AN APPLICATION OF MULTIVARIATE VARIANCE ANALYSIS TO MINERALOGICAL VARIATION; PREISSAC-LACORNE BATHOLITH, ABITIBI COUNTY, QUEBEC[1]

K. R. DAWSON[2]

Geological Survey of Canada, Ottawa

ABSTRACT

Seventy-eight specimens of the quartz monzonite from the Preissac-Lacorne batholith were thin sectioned and modal analyses were made using the point count technique. The constituent minerals are grouped into four categories; total mafics, quartz, plagioclase, and potassium feldspar. A qualitative univariate analysis of the geographic distribution and percentage data is illustrated by map figures and compared with the quantitative method. The geological significance of areal variations is discussed and the data are subjected to multivariate variance analysis which confirms suspected regional homogeneity and disproves the existence of significant local variations.

Introduction

It is proposed to compare the application of multivariate hierarchal analysis (Krumbein & Tukey, 1956) with the qualitative approach to the distribution of the mineralogical constituents of the quartz monzonite found in the Preissac-Lacorne batholith. The batholith is exposed within an area 40 miles long by 16 miles wide, in Abitibi County, northwestern Quebec. It occupies the greater part of the La Motte (Norman, 1944) and Fiedmont (Tremblay, 1950) map areas, and extends beyond the southern limit of the latter. The Preissac-Lacorne batholith outcrops within the belt of Archaean lavas and metasedimentary rocks, that extends from the Ontario boundary to a point southeast of Senneterre (Dugas & Gilbert, 1953). The batholith is easily reached by highway from Malartic, Val d'Or, and Amos on routes Nos. 60 and 61. The structural geology of the batholith has been described by Dawson (1953) and the associated beryllium and lithium deposits by Rowe (1953).

Procedure

78 modal analyses of the quartz monzonite have been made using the point count technique (Chayes, 1956), aided by staining the potassium feldspar. Single thin sections were cut from hand-specimens collected as nearly on mile centres as the outcrops permitted. These thin sections

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[2]Geologist, Geological Survey of Canada.

have a minimum of holes, average 390 square millimetres in area, and have a Chayes I. C. factor of 59[3] (Chayes, 1955). The mineralogical constituents of the quartz monzonite have been divided into four categories, total mafics, quartz, plagioclase, and potassium feldspar (*see* Table 1). All biotite, muscovite, hornblende, and epidote present in amounts exceeding 1 per cent were grouped together as total mafics, and sericite and epidote inclusions in plagioclase have been counted as plagioclase. No distinctions have been made on the basis of the anorthite content of the plagioclase which is a sodic variety ranging from albite to sodic oligoclase. The geographic distribution of these four classes of minerals is illustrated by Figures 1, 2, 3, and 4, and the arithmetic mean, standard deviation, and precision by Table 1.

TABLE 1. AVERAGE MINERALOGICAL COMPOSITION OF THE PREISSAC-LACORNE QUARTZ MONZONITE BASED UPON 78 MODAL ANALYSES

Constituent	Percentage	Standard deviation	Precision ±
Total mafics	7.00	4.35	0.49
Quartz	27.00	7.23	0.82
Plagioclase	38.10	5.08	0.58
Potassium feldspar	28.10	5.04	0.57

The standard deviation is a measure of the spread of the values about the arithmetic mean. It is the root of the sum of the squares of deviation of the individual values from the arithmetic mean. Two thirds of the determinations in a normal distribution occur within one standard deviation of the arithmetic mean and 95% within two standard deviations.

Univariate Qualitative Analysis

Distribution of mafics. The mafic content of the quartz monzonite (*see* Fig. 1), is almost uniformly less than 10% of the mineralogical constituents and few of the analyses vary more than one standard deviation from the arithmetic mean. The anomalies are restricted to local highs due to single analyses, which, in most cases, lie close to the contacts of the country rocks. Most of the anomalies are elliptical rather than linear in shape.

The quartz monzonite shows a remarkable degree of homogeneity with respect to its mafic content both on a massif- and batholith-wide

[3]The I. C. (identity change) factor is an estimate of the number of grain contacts between major constituents per inch (25 mm.) of traverse used to characterize the coarseness of two feldspar granites.

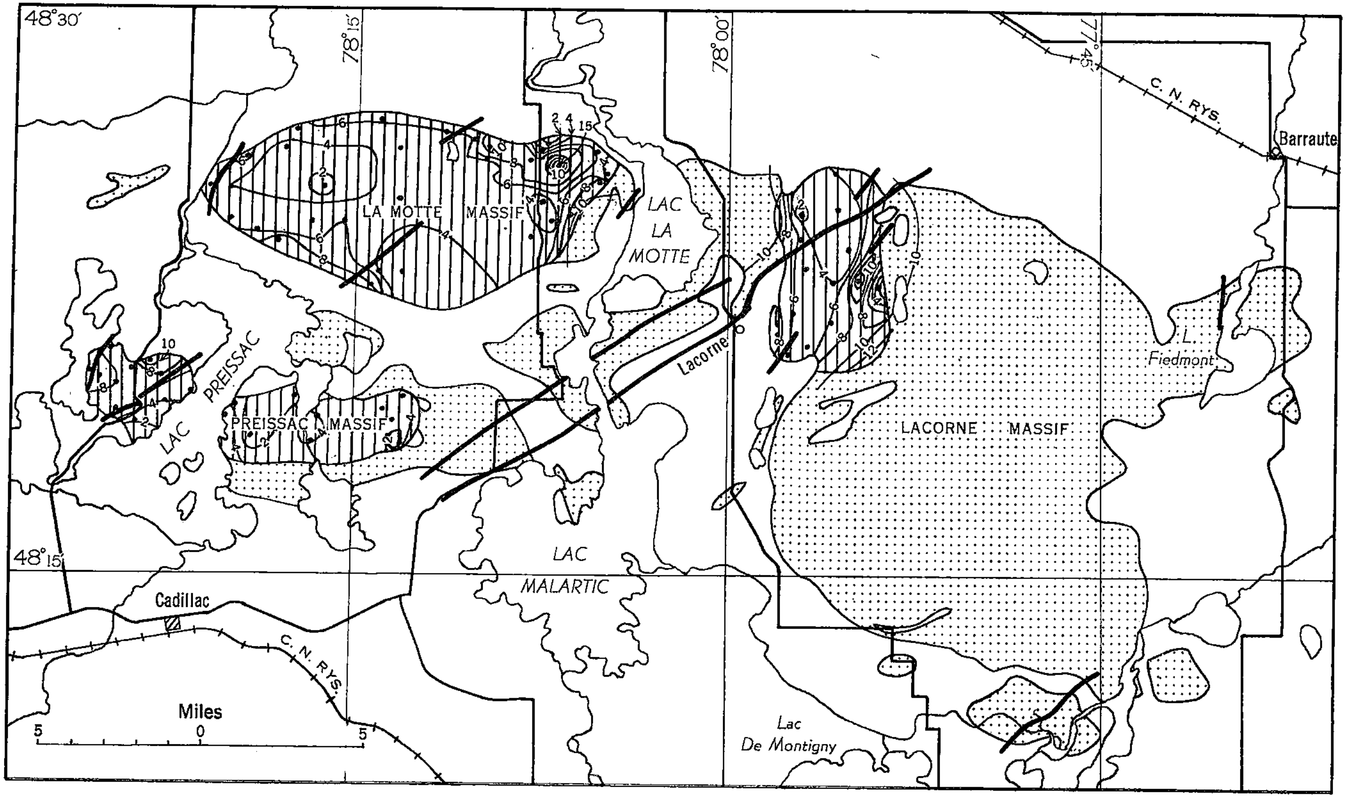

FIG. 1. Distribution of the total mafic content of the Preissac-Lacorne quartz monzonite is shown by contours having an interval of 2 percent. The quartz monzonite is shown by the ruled areas; the other batholithic rocks by the stipple; the gabbro dykes by heavy black lines, and the country rock has not been patterned.

scale. The anomalies lying near the country rock may be due to incorporation of some mafic material, although care was taken to avoid specimens with obvious xenoliths. The lack of linear anomalies parallel with the strike of the enclosing rocks (Dawson, 1953) and the low content of mafic minerals make it unlikely that the quartz monzonite is a granitization product of the enclosing biotite schist, greenstone, and serpentinite.

Distribution of quartz. The geographical distribution of the quartz, which is illustrated by Figure 2, is quite uniform although some values vary from the arithmetic mean by more than two standard deviations. The anomalies are small in area, show elliptical rather than linear shapes, and with the exception of those in the Preissac massif do not form concentric zones.

The quartz distribution exhibits a batholith- but not a massif-wide homogeneity. The range of values is wider than those for the other constituents. Some of the anomalies overlie areas where pegmatites and quartz veins have been mapped (Rowe, 1953) and may be due to late concentrations of quartz. The lack of linear anomalies and the high values for quartz do not support an origin of the quartz monzonite by granitization of the country rocks. The absence of a continuous peripheral zone indicates that the relatively cold country rocks had little effect on the crystallization differentiation of the magma, and might also indicate that effects due to any post-intrusion process of metamorphism are limited.

Distribution of plagioclase. The distribution of plagioclase as illustrated by Figure 3, is somewhat irregular although there is a batholith-wide homogeneity present. Concentric zones and linear trends are not strongly developed and most anomalies are local features resulting from single analyses which may vary from the arithmetic mean by one standard deviation.

The weak development of the concentric zones indicates that little differentiation took place after intrusion and also that post-intrusion metamorphism probably played an insignificant role. Some anomalies overlie areas in which pegmatites or quartz veins have been mapped (Rowe, 1953) and these may represent local areas enriched in plagioclase. Elsewhere, anomalies are associated with the younger gabbro dykes that appear to have thermally metamorphosed the enclosing quartz monzonite increasing its plagioclase content somewhat.

Distribution of potassium feldspar. The distribution of the potassium feldspar, which is illustrated by Figure 4, is uniform on both a local and a regional scale. The range of values is within two standard deviations of the arithmetic mean. The anomalies are not linear in shape but vary

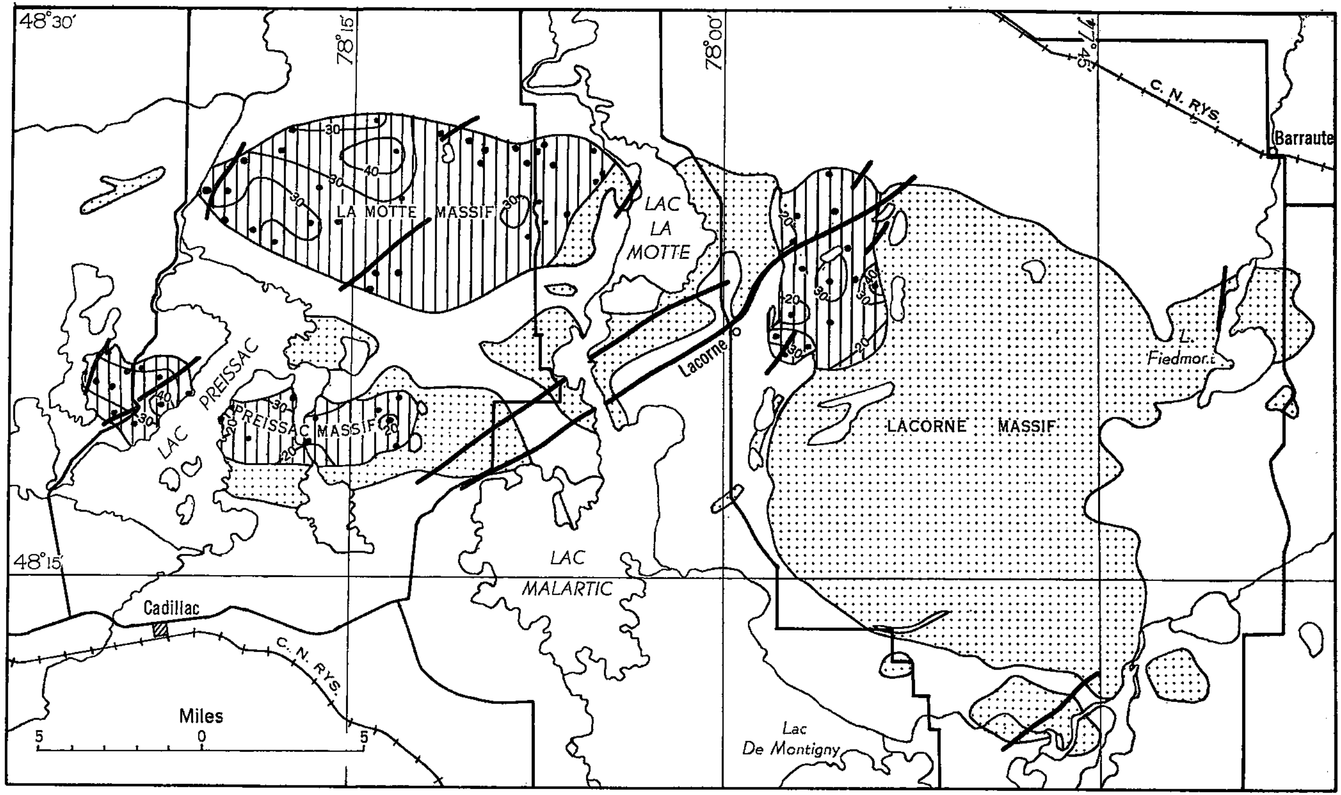

FIG. 2. Distribution of the quartz content of the Preissac-Lacorne quartz monzonite is shown by contours having an interval of 10 percent. The quartz monzonite is shown by the ruled area, the other batholithic rocks by the stipple, the gabbro dykes by heavy black lines, and the country rocks have not been patterned.

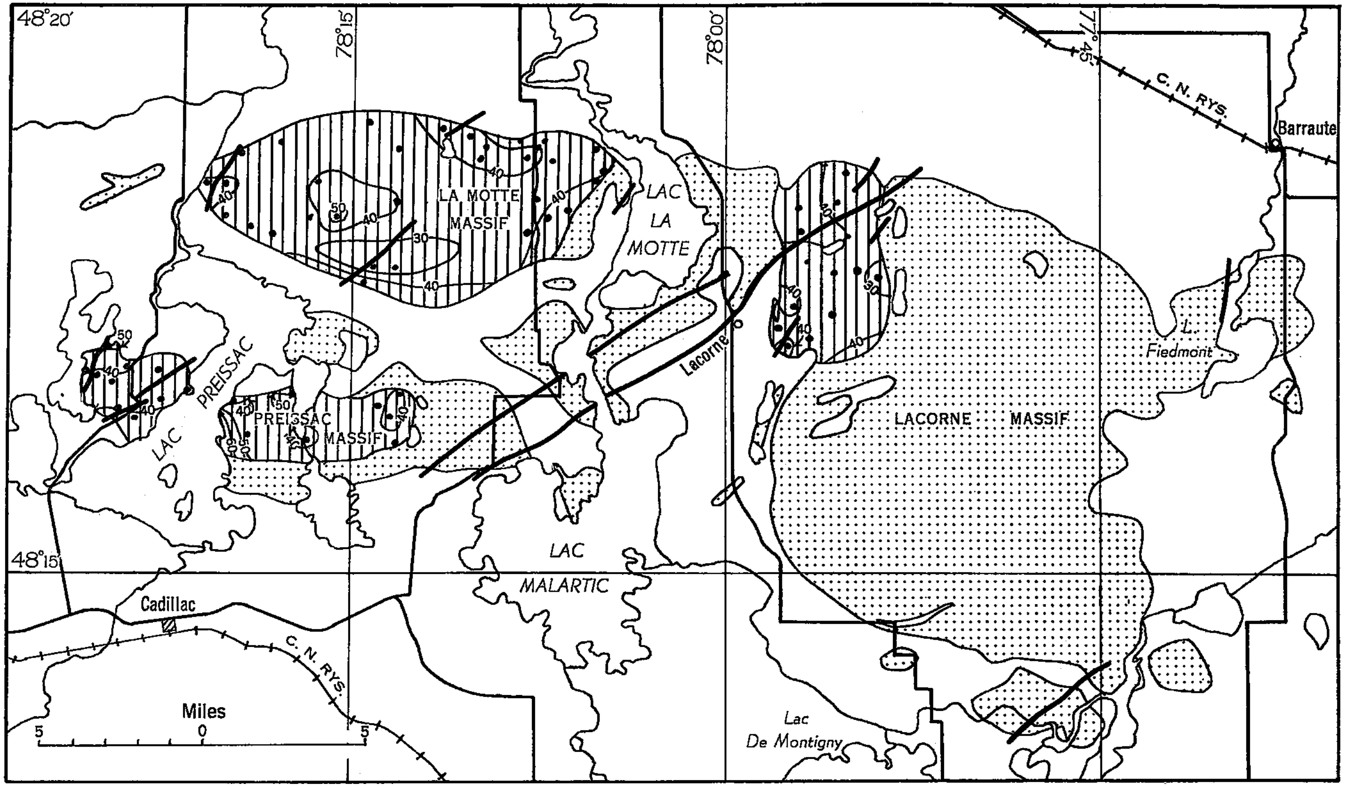

FIG. 3. Distribution of the plagioclase content of the Preissac-Lacorne quartz monzonite is shown by contours having an interval of 10 percent. The quartz monzonite is shown by the ruled areas, the other batholithic rocks by the stipple, the gabbro dykes by heavy black lines, and the country rock has not been patterned.

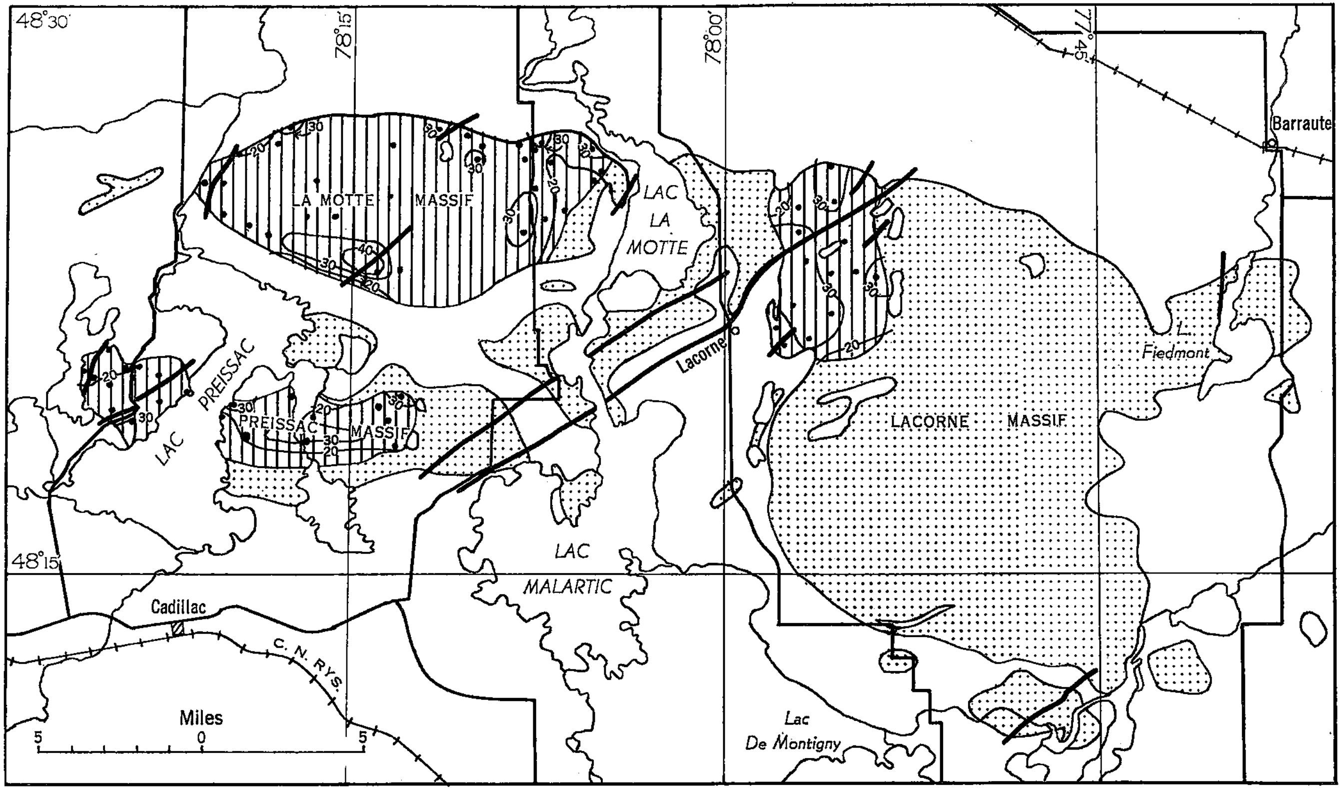

FIG. 4. Distribution of the potassium feldspar content of the Preissac-Lacorne quartz monzonite is shown by contours having an interval of 10 percent. The quartz monzonite is shown by the ruled areas, the other batholithic rocks by the stipple, the gabbro dykes by heavy black lines, and the country rock has not been patterned.

from a discontinuous peripheral zone in each of the massifs to discrete anomalies due to single analyses.

The range of values is within two standard deviations of the mean, which is nearly as wide a spread as that shown by the quartz. Several of the plus 30% areas overlie known outcrops of pegmatites and quartz veins (Rowe, 1953) so there may have been a late concentration of he potassium feldspar in such localities. The high content of potassium feldspar and the lack of well developed linear concentrations would suggest that the quartz monzonite could not have formed by granitization of the biotite schist, greenstone, and serpentinite.

Multivariate Variance Analysis

A comparison is made in this paper between qualitative univariate and quantitative multivariate analysis, utilizing the modal analyses of the quartz monzonite. These analyses show that the quartz monzonite exhibits the same range of values in each massif with some local irregularities of uncertain significance. Most applications of statistical methods to geology have been univariate, that is they have dealt with a single constituent at a time and these comparisons have sometimes led to confusion arising from contradictions within the data. When, for example, the univariate analyses for mineralogical or other data are combined and evaluated a composite judgment is arrived at which is rather difficult to express in quantitative probability terms. However, the recent work of Krumbein & Tukey (1956) in devising a multivariate variance analysis technique, makes it possible to arrive at a conclusion expressed in quantitative probability terms. This technique makes it possible to test the apparent small scale heterogeneities against the batholith-wide homogeneity of the quartz monzonite.

The four component modal analyses and the geographical distribution of the quartz monzonite provides a basis for the multivariate analysis, which permits examination of variations between segments, and localities within segments. Krumbein & Tukey (1956) describe a nested or hierarchal sampling plan which is suited to this problem. It combines two standard statistical techniques widely used for univariate analysis, a nested sampling plan, and a cross-classification of constituents expressed as transforms of percentages. The calculations are those customarily made, and the tests are similar to those used in conventional sampling designs.

The design has been modified to fit the geographical distribution of the quartz monzonite, the distribution of outcrops and the lack of duplicate analyses from collected specimens (*see* Fig. 5). To compensate for the lack of duplicate analyses, those available were paired on the basis

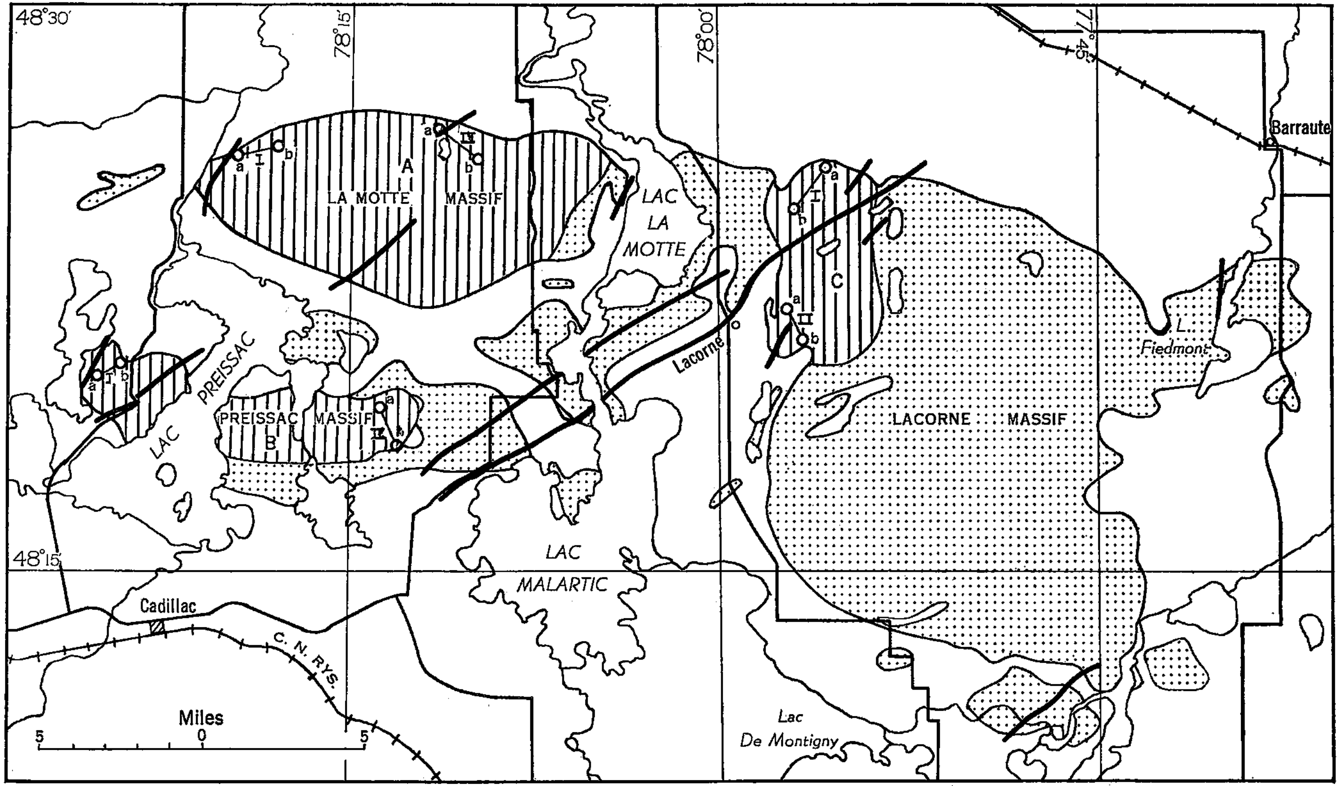

FIG. 5. Hierarchal sampling plan showing the distribution of the analyses utilized in the calculations. The quartz monzonite areas are shown by the vertical ruling, the other batholithic rocks by the stipple, the gabbro dykes by the heavy black lines, and the country rocks have not been patterned.

of their proximity to each other, and pairs were then selected at random within each locality. The segments, respectively the quartz monzonite areas of the La Motte, Preissac, and Lacorne massifs are represented by capital letters "*A*," "*B*," and "*C*," the localities by the Roman numerals "I" and "II" respectively for the east and west ends of the La Motte and Preissac massifs, and the north and south ends of the Lacorne area; and finally individual analyses by script letters "*a*" and "*b*" in the vicinity of each locality. The average spacing between segments, between localities, and between analyses was found to be 12.8, 6.1, and 1.3 miles respectively so that each sampling level has a sufficiently different scale or areal variability (Krumbein, 1957).

The modal analyses of Table 2 have been adjusted to 100%, and have been rounded on the decimal point to facilitate calculations. The analytical data have been subjected to the arc sin root transformation

TABLE 2. 12 SELECTED MINERALOGICAL ANALYSES OF PREISSAC-LACORNE QUARTZ MONZONITE

Segments	*A*				*B*				*C*			
Localities	I		II		I		II		I		II	
Analyses	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
	%	%	%	%	%	%	%	%	%	%	%	%
Total mafics	4	3	6	5	8	7	3	2	2	5	6	5
Quartz	24	39	21	24	38	30	27	25	27	24	16	32
Plagioclase	44	31	41	40	35	45	37	41	46	38	45	31
Potassium feldspar	28	27	32	31	19	18	33	32	25	33	33	32

[4]*F*, the variance ratio equals the mean square of sample means divided by the mean square of individuals (Snedecor, 1957). Ratios calculated for this data show no significant variance on either 5 or 1 per cent. levels of probability.

TABLE 3. ARC SIN TRANSFORMS OF 12 SELECTED MINERALOGICAL ANALYSES OF PREISSAC-LACORNE QUARTZ MONZONITE

Segments	*A*				*B*				*C*			
Localities	I		II		I		II		I		II	
Analyses	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
Total mafics	12	10	14	13	16	15	10	8	8	13	14	13
Quartz	29	39	27	29	38	33	31	30	31	29	24	35
Plagioclase	42	34	40	39	36	42	38	40	43	38	42	34
Potassium feldspar	32	31	35	34	26	25	35	35	30	35	35	35

(Snedecor, 1957) and the results appear in Table 3. The multivariate analysis calculations follow the procedure outlined by Krumbein & Tukey (1956) and the results have been shown in Table 4. The F-tests[4] indicate that there is no significant variability between segments as compared with the variability between localities within a segment, and that the variability between localities is not significantly greater than that between analyses within a locality.

TABLE 4. ANALYSIS OF VARIANCE OF 12 SELECTED MINERALOGICAL ANALYSES OF PREISSAC-LACORNE QUARTZ MONZONITE

Source	Sum of squares	*df*	Mean squares	*F*-ratio
Segments vs. types interaction	50	6	8.3	0.3*
Localities vs. types interaction	230	9	25.6	1.8*
Analyses vs. types interaction	254	18	14.1	
Total	534	33		

*No significant variability either at the 5 per cent. or the 1 per cent. levels of probability.

Conclusions

Examination of the contoured figures suggests that the quartz monzonite is homogeneous on a batholith-wide scale and less homogeneous within the individual massifs.

The multivariate variance analysis shows that the quartz monzonite is homogeneous on a batholith-wide scale and also within individual massifs.

The mineralogical homogeneity of the quartz monzonite supports the hypothesis that it has been derived from a single magma source at depth.

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