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ADDITIONAL DATA ON THE DELESSE-ROSIWAL METHOD

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Abstract

Delesse-Rosiwal modal determinations of mineral composition from rock thin sections should not be computed to an accuracy within 1 per cent, unless the rock formation subjected to investigation is known to have uniform composition, or unless modal composition is to be related to chemical composition in a given sample.

When rock formations are known to have regional variability in mineral composition, modal determinations should be made to an accuracy just within the largest known regional variation for a single mineral constituent.

Statistical analysis shows that modal analyses accurate to within 10 per cent can be obtained by taking six traverses, 15 mm. in length, across the thin section, providing that the thin section is an adequate sample of the specimen from which it was made.

Introduction

A recent paper by Esper S. Larsen and Franklin S. Miller (1) gives an excellent description of the factors that must be observed to obtain Delesse-Rosiwal modal analyses of rocks of a given degree of accuracy.* The paper also discusses the different sources of error that may make it impossible to obtain a given degree of accuracy. Larsen and Miller draw particular attention to the error due to "failure of the thin section to provide a proper sample of the rock from which it is cut" (1, p. 262), a point not clearly emphasized by earlier authors. Larsen and Miller do not, however, discuss the significance of this important fact in relation to the desirability, or lack of it, of making very accurate modal determinations.

Using a modified type of the Wentworth stage, Larsen and Miller say that a modal analysis can be made accurate to 1 per cent, on rocks with an average grain size of 1 mm., by running 10 to 20 traverses, spaced about 1 mm. apart, over the thin section. Due to the tediousness of this procedure, it was decided to investigate the relationship of the error factor produced by normal variability of mineral composition for

* No bibliography is given on the Delesse-Rosiwal method, as a very complete one may be had in the paper cited.

a single rock formation to the degree of accuracy obtained from a given number of traverses per thin section.

Significance of the Sampling Power of a Thin Section in Terms of Regional Variability

Obviously, when the accuracy of a modal analysis is referred to, it applies only to the thin section from which it was obtained; it does not indicate the possibility of great variation of mineral composition throughout a formation. In terms of time and expenditure of effort, it would appear inadvisable to make an analysis of an accuracy substantially greater than the normal regional variation, once the regional variability has been established. For example, if it has been established that a constituent of a rock varies 10 per cent in different parts of a formation, it is of no value, in general, to determine that constituent to 1 per cent in a given thin section, as that thin section is not a representative sample of the whole formation. Statistically, an accuracy of 1 per cent is not warranted unless the thin sections dealt with represent the same "population." Thin sections that show a variation of 10 per cent for a given constituent through a formation may represent samples gathered from different "populations." This line of reasoning was suggested by the statement made by Larsen and Miller in section 3 of their conclusion: "Failure of a thin section to sample a hand specimen or rock outcrop introduces a much larger error than that of the Rosiwall measurement on a thin section" (1, p. 271).

Experimental Data

To investigate the relationship of the foregoing factors, a rock known to show regional variation in mineral composition was chosen: the Springfield aplitic granodiorite. This rock occurs as an intrusive in the Philadelphia area (2). Megascopically, it is a light gray rock, and appears to have uniform texture and composition. The grain size ranges from 0.5 to 2.0 mm., the average grain size being very close to 1.0 mm. The rock has a faint foliation due to the orientation of the biotite.

The Springfield aplitic granodiorite was also chosen because it illustrates another source of error mentioned by Larsen and Miller (1, p. 263), namely: the personal error caused by the inability of the investigator to be certain always of the identity of the mineral grains encountered during a traverse. A portion of the oligoclase present in the rock is untwinned, shows no cleavage, and has indices nearly identical with quartz. On the raised platform of the micrometer stage it must be differentiated from quartz by the character of its extinction, and its inclusions, or by etching with hydrofluoric acid. If etching is not resorted to, the error of confusion between these two components cannot be eliminated, as sections nearly perpendicular to an optic axis give similar hazy extinction, and the inclusions are not always reliable.

All the modal analyses reported here were made with the modified Wentworth type of stage. The procedure followed is that described by Larsen and Miller.

Table 1 demonstrates the regional variation in mineral composition in the Springfield aplitic granodiorite. This table also gives the standard deviation of the mean for the major constituents. To compute the standard deviation, the percentage composition of the major constituents was carried out to two decimal places. The standard error of the mean* shows the value of the mean which one would expect in 95 per cent of the cases, if one adds or subtracts twice the standard error of the mean from the mean of the sample. In all cases this is very small in comparison to the mean itself.

Consideration of Table 1 shows that the largest variation for any single constituent, quartz, is 12.3 per cent; the microcline content shows a variation of over 9 per cent.

To establish a standard composition, a large typical hand specimen of the aplite was collected. From this specimen four parallel and closely spaced thin sections were made. The volume of rock needed to make these sections was approximately 1 cubic inch. This operation was carried out in order to get several thin sections of as nearly identical composition as possible, so as to permit the addition of traverse lengths obtained from the different slides. These thin sections are designated in the tables as S 16-1, S 16-2, S 16-3, and S 16-4. S 16-1 was unetched, but to eliminate the error of confusion between quartz and oligoclase, half the areas of S 16-3 and S 16-4, and the whole area of S 16-2, were etched with hydrofluoric acid before the cover glasses were applied.

A comparison of modal compositions, based on thirty-eight etched and thirty-eight unetched traverses, showed an error for the unetched determinations of +3.8 per cent for quartz, and −3.7 per cent for oligoclase, the oligoclase being erroneously included with the quartz. (Student errors often went well over 10 per cent.)

* Standard deviation of the mean =

$$\frac{\text{Standard deviation of the sample}}{\text{Square root of the number of individuals in the sample}}.$$

TABLE 1

Specimen	S 16[a]		S 16-1[a]		R 1[b]	
Number of traverses	20		20		20	
Total length in mm.	371.16		362.52		373.60	
Area of section[c] in sq. mm.	425		510		425	
		SDM[d]		SDM		SDM
Biotite	8.2	±0.55	7.6	±0.42	9.1	±0.55
Microcline	23.9	±1.62	16.8	±1.11	14.7	±1.72
Oligoclase	45.4	±1.19	41.1	±1.13	46.5	±1.99
Quartz	20.7	±1.52	33.0	±1.27	26.9	±1.29
Accessories	1.8		1.6		2.9	

[a] These specimens were taken from the same dike, about two feet apart.

[b] This specimen came from a dike about 9½ miles to the northeast of locality S 16 and S 16-1.

[c] The areas of the sections were obtained by multiplying the average length of the section by the length of the average traverse.

[d] The standard deviation of the mean.

Table 2 gives the modal compositions as computed from the etched sections. As the change in composition from an analysis based on thirty-eight traverses to an analysis based on fifty-three traverses was less than 1 per cent for any constituent, the latter analysis was taken as the standard for comparison; hereafter it will be referred to as the standard.

In order to see what variation in modal composition would occur, in terms of the standard, when composition was determined on the basis of a small number of traverses, several modal compositions were calculated on the basis of three and five traverses. Table 2 *a* gives the composition of S 16-2 as computed from partial traverses. The partial traverses were taken by spaced selection from the traverses used to establish Table 2; the individual numbers of the traverses used are designated in the table. To the right of each composition column is the percentage variation of the partial composition from the standard, Column 1, Table 2.

This table shows that the variations from the standard in the compositions calculated from the short traverses are less than the maximum regional variation for quartz and microcline, as shown in Table 1. Compositions based on the selection of other combinations of traverses, i.e., the fifth, fifteenth, and twentieth traverses, and the second, sixth, eleventh, sixteenth, and nineteenth traverses give variations from the standard that are smaller than those shown in Table 2 *a*.

TABLE 2

Specimen	S 16-2 S 16-3 S 16-4	S 16-2 S 16-3 S 16-4	S 16-2	S 16-3	S 16-4
Number of traverses	53	38	28	10	15
Total length in mm.	932.87	705.06	466.92	185.90	280.05
Area of section[a] in sq. mm.			510	290	340
Biotite	8.7	8.5	8.8	8.1	8.7
Microcline	17.2[b]	17.2[b]	17.2[b]	17.6[c]	18.4[c]
Oligoclase	43.0	42.8	43.4	40.6	42.2
Quartz	29.8	30.2	29.2	32.4	29.1
Accessories	1.3	1.2	1.3	1.2	1.5

[a] This refers only to the etched area of the thin section.
[b] Microcline content computed from the average obtained from the unetched portions of S 16-3 and S 16-4, and S 16-1.
[c] Microcline content calculated from the unetched portions of the sections.

TABLE 2 *a*

Specimen	S 16-2		S 16-2		S 16-2	
Numbers of the individual traverses taken	1st, 10th, 20th		1st, 14th, 28th		1st, 5th, 10th, 15th, 20th	
Total length in mm.	48.94		49.48		85.13	
		%VS[a]		%VS		%VS
Biotite	8.7	0.0	12.1	+3.4	9.3	+0.6
Microcline	17.2	0.0	17.2	0.0	17.2	0.0
Oligoclase	36.6	−6.4	38.8	−4.2	37.1	−5.9
Quartz	36.0	+6.2	30.0	+0.2	34.4	+4.6
Accessories	1.4	+0.1	1.8	+0.5	2.0	+0.7

[a] Percentage of variation from the standard.
+ Above the standard.
− Below the standard.

Table 3 gives the modal compositions determined from the unetched areas of S 16-1, S 16-3, and S 16-4, and their percentage variations from the standard, Column 1, Table 2. Table 3 also shows that fewer traverses give only small variations from the standard, and if the oligoclase-quartz correction factor is applied, the variation becomes negligible. Comparison of the modal compositions as obtained from the two halves of S 16-1 (ten traverses for each half) shows that there is less than 1 per cent variation between the halves for all constituents.

TABLE 3

Specimen	S 16-1		S 16-3			S 16-4			S 16-1 S 16-3 S 16-4	
Number of traverses	20		10			8			38	
Total length in mm.	362.16		184.76			146.76			702.45	
		%VS		%VS	SDM[a]		%VS	SDM		%VS
Biotite	7.6	−1.1	7.2	−1.5	±0.72	7.9	−0.8	±1.11	8.1	−0.6
Microcline	16.8	−0.4	17.6	+0.4	±1.26	18.4	+1.2	±1.33	17.2	0.0
Oligoclase	41.1	−1.9	38.6	−4.4	±2.57	38.2	−4.8	±1.21	39.1	−3.9
Quartz	33.0	+3.2	35.0	+5.2	±1.66	34.1	+4.3	±1.73	34.0	+4.2
Accessories	1.6	+0.3	1.6	+0.3		1.4	+0.1		1.5	+0.2

[a] Standard deviation of the mean.

Table 3 *a* gives modal compositions obtained from unetched S 16-1 on the basis of partial traverses, and the percentage variations from the standard, Column 1, Table 2.

TABLE 3*a*

Specimen	S 16-1		S 16-1	
Numbers of the individual traverses taken	1st, 10th, 20th		1st, 5th, 10th, 15th, 20th	
Total length in mm.	52.54		89.42	
		%VS		%VS
Biotite	7.7	−1.0	7.0	−1.7
Microcline	14.1	−3.1	15.3	−1.9
Oligoclase	39.6	−3.4	42.0	−1.0
Quartz	37.3	+7.5	34.2	+4.4
Accessories	1.3	0.0	1.4	+0.1

In comparing the modal compositions given in Table 3*a* with the standard, it can be seen that the variations are small—smaller than the regional variation shown in Table 1. It is also to be seen that the variations of the partial modal compositions obtained from the unetched sections are smaller than the variations obtained from the etched sections; this may be due to variability in the quartz-oligoclase confusion factor.

Partial analyses were also computed for the unetched thin sections S 16, and R 1, based on the first, tenth, and twentieth traverses. These partial analyses did not vary from the compositions as determined by the full twenty traverses by more than 5 per cent for any constituent.

Statistical Treatment

It was considered advisable to check the foregoing data by statistical methods, in terms of the principles involved in sampling. This was done in an attempt to show that the individual sections were homogeneous within themselves, but that when they were compared with each other they could not be considered, as a group, a homogeneous sample of the Springfield aplitic granodiorite. To do this the readings for each traverse were weighted inversely for each mineral with the length of each traverse, and multiplied by 100, so that each mineral is given in terms of its percentage. It seemed best to make use of the standard deviation rather than the mean deviation, since the standard deviation can be better used to determine the variations between the means of the different thin sections, and also those in which the traverses were divided into two sections of 10 traverses each.

The method employed here was that of making use of the value "t" to determine whether the difference of the means of the different parts of the thin sections, and between the thin sections, was significantly different, or whether they came from the same, or different, theoretical "populations." The value "t" gives a precise measure of the variation of the differences between the means of the random samples drawn from a homogeneous "population." The size of the samples has no effect on the values of "t." The tables for the values of "t" for different percentages may be found in the references cited.

The value of "t" used was that in which the values of the difference were less than the 5 per cent level, or that the probability was 95/100 that they came from the same "population" (3). It may be said that a value of "t" less than the 5 per cent level means, generally, that the samples came from the same theoretical "population," or from similar random samples. The method is that of Snedecor (4, pp. 71–76, 182–203).

In the thin sections S 16, S 16-1, and R 1, the traverses were separated into two groups of ten consecutive traverses. In all these slides the values of "t" were less than the 5 per cent level, so that each part of the slide can be considered as belonging to the same set of data.

Using the same method, the thin sections were compared in the following manner: S 16-1 with S 16, S 16-1 with R 1, and S 16 with R 1. Table 4 shows the results.

TABLE 4

	S 16-1, S 16	S 16-1, R 1	S 16, R 1
Biotite	Same	Different	Same
Microcline	Different	Same	Different
Oligoclase	Different	Different	Same
Quartz	Different	Different	Same

Table 4 shows that, in general, the major constituents of these three thin sections are not from the same "population," and therefore they do not represent an adequate sample of the rock formation.

It was also decided to test, statistically, the assumption that the slides S 16-1, S 16-3, and S 16-4 represented a homogeneous sample of the specimen from which they were taken. No significant differences between the means of the different minerals were found. In this case the difference between the three means for the different minerals was again less than the 5 per cent level, which indicates that they come from the same "population," or from the same random sample.

The question in regard to the number of traverses necessary to obtain a mean comparable, i.e. within the 90 per cent level, was investigated. It was found that this degree of accuracy could be obtained by basing modal composition on 6 traverses, 15 mm. in length. As a check, samples of 6 traverses were selected by the use of random sampling numbers (3). Random sampling numbers permit the reduction of a large bulk of data to a smaller group that may be more readily handled, and give an indiscriminant sampling of the whole. Taking S 16–1, it was found that all the means were comparable (5, p. 118).

DISCUSSION AND CONCLUSION

Consideration of the foregoing data would seem to make it a practical procedure to gauge the number of traverses necessary for a series of Delesse-Rosiwal analyses in terms of the regional variation of the rock type being considered. The accuracy of each analysis, as controlled by a given number of traverses, should be kept just below the largest known regional variation.

The modal composition tables indicate that an analysis accurate to about 6 per cent can be obtained by taking 5 well spaced traverses across the thin section, if the average grain size is about 1 mm. The use of random sampling numbers puts this more concisely, and shows that an analysis can be made accurate to within 10 per cent if 6 traverses, 15 mm. in length, are determined.* In comparison to the work involved in determining analyses to an accuracy within 1 per cent, the time and effort saved is considerable, if this procedure is adopted, particularly, when no significance can be attached to an analysis that is accurate to within 1 per cent if it fails to sample the formation.

Two plans of approach to a regional problem involving large numbers of thin sections may be suggested. Three or four thin sections may be analyzed to an accuracy within 1 per cent, according to the criteria set up by Larsen and Miller (1, pp. 271–272), to establish the regional variability; all succeeding thin sections can then be investigated on the basis of fewer traverses, to an accuracy within the regional variation. The alternative procedure is that a series of thin sections may be analyzed to an accuracy within 10 per cent; then all variations above 10 per cent may be assumed to be due to the regional variation factor.

It should be emphasized that some circumstances necessitate Delesse-Rosiwal analyses of much greater accuracy than advocated here. This is certainly true when rock formations of uniform composition are being subjected to investigation, or when chemical composition is to be related to modal composition.

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* The average length of traverse used to compute the modal composition tables was 17 mm.