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A Laboratory Study of the Beech Granite Plagioclase

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To the Graduate Council:

I am submitting herewith a thesis written by Joseph Taylor Carlisle entitled "A Laboratory Study of the Beech Granite Plagioclase." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

F. Donald Bloss, Major Professor

We have read this thesis and recommend its acceptance:

Paris B. Stockdale, George D. Swingle, Harry J. Klepser

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

September 17, 1956

To the Graduate Council:

I am submitting herewith a thesis written by Joseph Taylor Carlisle entitled "A Laboratory Study of the Beech Granite Plagioclase." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

F. Donald Bloss

Major Professor

We have read this thesis and recommend its acceptance:

Paris B. Stockdale

George D. Swingle

Harry J. Klepser

Accepted for the Council:

Charles P White for

Dean of the Graduate School

A LABORATORY STUDY OF THE BEECH GRANITE PLAGIOCLASE

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Joseph Taylor Carlisle

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J. T. C.

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CHAPTER I

INTRODUCTION

The Nature of the Problem

Description and Location of Rocks Studied

In northeast Tennessee a complex basement of Pre-Cambrian crystalline rocks either unconformably underlies the oldest Cambrian sediments, or bears a faulted relationship to them. The complexity of these rocks is, indeed, so great that much doubt exists as to the origin and even the nature of their component rock units. Keith (1907, p. 3) subdivided these rocks into two large units: (1) the Cranberry "granite," in this region a highly contorted gneiss of complex lithology, and (2) the Beech granite, a rather porphyritic, generally coarse-grained granite which he considered to have been considerably squeezed and mashed. Of these Keith regarded the Beech to be the younger, since he believed it to have intruded the Cranberry.

The rock samples studied were collected from the White Rocks Mountain Quadrangle, particularly its northern portion, in which the Beech granite shows a very

typical and rather extensive development (Plate I, in pocket). Beech samples were collected from both sides of the Beech-Cranberry contact as mapped by Keith (1907).

Statement of the Problem

Two Possible Modes of Origin for a Granite

Two theories for the origin of granites are prevalent today. One of these, the Magmatic Theory, considers granite to be formed by the congelation of a magma of granitic composition. The other, the Granitization Theory, believes granite to be the results of ultra-metamorphism of pre-existing rocks without passing through a magmatic stage. Geological opinion is strongly divided between these two theories. Grout (Gilluly et al, 1948, p. 53) believes that 85 per cent of all exposed granites were formed from cooling magmas. Backlund (1946, p. 110), on the other hand, thinks there is no evidence of vulcanicity to support an igneous origin for exposed granites and attributes their origin to the processes of granitization. Read (Gilluly et al, 1948, p. 9) considers both processes to have been active in the formation of granites. He believes granitization

to be the results of emanations from a granitic magma. The problem is, as yet, unsettled.

Plagioclase in Granitic Rocks

Bowen's melting relationships for the plagioclases clearly show that the more calcic plagioclases crystallize at higher temperatures than do the albitic plagioclases. If one accepts the general belief that the borders of rock masses of magmatic origin have solidified at a higher temperature than the core, one would logically expect the anorthite content of the plagioclases to decrease from the border inward for all bodies of normal igneous origin.

To the writer's knowledge, no discussion exists in the literature regarding any variation of the anorthite content of plagioclases in granitic bodies of metasomatic origin. Inferences may be drawn, however, if one reviews the chemical nature of the granitization processes as presented by Reynolds (1946, pp. 389-446). During the granitization of pelitic sediments, Reynolds (1946, p. 390) believes, "Silica and one of the alkalis are added, whilst alumina and cafemic constituents . . . decrease." The meager chemical data concerning the granitization of psammitic rocks near granite contacts

appear to indicate (Reynolds, 1946, p. 413) that, if the original sediment was richer in Na_2O than K_2O, the granitized rock is similarly richer (and vice versa). Reynolds believes (1946, p. 413) further granitization of the psammite produces adjustments in the relative proportions of the alkalis so that the composition of the parent granite is approached.

This chemical interpretation of granitization by D. L. Reynolds is by no means universally accepted even among the proponents of granitization. Applying its principles, however, one could expect a granitized psammitic body to be locally richer in Na_2O in the manner of its pre-granitization composition during the early stages of the process. In the later stages of granitization, the portions of the body closest to the granitizing force (possibly a granitic magma in Reynolds' concept) presumably would either gain or lose in Na_2O according to whether the body was lower or higher in Na_2O than the granite itself.

The distribution of sodic plagioclases, if a reflection of these variations in Na_2O content, might be somewhat variable therefore among granitized psammites. Rock bodies in the early stages of granitization could show distributions of sodic plagioclases in a relatively

capricious manner with respect to the areas of higher granitization activity. In the later stages, if one follows Reynolds, one could expect the plagioclases in the central area of the body to be either enriched or depleted in the albite molecule, depending on the amount of sodium in the granite promoting the activity.

In granitized pelitic sediments, Reynolds (1947, p. 209) believes that basic fronts are established whereby Ca, Al, Fe, and Mg enrich the outer zones of the rock, whereas the inner zones are enriched in SiO_2, K_2O, and Na_2O. In granitized pelites, therefore, if the albite content of the plagioclases should reflect this incipient chemical partition, one would expect the more anorthic plagioclases to be located near the periphery of the body, whereas the more albitic plagioclases would be located nearer to the center. This situation would be very similar to the type of plagioclase distribution earlier postulated for a body of igneous origin.

Ramberg (1949, p. 24) thinks that most granites in folded mountain regions result from granitization and that the regional metamorphism producing the granites was uniform over large areas.

Regarding the characteristics of a regionally metamorphosed body, Tuttle (1952, p. 121) considers many perthites to be the result of the unmixing of alkali feldspars by regional metamorphism. If this metamorphism is of long duration, the unmixing, Tuttle contends, will probably produce microcline, acidic plagioclases, and perthites. Any variation in the anorthite content of the plagioclases in rocks of either igneous or metamorphic origin could conceivably be altered in response to regional metamorphism. According to Ramberg (1952, p. 50) geologists have long recognized that ". . . the anorthite content of plagioclase in metamorphic rocks often increases with increasing degree of metamorphism. . . ."

Concerning zoning in plagioclases, Turner and Verhoogen (1951, p. 289) contend that zoning is much more in evidence in igneous than in metamorphic rocks.

Scope of the Study

The areal variation of the Beech granite plagioclases was therefore studied as a possible aid to determine whether criteria could be established to aid in determining the origin of the Beech granite, and to aid in distinguishing the Beech from other crystalline rocks in northeast Tennessee.

CHAPTER II

EXPERIMENTAL DETAILS

Sample Locations and Descriptions

The locations of the samples of typical Beech granite studied are shown on Plate I by single circles. Double circles represent sample locations of lithologies other than Beech. Brief descriptions of these samples and their locales are given in Table I.

Resumé of Tsuboi's Method

Explanation of the Method

The anorthite content of individual grains of plagioclase was determined by the single variation immersion method as modified by Tsuboi (1933, p. 325). This method is considered by Poldervaart (1950, p. 1071) to be, for most purposes, the most accurate and convenient for determining plagioclase compositions.

Comparison with Chemical Analyses

A comparison of several popular methods of determining the anorthite content of plagioclases was made by Crump and Ketner (Emmons *et al*, 1953, p. 23),

TABLE I

DESCRIPTION OF SITE OF SAMPLE STATIONS

Station Number on Plate I	Brief Descriptions
1	Carter County road quarry. Coarse-grained, porphyritic Beech granite. Two basic dikes cut across the quarry.
2	Highway 19E road cut. Medium to coarse-grained Beech granite.
3	Carter County road cut. Badly altered, coarse-grained Beech granite.
4	Stream bed near Carter County road. Unaltered, medium-grained, strongly lineated Cranberry gneiss.
5	Carter County road cut. Unaltered, medium-grained Cranberry gneiss with large feldspar crystals.
6	Highway 19E road cut at North Carolina-Tennessee line. Badly sheared Beech in contact with mylonitic phase of Beech.
7	Carter County road cut. Slightly sheared, coarse-grained, unaltered Beech granite.
8	Carter County road cut. Altered medium-grained Beech granite.
9	Carter County road cut. Badly weathered, medium-grained Beech granite.
10	Carter County road cut. Coarse-grained, badly weathered Beech granite.
11	Near Carter County road. Very fine-grained gabbro with white, altered feldspar laths.
12	Along a trail on White Rocks Mountain. Massive, coarse-grained Beech granite.

TABLE I

DESCRIPTION OF SITE OF SAMPLE STATIONS
(continued)

Station Number on Plate I	Brief Descriptions
13	Along a trail on White Rocks Mountain. Massive, coarse-grained Beech granite.
14	Carter County road cut. Massive, unaltered Cranberry gneiss.
15	Along a trail on White Rocks Mountain. Massive, coarse-grained Beech granite.
16	Along a trail on White Rocks Mountain. Massive, coarse-grained Beech granite.
17	Carter County road cut. Medium-grained Cranberry gneiss.
18	Carter County road cut. Massive, unaltered, fine-grained Cranberry gneiss.
19	Carter County road cut. Massive, strongly lineated, fine-grained Cranberry gneiss.
20	Carter County road cut. Fine-grained, massive, weakly lineated Cranberry gneiss.
21	Trail near highway 19E. Massive, sheared, medium-grained Beech granite.
22	Trail near highway 19E. Massive, medium-grained, weakly lineated Cranberry gneiss.
23	Carter County road cut. Medium-grained, slightly sheared Cranberry gneiss.
24	Highway 19E road cut. Altered, coarse-grained Beech granite.

and the results were weighed against the actual chemical analyses. Table II, which is drawn from their data, shows the very favorable comparison of the Tsuboi method with the chemical analyses. The greatest difference noted in the comparison was 5.20 per cent and the average difference was 1.91 per cent. The writer had access to a specimen collected by F. G. Snyder from the same area as Crump and Ketner's number 27 (Table II). The per cent anorthite of the plagioclase taken from this sample was measured by the writer to be 79.80.

Apparatus and Materials

Laboratory Equipment

Microscope and accessories. A Bausch and Lomb polarizing microscope with standard accessories was used in this study. A thermometer was attached to its stage to determine the temperature of the oil mounts containing the plagioclase grains.

Abbe refractometer. The indices of refraction of all the oils used were measured by means of a Bausch and Lomb abbe refractometer. The temperature of the refractometer prisms (and therefore of the oils between them) was determined by the thermometer attached for that purpose.

TABLE II

COMPARISON OF CHEMICAL ANALYSES AND THE TSUBOI METHOD AS BASED ON DATA OF CRUMP AND KETNER (Emmons *et al*, 1953, p. 23)

Sample Number*	Measured Per Cent Anorthite		Difference
	Chemical Analyses	Tsuboi Method	
1	00.15	00.35	00.20
3	16.10	16.10	00.00
4	16.10	17.80	01.20
5	19.50	19.20	00.30
6	35.90	38.00	02.10
7	36.10	34.20	01.90
8	38.00	43.20	05.20
9	49.00	47.80	01.20
10	51.60	51.80	00.20
11	52.20	49.50	02.70
12	56.50	52.50	04.00
13	56.20	54.20	02.00
14	59.70	54.90	04.80
15	60.00	62.00	02.00
17	64.50	62.00	02.50
19	70.20	71.00	00.80
20	70.30	69.00	01.30
21	70.30	67.50	02.80
22	70.70	68.00	02.70
23	73.80	73.50	00.30
24	76.80	77.30	00.50
25	77.20	74.80	02.40
26	78.40	74.70	03.70
27	81.50	80.60	00.90

*Sample numbers are those of Crump and Ketner.

Monochromator. A Bausch and Lomb monochromator was used as a source of illumination to provide light of known wavelengths. Both for the Abbe refractometer (during the calibration of the oils) and for the microscope (during the measurement of the plagioclase grains), the band of the carbon arc spectrum, isolated for the 589.3 millimicron setting of the monochromator, ranged from 594 to 583 millimicrons in wavelength.

Light source. Two light sources were used during the experiment. A sodium vapor lamp was used as the microscope illuminant during the initial preparation and calibration of the oils. The D (Na) line index of refraction of the oils, as determined with the sodium vapor lamp, was later checked with the D line value as determined with the carbon arc light when the dispersion of the oils was measured. The carbon arc was the light source for the actual study.

Special Immersion Oils

Selection of the oils. In order to facilitate the measurement of the plagioclases indices of refraction, oils with a very high dispersion were desired. The mixtures of cassia oil and oil of cloves recommended by Winchell (1937, p. 81) to produce oils with indices

of refraction and dispersion suitable for use with the Tsuboi method were therefore used in this study.

Mixing of the oils. The mixing of the oils was simplified by the use of a burette, whereby known volumes of each oil could be delivered into a beaker for mixing. Twenty-two oils, ranging from 1.580 to 1.529 in index of refraction, were thus prepared and carefully measured.

Calibration of the oils. Using a sodium vapor lamp for the light source, the index of refraction of the oils for the D line of sodium (wavelength 589.3 millimicrons) was measured at 28 degrees centigrade with the Abbe refractometer. Following this initial calibration, the refractive indices of the oils for the C line (wavelength 656 millimicrons) and the F line (wavelength 486 millimicrons), as well as a repeat check for the D line, were again measured with the Abbe refractometer. The light source this time was the monochromator as illuminated by the carbon arc.

The indices of refraction and the dispersion of the set of oils prepared for this study are presented in Table III.

TABLE III

INDICES OF REFRACTION AND DISPERSION OF IMMERSION OILS USED

Bottle Label	Measured Index of Refraction*				Dispersion
	Sodium Light	Monochromatized Carbon Arc Light			
	Nd	Nc	Nd	Nf	
1.580	1.5785	1.5711	1.5785	1.5996	0.0285
1.575	1.5735	1.5663	1.5734	1.5938	0.0275
1.570	1.5684	1.5617	1.5684	1.5881	0.0264
1.565	1.5631	1.5564	1.5632	1.5819	0.0255
1.560	1.5586	1.5522	1.5585	1.5762	0.0240
1.555	1.5544	1.5482	1.5545	1.5718	0.0236
1.550	1.5485	1.5428	1.5485	1.5647	0.0219
1.548	1.5468	1.5411	1.5468	1.5628	0.0217
1.546	1.5446	1.5390	1.5447	1.5603	0.0213
1.544	1.5434	1.5378	1.5433	1.5586	0.0208
1.542	1.5411	1.5360	1.5411	1.5562	0.0202
1.540	1.5385	1.5334	1.5386	1.5534	0.02 0
1.538	1.5369	1.5319	1.5369	1.5514	0.0195
1.537	1.5357	1.5308	1.5357	1.5500	0.0192
1.536	1.5345	1.5294	1.5345	1.5483	0.0189
1.535	1.5333	1.5285	1.5334	1.5472	0.0187
1.534	1.5322	1.5275	1.5322	1.5485	0.0184
1.533	1.5316	1.5266	1.5315	1.5450	0.0183
1.532	1.5302	1.5255	1.5302	1.5437	0.0182
1.531	1.5294	1.5247	1.5295	1.5427	0.0180
1.530	1.5290	1.5244	1.5290	1.5423	0.0179
1.529	1.5275	1.5230	1.5275	1.5402	0.0172

*All data corrected to 28 degrees centigrade.

CHAPTER III

DETERMINING ANORTHITE CONTENT OF CRYSTALLINE ROCKS OF NORTHEAST TENNESSEE

Beech Granite Specimens

Variability of The Anorthite Content of The Beech Granite Plagioclase within a Confined Area

Normal Beech. At the Carter County road quarry near the town of Roan Mountain, Tennessee (Plate I, station 1), twenty-five rather closely spaced samples (Figure 1) were taken from the typical, coarse-grained Beech granite. Except for samples taken near the two basic dikes which cut the granite in the quarry, the average[1] anorthite content of the plagioclases in these specimens varied (Figure 1) from a minimum of 7.8 per cent (station D) to a maximum of 9.1 per cent (station C). The more altered and decomposed rocks seemed to yield plagioclases approximately one per cent lower in anorthite content than did fresh, unaltered specimens.

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[1] For each rock specimen ten plagioclase fragments were measured and their average anorthite content computed.

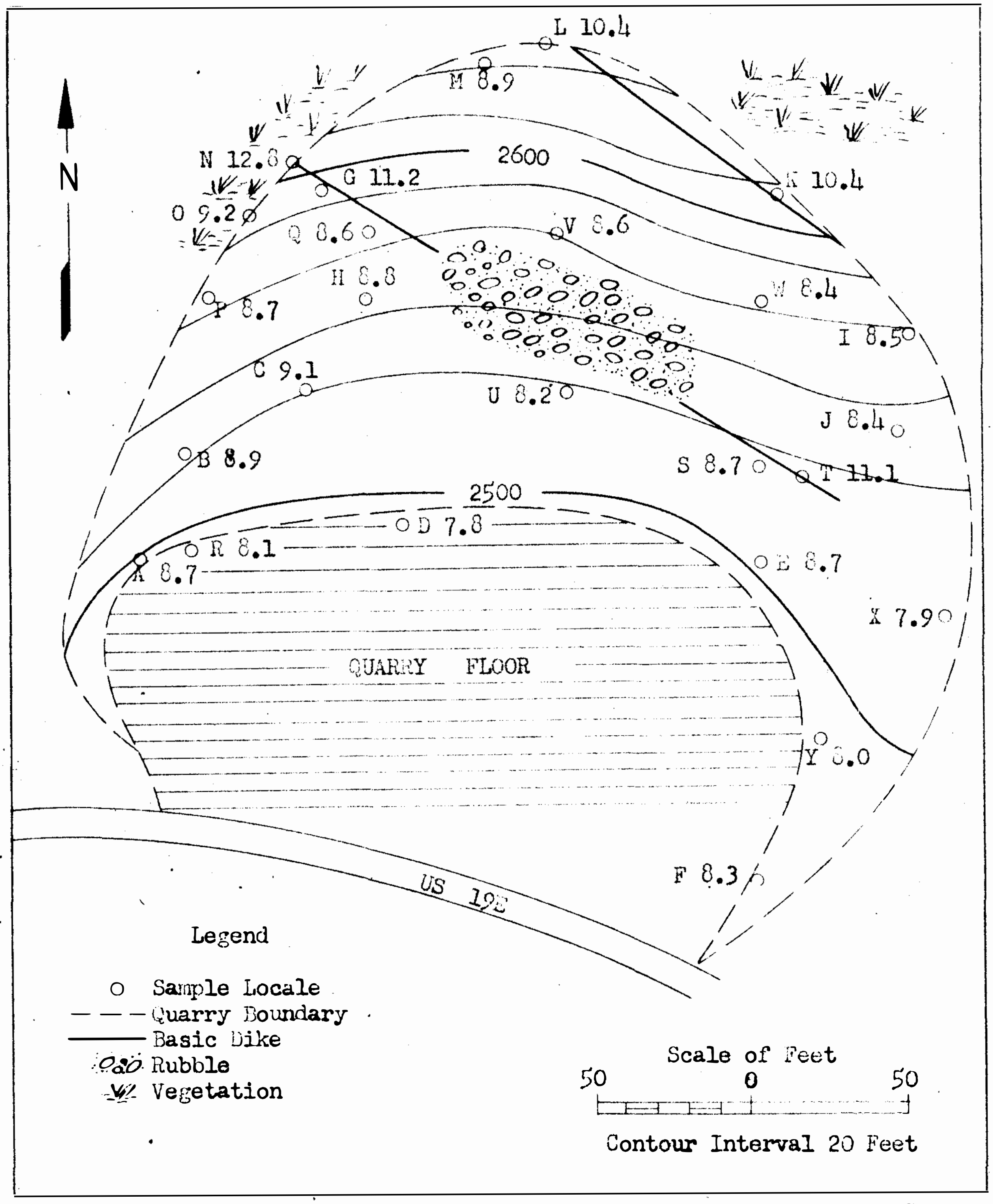

Figure 1. Contour map of Carter County road quarry (Station 1 on Plate I) in the Beech Granite. Letters indicate sample stations. Numbers show the per cent anorthite.

Figure 2 shows the frequency distribution of the anorthite content of the plagioclase taken from the quarry samples.

Beech near the basic dikes. Quarry samples G, K, L, N, and T (Figure 1), collected within five feet of the basic dikes, contained plagioclases of significantly higher anorthite content than did the normal Beech specimens. The values ranged from 10.4 per cent at stations K and L to 12.8 per cent at station N, the anorthite per cent increasing with increasing proximity to the dikes. The rock specimen collected at station N, for example, was in direct contact with the basic dike.

Variability of the Anorthite Content of the Beech Granite Plagioclases Over a Large Area

The average anorthite content of the plagioclases in the Beech granite was determined for fourteen samples collected at the sites indicated on Plate I. Excluding samples collected near basic dikes, the results indicate that, within a linear distance of slightly over eight miles, the determined anorthite values of the plagioclases range from 7.4 per cent to a maximum of 9.8 per cent. This range is surprisingly similar to the 7.8

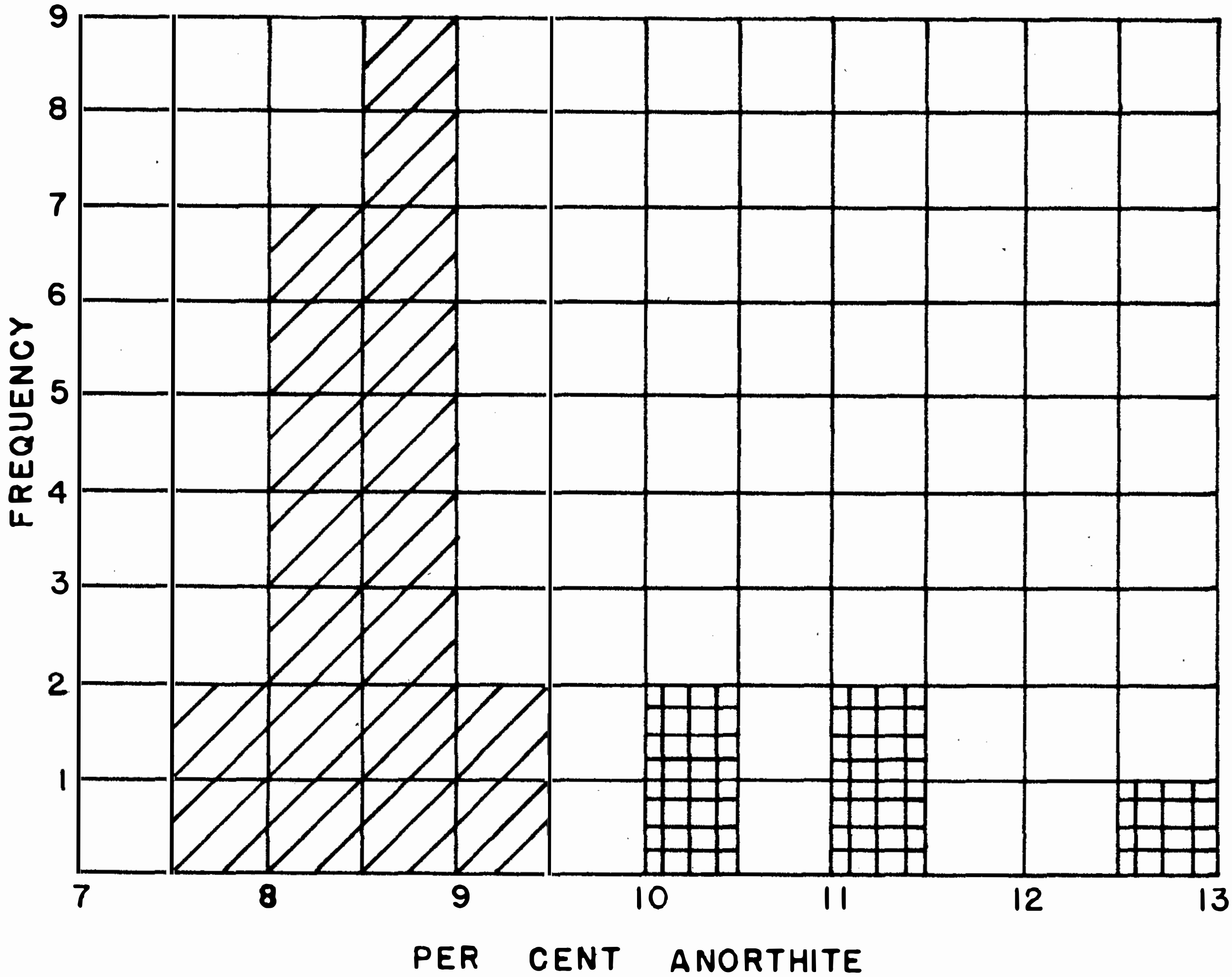

Figure 2. Frequency distribution of the anorthite content of the plagioclases from the 25 Beech granite specimens taken from the quarry shown in Figure 1. Diagonally lined squares indicate normal Beech specimens. Grid patterned squares indicate specimens located within five feet of the basic dikes (i.e. at locales G, K, L, N, and T on Figure 1).

to 9.1 per cent range found within the confines of the Carter County road quarry.

Contrary to the trend one would logically expect in a granite of igneous origin, there is an apparent tendency of the Beech granite plagioclase to become more anorthic toward the interior (as evidenced by coarser textures as well as by distance from the borders) portions of the body. The anorthite content of the plagioclases successively decreases from stations 7 to 8 to 9 (Plate I) and also from stations 15 to 16 to 13 to 2. It is realized, however, that the sample stations are relatively few and, therefore, the conclusions as to this trend must be somewhat tentative.

Another point worthy of note is the tendency of the Beech granite plagioclases in shear zones to have slightly higher anorthite contents than do plagioclase grains in fresh, unsheared specimens of Beech. Stations 6 and 21 (Plate I) are located within areas of sheared Beech.

Rocks Other Than Beech in the White Rocks Mountain Quadrangle

Gabbro

Station 11 on Plate I represents an outcrop of a gabbro. The average anorthite content of the plagioclases in a specimen from this rock was measured to be 32.9 per cent.

Cranberry Gneiss

On Plate L, stations 4, 5, 14, 17, 18, 19, 20, 22, and 23 represent locales mapped by Keith as Cranberry granite. The anorthite of the plagioclases in these samples was rather irregular, ranging from 12.4 per cent in rocks from station 22, to 25.4 per cent at station 5.

Summary

Table IV summarizes the data upon which this study was based. The station numbers correspond to those shown on Plate I. The per cent anorthite refers to the average of 10 determinations by the Tsuboi method on as many grains with the exception of station 1 which

TABLE IV

SUMMARY OF LOCATIONS AND PER CENT ANORTHITE OF SAMPLES STUDIED

Station Number on Plate I	Per Cent Anorthite	Location by Tennessee Co-ordinate System*
1	8.47	682,000N : 3,154,350E.
2	8.50	685,025N : 3,142,650E.
3	7.80	680,825N : 3,156,700E.
4	13.40	679,800N : 3,164,925E.
5	25.40	676,025N : 3,165,200E.
6	9.80	671,650N : 3,179,150E.
7	9.20	692,225N : 3,174,500E.
8	8.60	689,825N : 3,170,000E.
9	7.40	687,650N : 3,168,875E.
10	8.00	664,650N : 3,150,050E.
11	32.90	657,425N : 3,149,500E.
12	9.20	689,500N : 3,150,700E.
13	9.00	689,850N : 3,145,175E.
14	17.70	677,025N : 3,165,525E.
15	9.00	692,500N : 3,142,700E.
16	9.20	691,075N : 3,142,900E.
17	13.10	676,925N : 3,158,050E.
18	15.10	674,825N : 3,157,025E.
19	15.20	674,225N : 3,156,375E.
20	14.90	672,350N : 3,155,600E.
21	9.80	682,825N : 3,143,275E.
22	12.40	682,375N : 3,142,925E.
23	13.10	682,100N : 3,166,500E.
24	7.80	682,575N : 3,151,900E.

*This system was established by the U. S. Coast and Geodetic Survey.

was the quarry site. Here the per cent anorthite represents the average of 10 determinations on twenty-five samples, or the average of 250 determinations in all.

CHAPTER IV

CONCLUSIONS AND DISCUSSION

(1). Within a confined area (quarry, Plate I, station 1), the anorthite content of the Beech granite plagioclases ranged from 7.8 to 9.1 per cent.

(2). Over a linear distance of about eight miles, the anorthite content of the normal Beech granite plagioclases ranged from 7.4 to 9.8 per cent.

(3). In badly sheared Beech granite, the anorthite content of the plagioclases tended to be about 1 per cent higher than in non-sheared Beech.

(4). In badly altered and decomposed Beech granite, the plagioclases seemed to be about 1 per cent lower in anorthite content than in fresh Beech.

(5). Within five feet of the basic dikes, the anorthite content of the Beech granite plagioclases was higher than normal and became increasingly so with increased proximity to the dikes. One sample (at station N, Figure 1), in direct contact with the basic dike, contained plagioclases of 12.8 per cent anorthite in composition.

(6). In the White Rocks Mountain Quadrangle, rocks other than those of typical Beech lithology

contained plagioclases with consistently higher anorthite contents than did the samples of typical Beech. Except for the gabbro, which had plagioclase of 32.9 per cent anorthite, these rocks contained plagioclases ranging from 12.4 (station 22, Plate I) to 25.4 (station 5) per cent anorthite.

(7). The most anorthic Beech granite plagioclase was lower in anorthite content than would be expected in the average granite. This percentage, according to Gates and Clabaugh (Emmons et al, 1953, p. 10), would be expected to fall in the 23 to 26 per cent anorthite range.

(8). There is an apparent increase in the anorthite content of the Beech granite plagioclases toward the interior portions of the body studied. A relative paucity of sample stations renders this conclusion rather tentative. This trend is precisely the opposite of the trend one would expect in a granitic body of typical igneous origin and, if valid, suggests a different mode of origin for the Beech granite.

A further study, involving many more determinations as well as a statistical analysis thereof will be necessary to satisfactorily establish the validity of this trend.

(9). The plagioclases of the Beech granite (as mapped by Keith) are decidedly more albitic than those of the Cranberry gneiss. A criterion to aid in their distinction is thus suggested.

(10). The lack of zoning in the plagioclases of the Beech, as well as their consistent sericitization, support according to Turner and Verhoogen (1951, p. 289) and Ramberg (1952, p. 51) the thesis that the Beech granite has undergone regional metamorphism.

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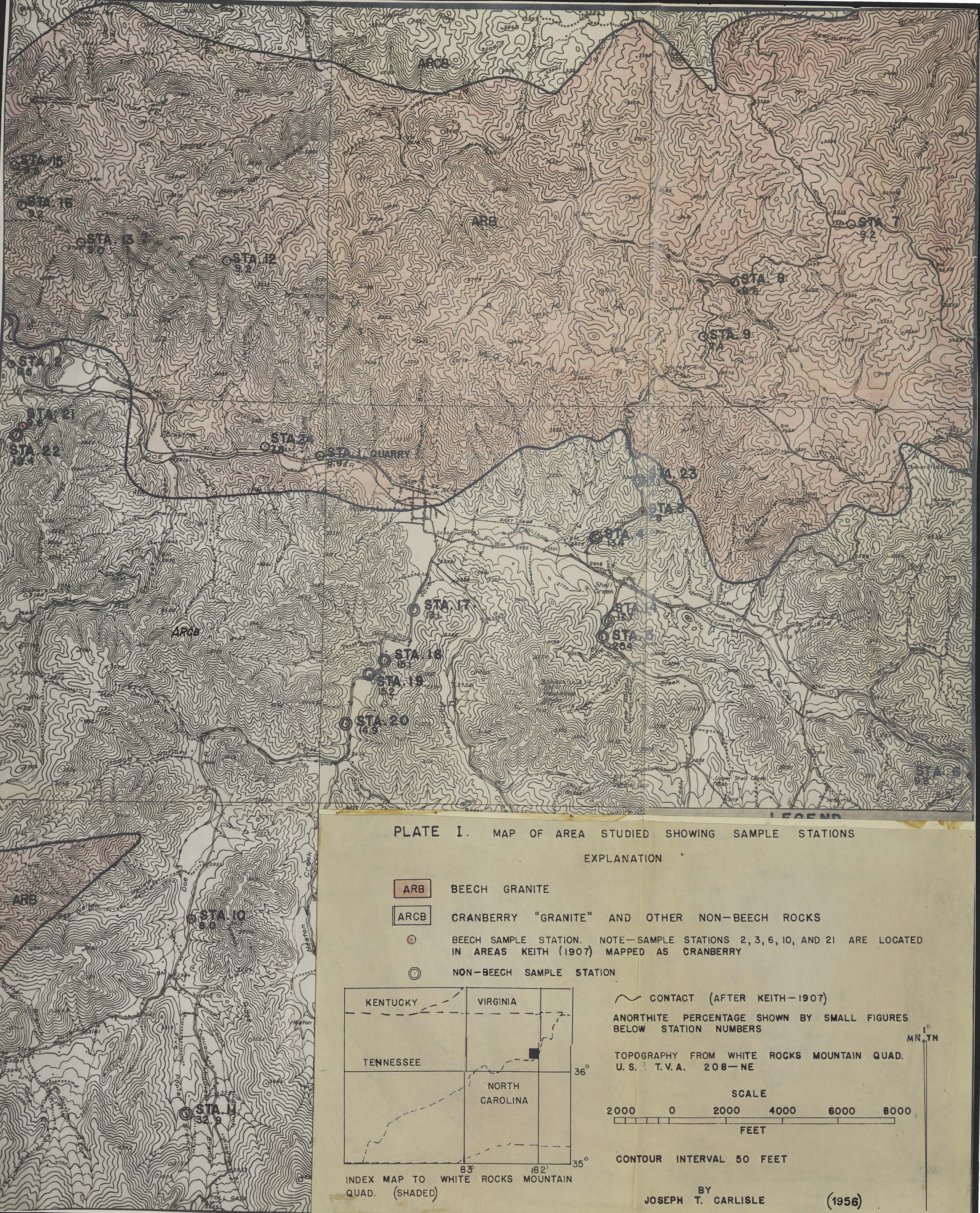
ARB
ARCB
STA. 15
STA. 16
STA. 13
STA. 12
STA. 7
STA. 8
STA. 9
STA. 21
STA. 22
STA. 24
QUARRY
STA. 23
STA. 17
STA. 18
STA. 19
STA. 20
STA. 10
STA. 11
LEGEND
PLATE I. MAP OF AREA STUDIED SHOWING SAMPLE STATIONS
EXPLANATION
ARB BEECH GRANITE
ARCB CRANBERRY "GRANITE" AND OTHER NON-BEECH ROCKS
BEECH SAMPLE STATION. NOTE—SAMPLE STATIONS 2, 3, 6, 10, AND 21 ARE LOCATED IN AREAS KEITH (1907) MAPPED AS CRANBERRY
NON-BEECH SAMPLE STATION
CONTACT (AFTER KEITH—1907)
ANORTHITE PERCENTAGE SHOWN BY SMALL FIGURES BELOW STATION NUMBERS
TOPOGRAPHY FROM WHITE ROCKS MOUNTAIN QUAD. U. S. T. V. A. 208—NE
MN TN
SCALE
2000 0 2000 4000 6000 8000
FEET
CONTOUR INTERVAL 50 FEET
KENTUCKY
VIRGINIA
TENNESSEE
NORTH CAROLINA
36°
35°
83°
82°
INDEX MAP TO WHITE ROCKS MOUNTAIN QUAD. (SHADED)
BY
JOSEPH T. CARLISLE
(1956)