6. (Continued)

```
123456789012345678901234567890123456789012345678901234567890123456789012345678 90
C***CHECK TO SEE IF ALL SIDES HAVE BEEN DONE.
      J = J + 1
      JR = J - 1
      IF(JR-NSIDP1) 20,150,150
  150 CONTINUE
      RETURN
      END
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
      SUBROUTINE CONARY (ARRAY1,I,J,ARRAY2,NFPTS)
      DIMENSION ARRAY1(200,10,2),ARRAY2(200)
C***********************************************************************************
C    THIS SUBROUTINE SELECTS THE DESIGNATED ELEMENTS OF THE THREE DIMENSIONAL
C       ARRAY, ARRAY1  AND PUTS THEM INTO A ONE DIMENSIONAL ARRAY, ARRAY2)
C       THAT IS  ARRAY2(1) = ARRAY1(1,I,J)  THRU TO
C                ARRAY2(NFPTS) = ARRAY1(NFPTS,I,J)   ARE PERFORMED.
C***********************************************************************************
      DO 10 K = 1,NFPTS
   10 ARRAY2(K) = ARRAY1(K,I,J)
      RETURN
      END
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Table 6. (Continued)

```
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
      SUBROUTINE SPLOT (NFPTS,FLDPT,A,B,C,FSCALE,REMFLG,MAX,IEXPO,
     * ITICKS)
      DIMENSION  A(200),B(200),C(200),FLDPT(200),ALINE(101)
      REAL II
      DATA BLNK/1H /,AST/1H*/,DOT/1H./,RR/1HR/,II/1HI/,DASH/1H-/,PLS/1H+
C**********************************************************************
C  THIS SUBROUTINE GENERATES A LINE PRINTER PLOT OF THE ELEMENTS OF THE ARRAYS
C    A , B , AND  C  VS. THE FIELD POINTS, FLDPT .
C    FLDPT  ELEMENTS ARE LISTED ALONG THE ABSCISSA AND THE ARRAY ELEMENTS
C    PLOTTED ALONG THE ORDINATE. HATCH MARKS ARE PLACED ALONG THE ABSCISSA
C    EVERY  ITICKS TH POINT.
C    FSCALE  IS THE FULL SCALE LIMIT OF THE PLOT.
C    FSCALE  =  MAX  * 10 **  IEXPO
C    REMFLAG  PERMITS CHOICE OF PLOTTING SYMBOLS DEPENDING ON WHETHER THE MAG-
C     NETIZATION IS MIXED OR NOT.
C    REMFLAG     0 , USE SYMBOLS FOR INDUCTION ONLY
C               = 1 , USE SYMBOLS FOR MIXED MAGNETIZATION
C**********************************************************************
      N = ITICKS
      WRITE (6,500) IEXPO,IEXPO,MAX,MAX
  500 FORMAT (1H ,17X,I1,99X,I1,/,12X,'-',I2,'X10',47X,'0',46X,'+',
     1 I2,'X10',/,' FIELD POINT',3X,21('.    '),/,15X,21(5H'    ))
      WRITE (6,600)
  600 FORMAT (1H+,14X,20('+....'),'+')
      DO 10 I = 1,101
   10 ALINE(I) = BLNK
      ALINE(  1) = DOT
      ALINE( 51) = DOT
      ALINE(101) = DOT
      DO 30 I = 1,NFPTS
      IF (ITICKS-N) 13,12,13
   12 N = 1
      ALINE(  1) = PLS
      ALINE(  2) = DASH
      ALINE( 50) = DASH
      ALINE( 51) = PLS
      ALINE( 52) = DASH
      ALINE(100) = DASH
      ALINE(101) = PLS
      GO TO 14
   13 N = N + 1
   14 J = 51.500001 + (A(I)/FSCALE)*50
      M = IFIX (1000.0 * REMFLG)
      IF (M) 16,15,16
   15 ALINE(J) = AST
      L = J
      K = J
      GO TO 18
   16 ALINE(J) = II
      K = 51.500001 + (B(I)/FSCALE) * 50.0
      ALINE(K) = RR
      L = 51.500001 + (C(I)/FSCALE) * 50.0
      ALINE(L) = AST
   18 WRITE (6,1000) FLDPT(I),ALINE
 1000 FORMAT(1H ,F10.2,4X,101A1)
      WRITE (6,2000)
 2000 FORMAT (1H+,14X,1H',99X,1H')
      IF (N-1) 25,20,25
   20 ALINE (  2) = BLNK
      ALINE ( 50) = BLNK
      ALINE ( 52) = BLNK
      ALINE (100) = BLNK
   25 ALINE(L) = BLNK
      ALINE(K) = BLNK
      ALINE(J) = BLNK
      ALINE(  1) = DOT
      ALINE( 51) = DOT
      ALINE(101) = DOT
   30 CONTINUE
      WRITE (6,3000)
 3000 FORMAT (1H ,14X,20('+....'),'+')
      RETURN
      END
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Table 6. (Concluded)

```
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
      SUBROUTINE CPLOT(NPOLY,NFPTS,FLDPT,A,K,B,FSCALE,INDEX,MAX,IEXPO,
     * ITICKS)
      DIMENSION FLDPT(200),A(200,10,2),B(200),ALINE(101),SUM(3),LINE(11)
      REAL NUM(10)
      DATA BLNK/1H /,DOT/1H./,(NUM(I),I=1,10)/1H1,1H2,1H3,1H4,1H5,1H6,
     *  1H7,1H8,1H9,1H0/,(SUM(I),I=1,3)/1HV,1HH,1HT/,DASH/1H-/,PLS/1H+/
C  THIS SUBROUTINE GENERATES A COMPOSITE LINE PRINTER PLOT OF THE ELEMENTS OF
C     THE ARRAY  A  AS FOLLOWS . NOTE  A  IS DIMENSIONED AS  A(200,10,2) .
C     THIS SUBROUTINE WILL PLOT THE POINTS  A(ALPHA,BETA,1)  OR
C      A(ALPHA,BETA,2) AS DESCRIBED BY THE FOLLOWING.  NPOLY  PLOTTING SYMBOLS
C     ARE PLOTTED FOR EACH VALUE OF THE ABSCISSA. FOR  NFPTS  FIELD POINTS. ALSO
C     FOR EACH VALUE OF THE ABSCISSA A PLOTTING SYMBOL REPRENTING THE CORRESPOND-
C     ING ELEMENT OF THE ARRAY  B , WHICH IN THIS CASE REPRESENTS THE ALGEBRAIC
C     SUM OF THE  NPOLY  VALUES FOR ARRAY  A  IS ALSO PLOTTED.
C     FLDPT  ELEMENTS ARE LISTED ALONG THE ABSCISSA AND THE ARRAY ELEMENTS OF
C      A  AND  B  ARE PLOTTED ALONG THE ORDINATE.  HATCH MARKS ARE PLACED ALONG
C     THE ABSCISSA EVERY  ITICKS TH POINT.   FSCALE  IS THE FULL SCALE LIMIT OF
C     THE PLOT.   FSCALE  = MAX  * 10 **  IEXPO .
      N = ITICKS
      WRITE (6,500) IEXPO,IEXPO,MAX,MAX
  500 FORMAT (1H ,17X,I1,99X,I1,/,12,'-',I2,'X10',47X,'0',46X,'+',
     1 I2,'X10',/,' FIELD POINT',3X,21('.    '),/,15X,21(5H'    ))
      WRITE (6,600)
  600 FORMAT (1H+,14X,20('+....'),'+')
      DO 10 I = 1,101
   10 ALINE(I) = BLNK
      ALINE(  1) = DOT
      ALINE( 51) = DOT
      ALINE(101) = DOT
      DO 40 I = 1,NFPTS
      IF (ITICKS-N) 13,12,13
   12 N = 1
      ALINE(  1) = PLS
      ALINE(  2) = DASH
      ALINE( 50) = DASH
      ALINE( 51) = PLS
      ALINE( 52) = DASH
      ALINE(100) = DASH
      ALINE(101) = PLS
      GO TO 14
   13 N = N + 1
   14 DO 20 J = 1,NPOLY
      L = 51.500001 + (A(I,J,K)/FSCALE) * 50.0
C***SAVE NUMBER OF THE ELEMENT WHICH WAS CHANGED FROM BLANK
      LINE(J) = L
C***REPLACE BLANK LINE ELEMENT BY CHARACTER FOR DATA POINT.
   20 ALINE(L) = NUM(J)
      L = 51.500001 + (B(I)/FSCALE) * 50.0
      ALINE(L) = SUM(INDEX)
C***J IS NOW = NPOLY + 1
      LINE(J) = L
      WRITE(6,1000) FLDPT(I),ALINE
 1000 FORMAT(1H ,F10.2,4X,101A1)
      WRITE (6,2000)
 2000 FORMAT (1H+,14X,1H',99X,1H')
C***RESTORE BLNKS TO THOSE LINE ELEMENTS WHICH WERE CHANGED
      DO 30 L = 1,J
      M = LINE(L)
   30 ALINE(M) = BLNK
C***RESTORE DOTS TO THOSE LINE ELEMENTS WHICH MAKE UP THE AXIS AND MAY HAVE
C***     BEEN CHANGED.
      IF (N-1) 38,35,38
   35 ALINE (  2) = BLNK
      ALINE ( 50) = BLNK
      ALINE ( 52) = BLNK
      ALINE (100) = BLNK
   38 ALINE(  1) = DOT
      ALINE( 51) = DOT
      ALINE(101) = DOT
   40 CONTINUE
      WRITE (6,3000)
 3000 FORMAT (1H ,14X,20('+....'),'+')
      RETURN
      END
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
```

APPENDIX IV

PALEOMAGNETIC DATA COLLECTION AND REDUCTION

Samples from the Meriwether dike were collected and analyzed for NRM (Natural Remanent Magnetization) by Doyle Watts of the Ohio State University. Thirteen cores were obtained from a single outcrop of the Meriwether dike 5.5 miles northeast of Greenville on Georgia State Highway 362. In all, 26 one inch cylinders were cut from the cores. The samples were analyzed for Natural Remanent Moment (no magnetic cleaning) using a Schonstedt SSM1 Spinner Magnetometer. Direction and magnitude of the NRM are given for each sample in Table 7. Sample numbers are those used by Watts (personal communication) and the letter A, B, or C following the number indicates the first, second, or third cylinder cut from a core. Cores NW73174 through NW73182 were taken from the center portion of the dike and the remaining cores from the chilled edges of the dike.

Table 7. Natural Remanent Moments of Cores Taken From

The Meriwether Dike (Watts, Personal Communication)

Ohio State University Sample Number	Remanent Moment Magnitude	Declination	Inclination
NW73174B	0.00144	7.82	26.26
NW73175A	0.00144	2.98	28.54
NW73175B	0.00156	8.86	35.49
NW73176B	0.00150	1.03	35.39
NW73177B	0.00150	21.69	27.86
NW73177C	0.00151	18.31	35.96
NW73178B	0.00174	12.42	25.20
NW73178C	0.00168	13.94	26.29
NW73179B	0.00152	18.10	22.61
NW73179C	0.00149	22.29	21.84
NW73180B	0.00173	10.08	26.39
NW73180C	0.00175	14.89	25.46
NW73180D	0.00170	12.01	27.20
NW73181B	0.00166	14.77	29.96
NW73182B	0.00162	16.20	23.21
NW73182C	0.00153	19.51	25.58
NW73183B	0.00215	36.16	27.72
NW73183C	0.00220	36.84	31.15
NW73184B	0.00211	33.78	23.38
NW73184C	0.00173	30.42	16.23
NW73185B	0.00201	42.87	27.96
NW73185C	0.00193	46.15	27.09
NW73186B	0.00220	42.11	32.70
NW73186C	0.00210	46.66	31.44
NW73187B	0.00212	49.75	30.89
NW73187C	0.00216	42.37	30.95

BIBLIOGRAPHY

BIBLIOGRAPHY

Armstrong, R.L., and J. Besancon. A triassic time scale dilemma: K-Ar dating of Upper Triassic mafic igneous rocks of eastern U.S.A. and Canada and Post-Upper Triassic plutons, western Idaho, U.S.A. Eclogae geol. Helv., 63(1), 15-38, 1970.

Balsley, J.R., and A.F. Buddington. Iron-Titanium Oxide minerals, rocks, and aeromagnetic anomalies of the Adirondack Area, New York. Economic Geology, 53, 777-805, 1958.

Bentley, R.D., and T.L. Neathery. Geology of the Brevard zone and related rocks of the inner Piedmont of Alabama. Alabama Geol. Survey, 8th Annual Field Trip Guidebook, Dec. 4-5, 1970.

Cohee, C.V., Chairman. Tectonic Map of the United States excluding Alaska and Hawaii. U.S. Geological Survey and American Association of Petroleum Geologists, scale 1:2,500,000, 1962.

de Boer, Jelle. Paleomagnetic-tectonic study of Mesozoic dike swarms in the Appalachians. J. Geophys. Res., 72(8), 2237-2250, 1967.

Dobrin, M.B. Introduction to Geophysical Prospecting. Second edition, McGraw-Hill, 446 pages, 1960.

Dorman, Leroy M., and Robert E. Ziegler. Gravimetric reference base net, State of Georgia. Georgia Geological Survey, in preparation.

Garland, George D. Introduction to Geophysics - Mantle, Core, and Crust. Saunders, 420 pages, 1971.

Georgia Department of Mines, Mining, and Geology. Geologic Map of Georgia, scale 1:500,000, 1939.

Green, R. Remanent magnetization and the interpretation of magnetic anomalies. Geophysical Prospecting, 8, 98-110, 1960.

Hood, Peter. Remanent magnetism - a neglected factor in aeromagnetic interpretation. Canadian Mining Journal, 84(4), 76-79, 1963.

Johnson, Robert W., and Joel S. Watkins, Aeromagnetic map of Staunton and vicinity, Virginia. U.S. Geological Survey, Geophysical Investigations Map GP-414, scale 1:62,500, 1963.

King, P.B. Systematic pattern of Triassic dikes in the Appalachian region. Geological Survey Research 1961, U.S. Geol. Survey Prof. Paper 424-B, B93-B95, 1961.

Lee, Doyce L. A diabase dike in Meriwether County, Georgia (abstr.) Bull. of the Ga. Acad. of Sci., 29(2), 127, 1971.

Lester, J.G., and A.T. Allen. Diabase of the Georgia Piedmont. Bull. of the Geol. Soc. of Amer., 61, 1217-1224, 1950.

Matshusita, S., and Wallace H. Campbell, editors. Physics of Geomagnetic Phenomena, Vol 1. Academic Press, 1967.

May, P.R. Pattern of Triassic-Jurassic diabase dikes around the North Atlantic in the context of predrift position of the continents. Geol. Soc. of Amer. Bull., 82, 1285-1292, 1971.

National Aeronautics and Space Administration. Earth Resources Aircraft Program, Screening and Indexing Report, Mission 131. Manned Spacecraft Center; Houston, Texas; September 1970. Film: Mission 131, site 217, roll 3, Color infrared Zeiss camera, frames 43, 44, and 45, 1970.

Petty, A.J., F.A. Petrafeso, and F.C. Moore, Jr. Aeromagnetic Map of the Savannah River Plant Area South Carolina and Georgia. U.S. Geological Survey, Geophysical Investigations Map GP-489, scale 1:250,000, 1965.

Philbin, P.W., F.A. Petrafeso, and C.L. Long. Aeromagnetic Map of the Georgia Nuclear Laboratory Area, Georgia. U.S. Geological Survey Geophysical Investigations Map GP-488, scale 1:250,000, 1964.

Privett, Donald R. Structure and petrography of some diabase dikes in central South Carolina (abstr.). Geol. Soc. Amer. Spec. Paper 87, p. 260, 1966.

Stockwell, C.H., Chairman. Tectonic Map of Canada. Canada Geological Survey, Map 1251A, scale 1:5,000,000, 1969.

Strangway, D.W. Interpretation of the magnetic anomalies over some Precambrian dikes. Geophysics , XXX(5), 783-796, 1965.

Talwani, Manik, J.L. Worzel, and Mark Landisman. Rapid gravity computations for two-dimensional bodies with application to the Mendocino submarine fracture zone. J. Geophys. Res., 64(1), 49-59, 1959.

Talwani, Manik, and James R. Heirtzler. Computation of magnetic anomalies caused by two-dimensional structures of arbitrary shape. Computers in the Mineral Industries, Part I, Stanford University Publications, Geol. Sci., 9(1), 464-480, 1965.

U.S. Geological Survey. North-Central Georgia Aeromagnetic Map. Georgia Geological Survey, in preparation.

Watson, Thomas L. Granites and gneisses of Georgia. Geological Survey of Georgia Bull. 9A, 1902.

Weigand, Peter W., and Paul C. Ragland, Geochemistry of Mesozoic dolerite dikes from eastern North America. Contr. Mineral and Petrol., 29, 195-214, 1970.

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EFFECTS OF CRUSTAL FEATURES ON THE GRAVITY FIELD AND ISOSTATIC COMPENSATION

FINAL REPORT

Leland Timothy Long

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13. ABSTRACT

The main purpose of the gravity analysis was to investigate the effects of crus features and major geologic units on gravity anomalies and on isostatic compensation The study of isostatic compensation utilized the theory of Dorman and Lewis in which topographic features were assumed to be related linearly to compensation and its corresponding Bouguer anomaly. An isostatic response function was derived directly from the relation between topography and Bouguer anomalies in the southeastern Unite States. The results of the analysis indicate over compensation with either undercom pensation at 150 km depths or lateral compensation. Another possibility is lateral crustal inhomogeneity. Interpretations with lateral inhomogeneities are preferred because detailed gravity data have revealed numerous anomalously shallow high-densit crustal structures in the southeastern United States.

In general in the southeastern United States lateral inhomogeneities in the cru are significant and must be considered in any analysis of the crustal response to applied stresses. This fact was particularly evident in attempting to compute an isostatic response function. The analysis also strongly supports vertical movement crustal blocks as a major tectonic mechanism in the southeastern United States.

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EFFECTS OF CRUSTAL FEATURES ON THE GRAVITY FIELD AND ISOSTATIC COMPENSATION

Statement of Problem Studied

The main purpose of the gravity analysis was to investigate the effects of crustal features and major geologic units on the gravity field and isostatic compensation.

Crustal features and major geologic units have been examined by obtaining detailed field data near known structures or by obtaining detailed gravity data in lines across structures. Conventional analysis methods have been used to relate the observed gravity anomalies to the interpreted shape of these structures. Conventional analysis methods have also been applied to gridded regional gravity data in the southeastern United States. The analysis in these investigations was directed toward accumulating evidence implicating recent crustal movement in response to isostatic stresses as a major tectonic mechanism of the southeastern United States.

The study of isostatic compensation utilized the theory presented by Dorman and Lewis (1970) and Lewis and Dorman (1970). In application of the theory, topographic features were assumed to be related linearly to compensating masses. The object was then to derive the functional relation between the topography and the Bouguer anomalies derived from the compensating masses. Similarly density anomalies in the crust should be functionally related to Bouguer anomalies. Attempts were made to include surface densities and short wavelength anomalies in the derivation of the response function. Attempts were also made to interpret the response function in terms of isostatic mechanisms or crustal structure.

Results and Conclusions Reached

The research covered by this grant proceeded in two stages. The first stage was a preliminary analysis based on incomplete data. As a result of the preliminary analysis tentative conclusions were derived and utilized to establish more specific goals for the second stage of research. The second stage in the analysis in most cases supported the conclusions of the first stage of analysis.

Preliminary results

An isostatic response function can be derived for an area as small as the southeastern United States. However, the truncation of structures at the edge of the 512 x 512 km square area requires that the derivation of Dorman and Lewis (1970) be modified to utilize the first derivatives in the computation of the isostatic response function. Also, the numerical precision of the data must be carefully evaluated to prevent these errors from dominating the results. At wavelengths less than 30 km the Bouguer anomalies and elevation were virtually random functions and uncorrelated in the southeastern United States.

The response function derived for the southeastern United States showed a significant oscillatory character. The response function for a linear impulse in topography according to the derived function would be positive from 50 to 125 km and slightly negative from 125 to 250 km. The positives in the response function effectively balance an anomalously high ratio of Bouguer anomalies to elevation of -0.14 mgals/meter. This anomalously high value at long wavelengths implies that mountains in the southeastern United States are over compensated and should be experiencing isostatic forces compatible with uplift. Contemporary uplift is supported by releveling data (Meade, 1971). The response function for the southeastern United States also showed significant asymmetry which is probably related to the asymmetry of the continental margin.

The existence of oscillations in the response function as opposed to the nearly uniform decay such as observed by Dorman and Lewis (1970) has significant tectonic implications. Primarily, the response function observed contains wavelengths much shorter than typically observed in crustal loading or unloading such as caused by glacial rebound. The significance of this difference is perhaps that two independent mechanisms are involved. The mechanism for glacial rebound is a short-term elastic deformation of the crust, in which the rate of deformation is controlled primarily by the viscosity of the upper mantle. The mechanism for the observed isostatic response function is perhaps a non-linear deformation of the crust. The causitive stresses would be long-term stresses related to the inherent isostatic inequilibrium of crustal structures (Artyushkov, 1974). For the longer durations involved the mantle is virtually a perfect fluid.

Inversion of the isostatic response function requires that constraints be applied to obtain a solution because potential data are inherently non-unique. The most common restraint for isostasy is to assume local compensation (Dorman and Lewis, 1972). For the southeastern United States a solution constrained by local compensation would require significant negative compensation below 150 km. A physical mechanism which can explain the existence of negative compensation at depths of 150-200 kilometers can be derived from recent movement of the North American plate. This mechanism requires that the roots of the mountainous regions displace the upper mantle downward. Because the downward displaced material is cooler, the equilibrium depths of phase changes in the crystalline structure shifts upward causing increased density of the material and consequently negative compensation. This mechanism introduces a momentary density instability in the mantle which has been utilized as a driving mechanism for a model of mantle convection (Lowell and Bodvarsson, 1973). However, significant phase transformations are currently unknown in the depth range of 150 to 250 km. This physical model could have also explained the existence of asymmetry in the response function.

While the physical model for negative compensation at depth is plausable, the model is not supported by gravity data which indicate that many of the geologic structures which undoubtedly contribute to the oscillation of the response function are within the crust. The oscillation wavelength of the isostatic response function indicates that a block width of 50 to 100 km would be appropriate for lateral compensation. At least three physical models can explain the existence of the lateral inhomogeneity of the crust. The first is an isostatic reaction of crustal blocks to erosion or depositional loading such as has occurred in the coastal plain regions of the southeastern United States. The second is an attachment of island arcs or crustal fragments onto the southeast edge of the North American Plate during the closing of a proto-Atlantic ocean. Evidence for island arc configurations exist in the Piedmont Province of Georgia and South Carolina (Denman, 1974). The third is the intrusion of basic rocks during the early development stage of the Atlantic ocean. (See Long and Lowell, 1973).

Revised objectives

The main objective for the second stage of the gravity analysis was, as in the first stage, to investigate the effects of crustal features and major geologic units on the gravity field and isostatic compensation. As a consequence of the preliminary results from the first stage the following six more specific objectives were developed.

1. Compute and invert the response function with a revised and expanded data set.

2. Evaluate the significance in the difference between the isostatic response function and observed deformation of glacial rebound.

3. Evaluate the significance and influence of an intermediate crustal layer.

4. Compare classical models for computing isostatic anomalies to the observed response functions.

5. Model the isostatic response of the crust by use of numerical methods and include in the model the effects of temperature changes, viscosity, erosion, deposition and other parameters which might influence the isostatic response function.

6. Support detailed gravity field work.

Conclusions

The complete data set did not change the preliminary isostatic response function significantly. Consequently most of the preliminary results remain unchanged. Evaluation of the revised objectives indicate the following conclusions.

1. The isostatic response function obtained with the more complete data set was virtually the same as was obtained previously. Inversion techniques have been investigated by Dorman and Lewis (1972). However, for the southeastern United States data inversions with local compensation do not give realistic solutions for density distributions with depth. The conclusions with respect to lateral compensation are the same as given above.

2. The best explanation for the difference between the crustal response to glacial unloading and the observed isostatic response function perhaps relates to the manner in which the isostatic stresses are distributed and the character of material flow in the upper mantle. Glacial unloading at the earth's surface creates a regional or smooth stress at the crust-mantle contact which remains within the elastic limit of the crust and which excites viscus flow in the mantle. In contrast the stresses for the long-term non-elastic, non-linear deformation of the crust are localized stresses related to Moho topography or anomalous density structures in the crust. The mantle is a virtual fluid for the longer time periods involved.

3. A detailed gravity data line across north Georgia (Long, 1974) indicates that intermediate layer undulates with the topography. In the Coastal Plain an intermediate layer may not exist as a discrete layer since in places crustal material with perhaps composition similar to that expected for the intermediate layer approaches the surface. Explanations for the correlation of density anomalies at depth with topography could include the influence of vertical uplift of discrete crustal blocks and lateral variations in crustal structure generated by some currently inactive tectonic mechanism.

4. None of the classical models for computing isostatic anomalies are compatible with the strong negative compensation at greater depths or the effects of lateral variations in crustal structure like those observed in the isostatic response function for the southeastern United States. Smoothed free air anomalies were utilized almost entirely for the evaluation of isostatic equilibrium.

5. The utilization of numerical methods to generalize the crustal response was not attempted beyond the evaluation of elevation versus heat flow (Long and Lowell, 1973). Such an analysis would require computations which are significantly more involved than allowed by the available time or resources on this grant. Preliminary analysis indicates that there exists a significant potential for results through application of numerical techniques to problems of the crustal response to stress.

6. The support for detailed gravity studies in the field has made possible a number of gravity anomaly maps of significant

structures in the southeastern United States (see Long, 1974). Additional data were obtained with the objective of obtaining evidence of vertical crustal movement. In general the data support the existence of recent vertical movements.

Some of the detailed gravity studies were in conjunction with seismic monitoring in the epicentral regions of recent earthquakes. Partially as a result of the detailed gravity data a relation has been shown to exist between interpreted structures and the locations of aftershocks. In the case of Bowman and Summerville, South Carolina, high-density and high-velocity geologic units in the crust are spacially associated with earthquakes. These units have higher rigidity than the surrounding crustal material and the rigidity contrast allows amplification of low-level regional stresses. Earthquakes occur where the geometry would predict the greatest amplification of regional stress.

Recommendations

This research has shown that the lateral inhomogeneity of the crust in the southeastern United States prohibits the application of techniques which are based on uniform layers. Therefore, it is recommended that the study of tectonics or crustal deformation be investigated by numerical methods as suggested in objective 5 above.

Continued support for detailed studies are recommended so that more areas may be mapped with the one kilometer spacing required for resolution of structures in the upper crust.

Although direct computation of the isostatic response function does not always yield results directly related to isostasy, similar analyses are recommended for other areas so that the variation in the influence of lateral variations may be evaluated.

Bibliography

Artyushkov, E. V. (1974). Can the earth's crust be in a state of isostasy, J. Geophys. Res., 79, pp. 741-752.

Denman, H. E. (1974). Implications of seismic activity at the Clark Hill Reservoir. Masters Thesis, Georgia Institute of Technology. 103 pp.

Dorman, L. M., and B. T. R. Lewis (1970). Experimental isostasy, 1, Theory of the determination of the earth's isostatic response to a concentrated load, J. Geophys. Res., 75, pp. 3357-3365.

Dorman, L. M., and B. T. R. Lewis (1972). Experimental isostasy, 3, Inversion of the isostatic Green function and lateral density changes, J. Geophys. Res., 77, pp. 3068-3077.

Lewis, B. T. R., and L. M. Dorman (1970). Experimental isostasy, 2, An isostatic model for the U.S.A. derived from gravity and topographic data, J. Geophys. Res., 75, pp. 3367-3386.

Lowell, R. P., and G. Bodvarsson (1973). A one-dimensional convection model: Application to an internally heated two-phase mantle. Jokull, 23, pp. 19-36.

Meade, B. K. (1971). Report of the sub-commission on recent crustal movement in North America, Paper presented at XV Gen. Assembly of IUGG - International Association of Geodesy, Moscow, USSR. Aug. 2-14, NOS, NOAA.

Publications Supported by Grant

Long, L. T., S. R. Bridges and LeRoy Dorman (1972). Simple Bouguer gravity map of Georgia, Georgia Geological Survey, 8.5 x 11 inches 2 pp explanation.

Long, L. T., and R. P. Lowell (1973). Thermal model for some continental margin sedimentary basins and uplift zones, Geology, Vol. 1, No. 2, pp 87-88.

Long, Leland Timothy (1974). Bouguer gravity anomalies of Georgia, Bulletin 87, Georgia Geological Survey, Symposium on the Petroleum Geology of the Georgia Coastal Plain, pp 141-166.

Long, Leland Timothy, Pradeep Talwani, and S. R. Bridges (1975). Simple Bouguer Gravity of South Carolina, South Carolina Division of Geology, Map with explanation (in preparation).

Thesis

Rothe, George H., III (1973). Geophysical Investigation of a diabase dike, Masters Thesis, Georgia Institute of Tecnnology, Atlanta, Georgia.

Presentations at Scientific Meetings

Bridges, S. R., Study of a positive Bouguer gravity anomaly in Tift County, Georgia. Presented at Georgia Academy of Science, April, 1973.

Long, L. T., S. R. Bridges, and LeRoy Dorman, Bouguer anomaly map of Georgia, Presented at Southeastern Section meeting of the Geological Society of America, March, 1972.

Talwani, Pradeep, Leland T. Long and Samuel R. Bridges, Regional gravity anomalies and crustal structure in South Carolina. Presented at Annual meeting of the Geological Society of America, November, 1974.

Participating Personnel

The research has provided an opportunity to exchange ideas with researchers in southeastern universities and government agencies. At Georgia Tech the research has contributed to the education of many graduate and undergraduate students. The following students worked full time for at least one term on the research.

S. K. Bridges (undergraduate and graduate assistant) B.S. in Physics with Geophysics Minor.

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