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The Lakeview Mountains Pluton,
Southern California Batholith
Part II: Chemical Composition and Variation



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Abstract: Major elemental analyses and specific gravity determinations were made on bulked rock samples from 162 localities over the Lakeview Mountains pluton. Mineral separates from 126 localities were also analyzed. Results show that the pluton is highly homogeneous on the large scale with high heterogeneity on the small scale. Despite the high homogeneity, all analytical results define consistent zonal patterns approximately parallel to the walls of the body and to the concordant schlieren. This zonation shows that the Lakeview Mountains pluton has a relatively basic and dense core compared to its margin and implies that the last rock to crystallize was more basic than rock formed earlier.

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INTRODUCTION

The small- and intermediate-scale mineralogic heterogeneity of the Lakeview Mountains pluton has prevented us from delineating compositional zonations throughout the body by conventional field mapping methods, even though the preferred orientations of certain planar structures define a strong pattern parallel to the walls of the pluton. To test for the presence of possible compositional variation (and, if present, its relation to the structure of the mass) a means of averaging the local heterogeneity must be sought, thereby permitting valid comparisons of rock differences from locality to locality. Modal analyses, widely and successfully used to document the variations found in obviously zoned bodies (for example, Compton, 1955; Reesor, 1958; Moore, 1963) cannot be applied easily to the Lakeview Mountains pluton where schlieren rock types, in single exposures of 1 m², range from leucocratic to melanocratic. Clearly, the number of thin sections required per outcrop would be prohibitively large (*see* Emerson, 1964). For this reason, analyses of bulked samples per locality were made, aimed at detection of systematic changes in major elemental chemistry and specific gravity. Described here are the results of nearly 2000 elemental and specific gravity determinations from 162 localities over the exposed area of the Lakeview Mountains pluton; these demonstrate both whole-rock and individual mineral changes, arranged systematically and in correlation with the large-scale structure.

ACKNOWLEDGMENTS

Analytical and computational work reported here is part of a study of batholithic rocks in southern California, supported by National Science Foundation Grant GA-686 and by Pomona College. We are indebted to Professor D. B. McIntyre of Pomona College, who prepared all of the computer programs used in this study. Professor A. O. Woodford of Pomona College and Professor R. R. Compton of Stanford University made valuable criticisms of an earlier form of the manuscript; the authors alone, however, must assume full responsibility for the present form and content. E. E. Welday, now of Bear Creek Mining Company, San Diego, helped with the sample preparation and provided useful counsel as research associate while at Pomona College.

SAMPLING AND DATA-HANDLING CONSIDERATIONS

Prior studies of chemical variability in plutonic igneous rocks (for example, Baird and others, 1964, 1967a; Richmond, 1965) provided general guidelines to the sampling of the Lakeview Mountains pluton, but none of the earlier studies included rocks in which the small-scale heterogeneity was marked by pronounced compositional banding. A preliminary sampling of 30 localities and 344 whole-rock analyses, in the southern part of the Lakeview Mountains, was therefore necessary to test:

- (1) the required adequate volume of a single specimen;
- (2) the chemical variability of specimens collected 1.5 m (5 feet) apart (termed "within outcrop variability");
- (3) the chemical variability of specimens collected 91 m (300 feet) apart (termed "between outcrop variability"); and
- (4) the presence or absence of systematic variation over the 26-km² (10-square-mile) area of the preliminary test.

This test (detailed discussion and results in Baird and others, 1967b) showed that:

- (1) a 40-gram individual specimen was adequate; and
- (2) systematic chemical variations do exist in the pluton; but
- (3) the components of variability within and between outcrops were large compared with the variability over 26 km² (10 square miles).

To make possible the detection of the systematic areal variations in the Lakeview Mountains pluton, the small- and intermediate-scale variability must be reduced. It was concluded that nine specimens per sample locality should be obtained. Sample-locality spacing is a compromise between the expense of collection and analysis and the intended use of the derived data. From the preliminary study we knew that patterns of large-scale variation would be partly obscured by the high components of variability on small and intermediate scales, even with nine specimens bulked per locality sample. It was planned, therefore, to treat the derived chemical data by "trend surface analysis" (Grant, 1957; McIntyre, 1963, 1967; McIntyre and others, 1968), "... a procedure by which each map observation [chemical value] is divided into two or more

parts: some associated with the 'large-scale' systematic changes that extend from one map edge to the other and the others associated with 'small-scale' apparently nonsystematic fluctuations that are superimposed on the large-scale patterns" (Krumbein and Graybill, 1965, p. 321). Polynomial expressions for the trend surfaces are derived by least-squares techniques (in a manner directly analogous to least-squares curve fitting), and the large number of coefficients in the expressions requires a correspondingly large number of data points (that is, sample localities). We believe there should be approximately twice as many data points as required coefficients, or about 100 localities over the Lakeview Mountains pluton. A 610-m (2000-foot) grid over the exposed area yields 165 sample localities (Fig. 1), with a substantial margin for possible un-

collectible sites; however, we found only three sites that proved to be uncollectible and thus a grid of 800-m spacing would have been adequate. At each sample locality the nine individual specimens were collected on a grid of 15-m (50-foot) spacing; this interval was selected as a compromise between the small (outcrop) and intermediate (subarea) scales (*see* Baird and others, 1967b).

This sampling plan was specifically devised to minimize the small-scale inhomogeneity of the rock of the Lakeview Mountains pluton. Trend-surface analysis is considered here only as a constraint on the minimum number of localities that should be incorporated into the plan. If trend-surface analysis subsequently proved to be unnecessary or undesirable, then our only loss would be the effort expended in possibly "overcollecting" the pluton.

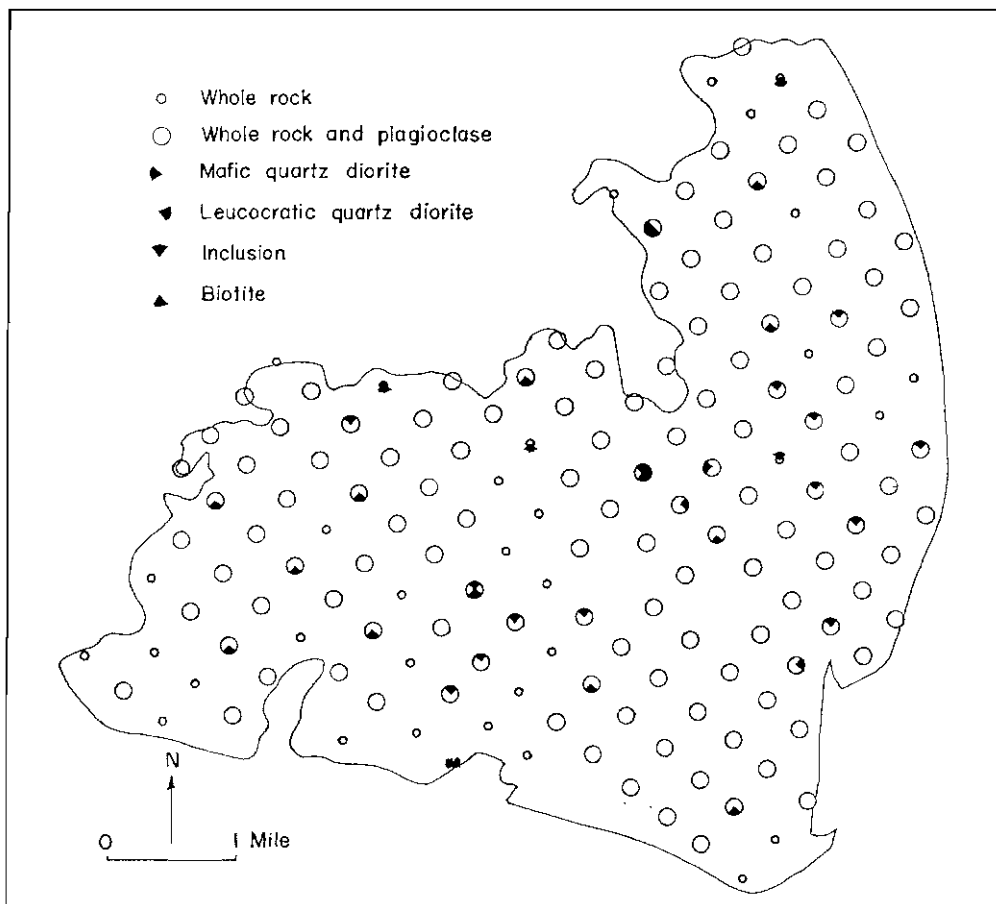


Figure 1. Sample locality map, Lakeview Mountains pluton.

COLLECTIONS AND ANALYSES PERFORMED

Individual specimen-collection sites were established by pacing from each field-located grid intersection. Specimens were obtained (by hammer) at the closest collectible rock within a 7.5-m radius. These weighed between 400 and 900 grams each. The sample obtained from each of 162 localities thus consisted of nine individual specimens bulked together, a total of 3.6 to 8 kg. Bulking was achieved by crushing, plate-pulverizing, and mixing the nine specimens; a riffle splitter was used to obtain two samples for chemical analysis (162 localities), one sample for mineralogic separation

(126 localities), and one sample for specific gravity determinations (162 localities). In addition, four specimens each of melanocratic and leucocratic quartz diorite and 22 inclusions were obtained for analysis.

Whole-rock chemical analyses for Na, Mg, Al, Si, K, Ca, and Fe were made by X-ray fluorescence spectrography. Plagioclase-quartz mineral separates were analyzed for Na, K, and Ca, and 18 biotite separates were analyzed for Na, Mg, K, Ca, and Fe by the same method. Specific gravity determinations were made on pulverized powders using air-comparison pycnometry. Analytical methods are discussed in Appendix A; Figure 1 shows the locations of analyzed mineral separates.

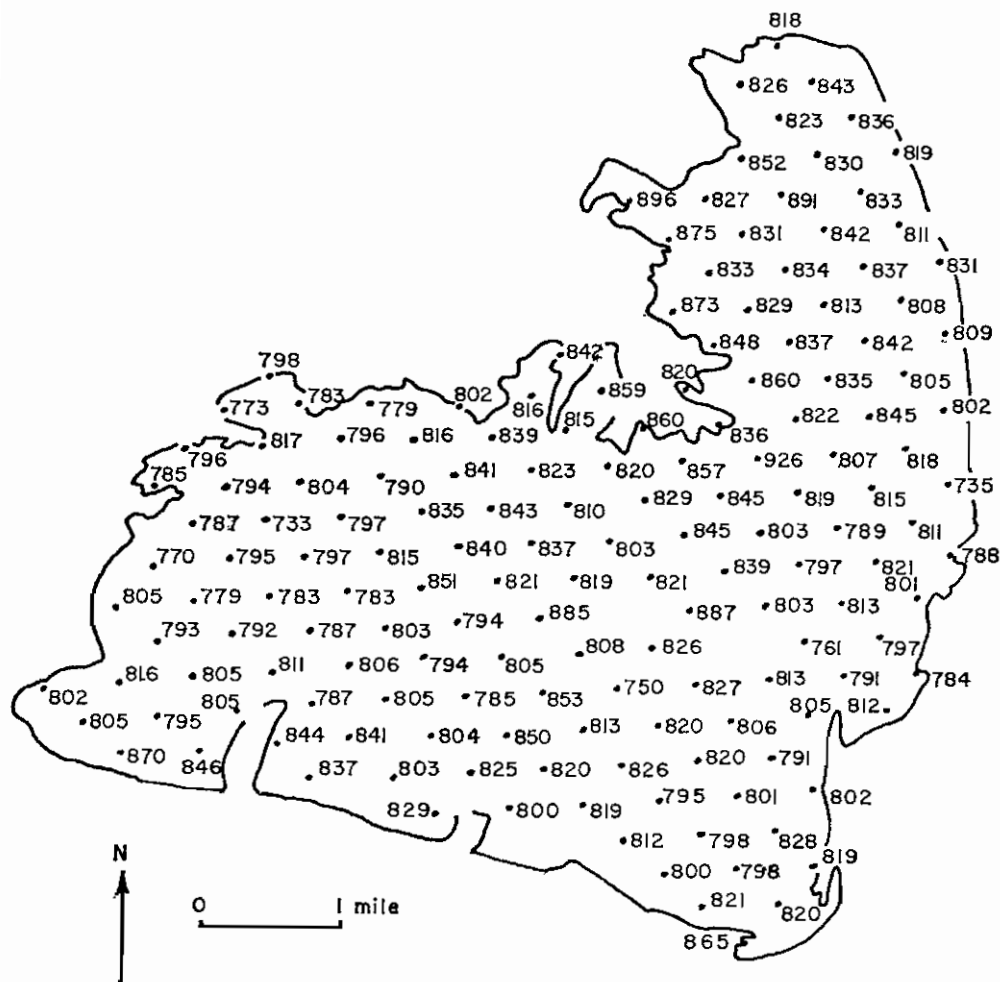


Figure 2. Specific gravity distribution of the Lakeview Mountains pluton. Values shown are minus 2.000 at three decimal places.

ANALYTICAL RESULTS

All chemical and specific gravity results have been deposited with the National Auxiliary Publications Service as Appendix B of this paper.¹ Results are keyed to a coordinate map of the Lakeview Mountains pluton that is included in Appendix B. For a discussion of results, whole-rock specific gravity and sodium

values from Appendix B have been plotted on Figures 2 and 3, respectively. All results are summarized in Tables 1 through 5 as mean values and standard deviations for whole-rock analyses and mean calculated anorthite contents and standard deviations for plagioclase analyses, with the equivalent K/Na ratios. Except in Table 1, all chemical values are expressed as weight-percent element because the spectrographic method used provides an elemental analysis. In Table 1, equivalent values of weight-percent oxide have been calculated to permit comparisons with other studies based upon wet-chemical silicate analyses.

¹For Appendix B, order NAPS Document 00305 from ASIS National Auxiliary Publications Service, c/o CCM Information Sciences, Inc., 22 West 34th Street, New York, New York 10001, remitting \$1.00 for microfiche or \$3.00 for photocopies. Checks may be made payable to ASIS-NAPS.

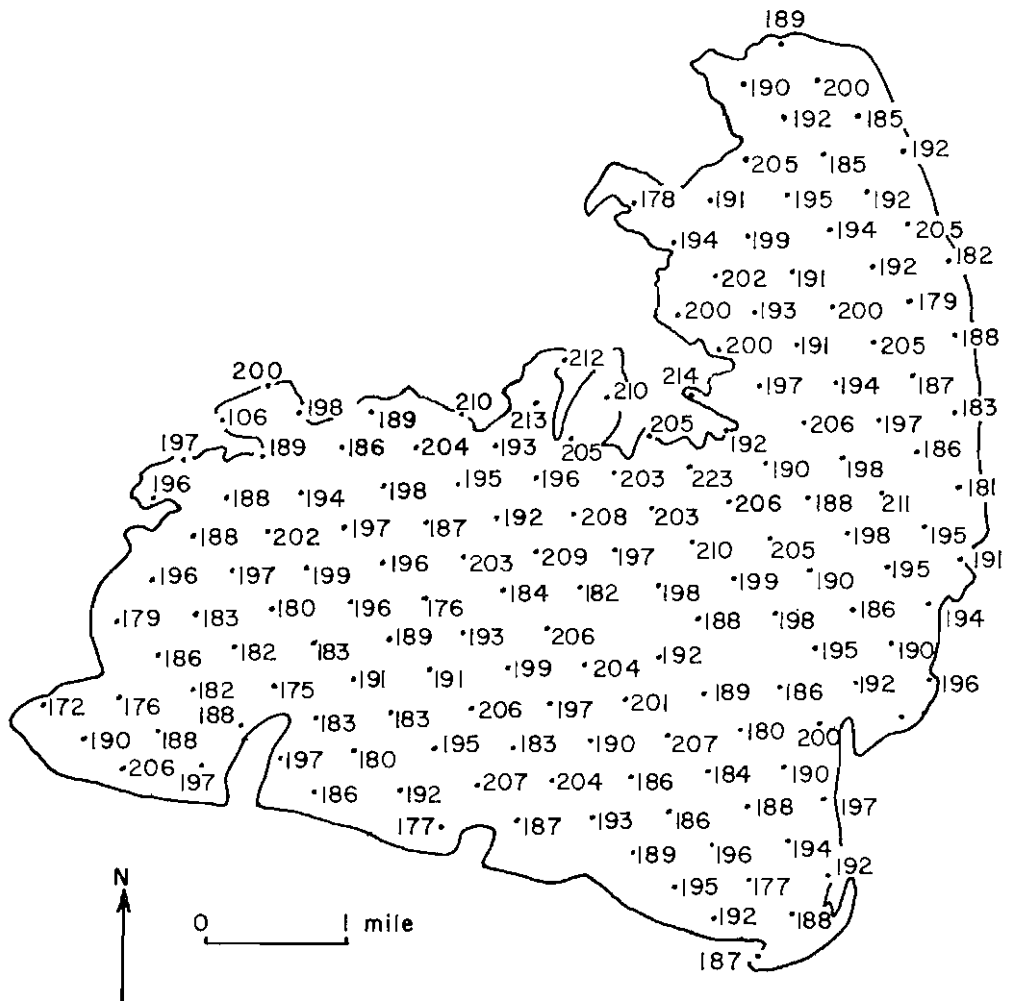


Figure 3. Sodium distribution of the Lakeview Mountains pluton. Values are weight-percent Na at two decimal places (decimal point not shown).

TABLE 1. QUARTZ DIORITE OF THE LAKEVIEW MOUNTAINS PLUTON: MEAN CHEMICAL COMPOSITION AND SPECIFIC GRAVITY

Element/ Oxide	Mean (wt %)		Standard deviation	
	Element	Oxide	Element	Oxide
Na/Na ₂ O	1.94	2.62	0.09	0.12
Mg/MgO	2.12	3.52	0.26	0.43
Al/Al ₂ O ₃	9.50	17.95	0.39	0.74
Si/SiO ₂	27.46	58.75	0.82	1.75
K/K ₂ O	1.21	1.46	0.31	0.37
Ca/CaO	4.92	6.88	0.47	0.66
Fe/Fe ₂ O ₃	5.09	7.28	0.49	0.70
Specific gravity	2.817		0.028	

DISCUSSION OF RESULTS

Whole-Rock Variation within the Lakeview Mountains Pluton

Comparison of results in Tables 1 and 3 demonstrates that the quartz diorite of the pluton is highly homogeneous on the largest scale, despite the heterogeneity on a local scale (see Part I, Pl. 3). We emphasize that the values of standard deviation in Table 1 not only include a component of variance related to real differences of chemistry and specific gravity between localities over the pluton, but also components of variance related to both analytical precision and local rock variation not completely eliminated by the sampling procedures at the locality level. This high large-scale homogeneity is evident if values of standard deviations in Table 1 are compared with the analytical precisions (standard deviations) of analyses of the U.S. Geological Survey standard rocks G-1 and W-1 (Stevens and others, 1960, Tables 3, 4). The differences between localities over the Lakeview Mountains pluton are only two or three times greater than the errors in analyses of the single standard rocks for most elements, and for one element, Na, the differences between localities is less than the analytical errors in G-1 and W-1.

In view of this high large-scale homogeneity, the detection of meaningful systematic changes in chemistry or specific gravity over the Lakeview Mountains pluton is difficult using only

TABLE 2. PARTIAL ANALYSIS OF PLAGIOCLASE, LAKEVIEW MOUNTAINS PLUTON

	Mean (wt %)	Standard deviation
Anorthite content	43.9	2.8
K/Na ratio	0.045	0.029

TABLE 3. SCHLIEREN OF THE LAKEVIEW MOUNTAINS PLUTON: MEAN CHEMICAL COMPOSITION AND SPECIFIC GRAVITY

Element	Melanocratic schlieren mean of four samples		Leucocratic schlieren mean of four samples	
	(wt. %)	<i>s</i> ^a	(wt. %)	<i>s</i> ^b
Na	1.36	0.25	2.69	0.50
Mg	5.32	0.63	0.25	0.24
Al	5.93	0.43	12.65	2.56
Si	23.03	2.13	29.70	2.95
K	2.65	1.47	0.37	0.13
Ca	4.25	0.36	5.52	1.06
Fe	11.00	0.91	0.53	0.48
Specific gravity	3.072	0.054	2.695	0.014

^a*s* = standard deviation.

direct map plots of the basic data. For example, specific gravity results (plotted in Fig. 2) have been contoured independently by each author. Each map shows a general specific gravity high in the central part of the pluton and a general specific gravity low in the southwestern part of the pluton, but the maps differ in all other details, apparently depending upon the contour interval selected and the individual's procedures (see Dodd and others, 1965, for a discussion of contouring problems). Over most of the pluton, the three maps resemble topographic maps of karst topography with scattered closed "depressions." We believe that the general areas of high and low specific gravity are evident by mere inspection and that objective hand contouring of the data is not practical and does not yield systematic patterns with possible geologic meaning. Some

TABLE 4. INCLUSIONS OF THE LAKEVIEW MOUNTAINS PLUTON: MEAN CHEMICAL COMPOSITION AND SPECIFIC GRAVITY

Element	Mean (wt %) of 8 inclusions, single locality	Standard deviation	Mean (wt %) of 14 inclusions, 13 localities	Standard deviation
	Na		2.13	
Mg	3.32	0.29	3.22	0.25
Al	9.83	0.52	10.22	0.30
Si	23.12	0.60	24.14	0.86
K	1.34	0.27	1.08	0.53
Ca	6.35	0.27	6.57	0.53
Fe	7.57	1.65	6.70	0.49
Specific Gravity			2.917	0.021

TABLE 5. PARTIAL ANALYSES OF BIOTITE,
LAKEVIEW MOUNTAINS PLUTON

Element	Mean (wt %)	Standard deviation
Na	0.62	0.08
Mg	15.4	0.29
K	7.4	1.00
Ca	0.86	0.55
Fe	15.1	0.49

chemical elements (for example, Na and Al) present even more difficult problems of hand contouring. Some data are shown in Figure 3.

Chemical and specific gravity results were, therefore, treated by trend-surface analysis to provide smoothed, objective maps (Pl. 1) of variation. This technique can be applied in several different ways (see discussion in Krumbain and Graybill, 1965, Chap. 13); here we are concerned only with the detection of large-scale patterns that are partly obscured by the small-scale heterogeneity of the pluton. Surfaces of successively increasing complexity were computed through the 8th degree (or order), and the increases in the closeness of fit of each successive surface over the next lower order surface were studied (Tables 6, 7). Theoretically, this procedure could be carried on indefinitely, assuming that an adequate number of data points and computer memory were available. Eventually one could derive a very complex surface that would exactly fit all the data for a given element over the pluton. The resulting map *would be* objective, but it would include all the small-scale variability we know to be partly obscuring any large-scale pattern. Clearly, the successive computations should stop at some optimum degree where the desired large-scale patterns are evident and where the

TABLE 7. SUMMARY OF TREND-SURFACE ANALYSES,
LAKEVIEW MOUNTAINS PLUTON:
PLAGIOCLASE FELDSPAR

Degree of surface	Degrees of freedom for residual	Percent sum of squares accounted for	
		Anorthite content	K/Na Ratio
1	123	13.0	10.5
2	120	24.6	21.2
3	116	31.5	23.3
4	111	37.2	39.8
5	105	43.4	44.1
6	98	52.5	52.4
7	90	55.1	57.2
8	81	60.5	65.9

surface derived does not ignore possibly meaningful data. We have no firm criteria for selection of this best, or most appropriate, degree of surface fitted to each variable, but we followed a suggestion made by McIntyre (1967, p. 47). We chose the surface of lowest degree in a succession of surfaces whose sum of squares of residuals approaches a constant value. Accordingly, Plate 1 shows 5th degree surfaces of elemental and specific gravity variations. For some elements (for example, Na and Al), a higher degree surface could have been selected under this criterion, but in the interests of direct comparison of one map with another use of a single, common degree seems most appropriate. By using this criterion and presenting 5th-degree trend surfaces, we do not imply that *all* meaningful information in the data has been utilized and that *only* useless "noise" remains in the residuals from the surfaces. We do contend, however, that patterns of large-scale variation are present.

To evaluate these statements we show trend surfaces from 1st through 8th degree for K in

TABLE 6. SUMMARY OF TREND-SURFACE ANALYSES, LAKEVIEW MOUNTAINS PLUTON:
WHOLE-ROCK CHEMISTRY AND SPECIFIC GRAVITY

Degree of surface	Degree of freedom for residual	Percent sum of squares accounted for							Specific gravity
		Sodium	Magnesium	Aluminum	Silicon	Potassium	Calcium	Iron	
1	159	4.2	17.2	3.2	9.5	17.2	24.0	8.5	9.5
2	156	17.7	24.9	11.7	22.9	42.9	40.3	22.5	26.1
3	152	23.6	42.7	22.1	41.5	61.1	55.8	33.4	42.9
4	147	27.6	48.1	28.7	51.8	71.0	65.1	35.3	46.6
5	141	30.9	52.0	34.9	60.3	77.7	72.1	41.0	48.3
6	134	34.4	54.4	40.1	63.2	79.0	75.8	44.9	50.2
7	126	40.9	55.1	44.1	65.2	82.6	79.8	45.5	51.7
8	117	49.1	58.5	48.6	68.5	83.6	81.2	50.2	54.5

Plate 2. The pattern of chemical variation remains the same for degrees 3 through 8 (our computational limit) with only minor irregularities appearing in the higher degree surfaces. It should be noted that the pattern defined by the 8th-degree surface for K accounts for 83.6 percent of the total sums of squares; the 5th-degree surface for Na (Pl. 1) is essentially identical in pattern but accounts for only 30.9 percent of the total sums of squares. The 3rd-degree surface for Na (Fig. 4), which accounts for only 23.6 percent of the total sums of squares, still shows the same basic variation pattern.

Howarth (1967) has shown that trend surfaces of random numbers can account for a maximum of 6.0 percent, 12.0 percent, and 16.2 percent of the total sums of squares (95-percent confidence) for 1st-, 2nd-, and 3rd-degree surfaces, respectively. Using these limits, only the 1st-degree surface for Na and the 1st- and 2nd-degree surfaces for Al could be ascribed to random distributions (see Table 6). Tinkler has recently suggested (1969) that meaningful trend-surface patterns of geologic data may exist below Howarth's limits.

We conclude, therefore, that consistent, large-scale variations over the Lakeview Mountains pluton have been demonstrated.² Patterns of elemental and specific gravity trend maps are in close, sympathetic agreement and demonstrate a regular systematic zoning generally parallel to the walls of the pluton. It is clear that the Lakeview Mountains pluton has a relatively dense and basic center with progressively less dense and less basic rocks toward the margins and a subsidiary basic low near the southwestern margin.

Schlieren and Inclusions

Analyses of melanocratic and leucocratic schlieren (Table 3) emphasize the extreme local heterogeneity of the banded quartz dioritic rock of the pluton. Inclusions analyzed were collected in two groups: 8 from outcrops in a single small area of 6-m radius and 14 from separate sites scattered over the pluton (see Fig. 1). Comparison of results (Table 4) for these two groups shows that the composition

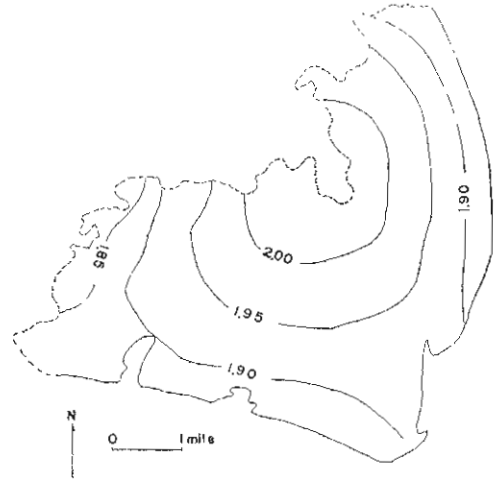


Figure 4. Trend surface (3rd degree) of sodium variation, Lakeview Mountains pluton. Contour lines are weight-percent Na. Surface accounts for 23.6 percent of the total sums of squares.

of inclusions is relatively uniform, with as much variation in one small area as over the entire Lakeview Mountains pluton. If systematic chemical variations in inclusions do exist over the pluton, a much more elaborate sampling and analytical plan is required to detect it.

A comparison of specific gravity values between melanocratic schlieren and inclusions is of particular interest; the presence of layers as dense as 3.07 lends little support to a concept of sinking of included material in the magma forming the pluton.

Mineralogic Variation within the Lakeview Mountains Pluton

The quartz diorite making up the Lakeview Mountains pluton is a mixture of essentially four minerals only. One mineral (quartz) is of fixed composition; the remaining three (plagioclase feldspar, biotite, and hornblende) are of variable composition. Here we consider changes in both mineralogic composition and mineralogic content across the body.

The anorthite content of plagioclase and the K/Na ratio (Table 7 and Pl. 1) yield trend patterns geometrically similar to patterns from whole-rock analyses. A sympathetic relation exists between the anorthite content and the whole-rock Mg and specific gravity. Similarly, the K/Na ratio of plagioclase and whole-rock K are in agreement.

² At present it is not possible to provide rigorous confidence intervals on these surfaces. As pointed out by Krumbain and Graybill (1965, p. 345), confidence intervals on surfaces higher than 1st degree are very complex.

Analyses of biotite (Table 5) also show systematic variations. Most marked is the K content; less obvious is the change in Fe, Mg, and Ca. Whole-rock K analyses show the greatest elemental range in proportion to the amount of the element present, and the mineralogy of the quartz diorite dictates that only biotite can contain K in an amount exceeding about 0.6 percent. The K variation, therefore, is largely a reflection of change in the biotite content or biotite composition, or both, across the pluton.

The mean K content of six biotite samples from the most basic part of the pluton, and within the 1-percent whole-rock K contour of Plate 1, is 6.6 percent, and that of four samples from the basic low, within the 1.4-percent whole-rock K contour, is 8.2 percent. This range in the K content of biotite in the Lakeview Mountains pluton covers the entire range of K values reported for biotites of igneous origin (Deer and others, 1962) and raises the question of possible sample contamination by incompletely separated hornblende, the only other dark-colored, non-magnetic, mafic mineral in the rock. This possibility is readily discounted; to reduce the K content of a biotite sample by 1.9 percent, through admixing hornblende containing 0.6 percent K (Larsen and Draisen, 1950, p. 71), would require about 20 percent hornblende in the sample. Such a level of contamination would have been easily detected in the optical examination of the mineral separates. Furthermore, the addition of 20 percent hornblende would have raised the Ca content of the sample to a value significantly higher than that actually determined. We conclude, therefore, that a relatively large change in composition of biotite mica must occur across the Lakeview Mountains pluton.

The available chemical data on mineralogic variations, taken with the whole-rock chemical analyses, allow reasonable calculations of the range of mineralogic variation in the quartz diorite. Because the total differences in whole-rock chemistry are small (for example, the range of Na is only 0.7 percent), the extremes were used in the calculations of ranges: the mean chemistry of the central basic high and the marginal basic low. Because the occurrence of K with respect to mineral phases present is readily fixed, the amounts of K were divided proportionally between biotite, hornblende, and plagioclase. Mg, present only in the mafic phases hornblende and biotite, was used to

TABLE 8. CALCULATED MINERALOGY AND SPECIFIC GRAVITY AND MODAL MINERALOGY, LAKEVIEW MOUNTAINS PLUTON

	Calculated Mineralogy		Modal Mineralogy	
	Volume Basic high	Percent Basic low	(from Part I, Table 1) Mean Range	
Plagioclase	An ₅₀ 40	An ₄₄ 39	An ₄₀ 50.3	34-70
Quartz	29	33	22.2	13-32
Hornblende	24	14	12.1	4-29
Biotite	7	14	14.4	7-23
Specific gravity	2.85	2.82

adjust the relative amounts of these phases determined from the K content. Ca not used in mafic phases enters the calculated plagioclase. Accessory minerals are not considered. Results are shown in Table 8.

A comparison of these results with the modes measured from 16 standard thin sections (Table 8) reveals that the *mean* mode, as measured, lies outside the ranges of calculated mineralogy for all minerals. However, it is important to note the extreme ranges of modal mineralogy (Part I, Table 1): one rock had less than 15 percent total mafic minerals and another had almost 50 percent. We conclude that modes measured from 16 thin sections are of little value in estimating, quantitatively, the mineralogy of the Lakeview Mountains pluton.

CONCLUSIONS

The detection of systematic zoning in a plutonic body with such high small-scale heterogeneity and large-scale homogeneity is an important result of this study. This zoning, moreover, is the inverse of that typically found in plutonic rock bodies: descriptions of granitic masses with more siliceous or potassic margins are few in number. For those described, two mechanisms have been advanced in explanation: one consists of alteration of the margins of the body by late magmatic fluids (Gilluly, 1937); the other invokes transfer of sodium and silicon from heated country rock into the margins of the pluton (Saha, 1958). The former process results in the formation of a readily recognizable mineral assemblage and texture; the latter requires a specific geologic setting (Saha, 1958, p. 616-617). Clearly, neither process is applicable to the Lakeview Mountains pluton.

On petrologic grounds it was suggested (Part I) that the part of the pluton containing the greatest concentration of pegmatite bodies was the locus of the last magma to crystallize. Support for this suggestion was lent by the structural analysis. This part of the pluton is also the most basic; the most silicic rock occurs in an area which was suggested to have crystallized earlier.

Thus chemical and field data together suggest that the magma forming the Lakeview Mountains pluton became more basic as the body expanded toward the east. Mappable masses of hypersthene gabbro, in disequilibrium with the main rock of the pluton, are more common in the central area than near the margins. Appeal to a process of assimilation of this more basic material by the magma raises spatial and temporal problems, however. If these masses represent relics of partial assimila-

tion, now frozen *in situ*, their scarcity in most marginal parts of the pluton might be attributed to their *total* assimilation in the early-formed magma. The chemical evidence clearly contradicts this concept, except very close to the southern contact of the pluton, adjacent to the lenticular, layered gabbro body where partial contamination may have occurred. The fact remains, however, that included mafic rock and the most basic quartz diorite of the Lakeview Mountains pluton are spatially associated.

Significant incorporation of siliceous wall rock in the marginal portions of the pluton is apparently ruled out by structural evidence. The marked concordance of the pluton and the conformity of its internal structures to the walls preclude all but minor and local assimilation or replacement, or both. Obviously, any such reactions would serve to intensify the observed chemical zoning.

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APPENDIX A: ANALYTICAL METHODS

X-Ray Fluorescence Spectrography

Elemental determinations were made in a vacuum-path spectrograph using tungsten excitation for K, Ca, and Fe. A demountable X-ray source (Henke, 1962) with interchangeable targets was used for the lighter elements: Ag $L\alpha$ excitation for Al and Si and Al $K\alpha$ excitation for Na and Mg. Details of this equipment are published elsewhere (Henke, 1963; Baird and others, 1965). Samples, except feldspars, were prepared by the moderate-dilution lithium tetraborate method described in Welday and others (1964). A computer program written by McIntyre (1964) and described by Baird and others (1965) was used to relate unknowns to wet-chemically analyzed standard rocks, including those of the U.S. Geological Survey. Feldspar-quartz separates were fine-ground and briquetted for analysis and related to similarly ground pure-feldspar standards. Because of the presence of quartz in the samples, ratios of emission intensities were used: Na/Ca (for calculation of the anorthite content, assuming stoichiometric proportions) and K/Na.

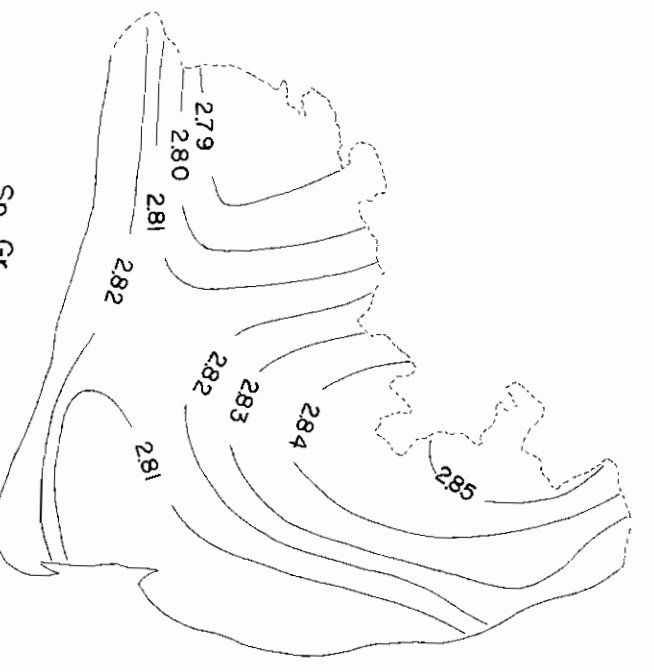
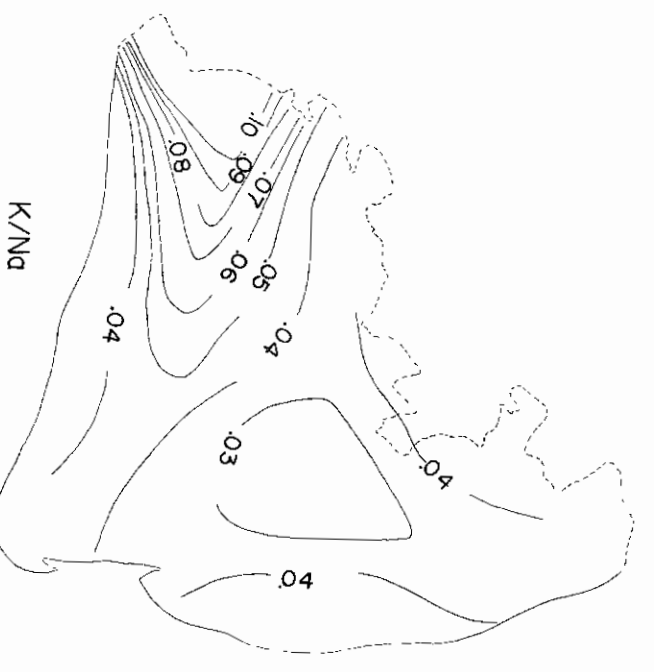
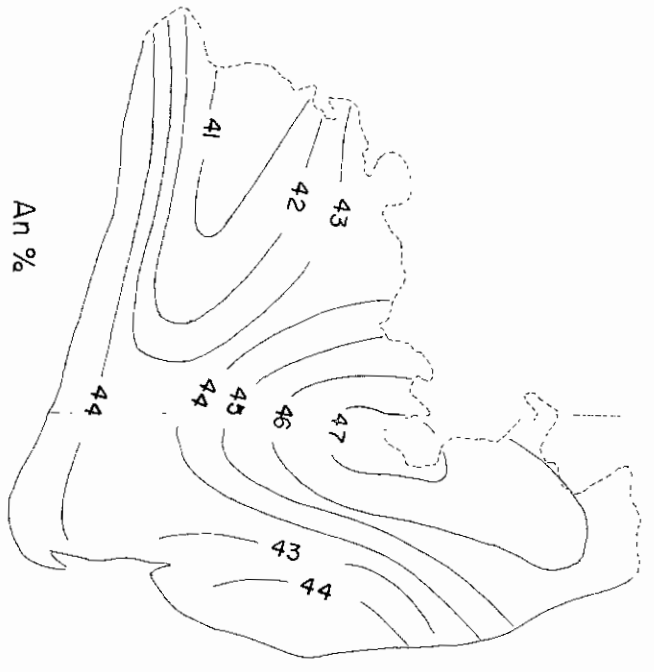
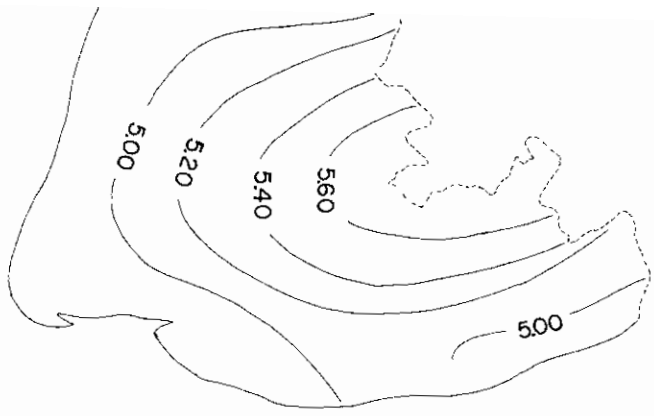
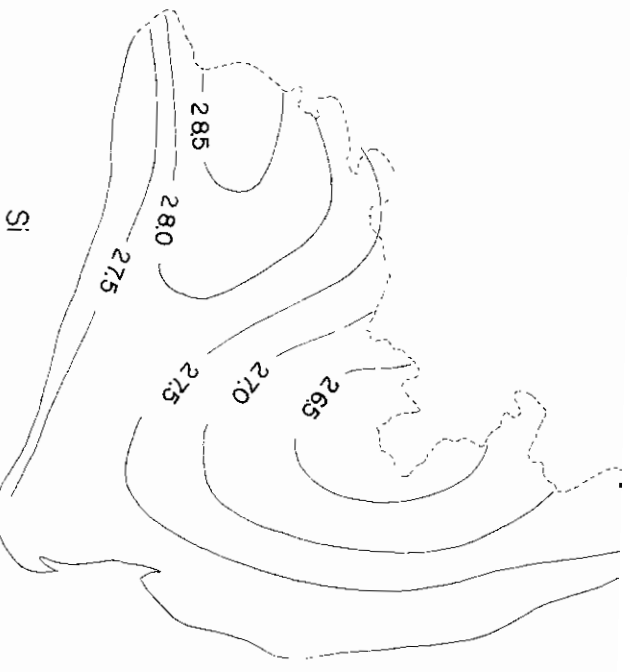
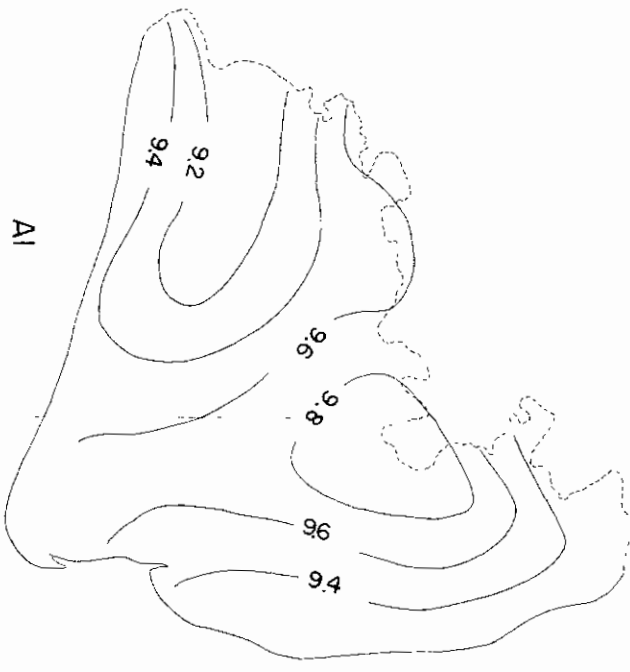
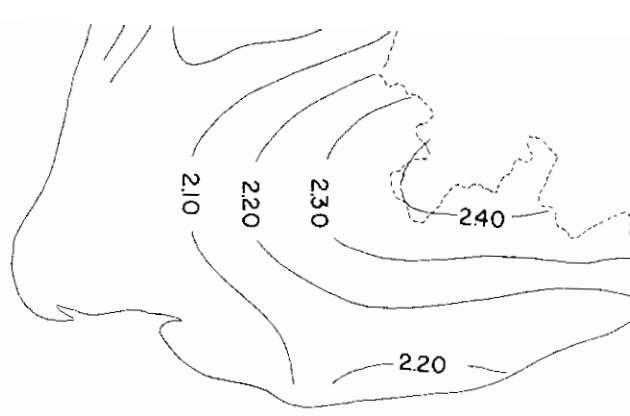
The analytical precision of this X-ray method has been shown to be equal to or better than conventional wet-chemical procedures (Baird and Welday, 1968). The accuracy is more difficult to evaluate (*see* discussion in Baird and Welday, 1968), but in this study it is largely irrelevant because we are concerned only with relatively small compositional changes in one rock type, quartz diorite.

Specific Gravity

Coarse powders (–80 mesh) from the plate-pulverizer were measured volumetrically by an air-comparison pycnometer (Beckman model 930) and weighed on a top-loading balance (Mettler P120). The method was calibrated using optically clear quartz fragments. Use of the pycnometer and its precision have been discussed in detail elsewhere (McIntyre and others, 1965).

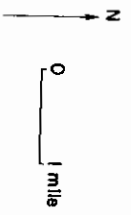
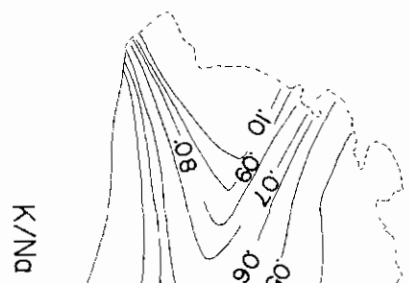
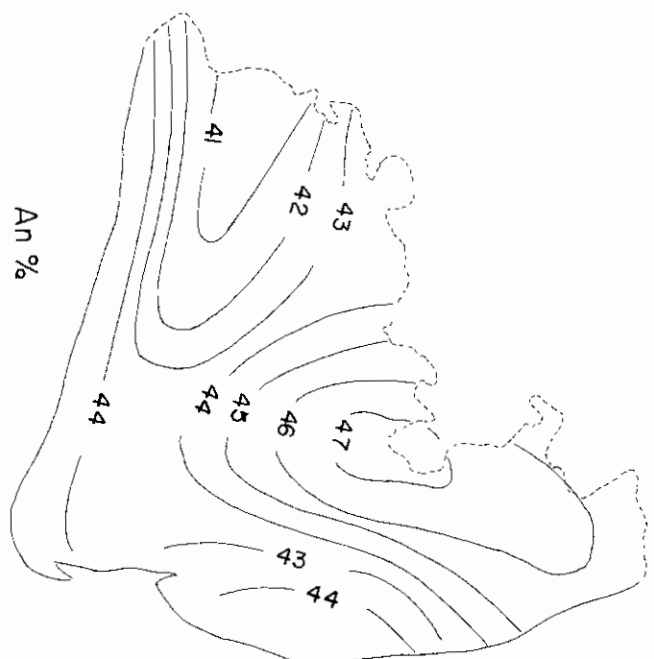
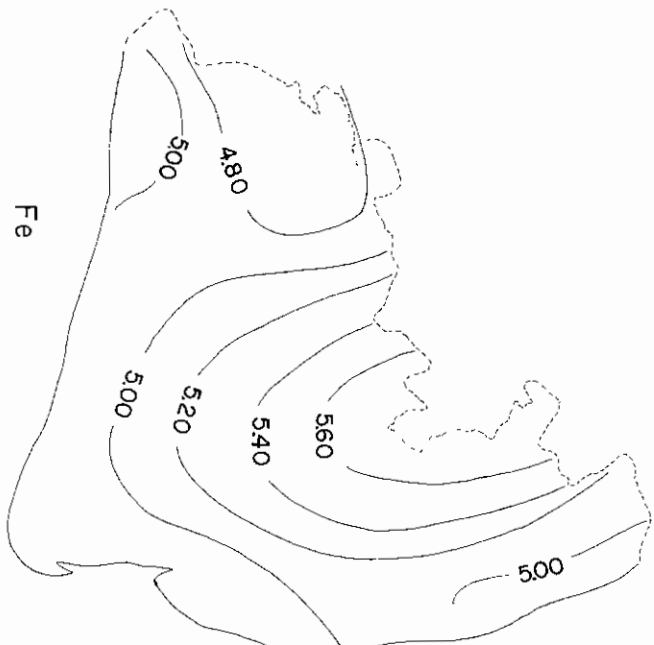
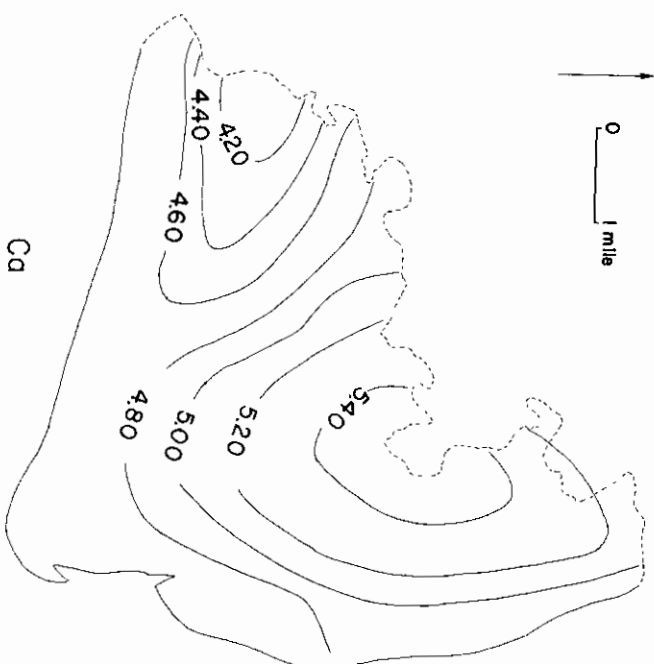
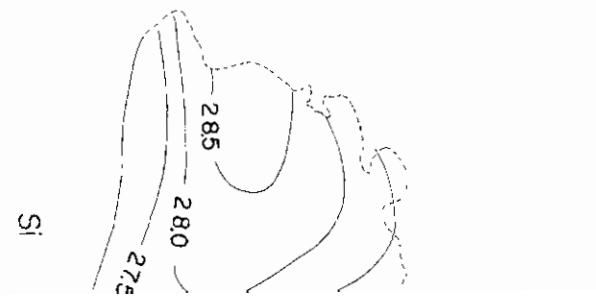
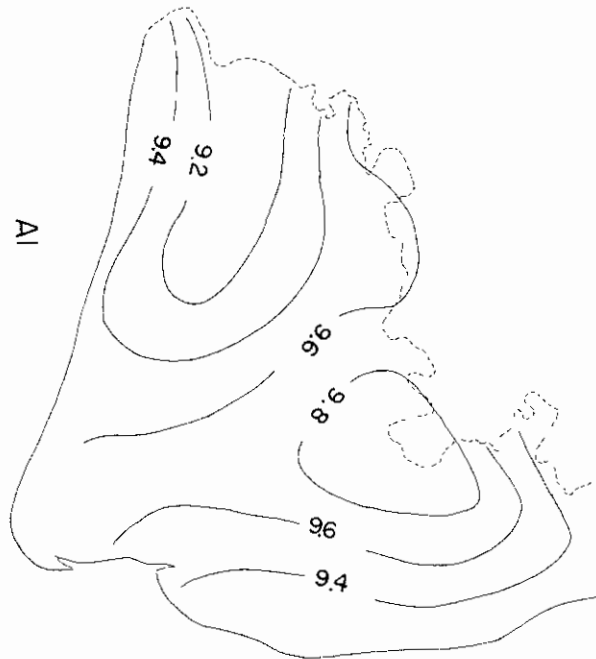
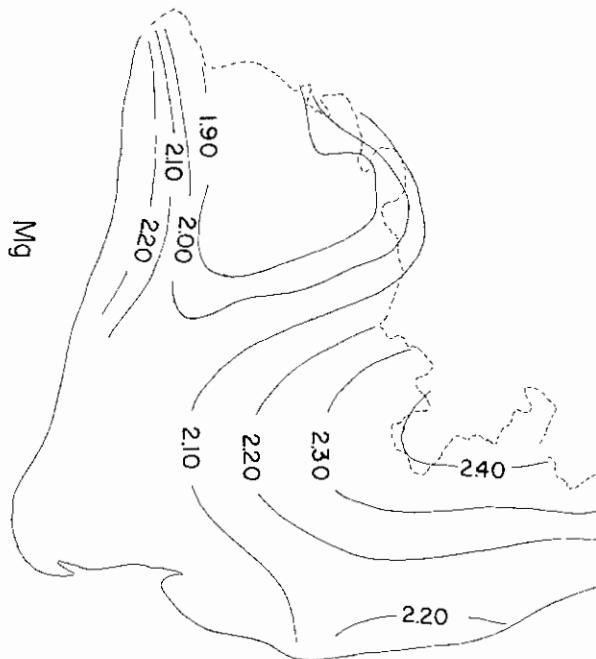
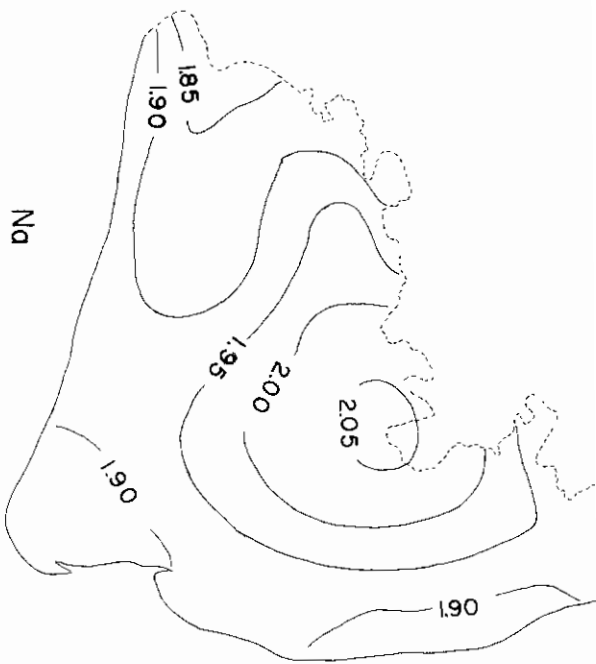
Mineral Separation

Splits of pulverized, bulked samples were passed through a Frantz separator in the inclined chute mode, after removal of the strongly magnetic fraction with a hand magnet. Resulting fractions were cleanly divided as quartz-feldspar and biotite-hornblende. The former split was fine-ground for analysis. Biotite was removed from hornblende by a vibratory technique across a sloping surface. Mica separates were hand-cleaned of remaining amphibole under the microscope.



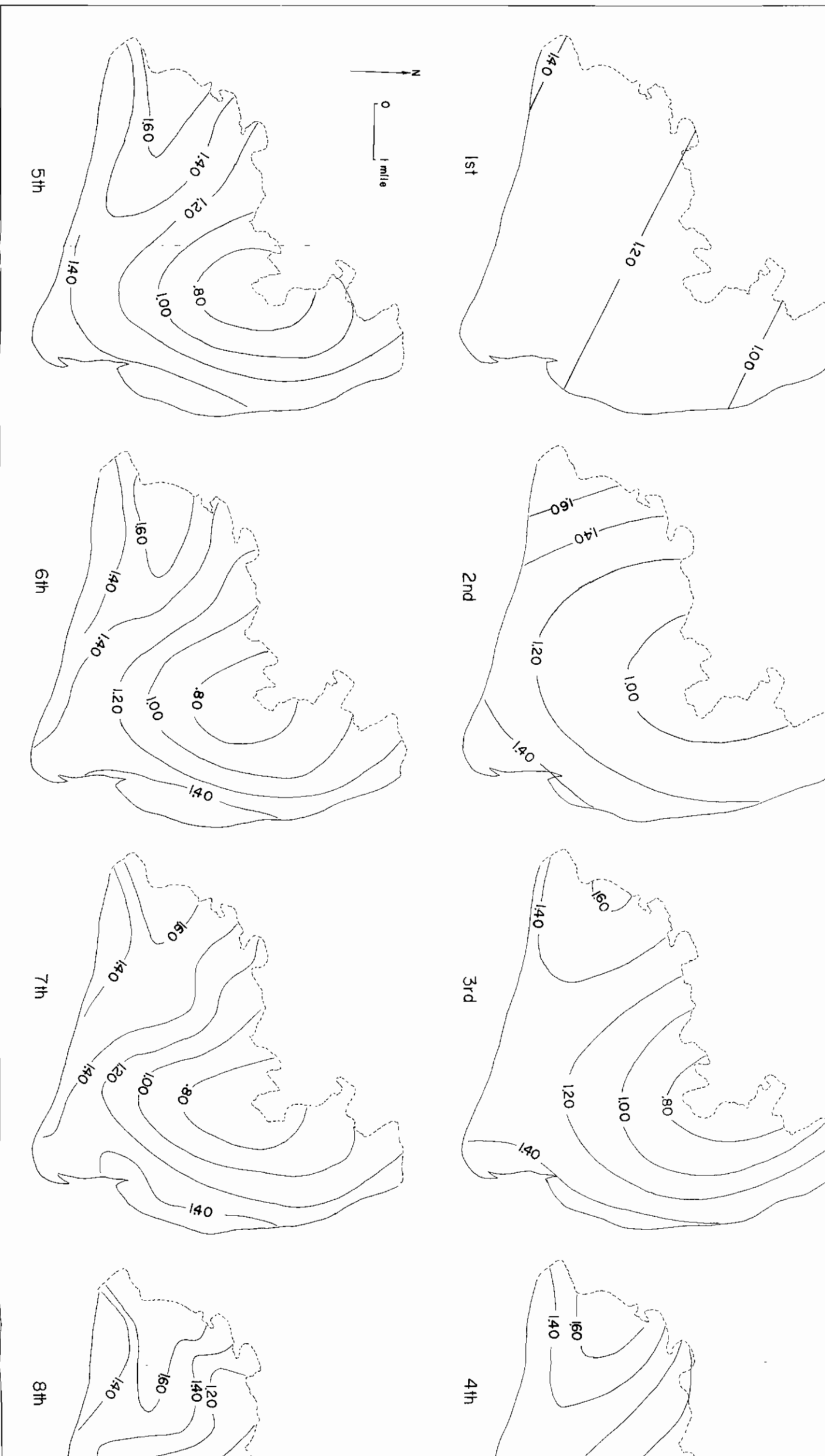
TREND SURFACES (5th DEGREE) OF ELEMENTAL AND SPECIFIC-GRAVITY VARIATIONS, LAKEVIEW MOUNTAINS PLUTON

Contours of elemental values are weight-percent element. See Tables 6 and 7 for percentages of total sums of squares.



TREND SURFACES (5th DEGREE) OF ELEMENTAL, AND SPECIFIC-GRAVITY VARIATIONS, LAKEVIEW MOUNTAINS PLUTON

Contours of elemental values are weight-percent element. See Tables 6 and 7 for percentages of total sums of squares.



TREND SURFACES (1st THROUGH 8th DEGREE) OF POTASSIUM VARIATIONS,
LAKEVIEW MOUNTAINS PLUTON

Contours are weight-percent K. See Table 6 for percentages of total sums of squares.