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EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES

Progress Report

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ABSTRACT AND OVERVIEW

Costain and Perry report a new heat flow value from the Petersburg granite of 1.24 x 10^{-6} cal/cm^2-sec. This value lies above that predicted by the linear relation as do the Rolesville 2 and Castalia values. The interpretation of the linear heat production-heat flow relation continues to receive close attention. In this report, the points lying above the line are interpreted as resulting from increased thicknesses of the granite layer. If this is true, it is an important result in enumerating areas of high heat flow. The condition can be satisfied by rock bodies of high U and Th contents or by much thicker rock bodies of lower U and Th contents.

The behavior of the heat flow and temperature fields with different granite country rock heat production contrast, geometries, and presence and absence of an insulating cover are modeled by Dunbar. His results summarize our expectations of the shape and size of the thermal anomalies associated with the radiogenic source ancmalies both in the Piedmont and in the Coastal Plain.

If the interpretation of the linear relation by Costain and Perry is correct, gravity modeling is the best method of locating low density granites and determining their relative thicknesses. Cogbill again reports on assembling existing gravity data as well as reporting on new readings taken during the last quarter in the Coastal Plain and Piedmont.

The location and behavior of U and Th has always been a central part of understanding the variation of heat production among rocks of the southeast. The problem is inextricably bound up with geologic setting. Six of the reports from various areas and different points of view deal with the problem. Sinha and Merz's preliminary U-Th-Pb disequilibrium studies demonstrate the labile behavior of U whereas Th acts as a closed system. The most likely time of U loss appears to be the Mesozoic, a time of extense fracturing and hydrothermal activity throughout the Piedmont. Merz's leaching experiments supplement these results, revealing that the existing U and Th are in fairly retentive sites. Becker and Speer find that for the Liberty Hill pluton the Th is present in allanite as well as in anorthite. The Th is present in fairly substantial amounts in the ubiquitous allanite and this may be the major Th site in the granite. Sans discusses in two separate reports the distribution of K, U, and Th in the granitic rocks of Maryland. He finds a depletion of U and preservation of Th contents. In the Woodstock granite he finds a concentric Th distribution.

In attempting to predict areas where the granitic rocks have high heat productions, knowing the probable source areas would facilitate this search. Hanan explores the possibility of the origin of the Winnsboro pluton by crustal anatexis. Hall examines the evidence for the Blue Ridge gneisses as the possible source material for the granites.

In order to have any basis for any of the work in the southeast, a description of the rocks that are present is essential. This continues and includes the petrography and petrology of the Cuffytown Creek pluton. A highly differentiated granite with a high heat production and an unusual mineralogy--including Bi and Te phases. Merz has a discussion of the chemistry of the Siloam pluton, a granite whose petrography was discussed in the previous report by Speer. Both of Sans' reports contain descriptions of the granitic rocks of Maryland.

The coastal plain drilling program has only begun but two reports concerning the program are given. Lambiase discusses the lithologic character of the Atlantic coastal plain sediments. The nature of these sediments are important for they serve as the insulating cover as well as control the hydrology in the coastal plain. Both determine the extent of any geothermal resources in the coastal plain. Gleason reports on the nature of the basement core recovered in the Jessup, Georgia, drill hole. It is core such as this that provides the only tangible evidence of what underlies the coastal plain.

While most of the reports are concerned with heat flow by conduction, heat flow by mass transfer is of local importance in several areas of the southeast. Geiser reports on the structural controls of the thermal springs at Warm Springs, Virginia.

RESEARCH OBJECTIVES

The objective of this research is to develop and apply targeting procedures for the evaluation of low-temperature radiogenically-derived geothermal resources in the eastern United States utilizing geological, geochemical, and geophysical data.

The optimum sites for geothermal development in the tectonically-stable Eastern United States will probably be associated with areas of relatively high heat flow derived from crustal igneous rocks containing relatively high concentrations of radiogenic heat-producing elements. The storage of commercially-exploitable geothermal heat at accessible depths (1-3 km) will also require favorable reservoir conditions in rocks overlying a radiogenic heat source. In order to systematically locate these sites, a methodology employing geological, geochemical, and geophysical propspecting techniques is being developed and applied. The distribution of radiogenic sources within the igneous rocks of various ages and magma types will be determined by a correlation between radioelement composition and the bulk chemistry of the rock. Surface sampling and measurement of the radiogenic heat-producing elements are known to be unreliable as they are preferentially removed by ground-water circiulation and weathering. The correlation between the bulk chemistry of the rock (which can be measured reliably from surface samples) and radiogenic heat generation is being calibrated by detailed studies at a number of locations in the eastern United States.

Initial studies are developing a methodology for the location of radiogenic heat sources buried beneath the insulating sedimentary rocks of the Atlantic Coastal Plain. Choice of a drill site in the Atlantic Coastal Plain with a high geothermal resource potential depends on favorable:

(1) concentration of radiogenic elements in granitic rocks beneath a sedimentary insulator;

(2) thermal conductivity of the sedimentary insulator;

(3) thickness of the sedimentary insulator; and

(4) reservoir conditions in the permeable sedimentary rocks overlying the radiogenic heat source.

Because it is not economically feasible to select drilling sites on the Atlantic Coastal Plain without geophysical and geological models, it is advisable to base the development of these models on a substantial and accurate data base which can be partially derived from the exposed rocks of the Piedmont and enhanced by basement studies beneath the Atlantic Coastal Plain.

PERSONNEL OF PROGRAM

(April 1, 1978 - June 30, 1978)

GEOLOGY AND PETROLOGY, Lynn Glover III, Principal Investigator

J. A. Speer, Research Associate
S. S. Farrar, Research Associate
S. W. Becker, Research Associate
R. J. Gleason, Research Associate
A. Baldasari, Laboratory Aide

GEOCHEMISTRY, A. Krishna Sinha, Principal Investigator

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J. J. Lambiase, Research Associate
J. A. Dunbar, Research Specialist
S. Dashevsky, Research Specialist
B. U. Conrad, Research Specialist
M. Svetlichny, Research Specialist
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T. H. Arnold, part-time Laboratory Aide
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R. W. Meier, Co-op Student
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Margaret Paterson

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Margie Strickler
Linda Comeau
Nhury Schurig

DRAFTSMAN-PHOTOGRAPHER

David Brown

DRILLERS
W. G. Coulson, Core Driller
R. G. Gravley, Driller Helper

TALKS PRESENTED TO DATE

1. Low-temperature resources of the eastern United States, Second NATO-CCMS Meeting on Dry Hot Rock Geothermal Energy, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, June 28, 1977 (Speaker: J. K. Costain).

2. Low-temperature geothermal resources of the eastern United States, Geological Society of Washington, Washington, D. C., October 12, 1977 (Speaker: J. K. Costain).

3. Low-temperature geothermal resources in the eastern United States, 1977 Annual Meeting of the Geological Society of America, November 8, 1977 (Speaker: J. K. Costain).

4. Evaluation of the geothermal potential of hot springs in Northwestern Virginia, American Nuclear Society, Denver, Colorado, April 13, 1977 (Speaker: P. A. Geiser, University of Connecticut).

5. Low-temperature geothermal resources in the eastern United States, Potomac Geophysical Society, November 17, 1977 (Speaker: J. K. Costain).

6. Structural controls of thermal springs in the Warm Springs anticline, by P. A. Geiser and J. K. Costain, Southeastern Geological Society of America meeting, Winston-Salem, North Carolina, 1977 (Speaker: P. A. Geiser).

7. Geothermal resource potential of the eastern United States, Geothermal Resource Council Special Short Course No. 7, "Geothermal Energy: A National Opportunity" (The Federal Impact), May 17-18, 1978, Washington, DC (Speaker: J. K. Costain).

8. Geothermal resource potential of the eastern United States, Nordic Symposium on Geothermal Energy, Gothenburg, Sweden, May 29-31, 1978 (Speaker: J. K. Costain).

ABSTRACTS PUBLISHED TO DATE

1. Evaluation of the geothermal potential of the hot springs of northwestern Virginia, by P. A. Geiser and J. K. Costain, Abstracts of ANS Topical Meeting on Energy and Mineral Resource Recovery, Golden, Colorado, April 12-14, 1977, p. 33.

2. Structural controls of thermal springs in the Warm Springs anticline, Virginia, by P. A. Geiser and J. K. Costain, Abstracts, Geol. Soc. America SE Section, Winston-Salem, North Carolina, 1977.

3. Low-temperature geothermal rescurces in the eastern United States, by J. K. Costain, L. Glover III, and A. K. Sinha, Program with Abstracts, Annual Meeting of Geolcgical Society of America, Seattle, Washington, 1977.

4. Relationship between heat flow and heat generation in the southeastern United States, by J. K. Costain and A. K. Sinha, Program with Abstracts, Geological Society of America, SE Section Meeting, April, 1978.

5. A new model for the linear relationship between heat flow and heat generation, J. K. Costain, Transactions, American Geophysical Union, 59, 1978, p. 392.

PAPERS SUBMITTED FOR PUBLICATION

1. Molybdenum mineralization in the Liberty Hill and Winnsboro Plutons, South Carolina, by J. Alexander Speer, Economic Geology, 1978 (in press).

2. Low-temperature geothermal resource potential of the eastern United States, by J. K. Costain, L. Glover, III, and A. K. Sinha, submitted for publication in EOS, Transactions, American Geophysical Union.

PROGRESS

A. GEOLOGY

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OPERATIONS

During the period 1-1-78 to 3-31-78, 44 man days were spent in the field. Speer completed field work at the Liberty Hill and Siloam plutons and conducted reconnaissance sampling of the Town Creek, Georgia, pluton. He is working on a paper concerning the contact aureole of the Liberty Hill pluton. Farrar continued mapping the structure and lithologies of the northern half of the Raleigh belt and eastern Carolina slate belt. In addition, he wrote the results of a reconnaissance survey of the southern Raleigh belt and adjacent slate belt. Becker continued field work and analysis of the Cuffytown Creek pluton and its contact aureole; preliminary results are presented in this report. Gleason began study of the geology of the basement rocks underlying the Coastal Plain.

During the period 4-1-78 to 6-30-78, 61 man days were spent in the field. Farrar investigated the relations of geologic structure and lithologies to the location of hot springs in Warm Springs, Virginia and Warm Springs, Georgia as well as a suspected hot spring in Pearisburg, Virginia. Becker finished field work for the Cuffytown Creek pluton of South Carolina and undertook a gamma-ray spectrometer survey of the granite and its country rock. Speer and Becker finished field work for the Palmetto pluton of Georgia. Speer also began some field work in the Petersburg granite.

Baldasari completed a gamma-ray spectrometer survey of the Siloam, Georgia and Liberty Hill, South Carolina plutons as well as the adjacent country rock. Rock and soil samples were also collected in order to better understand the results of the portable gamma-ray spectrometer.

Other activities of the petrology group included a talk by Becker at the Southeastern Geological Society of America meeting at Chattanooga, Tennessee on the Cuffytown Creek pluton. Speer and Becker spent a good deal of time working with the Radiation Safety Office of the University to determine and satisfy the regulations concerning fission track samples. The Siloam 1 (688'), Siloam 2 (688'), and Palmetto (692') drill holes were completed during this quarter and were logged. A drill hole at Pearisburg, Virginia was located and drilling begun.

Gleason's work on the completion of the basement geology underlying the Coastal Plain is well underway, with Georgia being the first state completed during this period. He has also studied in some detail the basement core recovered from the Jesup, Georgia, drill hole and which is described in a section of this report.

PETROLOGY OF THE CUFFYTOWN CREEK PLUTON

S. W. Becker

Introduction

The Cuffytown Creek pluton, located in western South Carolina, is one of a belt of ca. 300 m.y., unmetamorphosed plutons in the eastern Piedmont. This pluton was selected for study because of its high heat production, averaging 11.3 x 10^{-13}cal/cm^3-sec (five samples, Table A-1). Detailed work on a granite with high heat production should facilitate determination of the location of U and Th in the granite and identification of petrologic factors affecting the distribution of these elements. In addition, reconnaissance studies of the granite indicated the presence of an unusual mineralogy--garnet and fluorite are common accessory phases--which suggested that the exposed Cuffytown Creek pluton is appreciably different in composition and petrogenesis from previously studied post-metamorphic granites. Work on several types of granite should allow identification of a variety of processes affecting the distribution of radiogenic elements.

TABLE A1

U, TH, K CONTENTS AND HEAT PRODUCTION OF
THE CUFFYTOWN CREEK PLUTON

	U (ppm)	TH (ppm)	K (%)	HGVU*
CB7-15	9.1	32.2	3.7	11.8
S7-50A	10.8	35.7	3.4	12.9
S7-53	9.1	33.2	3.5	11.7
S7-54	4.4	26.6	3.5	7.8
S7-55	10.2	33.2	3.3	12.4
AVERAGE	8.0	30.0	3.8	10.6

*HGVU = x 10^{-13} CAL/CM^3-SEC

Previous Work

The Cuffytown Creek pluton has previously been referred to as the Edgefield granite, one of two Edgefield granites in South Carolina. The other Edgefield granite, which has been studied by Metzgar (1977), crops out near the town of Edgefield, along the northern border of the Kiokee belt. To eliminate the duplication of names, several workers in the area agreed that the granite discussed in this study should be renamed because it is the farther of the two granites from the town of Edgefield. The pluton has been named (Becker, 1978) after the largest geographical feature in the area, the creek that runs just northwest of the pluton.

The outcrop area of the Cuffytown Creek pluton is shown by Overstreet and Bell (1965, Plate I), who note its quartz-rich nature. Butler and Ragland (1969) include it in their group of miscellaneous, mainly syntectonic plutons. Wagener (1977) includes a map of the pluton in his report and provides descriptions of a sample in hand specimen and thin section. A Rb-Sr isotopic age for the pluton of 299 ± 14 m.y. was obtained by Fullagar and Butler (1977). The initial Sr^{87}/Sr^{86} was not determined because of the very high rubidium to strontium ratio; it was assumed to be 0.705.

Geologic Setting

Low-grade metamorphic rocks of the Carolina slate belt surround the pluton (Fig. A-1). Boundaries of lithologic units within the slate belt are based on reconnaissance mapping. The granite intrudes a belt of mafic metavolcanic rocks, predominantly tuffs, bordered to the northwest and southeast by meta-argillite. The location of the contact between the meta-argillite and metavolcanics southeast of the pluton coincides with that mapped by Pirkle (1977). Along the contact in the country rocks northwest of the pluton, abundant quartz occurs and supports the steep ridge northwest of Cuffytown Creek, suggesting that this contact may be a fault zone. The regional foliation trends consistently N45°E, parallel to the lithologic contacts, and dips vertically (Fig. A-2). It was apparently not disturbed by intrusion of the granite.

The Cuffytown Creek pluton occupies a topographically high area, 20 km^2, where the granite is generally well exposed, cropping out as pavements and boulders. Most natural exposures are extensively weathered, and fresh samples were obtained only from an abandoned quarry, blasted roadcuts, and a core, 316 m deep, drilled for this project. Fractures and joints pervade the rock, and where one joint set predominates, the outcrop weathers into elongate mounds parallel to the joint direction. Pegmatite veins are rare,

EXPLANATION

g	Cuffytown Creek pluton

Carolina Slate Belt

mar	Greenschist grade meta-argillite, phyllite, and quartz-muscovite schist
mv	Greenschist grade metavolcanic rocks
	Contact, dashed where inferred
	Maximum extent of granite at depth, inferred from geophysical data
B8-56 ●	Sample locality
⊕ ED-1	Drill hole site

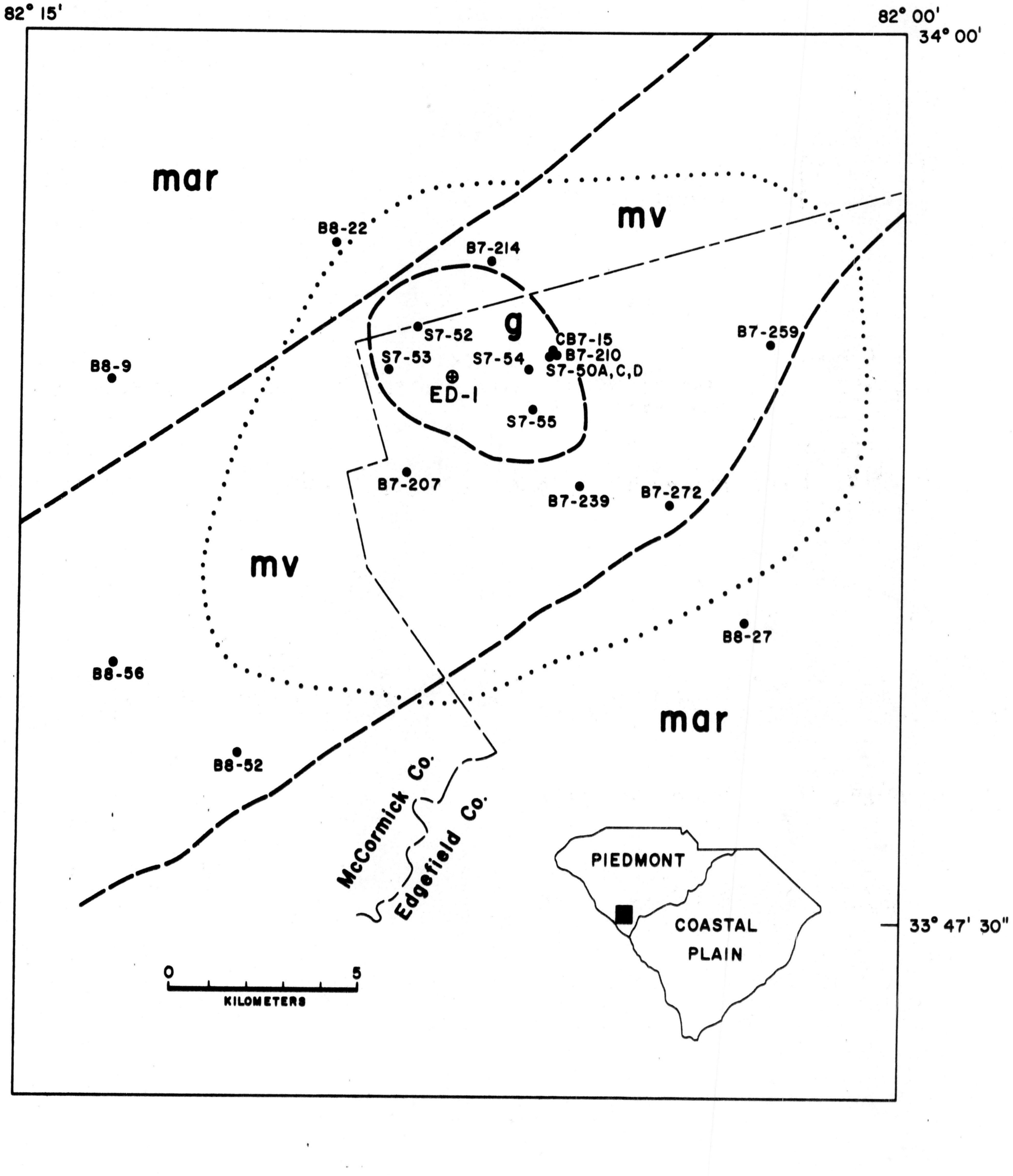
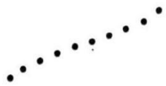
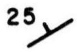


Figure A-1. Geologic map of the Cuffytown Creek pluton, showing sample localities. Dotted line indicates maximum extent of granite at depth, inferred from geophysical data (cf. Fig. A-3).

EXPLANATION

g	Cuffytown Creek pluton

Carolina Slate Belt

mar	Greenschist grade meta-argillite, phyllite, and quartz-muscovite schist
mv	Greenschist grade metavolcanic rocks
	Contact, dashed where inferred
	Maximum extent of granite at depth, inferred from geophysical data
	Strike and dip of bedding
	Strike and dip of foliation
	Strike and dip of joints

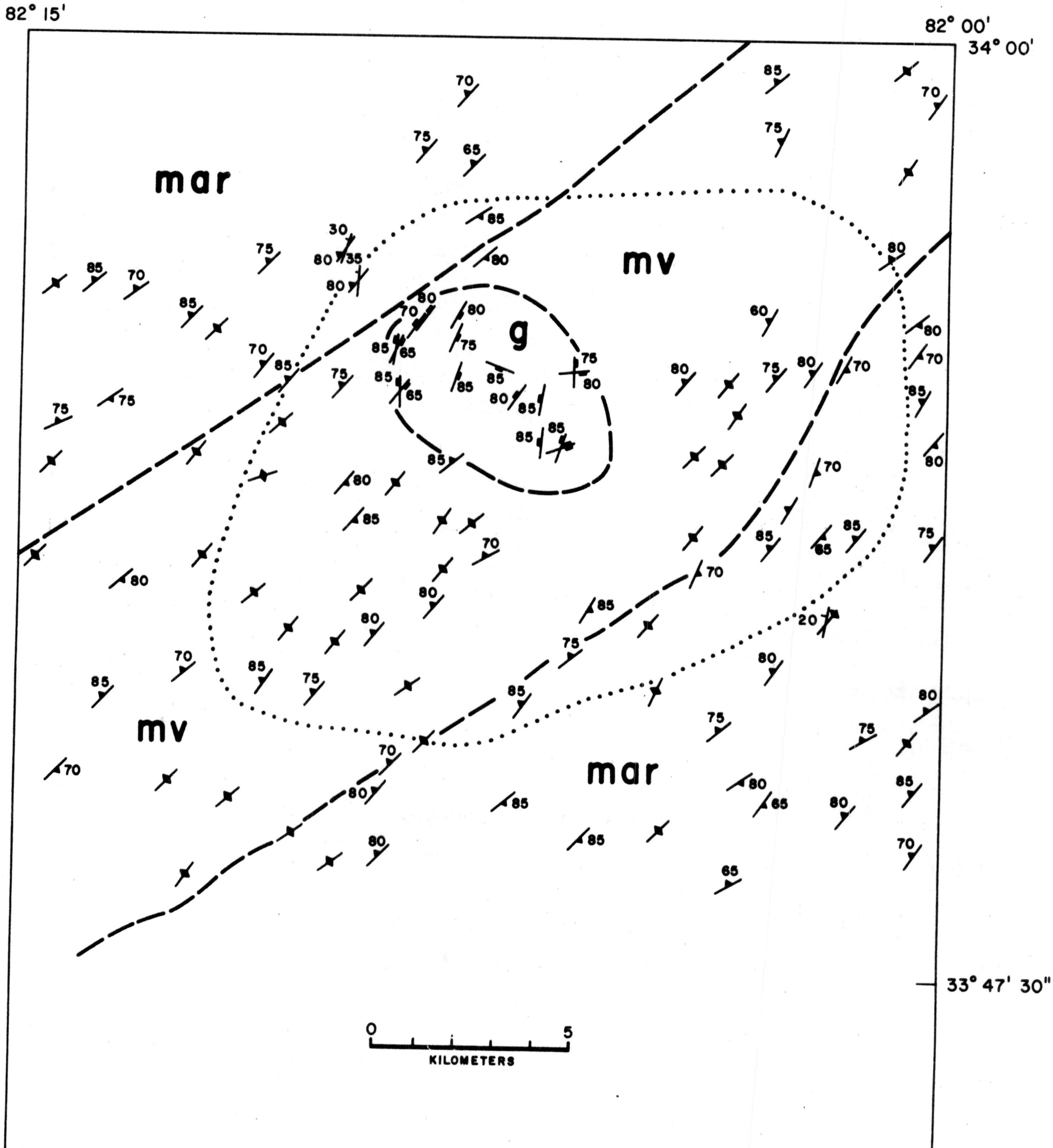


Figure A-2. Map showing structure in the vicinity of the Cuffytown Creek pluton.

and an aplite dike was found at only one location. Quartz veins up to 3 cm across are common.

Geophysical Model

A large gravity low with a residual Bouguer anomaly of -27 mgal is centered over the pluton. Modelling of the anomaly, discussed by Cogbill in a previous report (VPI&SU-5648-1), indicates that the pluton is approximately 6 km deep and has a much greater diameter at depth than at the surface (Fig. A-3). At a depth of 1 km, for example, the model proposes a diameter of 13 to 20 km, in contrast with the surface diameter, which varies from 3 to 5 km (Fig. A-1). The model suggests that the exposed granite is the uppermost part of the pluton, comprising rocks formed in the top of a magma chamber.

Petrography and Microprobe Analyses

Fresh samples of the granite are grey to pink. The rock is unfoliated, and contains quartz, potassium feldspar, and plagioclase grains 1-5 mm in diameter, and white mica flakes about 1 mm across. Scarce phenocrysts of quartz and potassium feldspar range up to 1 cm long. Some samples are spotted by small, red-brown specks of hematite.

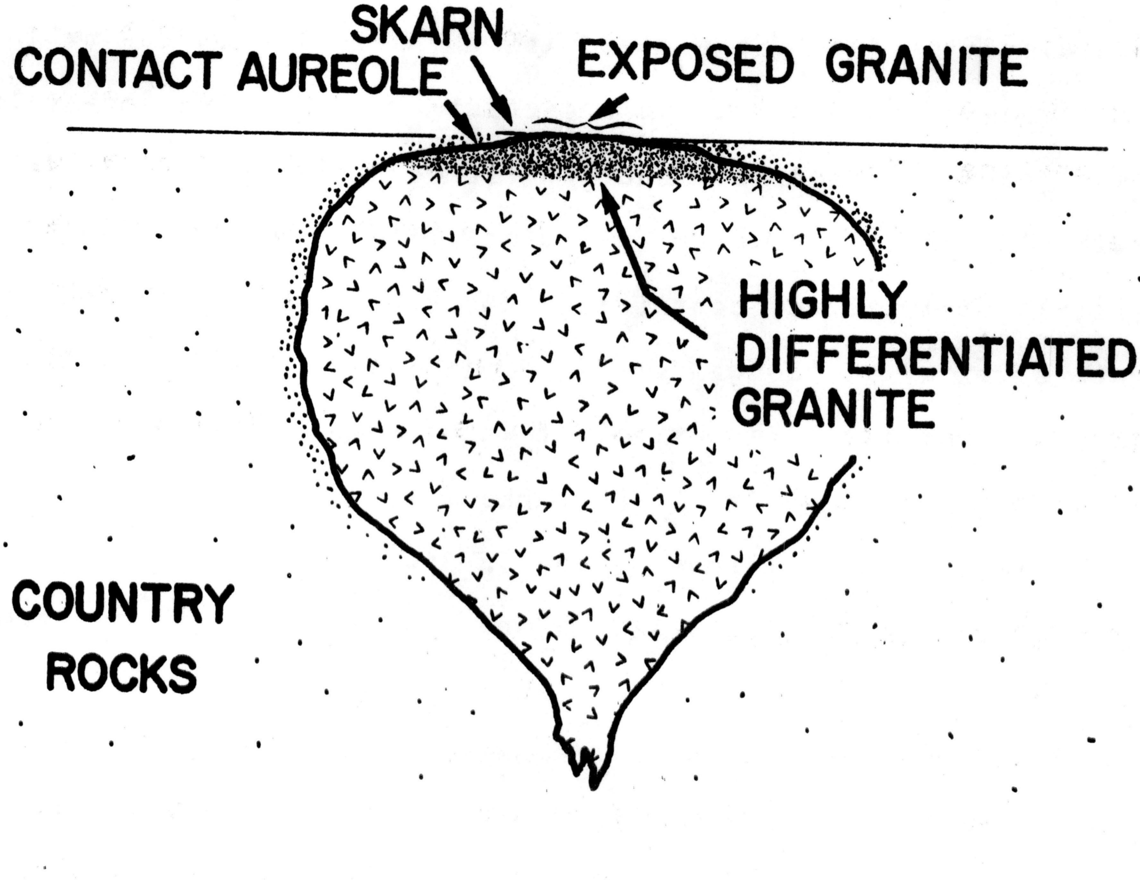


Figure A-3. Schematic cross-section of the Cuffytown Creek pluton, showing hypothetical position of exposed granite, at top of magma chamber.

Modal analyses (Table A-2) show that quartz and the two feldspars constitute 96-97% of the rock. Quartz occurs as large, anhedral grains with undulose extinction. Subhedral to anhedral microcline microperthite is unzoned and highly kaolinized; a small percentage of grains are twinned according to the Carlsbad law. Some grains are poikilitic and contain blebs of quartz. Plagioclase grains, also unzoned, have albite twinning. They are generally euhedral parallel to (010), the composition plane of albite twins. Along grain boundaries perpendicular to (010), the crystals are usually anhedral, sharing irregular grain boundaries with neighboring quartz or microcline. Most grains are highly sericitized, containing numerous small inclusions of white mica, although some grains are nearly entirely replaced by a single crystal of white mica.

Microprobe analyses show that the feldspars are near end-member compositions (Table A-3). Plagioclase ranges from $An_9Ab_{90}Or_1$ to $An_0Ab_{99}Or_1$, and microcline from $An_0Ab_{11}Or_{89}$ to $An_0Ab_2Or_{98}$. Additional work is needed to determine whether this compositional variation is characteristic of all samples.

The white mica, which occurs as large crystals and as a sericitization product of plagioclase, is a phengite containing 2-3% fluorine (Table A-4). Phengite is intermediate in composition between end members muscovite, $K_2Al_4(Al_2Si_6O_{20})(OH,F)_4$, and celadonite, $K_2(Mg,Fe^{2+})Al_3(AlSi_7O_{20})(OH,F)_4$. The samples analyzed

TABLE A2

CUFFYTOWN CREEK MODAL ANALYSES

	CB7-15	S7-50A	S7-50D	S7-52	S7-53
QUARTZ	36.1	33.9	39.5	41.8	32.6
K-FELDSPAR	27.8	30.0	24.0	25.1	32.2
PLAGIOCLASE	33.4	34.7	32.4	30.7	32.2
WHITE MICA	2.6	2.6	3.4	2.3	1.5
BIOTITE	0.4	-	-	-	-
GARNET	-	-	0.1	-	-
OPAQUES	0.2	0.5	0.4	0.1	0.6
FLUORITE	0.4	0.2	0.2	-	1.0
ACC.	0.1	0.1	TR	TR	TR
NO. PTS.	1732	1356	1502	1553	1502

TABLE A3

MICROPROBE ANALYSES, CUFFYTOWN CREEK FELDSPARS

	S7-50C			
	PLAG.	PLAG.	PLAG.	ALK. FSP.
SIO2	68.34	67.87	66.88	65.86
AL203	21.15	20.81	21.73	18.71
CAC	0.63	0.62	1.86	0.0
NA20	11.28	11.39	10.37	0.24
K2C	0.17	0.18	0.27	16.27
SUM	101.57	100.87	101.11	101.08
	NUMBER OF IONS ON THE BASIS OF 8 (0)			
SI	2.94	2.94	2.90	3.00
AL	1.07	1.06	1.11	1.00
CA	0.03	0.03	0.09	0.00
NA	0.94	0.95	0.87	0.02
K	0.01	0.01	0.02	0.95
ΣZ*	4.01	4.00	4.01	4.00
ΣX	0.98	0.99	0.98	0.97
AN	2.07	2.89	8.88	9.0
AB	96.08	96.11	89.59	2.19
OR	0.95	1.00	1.53	97.81

* ΣZ = SUM OF IONS IN TETRAHEDRAL SITE; ΣX = SUM OF CA, NA, AND K IONS.

TABLE A3, CONTINUED

MICROPROBE ANALYSES, CUFFYTOWN CREEK FELDSPARS

	S7-55			S7-50A
	PLAG.	ALK. FSP.	ALK. FSP.	ALK. FSP.
SIO2	69.73	64.90	63.30	64.64
AL2O3	20.23	18.85	19.79	19.21
CAO	0.13	0.0	0.02	0.0
NA2O	11.55	1.27	0.23	0.51
K2O	0.13	14.96	15.66	16.19
SUM	101.77	99.98	99.00	100.55
SI	2.98	2.98	2.94	2.97
AL	1.02	1.02	1.09	1.04
CA	0.01	0.0	0.0	0.0
NA	0.96	0.11	0.02	0.04
K	0.01	0.88	0.93	0.95
ΣZ	4.00	4.00	4.03	4.01
ΣX	0.98	0.99	0.95	0.99
AN	0.61	0.0	0.10	0.0
AB	98.66	11.43	2.18	4.57
OR	0.73	88.57	97.71	95.43

TABLE A4
MICROPROBE ANALYSES, CUFFYTOWN CREEK WHITE MICA

	S7-50A	S7-50C	S7-55	S7-55A	S7-54	S7-54
SIO2	48.41	46.63	48.20	45.40	49.05	47.43
TIO2	0.31	0.76	0.14	0.57	0.47	0.64
AL2O3	31.63	31.36	32.42	31.22	30.57	31.02
FEO*	5.40	6.20	6.43	7.96	6.59	7.61
MGO	1.84	1.82	1.02	1.88	2.09	1.73
MNO	0.45	0.58	0.63	0.98	0.60	0.83
CAO	0.0	0.0	0.0	0.03	0.0	0.01
NA2O	0.19	0.24	0.14	0.31	0.0	0.15
K2O	8.11	9.59	7.99	7.90	7.49	7.58
H2O**	4.53	4.48	3.44	3.13	4.54	4.50
F	N.D.	N.D.	2.37	2.81	N.D.	N.D.
O-F	-	-	1.00	1.18	-	-
SUM	100.87	101.66	101.78	101.01	101.40	101.50

NUMBER OF IONS BASED ON 24 (O,H,F)

	S7-50A	S7-50C	S7-55	S7-55A	S7-54	S7-54
SI	6.41	6.23	6.22	5.98	6.47	6.31
AL	1.59	1.77	1.78	2.02	1.53	1.69
AL	3.34	3.17	3.16	2.83	3.22	3.18
TI	0.03	0.08	0.01	0.06	0.05	0.06
FE	0.60	0.69	0.69	0.88	0.73	0.85
MG	0.36	0.36	0.20	0.37	0.41	0.34
MN	0.05	0.07	0.07	0.11	0.07	0.09
CA	0.0	0.0	0.0	0.0	0.0	0.0
NA	0.05	0.06	0.04	0.08	0.0	0.04
K	1.37	1.64	1.32	1.33	1.26	1.29
ΣW***	1.42	1.70	1.38	1.41	1.26	1.31
ΣY	4.38	4.37	4.13	4.25	4.48	4.52
ΣZ	8.00	8.00	8.00	8.00	8.00	8.00

*ALL IRON AS FEO.
**H2O CALCULATED.
***ΣW = SUM OF IONS IN 12-COORDINATED SITE; ΣY = SUM OF IONS IN OCTAHEDRAL SITE; ΣZ = SUM OF IONS IN TETRAHEDRAL SITE.

average about 40% celadonite end member, and less than 0.05 paragonite component.

Brown biotite is scarce, and generally partially altered to chlorite and hematite.

Accessory and opaque minerals form clusters between the feldspar and quartz grains. The stable opaque assemblage is rutile plus hematite, pseudomorphed after ilmenite and magnetite. Former ilmenite grains are composed of intergrown rutile and hematite; euhedral magnetite grains have been replaced to varying degrees by hematite.

Fluorite is present in all samples examined, comprising 1/2 to 1 modal percent of the rock. Other accessory minerals thus far identified are garnet, zoned allanite, titanite, zircon, and a rare earth phosphate.

The garnet in the granite (Table A-5) is an almandine-spessartite. Garnets have the formula X3Y2Z3O12, where X is 8-coorinated, Y is 6-coordinated, and Z is in tetrahedral coordination. Calculated formulas for the Cuffytown Creek garnets do not fit the standard garnet configuration. An excess of Al appears in the octahedrally coordinated site (Y, average 2.56 instead of 2.0), so that a deficiency appears in the 8-coordinated site (average 2.32 instead of 3.0). A possible explanation for this is the presence of an additional, undetected element, which is also suggested by the sums of the analyses. Microprobe analyses of garnets generally sum to 103-104 wt. %, probably because of the high

TABLE A5
MICROPROBE ANALYSES, CUFFYTOWN CREEK GARNET

	S7-54		B7-210	
SIO2	35.99	36.69	36.44	37.48
TIO2	0.27	0.26	0.17	0.18
AL2O3	25.48	26.26	25.42	26.20
FEO*	10.69	11.12	12.37	12.63
MGO	0.0	0.0	0.0	0.0
MNO	26.69	27.19	24.70	24.94
CAO	0.75	0.65	0.48	0.60
NA2O	0.0	0.0	0.0	0.0
K2O	0.01	0.02	0.02	0.02
SUM	99.88	102.19	99.60	102.05
	NUMBER OF IONS ON THE BASIS OF 12(O)			
SI	2.88	2.87	2.92	2.92
TI	0.02	0.02	0.01	0.01
ALz	0.10	0.11	0.07	0.07
ALx	2.30	2.31	2.33	2.34
FEX	0.0	0.0	0.0	0.0
FEy	0.72	0.73	0.83	0.82
MG	0.0	0.0	0.0	0.0
MN	1.81	1.80	1.67	1.65
CA	0.06	0.06	0.04	0.05
NA	0.0	0.0	0.0	0.0
K	0.0	0.0	0.0	0.0
ΣX**	2.30	2.31	2.33	2.34
ΣY	2.59	2.59	2.54	2.52
ΣZ	3.00	3.00	3.00	3.00
AL	27.63	28.16	32.55	32.67
PY	0.0	0.0	0.0	0.0
SP	69.88	69.73	65.83	65.34
GR	2.48	2.11	1.62	1.99

*ALL IRON AS FEO.
**ΣX = SUM OF IONS IN TRIVALENT OCTAHEDRAL SITE; ΣY = SUM OF IONS IN DIVALENT OCTAHEDRAL SITE; ΣZ = SUM OF IONS IN TETRAHEDRAL SITE.

density of the mineral. The sums shown in Table A-5 are therefore actually low. Yttrium is the most probable candidate for the undetected element. The Cuffytown Creek garnet may be an almandine-spessartite with limited solid solution toward yttrogarnet ($Y_3Al_2Al_3O_{12}$), which would account for the unusually high concentration of aluminum.

The phosphate is surrounded by radiation damage halos noticeably larger than those surrounding zircon. Qualitative analyses with a Kevex solid state detector show that the mineral is composed of Ce, La, Th, and P, with lesser amounts of U and Sm. It is probably monazite. Further optical and microprobe analyses will help to identify the mineral. Scans of zircon showed no large amounts of elements other than Zr and Si, although the presence of small quantities of U or Th is indicated by the radiation damage halos.

Fracture Assemblages

The pluton is cut by numerous, steeply dipping fractures, which probably formed during cooling and contraction of the granite. Several types of fracture fillings, up to several cm thick, were observed in core from the drill hole. Some fractures are filled by quartz; a few are filled by fluorite or quartz + fluorite. Others contain carbonate ± chlorite ± sulfides. Pyrite is the sulfide most commonly associated with the fractures; sphalerite and chalcopyrite were found in one sample (305.2 m); in another (267.5 m), intergrown Bi-Pb and Bi-Te sulfides were identified by microprobe analysis.

Also occurring in the fractures are conspicuous black dendrites. Microprobe analysis shows they are composed predominantly of Mn oxides. Mn occurs in a variety of oxidation states, and its oxides are difficult to distinguish, preventing mineral identification. In thin section, the dendrites appear as opaque linings along cleavage traces and grain boundaries.

Whole Rock Chemistry

Major element, whole rock analyses of five samples by x-ray fluorescence are listed in Table A-6. The high sums are probably due to silica analyses that are 1-2% too high. The rock is high in silica and low in Fe, Mg, and Ca. All samples are slightly peraluminous. Corundum appears in the norm, and molecular $(K_2O+Na_2O+CaO)/Al_2O_3 = 0.91$ (average, five samples).

Contact Aureole

The Cuffytown Creek pluton is bounded by a contact aureole, approximately 0.5 km wide, which is best exposed on the northwest side of the pluton. Outside the aureole, the

TABLE A6
CHEMICAL ANALYSES OF THE CUFFYTOWN CREEK PLUTON

	CB7-15	S7-53	S7-55	S7-50A	S7-54
SIO2	76.85	76.65	76.35	76.51	76.41
TIO2	0.06	0.06	0.06	0.07	0.06
AL2O3	14.12	14.61	14.65	14.40	15.12
FEO*	0.60	0.60	0.50	0.62	0.45
MGO	0.06	0.06	0.06	0.06	0.07
MNO	0.09	0.06	0.06	0.14	0.05
CAO	0.58	0.53	0.61	0.58	0.15
NA2O	4.28	4.53	4.23	4.19	4.20
K2O	4.98	5.02	5.04	4.88	4.99
P2O5	0.02	0.02	0.02	0.02	0.02
SUM	101.64	102.14	101.58	101.47	101.52
Q	30.59	28.80	30.22	31.15	31.66
C	0.67	0.79	1.16	1.20	2.55
OR	28.95	29.04	29.32	28.42	29.05
AB	35.63	37.53	35.24	34.94	35.01
AN	2.70	2.45	2.85	2.71	0.60
EN	0.15	0.15	0.15	0.15	0.17
FS	1.15	1.09	0.92	1.27	0.81
IL	0.11	0.11	0.11	0.13	0.11
AP	0.05	0.05	0.05	0.05	0.05
HY	1.30	1.24	1.06	1.41	0.98
HY-EN	0.15	0.15	0.15	0.15	0.17
HY-FS	1.15	1.09	0.92	1.27	0.81
D.I.	95.17	95.37	94.77	94.51	95.71

*ALL IRON AS FEO.

assemblage of the mafic metavolcanic rocks is in the greenschist facies (Fig. A-4a): quartz + plagioclase (probably albite) + epidote + chlorite + opaques ± carbonate. Rocks collected from the aureole (Fig. A-4b) contain quartz + plagioclase + epidote + chlorite + hornblende + opaques. Samples that were collected as float within the granite boundary, and that probably represent xenoliths, contain quartz + plagioclase (An43) + hornblende + clinopyroxene + opaques (Fig. A-4c).

Skarn

A skarn, approximately 10-20 m wide, crops out locally along the northwest contact of the pluton. The rock is composed mainly of quartz, fluorite, and an andradite-grossular garnet containing 5-6 wt. % MnO. Also present are actinolite, bearing 2% MnO, and epidote, Ps23Cz76Pd1. Some amphiboles grains enclose a core of ferrosalite, Wo50Fs25En22Mn3.

Petrogenesis of the Cuffytown Creek Pluton

Two lines of evidence suggest that the presently exposed granite represents the top of a much larger pluton (Fig. A-3): the large gravity anomaly centered over the pluton, and the highly differentiated nature of the granite,

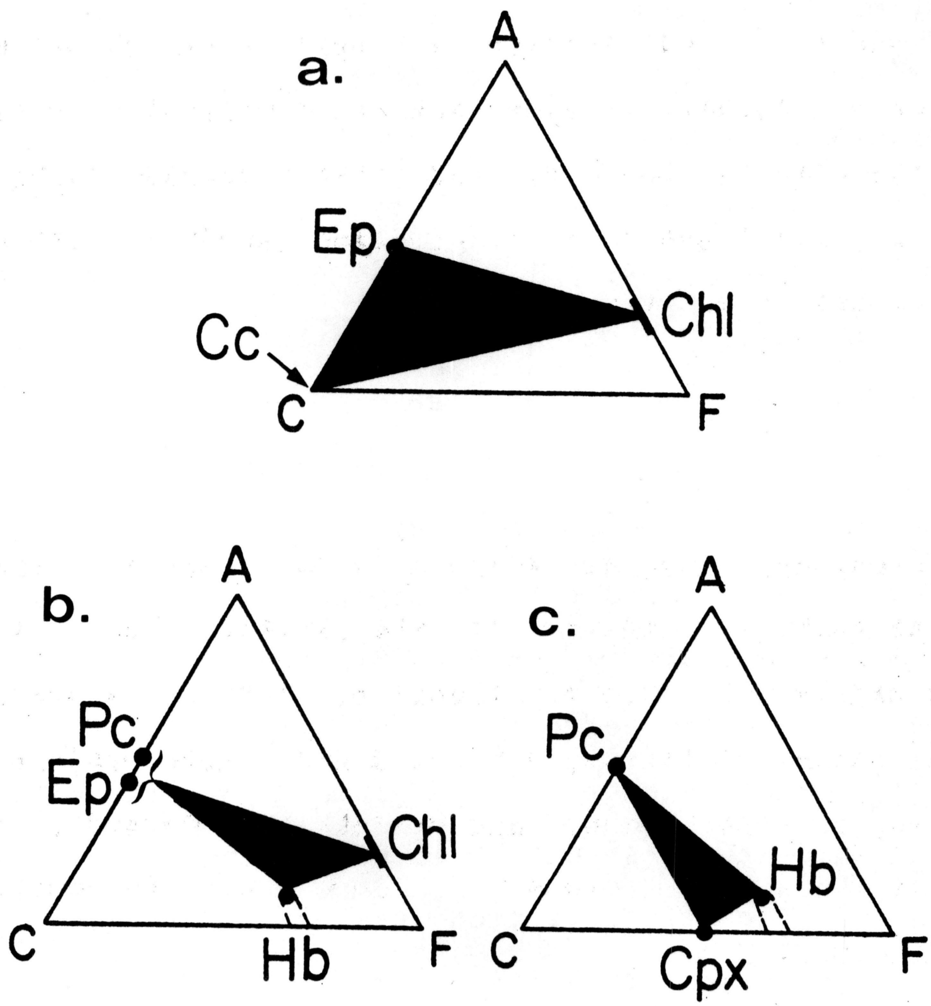


Figure A-4. AFM diagrams illustrating assemblages in the country rock. a--Greenschist facies assemblage outside the contact aureole; b--assemblage in contact aureole; c--assemblage in presumed xenoliths collected as float within the granite boundary.

with its large proportion of quartz and low concentrations of Fe, Mg, and Ca. The ubiquitous presence of fluorite in the granite, and its abundance in the skarn, support the hypothesis that the granite crystallized in the cupola of a magma chamber, because volatiles, as well as the most differentiated liquid, would collect near the top of a crystallizing granite mush.

To estimate the pressure of crystallization, normative whole rock compositions were plotted on a ternary diagram showing compositions of minimum melting for varying pressures at PH2O = 0 and PH2O = Ptot (Fig. A-5). Compositions of the granite plot near the wet minima for anorthite-free systems. The discrepancy between the experimentally determined granite minima and the composition of the granite may be due to the influence of fluorine on the system, or to the effect of anorthite. Approximately 2.6 percent normative anorthite is present, and the addition of anorthite to the Q-Ab-Or system moves the minima toward the Q-Or join, in the direction that the Cuffytown Creek samples are displaced from the anorthite-free minima. The pressure suggested by the diagram is about 2.5 kb.

After crystallization of the magma and during cooling, the minerals continued to re-equilibrate, aided by interactions with late stage magmatic fluids. Plagioclase and microcline compositions indicate that equilibration between the feldspars persisted to low temperatures.

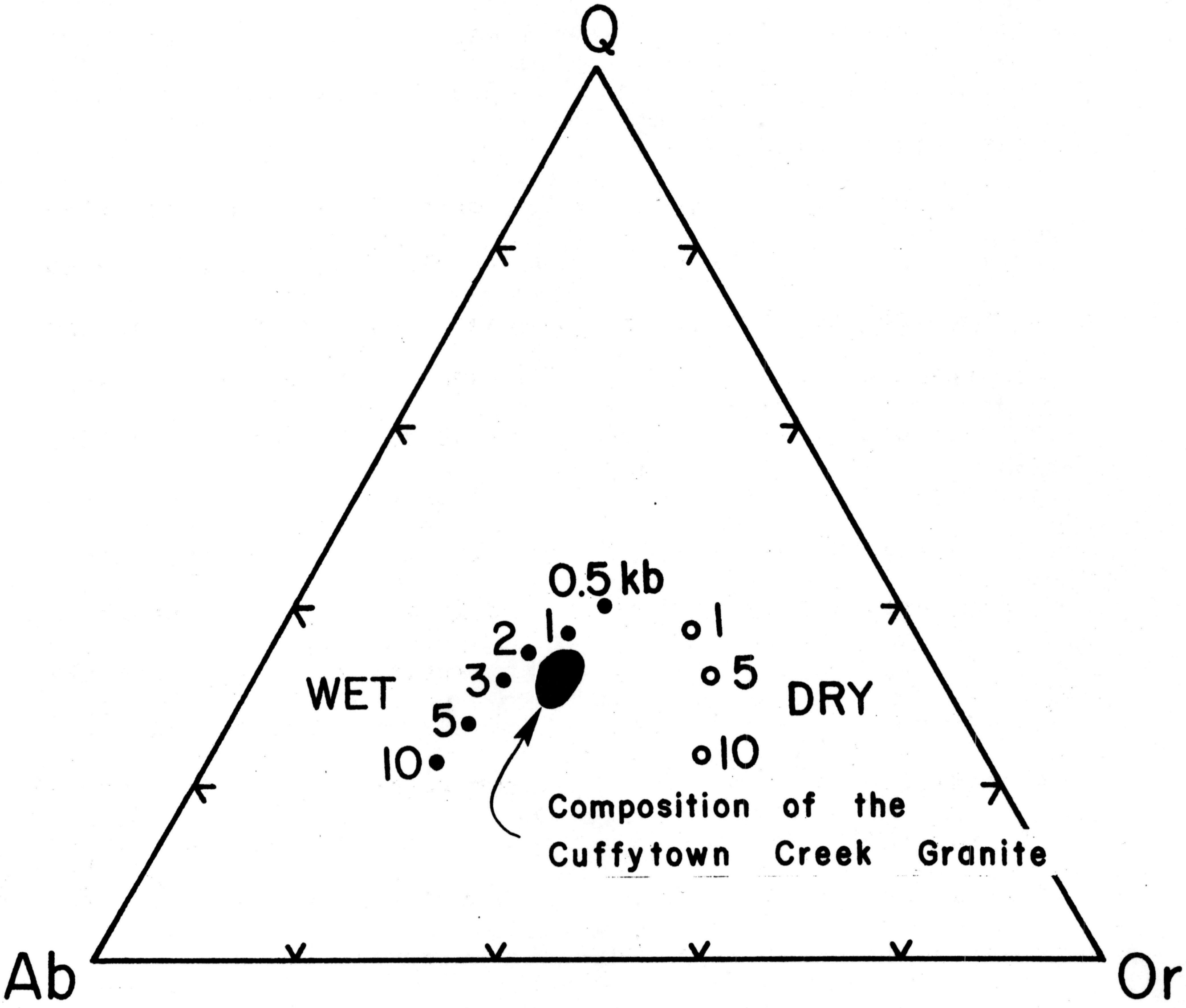


Figure A-5. Normative quartz-albite-orthoclase diagram showing compositions of Cuffytown Creek granite, and experimentally determined minima for wet (PH2O = Ptot; Tuttle and Bowen, 1958 and Luth et al., 1964) and dry systems (PH2O = 0; Luth, 1969).

Exchange of alkalies would be facilitated by the high concentration of volatiles (Orville, 1963). To determine the temperature of crystallization, the value of 2.5 kb was used in Whitney and Stormer's (1977) geothermometer for low temperature feldspars. The range of equilibration temperatures is 350-440°C, similar to the ca. 400°C temperature determined by Whitney and Stormer (1977) for perthites in the Danburg, Siloam, and Stone Mountain plutons in Georgia.

The white mica may also have changed composition during cooling. Phengitic micas more typically occur as a constituent of rocks metamorphosed at low temperatures and moderate pressures than as a primary phase of igneous rocks.

The oxides reacted from ilmenite + magnetite to hematite + rutile. Rumble (1976) showed that increasing oxygen fugacity, in this case supplied by the late stage fluids, would drive the reaction (Fig. A-6):

$$1/2\ O_2 + FeTiO_3 + FeFe_2O_4 \rightarrow TiO_2 + 2Fe_2O_3$$

During solidification, contraction probably caused the extensive fracturing of the rock, creating passages for the percolating fluids. Quartz, fluorides, and sulfides, enriched in the late differentiates, were deposited along these paths of easy migration. Much later, after uplift and erosion, leaching of overlying rock allowed deposition of manganese oxides along the fractures by meteoric water.

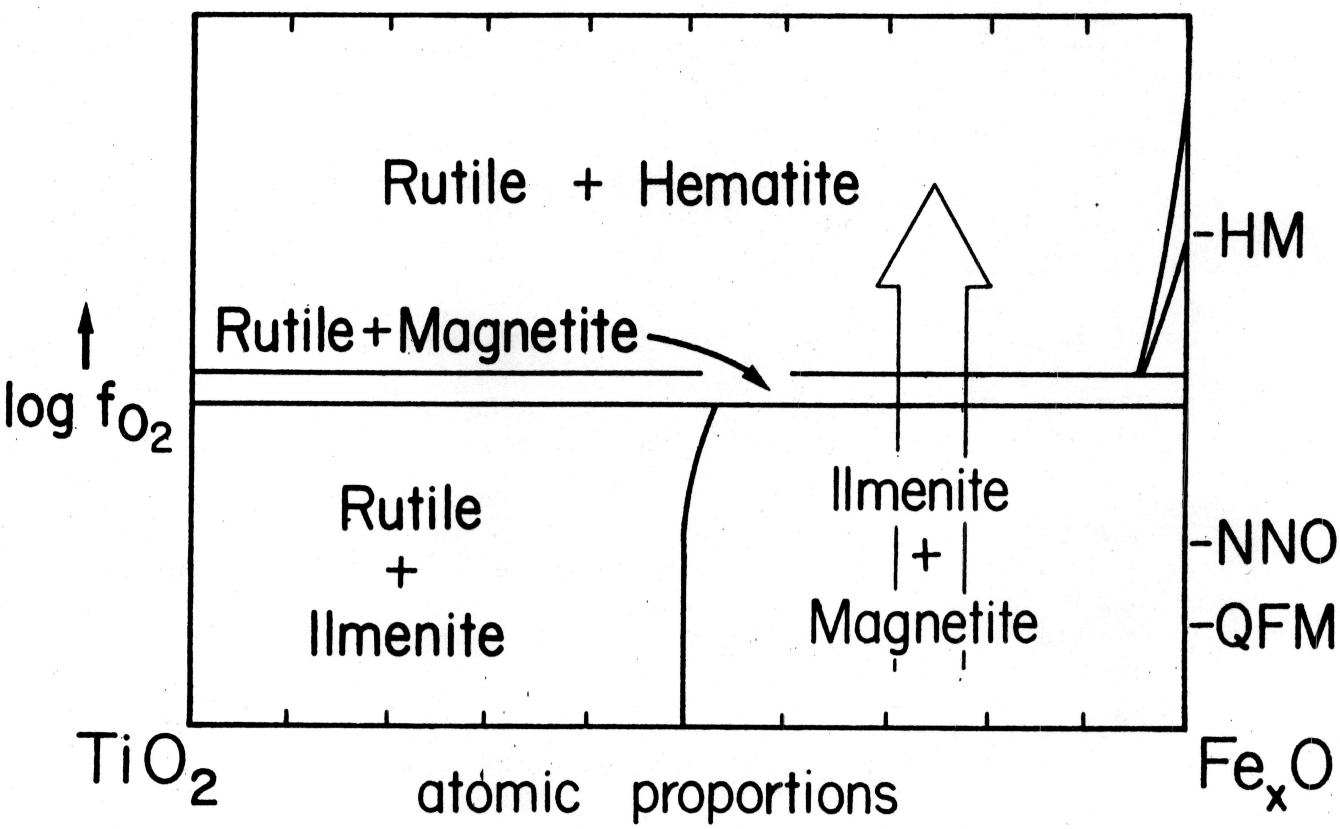


Figure A-6. X-fO2 diagram from Rumble (1977). Arrow shows the direction of reaction produced by increasing fO2, from magnetite + ilmenite to hematite + rutile.

Location of Radiogenic Elements

Work completed to date on the Cuffytown Creek pluton indicates that U and Th are concentrated in the accessory minerals monazite and zircon. Further work, including autoradiographs, microprobe analyses, and fission track studies, are needed to determine if these elements are present in other sites. The drill core should provide good samples for studying the effects of alteration on the location of T and Th; the granite from the hole varies from fresh to severely altered. In fresh rocks, U and Th appear to be concentrated in the accessory phases.

The reaction seen in the iron-titanium oxides provides evidence for a change in oxygen fugacity subsequent to the crystallization of the granite. In highly oxidized rocks, uranium will be highly mobile as U^{6+}; in environments of low fO2, uranium will be relatively immobile as U^{4+}. It may be possible in future studies to correlate the level of oxygen fugacity determined from silicates and iron-titanium oxides with the amount of uranium lost after crystallization.

PROGRESS IN FISSION TRACK ANALYSES

S. W. Becker and J. Alexander Speer

Introduction

Three elements contribute to the heat generated in rocks by radioactive decay: K, Th, and U. According to data collected thus far, K generally creates less than 10% of the heat produced. Even in highly potassic rocks, the contribution from K is no greater than 2.6 HGVU, about one third of the total. Thus for nearly all rocks, U and Th produce most of the heat. Relative contributions from U and Th can be calculated from Rybach's (1976) equation:

$$H = 0.718U + 0.193Th + 1.262K$$

(H in mass units, ucal/gm-yr, U and Th in ppm, K in wt %). When Th/U is greater than 4.0, Th contributes more than half of the heat produced. The average Th/U for samples from the southeastern U. S. is 3.8, so that a significant proportion of the heat generation comes from Th. Questions concerning the quantity and distribution of heat-producing elements in the crust settle on the behavior of U and Th.

Understanding the behavior of U and Th should aid in locating areas where their concentrations are high, resulting in higher heat generation. Because of the different geochemical characteristics of U and Th, and the various processes affecting their distribution, bulk U and

Th analyses do not significantly contribute to understanding their behavior. Progress can be made by learning the locations of the elements, the textural relation between the mineral phases involved, and the abundance of the elements. Knowledge of these factors allows the behavior of U and Th to be correlated with the petrologic evolution of the rocks, which can be more readily determined from a study of the major mineralogy.

Our work on the granites in the southeastern U. S. has identified at least four episodes subsequent to the original crystallization which could provide suitable conditions for the solution, transport, and redeposition of uranium, which would complicate the understanding of the U and Th distribution resulting from igneous crystallization. The episodes are deuteric alteration during the last stage of magmatic crystallization, hydrothermal activity during the Mesozoic(?), the supergene stage, and weathering. The country rocks have been subjected to the last three episodes, as well as the effects of contact metamorphism, which complicates the understanding of the distribution of the radiogenic elements achieved during an earlier metamorphic event(s). Such intricate geologic histories make uncertain the choice of criteria that should be used to locate areas of high heat production if the only information available is bulk rock U and Th contents.

Previous Work

Data from fission track studies in the literature indicate variable amounts of U in minerals and along grain boundaries. Quantitative studies show that U and Th occur primarily in accessory minerals. Qualitative fission track work shows significantly more U distributed along cleavages, grain boundaries, and cracks, and associated with iron and manganese minerals. The location of U is probably variable, and depends on the effects of deuteric and hydrothermal alteration and groundwater leaching superimposed on the original igneous or metamorphic distribution. Samples chosen for quantitative work generally have the least complex geologic history; hence, a large percentage of the U and Th in these studies is found in the original crystallographic sites. Samples examined by qualitative methods have usually been subject to post-crystallization processes, and thus show a more varied distribution. The U lining grain boundaries, microcracks, and Fe-Mn minerals has been probably been leached, transported, and redeposited. Because Th does not form readily soluble complexes, as does U, it is believed to remain in sites reached during crystallization.

Progress

During the past two months, progress was made toward determining the distribution of U in granitic rocks by fission track analysis. Several thin sections were irradiated at the U. S. Geological Survey in Denver and have been returned to the Radiation Safety Office at VPI & SU. Steps are currently being taken to comply with the University safety regulations concerning the use of radioisotopes. J. A. Speer and S. W. Becker have passed the course and test required of all personnel involved in the study of radioactive material. An application for using an area in Dr. A. K. Sinha's laboratory to examine the irradiated samples has been submitted and is awaiting approval by the University Radioisotope Committee.

Preliminary work on the distribution of U and Th has been performed using the electron micrprobe to test the applicability of this approach. Figure A-7,a-e, are x-ray scanning photographs of overlapping grains of uraninite and apatite in a biotite matrix. Each photograph shows the relative concentrations of one element in the various minerals; high concentrations appear as light-colored areas. The uraninite, in addition to uranium, contains significant amounts of thorium and lead. Calcium in the biotite is concentrated in a ring surrounding the uraninite grain, apparently as a result of radiation damage.

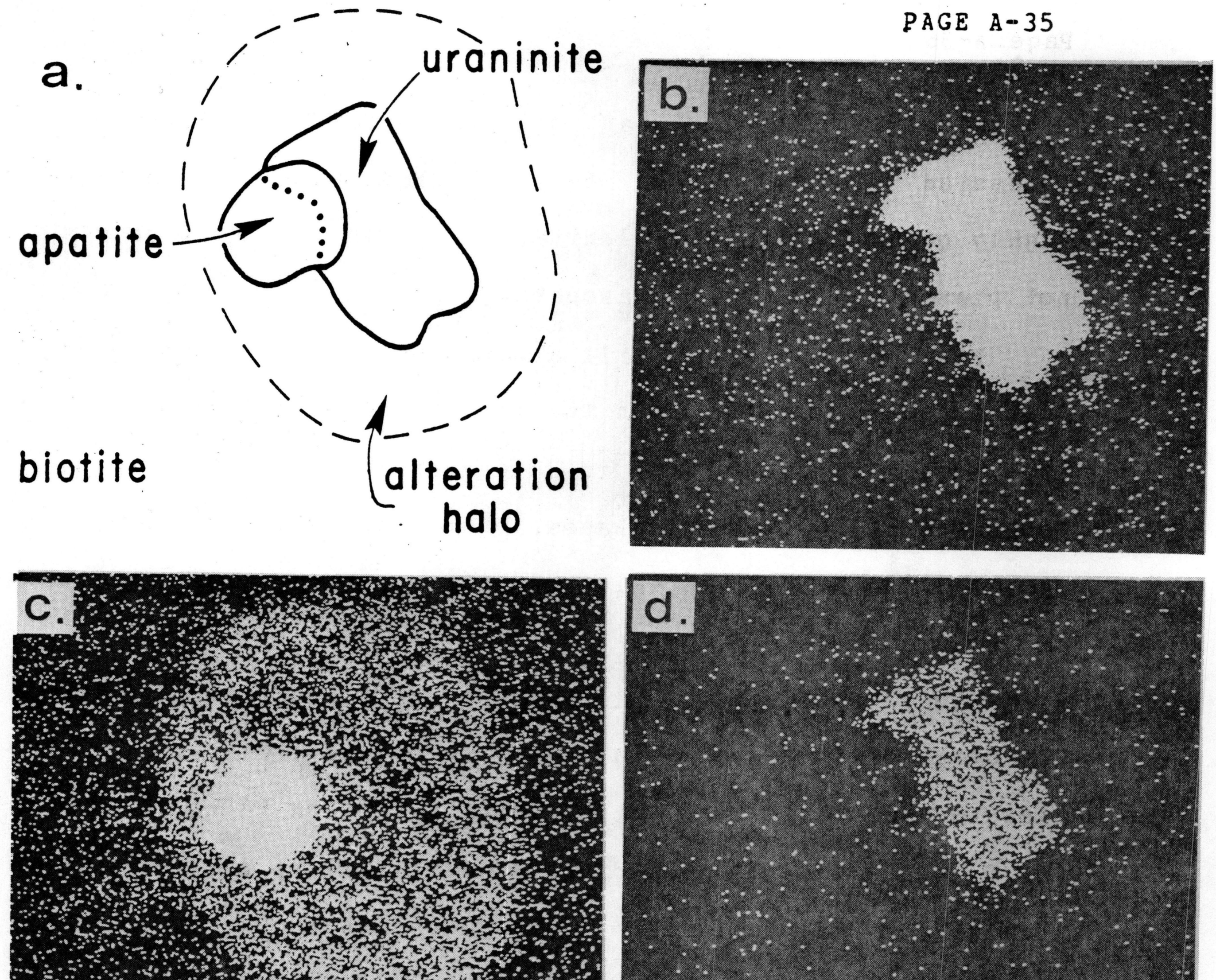


Figure A7. X-ray scanning photographs of uraninite and apatite grains enclosed in biotite; field width = 0.11 mm. (a) Map showing grain boundaries, (b) scan for U, (c) scan for Ca, showing zone of Ca-enrichment in radiation-damaged area of biotite, (d) Th scan, (e) Fe scan, (f) Pb scan.

Similar scans of an allanite grain adjacent to potassium feldspar (Fig. A-8,a-c) show that thorium is highly concentrated in allanite, at 1-2 wt %. Uranium was not present in detectable amounts.

Fission track work will allow more detailed study of uranium concentrations than the microprobe x-ray scans. Not only should it be possible to determine the absolute uranium contents of the various phases, but small amounts located along grain boundaries, cleavage traces, and cracks should be detectable as well.

Study of thorium will require more complex methods. The decay of Th-232, the naturally occurring isotope, is too slow to use fission track techniques analogous to those used for U detection. Thorium distributions will be studied by a combination of microprobe, particle track mapping, and neutron activation techniques. Combined with the fission track work, these studies should provide an accurate guide to the distribution of radiogenic elements in granitic rocks.

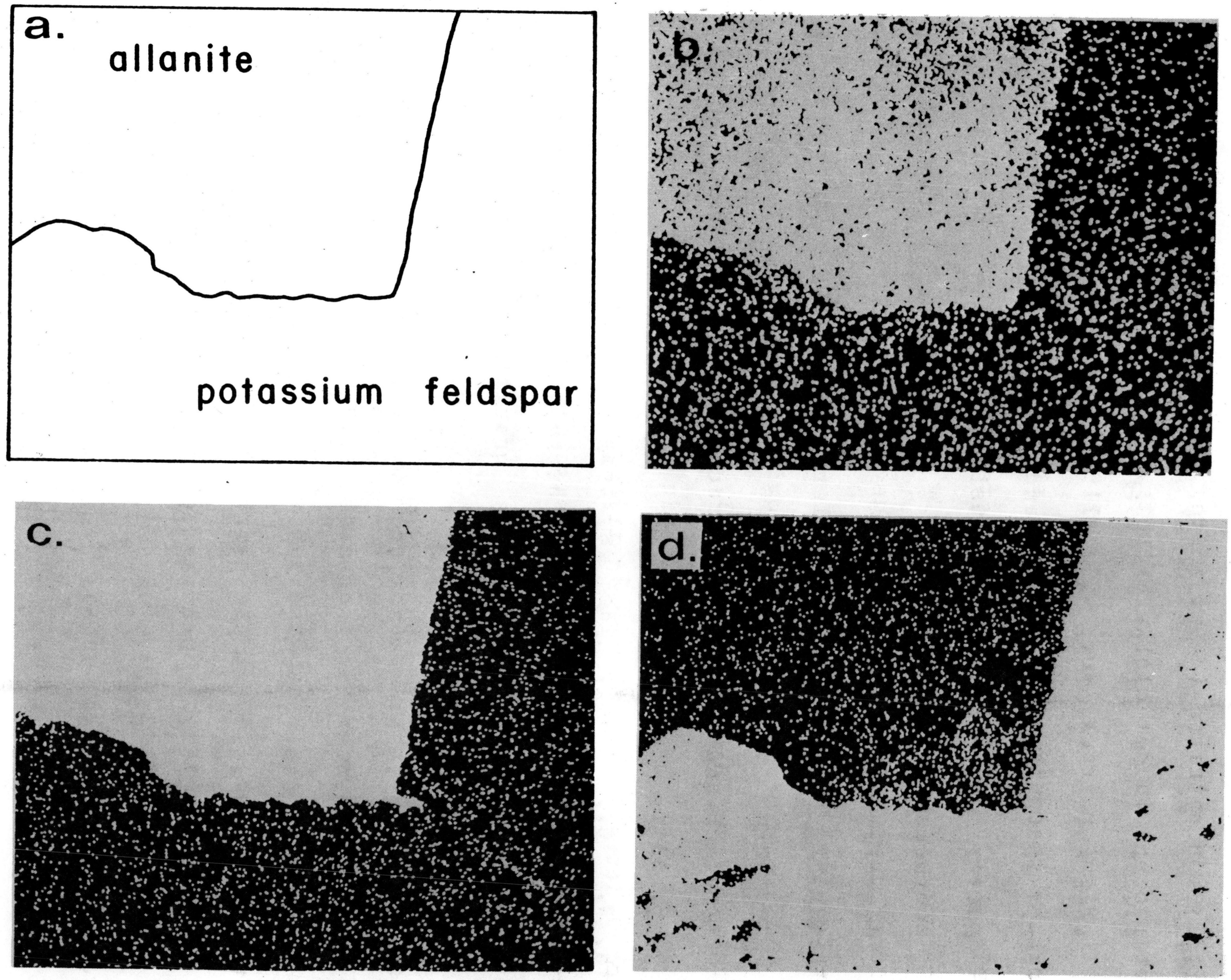


Figure A8. X-ray scanning photographs of allanite adjacent to potassium feldspar; field width = 0.11 mm. (a) Map showing grain boundary, (b) scan for Th, showing high concentration in allanite, (c) Ca scan, (d) K scan.

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PETROGRAPHIC AND PETROLOGIC DESCRIPTION OF A SUB-COASTAL PLAIN BASEMENT CORE FROM NEAR JESUP, GEORGIA

Richard J. Gleason

Introduction

The Atlantic Coastal Plain geologic province is composed of a sequence of Cretaceous to Recent sediments, predominantly continental clastics north of southern Georgia, though becoming progressively marine toward the coast, and predominantly marine carbonates in southern Georgia and Florida (Maher, 1971). In general, the Coastal Plain sediments thicken toward the Atlantic Coast, with overall structure contours approximately parallel to the predominant Appalachian trends to the west (Fig. A-9). Locally, subsurface structures interrupt this trend, most notably the Salisbury Embayment and Southeast Georgia Embayment, where onshore thicknesses of sediment exceed 10,000 feet and 5,000 feet, respectively, and the Cape Fear Arch, where the sediment thickness at the coast thins to just over 1,000 feet. Offshore, the Coastal Plain continues to the edge of the Continental Shelf. At the western limit of the Coastal Plain province, Cretaceous and Tertiary sediments overlie the Piedmont province, composed of metamorphic rocks and igneous plutons. The Piedmont is interrupted by deep, early Mesozoic (Triassic-early Jurassic), fault-bounded troughs of immature continental

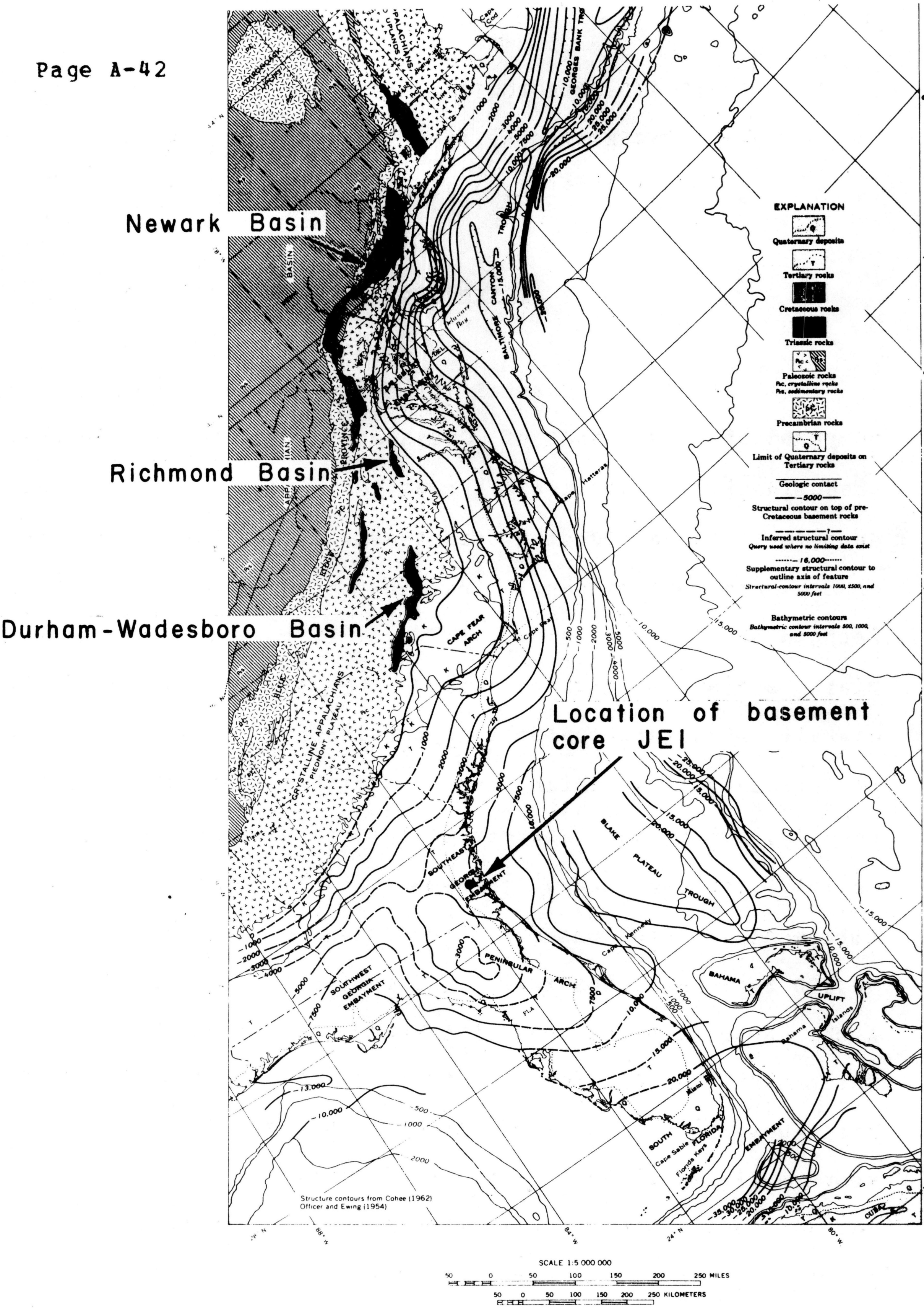

Figure A-9. Regional geology and structure of the Atlantic Coastal Plain, showing approximate location of basement core #Je 1. (Adapted from Maher, 1971.)

clastics and mafic volcanics; for example, the Newark Basin of New Jersey, the Richmond Basin of Virginia, and the Durham-Wadesboro Basin of North Carolina (Fig. A-9).

"Basement" as defined for the DOE geothermal project consists of any material underlying Coastal Plain sediment, and thus may be generalized as "pre-Cretaceous" in age. Current knowledge and understanding of this pre-Cretaceous basement is dependent on existing data for wells which have penetrated the entire Coastal Plain sequence, as well as on magnetic and gravity data. Because of the considerable depth of much of this sequence, well data is somewhat scanty, consisting of wells drilled for local water supply, and a very few deeper oil test wells.

Because any potential heat source for low-temperature geothermal energy along the Atlantic Coastal Plain will be part of the underlying pre-Cretaceous basement, it is essential that the level of understanding of this basement be vastly improved. To meet this objective, research has been ongoing at VPI & SU and consists of two parts. The first aspect of this research is a compilation from literature of all existing data for wells which penetrate basement. This work is being performed for each state and will provide existing data points as well as an indication of areas where data are scarce. The second aspect consists of direct observation of drill-core samples obtained from wells which have penetrated and recovered basement material from beneath the Coastal Plain.

The first such core obtained for study was recovered from a well drilled near Jesup (Wayne County) in southeastern Georgia (Fig. A-9). This well was located approximately 130 miles southeast of the edge of the Coastal Plain province, and basement material was cored from 4341' to 4371' below the drilling datum. The following discussion concerns the state of the research concerning this core, and is intended primarily as a descriptive summary, though some mention will be made of its relation to other basement data from the area.

Previous Investigations

Because of its proximity to the highly productive petroleum province of the Gulf Coast, Georgia has benefitted from considerably more deep drilling activity than any of the other states lying along the Atlantic Coastal Plain to the north. A literature survey has provided a list of 80 deep wells which penetrate pre-Cretaceous basement below the Georgia Coastal Plain. A number of articles referring to this basement, based on well-data have been published. Perhaps the most complete descriptive summary of basement well data was prepared by Milton and Hurst (1965), who provided general petrographic summaries of basement material from 39 wells in Georgia.

A general interpretation of the basement geology in the vicinity of the Jesup drill hole was discussed by Applin (1951). Ross (1958) gave a petrographic description of welded tuff obtained in a well from Clinch County, approximately 70 miles to the southwest of Jesup. Bass (1969) described crystalline basement rocks of Florida and southeastern Georgia, with specific attention to regional age relationships and tectonic implications.

Drilling and Recovery of Core

Basement core #Je 1 was obtained from the State of Georgia C. D. Hopkins et al. well, which was located approximately 8.5 miles southeast of Jesup (Wayne County), Georgia. This well was completed on December 12, 1977 and basement material was cored between 4341' and 4371' below the drilling datum. From this 30' interval, approximately 27.5' of core was recovered. The core was then split by the USGS, and half of the core was sent to VPI & SU for analysis.

Macroscopic Description

The core is an extremely fine-grained, dark gray to black rock with interbedded, light gray beds and laminae. The light gray units range in thickness from a few millimeters up to approximately three centimeters. The darkest portions of the core locally contain well-defined, fine laminations of less than a millimeter in thickness and elsewhere appear massive. The light gray zones have no internal bedding within given units. Much of the core is composed of rock which is intermediate between these two extremes, both in color and development of laminations. This implies that the material in the core may represent a full range of depositional conditions between those responsible for the formation of darker, well-bedded material and the light gray, massive units.

Perhaps the most notable characteristic of the core is its deformational fabric. Bedding orientation of the gray layers varies from subhorizontal to subvertical, with perhaps 25-30% of the core having dips steeper than 60°. Much of the core has a chaotic appearance, with abrupt dip variations and numerous fin er-scale deformation features resembling drag folds and crenulations. This pervasive deformation resembles slumping of sediments in a semi-consolidated state, with larger slump blocks deforming relatively coherently and retaining features such as bedding. This presumed slumping was responsible for small-scale faults which locally offset laminae by up to several millimeters. Softer, less consolidated portions of the sedimentary sequence appear to have deformed somewhat more plastically, causing such fine-scale features as "drag folds" and fine crenulations of bedding laminae. Figure

A-10 is a schematic representation of the core, indicating bedding as well as fracture orientations. The high degree of deformation is evident from this figure.

In addition to the apparent slump deformation, the core is cut by a large number of fine fractures, most of which are filled by calcite. These fractures range from barely visible on the macroscopic scale up to a few millimeters in width. In a few areas the calcite veinlets open into irregular pods approximately one cm long. Texturally, the calcite veinlets crosscut the apparent slump deformation features described above, although several of the calcite veinlets, particularly the coarser ones, were formed along fracture zones related to the earlier deformation. Macroscopically visible fractures, many of which are filled by calcite, are also depicted on Figure A-10.

On the macroscopic scale, the mineralogy of the core is somewhat indeterminable, due to the fine-grained nature of the core material. Pyrite is visible as disseminated euhedral grains finer than 0.1 mm and as amorphous blebs oriented both along bedding and long some of the larger veinlets. A mineralogical difference between the dark and light units is suggested by the difference in hardness--the considerably softer nature of the light gray laminae implies a higher clay/mica content than in the gray-black sections. Calcite is identifiable in most of the coarser fractures in the core. Apart from these minimal observations, no

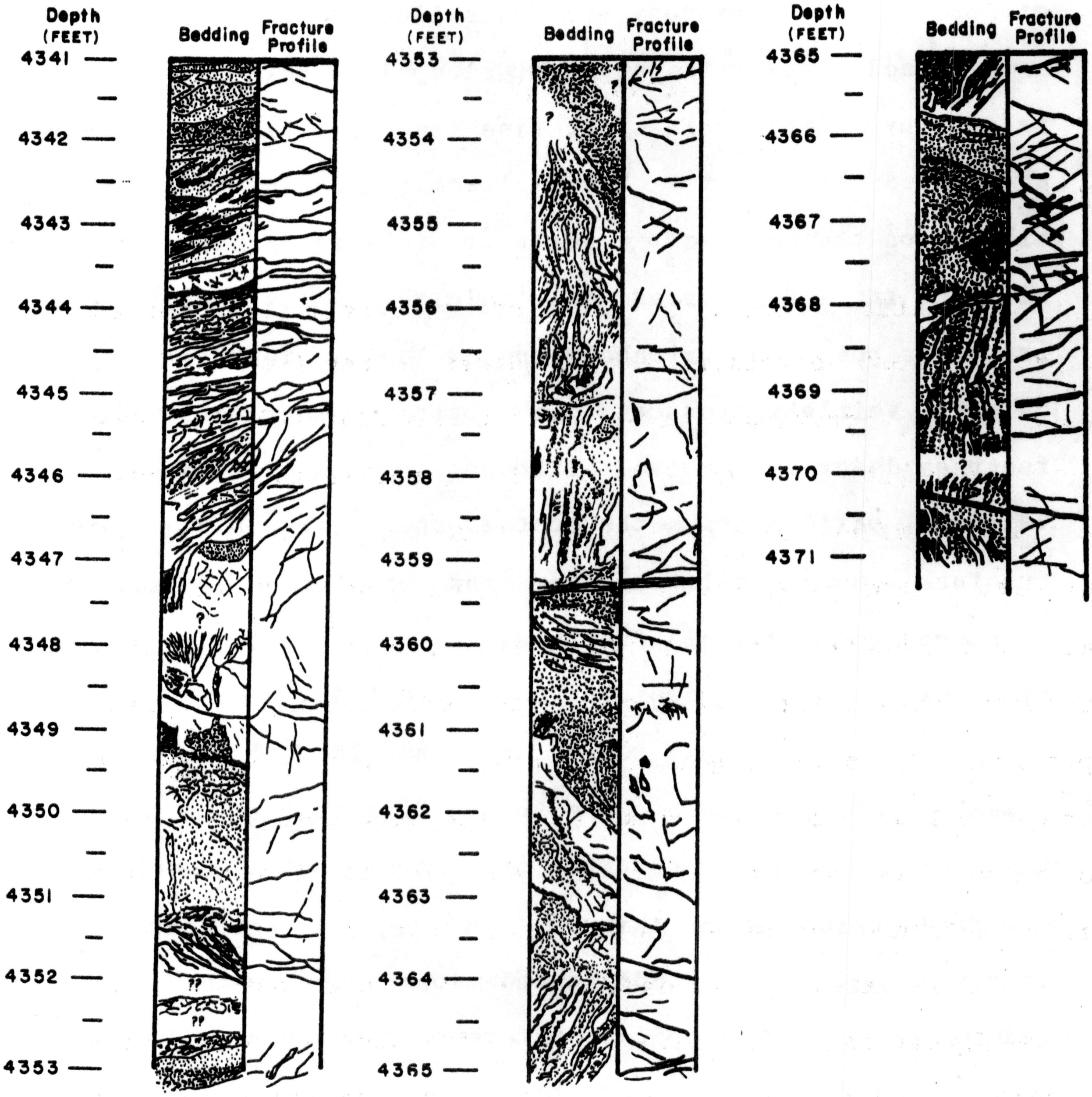

Figure A-10. Pictorial representation of the orientation of gross bedding and fractures in basement core #Je 1. Question marks indicate missing core segments.

further identification of the mineralogy is possible on the macroscopic scale.

Petrography

Texture

The entire core is composed of extremely fine-grained material, most of which is groundmass finer than .01 mm. Much of this groundmass may be as fine as .002-.005 mm. The core exhibits a well-developed pyroclastic texture, primarily defined by a variable but considerable content of angular phenocrysts ranging up to .05-.06 mm in size, which are most abundant in the light gray layers. A few local features resembling shard structures were also identified, particularly in the light gray layers. The fine grain size and pyroclastic texture of much of the core imply that much of it may have originated as volcanic ash which was erupted from vents and deposited as ash-fall tuffs.

The variability in darkness of the core material is identifiable in thin section as a function of the opaque content. The darkest sections of the core generally contain the highest amount of pyrite and brown iron oxide stain, while the light gray layers have a much lower mafic content.

The darkest sections of the core commonly exhibit well-developed microscopic laminations resembling fine-scale bedding features. These laminations are largely a result of the concentration of opaque grains and contrasting degrees of brown staining in lenticular zones. The sections that exhibit the best-developed laminations correspondingly contain the lowest amount of phenocrysts. Conversely, the light gray layers characteristically contain the highest pyroclastic content in the form of phenocrysts, but are almost always massive within the layers.

As the macroscopic appearance of the core suggests, much deformation is visible in thin section. Microscopic laminations exhibit micro-folds and crenulations, and offsets of these structures indicate the presence of microscopic faults. These deformational features resemble the macroscopic ones which were attributed to soft-sediment slumping of the core sequence. Microscopic features related to a later deformation episode(s) are also recognizable; felsic apophyses and veinlets of feldspar or quartz are ubiquitous throughout the core and are crosscut by later carbonate veinlets.

Mineralogy

The mineralogy of the core is relatively constant, with slight variations between the light gray layers and the dark, laminated rock. The groundmass of the core is composed primarily of felsic material and sericite. The sericite blades have a maximum length of approximately .005

mm, while the felsic grains are finer than .002 mm and are unidentifiable in thin section. Sericite content increases visibly in the light gray layers, where it composes the bulk of the groundmass; however, in the darkest and best-laminated sections, the sericite content decreases to a groundmass accessory, with the groundmass instead being composed almost exclusively of felsics. X-ray diffraction analyses of both the light gray and dark material verify this mineralogical contrast, as the diffractograms indicate that the predominant mineralogy of the light gray material is a 10 angstrom white mica phase with subordinate quartz and albite, while the dark material is composed primarily of quartz and albite.

The phenocryst population of the core is comprised mostly of quartz and altered feldspar. The relative abundances of these two phases vary between tuff units. Feldspar phenocrysts are commonly altered to fine-grained calcite, sericite, quartz(?) and occasionally are stained brown by iron oxide and locally rutile. Accessory phenocrysts are apatite, chloritized biotite, and zircon. Although phenocrysts are most abundant in the light gray tuff units, compositionally the phenocryst population is apparently constant throughout the core.

A mineralogical feature peculiar to the light gray tuff layers is the presence of anhedral calcite of approximately the same size range as the phenocrysts. The occurrence of these grains disseminated through the groundmass of these layers and their porphyroblastic appearance implies a possible origin during a post-depositional recrystallization.

The mafic phases of the core are predominantly contained in the darker sections. Minor disseminated euhedral pyrite finer than approximately .01 mm is present in the light gray units; the darker sections of the core, however, contain considerable pyrite, both as euhedral crystals up to .1 mm and as anhedral, flattened lenses localized between apparent bedding laminations. Chlorite is a minor constituent of the groundmass of all but the lightest sections of the core. A few well-bedded sections of the core contain small masses of egg-shaped grains, approximately .005 mm in size which appear to be concentrated along bedding. Later microprobe work identified these as chlorite. Semi-opaque masses of calcite, rutile, and leucoxene are disseminated through the core, presumably from alteration of titanite. Dark brown, hydrated iron oxides are the remaining mafic phases present and are to a large degree responsible for the dark color of much of the core.

Much of the core is cut by irregular, somewhat discontinuous veinlets of quartz, albite, and quartz with albite, indicative of several episodes of veinlet formation. These veinlets are crosscut by later carbonate veinlets, some of which contain subordinate subhedral to euhedral quartz or accessory pyrite.

Mineral Chemistry

Feldspars. Microprobe analyses were run on five veinlet feldspar grains and over 50 feldspar phenocrysts. The recalculated mole percent analyses of An-Ab-Or are listed in Table A7 and are plotted on a feldspar ternary diagram in Figure A-11. The five veinlet feldspars (analyses 1-5 in Table A7) show a mean composition of 96.7 mol % albite, with values ranging from 94.5% to 98.9%. The An content of these feldspar grains ranges from .6% to 3.1%, with a mean value of 1.7%.

The phenocryst analyses varied from nearly albite to nearly orthoclase composition. Figure A-11 gives an indication of the complete range of phenocryst compositions. To test whether the wide range of compositions was a result of grouping phenocrysts from separate, possible unrelated tuff units into one analytical population, the phenocrysts were reanalyzed by including numerous grains from each of several tuff units. The results showed that the range of compositions of phenocrysts within a given tuff unit was nearly as extreme was was that of the total phenocryst population as a whole. In fact, several phenocrysts were analyzed in several locations, and compositional variation

TABLE A7

RECALCULATED AB-AN-OR COMPOSITIONS OF FELDSPARS FROM MICROPROBE ANALYSES

	(1)	(2)	(3)	(4)	(5)	(6)
SAMPLE	Ga/Je 1-15a	Ga/Je 1-15b	Ga/Je 1-20a	Ga/Je 1-25a	Ga/Je 1-25b	Ga/Je 1-15c
AN	2.18	3.11	2.00	0.60	0.87	11.20
AB	97.76	95.77	94.52	96.33	98.85	2.43
OR	0.06	1.12	3.48	3.06	0.28	86.38
	(7)	(8)	(9)	(10)	(11)	(12)
	Ga/Je 1-15d	Ga/Je 1-15e	Ga/Je 1-15f	Ga/Je 1-15g	Ga/Je 1-15h	Ga/Je 1-15i
AN	1.41	2.26	5.25	2.46	1.93	2.41
AB	27.29	81.79	1.33	84.88	0.73	65.86
OR	71.30	15.95	93.42	12.66	97.34	31.73
	(13)	(14)	(15)	(16)	(17)	(18)
	Ga/Je 1-15j	Ga/Je 1-15k	Ga/Je 1-15l	Ga/Je 1-15m	Ga/Je 1-15n	Ga/Je 1-15o
AN	1.64	2.23	0.71	0.38	2.73	2.26
AB	56.16	85.84	98.81	98.82	66.61	64.02
OR	42.20	11.93	0.48	0.80	30.66	33.72
	(19)	(20)	(21)	(22)	(23)	(24)
	Ga/Je 1-15p	Ga/Je 1-15q	Ga/Je 1-15r	Ga/Je 1-15s	Ga/Je 1-15t	Ga/Je 1-15u
AN	5.89	1.00	6.55	6.35	3.16	2.34
AB	83.41	91.75	87.87	76.99	61.82	90.02
OR	10.70	7.25	5.58	16.66	35.02	7.64
	(25)	(26)	(27)	(28)	(29)	(30)
	Ga/Je 1-15v	Ga/Je 1-16a	Ga/Je 1-16b	Ga/Je 1-16c	Ga/Je 1-16d	Ga/Je 1-16e
AN	2.41	0.66	9.16	3.30	4.18	0.44
AB	95.10	79.62	70.39	76.31	1.47	99.32
OR	2.48	19.71	20.45	20.39	94.35	0.24
	(31)	(32)	(33)	(34)	(35)	(36)
	Ga/Je 1-16f	Ga/Je 1-16g	Ga/Je 1-18a	Ga/Je 1-18b	Ga/Je 1-18c	Ga/Je 1-18d
AN	2.02	2.37	3.14	4.01	0.69	1.67
AB	68.25	87.56	28.32	63.35	46.65	32.87
OR	29.73	10.07	68.54	32.63	52.66	65.46

TABLE A7 (CONTINUED).

	(37)	(38)	(39)	(40)	(41)	(42)
SAMPLE	Ga/Je 1-20b	Ga/Je 1-20c	Ga/Je 1-20d	Ga/Je 1-20e	Ga/Je 1-20f	Ga/Je 1-20g
AN	1.40	1.37	5.96	0.91	0.0	0.61
AB	88.98	97.74	82.58	12.47	4.53	33.83
OR	9.62	0.89	11.46	86.61	95.47	65.56

	(43)	(44)	(45)	(46)	(47)	(48)
	Ga/Je 1-20g	Ga/Je 1-20g	Ga/Je 1-20g	Ga/Je 1-20g	Ga/Je 1-20h	Ga/Je 1-20h
AN	1.46	0.63	3.31	2.64	0.57	3.19
AB	83.70	90.14	85.60	90.44	27.10	83.81
OR	14.84	9.23	11.09	6.92	72.33	12.99

	(49)	(50)	(51)	(52)	(53)	(54)
	Ga/Je 1-20i	Ga/Je 1-20i	Ga/Je 1-20i	Ga/Je 1-20j	Ga/Je 1-20k	Ga/Je 1-20l
AN	0.54	0.48	0.31	0.31	0.80	0.92
AB	6.57	7.68	5.19	10.94	96.35	46.99
OR	92.89	91.84	94.50	88.74	2.85	52.09

	(55)	(56)	(57)	(58)	(59)	(60)
	Ga/Je 1-20m	Ga/Je 1-20n	Ga/Je 1-20o	Ga/Je 1-22a	Ga/Je 1-22b	Ga/Je 1-22c
AN	1.68	0.23	0.49	0.10	3.04	0.40
AB	47.74	6.15	9.46	85.82	58.41	55.28
OR	50.58	93.62	90.05	14.08	38.55	44.32

	(61)	(62)	(63)
	Ga/Je 1-22d	Ga/Je 1-22e	Ga/Je 1-25c
AN	1.71	1.48	1.28
AB	77.49	52.01	97.08
OR	20.80	46.52	1.65

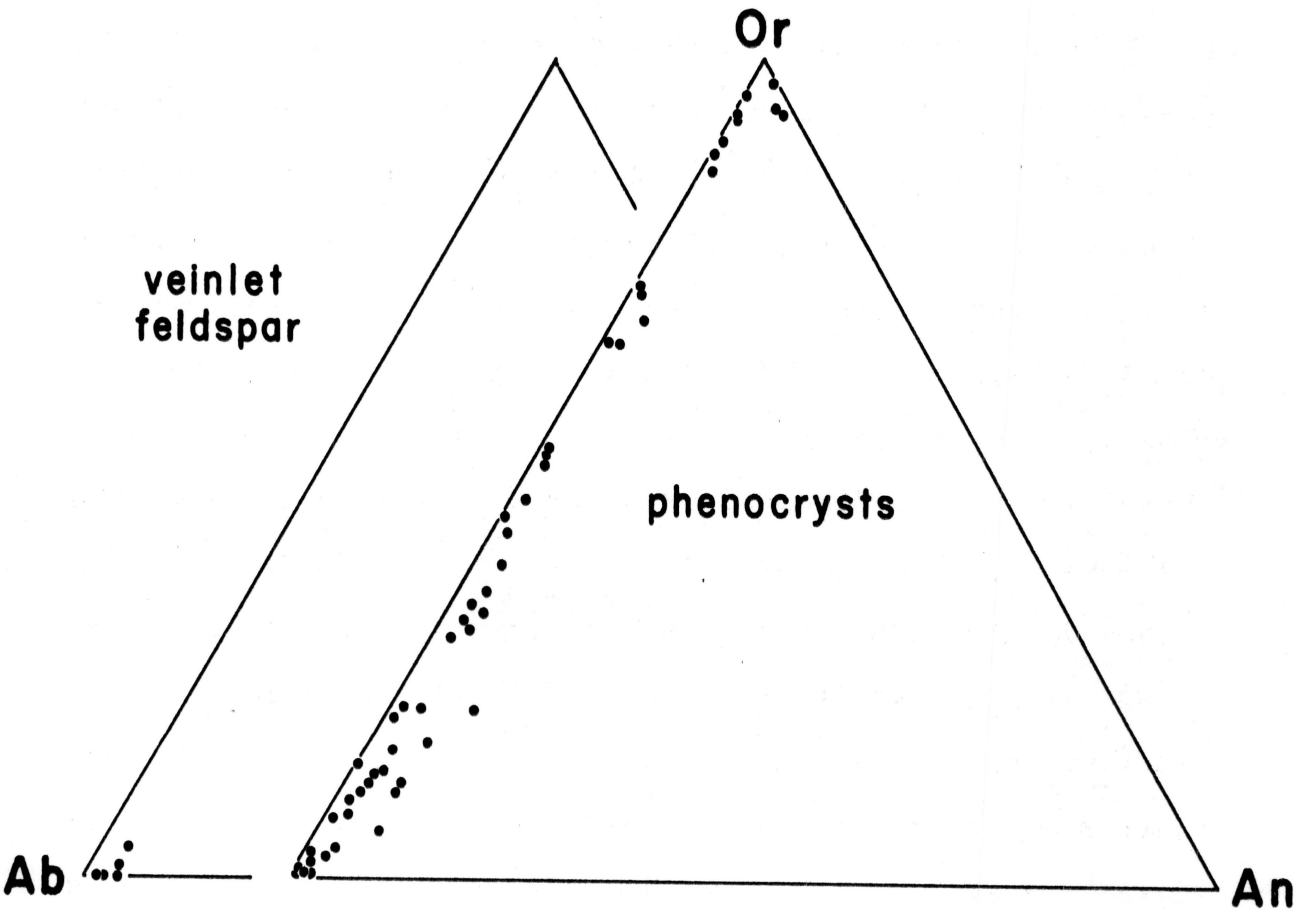

Figure A--11. Ternary diagram of the An-Ab-Or system showing veinlet feldspar and feldspar phenocryst compositions determined by microprobe analysis.

even within the individual phenocrysts was extreme (see analyses 42-46, 47-48 in Table A7).

Although the majority of phenocrysts have predominatly sodic compositions, the variation is too extreme to predict phenocryst compositions. No distinction can be made between feldspars of contrasting composition based on optical properties alone, due to the state of alteration of the phenocrysts. It is concluded then that the compositional variation is a reflection of the alteration of the original phenocrysts. Virtually all (12 of 15) of the phenocrysts with Or content greater than 52% show wt % analyses of oxides which are deficient in silica and enriched in aluminum, and therefore appear to be better represented as phengitic mica analyses instead of feldspar analyses. The analyses of these same phenocrysts exhibit enrichment in combined iron plus magnesium, supporting this idea. The three analyses which did not show silica enrichment and aluminum deficiency (analyses, 9, 11, 29 in Table A7) were instead enriched in calcium and titanium by two to three times the amount contained in the rest of the feldspars analyzed.

The feldspar phenocrysts were probably originally alkali feldspars of anorthoclase to sanidine composition. Subjected to post-depositional metamorphism, they were altered primarily to ablite, phengite, and quartz.

Upon microprobe analysis, a given phenocryst shows a composition reflecting the bulk composition of the fine-grained alteration products located under the beam. The three K-rich phenocrysts which were enriched in calcium and titanium may represent phenocrysts containing more calcite and rutile than the other more sericite-rich phenocrysts.

Some of the chemical components taking part in the alteration of the original phenocrysts may have been contributed from alteration of the surrounding groundmass. Nonetheless, the original phenocrysts were probably compositionally alkali feldspars.

Chlorite. Six microprobe analyses of chlorite appear in Table A8. Three were analyses of chlorite nucleation "eggs" (analyses 1-3), one was of a chloritized biotite (analysis 4), and two were of groundmass chlorite (analyses 5-6). All chlorite analyses indicate intermediate Fe-Mg varieties, and the "eggs" are the most iron rich.

White Mica. Microprobe analyses were obtained for six groundmass micas (analyses 1-6 in Table A9). In addition, two K-rich feldspar phenocryst analyses were recalculated to fit a mica formula (analyses 7-8). All analyses indicate micas of phengitic composition with slight aluminum deficiency in the octahedral sites caused by enrichment of iron and magnesium (up to combined Fe + Mg = 0.8-0.9 per 24 oxygen structural formula). As expected for phengitic micas, they are also enriched in silica in the tetrahedral sites, causing aluminum deficiency in these sites. In

TABLE A8

MICROPROBE ANALYSES OF CHLORITES

OXIDE/SAMPLE#	(1) Ga/Je 1-15a	(2) Ga/Je 1-15b	(3) Ga/Je 1-15c	(4) Ga/Je 1-15d	(5) Ga/Je 1-0a	(6) Ga/Je 1-20b
SiO2	26.48	29.20	26.98	28.86	29.30	29.08
Al2O3	21.00	22.82	22.17	21.08	20.45	21.63
FeO	32.86	29.04	31.10	27.29	21.38	22.21
TiO2	0.0	0.0	0.0	1.47	0.0	0.0
MnO	0.92	0.82	0.86	0.85	0.88	0.77
CaO	0.02	0.09	0.10	0.10	0.14	0.12
MgO	9.54	9.32	8.46	11.91	13.14	14.89
Na2O	0.01	0.10	0.04	0.06	0.24	0.05
K2O	0.0	1.05	0.40	0.55	0.11	0.16
H2O	11.35	11.85	11.38	11.90	11.42	11.82
SUM	102.18	104.29	101.49	104.07	97.06	100.73
Formulas based on 18 oxygens						
Si	2.796	2.952	2.842	2.906	3.074	2.948
Al	1.204	1.048	1.158	1.094	0.926	1.052
SUM	4.000	4.000	4.000	4.000	4.000	4.000
Al	1.408	1.670	1.594	1.408	1.603	1.532
Ti	0.0	0.0	0.0	0.111	0.0	0.0
Fe	2.901	2.455	2.740	2.298	1.876	1.883
Mn	0.082	0.070	0.077	0.073	0.078	0.066
Mg	1.501	1.404	1.328	1.788	2.055	2.250
Ca	0.002	0.010	0.011	0.011	0.016	0.013
Na	0.002	0.020	0.008	0.012	0.049	0.010
K	0.0	0.135	0.054	0.071	0.015	0.021
SUM	5.898	5.765	5.812	5.771	5.692	5.774
H	8.000	8.000	8.000	8.000	8.000	8.000
O	18.000	18.000	18.000	18.000	18.000	18.000
F/M	1.987	1.798	2.120	1.326	0.951	0.866
F/FM	0.665	0.643	0.680	0.570	0.487	0.464

TABLE A9

MICROPROBE ANALYSES OF WHITE MICAS

OXIDE/SAMPLE#	(1) Ga/Je 1-22a	(2) Ga/Je 1-22b	(3) Ga/Je 1-22c	(4) Ga/Je 1-22d
SiO_2	50.50	51.89	54.53	48.45
Al_2O_3	30.38	32.10	30.51	30.52
FeO	1.18	1.53	2.28	1.40
TiO_2	2.82	0.0	0.0	0.0
MnO	0.04	0.06	0.09	0.07
CaO	0.05	0.05	0.07	0.04
MgO	1.71	1.79	2.58	1.68
Na_2O	0.03	0.02	0.03	0.03
K_2O	7.55	8.14	7.40	7.95
H_2O	4.56	4.62	4.73	4.35
SUM	98.82	100.20	102.22	94.49
Formulas based on 24 oxygens				
Si	6.636	6.723	6.908	6.673
Al	1.364	1.277	1.092	1.327
SUM	8.000	8.000	8.000	8.000
Al	3.340	3.624	3.463	3.625
Ti	0.279	0.0	0.0	0.0
Fe	0.130	0.166	0.242	0.161
Mn	0.004	0.007	0.010	0.008
Mg	0.335	0.346	0.487	0.345
SUM	4.087	4.142	4.201	4.140
Ca	0.007	0.007	0.010	0.006
Na	0.008	0.005	0.007	0.008
K	1.265	1.345	1.196	1.396
SUM	1.280	1.357	1.213	1.410
H	4.000	4.000	4.000	4.000
O	24.000	24.000	24.000	24.000
F/M	0.400	0.499	0.516	0.491
F/Fm	0.286	0.333	0.340	0.329

TABLE A9 (CONTINUED)

OXIDE/SAMPLE#	(5) Ga/Je 1-15a	(6) Ga/Je 1-15b	(7) Ga/Je 1-15c	(8) Ga/Je 1-20a
SiO2	47.37	46.93	51.52	49.98
Al2O3	32.39	32.61	35.36	35.75
FeO	4.64	4.94	2.01	1.61
TiO2	0.23	0.31	0.0	0.0
MnO	0.13	0.17	0.12	0.06
CaO	0.14	0.0	0.06	0.0
MgO	1.79	1.67	1.07	1.23
Na2O	0.14	0.12	0.59	0.38
K2O	8.67	10.20	7.66	8.12
H2O	4.49	4.50	4.75	4.68
SUM	99.99	101.45	103.14	101.81
Formulas based on 24 oxygens				
Si	6.322	6.243	6.497	6.395
Al	1.678	1.757	1.503	1.605
SUM	8.000	8.000	8.000	8.000
Al	3.416	3.355	3.751	3.784
Ti	0.023	0.031	0.0	0.0
Fe	0.518	0.550	0.212	0.172
Mn	0.015	0.019	0.013	0.007
Mg	0.356	0.331	0.201	0.235
SUM	4.328	4.286	4.177	4.198
Ca	0.020	0.0	0.008	0.0
Na	0.036	0.031	0.144	0.094
K	1.476	1.731	1.232	1.325
SUM	1.532	1.762	1.384	1.419
H	4.000	4.000	4.000	4.000
O	24.000	24.000	24.000	24.000
F/M	1.496	1.718	1.118	0.762
F/Fm	0.599	0.632	0.528	0.433

addition, the interlayer charge (K + accessory Na + Ca) is reduced to less than 1.8 per 24 oxygen structural formula, as compared to a value of 2.0 for ideal muscovite.

Interpretation of Origin and Deformation

Textural and mineralogical contrasts between the extreme types of rock in the core--the light gray, massive layers and the dark, laminated sections--imply that depositional conditions fluctuated during the formation of this sequence of volcaniclastic material. In the light gray units, the poorly developed to massive internal bedding and high pyroclastic phenocryst content, along with local shard-like structures, support an interpretation of these units as ash-fall crystal tuffs. The contrasting dark, well-laminated sections of the core exhibit fine sedimentary bedding features and a reduced phenocryst component, seeingly representing reworked volcaniclastic or epiclastic debris probably derived from a subaerial source. The preservation of fine textural features such as tuff laminations and apparent bedding laminations, as well as the extremely fine grain size, imply deposition in a deep basin in which bottom currents would have been too gentle to have disrupted the sequence.

This deep basin was probably located in close proximity to a volcanic province. Eruptive vents would have provided volcaniclastic material which would have included occasional bursts of tuffaceous debris carried out over the basin as ash-clouds and subsequently deposited as ash which would settle out rapidly on the floor of the basin as fairly pure ash units, presently represented by the light gray sections of the core. During periods of relative quiescence, reworking of a previously existing, possibly subaerial terrain would provide an influx of fine clastic debris which presently comprises the bulk of the darker sections of the core. The mineralogical and grain-size similarity of the darker sections and light gray layers of the core imply similarity of source material; therefore, it is probable that the darker sections were derived from reworking of pyroclastic debris. The presence of pyroclastic phenocrysts in the darker rock, although in lesser quantity than in the light gray tuff units, implies that semicontinuous though less voluminous or more distal eruptions of tuffaceous debris occurred during much of the period of deposition.

The large proportion of opaques present in the dark, laminated, reworked volcaniclastic sections might be related to the chemical erosion of volcanic debris; iron might be taken into solution, to later slowly precipitate out as pyrite or hydrous oxides during the sedimentary sequence. Alternatively, the high opaque content may instead have been caused by exhalations of iron along with sulfur from a subterranean vent (or vents). The relatively slow build-up of the sedimentary sequence as opposed to the rapid deposition of the ash-fall tuff units would allow more time for the precipitation of pyrite and hydrated oxides, thereby accounting for the great difference in mafic content of the dark, bedded material as compared to the light gray tuffaceous units.

The first deformational episode to affect the core sequence apparently was the result of slumping of the material while in a semi-consolidated state. This deformation may have occurred during the interval of deposition or may have continued after the end of deposition. The environment of deposition as visualized in the above description would have been conducive to slumping. The sediments would have been water-saturated, and the slope of the basin floor could have been quite irregular. In a volcanotectonic setting such as has been proposed for the formation of the material in the core, considerable seismic activity could be expected to cause earthquakes, leading to instability and slumping of the sedimentary sequence.

Metamorphism

The mineral assemblages present in the core have re-equilibrated at conditions different from those prevailing during deposition. It is not possible to determine whether metamorphism was imposed by conditions accompanying deep burial or by the existence of a high geothermal gradient related to a local thermal event. The original detrital assemblage was probably composed of clay minerals (perhaps mixed layer illite-montmorillonite), quartz, and alkali feldspar with accessory minerals such as titanite, apatite, and zircon. With metamorphism, the current assemblage was obtained. Clay minerals were transformed to phengitic mica and chlorite, a portion of which is present as "eggs" apparently representing the initial stages of chlorite growth. Titanite was altered to rutile, calcite, and quartz, and alkali feldspar was altered to albite, phengitic mica, and calcite. Calcium released during the alteration of titanite and feldspar appears to have been scavenged to form calcite porphyroblasts concentrated in many of the ash-fall tuff units, while albite and quartz were recrystallized and mobilized during several episodes of veinlet formation.

X-ray diffractograms of mica-rich material from the core were obtained in an attempt to determine a "crystallinity index" as an index of metamorphic conditions (Kubler, 1968; Weaver, 1960). Kubler's indexing method was not applicable in this case because it relies upon a half-peak width of the 10 angstrom mica peak, a criteria dependent upon laboratory and apparatus conditions. No attempt to standardize such parameters was made for this study. Weaver's method of crystallinity indexing is to divide the height of the 10 angstrom peak at 10.0 angstroms by the height of the side of the peak at 10.5 angstroms.

This ratio from four separate diffractograms resulted in a value of 2.82, midway between Weaver's "incipient" and "incipient to weak" metamorphism categories.

A transformation from a 1Md to a 1M to a 2M structural polymorph during the structural rearrangement that occurs in changing illite to muscovite is well documented (Reynolds, 1963; Velde and Hower, 1963, Hower and Mowatt, 1966; Maxwell and Hower, 1967). A ratio of the intensities of the 2.80 angstrom and 2.57 angstrom mica peaks was used to determine the degree of development of the 2M polymorph (Maxwell and Hower, 1967). According to guidelines set by Maxwell and Hower, the values of this ratio from four diffractograms indicated that the phengitic micas of the core were approximately 75-77% converted to the 2M polymorph.

The crystallinity index measurements and polymorph determination, along with the 10 angstrom basal reflection of the mica, indicates that it obtained a moderate to high level of transformation from illite to a metamorphic mica. No interlayered montmorillonite is present and the polymorph type is nearly a metamorphic 2M rather than a low-grade diagenetic 1Md polymorph.

The mica polymorph data, its phengitic composition, the presence of chlorite "eggs" implying formation at an incipient nucleation stage, the alteration of alkali feldspar to albite, sericite, and calcite, the presence of albite-quartz veinlets, and the coexistence of rutile, calcite, and quartz all provide an indication of the facies conditions under which the core was metamorphosed. Conditions were likely similar to those of Winkler's (1976) "very low grade." This category corresponds to conditions just below or at the lower boundary of the greenschist facies.

Experimental data on the stability fields of several reactions pertinent to the mineral assesmblage of core #Je 1 provide rough constraints on the pressure and temperature attained during metamorphism. Conditions exceeded those necessary for a conversion from analcime + quartz to albite (Liou, 1971) but were below those necessary for the formation of biotite. Other limiting reactions are the conversion of albite to jadeite + quartz (Newton and Fyfe, 1976), the conversion of muscovite + calcite + quartz to andalusite + K feldspar + vapor (Hewitt, 1973), and the conversion of rutile + calcite + quartz to titanite + CO_2 (Hunt and Kerrick, 1977).

The location in P-T space of these reaction curves will vary depending upon the partial pressures of H_2O and CO_2 prevailing during metamorphism. The reaction transforming rutile + calcite + quartz to titanite + CO_2 is particularly dependent on pCO_2. The assemblage present in the #Je 1 core indicates that both CO_2 and H_2O were present in unknown but substantial amounts. In order to relate the above reactions to the mineral asssemblage of the core, it would be necessary to assume a specific partial pressure for both H_2O and CO_2. Figure A-12 is adapted from Thompson and Thompson (1976) and schematically depicts the bounding reactions and the stability field of the core assesmblage assuming Ptotal equal to Pfluid for an intermediate CO_2-H_2O fluid.

Combining the facies interpretation with the experimental constraints, it remains difficult to speculate on specific pressure and temperature co:'itions. A temperature range is perhaps 225-330°C, and pressure likely was below a maximum of 2-3 kb.

Formation of late-stage carbonate veinlets occurred after the metamorphism of the core. Microprobe analyses indicate that the veinlets are filled by carbonates of both calcitic and zoned iron-magnesium-manganese-rich ankerite varieties, probably reflective of multiple episodes of veinlet-filling.

Most of the carbonate veinlets present in the core cross-cut the earlier albite-quartz veinlets, though a minor amcunt of carbonate veinlets may have been generated during the earlier metamorphism. Most are related to a later, perhaps separate phase of hydrothermal activity, however. A few of the coarser calcite veinlets contain euhedral quartz, implying that these veinlets filled fractures which were prcbably subjected to minimal and hydrostatic pressure. Some of these later, coarser calcite veinlets are localized alcng minor faults, apparently representing the final

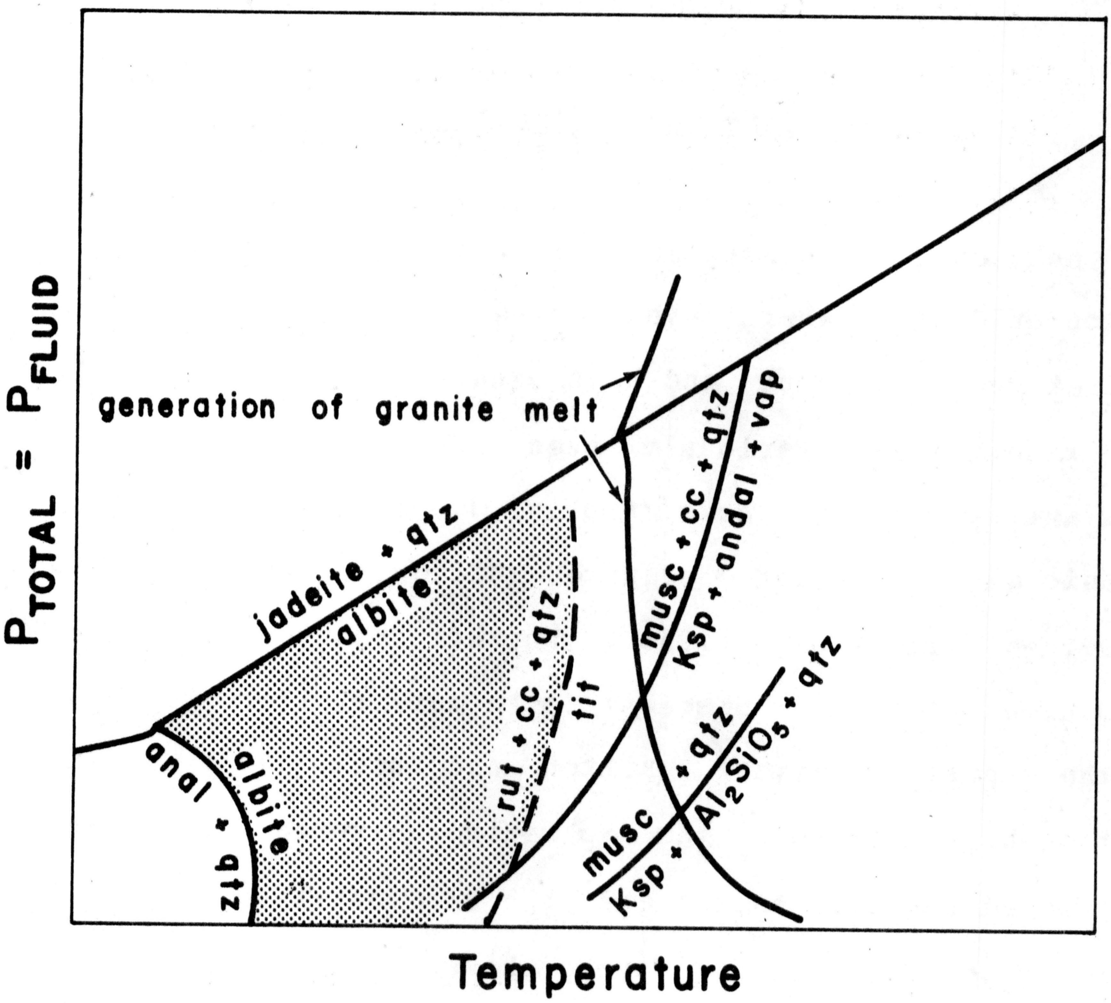

Figure A-12. Schematic pressure-temperature diagram for metamorphic reactions in a system similar to that of basement core #Je 1. The shaded area represents the stability field of the mineral assemblage of the core. Ptotal is equal to Pfluid, which is assumed to have an intermediate H2O-CO2 composition. Figure adapted from Thompson and Thompson (1976) with the exception of the rutile + calcite + quartz -> titanite, which is estimated frcm Hunt and Kerrick (1977), for an intermediate H2O-CO2 fluid composition.

episode of deformation affecting the core sequence; thus, it possible that some hydrothermal activity accompanied this episode.

General Tectonic and Regional Implications

The Jesup, Georgia basement core #Je 1 is located in a section of Georgia where several other wells have penetrated pre-Cretaceous basement and have exhumed similar material. This material has variously been described as rhyolitic lavas and pyroclastic rocks (Applin, 1951), rhyolitic tuffs, volcanic ash, and altered granite (Milton and Hurst, 1965), and welded tuff (Ross, 1958). Further to the northwest, wells have penetrated basement rocks more similar to those of the exposed Piedmont (Milton and Hurst, 1965). The relationship between the volcanic basement province represented by core #Je 1 and the Piedmont-type basement rocks is not known and is beyond the scope of this report.

Taylor, Zietz, and Dennis (1968) have discussed the East Coast magnetic anomaly which approximately parallels the edge of the continental shelf from the Canadian Maritimes south to about 31°N latitude, where it bends abruptly, trending perpendicular to the coast, and crosses the shoreline at Brunswick, Georgia, approximately at the southern boundary of the basement volcanic province discussed above. South of this boundary, undeformed lower

Paleozoic clastic sediments have been encountered in basement wells, and although it has been postulated that these sediments overlie a continuation of the volcanic province to the north (Applin, 1951), the nature of the contact zone between the volcanics and the clastic sediments is unclear.

The basement province represented by core #Je 1 therefore represents a region of considerable tectonic uncertainty. The very low-grade metavolcanic rocks such as those discussed in this report may simply be a southeast continuation along strike of Slate Belt rocks of the Piedmont which dip below the Coastal Plain in central North Carolina. Alternatively, they might be representative of a separate region of very low metamorphic grade pre- or lower Paleozoic volcanic rocks which are onlapped to the south by lower Paleozoic sediments. A third possibility might relate these volcanic rocks to the East Coast magnetic anomaly, which may bear some relation to the Triassic-Jurassic breakup of North America and Africa. A conclusion regarding the full tectonic implication of the southeast Georgia basement volcanic province is not possible at this time; further research may shed light on the subject.

Work in Progress

At this time, research is continuing on basement core #Je 1. Several samples of variable lithologies from the core have been given to Dr. Dewey McLean of VPI & SU for palynological study. In addition, samples have been sent to Dr. John Sutter of Ohio State University for $^{40}Ar/^{39}Ar$ whole-rock age determinations. Completion of research on core #Je 1 also awaits the results of whole-rock and trace element chemistry analyses being performed on six characteristic samples by the USGS in Reston, Virginia. The results of these final analyses will supplement the research presently completed and discussed in this report, and the palynology and $^{40}Ar/^{39}Ar$ analyses may provide some age-dating criteria which could aid in a tectonic and genetic interpretation of both the core material and the surrounding basement province.

Conclusions

In-depth research of basement core material such as core #Je 1 provides a considerable amount of data useful in the interpretation of the basement geology and tectonics of the sub-Coastal Plain surface. Information such as that contained in this report will be valuable during later preparation of a map of this basement surface. In addition to the data provided specifically concerning the #Je 1 basement material, the information gleaned will be additionally valuable in helping to interpret other basement data from nearly wells discussed in the literature or available at the state Geological Survey. The goal of the basement research ongoing presently at VPI & SU then is to formulate as complete an understanding as possible of the pre-Cretaceous basement below the Coastal Plain and ultimately, to use this data in the interpretation of likely heat sources for future geothermal target areas.

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SILOAM GRANITE

B.A. Merz

Fourteen (14) samples from the Siloam, Georgia pluton have been analyzed for major element chemistry. According to the petrology section of report VPI&SU -5648-1, seven (7) of these samples were from the porphyritic phase, four (4) from the mafic, "possibly contaminated", phase, two (2) from the medium grained phase, and one (1) from the garnet bearing phase. However, two of the "possibly contaminated" samples were not chemically contaminated and were indistinguishable chemically from the porphyritic samples. In the average compositions presented in Table B-1 these two (2) samples are included with the porphyritic phase. The porphyritic and medium grained phases are very similar in composition. This was to be expected since they are "mineralogically identical" (petrology section cited above). The single gamma-ray U and Th analysis available for the medium grained phase is not sufficient evidence to suggest a contrast in U contents between the two phases. Areal chemical variations, such as the increase in K2O/ K2O+Na2O+CaO) from the margin to the core of the pluton as observed by Radcliffe and Humphrey (1971), were not found in this study, but we have analyzed less than half as many samples as they did.

In common with the Rolesville samples, (geochemistry section report VPI&SU-5103-5) the Siloam porphyritic and medium grained samples, which all have >17% normative Qz, plot on the boundaries of the syenogranite and monzogranite fields of Strekeisen's (1976) Or-Ab-An normative classification diagram. The one garnet bearing sample plots on the alkali-feldspar granite, syenogranite boundary and this reflects the more felsic nature of this phase as described in the petrology report. The two mafic, possibly contaminated samples, have <17% normative Qz and are defined as calcalkaline syenites.

Figure B-1 shows the Siloam normative Qz-Ab-Or data plotted on the water saturated phase diagram. Plotting only the porphyritic and medium grained samples results in a field occupying the right half of that shown. It can be seen that the Siloam field extends towards lower pressures than do the Liberty Hill or Winnsboro fields. The latter plutons are believed to have pressures of emplacement of 4-5 Kb (geochemistry section report VPI&SU-5103-5). The Siloam samples, other than the two mafic and one garnet bearing ones, have Ab/An ratios of 2-4. The effect of an An component on the Qz-Ab-Or 2 Kb saturated system is shown in Figure B-2 and it can be seen that, for the appropriate Ab/An ratios, the Siloam field lies at pressures a little higher than 2 Kb. A pressure between 2 and 4 Kb is suggested and this is in good agreement with the results of

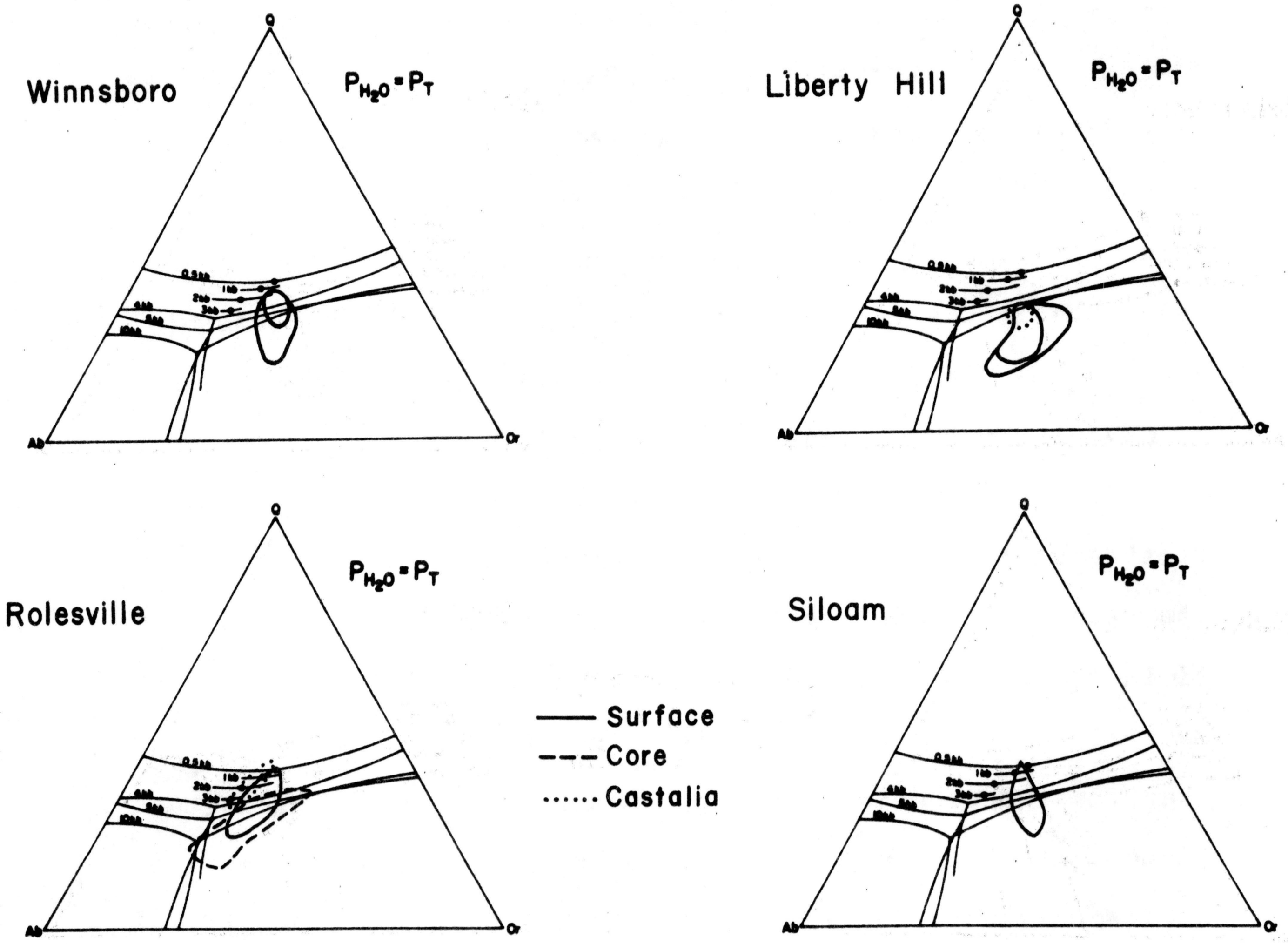

Figure B-1. Normative Qz-Ab-Or diagrams for the saturated system.

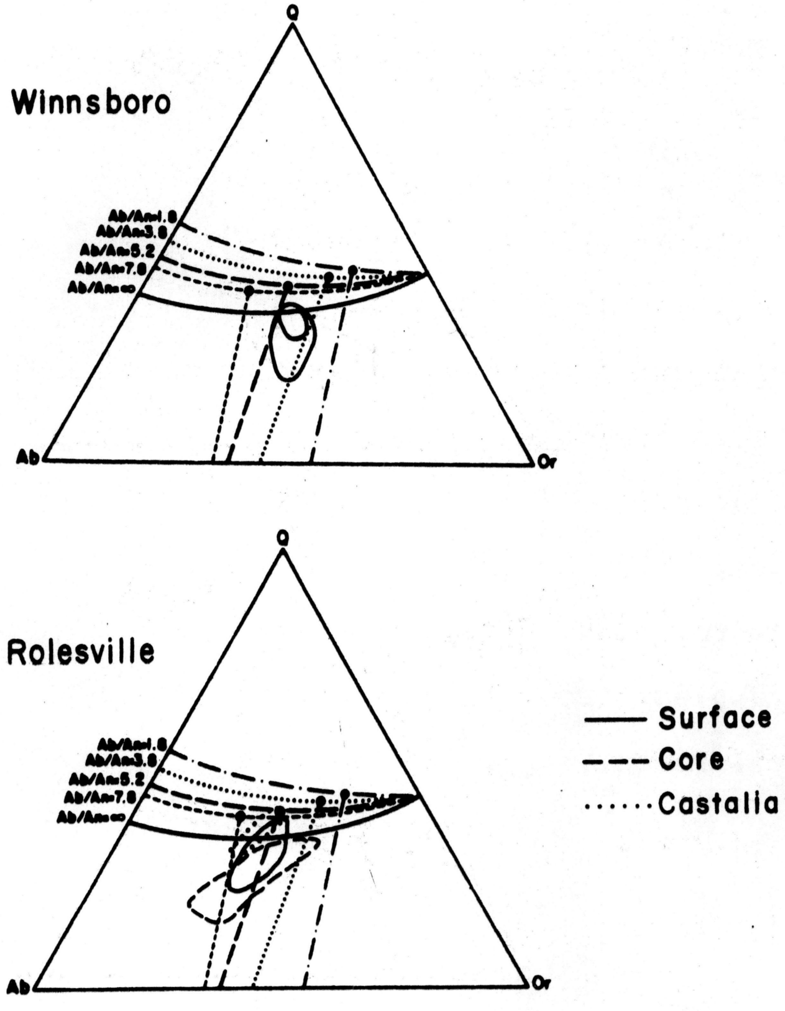

Figure B-2. Normative Qz-Ab-Or diagrams for P H2O = 2 Kb showing the effect of an An component.

Whitney and Stormer (1977) who suggest, on the basis of two (2) feldspar compositions, a depth of emplacement of 7-10 km.

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TABLE B-1. SUMMARY OF EXPERIMENTAL CONDITIONS

CHEMICAL COMPOSITIONS OF SILOAM SAMPLES

Phase	Porphyritic	Medium Grain	GA Bearing	Mafic
No. Samples	9	2	1	2
No. U & Th	5	1	0	2
SiO2	71.15	70.42	75.60	64.06
(st. dev.)	(2.1)	(0.65)		(0.91)
Al2O3	15.26	15.74	15.41	15.35
(st. dev.)	(0.06)	(0.03)		(0.19)
CaO	1.88	1.63	1.85	3.18
(st. dev.)	(0.4)	(0.01)	(0.24)	
O	0.96	0.82	0.88	2.58
(st. dev.)	(0.4)	(0.12)		(0.27)
K2O	5.17	5.72	5.29	4.67
(st. dev.)	(0.6)	(0.23)		(0.35)
FeO	2.20	2.26	2.11	4.62
(st. dev.)	(0.5)	(0.23)		(0.21)
Na2O	3.35	3.19	3.24	3.14
(st. dev.)	(0.2)	(0.11)		(0.01)
MnO	0.05	0.04	0.04	0.08
(st. dev.)	(0.01)	(0.00)		(0.01)
TiO2	0.41	0.40	0.39	1.08
(st. dev.)	(0.09)	(0.03)		(0.11)
P2O5	0.19	0.16	0.20	0.56
(st. dev.)	(0.05)	(0.01)		(0.12)
U ppm	7.0	4.9		6.6
(st. dev.)	(2.8)		(0.8)	
Th ppm	33.0	33.3		25.3
(st. dev.)	(5.5)		(6.3)	

LEACHING EXPERIMENTS

B.A. Merz

Abstract

The results of early radioelement leaching experiments in which crushed rock samples were leached with strong mineral acids are difficult to interpret for two reasons. Firstly, the locations within the rock from which the radioelements were leached are not well known and, secondly, since the action of a strong acid over a short period probably is not equivalent to to the action of groundwater during weathering, the results cannot be related to processes occurring in nature.

In this series of experiments, portions of a sample from the Rion, South Carolina, pluton were leached with dilute acid and alkali solutions as well as with natural groundwater. No appreciable loss of either U or Th was observed and this is believed to be due to prior loss of the readily removable radioelement fraction.

The hypothesis that the most easily removed fraction of the radioelement content is that held on grain boundries is being tested.

I. Previous Work

During the 1950's and early 1960's there was considerable interest in the use of leaching experiments as a way of determining the location of U and Th within rocks. A few examples of such experiments are presented here. The methods used varied widely as did the results.

Tilton et al. (1955) leached a Precambrian granite, with 2.7 ppm U and 41.9 ppm Th, for five minutes in cold, 6N HCl and found that 34% of the U and 42% of the Th were lost. A series of samples, ranging in composition from tonalite to granite, were leached by Brown and Silver (1955). 1N HNO_3 was used to leach the samples for fifty minutes at room temperature. Up to 40% of both the U and Th were removed. Larsen and Gottfried (1961) leached quartz monzonites and a granodiorite from the Southern California batholith for twenty-four hours in approximately 2.5N HCl on a steam bath and found that 72% to 83% of the U from the quartz monzonite was lost while the granodiorite lost 52%. Th was not determined in their study.

A fresh sample of granodiorite from Boulder Creek, Colorado, was leached by Pliler and Adams (1962) as part of their study of a weathering profile on that body. They found that 67% of the U and 90% of the Th were removed by leaching for twenty hours at 80-100°C in 2N HCl.

French geologists routinely report U contents in the form of "U total" and "U fixe" where the fixed U is the content after leaching a sample twice with 1N HCl on special filter paper. For example, Barbier and Ranchin (1969) found that 65% of the U content of a weathered sample and zero to about 50% of the U from fresh samples of the St. Syvestre granite (France) could be leached in this way. In a more recent experiment, Harshman (1972) used a solution, made up to resemble groundwater, to leach crushed granitic samples from the mountains adjacent to the Shirley Basin, Wyoming. Fifty millilitres of the solution were dripped through each 5g sample in a 10-hour period. It appears that the solution itself was analyzed, after use as the leaching agent, to determine the quantity of U leached, but the method used is not specified. Losses of 0.2 to 0.9% of the original U contents, which were 1 to 7 ppm, are reported but with the U concentrations in the solution being extremely low, experimental error, which is not discussed, could be considerable.

Problems arise when the interpretation of such data is attempted. The material which has been leached could be either intergranular, i.e. grain boundary material, acid soluble mineral grains such as allanite or apatite or mineral grains whose solubility has been increased by metamictization. Brown and Silver (1955) used alpha track studies as an aid in the interpretation of their leaching study and concluded that most of the radioactive element content was to be found in accessory minerals with less than

10% to rarely more than 25% being located on grain boundaries. On the other hand, Tilton et al. (1955) cited autoradiographic evidence that showed that a large fraction of the radioactive element content was to be found in "mineral interstices and intracrystalline fractures" and used this to conclude that the leached U and Th came from such locations.

Ancther problem in the interpretation of leaching data is in relating the exerimental results to processes which might be expected to occur in nature. The concept of total and fixed U as used by French geologists carries with it the implication that "non-fixed" U can easily be leached from a rock in nature. However, if U and Th behavior under near surface weathering conditions is to be investigated, the results of the leaching experiments described above might not have direct applications. Pliler and Adams, in their study of the Boulder Creek granodiorite, found a drop of 25% in Th and 60% in U going from fresh granodiorite to that which had undergone the first stages of weathering. At no point in the entire weathering profile was the Th content less than 65% of the original and, in fact, the uppermost, most weathered rock material had concentrated U and relative to the fresh material. In contrast, leaching, as described above, removed more of the Th (90% of the total) than of the U (67%). The authors point out that the behavior of U was essentially the same under weathering and laboratory leaching conditions while that of Th was very different. Many authors (e.g. Adams et al., 1959, Whitfield et al., 1959) have stated that U is more soluble than Th since U is readily oxidized from U^{4+} to U^{6+}, which is commonly found as the scluble $UO2^{2+}$ ion. Th has no hexavalent state. In the leaching experiments described above, the proportion of the Th content removed was equal to or greater than that of U. This shows clearly the contrast that might exist between the effects of laboratory leaching experiments and those occurring in nature.

II. Leaching of a Rion Granite Sample.

Introduction

A series of leaching experiments was undertaken with two aims: firstly, to investigate the behavior of U and Th under conditions more closely resembling weathering conditions than did earlier leaching experiments and secondly to provide data which, in connection with fission track and other investigations, could help determine the distribution of U and Th within a rock.

In most leaching experiments, strong mineral acids are used as the leaching agents. Such acids, even in concentrations as low as 1N, have pH values less than 1. Groundwater commonly has a pH in the range 5 to 8, where the groundwater found in granitic areas has a slightly acid pH and that in more mafic terrains a slightly alkaline pH (Le Grand, 1958). Only rare exceptions such as hot springs have pH values significantly outside this range. Leaching for short periods with strong acids might not be equivalent in effect to the leaching action of groundwater over a long period. For this reason it was decided to perform a series of experiments using relatively dilute mineral acid and alkali solutions as well as natural groundwater, as the leaching agents.

Sample Description

The sample used was a medium grained granite from the quarry in the main Rion part of the Winnsboro-Rion complex (see map Figure A-5, Progress Report VPI&SU-5103-2). The quarry location was preferred because of the ease with which a large, fresh sample could be obtained and because, at the time, samples from the area had amongst the highest radioelement conentrations determined. A sample, in one piece, weighing about 26 Kg together with more than 20 litres of groundwater from a nearby well, were collected by S.W. Becker.

The Rion pluton has been described (see petrology section, Progress Report VPI&SU-5103-2) as a medium grained biotite monzogranite. Two modes, from samples S6-10 and S6-13 from the Rion quarry, were published in the above report and were: S6-10 quartz 23.2%, plagioclase 28.9%, K-feldspar 46%, others 1.9%, S6-13 quartz 28.9%, plagioclase 29.4%, K-feldspar 39:%, others 2.7%. Secondary chlorite, white mica and epidote were present and the accessory minerals were opaques, zircon and apatite with allanite being found in S6-10. The leaching sample is believed to be similar to these samples.

Experimental Procedure

A handspecimen of about 1 Kg was retained and all the other material was crushed using a jaw crusher and rollermill until a sand, with grains ranging from fine dust up to 5 mm in diameter, was obtained. It was not crushed further in order to avoid the powdering up of the majority of mineral grains. The sample was then divided into 31 portions of 700 g each, numbered M1 to M31.

Three different leaching solutions were used. The groundwater collected with the sample was found to have a pH of 6, this slight acidity agreeing with the findings of Le Grande (1958) concerning the pH of groundwater in acid rock terrains. A 0.1N solution of hydrochloric acid was made up from analytical grade HCl and deionised water and this had a pH of 1.2. A 0.1N sodium hydroxide solution prepared from analytical grade NaOH pellets and deionized water had a pH of 12.8. Theoretically 0.1N HCl should be pH 1.07 and 0.1N NaOH pH 13.07 (Gordon and Ford, 1972).

Samples were leached by mixing the 700 g sample with 700 ml of the leaching solution and allowing the mixture to stand for the specified time. The solution was then filtered off and the sample was rinsed twice with deionized water which was also filtered off. The sample was dried under heat lamps. In the cases where leaching took place at temperatures above room temperature, the beaker containing sample and solution, covered by a watchglass, was heated in a waterbath. Table B-1 gives a summary of the conditions under which leaching took place.

Results

Prior to leaching, each 700 g sample was analyzed for U and Th by gamma-ray spectrometry. The twelve leached and one unleached sample, which appear in Table B-1, all had gamma-ray U values in the range 7.3 to 7.8 ppm and Th 29.3 to 31.2 ppm. The reproducibility of the data was good, U±0.2 ppm and Th±1 ppm suggesting that the starting material for the different leaching experiments was homogeneous.

It was decided not to use the gamma-ray method to analyze for U and Th after leaching because it was suspected that disequilibrium between radon, whose decay produces the measured gamma-rays, and the parent U and Th would lead to erroneous results. The dried samples were, therefore, coned and quartered down to about 100 g, which was powdered in a tungsten carbide shatterbox. The fine powder was further coned and quartered to 10 g. These small samples were then analyzed by the delayed neutron activation method by H.T. Millard, Jr. at the U.S. Geological Survey in Denver. The

TABLE B-1. SUMMARY OF EXPERIMENTAL CONDITIONS.

Sample	Leaching Solution	Time	Temperature	U(ppm)	Th(ppm)
M1	Groundwater	2400hr	room	8.03	38.8
M2	Goundwater	1 hr	room	7.83	36.3
M3	0.1N HCl	1 hr	room	6.44	31.8
M6	0.1N HCl	2400hr	room	6.96	34.2
M8	0.1N NaOH	2400hr	room	7.18	37.1
M11	0.1N NaOH	1 hr	room	7.23	35.5
M16	Groundwater	1 hr	60°C	8.16	35.3
M20	0.1N HCl	1 hr	60°C	6.32	35.4
M24	-.1N NaOH	48 hr	room	6.85	34.4
M25	0.1N NaOH	1 hr	60°C	6.92	34.5
M27	Groundwater	720hr	70°C	7.35	37.4
M21	Unleached			6.59	33.4

The U and Th values are those after leaching.

results are given in Table B-1. It can be seen that, in comparison with the data from the unleached sample, none of the leached samples show any appreciable loss of either U or Th. The scatter in the data and the fact that many of the leached samples have higher U and Th values than the unleached one, are probably due largely to splitting error. In splitting the sample from 700 g to 10 g it is likely that slightly non-representative sample was obtained.

Discussion

There are several possible reasons why U and Th were not leached in this experiment. Firstly, leaching with dilute solutions simply did not remove the U and Th whatever its location. Alternatively, the U and Th in this particular sample could be in stable locations. This would be the case if the readily removed U and Th had already been lost by interaction with groundwater during weathering. There is some evidence to suggest that the second explanation is true. Lead isotopic investigations show disequilibrium between radiogenic Pb isotopes and their parent U and Th, when an age for the granite (300 m.y.) is assumed (see report by Sinha and Merz). Further experiments should be carried out on a sample which shows equilibrium between Pb and parent U and Th.

It is possible that the most readily leached part of the radioelement content of a sample is that part held on grain boundaries. Currently we are using the fission track method to test the hypothesis the samples displaying disequilibrium U, Th, Pb isotopes have lost grain boundary radioelements whereas samples in equilibrium have appreciable grain boundary U and Th. Leaching experiments will be used to provide additional evidence.

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U-Th-Pb DISEQUILIBRIUM STUDIES

A.K. Sinha and B.A. Merz

Recent investigations in the Granite Mountains of Wyoming have documented the labile nature of uranium in surface weathering regimes (Stuckles and Nkomo, 1978). The importance of such loss/gain of uranium cannot be underestimated because extensive loss to significant depths may have a direct bearing on the measured values of heat production. Therefore, evaluation of the mobility of uranium/thorium in drill cores is necessary in understanding the magnitude of loss of uranium as correlated with depth.

In this section we present preliminary data on some selected samples from three plutons (Liberty Hill-core, Winnsboro surface and core and Rolesville-surface). The U and Th concentrations were determined by gamma ray spectrometry, while lead concentrations were determined by gamma-ray fluorescence. Therefore, the analytical uncertainty is rather large (approx. 10%) and we are currently in the process of determining the concentrations by isotope dilution using the 35 cm radius mass spectrometer.

Figure B-1 shows graphically the plot of U^{238}/Pb^{204} versus Pb^{206}/Pb^{204} and Th^{232}/Pb^{204} versus Pb^{208}/Pb^{204}. The interpretation of the diagram is similar to that used for Rb-Sr isochron diagrams, although initial ratios in U-Th-Pb

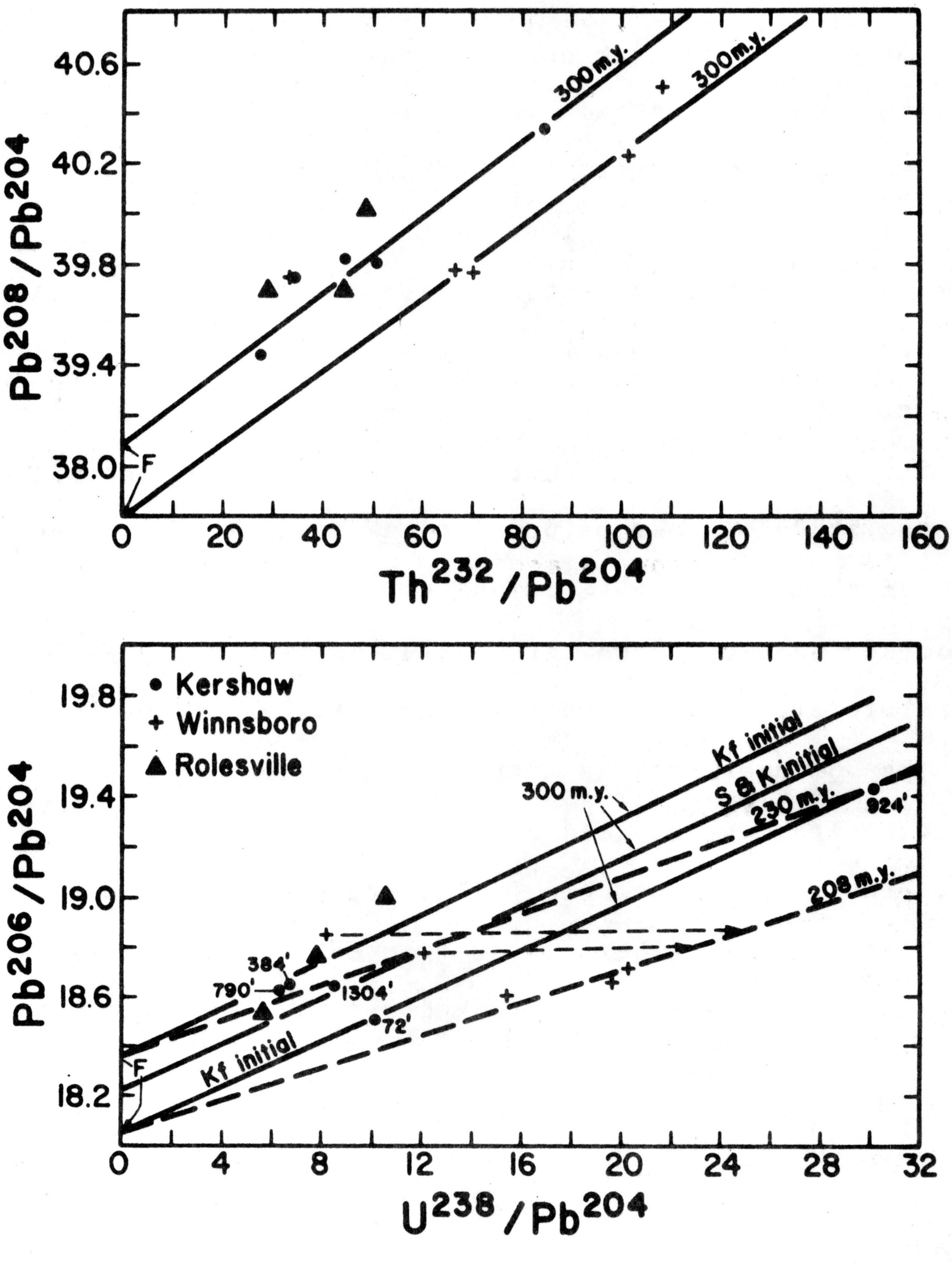

Figure B-1. Diagram showing the relationship between Pb^{206}/Pb^{204} and U^{238}/Pb^{204} and Pb^{208}/Pb^{204} and Th^{232}/Pb^{204}.

systematics cannot be uniquely determined because of variations in models as related to evolution of common lead (Sinha and Tilton, 1973; Stacey and Kramers, 1975). Usually, the lead isotopic composition of potassium feldspars gives a close approximation of the common lead ratios during magma formation because the U^{238}/Pb^{204} and Th^{232}/Pb^{204} ratios are invariably less than 0.1.

As shown in Figure B-1, the U-Pb isochrons can be integrated both as open and closed systems for the Kershaw drill core data. The choice is based on whether one uses the measured lead isotopic composition of the potassium feldspar from the rock, or the theoretical value of common lead (300 m.y. old) from Stacey and Kramer (1975). Because the Winnsboro data would not fit the Stacey and Kramer ratio and the isochron indicates an age of nearly 208 m.y., we prefer to interpet the Kershaw core data similarly. It means that both plutons suffered redistribution of uranium nearly 220 m.y. ago and have acted as a closed system since that time. The Kershaw core from 72' indicates uranium enrichment and is probably related to reprecipitation in the sample by ground waters. The two surface samples from the Winnstoro pluton show significant loss of uranium at recent times, suggesting that even non-labile uranium can be lost by surface weathering.

In the Th-Pb isochron diagram, the approximate colinearity of the data suggests that Th has acted as a closed system since the crystallization of the magma. This observation is in agreement with that of Stuckless and Nkomo (1978). In an earlier report (VPI&SU-5103-3) we had mentioned possible loss of thorium; we believe that the lead concentrations as determined then were in error. As such, consideration of the closed system behavior of thorium with respect to uranium is justified.

A point of interest to note is that the apparent isochrons of 220 m.y. for the U-Pb systems suggest no significant loss since the disturbance in the Traissic. We interpret this to mean that these two plutons were exposed to meteoric waters to facilitate removal of uranium at that time and as all the labile uranium was removed, subsequent ground water interaction has had no observed effects. This timing of uranium loss can be correlated with the uranium deposits in the Triassic basins of New Jersey and perhaps in others. With additional high precision data, it is conceivable that we can demonstrate for individual plutons the timing of uranium loss and develop a predictive capability of where it might be concentrated along the eastern U.S. Additionally, the kind of data presented here will permit a much better correlation of the distribution of uranium as determined by fission track mapping, i.e. if the labile uranium (presumably from grain boundaries) was lost during the Triassic, then there should be no primary uranium left along grain boundaries.

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THE GRANITIC ROCKS OF THE MARYLAND PIEDMONT

John R. Sans

Introduction

During the contract period from January 1, 1978 to March 31, 1978, the geochemistry section initiated its comprehensive study of the granitic rocks of the Maryland Piedmont. The purpose of the study is to determine the chemical and isotopic parameters which characterize a uranium-rich granite. At present it is thought that uranium should be concentrated in the most highly differentiated, unmetamorphosed granitic bodies. Hence we have begun the study with those granites which appear least deformed or metamorphosed.

The Geologic Map of Maryland (Cleaves and others, 1968) shows nine rock units under the "Granitic Series" as fomulated by Hopson (1964). Two of the units located in Harford County have no formal name. In any case, they are strongly-foliated, metamorphosed units and will not be considered further in the present report. On the map, seven of the units are identified by the following names: Woodstock Quartz Monzonite, Guilford Quartz Monzonite, Ellicott City Granodiorite, Norbeck Quartz Diorite, Port Deposit Gneiss, Kensington Quartz Diorite, and Gunpowder Granite. Three of the units, namely Norbeck, Port-Deposit, and Kensington are strongly-foliated, synmetamorphic bodies.

They have not been examined in the initial phase of the study. The remaining four named units are: Woodstock, Guilford, Ellicott City, and Gunpowder. These four are the best candidates for the initial phase of the study because they are weakly foliated, postmetamorphic granitic units. Figure B-1 is a sketch map of Baltimore County, Maryland, and vicinity. This map shows the location and approximate areal extent of the four granitic bodies considered in this report.

Petrology has long been burdened with confusing and contradictory rock names. Consequently, we feel that the classification and nomenclature recommended by the Subcommission on the Systematics of Igneous Rocks of the International Union of Geological Sciences (IUGS) should be supported with vigor. Streckeisen (1973) summarized the IUGS recommendations. According to that system of nomenclature, the four granitic bodies under consideration would be renamed: Woodstock Granite, Guilford Granite, Ellicott City Granodiorite, and Gunpowder Granite.

Field Relations of the Woodstock Granite

The Woodstock Granite is a small oval-shaped pluton located in westernmost Baltimore County, Maryland. See Figure B-1 for the exact location. The pluton is about 2.6 kilometers long and 1.9 kilometers wide. Figure B-2 is a

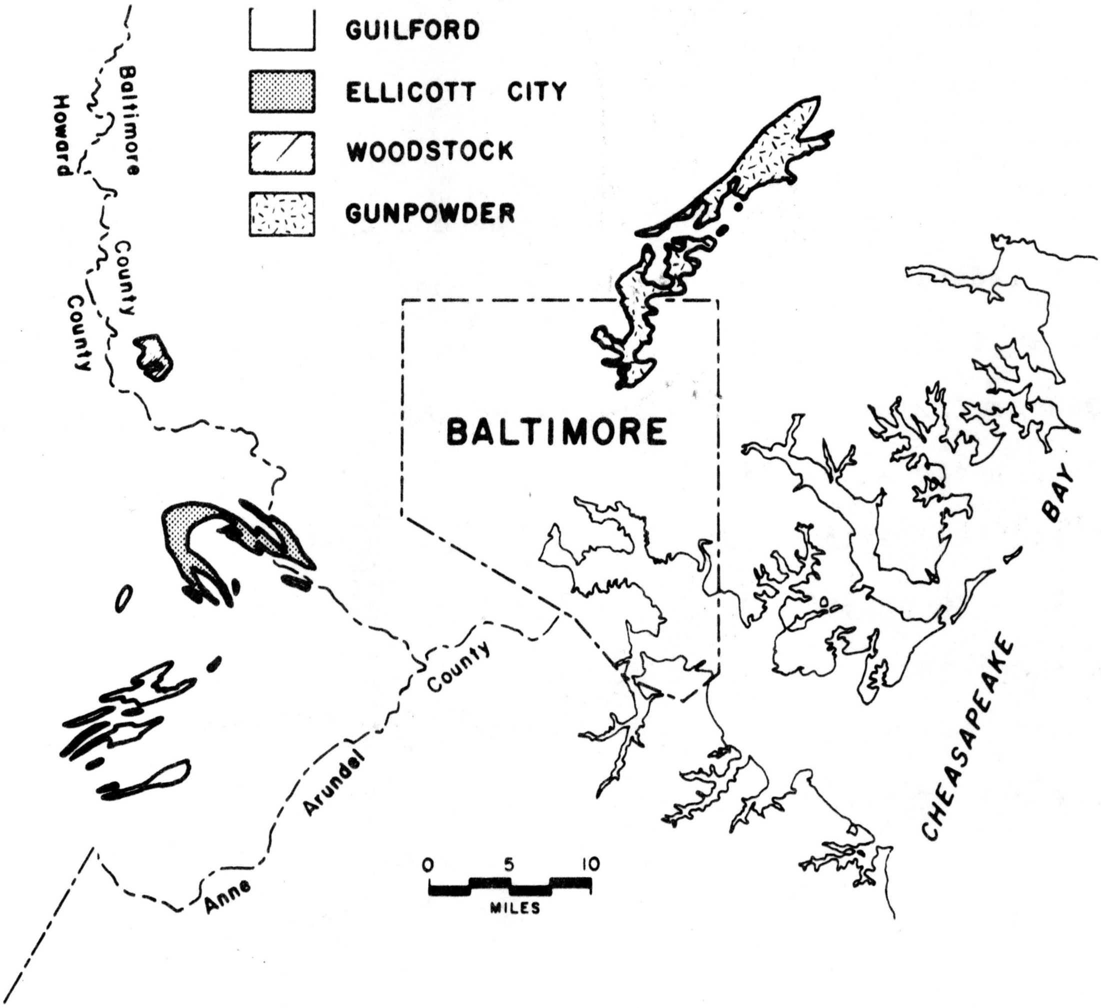

Figure B-1. Sketch map of Baltimore and vicinity showing the locations of the weakly-foliated granitic plutons.

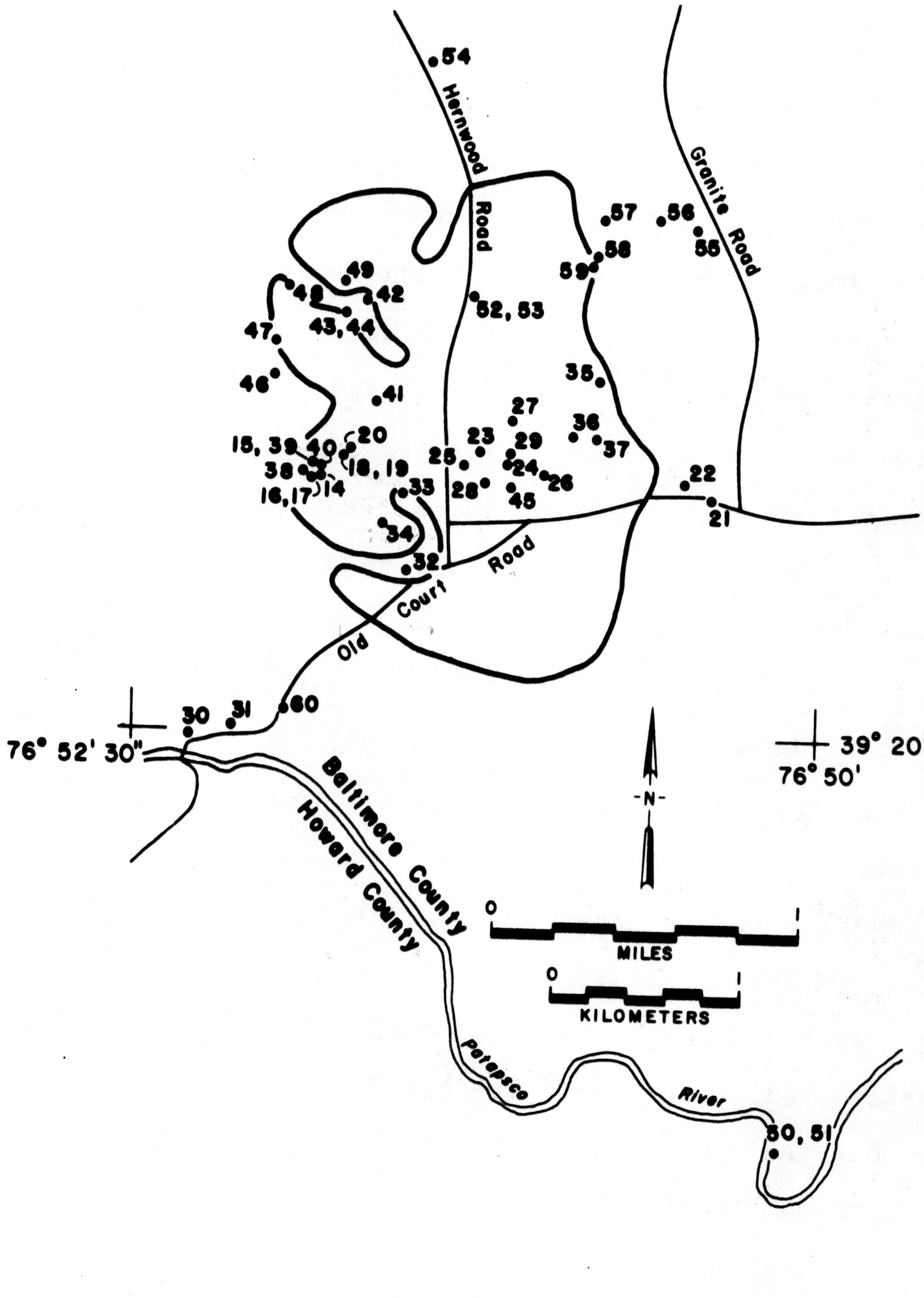

Figure B-2. Geological sketch map showing the shape of the Woodstock Granite. The area inside the heavy black line is granite. Outside the line is the part of the Baltimore Gneiss known as the Woodstock Dome. The numbered dots indicate locations of samples for chemical analysis. For example, 45 indicates sample MJ8045.

geological sketch map of the Woodstock Granite showing the actual shape of the pluton. As far as can be determined from surface exposures, all of the area enclosed by the heavy line is Woodstock Granite and all of the area outside the line consists of the part of the Baltimore Gneiss known as the Woodstock Dome. The numbered dots on the sketch map indicate the location of samples for chemical, petrologic and radioelement analyses. The location of the contact between granite and gneiss can be established fairly well on the basis of saprolite and float, but the actual nature of the contact is obscure, because it is not exposed anywhere.

Since it cannot be directly demonstrated that the Woodstock Granite intrudes the Woodstock Gneiss Dome, one must rely on several indirect lines of evidence. Keyes (1895) reported xenoliths of gneiss within the Woodstock Granite. He only devoted a few lines to the subject: "They (the xenoliths) are chiefly of gneiss, and occur in huge irregular blocks 6 to 8 or even 10 feet (1.8 to 2.4 or even 3.0 meters) in size. Some of the included masses are beautifully puckered and wrinkled. Being much richer in ferromagnesian silicates than the granite itself, their irregular outlines contrast sharply with the light background. These inclusions furnish further evidence of the eruptive nature of the granite. The contact phenomena are essentially the same as in the Sykesville examples of gneissic inclusions, described fully further on; and the metamcrphosed zone is, as in those cases, quite narrow."

Keyes (1895) also provides two illustraions of the xenoliths. One is a line drawing of a xenolith with no locality given. The second illustration is a photograph of a xenolith reportedly from the Waltersville quarry. The quarry was visited but no xenoliths could be found. The quarry has been abandoned for many years, hence, it is flooded and overgrown by vegetation. The xenoliths must be obscured. Even though eight man-days were devoted to intensive examination of the entire areal extent of the Woodstock Granite, no xenoliths were found.

Since we are unable to describe any of the gneissic xenoliths ourselves, Keyes' description (p. 278) of the contact effects is the only evidence available. "Biotitic and hornblendic gneiss fragments are distributed through the granite. The margins are usually changed considerably for a distance of 1 cm. The interior of the gneiss pieces is practically unmetamorphosed. It is much lighter in color than the contact border. The constituents have undergone much crushing, and the feldspars are scarely recognizable. The biotite is nearly all bleached, and chlorite is very abundant. Considerable secondary epidote and muscovite and a few large decomposed cubes of pyrite are also present. The margins of the gneiss blocks are dark-colored and much finer in grain. No traces of pressure are observable, and apparently complete recrystallization has taken place. Biotite is very abundant in small flakes oriented in the direction of foliation. A little plagioclase and orthoclase and small quanitites of pyrite occur."

Little work has been done on the geology of the Woodstock Granite since Keyes (1895). Mathews (1925) published a geologic map of Baltimore County which showed the Woodstock Granite. Hopson (1964) reported one chemical analysis and some petrographic information. Crowley (1976) showed the Woodstock Granite on his map of the crystalline rocks near Baltimore. Crowley has mapped the Woodstock for his forthcoming geologic map of the Ellicott City 7 1/2 minute quadrangle.

The one recent development of interest is that five water-supply wells have been drilled within the area mapped as Woodstock Granite. These wells are identified by numbers assigned by the State of Maryland Water Resources Administration. Two of the wells BA-73-4967 and BA-73-5036 brought up granite chips. These chips correspond to our sample numbers MJ8025 and MJ8028 respectively. The remaining three wells brought up gneiss chips. Chips from wells B-73-4870, BA-73-4733, and BA-73-5525 correspond to our samples MJ8024, MJ8029, and MJ8045 respectively. Apparently these three wells pierced a finger of gneiss similar to the ones which extend into the western boundary of the Woodstock Granite.

DISTRIBUTION OF URANIUM, THORIUM AND POTASSIUM IN THE WEAKLY-FOLIATED GRANITIC ROCKS OF THE MARYLAND PIEDMONT

John R. Sans

Fifty-eight rocks samples from the Maryland Piedmont were analyzed for uranium, thorium, and potassium by means of gamma-ray spectroscopy. The implications of this data for heat flow are discussed in the geophysics section of the report. This chapter is devoted to geochemical interpretation of the information. The four weakly-foliated granitic plutons of the Maryland Piedmont are: the Woodstock Granite, the Guilford Granite, the Ellicott City Granodiorite, and the Gunpowder Granite. The Woodstock was analyzed in detail (thirty-nine samples). The Guilford (six samples), Ellicott City (three samples) and Gunpowder (ten samples) were analyzed on a reconnaissance basis.

The Woodstock Granite intrudes the part of the Baltimore Gneiss known as the Woodstock Dome. Twenty-three of the samples were from the area mapped as Woodstock Granite, and the remaining sixteen were from the surrounding gneiss dome. Sample MJ8045 does not fit this pattern. The sample consists of chips from a well drilled near the center of the area mapped as Woodstock Granite. However, the chips are clearly gneiss, not granite. See the chapter of field relations for a more detailed discussion of well data. For the subsequent discussion here MJ8045 will be considered as a specimen of the gneiss dome.

The uranium concentration of samples from the Woodstock Granite itself ranged from 2.0 to 4.7 parts per million (ppm) with a median value of 3.1 ppm. In contrast, the uranium content of the surrounding gneiss dome is considerably lower. The uranium content of the gneiss ranged from 0.3 to 1.6 ppm with a median value of 0.9 ppm. In other words, all the granite samples contain 2.0 ppm or more, and all the gneiss samples contain 1.6 ppm uranium or less. Sample MJ8062 deserves special mention, because it is the only exception to this simple pattern. MJ8062 was a sample from a set of granitic dikes which cut through the gneiss dome as exposed along the Patapsco River about 2.75 kilometers southeast of the edge of the Woodstock Granite. William C. Crowley of the Maryland Geological Survey (personal communication) has suggested that these dikes may be related to the Woodstock Granite. MJ8062 contained 1.8 ppm uranium. This value falls exactly halfway between the lowest value for the Woodstock Granite and the highest value for the Woodstock Gneiss Dome. The origin of the granitic dikes along the Patapsco River remains uncertain.

The Gunpowder Granite intrudes the part of the Baltimore Gneiss known as the Towson Dome. Six samples were from the Gunpowder Granite itself and range from 0.7 to 1.3 ppm in uranium concentration. Three samples were from the

Towson Gneiss Dome and contain from 1.5 to 2.3 ppm uranium. The remaining sample was from a pegmatite cutting the Gneiss Dome and contains 6.1 ppm uranium. All in all, the uranium concentrations are very low except for the pegmatite.

The three samples from the Ellicott City Granodiorite contained from 2.3 to 3.0 ppm uranium. The samples from the Guilford Granite consisted of four actual granites, one pegmatite and one wall rock. The pegmatite and wall rock contained 1.3 and 1.8 ppm uranium respectively. In contrast, the granite samples ranged from 3.9 to 10.7 ppm uranium - the highest concentrations of any of the analyzed rocks.

From past studies of uranium distribution in rocks (Rogers and Adams, 1969A, 1969B) several generalizations can be made. It is difficult to evaluate "the uranium concentration of granite," because granites do not consist of a single petrological population. Radiometric differences have been demonstrated between different types of granite. Even in our own study, the uranium concentrations vary over an order of magnitude, even when one considers only the "granites". Nonetheless, the uranium concentration of an igneous rock is closely linked to its chemical composition. For ordinary rocks with silica contents in excess of 70 percent, one expects uranium concentrations in the range of 1 to 4 ppm. Concentrations considerably outside that range indicate a peculiar rock.

In this context, the Gunpowder Granite appears significantly depleted in uranium. The Ellicott City and Woodstock have fairly typical uranium contents for siliceous rocks. In contrast, the Guilford Granite appears somewhat enriched in uranium.

The thorium concentration in the weakly-foliated granitic rocks of the Maryland Piedmont is much more variable than the uranium concentration. For the Woodstock Granite, nineteen of the samples vary from 11.4 to 17.6 ppm thorium with a median of 14.8 ppm. The remaining three granite samples from the western edge of the pluton have only 6.3 to 9.0 ppm thorium. The thorium concentrations in the Woodstock Gneiss Dome are highly variable. The values range from 0.7 to 47.3 ppm thorium but are mostly higher than the values fro the Woodstock Granite. The median value for the gneiss is 16.1 ppm. Sample MJ8062 from the granitic dikes along the Patapsco River contains 21.9 ppm thorium - higher than for any of the samples from the Woodstock Granite.

The thorium concentration of the Gunpowder Granite varies from 11.3 to 29.2 ppm with a median of 27.5 ppm. In contrast the Towson Gneiss Dome contains only 3.2 to 8.5 ppm thorium. The pegmatite sample has only 2.4 ppm thorium. Thus, the thorium in the Gunpowder Granite is distinctly higher than in the surrounding Towson Gneiss Dome. This relationhip is the opposite of that observed between the Woodstock granite and the enclosing Woodstock Gneiss Dome.

The thorium in samples from the Ellicott City Granodiorite ranged from 17.7 to 36.1 ppm. The Guilford Granite varied from 9.6 to 12.7 ppm thorium. The pegmatite and wall rock associated with the Guilford contained 1.4 and 14.9 ppm thorium respectively. These thorium concentrations are surprisingly low in view of the high uranium concentrations in the Guilford Granite.

Interpretation of the meaning of the thorium concentration is subject to the difficulties discussed above for uranium plus some additional ones. In siliceous igneous rocks such as the ones analyzed for this study, one would expect 10 to 20 ppm thorium. Almost all of the granitic samples from the Woodstock, Ellicott City and Guilford fall in this range. There are only four exceptions. Sample MJ8005 from the Ellicott City is distinctly high at 36.1 ppm thorium. There is no obvious difference between sample MJ8005 and the other samples from the Ellicott City Granodiorite. The other three exceptions are the three samples mentioned above from the western contact of the Woodstock Granite. These samples are somewhat low in thorium (6.3 to 9.0 ppm) but they are only slightly outside the expected range so that the difference is probably of no petrogenetic significance. The thorium concentrations in the Gunpowder Granite seem to be systematically higher than one would expect.

The relationships among uranium, thorium and potassium for the Woodstock Granite are fairly clear. Figure B-1 is a plot of uranium concentration versus the ratio $(U/K)\times10^{-4}$. The triangles on Figure B-3 are data points for the twenty-two analyzed rock samples from the Woodstock Granite. Note that only twenty-one triangles are shown, because two samples plotted at the same point (U/K = 3.9, U ppm = 4.7). The dashed line is a least-squares fit to the raw data. The solid line is one of a family of theoretical lines showing the relationship expected on Figure B-3 if all of the decrease in the U/K ratio is due to decreasing uranium concentration. The dashed line (slope 3.19) is almost exactly parallel to the solid line (slope 3.22). Hence we conclude that all of the decrease in the U/K ratio in the Woodstock Granite is due to decreasing uranium. In other words, there is just about zero correlation between the uranium and potassium concentrations in the rocks. If the rocks preserve primary magmatic concentrations, such a relationship is surprising although possible.

Many investigators have shown that primary magmatic abundances of thorium and uranium can be disturbed by later alteration (Hurley, 1950; Tilton and others, 1955; Neuerburg and others, 1956; Larsen and Gottfried, 1961; Ragland and others, 1967; Rosholt and others, 1973; Rye and Roy, 1978). Large variations in primary uranium seem unlikely for the Woodstock Granite for a number of reasons. (1) The

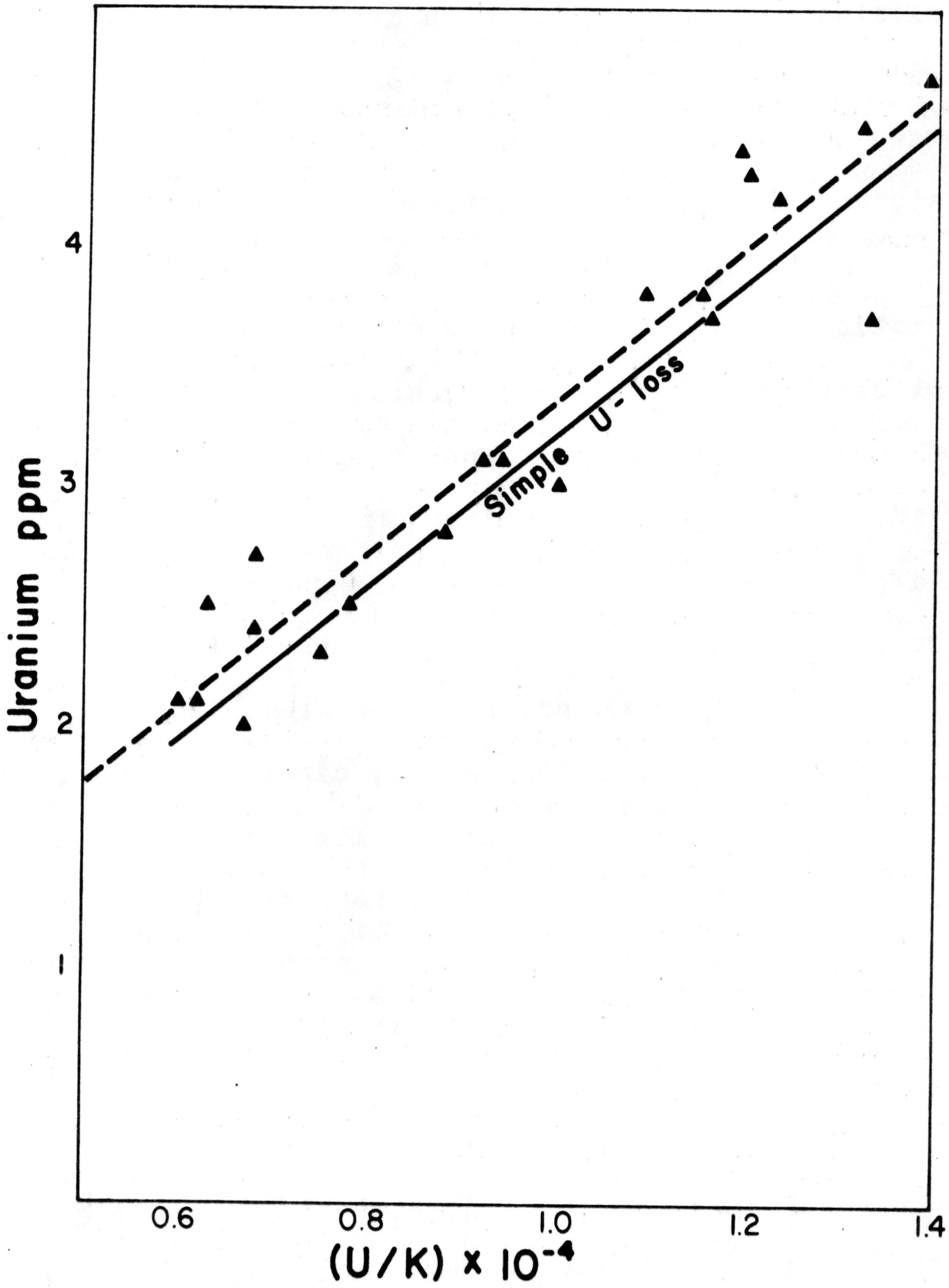

Figure B-3. Diagram showing the relationship between U and U/Kx10⁻⁴.

Woodstock is a very small pluton (2.6 km by 1.9 km). (2) The rock samples from this intrusion are very uniform. They contain no phenocrysts, rare xenoliths, and exhibit little or no foliation or change in grain size. (3) The high and low concentrations of uranium seem to be randomly distributed over the areal extent of the pluton. (4) All of the analyzed samples are surface samples and must be weathered to some degree. Thus the most plausible interpretation of Figure B-1 is simply that all of the Woodstock samples initially had uranium concentrations close to the highest observed (4.7 ppm) or perhaps even higher. The spread of uranium concentrations now observed is due to various degrees of uranium depletion by weathering.

Figure B-4 is a plot of uranium versus U/Th ratio. The triangles are again data points. However, in this case three anomalous samples indicated by circles were ignored when the least-squares fit (dashed line) was calculated. The solid lines are uranium-loss lines just as on Figure B-3. In this case the dashed line is not exactly parallel to the solid lines, although it is close. Most of the decrease in U/Th ratio can be acounted for by uranium depletion. Note that if a sample were also depleted in thorium it would shift to the right on the diagram, and the slope of a least-squares fit to such data would have a slope steeper than the solid theoretical lines. The three data points shown by circles fit such an interpretation and are,

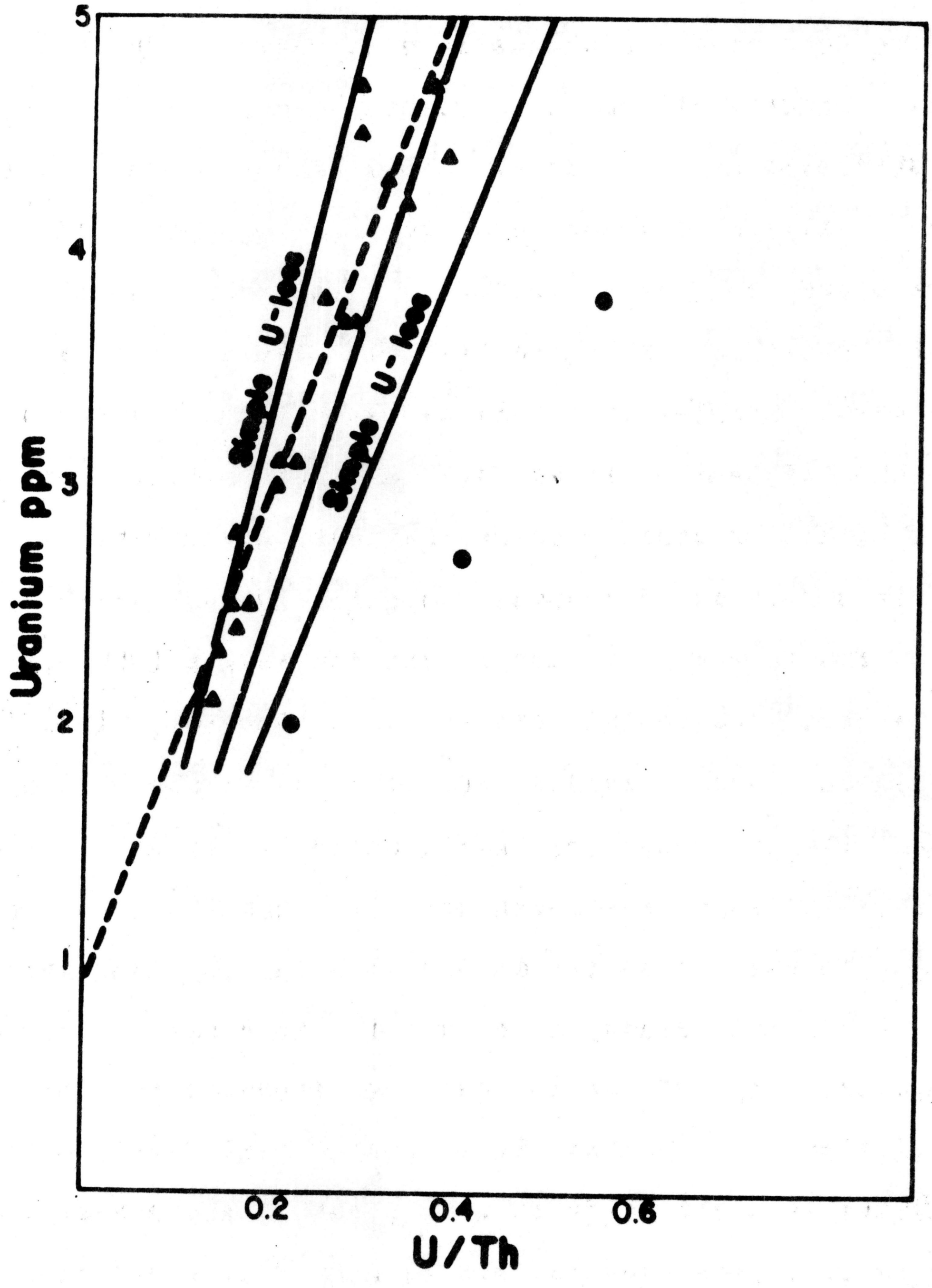

Figure B-4. Diagram showing the relationship between U and the U/Th relationship.

in fact, depleted in thorium. However, the bulk of the data fits a line with a smaller slope than the uranium-depletion lines. There seems to be some apparent thorium enrichment as the U/Th ratio decreases. There are three possible interpretations. The first possibility is supergene enrichment of thorium. This possibility does not seem likely, because of the severe thorium depletion in three of the samples. The second interpretation is that the thorium enrichment is a magmatic effect. If the thorium concentrations are recalculated to the least squares fit to remove scatter and then plotted on a map of the Woodstock Granite, an interesting pattern emerges. The pluton seems to be concentrically zoned in thorium with low values of about 12 ppm at the margins and high values of about 17 ppm in the center. The third possible interpretation is that the Woodstock Granite is contaminated by thorium from the surrounding Woodstock Gneiss Dome which has higher thorium concentrations. This interpretation seems unlikely, because the highest thorium concentrations are in the center of the pluton, not the margins.

Summing up, we draw the following major conclusions about the radioelement distribution in the Woodstock Granite. (1) The initial uranium concentration was 4.7 ppm or higher. (2) Most surface samples are depleted in uranium by weathering processes. (3) Magmatic concentrations of thorium seem to be preserved except in very badly weathered samples. (4) The concentric thorium distribution with highest values in the center suggests differentiation inward from the walls of the pluton.

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BLUE RIDGE GNEISSES AS POSSIBLE SOURCE MATERIALS FOR GRANITES

S.T. Hall

The roles of migmatites and paragneisses in the formaticn of granites has been established through many careful studies as being one of the most important considerations in granite paragenesis. Buried, high-grade gneisses which are undergoing metamorphism are subjected to increasingly higher temperatures until a certain level is reached and anatexis sets in, i.e., the gneiss is partially melted in the presence of H2O. The resulting melt is predominantly composed of quartz, plagioclase, and alkali felspar which is basically a granite (Winkler, 1976).

The high grade, granulite facies gneissic rocks of the Blue Ridge Providence in west-central Virginia are being studied as a probable source of granitic rocks in the southeastern United States. This is reasonable since these gneisses, the Lovingston and and Pedlar formations, are some of the oldest and highest metamorphic grade rocks on the eastern continental margin.

The purpose of this study will be to see if it is possible to derive, chemically, some of the typical southeastern granites by partial melting of the Blue Ridge gneisses and subsequent fractional and/or equilibrium crystallization. This will be done by employing general theoretical and empirical working models of melting and crystallization trends that are followed by both the major and trace elements, given an initial bulk chemical composition, i.e., the Blue Ridge gneisses.

The Blue Ridge Rocks

The study area is a traverse between Buena Vista and Lovingston, Virginia through the Pedlar and Lovingston formations which represent the major rock units of the Blue Ridge in west-central Virginia. The Pedlar is a green to dark blue-gray, coarse-grained, massive to mylonitic, "granodioritic" gneiss or charnockite often bearing hypersthene and with garnet along the western margin. The Lovingston is a dark gray, massive to foliated, biotitic augen gneiss.

The two formations are Precambrian in age with somewhat later premetamorphic injections of granitic rock into the Lovingston with zircon ages of 1.1 billion years. Subsequent Grenville granulite-grade metamorphism occurred about 900 million years ago (Davis, 1974). A second event produced injected granites into the Lovingston with ages of about 720 million years. Another metamorphic event during the Paleozoic partially retrograded the rocks to lower amphibolite or upper greenschist grade, as evidenced by two generations of biotite in some of the rocks.

Chemical Petrogenesis: Major Elements

Table B-1 shows average chemical compositions for the Pedlar and Lovingston formations and also the Winnsboro granite, exclusive of the Rion.

The Winnsboro was chosen as a representative granite since its bulk composition is close to an average of the granites previously studied in this project and since it is post-metamorphic and therefore chemically and mineralogically unchanged for the most part.

Even though major elements are not as definitive as trace elements as indicators of melting trends, it will be necessary to determine if the calculated quantities and chemical compositions of the phases subtracted during melting of the Blue Ridge rocks to yield southeastern granitic compositions are, in fact, plausible and correlate with the phases seen in the actual rocks. One method of calculating amounts of phases subtracted during fractional crystallization of a given parental composition is the basic least-squares approximation in matrix form, Y = BX, as applied by Bryan, Finger, and Chayes (1969). This method may be applied in increments so that the compositions of the phases being subtracted or added can be varied as in a real system. Nathan and Van Kirk (1978) have employed a similar method whereby new phase compositions and melting temperatures are recalculated continuously for each incremental step of subtraction of 2% solid from the melt until the quantities and compositions of the solid phases fractionated are determined which all have the same crystallization temperatures appropriate for the composition of the residual melt.

The problems with these models are that they are applicable for fractional crystallization only and for low pressure fractionation in that the effects of PH2O and hydrous phases are not considered. Current manipulations of these models are being done to incorporate PH2O and hydrous phases for both fractional and partial melting.

Trace Element Fractionation

Theoretical models for the quantitative behavior of trace elements during various kinds of fractionation during melting and also for equilibrium and fractional crystallization have been derived and reviewed by by several writers including Shaw (1970), Hertogen and Gijbels (1976), Arth (1976), and Schilling and Winchester (1967). Langmuir et al. (1977), Hanson (1978), Schilling (1971), Arth and Hanson (1975), and others have applied these models to natural systems and verified their validity.

For elements which are non-stoichiometric constituents of a phase, such as many trace elements, and which form dilute solid solutions, it is assumed that Henry's Law and therefore the Nernst equation apply during equilibrium where the chemical potential of an element in one phase ( ) is equal to the chemical potential of that element in another phase (β).

Mathematical derivations of the Nernst equation by Shaw (1970) yielded the general equation:

$$\frac{d\,w^{\ell}}{d\,L} = \frac{w_o - w^{L}}{W_o - L} \Bigg/ \left(\frac{x^{\alpha}}{K^{\ell/\alpha}} + \frac{x^{\beta}}{K^{\ell/\alpha}\;K^{\alpha/\beta}} + \cdots \right)$$

or

$$\frac{d\,w^{\ell}}{w_o - w^{\ell}} = \frac{1}{D}\,\frac{d\,F}{1-F} \qquad (2)$$ (Hertogen and Gijbels, 1976)

This can be integrated in several ways depending upon which crystallization or melting process is applied. The definitions of the symbols are as follows:

w_o, w^{ℓ}	mass of a trace element in the initial solid and in a liquid formed during melting;
x_o	mass of the initial solid;
x^{i}	mass fraction of phase i in the solid;
$K^{L/i}$	solid-liquid distribution or partition coefficient of a trace element in phase i;
D	bulk solid-liquid distribution coefficient of a trace element for the residual phases at time of separation of melt and residue; c^{s}/c^{ℓ}
F	degree of melting, i.e., weight fraction of melt reactive to the initial solid;

c^s, c^ℓ, c_o, c^L — the concentration of a trace element, respectively, in the residual solid, in an incremental liquid fraction formed during fractional fusion, in the parent or initial solid, and in a derived melt;

L — mass of the liquid formed upon melting;

D_o — bulk distribution coefficient of a trace element at the beginning of melting.

Some of the different melting models are: Partial melting whereby only part of the initial solid is melted; Batch partial melting whereby each batch of melt remains in contact with the residual solid until melting is complete and then the melted batch is completely removed, all at once; Fractional fusion (or melting) whereby the melt produced is continuously removed from the residual solid; Equilibrium partial fusion whereby the melt remains in equilibrium with the residual solid phases until it is removed; Simple modal equilibrium melting whereby the initial solid is of a eutectic composition so that the percentages of the phases in the solid remain constant during equilibrium melting; and Dynamic melting whereby melt is continuously removed from the solid with some melt always remaining in contact with the solid. This is expressed as a combination of fractional fusion with either batch partial melting or some type of equilibrium fusion.

For the purposes of this study, batch partial melting is considered to be the most appropriate. For this process, equations (1) and (2) integrate to:

$$\frac{c^L}{c_o} = \frac{1}{D(1-F) + F}$$

<u>Applications to the Winnsboro</u>

During melting of a rock that is predominantly composed of plagicclase, quartz, and alkali feldspar, such as a gneiss, the compositions of the melt or melts formed would be expected to lie along the quaternary cotectic in the water-saturated system, anorthite-quartz-albite-orthoclase or at the ternary eutectic in the system, Q-Ab-Or. In this report, Hanan's Figure B-1 shows eutectic (minimum melt) compositions at various pressures, where PH2O = PT, in the Q-Ab-Or projected system where Ab/An = 3, for a parental composition of a greywacke with K-feldspar, i.e., the same composition as a gneiss. The majority of the normative Winnsboro compositions cluster around the 7 kb, 655°C eutectic which indicates that a gneiss is a plausible parent for the Winnsboro at these P and T conditions.

"Minimum melt" compositions can be generated by a starting bulk composition of plagioclase, alkali feldspar, and quartz, such as a gneiss, anywhere within the Q-Ab-Or-An-H2O system. However, some starting compositions require

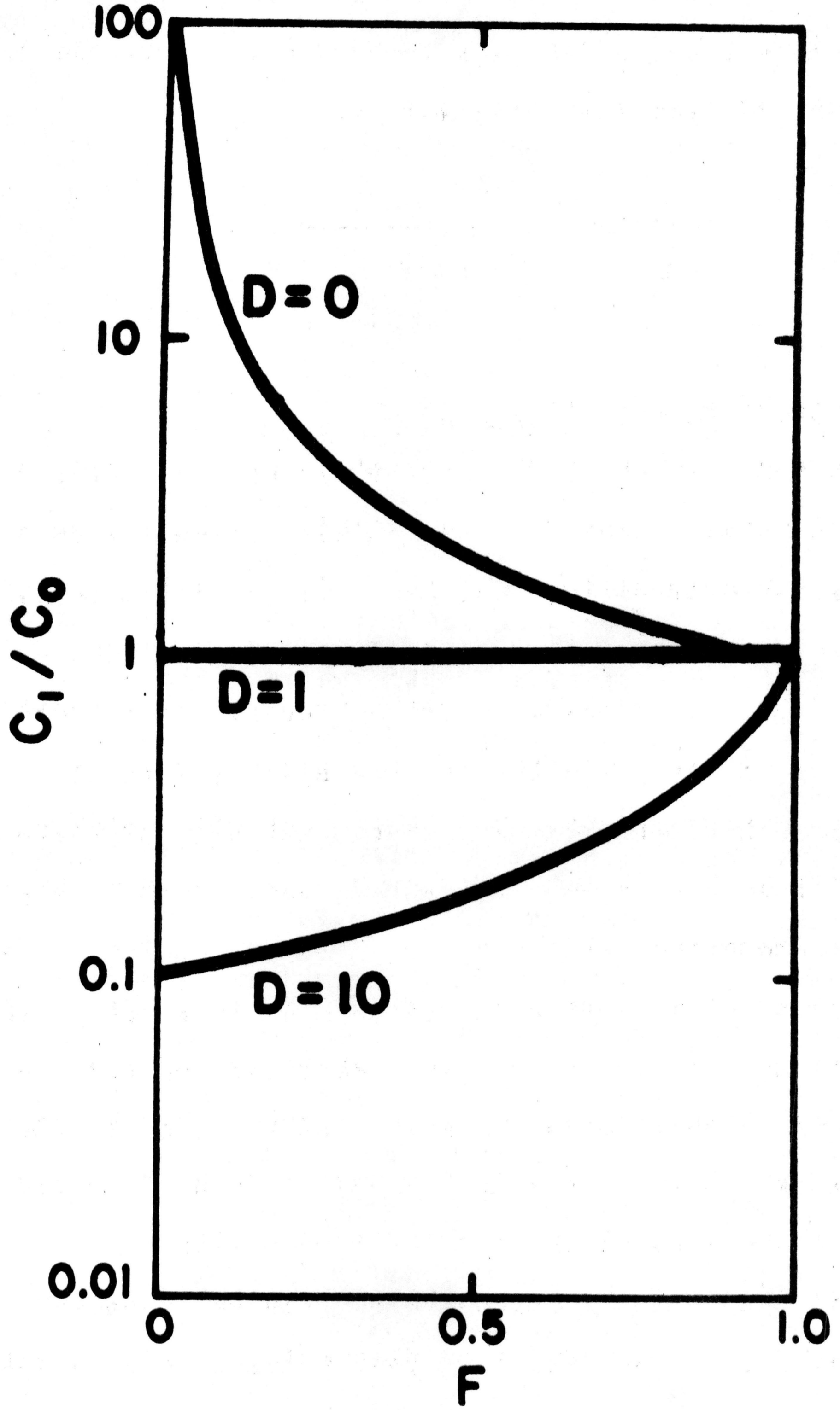

Figure B-1. The concentration of a trace element in a melt relative to its concentration in the parent rock, c(L)/c(0), versus the weight fraction of partial melt, F.

huge volumes to derive a reasonable amount of minimum granitic melt. The Pedlar and Lovingston normative compositions show that they would not require such unreasonable volumes to arrive at the Winnsboro composition.

To look at the trace element fractionation patterns between the Blue Ridge rocks and the Winnsboro, equation (3) was applied to U and Th values, Table B-1, and results plotted on Figure B-1 from Hanson (1978). For U, D-values indicated that if all the U were concentrated in the melt (the Winnsboro) relative to the residual solid, i.e., D = 0, the maximum degree of melting indicated when the Pedlar is used as a parent material is 45%, whereas the Lovingston indicates only 30% maximum degree of melting. Th values for the Lovingston indicate 15% maximum degree of melting which is not correlative with U data results. Th contamination is quite possible. Th values for the Pedlar indicate 50% maximum degree of melting which correlates well with U results from the Pedlar and therefore indicates that the Pedlar is a plausible source rock for the Winnsboro.

The Rb/Sr ratio and Sr^{87}/Sr^{86} values obtained by Fullagar and Odom (1978) for Blue Ridge gneisses of Virginia and Tennessee yield a Sr^{87} growth curve far too Sr^{87}-rich to produce the Sr^{87}/Sr^{86} values observed in the Piedmont plutons. Therefore, to account for observed trace element contents of the Piedmont plutons, a source must be found that is similar to the Blue Ridge rocks but with a low initial Rb content which will yield a growth curve similar to that of mantle rocks along which the granites plot. Then, to account for the relatively high radiogenic Pb contents of the plutons, Pb contamination of the parent rock must also be assumed.

Using future trace element data, applications of the various fractionation models should determine if the southeastern granites can, in fact, be considered as partial melts of the Blue Ridge gneisses.

TABLE B-1. AVERAGE CHEMICAL COMPOSITIONS

	Lovingston	Pedlar	Winnsboro
SiO_2	63.86	65.01	72.91
Al_2O_3	14.46	15.98	15.02
CaO	3.30	3.08	1.14
MgO	1.65	0.96	0.48
K_2O	4.79	5.15	5.47
FeO	6.07	5.03	2.50
Na_2O	2.80	2.59	3.62
MnO	0.09	0.08	0.08
TiO_2	1.35	0.82	0.33
P_2O_5	0.67	0.46	0.11
U	0.77	1.20	2.68
Th	2.30	7.47	14.64

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ORIGIN OF THE WINNSBORO GRANITE BY CRUSTAL ANATEXIS

Barry B. Hanan

An outstanding problem in petrology has been to determine the conditions for the formation of granitic rocks. Following the work of Tuttle and Bowen (1958) many experimentalists (see Winkler, 1976 for a current summary of the experimental data) have shown that liquids of granitic composition could be produced as the first melts of crustal material at temperatures in the nighborhood of 650°C if the melts were water saturated. These fusion temperatures are, in fact, lower than those recorded in the minerals formed during high grade metamorphism of the crust (Epstein and Taylor, 1967; Carmichael, 1967; Brown and Fyfe, 1970).

The association of metagreywacke and granite in the central and southern Appalachians (Hopson, 1964; Neathery and Reynolds, manuscript in preparation) suggest that partial fusion of metagreywacke be considered for the origin of the granites. Metagreywackes are found in the Wissahickon Formation, Maryland (Hopson, 1964), the Lynchburg Formation, Virginia (Brown, 1958) and the Wedowee Group, Alabama (Neathery and Reynolds, manuscript in preparation). These greywackes typically lack K-feldspar, have little muscovite, and have appreciable biotite. The Winnsboro pluton is a post-metamorphic granite, with little chemical or mineralogical redistribution since its initial crystallization. The bulk composition of the Winnsboro approximates the average chemical composition of the Piedmont granite plutons examined thus far in the project.

Winkler and von Platen (summarized by Winkler, 1967) showed that a significant amount of granitic melt can be produced by partial fusion of rocks of greywacke composition under conditions comparable to those found at crustal depths. The prerequisite for obtaining granitic melts by partial fusion of greywacke is that plagioclase, quartz, muscovite, and/or biotite be present because all three or four minerals are required in order for anatexis to take place. The minimum melt composition in the system Q-Ab-An-Or-H2O varies with the Ab/An ratio pressure and degree of volatile saturation. Figure B-1 shows the position for minimum melt compositions determined by Winkler and von Platen (summarized in Winkler, 1976) for paragneiss containing K-feldspar and natural greywackes without K-feldspar but having muscovite and/or biotite. The normative data for the Winnsboro pluton is also outlined. It is not likely that the Winnsboro was derived from partial fusion of greywackes lacking K-feldspar. Minimum melts produced from greywackes with quartz-plagioclase-biotite assemblages produce dioritic to granodioritic compositions, because biotite melts incongruently to form the K-feldspar component. During the initial stages of anatexis only a small fraction of the biotite is consumed. The amount of K-

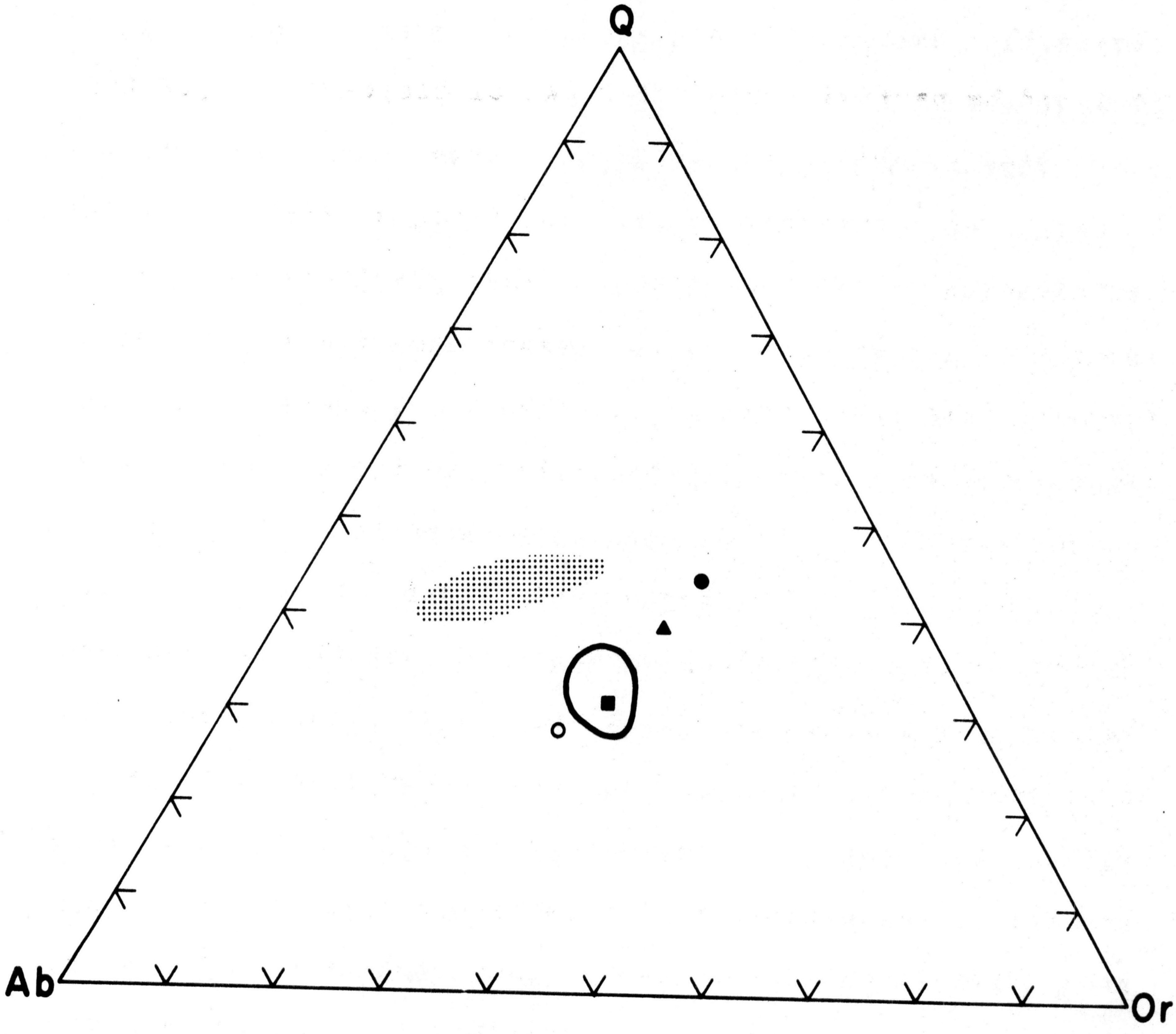

Figure B-1. Ternary plot for the system Q-Ab-Or projected from H2O. The stippled area represents minimum melts derived from gneisses without K-feldspar at PH2O = 2Kb. The closed circle, triangle, square, and open circle represent minimum melts derived from gneisses with K-feldspar at 2Kb, 4Kb, 7Kb, and 10Kb, respectively. The outlined field encircles normative mineral compositions for the Winnsboro granite.

feldspar component relative to the amount of plagioclase and quartz components is small, resulting in the formation of a granodioritic melt. The normative data for the Winnsboro plots around the experimental data for minimum melts derived by partial fusion of gneiss containing K-feldspar at PH2O = 7Kb (see Figure 1).

Further objections for the production of the Winnsboro granite by partial fusion of greywacke comes from examination of the available trace element data. Trace element fractionation calculations using average greywacke (Rogers and Adams, 1969A, 1969B) as the parent and the Winnsboro as the derivative liquid indicate that the U concentration in the Winnsboro can be explained by approximately 25% fusion of greywacke. The same calculations for Th indicate that about 15% melting would be required. Obviously these results are in conflict. Rubidium and strontium studies on greywackes from the Wissahickon Formation (Hanan and Sinha, 1976; Hanan, 1976) and the Lynchburg Formation (Fullagar and Dietrich, 1976) negate simple fusion of greywacke to produce granites like the Winnsboro. Fullagar (1971) showed that the Paleozoic igneous rocks of the Piedmont closely conform to the average mantle growth curve for radiogenic strontium (Rb/Sr = 0.025). The time interval between deposition of the greywackes and crystallization of the granites is on the order of 100 m.y. for most plutons. Rb/Sr in the greywackes ranges from 0.3 to 0.7 which is similar to estimates of the upper crust made by Hurley and others (1962), Gast (1960), and Taylor (1965) the $^{87}Sr/^{86}Sr$ ratios are greater than 0.720. This means that ^{87}Sr in the greywackes had evolved along a crustal growth curve at the time of the proposed genesis of the granites and, therefore, the greywackes could not be parental to granites following a mantle growth curve.

Although partial fusion of greywacke is an acceptable process for the concentration of U, Th, and K into granitic plutonic rocks, the existing major element and trace element data does not substantiate this process with regard to the Winnsboro. It is unlikely that greywacke was the source for these rocks.

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CHEMICAL FILE SYSTEM

Frank Galligan and George Crum

An interactive real time geological chemical data system was required for immediate analysis of chemical components, isotopic ratios, etc.. The data system designed incorporated file structure techniques oriented toward space and time saving interactions of the system along with concise and superlative techniques of data analysis and processing. The system is logically separated into modules which all are linked to a main user interactive driver routine. This enables the user to access multi levels of the total file structure and to be able to save any analysis for future access.

The file system is designed in modular routines to allow for modifications and future development as the interactive environment changes.

The main computing system consists of the central processing unit, communications controller, high speed printer, digital drum plotter and disk storage system. This complete system is capable of program execution, storage utilization and interactive terminal usage. The IBM 370 is a large and complex system, but only the necessary integral communications controller function is to allow a terminal via telephone to transmit and receive data to the main computer. The data may be program logic or input/output chemical analysis. The terminal located in the laboratory has real time or immediate access to the data file structure and the controlling program. The data file structure is logically divided into specific routines. These routines are linked and run under a main driver which is written in CMS execs. The exec are controlling programs which run in the environment of the CMS operating system. The routines are written in Fortran and compiled into load modules which are executed by the controlling execs. The execs, being the controlling process of all routines, can select, execute, and control the flow of input/output.

The Fortran routines are editor, file, search, list, statistics, and plot.

The editor has two main functions, file organization and setting up the data files along with delete, rename, list, print, and space.

Each df (data file) can be logically divided into named blocks where each name is unique. Each block can be further subdivided into named elements where each element name is unique to the block which it belongs. The existing file organization defines the organization of all existing df's in the data base for the current block and element name structure defined. The file organization can be edited by the use of the editor command "EDORG". The subcommands of the "EDORG" command allow the user to "add, rename, delete list" block and element names which describe the organization of all existing df's. "Edorg" amd its subcommands are documented separately.

The initial block is special since each element name defined for this block allows the user to identify character data in all existing df's. All other blocks and their element names allow the user to identify numeric data in existing df's. Df's therefore contain nonhomogeneous data.

The information that describes the current file organization is contained in a file called "ORGDR". The data structure implemented to represent the block-element structure is a multiple linked list structure. This data structure allows such operations as additional deletion, and space management of the organization directory to be performed by several fundamental list processing routines. An example diagram of the data structure utilized is documented separately with information on functional fields of each node in the list processing system.

The access method bdam (basic direct access method) is utilized to allow direct access file organization. The records of a file under bdam can be directly accessed by supplying the desired record pointer. Space for direct access files is allocated in entirety when the file is created, the amount of space having been provided previously. Information regarding the current df and organization directory files is open to all channels of operaticn.

Each df created requires 5k bytes, where k = 1024. The organization directory utilization is 10k bytes. Under CMS operating system, space is allocated in cylinders with each cylinder being 456k bytes. Each cylinder therefore can store 91 df's.

Each record in the organization directory has a functional relationship to each record of any existing df. This function is a 1-1, onto mapping from the records of ORGDR (domain) to the records of a df (range). The number of values (numeric or character) that are stored in a df is dependent on file organization and can be determined by counting all element names. Block names serve only as qualifiers; however, records in ORGDR which serve as block name identifies do map into records of a df (these records being unused).

A listing of the current file organization can be obtained by entering the command "LISORGDR".

Block or element name can be added, deleted, renamed, and listed. Operations performed by "EDORG" command effect all existing df's. Care should be exercised when using the "EDORG" command and its subcommands since the effects of this edit command subset are universal over the entire data base. The user simply enters the command "EDORG" to invoke the file organization editor. All further interaction between the user and editor is in the form (question list prompt from computer)-(digital response by user) or (enter character string response from computer)-(character string response from the user).

The user may enter up to 20 characters for either block or element names; however, only the first eight characters are utilized by the system. Since the block and element names are required to access data in a given df and may be used by other systems, it is wise to choose meaningful names. These names may be composed of letters of the alphabet (A-Z), the special characters (#,_,.,!), and the digits (0-9), the first character of which must be alphabetic with no embedded blanks.

When entering responses, corrections can be made on the current line of input by using the character delete symbol. All responses entered by the user are echoed for user verification. The user may find it necessary to use an "EDORG" subcommand to make certain corrections to entered responses not corrected on the current line of input.

Add; allows addition of block or element names to be made at the end of the current block names list or element name list of a block. Allows addition of block or element names to be made before an existing block name in the current block list or element in the current element names list of a block.

Delete; allows block or element names to be deleted from the file organization. A deletion of a block removes all existing element names of the block being deleted as well as the block name.

Rename; allows block or element names to be renamed.

List; allows listing of current block name list or element name list of a given block on the terminal.

Edit df subcommands allow data to be entered, corrected, or listed on a block by block basis where the user may optionally sequence to a desired block explicitly specifying the block to be edited by supplying the block name. The user simply enters the command "EDSAM" to envoke the df editor. All further interaction between the user and editor is in the form (question list prompt from computer)-(digital response by user) or (character string prompt from computer) -(character string response from the user).

Once the df editor has been envoked the computer will initially prompt the user for a df name. Df names may be up to eight characters long and may consist of letters of the alphabet (A-Z), the special character #, and digits (0-9), the first character of which must be alphabetic with no embedded blanks. If the name supplied is new, the computer will allocate space for a new data file with a file organization as described by "ORGDR" (organization directory) and will indicate the df is new. If the name supplied is old, the computer will acknowledge the file with the given name is old. All character fields of new df's are blanked out while all numeric fields are zeroed out. Fields of old df's will be unaffected. When the computer has acknowledged the df as new or old, df editing can proceed on a block by block basis where the current block is always identified by the computer.

Move to the next block; will move sequentially from the current block to the next block. The new block will be identified by the computer.

Enter block name; will prompt the user for a block name and move to this block.

Make corrections to data; will prompt the user for an element name and display the current value for this element prompting the user for a new value.

Enter data; will display an element name prompting the user for a value for all elements of the current block.

List data; will display an element name and value for all elements of the current block on the terminal.

Delete data file; df's can be deleted from the data base by entering the command "DELSAM" followed by the name of the df to be deleted.

Example: DELSAM S168#2.

This would delete sample S168#2 from the data base.

Rename; df's can be renamed by entering the command "RENSAM" followed by the original df name and then the desired new df name.

Example: rensam S5567 S5566.

This would rename sample S5567 to the new name of S5566.

List data file names; A listing of all existing df names currently in the data base can be obtained by entering the command "PRTSAM", which lists on the terminal.

Print data files; Data files may be printed at any possible locations, the user's terminal, remote job entry stations, main computer room. The command is "PRTSAM" followed by the location that the printout is to be sent. The computer will prompt the user for the names of sample files to be printed.

List data file; A df may be listed on the terminal for instant display of data by entering the command "LISSAM". The user will be prompted to enter a df name.

Example: LISSAM

enter sample name:

S5589

string is S5589

listing follows

Space; The current percent of space being utilized can be found by entering the command "space". In addition, the total number of files, 800 byte records in use and total cylinders on the current user disk is displayed.

Data entry from another Fortran program is incorporated into the data file system. The program is called _____ by _____ and was modified to take card data input, run the program and for the data output to be entered in the data file system.

The norm program setup is as follows:

Format analysis cards; Columns 73-80 of analysis cards are reserved for the sample identifier which must be left justified in this field. The sample identifier must begin with an alphabetic character and may contain alphabetic characters, the character #, and the digits (0-9). Since sample identifiers may contain eight characters, standard format #1 from norm program description cannot be used. Refer to norm procedures. The analysis cards must be preceded by a modify command and oxides command card which override standard format #1. The format described by the modify command must not use columns 73-80; these columns are reserved for sample identification.

Data entry; Analysis cards may be prepared offline on a keypunch or optically may be entered into a CMS file using the CMS editor internal to IBM 370 operating system. If the cards are prepared offline on a keypunch, they may be read into your CMS virtual reader by preceding the data deck with the control card needed to read in the cards in at a remote job entry station.

To have the cards read from the virtual reader into a CMS file issue the command "RDRDAT". The data file may now be displayed on the user's terminal by the command "PRTDAT". This prints the data file to ensure a proper listing. Next command is the execute command to run the norm program by the "norm" command.

Output from the norm program may be printed at any possible terminal or print station desired. This location is specified after the norm command.

Example: norm terminal.

This would execute the norm program and print the output at the terminal.

The user may edit another CMS da (a file using the CMS editor) or read another data file from the virtual reader using using the "RDRDAT" command, then the "norm" command to calculate the cipw norm for each new data file.

Norm input to data base; In addition to providing a summary printout of the samples, the summary command will edit sample files in the CMS data base defining several alues, blocks, major-elements, adjusted-oxides, norm, Barth's-cations, niggli-values, and index are defined in entirety. Elements sample-name and pluton-name of block identification are also defined. The printout provided by the summary command will list all sample identifiers, indicating whether the sample is new or old. Since data in other areas of the sample file is unaffected, values for these elements may be defined by other means (editor) either before or after running the norm program.

No changes should be made to the block or element names mentioned above since the norm program will search the file organization for these specific names.

File routine ----------------------------

A universal population of all samples has now been built by the editor. To this list samples and data may be added in a continuous update of the chemical file. Chemical analysis being performed in many cases does not require the access of all samples. To aid in storage and speed analysis a subset is required. This is accomplished by the file and search routines. The file routine has the capabilities of setting up a new file which is given a name by the user. This name is unique to all files, and for the first time it is set up containing a list of all available samples. This newly named file is translated into a subset of samples by the use of the search routine. Once the search routine has created a subset the named file now becomes an old file. The distinction between an old and new file is that a new file has a list of all samples and the old file has a subset list cf samples after the search routine has been applied. The old named file is automatically saved in storage and may be used recursively at a future time. The file routine has the capabilities of functional operations on old named files. The operations are; add, erase, input, rename, copy, list, intersect, and concat.

Add; The add operation allows the user to create a new named file which contains a list of all samples.

Erase: This will let the user delete any old or new named filed, thus freeing more space for the user.

Input: The user may insert into any named file a sample or set of sample names for analysis.

This allows the user to individually select samples for a low level analysis.

Rename: A new or old file may be renamed at any time.

Copy: The copy command lets the user make copies of old or new files. The copy name must be other than the original named file.

List: This allows the user to printout the names of all the old and new files created.

Intersect: This command performs the intersection of two named files and creates a list of samples which is named by the user.

Concat: Performs a union of two named files, thus creating a list of samples which is named by the user.

The procedures of the file structure enable the user to set up a sample file for analysis and stores all data for future useage. The structure dynamically allocates space and recursive techniques necessary for interactive statistics. All files that are set up must be processed in the search routine.

The search routine enables the user to predefine any arithmetic expression for the selection and search criteria performed on any named file of samples. The result is a subset of the named file being operated on and the results are rewritten into the named file. Recursively the user may repeat with different search criteria until the subset of samples is satisfied.

The search criteria or expression must be set up in a named file system similar to the file routine operations. A name for the expression file is required along with the expression to be entered by the user into that file. The search has two main sections, the file setup and the search on the samples. The file setup has eight commands: add, copy, list, erase, intersect, concat, rename and input search string or the expression.

Add; Request the name of the new search file to be given by the user.

Copy: Creates a copy of the search file with a different name.

List: Enables the user to printout all existing names of the search files or prints the expression of a particular search file that the user must specify.

Erase: The user may delete any search file.

Intersect: Two search files may be logically or together to create a search file named by the user.

Concat: Two search files may be logically and together to create a new search file named by the user.

Rename: A search file name can be changed by this command.

Input search string: This command allows the user to input through the terminal a mathematical expression up to 130 buffer length. The expression may contain character string or numeric values with operators of -,+,*,/,°,<,>,=,&. The qualifier between block and element is the semicolon. The following are examples of search expressions:

Major-elements;SiO2 < 69.032 & major-oxides; Al > 5.01

Identification;pluton-name = Liberty Hill

Norm;Ab + norm;An > 31.00

The block and elements of the search file are error checked for the correct character sequence in the organization directory. If a block or elements does not exist the error is printed and logic flow returns to the main driver of the chemical structure. This allows the user to recover from any severe errors and to continue with the analysis.

Once the expression is setup in a search file the user may now use this search file to select a subset of samples names by applying the expression to the named file of samples. This is achieved by using the search samples command in the search routine.

The search samples command will first request the user to specify what the name of the sample file to be searched is named. Next the routine request the user to select what search file expression is to be performed on the sample file. Execution of this command will process the sample file and create a subset of samples by the expression criteria and rewrite the sample names into the named file by the user. This procedure may be done with any number of expression until the desired population of samples is achieved. The processing flow returns to the main routine where list, statistics or plot commands may now be selected.

The list commands enables the user to print on the printer or to scan on the graphics any created files or data. The list structure requests the user to specify a named file for printing and for data a particular sample name must be supplied. The location of printing can be specified on the printer or the high speed device. The device may be used for large printouts of data or analysis needed at a future time. With the capabilities of scanning data and files on the terminal the user now can proceed to the analysis section of the main routine called statistical routine.

The statistical routine must have a sample file name to do any analysis. This file name is defined by the user, and may be any one file that was created from file or search routines. This file or files may be applied to any one of five statistical routines. They are regular statistics, linear regression, Statistical Analysis System (SAS), Scientific Subroutine Package (SSP), and the International Math and Statistical Library (IMSL).

The results from the processed data must go into a named file by the user. The routine before processing starts will request the user to name the file for further usage as a plot or printed data. The resultant statistics named file is saved in storage and can be operated on by the commands list, copy, rename, delete. These commands are applied to the statistics file and function the same as operations in file setup and search file setup. No necessary explanation is needed since they are similar in structure.

The regular statistics routine requires one file name set to do the performed calculations. They calculate standard deviation, standard error, maxium, minium, average, and range of input data.

The linear regression routine requires two files of samples to apply the regression analysis. The calculations printed are the slope, intercept, maxium, minium, average, and range. A coefficient correlation is calculated along with errors and residuals. The printout may be on the terminal or the high speed printer for future reference.

The Statistical Analysis System, Scientific Subroutine Package, and the International Math and Statistical Library are not implemented as of this publication. Future interaction requires further development.

The statistics routine output provides a named file supplied by the user which is an input file to the plot routine.

The plot routine utilizes a graphics terminal or a calcomp digital plotter. The routine has three plot commands. They are the X-Y plot, ternary plot, and surface II analysis.

The X-Y command will request the user supply a named file of samples which was produced from file or search. The user is then prompted for the block and element of the X coordinate and the Y coordinate. A plot is then displayed on the graphics terminal. The user may now scale, rotate, window, or change the axis scale for a more precise plot. When the user is satisfied with the plot it can be sent to the digital plotter or a hard copy can be made. The ternary plot is the same system of logic except the user will be working with three coordinates.

The Surface II analysis (Sampson, 1977) has not been implemented as of this publication.

The chemical file system is oriented toward the user for a quick and ready analysis. The logic flow of the entire system makes it feasible to do large amounts of data analysis with the interactive user. The design is flexible enough to modify quite easily and yet simple to implement.

The main driver and commands were user language oriented for easy interpretation.

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THE LITHOLOGIC CHARACTER OF ATLANTIC COASTAL PLAIN SEDIMENTS IN GEORGIA, SOUTH CAROLINA, AND NORTH CAROLINA WITH SPECIAL REFERENCE TO THE 1978 DRILLING PROGRAM

Joseph J. Lambiase

INTRODUCTION

The resource potential of geothermal energy in sedimentary rocks above the basement rock is dependent upon, among other things, the nature of the rocks overlying the basement, and on the availability and circulation of groundwater (Costain et al., 1977). The amount of heat retained or dissipated is a function of overburden lithology, and the groundwater regime determines the amount of heat that can be conveyed to the surface. Recoverable groundwater also is affected by lithology since porosity and permeability control the groundwater regime.

The Atlantic Coastal Plain is a thick wedge of sediments of Cretaceous and younger ages that extends from New York to Florida. Generally, the wedge is thinnest where it abuts the Piedmont to the west and thickest along the Atlantic Coast. Coastal Plain sediments have a varied lithology that includes limestone, shale, sandstones, and conglomerates.

Detailed information about sediments and groundwater is not available for much of the Atlantic Coastal Plain. It is the aim of this report to summarize the existing data on sediments and groundwater. Another goal is to predict the lithologic sequences that will be encountered in the wells to be drilled by Gruy Federal in each state.

Because of the large area covered by this study (New Jersey to Florida), it is not practical to incorporate the entire area into one report. VPI & SU's 1978 drilling program is beginning at the northern end of the Coastal Plain with the operation progressing southward during the summer; however, at the time this report was prepared, it was anticipated that the drilling program would start at the south end of the study area. Consequently, this report is restricted to Georgia, South Carolina, and North Carolina; other states will be discussed in subsequent reports.

REGIONAL STRATIGRAPHY

Numerous workers have identified stratigraphic units from the subsurface and surface of Georgia, South Carolina, and North Carolina (Cooke, 1936, 1943; Richards, 1950; among others), and others have correlated stratigraphic units over much broader areas (Murray, 1961; Maher, 1971; Brown et al., 1972; Richards, 1945; Spangler and Peterson, 1950). The results of the latter workers indicate that, generally, the stratigraphy of Georgia and North and South Carolina is comprised of equivalent stratigraphic units that can be correlated within the tri-state area, and that the correlation can be extended to the Gulf Coast and northward through Virginia, Maryland, Delaware, and New Jersey. A generalized stratigraphy of Georgia, North Carolina, and South Carolina is presented below; it is taken primarily from Brown et al. (1972), Brown (1974), Richards (1950), Spangler and Peterson (1950), and Cooke (1936, 1943).

The oldest rocks that most workers have identified in the tri-state area are of Lower Cretaceous age, although Brown et al. (1972) report a sequence of Jurassic rocks from North Carolina. Lower Cretaceous rocks are restricted to Georgia and consist of sandstones, shaley sandstones, and sandy shales. Most reports do not assign formational names to these rocks, and it is not appropriate to attempt this in the present report, especially because the VPI & SU drilling program will not penetrate these units. For this reason, only rocks of Upper Cretaceous age and younger will be considered.

Upper Cretaceous

The lowest unit in the Upper Cretaceous in all three states is the Tuscaloosa Formation which is primarily sandstone with lenses of shale. In Georgia and North Carolina, the Tuscaloosa is overlain by the sands and sandy clays of the Eutaw Formation; this unit is apparently absent in South Carolina. The Black Creek Formation overlies the Tuscaloosa Formation in South Carolina. It is primarily black shale with some fine sands and marl, and is equivalent to the Cusseta sand (fine sand with clay) of the Ripley Formation of Georgia. The overlying sand with clay bases of the Providence sand of Georgia's Ripley Formation is equivalent to the Peedee Formation (sandy shale and shaley sand with some limestone) of North and South Carolina.

Tertiary

Paleocene. The Clayton Formation of Georgia is the only unit of Paleocene age in the tri-state area. It is composed of calcareous clay and sandy limestone.

Eocene. The oldest Eocene rocks are the fine sands with clay laminations of the Wilcox Group of Georgia, and the equivalent sands and shales of the Black Mingo Formation in South Carolina and the sands of the Aquia Formation in North Carolina. The McBean Formation (sand with siliceous limestone and glauconitic marl) overlies the Wilcox and Black Mingo in Georgia and South Carolina. The Nanjemoy Formation (argillaceous sand) is the North Carolina equivalent of the McBean. The Upper Eocene is represented by the Castle Hayne Formation (limestone) in North Carolina, the Santee Limestone and Cooper Marl in North Carolina, and the Twiggs Clay, Barnwell Sand and Cooper Marl in South Carolina.

Oligocene. In Georgia and South Carolina, the Flint River Formation and the Suwanee Limestone comprise the Oligocene section. Both are limestone with the Flint River being more sandy than the Suwannee. Oligocene rocks are apparently absent in North Carolina.

Miocene. The oldest Miocene rocks in Georgia are the sandy limestones of the Tampa Limestone; there is no equivalent unit in the Carolinas. Hawthorn Formation shales and limestones overlie the Tampa Limestone in Georgia, and are the oldest Miocene rocks in South Carolina, but there are no equivalents in North Carolina. Yorktown Formation clayey sands and marls are the oldest Miocene units in North Carolina. They are equivalent to the Raysor Marl in South Carolina, but there is no corresponding unit in Georgia. The uppermost Miocene unit in all three states is the Duplin marl which is a shelly, sandy marl.

Pliocene. The Pliocene is represented by the Charlton Formation (calcareous clays and limestones) in Georgia and the equivalent Waccamaw Formation (shelly sands) in the Carolinas.

Quaternary

Pleistocene. The Pleistocene of all three states consists of a series of sand units that contain minor amounts of silt, clay, and gravel (Dubar, 1971). From oldest to youngest, these are the Brandywine, Coharie, Sunderland, Wicomico, Penholoway, Talbot and Pamlico Formations (Richards, 1969).

Holocene. Holocene sediments include sands, silts and clays deposited along the Atlantic coast of all three states. No stratigraphic units have been defined for Holocene deposits.

STATE SUMMARIES

Georgia

Coastal Plain Sediment

The Coastal Plain of Georgia comprises an area of about 86,000 km^2 to the southeast of the fall line (Figure C-1.1). Coastal Plain sediments increase in thickness to the south and east with a maximum thickness of over 1,500 m along the Atlantic Coast of the state (Figure C-1.1). The isopachs in Georgia on Figure C-1.1 were taken from Cramer (1974) and are based on data compiled by Herrick (1961), Applin and Applin (1964), and Woollard et al. (1957). Generally, rocks of successively younger ages are restricted to areas progressively closer to the Atlantic Coast.

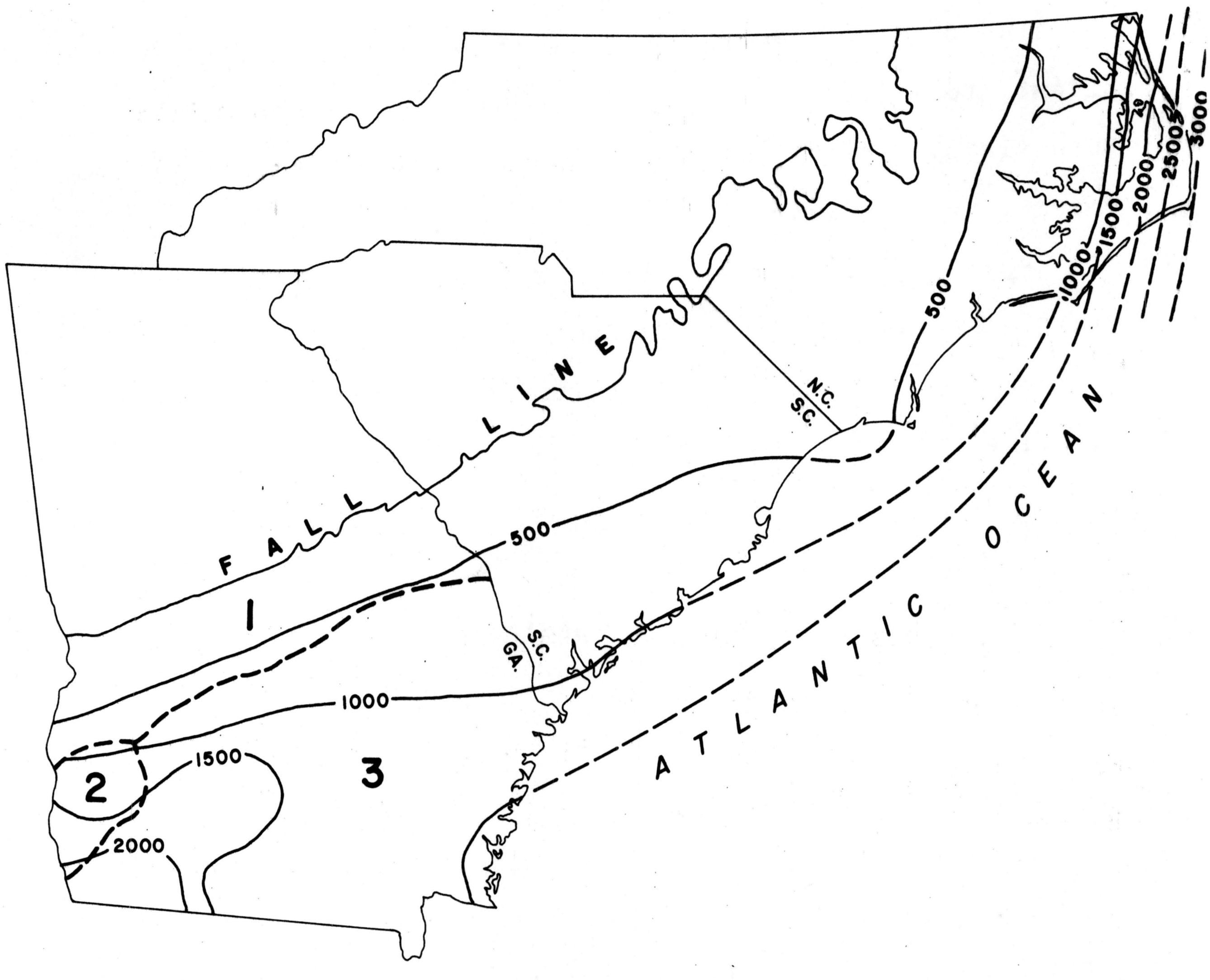

Figure C-1.1. The total approximate thickness (meters) of Coastal Plain sediments in Georgia, South Carolina, and North Carolina. The Fall Line is the western edge of the Coastal Plain. Thicknesses were modified from Le Grand (1964). The three (3) groundwater regions of the Georgia Coastal Plain as defined by Thomson et al. (1956) also are illustrated. See the text for descriptions of the groundwater regions.

The lithology of Coastal Plain sediments in Georgia is quite variable. Carbonate sediments are abundant in addition to clays, sands, and gravels. Lower Cretaceous rocks are less than 30 m thick in the east but thicken westward to 760 m in the southwest (Cramer, 1974). Lower Cretaceous rocks are entirely clastic and are chiefly sands (Cramer, 1974). The Upper Cretaceous Series (Tuscaloosa Fm., Eutaw Fm., Blufftown Fm., and Ripley Fm.) is 760 m thick in the west central region of the Coastal Plain and is over 304 m thick everywhere except near the fall line (Applin and Applin, 1967). Sands dominate the lithology from the fall line to approximately halfway to the Atlantic Coast where shales and clays become the most abundant lithology (Cramer, 1974). Sandy carbonates dominate a relatively small area along the Atlantic Coast.

Paleocene sediments (Clayton Fm.) are mainly sandy limestones with scattered patches of sand (Cooke, 1943). Maximum thickness is 182 m in the southeast Coastal Plain; typical thickness is about 122 m (Cramer, 1974). Lower Eocene units (Wilcox Gp.) increase in thickness from 0 m near the fall line to 243 m on the Atlantic Coast. The central region is sandy limestone. This is enclosed by an area of calcareous sandstone. The coastal area is limestone, and sandy shale and shaley sandstone occupy the western part of the Coastal Plain in Georgia. Middle Eocene sediments (Tallahatta Fm. and Lisbon Fm.) are mainly calcareous sands near the fall line. To the southeast, the lithology becomes dominated by sandy limestone, and the central, south, and eastern areas have shaley limestones (Cramer, 1974). Middle Eocene sediments are over 304 m in the southeast, but are 152 to 213 m thick in most places. The Upper Eocene series (Barnwell Fm., Jackson Gp.) is mainly limestone with small areas of sandy limestone at the north. Maximum thickness is 243 m in the south but few areas have thicknesses over 61 m.

Oligocene sediments (Flint River Fm.) are always less than 152 m thick and usually are less than 61 m thick. Limestone dominates the lithology, and there are scattered areas of sandy limestone and calcareous sand (Cramer, 1974). Miocene and Pliocene sediments are calcareous sands and clays with some limestone. Maximum thickness is 182 m near the Atlantic Coast. Pleistocene and Holocene sediments are restricted to a strip along the Atlantic Coast and are mainly sands with sandy shale and calcareous sand (Herrick, 1965; Herrick and Vorhis, 1963). Most deposits are about 30 m thick, but thicknesses up to 61 m occur along the Atlantic Coast.

Groundwater

Thomson et al. (1956) have identified three regions with distinct groundwater characteristics in the Coastal Plain of Georgia (Figure C-1.1). Near the fall line the major aquifers are the Cretaceous sands of the Tuscaloosa Formation and the Ripley Formation (Cusseta and Providence sands - Figure C-1.1). Wells producing up to 1,850 gpm (7003 l/m) have been reported (Le Grand, 1962), and most counties in this region have wells that produce 200-500 gpm (757-1893 l/m - La Moreaux, 1946; Le Grand, 1962).

A second groundwater region occupies a small area in the southwest part of the state (Figure C-1.1). The principal aquifers are the sand members of the Eocene Wilcox Group, especially the Tuscahoma sand, limestone units of Paleocene and Eocene age (Ocala limestone and Clayton Formation), and the Eocene Barnwell Formation (Thomson et al., 1956). Wells in this region often produce 500-900 gpm (189-340 l/m).

The third groundwater region covers the remainder of the Coastal Plain in Georgia (Figure C-1.1). Wells produce up to 4,000 gpm (15,141 l/m) in this area, and the principal aquifers are limestone (Owen, 1963a,b; Sever, 1965; Thomson et al., 1956). These include units primarily of Paleocene to Pliocene age.

Expected Lithologic Sequence

It is anticipated that the wells to be drilled in Georgia will encounter 30-60 m of Pliocene to Holocene sands with some calcareous sand and clays. Underlying this will be Miocene sediments consisting of 180 m of calcareous sands and shales in the southern part of the state and 90 m of calcareous shale near the north. Beneath the Miocene units, all wells should penetrate 30 m of Oligocene limestone and sandy limestone. From the base of the Oligocene deposits to the 300 m drilling depth, all wells should encounter Upper Eocene limestone. It is possible that a few wells will penetrate a few meters of Middle Eocene limestone at their base.

South Carolina

Coastal Plain Sediment

The total thickness of Coastal Plain sediments is generally less in South Carolina than in Georgia. The sediment wedge thickens eastward, and the maximum thickness attained near the Atlantic Coast varies between 608 m and over 912 m (Bonini and Woollard, 1960). In South Carolina, Coastal Plain sediments have a varied lithology that includes carbonates and clastic sands, shales, and gravels. However, the proportion of carbonates is less in South Carolina than it is in Georgia.

In most places, the oldest rocks in the Atlantic Coastal Plain are Upper Cretaceous in age. They consist of over 486 m of sands, shales, and marls (Tuscaloosa Fm., Black Creek Fm., and Peedee Fm.).

Eocene rocks (Black Mingo and McBean Fms., Santee Limestone, Cooper Marl, and Barnwell Sand) are primarily sands with some shale, marl, and limestone. The Eocene sequence can be up to 213 m thick. Oligocene sediments (Flint River Fm.) are limestones and sands that are 15 m thick. Up to 90 m of Miocene (Hawthorn Fm. and Duplin Marl) shales and marls with some limestone overlie the Oligocene units. Miocene sediments are in turn overlain by 8 m of Pliocene (Waccamaw Fm.) sands and shell beds.

Fifty meters of Pleistocene sediments comprise the uppermost segment of the Coastal Plain in South Carolina. These are primarily sands, although there are minor amounts of gravel, silt and clay associated with each of the seven Pleistocene formations (Brandywine, Coharie, Sunderland, Wicomicc, Penholoway, Talbot, and Pamlico Fms.).

Groundwater

Several studies have been done on the groundwater of South Carolina (Siple, 1957, 1967, 1975; Callahan, 1964; Stock and Siple, 1969). These works provide a basis for generalizing the groundwater regime of each stratigraphic unit.

The most important aquifer in South Carolina is the Tuscaloosa Formation. It covers a large area, is thick, and its coarse sand and gravel lithology produce high hydraulic conductivities. Wells drilled into the Tuscaloosa have produced over 3,500 gpm (13,248 l/m) (Siple, 1975).

Another major aquifer is of Eocene age and is comprised of the Santee Limestone, Barnwell Sand and McBean Formation. Wells are capable of producing 2,600 gpm (9,842 l/m) from the coarse sands and limestones.

Most other stratigraphic units in the South Carolina Coastal Plain are low-yield aquifers. An exception is the Peedee Formation which is a potentially productive aquifer in the western part of the Coastal Plain because of the high permeability developed in its sand members. In the eastern Coastal Plain, the Peedee is not very permeable and, consequently, is not a productive aquifer.

Expected Lithologic Sequence

Most of the heat flow wells to be drilled as part of our D.O.E. program in the South Carolina Coastal Plain sediments are located near the Atlantic Coast. It is anticipated that the lithologic sequences in these wells will be similar to wells drilled on Parris Island (Richards, 1967) and near Charleston (Gohn et al., 1977).

The uppermost units penetrated will be Pleistocene sands that are 20 m thick. These will be underlain by 150 m of Eocene limestone, clayey sands and sands. The final 130 m will penetrate sandy clays, sand with clays and silty sands of Upper Cretaceous age.

One well will be drilled away from the Atlantic Coast but should penetrate the lithologies described above with some exceptions. The top of the section should be Eocene sediments, and the well will penetrate further into Cretaceous sediments (primarily sands and clayey sands) than wells drilled near the Atlantic Coast. All the thicknesses of the previously described units are expected to be less than those listed above because the total thickness of Coastal Plain sediments is less in this area. It is probable that a 300 m well will reach pre-Cretaceous basement in this location.

North Carolina

Coastal Plain Sediment

Near the Atlantic Coast of North Carolina, the thickness of Coastal Plain sediments varies between 456 m in the southern part of the state and more than 3040 m in northern North Carolina (Bonini and Woollard, 1960). The wedge thins westward, pinching out near the fall line (Figure C-1.1).

The Coastal Plain units of North Carolina are as varied lithologically as their counterparts in South Carolina and Georgia. However, the proportion of carbonates is much less in North Carolina than in South Carolina and Georgia.

The oldest rocks in the North Carolina Coastal Plain are of Upper Cretaceous age (Tuscaloosa Fm., Eutaw Fm., Black Creek Fm., and Peedee Fm.). They are 342 to 1120 m thick, and are sandstones with sandy shale lenses and some limestones, clays and marls (Spangler, 1950).

Tertiary units are represented by 14 to 152 m of Eocene (Castle Hayne Fm.) clayey sands and sandy limestone, 167 to 274 m of Miocene (Duplin Marl and Yorktown Fm.) clayey sands, marls, and calcareous sands, and Pliocene and Pleistocene sands, gravels and clays. Pliocene, Pleistocene and Recent sediments are 18 to 91 m thick.

Groundwater

The numerous reports on groundwater in various parts of the North Carolina Coastal Plain (Mundorff, 1946; Le Grand, 1960; Brown, 1959; among others) indicate that the major aquifers are the Tuscaloosa, Peedee, Yorktown, and Castle Hayne formations. The coarse sands of the Tuscaloosa produce up to 300 gpm (1136 l/m) while the Peedee produces 100 gpm (379 l/m). The Castle Hayne and Yorktown formations both produce up to 1000 gpm (3785 l/m), and are considered to be major aquifers.

The Black Creek Formation is a moderate aquifer with a production of 50 gpm (189 l/m). Some of the Pleistocene sands are low-yield aquifers; other stratigraphic units are unimportant as aquifers.

Expected Lithologic Sequence

The 300 m wells that will be drilled in the North Carolina Coastal Plain should encounter the following lithologic sequence. All thicknesses are approximate. The uppermost 12 m will be Holocene sands, gravels and clays which will overlie about 8 m of Pliocene sands. Below the Pliocene should be 60 m of Miocene sands, limestones and marls, followed by 30 m of Eocene sands and limestones.

After the Eocene units, the drill will pass through 150 m of Upper Cretaceous sands with minor amounts of clay. The final 40 m will penetrate clays and sandy clays of Upper Cretaceous age.

The sequence listed above is generalized for the North Carolina Coastal Plain. In areas with an abnormally thick or thin sediment wedge, the thickness of each lithologic unit and the number of units penetrated will be different from the above description.

CONCLUSIONS

The preceding discussion reveals several general trends about the Atlantic Coastal Plain in Georgia, South Carolina, and North Carolina. Upper Cretaceous rocks account for the largest volume and thickness of Coastal Plain sediments. Lithology is complex both vertically and laterally throughout the tri-state area, but a major trend is that the proportion of carbonate rocks decreases northward from Georgia to North Carolina.

The most important Coastal Plain aquifers also are of Upper Cretaceous age, although some Eocene units are highly productive. Generally, the younger sedimentary units tend to be poorer aquifers than the older ones. Most wells to be drilled near the Atlantic Coast in Georgia, South Carolina, and North Carolina during VPI & SU's 1978 program will penetrate Upper Cretaceous sediments, and a few may encounter pre-Cretaceous basement.

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GEOTHERMAL GRADIENTS IN THE SOUTHEASTERN UNITED STATES

Samuel S. Dashevsky

Within the period covered by this report, equilibrium temperature gradients were determined in drill holes RL1, RL2, RL3, RL4, RL5, PT1, PG1, and ED1. Preliminary gradients have been determined for SM1, SM2, PM1, and StF1. Locations are shown in Figure C-2.1; temperature logs and gradients in Figures C-2.3 and C-2.4; and gradients are tabulated in Table C-3.1 in the next section. Several more weeks are required before the latter group of holes will reach thermal equilibrium.

An equilibrium gradient was also determined from drill hole FD1, a hole drilled by private industry in the slate belt of North Carolina (Figure C-2.1). Heat flow determinations for this site should be completed in the next report period.

Attempts to measure an equilibrium temperature profile in the Jesup well in Georgia (JE1) were unsuccessful due to congealed drilling mud left in the hole. A preliminary temperature profile of this well was given in Progress Report VPI&SU-5648-1.

As reconnaissance to the upcoming drilling program on the Atlantic Coastal Plain, a survey was made of the existing deep wells in the Coastal Plain sediments of New

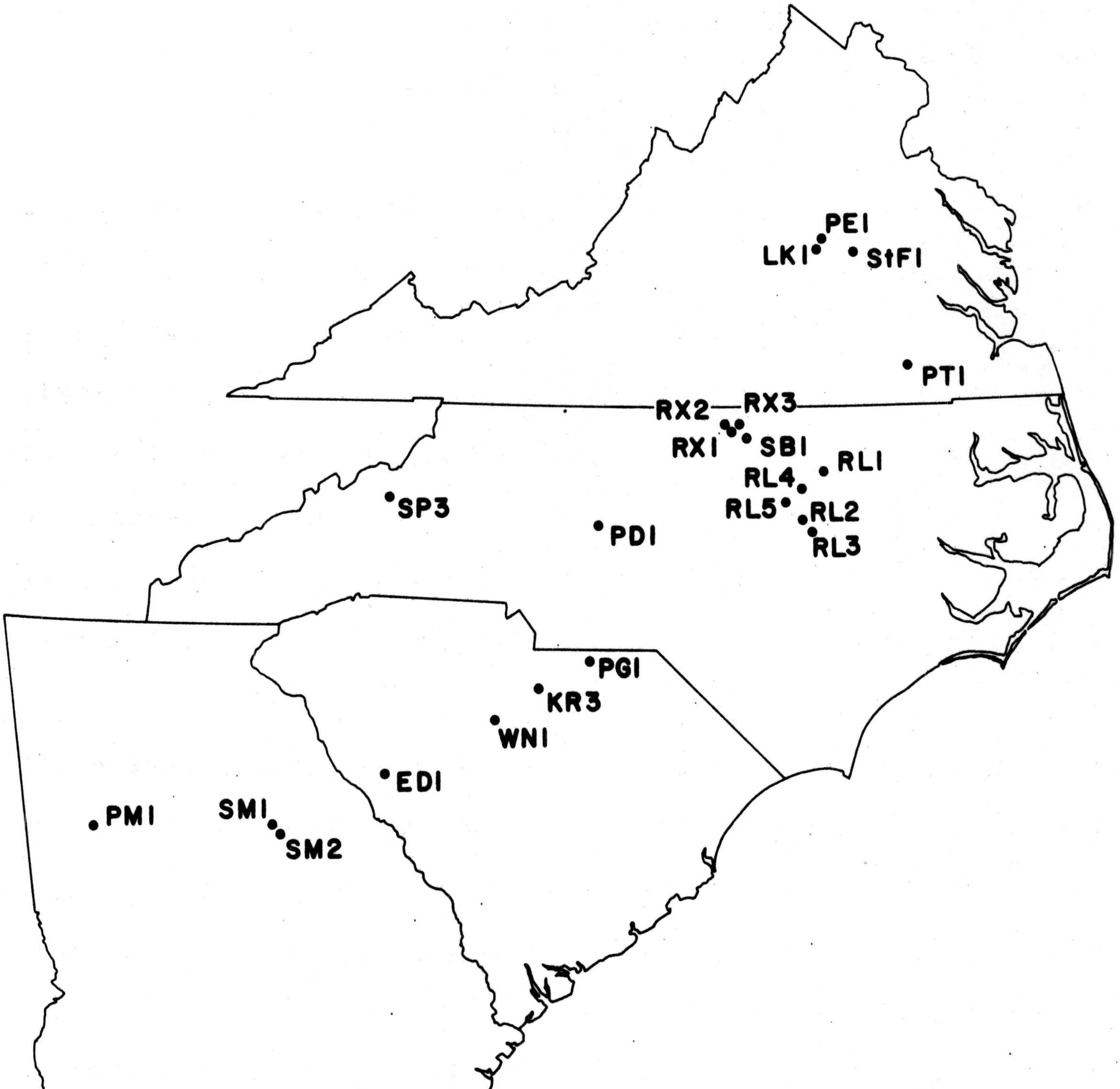


Figure C-2.1. Locations of drill holes yielding heat flow values.

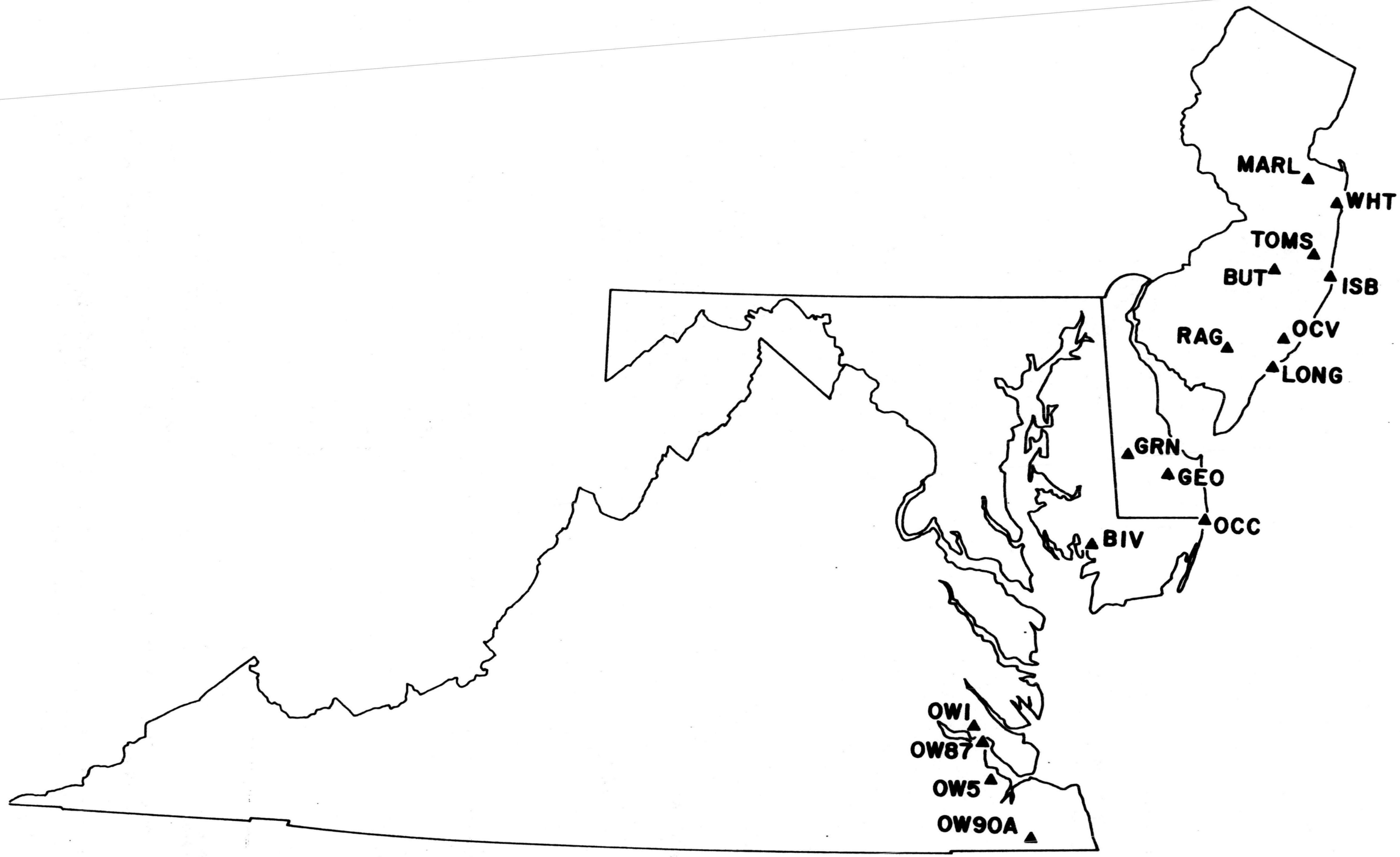


Figure C-2.2. Locations of existing deep wells logged for geothermal gradients in the Atlantic Coastal Plain.

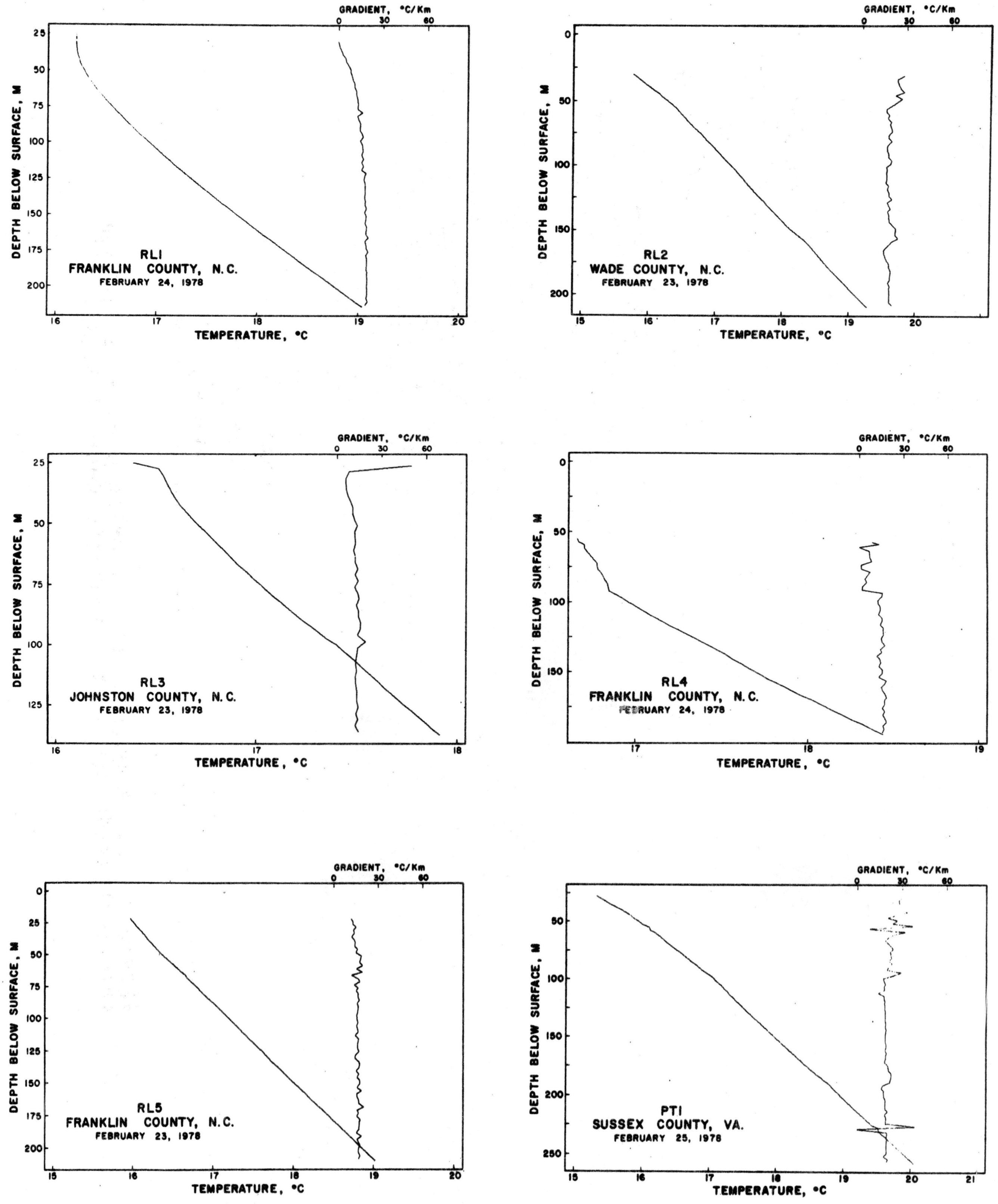
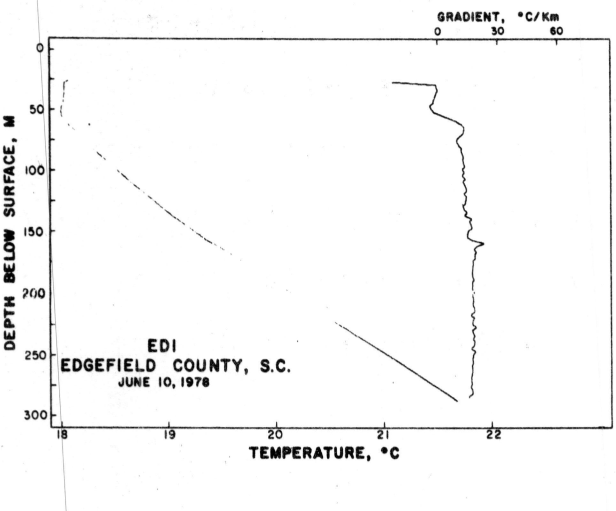
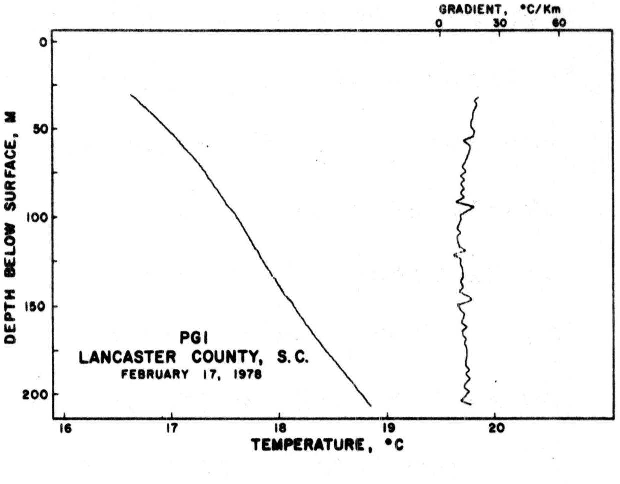
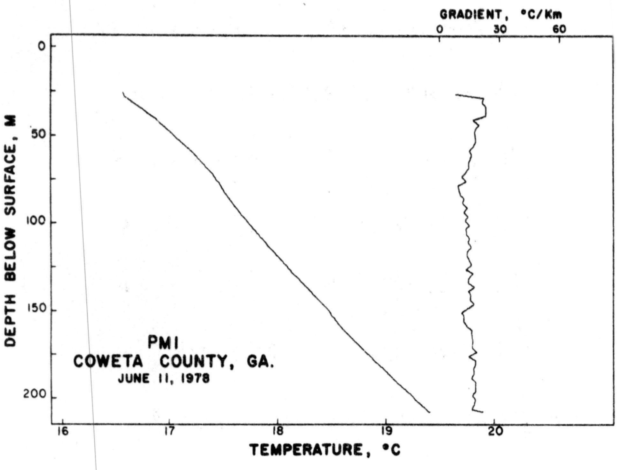
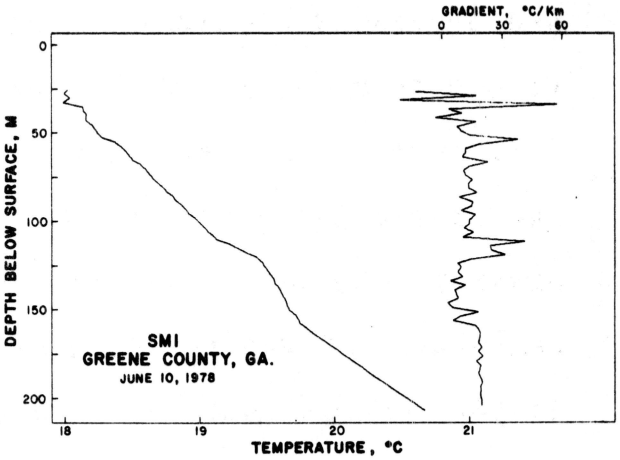


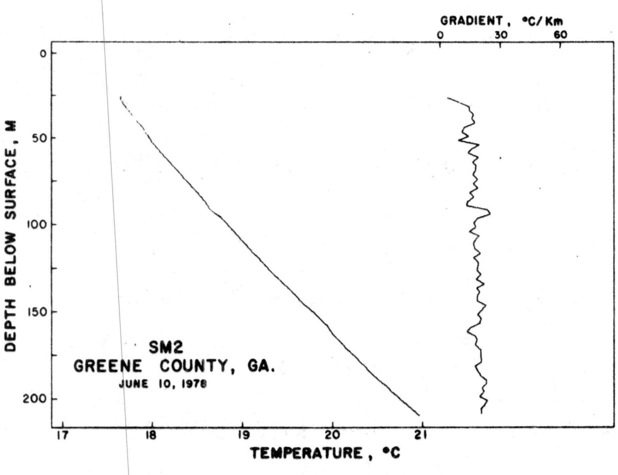
Figure C-2.3. Temperature and gradient logs of wells drilled by VPI&SU and logged during present report period.











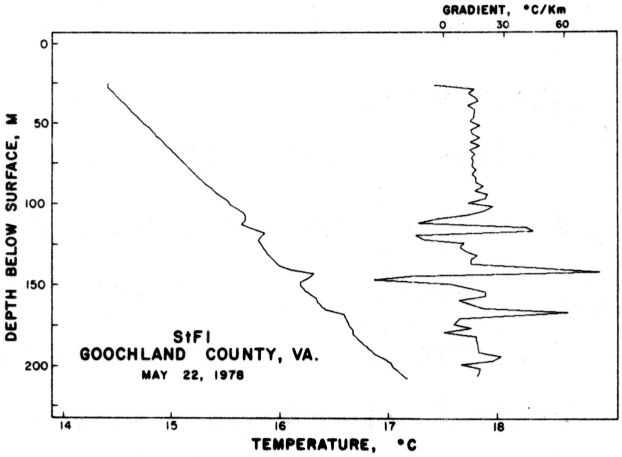


Figure C-2.4. Temperature and gradient logs of wells drilled by VPI&SU and logged during present report period.

Jersey, Delaware, Maryland, and Virginia. Geothermal gradients were determined for sixteen (16) of these wells, the locations of which are shown in Figure C-2.2. Least-square gradients for these wells (Figures C-2.5 to C-2.7) range from 15.6°C/km in Marlboro OW to 37.9°C/km in Ragovin OW. Over small intervals many wells have gradients exceeding 40°C/km (Table C-2.1).

The effect of water circulation around an uncemented well may be observable as unsteady temperature measurements and as upward deformation of isotherms where water flow is upward from below. The interval 210-255 m at Bivalve Harbor 1 (Figure C-2.7) may exhibit this effect. Alternatively, the decreasing gradient below 210 m may be the result of a gradual decrease in the thermal conductivity of the sediments. Likewise, downwarping of isotherms as exhibited in the Ragovin and Tom's River observation wells (Figure C-2.5) may be the result of fluid motion from shallow to greater depth along the cased well.

Observation Well 1 in James City County, Virginia (Figure C-2.7) is an illustration of internal mixing and aquifer communication via a screened well. Screens are located at 125 m and 167.5 m.

During the period covered by this report, the temperature logging instrumentation was upgraded to a digital well logging system. A precision Fluke multimeter is triggered by a microcomputer to sample a resistance

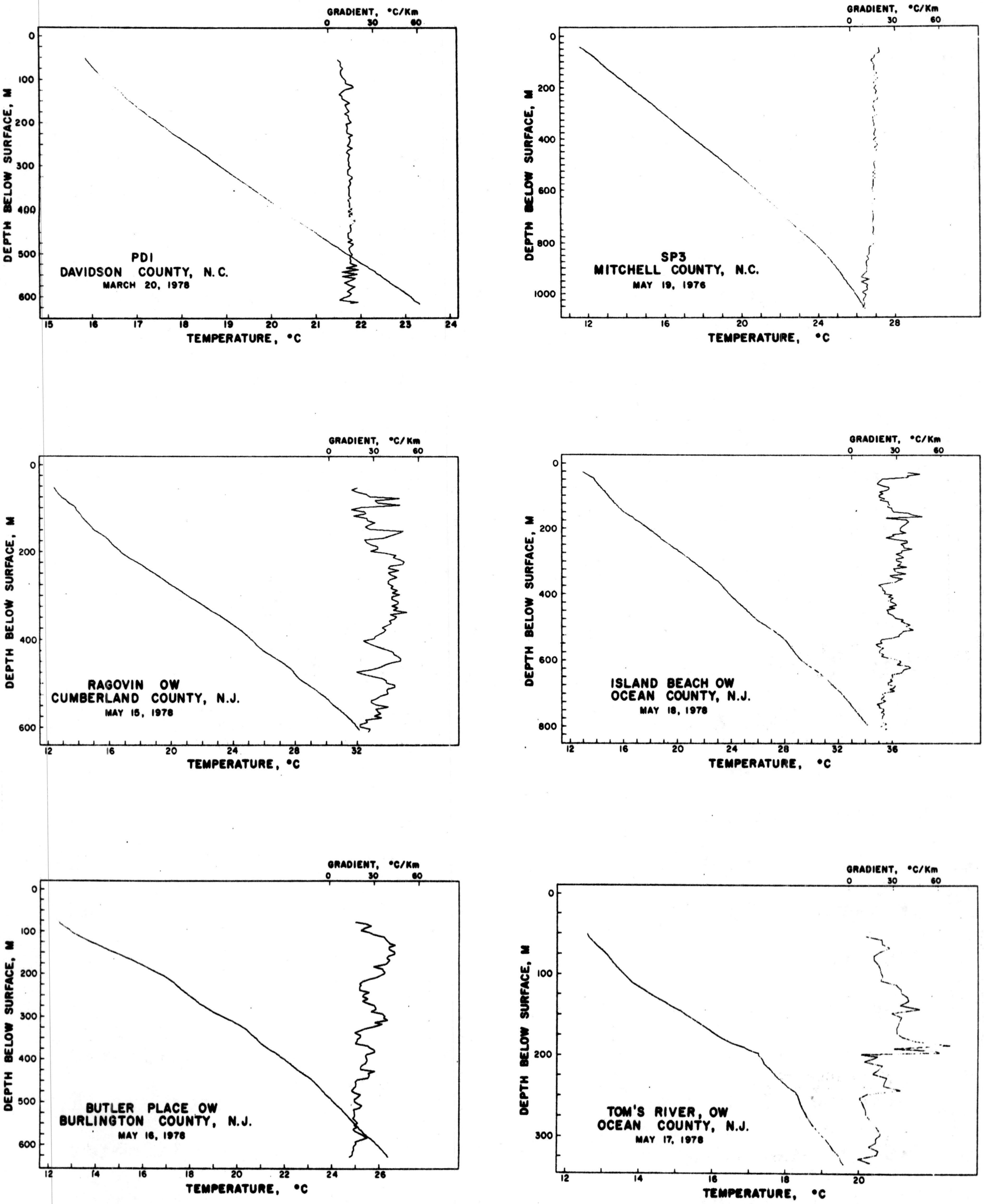
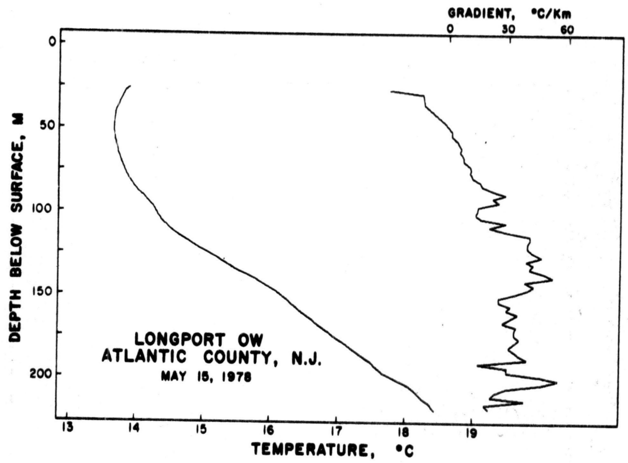
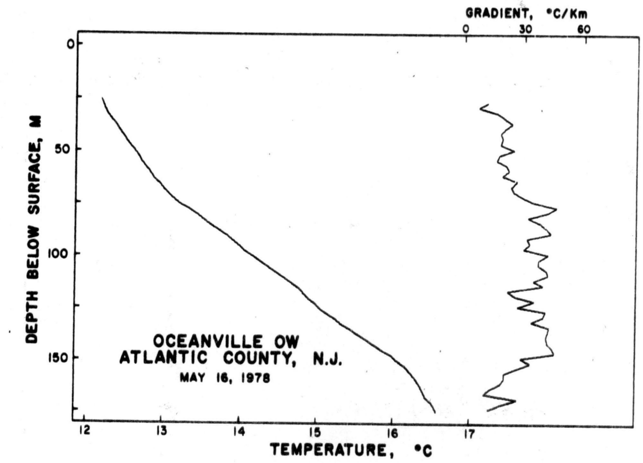
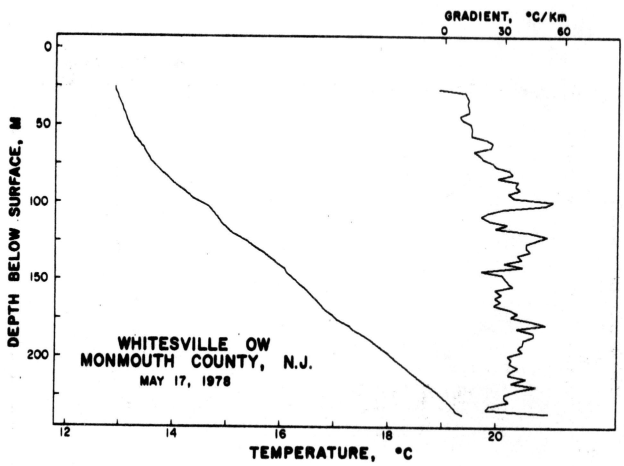
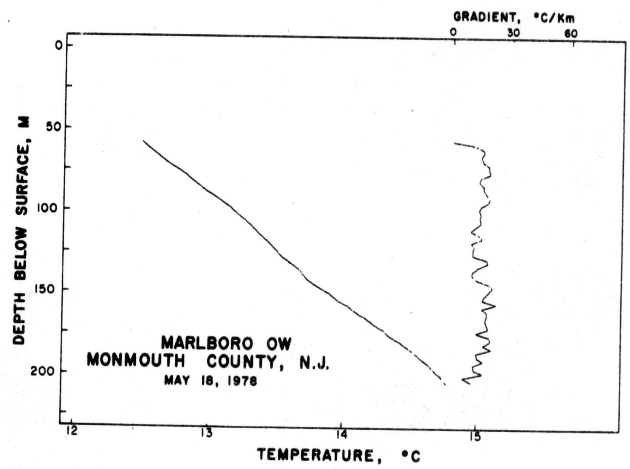


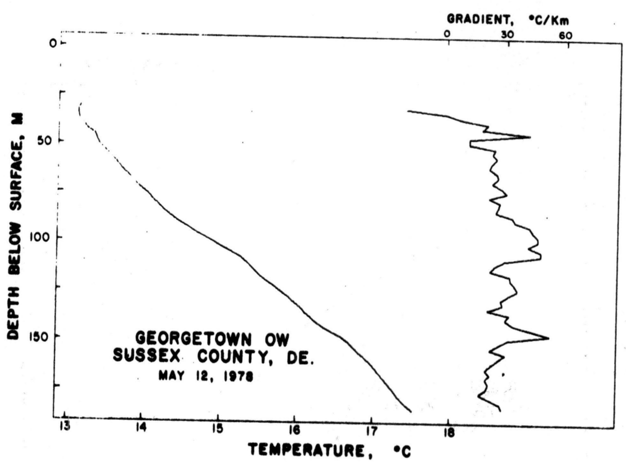
Figure C-2.5. Temperature and gradient logs of wells logged during present report period.











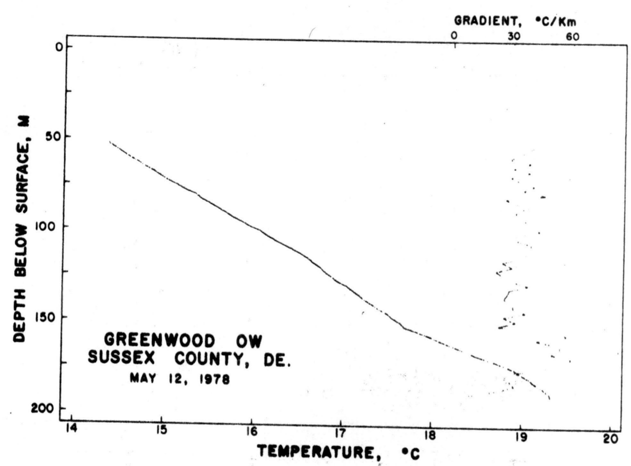


Figure C-2.6. Temperature and gradient logs for wells logged during present report period.

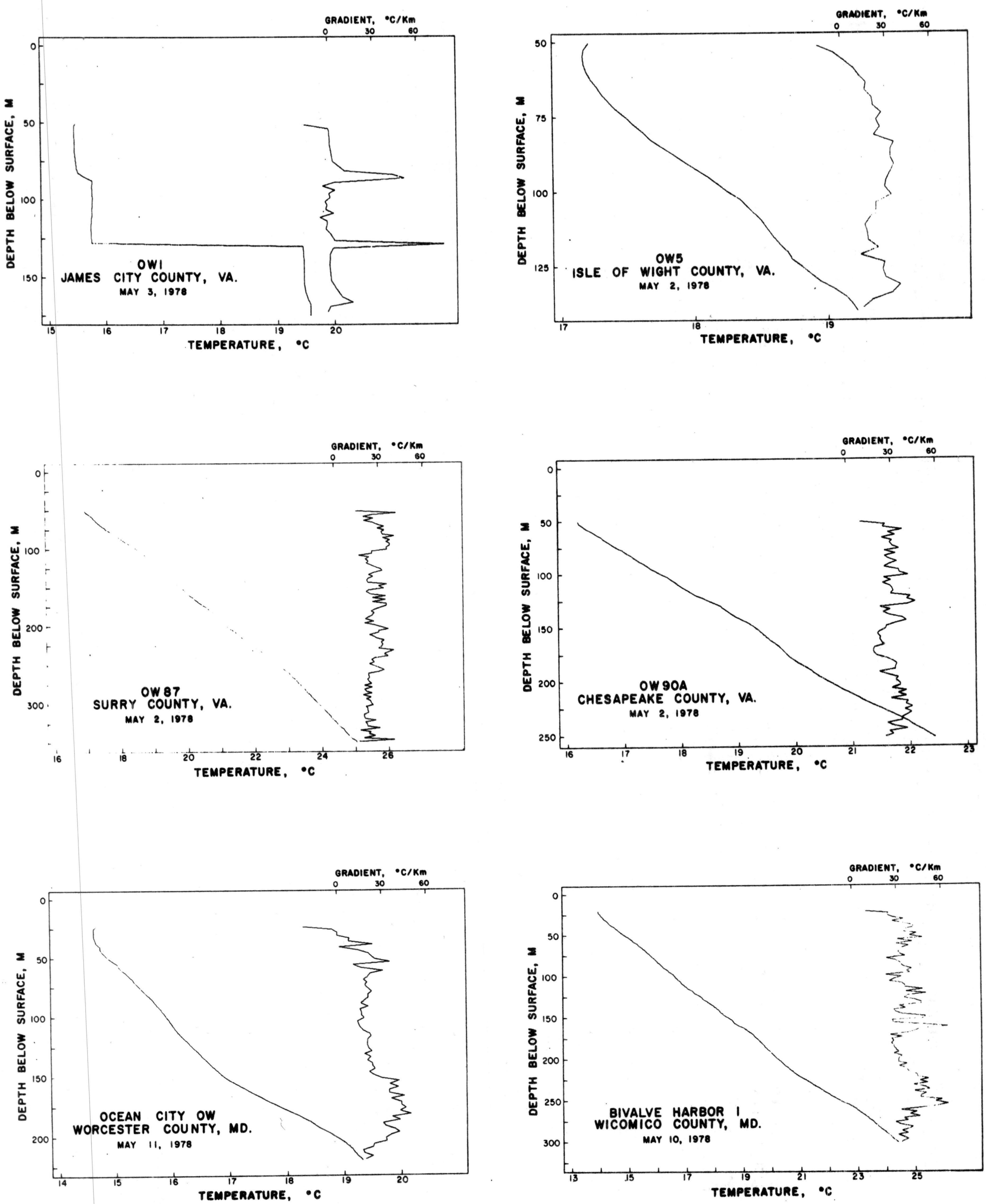


Figure C-2.7. Temperature and gradient logs of wells logged during present report period.

TABLE C-2.1 SUMMARY OF GEOTHERMAL GRADIENT DATA FOR EXISTING WELLS IN COASTAL PLAIN JUNE 30, 1978

LOCATION	LATITUDE LONGITUDE	DATE LOGGED	HOLE DEPTH (METERS)	DEPTH INTERVAL (METERS)	GRADIENT (°C/KM)
OBSERVATION WELL #1 JAMES CITY CO., VA.	37°16'57" 76°44'49"	5/ 3/78	175.0	50.0-175.0	24.67*
OBSERVATION WELL #5 ISLE OF WIGHT CO., VA.	36°58'26" 76°37'24"	5/ 2/78	140.0	37.5-140.0	23.03 ±1.03 (38)
				85.0-100.0	33.14 ±0.54 (7)
				110.0-122.5	19.01 ±0.84 (6)
				122.5-132.5	30.80 ±1.01 (5)
OBSERVATION WELL #87 SURRY CO., VA.	37°11'33" 76°40'53"	5/ 3/78	351.0	52.5-350.0	27.39 ±0.11 (120)
				52.5-110.0	32.20 ±0.44 (24)
				112.5-240.0	28.16 ±0.13 (52)
				242.5-350.0	22.86 ±0.11 (44)
OBSERVATION WELL 90A CHESAPEAKE CO., VA.	36°38'37" 76°20'18"	5/ 2/78	252.5	52.4-249.0	30.36 ±0.16 (80)
				52.4-124.9	30.56 ±0.13 (30)
				127.4-174.9	26.59 ±0.58 (20)
				177.4-249.9	35.15 ±0.31 (30)
BIVALVE HARBOR 1 WICOMICO CO., MD.	38°18'44" 75°53'06"	5/10/78	307.5	27.5-300.0	37.73 ±0.18 (140)
				27.5-165.0	35.78 ±0.16 (50)
				167.5-215.0	30.39 ±0.29 (20)
				217.5-260.0	49.45 ±0.55 (18)
				262.5-300.0	36.19 ±0.29 (16)
OCEAN CITY OW WORCESTER CO., MD.	38°26'35" 75°03'06"	5/11/78	219.8	52.5-200.0	24.93 ±0.59 (60)
				52.5-150.0	19.21 ±0.14 (40)
				152.5-200.0	39.81 ±0.29 (20)
GEORGETOWN OW SUSSEX CO., DE.	38°42'44" 75°19'13"	5/12/78	185.0	32.5-185.0	31.55 ±0.30 (62)
				52.5- 85.0	25.62 ±0.25 (14)
				87.5-110.0	44.02 ±0.54 (10)
				112.5-150.0	33.06 ±0.59 (16)
				152.5-185.0	23.49 ±0.35 (14)
GREENWOOD OW SUSSEX CO., DE.	38°49'35" 75°11'43"	5/12/78	190.0	55.0-190.0	36.18 ±0.33 (55)
				122.5-152.5	30.57 ±0.28 (13)
				157.5-170.0	53.03 ±1.14 (6)
				172.5-190.0	30.52 ±1.64 (8)

*CALCULATED FROM BOTTOM HOLE TEMPERATURE AND MEAN ANNUAL SURFACE TEMPERATURE.

TABLE C-2.1 SUMMARY OF GEOTHERMAL GRADIENT DATA FOR EXISTING WELLS IN COASTAL PLAIN JUNE 30, 1978

RAGOVIN OW CUMBERLAND CO., N.J.	39°25'12" 74°52'12"	5/15/78	620.0	60.0-620.0	37.85 ±0.18 (113)
				60.0-150.0	27.59 ±0.58 (19)
				155.0-365.0	42.07 ±0.29 (43)
				370.0-620.0	34.42 ±0.26 (51)
LONGPORT OW ATLANTIC CO., N.J.	39°18'21" 74°32'08"	5/15/78	220.0	77.5-220.0	36.64 ±0.31 (58)
				77.5-110.0	20.39 ±0.45 (14)
				112.5-150.0	43.43 ±0.28 (16)
				152.5-220.0	34.11 ±0.28 (28)
OCEANVILLE OW ATLANTIC CO., N.J.	30°27'54" 74°27'01"	5/16/78	175.0	30.0-175.0	30.03 ±0.37 (59)
				30.0- 70.0	20.45 ±0.23 (17)
				72.5-152.5	37.04 ±0.20 (33)
				155.0-175.0	18.00 ±0.53 (9)
BUTLER PLACE OW BURLINGTON CO., N.J.	39°51'22" 74°30'17"	5/16/78	632.5	80.0-635.0	25.19 ±0.30 (112)
				80.0-125.0	29.03 ±1.07 (10)
				135.0-210.0	38.01 ±0.43 (16)
				215.0-445.0	26.26 ±0.22 (47)
				455.0-635.0	18.01 ±0.08 (37)
TOM'S RIVER OW OCEAN CO., N.J.	39°56'09" 74°12'40"	5/17/78	335.0	60.0-335.0	26.84 ±0.61 (59)
				60.0-110.0	20.82 ±0.33 (11)
				115.0-180.0	36.05 ±0.38 (14)
				185.0-195.0	55.31 ±4.95 (4)
				197.5-245.0	20.63 ±0.79 (12)
				250.0-335.0	16.08 ±0.42 (18)
WHITESVILLE OW MONMOUTH CO., N.J.	40°13'23" 74°01'56"	5/17/78	237.5	27.5-237.5	32.89 ±0.35 (85)
				107.5-237.5	35.86 ±0.19 (53)
				167.5-190.0	41.77 ±0.73 (10)
ISLAND BEACH OW OCEAN CO., N.J.	39°48'29" 74°05'35"	5/18/78	822.5	35.0-820.0	28.23 ±0.11 (158)
				155.0-360.0	32.77 ±0.11 (42)
				465.0-525.0	35.65 ±0.40 (13)
				645.0-815.0	21.69 ±0.22 (35)
MARLBORO OW MONMOUTH CO., N.J.	40°22'08" 74°14'52"	5/18/78	212.5	57.5-205.0	15.61 ±0.09 (60)
				62.5-105.0	16.64 ±0.11 (18)
				107.5-140.0	13.14 ±0.22 (14)
				142.5-197.5	17.56 ±0.16 (23)

thermometer at intervals of 0.5 m. The microcomputer has data storage capability on magnetic casette tape and is capable of data selection and transmission via modem and radiotelephone to the Computing Center at VPI&SU in Blacksburg, Virginia.

Geothermal gradients measured at a rate of 5 m/min by this system reproduce those measured by our conventional technique using a Mueller Resistance Bridge, and do so with greater precision and higher resolution.

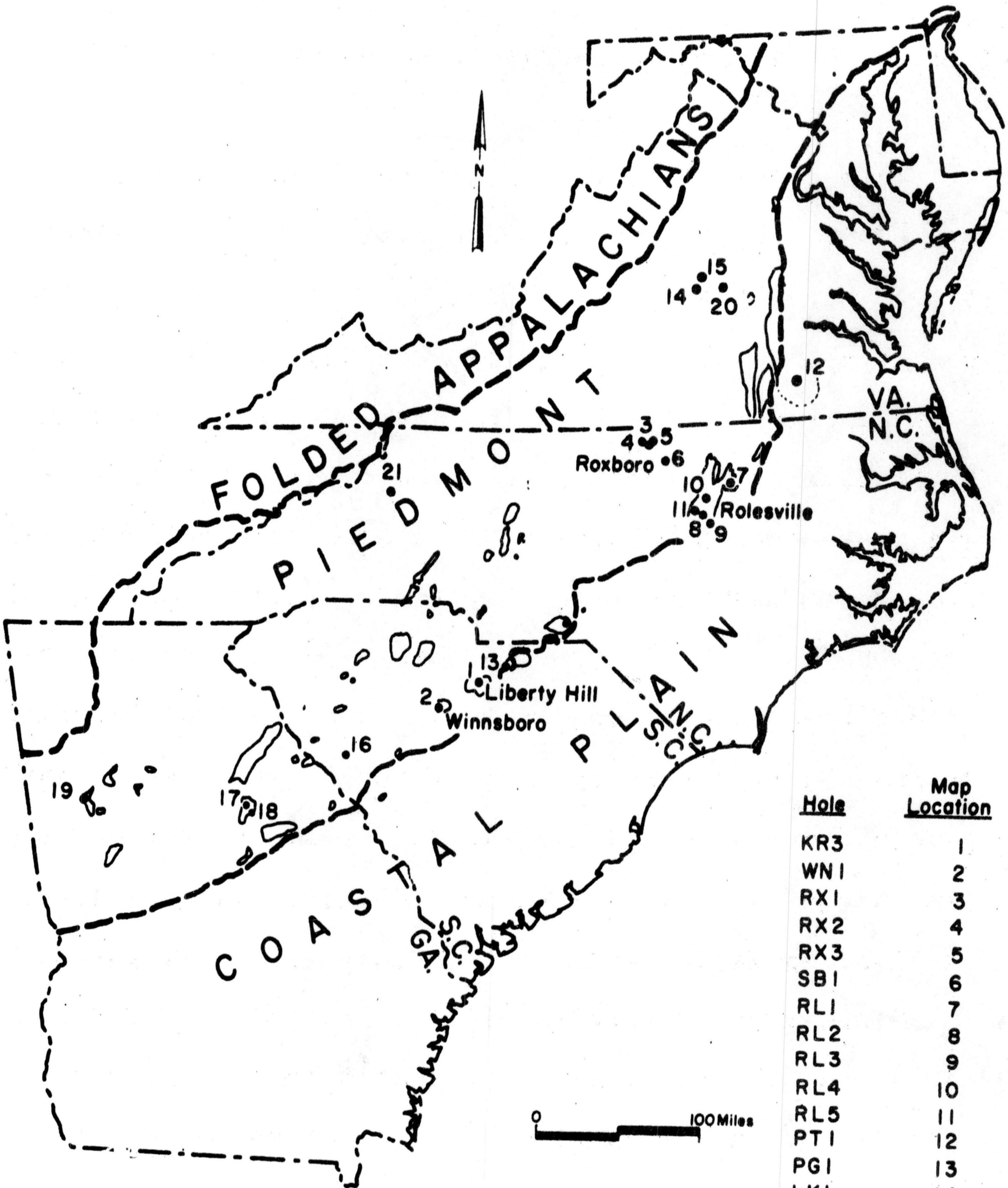
Measurement of absolute temperature at the ice point agrees to within 0.1°C with calibration tables supplied by the manufacturer of the thermistor probes; precision of temperature measurements is considerably better than 0.01°C.

HEAT FLOW AND HEAT GENERATION

J.K. Costain, L.D. Perry, S. Dashevsky, and B.U. Conrad

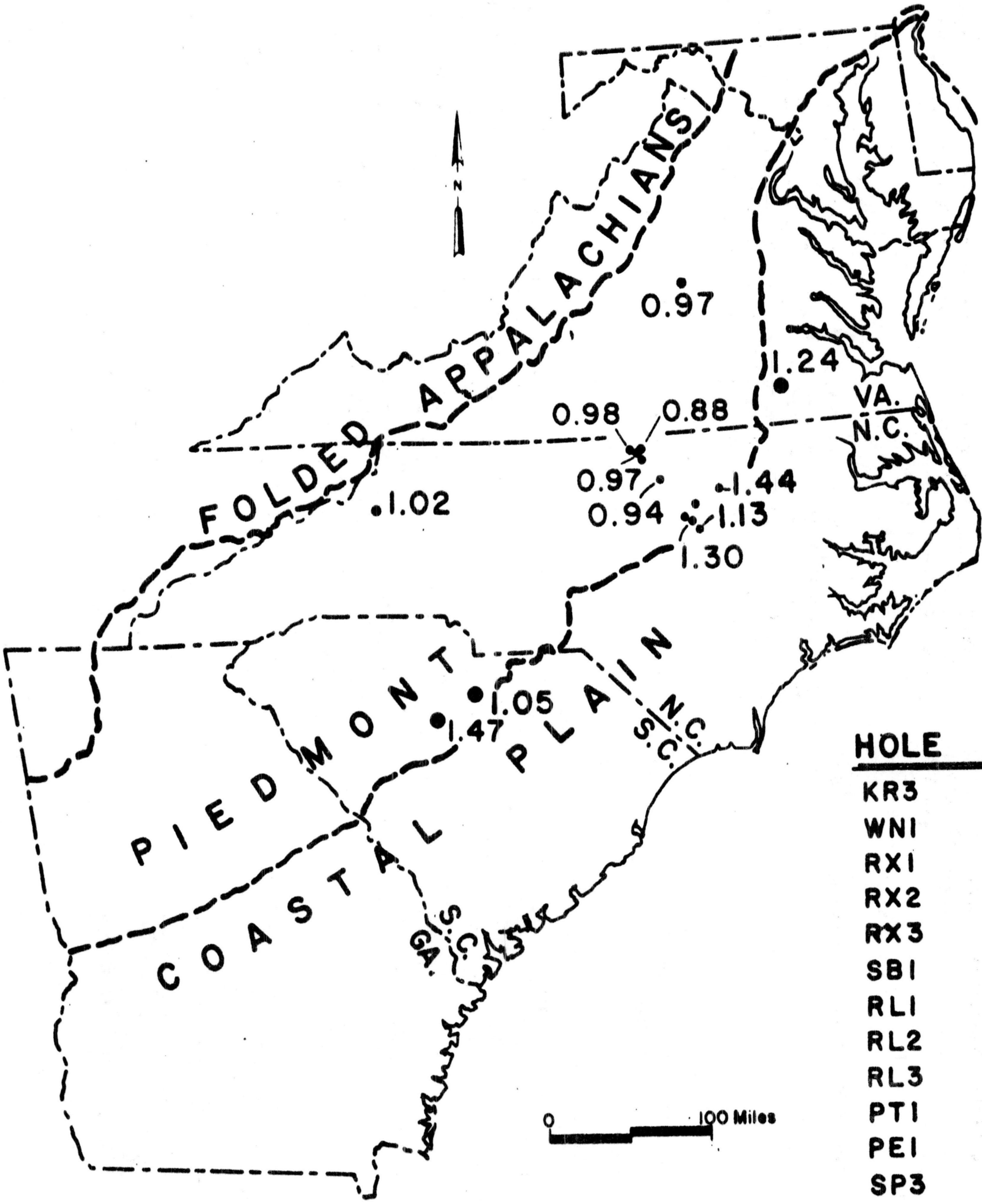
Figure C-3.1 shows locations of holes drilled to date by VPI&SU in the southeastern United States. Figure C-3.2 summarizes heat flow values. Table C-3.1 summarizes geothermal gradients, thermal conductivities and heat flow determinations available to date for this contract. This table appears in each report, beginning with VPI&SU-5103-4, and is periodically updated as thermal conductivity and heat flow determinations are completed. Slight changes in the gradients that will appear in Table C-3.1 are the result of relogging these holes as they reach thermal equilibrium. Changes in gradients are not expected to be more than a few percent; drill hole StF1 (Figure C-2.4 in previous section) was logged a few days after drilling was completed; the gradient anomalies will be attenuated in a few weeks.

Access to two holes drilled by private industry will result in new heat flow values at Spruce Pine, NC (SP3) and near Lexington, NC (PD1). Both of these holes will yield reliable heat flow values. Changes in the gradient in the hole at Spruce Pine (SP3) are not consistent with changes in thermal conductivity of core from corresponding intervals in the hole, especially over the interval below about 800 m. The most probable explanation for this is deviation of the hole from the vertical as the depth of the hole increases.



Hole	Map Location
KR3	1
WN1	2
RX1	3
RX2	4
RX3	5
SB1	6
RL1	7
RL2	8
RL3	9
RL4	10
RL5	11
PT1	12
PG1	13
LK1	14
PE1	15
ED1	16
SM1	17
SM2	18
PM1	19
SF1	20
SP3	21

Figure C-3.1. Locations of holes drilled to date by VPI&SU in the southeastern United States.



HOLE	Q
KR3	1.05
WN1	1.47
RX1	0.98
RX2	0.97
RX3	0.88
SB1	0.94
RL1	1.44
RL2	1.30
RL3	1.13
PT1	1.24
PE1	0.97
SP3	1.02

Figure C-3.2. Heat flow values available to date.

TABLE C-3.1

SUMMARY OF HEAT FLOW DATA

LOCATION	LATITUDE	LONGITUDE	DATE LOGGED	HOLE DEPTH (METERS)	DEPTH INTERVAL (METERS)	GRADIENT[3] (°C/KM)	CONDUCTIVITY[3] (MCAL/CM-SEC-°C)	HEAT FLOW (μCAL/CM²-SEC)
LIBERTY HILL - KERSHAW PLUTON, LANCASTER CO., S.C.								
KP3	34°32'20"	80°44'51"	11/18/76	277	316.8-404.3	14.91 ±0.02 (36)	7.14 ±0.57 (24)[4]	1.06 ±0.09[1]
					334.3-341.8	14.68 ±0.07 (4)	6.94 ±0.47 (3)[4]	1.02 ±0.07
					344.3-356.8	15.06 ±0.07 (6)	7.09 ±0.54 (5)[4]	1.07 ±0.0
					359.3-369.3	14.88 ±0.07 (5)	7.33 ±0.20 (4)[4]	1.09 ±0.04
					371.8-384.3	14.85 ±0.06 (6)	7.07 ±0.28 (5)[4]	1.05 ±0.05
					386.8-401.8	15.00 ±0.13 (7)	6.94 ±0.69 (6)[4]	1.04 ±0.11
RION PLUTON, FAIRFIELD CO., S.C.								
WN1	34°18'48"	81°08'42"	7/5/77	574.3	242.4-571.74	18.18 ±0.04 (220)	8.06 ±0.24 (26)	1.47 ±0.05[1]
ROXBORO METAGRANITE, PERSON CO., N.C.								
RX1	36°23'12"	78°58'00"	5/19/77	240	146.8-249.3	10.83 ±0.03 (42)	8.97 ±0.41 (32)	0.97 ±0.05[1]
					146.8-184.3	11.03 ±0.06 (16)	9.08 ±0.11 (15)	1.00 ±0.02[1]
					219.3-231.8	10.94 ±0.12 (16)	8.76 ±0.59 (5)	0.96 ±0.08[1]
RX2	36°25'31"	79°01'53"	5/19/77	214	149.3-209.3	11.20 ±0.04 (25)	8.77 ±0.45 (23)	0.98 ±0.05[1]
					149.3-189.3	11.30 ±0.07 (17)	8.87 ±0.21 (16)	1.00 ±0.03[1]
					191.8-209.3	11.05 ±0.04 (8)	8.54 ±0.73 (7)	0.94 ±0.08[1]
RX3	36°25'39"	78°53'42"	8/7/77	211.5	134.9-199.9	10.36 ±0.22 (14)	8.33 ±0.58 (14)	0.86 ±0.08[1]
					144.3-169.9	10.43 ±0.37 (6)	8.40 ±0.67 (10)	0.88 ±0.10[1]
					181.9-194.9	9.00 ±0.46 (3)	8.14 ±0.25 (4)	0.73 ±0.06[1]
SLATE BELT PERSON CO., N.C.								
SB1	36°19'40"	78°50'00"	6/5/77	211.5	41.7-209.2	11.63 ±0.11 (66)	8.06 ±0.66 (47)	0.94 ±0.09[1]
ROLESVILLE BATHOLITH AND CASTALIA PLUTON FRANKLIN CO., N.C.								
CS1	36°04'15"	78°07'43"	2/24/78	210.6	142.2-209.7	19.26 ±0.03 (28)	7.52 ±0.39 (26)	1.45 ±0.08[1]
					145.0-210.0	19.06 ±0.12 (27)	7.52 ±0.39 (26)	1.43 ±0.08[1]

TABLE C-3.1

SUMMARY OF HEAT FLOW DATA

RL2	36°47'17"	78°25'04"	2/24/78	212.8	29.7-209.7	18.92 ±0.07 (73)	7.23 ±0.34 (14)	1.37 ±0.07
					104.7-124.7	17.40 ±0.18 (9)	7.30 ±0.38 (7)	1.27 ±0.08
					192.2-209.7	18.71 ±0.18 (9)	7.16 ±0.31 (6)	1.34 ±0.07
RL3	35°57'05"	78°20'00"	2/23/78	121.9	42.4-129.9	14.06 ±0.08 (36)	8.03 ±0.93 (27)	1.13 ±0.14
					42.4- 94.9	13.57 ±0.15 (22)	8.22 ±0.70 (12)	1.12 ±0.11
					97.4-129.9	13.79 ±0.10 (14)	7.88 ±1.08 (15)	1.09 ±0.16
RL4	35°43'36"	78°19'45"	2/24/78	196.3	54.7-194.7	13.26 ±0.27 (57)		
					54.7- 89.7	5.23 ±0.23 (15)		
					92.2-194.7	15.44 ±0.08 (42)		
RL5	35°51'17"	78°28'54"	2/23/78	211.5	22.3-209.8	16.31 ±0.03 (76)		
					22.3- 69.8	15.57 ±0.22 (20)		
					72.3-129.8	16.02 ±0.06 (24)		
					132.3-209.8	16.87 ±0.03 (32)		
PETERSBURG GRANITE, SUSSEX CO., VA. PT1	36°49'45"	77°19'15"	10/21/77	253.0	94.7-159.7	18.18 ±0.08 (27)	6.67 ±0.54 (25)	1.21 ±0.10
					197.2-249.7	19.20 ±0.12 (26)	6.57 ±0.57 (25)	1.26 ±0.12
PAGELAND PLUTON, LANCASTER CO., S.C. PG1	34°42'02"	80°27'51"	2/17/78	213.4	32.5-205.0	11.71 ±0.08 (70)		
					32.5- 75.0	15.31 ±0.23 (18)		
					77.5-165.0	10.73 ±0.06 (36)		
					167.5-205.0	12.83 ±0.03 (10)		
LAKESIDE CUMBERLAND CO., VA. LK1	37°41'25"	78°08'52"	9/16/77	205.0	59.3-204.3	13.46 ±0.07 (58)		
					59.3- 81.8	11.49 ±0.07 (10)		
					121.3-144.3	14.30 ±0.17 (10)		
					164.3-204.3	13.31 ±0.05 (17)		

PEGMATITE BELT,

GOOCHLAND CO., VA.								
PE1	37°45'56"	78°05'37"	9/21/77	200.0	41.8-201.8	13.27 ±0.15 (65)	6.37 ±0.99 (40)	0.85 ±0.14[1]
					41.8- 59.3	8.39 ±0.27 (9)	7.22 ±0.34 (3)	0.61 ±0.05[1]
					116.8-194.3	15.40 ±0.09 (34)	6.30 ±0.98 (37)	0.97 ±0.16[1]
CUFFYTOWN								
EDGEFIELD, S.C.								
ED1	33°55'11"	82°07'10"	6/10/78	294.0	62.5-290.0	16.55 ±0.10 (92)		
					62.5-175.0	14.29 ±0.16 (46)		
					177.5-290.0	17.59 ±0.04 (46)		
PALMETTO								
COWETA CO., GA								
PM1	33°29'55"	84°41'58"	6/11/78	208.3	30.0-208.3	14.64 ±0.08 (73)		
					30.0- 82.5	16.74 ±0.38 (22)		
					85.0-160.0	14.41 ±0.74 (31)		
					162.5-208.3	16.94 ±0.05 (20)		
SILOAM								
GREENE CO., GA.								
SM1	32°27'17"	83°08'53"	6/10/78	210.0	27.5-207.0	14.56 ±0.12 (73)		
					27.5- 55.0	12.15 ±1.20 (12)		
					57.5-110.0	13.62 ±0.03 (22)		
					112.5-120.0	26.40 ±1.39 (4)		
					122.5-157.5	18.50 ±0.03 (15)		
					160.0-205.0	18.88 ±0.08 (19)		
SM2	33°28'41"	83°11'35"	6/10/78	210.0	27.5-210.0	18.27 ±0.08 (74)		
SPRUCE PINE								
MITCHELL CO., N.C.								
SP3	35°54'50"	82°07'18"	5/19/76	1220.0	209.1-1059.1	14.45 ±0.13 (89)	6.62 ±1.19 (88)	0.96±0.18[1]
					209.1- 519.1	16.39 ±0.03 (32)	6.72 ±1.51 (35)	1.10 ±0.25[1]
					534.1- 849.1	14.72 ±0.04 (35)	6.38 ±0.97 (36)	0.94 ±0.15[1]
					849.1-1059.1	9.36 ±0.07 (19)	6.74 ±0.94 (32)	0.63 ±0.09[1]
STATE FARM								
GOOCHLAND CO., VA.								
SF1	37°40'01"	77°48'06"	5/22/78	207.5	27.5-107.5	15.03 ±0.10 (72)		
					32.5-100.0	15.50 ±0.11 (28)		

					102.5-207.5	15.10 ±0.30 (42)
PHELPS DODGE						
DAVIDSON CO., N.C.						
PD1	35°42'24"	80°02'19"	3/20/78	630.0	50.0-630.0	13.58 ±0.05(117)
					250.0-550.0	14.11 ±0.07 (61)

1 - INDICATES HEAT FLOW VALUE IS THE PRODUCT OF A MEAN GRADIENT AND A MEAN THERMAL CONDUCTIVITY
3 - VALUE IN PARENTHESES IS THE NUMBER OF TEMPERATURE POINTS OR THE NUMBER OF THERMAL CONDUCTIVITY VALUES
4 - THERMAL CONDUCTIVITY VALUES FROM 1.270 CM THICK SAMPLES
5 - GRADIENT FROM THE SEDIMENTARY COVER OF THE PLUTON
6 - GRADIENT FROM WITHIN THE PLUTON

TABLE C-3.2

THERMAL CONDUCTIVITY VALUES FROM CORE OF DRILL HOLE SP3
(SAMPLES ARE 2.680 CM IN DIAMETER BY 1.270 CM THICK)

SAMPLE NAME	DEPTH (METERS)	THERMAL CONDUCTIVITY MCAL/CM-SEC-°C
SP3-693	211.2	5.47
SP3-712	217.0	4.76
SP3-789	240.5	5.84
SP3-793	241.7	7.13
SP3-812	247.5	5.52
SP3-840	256.0	5.50
SP3-841	256.3	5.47
SP3-846	257.9	4.98
SP3-857	261.2	5.25
SP3-893	272.2	7.23
SP3-927	282.5	4.38
SP3-998	304.2	7.72
SP3-1055	321.6	6.38
SP3-1088	331.6	7.61
SP3-1095	333.8	7.86
SP3-1112	338.9	7.15
SP3-1141	347.8	9.38
SP3-1146	349.3	7.57
SP3-1170	356.6	4.31
SP3-1179	359.4	7.79
SP3-1198	365.1	9.32
SP3-1231	375.2	4.14
SP3-1267	386.2	9.03
SP3-1295	394.7	7.93
SP3-1322	402.9	7.64
SP3-1382	421.2	8.87
SP3-1409	429.5	4.77
SP3-1416	431.6	8.37
SP3-1440	438.9	7.79
SP3-1496	456.0	7.37
SP3-1504	458.4	3.43
SP3-1545	470.9	5.00
SP3-1574	479.8	7.50
SP3-1602	488.3	6.70
SP3-1621	494.1	3.33
SP3-1652	503.5	8.14
SP3-1657	505.0	7.64
SP3-1680	512.0	7.55
SP3-1707	520.3	4.56
SP3-1719	523.9	7.68
SP3-1747	532.5	4.67

TABLE C-3.2 (continued)

THERMAL CONDUCTIVITY VALUES FROM CORE OF DRILL HOLE SP3
(SAMPLES ARE 2.680 CM IN DIAMETER BY 1.270 CM THICK)

SAMPLE NAME	DEPTH (METERS)	THERMAL CONDUCTIVITY MCAL/CM-SEC-°C
SP3-1766	538.3	7.02
SP3-1800	548.6	6.51
SP3-1816	553.5	8.13
SP3-1832	558.4	6.61
SP3-1873	570.9	7.49
SP3-1877	572.1	3.29
SP3-1896	577.9	3.61
SP3-1936	590.1	5.34
SP3-1954	595.6	7.28
SP3-1982	604.1	5.80
SP3-2011	612.9	6.93
SP3-1041	622.1	7.38
SP3-1067	630.0	7.28
SP3-1097	639.2	6.94
SP3-2125	647.7	4.84
SP3-2152	655.9	6.61
SP3-2181	664.8	5.32
SP3-2238	682.1	7.55
SP3-2267	691.0	6.85
SP3-2296	699.8	4.51
SP3-2324	708.4	6.29
SP3-2331	710.5	6.59
SP3-2383	726.3	5.14
SP3-2411	734.9	5.82
SP3-2438	743.1	3.79
SP3-2499	761.7	5.48
SP3-2469	752.5	7.41
SP3-2527	770.2	7.04
SP3-2534	772.4	6.93
SP3-2554	778.5	6.37
SP3-2583	787.3	7.49
SP3-2614	796.7	4.53
SP3-2640	804.7	5.98
SP3-2669	813.5	6.33
SP3-2698	822.3	6.22
SP3-2727	831.2	7.00
SP3-2759	840.9	6.63
SP3-2786	849.2	6.23
SP3-2815	858.0	2.91
SP3-2883	878.7	6.53
SP3-2943	897.0	6.96

TABLE C-3.2 (continued)

THERMAL CONDUCTIVITY VALUES FROM CORE OF DRILL HOLE SP3
(SAMPLES ARE 2.680 CM IN DIAMETER BY 1.270 CM THICK)

SAMPLE NAME	DEPTH (METERS)	THERMAL CONDUCTIVITY MCAL/CM-SEC-°C
SP3-2945	897.6	16.18
SP3-2969	904.9	5.86
SP3-2999	914.1	6.50
SP3-3027	922.6	4.98
SP3-3029	923.2	5.85
SP3-3057	931.8	8.03
SP3-3104	946.1	6.16
SP3-3134	955.2	6.84
SP3-3163	964.1	6.36
SP3-3194	973.5	7.57
SP3-3258	993.0	6.07
SP3-3286	1001.6	8.17
SP3-3313	1009.8	7.46
SP3-3349	1020.8	7.90
SP3-3371	1027.5	6.38
SP3-3428	1044.9	6.64
SP3-3457	1053.7	7.18
SP3-3488	1063.1	6.33
SP3-3517	1072.0	6.94
SP3-3558	1084.5	5.03
SP3-3578	1090.6	6.40
SP3-3614	1101.5	7.72
SP3-3635	1107.9	5.90
SP3-3666	1117.4	6.08
SP3-3695	1126.2	7.73
SP3-3722	1134.5	7.56
SP3-3750	1143.0	6.94
SP3-3790	1155.2	4.80
SP3-3829	1167.1	7.82
SP3-3849	1173.2	7.24
SP3-3857	1175.6	4.21
AVERAGE		6.52
STANDARD DEVIATION		1.19

A check of deviation from the vertical will be made in the near future. The most reliable depth interval for a heat flow determination in SP3 is the interval between 209-849 m. The average heat flow over this interval is 1.0 HFU. Core is available from SP3 for determinations of heat generation. Results will be given in the next Quarterly Report. Thermal conductivity values determined from core from drill hole SP3 are given in Table C-3.2.

The value of 1.02 HFU for SP3 is about 10% higher than the only other value in the Blue Ridge, 0.88 HFU, at Poor Mountain, VA., reported by Perry (1976). Correlation of heat flow with heat generation might not be justified for either of these locations since the Blue Ridge in the southern Appalachians is allocthonous. The average heat generation of core from Poor Mountain is 4.3 HGU. Our linear relationship developed to date (see next section) predicts a value of about 1.0 HFU at Poor Mountain, or about 12% higher than actually observed. The heat flow value at Spruce Pine is about the same as that determined by Reiter and Costain (1973) at Cripple Creek, VA, about 140 km from Spruce Pine. The value at Cripple Creek is 1.03±0.15 HFU. Similar values of about 1.0 HFU are reported by Diment et al. (1965) for several holes near Aiken, SC. A new heat flow determination at Goochland, VA (PE1, Table C-3.1) gives a value of 0.97 HFU. The value of 1.0 HFU thus appears to be a general background value for the southern Appalachians.

None of these values have been corrected for any affects of Pleistocene glaciation, and such a correction may not be necessary.

The heat flow determined by us in the Petersburg granite at Sussex Co., VA (PT1, Table C-3, Figure C-4) is 1.24 HFU. Studies in progress will attempt to reconcile this higher value with the gravity data and the heat production of the Petersburg granite (see following section).

The Rolesville/Castalia plutons continue to offer an opportunity to understand the physical significance of the linear relationship. The heat flow in the Rolesville (RL1, RL2, RL3, Table C-3, Figure C-4) does not follow the linear relationship developed for the rest of the 300 m.y. plutons, but is not inconsistent with pluton thickness as inferred from gravity data; we need additional density control, however.

Thermal conductivity values for PE1, PT1, and RL3 are given in Tables C-3.3 through C-3.5, respectively.

Heat generation values from drill core from Poor Mountain (V106) and the Slate belt (SB1) are 4.3±1.26 HGU and 3.3±0.3 HGU, respectively. Uranium, thorium, and potassium values are tabulated in Tables C-3.6 and C-9.

A reconnaissance survey of surface samples from Maryland plutons yielded values of about 3-5 HGU (Table C-3.8).

TABLE C-3.3.

THERMAL CONDUCTIVITY VALUES FROM CORE OF DRILL HOLE PE1
(SAMPLES ARE 2.680 CM IN DIAMETER BY 1.270 CM THICK)

SAMPLE NAME	DEPTH (METERS)	THERMAL CONDUCTIVITY MCAL/CM-SEC-°C
PE1-388	118.3	5.35
PE1-397A	121.0	5.66
PE1-397B	121.0	8.11
PE1-405A	123.4	5.23
PE1-405B	123.4	5.29
PE1-409	124.7	7.94
PE1-413	125.9	4.86
PE1-414	126.2	7.85
PE1-421	128.3	5.53
PE1-422A	128.6	5.54
PE1-422B	128.6	6.22
PE1-429	130.8	5.36
PE1-430	131.1	5.49
PE1-438A	133.5	5.30
PE1-438B	133.5	5.42
PE1-445	135.6	5.76
PE1-446A	135.9	5.67
PE1-446B	135.9	5.73
PE1-455	138.7	5.37
PE1-463A	141.1	7.39
PE1-463B	141.1	5.29
PE1-470	143.2	7.87
PE1-478	145.7	8.49
PE1-479	145.9	8.44
PE1-487	148.4	6.16
PE1-488	148.7	5.48
PE1-496	151.2	8.24
PE1-504A	153.6	5.93
PE1-504B	153.6	7.91
PE1-513	156.4	6.38
PE1-520	158.5	6.48
PE1-528A	160.9	6.32
PE1-528B	160.9	7.71
PE1-537A	163.6	6.94
PE1-537B	163.6	5.88
PE1-545A	166.1	7.24
PE1-545B	166.1	4.37
PE1-545C	166.1	6.22
PE1-553	168.5	5.31
PE1-561	170.9	5.57
PE1-569	173.4	5.07

TABLE C-3.3 (continued)

THERMAL CONDUCTIVITY VALUES FROM CORE OF DRILL HOLE PE1
(SAMPLES ARE 2.680 CM IN DIAMETER BY 1.270 CM THICK)

SAMPLE NAME	DEPTH (METERS)	THERMAL CONDUCTIVITY MCAL/CM-SEC-°C
PE1-572	174.3	6.39
PE1-578A	176.2	7.28
PE1-578B	176.2	5.52
PE1-586A	178.6	6.92
PE1-586B	178.6	5.97
PE1-594	181.0	7.42
PE1-610A	185.9	7.27
PE1-610B	185.9	4.46
PE1-602	183.5	7.53
PE1-619	188.7	4.93
PE1-627A	191.1	5.36
PE1-627B	191.1	6.69
PE1-634	193.2	6.80
PE1-635	193.5	5.13
PE1-643	195.9	7.16
AVERAGE		6.27
STANDARD DEVIATION		1.10

TABLE C-3.4.

THERMAL CONDUCTIVITY VALUES FROM CORE OF DRILL HOLE PT1
(SAMPLES ARE 2.680 CM IN DIAMETER BY 1.270 CM THICK)

SAMPLE NAME	DEPTH (METERS)	THERMAL CONDUCTIVITY MCAL/CM-SEC-°C
PT1-142	43.3	7.61
PT1-150	45.8	7.05
PT1-190	57.9	6.99
PT1-316	96.2	5.99
PT1-324	98.6	6.61
PT1-330	100.4	7.23
PT1-347	105.6	7.22
PT1-356	108.6	7.87
PT1-365	111.3	5.72
PT1-373	113.6	6.66
PT1-381	116.1	6.56
PT1-390	118.7	6.40
PT1-398	121.3	5.79
PT1-405	123.5	6.19
PT1-410	125.0	6.87
PT1-423	128.9	6.84
PT1-430	131.1	6.92
PT1-439	133.8	6.44
PT1-446	135.8	6.91
PT1-456	138.9	6.65
PT1-470	143.3	6.27
PT1-475	144.9	6.93
PT1-479	145.9	6.50
PT1-488A	148.6	6.16
PT1-488B	148.6	6.23
PT1-490	149.5	6.23
PT1-493	150.4	6.42
PT1-496	151.2	6.52
PT1-499	152.0	7.04
PT1-511	155.8	6.53
PT1-516	157.3	6.97
PT1-523	159.4	7.76
PT1-628	191.3	6.00
PT1-632	192.8	3.94*
PT1-635	193.5	6.70
PT1-642	195.7	7.29
PT1-652	198.7	6.30
PT1-661	201.5	6.98
PT1-665	202.6	14.42*
PT1-675	205.8	13.82*
PT1-676	206.2	6.38

TABLE C-3.4 (continued)

THERMAL CONDUCTIVITY VALUES FROM CORE OF DRILL HOLE PT1
(SAMPLES ARE 2.680 CM IN DIAMETER BY 1.270 CM THICK)

SAMPLE NAME	DEPTH (METERS)	THERMAL CONDUCTIVITY MCAL/CM-SEC-°C
PT1-700	213.4	6.32
PT1-718	218.8	5.98
PT1-723	220.3	6.59
PT1-733	223.4	6.54
PT1-742	226.2	6.92
PT1-750	228.7	6.93
PT1-753	229.5	7.03
PT1-758	231.0	6.77
PT1-776	236.5	7.27
PT1-781	238.0	6.65
PT1-787	239.9	5.98
PT1-790	240.8	6.09
PT1-800	243.7	7.10
PT1-807	246.0	6.24
PT1-815	248.4	7.55
PT1-823	250.0	7.50
AVERAGE		6.71
STANDARD DEVIATION		0.51

*...OMITTED FROM AVERAGE VALUES.

TABLE C-3.5.

THERMAL CONDUCTIVITY VALUES FROM CORE OF DRILL HOLE RL3
(SAMPLES ARE 2.680 CM IN DIAMETER BY 1.270 CM THICK)

SAMPLE NAME	DEPTH (METERS)	THERMAL CONDUCTIVITY MCAL/CM-SEC-°C
RL3-144	43.9	7.57
RL3-152	46.3	7.83
RL3-209	63.7	8.67
RL3-217	66.1	9.62
RL3-234	71.3	7.87
RL3-242	73.8	8.85
RL3-250	76.2	8.93
RL3-258	78.6	7.64
RL3-275	83.8	7.14
RL3-283	86.3	7.90
RL3-291	88.7	8.39
RL3-299	91.1	8.29
RL3-316A	96.3	8.57
RL3-316B	96.3	8.23
RL3-324	98.8	9.03
RL3-332	101.2	7.34
RL3-349A	106.4	8.98
RL3-349B	106.4	8.09
RL3-357	108.8	9.13
RL3-365	111.3	6.48
RL3-373	113.7	10.39*
RL3-381	116.1	6.45
RL3-389	118.6	6.79
RL3-390	118.9	8.99
RL3-398	121.3	7.03
RL3-406	126.2	6.15
MEAN		8.03
STANDARD DEVIATION		0.93

*...OMITTED FROM AVERAGE VALUE.

TABLE C-3.6 HEAT GENERATION DATA FROM CORE OF DRILL HOLE V106

DEPTH (METRES)	DEPTH (FEET)	SAMPLE NO.	DENSITY, GM/CM³	URANIUM (U), PPM	THORIUM (TH), PPM	POTASSIUM (K), %	RATIO, TH/U	HEAT GENERATION, A X 10^{-13} CAL/CM³-SEC
116.1	381	V106Q	(2.67)	0.8	18.9	5.4	23.1	4.8
118.9	390	V106G	(2.67)	0.5	2.0	1.0	4.1	0.8
221.0	725	V106F	(2.67)	2.4	8.7	6.0	3.6	4.2
230.7	757	V106N	(2.67)	1.9	9.6	5.8	4.9	4.0
234.7	770	V106B	(2.67)	4.8	5.7	5.1	1.2	5.0
237.4	779	V106J	(2.67)	4.2	6.7	5.3	1.6	4.9
250.5	822	V106K	(2.67)	5.8	7.6	4.9	1.3	5.8
253.3	831	V106P	(2.67)	0.5	8.7	3.6	18.2	2.5
255.0	837	V106D	(2.67)	5.9	9.1	5.3	1.5	6.3
285.0	935	V106C	(2.67)	11.7*	9.2	5.3	0.8	9.8*
328.9	1079	V106M	(2.67)	2.9	12.9	6.4	4.4	5.3
332.2	1090	V106H	(2.67)	0.6	5.1	5.7	9.0	2.4
338.0	1109	V106L	(2.67)	1.0	55.7*	5.6	53.2	11.0*
344.4	1130	V106	(2.67)	0.6	11.4	4.0	18.1	3.1
350.2	1149	V106E	(2.67)	0.6	13.3	4.5	24.2	3.5
MEAN VALUES				2.3	9.2	4.9		4.3
STANDARD DEVIATION				2.05	4.11	1.31		1.26

(2.67)...ASSUMED DENSITY

*........VALUE NOT INCLUDED IN COMPUTATION OF THE MEAN VALUES

TABLE C-3.7 HEAT PRODUCTION SAMPLES FROM CORE OF SLATE BELT HOLE SB1

DEPTH (FEET)	DEPTH (METERS)	SAMPLE NO.	DENSITY, GM/CM^3	URANIUM (U), PPM	THORIUM (TH), PPM	POTASSIUM (K), %	RATIO, TH/U	HEAT GENERATION, A X 10^{-13} CAL/CM^3-SEC
574	175	SB1-175	2.75	2.9	5.1	2.1	1.8	3.1
654	199	SB1-199	2.75	3.1	6.4	1.8	3.6	3.4
174	53	SB1-53	2.74	3.2	6.3	2.2	2.0	3.6
261.8	80	SB1-80	2.75	3.0	5.6	2.0	1.9	3.2
504	154	SB1-154	2.68*	9.0*	6.1	2.9	0.7*	7.1*
394	120	SB1-120	2.74	3.2	6.5	2.6	2.0	3.6
MEAN			2.75	3.1	6.0	2.3	2.0	3.4
STANDARD DEVIATION			0.01	0.1	0.5	0.4	0.1	0.3

*VALUE OMITTED FROM AVERAGE VALUES.

TABLE C-3.8 SURFACE SAMPLES OF MARYLAND RECONNAISSANCE SURVEY C-3.8-1

LOCATION	SAMPLE NO.	DENSITY, GM/CM³	URANIUM (U), PPM	THORIUM (TH), PPM	POTASSIUM (K), %	K20, %	HEAT GENERATION, A X 10^{-13} CAL/CM³-SEC
ELLICOTT CITY	MJ8001	(2.67)	3.0	17.7	2.7	3.2	5.3
ELLICOTT CITY	MJ8004	2.72	2.3	18.5	2.8	3.4	5.1
ELLICOTT CITY	MJ8005	(2.67)	2.6	36.1	3.1	3.8	8.2
MEAN VALUES			2.6	24.1	2.9	3.5	6.2
STANDARD DEVIATION			0.4	10.4	0.2	.3	1.7
GUILFORD	MJ8008	2.64	8.0	12.7	3.2	3.9	7.6
GUILFORD	MJ8009	(2.67)	1.3	1.4	1.8	2.1	1.4
GUILFORD	MJ8010	2.62	3.9	9.6	3.5	4.1	4.7
GUILFORD	MJ8011	(2.67)	10.7	12.3	3.2	3.8	9.2
GUILFORD	MJ8012	(2.67)	6.5	11.5	3.4	4.1	6.6
GUILFORD	MJ8013	2.64	1.8	14.9	3.4	4.1	4.2
MEAN VALUES			5.4	10.4	3.1	3.7	5.6
STANDARD DEVIATION			3.7	4.7	0.6	0.8	2.8
WOODSTOCK	MJ8014	(2.67)	3.8	15.0	3.3	4.0	5.5
WOODSTOCK	MJ8015	(2.67)	4.5	15.5	3.4	4.1	6.0
WOODSTOCK	MJ8016	(2.67)	4.7	12.7	3.4	4.1	5.7
WOODSTOCK	MJ8017	(2.67)	3.7	12.9	3.3	3.9	5.1
WOODSTOCK	MJ8018	(2.67)	2.5	14.3	4.0	4.8	4.7
WOODSTOCK	MJ8020	(2.67)	3.1	13.8	3.3	3.9	4.9
WOODSTOCK	MJ8021	2.73	1.6	13.4	3.3	4.0	4.0
WOODSTOCK	MJ8022	2.66	0.8	16.1	4.1	4.9	4.0
WOODSTOCK	MJ8025	(2.67)	2.8	17.6	3.2	3.8	5.3
WOODSTOCK	MJ8026	(2.67)	3.0	14.8	3.0	3.6	4.9
WOODSTOCK	MJ8027	(2.67)	2.1	17.3	3.4	4.1	4.9
WOODSTOCK	MJ8030	2.57	0.6	20.0	3.9	4.7	4.3
WOODSTOCK	MJ8031	(2.67)	1.2	33.0	4.3	5.2	7.1
WOODSTOCK	MJ8032	(2.67)	0.5	9.6	4.8	5.8	2.9
WOODSTOCK	MJ8034	(2.67)	2.1	15.3	3.5	4.2	4.5
WOODSTOCK	MJ8035	(2.67)	3.1	15.2	3.4	4.1	5.1
WOODSTOCK	MJ8036	(2.67)	4.7	16.2	3.4	4.0	6.2
WOODSTOCK	MJ8038	2.65	4.2	12.4	3.4	4.0	5.3
WOODSTOCK	MJ8039	2.65	4.3	13.5	3.6	4.3	5.5
WOODSTOCK	MJ8041	2.63	2.3	16.2	3.1	3.8	4.7
WOODSTOCK	MJ8042	(2.67)	0.6	8.6	5.5	6.6	3.0

LOCATION	SAMPLE NO.	DENSITY, GM/CM³	URANIUM (U), PPM	THORIUM (TH), PPM	POTASSIUM (K), %	K20, %	HEAT GENERATION, A X 10^{-13} CAL/CM³-SEC
WOODSTOCK	MJ8043	2.60	2.7	6.7	4.0	4.8	3.5
WOODSTOCK	MJ8044	2.66	0.5	8.6	2.6	3.1	2.2
WOODSTOCK	MJ8045	(2.67)	1.5	15.0	2.6	3.1	3.9
WOODSTOCK	MJ8046	2.58	0.9	47.3	3.0	3.6	8.7
WOODSTOCK	MJ8047	2.59	3.8	6.3	3.5	4.2	4.0
WOODSTOCK	MJ8048	(2.67)	2.0	9.0	3.0	3.6	3.3
WOODSTOCK	MJ8049	2.65	4.4	11.4	3.7	4.4	5.3
WOODSTOCK	MJ8051	(2.67)	1.0	12.3	4.0	4.7	3.5
WOODSTOCK	MJ8052	(2.67)	2.5	15.9	3.2	3.8	4.8
WOODSTOCK	MJ8053	2.66	2.4	14.8	3.5	4.2	4.6
WOODSTOCK	MJ8054	(2.67)	1.4	14.6	2.8	3.4	3.9
WOODSTOCK	MJ8055	2.60	0.5	28.3	4.1	4.9	5.7
WOODSTOCK	MJ8056	2.58	0.9	22.7	4.5	5.4	5.1
WOODSTOCK	MJ8057	2.64	0.7	18.3	4.6	5.5	4.4
WOODSTOCK	MJ8058	(2.67)	0.9	43.1	5.0	6.0	8.7
WOODSTOCK	MJ8059	(2.67)	3.7	13.5	3.2	3.8	5.1
WOODSTOCK	MJ8060	2.68	0.3	0.7	0.2	0.2	0.3
WOODSTOCK	MJ8062	2.61	1.8	21.9	2.3	2.8	5.0
MEAN VALUES			2.3	16.3	3.5	4.2	4.8
STANDARD DEVIATION			1.4	8.8	0.9	1.0	1.5
BEREA, VA	MJ8061	2.60	2.9	7.9	4.3	5.1	3.9
GUNPOWDER	MJ8063	(2.67)	6.1	2.4	2.2	2.7	4.6
GUNPOWDER	MJ8064	(2.67)	0.7	23.5	4.7	5.6	5.3
GUNPOWDER	MJ8065	2.64	2.3	8.4	7.2	8.7	4.4
GUNPOWDER	MJ8066	(2.67)	1.1	27.5	4.8	5.8	6.2
GUNPOWDER	MJ8069	(2.67)	0.7	11.3	4.4	5.2	3.2
GUNPOWDER	MJ8074	(2.67)	1.2	29.2	4.7	5.6	6.5
GUNPOWDER	MJ8075	(2.67)	1.5	8.5	3.5	4.1	3.1
GUNPOWDER	MJ8077	(2.67)	1.6	3.2	3.5	4.2	2.3
GUNPOWDER	MJ8078	(2.67)	1.3	28.2	5.0	6.0	6.5
GUNPOWDER	MJ8079	(2.67)	1.0	19.3	5.1	6.1	4.9
MEAN VALUES			1.8	16.2	4.5	5.4	4.7
STANDARD DEVIATION			1.6	10.6	1.3	1.6	1.5

(2.67)...ASSUMED DENSITY

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LINEAR RELATIONSHIP BETWEEN HEAT FLOW AND HEAT GENERATION

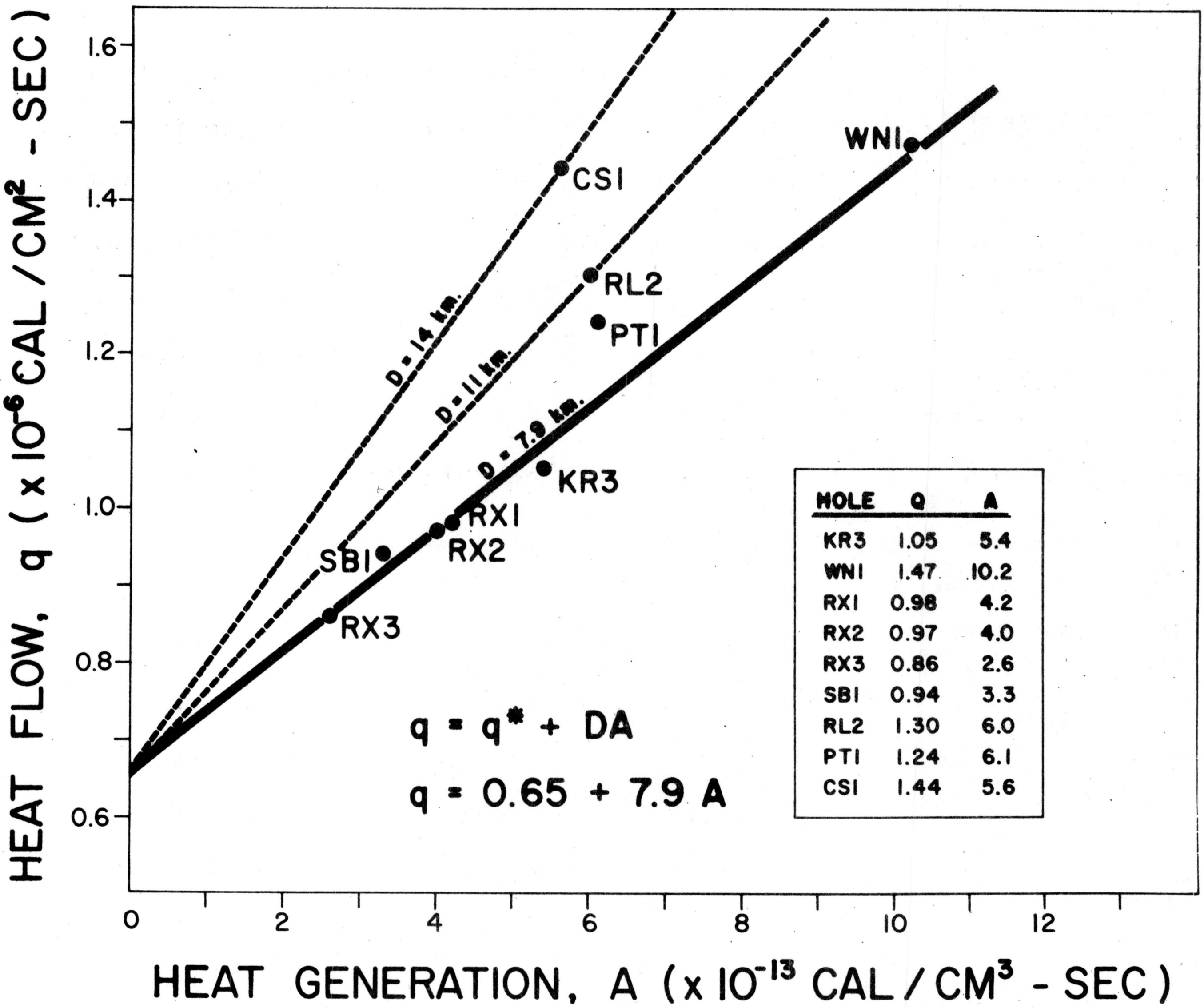
J.K. Costain and L.D. Perry

Figure C-4.1 shows the relationship between heat flow and heat generation for all holes available to date in the southeastern United States. Table C-4.1 summarizes heat flow and heat generation values used in the linear relationship. With the exception of values derived from plutonic rocks with a large geographic outcrop (Castalia/Rolesville batholith and Petersburg batholith) all of the values define a linear relationship of the form:

$$q = 0.65 + 7.9A$$

It is noteworthy that:

1) Hole SB1 was drilled into volcanics of the Slate Belt but still falls on the linear relationship. This is the only heat flow hole not drilled into granitic rocks. The agreement between heat flow and heat generation is thus consistent with the microcrack model proposed by Costain (1978) and described in Progress Report VPI&SU-5648-1.
2) The values of heat flow/heat generation in the Castalia Pluton (CS1) are consistent with a thickness of approximately 14 km for the Castalia plutonas noted by Cogbill elsewhere in



HOLE	Q	A
KR3	1.05	5.4
WN1	1.47	10.2
RX1	0.98	4.2
RX2	0.97	4.0
RX3	0.86	2.6
SB1	0.94	3.3
RL2	1.30	6.0
PT1	1.24	6.1
CS1	1.44	5.6

Figure C-4.1. Linear relationship between heat flow and heat generation in the southeastern United States.

TABLE C-4.1
HEAT FLOW (q) AND HEAT PRODUCTION (A) VALUES FROM PLUTONS OF THE SOUTHEASTERN UNITED STATES

LOCATION	LATITUDE	LONGITUDE	q, CAL/CM^2-SEC x 10^{-6}	A, CAL/CM^3-SEC x 10^{-13}
LIBERTY HILL-KERSHAW PLUTON, LANCASTER CO., S.C.				
KR3	34°32'20"	80°44'51"	1.05	5.4
RION PLUTON, FAIRFIELD CO., S.C.				
WN1	34°18'48"	81°08'42"	1.47	10.2
ROXBORO METAGRANITE, PERSON CO., N.C.				
RX1	36°23'12"	78°58'00"	0.98	4.2
RX2	32°25'31"	79°01'53"	0.97	4.0
RX3	32°25'39"	78°53'42"	0.88	2.6
SLATE BELT, PERSON CO., N.C.				
SB1	36°19'40"	78°50'00"	0.94	3.3
ROLESVILLE BATHOLITH AND CASTALIA PLUTON (CS1), FRANKLIN CO., N.C.				
CS1	36°04'15"	78°07'43"	1.44	5.6
RL2	36°47'28"	78°25'04"	1.30	6.0
PETERSBURG GRANITE, SUSSEX CO., VA.				
PT1	36°49'45"	77°19'15"	1.24	6.1

this report. We need additional values of heat flow/heat generation to strengthen the apparent correlation between gravity and thermal data. At the present time we continue to prefer the interpretation that the physical significance of D is related to an approximately uniform distribution of heat producing elements down to a depth D. In some locations (RX1, RX2, RX3, WN1, KR3, SB1) this depth may correspond to the effective depth of penetration of microcracks. In other locations (CS1, RL2, PT1) the granites (and thus U and Th) extend below the effective depth of penetration of microcracks and define new members of a family of curves with different values of D, as shown in Figure C-4.1.

Different values of D have a significant effect on subsurface temperatures. Figures C-4.2 and C-4.3 show subsurface temperature distributions based on values of D of 7.9 and 14 km, respectively.

Optimum sites for geothermal resource development would, of course, be associated with thick, radiogenic plutons of large areal extent. Edge effects would be minimal, and subsurface temperatures could be predicted from Figure C-4.2 or C-4.3. Figure C-4.3 emphasizes indirectly, however, the importance of <u>small</u> plutons high in

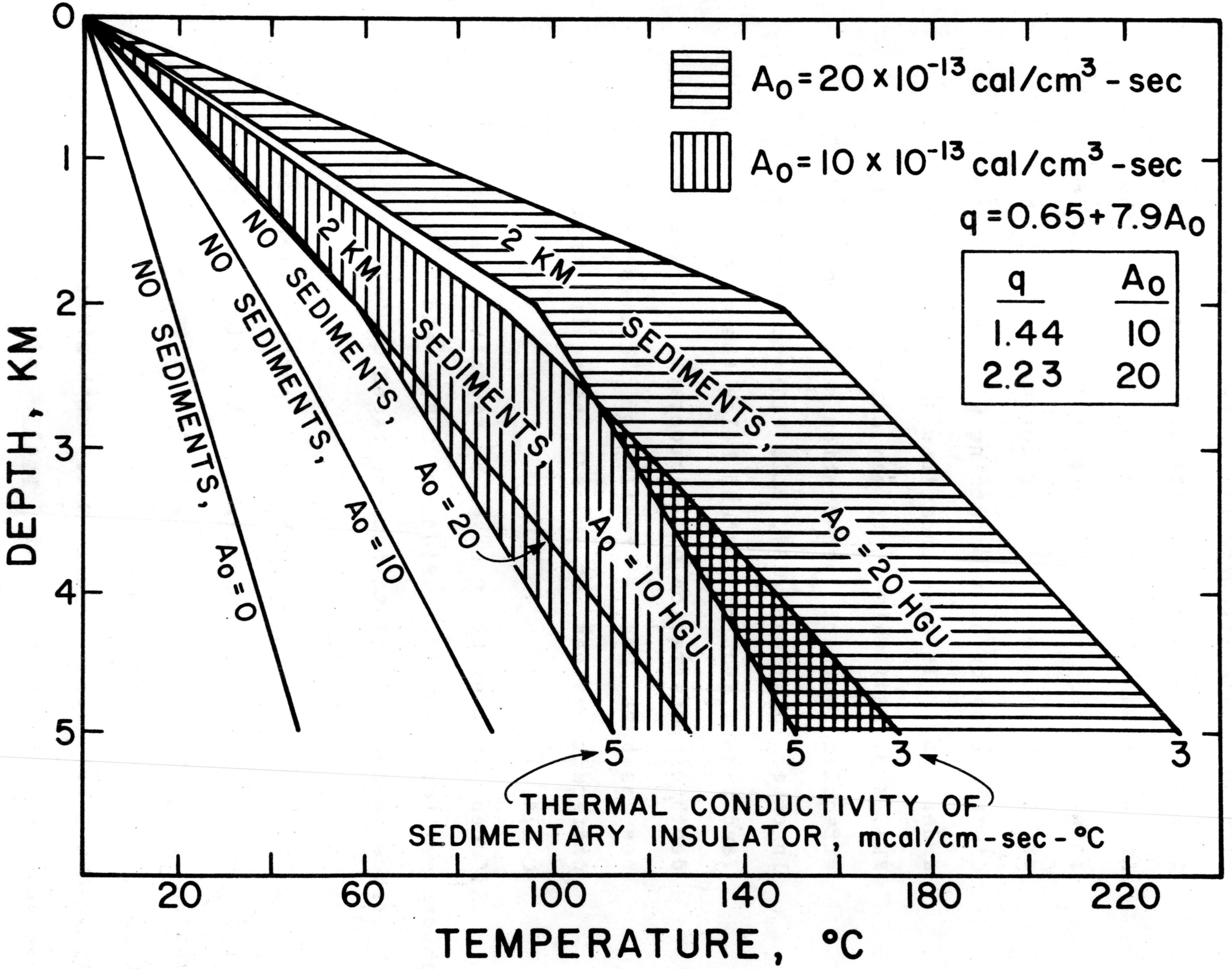


Figure C-4.2. Temperature distribution based on the linear relationship q = 0.65 + 7.9A.

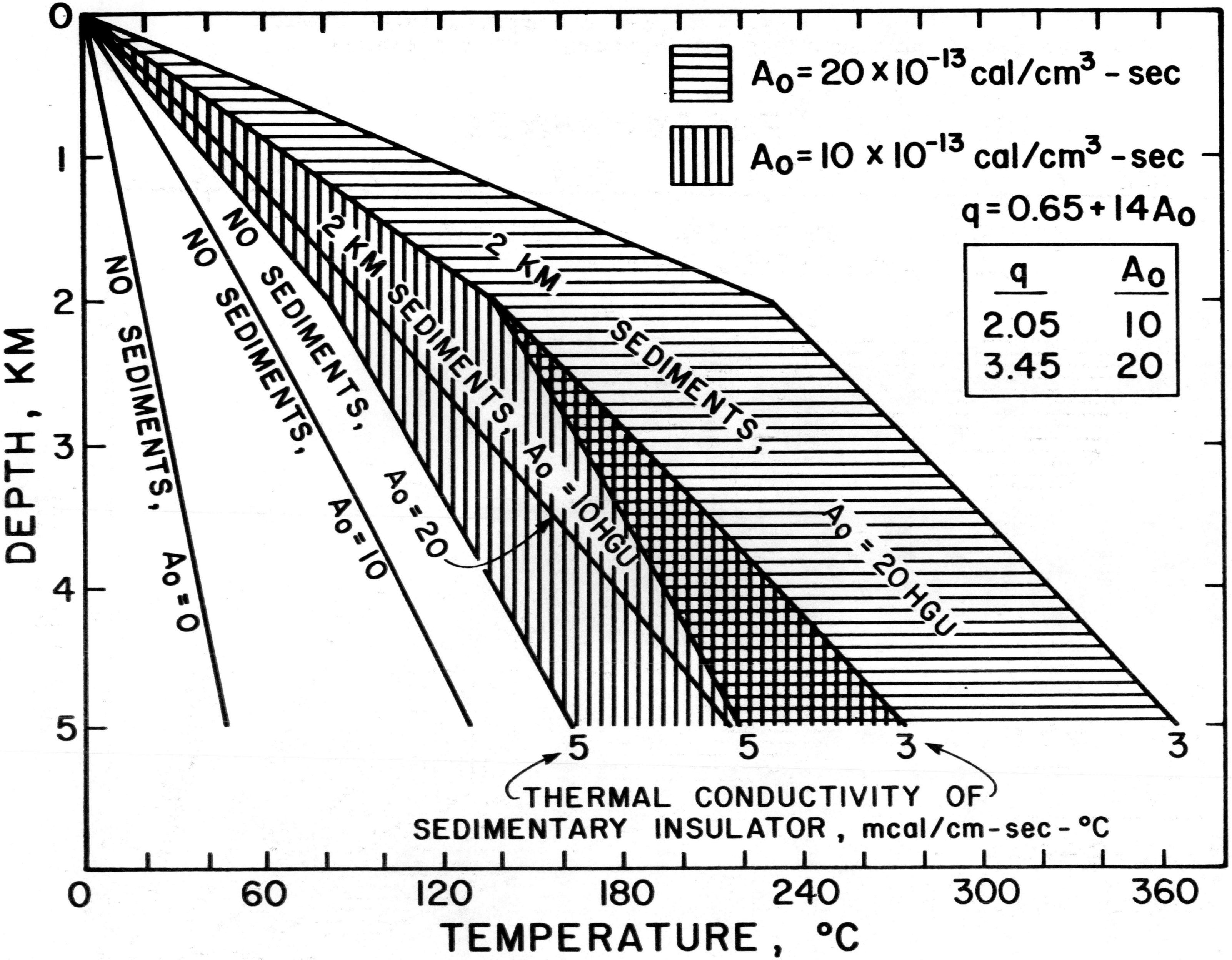


Figure C-4.3. Temperature distribution based on the linear relationship q = 0.65 + 14A.

radioelement concentrations but with a relatively small width/depth ratio. The prediction of the subsurface temperature from Figure C-4.3 would require a correction for a small pluton; however, the greater thickness, of course, makes the smaller pluton a more attractive target than a larger one with the same concentration of radiogenic elements. Small gravity anomalies might be attractive targets if they are associated with members of a younger generation of plutons having a greater thickness (such as the Castalia pluton) but the same concentration of radiogenic elements. Without considering edge effects, the temperature at the base of 3 km of sediments increases by 37°C if the thickness changes from 7.9 km to 14 km but the concentration of radioelements remains at 10 HGU. We have reached a stage in our investigations where an attempt to measure pluton thickness directly using reflection seismology is appropriate.

GRAVITY DATA IN THE SOUTHEASTERN UNITED STATES

A. H. Cogbill

Efforts to utilize gravity data to predict the locations and approximate sizes of granitic plutons beneath the Atlantic Coastal Plain (ACP) have continued along two lines. First, major efforts have been made to augment our collection of gravity measurements made on the ACP, for there data are more sparse than in the Piedmont and because interest in the ACP is understandably high. Additionally, we have attempted to collect more gravity measurements over exposed granitic rocks in the Piedmont, concentrating thus far upon those granitic bodies for which the lithologies and structures in the surrounding country rocks were more or less well-understood. In both the Piedmont and the ACP, data collection is continuing and is expected to continue throughout the summer. Because the ACP drilling program is now in progress, new data acquired along the ACP must be reduced and analyzed rapidly in order to be useful to the drilling program. We are confident that we are in a position to interpret the gravity data along the ACP rapidly; hence the major problem is to obtain those new measurements thought needed as soon as possible.

Gravity measurements gathered over exposed plutons in the Piedmont may be used to place bounds upon the minimum magnitude of the density contrast between a given pluton and its surrounding host rocks with the aid of Parker's (1974, 1975) theory of ideal bodies. Additional constraints upon the density contrast applicable to a pluton are provided by a detailed knowledge of the lithologies of the country rocks into which the body has intruded, but such information is rarely available because exposures are sparse. Because we have little or no geologic information regarding the crystalline rocks lying beneath the ACP, we are forced to extrapolate results obtained in the Piedmont beneath the sediments of the ACP. In particular, if the density contrast between a pluton and its host rocks can be constrained to be larger than a given value, we can place a bound upon the maximum depth to the top of the pluton beneath the sediments. Having such a bound facilitates the remainder of the interpretation for the size and depth to the base of a pluton.

Data Acquisition

Atlantic Coastal Plain. Gravity measurements have been obtained in three separate areas of the ACP by VPI personnel. These areas are (1) southeastern Georgia and northeastern Florida, (2) southeastern New Jersey, and (3) south-central Delaware. In each of these areas, gravity measurements were made using LaCoste-Romberg model G gravity meters and were referenced to established base stations. The meters used were made available by both the National

Geodetic Survey and the U.S. Geological Survey and were models G58, G107, and G2. Data acquired in each of the areas (1)-(3) are tabulated in Tables C-5.1, C-5.2, and C-5.3. Plots of the station distributions of these data are given in Figures C-5.1, C-5.2, and C-5.3.

We have also taken approximately 1500 gravity measurements from Champion (1975). These are all located in the ACP of South Carolina. In order to further increase the number of gravity measurements in the ACP of that state, an independent geophysical company has been contracted to supply several thousand gravity measurements from South Carolina and southeastern Virginia. This company has been contracted by the Los Alamos Scientific Laboratory of the University of California. Measurements acquired by this company will begin to be available in mid-summer.

Piedmont. Data acquisition in the Piedmont has been limited to the immediate vicinity of the Rolesville batholith near Raleigh, NC. To date we have seventy-four (74) new measurements in that region, with more measurements being obtained now. These new data are located in the southern half of the Rolesville batholith. The additional measurements will be concentrated in the northern portion of the batholith with emphasis upon the Castalia pluton, which lies immediately NE of the batholith. The Castalia is anomalous because of its abnormally high heat flow, considering its measured heat production (VPI&SU-5648-1).

TABLE C-5.1.

LISTING OF PRINCIPAL FACTS FOR GRAVITY MEASUREMENTS ACQUIRED BY VPI PERSONNEL IN SOUTHEASTERN GEORGIA AND NORTHEASTERN FLORIDA

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/0[illegible]/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
510	30 37.82	81 41.20	7.0	979384.09	11.12	10.88	0.00	11.12	10.88	YUFL	510	51
520	30 38.20	81 44.66	14.0	979381.25	8.44	7.96	0.01	8.44	7.96	YUFL	520	52
530	30 40.27	81 38.54	2.0	979387.89	11.22	11.15	0.00	11.22	11.15	YUFL	530	53
540	30 42.70	81 37.51	25.0	979389.72	12.00	11.14	0.01	12.00	11.15	YUFL	540	54
550	30 18.88	81 41.35	21.0	979361.46	14.73	14.01	0.01	14.73	14.01	JAFL	550	55
560	30 16.91	81 43.21	14.0	979358.74	13.94	13.45	0.01	13.94	13.46	JAFL	560	56
570	30 16.15	81 46.89	82.0	979353.95	16.54	13.71	0.04	16.54	13.74	JAFL	570	57
580	30 18.79	81 47.02	69.0	979357.26	15.17	12.78	0.03	15.16	12.81	JAFL	580	58
590	30 20.75	81 48.42	56.0	979359.12	13.23	11.30	0.02	13.23	11.32	JAFL	590	59
600	30 20.62	81 43.87	24.0	979364.75	16.02	15.19	0.01	16.02	15.20	JAFL	600	60
610	30 16.49	81 49.93	65.0	979353.93	14.47	12.23	0.03	14.47	12.26	JAFL	610	61
620	30 15.31	81 52.44	84.0	979350.59	14.47	11.57	0.04	14.47	11.60	JAFL	620	62
630	30 18.91	81 50.67	87.0	979355.42	14.86	11.86	0.04	14.86	11.89	JAFL	630	63
640	30 20.68	81 52.19	86.0	979357.10	14.12	11.15	0.04	14.12	11.19	JAFL	640	64
650	30 18.56	81 53.68	88.0	979355.53	15.52	12.48	0.04	15.52	12.52	JAFL	650	65
660	30 21.16	81 54.79	83.0	979355.50	11.61	8.74	0.04	11.61	8.78	JAFL	660	66
670	30 18.82	81 53.12	80.0	979349.30	8.26	5.50	0.04	8.26	5.53	JAFL	670	67
680	30 16.23	81 59.30	89.0	979344.17	7.31	4.24	0.04	7.31	4.28	JAFL	680	68
690	30 15.55	81 57.15	83.0	979347.76	11.23	8.36	0.04	11.23	8.40	JAFL	690	69
700	30 18.37	81 55.48	86.0	979355.60	13.84	10.80	0.04	13.84	10.84	JAFL	700	70
710	30 43.80	81 41.15	25.0	979380.85	7.68	6.81	0.01	7.67	6.82	JAFL	710	71
720	30 43.01	81 43.74	26.0	979384.94	6.90	6.01	0.01	6.90	6.02	JAFL	720	72
730	30 41.76	81 43.67	45.0	979382.10	7.50	5.95	0.02	7.50	5.97	JAFL	730	73
740	30 41.51	81 40.92	20.0	979385.89	9.27	8.58	0.01	9.27	8.59	JAFL	740	74
750	30 46.63	81 42.52	17.0	979390.79	7.12	6.53	0.01	7.12	6.54	KLGA	751	75
760	30 46.56	81 44.70	20.0	979369.70	6.40	5.77	0.01	6.40	5.79	KLGA	760	76
770	30 49.55	81 40.93	25.0	979395.98	9.01	8.21	0.01	9.01	8.22	KLGA	770	77
780	30 49.14	81 38.48	17.0	979391.12	10.73	10.14	0.01	10.72	10.14	KLGA	780	78
790	30 45.29	81 43.44	20.0	979393.26	7.67	6.98	0.01	7.67	6.99	KLGA	790	79
800	30 48.63	81 45.86	24.0	979393.28	7.62	6.79	0.01	7.62	6.80	KLGA	800	80
810	30 48.54	81 48.17	22.0	979393.43	7.70	6.94	0.01	7.70	6.95	KLGA	810	81
820	30 48.51	81 49.90	19.0	979395.51	7.54	6.88	0.01	7.54	6.89	KLGA	820	82
830	30 50.03	81 49.16	18.0	979398.28	8.20	7.58	0.01	8.20	7.59	KLGA	830	83
840	30 51.50	81 48.77	12.0	979398.91	8.32	7.90	0.01	8.32	7.91	KLGA	840	84
850	30 52.32	81 49.59	14.0	979400.92	9.43	8.94	0.01	9.43	8.95	KLGA	850	85
860	30 51.60	81 51.31	20.0	979399.48	9.51	8.82	0.01	9.51	8.82	KLGA	860	86
870	30 50.13	81 53.38	15.0	979397.62	9.13	8.61	0.01	9.13	8.61	KLGA	870	87
880	30 49.19	81 51.29	16.0	979395.45	8.29	7.74	0.01	8.29	7.75	KLGA	880	88
890	30 50.97	81 55.71	18.0	979399.28	9.95	9.33	0.01	9.95	9.34	KLGA	890	89
900	30 50.38	81 58.56	65.0	979393.85	9.73	7.48	0.03	9.73	7.51	KLGA	900	90
910	30 49.70	82 1.33	63.0	979393.10	9.75	7.57	0.03	9.75	7.60	KLGA	910	91
920	30 49.45	82 4.31	77.0	979392.60	10.30	7.64	0.03	10.30	7.67	KLGA	920	92
930	30 48.73	82 6.79	14.0	979388.63	-0.70	-1.19	0.01	-0.70	-1.18	KLGA	930	93
940	30 47.32	82 6.19	11.0	979387.21	2.06	1.68	0.00	2.06	1.69	KLGA	940	94
950	30 48.09	82 1.83	4.0	979392.51	5.68	5.54	0.00	5.68	5.55	KLGA	950	95
960	30 46.84	82 3.05	63.0	979389.67	10.05	7.87	0.03	10.05	7.90	KLGA	960	96
960	30 46.84	82 3.05	6.0	979389.67	4.69	4.48	0.00	4.69	4.48	KLGA	960	97
970	30 45.01	82 4.19	7.0	979387.62	3.76	3.52	0.00	3.76	3.52	KLGA	970	98
980	30 47.31	81 58.91	22.0	979391.44	7.34	6.58	0.01	7.34	6.59	KLGA	980	99
990	30 54.60	82 0.61	90.0	979400.68	13.31	10.20	0.04	13.31	10.24	KLGA	990	100

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/7[illegible]

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
1000	30 56.67	82 0.06	87.0	979404.39	13.99	10.99	0.04	13.99	11.03	KLGA	1000	101
1010	30 59.21	82 1.55	75.0	979412.59	17.69	15.10	0.03	17.69	15.13	KLGA	1010	102
1020	30 55.51	82 2.63	74.0	979402.81	12.73	10.17	0.03	12.73	10.21	KLGA	1020	103
1030	30 54.56	82 3.56	67.0	979401.11	11.63	9.32	0.03	11.63	9.35	KLGA	1030	104
1040	30 55.75	82 4.83	79.0	979402.86	12.93	10.20	0.04	12.93	10.24	KLGA	1040	105
1050	30 53.51	82 5.18	61.0	979398.85	10.20	8.09	0.03	10.20	8.12	KLGA	1050	106
1060	30 51.77	82 4.07	66.0	979395.85	9.99	7.71	0.03	9.99	7.74	KLGA	1060	107
1070	30 57.06	81 46.77	23.0	979415.00	18.07	17.27	0.01	18.06	17.28	KLGA	1070	108
1080	30 53.84	81 48.32	11.0	979404.47	10.68	10.30	0.00	10.68	10.39	KLGA	1080	109
1090	30 46.70	81 57.19	96.0	979385.41	9.00	5.68	0.04	9.00	5.72	FUGA	1090	110
1100	30 47.02	81 55.48	52.0	979389.07	8.18	6.38	0.02	8.17	6.40	FUGA	1100	111
1110	30 47.08	81 53.34	20.0	979391.05	7.07	6.37	0.01	7.06	6.38	FUGA	1110	112
1120	30 47.15	81 51.77	17.0	979393.42	6.06	5.47	0.01	6.06	5.48	FUGA	1120	113
1130	30 46.90	81 49.99	15.0	979390.33	6.11	5.59	0.01	6.11	5.60	FUGA	1130	114
1140	30 45.17	81 46.62	16.0	979387.03	5.20	4.64	0.01	5.20	4.65	FUGA	1140	115
1150	30 45.56	81 51.16	18.0	979387.61	5.45	4.83	0.01	5.45	4.83	FUGA	1150	116
1160	30 46.10	81 58.41	58.0	979386.74	7.55	5.54	0.03	7.55	5.57	FUGA	1160	117
1170	30 59.42	82 2.35	77.0	979395.84	0.85	-1.81	0.03	0.85	-1.78	FUGA	1170	118
1180	30 57.52	82 4.46	73.0	979407.60	14.76	12.24	0.03	14.76	12.27	FUGA	1180	119
1190	30 59.07	82 4.26	86.0	979411.68	18.00	15.03	0.04	18.00	15.07	FUGA	1190	120
1200	30 57.95	82 6.09	96.0	979407.62	16.37	13.05	0.04	16.37	13.09	FUGA	1200	121
1210	30 59.45	82 6.97	12.0	979408.47	7.33	6.91	0.01	7.33	6.92	FUGA	1210	122
1220	31 12.25	81 53.64	72.0	979431.64	19.10	16.61	0.03	19.09	16.64	HUGA	1220	123
1230	31 10.46	81 54.11	71.0	979431.71	21.46	19.01	0.03	21.46	19.04	HUGA	1230	124
1240	31 7.13	81 57.80	68.0	979423.88	17.79	15.44	0.03	17.78	15.46	HUGA	1240	125
1250	31 2.31	82 1.50	71.0	979416.43	17.03	14.58	0.03	17.03	14.61	HUGA	1250	126
1260	31 12.57	81 56.25	78.0	979434.90	22.55	19.86	0.03	22.55	19.89	HUGA	1260	127
1270	31 9.90	81 51.20	55.0	979430.14	19.13	17.23	0.02	19.13	17.25	HUGA	1270	128
1280	31 5.06	81 52.91	54.0	979425.84	20.39	18.52	0.02	20.39	18.54	HUGA	1280	129
1290	31 8.40	81 22.85	7.0	979437.38	23.77	23.53	0.00	23.77	23.54	SSGA	1290	130
1300	31 9.17	81 24.33	9.0	979433.71	19.35	19.04	0.00	19.35	19.04	SSGA	1300	131
1310	31 10.43	81 22.76	12.0	979434.22	18.46	18.04	0.01	18.46	18.05	SSGA	1310	132
1320	31 12.33	81 22.56	18.0	979430.52	12.79	12.17	0.01	12.79	12.17	SSGA	1320	133
1330	31 13.70	81 21.77	17.0	979428.53	8.88	8.29	0.01	8.88	8.30	SSGA	1330	134
1340	31 14.75	81 21.08	19.0	979426.22	5.35	4.70	0.01	5.35	4.70	SSGA	1340	135
1350	31 10.76	81 21.23	8.0	979430.62	20.04	19.77	0.00	20.04	19.77	SSGA	1350	136
1360	31 12.29	81 19.42	8.0	979432.78	14.16	13.89	0.00	14.16	13.89	SSGA	1360	137
1370	31 10.27	81 25.77	6.0	979428.84	12.73	12.52	0.00	12.73	12.52	SSGA	1370	138
1380	31 9.76	81 26.92	10.0	979428.96	13.88	13.53	0.00	13.88	13.54	SSGA	1380	139
1390	31 10.14	81 28.50	9.0	979427.90	12.24	11.93	0.00	12.24	11.94	SSGA	1390	140
1400	31 10.96	81 28.29	8.0	979420.72	9.96	9.68	0.00	9.96	9.68	SSGA	1400	141
1410	31 11.85	81 28.12	6.0	979425.99	7.77	7.56	0.00	7.77	7.57	SSGA	1410	142
1420	31 12.84	81 27.97	12.0	979425.44	6.46	6.05	0.01	6.46	6.05	SSGA	1420	143
1430	31 13.57	81 24.91	11.0	979425.49	5.45	5.07	0.00	5.45	5.07	SSGA	1430	144
1440	31 13.54	81 29.32	21.0	979424.61	5.55	4.82	0.01	5.55	4.83	SSGA	1440	145
1450	31 13.46	81 31.61	29.0	979425.22	6.99	5.99	0.01	6.99	6.00	SSGA	1450	146
1460	31 12.20	81 30.42	17.0	979425.63	7.98	7.39	0.01	7.98	7.4[illegible]	SSGA	1460	147
1470	31 10.72	81 32.50	11.0	979427.90	11.72	11.34	0.00	11.72	11.34	SSGA	1470	148
1480	31 8.71	81 34.56	12.0	979429.34	15.87	15.46	0.01	15.87	15.46	SSGA	1480	149
1490	31 10.43	81 37.15	35.0	979429.82	16.22	15.01	0.02	16.22	15.03	SSGA	1490	150

TABLE C-5.1 , continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/76

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
150D	31 9.17	81 28.79	10.0	979429.64	15.37	15.02	0.00	15.37	15.03	SSGA	150D	151
151D	31 30.27	81 54.44	11.0	979437.29	-13.16	-13.54	0.00	-13.16	-13.53	JEGA	151D	152
152D	31 30.25	81 57.87	13.0	979438.02	-12.21	-12.66	0.01	-12.21	-12.66	JEGA	152D	153
153D	31 30.74	81 59.48	11.0	979437.58	-13.50	-13.88	0.00	-13.50	-13.87	JEGA	153D	154
154D	31 35.00	81 59.50	13.0	979437.90	-11.54	-11.99	0.01	-11.54	-11.98	JEGA	154D	155
155D	31 34.92	81 59.80	13.0	979437.14	-10.71	-11.15	0.01	-10.71	-11.15	JEGA	155D	156
156D	31 33.82	81 59.81	12.0	979437.22	-9.84	-10.26	0.01	-9.84	-10.25	JEGA	156D	157
157D	31 32.84	81 59.41	13.0	979435.94	-9.71	-10.16	0.01	-9.71	-10.16	JEGA	157D	158
158D	31 31.91	81 59.51	13.0	979434.78	-9.62	-10.07	0.01	-9.62	-10.07	JEGA	158D	159
159D	31 30.45	81 57.84	87.0	979434.23	-1.25	-4.26	0.04	-1.25	-4.27	JEGA	159D	160
160D	31 34.05	81 57.53	14.0	979435.57	-12.42	-12.90	0.01	-12.42	-12.90	JEGA	160D	161
161D	31 38.65	81 54.44	11.0	979431.86	-15.79	-16.17	0.00	-15.79	-16.16	JEGA	161D	162
162D	31 40.27	81 55.18	73.0	979442.94	-7.05	-9.58	0.03	-7.05	-9.54	JEGA	162D	163
163D	31 42.51	81 54.95	11.0	979443.41	-15.43	-15.81	0.00	-15.43	-15.81	JEGA	163D	164
164D	31 43.92	81 56.72	15.0	979445.82	-14.54	-15.06	0.01	-14.54	-15.06	JEGA	164D	165
165D	31 44.03	81 58.74	16.0	979446.58	-13.84	-14.39	0.01	-13.84	-14.38	JEGA	165D	166
166D	31 41.76	81 59.73	11.0	979447.17	-10.66	-11.04	0.00	-10.66	-11.04	JEGA	166D	167
167D	31 41.57	81 56.86	14.0	979442.69	-14.60	-15.09	0.01	-14.60	-15.08	JEGA	167D	168
168D	31 36.94	81 57.16	14.0	979439.41	-14.34	-14.83	0.01	-14.35	-14.82	JEGA	168D	169
169D	31 39.20	81 59.71	14.0	979441.94	-12.16	-12.65	0.01	-12.16	-12.64	JEGA	169D	170
170D	31 36.39	81 51.89	63.0	979437.21	-8.51	-10.68	0.03	-8.51	-10.66	JEGA	170D	171
171D	31 36.69	81 50.25	63.0	979435.73	-10.39	-12.57	0.03	-10.39	-12.54	JEGA	171D	172
172D	31 35.22	81 49.85	65.0	979434.65	-9.31	-11.55	0.03	-9.31	-11.52	JEGA	172D	173
173D	31 34.36	81 48.20	36.0	979434.87	-10.66	-11.90	0.02	-10.66	-11.89	JEGA	173D	174
174D	31 32.23	81 47.80	64.0	979432.57	-7.53	-9.74	0.03	-7.53	-9.72	JEGA	174D	175
175D	31 32.41	81 46.02	46.0	979432.28	-9.69	-11.28	0.02	-9.69	-11.26	JEGA	175D	176
176D	31 32.00	81 45.30	59.0	979430.77	-10.23	-12.27	0.03	-10.23	-12.25	JEGA	176D	177
177D	31 32.87	81 47.20	50.0	979432.95	-9.26	-10.99	0.02	-9.26	-10.97	JEGA	177D	178
178D	31 33.40	81 46.06	60.0	979431.59	-10.47	-12.55	0.03	-10.47	-12.52	JEGA	178D	179
179D	31 31.17	81 46.62	66.0	979430.95	-7.41	-9.76	0.03	-7.48	-9.73	JEGA	179D	180
180D	31 31.40	81 49.28	61.0	979433.92	-5.28	-7.39	0.03	-5.28	-7.37	JEGA	180D	181
181D	31 30.20	81 50.48	58.0	979434.51	-3.37	-5.37	0.03	-3.37	-5.34	JEGA	181D	182
182D	31 33.40	81 49.02	65.0	979434.34	-7.44	-9.62	0.03	-7.44	-9.59	JEGA	182D	183
183D	31 30.01	81 51.49	101.0	979435.58	-9.55	-13.04	0.04	-9.55	-12.99	JEGA	183D	184
73H	30 56.62	81 41.04	23.0	979415.00	18.65	17.85	0.01	18.65	17.86	KLGA	73H	185
74H	31 14.52	82 3.05	66.0	979432.55	16.41	14.13	0.03	16.41	14.16	HUGA	74H	186
75H	31 12.37	82 3.92	104.0	979424.02	14.33	10.73	0.05	14.32	10.78	HUGA	75H	187
76H	31 12.42	82 6.02	134.0	979420.51	13.57	8.94	0.06	13.57	9.00	HUGA	76H	188
77H	31 14.95	82 4.98	102.0	979427.16	15.04	11.51	0.05	15.03	11.56	HUGA	77H	189
78H	31 10.33	82 2.50	97.0	979418.49	10.86	7.51	0.04	10.86	7.55	HUGA	78H	190
79H	31 9.34	82 2.59	59.0	979420.00	10.77	8.74	0.03	10.77	8.76	HUGA	79H	191
80H	31 9.60	82 0.64	52.0	979424.73	13.84	12.04	0.02	13.84	12.06	HUGA	80H	192
81H	31 11.00	82 0.21	66.0	979427.75	16.31	14.03	0.03	16.31	14.06	HUGA	81H	193
82H	31 12.03	82 0.30	63.0	979430.15	17.05	14.88	0.03	17.05	14.90	HUGA	82H	194
83H	31 11.69	82 2.48	64.0	979420.48	13.93	11.72	0.03	13.93	11.75	HUGA	83H	195
84H	31 8.75	82 4.92	94.0	979414.64	8.83	5.56	0.04	8.83	5.63	HUGA	84H	196
85H	31 8.24	82 6.26	141.0	979409.58	8.87	4.00	0.06	8.87	4.06	HUGA	85H	197
86H	31 8.19	82 7.91	125.0	979416.63	7.89	3.57	0.06	7.88	3.62	HUGA	86H	198
87H	31 5.90	82 6.12	123.0	979409.75	10.39	6.14	0.05	10.39	6.19	HUGA	87H	199
88H	31 5.55	82 3.34	88.0	979414.40	12.35	9.31	0.04	12.35	9.35	HUGA	88H	200

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/78

STATION	LATITUDE		LONGITUDE		ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
89H	31	5.49	82	1.30	57.0	979418.50	13.55	11.59	0.03	13.55	11.61	HUGA	89H	201
90H	31	3.83	82	0.85	67.0	979416.86	15.06	12.75	0.03	15.06	12.76	HUGA	90H	202
91H	31	7.19	82	0.03	55.0	979421.92	14.52	12.62	0.02	14.52	12.65	HUGA	91H	203
92H	31	0.82	82	7.58	143.0	979408.98	18.34	13.40	0.06	18.34	13.46	HUGA	92H	204
93H	31	3.92	82	7.21	144.0	979408.28	13.61	8.63	0.06	13.61	8.70	HUGA	93H	205
94H	31	5.57	82	8.24	123.0	979408.81	9.97	5.72	0.05	9.97	5.77	HUGA	94H	206
95H	31	8.96	82	9.14	115.0	979411.62	7.71	3.74	0.05	7.71	3.78	HUGA	95H	207
96H	31	8.22	82	10.92	110.0	979411.31	7.71	3.91	0.05	7.71	3.96	HUGA	96H	208
97H	31	10.14	82	11.76	124.0	979415.02	10.78	6.50	0.05	10.78	6.55	HUGA	97H	209
98H	31	10.65	82	9.65	127.0	979415.54	10.30	5.92	0.06	10.30	5.97	HUGA	98H	210
99H	31	5.47	82	10.98	133.0	979408.15	10.38	5.79	0.06	10.38	5.84	WAGA	99H	211
100H	31	6.65	82	10.82	131.0	979408.65	8.52	4.00	0.06	8.52	4.05	WAGA	100H	212
101H	31	4.04	82	11.15	135.0	979409.53	13.85	9.19	0.06	13.85	9.25	WAGA	101H	213
102H	31	2.04	82	9.24	130.0	979410.58	17.09	12.60	0.06	17.09	12.66	WAGA	102H	214
103H	31	6.20	82	13.08	136.0	979409.49	11.03	6.33	0.06	11.03	6.39	WAGA	103H	215
104H	31	9.31	82	13.14	135.0	979413.78	11.08	6.42	0.06	11.08	6.48	HUGA	104H	216
105H	31	6.03	82	14.36	138.0	979411.06	10.35	5.58	0.06	10.35	5.64	HUGA	105H	217
106H	31	10.38	82	14.00	129.0	979410.81	12.12	7.67	0.06	12.12	7.72	HUGA	106H	218
108H	31	11.85	82	11.24	77.0	979421.53	9.99	7.33	0.03	9.99	7.36	HUGA	108H	219
109H	31	11.9.	82	13.83	116.0	979421.07	13.12	9.11	0.05	13.12	9.16	HUGA	109H	220
110H	31	13.23	82	9.98	72.0	979426.56	12.71	10.22	0.03	12.71	10.25	HUGA	110H	221
111H	31	14.66	82	12.79	130.0	979428.15	17.58	13.09	0.06	17.58	13.14	HUGA	111H	222
112H	31	13.63	82	12.24	124.0	979424.93	15.44	11.15	0.05	15.43	11.20	HUGA	112H	223
113H	31	10.85	82	8.12	130.0	979415.92	10.70	6.21	0.06	10.70	6.26	HUGA	113H	224
114H	31	6.35	81	37.67	20.0	979433.93	24.36	23.67	0.01	24.36	23.68	BRGA	114H	225
115H	31	6.37	81	40.57	21.0	979435.81	26.31	25.58	0.01	26.31	25.59	BRGA	115H	226
116H	31	5.15	81	34.91	25.0	979437.83	30.33	29.46	0.01	30.33	29.47	BRGA	116H	227
117H	31	3.59	81	34.16	11.0	979439.68	32.94	32.56	0.00	32.94	32.56	BRGA	117H	228
118H	31	2.90	81	36.67	26.0	979437.09	32.68	31.78	0.01	32.67	31.79	BRGA	118H	229
119H	31	1.55	81	34.58	22.0	979435.25	32.25	31.49	0.01	32.25	31.50	BRGA	119H	230
120H	31	2.91	81	32.92	15.0	979439.38	33.92	33.40	0.01	33.92	33.41	BRGA	120H	231
121H	31	7.07	81	32.39	12.0	979431.92	20.64	20.22	0.01	20.64	20.23	BRGA	121H	232
122H	31	10.70	81	37.88	36.0	979430.35	16.41	15.16	0.02	16.41	15.18	BRGA	122H	233
123H	31	10.29	81	43.23	17.0	979430.64	15.54	14.95	0.01	15.54	14.96	BRGA	123H	234
124H	31	12.83	81	40.42	12.0	979428.77	9.81	9.39	0.01	9.81	9.40	BRGA	124H	235
125H	31	14.66	81	37.83	13.0	979420.15	4.84	4.39	0.01	4.84	4.39	BRGA	125H	236
126H	31	12.77	81	42.64	22.0	979427.16	9.22	8.46	0.01	9.22	8.47	BRGA	126H	237
127H	31	31.20	81	25.51	15.0	979424.87	-18.47	-18.99	0.01	-18.47	-18.99	SSGA	127H	238
128H	31	30.35	81	23.55	44.0	979420.62	-18.57	-20.09	0.02	-18.57	-20.08	SSGA	128H	239
129H	31	32.98	81	25.34	15.0	979425.29	-20.36	-20.88	0.01	-20.36	-20.87	SSGA	129H	240
130H	31	32.93	81	23.17	14.0	979423.54	-22.14	-22.62	0.01	-22.14	-22.62	SSGA	130H	241
131H	31	35.53	81	24.07	23.0	979426.32	-22.00	-22.80	0.01	-22.00	-22.79	SSGA	131H	242
132H	31	32.24	81	27.32	15.0	979427.34	-17.32	-17.84	0.01	-17.32	-17.83	SSGA	132H	243
133H	31	32.33	81	29.88	19.0	979427.76	-16.64	-17.30	0.01	-16.64	-17.29	SSGA	133H	244
134H	31	43.76	81	25.63	16.0	979438.99	-21.06	-21.62	0.01	-21.06	-21.61	SSGA	134H	245
135H	31	42.00	81	25.79	19.0	979436.49	-20.91	-21.57	0.01	-20.91	-21.56	SSGA	135H	246
136H	31	43.27	81	29.59	18.0	979441.44	-17.77	-18.39	0.01	-17.77	-18.38	SSGA	136H	247
137H	31	40.30	81	24.13	12.0	979432.77	-23.00	-23.42	0.01	-23.00	-23.41	SSGA	137H	248
138H	31	37.72	81	26.78	19.0	979431.23	-20.41	-21.07	0.01	-20.41	-21.06	SSGA	138H	249
139H	31	22.27	81	27.43	19.0	979425.91	-10.01	-10.67	0.01	-10.01	-10.66	SSGA	139H	250

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/01/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
140H	31 18.05	81 25.32	21.0	979419.07	-6.02	-6.74	0.01	-6.02	-6.75	SSGA	140H	251
1H	30 31.55	81 48.19	23.0	979373.23	10.03	9.24	0.01	10.03	9.25	CAFL	1H	252
2H	30 28.44	81 47.09	20.0	979370.61	11.23	10.54	0.01	11.23	10.54	CAFL	2H	253
3H	30 26.17	81 46.48	17.0	979369.59	12.91	12.32	0.01	12.91	12.33	CAFL	3H	254
4H	30 26.12	81 49.17	40.0	979364.38	9.93	8.55	0.02	9.93	8.57	CAFL	4H	255
5H	30 26.10	81 55.31	75.0	979359.58	8.26	5.74	0.03	8.26	5.77	CAFL	5H	256
6H	30 23.14	81 56.49	69.0	979355.47	7.66	5.28	0.03	7.66	5.31	CAFL	6H	257
7H	30 26.17	81 51.99	66.0	979361.19	9.12	6.84	0.03	9.12	6.87	CAFL	7H	258
8H	30 23.63	81 45.14	24.0	979367.32	14.64	13.81	0.01	14.64	13.82	CAFL	8H	259
9H	30 24.49	81 46.52	21.0	979367.31	13.22	12.49	0.01	13.22	12.50	CAFL	9H	260
10H	30 24.44	81 49.19	45.0	979362.04	10.65	8.95	0.02	10.64	8.97	CAFL	10H	261
11H	30 24.42	81 50.96	69.0	979359.83	10.34	7.96	0.03	10.34	7.99	CAFL	11H	262
12H	30 27.50	81 49.83	22.0	979366.93	8.97	8.21	0.01	8.97	8.22	CAFL	12H	263
13H	30 28.17	81 54.51	71.0	979363.31	9.08	6.63	0.03	9.08	6.66	CAFL	13H	264
14H	30 33.67	81 59.57	75.0	979370.00	8.90	6.31	0.03	8.90	6.34	CAFL	14H	265
15H	30 31.44	81 59.60	81.0	979365.97	8.38	5.58	0.04	8.37	5.61	CAFL	15H	266
16H	30 24.00	81 58.83	78.0	979354.99	6.82	4.13	0.03	6.82	4.16	CAFL	16H	267
17H	30 27.80	81 59.96	79.0	979360.56	7.57	4.84	0.04	7.57	4.87	CAFL	17H	268
18H	30 30.97	81 55.89	72.0	979366.54	8.72	6.23	0.03	8.72	6.26	CAFL	18H	269
19H	30 30.60	81 53.52	88.0	979365.31	9.48	6.44	0.04	9.48	6.48	CAFL	19H	270
20H	30 32.85	81 40.97	16.0	979375.61	10.04	9.49	0.01	10.04	9.50	CAFL	20H	271
21H	30 30.72	81 44.94	22.0	979375.22	13.02	12.26	0.01	13.02	12.27	CAFL	21H	272
22H	30 32.24	81 43.52	16.0	979377.16	12.40	11.84	0.01	12.40	11.85	CAFL	22H	273
23H	30 34.09	81 49.55	19.0	979375.36	8.44	7.78	0.01	8.44	7.79	CAFL	23H	274
24H	30 35.25	81 47.68	13.0	979377.59	8.58	8.13	0.01	8.58	8.13	CAFL	24H	275
25H	30 35.36	81 49.79	16.0	979376.74	7.86	7.31	0.01	7.86	7.32	CAFL	25H	276
26H	30 36.91	81 50.49	22.0	979379.10	8.74	7.98	0.01	8.74	7.99	CAFL	26H	277
27H	30 35.83	81 51.61	29.0	979376.52	8.25	7.25	0.01	8.25	7.26	CAFL	27H	278
28H	30 34.67	81 50.85	20.0	979375.79	8.20	7.51	0.01	8.20	7.52	CAFL	28H	279
29H	30 36.67	81 48.31	16.0	979377.84	7.24	6.68	0.01	7.24	6.69	CAFL	29H	280
30H	30 33.54	81 51.61	48.0	979372.65	9.18	7.53	0.02	9.18	7.55	CAFL	30H	281
31H	30 20.00	81 36.20	29.0	979359.65	12.20	11.20	0.01	12.20	11.21	JAFL	31H	282
32H	30 21.11	81 35.40	49.0	979360.46	13.44	11.75	0.02	13.44	11.77	JAFL	32H	283
33H	30 21.14	81 33.15	40.0	979358.78	10.87	9.49	0.02	10.87	9.51	JAFL	33H	284
34H	30 22.18	81 29.19	35.0	979357.69	8.15	6.94	0.02	8.15	6.95	JAFL	34H	285
35H	30 21.33	81 31.26	27.0	979358.62	9.24	8.31	0.01	9.24	8.32	JAFL	35H	286
36H	30 19.73	81 31.40	38.0	979355.81	9.57	8.25	0.02	9.56	8.27	JAFL	36H	287
37H	30 16.18	81 30.68	24.0	979354.55	11.62	10.79	0.01	11.62	10.80	JAFL	37H	288
38H	30 16.29	81 34.29	24.0	979353.46	10.41	9.58	0.01	10.41	9.59	JAFL	38H	289
39H	30 16.39	81 23.34	7.0	979351.97	7.19	6.95	0.00	7.19	6.95	JAFL	39H	290
40H	30 18.15	81 24.41	17.0	979352.16	6.04	5.45	0.01	6.04	5.46	JAFL	40H	291
41H	30 20.12	81 24.99	13.0	979354.12	5.01	4.56	0.01	5.01	4.57	JAFL	41H	292
42H	30 21.95	81 25.55	9.0	979357.20	5.31	5.00	0.00	5.31	5.01	JAFL	42H	293
43H	30 20.50	81 27.71	13.0	979356.07	6.46	6.01	0.01	6.46	6.02	JAFL	43H	294
44H	30 19.25	81 27.66	14.0	979353.69	6.02	5.53	0.01	6.02	5.54	JAFL	44H	295
45H	30 17.20	81 26.30	9.0	979352.62	6.89	6.58	0.00	6.89	6.58	JAFL	45H	296
46H	30 15.12	81 26.24	15.0	979351.33	8.97	8.45	0.01	8.97	8.45	JAFL	46H	297
47H	30 21.80	81 39.21	18.0	979366.26	15.42	14.79	0.01	15.42	14.80	JAFL	47H	298
48H	30 18.24	81 39.36	6.0	979361.17	13.87	13.66	0.00	13.87	13.66	JAFL	48H	299
49H	30 24.41	81 38.33	11.0	979370.91	15.98	15.60	0.00	15.98	15.61	YUFL	49H	300

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/75

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
50H	30 24.32	81 41.66	19.0	979370.81	16.75	16.09	0.01	16.75	16.10	YUFL	50H	301
51H	30 23.48	81 43.86	24.0	979368.11	15.62	14.80	0.01	15.62	14.81	YUFL	51H	302
52H	30 40.77	81 32.15	22.0	979392.94	17.49	16.73	0.01	17.49	16.74	YUFL	52H	303
53H	30 45.70	81 36.40	17.0	979393.03	10.59	10.00	0.01	10.59	10.01	KLGA	53H	304
54H	30 46.67	81 35.55	17.0	979395.07	11.35	10.76	0.01	11.35	10.77	KLGA	54H	305
55H	30 46.00	81 34.60	23.0	979394.59	12.32	11.52	0.01	12.32	11.53	KLGA	55H	306
56H	30 44.53	81 33.21	15.0	979396.13	15.05	14.53	0.01	15.05	14.54	KLGA	56H	307
57H	30 45.85	81 35.00	20.0	979397.39	15.03	14.34	0.01	15.03	14.35	KLGA	57H	308
58H	30 46.15	81 31.03	11.0	979400.44	16.84	16.46	0.00	16.84	16.46	KLGA	58H	309
59H	30 49.99	81 33.86	22.0	979401.79	14.14	13.38	0.01	14.14	13.39	KLGA	59H	310
60H	30 48.35	81 35.48	18.0	979398.74	12.91	12.29	0.01	12.91	12.30	KLGA	60H	311
61H	30 47.19	81 38.80	15.0	979393.93	9.33	8.81	0.01	9.33	8.82	KLGA	61H	312
62H	30 45.25	81 39.02	12.0	979392.09	9.77	9.36	0.01	9.77	9.36	KLGA	62H	313
63H	30 50.92	81 38.45	14.0	979400.96	11.32	10.84	0.01	11.32	10.85	KLGA	63H	314
64H	30 52.27	81 36.53	16.0	979404.05	12.81	12.26	0.01	12.81	12.27	KLGA	64H	315
65H	30 51.67	81 42.15	13.0	979400.76	10.04	9.59	0.01	10.04	9.59	KLGA	65H	316
66H	30 55.40	81 42.98	20.0	979409.08	14.67	13.98	0.01	14.67	13.98	KLGA	66H	317
67H	30 57.94	81 43.53	15.0	979418.65	19.79	19.28	0.01	19.79	19.28	KLGA	67H	318
68H	31 0.3[illegible]	81 43.94	17.0	979425.43	23.59	23.00	0.01	23.59	23.01	KLGA	68H	319
69H	31 2.74	81 43.28	16.0	979429.82	24.68	24.12	0.01	24.68	24.13	KLGA	69H	320
70H	31 5.93	81 44.71	19.0	979433.61	24.50	23.85	0.01	24.50	23.86	KLGA	70H	321
71H	31 3.60	81 38.94	23.0	979435.67	30.04	29.25	0.01	30.04	29.26	KLGA	71H	322
72H	30 55.51	81 40.28	30.0	979410.87	16.65	15.61	0.01	16.65	15.63	KLGA	72H	323
M1	31 16.57	81 26.27	16.0	979423.42	-0.16	-0.71	0.01	-0.16	-0.71	GASS	M1	324
M2	31 19.50	81 26.87	23.0	979419.59	-7.25	-8.04	0.01	-7.25	-8.03	GASS	M2	325
M3	31 21.87	81 26.30	20.0	979418.94	-11.35	-12.04	0.01	-11.35	-12.03	GASS	M3	326
M4	31 23.33	81 25.98	26.0	979420.89	-10.79	-11.69	0.01	-10.79	-11.68	GASS	M4	327
M5	31 22.75	81 24.93	25.0	979419.37	-11.65	-12.49	0.01	-11.65	-12.48	GASS	M5	328
M6	31 24.52	81 24.63	24.0	979420.52	-12.94	-13.77	0.01	-12.94	-13.76	GASS	M6	329
M7	31 26.26	81 23.62	25.0	979420.71	-14.99	-15.85	0.01	-14.99	-15.84	GASS	M7	330
M8	31 28.48	81 21.68	19.0	979420.54	-18.70	-19.35	0.01	-18.70	-19.35	GASS	M8	331
M9	31 29.02	81 23.72	41.0	979421.04	-16.85	-18.27	0.02	-16.85	-18.25	GASS	M9	332
M10	31 28.95	81 26.67	23.0	979424.40	-15.09	-15.89	0.01	-15.09	-15.88	GARB	M10	333
M11	31 27.98	81 26.36	18.0	979423.90	-14.76	-15.38	0.01	-14.76	-15.38	GARB	M11	334
M12	31 27.42	81 29.09	18.0	979422.53	-15.38	-16.00	0.01	-15.38	-16.00	GARB	M12	335
M13	31 25.22	81 29.06	13.0	979419.98	-15.45	-15.90	0.01	-15.45	-15.90	GARB	M13	336
M14	31 26.09	81 25.75	34.0	979421.29	-13.33	-14.51	0.02	-13.33	-14.49	GARB	M14	337
M15	31 34.54	81 25.23	19.0	979425.98	-21.39	-22.05	0.01	-21.39	-22.04	GARB	M15	338
M16	31 35.29	81 27.24	18.0	979428.12	-20.35	-20.97	0.01	-20.35	-20.97	GARB	M16	339
M17	31 35.98	81 29.27	14.0	979432.31	-17.47	-17.95	0.01	-17.47	-17.94	GARB	M17	340
M18	31 34.87	81 22.92	19.0	979424.46	-23.35	-24.01	0.01	-23.35	-24.00	GARB	M18	341
M19	31 34.60	81 20.48	24.0	979423.64	-23.34	-24.17	0.01	-23.34	-24.16	GARB	M19	342
M20	31 35.99	81 19.55	24.0	979425.51	-23.34	-24.17	0.01	-23.34	-24.16	GARB	M20	343
M21	31 37.51	81 21.39	26.0	979426.68	-24.02	-24.92	0.01	-24.02	-24.91	GARB	M21	344
M22	31 38.23	81 23.73	18.0	979427.08	-25.34	-25.97	0.01	-25.34	-25.96	GARB	M22	345
M23	31 37.36	81 22.85	21.0	979427.32	-23.68	-24.40	0.01	-23.68	-24.40	GARB	M23	346
M24	31 41.63	81 23.26	21.0	979434.38	-22.34	-23.06	0.01	-22.34	-23.05	GARB	M24	347
M25	31 42.26	81 24.92	27.0	979435.90	-21.10	-22.03	0.01	-21.10	-22.02	GARB	M25	348
M26	31 37.69	81 19.20	13.0	979429.52	-23.12	-23.57	0.01	-23.12	-23.56	GARB	M26	349
M27	31 37.24	81 16.45	20.0	979429.76	-21.14	-21.54	0.01	-21.14	-21.83	GARB	M27	350

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
M28	31 38.31	81 29.10	13.0	979435.39	-17.61	-18.06	0.01	-17.61	-18.06	GARB	M28	351
M29	31 39.97	81 28.78	18.0	979437.17	-17.59	-18.22	0.01	-17.59	-18.21	GARB	M29	352
M30	31 44.13	81 28.22	17.0	979441.98	-18.48	-19.07	0.01	-18.46	-19.06	GARB	M30	353
M31	31 46.13	81 27.49	15.0	979444.10	-19.24	-19.76	0.01	-19.24	-19.75	GARB	M31	354
M32	31 45.34	81 26.58	14.0	979442.87	-19.50	-19.96	0.01	-19.50	-19.98	GARB	M32	355
M33	31 47.97	81 25.99	10.0	979445.91	-20.38	-20.73	0.00	-20.38	-20.72	GARB	M33	356
M34	31 47.27	81 23.68	15.0	979444.60	-20.28	-20.80	0.01	-20.28	-20.79	GARB	M34	357
M35	31 46.43	81 20.77	37.0	979443.64	-18.04	-19.31	0.02	-18.04	-19.30	GARB	M35	358
M36	31 46.33	81 18.93	31.0	979445.55	-16.56	-17.63	0.01	-16.56	-17.61	GARB	M36	359
M37	31 44.40	81 19.58	29.0	979442.38	-17.31	-18.32	0.01	-17.31	-18.30	GARB	M37	360
M38	31 43.59	81 18.07	10.0	979444.49	-15.90	-16.25	0.00	-15.90	-16.24	GARB	M38	361
M39	31 42.72	81 17.25	9.0	979443.68	-15.43	-15.74	0.00	-15.43	-15.74	GARB	M39	362
M40	31 42.61	81 15.46	23.0	979443.92	-13.93	-14.72	0.01	-13.93	-14.71	GARB	M40	363
M41	31 48.10	81 27.98	22.0	979446.53	-18.81	-19.57	0.01	-18.81	-19.56	GARB	M41	364
M42	31 49.39	81 31.35	15.0	979450.82	-16.92	-17.44	0.01	-16.92	-17.43	GARB	M42	365
M43	31 50.95	81 33.12	20.0	979454.70	-14.67	-15.36	0.01	-14.67	-15.35	GARB	M43	366
M44	31 50.30	81 35.70	48.0	979451.36	-14.50	-16.16	0.02	-14.50	-16.14	GARB	M44	367
M45	31 47.02	81 36.47	60.0	979444.47	-15.84	-17.91	0.03	-15.84	-17.88	GARB	M45	368
M46	31 45.65	81 33.91	19.0	979445.61	-16.71	-17.36	0.01	-16.71	-17.36	GARB	M46	369
M47	31 47.01	81 32.91	14.0	979443.20	-16.42	-16.91	0.01	-16.42	-16.90	GARB	M47	370
M48	31 47.77	81 32.25	18.0	979440.59	-16.68	-17.30	0.01	-16.68	-17.29	GARB	M48	371
M49	31 49.18	81 25.78	10.0	979447.13	-20.79	-21.14	0.00	-20.79	-21.14	GARB	M49	372
M50	31 50.65	81 24.93	17.0	979448.78	-20.47	-21.06	0.01	-20.47	-21.05	GARB	M50	373
M51	31 51.71	81 25.98	19.0	979451.64	-19.45	-20.11	0.01	-19.45	-20.10	GARB	M51	374
M52	31 50.56	81 23.51	18.0	979449.70	-19.33	-19.96	0.01	-19.33	-19.95	GARB	M52	375
M53	31 52.89	81 25.64	19.0	979454.37	-17.72	-18.37	0.01	-17.72	-18.36	GARB	M53	376
M54	31 54.79	81 25.10	22.0	979460.68	-13.69	-14.45	0.01	-13.69	-14.44	GARB	M54	377
M55	31 57.32	81 26.01	21.0	979467.31	-10.57	-11.30	0.01	-10.57	-11.29	GARB	M55	378
M56	31 56.76	81 31.90	29.0	979471.17	-5.20	-6.21	0.01	-5.20	-6.19	GARB	M56	379
M57	31 58.11	81 24.28	19.0	979467.56	-11.58	-12.24	0.01	-11.58	-12.23	GARB	M57	380
M58	31 57.85	81 20.48	18.0	979465.89	-12.99	-13.61	0.01	-12.99	-13.61	GARB	M58	381
M59	31 57.27	81 19.21	11.0	979466.29	-12.47	-12.85	0.00	-12.47	-12.84	GARB	M59	382
M60	31 56.21	81 19.21	21.0	979464.94	-11.44	-12.17	0.01	-11.44	-12.16	GARB	M60	383
M61	31 55.85	81 17.85	18.0	979465.61	-10.57	-11.19	0.01	-10.57	-11.18	GARB	M61	384
M62	31 54.49	81 16.38	13.0	979465.51	-9.30	-9.75	0.01	-9.30	-9.74	GARB	M62	385
M63	31 52.84	81 15.73	14.0	979461.99	-10.50	-10.98	0.01	-10.50	-10.98	GARB	M63	386
M64	31 52.23	81 15.59	16.0	979460.83	-10.65	-11.20	0.01	-10.65	-11.19	GARB	M64	387
M65	31 50.25	81 15.24	12.0	979457.57	-11.61	-12.02	0.01	-11.61	-12.02	GARB	M65	388
M66	31 47.78	81 14.79	24.0	979452.18	-12.54	-13.37	0.01	-12.54	-13.36	GARB	M66	389
M67	31 47.80	81 13.42	19.0	979453.92	-11.30	-11.95	0.01	-11.30	-11.94	GARB	M67	390
M68	31 46.41	81 13.68	16.0	979451.19	-12.43	-12.99	0.01	-12.43	-12.98	GARB	M68	391
M69	31 48.76	81 12.76	19.0	979456.23	-10.28	-10.94	0.01	-10.28	-10.93	GARB	M69	392
M70	31 47.03	81 11.61	20.0	979459.66	-4.55	-5.24	0.01	-4.55	-5.23	GARB	M70	393
M71	31 51.97	81 11.03	16.0	979463.28	-7.85	-8.40	0.01	-7.85	-8.39	GARB	M71	394
M72	31 51.23	81 13.83	29.0	979459.67	-9.23	-10.24	0.01	-9.23	-10.22	GARB	M72	395
M73	31 51.51	81 17.47	12.0	979456.73	-14.15	-14.56	0.01	-14.15	-14.56	GARH	M73	396
M74	31 49.61	81 18.22	17.0	979451.64	-16.21	-16.79	0.01	-16.21	-16.79	GARH	M74	397
M75	31 51.91	81 19.28	20.0	979456.10	-14.51	-15.20	0.01	-14.51	-15.19	GARH	M75	398
M76	31 54.23	81 17.76	17.0	979463.34	-10.74	-11.33	0.01	-10.74	-11.32	GARH	M76	399
M77	31 53.12	81 21.50	16.0	979458.69	-13.99	-14.54	0.01	-13.99	-14.53	GARH	M77	400

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
M78	31 52.59	81 23.76	19.0	979455.45	-16.23	-16.69	0.01	-16.23	-16.88	GARH	M78	401
M79	31 51.34	81 24.14	13.0	979451.47	-19.09	-19.54	0.01	-19.09	-19.53	GARH	M79	402
M80	31 53.92	81 20.27	22.0	979465.81	-7.38	-8.14	0.01	-7.38	-8.13	GARH	M80	403
M81	32 4.89	81 5.74	37.0	979476.93	-9.70	-10.97	0.02	-9.70	-10.96	GASA	M81	404
M82	32 4.20	81 4.09	7.0	979478.03	-10.59	-10.83	0.00	-10.59	-10.83	GASA	M82	405
M83	32 3.39	81 1.09	19.0	979479.65	-6.64	-7.29	0.01	-6.64	-7.28	GASA	M83	406
M84	32 1.28	81 0.84	13.0	979476.35	-7.64	-8.09	0.01	-7.64	-8.09	GASA	M84	407
M85	32 2.06	81 3.21	21.0	979475.56	-8.74	-9.46	0.01	-8.74	-9.45	GASA	M85	408
M86	32 2.88	81 5.11	16.0	979475.94	-9.94	-10.49	0.01	-9.94	-10.48	GASA	M86	409
M87	32 1.45	81 5.66	23.0	979473.74	-9.54	-10.34	0.01	-9.54	-10.33	GASA	M87	410
M88	32 1.13	81 4.58	27.0	979472.56	-9.51	-10.45	0.01	-9.51	-10.43	GASA	M88	411
M89	32 1.85	81 6.86	33.0	979474.29	-8.59	-9.73	0.01	-8.59	-9.72	GASA	M89	412
M90	32 3.46	81 8.28	42.0	979475.14	-9.08	-10.53	0.02	-9.08	-10.51	GASA	M90	413
M91	32 6.08	81 11.77	16.0	979482.60	-8.12	-8.46	0.00	-8.12	-8.46	GASA	M91	414
M92	32 3.97	81 12.40	16.0	979479.94	-7.41	-7.97	0.01	-7.41	-7.96	GASA	M92	415
M93	32 1.35	81 13.63	17.0	979476.11	-7.57	-8.16	0.01	-7.58	-8.15	GASA	M93	416
M94	32 2.21	81 12.96	18.0	979477.73	-7.05	-7.67	0.01	-7.05	-7.67	GASA	M94	417
M95	32 2.62	81 11.06	37.0	979477.11	-6.44	-7.72	0.02	-6.44	-7.70	GASA	M95	418
M96	32 2.14	81 9.49	15.0	979477.46	-7.51	-8.03	0.01	-7.51	-8.02	GASA	M96	419
M97	32 3.35	81 7.96	21.0	979477.58	-8.44	-9.16	0.01	-8.44	-9.15	GASA	M97	420
M98	32 1.05	80 58.63	18.0	979476.98	-6.23	-6.85	0.01	-6.23	-6.85	GASA	M98	421
M99	32 1.26	80 53.93	10.0	979470.25	-8.00	-8.34	0.00	-8.00	-8.34	GASA	M99	422
M100	32 0.78	80 53.75	8.0	979470.26	-13.53	-13.80	0.00	-13.53	-13.80	GASA	M100	423
M101	32 1.35	80 54.71	5.0	979477.88	-6.96	-7.13	0.00	-6.96	-7.13	GASA	M101	424
M102	32 1.91	80 55.93	5.0	979479.89	-5.71	-5.88	0.00	-5.71	-5.88	GASA	M102	425
M103	31 58.23	81 9.31	21.0	979473.28	-5.83	-6.56	0.01	-5.83	-6.55	GARH	M103	426
M104	31 59.48	81 14.07	14.0	979473.87	-7.59	-8.08	0.01	-7.59	-8.07	GARH	M104	427
M105	31 59.18	81 10.50	13.0	979475.89	-5.26	-5.71	0.01	-5.26	-5.71	GARH	M105	428
M106	31 58.71	81 8.98	15.0	979474.82	-5.51	-6.03	0.01	-5.51	-6.02	GARH	M106	429
M107	31 56.21	81 9.21	17.0	979471.58	-5.18	-5.77	0.01	-5.18	-5.76	GARH	M107	430
M108	31 55.07	81 8.26	15.0	979473.23	-2.18	-2.69	0.01	-2.18	-2.69	GARH	M108	431
M109	31 59.27	81 7.73	27.0	979473.84	-6.12	-7.05	0.01	-6.12	-7.04	GARH	M109	432
M110	31 37.32	81 54.41	106.0	979437.22	-5.70	-9.36	0.05	-5.70	-9.32	GAJE	M110	433
M111	31 37.97	81 56.09	152.0	979436.71	-2.76	-8.01	0.07	-2.76	-7.94	GAJE	M111	434
M112	31 38.73	81 58.30	143.0	979440.69	-0.65	-5.59	0.06	-0.65	-5.53	GAJE	M112	435
M113	31 37.92	81 59.80	142.0	979440.31	-0.03	-4.94	0.06	-0.03	-4.88	GAJE	M113	436
M114	31 36.95	81 56.95	157.0	979436.40	-1.23	-6.65	0.07	-1.23	-6.58	GAJE	M114	437
M115	31 35.81	81 56.28	123.0	979437.19	-2.10	-6.35	0.05	-2.10	-6.30	GAJE	M115	438
M116	31 30.61	81 59.80	129.0	979431.70	0.01	-4.44	0.06	0.01	-4.39	GAJE	M116	439
M117	31 31.17	81 59.46	108.0	979434.74	0.27	-3.46	0.05	0.26	-3.42	GAJE	M117	440
M118	31 32.29	81 57.73	108.0	979436.04	0.06	-3.67	0.05	0.06	-3.62	GAJE	M118	441
M119	31 33.22	81 58.31	143.0	979435.22	1.29	-3.65	0.06	1.29	-3.59	GAJE	M119	442
M120	31 33.14	81 55.90	72.0	979438.37	-2.13	-4.62	0.03	-2.14	-4.59	GAJE	M120	443
M121	31 31.69	81 56.42	65.0	979437.97	-1.25	-3.49	0.03	-1.25	-3.46	GAJE	M121	444
M122	31 30.66	81 55.77	47.0	979437.85	-1.68	-3.30	0.02	-1.66	-3.28	GAJE	M122	445
M123	31 30.20	81 54.59	51.0	979437.20	-1.33	-3.10	0.02	-1.34	-3.07	GAJE	M123	446
M124	31 30.53	81 53.39	69.0	979436.28	-1.00	-3.39	0.03	-1.00	-3.36	GAJE	M124	447
M125	31 31.85	81 54.15	90.0	979435.50	-1.58	-4.69	0.04	-1.58	-4.65	GAJE	M125	448
M126	31 33.24	81 53.77	98.0	979435.09	-3.10	-6.49	0.04	-3.10	-6.45	GAJE	M126	449
M127	31 34.08	81 53.24	98.0	979435.04	-4.28	-7.67	0.04	-4.28	-7.62	GAJE	M127	450

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/73

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
M128	31 34.67	81 54.74	106.0	979436.19	-3.44	-7.10	0.05	-3.44	-7.06	GAJE	M128	451
M129	31 34.63	81 49.08	57.0	979434.47	-9.45	-11.42	0.03	-9.45	-11.39	GAJE	M129	452
M130	31 34.71	81 51.66	59.0	979436.11	-7.73	-9.76	0.03	-7.73	-9.74	GAJE	M130	453
M131	31 32.71	81 51.57	46.0	979437.10	-5.27	-6.86	0.02	-5.27	-6.84	GAJE	M131	454
M132	31 31.12	81 52.29	57.0	979436.65	-2.55	-4.52	0.03	-2.56	-4.50	GAJE	M132	455
M133	31 32.34	81 52.55	56.0	979436.91	-4.03	-5.96	0.02	-4.03	-5.94	GAJE	M133	456
M134	31 31.96	81 50.83	57.0	979436.06	-4.27	-6.24	0.03	-4.27	-6.22	GAJE	M134	457
M135	31 30.59	81 51.27	52.0	979435.91	-3.05	-4.85	0.02	-3.05	-4.83	GAJE	M135	458
	0 0.0	0 0.0	0.0	978986.29	954.44	954.44	0.0	954.44	954.44	( )		459
M136	31 40.42	81 59.79	149.0	979443.35	0.30	-4.84	0.07	0.30	-4.78	GAJE	M136	460
M137	31 40.23	81 57.97	129.0	979443.20	-1.47	-5.93	0.06	-1.47	-5.87	GAJE	M137	461
M138	31 39.42	81 55.94	113.0	979440.04	-5.05	-8.95	0.05	-5.05	-8.90	GAJE	M138	462
M139	31 43.04	81 58.92	151.0	979446.68	0.30	-4.92	0.07	0.29	-4.86	GAJE	M139	463
M140	31 42.67	81 57.53	113.0	979447.72	-1.74	-5.64	0.05	-1.74	-5.60	GAJE	M140	464
M141	31 39.76	81 53.17	113.0	979437.23	-8.31	-12.22	0.05	-8.32	-12.17	GAJE	M141	465
M142	31 40.71	81 55.12	109.0	979436.74	-8.46	-12.22	0.05	-8.46	-12.18	GAJE	M142	466
M143	31 40.63	81 52.14	104.0	979438.36	-9.47	-13.06	0.05	-9.47	-13.02	GAJE	M143	467
M144	31 39.66	81 50.92	103.0	979436.06	-10.29	-13.85	0.05	-10.29	-13.81	GAJE	M144	468
M145	31 40.76	81 43.80	56.0	979439.53	-13.29	-15.01	0.02	-13.29	-14.99	GAJE	M145	469
M146	31 32.60	81 47.52	60.0	979432.35	-8.56	-10.63	0.03	-8.56	-10.61	GAJE	M146	470
M147	31 33.25	81 46.83	61.0	979431.95	-9.74	-11.84	0.03	-9.74	-11.82	GAJE	M147	471
M148	31 33.99	81 45.47	51.0	979432.55	-11.27	-13.03	0.02	-11.27	-13.01	GAJE	M148	472
M149	31 32.57	81 46.18	61.0	979431.06	-9.77	-11.88	0.03	-9.77	-11.86	GAJE	M149	473
M150	31 32.73	81 46.65	60.0	979431.79	-9.29	-11.37	0.03	-9.29	-11.34	GAJE	M150	474
M151	31 33.81	81 48.06	40.0	979434.47	-9.94	-11.33	0.02	-9.95	-11.31	GAJE	M151	475
M152	31 43.30	81 45.33	62.0	979443.24	-11.87	-14.01	0.03	-11.87	-13.98	GAJE	M152	476
M153	31 44.19	81 46.72	70.0	979444.81	-10.74	-13.16	0.03	-10.74	-13.13	GAJE	M153	477
M154	31 45.62	81 49.78	58.0	979448.49	-10.12	-12.12	0.03	-10.12	-12.10	GAJE	M154	478
M155	31 46.99	81 51.51	62.0	979453.67	-6.21	-8.35	0.03	-6.21	-8.32	GAJE	M155	479
M156	31 49.35	81 51.04	83.0	979457.45	-3.84	-6.70	0.04	-3.84	-6.67	GAJE	M156	480
M157	31 47.51	81 49.63	79.0	979452.34	-6.84	-9.57	0.04	-6.84	-9.54	GAJE	M157	481
M158	31 48.26	81 48.37	74.0	979454.30	-6.39	-8.95	0.03	-6.39	-8.91	GAJE	M158	482
M159	31 49.30	81 46.09	86.0	979455.83	-5.11	-8.08	0.04	-5.11	-8.04	GAJE	M159	483
M160	31 50.73	81 46.43	86.0	979459.82	-3.05	-6.02	0.04	-3.05	-5.98	GAJE	M160	484
M161	31 51.78	81 45.02	85.0	979462.13	-2.25	-5.18	0.04	-2.25	-5.15	GAJE	M161	485
M162	31 51.98	81 47.40	99.0	979462.16	-1.17	-4.59	0.04	-1.17	-4.55	GAJE	M162	486
M163	31 46.09	81 46.62	75.0	979448.27	-9.37	-11.96	0.03	-9.37	-11.93	GAJE	M163	487
M164	31 52.40	81 42.49	84.0	979460.27	-5.04	-7.94	0.04	-5.04	-7.90	GAJE	M164	488
M165	31 51.67	81 43.12	74.0	979458.51	-6.35	-8.91	0.03	-6.35	-8.88	GAJE	M165	489
M166	31 50.29	81 41.48	85.0	979451.91	-10.46	-13.39	0.04	-10.46	-13.36	GAJE	M166	490
M167	31 48.01	81 39.63	85.0	979444.91	-14.38	-17.32	0.04	-14.38	-17.28	GAJE	M167	491
M168	31 47.66	81 40.46	92.0	979443.87	-14.32	-17.50	0.04	-14.32	-17.46	GAJE	M168	492
M169	31 45.34	81 42.65	63.0	979443.14	-14.62	-16.80	0.03	-14.62	-16.77	GAJE	M169	493
M170	31 47.24	81 44.00	84.0	979446.38	-11.97	-14.87	0.04	-11.97	-14.83	GAJE	M170	494
M171	31 55.17	81 56.30	175.0	979460.04	-0.64	-6.61	0.08	-0.64	-6.54	GAGV	M171	495
M172	31 52.75	81 53.73	193.0	979454.97	-0.56	-7.22	0.08	-0.56	-7.14	GAGV	M172	496
M173	31 52.71	81 51.83	154.0	979454.36	-4.78	-10.10	0.07	-4.78	-10.04	GAGV	M173	497
M174	31 50.77	81 51.97	122.0	979455.43	-4.10	-8.32	0.05	-4.10	-8.27	GAGV	M174	498
M175	31 55.18	81 51.26	150.0	979457.65	-5.22	-10.41	0.07	-5.23	-10.34	GAGV	M175	499
M176	31 53.60	81 54.98	122.0	979458.39	-4.96	-9.18	0.05	-4.97	-9.13	GAGV	M176	500

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
M177	31 55.31	81 55.12	171.0	979459.96	-1.09	-7.00	0.08	-1.10	-6.93	GAGV	M177	501
M178	31 52.28	81 56.03	64.0	979459.69	-5.46	-8.36	0.04	-5.46	-6.32	GAGV	M178	502
M179	31 49.91	81 54.27	73.0	979457.77	-5.21	-7.73	0.03	-5.21	-7.76	GAGV	M179	503
M180	31 48.28	81 51.68	79.0	979455.71	-4.51	-7.24	0.04	-4.51	-7.20	GAGV	M180	504
M181	31 48.59	81 57.17	53.0	979458.13	-4.95	-6.78	0.02	-4.95	-6.76	GAGV	M181	505
M182	31 47.60	81 57.32	53.0	979457.52	-4.78	-6.61	0.02	-4.78	-6.59	GAGV	M182	506
M183	31 51.13	81 54.89	85.0	979457.76	-5.72	-8.66	0.04	-5.72	-8.62	GAGV	M183	507
M184	31 52.20	81 57.62	76.0	979461.75	-4.04	-6.67	0.03	-4.04	-6.63	GAGV	M184	508
M185	31 51.93	81 59.74	64.0	979463.41	-3.15	-5.36	0.03	-3.15	-5.33	GAGV	M185	509
M186	31 54.33	81 59.09	93.0	979466.61	-0.46	-3.67	0.04	-0.46	-3.63	GAGV	M186	510
M187	31 53.93	81 57.14	148.0	979459.28	-2.03	-7.15	0.07	-2.04	-7.08	GAGV	M187	511
M188	31 55.98	81 58.27	175.0	979462.77	1.19	-4.86	0.08	1.18	-4.79	GAGV	M188	512
M189	31 58.25	81 58.97	173.0	979465.43	0.59	-5.39	0.08	0.59	-5.31	GAGV	M189	513
M190	31 59.43	81 59.68	175.0	979466.06	-0.19	-6.24	0.08	-0.19	-6.16	GAGV	M190	514
M191	31 59.92	81 58.01	178.0	979466.84	0.21	-5.94	0.08	0.21	-5.86	GAGV	M191	515
M192	31 58.78	81 57.05	165.0	979466.71	0.21	-5.42	0.07	0.21	-5.35	GAGV	M192	516
M193	31 56.99	81 56.68	175.0	979465.82	0.68	-5.29	0.08	0.68	-5.22	GAGV	M193	517
M194	32 1.54	81 58.82	185.0	979468.23	0.07	-6.33	0.08	0.06	-6.25	GAGV	M194	518
M195	32 4.31	81 58.88	191.0	979468.61	-2.74	-9.34	0.08	-2.74	-9.26	GAGV	M195	519
M196	32 5.43	81 57.33	193.0	979469.99	-2.69	-9.36	0.08	-2.69	-9.28	GAGV	M196	520
M197	32 4.57	81 57.71	193.0	979468.19	-3.33	-9.99	0.08	-3.33	-9.91	GAGV	M197	521
M198	32 6.18	81 55.78	194.0	979469.14	-4.46	-11.17	0.09	-4.47	-11.08	GAGV	M198	522
M199	32 4.96	81 54.28	186.0	979467.75	-4.95	-11.38	0.08	-4.96	-11.30	GAGV	M199	523
M200	32 3.91	81 55.32	188.0	979467.14	-3.95	-10.45	0.08	-3.95	-10.37	GAGV	M200	524
M201	32 2.11	81 55.60	186.0	979468.12	-0.72	-7.15	0.08	-0.72	-7.07	GAGV	M201	525
M202	32 0.05	81 55.52	150.0	979471.02	1.58	-3.60	0.07	1.58	-3.54	GAGV	M202	526
M203	31 58.37	81 54.12	177.0	979466.58	1.95	-4.16	0.08	1.95	-4.09	GAGV	M203	527
M204	31 57.75	81 55.72	172.0	979465.92	1.69	-4.25	0.08	1.69	-4.18	GAGV	M204	528
M205	31 59.57	81 53.56	165.0	979467.88	0.50	-5.20	0.07	0.50	-5.13	GAGV	M205	529
M206	32 3.88	81 52.73	134.0	979460.97	-4.46	-10.81	0.08	-4.46	-10.74	GAGV	M206	530
M207	32 3.14	81 51.60	183.0	979465.93	-4.59	-10.91	0.08	-4.59	-10.83	GAGV	M207	531
M208	32 2.23	81 50.81	186.0	979464.45	-5.12	-11.34	0.08	-5.12	-11.26	GAGV	M208	532
M209	32 0.05	81 51.12	177.0	979465.15	-1.75	-7.87	0.08	-1.75	-7.79	GAGV	M209	533
M210	31 58.88	81 52.01	173.0	979464.34	-1.35	-7.33	0.08	-1.36	-7.26	GAGV	M210	534
M211	32 11.84	81 57.71	116.0	979484.59	-3.84	-7.92	0.05	-3.84	-7.87	GACX	M211	535
M212	32 13.08	81 55.55	200.0	979482.36	-0.04	-6.95	0.09	-0.04	-6.87	GACX	M212	536
M213	32 13.84	81 53.95	200.0	979484.45	1.02	-5.89	0.09	1.01	-5.81	GACX	M213	537
M214	32 13.20	81 51.30	179.0	979483.54	-1.00	-7.18	0.08	-1.00	-7.11	GACX	M214	538
M215	32 13.07	81 48.14	94.0	979489.69	-2.67	-5.92	0.04	-2.67	-5.88	GACX	M215	539
M216	32 14.66	81 46.75	165.0	979489.62	1.78	-3.92	0.07	1.78	-3.85	GACX	M216	540
M217	32 13.11	81 45.49	175.0	979484.03	-0.76	-6.81	0.08	-0.77	-6.74	GACX	M217	541
M218	32 9.61	81 45.49	130.0	979475.59	-8.12	-12.62	0.06	-8.12	-12.76	GACX	M218	542
M219	32 9.60	81 52.07	181.0	979474.91	-4.56	-10.81	0.08	-4.56	-10.73	GACX	M219	543
M220	32 5.73	81 52.91	184.0	979467.74	-6.19	-12.55	0.08	-6.20	-12.47	GACX	M220	544
M221	32 5.78	81 52.15	174.0	979467.03	-7.91	-13.92	0.08	-7.92	-13.85	GACX	M221	545
M222	32 7.25	81 52.12	173.0	979468.69	-8.34	-14.32	0.08	-8.34	-14.24	GACX	M222	546
M223	32 8.31	81 47.70	102.0	979474.61	-10.54	-14.06	0.05	-10.54	-14.02	GACX	M223	547
M224	32 11.57	81 48.37	163.0	979480.11	-3.72	-9.35	0.07	-3.72	-9.28	GACX	M224	548
M225	32 12.64	81 52.70	150.0	979484.57	-1.94	-7.12	0.07	-1.94	-7.06	GACX	M225	549
M226	32 6.98	81 57.67	104.0	979470.91	-6.25	-9.84	0.05	-6.25	-9.74	GACX	M226	550

TABLE C-5.1, continued

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
M227	32 7.94	81 52.65	105.0	979474.54	-9.82	-13.45	0.05	-9.82	-13.41	GACX	M227	551
M228	32 6.49	81 42.57	76.0	979474.57	-10.55	-13.18	0.03	-10.56	-13.15	GACX	M228	552
M229	32 7.75	81 40.39	102.0	979473.65	-10.74	-14.26	0.05	-10.74	-14.22	GACX	M229	553
M230	32 9.09	81 37.94	102.0	979477.96	-8.25	-11.77	0.05	-8.25	-11.73	GACX	M230	554
M231	32 12.39	81 39.66	102.0	979485.73	-4.95	-8.48	0.05	-4.96	-8.43	GACX	M231	555
M232	32 13.50	81 38.77	100.0	979487.08	-5.30	-8.75	0.04	-5.30	-8.71	GACX	M232	556
M233	32 13.37	81 40.99	113.0	979487.90	-3.08	-6.98	0.05	-3.08	-6.94	GACX	M233	557
M234	32 14.88	81 43.89	150.0	979490.62	1.07	-4.11	0.07	1.07	-4.05	GACX	M234	558
M235	32 6.49	81 43.13	145.0	979472.42	-8.93	-13.94	0.06	-8.93	-13.87	GACX	M235	559
M236	32 9.09	81 37.07	101.0	979479.47	-6.83	-10.32	0.04	-6.85	-10.28	GACX	M236	560
M237	32 10.66	81 37.12	100.0	979482.45	-6.07	-9.53	0.04	-6.07	-9.49	GACX	M237	561
M238	32 11.78	81 37.30	92.0	979484.10	-6.70	-9.88	0.04	-6.70	-9.84	GACX	M238	562
M239	32 13.46	81 37.33	101.0	979485.69	-6.54	-10.03	0.04	-6.54	-9.99	GACX	M239	563
M240	32 14.14	81 36.48	96.0	979486.05	-7.58	-10.89	0.04	-7.58	-10.85	GACX	M240	564
M241	32 12.77	81 34.10	70.0	979502.77	8.56	6.14	0.03	8.56	6.17	GACX	M241	565
M242	32 11.22	81 34.38	71.0	979501.44	9.43	6.97	0.03	9.43	7.01	GACX	M242	566
M243	31 59.47	81 5.72	22.0	979473.44	-7.26	-8.02	0.01	-7.26	-8.01	GASA	M243	567
M244	31 56.57	81 7.07	18.0	979470.87	-6.28	-6.90	0.01	-6.28	-6.90	GASA	M244	568
M245	31 55.83	81 5.61	8.0	979469.27	-7.82	-8.10	0.00	-7.82	-8.09	GASA	M245	569
M246	31 57.57	81 5.79	18.0	979470.92	-7.58	-8.21	0.01	-7.58	-8.20	GASA	M246	570
M247	31 59.05	81 3.25	12.0	979470.05	-11.02	-11.43	0.01	-11.02	-11.43	GASA	M247	571
M248	32 1.37	81 18.97	11.0	979471.37	-12.93	-13.31	0.00	-12.93	-13.31	GASA	M248	572
M249	32 8.05	81 29.38	81.0	979484.59	-2.18	-4.98	0.04	-2.18	-4.94	GASA	M249	573
M250	32 9.34	81 29.34	72.0	979468.38	-20.99	-23.47	0.03	-20.99	-23.44	GASA	M250	574
M251	32 12.89	81 25.05	77.0	979492.91	-0.81	-3.47	0.03	-0.81	-3.43	GASA	M251	575
M252	[illegible]	81 26.92	66.0	[illegible]	[illegible]	-2.10	0.03	0.18	[illegible]	GASA	M252	[illegible]

TABLE C-5.2.

LISTING OF PRINCIPAL FACTS FOR GRAVITY MEASUREMENTS ACQUIRED BY VPI PERSONNEL IN SOUTHEASTERN NEW JERSEY.

THESE ARE GRAVITY MEASUREMENTS TAKEN BY R. MEIER OF V. P. I. IN SOUTH-CENTRAL DELAWARE. ALL THE DATA WERE REFERENCED TO BASE STATIONS USING BASE VALUES PROVIDED BY THE U. S. AIR FORCE. 13.71 MILLIGALS HAVE BEEN SUBTRACTED FROM EACH MEASUREMENTS IN ORDER TO CONVERT THE DATA TO THE IGSN 1971.

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1976. OBSERVATIONS ON IGSN71. DATE: 29/06/76

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
R1	38 44.90	75 37.68	46.0	980020.80	-32.83	-34.42	0.02	-32.83	-34.40	DEBV	R1	1
R2	38 45.43	75 38.02	52.0	980021.20	-32.65	-34.44	0.02	-32.65	-34.42	DEBV	R2	2
R3	38 46.15	75 39.14	62.0	980023.02	-31.00	-33.15	0.03	-31.00	-33.12	DEBV	R3	3
R4	38 46.76	75 39.98	46.0	980025.76	-30.42	-32.08	0.02	-30.42	-32.06	DEBV	R4	4
R5	38 47.31	75 40.28	61.0	980026.86	-28.91	-31.01	0.03	-28.91	-30.99	DEBV	R5	5
R6	38 47.53	75 41.54	33.0	980029.08	-29.72	-30.86	0.01	-29.72	-30.84	DEBV	R6	6
R7	38 47.83	75 42.14	38.0	980029.21	-29.49	-30.80	0.02	-29.49	-30.78	DEBV	R7	7
R8	38 48.19	75 43.70	50.0	980029.92	-28.18	-29.90	0.02	-28.18	-29.88	DEBV	R8	8
R9	38 47.82	75 43.89	47.0	980029.35	-28.48	-30.11	0.02	-28.48	-30.09	DEBV	R9	9
R10	38 47.42	75 44.75	47.0	980029.37	-27.88	-29.50	0.02	-27.88	-29.48	DEBV	R10	10
R11	38 46.72	75 44.77	43.0	980028.36	-28.23	-29.72	0.02	-28.23	-29.70	DEBV	R11	11
R12	38 46.44	75 44.00	39.0	980027.41	-29.15	-30.49	0.02	-29.15	-30.48	DEBV	R12	12
R13	38 45.85	75 44.46	36.0	980026.75	-29.19	-30.43	0.02	-29.19	-30.42	DEBV	R13	13
R14	38 45.59	75 43.56	37.0	980026.34	-29.74	-31.02	0.02	-29.74	-31.00	DEBV	R14	14
R15	38 47.17	75 43.75	41.0	980028.41	-29.03	-30.45	0.02	-29.03	-30.43	DEBV	R15	15
R16	38 47.00	75 42.50	39.0	980027.70	-29.68	-31.03	0.02	-29.66	-31.01	DEBV	R16	16
R17	38 48.88	75 42.55	51.0	980031.01	-28.01	-29.77	0.02	-28.01	-29.75	DEBV	R17	17
R18	38 48.70	75 44.42	50.0	980031.41	-27.44	-29.16	0.02	-27.44	-29.14	DEBV	R18	18
R19	38 49.34	75 44.00	55.0	980031.67	-27.65	-29.55	0.02	-27.65	-29.52	DEBV	R19	19
R20	38 49.51	75 43.30	53.0	980031.62	-27.84	-29.67	0.02	-27.84	-29.65	DEBV	R20	20
R21	38 49.97	75 43.39	54.0	980032.72	-27.62	-29.49	0.02	-27.62	-29.46	DEBV	R21	21
R22	38 50.79	75 43.46	57.0	980033.78	-27.49	-29.46	0.03	-27.49	-29.43	DEBV	R22	22
R23	38 50.93	75 42.56	50.0	980034.30	-27.83	-29.56	0.02	-27.83	-29.54	DEBV	R23	23
R24	38 51.40	75 44.03	57.0	980034.93	-27.23	-29.20	0.03	-27.23	-29.18	DEBV	R24	24
R25	38 52.08	75 43.55	58.0	980035.91	-27.16	-29.17	0.03	-27.16	-29.14	DEBV	R25	25
R26	38 52.10	75 42.56	56.0	980035.91	-27.47	-29.40	0.02	-27.47	-29.38	DEBV	R26	26
R27	38 51.65	75 41.96	57.0	980035.25	-27.28	-29.25	0.03	-27.28	-29.22	DEBV	R27	27
R28	38 51.03	75 41.71	50.0	980034.08	-28.20	-29.93	0.02	-28.20	-29.90	DEBV	R28	28
R29	38 50.65	75 42.31	48.0	980032.80	-28.22	-29.88	0.02	-28.22	-29.86	DEBV	R29	29
R30	38 49.57	75 41.41	38.0	980032.69	-29.01	-30.32	0.02	-29.01	-30.30	DEBV	R30	30
R31	38 49.20	75 41.62	41.0	980031.50	-28.87	-30.29	0.02	-28.87	-30.27	DEBV	R31	31
R32	38 45.88	75 36.65	48.0	980022.34	-32.54	-34.20	0.02	-32.54	-34.18	DEBV	R32	32
R33	38 46.53	75 37.22	49.0	980023.74	-32.01	-33.70	0.02	-32.01	-33.68	DEBV	R33	33
R34	38 46.92	75 38.21	57.0	980024.71	-30.86	-32.83	0.03	-30.86	-32.80	DEBV	R34	34
R35	38 47.42	75 38.99	57.0	980026.16	-30.14	-32.11	0.03	-30.14	-32.09	DEBV	R35	35
R36	38 48.17	75 39.61	51.0	980028.55	-29.42	-31.18	0.02	-29.42	-31.16	DEBV	R36	36
R37	38 48.46	75 40.75	47.0	980030.01	-28.77	-30.39	0.02	-28.77	-30.37	DEBV	R37	37
R38	38 49.92	75 40.61	47.0	980032.05	-28.88	-30.50	0.02	-28.88	-30.48	DEBV	R38	38
R39	38 50.65	75 39.94	55.0	980032.60	-28.69	-30.59	0.02	-28.69	-30.57	DEBV	R39	39
R40	38 51.84	75 40.73	51.0	980035.55	-27.83	-29.59	0.02	-27.83	-29.57	DEBV	R40	40
R41	38 52.30	75 39.30	46.0	980036.07	-28.45	-30.04	0.02	-28.45	-30.02	DEBV	R41	41
R42	38 52.01	75 38.74	50.0	980035.27	-28.45	-30.18	0.02	-28.45	-30.16	DEBV	R42	42
R43	38 51.58	75 37.60	57.0	980033.66	-28.77	-30.74	0.03	-28.77	-30.71	DEBV	R43	43
R44	38 51.15	75 33.79	55.0	980033.23	-28.75	-30.65	0.02	-28.75	-30.63	DEBV	R44	44
R45	38 49.72	75 40.04	51.0	980031.39	-28.86	-30.63	0.02	-28.86	-30.60	DEBV	R45	45
R46	38 49.23	75 39.13	56.0	980029.67	-29.19	-31.13	0.02	-29.19	-31.10	DEBV	R46	46
R47	38 46.03	75 42.63	37.0	980027.29	-29.86	-31.14	0.02	-29.86	-31.13	DEBV	R47	47
R48	38 45.84	75 42.47	40.0	980025.24	-30.34	-31.72	0.02	-30.34	-31.70	DEBV	R48	48
R49	38 45.45	75 42.77	44.0	980024.37	-30.26	-31.78	0.02	-30.26	-31.76	DEBV	R49	49
R50	38 45.66	75 41.65	46.0	980024.32	-30.43	-32.02	0.02	-30.43	-32.00	DEBV	R50	50

TABLE C-5.2, continued

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1978. OBSERVATIONS ON IGSN71. DATE: 29/0[illegible]/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
R51	38 46.05	75 41.09	49.0	980024.84	-30.25	-31.94	0.02	-30.24	-31.92	DEBV	R51	51
R52	38 46.39	75 40.55	47.0	980025.15	-30.58	-32.20	0.02	-30.58	-32.18	DEBV	R52	52
R53	38 45.20	75 39.22	60.0	980020.92	-31.84	-33.91	0.03	-31.84	-33.88	DEBV	R53	53
R54	38 45.22	75 40.4[illegible]	52.0	980022.18	-31.36	-33.15	0.02	-31.36	-33.13	DEBV	R54	54
R55	38 44.57	75 41.21	50.0	980020.82	-31.95	-33.66	0.02	-31.95	-33.65	DEBV	R55	55
R56	38 44.43	75 42.35	45.0	980021.55	-31.48	-33.04	0.02	-31.48	-33.02	DEBV	R56	56
R57	38 44.04	75 43.67	38.0	980022.64	-30.48	-31.79	0.02	-30.48	-31.77	DEBV	R57	57
R58	38 43.49	75 44.34	42.0	980022.28	-29.75	-31.16	0.02	-29.75	-31.15	DEBV	R58	58
R59	38 41.93	75 44.27	40.0	980021.84	-27.99	-29.37	0.02	-27.99	-29.35	DEBV	R59	59
R60	38 41.84	75 45.[illegible]	46.0	980019.92	-29.21	-30.80	0.02	-29.21	-30.78	DEBV	R60	60
R61	38 42.49	75 43.29	44.0	980020.64	-29.63	-31.15	0.02	-29.63	-31.13	DEBV	R61	61
R62	38 43.46	75 42.[illegible]	43.0	980020.33	-31.46	-32.95	0.02	-31.46	-32.93	DEBV	R62	62
R63	38 43.54	75 41.71	42.0	980019.91	-32.10	-33.55	0.02	-32.10	-33.53	DEBV	R63	63
R64	38 43.69	75 40.95	47.0	980019.21	-32.55	-34.17	0.02	-32.55	-34.15	DEBV	R64	64
R65	38 43.91	75 39.29	52.0	980019.45	-32.16	-33.96	0.02	-32.16	-33.93	DEBV	R65	65
R66	38 45.40	75 39.25	52.0	980019.07	-31.88	-33.67	0.02	-31.88	-33.65	DEBV	R66	66
R67	38 44.93	75 39.22	53.0	980020.66	-32.16	-33.99	0.02	-32.16	-33.96	DEBV	R67	67
R68	38 44.61	75 37.96	51.0	980020.31	-32.42	-34.19	0.02	-32.42	-34.16	DEBV	R68	68
R69	38 43.85	75 37.04	47.0	980019.95	-32.04	-33.67	0.02	-32.04	-33.65	DEBV	R69	69
R70	38 43.04	75 33.19	49.0	980019.79	-31.71	-33.40	0.02	-31.70	-33.38	DEBV	R70	70
R71	38 42.86	75 39.18	51.0	980018.61	-31.55	-33.31	0.02	-31.55	-33.29	DEBV	R71	71
R72	38 42.59	75 40.78	50.0	980018.38	-31.48	-33.20	0.02	-31.48	-33.18	DEBV	R72	72
R73	38 42.21	75 41.62	49.0	980018.79	-30.60	-32.29	0.02	-30.60	-32.27	DEBV	R73	73
R74	38 41.15	75 44.46	42.0	980021.60	-26.85	-28.27	0.02	-26.85	-28.25	DEBV	R74	74
R75	38 40.45	75 43.53	46.0	980020.41	-26.68	-28.26	0.02	-26.68	-28.24	DEBV	R75	75
R76	38 39.42	75 44.54	42.0	980021.56	-24.89	-26.34	0.02	-24.89	-26.32	DEBV	R76	76
R77	38 39.12	75 43.38	46.0	980018.56	-26.57	-28.16	0.02	-26.57	-28.14	DEBV	R77	77
R78	38 38.66	75 44.28	47.0	980019.47	-24.89	-26.51	0.02	-24.89	-26.49	DEBV	R78	78
R79	38 37.89	75 44.75	46.0	980018.77	-24.55	-26.14	0.02	-24.55	-26.12	DEBV	R79	79
R80	38 37.82	75 45.77	44.0	980017.31	-26.04	-27.56	0.02	-26.04	-27.54	DEBV	R80	80
R81	38 38.12	75 42.47	45.0	980016.40	-27.29	-28.85	0.02	-27.29	-28.83	DEBV	R81	81
R82	38 37.71	75 41.90	41.0	980015.77	-27.76	-29.17	0.02	-27.76	-29.16	DEBV	R82	82
R83	38 38.32	75 41.49	39.0	980016.31	-28.30	-29.65	0.02	-28.30	-29.63	DEBV	R83	83
R84	38 38.98	75 41.88	46.0	980016.87	-28.05	-29.64	0.02	-28.05	-29.62	DEBV	R84	84
R85	38 40.07	75 42.51	48.0	980018.41	-27.93	-29.59	0.02	-27.93	-29.57	DEBV	R85	85
R86	38 41.05	75 42.75	48.0	980019.24	-28.54	-30.20	0.02	-28.54	-30.18	DEBV	R86	86
R87	38 41.53	75 41.93	48.0	980018.89	-29.67	-31.33	0.02	-29.67	-31.31	DEBV	R87	87
R88	38 43.29	75 37.11	48.0	980019.51	-31.56	-33.22	0.02	-31.56	-33.20	DEBV	R88	88
R89	38 42.45	75 37.68	46.0	980019.60	-31.03	-32.62	0.02	-31.03	-32.60	DEBV	R89	89
R90	38 42.15	75 38.67	45.0	980018.20	-31.48	-33.03	0.02	-31.48	-33.01	DEBV	R90	90
R91	38 41.75	75 40.30	47.0	980017.98	-30.92	-32.55	0.02	-30.92	-32.53	DEBV	R91	91
R92	38 40.89	75 40.45	47.0	980018.33	-29.31	-30.93	0.02	-29.31	-30.91	DEBV	R92	92
R93	38 40.70	75 41.55	51.0	980017.46	-29.50	-31.26	0.02	-29.50	-31.24	DEBV	R93	93
R94	38 39.96	75 40.56	45.0	980016.57	-29.89	-31.44	0.02	-29.89	-31.42	DEBV	R94	94
R95	38 39.00	75 40.49	40.0	980016.51	-29.01	-30.39	0.02	-29.01	-30.37	DEBV	R95	95
R96	38 38.44	75 40.29	29.0	980014.94	-30.79	-31.79	0.01	-30.79	-31.78	DEBV	R96	96
R97	38 37.01	75 40.11	36.0	980016.03	-27.82	-29.06	0.02	-27.82	-29.05	DEBV	R97	97
R98	38 38.49	75 39.24	35.0	980017.03	-28.21	-29.42	0.02	-28.21	-29.40	DEBV	R98	98
R99	38 39.93	75 39.55	41.0	980017.15	-29.63	-31.05	0.02	-29.63	-31.03	DEBV	R99	99
R100	38 39.74	75 33.24	37.0	980017.16	-29.73	-31.01	0.02	-29.73	-30.99	DEBV	R100	100

TABLE C-5.2, continued

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1978. OBSERVATIONS ON IGSN71. DATE: 29/06/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	CONT
R101	38 38.71	75 37.80	32.0	980016.57	-29.27	-30.38	0.01	-29.27	-30.37	DEBV	R101	101
R102	38 40.38	75 37.24	37.0	980017.70	-30.13	-31.41	0.02	-30.13	-31.39	DEBV	R102	102
R103	38 40.59	75 39.27	46.0	980017.69	-30.04	-31.65	0.02	-30.04	-31.61	DEBV	R103	103
R104	38 41.17	75 35.26	41.0	980018.05	-30.56	-31.98	0.02	-30.56	-31.96	DEBV	R104	104
R105	38 41.07	75 37.13	35.0	980018.85	-30.36	-31.50	0.01	-30.36	-31.49	DEBV	R105	105
R106	38 41.98	75 35.93	43.0	980019.24	-30.38	-31.86	0.02	-30.38	-31.84	DEBV	R106	106
R107	38 44.97	75 35.90	43.0	980021.36	-32.66	-34.14	0.02	-32.66	-34.12	DEBV	R107	107
R108	38 46.02	75 35.60	42.0	980022.81	-32.85	-34.30	0.02	-32.85	-34.28	DEBV	R108	108
R109	38 47.79	75 35.34	46.0	980026.25	-31.63	-33.22	0.02	-31.63	-33.20	DEBV	R109	109
R110	38 42.16	75 36.31	49.0	980025.23	-24.12	-25.81	0.02	-24.12	-25.79	DEBV	R110	110
R111	38 46.64	75 36.35	48.0	980024.68	-31.92	-33.58	0.02	-31.92	-33.56	DEBV	R111	111
R112	38 47.66	75 37.67	55.0	980026.29	-30.57	-32.47	0.02	-30.57	-32.44	DEBV	R112	112
R113	38 48.63	75 38.05	61.0	980028.00	-29.67	-31.77	0.03	-29.67	-31.75	DEBV	R113	113
R114	38 49.43	75 38.25	58.0	980029.95	-29.22	-31.22	0.03	-29.22	-31.20	DEBV	R114	114
R115	38 50.05	75 38.12	56.0	980030.95	-29.13	-31.14	0.03	-29.13	-31.11	DEBV	R115	115
R116	38 50.39	75 37.16	60.0	980031.47	-28.92	-31.00	0.03	-28.92	-30.97	DEBV	R116	116
R117	38 49.36	75 37.33	53.0	980028.60	-30.00	-32.17	0.03	-30.00	-32.14	DEBV	R117	117
R118	38 48.70	75 37.51	59.0	980027.58	-30.51	-32.55	0.03	-30.51	-32.52	DEBV	R118	118
R119	38 48.10	75 36.93	54.0	980026.31	-30.78	-32.64	0.02	-30.78	-32.62	DEBV	R119	119
R120	38 49.11	75 35.42	54.0	980028.27	-30.80	-32.67	0.02	-30.80	-32.65	DEBV	R120	120
R121	38 49.50	75 36.28	56.0	980029.25	-30.21	-32.15	0.02	-30.21	-32.12	DEBV	R121	121
R122	38 50.91	75 35.65	64.0	980031.82	-28.96	-31.18	0.03	-28.96	-31.15	DEBV	R122	122
R123	38 51.56	75 36.74	59.0	980033.33	-28.88	-30.92	0.03	-28.88	-30.89	DEBV	R123	123
R124	38 51.82	75 35.79	60.0	980033.82	-28.68	-30.75	0.03	-28.68	-30.73	DEBV	R124	124
R125	38 52.14	75 34.77	63.0	980034.37	-28.39	-30.57	0.03	-28.39	-30.54	DEBV	R125	125
R126	38 52.63	75 34.10	63.0	980034.12	-28.41	-30.58	0.03	-28.41	-30.56	DEBV	R126	126
R127	38 51.60	75 33.32	59.0	980032.47	-28.92	-30.96	0.03	-28.92	-30.93	DEBV	R127	127
R128	38 50.17	75 33.49	50.0	980031.22	-29.79	-31.52	0.02	-29.79	-31.50	DEBV	R128	128
R129	38 49.72	75 34.52	53.0	980029.82	-30.25	-32.08	0.02	-30.25	-32.05	DEBV	R129	129
R130	38 48.69	75 34.65	54.0	980027.73	-31.02	-32.89	0.02	-31.02	-32.86	DEBV	R130	130
R131	38 48.29	75 34.59	53.0	980026.57	-31.39	-33.22	0.02	-31.39	-33.20	DEBV	R131	131
R132	38 47.61	75 34.47	45.0	980025.85	-31.88	-33.44	0.02	-31.88	-33.42	DEBV	R132	132
R133	38 47.11	75 34.06	45.0	980025.01	-31.97	-33.52	0.02	-31.97	-33.50	DEBV	R133	133
R134	38 46.10	75 33.21	45.0	980024.77	-30.81	-32.36	0.02	-30.81	-32.34	DEBV	R134	134
R135	38 45.50	75 35.05	41.0	980022.96	-32.14	-33.56	0.02	-32.14	-33.54	DEBV	R135	135
R136	38 48.30	75 35.15	58.0	980026.53	-31.06	-33.07	0.03	-31.06	-33.04	DEBV	R136	136
R137	38 50.68	75 34.84	56.0	980031.99	-29.21	-31.14	0.02	-29.21	-31.12	DEBV	R137	137
R138	38 51.37	75 34.72	61.0	980033.63	-28.71	-30.82	0.03	-28.71	-30.79	DEBV	R138	138
R139	38 52.15	75 32.18	59.0	980034.76	-28.32	-30.36	0.03	-28.32	-30.33	DEBV	R139	139
R140	38 51.65	75 31.61	57.0	980034.20	-28.33	-30.30	0.03	-28.33	-30.28	DEBV	R140	140
R141	38 52.16	75 30.98	59.0	980035.11	-28.01	-30.05	0.03	-28.01	-30.03	DEBV	R141	141
R142	38 50.95	75 31.12	57.0	980032.53	-28.90	-30.87	0.03	-28.90	-30.84	DEBV	R142	142
R143	38 50.50	75 30.45	56.0	980031.31	-28.89	-30.82	0.02	-28.89	-30.80	DEBV	R143	143
R144	38 50.13	75 31.60	55.0	980031.15	-29.33	-31.23	0.02	-29.33	-31.21	DEBV	R144	144
R145	38 50.12	75 32.58	54.0	980031.08	-29.48	-31.35	0.02	-29.48	-31.32	DEBV	R145	145
R146	38 49.49	75 33.27	50.0	980028.99	-30.46	-32.39	0.02	-30.46	-32.37	DEBV	R146	146
R147	38 48.47	75 31.40	50.0	980028.79	-29.24	-31.18	0.02	-29.24	-31.15	DEBV	R147	147
R148	38 47.65	75 32.18	49.0	980027.61	-29.85	-31.54	0.02	-29.85	-31.52	DEBV	R148	148
R149	38 46.65	75 32.60	43.0	980027.29	-29.52	-31.00	0.02	-29.52	-30.99	DEBV	R149	149
R150	38 46.17	75 33.65	43.0	980026.55	-29.23	-30.72	0.02	-29.23	-30.70	DEBV	R150	150

TABLE C-5.2, continued

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY K. MEIER OF V.P.I. IN MAY, 1978. OBSERVATIONS ON IGSN71. DATE: 29/06/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	TC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
R151	38 45.16	75 35.36	38.0	980026.39	-28.41	-29.72	0.02	-28.41	-29.70	DEBV	R151	151
R152	38 46.05	75 33.44	47.0	980026.83	-31.34	-32.97	0.02	-31.34	-32.95	DEBV	R152	152
R153	38 45.16	75 32.41	55.0	980027.26	-30.33	-32.23	0.02	-30.33	-32.21	DEBV	R153	153
R154	38 43.36	75 30.36	49.0	980031.64	-26.80	-28.49	0.02	-26.80	-28.47	DEBV	R154	154
R155	38 40.39	75 29.37	49.0	980032.89	-25.59	-27.29	0.02	-25.59	-27.27	DEBV	R155	155
R156	38 43.41	75 27.96	50.0	980034.23	-24.19	-25.92	0.02	-24.19	-25.90	DEBV	R156	156
R157	38 47.72	75 26.66	47.0	980033.05	-24.45	-26.14	0.02	-24.45	-26.12	DEBV	R157	157
R158	38 46.[illegible]	75 27.34	48.0	980033.73	-24.36	-26.01	0.02	-24.36	-25.99	DEBV	R158	158
R159	38 45.7[illegible]	75 29.19	47.0	980030.33	-24.55	-26.17	0.02	-24.55	-26.15	DEBV	R159	159
R160	38 45.22	75 30.61	45.0	980029.41	-24.79	-26.34	0.02	-24.79	-26.32	DEBV	R160	160
R161	38 45.08	75 32.36	45.0	980027.94	-26.06	-27.61	0.02	-26.06	-27.59	DEBV	R161	161
R162	38 44.75	75 34.24	39.0	980024.90	-30.13	-31.48	0.02	-30.13	-31.46	DEBV	R162	162
R163	38 46.96	75 33.67	53.0	980030.18	-28.66	-30.51	0.02	-28.66	-30.49	DEBV	R163	163
R164	38 51.41	75 30.16	57.0	980034.20	-27.95	-29.95	0.03	-27.96	-29.92	DEBV	R164	164
R165	38 52.24	75 27.48	52.0	980036.20	-27.67	-29.47	0.02	-27.67	-29.44	DEBV	R165	165
R166	38 52.59	75 28.51	54.0	980037.74	-27.57	-28.92	0.02	-27.57	-28.91	DEBV	R166	166
R167	38 51.39	75 28.66	50.0	980035.19	-27.62	-29.35	0.02	-27.62	-29.32	DEBV	R167	167
R168	38 50.85	75 23.82	51.0	980033.95	-27.98	-29.75	0.02	-27.98	-29.72	DEBV	R168	168
R169	38 49.92	75 29.42	56.0	980032.10	-27.98	-29.91	0.02	-27.96	-29.89	DEBV	R169	169
R170	38 47.25	75 30.51	45.0	980031.13	-26.05	-27.61	0.02	-26.05	-27.59	DEBV	R170	170
R171	38 47.25	75 31.51	44.0	980029.41	-27.87	-29.39	0.02	-27.87	-29.37	DEBV	R171	171
R172	38 46.01	75 31.03	42.0	980029.72	-25.92	-27.37	0.02	-25.92	-27.35	DEBV	R172	172
R173	38 46.39	75 31.97	40.0	980029.82	-27.57	-28.95	0.02	-27.57	-28.93	DEBV	R173	173
R174	38 45.66	75 28.96	43.0	980030.87	-24.46	-25.94	0.02	-24.46	-25.92	DEBV	R174	174
R175	38 46.25	75 27.53	44.0	980032.40	-23.41	-24.93	0.02	-23.41	-24.91	DEBV	R175	175
R176	38 47.28	75 26.66	51.0	980032.64	-24.02	-25.79	0.02	-24.02	-25.76	DEBV	R176	176
R177	38 47.22	75 27.64	47.0	980034.33	-22.62	-24.24	0.02	-22.62	-24.22	DEBV	R177	177
R178	38 49.03	75 25.52	52.0	980033.26	-25.86	-27.66	0.02	-25.86	-27.66	DEBV	R178	178
R179	38 49.49	75 23.42	53.0	980034.08	-25.65	-27.48	0.02	-25.65	-27.46	DEBV	R179	179
R180	38 49.85	75 27.76	50.0	980034.71	-25.80	-27.53	0.02	-25.80	-27.51	DEBV	R180	180
R181	38 50.49	75 27.42	48.0	980037.34	-24.33	-25.99	0.02	-24.33	-25.97	DEBV	R181	181
R182	38 52.01	75 27.51	44.0	980037.64	-26.64	-28.17	0.02	-26.64	-28.15	DEBV	R182	182
R183	38 52.17	75 25.45	44.0	980036.54	-27.98	-29.50	0.02	-27.98	-29.48	DEBV	R183	183
R184	38 51.52	75 25.79	46.0	980035.52	-27.86	-29.44	0.02	-27.86	-29.42	DEBV	R184	184
R185	38 50.97	75 26.37	50.0	980035.49	-26.70	-28.43	0.02	-26.70	-28.40	DEBV	R185	185
R186	38 50.05	75 26.37	44.0	980034.54	-26.86	-28.38	0.02	-26.86	-28.36	DEBV	R186	186
R187	38 49.02	75 26.36	50.0	980035.90	-25.42	-27.15	0.02	-25.42	-27.12	DEBV	R187	187
R188	38 46.45	75 26.55	51.0	980039.74	-27.57	-29.33	0.02	-27.57	-29.31	DEBV	R188	188
R189	38 45.57	75 26.52	44.0	980021.13	-33.67	-35.20	0.02	-33.67	-35.18	DEBV	R189	189
R190	38 52.21	75 24.02	44.0	980037.36	-27.22	-28.74	0.02	-27.22	-28.72	DEBV	R190	190
R191	38 51.69	75 23.30	33.0	980037.76	-27.09	-28.23	0.01	-27.09	-28.21	DEBV	R191	191
R192	38 51.04	75 23.98	35.0	980037.25	-26.47	-27.68	0.02	-26.47	-27.67	DEBV	R192	192
R193	38 50.86	75 24.04	38.0	980036.01	-26.25	-27.56	0.02	-26.25	-27.55	DEBV	R193	193
R194	38 50.06	75 25.37	50.0	980035.36	-25.40	-27.13	0.02	-25.40	-27.11	DEBV	R194	194
R195	38 49.23	75 24.52	49.0	980034.70	-25.02	-26.71	0.02	-25.02	-26.69	DEBV	R195	195
R196	38 50.16	75 23.74	44.0	980035.95	-25.52	-27.04	0.02	-25.52	-27.02	DEBV	R196	196
R197	38 49.96	75 22.69	47.0	980035.69	-25.29	-26.92	0.02	-25.29	-26.90	DEBV	R197	197
R198	38 45.92	75 23.36	42.0	980034.59	-25.33	-26.78	0.02	-25.33	-26.77	DEBV	R198	198
R199	38 48.42	75 25.04	49.0	980033.79	-24.74	-26.43	0.02	-24.74	-26.41	DEBV	R199	199
R200	38 48.42	75 23.63	48.0	980035.77	-24.85	-26.51	0.02	-24.85	-26.49	DEBV	R200	200

TABLE C-5.2, continued

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1978. OBSERVATIONS ON IGSN71. DATE: 24/06/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
R201	38 47.44	75 24.16	50.0	980032.39	-24.60	-26.33	0.02	-24.60	-26.31	DEBV	R201	201
R202	38 46.55	75 23.98	49.0	980031.57	-24.21	-25.90	0.02	-24.21	-25.88	DEBV	R202	202
R203	38 45.93	75 22.92	46.0	980030.71	-24.25	-25.91	0.02	-24.25	-25.89	DEBV	R203	203
R204	38 45.31	75 24.37	47.0	980030.29	-23.85	-25.47	0.02	-23.85	-25.45	DEBV	R204	204
R205	38 45.86	75 24.10	49.0	980030.92	-23.84	-25.53	0.02	-23.84	-25.51	DEBV	R205	205
R206	38 45.13	75 25.10	41.0	980030.42	-24.02	-25.44	0.02	-24.02	-25.42	DEBV	R206	206
R207	38 42.67	75 23.95	50.0	980026.71	-23.26	-24.99	0.02	-23.26	-24.97	DEBV	R207	207
R208	38 43.56	75 22.99	50.0	980028.17	-23.26	-24.99	0.02	-23.26	-24.97	DEBV	R208	208
R209	38 42.97	75 22.65	46.0	980027.20	-23.53	-25.12	0.02	-23.53	-25.10	DEBV	R209	209
R210	38 44.94	75 22.85	43.0	980029.78	-23.72	-25.38	0.02	-23.72	-25.36	DEBV	R210	210
R211	38 44.54	75 25.61	46.0	980029.47	-23.63	-25.22	0.02	-23.63	-25.20	DEBV	R211	211
R212	38 44.67	75 26.80	43.0	980029.59	-23.98	-25.47	0.02	-23.98	-25.45	DEBV	R212	212
R213	38 44.94	75 23.24	40.0	980029.91	-24.34	-25.73	0.02	-24.34	-25.71	DEBV	R213	213
R214	38 44.27	75 29.51	39.0	980029.15	-24.21	-25.56	0.02	-24.21	-25.54	DEBV	R214	214
R215	38 44.25	75 27.93	42.0	980028.79	-24.26	-25.71	0.02	-24.26	-25.69	DEBV	R215	215
R216	38 44.06	75 27.61	44.0	980028.54	-24.07	-25.59	0.02	-24.07	-25.57	DEBV	R216	216
R217	38 43.95	75 25.15	46.0	980028.75	-23.48	-25.07	0.02	-23.48	-25.05	DEBV	R217	217
R218	38 42.78	75 25.13	51.0	980026.60	-23.44	-25.20	0.02	-23.44	-25.18	DEBV	R218	218
R219	38 43.39	75 26.01	44.0	980026.64	-23.56	-25.08	0.02	-23.56	-25.06	DEBV	R219	219
R220	38 42.96	75 26.61	40.0	980027.29	-24.08	-25.46	0.02	-24.08	-25.44	DEBV	R220	220
R221	38 43.54	75 27.98	42.0	980027.69	-24.32	-25.77	0.02	-24.32	-25.75	DEBV	R221	221
R222	38 42.89	75 25.50	41.0	980026.91	-24.23	-25.65	0.02	-24.23	-25.63	DEBV	R222	222
R223	38 43.00	75 33.65	43.0	980021.10	-30.02	-31.50	0.02	-30.02	-31.48	DEBV	R223	223
R224	38 41.72	75 36.29	36.0	980019.95	-29.94	-31.19	0.02	-29.94	-31.17	DEBV	R224	224
R225	38 40.41	75 35.75	[illegible]	980019.52	-28.73	-29.87	0.01	-28.73	-29.85	DEBV	R225	225
R226	38 39.76	75 36.01	28.0	980018.80	-28.96	-29.93	0.01	-28.96	-29.92	DEBV	R226	226
R227	38 38.18	75 37.96	27.0	980016.25	-29.28	-30.21	0.01	-29.28	-30.20	DEBV	R227	227
R228	38 38.24	75 37.22	26.0	980016.77	-28.95	-29.85	0.01	-28.95	-29.83	DEBV	R228	228
R229	38 [illegible]	75 35.75	15.0	980019.43	-28.51	-29.03	0.01	-28.51	[illegible]	DEBV	R229	229
R230	38 41.53	75 35.09	36.0	980021.33	-28.10	-29.41	0.02	-28.10	-29.39	DEBV	R230	230
R231	38 42.11	75 33.11	33.0	980021.73	-28.55	-29.86	0.02	-28.55	-29.85	DEBV	R231	231
R232	38 43.01	75 34.14	39.0	980022.78	-28.73	-30.08	0.02	-28.73	-30.06	DEBV	R232	232
R233	38 42.60	75 31.39	34.0	980027.88	-23.50	-24.67	0.02	-23.50	-24.66	DEBV	R233	233
R234	38 41.66	75 29.70	36.0	980026.22	-23.88	-25.12	0.02	-23.88	-25.11	DEBV	R234	234
R235	38 41.51	75 28.69	36.0	980025.27	-24.31	-25.56	0.02	-24.31	-25.54	DEBV	R235	235
R236	38 41.83	75 27.31	39.0	980025.45	-24.32	-25.67	0.02	-24.32	-25.65	DEBV	R236	236
R237	38 41.50	75 23.96	48.0	980025.46	-22.98	-24.64	0.02	-22.98	-24.62	DEBV	R237	237
R238	38 40.79	75 22.80	48.0	980024.95	-22.45	-24.11	0.02	-22.45	-24.09	DEBV	R238	238
R239	38 40.27	75 23.19	50.0	980024.53	-21.91	-23.64	0.02	-21.91	-23.62	DEBV	R239	239
R240	38 39.58	75 22.53	50.0	980024.89	-20.54	-22.27	0.02	-20.54	-22.25	DEBV	R240	240
R241	38 39.13	75 25.01	46.0	980024.35	-20.61	-22.26	0.02	-20.61	-22.24	DEBV	R241	241
R242	38 38.21	75 22.63	49.0	980023.97	-19.54	-21.23	0.02	-19.54	-21.21	DEBV	R242	242
R243	38 38.34	75 24.08	51.0	980023.40	-20.11	-21.88	0.02	-20.11	-21.85	DEBV	R243	243
R244	38 38.57	75 25.05	50.0	980023.05	-20.90	-22.62	0.02	-20.90	-22.60	DEBV	R244	244
R245	38 37.72	75 25.44	50.0	980022.21	-20.49	-22.21	0.02	-20.49	-22.19	DEBV	R245	245
R246	38 39.70	75 24.37	50.0	980023.74	-21.87	-23.59	0.02	-21.87	-23.57	DEBV	R246	246
R247	38 40.64	75 24.13	51.0	980024.19	-22.70	-24.47	0.02	-22.70	-24.44	DEBV	R247	247
R248	38 40.64	75 25.31	51.0	980024.27	-22.92	-24.68	0.02	-22.92	-24.66	DEBV	R248	248
R249	38 41.07	75 26.22	42.0	980024.79	-23.56	-25.03	0.02	-23.55	-25.02	DEBV	R249	249
R250	38 40.05	75 26.90	42.0	980025.60	-23.87	-25.32	0.02	-23.87	-25.31	DEBV	R250	250

TABLE C-5.2, continued

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1978. OBSERVATIONS ON IGSN71. DATE: 29/07/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
R251	38 40.14	75 25.91	47.0	980023.45	-23.09	-24.71	0.02	-23.09	-24.69	DEBV	R251	251
R252	38 41.85	75 24.79	47.0	980025.66	-23.39	-25.01	0.02	-23.39	-24.99	DEBV	R252	252
R253	38 42.45	75 33.11	33.0	980025.69	-25.36	-26.50	0.01	-25.36	-26.49	DEBV	R253	253
R254	38 40.20	75 34.39	27.0	980021.35	-27.20	-28.14	0.01	-27.20	-28.13	DEBV	R254	254
R255	38 39.97	75 31.55	32.0	980023.44	-24.26	-25.36	0.01	-24.26	-25.35	DEBV	R255	255
R256	38 39.87	75 29.63	34.0	980022.61	-24.55	-25.73	0.02	-24.55	-25.71	DEBV	R256	256
R257	38 40.37	75 28.91	36.0	980023.65	-24.26	-25.50	0.02	-24.26	-25.49	DEBV	R257	257
R258	38 39.24	75 28.41	48.0	980021.71	-23.41	-25.07	0.02	-23.41	-25.05	DEBV	R258	258
R259	38 39.05	75 29.19	41.0	980021.50	-24.00	-25.41	0.02	-24.00	-25.40	DEBV	R259	259
R260	38 39.21	75 27.16	47.0	980022.13	-23.04	-24.66	0.02	-23.04	-24.64	DEBV	R260	260
R261	38 38.66	75 26.42	48.0	980022.42	-21.85	-23.50	0.02	-21.85	-23.48	DEBV	R261	261
R262	38 38.20	75 27.26	48.0	980021.38	-22.21	-23.87	0.02	-22.21	-23.85	DEBV	R262	262
R263	38 37.94	75 28.27	44.0	980020.85	-22.73	-24.25	0.02	-22.73	-24.23	DEBV	R263	263
R264	38 38.03	75 29.28	38.0	980020.46	-23.82	-25.13	0.02	-23.82	-25.12	DEBV	R264	264
R265	38 37.85	75 30.21	36.0	980019.72	-24.48	-25.73	0.02	-24.48	-25.71	DEBV	R265	265
R266	38 36.19	75 30.92	34.0	980019.63	-25.06	-26.24	0.02	-25.06	-26.22	DEBV	R266	266
R267	38 37.92	75 32.59	35.0	980018.67	-25.58	-26.79	0.02	-25.58	-26.78	DEBV	R267	267
R268	38 38.38	75 33.40	29.0	980019.52	-26.12	-27.12	0.01	-26.12	-27.11	DEBV	R268	268
R269	38 38.47	75 34.19	24.0	980018.62	-27.62	-28.45	0.01	-27.62	-28.44	DEBV	R269	269
R270	38 39.17	75 35.21	19.0	980019.56	-28.18	-28.84	0.01	-28.18	-28.83	DEBV	R270	270
R271	38 44.50	75 32.63	35.0	980027.60	-26.48	-27.69	0.02	-26.48	-27.67	DEBV	R271	271
R272	38 44.44	75 31.27	42.0	980028.55	-24.78	-26.23	0.02	-24.78	-26.21	DEBV	R272	272
R273	38 44.51	75 30.60	43.0	980029.08	-24.26	-25.75	0.02	-24.26	-25.73	DEBV	R273	273
R274	38 43.47	75 33.29	44.0	980026.83	-22.89	-24.41	0.02	-22.89	-24.39	DEBV	R274	274
R275	38 42.65	75 29.20	37.0	980027.47	-23.99	-25.27	0.02	-23.99	-25.25	DEBV	R275	275
R276	38 43.57	75 32.11	42.0	980027.54	-24.51	-25.96	0.02	-24.51	-25.94	DEBV	R276	276
R277	38 43.62	75 33.62	43.0	980026.27	-25.76	-27.25	0.02	-25.76	-27.23	DEBV	R277	277
R278	38 41.55	75 33.38	29.0	980024.73	-25.54	-26.54	0.01	-25.54	-26.53	DEBV	R278	278
R279	38 39.21	75 34.26	22.0	980020.40	-27.12	-27.88	0.01	-27.12	-27.87	DEBV	R279	279
R280	38 39.35	75 35.07	36.0	980021.04	-25.37	-26.61	0.02	-25.37	-26.60	DEBV	R280	280
R281	38 38.96	75 32.34	29.0	980021.21	-25.28	-26.29	0.01	-25.28	-26.27	DEBV	R281	281
R282	38 40.65	75 33.06	35.0	980024.59	-24.12	-25.33	0.02	-24.12	-25.31	DEBV	R282	282
R283	38 41.13	75 31.91	32.0	980025.72	-23.68	-24.79	0.01	-23.68	-24.77	DEBV	R283	283
R284	38 40.42	75 32.83	35.0	980023.44	-24.64	-25.85	0.02	-24.64	-25.83	DEBV	R284	284
R285	38 41.48	75 33.64	24.0	980025.16	-25.51	-26.34	0.01	-25.51	-26.33	DEBV	R285	285
R286	38 39.83	75 37.27	36.0	980017.33	-29.78	-31.03	0.02	-29.78	-31.01	DEBV	R286	286
R287	38 39.13	75 37.19	31.0	980017.12	-29.44	-30.51	0.01	-29.44	-30.49	DEBV	R287	287
R288	38 40.01	75 37.23	35.0	980018.23	-30.13	-31.33	0.02	-30.13	-31.32	DEBV	R288	288

TABLE C-5.3

LISTING OF PRINCIPAL FACTS FOR GRAVITY MEASUREMENTS ACQUIRED BY VPI PERSONNEL IN SOUTH-CENTRAL DELAWARE.

THESE ARE GRAVITY MEASUREMENTS TAKEN BY R. MEIER OF V. P. I. IN
SOUTHEASTERN NEW JERSEY. ALL THE DATA WERE REFERENCED TO BASE
STATIONS USING BASE VALUES PROVIDED BY THE U. S. AIR FORCE. 13.71
MILLIGALS HAVE BEEN SUBTRACTED FROM EACH MEASUREMENTS IN ORDER TO CONVERT
THE DATA TO THE IGSN 1971.

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1978. OBSERVATIONS ON IGSN71. DATE: 29/06/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
P1	39 22.42	74 25.22	5.0	980108.61	-4.23	-4.40	0.00	-4.23	-4.40	NJPV	P1	1
P2	39 22.00	74 24.67	8.0	980107.37	-4.55	-4.83	0.00	-4.55	-4.82	NJPV	P2	2
P3	39 21.54	74 26.16	11.0	980106.69	-4.27	-4.65	0.00	-4.27	-4.64	NJPV	P3	3
P4	39 21.03	74 27.64	5.0	980106.35	-4.44	-4.61	0.00	-4.44	-4.61	NJPV	P4	4
P5	39 21.14	74 27.58	5.0	980107.49	-3.44	-3.61	0.00	-3.44	-3.61	NJPV	P5	5
P6	39 20.27	74 29.93	9.0	980105.22	-4.05	-4.36	0.00	-4.05	-4.36	NJPV	P6	6
P7	39 19.64	74 30.07	8.0	980103.06	-4.75	-5.03	0.00	-4.75	-5.03	NJPV	P7	7
P8	39 18.70	74 31.65	6.0	980102.07	-5.16	-5.37	0.00	-5.16	-5.37	NJPV	P8	8
P9	39 26.39	74 26.76	21.0	980125.01	7.82	7.10	0.01	7.82	7.11	NJPV	P9	9
P10	39 27.80	74 27.63	42.0	980128.91	11.61	10.16	0.02	11.61	10.18	NJPV	P10	10
P11	39 28.86	74 26.89	47.0	980132.61	14.21	12.59	0.02	14.21	12.61	NJPV	P11	11
P12	39 29.65	74 27.49	34.0	980137.70	16.94	15.77	0.02	16.94	15.78	NJPV	P12	12
P13	39 29.75	74 29.32	45.0	980138.69	18.79	17.23	0.02	18.79	17.25	NJPV	P13	13
P14	39 29.46	74 28.51	25.0	980136.44	17.09	16.22	0.01	17.09	16.23	NJPV	P14	14
P15	39 28.31	74 29.57	54.0	980132.70	15.78	13.91	0.02	15.78	13.93	NJPV	P15	15
P16	39 27.78	74 29.67	67.0	980129.70	14.78	12.47	0.03	14.78	12.50	NJPV	P16	16
P17	39 27.26	74 28.61	47.0	980127.53	11.50	9.88	0.02	11.50	9.90	NJPV	P17	17
P18	39 27.15	74 29.77	54.0	980123.16	12.69	11.03	0.02	12.69	11.05	NJPV	P18	18
P19	39 26.55	74 29.50	36.0	980125.74	9.73	8.48	0.02	9.73	8.50	NJPV	P19	19
P20	39 30.06	74 27.43	14.0	980140.59	17.31	16.83	0.01	17.31	16.84	NJPV	P20	20
P21	39 31.44	74 27.58	14.0	980145.33	20.01	19.53	0.01	20.01	19.54	NJPV	P21	21
P22	39 32.21	74 27.96	13.0	980148.26	21.71	21.26	0.01	21.71	21.27	NJPV	P22	22
P23	39 32.11	74 29.27	18.0	980147.36	21.43	20.81	0.01	21.43	20.81	NJPV	P23	23
P24	39 31.49	74 29.13	11.0	980146.28	20.61	20.23	0.00	20.61	20.23	NJPV	P24	24
P25	39 31.12	74 29.85	15.0	980144.76	20.01	19.49	0.01	20.01	19.50	NJPV	P25	25
P26	39 30.94	74 29.08	5.0	980145.11	19.69	19.51	0.00	19.69	19.52	NJPV	P26	26
P27	39 30.56	74 28.20	20.0	980142.65	19.17	18.48	0.01	19.17	18.49	NJPV	P27	27
P28	39 24.11	74 33.00	45.0	980118.07	6.51	4.96	0.02	6.51	4.98	NJPV	P28	28
P29	39 24.65	74 32.09	47.0	980120.76	8.32	6.70	0.02	8.32	6.72	NJPV	P29	29
P30	39 25.35	74 31.49	15.0	980124.62	8.63	8.12	0.01	8.63	8.12	NJPV	P30	30
P31	39 25.64	74 31.57	21.0	980130.25	12.69	11.97	0.01	12.69	11.99	NJPV	P31	31
P32	39 27.00	74 30.47	46.0	980131.24	14.61	13.02	0.02	14.61	13.04	NJPV	P32	32
P33	39 27.99	74 30.02	57.0	980131.84	15.67	13.70	0.03	15.67	13.73	NJPV	P33	33
P34	39 28.32	74 30.82	55.0	980133.90	17.06	15.15	0.02	17.06	15.18	NJPV	P34	34
P35	39 25.75	74 34.24	52.0	980127.10	13.77	11.98	0.02	13.77	12.00	NJPV	P35	35
P36	39 25.29	74 33.16	54.0	980123.09	11.43	9.57	0.02	11.43	9.59	NJPV	P36	36
P37	39 24.90	74 34.64	54.0	980124.10	12.22	10.35	0.02	12.22	10.38	NJPV	P37	37
P38	39 25.29	74 35.32	60.0	980125.65	13.76	11.68	0.03	13.76	11.71	NJPV	P38	38
P39	39 25.66	74 35.93	67.0	980125.95	14.17	11.83	0.03	14.17	11.86	NJPV	P39	39
P40	39 26.26	74 36.34	65.0	980126.32	13.43	11.19	0.03	13.43	11.22	NJPV	P40	40
P41	39 25.19	74 37.11	61.0	980124.74	13.09	10.98	0.03	13.09	11.01	NJPV	P41	41
P42	39 24.94	74 36.29	54.0	980125.07	13.13	11.26	0.02	13.13	11.29	NJPV	P42	42
P43	39 23.09	74 37.23	46.0	980120.05	10.09	8.50	0.02	10.09	8.52	NJPV	P43	43
P44	39 23.75	74 36.51	44.0	980121.94	10.82	9.30	0.02	10.82	9.32	NJPV	P44	44
P45	39 22.97	74 36.51	54.0	980117.51	8.88	7.02	0.02	8.86	7.04	NJPV	P45	45
P46	39 22.13	74 37.40	48.0	980115.71	7.36	5.70	0.02	7.36	5.72	NJPV	P46	46
P47	39 21.84	74 36.55	57.0	980112.91	5.84	3.87	0.03	5.84	3.89	NJPV	P47	47
P48	39 21.80	74 35.51	30.0	980114.10	4.46	3.42	0.01	4.46	3.43	NJPV	P48	48
P49	39 22.72	74 35.01	18.0	980117.19	5.15	4.52	0.01	5.15	4.53	NJPV	P49	49
P50	39 23.72	74 35.63	26.0	980122.17	9.42	8.52	0.01	9.42	8.53	NJPV	P50	50

TABLE C-5.3,continued

THE FOLLWING GRAVITY MEASUREMENTS WERE TAKEN BY J. A. DUNBAR,
D. HIGBY, AND R. W. MEIER OF VPI, WITH LACOSTE & ROMBERG GRAVITY
METERS G-2, G-58, AND G-107, BETWEEN JACKSONVILLE FL AND
SAVANNAH GA. THE MEASUREMENTS WERE REFERENCED TO THE GEORGIA
STATE GRAVITY NET, BULLETIN 86 OF THE GEORGIA DEPARTMENT
OF NATURAL RESOURCES (1976), WHICH WAS REFERRED TO THE POTSDAM
DATUM. A CONSTANT 13.71 MGAL WAS THEN SUBTRACTED
FROM THE OBSERVATIONS TO BRING THEM INTO AGREEMENT WITH IGSN-1971.

GRAVITY REDUCTIONS: GRAVITY MEASUREMENTS BETWEEN JACKSONVILLE FL. AND SAVANNAH GA. DATA ON IGSN71. DATE: 03/07/7[illegible]

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
10	30 39.66	81 53.03	46.0	979379.25	7.52	5.93	0.02	7.52	5.95	CAFL	10	1
20	30 41.63	81 54.81	56.0	979380.44	6.79	4.85	0.02	6.79	4.88	CAFL	20	2
30	30 43.82	81 56.27	96.0	979379.75	7.23	3.91	0.04	7.23	3.95	CAFL	30	3
40	30 43.59	81 59.27	77.0	979375.33	1.32	-1.34	0.03	1.32	-1.30	CAFL	40	4
50	30 40.95	81 58.72	82.0	979377.09	7.04	4.21	0.04	7.04	4.25	CAFL	50	5
60	30 41.02	81 55.42	92.0	979376.68	7.48	4.30	0.04	7.48	4.34	CAFL	60	6
70	30 39.21	81 55.45	84.0	979375.32	7.76	4.86	0.04	7.76	4.89	CAFL	70	7
80	30 37.44	81 58.11	78.0	979373.76	7.97	5.28	0.03	7.97	5.31	CAFL	80	8
90	30 34.81	81 58.44	77.0	979371.13	8.72	6.06	0.03	8.72	6.09	CAFL	90	9
100	30 33.61	81 56.55	75.0	979370.52	9.50	6.91	0.03	9.50	6.94	CAFL	100	10
110	30 33.27	81 53.48	72.0	979370.25	9.40	6.91	0.03	9.40	6.94	CAFL	110	11
120	30 41.67	81 50.76	17.0	979383.34	6.23	5.64	0.01	6.23	5.65	CAFL	120	12
130	30 41.73	81 49.26	25.0	979385.30	6.86	6.00	0.01	6.86	6.01	CAFL	130	13
140	30 41.99	81 46.65	12.0	979384.39	6.39	5.97	0.01	6.38	5.98	CAFL	140	14
150	30 44.00	81 47.19	19.0	979385.61	5.61	4.95	0.01	5.61	4.96	CAFL	150	15
160	30 39.60	81 47.76	24.0	979380.89	7.17	6.34	0.01	7.17	6.35	CAFL	160	16
170	30 38.14	81 45.76	12.0	979380.88	7.96	7.55	0.01	7.96	7.55	CAFL	170	17
180	30 37.65	81 49.21	21.0	979379.26	7.83	7.11	0.01	7.83	7.12	CAFL	180	18
190	30 37.76	81 50.78	22.0	979379.10	7.62	6.86	0.01	7.62	6.87	CAFL	190	19
200	30 36.61	81 44.02	12.0	979380.77	9.87	9.45	0.01	9.87	9.46	CAFL	200	20
210	30 36.79	81 40.33	16.0	979382.65	11.87	11.32	0.01	11.87	11.32	CAFL	210	21
220	30 37.21	81 39.01	23.0	979384.74	14.08	13.29	0.01	14.08	13.30	CAFL	220	22
230	30 31.17	81 39.24	23.0	979377.36	14.67	13.87	0.01	14.68	13.89	CAFL	230	23
240	30 28.03	81 40.13	25.0	979374.97	16.60	15.73	0.01	16.60	15.74	CAFL	240	24
250	30 27.13	81 41.63	22.0	979373.31	15.77	15.01	0.01	15.77	15.02	CAFL	250	25
260	30 29.17	81 43.15	23.0	979374.79	14.73	13.93	0.01	14.73	13.94	CAFL	260	26
270	30 36.60	81 35.70	35.0	979384.52	15.80	14.59	0.02	15.80	14.60	YUFL	270	27
280	30 34.44	81 36.57	11.0	979382.14	14.01	13.63	0.00	14.01	13.63	YUFL	280	28
290	30 31.04	81 37.39	33.0	979376.35	14.77	13.63	0.01	14.77	13.64	YUFL	290	29
300	30 26.63	81 36.91	13.0	979373.81	16.15	15.70	0.01	16.15	15.71	YUFL	300	30
310	30 27.76	81 33.74	21.0	979373.41	15.02	14.29	0.01	15.02	14.30	YUFL	310	31
320	30 30.21	81 34.69	24.0	979375.91	14.57	13.74	0.01	14.57	13.75	YUFL	320	32
330	30 29.52	81 32.02	24.0	979374.46	14.03	13.20	0.01	14.03	13.21	YUFL	330	33
340	30 27.56	81 28.45	9.0	979370.52	11.23	10.92	0.00	11.23	10.93	YUFL	340	34
350	30 29.67	81 28.32	11.0	979374.68	12.83	12.45	0.00	12.83	12.46	YUFL	350	35
360	30 29.03	81 30.24	19.0	979376.21	16.00	15.34	0.01	16.00	15.35	YUFL	360	36
370	30 37.57	81 32.85	31.0	979384.04	13.66	12.59	0.01	13.66	12.60	YUFL	370	37
380	30 36.84	81 31.07	13.0	979387.70	16.59	16.14	0.01	16.59	16.15	YUFL	380	38
390	30 34.50	81 31.12	20.0	979382.04	14.60	13.90	0.01	14.60	13.91	YUFL	390	39
400	30 38.37	81 27.51	16.0	979391.12	18.27	17.72	0.01	18.27	17.73	YUFL	400	40
410	30 40.66	81 20.75	26.0	979394.64	19.71	18.81	0.01	19.71	18.82	YUFL	410	41
420	30 38.31	81 26.21	16.0	979391.41	18.64	18.09	0.01	18.64	18.10	YUFL	420	42
430	30 35.55	81 27.51	18.0	979384.73	15.79	15.17	0.01	15.79	15.18	YUFL	430	43
440	30 32.55	81 26.65	8.0	979379.01	13.09	12.81	0.00	13.09	12.81	YUFL	440	44
450	30 27.04	81 24.96	12.0	979367.26	8.97	8.55	0.01	8.97	8.56	YUFL	450	45
460	30 24.17	81 25.93	7.0	979361.47	6.48	6.24	0.00	6.48	6.24	YUFL	460	46
470	30 23.96	81 28.59	6.0	979357.00	2.19	1.98	0.00	2.19	1.99	YUFL	470	47
480	30 24.71	81 25.48	5.0	979367.23	11.34	11.17	0.00	11.34	11.17	YUFL	480	48
490	30 25.04	81 28.36	19.0	979370.08	15.07	14.42	0.01	15.07	14.43	YUFL	490	49
500	30 38.15	81 38.04	23.0	979380.70	14.80	14.01	0.01	14.80	14.02	YUFL	500	50

TABLE C-53, continued

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1978. OBSERVATIONS ON IGSN71. DATE: 29/06/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
P101	39 10.97	74 43.64	26.0	980062.07	-11.86	-12.76	0.01	-11.86	-12.75	NJCM	P101	101
P102	39 12.43	74 42.37	25.0	980087.09	-9.28	-10.03	0.01	-9.28	-10.07	NJCM	P102	102
P103	39 11.96	74 43.29	25.0	980085.57	-10.11	-10.90	0.01	-10.11	-10.89	NJCM	P103	103
P104	39 11.46	74 44.22	25.0	980083.96	-10.98	-11.77	0.01	-10.98	-11.76	NJCM	P104	104
P105	39 10.67	74 45.73	22.0	980081.59	-12.28	-13.04	0.01	-12.28	-13.03	NJCM	P105	105
P106	39 10.41	74 46.28	23.0	980080.80	-12.59	-13.38	0.01	-12.59	-13.37	NJCM	P106	106
P107	39 10.09	74 45.93	27.0	980079.30	-13.24	-14.17	0.01	-13.24	-14.16	NJCM	P107	107
P108	39 9.72	74 46.03	24.0	980073.22	-13.96	-14.79	0.01	-13.96	-14.78	NJCM	P108	108
P109	39 6.10	74 49.19	20.0	980069.73	-17.58	-18.27	0.01	-17.58	-18.26	NJCM	P109	109
P110	39 7.67	74 49.41	13.0	980073.22	-17.07	-17.52	0.01	-17.07	-17.51	NJCM	P110	110
P111	39 8.32	74 50.97	17.0	980075.29	-15.58	-16.17	0.01	-15.58	-16.16	NJCM	P111	111
P112	39 10.24	74 49.29	17.0	980080.80	-12.90	-13.49	0.01	-12.90	-13.48	NJCM	P112	112
P113	39 11.52	74 49.47	13.0	980085.78	-10.19	-10.64	0.01	-10.19	-10.63	NJCM	P113	113
P114	39 14.30	74 45.91	31.0	980093.30	-5.08	-6.15	0.01	-5.08	-6.14	NJCM	P114	114
P115	39 14.92	74 44.38	24.0	980095.91	-4.04	-4.87	0.01	-4.04	-4.86	NJCM	P115	115
P116	39 14.90	74 45.70	25.0	980095.88	-3.95	-4.81	0.01	-3.95	-4.80	NJCM	P116	116
P117	39 13.25	74 46.80	38.0	980089.36	-6.81	-8.12	0.02	-6.81	-8.11	NJCM	P117	117
P118	39 14.03	74 47.49	40.0	980091.91	-5.22	-6.61	0.02	-5.22	-6.59	NJCM	P118	118
P119	39 14.45	74 48.39	38.0	980093.77	-4.17	-5.49	0.02	-4.17	-5.47	NJCM	P119	119
P120	39 13.71	74 49.44	35.0	980091.53	-5.60	-6.81	0.02	-5.60	-6.80	NJCM	P120	120
P121	39 13.36	74 50.04	27.0	980091.10	-6.27	-7.20	0.01	-6.27	-7.19	NJCM	P121	121
P122	39 12.40	74 50.95	17.0	980088.46	-8.43	-9.02	0.01	-8.43	-9.01	NJCM	P122	122
P123	39 12.04	74 51.29	14.0	980087.62	-9.02	-9.51	0.01	-9.02	-9.50	NJCM	P123	123
P124	39 6.11	74 50.12	19.0	980070.12	-17.30	-17.96	0.01	-17.30	-17.95	NJCM	P124	124
P125	39 5.41	74 49.90	19.0	980067.84	-18.55	-19.20	0.01	-18.55	-19.20	NJCM	P125	125
P126	39 5.36	74 50.75	19.0	980067.58	-18.73	-19.39	0.01	-18.73	-19.38	NJCM	P126	126
P127	39 5.40	74 52.80	19.0	980067.90	-18.41	-19.07	0.01	-18.41	-19.06	NJCM	P127	127
P128	39 5.00	74 51.75	13.0	980067.42	-18.93	-19.38	0.01	-18.93	-19.37	NJCM	P128	128
P129	39 4.98	74 50.78	19.0	980066.68	-19.07	-19.73	0.01	-19.07	-19.72	NJCM	P129	129
P130	39 4.42	74 49.49	18.0	980065.34	-19.68	-20.30	0.01	-19.68	-20.29	NJCM	P130	130
P131	39 4.63	74 52.20	12.0	980067.20	-18.99	-19.40	0.01	-18.99	-19.40	NJCM	P131	131
P132	39 3.69	74 52.17	16.0	980064.15	-19.98	-20.54	0.01	-19.98	-20.53	NJCM	P132	132
P133	39 3.37	74 50.76	19.0	980062.42	-20.96	-21.61	0.01	-20.96	-21.61	NJCM	P133	133
P134	39 4.18	74 50.35	23.0	980064.17	-20.03	-20.82	0.01	-20.03	-20.81	NJCM	P134	134
P135	39 4.31	74 49.54	18.0	980064.56	-20.30	-20.92	0.01	-20.30	-20.91	NJCM	P135	135
P136	39 1.41	74 53.76	16.0	980058.41	-22.36	-22.91	0.01	-22.36	-22.91	NJCM	P136	136
P137	39 1.13	74 54.03	21.0	980057.34	-22.55	-23.27	0.01	-22.55	-23.26	NJCM	P137	137
P138	39 0.99	74 54.07	9.0	980057.79	-23.02	-23.33	0.00	-23.02	-23.33	NJCM	P138	138
P139	39 1.00	74 55.42	6.0	980058.67	-22.35	-22.56	0.00	-22.35	-22.56	NJCM	P139	139
P140	39 1.35	74 56.05	17.0	980058.88	-21.71	-22.30	0.01	-21.71	-22.29	NJCM	P140	140
P141	39 2.12	74 55.98	9.0	980061.32	-21.16	-21.47	0.00	-21.16	-21.46	NJCM	P141	141
P142	39 2.55	74 55.49	7.0	980062.70	-20.60	-20.84	0.00	-20.60	-20.84	NJCM	P142	142
P143	39 2.77	74 54.09	16.0	980062.36	-20.42	-20.97	0.01	-20.42	-20.96	NJCM	P143	143
P144	39 2.57	74 51.32	20.0	980060.75	-21.35	-22.05	0.01	-21.35	-22.04	NJCM	P144	144
P145	39 1.78	74 51.77	19.0	980058.57	-22.46	-23.12	0.01	-22.46	-23.11	NJCM	P145	145
P146	39 0.00	74 52.80	17.0	980056.09	-23.39	-23.98	0.01	-23.39	-23.97	NJCM	P146	146
P147	39 0.08	74 53.56	17.0	980055.00	-23.72	-24.30	0.01	-23.72	-24.30	NJCM	P147	147
P148	38 59.66	74 53.85	17.0	980054.62	-23.77	-24.36	0.01	-23.77	-24.35	NJCM	P148	148
P149	38 59.41	74 53.71	14.0	980053.98	-24.03	-24.51	0.01	-24.03	-24.51	NJCM	P149	149
P150	38 57.78	74 55.53	15.0	980052.21	-23.30	-23.82	0.01	-23.30	-23.81	NJCM	P150	150

TABLE C-5.3, continued

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1973. OBSERVATIONS ON IGSN71. DATE: [illegible]

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	TC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
P51	39 24.61	74 35.24	46.0	980124.23	12.05	10.44	0.02	12.03	10.46	NJPV	P51	51
P52	39 24.34	74 34.34	36.0	980122.38	9.65	8.39	0.02	9.63	8.41	NJPV	P52	52
P53	39 23.65	74 33.50	44.0	980117.16	6.19	4.67	0.02	6.19	4.69	NJPV	P53	53
P54	39 23.01	74 33.36	28.0	980115.11	3.56	2.61	0.01	3.56	2.62	NJPV	P54	54
P55	39 21.87	74 33.16	28.0	980111.40	1.61	0.65	0.01	1.61	0.66	NJPV	P55	55
P56	39 20.65	74 34.14	25.0	980109.11	0.35	-0.46	0.01	0.33	-0.45	NJPV	P56	56
P57	39 19.51	74 35.24	28.0	980105.17	-1.38	-2.28	0.01	-1.38	-2.26	NJPV	P57	57
P58	39 18.86	74 35.75	31.0	980102.29	-1.56	-2.93	0.01	-1.66	-2.91	NJPV	P58	58
P59	39 13.71	74 36.50	10.0	980105.05	-1.76	-2.15	0.00	-1.78	-2.12	NJPV	P59	59
P60	39 19.14	74 36.25	6.0	980107.69	0.01	-0.20	0.00	0.01	-0.20	NJPV	P60	60
P61	39 20.34	74 38.27	7.0	980112.15	2.59	2.35	0.00	2.59	2.35	NJPV	P61	61
P62	39 21.47	74 39.35	32.0	980113.13	6.25	5.14	0.01	6.25	5.16	NJPV	P62	62
P63	39 21.64	74 40.45	25.0	980113.36	8.57	7.71	0.01	8.57	7.72	NJPV	P63	63
P64	39 21.35	74 41.28	22.0	980118.32	8.68	7.92	0.01	8.68	7.93	NJPV	P64	64
P65	39 21.07	74 40.77	13.0	980117.24	7.15	6.72	0.01	7.16	6.72	NJPV	P65	65
P66	39 20.63	74 39.13	12.0	980113.91	4.39	3.98	0.01	4.39	3.98	NJPV	P66	66
P67	39 20.75	74 36.35	20.0	980111.11	2.20	1.50	0.01	2.20	1.51	NJPV	P67	67
P68	39 20.34	74 35.96	7.0	980109.96	0.42	0.16	0.00	0.42	0.16	NJPV	P68	68
P69	39 21.32	74 35.03	21.0	980111.91	2.22	1.49	0.01	2.22	1.50	NJPV	P69	69
P70	39 24.24	74 30.70	34.0	980117.00	4.21	3.04	0.02	4.21	3.05	NJPV	P70	70
P71	39 23.39	74 31.47	22.0	980115.03	2.37	1.61	0.01	2.37	1.62	NJPV	P71	71
P72	39 16.87	74 34.79	6.0	980098.69	-5.84	-6.04	0.00	-5.84	-6.04	NJPV	P72	72
P73	39 16.91	74 33.94	12.0	980098.24	-5.76	-6.20	0.01	-5.76	-6.19	NJPV	P73	73
P74	39 16.35	74 35.15	6.0	980097.49	-6.27	-6.45	0.00	-6.27	-6.47	NJPV	P74	74
P75	39 15.54	74 35.83	6.0	980096.38	-6.63	-6.83	0.00	-6.63	-6.83	NJPV	P75	75
P76	39 15.07	74 36.66	6.0	980094.65	-7.22	-7.43	0.00	-7.22	-7.42	NJPV	P76	76
P77	39 14.00	74 37.05	4.0	980093.42	-7.94	-8.08	0.00	-7.94	-8.08	NJPV	P77	77
P78	39 13.92	74 37.68	7.0	980091.46	-8.62	-8.86	0.00	-8.62	-8.86	NJPV	P78	78
P79	39 13.45	74 38.06	7.0	980090.08	-9.30	-9.54	0.00	-9.30	-9.54	NJPV	P79	79
P80	39 12.01	74 39.23	7.0	980085.60	-11.46	-11.70	0.00	-11.46	-11.70	NJPV	P80	80
P81	39 10.85	74 40.31	6.0	980082.02	-13.62	-13.83	0.00	-13.62	-13.82	NJPV	P81	81
P82	39 10.18	74 40.80	5.0	980079.77	-14.97	-15.15	0.00	-14.97	-15.14	NJPV	P82	82
P83	39 9.25	74 41.84	6.0	980076.66	-16.42	-16.62	0.00	-16.42	-16.62	NJPV	P83	83
P84	39 8.00	74 41.91	6.0	980075.57	-17.04	-17.25	0.00	-17.04	-17.25	NJPV	P84	84
P85	39 16.91	74 37.92	22.0	980099.36	-3.62	-4.42	0.01	-3.63	-4.41	NJPV	P85	85
P86	39 16.17	74 38.63	25.0	980097.43	-4.23	-5.09	0.01	-4.23	-5.08	NJPV	P86	86
P87	39 15.87	74 39.18	32.0	980096.47	-4.13	-5.24	0.01	-4.13	-5.23	NJPV	P87	87
P88	39 15.35	74 39.97	32.0	980095.32	-4.49	-5.59	0.01	-4.49	-5.58	NJPV	P88	88
P89	39 15.69	74 40.25	14.0	980097.77	-4.26	-4.75	0.01	-4.26	-4.74	NJPV	P89	89
P90	39 15.60	74 41.50	7.0	980098.71	-3.85	-4.09	0.00	-3.85	-4.09	NJPV	P90	90
P91	39 15.57	74 43.86	24.0	980099.15	-2.21	-3.04	0.01	-2.21	-3.03	NJPV	P91	91
P92	39 15.51	74 44.05	30.0	980098.90	-2.80	-4.04	0.02	-2.80	-4.02	NJPV	P92	92
P93	39 13.43	74 42.31	18.0	980090.06	-7.44	-8.06	0.01	-7.44	-8.05	NJPV	P93	93
P94	39 13.01	74 41.64	20.0	980088.92	-8.59	-9.28	0.01	-8.59	-9.27	NJPV	P94	94
P95	39 14.56	74 40.86	27.0	980093.66	-5.46	-6.41	0.01	-5.48	-6.40	NJPV	P95	95
P96	39 6.09	74 43.63	16.0	980066.69	-18.98	-19.54	0.01	-18.98	-19.53	NJCM	P96	96
P97	39 7.31	74 47.52	16.0	980071.91	-17.56	-18.12	0.01	-17.56	-18.11	NJCM	P97	97
P98	39 7.75	74 46.80	16.0	980072.69	-17.04	-17.67	0.01	-17.04	-17.66	NJCM	P98	98
P99	39 9.06	74 45.81	18.0	980076.66	-15.21	-15.83	0.01	-15.21	-15.82	NJCM	P99	99
P100	39 10.25	74 44.40	17.0	980080.15	-13.54	-14.13	0.01	-13.54	-14.12	NJCM	P100	100

TABLE C-5.3, continued

GRAVITY REDUCTIONS: GRAVITY DATA TAKEN BY R. MEIER OF V.P.I. IN MAY, 1978. OBSERVATIONS ON IGSN71. DATE: 29/06/78

STATION	LATITUDE	LONGITUDE	ELEV	OBS GRAV	(USGS) FREE-AIR	(USGS) BOUGUER	CC	(NOAA) FREE-AIR	(NOAA) BOUGUER	REFERENCE STATION	STATION	COUNT
P151	38 58.00	74 55.99	18.0	980052.24	-23.32	-23.94	0.01	-23.32	-23.93	NJCM	P151	151
P152	38 58.42	74 55.56	21.0	980052.68	-23.21	-23.94	0.01	-23.21	-23.93	NJCM	P152	152
P153	38 58.85	74 56.57	19.0	980053.41	-23.30	-23.96	0.01	-23.30	-23.95	NJCM	P153	153
P154	38 59.58	74 56.19	16.0	980054.85	-23.22	-23.78	0.01	-23.22	-23.77	NJCM	P154	154
P155	38 59.48	74 55.33	21.0	980054.17	-23.28	-24.01	0.01	-23.28	-24.00	NJCM	P155	155
P156	38 59.66	74 54.71	25.0	980054.14	-23.20	-24.07	0.01	-23.20	-24.06	NJCM	P156	156
P157	39 0.06	74 56.10	14.0	980055.83	-23.17	-23.65	0.01	-23.17	-23.64	NJCM	P157	157
P158	39 0.04	74 56.58	18.0	980056.38	-23.07	-23.69	0.01	-23.07	-23.68	NJCM	P158	158
P159	38 57.73	74 56.36	14.0	980052.32	-23.21	-23.70	0.01	-23.21	-23.69	NJCM	P159	159
P160	38 56.96	74 56.31	16.0	980051.60	-22.61	-23.16	0.01	-22.61	-23.16	NJCM	P160	160
P161	38 56.26	74 56.57	6.0	980051.63	-22.49	-22.70	0.00	-22.49	-22.69	NJCM	P161	161
P162	38 56.27	74 57.74	9.0	980051.33	-22.52	-22.83	0.00	-22.52	-22.83	NJCM	P162	162
P163	38 56.48	74 55.64	8.0	980051.75	-22.51	-22.78	0.00	-22.51	-22.78	NJCM	P163	163
P164	38 55.81	74 54.66	7.0	980050.76	-22.58	-22.82	0.00	-22.58	-22.82	NJCM	P164	164
P165	38 56.07	74 54.10	6.0	980050.73	-23.11	-23.32	0.00	-23.11	-23.31	NJCM	P165	165
P166	38 56.53	74 54.35	11.0	980051.22	-22.83	-23.21	0.00	-22.83	-23.20	NJCM	P166	166

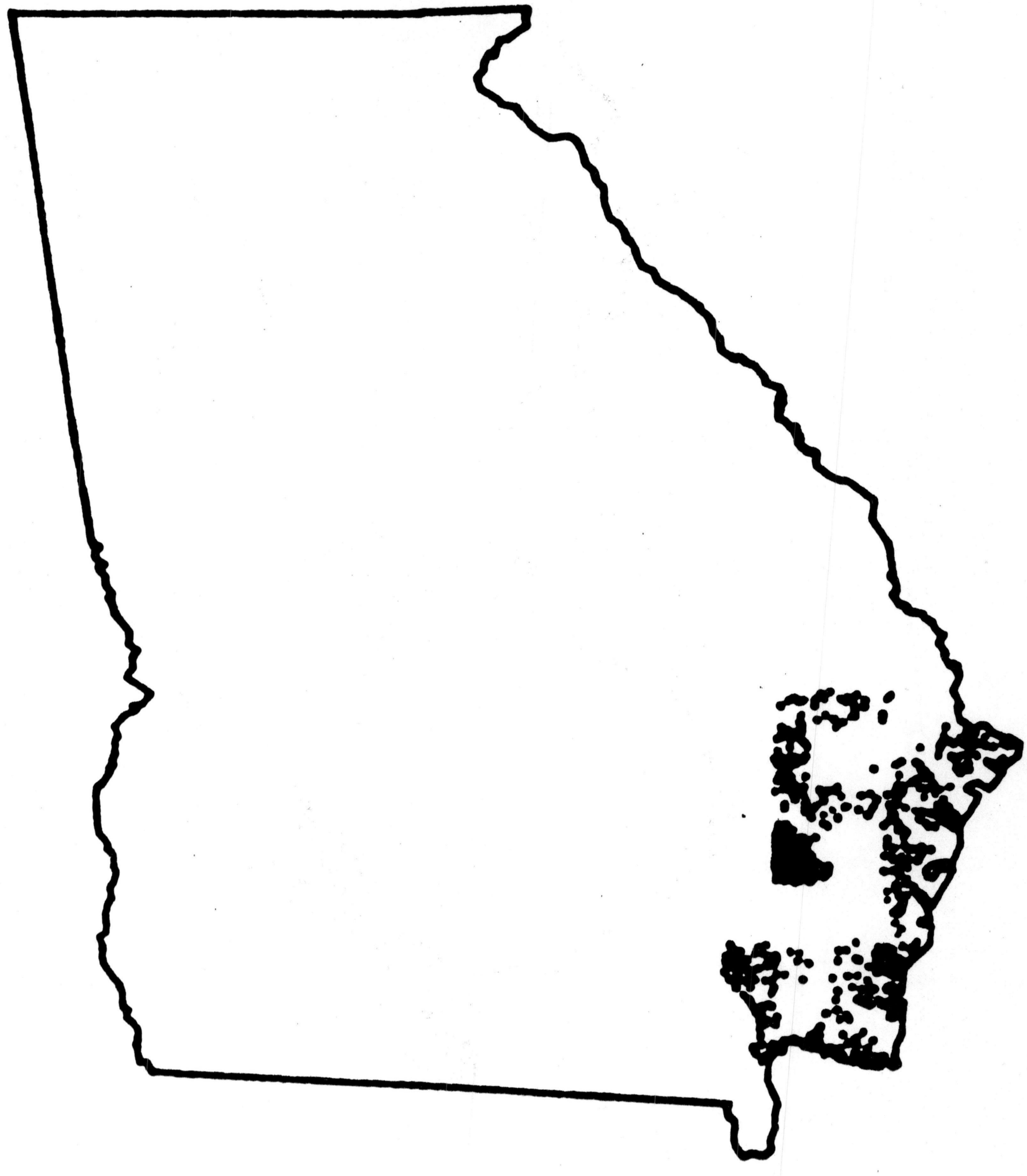


Figure C-5.1. Sketch map showing the distribution of gravity measurements acquired by VPI personnel in southeastern Georgia.

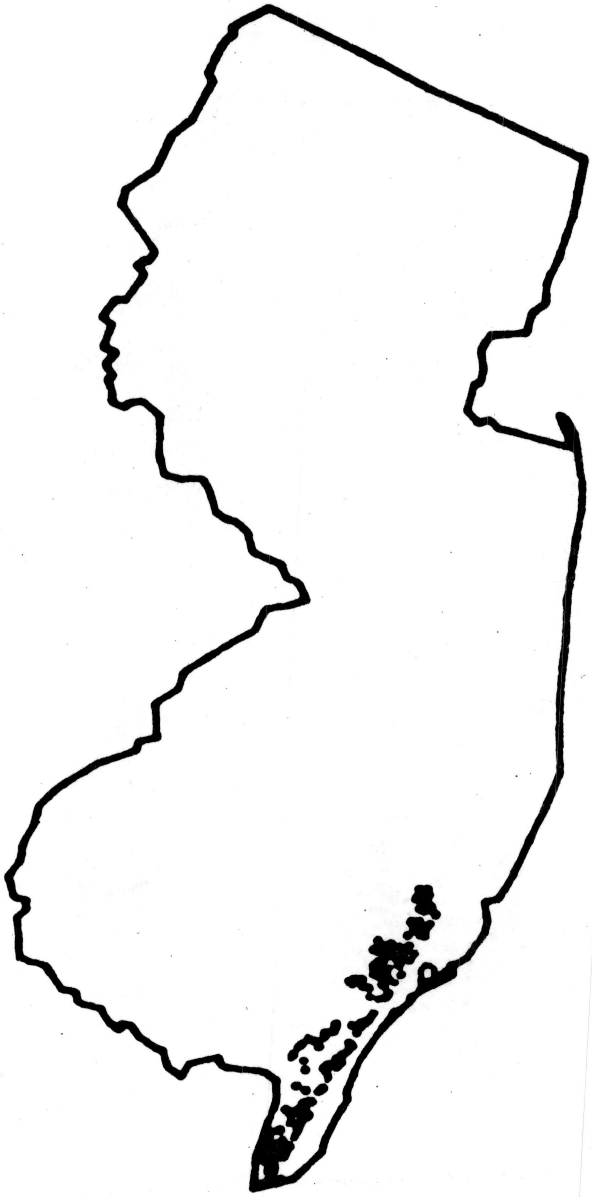


Figure C-5.2. Sketch map showing the distribution of gravity measurements acquired by VPI personnel in southeastern New Jersey.

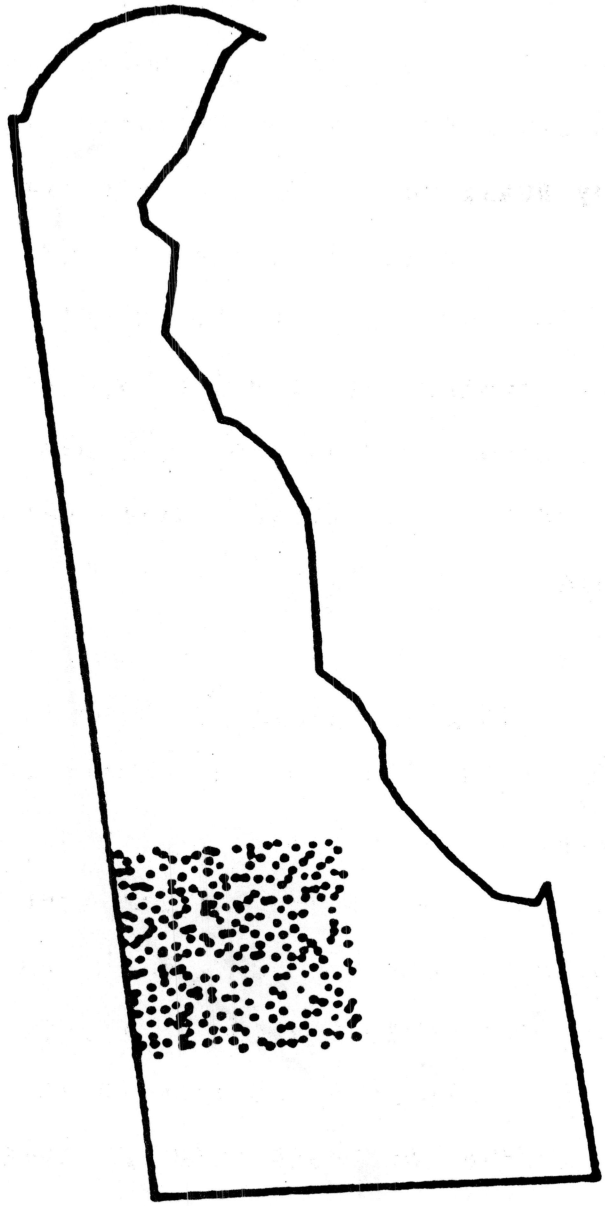


Figure C-5.3. Sketch map showing the distribution of gravity measurements acquired by VPI personnel in south-central Delaware.

Present Data Distribution

The present distribution of gravity measurements at our disposal is shown in Figures C-5.4 through C-5.10, each of which shows the distribution of gravity stations within the states of interest. For the states of North Carolina and Virginia, the distributions are essentially the same as those provided us by NOAA; that is, in those states we have not yet obtained a substantial number of additional measurements. We do not expect to obtain many new measurements in the states of New Jersey, Delaware, or Georgia during the coming months. However, major additions will be made in South Carolina, North Carolina, and southeastern Virginia.

Rolesville Batholith

The Rolesville batholith is a granitic batholith located near Raleigh, NC (VPI&SU-5103-3). Five holes have been drilled in this body for heat flow and heat production determinations. At least one of the results to date, that from drill hole RL1, is clearly inconsistent with the linear relation between heat flow and surface heat production observed elsewhere in the southeast (VPI&SU-5648-1, Figure C-14). A possible explanation for this is that the Rolesville batholith is abnormally deep beneath drill hole RL1. In order to estimate the depth of the batholith, we have initiated a gravity study of it. Results are as yet

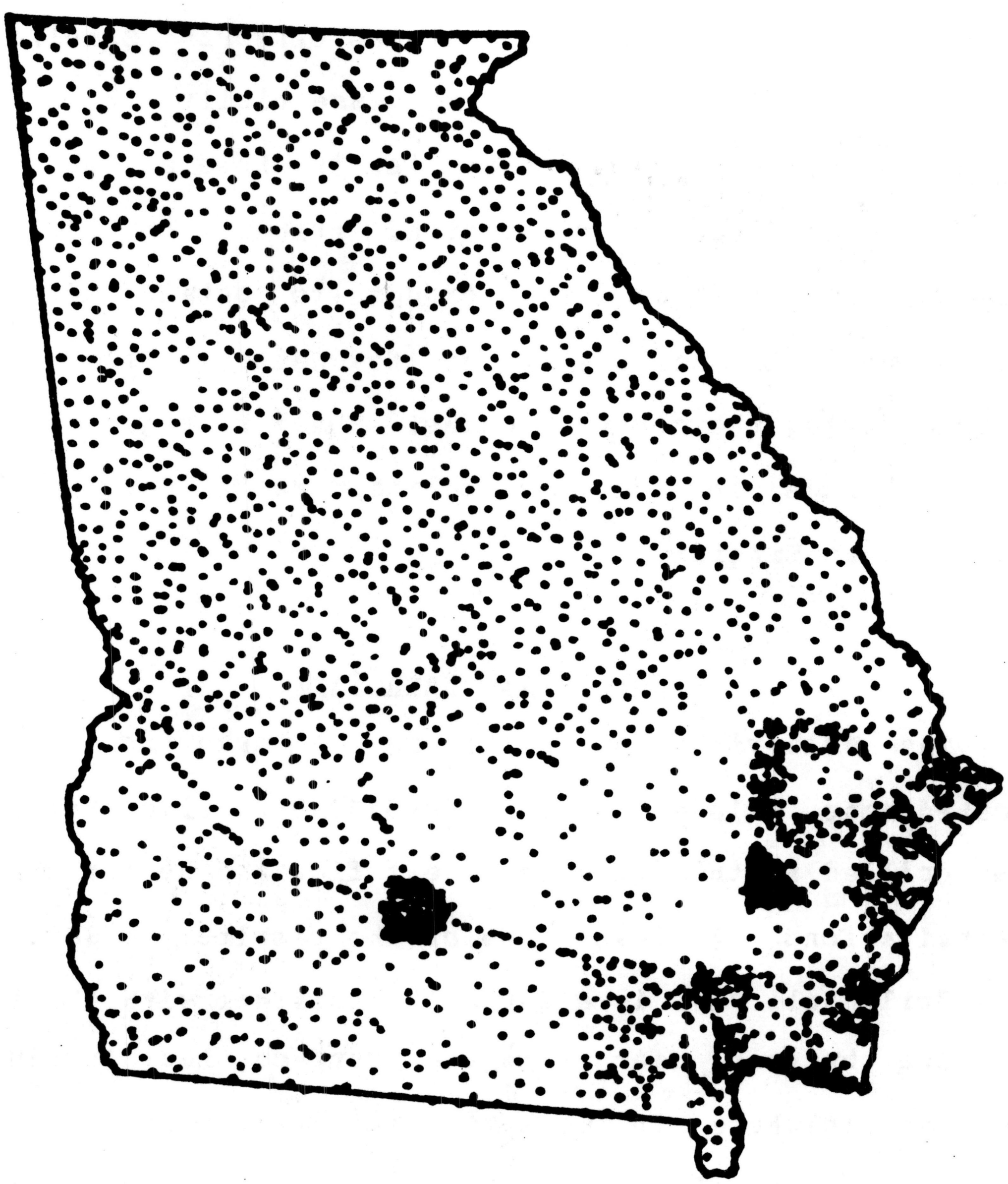


Figure C-5.4. Sketch map showing the distribution of gravity measurements available in Georgia.

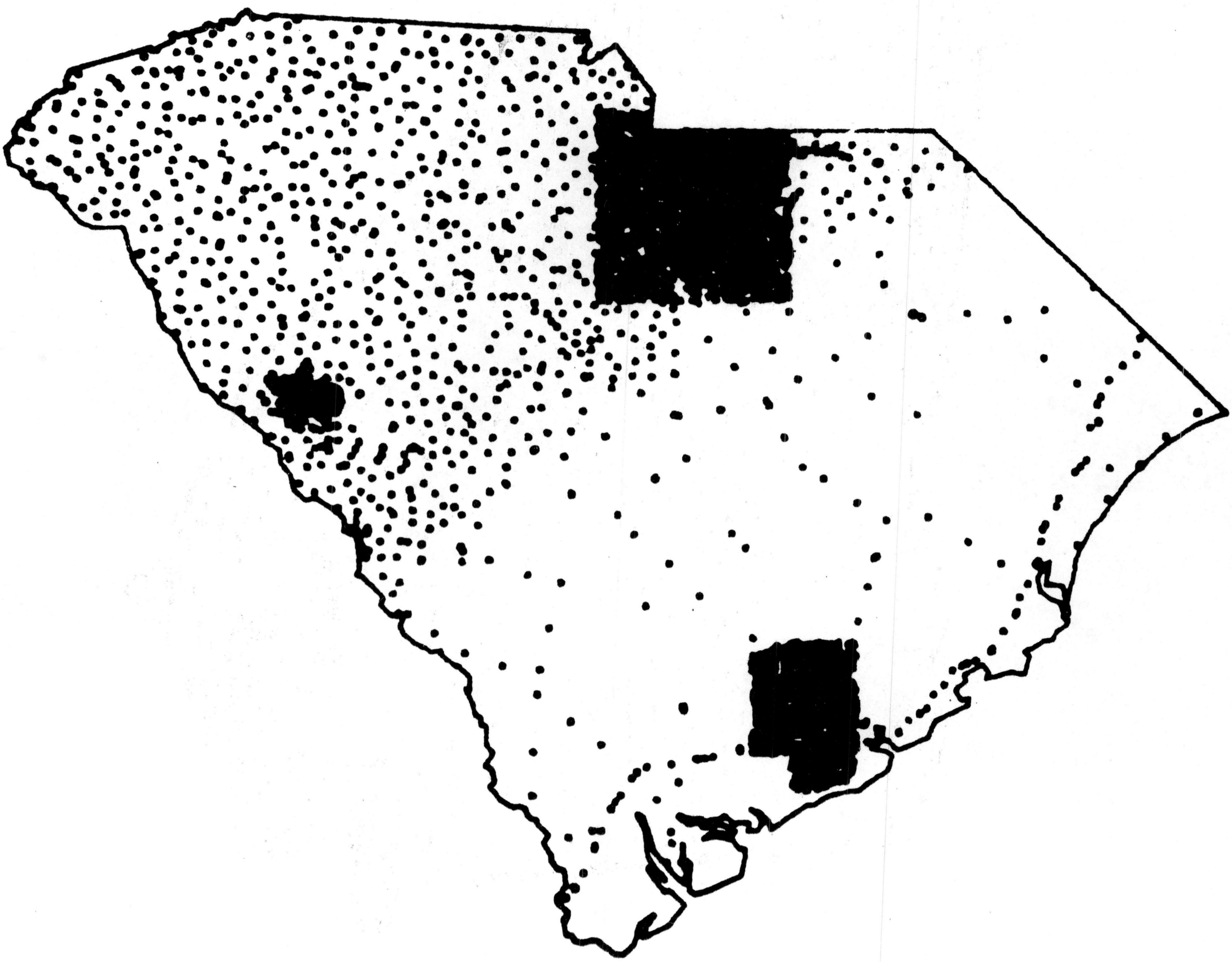


Figure C-5.5. Sketch map showing the distribution of gravity measurements available in South Carolina.

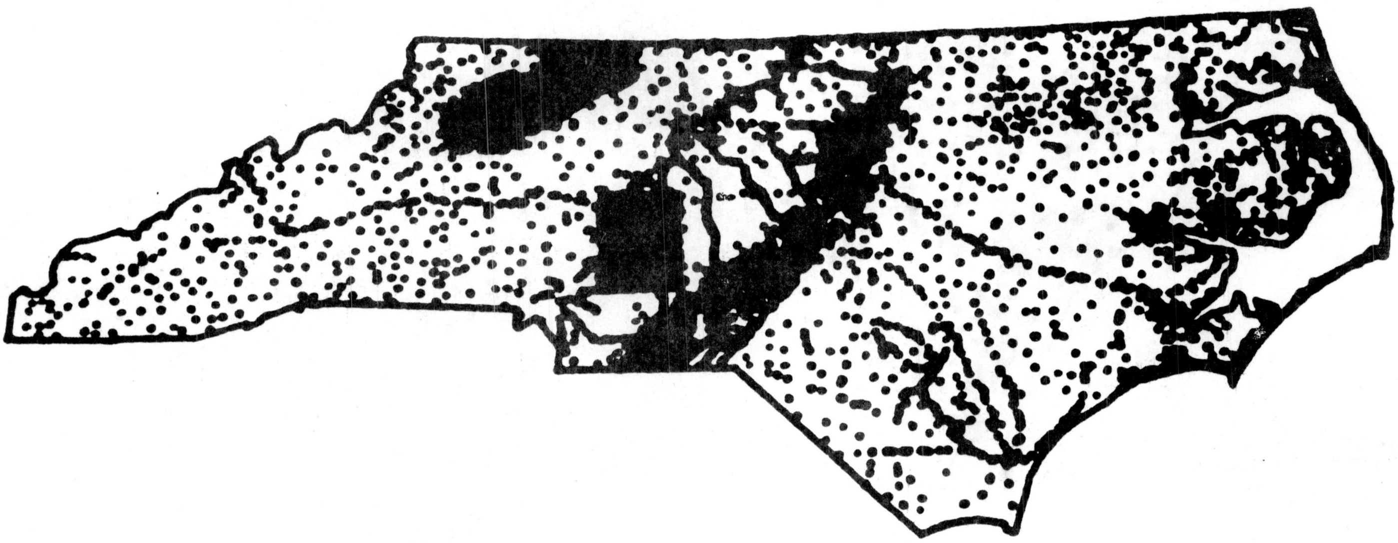


Figure C-5.6. Sketch map showing the distribution of gravity measurements available in North Carolina.

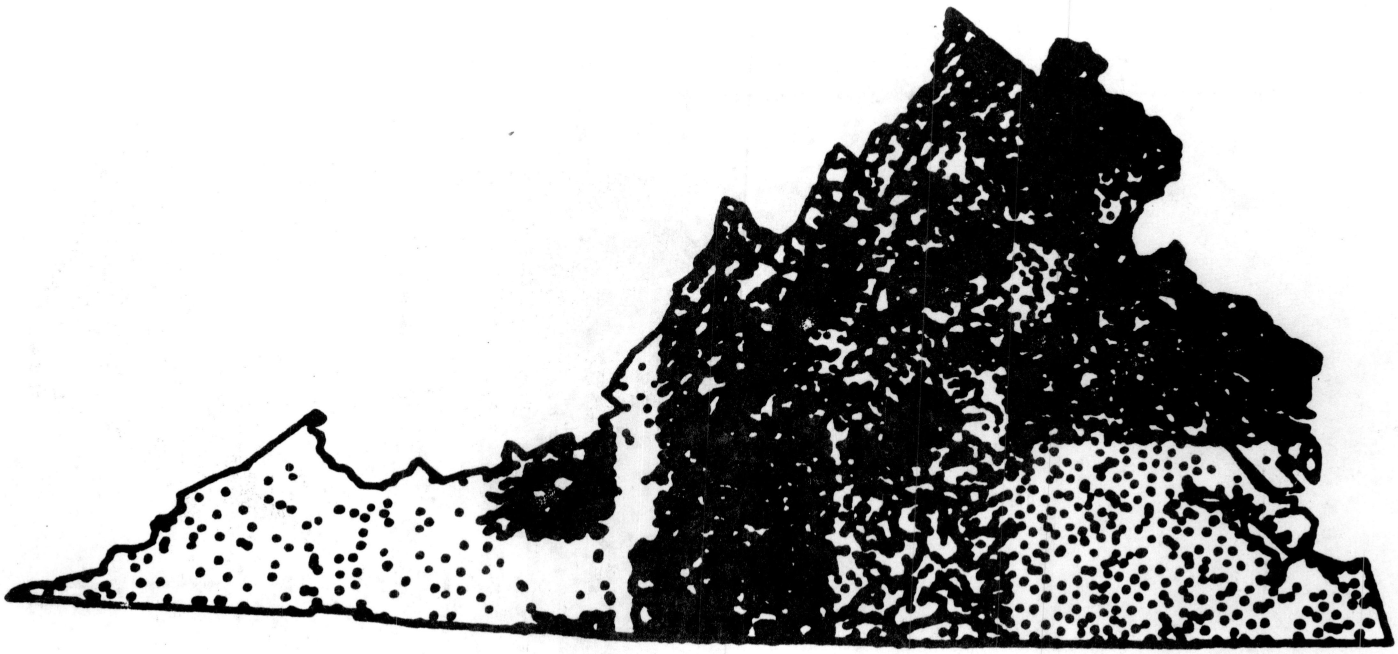


Figure C-5.7. Sketch map showing the distribution of gravity measurements available in Virginia (the Virginia portion of the Delmarva peninsula is not shown).

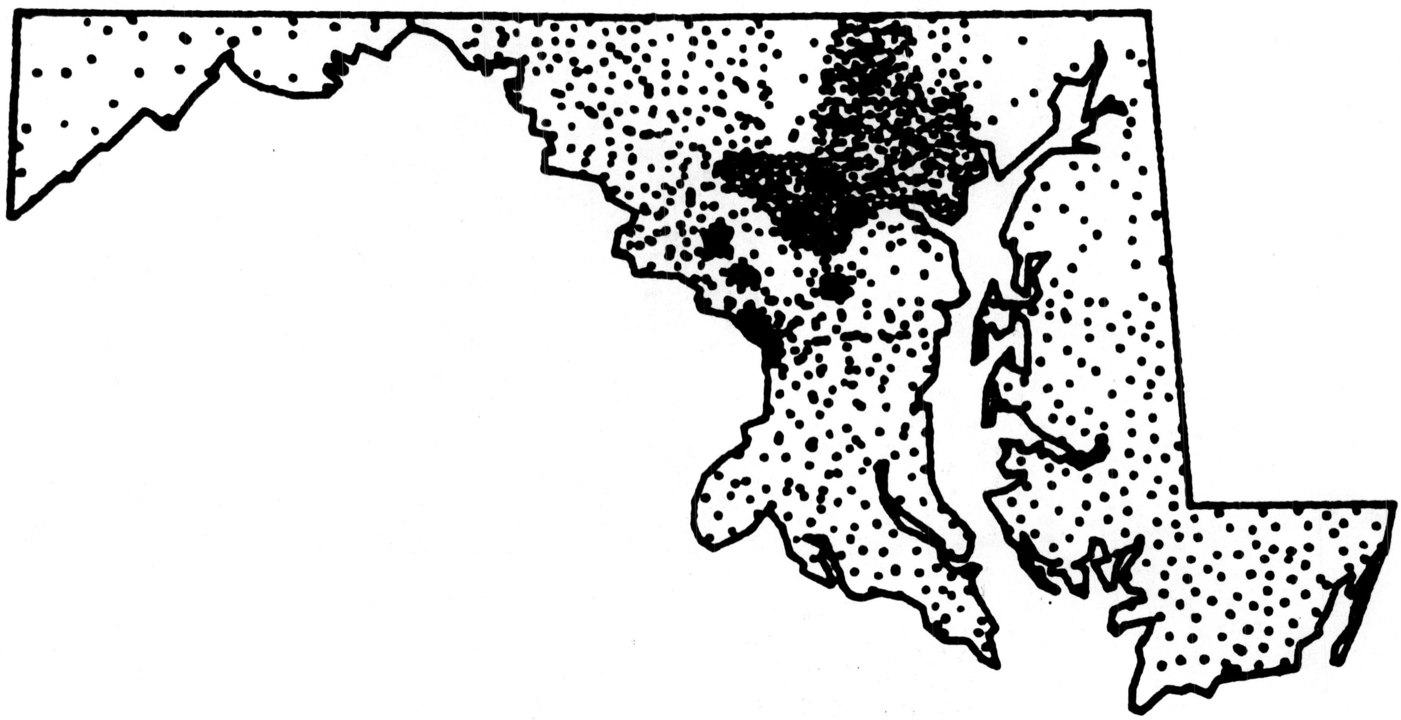


Figure C-5.8. Sketch map showing the distribution of gravity measurements in Maryland.

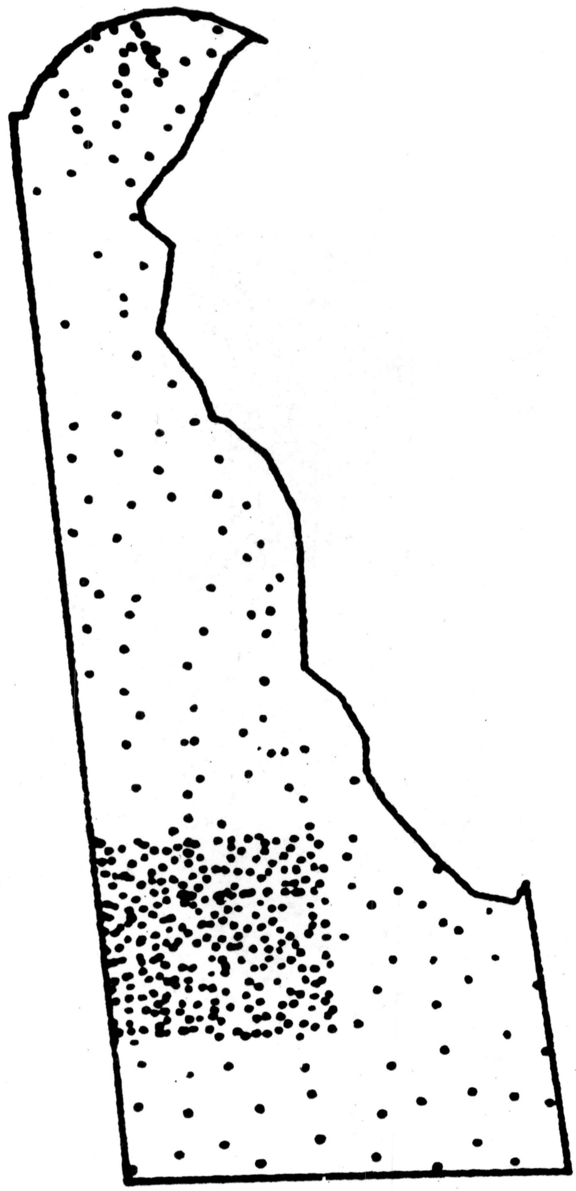


Figure C-5.9. Sketch map showing the distribution of gravity measurements in Delaware.

Figure C-5.10. Sketch map showing the distribution of gravity measurements in New Jersey.

incomplete, due in part to the absence of much data in the northern portion of the batholith, but some inferences concerning the total depth of much of the batholith may be made now.

Figure C-5.11 shows the contoured Bouguer gravity field in the vicinity of the batholith as well as the locations of the stations used to produce the map. Besides the obvious gravity minimum associated with the batholith, there exists an apparent gradient to the northwest in the regional Bouguer field. Initial efforts to estimate this regional trend were described in the previous progress report (VPI&SU-5648-1).

Further efforts along the same lines have led to the third-order trend-surface estimate of the regional Bouguer field shown in Figure C-5.12: this surface was calculated using the orthogonal polynomial scheme described previously (VPI&SU-5648-1). This particular surface predicts regional values of 0 to +12 mgal over the batholith. A simple, third-order, least-square's surface fit to the same data predicts values of -8 to +4 mgal over the batholith, but is otherwise roughly parallel to the surface of Figure C-5.12. This observation may be used to estimate the uncertainty of the estimated regional field as about 8 mgal. Thus, the maximum amplitude of the anomaly due to the batholith is probably ±8 mgal. This is admittedly a crude estimate of the uncertainty associated with the surface, but may be adequate for the analysis at hand.

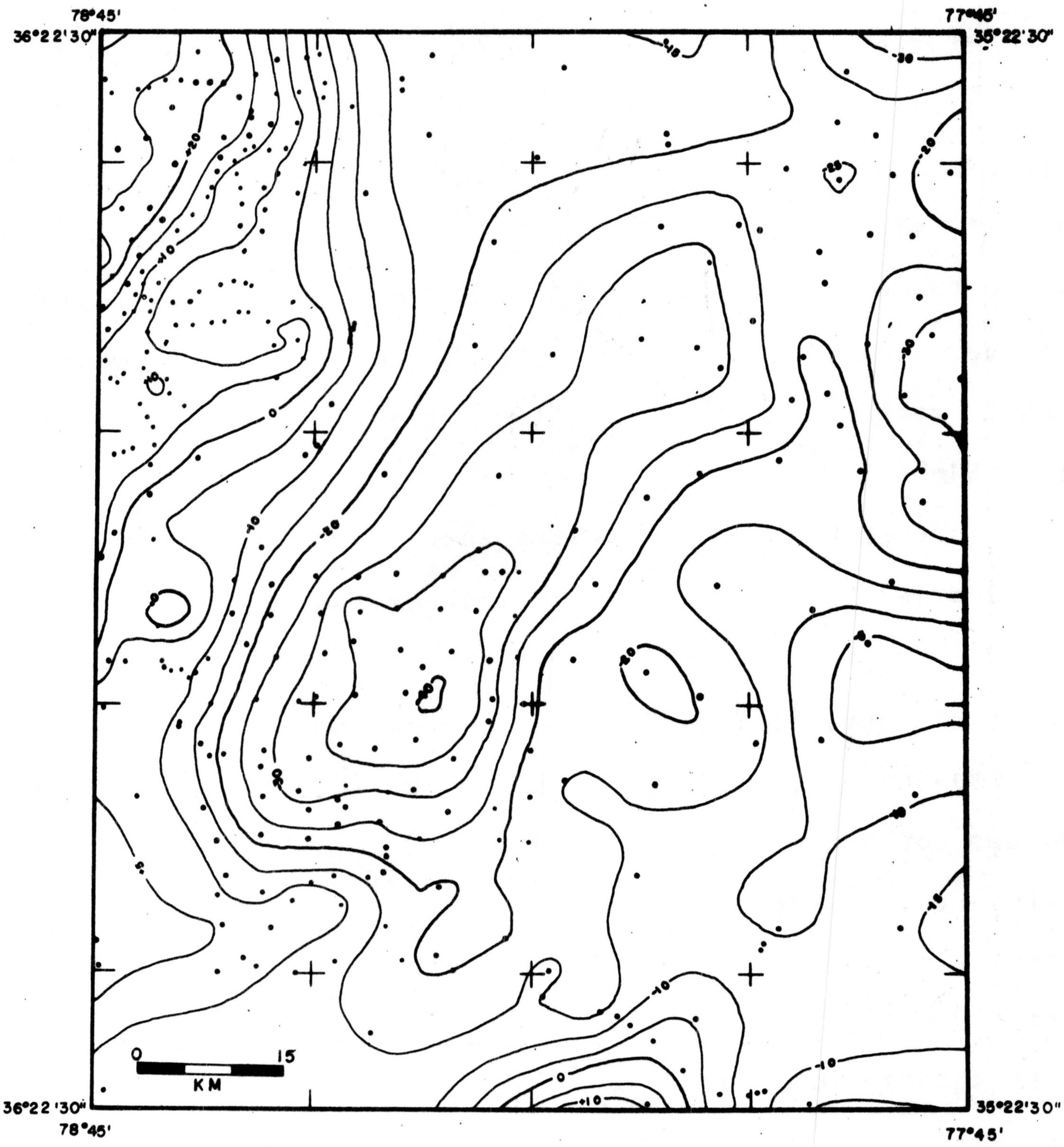


Figure C-5.11. Bouguer gravity field in the vicinity of the Rolesville batholith; dots indicate measurement locations.

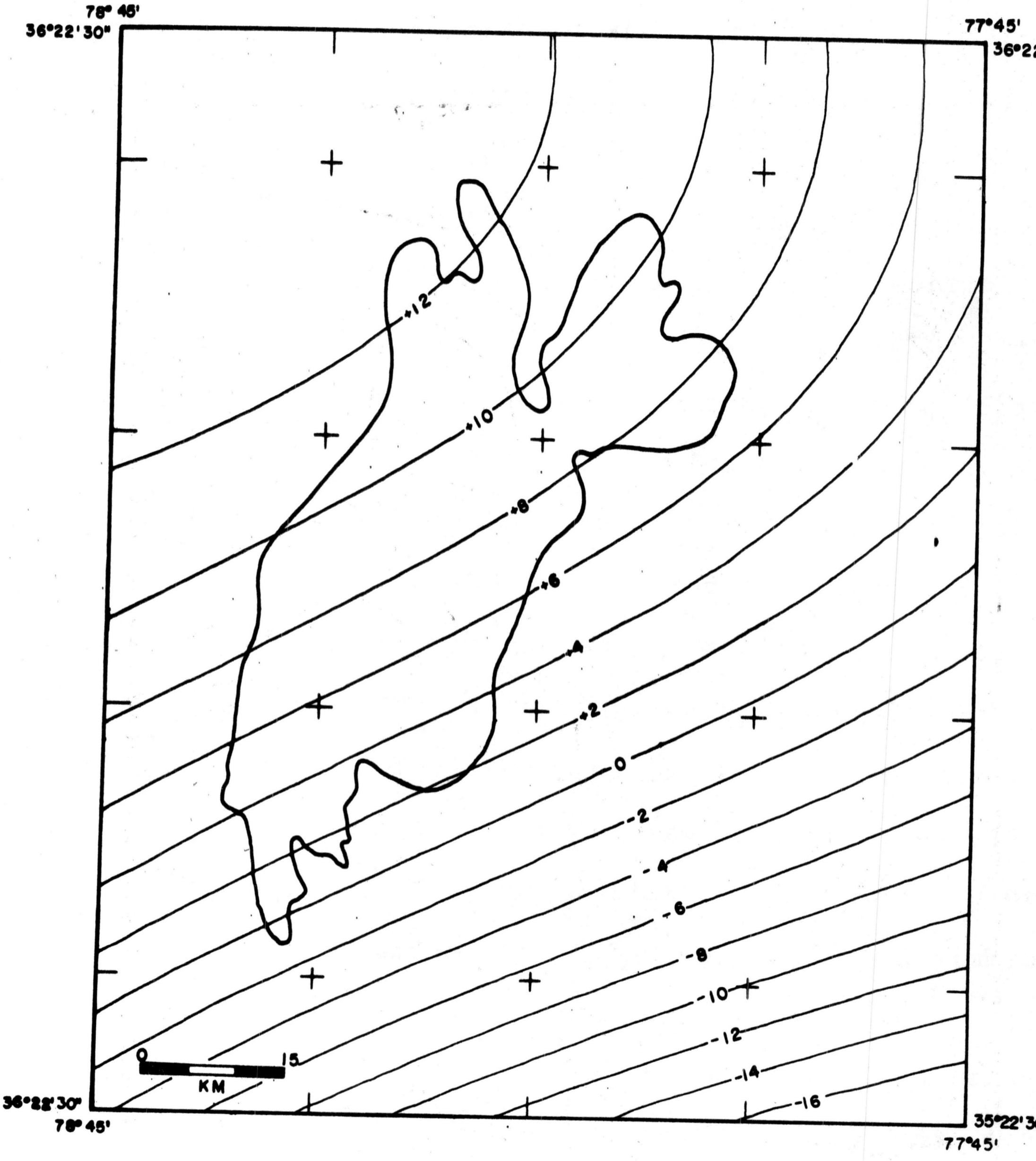


Figure C-5.12. Third-order trend surface of the Bouguer gravity field in the vicinity of the Rolesville batholith. Bold outline is the exposed portion of the batholith.

Density Contrast. A major difficulty in the interpretation of the batholith is the lack of information regarding the appropriate density contrast between the bathclith and its host rocks. This stems chiefly from our poor knowledge of the distribution of the major lithic units surrounding the batholith; the densities of the batholithic rocks themselves are known rather well from the drill cores and surface samples and group rather closely about 2.65 gm/cm^3. The lithologies of the country rocks include pelitic schists, granitic gneisses, mafic and felsic metavclcanic rocks, and amphibolites. Densities measured on surface samples of these rocks range from 2.64-2.91 gm/cm^3, the higher densities being from the amphibolites. The area of exposed amphibolites is relatively small in proportion to that of all the country rocks. For this reason the amphibolites are presumed to constitute a negligible amount of the near-surface mass. This assumption restricts the range of allowable densities for the country rocks to the interval 2.64-2.85 gm/cm^3. The actual density probably falls somewhere within this interval but may vary systematically from one locality to another. Clearly, though, the bulk density of the country rocks must exceed 2.65 gm/cm^3 in order to generate the -43 mgal anomaly which characterizes the Rolesville. In the absence of further information concerning the host rocks, the density contrast is only restricted to the interval 0 to -0.2 gm/cm^3.

<u>Comparison with heat flow measurements</u>. If we assume that the density contrast/heat production contrast in the Rolesville batholith is constant, then the ratio of heat flow anomaly/gravity anomaly must also remain fixed, because both the heat flow field and the gravity field depend upon the geometrical configuration of the source body in the same manner (Simmons, 1967). Although we have no reason to expect variations in heat production contrast to reflect variations in density contrast, the simple case of a single source body having a constant heat production and constant density is a case to which we can apply the result noted above. Regarding the case at hand, we may apply the heat flow gravity field relation to the Rolesville batholith if the following conditions hold true:

(1) both heat production and density contrast are uniform throughout the batholith,

(2) heat production within the country rocks is slowly-varying or constant,

(3) reliable estimates for both the heat flux from the lower crust and the heat flux due to heat production within the country rocks are available.

The major obstacles to the application of this method to our problem lie in the assumption that the density <u>contrast</u> is uniform throughout the batholith and that we are able to estimate the contribution, measured over the batholith, to the heat flow field from the surrounding country rocks.

Violation of the uniform density contrast rule does not seriously affect our results, provided that the density contrast varies slowly. Estimating the heat flow over the batholith due to heat production within the country rock is more critical, but, unfortunately, there exist few heat production measurements away from granitic plutons. Presumably the heat production within the country rocks is smaller than within the granitic rocks: we have assumed heat production values of 2.5 HGU for the country rocks.

The relationship between the heat flow field, measured upon or near the earth's surface, and the gravity field is (Simmons, 1967)

$$q(x) = (2\pi G)^{-1} (A/\rho)\ g(x) \qquad *$$

where

q = vertical component of the rate of heat flux through the earth's surface due to the source,

G = Newton's gravitational constant,

A = rate of heat production within the source,

ρ = density of the body,

g = gravity anomaly due to the source,

and

x = position vector of the observation point.

Note that (*) assumes that there exists but one source for both the gravity anomaly and the heat flow field. * may be rewritten as

$$\rho = A/2G \quad g(x)/q(x) \qquad **$$

(**) may be used to estimate the density contrast from the heat flow measurements, under the assumptions discussed previously. As data for the problem we have only two heat flow and heat production measurements, one at RL1, the other at RL2. There the heat flow and heat production measurements are 1.44, 1.30 HFU and 5.6, 6.0 HGU, respectively. At each site the gravity anomaly is 42±8 mgal; however, the gravity anomaly near RL1 is as yet very poorly defined, due to a lack of data. Using these values for heat production and heat flow, and assuming (1) a lower crustal heat flow of 0.69 HFU, a value equal to the intercept of the observed linear heat flow - heat production relation, and (2) a contribution of 0.15 HFU to the heat flow field from heat production within the country rocks. The contribution from the country rocks was estimated by assuming that the heat sources in the country rocks were uniformly distributed to a depth of 7 km. The estimated density contrasts are 0.09±0.02 and 0.12±0.02 gm/cm^3 for RL1 and RL2, respectively. Despite the rather simple assumptions made for the density estimates, each estimate yields density contrasts that are entirely reasonable, based upon the known lithology of the batholithic rocks and the less well-understood lithologic variations within the country rocks. Hopefully, as additional heat flow and heat production data are acquired from the remaining three drill holes within the batholith, these density contrast estimates will be given further support.

Modelling. Only preliminary gravity modelling of the Rolesville has been attempted thus far because of the sparse data base over the pluton itself. Two-dimensional models have been erected based upon observations interpolated along profile A-A' and B-B' of Figure C-5.13, which shows the Bouguer anomaly over the batholith after subtraction of the observed Bouguer field. Using a density contrast of -0.10 gm/cm^3, the total depth of the batholith among B-B' is about 14 km, based upon two-dimensional models. Preliminary three-dimensional models indicate that this depth should be increased to 15-16 km, using the same density contrast. These depths are lowered to approximately 6.5-7 km if a density contrast of -0.2 gm/cm^3 is appropriate.

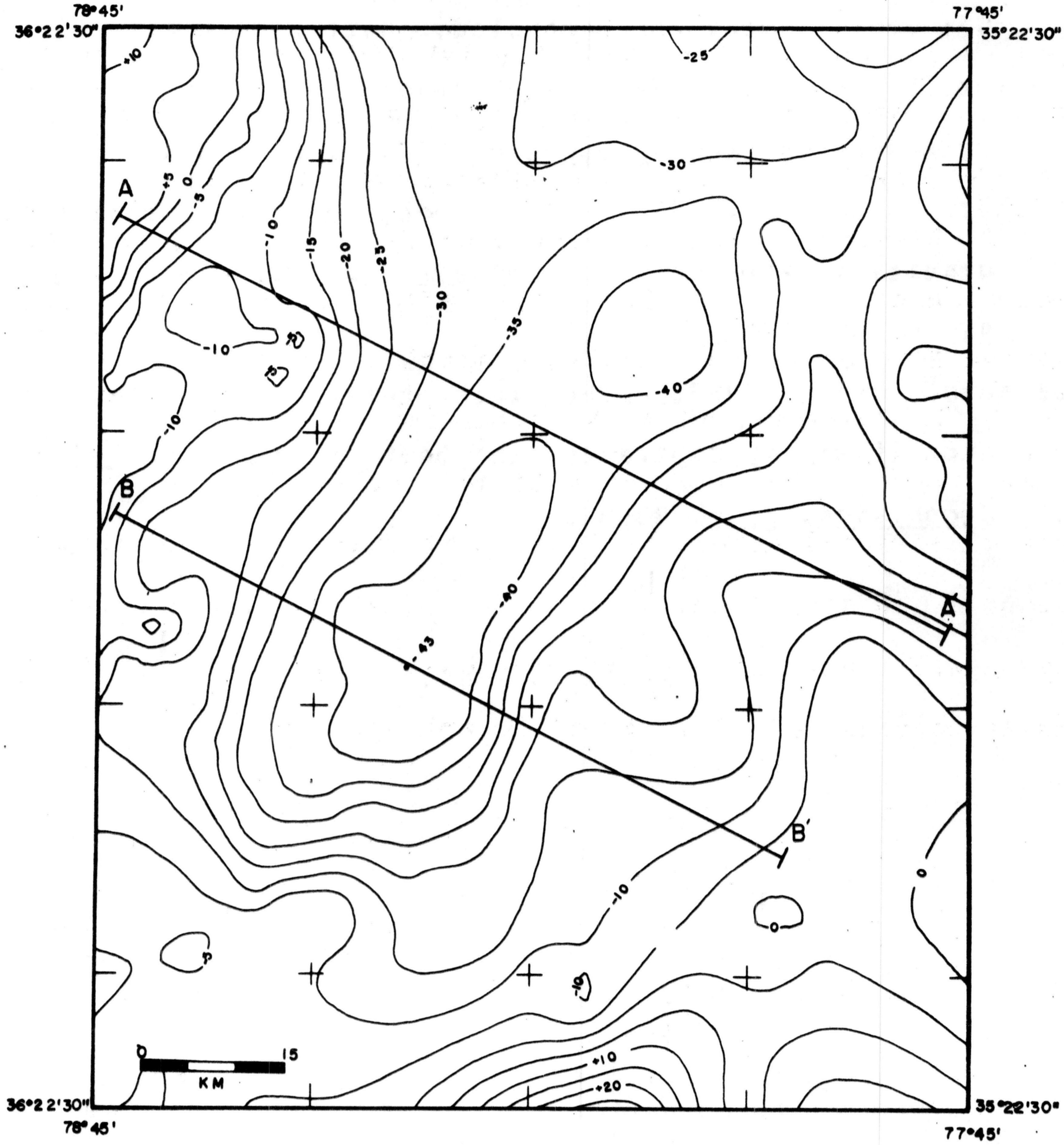


Figure C-5.13. Residual Bouguer anomaly after subtraction of the trend surface of Figure C-12 from the field of Figure C-11.

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THERMAL MODELING

John Dunbar

INTRODUCTION

In this contract period two thermal modeling computer programs were developed. The first program computes theoretical heat flow anomalies in regions affected by arbitrarily shaped, three-dimensional radiogenic volumes. The modeling technique is based on theory given by Simmons (1967) and Plouff (1976). The second program computes the temperature field in a half space containing three-dimensional sources and in an overlying insulating layer. The theory for this program appeared in the last report (VPI&SU-5648-1, pp. C-63 to C-73).

For this report the heat flow program was used to generate theoretical heat flow anomaly maps of the Liberty Hill, Pageland and Cuffytown Creek plutons. At present, the model parameters are better defined for these bodies than for any other bodies in the Southeast. Even so, the information is still rather sketchy. The maps are, as a result, presented as tentative models to direct further work and will be modified as the model parameters become better known. The temperature modeling program is used to illustrate the effect that different radiogenic sources have on the temperature field. Six hypothetical examples are given which provide some insight into what sort of source is required to produce a useful geothermal reservoir.

As a further application, these two programs will provide a quantitative approach to the interpretation of the heat flow data that will be gathered in the Coastal Plain of Southestern U.S. in the coming months. A heat flow model of the radiogenic source body could be developed based on gravity and magnetic models, or seismic data, which would reproduce the observed heat flow values over the body. This heat flow model could then be used as the basis for a model of the geothermal field itself. With this approach, production wells could be sited on the basis of surface and shallow-well measurements.

HEAT FLOW MODELING IN THE PIEDMONT

In order to predict the heat flow anomaly produced by a radiogenic body one must be able to estimate the contrast in the rate of heat production between the body and the country rock and estimate the size and shape of the body. To predict the total heat flow, the regional heat flow field must also be estimated. The heat production contrasts assigned to the plutons considered in this section were computed by subtracting the average heat productions of surface samples of Carolina Slate belt argillites, phyllites, and metavolcanics from the average heat productions of surface and well samples from the three plutons. Table C-6.1 gives the averages of the samples and the heat production contrasts between the plutons and the country rock. The geometries of these plutons, which were used in the heat flow models, were taken from existing gravity models prepared by other workers. Models of the Liberty Hill and Pageland Plutons were given by Bell and Popenoe (1976). The Cuffytown Creek pluton was modeled by A.H. Cogbill (VPI&SU-5648-1, 1978). Each of these models is plagued by uncertainty in the density contrast between the body and the country rock. Cogbill illustrates this uncertainty in his Figure C-7 (VPI&SU-5648-1,1978), which shows that, for a maximum gravity anomaly of -25 mgals, the total depth of the model changes from 3 km to over 11 km as the density contrast is allowed to vary between the limits of -0.15 and -0.25 gm/cm^3. Bell and Popenoe (1976) show a similar uncertainty for their model of the Pageland pluton, which varies from about 3 km to about 10 km in total depth as the density contrast is changed from -0.10 to -0.20 gm/cm^3. This uncertainty in the geometry of the source bodies causes a corresponding uncertainty in the theoretical heat flow anomaly.

The final model parameter, the regional heat flow field, may be estimated from the linear relationship between heat flow and heat production. The only well data in the Southeast from locations away from the influence of granitic bodies is the 0.94 HFU value from VPI&SU well SB-1 near Roxboro, NC, and the 1.2 HFU value (1.0 HFU = 1.0 x 10^{-6} cal/cm^2-sec) from USGS well CCCHW1 near Charleston, SC. (USGS Open File Report 76-148). Neither well is within 200 km of the three plutons. Therefore, the regional field was assumed to be a constant 0.9 HFU for all three model areas. This heat flow corresponds to the average country rock heat production of 3.08 HGU (1 HGU = 1.0 x 10^{-13} cal/cm^3-sec) on the linear relationship between heat flow and heat production (VPI&SU-5103-5, p. C-26).

The theoretical heat flow anomalies associated with the three plutons are shown in Figure C-6.3A, C-6.3B, and C-6.3C. If the assumed regional heat flow of 0.9 HFM is added to the three anomalies, the predicted heat flow at KR3 and PG1 would be about 0.96 HFU. At ED1 the predicted valve would be 1.20 HFU. The actual heat flow at KR3 was determined to be 1.06 HFU (VPI&SU-5103-5, p. C-5), which is 0.10 HFU greater than predicted by the model. If the estimate of the regional field is in error by 0.10 HFU, then PG1 would be expected to yield a heat flow of 1.06 HFU also, and the heat flow at ED1 would be expected to be as high as 1.30 HFU. If the estimate of the anomalous heat flow at KR3 is in error by 0.1 HFU, then either the heat production increases with depth in the pluton, or the base of the pluton is over twice as deep as in Bell and Popenoe's preferred model, which would place it near 14 km. In either case, it is clear that more heat flow and heat generation data are needed in these study areas before the heat flow modeling technique itself can be evaluated.

TEMPERATURE MODELING

In the following section a series of hypothetical models is used to demonstrate how radiogenic bodies with different rates of heat production and geometries affect the temperature field. The model region for each of the six examples is characterized by the parameters listed in Table C-6.2 and depicted in Figure C-6.2A.

Note that if the heat flow from the lower crust is 0.7 HFU, then a layer with a heat production of 1.0 HGU would have to be 30 km thick to raise the regional heat flow to the 1.0 HFU assumed in the models. This arrangement was chosen so that the plates in the body could be variously oriented without penetrating the base of this heat producing layer and taking on a different heat production contrast.

Figures C-6.3A, C-6.3B, and C-6.3C show cross-sections through the model region along the line X to X' shown in Figure C-6.2A. The anomalous bodies A, B, and C have heat productions of 10, 17 and 25 HGU respectively. The contours describe the calculated temperature field.

The amplitude of the thermal anomaly at any point in the temperature field is linearly related to the heat production contrast of the body. As a result, the temperature anomaly at each location in Figure C-6.3C is 2.64 (24/9) times larger than the temperature anomaly at the same location in Figure C-6.3A. The heat flow anomalies shown over the cross-sections also demonstrates this linear relationship.

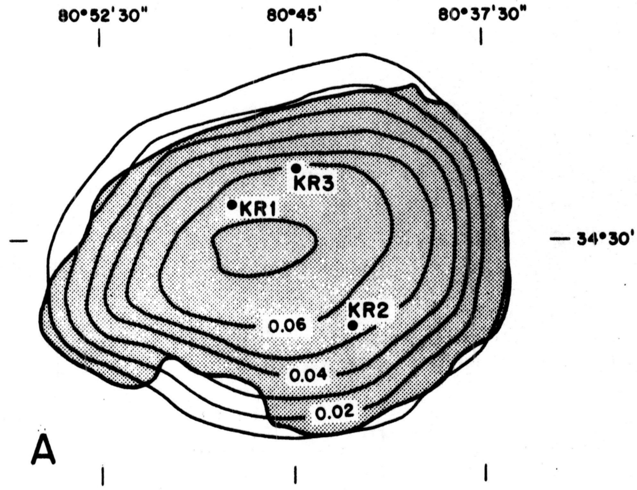
It is important to note from Figure C-6.3 that even with a heat production contrast of 24 HGU there is only a subtle temperature anomaly at shallow depths. There are, however, sizeable anomalies at depth in all three cases.

Figures C-6.4A, C-6.4B, and C-6.4C show the effect of changing the geometry of the anomalous body. In the sequence of Figures C-6.3B, C-6.4A, and C-6.4C the larger plates of the body are shifted to deeper positions in the model. All other model parameters are held constant. As the plates are shifted, the maximum amplitude of the thermal anomaly at a depth of 2 km remains nearly constant, but the lateral extent of the anomaly varies. At a depth of 8 km the maximum amplitude increases as the larger plates are moved downward. In Figure C-6.4C the plates used in the other examples are turned on end. The cross-section is along the line Y - Y' shown in Figure C-6.2C. This diagram demonstrates that bodies with small lateral dimensions do not produce large temperature anomalies even if they extend to great depths.

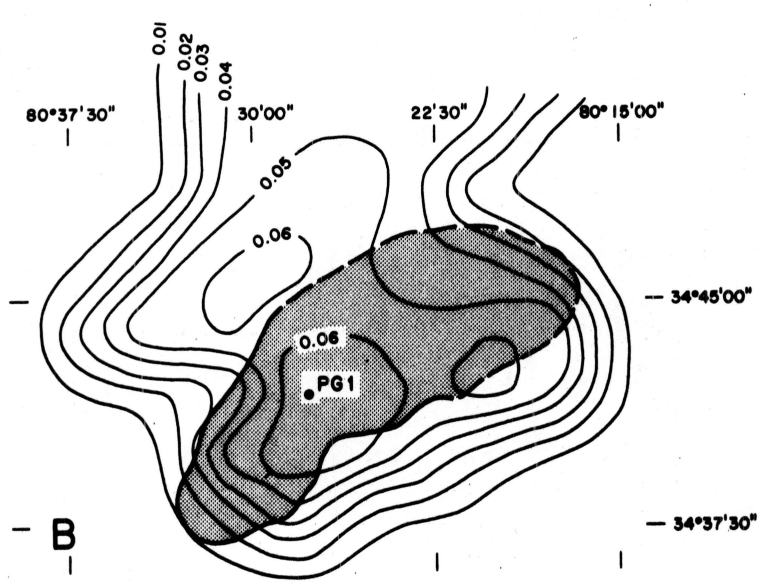
Figure C-6.4D shows the effect of doubling the thickness of each plate, which increases the maximum thickness of the body from 7 km to 14 km. The heat production in the body is 10 HGU. The maximum amplitude of the temperature anomaly at 2 km is about the same as the maximum value shown in Figure 3B for the orgional body with a heat production of 17 HGU.

These examples were intended to provide some understanding as to what size plutons with what rates of heat generation would produce significant thermal anomalies. They also point out two important facts about radiogenically derived thermal anomalies: (1) In general, the amplitude of a thermal anomaly over a radiogenic body will increase with depth. The increase is due, in part, to the fact that the source is finite and, in part, to the constant temperature boundary condition at the surface. (2) The temperature field is more sensitive to differences in the source bodies at depth than nearer the surface. This is a direct result of the boundary condition at the surface. These suggest that the deeper the production well, the more critical its location will be. This would be particularly true for hot-dry-rock wells penetrating the pluton itself.

Calculated Heat Flow Anomalies
Liberty Hill Pluton



Pageland Plutons



Cuffytown Creek Pluton

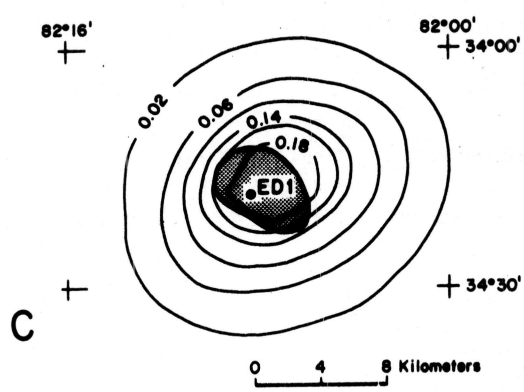


Figure C-6.1. Contour maps of the calculated heat flow ancmalies. The areas are the surface outcrop patterns of each pluton. The contour intervals for diagrams A and C are 0.01 HFU. For diagram C the interval is 0.02 HFU (1 HFU = 1.0 x 10^6 cal/cm^2-sec).

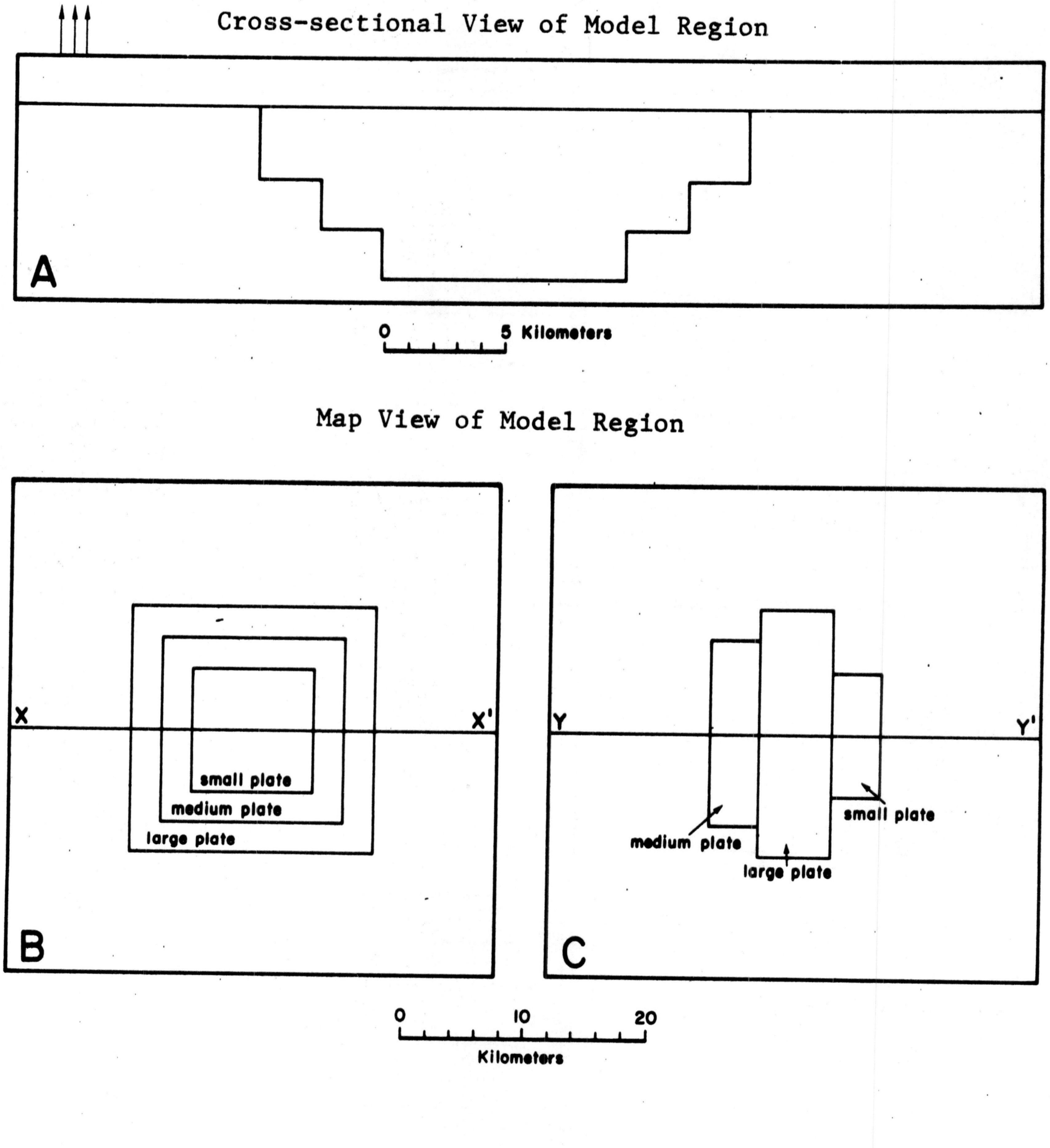


Figure C-6.2. Diagram A shows the parameters characterizing the model region. Diagram B is a map view of the model region for Figures C-6.3A, B, and C, and C-6.4A, B, and C. Diagram C shows the map view of the model region for Figure C-6.4C.

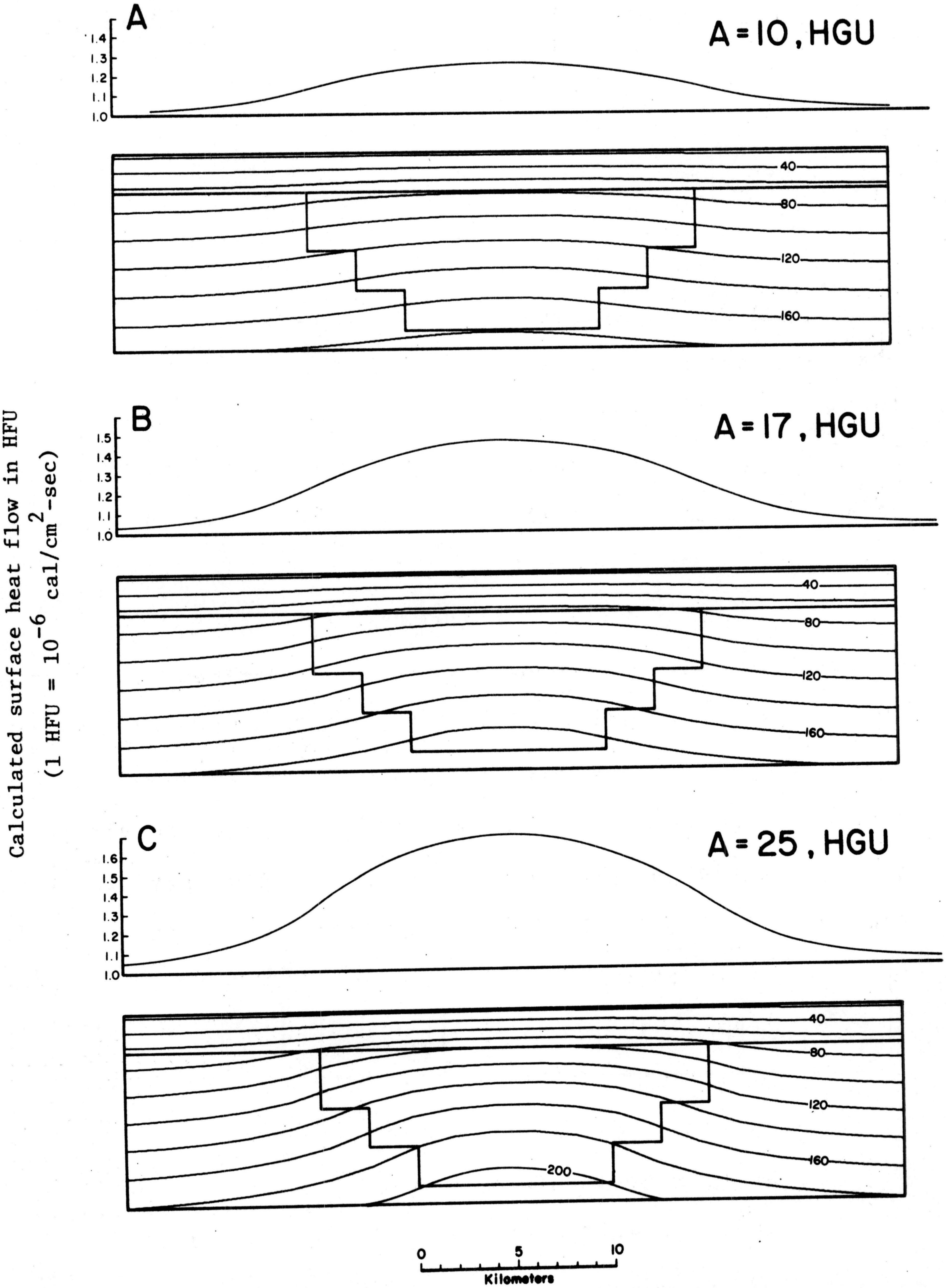


Figure C-6.3. Cross-sections through model regions from X-X¹, Figure C-6.2B. The calculated temperature and heat flow fields are shown for different rates at heat generation (A) within the body. The contour interval is 20°C.

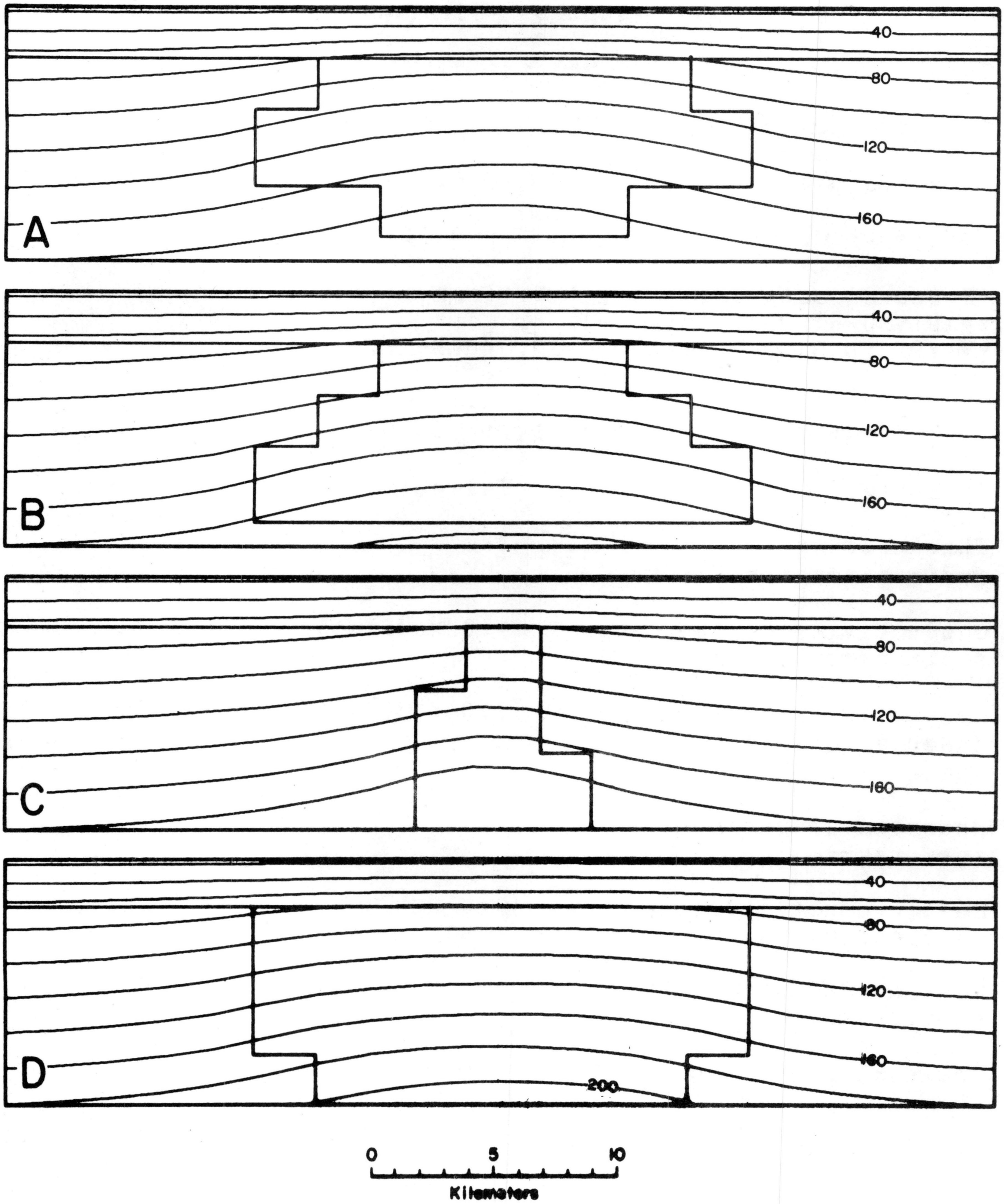


Figure C-6.4. Calculated temperature fields associated with radiogenic bodies of different geometries. For bodies A, B, and C, the rate of heat generation is 17 HGU. For body D, the rate is 10 HGU.

TABLE C-6.1. HEAT PRODUCTION VALUES.

Source of Same	No. Samples	Average in HGU	Contrast in HGU
Carolina Slate Belt	9	3.09*	---
Liberty Hill pluton	18	5.69**	2.60
Pageland pluton	3	5.97***	2.88
Cuffytown Creek pluton	2	9.30***	6.21

*Personal communication, L.D. Perry (1978).
**VPI&SU-5103-4, page C-12.
***VPI&SU-5103-5, pages C-22 and C-23.

TABLE C-6.2. TEMPERATURE ASSUMED FOR MODELS.

Parameter	Value Assigned for Models
Thickness of sedimentary insulator	2km
Conductivity of the sedimentary layer	4.0 x 10^{3} cal/cm^{2}-sec-^{o}C
Conductivity of the underlying half space	7.0 x 10^{3} cal/cm^{2}-sec-^{o}C
Mean annual surface temperature	15^{o}C
Heat production in the sedimentary layer	0.0 HGU 1 HGU = 1.0 x 10^{-13} cal/cm^{3}-sec)
Heat production of the country rock layer	1.0 HGU
Regional heat flow	1.0 HFU
Physical dimensions of Radiogenic body plate 1	20 km x 20 km x 3 km
Physical dimensions of Radiogenic body plate 2	15 km x 15 km x 2 km
Physical dimensions of Radiogenic body plate 3	10 km x 10 km x 2 km

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STRUCTURAL CONTROLS OF THERMAL SPRINGS IN THE WARM SPRINGS ANTICLINE

P.A. Geiser

INTRODUCTION

This report is a preliminary summary of the results of a structural investigation on the origin of thermal springs in the Warm Springs Anticline in northwestern Virginia. The investigation has suggested an hypothesis of deep meteoric circulation on a normal geothermal gradient. An alternative mechanism, of a shallow still-cooling pluton, has been rejected.

The hypothesized system is based on evidence which suggests that the presence of deep zones of enhanced permeability are associated with cross-strike strike linears. These linears may reflect structural discontinuities in the continental plate along which flexing may be occurring, producing a zone above it in which extensive fracturing occurs.

THE PROBLEM

The thermal springs of Virginia are part of the belt of warm springs occupying both the Valley and Ridge and Piedmont Provinces from Pennsylvania to Georgia. A number of studies on the origin of these springs have been made and are summarized by Costain (1975). In essence, two models have been proposed: a) shallow circulation above a still-cooling pluton; and b) deep circulation of meteoric groundwater structurally controlled.

Heat flow studies by Costain (1976) have shown no evidence for the existence of a shallow pluton. An alternative hypothesis that the springs were controlled by cross faults associated with a doubly-plunging anticline (Costain, 1976, p. 40) was also abandoned because at only a single location (Falling Springs) was any evidence of faulting found, and this was of a local nature. Instead, a different hypothesis of structural control emerged. The thermal springs are localized by a zone of transverse, approximately east-west, fracturing possibly associated with flexing. Evidence for such a structure was first recognized from photolinears on U-2 and ERTS imagery. (Figure C-7.1) Study of these linears on topographic maps revealed that they are associated with water gaps, east-west trending valleys, and apparent perturbations in the structural trends.

Each area of thermal springs area in the Warm Springs Anticline can be associated with one of a set of parallel transverse photo and topographic lineaments (see Dennis, 1967). Field work has been focused on further defining these lineaments. In so doing, it was fully appreciated

Figure C-7.1. ERTS photos showing linears include spring locations and location of Falling Springs Linear.

that the problem of structural lineaments is a truly difficult one, the principal problem being that their identification by unequivocal structural evidence has yet to be accomplished anywhere in the country. The reason for this is that possible origins for such large-scale features are, with a few exceptions, essentially unknown. General agreement exists that deep-seated transcurrent faults, and tear faults associated with thrusting, can produce structural lineaments, both of which can be expected to produce a recognizable set of features at the surface, in terms of folding, faulting, and jointing.

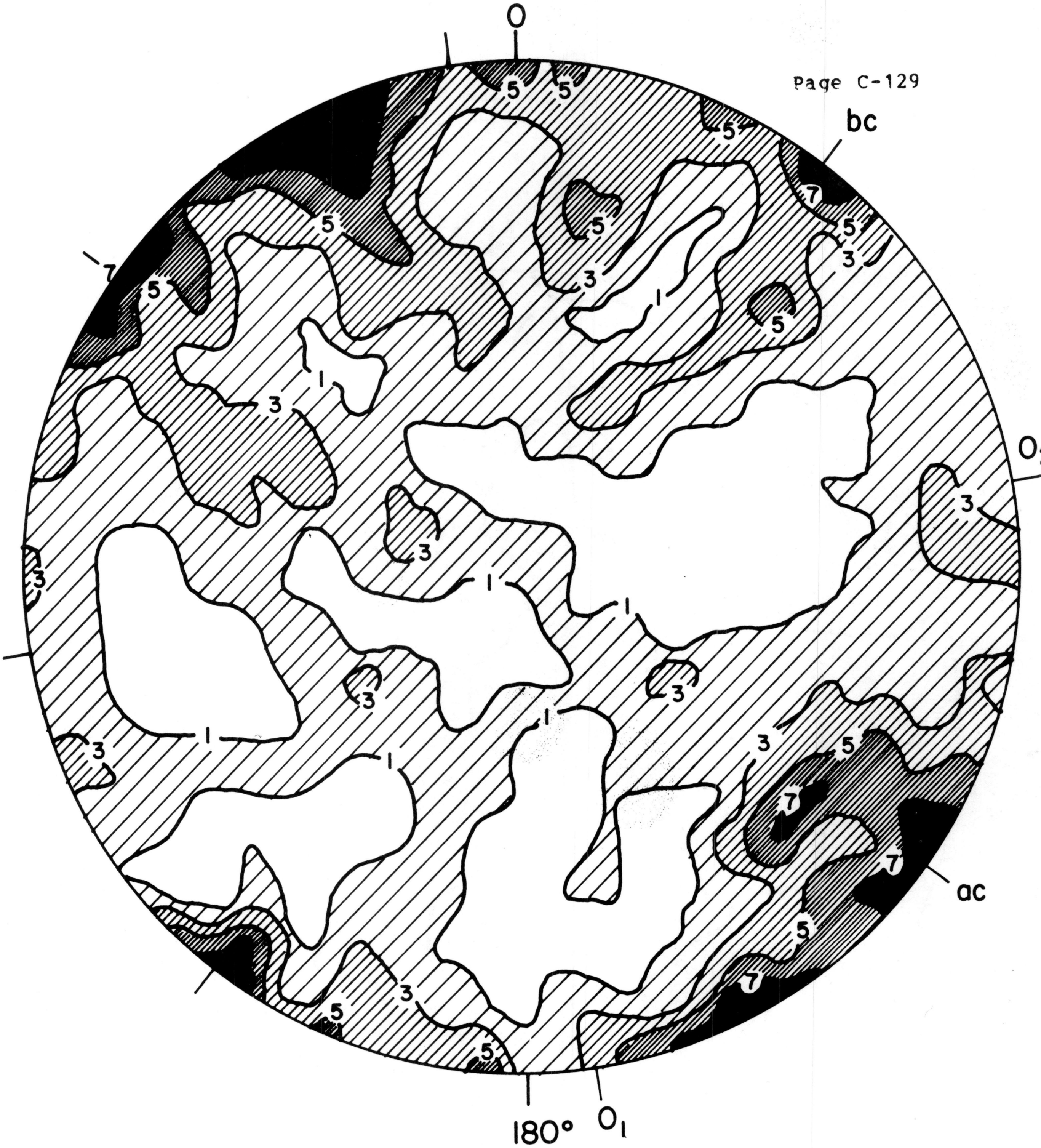
This knowledge was used to establish the following structural features to be mapped. The structures included: a) joints and joint density (number/foot); b) faults; c) folds. In addition, a detailed study of the Tuscarora sandstone was made along the length of the west limb of the Warm Springs Anticline and the Falling Springs Lineament. The following data from these studies is considered significant in determining the validity of the hypothesis of deep seated basement motion producing enhanced permeability in the overlying sediments.

Faulting: Two mappable offsets associated with east-west structures were found: a) Falling Springs; b) Indian Draft. Mapping undertaken by the Army Corp of Engineers during the construction of Gathright Dam (Gathright Dam, James River Basin, Jackson River, VA, Supplement to design memorandum #11; Geology and Foundations; Prep. by Dept. of the Army, Norfolk district, Corps of Engineers.) also revealed a similar set of faults. These faults show both normal as well as strike-slip components; however, the absolute motion could not be determined.

Folds: Folds associated with the east-west structure are the northward termination of Hide Creek Mountain and the southward termination of Morris Hill. Particular attention was focused on the east-west valley containing Dry Branch. On the west limb of Morris Hill Anticline, the Oriskany-Milboro contact is offset by a rapid increase in dip along strike crossing from the south to north side of Dry Branch Valley. Although there is no evidence of faulting, the fold seems to have been rotated about an east-west vertical plane, in effect, twisted.

A final point suggesting large scale structural control can be made regarding the en echelon termination of Morris Hill and Lick Mountain along the line of proposed lineament.

Jointing: Measurement of joint sets in the Warm Springs Anticline revealed an anomalous set with respect to the geometry of the anticline (Figure C-7.2) (see Geiser 1976). Further mapping along the Falling Springs Lineament has shown that this set is the most prominent in this region. (Figure C-7.3). This joint set is found elsewhere in the anticline but seems to be much less prominent further north. A similar observation was made in the Gathright Dam



Contours ; 1%, 3%, 5% ≥ 7 %

Figure C-7.2. Summary Diagram - Orientation of Joints w/ Spacing > 1/ft. n = 235.

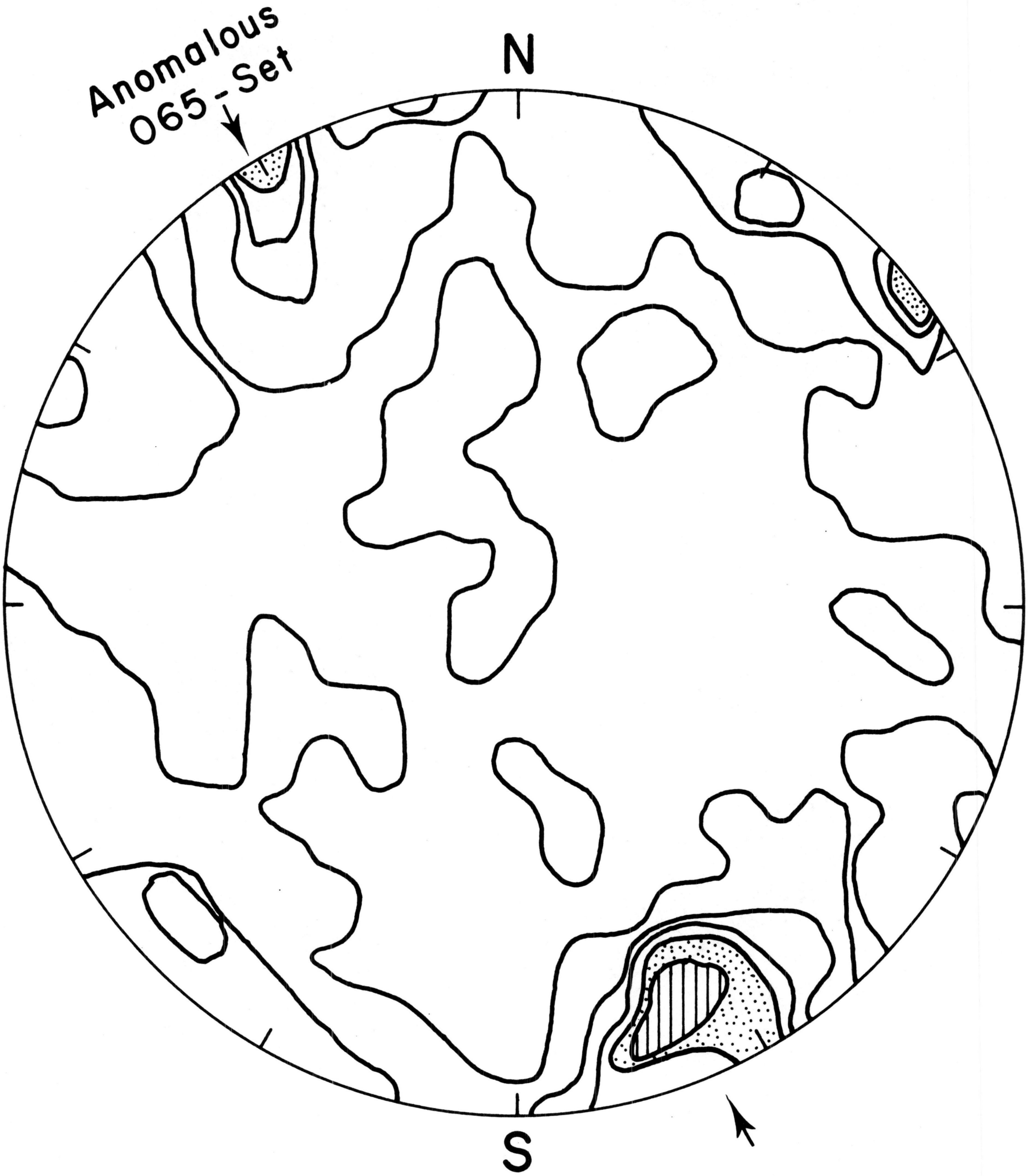


Figure C-7.3. Steroplot of joint data, all data combined. Contours at 1%, 2.5%, 3%, 4%. Total of 808 poles plotted. (data from Sallie Whitlow) study (p. 11) in the adjacent synclinorium. Thus the anomalous joint set cuts at least two first order folds.

<u>Deformation fabrics</u>: Results of a petrographic study of systematically sampled Tuscarora quartzite along the length of Little Mountain has produced somewhat ambiguous results. A series of samples taken across Falling Springs Gap does show maximum deformation of the quartzite in the gap. Evidence for deformation is given by sutured boundaries, deformation lamellea and undulatory and wavy extinction. Deformation gradually decreases proceeding northward from the gap. decreases. However, it was also noted that strong deformation fabrics were found on the ridge itself and one gap (Dunns) seem to lack any evidence of deformation.

Two additional considerations are also pertinent in this analysis:

1) On a regional scale, two other thermal springs can be found on the same lineament as Falling Springs (Figure C-7.1). Similar alignment of springs appears along the lineament through Corington, VA. Other lineaments can be recognized containing many of the other thermal springs in Virginia; however, the evidence is more tenuous.

2) A final note is the results of water well drilling in the Warm Springs Anticline. Three wells have been drilled in the lineaments crossing the Anticline; in the vicinity of Warm Springs, in the vicinity of Hot Springs, in

the Falling Springs area. Two of these wells, at Hot Springs and at Falling Springs, encountered hot water. No other hot water has been encountered elsewhere in the anticline at any other drill sites.

At present, the geologic evidence supports the hypothesis that there exists a transverse, somewhat diffuse zone of deformation which is also a zone of enhanced permeability. The zone appears to be on the order of two kilometers in width. There is topographic evidence that other transverse deformation zones may cut the Warm Springs Anticline in the vicinity of Hot Springs, Healing Springs, and Warm Springs. However, at this point none of the evidence can be considered conclusive, either in and of itself, or taken together; it is, rather, suggestive.

It should be indicated that the nature of the strain associated with the deep seated structure, whose motion is essentially that of flexing with both strike-slip as well as normal motion, would necessarily produce a zone of rather diffuse strain. Thus in many respects, such a subtle zone is better recognized by the <u>absence</u> of a set of structures rather than by their presence.

Other hypotheses: Alternative hypotheses may be suggested to explain the structures found. These hypotheses are:

1) The lineaments result from a step-up due to thrusting (e.g., Dahlstrom 1970, Harris 1971).

2) The structures are local perturbations due to interactions between growing folds (i.e., between the Oliver Mtn. structure and the Warm Springs).

3) The lineament is only apparent and due to chance concatenations of more homogeneously distributed structures.

These alternative hypotheses are held less teneable for several reasons:

1) The minor structures believed associated with the lineament cut across several major structures, but not at their termination, as they would for the first hypotheses.

2) The orientation of the deformation effects associated with the linear are consistent over several structures, which would not be expected under either the second hypothesis or third hypothesis.

3) The deformation associated with the lineament tends to increase towards the lineament area and thus is not homogeneously distributed, as indicated by the third hypothesis.

ADDITIONAL WORK

Future work should take two approaches; a) additional field work; and b) drilling. Additional field work should focus on defining the lineaments. The best method devised to date for mapping these poorly defined structures requires determining the areas in which the associated structural elements are absent as well as those areas in which they are present. This necessarily requires detailed mapping until the bounds of the lineament are found. With regard to the Falling Springs lineament, some additional mapping is needed to the north both in the Jackson River Valley and on Coles Mountain. The most critical area, however, is determining the southern boundary of the lineament where little mapping has been done.

A second target for mapping should be the next most prominent lineament, the one passing through Warm Springs. The procedure for mapping should be identical to that used to map the Falling Springs Lineament.

In summary, at our present stage of knowledge, mapping of linears necessarily requires detailed work over a fairly extensive region (on the order of 50 km^2). It is anticipated that as our knowledge of these structures is enlarged, a methodology will evolve, making the work more efficient.

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