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A STAINED SLICE METHOD FOR RAPID DETERMINATION OF PHENOCRYST COMPOSITION OF VOLCANIC ROCKS

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ABSTRACT. In recent stratigraphic studies of Tertiary ignimbrites in the Great Basin, correlation of units by distinctive lithologic features is independently verified by quantitative study of phenocrysts. The relative abundance of six mineral groups can be readily evaluated by area counts, with a binocular microscope, of etched and stained rock slices. The method obtains results rapidly and with sufficient accuracy to confirm field correlations, as is demonstrated by phenocryst study of four tuffs comprising the Quichapa formation.

INTRODUCTION

In the stratigraphic studies of Great Basin ignimbrites outlined in the preceding companion paper by Mackin, correlation is based primarily on distinctive lithologic features of individual units and similarity in sequence of a number of units. It was evident early in the investigation, however, that there was need for an independent method of identifying the units, particularly in areas where the lithology is blurred by alteration effects, and where stratigraphic and structural complexities make it impossible to depend on similarity in sequence.

Hand lens examination in the field and petrographic study of thin sections indicated that the mineralogy of the phenocryst assemblage would serve as a good check on correlations in most instances. But "hand lens mineralogy" is inadequate for distinguishing between certain of the ignimbrites, and does not provide the quantitative data needed for an objective statement of the basis of correlation in cases where identification of the ignimbrite depends on the percentages of the minerals present. Thin section study yields petrographic data not obtainable by other methods, but has the disadvantage that both preparation and study of the sections are rather slow. Moreover, especially in rocks with sparse phenocrysts, several standard size thin sections are required for a reasonably accurate evaluation of the phenocryst composition.

The stained slice method presented here was developed in response to a need for a method of evaluating the phenocryst composition of the ignimbrites (a) with sufficient accuracy for use in correlation, and (b) rapidly enough to make the data for a large number of specimens available promptly and without undue cost in time. The importance of rapidity is suggested by the fact that a single field season of work in the volcanics by members of the University of Washington group yields several hundred specimens requiring analysis of the phenocryst composition; more than 2500 specimens have been studied to date. If the specimens are handled in groups of 20 or more, and no special problems of identification are encountered, the whole procedure described here, from sawing of the slices to drafting of the histograms used to express the phenocryst composition, requires only about 20 minutes per specimen, most of which is spent in examination with the microscope.

This note is an outgrowth of work as field assistant to J. H. Mackin and E. F. Cook in the Great Basin during the 1955 field season, and laboratory study of specimen collections as a temporary employee of Gulf Refining Corporation. I am indebted to H. R. Blank and W. R. McCarthy for data on the volcanic sequence in the Bull Valley and Gunlock-Motoqua areas, and to Blank, Mackin and D. L. Schmidt for critical reading of the manuscript.

LABORATORY PROCEDURE

(1) A flat slice five to ten millimeters thick is sawed from the hand specimen. Four or five centimeters square is a convenient size.

(2) The slice is polished on a lap with no. 220 Carborundum. Polishing removes the saw marks and provides an even surface for staining. In the sawing and polishing of lightly welded and non-welded rocks, quartz and other phenocrysts tend to be plucked from the matrix. Plucking is prevented by impregnating the slice before polishing in a 10:1 xylene-canada balsam solution and heating until the balsam is thoroughly cooked.

(3) After the slice has dried thoroughly at room temperature, the polished surface is immersed for one second in 48 percent hydrofluoric acid, and blotted immediately on absorbent paper. The slice is placed face up and allowed to dry thoroughly.

(4) After drying, the slice is immersed in sodium cobaltinitrite solution for thirty seconds. It is then washed immediately in cold water to remove the excess stain, and allowed to dry face up. The staining technique is adapted from a method first described by Gabriel and Cox (1929). The stain solution is prepared by mixing, by weight, three parts of sodium cobaltinitrite powder with five parts of distilled water. Because the solution decomposes with age, it must be renewed every few weeks.

The stained slices are ready for study as soon as thoroughly dry. A binocular microscope is recommended; a magnification of nine to twelve diameters is sufficient for most rocks.

The five or six minerals or mineral groups that occur most frequently in the Great Basin ignimbrites can be quickly identified in the etched and stained slices by an experienced analyst. Crystal form is helpful but it is less distinctive than it would be in ordinary igneous rocks because many of the phenocrysts in ignimbrites are broken fragments.

Quartz phenocrysts appear as glassy, unstained and virtually unetched grains ranging from colorless to very dark, smoky varieties.

Before the acid treatment the feldspars are seen as clear grains that can be distinguished from quartz only under favorable circumstances by shape and cleavage. A coating produced by the acid remains white on plagioclase while that on sanidine is stained yellow by the sodium cobaltinitrite solution.

Because of the potassium in biotite, the usual black or dark green color of the mineral is modified by the stain to a yellowish green. The color change is less apparent on cleavage faces than on sections of the mineral cut across the cleavage.

The pyroxenes and amphiboles are identified chiefly on the basis of grain shape, cleavage, and color. Etch and stain effects are useful in distinguishing between these groups, but the criteria differ depending on the varieties present and on the freshness of the grains, and need not be spelled out here; each analyst will discover for himself ways of identifying the mineral types that characterize a given suite of rocks.

In dealing with the mafic minerals and to a lesser extent with the quartz and feldspar, it is advisable at the outset to cross check the binocular identifications by examination of the same minerals in oils or in thin sections.

The percentages of each phenocryst type are estimated with the aid of a transparent glass plate ruled in a 10 by 10 millimeter grid containing 100 squares. The grid is placed directly on the stained surface, and the analyst mentally "forces" the irregularly shaped grains to fill the grid squares. The use of a grid for percent estimation was first described by Williams (1905).

It seems to be well established that the area occupied by a given mineral component on a random plane surface cutting a rock is directly proportional to the volume of that mineral in the rock (Chayes, 1954, and works cited therein). This point is worth mention, but it is not critical for present purposes because the percentage estimates do not purport to represent quantities in an absolute sense; the estimates are only for comparative purposes, to be compared to percentages of the same minerals estimated in the same way in other volcanic units. It should be noted in this connection that the identity of mineral grains smaller than ¼ millimeter may be obscured by spread of the coating formed by the hydrofluoric acid. For this reason and because of the low magnification, neither the percentages of phenocrysts relative to groundmass nor the percentages of the individual minerals are necessarily comparable with percentages based on study of thin sections with a petrographic microscope.

In an effort to evaluate the reproducibility of the percent estimates, herein called probable error, a number of slices have been re-examined by the writer after a lapse of time, and by other analysts currently working with the Great Basin volcanics. The results indicate that the probable error is of the order of 10 percent for the more common mineral constituents in the average rock. The probable error is considerably greater for very small grains because of the difficulty of estimating their areas relative to the area of the grid squares. In tuffs with 25 percent or more of phenocrysts five different fields are examined, so that the estimates of mineral percentages are based on at least 125 grid squares "occupied" by phenocrysts. In dealing with tuffs with smaller percentages of phenocrysts a larger number of fields are examined, up to the limit allowed by the size of the slice. In some rocks with very small amounts of phenocrysts the number of "occupied" squares is as small as 25, and the probable error increases accordingly.

Point counting (Chayes, 1949) is more accurate than area estimates controlled by a grid, and there are other ways to reduce the limits of error of the technique, but their use defeats the purpose of the method, which is to make quickly available mineralogic data accurate enough to serve as a check on field correlation. In general the probable error in estimates based on a single stained slice of a given tuff is of the same order of magnitude as the actual mineralogic variation between specimens taken from different parts of the same outcrop of that tuff.

CORRELATION OF THE QUICHAPA FORMATION

Figure 1 consists of a number of columnar sections in which the phenocryst composition of the tuffs comprising the Quichapa formation is expressed by histograms. The histogram columns are arranged to show the correlation of the Quichapa members in an east-west belt across southwestern Utah and southeastern Nevada.

As indicated in the legend, the white bar on the right side of each histogram indicated the total amount of phenocrysts in the rock. The remaining bars represent the percentage of each of the major mineral groups with respect to the total volume of phenocrysts. For the sake of compactness all of the mafic minerals are plotted in the same bar; pyroxenes are shown by a diagonal line pattern, biotite in solid black, and amphiboles by vertical lines. If all three mafic groups are present in amounts that can be plotted, the arrangement is, from top to bottom, pyroxene, biotite, amphibole, regardless of their relative abundance. Trace amounts of a mineral are indicated by a short vertical line in the middle of the appropriate bar; in the mafic bar trace amounts of amphibole are indicated by a solid line, biotite by two dashes and pyroxene by three dashes. In our work sheets the histograms are accompanied by symbols, letters, or numbers expressing "degree of welding", proportion of lithic fragments and/or pumice, distinctive heavy minerals, index of refraction of the glass, thickness of the unit, and other properties bearing on correlation, but these are omitted in figure 1 because they involve problems of quantification and other questions which need no discussion here.

The four members comprising the Quichapa formation are defined and described in the preceding paper by Mackin (1960). The Harmony Hills tuff is a crystal-rich ignimbrite wholly different in lithology from the other Quichapa units. The Bauers tuff and Swett tuff are vitric ignimbrites, nearly identical in lithology, distinguishable on the basis of the presence or absence of sanidine—the contrast is strikingly shown by the histograms. The Leach Canyon tuff is characterized by conspicuous lithic fragments. It seems to contain two distinct phenocryst suites, one with about equal amounts of quartz and sanidine, and the other with a notable excess of quartz over sanidine.

The Leach tuff is present in the Swett Hills; a histogram for the unit at this locality is absent on figure 1 because the number of specimens available for study was inadequate. The absence of the Swett tuff in the Gunlock, Bull Valley and Pine Valley areas, and of the three upper Quichapa members at Isom Ranch and Brian Head, is probably due to non-deposition rather than to erosion.

As indicated by Mackin, correlation of the Quichapa ignimbrites from Brian Head to the narrows of the White River was based originally on the lithology of the individual units and especially on the similarity in sequence of the units in section after section. The phenocryst composition, determined from stained slices and expressed by histograms as in figure 1, serves as a valid criterion for confirming the correlations.

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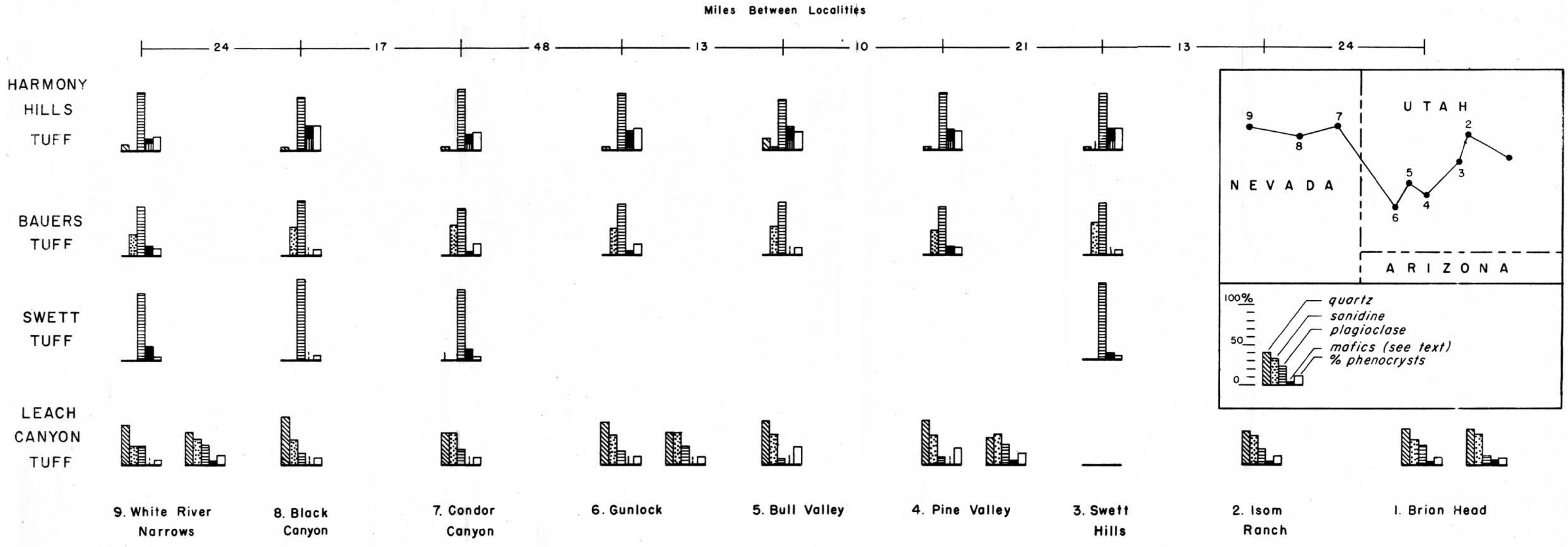

FIGURE 1 - PHENOCRYST COMPOSITION OF THE QUICHAPA FORMATION