It will be noted that whereas the datolite pseudomorphs have a lower specific gravity than the original, the specific gravity of the apophyllite has increased. Prehnite with the original gravity comparable to the substituted chlorite has not undergone a significant change in gravity.

X-ray powder patterns of the various pseudomorphs show dominant lines of the original minerals indicating that the degree of chlorite substitution is certainly less than 50%. A secondary optical examination disclosed that some of the crystals had undergone far less alteration than others, and although the unaltered portions were extremely minute, their optical properties were clearly those of the original minerals herein named. It would have been impossible to identify the substances directly by optical means, but with other data at hand the optical inspection proved fruitful.

ACKNOWLEDGMENTS

The authors are particularly grateful to Mr. Stephen Ridel for his offering the specimens for study and for his patient waiting for results. They also wish to thank Mr. Robert A. Lancaster for his crystal drawings and Mr. Phokian Karas for his photographs of the specimens. We are also very grateful to the officers of the Materials Service, Inc. for the privilege of visiting the quarry.

THE AMERICAN MINERALOGIST, VOL. 45, MARCH–APRIL, 1960

ERRORS IN POINT-COUNTER ANALYSIS

M. B. BAYLY, *Bureau of Mineral Resources, Geology and Geophysics, Canberra.*

The extension of modal analysis to sawn surfaces (Jackson & Ross, 1956; Plafker, 1956; Emerson, 1958; Fitch, 1959) increases interest in the effects of rock-coarseness, sample area and count length on precision. A comment on Dr. F. Chayes' recommendations with regard to these three factors is therefore offered.

In the course of his exhaustive study of point-counter technique, Chayes (1949; 1951; Chayes & Fairbairn, 1951) has clearly shown the presence of two sources of variance: one lies in using a point-count as a sample of a rock section, and the other lies in using a rock section as a sample of a specimen. In his most recent publication on the subject, Chayes (1956) sets out to compare the sizes of the two variance components but does not pursue this course to a conclusion (p. 89). It is the purpose of this note to suggest—

1. that Chayes' data do not oblige the abandonment of the original intention;
2. that the data do in fact make possible a comparison of the two variance components.

Chayes' analysis is founded on experimental estimates of the variance between a point-count and its parent rock specimen for twelve different samples. The variance estimates, V_p in Chayes' notation, thus contain the two variance components mentioned above, $V_{counting}$ and $V_{rock\ sampling}$. By using a fixed count length, $V_{counting}$ is maintained constant throughout the entire analysis; moreover its size is indicated by a great body of Chayes' earlier data. Thus the twelve estimates of V_p give by subtraction twelve estimates of $V_{rock\ sampling}$, in which the effects of sample area and rock coarseness may be studied.

The stumbling block in Chayes' analysis is the fact that two of the experimental estimates of V_p are *less* than the predicted value for $V_{counting}$ alone. Possible reactions to this discovery are—

1. the formula $V_p = V_{counting} + V_{sampling}$ may be rejected;
2. the value predicted for $V_{counting}$ from Chayes' earlier studies may be rejected, in favour of a smaller value.

The second possibility may be sub-divided into—

2a. a general modification of Chayes' estimate of $V_{counting}$;

2b. a postulate that on account of some quality of the particular rock from which the two anomalous results are derived, the predicted counting error is not generated in full.

It is considered that, independently of any measurements, the *design* of the test makes the first reaction unwarrantable.

Of the remaining possibilities, 2b is preferred. Each of the twelve estimates is based on thirty measurements, making 360 in all; but the evidence supporting Chayes' prediction for V_c is so great that it cannot be set aside by indirect indications even from 360 measurements. It is suggested alternatively that in the particular circumstances of the latest test, the conditions of randomness on which Chayes' prediction is based may not be fulfilled by one of the rocks. This last suggestion in only tentative pending experimental study; by contrast, it is considered that the rejection of the first possibility given above requires no empirical support, but is instead a necessary consequence of the experiment design.

A more constructive comment on Chayes' treatment may be made concerning comparable analyses on coarse and fine rocks. It is suggested that if IC determinations (Chayes, 1956, p. 72) show one rock to be twice as coarse as another, then if counts of equal length are made on each, but the point-spacing over the coarse rock is twice that over the fine one, then

the analyses will have the same precision; in other words, that a wide grid over a coarse rock behaves simply as a scale-model of a close grid over a fine rock. If this is so, the area sampled and the rock coarseness need not be treated as independent factors, having separate effects on precision, but may be combined into a single factor.

In actual fact, clotting frequently distinguishes a coarse rock from a fine one. However study of a theoretical model and a test on Chayes' results both indicate that the divergence of coarse rocks from scale models of fine ones is not detectable within the spread of the counting and sampling errors. Consequently, it is recommended that V_s is treated not as a function of sample area and IC where area and IC are independent, but as a function of a single variant, area x IC^2; for this product is constant through any series of analyses which are scale models of each other, being related to the actual number of grains in the sample.

To summarize, it is suggested that instead of comparing data with independent equations $V_p = f(\mathrm{A})$ and $V_p = f(\mathrm{IC})$, and considering the influence of count length separately, all the factors may be included in a single relation—

$$V_p = V_c + V_s = f(\text{count length}) + f(\mathrm{A.\,IC}^2)$$

Further, accepting Chayes' finding that except in the anomalous case mentioned, V_c may be equated to $p(1\text{-}p)/n$, (p = proportion of mineral in rock; n = count length), it can be suggested from theory and verified from Chayes' data that the function $f(\mathrm{A.IC}^2)$ is of the form $k.(\mathrm{A.IC}^2)^{-1}$; for A in mm.^{2}, these data give $k = 4.58 \times 10^6$. (Bayly, 1960)

References

Bayly, M. B. (1960), Modal analysis by point-counter the choice of sample area. *J. Geol. Soc. Australia*, **7** (in press).

Chayes, F. (1949), A simple point-counter for thin section analysis. *Am. Mineral.*, **34**, 1–11.

Chayes, F. (1951), in Fairbairn, H. W. *et al.*, A co-operative investigation of precision and accuracy in chemical, spectrochemical and modal analysis of silicate rocks. *U. S. Geol. Survey Bull.* **980**.

Chayes, F. (1956), Petrographic modal analysis, New York, Wiley and Sons.

Chayes, F. and Fairbairn, H. W. (1951), A test of the precision of thin-section analysis by point-counter. *Am. Mineral.*, **36**, 704–712.

Emerson, D. O. (1958), A stage for macro point counting. *Am. Mineral.*, **43**, 1000–1003.

Fitch, F. J. (1959), Macro point counting. *Am. Mineral.*, **44**, 667–669.

Jackson, E. D. and Ross, D. C. (1956), A technique for modal analysis of medium and coarse-grained (3–10 mm.) rocks. *Am. Mineral.*, **41**, 648–651.

Plafker, G. (1956), A technique for modal analysis of some fine and medium-grained (0.1–5 mm.) rocks. *Am. Mineral.*, **41**, 652–655.