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GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT INITIATION

Date: 5/5/71

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

Project No.: A-1331

Project Director: Dr. L. T. Long

Sponsor: Army Research Office - Durham

Effective . . . . . . May 3, 1971 . . . . Estimated to run until: . . . . . May 2, 1973

Type Agreement: . . Grant No. DA-ARO-D-31-124-71-G117 . . . . . Amount: $ 23,704.00*

*Georgia Tech Contribution of $1,248 brings the total amount available for the project to $24,952.00.

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Reports Required: Progress Reports - due 10/31/71, 4/30/72, 10/31/72
Final Technical - due 6/2/73

Assigned to . . . . Chemical Sciences & Materials . . . . . Division

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RA-62(12-66)

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT TERMINATION

Date August 2, 1973

PROJECT TITLE: Effects of Crust[illegible] Features on the Gravity Field and Isostatic Compensation

PROJECT NO: A-1331

PROJECT DIRECTOR: Dr. L. T. Long

SPONSOR: ARO - Durham

TERMINATION EFFECTIVE: 6/30/73 (Final Technical Report waived)*

CHARGES SHOULD CLEAR ACCOUNTING BY: 6/30/73

Grant Closeout Items Remaining - Final Fiscal Report ASAP

See also - E-100-544

*Follow-on project is G-35-608; that Final Report will cover this project period also.

SPECIAL TECHNIQUES

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Form EES 402 (R10-62)

A-1331

PROGRESS REPORT

1. ARO-D PROPOSAL NUMBER: 9110-EN

2. PERIOD COVERED BY REPORT: May 3, 1971 to September 30, 1971

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

4. CONTRACT OR GRANT NUMBER: DA-ARO-D-31-124-71-G117

5. NAME OF INSTITUTION: Georgia Institute of Technology

6. AUTHOR(S) OF REPORT: Leland Timothy Long

7. LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO-D SPONSORSHIP DURING THIS PERIOD, INCLUDING JOURNAL REFERENCES:

-none-

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

Leland Timothy Long
S. Rutt Bridges
C. A. Sparrow

Dr. L. T. Long
Georgia Institute of Technology
Atlanta, Georgia 30332

9110-EN

BRIEF OUTLINE OF RESEARCH FINDINGS

The research during the first report period has been concerned with two preliminary aspects in the analysis. The first is developing and implementing the computer programs required to manipulate the large number of data values expected. The second is accumulating and examining all sources of data.

The first was aided by Mr. C. A. Sparrow, at the Rich Electronic Computer Center, and has resulted in the establishment of an ordered file of gravity data, with the programs required to utilize the data. Programs have also been developed to convert data to standard format and change latitude and longitudes to map scales.

The second, the examination of the data, is complete for the State of Georgia. This portion of the work was aided by Mr. S. Rutt Bridges. In examining the data, a complete set of maps in one degree squares, covering the areas of 80° to 86°W and 30° to 36°N, were plotted and contoured, using a General Purpose Contouring Program. Anomalous, redundant, and obviously erroneous data points have been removed from the file of degree squares covering Georgia, and the maps where necessary, replotted. The current file includes 4,092 data points. Areas where the data are sparse have been identified and field trips are being designed to gather the needed extra data. The topographic effect has also been examined. Some stations in North Georgia (i.e., Brasstown Bald at -10 mgal.) are affected strongly by topography and more extensive reductions may be necessary.

Some additional data were obtained during the period. A detailed line spacing less than ½ mile across the Central Piedmont was initiated and is expected to provide valuable details in the gravity field. Data was also taken in South-Central Georgia to further define an anomalous gravity high. Rutt Bridges is extending this analysis to include other geophysical data as part of a directed study course in the School of Geophysical Sciences.

A file of data at appropriate map scale (Lambert Projection, two standard parallels) has also been established and will be contoured as soon as the data and programs are free of errors.

PROGRESS REPORT

1. ARO-D PROPOSAL NUMBER: 9110-EN

2. PERIOD COVERED BY REPORT: October 1, 1971 to March 31, 1972

3. TITLE OF PROPOSAL: EFFECTS OF CRUSTAL FEATURES ON THE GRAVITY FIELD AND ISOSTATIC COMPENSATION

4. CONTRACT OR GRANT NUMBER: DA-ARO-D-31-124-71-G117

5. NAME OF INSTITUTION: Georgia Institute of Technology

6. AUTHOR(S) OF REPORT: Leland Timothy Long

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   None

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   F. B. Jones
   J. H. McKee

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9110-EN

BRIEF OUTLINE OF RESEARCH FINDINGS

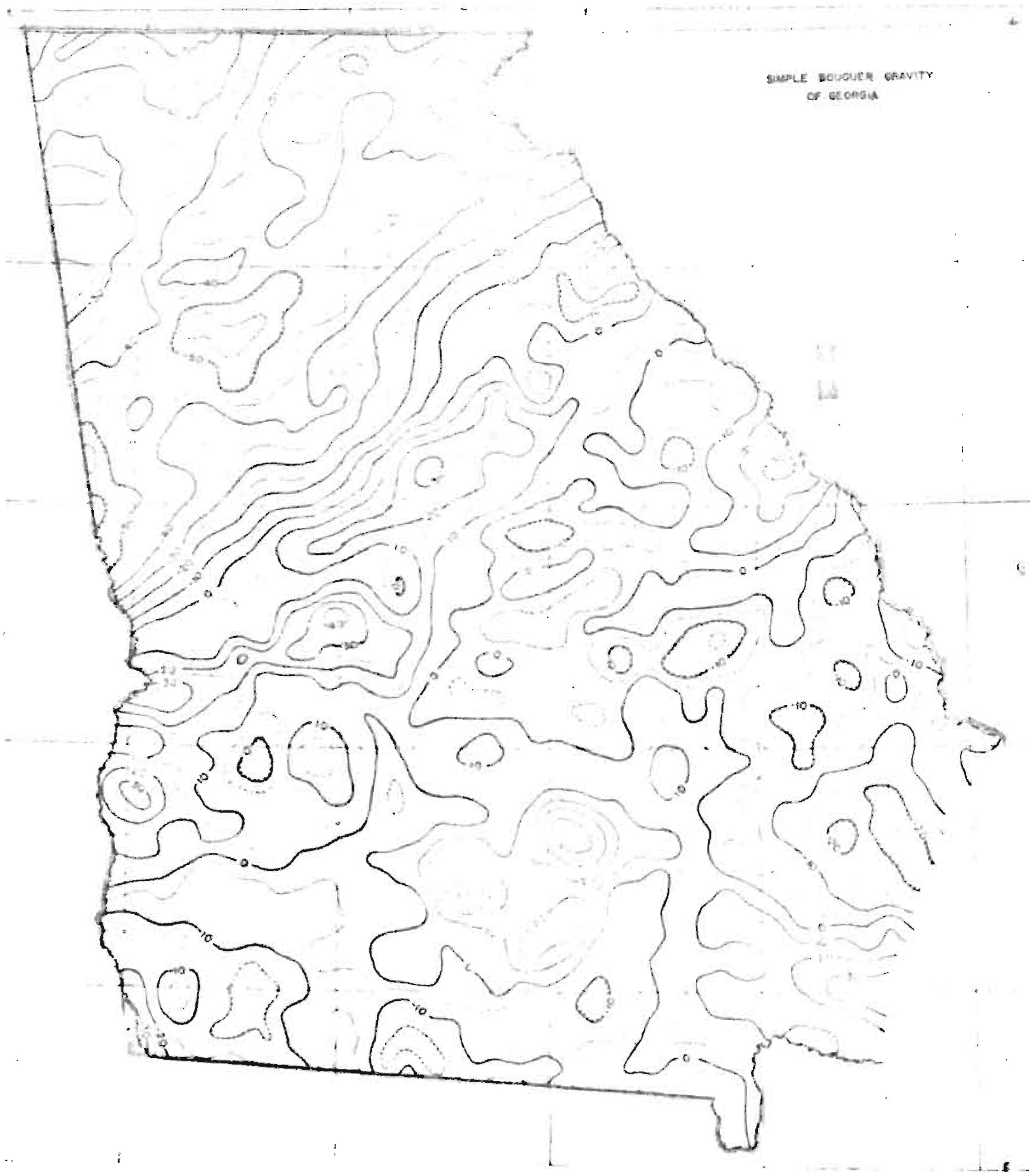
A simple Bouguer anomaly map for the State of Georgia has been generated from the data file. This map is a considerable improvement in the existing generally available maps. Publication (possibly through the Dept. of Mines Mining and Geology of Georgia) will be pursued as soon as the map can be checked against new data. The map was presented at the Southeastern Section meeting of the Geological Society of America, March 28, 1972 and a photo copy of the preliminary map is included in this report. The final map will be submitted as a Technical Report.

The rectangular area chosen for analysis unfortunately still contains some areas of weak coverage in South Carolina and Southeastern Alabama. Field data for Georgia now is generally satisfactory. During this report period, scattered weak areas in Georgia have been filled in as well as a portion of northwestern South Carolina. Additional data have been located and requested, but it is not known yet whether this will improve the coverage.

For the analysis of the data, a grid has been chosen which will allow line printer generated maps at 1 million scale. The grid point values are determined by a weighted average technique and grids have been generated from the existing data for Bouguer anomaly, Free Air anomaly, elevation and distribution of data.

A generalized smoothing operator for two dimensional data has been programmed and tested in the data. Also a two dimensional Fourier transform program has been tested successfully on the data.

The initial theoretical analysis of an isostatic response function along a line valid for two dimensional structures is complete. The theory will be tested on both an averaged profile and a detailed profile to be completed soon.


SIMPLE BOUGUER GRAVITY
OF GEORGIA

PROGRESS REPORT

1. ARO-D PROPOSAL NUMBER: 9110-EN

2. PERIOD COVERED BY REPORT: April 1, 1972 to September 30, 1972

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

4. CONTRACT OR GRANT NUMBER: DA-ARD-D-31-124-71-G117

5. NAME OF INSTITUTION: Georgia Institute of Technology

6. AUTHOR(S) OF REPORT: Leland Timothy Long

7. LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO-D SPONSORSHIP DURING THIS PERIOD, INCLUDING JOURNAL REFERENCES:

   Simple Bonguer Gravity Map of Georgia by Leland Timothy Long, Samuel R. Bridges, Leroy M. Dorman, Geological Survey of Georgia, 1972

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

A summary of the objectives and preliminary results on the contract were presented at the ARO-D Military Theme Review "Military Geographic Analyses" 31 October to 1 November 1972, Fort Belvoir, Virginia. The text of this talk including the major diagrams can be made available on request. The work represents a dry run of the computational techniques and preliminary evaluation of the results needed to guide the final analysis. A revised abstract of the conclusions is given below. In addition to the preliminary analysis performed last period, a large number of new data points were either occupied or obtained from other sources. The coverage has been significantly improved in all but a few scattered areas. With the exception, perhaps, of improving resolution along some detailed lines we anticipate no additional field work. In the next contract period the grid will be refined and expanded to include the additional data and the analysis will be continued.

Abstract of conclusions of talk: The gravity and elevation data for the Southeast U. S. have been gridded and compared to the Geology. The major features of each of these trends in the NE-SW direction, and therefore allows the application of a modified form of the Dorman-Lewis technique to measure directly the isostatic response function. The result implies over compensation of the crust in the crystaline Piedmont Plateau. Over compensation of the crust would require negative compensation at greater depth if the compensation function is not a function of distance. However, in the Southeast it is very likely that lateral variations in compensation are significant and that the long-term structural response of the crust can differ from the isostatic response function for a short-term static load. Also, detailed gravity profiles indicate that an intermediate layer in the crust may also contribute to the definition of the long-term isostatic response function.

A-1331

PROGRESS REPORT

1. ARO-D PROPOSAL NUMBER: 9110-EN

2. PERIOD COVERED BY REPORT: October 1, 1972 to March 31, 1973

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

4. CONTRACT OR GRANT NUMBER: DA-ARO-D-31-124-71-G117

5. NAME OF INSTITUTION: Georgia Institute of Technology

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   None

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

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   S. R. Bridges
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   G. H. Rothe

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   S. V. Harden +
   P. Gibbs +
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9110-EN

The primary goal of the work has been to utilize the Dorman and Lewis (1970) 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 modified technique has been applied to a preliminary and incomplete data set and a preliminary response function has been obtained. The final data set based on significant recent data acquisitions is now completed. It was derived from 10463 data points of Elevation and Bouguer anomalies. Surface densities are currently being compiled from geologic maps for inclusion in the data set. The technique will be applied to this improved data set when complete but the general conclusions are expected to remain the same. Analysis of the response function indicates that lateral compensation mechanisms may be important components of isostatic compensation. An alternate explanation which restricts the inversion of the response function to vertical (i.e. local) compensation only would require excessive negative compensation at depth in the Southeastern U.S. The observed response function which represents a cumulative long-term effect, involves wavelengths 50 to 100 km which are shorter than those indicated by Glacial rebound. The gravity data thus indicates a difference between the long and short term crustal response functions which may be related to the mechanical behavior of the crust. Also, an analysis of a detailed gravity profile across the Georgia Piedmont geologic province showed structures in the intermediate crustal layer which could be important in the interpretation of the mechanism. The detailed line has been extended southeast to the fall line and northwest to the Georgia-Alabama border. Final interpretation of the extended line data is currently underway.

The research has also aided detailed studies of basement structure in Tift Co., Georgia (Bridges, 1972) and the Cartersville fault near Alatoona Reservoir, Ga. A consideration of the possible thermal history of the Florida-Georgia crustal structure (Long and Lowell, 1973) may explain the general features of the thickness of sediments in that region. This work is currently being prepared for publication.

Bridges, S. R., 1972. Study of a Positive Bouguer Gravity Anomaly in in Tift County, Georgia. Unpublished report on file, School of Geophysical Sciences, Georgia Institute of Technology.

Long, T. T., and R. P. Lowell, 1973. A Mechansim for some Continental Margin Sedimentary Basins and Uplift Zones. Talk, presented at Southeastern Section, Geological Society of America, April 13, 1973, Knoxville, Tennessee.

A-1331

GEORGIA INSTITUTE OF TECHNOLOGY
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7 September 1972

U. S. Army Research Office-Durham
Box CM, Duke Station
Durham, North Carolina 27706

Reference: CRDARD-IP-9110-EN
Grant No. DA ARO-D-31-124-71-G117

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

Dear Sirs:

We are pleased to submit thirty (30) copies of a Simple Bouguer gravity map of Georgia published with the cooperation of the Georgia Geological Survey. Compilation of the data for the Georgia map was made possible through the support of U. S. Army Research Office-Durham grant to the Georgia Institute of Technology.

Respectfully submitted,

L. T. Long

Leland Timothy Long
Associate Professor of Geophysics

LTL:sh

Enclosures (30)

SIMPLE BOUGUER GRAVITY MA[P] OF GEORGIA

COMPILED BY

Leland Timothy Long   Samuel R. Bridges   LeRoy M. Dorm[an]
Georgia Institute of Technology

1972

STATE OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
Joe D. Tanner, COMMISSIONER
DIVISION OF EARTH AND WATER RESOURCES
Sam M. Pickering, Jr., DIVISION DIRECTOR
GEOLOGICAL SURVEY OF GEORGIA
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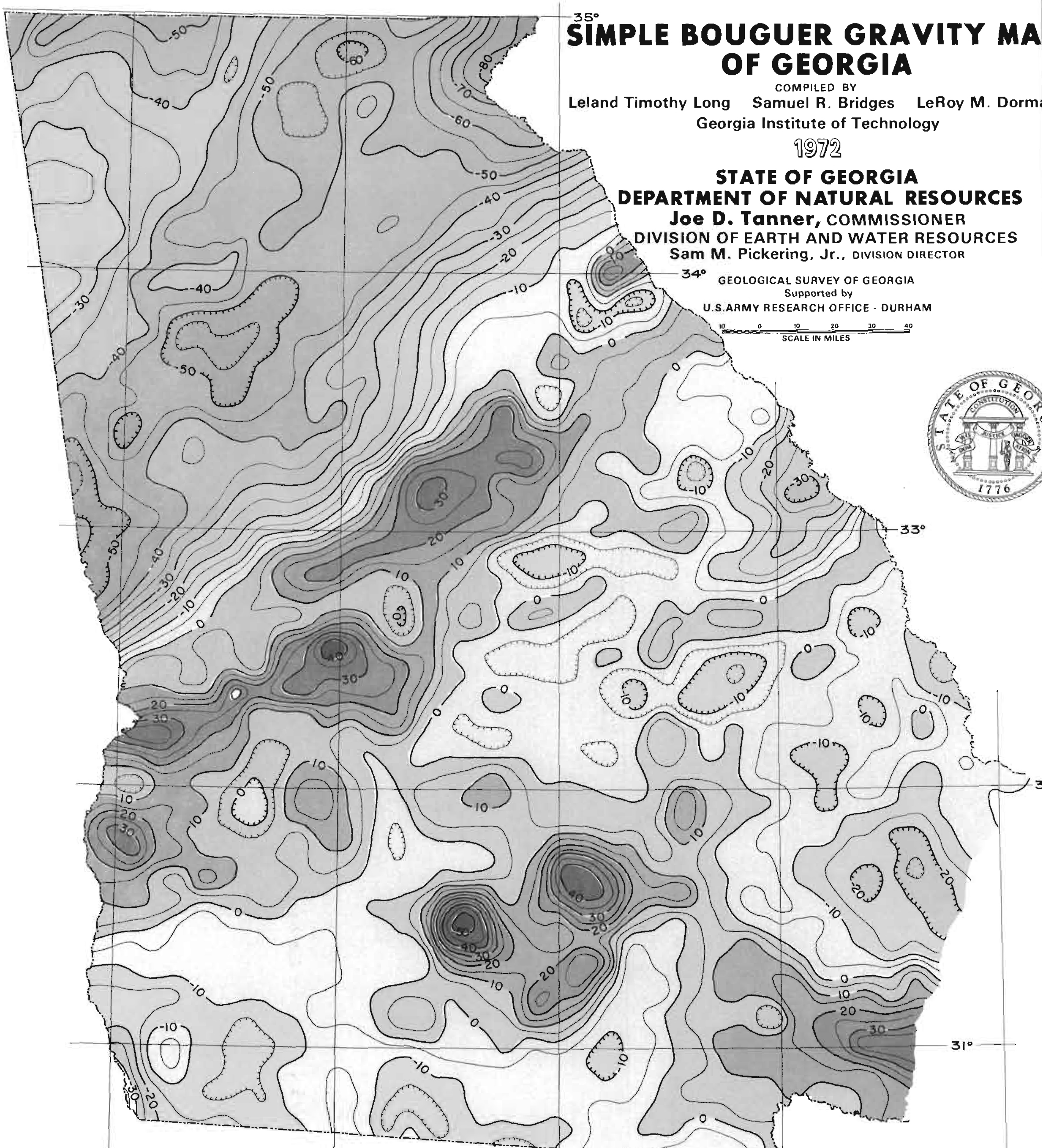
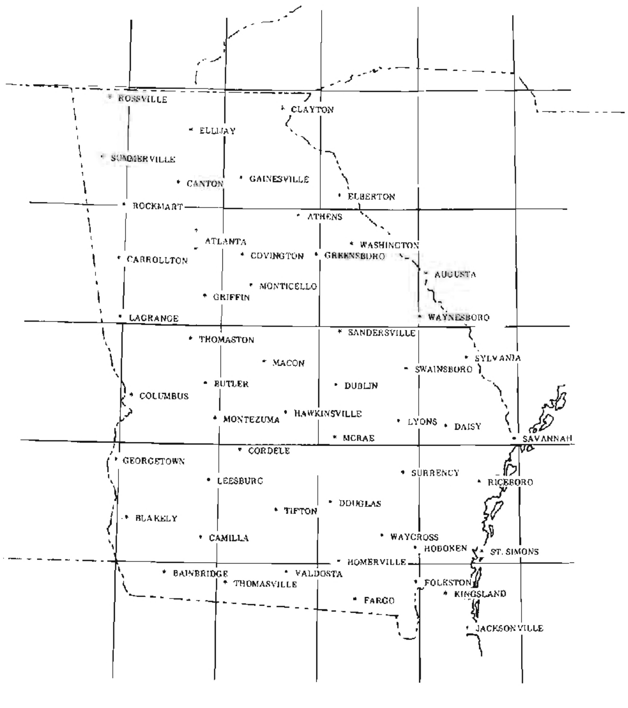


EXPLANATION

Interpretation of Bouguer Anomalies

Bouguer gravity anomalies are measures of the influence of local geology and crustal structure on the earth's gravitational field. The character of these anomalies is determined by the distribution of the variations of the density in the earth's crust which in turn is due to changes in rock type or structure. Positive and negative Bouguer anomalies indicate an excess or deficiency, respectively, of mass near the point of observation. Shallow density variations usually will cause anomalies of short length whereas density variations deep in the earth's crust will cause anomalies which will vary gradually over a distance comparable to their depth. The gravity map shown here is a representation of the Bouguer gravity anomalies (see section on computation for theoretical details) in the form of a contour map. The contour lines connect points of equal strength in the anomalous portion of the earth's gravity field in the same manner that topographic contours connect points of equal elevation. The scale of this map is best suited for illustrating the regional trends of the gravity surface, but it provides valuable information for more detailed future studies. Such studies will help solve geologic and mineral exploration problems by locating rock bodies and structures which are not exposed at the surface, and to give information on the 3-dimensional geometry of known rock bodies.



GRAVIMETRIC REFERENCE BASE NET
STATE OF GEORGIA

On a broad scale, the Bouguer gravity anomaly map shows regional patterns which correlate with the major geologic subdivisions in Georgia. The folded, unmetamorphosed Paleozoic rocks of the Valley and Ridge Province of northwest Georgia are characterized by -20 to -40 milligal anomalies with only moderate variation. Southeast of this zone the Brevard Fault Zone, which extends northeastward across Georgia through the northwestern portion of Atlanta, follows a region of broad gravity lows. These lows extend north of the Brevard Fault Zone into the northeast Georgia mountains where on the South Carolina border they attain the lowest value (-80 milligals) found in the State. The boundary of the zone of broad lows to the northwest generally corresponds to the Murphy Marble Belt. Continuing southward from the Brevard Fault Zone, the gravity increases smoothly until this trend culminates in a sharp northeast-trending "ridge" just north of the Fall Line. The negative anomalies north of the Fall Line can be accounted for almost entirely by the existence of low density roots for the crust which are required to support mountainous and elevated areas like north Georgia in isostatic equilibrium.

South of the Fall Line, the Bouguer anomalies average about zero but show a wide range of from -30 milligals to +50 milligals. The positive anomalies occur in the form of irregularly spaced knobs on ridges. The negative anomalies are the smoother intervening depressions which tend to be aligned along the northeasterly trend. One particularly prominent set of knobs and ridges occurs just south of the southwestern portion of the Fall Line. Another set of three prominent knobs, divided from the first by a series of irregular depressions, occurs further to the southeast. The Bouguer anomaly on one of those exceeds +50 milligals, the highest positive anomaly in the state. The positive Bouguer anomalies of the knobs and ridges are most likely due to the occurrence of dense basic rock types (like diabase or gabbro). The knobs show strong magnetic anomalies typical of basic rocks and furthermore basic rocks have been encountered in some deep wells. These rocks were either intruded into the crustal rocks now below a sedimentary blanket, intruded as sills (between the sedimentary strata), or extruded as flows on the former surface. Most of the prominent knobs show steeper anomalies on the northwest flank than to the southeast indicating a possible dip of the structures to the southeast. The gravity lows are related to increased thicknesses of sedimentary rock of pre-Cretaceous age. The younger rocks exposed at the surface do not significantly affect the gravity anomalies since they have uniform or only gradually varying thicknesses.

Computation of Bouguer Anomalies

The attraction of gravity at the earth's surface shows both regular and irregular variation. The regular variations are a consequence of the earth's shape and rotation. The irregular variations of primary interest to the geologist (see previous section) are a result of the distribution of mass in the earth's crust. In the Bouguer reduction of gravity data, the regular variations of the earth's gravity field are removed to allow the comparison of gravity anomalies with the densities of geologic structures.

Gravity meters, which are essentially very precise spring balances, are used to measure the gravitational attraction relative to base stations where the absolute value of gravity is known. Most gravity meters can rapidly measure relative values of gravity to less than 0.01 mgal (10^{-5}cm/sec^2) where absolute measures of gravitational attraction are considerably less accurate and more time consuming. The gravity data used in the Georgia Bouguer gravity map have been tied to the Gravimetric Reference Base Net of the State of Georgia. The Georgia net consists of 54 distributed base stations shown in the accompanying map. The Georgia net has been tied to a value of gravity of 980118.0 mgal at the U. S. Commerce Department base station "Washington A" in the National Gravity Base Net. Detailed information on the Georgia base net is contained in "Gravimetric Reference Base Net, State of Georgia" by Robert E. Ziegler and LeRoy M. Dorman (in preparation).

The international gravity formula of 1931 was used to remove regular latitude-dependent effects due to rotation and flattening of the earth. The effect of variations in gravitational attraction due to elevation differences were removed by theoretically reducing the observed gravity to mean sea level. The reduction requires adding a correction factor equal to 0.094 mgals per foot to each gravity value. The resulting reduced gravity values are called "Free Air" anomalies and are useful in the study of isostasy. However, they show local irregularities proportional to the elevation because the variations in mass above sea level were not taken into account.

The simple Bouguer reduction removes from the Free Air anomalies the short wavelength effects of mass variations related to elevation above sea level, by removing the attraction of a plate with thickness given by the elevation at the observation point. A standard crustal density of 2.67 gm/cm^3 was assumed in the simple Bouguer gravity map of Georgia. The complete Bouguer reduction includes corrections for the effects (always negative) of topography. No topographic corrections were applied to data used in the Georgia Bouguer gravity map. Test calculations in south Georgia indicate maximum values of less than 2 mgals. However, topographic corrections in the north Georgia mountains could be as high as 7 mgals.

The simple Bouguer gravity map of Georgia was computed from over 7,000 gravity observations with separations less than 10 km. Thirty percent of Georgia is covered with gravity observations at separations less than 4 km. The remainder is covered with gravity observations at a mean separation of 7 km. In order to achieve a uniform representation of the Bouguer anomalies throughout Georgia, contours were drawn on the basis of an average spacing of 7 km. Consequently, some details in areas of more dense coverage have been averaged. To significantly improve the representation of the Bouguer anomalies, a station spacing of less than one kilometer would be required.

Because a number of sources were utilized, all gravity observations were reviewed for redundency, typographical errors and questionable values. Redundant data were omitted and, where possible, typographical errors were corrected. Supplementary gravity observations were obtained to verify questionable values or to improve coverage. The complete file of compiled data for the simple Bouguer gravity map of Georgia includes the efforts of many individuals and organizations. The following individuals and/or organizations represent the sources consulted in compiling data for the Georgia Bouguer gravity map.

1. George P. Woollard and Associates, Univ. of Wisconsin and Univ. of Hawaii.
2. U. S. Coast and Geodetic Survey.
3. U. S. Army Topographic Command and Georgia Institute of Technology, 1965.
4. U. S. Army Topographic Command, 1968.
5. LeRoy M. Dorman, Georgia Institute of Technology, 1965.
6. Leland Timothy Long, Georgia Institute of Technology, 1970.
7. Samual R. Bridges, Georgia Institute of Technology, 1972.
8. Robert Carpenter and Preston Prather, Georgia Dept. of Mines, Mining and Geology.
9. Gravity Library, Aeronautical Chart and Information Center.

At least three private companies are known to have made gravity surveys within Georgia. The results of these studies had not been made available to the public prior to publication and hence are not included in the map.

Mr. Dorman is currently associated with the Atlantic Oceanographic and Meteorologic Lab.