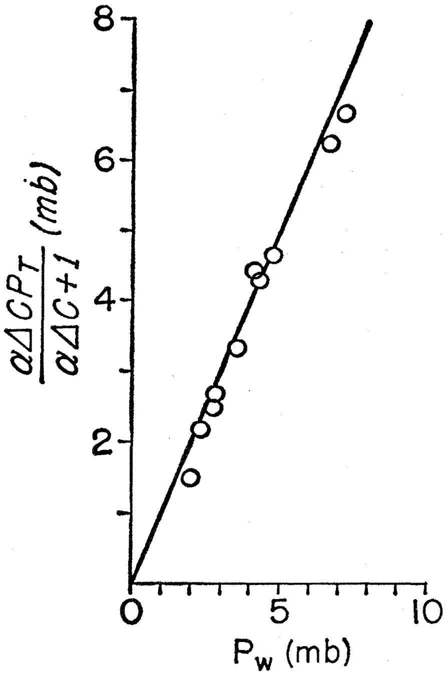

Fig. 2. Data from the hygrometer shown in Fig. 1.

The instrument conditions were the same as described earlier: 15 lit./min at 20°C. From these data, the following can be ascertained. (i) The output returns to zero when the humidity returns to zero. (ii) The time response is exponential. (The reader may verify this for himself by making a graph of log $[1 - (\alpha \Delta C/\mathcal{R})]$ versus time. The resultant plot is nearly linear in agreement with Eq. 4.) (iii) The response time is the same for both increasing and decreasing humidity. (iv) By virtue of (i) and (iii), hysteresis is very small.

At relative humidities above 0.1, the response can be described by an expression where the assumption that $n_w << n_s$ is not made. Experimentally, the response is not exponential; however, the times for half response for increasing and decreasing humidity are still identical. Further, the output reliably returns to zero at $\mathcal{R} = 0$, indicating a lack of hysteresis at these higher humidities. If the relative humidity at the temperature of the instrument exceeds about 0.7, the liquid phase begins to flow and irreversible changes occur in the sensor. In order to measure these higher humidities, the sensor and ancillary plumbing must be operated at an elevated temperature.

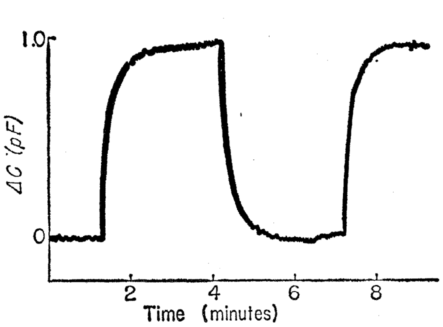

Fig. 3. Dynamic response to step-changes of humidity, ΔC(pf) versus time (minutes) for changes in relative humidity of 0 to 0.09 and back to 0, at 20°C.

Data have been obtained which show that the response time is independent of humidity but strongly dependent on both flow rate and temperature. The dependence on flow rate is probably due to the variation of the diffusion coefficient, K, with gas velocity. The effect of temperature arises in the dependence of P_T on temperature. By operating the instrument at 50°C and 15 lit./min, the time for half response is reduced to less than 1 second. Since P_T has been increased by almost an order of magnitude, some loss of sensitivity is encountered. However, sensitivity is still sufficient for measuring 0.1 mb of water with a signal noise ratio of 10. Experiments are now being conducted to determine the form of these temperature and flow rate dependences.

The accuracy of the liquid-film hygrometer is essentially dependent on three factors: noise, drift, and calibration. The noise is independent of humidity and represents about 0.01 mb of water vapor. The drift (indicating decreasing capacitance) corresponds to about -0.1 mb/hr. Most of this is due to the evaporation of the liquid phase. This evaporation drift, however, amounts to a change of only about 1 percent in the sensitivity coefficient (α) per 100 hours because of the large mass of liquid in the sensor (about 0.1 g) and the high dielectric constant of polyethylene glycols.

Calibration remains as the real problem in the accuracy of any hygrometer. Typical calibration devices are subject to inaccuracies of a few to several percent of P_w. For instance, other data show that the errors in Fig. 2 are the result of inaccuracies in the flowmeters used in combining a dry and saturated stream of air to produce the desired humidities. However, since the indicated humidity for a fixed reference point is repeated within 3 percent, relative errors are smaller than absolute errors. A field model of this hygrometer has been built and it includes a temperature-controlled sensor and sample flow. This instrument has proved useful in the measurement of (i) fluctuating humidities; (ii) humidities near and above saturation; and (iii) partial pressures of water vapor in the realm of 0 to 1 mb at room temperature.

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3. This work was sponsored by the Air Force Cambridge Research Laboratories, Office of Aerospace Research, under contract AF 19(628)303. The report is contribution No. 80, Department of Atmospheric Sciences, University of Washington.

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Analysis of Variance of Migmatite Composition II: Comparison of Two Areas

Abstract. *To obtain comparison with previous results an analysis of variance was made on measurements of proportion of granite and country rock in a second Colorado migmatite. The distributional parameters (mean and variance) of both regions are similar, but the distributions of variance among the three levels of the nested design differ radically.*

In a recent report (*1*) we presented an analysis of variance of the composition of a migmatite in northern Colorado with respect to the ratio of country rock to discrete small bodies of granite. The variance was partitioned into three components: regional (between groups of outcrops), areal (between outcrops), and local (between sample points within outcrops). Since there were no similar data for any other migmatite, we were without a basis for deciding whether or not the basic distributional characters ($\overline{X}$, S^2, and so forth) were typical for such rocks. We were also unable even to speculate whether the unexpected results from Poudre Canyon, such as the absence of any significant regional variation in composition, were strictly local.

During the summer of 1963, while examining migmatite areas in the western United States as possible sites for

Table 1. Analysis of variance.

Source of variation	Degrees of freedom	Sum of squares	Mean square	Estimated mean square
Between segments	$k-1$ 2	$np\sum(\bar{X}_{i\cdot\cdot} - \bar{X}_{\cdot\cdot\cdot})^2$ 1779.56 (906.23)	A 889.78 (453.12)	$\sigma^2+p\sigma_b^2+np\sigma_a^2$
Between outcrops within segments	$k(n-1)$ 18	$p\sum_i\sum_j(\bar{X}_{ij\cdot} - \bar{X}_{i\cdot\cdot})^2$ 1671.82 (4785.80)	B 92.88 (265.87)	$\sigma^2+p\sigma_b^2$
Between lines within outcrops	$kn(p-1)$ 63	$\sum_i\sum_j\sum_m(\bar{X}_{ijm} - \bar{X}_{ij\cdot})^2$ 3702.21 (6865.35)	C 58.77 (108.97)	σ^2
Total	$knp-1$ 83	$\sum_i\sum_j\sum_m(\bar{X}_{ijm} - \bar{X}_{\cdot\cdot\cdot})^2$ 7153.59 (12,557.38)		

Grand mean: $\bar{X} = 76.16$ (76.64); standard deviation: $\sigma = 7.7$ (10.1); range: 51.5 to 92.9 (24.4 to 97.1).
Between segments variance (a fixed effect): $\sigma_a^2 =$ 28.5 (6.3). Between outcrops variance: $\sigma_b^2 = 8.5$ (39.2). Between lines variance: $\sigma^2 = 58.8$ (109.0).

	Tabular values for F: 1%	Tabular values for F: 5%
$F = \frac{A}{B} = 3.34$ (1.70)	6.01	3.55
$F' = \frac{B}{C} = .145$ (2.44)	2.55	1.77

continuing this investigation, we made a series of preliminary lithologic measurements, for comparison purposes, on a migmatite in Gunnison River Canyon in southwestern Colorado. In the walls of the Gunnison River and its major tributaries there exist good to excellent natural and artificial exposures of a migmatite and some small granite stocks. The country rock portion of the migmatite consists of high metamorphic grade pelitic and quartzofeldspathic schists and gneisses with minor amphibolite (*2*).

In order to facilitate comparison, the sampling and measuring techniques and the statistical model were identical for both areas (*3*). There were three nonrandom segments (a fixed effect), seven randomly chosen outcrops per segment (an outcrop being defined as 100 feet of continuous exposure measured normal to the trace of the foliation in the *ac* plane), and four randomly chosen measurement points per outcrop (each measurement point is a line 10 feet long along which the distribution of granite and country rock was measured with steel tape). One difference between the two sets of measurements is that the three segments in Poudre Canyon were contiguous, while in the Gunnison the nature of the exposures made it necessary to use noncontiguous segments. However, the total areas covered by both studies are nearly identical.

Table 1 gives the results of the analyses of variance of both areas; the Poudre Canyon figures are in parentheses. The values are given in percentage of country rock (that is, country rock × 100/country rock + granite).

Some of the similarities and differences displayed by these provinces are worthy of note and comment. The arithmetic means for both areas are remarkably similar. This may be purely accidental, but it is equally likely that in selecting areas for study, migmatites where granite is more abundant appeared to be unsuitable for such a study because they contained large areas of granite gneiss which is not clearly distinguishable as either granite or country rock (*1*). On the other hand, areas markedly less granitic than these are likely to have been rejected as not being true migmatites. The matter of artificially limited domain must be remembered when making generalizations concerning the entire granite problem from the results presented here (*4*).

We take a certain amount of comfort in the fact that the population variances (σ^2) for the two areas, while not identical, are of the same order of magnitude. It also suggests that their variability is small enough that restrained generalization from a few sets of quantitative data may not be overly misleading.

It is in the analysis of variance (Table 1) that a major difference arises; in the Poudre migmatite we had found no significant regional (between segments) variance. This was contrary to our a priori expectation that large-scale regional variation should occur. The Gunnison area shows a substantial and statistically real regional variation ($\sigma_a^2 = 28.5$). The geologic factor most likely to account for this difference is that our traverse in Poudre Canyon was parallel to the regional strike and the lithologic units involved may have been sufficiently uniform over the three contiguous segments to ensure a gross similarity with respect to the production or emplacement of granitic material or both. In Gunnison River Canyon the trend of the exposures makes a high angle with the regional structural trend, and the segments are not contiguous.

In partitioning the variance in Poudre Canyon, that portion ($\sigma_b^2 = 39.2$) ascribable to there being outcrops within segments, or areal variation, is significantly large. In the Gunnison results σ_b^2 ($= 8.5$) is no larger than might occur from seven random samples of four lines each, considering the population variance (σ^2). From the Poudre results we had considered the possible reduction in σ_b^2, given some other variable, to be potentially the most fruitful avenue for continued study. In the second area we have little confidence that this variation is larger than zero.

These differences between the two migmatites have caused us to modify our further investigations of the Poudre area. Namely, attempts to describe additional migmatite characteristics by determining the regression of percentage granite upon some other measurable variable such as country rock composition cannot be restricted to a single level of a nested design on the assumption that others are inconsequentially small, but must consider possible meaningful relationships at every level.

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1. R. F. Ward and S. L. Werner, *Science* **140**, 978 (1963).
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3. Logically, of course, even these precautions cannot assure that similarities or differences in the statistical values result solely from similarities or differences in the rocks.
4. Much existing quantitative information concerning the nature of granites has this sort of limitation (restricted domain). For example, the summary of the normative composition of 933 granitic rocks given by Tuttle and Bowen [*Geol. Soc. Am. Mem. 74* (1958)] was limited to rocks where $Ab + Or + Q$ is not less than 80 percent.
5. Supported by funds from the Wayne State University Graduate Division and the Institute of Science and Technology. A copy of our data matrix is available on request.

24 December 1963