A method of constructing rock-analysis diagrams on a statistical basis.

By W. ALFRED RICHARDSON, M.Sc., B.Sc. (Eng.), F.G.S.
Lecturer in Petrology, University College, Nottingham.

[Read January 18, 1921.]

DR. HARKER[1] has familiarized us with the use of *variation diagrams,* in which the percentage amounts of a constituent are plotted against the amount of silica present. He applied these diagrams chiefly to study selected rock groups, but also gave certain generalized curves to illustrate the chemical properties of his 'Atlantic' and 'Pacific' facies. Such variation diagrams based on an adequate body of analytical data form a useful means of constructing diagrams for the comparison of rock analyses. Some means of generalizing analyses becomes a necessity as their number accumulates and the labour of comparing individual analyses increases.

Construction of the variation diagrams.—After some deliberation the analyses selected by Iddings[2] to illustrate rock classification were adopted as data for the construction of variation diagrams. The tables include rather more than a thousand analyses. The distribution of these analyses was checked by plotting their frequency curve to the same scale as that drawn by Harker[3] with Washington's collection as a basis. The two curves closely agreed, except that the selection by Iddings shows a slight excess of analyses in the neighbourhood of 75 per cent. silica.

Variation diagrams to a large scale were constructed in the usual way by plotting all percentages of the constituent against the corresponding silica value. As an example, the alumina plottings are reproduced in fig. 1 to a very much reduced scale. Out of the several types of curve that might be constructed, the maximum was found to be the most useful for purposes of comparison. The upper curve in fig. 1 encloses all

[1] A. Harker, Natural History of the Igneous Rocks, London, 1909, chaps. v and vi.

[2] J. P. Iddings, Igneous Rocks, New York, 1913, vol. 2, pp. 31–341.

[3] A. Harker, loc. cit., p. 148, fig. 42.

values of alumina except some three or four isolated cases. Alumina also shows a well-defined minimum curve, but in this respect is an exception. All other oxides give some values nearly zero for any silica percentage.

In the region from 0 to 30 per cent. silica there is some uncertainty, partly because of the small number of the analyses, and partly because of the liability for other constituents to increase rapidly as the silica fails. However, all constituents other than iron and titanium show decided tendencies to decrease sympathetically with silica.

The variation curves constructed in this way are collected in fig. 2. Ferrous and ferric oxides are added together, largely because, plotted

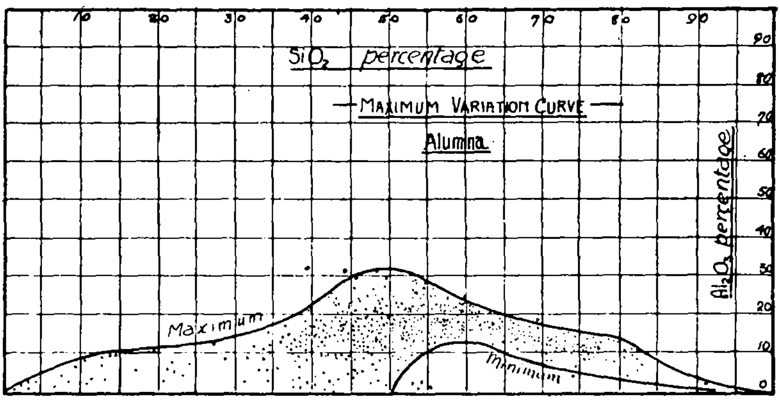

FIG. 1.—Variation curves for alumina in igneous rocks.

separately, they give rather irregular results. Phosphoric acid, and other constituents present only in small amounts, were not plotted.

Rock diagrams.—A vertical line drawn through a thickly clustered region of fig. 1 shows that a number of rocks of given silica percentage may have different values of alumina. A horizontal line indicates that a wide range of rocks with varying silica may possess the same value of alumina. It is suggested that these curves may be used to construct analysis diagrams to indicate

1. The percentage of silica.
2. The percentage of another given constituent.
3. The variation of this constituent in rocks with the same silica value.
4. The range of rocks with the same percentage of the given constituent.

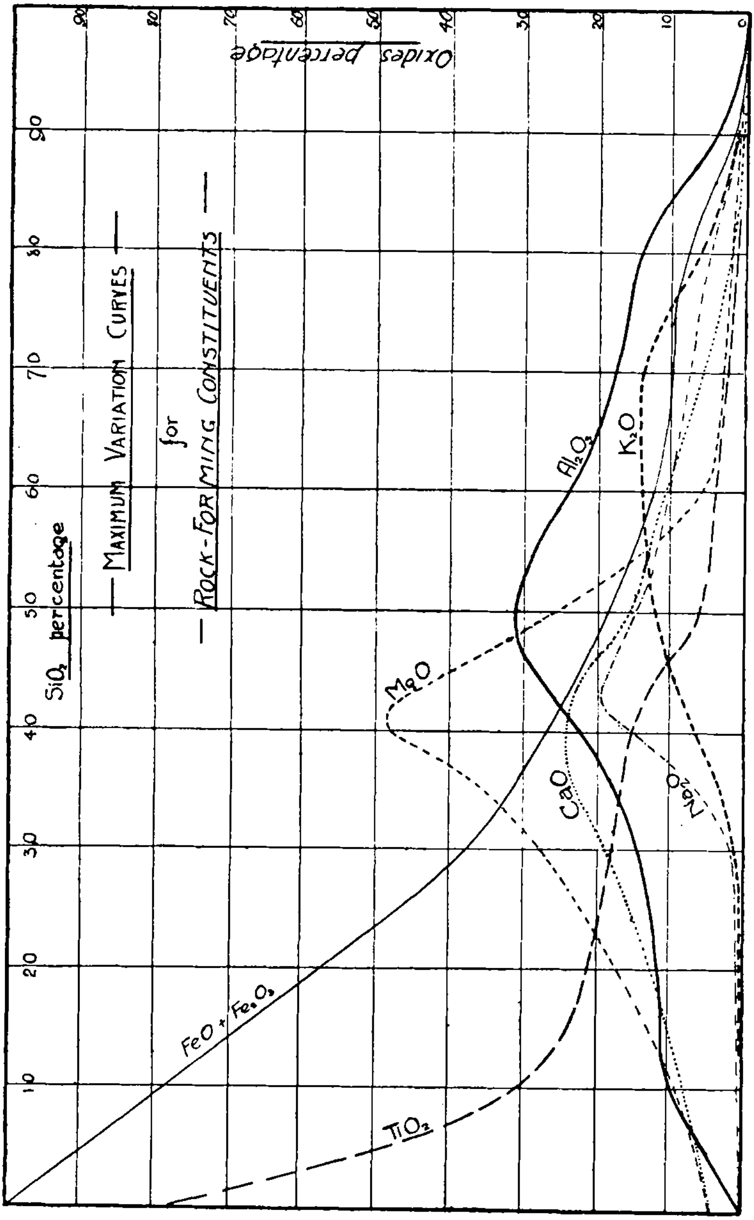

FIG. 2.—Curves of maximum variation of the basic oxides of igneous rocks.

In other words, the diagrams are designed to show both the vertical and lateral relation of the analysis with respect to a given constituent.

Let the curve, fig. 3, represent the maximum variation of an oxide with respect to silica. Let a chosen analysis report a silica percentage *B* and an oxide percentage *b*. If a vertical line be drawn through *B* to cut the curve at B′, the line *BB′* shows the total variation of that oxide for all rocks with *B* per cent. of silica. Similarly, if a horizontal line at height *b* be drawn cutting the curve at *H* and *K*, then *HK* shows the whole range of rocks that may possess *b* per cent. of the oxide. The point of intersection of the two lines gives the actual state of the analysis.

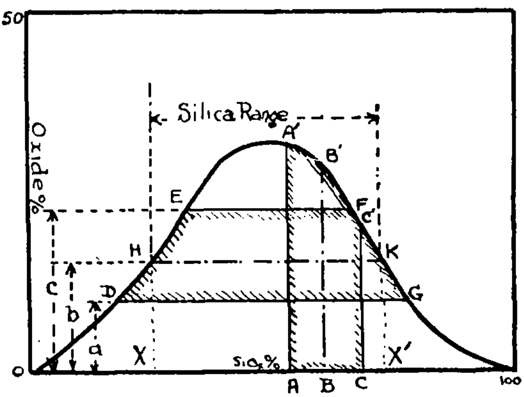

FIG. 3.—Showing mode of construction of individual and group diagrams of rock analyses.

Since the given percentage of the oxide may be found in all rocks with silica values between *X* and *X′*, these limits may conveniently be referred to as the *silica range* of that amount of the oxide.

If, instead of a single rock, it be desired to represent a rock family, the following construction may be adopted to show its chemical affinities. In fig. 3 let the extreme values of silica in the family be *A* and *C*, and let vertical lines be drawn through these points to meet the curve at *A′* and *C′*. Further let the extreme oxide values in the family be *a* and *c*, and at these heights let horizontal lines intersecting the curve at *DG* and *EF* respectively be drawn. The area enclosed (shaded in the figure) gives the affinities of the family with respect to the constituent oxide in a manner similar to the lines of the individual analysis.

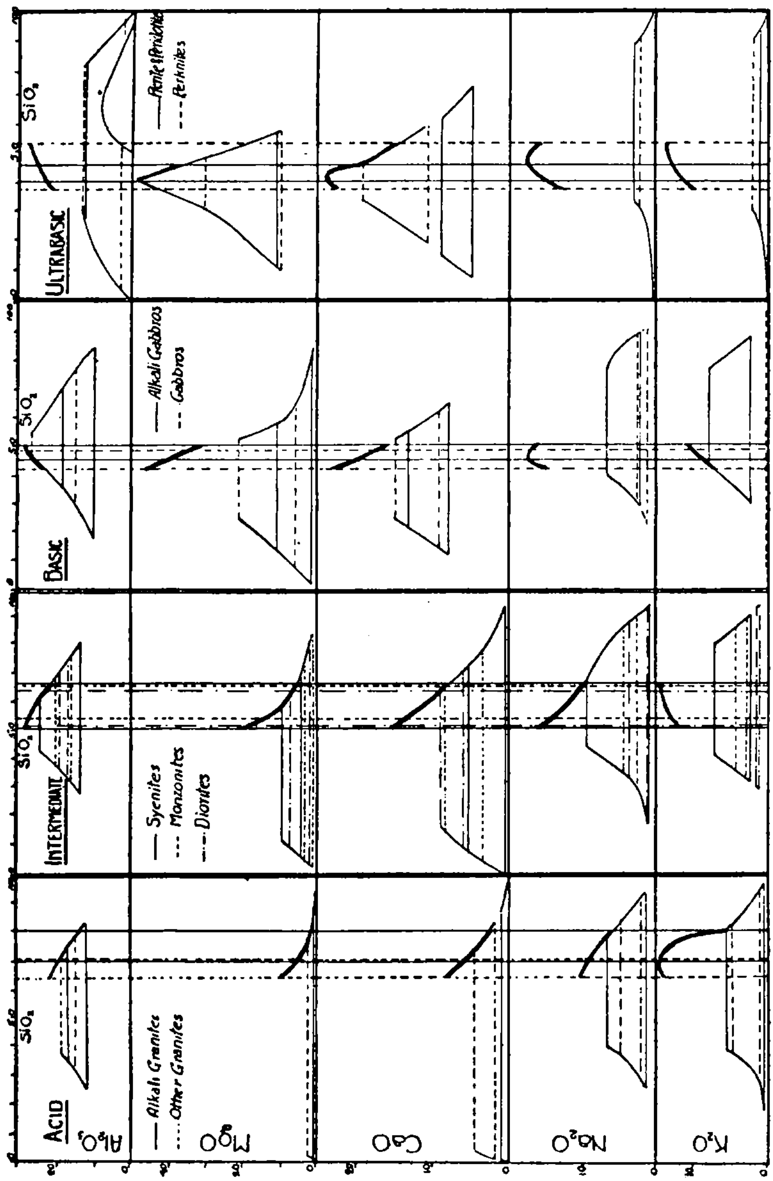

FIG. 4.—Rock-analysis diagrams of the plutonic groups.

Illustrations.

1. *Rock Groups.*—To illustrate the application of this method to rock classifications, diagrams of the plutonic groups as defined by Hatch[1] are given in fig. 4. The diagrams are constructed on the following plan :—The vertical columns represent the great groups—the acid, intermediate, basic, and ultrabasic. The width of the column represents 100 per cent. silica. Horizontal lines divide the columns into compartments, one of which is allotted to each constituent oxide.

The families within a group are differentiated by different types

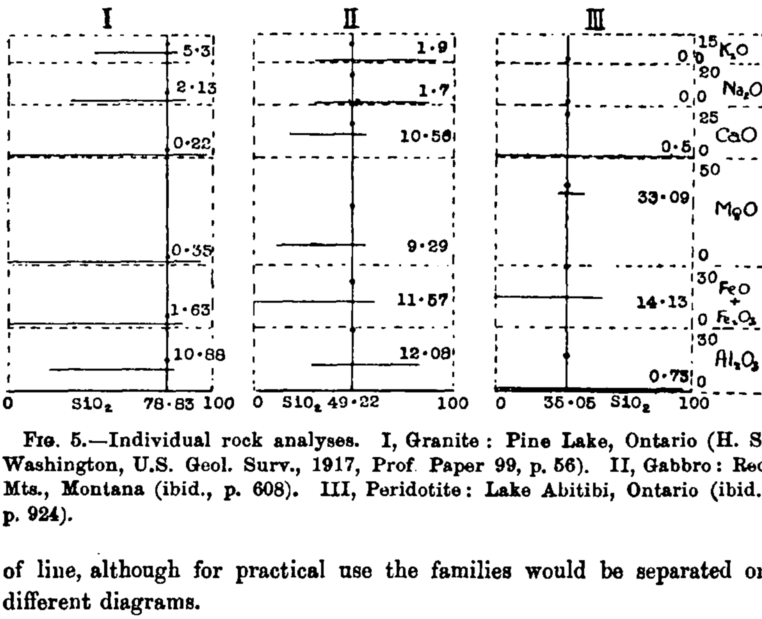

FIG. 5.—Individual rock analyses. I, Granite : Pine Lake, Ontario (H. S. Washington, U.S. Geol. Surv., 1917, Prof. Paper 99, p. 56). II, Gabbro : Red Mts., Montana (ibid., p. 608). III, Peridotite : Lake Abitibi, Ontario (ibid., p. 924).

of line, although for practical use the families would be separated on different diagrams.

The silica limits of the groups are defined by vertical lines in each column, and the upper limit to the variation of the oxides is shown by the thick lines that span the silica columns. These correspond to $A'C'$ in fig. 3.

Only those portions of the curves are drawn that form the boundaries of the group diagrams. Similar diagrams may be constructed for any other system of chemical grouping.

2. *Individual Analyses.*—Fig. 5 gives the diagrams of three individual analyses drawn on the same plan as the groups in fig. 4—the areas in

[1] F. H. Hatch, Petrology of the Igneous Rocks, London, 1914, p. 159 et seq.

the case of single analyses become lines. The width of each diagram represents 100 per cent. silica. The compartments allotted to the oxides are divided in this figure by the horizontal dotted lines. The full horizontal lines indicate the amount and silica range of each constituent present. The vertical line is drawn at the silica value, and the limit to the variation of the oxides at this silica percentage is indicated by the position of the large dot in each compartment.

For comparison with group diagrams, individual diagrams may be taken directly from the variation curves by means of tracing-paper.